NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

F/C POSITION JOB DESCRIPTIONS

LM CONSOLE HANDBOOK

LM-12

PCN 14

SYSTEM CONSOLE PROCEDURES

SYSTEM BRIEFS

OCTOBER 1, 1972

NOTES OF INTEREST

PREPARED BY

LUNAR MODULE SYSTEMS BRANCH

MALFUNCTION ANALYSES

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

LM CONSOLE HANDBOOK

LM-10 AND SUBSEQUENT VEHICLES

PCN-14

PREFACE

This document has been prepared by the LM Systems Branch, Manned Spacecraft Center, Houston, Texas, and contains briefs, procedures, position descriptions, notes of interest and malfunction analyses for LM Systems Flight Controllers for LM-10 and subsequent vehicles as of October 1, 1972. PCN-14 will serve as an update for Apollo 17.

Any comments concerning the contents of the document should be directed to Glenn Watkins, FC4, LM Systems Branch, 483-4717.

This document is not to be reproduced without the written approval of the chief, LM Systems Branch.

Approved by:

James E. Hannigan

James E. Hannigan
Chief, LM Systems Branch

UNIVERSAL LM CONSOLE HANDBOOK

LM-12

PCN-14

REVISION INSTRUCTION SHEET

Remove and replace pages as follows:

ii
iia
iiaa
Front Cover
II-i and II-ii
II-1-40 and II-1-41
II-9-7 and II-9-7a
II-9-12
II-11-1 thru II-11-8
II-11-11 thru II-11-12b
II-11-17 and II-11-18
II-11-23 thru II-11-26
II-11-33 thru II-11-36
II-12-1 thru II-12-6
III-i
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III-1-1 thru III-1-3
III-2-5 thru III-2-8
III-7-1 thru III-7-26a
III-12-18 thru III-12-28
III-12-30
III-13-17 thru III-13-20
III-13-36 and III-13-37

Notes of Interest Preface and Notes of Interest Index
Malfunction Analyses pages:
40 thru 42
44 thru 46
200
221 and 222
267 and 268
271 thru 276
279 thru 280b
281 thru 288
301 and 302
323 and 324
Back Cover

Add

II-11-50 thru II-11-52
II-16-1 thru II-16-4

Notes of Interest to be added:

General Section

LM Tracking Versus Telemetry Matrix for Descent/Ascent (9-28-72)
LM-12 Comm Plans (10-13-72)
Lunar Surface Contingency L/O Procedures (10-10-72)

INST

Failed LM Circuit Breaker Critical Bus Case (10-5-72)

EPS

Lunar L/O Through Impace on One Ascent Battery for Apollo 17 (10-31-72)

Remove:

II-9-13

Notes of Interest to be removed:

General

Tracking Versus Voice/Data for the Apollo 15 Descent (6-2-71)
Voice/Tracking and Data Trade Off's for Apollo 15 Ascent, Descent and Descent Aborts (7-7-72)

PROP

Ascent Limit Weight (4-3-72)

LM CONSOLE HANDBOOK

LM-10 AND SUBSEQUENT VEHICLES

PCN-13

PREFACE

This document has been prepared by the LM Systems Branch, Manned Spacecraft Center, Houston, Texas, and contains briefs, procedures, position descriptions, notes of interest and malfunction analyses for LM Systems Flight Controllers for LM-10 and subsequent vehicles as of April 1, 1972. PCN-13 will serve as an interim change for Apollo 16.

Any comments concerning the contents of the document should be directed to Glenn Watkins, FC4, LM Systems Branch, 483-4717.

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Approved by:

James E. Hannigan
Chief, LM Systems Branch

Prop Section

Ascent Limit Weight (4-3-72)

Remove and replace the following Malfunction Analyses pages:

41,
42
59
60

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PCN-13

REVISION INSTRUCTION SHEET

Update this document in accordance with the following instructions:

Remove and replace pages as follows:

ii
iia & iiaa
II-1-40 & II-1-41
II-12-1 thru II-12-6
III-1-1 thru III-1-5

Add the following pages:

II-1-49
II-9-12 & II-9-13

Note of Interest Section

Remove the following Notes of Interest:

EPS Section

LM Electrical Configuration for the Loss of One Ascent Battery (11-1-71)
Ascent Battery Considerations, Apollo.15 (7-20-71)
Addendum to Note of Interest: Ascent Battery Considerations Apollo 15 (7-22-71)

General Section

Apollo 16 Data Management Plan (11-1-71)

Add the following Notes of Interest:

General Section

Apollo 16 Data Management Plan, Rev. "A" (4-11-72
New Chart Recorder Timing (4-4-72)

PGNS Section

LM Platform Drift (2-25-72)
Ascent Guidance and Control Modes, Their Priority and Selection (4-10-72)
Change to the RR Antenna Parking Position on the Lunar Surface (4-11-72)

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LM-10 AND SUBSEQUENT VEHICLES

PCN-12

PREFACE

This document has been prepared by the LM Systems Branch, Manned Spacecraft Center, Houston, Texas, and contains briefs, procedures, position descriptions, notes of interest and malfunction analyses for LM Systems Flight Controllers for LM-10 and subsequent vehicles as of March 1, 1972.

Any comments concerning the contents of the document should be directed to Glenn Watkins, FC4, Lm Systems Branch, 483-4717.

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Approved by:

Donald R. Puddy for
James E. Hannigan
Chief, LM Systems Branch

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LM-10 AND SUBSEQUENT VEHICLES

PCN-12

REVISION INSTRUCTION SHEET

Update this document in accordance with the following instructions:

Remove and Replace pages as follows:

ii
iia
II-i, II-ii
II-1-5
II-1-7 and II-1-8 and II-1-8c
II-1-11 thru II-1-13
II-1-14
II-1-15, II-1-16
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II-1-24
II-1-33 and II-1-34
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II-11-39 and II-11-40
III-i and III-ii
III-1-1 and III-1-2 III-5-1, -2, -3
III-11-3 and III-11-4
III-11-5 and III-11-6
III-7-1 thru III-7-26a

Note of Interest Index

Malfunction Analyses Section

Remove and Replace the following pages:

23, 26 and 27, 28, 40, 41 and 42, 43 and 44, 45 and 46, 47 and 48, 49 and 50, 55 and 56, 59 and 60, 61 and 62, 63 and 64, 69 and 70, 71 and 72, 73 and 74, 187 and 188, 200, 201 and 202, 203 and 204, 205 and 206, 209 and 210, 211 and 212, 215 and 216, 217 and 218, 219 and 220, 221 and 222, 223 and 224, 225 and 226, 229 and 230, 235 and 236, 257 and 258, 259 and 260, and 261 and 262.

Remove

II-iii

Add New Pages:

iiaa
II-3-6a
III-2-38 thru III-2-69

Notes of Interest:

"Planned Operation of the LM Descent Cooling Valve", under EPS section.

"APS TPI and Depletion", under PROP section.

Malfunction Analyses Section - page 203a

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PCN-11

REVISION INSTRUCTION SHEET

Update this document in accordance with the following instructions:

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II-1-17 thru II-11-19
II-1-25 & II-1-26
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II-8-1 thru II-8-4
II-9-1 thru II-9-7a
II-11-15 & II-11-16
II-11-23 thru II-11-30
II-12-1 thru II-12-4
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III-7-3 thru III-7-16
III-9-11 & III-9-12
III-12-18 thru III-12-28
III-12-30
III-13-11 & III-13-12
III-13-17 thru III-13-28
III-13-33 thru III-13-38
III-15-1 thru III-15-6

Note of Interest Section

Malfunction Analyses Section - Pages 45, 46, and 55

Add New Pages:

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II-3-7 thru II-3-9
II-6-11
II-7-22 thru II-7-52
II-8-5 & II-8-6
II-11-16a thru II-11-16c
II-11-31 thru II-11-49
III-2-24 thru III-2-37
III-3-1 thru III-3-8
III-7-35 & III-7-36

7/26/71

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PCN-10

REVISION INSTRUCTION SHEET

Update this document in accordance with the following instructions:

Pen and Ink changes:

pII-i - Add under "EPS 2-1...", "EPS 2-2, Contingency Translunar Coast LM Battery Management, II-2-8, PCN-10/NEW, 7/26/71"

Add under "3 - PYRO...,"PYRO 3-1, Manual Staging on the Lunar Surface, II-3-1, PCN-10/NEW, 7/26/71"

pII-ii Change "PROP 11-15" from "PCN-8/NEW, 6/1/71" to "PCN-10, 7/26/71"

Add under "PROP 11-15", "PROP 11-16, SHe/LOI Abort Chart Update Procedures (LM-10 Only), II-11-28, PCN-10/NEW, 7/26/71"

pIII-i Add under "SCS 9-2", "SCS 9-3, Ascent Engine Adapter Cable Ignition, III-9-12, PCN-10/NEW, 7/26/71"

Remove and replace pages as follows:

ii	45
iia	46
II-11-26 through II-11-27	Note of Interest: "Apollo 15 Data Management Plan"

Add the following new pages:

II-2-8	RCS Thruster Failures and Apollo 15
II-2-9	Analysis of Vehicle Dynamics resulting from Isolation of Critical Jet Failed On during Powered Descent
II-3-1 through II-3-6	Monitoring Techniques for a Failed APS Inlet Pressure Transducer
II-11-28 through II-11-30	LOI Abort Subjects
III-9-12	LM-10 Non-Throttle Region

Notes of Interest:*

Pyro Battery Information
Ascent Battery Consideration, Apollo 15
Voice/Tracking and Data Tradeoffs for Apollo 15 Ascent, Descent, and Descent Aborts
Crew Unsuited Configuration while on the Lunar Surface

*See notes of interest index for order of insertion

944-5900

6/25/71

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PCN-9

REVISION INSTRUCTION SHEET

Update this document in accordance with the following instructions:

Remove and replace pages as follows:

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iia
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II-1-40 through II-1-48
III-i
III-ii
III-1-1 through III-1-5
III-2-5
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III-2-9
III-2-10
III-13-19
III-13-20
III-13-31
III-13-32
Notes of Interest PREFACE
Notes of Interest INDEX
Note of Interest: Pyrotechnic Relays and Battery Troubleshooting Procedures and GO/NO GO Criteria
Note of Interest: Apollo 15 and Subsequent PLSS Feedwater Calculations

Note of Interest: Apollo 15 Data Management Plan

Malfunction Analyses:
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Add the following new pages:

II-12-1 through II-12-6
Enclosure 1 of "LM Attitude Control Modes during PDI" Note of Interest
Note of Interest: PDI Procedure for LR Antenna Switching
Note of Interest: PDI Procedure for LR Antenna Switching Addendum
Note of Interest: Tracking Versus Voice/Data for the Apollo 15 Descent
Note of Interest: PGNS Automatic Control of GDA's for DPS Thirty Minute Burns

Malfunction Analyses:
108a through 108h
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LM-10 AND SUBSEQUENT VEHICLES

PCN-8

Revision Instruction Sheet

Update this document in accordance with the following instructions:

Remove and replace pages as follows:

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iia
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II-i
II-ii
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II-1-11 through II-1-14
II-1-25 through II-1-48
II-2-1 through II-2-7
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II-9-7b through II-9-11
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II-13-1 through II-13-5
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III-ii
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III-2-5 through III-2-23
III-6-9 through III-6-13
III-9-1 through III-9-10
III-11-1 through III-11-9
III-11-12 through III-11-18
III-12-1 through III-12-29
III-13-1
III-13-2
III-13-5 through III-13-12
III-13-17 through III-13-24
III-13-29 through III-13-32
III-14-3
III-14-4
III-15-7
III-15-8
Note of Interest Section

Add the following new pages:

II-11-26
II-11-27
III-12-30
Malfunction Analyses Section

LM CONSOLE HANDBOOK

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I. FLIGHT CONTROL POSITION JOB DESCRIPTIONS (FCPJD's)

II. SYSTEM CONSOLE PROCEDURES (SCP's)

III. SYSTEM BRIEFS (SB's)

IV. NOTES OF INTEREST P-8

V. MALFUNCTION ANALYSES P-8

I. FLIGHT CONTROLLER POSITION JOB DESCRIPTION (FCPJD) Index

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B.	Individual FCPJD		
	TELMU Engineer	I-2	
	LM ECS Engineer	I-3	
	LM INST Engineer	I-4	
	LM EPS Engineer	I-5	
	CONTROL Engineer	I-6	
	LM PGNS Engineer	I-7	
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THE FLIGHT CONTROLLER POSITION
JOB DESCRIPTION (FCPJD) SUMMARY
IS DELETED BY PCN-6

TELMU Engineer FCPJD P-3

POSITION: MOCR Console 9

SYSTEM RESPONSIBILITIES:

Electrical Power System (EPS)	Instrumentation System (INST)
Pyrotechnic System (PYRO)	Lunar Surface Equipments (MESA, SEQ BAY, RTG & LRV DPLY) P-8
Lighting System	Crew System
Environmental Control System (ECS)	Thermal System
Extravehicular Mobility Unit (EMU)	

DUTIES:

1. Reports to flight director, and other appropriate MOCR personnel as required, the current status and capability of his assigned system responsibilities.
2. Provides the flight director with systems GO/NO GO recommendations at specific intervals throughout the mission.
3. Maintains cognizance over the status of LM and EMU, H_2O, O_2, LiOH, and electrical consumables usage P-6 for comparison of the actual system operation against predicted values. Maintains a continual status of lifetime remaining. P-3
4. Monitors trend plots and chart displays on selected system parameters to verify system status and capability.
5. Recommends to the flight director alternate courses of action to accomplish mission objectives commensurate with crew safety.
6. Defines and recommends alternate crew procedures in the event of an onboard systems malfunction.
7. Provides inputs to real-time flight planning and alternate mission activity.
8. Insures that for the systems monitored alternate flight plans are within present systems capability.
9. Maintains cognizance of applicable DTO status and accomplishment.
10. Maintains cognizance over the RTCC TELMU system computations for the RTCC special processing. P-3
11. Maintains a mission log for assigned system operation.
12. Initiates TELMU RTCC-driven plots and/or displays at prescribed times. P-3
13. Initiates TELMU summary message transmittal. P-6
14. Initiates RTCC update requests for TELMU system tabs. P-3
15. Initiates RTCC limit sensing enable/disable.
16. Maintains cognizance of network high speed data formats and in conjunction with the CONTROL engineer, recommends appropriate changes to O&P.
17. Requests initiation of tape playback of real-time and dump data from MCC, CIF, and MSFN sites.
18. Requests Delogs and/or other RTCC information printouts as required.
19. Maintains cognizance of PCMGS formats and in conjunction with the CONTROL engineer, recommends P-6 appropriate changes.

LM ECS Engineer FCPJD

POSITION: SSR Console 21

SYSTEM RESPONSIBILITIES:

Environmental Control System (ECS)

Lunar Surface Equipments (MESA, SEQ BAY, RTG & LRV DPLY) P-8

Crew System

Thermal System

DUTIES:

1. Reports to TELMU engineer and other appropriate MOCR/SSR personnel, as required, the current status and capability of his assigned system responsibilities. P-3

2. Provides the TELMU engineer with systems GO/NO-GO recommendations at specific intervals throughout the mission. P-3

3. Maintains the status of H_2O, LiOH, and O_2 consumables usage for comparison of the actual system operation against predicted values. Maintains a continual status of vehicle lifetime remaining. P-6

4. Prepares and maintains trend plots and chart displays on selected ECS parameters to verify system status and capability.

5. Recommends to the TELMU engineer alternate courses of action to accomplish mission objectives commensurate with crew safety. P-3

6. Defines and recommends alternate crew procedures in the event of an onboard systems malfunction.

7. Provides inputs to real-time flight planning and alternate mission activity.

8. Insures that for the system monitored alternate flight plans are within present systems capability.

9. Initiates RTCC limit sensing value changes as required for system parameters.

10. Maintains cognizance of applicable DTO status and accomplishment.

11. Cross checks ground station readouts against ground displayed values and onboard readouts.

12. Inputs MED quantities to the RTCC special processing as required. P-3

13. Coordinates RTCC H_2O and O_2 consumable computations for the RTCC special processing. P-3

14. Maintains a mission log for assigned system operation.

15. Provides H_2O and O_2 weight updates to LM Prop.

16. Coordinates and prepares consumables budgets for various alternate or aborted missions in real-time. P-6

17. Initiates ECS RTCC-driven plots and/or displays at the appropriate times. P-8

LM INST Engineer FCPJD P-3

POSITION: SSR Console 30R

SYSTEM RESPONSIBILITIES:

Pyrotechnic System (PYRO) P-3

Instrumentation System (INST)

DUTIES:

1. Reports to TELMU engineer and other appropriate MOCR/SSR personnel, as required, the current status and capability of his assigned system responsibilities. P-3
2. Provides the TELMU engineer with system GO/NO-GO recommendations at specific intervals throughout the mission. P-3
3. Maintains trend plots and chart displays on selected EPS parameters to verify system status and capability. P-3
4. Recommends to the TELMU engineer alternate courses of action to accomplish mission objectives commensurate with crew safety. P-3
5. Defines and recommends alternate crew procedures in the event of an onboard systems malfunction.
6. Provides inputs to real-time flight planning and alternate mission activity.
7. Insures that for the systems monitored alternate flight plans are within present systems capability.
8. Initiates RTCC limit sensing value changes as required for system parameters.
9. Maintains cognizance of applicable DTO status and accomplishment.
10. Cross checks ground station readouts against ground displayed values and onboard readouts.
11. Maintains a mission log for assigned system operation.
12. Serves as a focal point for all suspected LM instrumentation malfunctions. P-6

LM EPS Engineer FCPJD

POSITION: SSR Console 30R P-3

SYSTEM RESPONSIBILITIES:

Electrical Power System (EPS)

Lighting System

DUTIES:

1. Reports to TELMU engineer and other appropriate MOCR/SSR personnel, as required, the current status and capability of his assigned system responsibilities. P-3

2. Provides the TELMU engineer with systems GO/NO-GO recommendations at specific intervals throughout the mission. P-3

3. Maintains the status of electrical power consumables usage for comparison of the actual system operation against predicted values. Maintains a continual status of vehicle lifetime remaining.

4. Prepares and maintains trend plots and chart displays on selected EPS parameters to verify system status and capability.

5. Recommends to the TELMU engineer alternate courses of action to accomplish mission objectives commensurate with crew safety. P-3

6. Defines and recommends alternate crew procedures in the event of an onboard systems malfunction.

7. Provides inputs to real-time flight planning and alternate mission activity.

8. Insures that for the systems monitored alternate flight plans are within present systems capability.

9. Initiates RTCC limit sensing value changes as required for system parameters.

10. Maintains cognizance of applicable DTO status and accomplishment.

11. Cross checks ground station readouts against ground displayed values and onboard readouts.

12. Inputs MED quantities to the RTCC special processing as required. P-3

13. Coordinates RTCC amp-hour computations for the RTCC special processing. P-3

14. Maintains a mission log for assigned system operation.

15. Coordinates and prepares consumables budgets for various alternate or aborted missions in real-time. P-6

CONTROL Engineer FCPJD

POSITION: MOCR Console 16

SYSTEM RESPONSIBILITIES:

Primary Guidance & Navigation System (PGNS)	Descent Propulsion System (DPS)
Abort Guidance System (AGS)	Ascent Propulsion System (APS)
Control Electronics System (CES)	Reaction Control System (RCS)
	Structures System P-6

DUTIES:

1. Reports to flight director and other appropriate MOCR personnel, as required, the current status and capability of his assigned system responsibilities.
2. Provides the flight director with systems GO/NO-GO recommendations at specific intervals throughout the mission.
3. Maintains cognizance over the status of propellant consumables usage for comparison of the actual system operation against predicted values. Maintains a continual status of vehicle burn time remaining.
4. Monitors trend plots and chart displays on selected system parameters to verify system status and capability.
5. Recommends to the flight director alternate courses of action to accomplish mission objectives commensurate with crew safety.
6. Defines and recommends alternate crew procedures in the event of an onboard systems malfunction.
7. Provides inputs to real-time flight planning and alternate mission activity.
8. Insures that for the systems monitored alternate flight plans are within present systems capability.
9. Maintains cognizance of applicable DTO status and accomplishment.
10. Maintains cognizance over the RTCC control system computations for the RTCC special processing.
11. Maintains a mission log for assigned system operation.
12. Initiates CONTROL summary message transmittal.
13. Initiates RTCC update requests for CONTROL system tabs.
14. Initiates RTCC limit sensing enable/disable.
15. Maintains cognizance of network high speed data formats and in conjunction with the TELMU engineer, recommends appropriate changes to O&P. P-3
16. Requests initiation of tape playbacks of real-time and dump data from MCC, CIF, and MSFN sites.
17. Maintains cognizance of weight, propellant, and Delta V remaining log, and provides updates to RETRO after any significant weight change or maneuver.
18. Requests delogs and/or other RTCC information printouts as required. P-6
19. Maintains cognizance of PCMGS formats and in conjunction with the TELMU engineer, recommends appropriate changes.

LM PGNS Engineer FCPJD

POSITION: SSR Console 29L

SYSTEM RESPONSIBILITIES:

Primary Guidance & Navigation System (PGNS) (including DAP)

Rendezvous Radar (RR)

Landing Radar (LR)

DUTIES:

1. Reports to CONTROL engineer and other appropriate MOCR/SSR personnel, as required, the current status and capability of his assigned system responsibilities.
2. Provides the CONTROL engineer with systems GO/NO-GO recommendations at specific intervals throughout the mission.
3. Prepares and maintains trend plots and chart displays on selected PGNS parameters to verify systems status and capability.
4. Recommends to the CONTROL engineer alternate courses of action to accomplish mission objectives commensurate with crew safety.
5. Defines and recommends alternate crew procedures in the event of an onboard systems malfunction.
6. Provides inputs to real-time flight planning and alternate mission activity.
7. Insures that for the systems monitored alternate flight plans are within present systems capability.
8. Initiates RTCC limit sensing value changes as required for system parameters.
9. Maintains cognizance of applicable DTO status and accomplishment.
10. Cross checks ground station readouts against ground displayed values and onboard readouts.
11. Inputs MED quantities to the RTCC special processing as required. P-6
12. Coordinates RTCC IMU resolver angles computations for the RTCC special processing.
13. Maintains a mission log for assigned system operation.
14. Monitors DAP status and performance. P-6
15. Determines corrective values of IMU accelerometer and gyro biases, and reports to CONTROL and GUIDO at appropriate times.
16. Maintains records of preflight loaded LGC eraseable load.
17. Calculates predicted PIPA readings for engine operations.
18. Monitors throttle loop during DPS operation.

LM AGS Engineer FCPJD

POSITION: SSR Console 29C

SYSTEM RESPONSIBILITIES:

Abort Guidance System (AGS)

Control Electronics System (CES) P-6

DUTIES:

1. Reports to CONTROL engineer and other appropriate MOCR/SSR personnel, as required, the current status and capability of his assigned system responsibilities.
2. Provides the CONTROL engineer with systems GO/NO-GO recommendations at specific intervals throughout the mission.
3. Prepares and maintains trend plots and chart displays on selected CES or AGS parameters to verify system status and capability. P-6
4. Recommends to the CONTROL engineer alternate courses of action to accomplish mission objectives commensurate with crew safety.
5. Defines and recommends alternate crew procedures in the event of an onboard systems malfunction.
6. Provides inputs to real-time flight planning and alternate mission activity.
7. Insures that for the systems monitored alternate flight plans are within present systems capability.
8. Initiates RTCC limit sensing value changes as required for system parameters.
9. Maintains cognizance of applicable DTO status and accomplishment.
10. Cross checks ground station readouts against ground displayed values and onboard readouts.
11. Inputs MED quantities to the RTCC special processing as required. P-6
12. Maintains a mission log for assigned system operation.
13. Monitors DPS gimbal loop, and RCS control loops and engine on/off.
14. Calculates DPS gimbal trim angles from c.g. positions for entry into the DSKY. P-6

LM PROP Engineer FCPJD

POSITION: SSR Console 29R

SYSTEM RESPONSIBILITIES:

Descent Propulsion System (DPS)

Ascent Propulsion System (APS)

Reaction Control System (RCS)

Structures Subsystem P-6

DUTIES:

1. Reports to CONTROL engineer and other appropriate MOCR/SSR personnel, as required, the current status and capability of his assigned system responsibilities.
2. Provides the CONTROL engineer with systems GO/NO-GO recommendations at specific intervals throughout the mission.
3. Maintains the status of propellant consumables usage for comparison of the actual system operation against predicted values. Maintains a continual status of vehicle burn time remaining.
4. Prepares and maintains trend plots and chart displays on selected PROP parameters to verify system status and capability.
5. Recommends to the CONTROL engineer alternate courses of action to accomplish mission objectives commensurate with crew safety.
6. Defines and recommends alternate crew procedures in the event of an onboard systems malfunction.
7. Provides inputs to real-time flight planning and alternate mission activity.
8. Insures that for the system monitored alternate flight plans are within present systems capability.
9. Initiates RTCC limit sensing value changes as required for system parameters.
10. Maintains cognizance of applicable DTO status and accomplishment.
11. Cross checks ground station readouts against ground displayed values and onboard readouts.
12. Inputs MED quantities to the RTCC special processing as required.
13. Coordinates and initiates RTCC propellant and propulsion computations for the RTCC special processing. P-6
14. Maintains a mission log for assigned system operation.
15. Initiates CONTROL RTCC-driven plots and/or displays as prescribed.
16. Determines weight, propellant, and Delta V remaining log, and provides updates to RETRO after any significant weight change or maneuver.
17. Utilizes the Olivetti and Hewlett Packard desk computer for various real-time calculations.
18. Calculates vehicle c.g. for determination of DPS gimbal location.
19. Coordinates and prepares consumables budgets for various alternate or aborted missions in real-time. P-6
20. Determines correct source to be used for descent hover time remaining callouts to the crew.

EMU Engineer FCPJD

Deleted by PCN-3

PLSS ENG 1 and 2 FCPJD

POSITION: SSR Console 33R and 33L

SYSTEM RESPONSIBILITIES: P-6

EMU

DUTIES:

1. Reports to TELMU engineer and other appropriate MOCR/SSR personnel the current status and capability of his assigned responsibilities. P-3

2. Provides the TELMU engineer with EVA GO/NO-GO recommendations.

3. If necessary, makes recommendations to the TELMU engineer for alternate courses of action to accomplish mission objectives commensurate with crew safety. P-6

4. Initiates RTCC limit sensing changes and inputs MED quantities to the RTCC special processing as required.

5. Cross checks ground station readouts against ground displayed values and onboard readouts.

6. Verifies CCATS and MCC PCMGS TM parameter readouts.

7. Maintains a mission log.

PLSS CONSUMABLES FCPJD

POSITION: OPAQUE TELEVIEWER - Channel 64 P-6

SYSTEM RESPONSIBILITIES:

EMU

DUTIES:

1. Maintains the status of O_2 (POS and OPS), feed H_2O, LiOH and electrical consumables usage for comparison of the actual system operation against predicted values. Maintains a continuous status of PLSS lifetime remaining for all consumables. P-11

2. Prepares and maintain trend plots and graphs on PLSS consumables.

3. Utilizes realtime consumable projections to maintain updated LRV traverse constraint profiles.

4. Maintains a consumables log.

5. Coordinates with Aeromedical Life Support personnel to obtain crewmen metabolic rates for consumable usage rate calculations. P-11

6. Maintains a record of above-nominal heat loads on the EMU's to determine degradations in consumables performance.

SOP's

			11/1/71
			11/1/71
			11/1/70
			5/12/69
			11/1/70
		-11	11/1/71
		CN-6/NEW	11/1/70
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		PCN-11/NEW	11/1/71
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	th.....II-7-42	PCN-11/NEW	11/1/71
	l Staging....II-7-51	PCN-11/NEW	11/1/71
	.....II-7-52	PCN-12	3/1/72

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SCP NO. **GEN 1-1**

This SCP is deleted
by PCN-8

SCP NO. **GEN 1-2**

S/C : LM
DATE : 3-1-72
REV : PCN-12
ORIGINATOR : B. Heselmeyer
APPROVAL : James E. Hannigan

TITLE : **LIMIT SENSE CONTROL**

PURPOSE : This SCP explains the implementation of the operational and critical limit sensing capability and the procedures associated with each.

PROCEDURE: A. Limit Sense Enable/Disable

1. TELMU and CONTROL have the capability to enable and disable groups of limits by means of the SMEK on each console. Each category affects both operational and critical limits except for the "ALL TELMU CRITICAL," "ALL CONTROL CRITICAL," and "LUNAR SURFACE CRITICAL" categories which affect critical limits only.
2. A list of parameters affected by the enable/disable function is contained in Table I.
3. Enable/Disable Categories

TELMU	CATEGORY	NOTES	
All TELMU	LEMCATECM		P-6
TELMU Critical	LEMCRTECM	Critical Limits only	P-9
Des Stage	LEMCAT 2		
Prelaunch	LEMCAT 3		
Asc Bat Curnt	LEMCAT 4		
EMU	LEMCAT 5		

CONTROL	CATEGORY	NOTES	
All CONTROL	LEMCATCON		P-6
All CONTROL Critical	LEMCRTCON	Critical Limits only	
Launch Limits	LEMCAT 6		P-9
Coast Limits	LEMCAT 7		
Staged Limits	LEMCAT 8		
Lunar Surface Critical	LEMCAT 10	Critical Limits only	

The category refers to the name as defined by the TR-170 document.

4. Disabling limits
   Depress the following
   a. "_____Limits"
   b. "Disable Limits" (TELMU) or "Disable" (CONTROL) P-6
   c. "Execute"
5. Enabling Limits
   Depress the following
   a. "_____Limits"
   b. "Enable Limits" (TELMU) or "Disable Remove" (CONTROL) P-6
   c. "Execute"

B. Inhibiting Limit Sensing (COMPUTER TM FUNCTION)

1. COMPUTER TM has control over the LM limit sensing in the RTCC. If limit sensing is DISABLED via the LM INHIBIT/ENABLE switch, all limit sensing for the LM is turned off.
2. Only the LM TELMU or CONTROL MOCR position will request changes to the limit sense INHIBIT/ENABLE switches. Other MOCR users of the same TM will be notified prior to changing the switch settings. The computer program is initialized with all limit sensing turned on and will not be inhibited until a request is made to Computer TM over the RTCC TM loop.
3. Critical limit sensing for an individual parameter can be inhibited by COMPUTER TM. (Note that this capability does not exist for operational limits). Only the LM TELMU or LM CONTROL MOCR position will request that individual parameter critical limit sensing be disabled. P-6

C. Resetting Limit Sense Lights

1. Operational Limits

a. The operational limit lights will remain on only when the parameters are out-of-limits. To MOMENTARILY reset ALL operational limit lights (as well as all functions driven by DDD's from the RTCC) depress:

1. "_____ Limits"
2. "RESET LIMIT LIGHTS"
3. "Execute"

2. Critical Limits

a. Critical limit lights will not illuminate until a specified number of valid frames of data have been processed with the parameter out-of-limits. The number of valid frames of data are counted sequentially in an "AOS CHECK" counter and a "CONSECUTIVE FRAME CHECK" counter. The number of frames of valid data required for each of these counters is medable, may be different for each counter, are independent for each vehicle, and may be within the range of 0 to 30 frames for the LM. For the LM, the computer will be initialized with a value of 3 frames for each of the counters. At every AOS, assuming initialized values, this means 6 frames of data are required before a critical limit light can illuminate. During solid data, only 3 frames must be processed.

b. An illuminated critical limit light will stay on until the parameter goes back into limits and the light is manually reset. The associated tone will last for 3 seconds and cannot be interrupted. If a light is reset and the parameter is still out of limits, the light will again illuminate after the number of frames meded into the "CONSECUTIVE FRAME CHECK" counter is satisfied but the tone will not reoccur. Critical limit lights are reset by depressing the MSK "CRITICAL ALARM RESET" on console 9 (TELMU LIMITS) or console 16 (CONTROL LIMITS). It should be noted that if a restart tape is cut during a 3-second period when the alarm tone is on, and the computer is recycled to that time, then the tone will remain on continuously. DISPLAY has the capability to terminate the continuous alarm. P-6

c. The "MASTER ALARM" and "ED A/B K1-6" lights on the TELMU critical limits module are actually sample and hold lights and not critical limits. Neither of the valid data frame counters or the tone apply to these lights, and they cannot be individually disabled. These two lights are reset by depressing the "LATCHING EVENT RESET" button on the console 9 MSK (TELMU).

D. Limit value Changes

1. Operational or Critical Limits P-9

a. Telemetry parameter limit changes may be entered into the mission operations computer and the dynamic standby computer during the prelaunch and orbit phases.

b. Requests for operational limit changes will be made by voice to COMPUTER TM on the RTCC TM loop for individual parameter limit changes (maximum of five parameters). This voice request will be followed by the standard Limit Table Change Request Form (Figure 1) via P-Tube to COMPUTER TM. Requests for critical limit changes will be made on the standard Limit Table Change Request Form (Figure 1) and signed by the MOCR operator. P-9

c. Requests for limit changes on more than five parameters will be made only on the standard form (Figure 1).

d. Tapes - The capability exists to place several parameter limits on paper tape. LM CONTROL uses this feature, and defines the tapes on a mission by mission basis for math model sims, LMS sims, and for the actual vehicle. P-6

SCP NO. GEN 1-2
PCN-9

COMPUTER TM:
P-TUBE STATION 31

DATE _____
TIME _____
INITIATOR _____

LIMIT TABLE CHANGE SHEET

1. VEHICLE: CSM S-IC S-IVB/IU LM AMD (CIRCLE ONE)
2. CRITICAL _____ OPERATIONAL _____
3. DATA:

MEASUREMENT NO.	LOW LIMIT	HIGH LIMIT	DISABLE LIMIT

NOTE 1: INDICATE MINUS SIGN VALUES AND DECIMAL POINTS, IF APPLICABLE. IT IS NOT REQUIRED TO SPECIFY UNITS (E.G., PSI, MMHG, F, ETC.).

NOTE 2: IF ONLY ONE LIMIT (HIGH OR LOW) CHANGE IS DESIRED, IT IS NOT NECESSARY TO WRITE IN THE UNCHANGED VALUE.

MOCR OPERATOR: _____

FD APPROVAL: _____

(ONLY IF CRITICAL LIMITS ARE TO BE CHANGED OR DISABLED)

FIGURE 1

MSC Form 1966 (Rev Jan 71)

TABLE I - TM vs RTCC LIMITS

SYSTEMS		UNITS	OPR. LIMITS (1)		CRIT. LIMITS (1)		ENABLE/DISABLE CATEGORIES								
							ALL TELMU	ALL TELMU CRITICAL	DES STAGE	PRE-LAUNCH	ASC BAT CURNT	EMU	ALL CONTROL	ABORT STAGED	
THERMAL SYSTEM			LOW	HIGH	LOW	HIGH	LEMCATECM	LEMCRTECM	2	3	4	5	LEMCATCON	8	
GB0541T	MESA 1 TEMP	°F	40	90	--	--	X		X						P-9
GB0542T	MESA 2 TEMP	°F	40	90	--	--	X		X						P-11
ELECTRICAL POWER SYSTEM															
GC0071V	AC BUS VOLT	VOLTS	115.8	118.2	--	--	X			X					
GC0155F	AC BUS FREQ	HZ	398	402	--	--	X			X					
GC0201V	BAT 1 VOLT	VOLTS	29	35	--	--	X		X	X					
GC0202V	BAT 2 VOLT	VOLTS	29	35	--	--	X		X	X					
GC0203V	BAT 3 VOLT	VOLTS	29	35	--	--	X		X	X					
GC0207V	BAT L VOLT	VOLTS	29	35	--	--	X		X	X					P-9
GC0204V	BAT 4 VOLT	VOLTS	29	35	--	--	X		X	X					
GC0205V	BAT 5 VOLT	VOLTS	29	38	36.5	38	X	X							
GC0206V	BAT 6 VOLT	VOLTS	29	38	36.5	38	X	X							
GC0301V	CDR BUS VOLT	VOLTS	28	32.5	27	32.5	X	X							
GC0302V	LMP BUS VOLT	VOLTS	28	32.5	27	32.5	X	X							
GC1201C	BAT 1 CUR	AMPS	5	20	0.5	20	X	X	X	X					
GC1202C	BAT 2 CUR	AMPS	5	20	0.5	20	X	X	X	X					
GC1203C	BAT 3 CUR	AMPS	5	20	0.5	20	X	X	X	X					
GC1207C	BAT L CUR	AMPS	5	20	0.5	20	X	X	X	X					P-9
GC1204C	BAT 4 CUR	AMPS	5	20	0.5	20	X	X	X	X					
GC1205C	BAT 5 CUR	AMPS	5	40	1.0	40	X	X		X	X				
GC1206C	BAT 6 CUR	AMPS	5	40	1.0	40	X	X		X	X				
GC9965U	BAT 5 MAL	N/A	N/A	N/A	BILEVEL			X							P-9
GC9966U	BAT 6 MAL	N/A	N/A	N/A	BILEVEL			X							
CLC LM4501C	TOT CUR	AMPS	40	80	--	--	X								P-6
LM4502C	DES CUR	AMPS	20	80	--	--	X		X						
LM4503C	ASC CUR	AMPS	10	80	--	--	X				X				
INSTRUMENTATION SYSTEM															
GL0401V	CAL 85 PCT	VOLTS	4.24	4.26	--	--	X								
GL0402V	CAL 15 PCT	VOLTS	.74	.76	--	--	X								
GL0422V	PCM OSC FAIL 2	VOLTS	3.2	5	--	--	X			X					
GL0423V	PCM OSC FAIL 3	VOLTS	3.2	5	--	--	X			X					
GL4047X	BAT MAL	N/A	N/A	N/A	BILEVEL (2)			X							
GL4069X	MST ALARM	N/A	N/A	N/A	BILEVEL (2)			X							
GL8275T	REF: GL9401U														
[1]GL9401U	SEL RTG/ECA 1T	°F	40	160	--	--	X								P-12
[2]GL9402U	SEL LR ANT/ECA 2T	°F	-15	+150	--	--	X						X	X	

NOTES: 1. GL9401U is the measurement assigned to the combined measurements of GT8275 RTG CASK T and GC6201T ECA 1T. Ground data systems use only GT8275T.

2. GL9402 is the measurement assigned to the combined measurements of GN7563T LR ANT T and GC6202T ECA 2T. Ground data systems use only GN7563T.

TABLE I - TM vs RTCC LIMITS - Continued

SYSTEMS		UNITS	OPR. LIMITS 1		CRIT. LIMITS 1		ENABLE/DISABLE CATEGORIES					
							ALL TELMU	ALL TELMU CRITICAL	DES STAGE	PRE-LAUNCH	ASC BAT CURNT	EMU
ENVIRONMENTAL CONTROL SYSTEM			LOW	HIGH	LOW	HIGH	LEMCATECM	LEMCRTECM				
*GF0521T	DES 2 H_2O TEMP	°F	40	90	--	--	X		X			
GF0584P	DES 2 O_2 PRESS	PSIA	2650	3000	2650	3000	X	X	X			
GF1083X	SUIT FAN 1 FAIL	N/A	N/A	N/A	BILEVEL			X				
GF1084X	SUIT FAN 2 FAIL	N/A	N/A	N/A	BILEVEL			X				
GF1281T	SUIT TEMP	°F	35	75	--	--	X	X				
GF1301P	SUIT PRESS	PSIA	3.6	5.0	4.5	5.2	X	X				
GF1521P	CO_2 PART PRESS	MMHG	0	7.6	--	--	X					
GF1651T	CABIN TEMP	°F	60	90	--	--	X					
GF2021P	PRI GLY PUMP ΔP	PSID	15	25	--	--	X			X		
GF2531T	W/B GLY IN T	°F	40	90	--	--	X					
GF2581T	W/B GLY OUT T	°F	32	95	32	80	X	X				
GF2921P	SEC GLY P	PSIA	5.5	9.0	7.2	23	X	X				
GF3571P	CABIN PRESS	PSIA	3.6	5.0	4.5	5.2	X	X				
GF3582P	ASC 1 O_2 PRESS	PSIA	800	950	800	950	X	X				
GF3583P	ASC 2 O_2 PRESS	PSIA	800	950	800	950	X	X				
GF3584P	DES 1 O_2 PRESS	PSIA	2650	3000	2650	3000	X	X	X			
GF3591P	U/H RLF PRESS	PSIA	3.6	5.0	--	--	X			X		
GF3592P	F/H RLF PRESS	PSIA	3.6	5.0	--	--	X			X		
GF4101P	PRI H_2O REG ΔP	PSID	0.5	1.0	0.4	1.9	X	X				
GF4501P	DES H_2O PRESS	PSIA	44	49	--	--	X		X			
GF4511T	PRI W/B H_2O TEMP	°F	35	120	--	--	X					
GF4500P	DES 1 H_2O TANK PRESS	%	30	48	--	--	X		X			
GF4502P	A/1 H_2O TANK PRESS	%	30	48	--	--	X					
GF4503P	A/2 H_2O TANK PRESS	%	30	48	--	--	X					
GF4585T	ASC 1 H_2O T	°F	40	90	--	--	X					
GF4586T	ASC 2 H_2O T	°F	40	90	--	--	X					
GF9986U	SEL GLY LOW LVL	N/A	N/A	N/A	BILEVEL			X				
GF9997U	SEL GLY PUMP PRESS	PSIA	20	28	19	28	X	X				
GF9998U	SEL GLY TEMP	°F	34	50	--	--	X			X		
GF9999U	SEL H_2O SEP RATE	RPM	900	3600	--	--	X			X		
CLC												
LM4611C	DES 1 H_2O LBS	LBS	260	270	250	270	X	X	X			
LM4617C	DES 2 H_2O LBS	LBS	260	339	250	270	X	X	X			
LM4609C	ASC 1 H_2O LBS	LBS	41	42.5	41	43	X	X				
LM4610C	ASC 2 H_2O LBS	LBS	41	42.5	41	43	X	X				
LM4601C	DES 1 O_2 QTY PCT	%	97	100	--	--	X		X			
LM4603C	A/1 O_2 QTY PCT	%	99	100	--	--	X					
LM4605C	A/2 O_2 QTY PCT	%	99	100	--	--	X					
LM4704C	DES 1 O_2 $\dot{Q}$, LBS/HR	LB/HR	0.0	0.4	--	--	X		X			
LM4708C	DES 2 O_2 $\dot{Q}$, LBS/HR	LB/HR	0.0	0.4	--	--	X		X			
LM4705C	ASC 1 O_2 $\dot{Q}$, LBS/HR	LB/HR	0	0.3	--	--	X					
LM4706C	ASC 2 O_2 $\dot{Q}$, LBS/HR	LB/HR	0	0.3	--	--	X					
LM4701C	DES 1 H_2O $\dot{Q}$, LBS/HR	LB/HR	0	7.0	--	--	X		X			
LM4707C	DES 2 H_2O $\dot{Q}$, LBS/HR	LB/HR	0	7.0	--	--	X		X			
LM4702C	ASC 1 H_2O $\dot{Q}$, LBS/HR	LB/HR	0	3.5	--	--	X					
LM4703C	ASC 2 H_2O $\dot{Q}$, LBS/HR	LB/HR	0	3.5	--	--	X					

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*REFER TO THIS PARAMETER AS GP0543P WHEN COMMUNICATING WITH RTCC.

"B"

TABLE I - TM vs RTCC LIMITS - Continued

PLSS [3]	UNITS	OPR. LIMITS [1]		CRIT. LIMITS [1]		ENABLE/DISABLE CATEGORIES					
						ALL TELMU	ALL TELMU CRITICAL	DES STAGE	PRE-LAUNCH	ASC BAT CURNT	EMU
		LOW	HIGH	LOW	HIGH	LEMCATECM	LEMCRTECM	2	3	4	5
GT8101V/GT8201V EVCS CAL 0	VDC	0	0.5	--	--	X					X
GT8102V/GT8202V EVCS CAL 5	VDC	4.95	5.0	--	--	X					X
GT8110P/GT8210P PLSS FEED H_2O PRESS	PSIA	2.5	3.7	2.5	4.0	X	X				X
GT8140C/GT8240C PLSS BAT CUR	AMP	2.4	2.8	2.0	3.0	X	X				X
GT8141V/GT8241V PLSS BAT VOLT	VDC	16.4	17.6	16	20.5	X	X				X
GT8154T/GT8254T LCG H_2O INL TEMP	°F	50	90	--	--	X					X
GT8168P/GT8268P PGA PRESS	PSID	3.75	4.05	3.7	4.05	X	X				X
GT8170T/GT8270T PLSS SUBL O_2 OUT TEMP	°F	41	46	40	50	X	X				X
GT8175P/GT8275P PLSS CO_2 PP	MMHG	0	6	--	--	X					X
GT8182P/GT8282P PLSS O_2 PRESS	PSIA	1200	1500	225	1500	X	X				X
GT8196T/GT8296T LCG H_2O ΔT	°F	0	10	--	--	X					X
LEM7309C(C12Q̇)/LEM7310C(C22Q̇) PLSS O_2 Q̇	LB/HR	0.1	0.4	--	--	X					X
LEM9301C(C11Q)/LEM9305C(C21Q) PLSS O_2 QTY	LB	0.37	1.90	--	--	X					X
LEM9303C(C15T)/LEM9307C(C25T) LCG H_2O OUT TEMP	°F	60	100	--	--	X					X
LEM9304C(C16Q)/LEM9308C(C26Q) AMP-HR REM	AMP-HR	3.0	25.8	--	--	X					X
LEM9309C(C14Q̇)/LEM9311C(C24Q̇) FEED H_2O Q̇	LB/HR	0.7	2.0	--	--	X					X
LEM9310C(C13Q)/LEM9312C(C23Q) FEED H_2O QTY	LB	4.5	12.2	--	--	X					X
PYRO											
GY0201X ED RLY A K1-6	N/A	N/A	N/A	BILEVEL [2]							
GY0202X ED RLY B K1-6	N/A	N/A	N/A	BILEVEL							

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TABLE I-TM vs RTCC LIMITS - Continued

PRIMARY GUIDANCE AND NAVIGATION SYSTEM		UNITS	OPR. LIMITS [1]		CRIT LIMITS [1]		ENABLE/DISABLE CATEGORIES					
			LOW	HIGH	LOW	HIGH	LAUNCH LIMITS	COAST LIMITS	ABORT STAGED LIMITS	ALL CONTROL	LUNAR SURF CRIT	ALL CNTRL CRIT
							6	7	8	LEMCATCON	10	LEMCRTCON
GG1040V	PLS TORQ REF	VDC	105	130	--	--				X		
GG1110V	2.5 VDC TM BIAS	VDC	2.35	2.6	--	--				X		
GG1201V	IMU 28 VAC 800 HZ	VRMS	26	30	--	--				X		
GG1331V	IRIG SUSP 3.2 KC	VRMS	26	30	--	--				X		
GG2001V	X PIPA OUT IN ϕ	VRMS	-1	+1	--	--				X		
GG2021V	Y PIPA OUT IN ϕ	VRMS	-1	+1	--	--				X		
GG2041V	Z PIPA OUT IN ϕ	VRMS	-1	+1	--	--				X		
GG2107V	IG SVO ERR IN ϕ	VRMS	-1	+1	--	--				X		
GG2137V	MG SVO ERR IN ϕ	VRMS	-1	+1	--	--				X		
GG2142V	MG RSVR OUT SIN	VRMS	0.93	4.07	0.218	4.782	X			X	X	X
GG2167V	OG SVO ERR IN ϕ	VRMS	-1	+1						X		
GG2219V	PITCH ATT ERR	DEG	-5	+5						X		
GG2249V	YAW ATT ERR	DEG	-5	+5						X		
GG2279V	ROLL ATT ERR	DEG	-5	+5						X		
GG2300T	PIPA TEMP	°F	120	140						X		
GG3304V	RR SHFT SIN	DEG	-5	+5						X		
GG3305V	RR SHFT COS	DEG	-5	+5						X		
GG3324V	RR TRUN SIN	DEG	-5	+5						X		
GG3325V	RR TRUN COS	DEG	-5	+5						X		
LEM 5603C	IMU/CDU (P)	DEG	-0.5	+0.5	-0.5	0.5	X			X	X	X
LEM 5604C	IMU/CDU (R)	DEG	-0.5	+0.5	-0.5	0.5	X			X	X	X
LEM 5605C	IMU/CDU (Y)	DEG	-0.5	+0.5	-0.5	0.5	X			X	X	X
LGC 8601C	X PGNS/AGS	DEG	-5.0	+5.0			X			X		
LGC 8602C	Y PGNS/AGS	DEG	-5.0	+5.0			X			X		
LGC 8603C	Z PGNS/AGS	DEG	-5.0	+5.0			X			X		
GG9001X	LGC WARN										X	X
GG9002X	ISS WARN										X	X
LCH11B01	ISS WARN										X	X
LCH33B14	LGC WARN										X	X
LGC43E	LGC RSTRT										X	X
	RADAR SYSTEM											
[2]GN7563T	REF GL9402U											
GN7723T	RR ANT TEMP	DEG	-50	+149						X		

2. GL9402U IS THE MEASUREMENT ASSIGNED TO THE COMBINED MEASUREMENTS OF GN7563TLR ANT T AND GC6202T ECA 2 T. GROUND DATA SYSTEMS USE ONLY GN7563T.

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TABLE I-TM vs RTCC LIMITS - Continued

STABILIZATION AND CONTROL SYSTEM		UNITS	OPR. LIMITS [1]		CRIT LIMITS [1]		ENABLE/DISABLE CATEGORIES					
							LAUNCH LIMITS	COAST LIMITS	ABORT STAGED LIMITS	ALL CONTROL	LUNAR SURF CRIT	ALL CNTRL CRIT
			LOW	HIGH	LOW	HIGH	6	7	8	LEMCATCON	10	LEMCRTCON
GH1247V	YAW ERR CMD	VOLTS	-0.8	0.8			X			X		
GH1248V	PITCH ERR CMD	VOLTS	-0.8	0.8			X			X		
GH1249V	ROLL ERR CMD	VOLTS	-0.8	0.8			X			X		
GH1311V	MAN THRUST CMD	PCT	10	92.5					X	X		
GH1313V	PITCH GDA POS	DEG	-4.0	+4.0					X	X		
GH1314V	ROLL GDA POS	DEG	-4.0	+4.0					X	X		
GH1331V	AUTO THRUST CMD	PCT	0	82.5					X	X		
GH1455V	YAW ATT ERR	DEG	-5.0	+5.0			X			X		
GH1456V	PITCH ATT ERR	DEG	-5.0	+5.0			X			X		
GH1457V	ROLL ATT ERR	DEG	-5.0	+5.0			X			X		
GH1461V	RGA YAW RATE	DEG/SEC	-5.0	+5.0						X		
GH1462V	RGA PITCH RATE	DEG/SEC	-5.0	+5.0						X		
GH1463V	RGA ROLL RATE	DEG/SEC	-5.0	+5.0						X		
GL4026X	CES AC FL										X	X
GL4027X	CES DC FL										X	X
GL4028X	AGS WARN										X	X
LEM 32E	CB37 FAIL										X	X
LEM 33E	CB69 FAIL											X
	ABORT GUIDANCE SYSTEM											
G13301T	ASA TEMP	°F	115	125						X		
	ASCENT PROPULSION											
GP0001P	APS HE 1 PRESS	PSIA	2970	3150	2970	3150				X		X
GP0002P	ASP HE 2 PRESS	PSIA	2970	3150	2970	3150				X		X
GP0018P	APS HE REG PRESS	PSIA	110	130	110	130				X		X
GP0025P	APS HE REG PRESS	PSIA	110	130	110	130				X		X
GP0041P	APS HE 1 R PRESS	PSIA	2970	3150	2970	3150				X		X
GP0042P	APS HE 2 R PRESS	PSIA	2970	3150	2970	3150				X		X
GP0718T	APS FUEL TEMP	°F	60	80	--	--				X		
GP1218T	APS OX TEMP	°F	60	80	--	--				X		
GP1501P	APS FUEL PRESS	PSIA	120	190	120	190				X		X
GP1503P	APS OX PRESS	PSIA	120	190	120	190				X		X
	DESCENT PROPULSION SYSTEM											
GQ3015P	DPS START TANK PRESS	PSIA	1450	1750					X	X		
GQ3018P	DPS HE REG PRESS	PISA	40	60					X	X		
GQ3025P	DPS HE REG PRESS	PSIA	40	60					X	X		
GQ3435P	DPS HE PRESS	PSIA	600	800					X	X		
GQ3603Q	DPS FUEL 1 QTY	PCT	55	96				X	X	X		
GQ3604Q	DPS FUEL 2 QTY	PCT	55	96				X	X	X		
GQ3611P	DPS FUEL PRESS	PSIA	120	250	120	250			X	X		X
GQ3718T	DPS FUEL 1 TEMP	°F	60	80					X	X		
GQ3719T	DPS FUEL 2 TEMP	°F	60	80					X	X		
GQ4103Q	DPS OX 1 QTY	PCT	55	96				X	X	X		

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TABLE I-TM vs RTCC LIMITS - Concluded

DESCENT PROPULSION SYSTEM		UNITS	OPR. LIMITS (1)		CRIT LIMITS (1)		ENABLE/DISABLE CATEGORIES					
							LAUNCH LIMITS	COAST LIMITS	ABORT STAGED LIMITS	ALL CONTROL	LUNAR SURF CRIT	ALL CNTRL CRIT
			LOW	HIGH	LOW	HIGH	6	7	8	LEMCATCON	10	LEMCRTCON
GQ4104Q	DPS OX 2 QTY	PCT	55	96				X	X	X		
GQ4111P	DPS OX PRESS	PSIA	120	250	120	250			X	X		X
GQ4218T	DPS OX 1 TEMP	°F	60	80					X	X		
GQ4219T	DPS OX 2 TEMP	°F	60	80					X	X		
GQ6806H	VAR INJ ACT POS	PCT	10	75				X	X	X		
LEM5801C	APS FUEL FLOW RATE	LBS/SEC	3.8	4.8						X		
LEM5802C	APS OX FLOW RATE	LBS/SEC	6.5	7.3						X		
LEM5602C	SP THRUST ERR	--	-4	+4				X	X	X		
LEM5601C	THRTL ERR	--	-4	+4				X	X	X		
REACTION CONTROL SYSTEM												
GR1085Q	RCS PROP A QTY	PCT	95	105						X		
GR1095Q	RCS PROP B QTY	PCT	95	105						X		
GR1101P	RCS A HE PRESS	PSIA	2950	3150						X		
GR1102P	RCS B HE PRESS	PSIA	2950	3150						X		
GR1201P	RCS A REG PRESS	PSIA	20	60						X		
GR1202P	RCS B REG PRESS	PSIA	20	60						X		
GR2121T	RCS A FUEL TEMP	°F	50	90						X		
GR2122T	RCS B FUEL TEMP	°F	50	90						X		
GR2201P	A FUEL MFLD PRESS	PSIA	20	60	20	60				X		X
GR2202P	B FUEL MFLD PRESS	PSIA	20	60	20	60				X		X
GR3201P	A OX MFLD PRESS	PSIA	20	60	20	60				X		X
GR3202P	B OX MFLD PRESS	PSIA	20	60	20	60				X		X
GR6001T	QUAD 4 TEMP	°F	120	190						X		
GR6002T	QUAD 3 TEMP	°F	120	190						X		
GR6003T	QUAD 2 TEMP	°F	120	190						X		
GR6004T	QUAD 1 TEMP	°F	120	190						X		
LEM 5429C	RCS CALC A PROP QTY	PCT			36	105						X
LEM 5430C	RCS CALC B PROP QTY	PCT			36	105						X

(1) LIMIT VALUES SHOWN ARE INITIALIZED VALUES.

(2) THESE PARAMETERS ARE SAMPLE AND HOLD ONLY, REF PARA C.2.C.

(3) LIMIT SENSED PARAMETERS ARE SHOWN FOR PLSS 1 ONLY. IDENTICAL LIMIT SENSING IS DONE FOR PLSS 2.

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SCP NO. GEN 1-3

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: C. L. Gruby
APPROVAL: James E. Hannigan

TITLE: D/TV DISPLAY DISCIPLINE

PURPOSE: The SCP establishes D/TV Display discipline rules for all MOCR and SSR positions.

PROCEDURE:

A. Prelaunch

Displays which are necessary to monitor prelaunch OCP's and consumables loading may be locked on by the SSR consoles.

B. Prepass

All displays required for pass-time activities will be locked on by SSR consoles at a time no later than H-5 minutes. MOCR personnel will always be advised by SSR as to which TV channels and displays are being used.

C. Postpass

All displays will be released during periods when incoming data is not being processed except when history displays are required for trend analysis.

SCP NO. GEN 1-4

S/C: LM
DATE: 6/20/69
REV: PCN-2
ORIGINATOR: C. L. Gruby
APPROVAL: James E. Hannigan

TITLE: TREND PLOTTING

PURPOSE: This SCP establishes ground rules for trend plotting.

PROCEDURE:

A. Trends will be plotted on yellow or green graph paper of a suitable size and scale so as to be readable on an opaque televiewer.

B. Actual values will be plotted with a dashed line.

C. Nominal values will be plotted with a solid line.

D. Data points will be enclosed in a circle.

E. The subsystem engineer should be able to explain any delta in data points from the predicted nominal data points.

F. Trends plotted for opaque televiewer presentation will be plotted for time spans of 15 minutes or longer.

G. At LOS of any site or series of overlapping sites, the trends will be updated within 5 minutes for FD or MOCR briefing.

H. Trend plots will normally be made for the following:

1. RCS Prop Usage
2. RCS Quad Temp
3. SHe Press
4. DPS Prop Usage
5. APS Prop Usage
6. Asc O_2 Qty
7. Des O_2 Qty
8. Asc H_2O Qty
9. Des H_2O Qty
10. Total Amp-Hrs Remaining Asc and Desc
11. Total Amp-Hrs Remaining (PLSS 1 and 2)
12. Mass of O_2 Remaining (PLSS 1 and 2)
13. Feed H_2O Remaining (PLSS 1 and 2)

I. The three available TV channels are:

1. 0058 Life Sys Opaque TV
2. 0064 Veh Sys Opaque TV (PLSS)
3. 0065 Veh Sys Opaque TV

SCP NO. GEN 1-5

S/C: LM
DATE: 10/27/69
REV: PCN-3
ORIGINATOR: L. Bourgeois
APPROVAL: James E. Hannigan

TITLE: **SHIFT CHANGE**

PURPOSE: The SCP defines the LM systems shift change procedures and contents of the briefing and associated documentation.

PROCEDURE:

A. Reporting Time

1. Prelaunch - the launch team members will be at their respective consoles for shift change briefing at T - 3:00 hours. Console handover will occur no later than T - 2:00 hours.
2. Routine - the relieving team will be at their respective consoles no later than one hour prior to the shift change.

B. Documentation

1. Console log books
2. TM history tables
3. Systems computer program printouts
4. Information relative to planning mission changes

C. Contents

1. Present vehicle status
   a. Switch/circuit breaker configuration
   b. History of vehicle anomalies
   c. Consumable status and lifetime capability
   d. MCC, ALDS, and MSFN support constraints, including console status
   e. Any other data pertinent to mission progress

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D. Procedure

1. Retiring AFD will summarize mission activities, completed and planned, and give the brief on the vehicle(s) status in general.
2. Relieving team members will review the documentation.
3. Retiring team members will brief their counterparts in detail.
4. MOCR operators will in general brief the Flight Director to insure a common understanding.

SCP NO. GEN 1-6

S/C: LM
DATE: 10/27/69
REV: PCN-3
ORIGINATOR: L. Bourgeois
APPROVAL: James E. Hannigan

TITLE: **STATUS LIGHTS**

PURPOSE: The purpose of this procedure is to define Vehicle Systems SSR and MOCR usage of the Status Lights at their respective consoles.

PROCEDURE:

A. Each TELMU/CONTROL MOCR and SSR console position has three status lights: red, yellow, and green. When the TELMU or CONTROL SSR position depresses his status light button, the same light in the TELMU or CONTROL position will illuminate respectively. Similarly, if any MOCR position depresses any one of his console, the respective light on the Flight Director's console will illuminate. If the MOCR flight Controller depresses the red status light, it illuminates the abort light event on all consoles.

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B. Meaning of the Status Lights:

1. RED Status Light - Indicates an abort type situation or a problem has arisen requiring immediate action.
2. AMBER Status Light - Indicates a problem (not abort) situation which may or may not require action.
3. GREEN Status Light - Indicates that all systems are functioning properly (no problems).

C. Usage of Status Lights:

1. MOCR and SSR will use the appropriate status lights when LM problems warrant as described in Paragraph B.
2. Status lights will also be used as a status check upon direction from the Flight Director/TELMU/CONTROL as the case may be.

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3. Normally the depression of any status light due to a S/C problem will be followed with a short discussion or narrative on the communications loop between the personnel involved.
4. If the requirement exists for immediate communications between the SSR and the respective MOCR position (TELMU/CONTROL), the SSR may use the Amber light to flag the MOCR TELMU/CONTROL.
5. The **amber light** will be used by the SSR to indicate to the MOCR that the console is not manned.

SCP NO. GEN 1-7

This SCP deleted by PCN-8
(See FCOH SOP 6.3 for comm loop usage)

SCP NO. **GEN 1-8**

S/C: LM
DATE: 3/1/72
REV: PCN 12
ORIGINATOR: R. D. Legler
APPROVAL:

TITLE: **LM TM PLAYBACK PROCEDURES**

PURPOSE: This procedure defines the method for LM TELMU and CONTROL to initiate tape playbacks of real-time and dump data from MCC, CIF, and MSFN sites. P-3

CAPABILITIES: A. Data Sources:

1. MCC facilities have the capability of processing:
   a. Individually:
      (1) Real-time data (live data from spacecraft).
      (2) Tape playback data (playback of real-time data from ground recorder).
      (3) Dump data (playback of data from onboard recorder).
      (4) Dump playback data (playback of dump data from ground recorder).
   b. Simultaneously:
      (1) Real-time data and tape playback data.
      (2) Real-time and dump data.
      (3) Real-time data and dump playback data.
2. MSFN facilities have the capability of processing and outputting data in 2.4 kbps formats. Two 2.4 kbps formats may be interleaved into a 4.8 kbps format: P-12
   a. HBR Data:
      (1) 51.2-kbps data real-time. P-5
      (2) 51.2-kbps data tape playback.
   b. LBR Data:
      (1) 1.6-kbps data real-time.
      (2) 1.6-kbps data tape playback.
      (3) 1.6-kbps data during dump from CSM at 51.2-kbps rate (32:1).
      (4) 1.6-kbps data during dump from CSM at 12.8-kbps rate (8:1).
      (5) Dump playback data at 32:1, 8:1 or 1:1.

   NOTE: When dump data are processed at the 51.2-kbps rate (32:1), displays will be updated each second; however, this corresponds to 32-second intervals of actual recorded data. Correspondingly when processing 12.8-kbps rate data each display update would be at 8-second intervals of recorded data. (Two hours of recorded data could be observed in 3.75 minutes at 32:1 and in 15 minutes at 8:1.)

B. Displays (see Table 1, Display Matrix) - The following options exist to control the display capability:

1. Remoted Site -
   a. Insert playback bit in individual vehicle status words by selecting the proper PCM ground station format.
   b. Insert dump bit in individual vehicle status words by selecting dump data on the PCM ground station priority switch.

   NOTE: If either of these bits are set, the data will be sent on the HSD line that was selected for dump data and in turn appear in CCATS "X" input buffers. CCATS may select these data to drive the PCM ground station with associated analog recorders, event lights and SPC GT0441 (MAP) event pens. These data will drive playback D/TV displays and playback driven special processing; however, they will not drive the real-time D/TV displays and real-time special processing. They may also be selected by Computer TM to drive event lights including limit sensed lights and event pens. P-5
2. CCATS -
   a. Insert playback bit to RTCC. Same capabilities in RTCC as if playback bit is set at remoted site.
   b. Select real-time or playback/dump data to drive the PCM ground station with associated analog recorders, event lights and event pens.

c. Select real-time and/or playback/dump data to drive RTCC.

d. Select HSD format 30 (subformats) to drive the dedicated analog recorder. P-5

e. Use FM/FM Voice/Data line for FM/FM contingency groups to drive the dedicated recorder.

f. Change the parameters on analog recorders 20L and/or 33R using "MEDable" capability with precut tapes or individual manual entry. P-12

3. RTCC -

Select real-time or playback/dump data to drive event lights including limit sensed lights, and all LM event recorder pens except for SPC GT0441 (MAP).

NOTE: Playback data, dump data, or dump playback could be processed without setting these bits at remoted sites or CCATS; therefore, the data would be treated entirely the same as real-time data. However, special computations, which are normally updated by real-time data only, will be updated by the playback data unless they are disabled by some manual means, that is, SMEK or MED. Conversely, any special computation which is normally updated by playback data only, will not be updated in this mode. P-5

TABLE 1 - DISPLAY MATRIX

TYPE OF DATA WITH OPTIONS	RTCC DRIVEN DISPLAYS					GROUND STATION DRIVEN DISPLAYS**
	RT D/TV	P/B D/TV	ALL EVENT LIGHTS AND EVENT PENS*	RT SPEC PROC	P/B SPEC PROC	ANALOG RECORDERS, EVENT LIGHTS
Real-time data	X		X	X		X
Tape playback (neither bit set at remoted site or CCATS)	X		X	X		X
Tape playback (bit set at remoted site)		X	X		X	X
Dump or dump playback (bit set at remoted site)		X	X		X	X
Tape playback (playback bit to RTCC set by CCATS)		X	X		X	X

*Event lights, both discretes and limit sensed, and RTCC driven event pens may be driven by real-time or playback/dump as selected by Computer TM. The only event pens driven by the PCM ground station are the two using SPC GT0441 (MAP). P-5

**The PCM ground station with associated displays may be driven by real-time or playback/dump as selected by CCATS TM.

NOTE

It should be recognized that some of the LM parameter pens, on the same event recorder, could be driven by real-time data while other pens are driven by playback/dump data. This is also true of event lights on the same panel.

C. The following is a list of special calculations and data source:

Amp-Hour Calculations	HS and P/B
Current Summations	HS and P/B
Descent/Ascent Oxygen Quantities	HS and P/B
Descent/Ascent Water Quantities	HS and P/B
Oxygen/Water Flow Rates	HS and P/B
APS $\dot{\omega}$ FU	HS and P/B
APS $\dot{\omega}$ OX	HS and P/B

APS FU Remaining	HS Only
APS OX Remaining	HS Only
T_b FU Remaining	HS Only
T_b OX Remaining	HS Only
APS FU Used	P/B Only
APS OX Used	P/B Only
RCS A&B Nominal FU Quantity	HS Only
RCS A&B Nominal OX Quantity	HS Only
DPS 1&2 OX Quantity	HS and P/B
DPS 1&2 FU Quantity	HS and P/B
LM Vehicle Weights	HS and P/B

PROCEDURE:

A. Determine which displays are required and select options accordingly.

B. Complete a MCC Data Request Form and submit this request to PROCEDURES. P-12

C. Select desired time source for analog recorder right-hand timing pen. Generally, this would be LM elapsed GMT (LMEGMT) for real-time pass tape playback and MET for a dump playback.

D. Select appropriate D/TV display format(s).

E. PROCEDURES will coordinate the playback with other applicable MOCR personnel and relay the necessary information to TIC. TIC will coordinate the playback and notify PROCEDURES when he is ready to begin the playback. PROCEDURES will then notify the originator. P-5

F. Subsequent to the completion of the playback, TIC will report to PROCEDURES when the system is ready to process real-time data again.

SCP NO. GEN 1-9

This SCP is deleted
by PCN-6

S/C: LM
DATE: 3/1/72
REV: PCN 12
ORIGINATOR: D. Whittle
APPROVAL: James E. Hannigan

SCP NO. **GEN 1-10**

TITLE: RUBBER PLOTS

PURPOSE: To define rubber plot capabilities and change procedures.

PROCEDURES: A. A series of paper tapes have been generated by computer TM to allow fast callup of predetermined rubber plots. The tapes presently defined are as follows:

TELMU TAPE I

MSK	UP NO.	TITLE	PLOT TIME
1053	28	Suit/Cab/PGA Press	15 min
1054	29	LM Glycol Temps	15 min
1055	30	LM CO_2 PP & DES O_2 P	9 hrs
1056	31	DES H_2O P & Qty	9 hrs
1057	32	Total Current	15 min
1058	33	Bat 1 - 4 Currents	3 min
1059	34	Bat 5 - 6, Bus Currents	3 min

TELMU TAPE II

MSK	UP NO.	TITLE	PLOT TIME
1055	30	PLSS Bat Cur/Volts	12 min
1056	31	PLSS H_2O Press/ΔT	12 min
1057	32	PLSS 1 T vs ΔT	45 min
1058	33	PLSS 2 T vs ΔT	45 min
1059	34	POS P and CO_2 PP	3 hrs

P-11

TELMU TAPE III

MSK	UP NO.	TITLE	PLOT TIME
1055	30	LM CO_2 PP & ASC O_2 P	6 hrs
1056	31	ASC H_2O P & Qty	6 hrs

TELMU TAPE IV

MSK	UP NO.	TITLE	PLOT TIME
1430	4	ECA 1 & 2 TEMPS	15 hrs

P-12

CONTROL TAPE I

MSK	UP NO.	TITLE	PLOT TIME
1180	35	DPS/APS TCP and GDA	15 min
1181	36	DPS/APS Helium Plot	9 min
1182	37	Percent Margin Plot	15 min
1183	38	PQGS Projection Program	N/A
1184	39	Accum on Time	15 min
1185	40	RCS Qty	15 min
1186	41	RPY PGNS/AGS ERRS	15 min

CONTROL TAPE II

MSK	UP NO.	TITLE	PLOT TIME
1180	35	DPS/APS TCP and GDA	15 min

CONTROL TAPE III

MSK	UP NO.	TITLE	PLOT TIME
1181	36	DPS/APS Helium Plot	9 min

CONTROL TAPE IV

MSK	UP NO.	TITLE	PLOT TIME
1182	37	Percent Margin Plot	15 min

CONTROL TAPE V

MSK	UP NO.	TITLE	PLOT TIME
1183	38	PQGS Projection Program	N/A

CONTROL TAPE VI

MSK	UP NO.	TITLE	PLOT TIME
1184	39	Accum on Time	15 min

CONTROL TAPE VII

MSK	UP NO.	TITLE	PLOT TIME
1185	40	RCS Qty	15 min

CONTROL TAPE VIII

MSK	UP NO.	TITLE	PLOT TIME
1186	41	RPY PGNS/AGS ERRS	15 min

CONTROL TAPE IX

MSK	UP NO.	TITLE	PLOT TIME
1183	38	APS ΔV	9 min

P-6

CONTROL TAPE X

MSK	UP NO.	TITLE	PLOT TIME
1184	39	ACCEL DRIFT	15 min

P-12

B. Premission generation of additional tapes or changes to present tapes should be forwarded to Ron Mayes, X3212, FS5. Tape generation or change should be done using the TM System Plot Change form (see Figure 1).

C. When changing a tape's contents or reading in a new tape, only those MSK numbers called out by the change or new tape will be affected. In other words, plots from previous tapes, whose MSK numbers are not specifically called out for change, will continue to plot as normal. Similarly, when changing a single MSK plot, only those items called out will be changed. Therefore, parameters previously assigned to that MSK will continue to plot unless specifically deleted or changed.

D. The "S/C" and "GND" times displayed on the rubber plots will be a function of what vehicle parameter is selected for the X axis of the plot. The following table lists time as function of vehicle selection.

X AXIS VEHICLE	GND	S/C
AMD	MGET	N/A
LM	LEM7802C	GL0501
AGS	AGS4103C	GI0001 X 4323
LGC	LGC4103C	LTIME2 TIME1

P-6

Any one of the GND or S/C times may be selected as the X - axis parameter. For EVA simulations where no LM time is available LEMGMTR can be used to run the plots.

P-12

E. Real-time changes to rubber plots are made on the TM System Plot Change form and sent to Computer TM at P-tube Station 31. These real-time changes are not permanent changes to individual tapes, but must be cleared through the appropriate MOCR position. Responsibility for initialization of plots will be as follows:

1. TELMU - All plots containing ECS parameters will be initialized from console 21 plots containing EPS parameters will be initialized from console 30. Console 9 has the capability to initialize all TELMU plots.

2. CONTROL - All control plots will be initialized from console 29.

Existing rubber plot allocations are as follows:

MSK #	
34	FDO
35	FDO
36	FDO
653	CSM
↓	CSM
671	CSM
1053	LM*
↓	LM*
1059	LM*
1180	LM*
↓	LM*
1186	LM*
1430*	BOOSTER
1431*	BOOSTER
1432	BOOSTER
1433	BOOSTER
1711	AMD
1712	AMD

P-12

* Console 30 rubber plot SMEK capability.

F. To load a tape, simply call Computer TM on the RTCC TLM loop and request the tape by its defined name (i.e., Telmu Tape I, or Control Tape I, etc.).

G. Computer TM can start plots for which a console has no SMEK start capability. P-12

TM SYSTEM PLOT CHANGES

FROM: PLSS 1 (Console Pos.)

TO: COMPUTER TM

DATE: _____

P-TUBE STA: 31

TIME: _____ (GMT)

COMM LOOP: RTCC TLM

MSK: 1055

V15:	VEH	SCALE (L,R)	PARAMETER RTCC EXTERNAL NUMBER	V17: LABEL
Y1 (×):	LM	R	GT8141V	PLSS 1 BAT V
Y2 (○):	LM	R	GT8241V	PLSS 2 BAT V
Y3 (+):	LM	L	GT8140V	PLSS 1 BAT C
Y4 (△):	LM	L	GT8240V	PLSS 2 BAT C
X T :	LEM		LEM7802C	("T" after X if time plot)

V16: UPDATE RATE(UR): 4 SEC. (Length in Min = 3 • UR)

	SCALE VALUES EU MIN	EU MAX	
YR :	12.0	22.0	
YL :	0.0	10.0	("D" if single scale plot)
X :			(Blank if time plot)

NOTES:

1. Underlined spaces left blank will assume the previously defined values except as noted above.
2. To delete a parameter, scale, or label use "D."
3. Decimal placement of the intermediate scale values will be determined by the format of the upper (or rightmost) bound (e.g., a scale of 0 to 3.333 will result in intermediate values of X.XXX).

NASA — MSC

FEC/TSG Form 438

Figure I. - TV system plot change form

SCP NO. **GEN 1-11**

S/C: LM
DATE: 3/1/72
REV: PCN 12
ORIGINATOR: R. Legler
APPROVAL: James E. Hannigan

TITLE: **TELEMETRY DATA FLOW**

PURPOSE: The data flow diagram and description contained in this SCP, although greatly simplified, will provide an outline of the basic capabilities of the ground data systems.

FACILITIES:

A. KSC

1. The data sources for the Central Instrumentation Facility (CIF) are:
   a. MIL - A USB site with video lines to the CIF.
   b. Pad Hardline - A video hardline from the vehicle to the CIF via the MSOB.
   c. CIF USB Site - The CIF has a 3-foot antenna on the roof with video lines to the receivers.

2. The CIF has facilities to discriminate the video data, decommutate in Data Core and route the reformatted data to ALDS. CIF has the capability to route video data to MIL for processing into the 2.4 Kbps HSD format.

3. The ALDS portion of the KSC facilities receives the data from Data Core, processes it into a 40.8 Kbps format for direct transmission to MCC.

   The ALDS/CCATS format contains the following characteristics:
   a. 40.8 kbs
   b. 10 bits/word (8 MSB's data, 2 LSB's zeros)
   c. 204 words/frame
   d. 20 frames = 1 data cycle
   e. 1 data cycle/sec
   f. Data is transmitted MSB first
   g. Available sample rates are 1, 2, 4, 5, 10, 20, 40, 60 s/s
   h. Bit 1 = MSB

   The first 16 words of each frame are reserved for synchronization pulses, a frame counter, a format status label and the vehicle status words.

B. Remoted Site

1. The S-band frequencies are received by 30-foot, 85-foot, or 210-foot S-band antennas and routed to the USB receivers which strip out the video consisting of various subcarriers. The PCM information on the 1.024-MHz subcarrier is demodulated and routed to the PCM ground station via the Decommutator Systems Distribution Unit (DSDU). The PCM ground station decommutates the serial bit stream and reformats the PCM data into 30-bit words, which are outputted in parallel to the RSTC. The RSTC processes and reformats the data for output on the dual 2.4 Kbps lines to GSFC. The PLSS PAM FM/FM parameters are discriminated and digitized before being routed to the RSTC. The biomed data may be routed to MCC via the voice data lines or via the 2.4 Kbps lines. When routed via the voice data lines, the biomed data is discriminated and routed to a bank of Voltage Control Oscillators (VCO's). The outputs of the VCO's are mixed and transmitted to MCC via GSFC or the voice data lines. Alternately, the biomed data is discriminated and routed to a Analog Multiplexer Quanitizer (AMQ) where the data is digitized and routed to the RSTC. The biomed data is formated into a 4.8 KBIT format for transmission to GSFC on a 4.8 Kbps line. P-12

2. The high-speed data (HSD) format contains the following characteristics:
   a. 2.4 Kbps
   b. 8 bits/word
   c. 300 words/frame
   d. 10 frames/data cycle
   e. 1 data cycle/10 secs
   f. Data is transmitted LSB first
   g. Available sample rates are .1, .2, .5, 1, 2, 5, and 10 s/s
   h. Bit 1 = MSB

Two 2.4 KBIT formats are interleaved to form one 4.8 KBIT format. P-12

The remoted sites have the capability to transmit groups of eight parameters over the voice/voice/data lines. Biomed data is also transmitted over these voice/data lines.

C. GSFC

The 2.4 and 4.8 Kbps data rmats from the remoted sites are received at GSFC, examined for proper sync, processed in the GSFC 494 communications processor (CP) and reformatted into five 600-bit segments. Each 600-bit segment consists of 480 data bits and 120 overhead bits which are for synchronization, source and destination, format code, message counts and status, error-code control and control bits. The telemetry and tracking formats are combined into a 50.0 Kbps format and transmitted to MCC over dual lines. One line is designated as the primary line which will handle up to 16 TLM/TRK formats, and any excess formats are placed on the second, or overflow, 50.0 Kbps line. P-12

D. MCC

The wide-band data is received at MCC and is converted from a serial bit stream to parallel data by the polynomial buffer terminals (PBT's) or communication line terminals (CLT) and routed to the CCATS communications processor (CP). The CP decommutates, repacks, converts some analogs to percent full scale, performs some truncation, and routes wide-band data to the RTCC and PCM ground stations. There are four interchangeable PCM ground stations - two are required for systems engineering data, one for biomed data and one is a spare. P-12

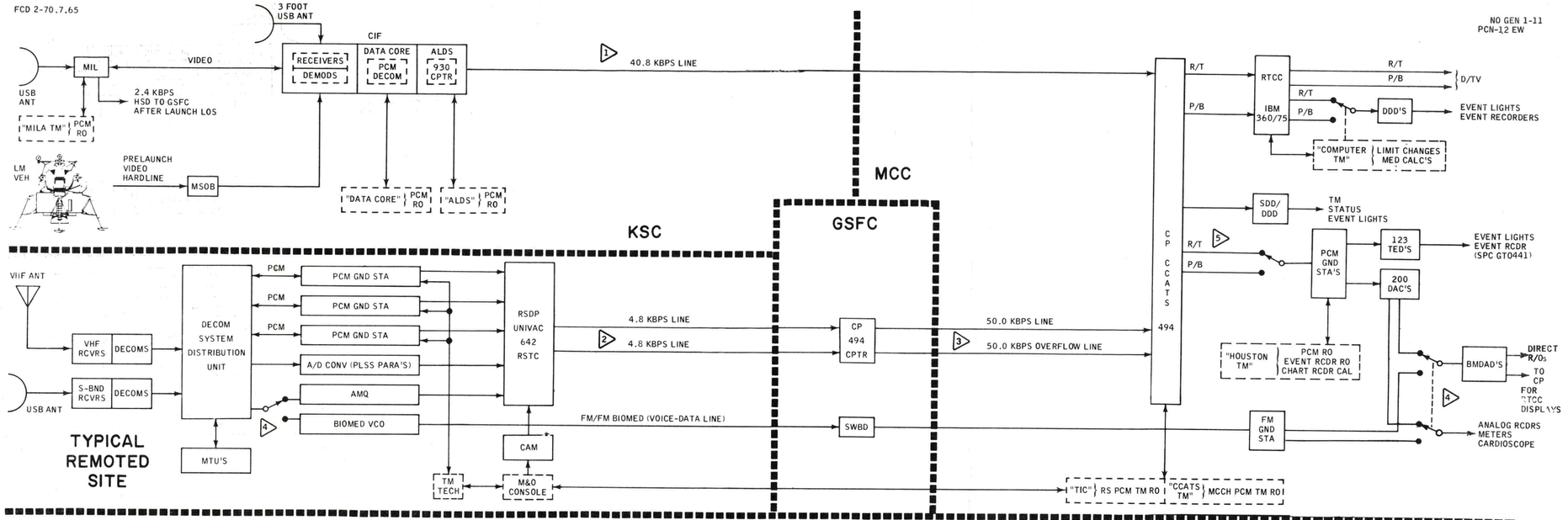
CCATS has the capability to route either real-time or playback data to the PCM ground stations; hence, the analog chart recorders and TED event lights and meters may be driven by either type of data. The only pen on event recorder number 3, which is driven via the ground station, is SPC GT0441. This is the MAP special processed word. The capability to select either real-time or playback data to drive the ground station is vehicle oriented; hence, the data source can be selected independently for each vehicle.

The analog recorder formats, with the exception of the dedicated recorder, and the MEDable chart recorders may be changed by selection of a specific PCM ground station format. LM data is routed to the analog recorders in ground station formats IV, V, VI, VII of tape 4. P-12

After launch, recorders 20L and 33R are released and a MEDable capability exists to change the parameters on these two recorders. The parameters may be changed individually or in 8 parameter groups. CCATS TM manually types in the individual parameters or reads in pre-cut tapes for the groups. The LM data groups are 21A-27A for recorder 20L and 21B-26B for recorder 33R. P-12

One of the dedicated recorder capabilities is the high-speed data format 30, which is in reality a number of subformats. Each subformat may contain the following: Four 50 s/s analogs, four 10 s/s analogs, seven 10 s/s bilevels, and two timing sources. The LM data is in subformats 31-47. Each subformat may be selected by TIC, but one of the regular HSD formats must be released to accomodate it. The FM/FM contingency format requirements were deleted by LSB. P-12

Real-time and playback data may be routed to the RTCC simultaneously. Real-time data will be displayed on real-time D/TV and computations only, and playback data on playback D/TV and computations only. However, real-time or playback data may be selected by computer TM to drive MOC driven event lights and event recorders.



TYPICAL REMOTED SITE

1. ALDS
   40.8 KBPS
   10 BITS/WORD
   8 MSB'S DATA
   2 LSB'S ZERO
   204 WORDS/FRAME
   FIRST 16 WORDS HEADER
   LAST 188 WORDS DATA
   20 FRAMES/DATA CYCLE = 1 DATA CYCLE/SEC

2. HSD LINES
   2.4 KBPS
   10 BITS/WORD
   300 WORDS/FRAME
   FIRST 20 WORDS AND LAST WORD OVERHEAD
   OTHER 279 WORDS DATA
   10 FRAMES/DATA CYCLE = 1 DATA CYCLE/SEC
   TWO 2.4 KBPS FORMATS ARE
   INTERLEAVED TO FORM ONE 4.8 KBPS
   FORMAT.
   BIOMED DATA MAY BE TRANSMITTED
   IN A FCM 4.8 KBPS FORMAT OR
   VIA BIOMED FM/FM LINE.

3. 50.0 KBPS
   5-600 BIT BLOCKS/EACH HSD FMT
   120 BITS OVERHEAD (FIRST 60 AND LAST 60 BITS)
   480 BITS DATA
   UP TO 16 TM OR TRK FMTS ON ONE LINE
   1 TRK FMT = 1 TM FMT

4. CAPABILITY EXISTS TO TRANSMIT
   LM BIOMED DATA VIA 4.8 KBPS
   DIGITAL LINE OR VIA FM/FM LINES.

5. CAPABILITY TO DRIVE PCM GND STATIONS BY
   R/T OR P/B IS VEHICLE SPECIFIC.

6. MTU MAGNETIC TAPE UNIT
   SDD SUBCHANNEL DATA DISTRIBUTOR
   DDD DIGITAL DISPLAY DRIVER
   R/T REAL TIME DATA
   P/B PLAYBACK DATA
   BMDADS BIOMED DATA ANALYSIS AND DISPLAY SUBSYSTEM
   TED TELEMETRY EVENT DRIVER

BITS

WHOSE CONFUSED ! ! !

REMOTE/REMOTED SITE EMR GND STN ADDRESSES DIFFER FROM LSH PCM ADDRESSES

RULE: SUBTRACT 3 FROM LSH CH NUMBER TO OBTAIN GND STN CH NUMBER. FRAME NUMBER REMAINS THE SAME EXCEPT FOR LGC WORDS. SUBCOM NUMBER IS DETERMINED AS FOLLOWS:

50, 100, 200 S/S = 0 — 1 S/S = 1 — LGC = 2 — 10 S/S = 4

EXAMPLE: GH1214 APPEARS IN CH/WD 98, FR 29, BIT A
EMR ADD: CH 95, FR 29, SUBCOM 1, BIT 1 (95-29-1 BIT 1)

WD/CH 98 FR 29

NEW (GAEC) *BIT NO (LSH) INTERIM OLD (CSM)	A	B	C	D	E	F	G	H
	8	7	6	5	4	3	2	1
	1	2	3	4	5	6	7	8
R/S EMR ADDR	1	2	3	4	5	6	7	8

M S B CH 95 FR 29 B — M S B CH 95 FR 29 B — L S B

*NEW = LED 360 - 318
INTERIM = LSH REV A
OLD = ORIGINAL

REG A (1) — REG B (2)

BIT NO LGC NEW INTERIM	WD/CH 121								WD/CH 122								WD/CH 123								WD/CH 124								WD/CH 125							
	WD	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	P	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	P	GARBAGE							
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1
	M S B		CH 118					L S B	M S B		CH 119					L S B	M S B		EXAMPLE					L S B	M S B		CH 120					L S B	M S B		CH 121					L S B	M S B		CH 122					L S B
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8

LGC WORDS: RULE: SAME AS ABOVE, EXCEPT FRAME NUMBER MUST BE REDUCED BY 1

EXAMPLE: DAPBOOLS BIT 11, DAP ENABLED IS LGC WORD 40 REG 2 (40B) APPEARS IN PCM CH 123, FRAME VARIABLE, BIT F.
EMR ADDRESS: CH 120, FR 39, SUBCOM 2, BIT 6, (120-39-2 BIT 6)

EMR AND DYNATRONICS GND STNS
R/O BIT 1 = MSB
BIT 8 = LSB
MSFT 1 = EMR
MSFT 2 = DYNATRONICS

DISPLAY MATRIX

		RTCC DRIVEN			GROUND STA	
		R/T D/TV	P/B D/TV	EL AND ER	AR	EL
DATA	R/T	X		2	1	1
	TAPE P/B (SET AT R/S)		X	2	1	1
	DUMP (SET AT R/S)		X	2	1	1
	P/B OR DUMP (NO SET BIT)	X		2	1	1
	P/B OR DUMP (SET AT CCATS)		X	2	1	1

X = DRIVEN
1 = SELECTABLE BY CCATS
2 = SELECTABLE BY RTCC

LM LBR DATA RECORDED ON CSM DSE

1. RECORD SPEED DETERMINED BY CSM BIT RATE
   A. CSM HBR = 15 INCHES/SEC (30 MIN MAX)
   B. CSM LBR = 3 3/4 INCHES/SEC (2 HR MAX)
2. CAN PLAY BACK ONLY ONE VEHICLE AT A TIME
3. LM DATA ALWAYS DUMPED AT 120 INCHES/SEC
   ∴ R/T MONITORING OF DUMP DATA IS 32/1, 8/1 OR 1/1, DEPENDING ON RECORD SPEED
4. CAN BE PLAYED BACK NON-R/T AT 32/1, 8/1 OR 1/1

SCP NO. CSM - A17
REF: LM GEN 1-12

S/C: LM/CSM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: J. J. Kelly
CSB APPROVAL: C. L. Dumis
LSB APPROVAL: J. E. Hannigan

TITLE: Loss of CSM Cabin Integrity with LM Available

PURPOSE: To provide procedures and guidelines for systems management in the event the CSM cabin integrity is lost. It is assumed that all efforts to restore cabin integrity have failed. This failure has two modes: (1) loss of CSM cabin integrity with LM unstaged (descent stage attached) and (2) loss of CSM cabin integrity after LM staging (ascent stage only). The detailed procedures of this SCP have been placed in the CSM crew checklist. Table IV contains the detailed procedures for LM suit loop configuration for initial LM ingress.

Mission Planning - LM Unstaged: The LM, with its descent stage consumables, will provide a long-term habitable environment for the crew. For the purpose of this SCP, it is assumed that all crew members will ingress to the LM where they will stay after a minimum CSM reconfiguration, and transferring any necessary supplies. The LM will perform all MCC's and crew support up to EI-8 hours. Table II lists the CSM supplies which should be transferred prior to pressurizing the LM.

Mission Planning - LM Staged: After LM staging, the ascent stage has meager consumables remaining. If the decision is made to keep the ascent stage, the crew will stay hardsuited in the CSM with the LM providing at least one rest period for the entire crew. This allows 0.5 lbs of oxygen in the LM ascent tanks for the final IVT (see Table I). Table II lists the CSM supplies which should be transferred prior to pressurizing the LM.

If the ascent stage is manned when CSM cabin integrity is lost, the LM will be powered down until the rest period is required.

In the event the ascent stage is unmanned when CSM cabin integrity is lost, the LM will remain powered up (35 amps) until after TEI when the LMP will ingress the LM and power it down. MCC will isolate all LM jets via uplink to prevent the LM from fighting CSM attitude control.

General OPS Information:

1. There are two OPS, each containing 5.78 lbs. of O_2 at 5,880 psia. Each OPS has a gauge reading from 0 to 6,000 psia, divided into increments of 1,000 psia.

2. When connected to the CMP's suit, the OPS has to be used in the "purge mode" to remove body heat and CO_2. To use the OPS in this mode, the OPS is connected to the suit inlet and the purge valve is connected to the suit outlet.

3. The suit purge valve has two flow positions - 7.4 lb/hr and 3.85 lb/hr. This will provide 41 minutes and 83 minutes of total usage, respectively. The 7.4 lb/hr flow rate provides cooling and CO_2 removal while the 3.85 lb/hr flow rate provides CO_2 removal and limited cooling. P-8

4. The OPS cannot be repressurized from the LM, or CSM. P-11

OPS Management: The CMP will perform both IVT's (CSM to LM, then LM to CSM) with use of the OPS and will be assisted during all vacuum transfers by another crewman. Due to the time limitation of the OPS in the "purge mode" operation, each IVT will be started with a full OPS. This will allow sufficient time to complete a transfer should any difficulty arise.

On the initial IVT, the OPS oxygen remaining in that OPS will be used to support LM cabin pressurization. Consequently, for the "Ascent Stage Only" case, the rest time is governed by the amount of OPS oxygen remaining after LM hatch closeout. To increase the rest time to the maximum, i.e., conserve as much oxygen as possible, the OPS should initially be used in the low (3.85 lb/hr) "purge mode" but may be switched to the high (7.4 lb/hr) "purge mode" as required for body cooling. P-8
On the initial transfer, the CMP will use 3.85 lb/hr OPS flow and once in the LM and the hatch is closed, he will place the OPS purge to max flow allowing the LM cabin to pressurize to 3.0 psi. Once the cabin has reached 3.0 psi, the OPS will be turned off and the CMP's helmet removed. The remaining oxygen in that OPS will then be dumped into the LM cabin. LM cabin pressurization will be completed using LM oxygen supply.
Table I shows two LM rest times (Ascent Stage Only) as a function of the two "purge modes" and an assumption that the CMP can complete an IVT within 15 minutes after connecting to the OPS.

CSM System Management with Descent Stage Available: The CSM will be left powered up with the exception of equipment that will be placed to standby or turned off for safety and/or nuisance alarm considerations. The G and N, SCS, ECS suit loop, HGA, C and W, and SM RCS quad heaters fall into this category. If this reconfiguration results in an overvoltage condition, fuel cell 2 will be open circuited. It is assumed there are no CSM failures which would require crew action within a 2-hour period. In the event a CSM ingress is required, the CDR or LMP will perform it using

the PLSS (CMP has no LCG), which can be recharged from the LM O_2 supply. The SCE is placed to Aux to disable its under/overvoltage sensing to prevent loss of EPS telemetry. This would normally occur at an overvoltage of 32.5 VDC as opposed to 35.5 VDC when the SCE is in Aux. The SM RCS heaters are placed to OFF because of the crew response time for a failed "ON" quad heater.

The caution and warning system is powered down to prevent transients from activating the system.

CSM System Management with Ascent Stage Only: The major difference between the ascent stage only and descent stage cases is that the CMC and IMU are left powered in the ascent stage only case.

LM Systems Management - Unstaged: The LM will be powered up to a basic configuration which will supply CO_2 scrubbing, equipment cooling, voice communications, onboard caution and warning and downlink TM (Table III). Since the LM will also perform all MCC's necessary prior to EI-8, any additional equipment will be powered up as required. The LM modularized checklist will be used as the baseline for the crew procedures.

It is not planned to transfer CSM power to the LM because it would be necessary to ingress the CSM to interrupt CSM power prior to powering up the LM. This is to prevent overloading the two LM power circuit breakers on MDC 5 when the LM is powered up for MCC's, etc. Should LM consumable trends project insufficient LM power, the necessary vacuum IVT to the CSM to provide CSM power can be planned in real-time.

LM Systems Management - Staged: With no known requirement to power up the LM beyond the basic configuration, the CSM will be configured to

P-8

power the LM buses via the transfer umbilical. Table III shows the power requirements for the basic configuration, which is just within the 10.8 amp capability of the transfer circuitry. Since removing CSM power requires ingressing the CSM, which cannot be done in this situation, powering up the LM would result in overloading the two LM power circuit breakers. Therefore, if it is known that the LM will be powered up beyond the basic configuration at the time of LM ingress, the LM will be configured for internal power only. P-8

TABLE I

LM REST TIME - ASCENT STAGE CASE

LM O_2 Available

2 OPS's at 5.1 lb. (Usable)	10.2 lb
Ascent Stabe O_2	3.4 lb
(Assumed Quantity Remaining After Normal LM Mission)	13.6

Usage Events	OPS Low Purge Flow (3.85 lb/hr)	OPS High Purge Flow (7.4 lb/hr)	P-8
IVT to LM			
OPS No. 1			
CMP Xfer (15 mins)	0.96 lbs	1.85 lbs	P-8
Available OPS O_2 for LM Press to 3.8 psia (after hatch closure)	4.14 lbs	3.25 lbs	
Ascent O_2 for LM Press to 5.0 psia	1.0 lbs	2.0 lbs	
	6.1 lbs TOTAL	7.1 lbs TOTAL	
Rest Period			
Ascent O_2	1.9 lbs*	0.9 lbs	
LM Cabin Breathed Down to 3.5 psia (Ascent O_2 Off)	1.6 lbs	1.6 lbs	
O_2 Available for Rest Period	3.5 lbs	2.5 lbs	
3.5 lbs at .3 lb/hr (3 men + cabin lkg)	11.6 hours	----	
2.5 lbs at .3 lb/hr (3 men + cabin lkg)	----	8.3 hours	

*0.5 lb ascent O_2 reserved for IVT to CSM

TABLE II

CSM TRANSFER ITEMS

1. Two CM LiOH cartridges
2. Food for three
3. Water bag with water
4. Crew hygiene equipment
   - o Towels
   - o Tissue Dispenser
   - o Urine Bags (empty)
   - o Fecal bags
   - o Medical Kit
5. Coveralls and comm carriers
6. Pens, pencils, scissors, penlights, etc.
7. Tape
8. Plastic bags for CO_2 cannister construction
9. Flight data file documents, contingency procedures, etc.

TABLE III

LM POWER DISTRIBUTION FOR CSM POWER USE

Equipment	LM Bus (Amps) CDR[1]	LMP[1]	
Suit Fan	5.85		
Glycol Pump	1.09		
SCERA 1 & 2	0.45	0.37	P-8
Sig Sensor		0.38	
PCM TEA		0.38	
CWEA		0.41	
S-Band Transceiver		1.29	
PMP		0.15	
Audio Centers	0.15	0.15	
CO_2 Sensor		0.04	
Anun/Dock/Cmpnt		0.07	
Total/Bus	7.54	3.24	P-8

Total LM Current Req for Rest 10.78 Amps.

[1]The CSM will be configured to supply power to the CDR Bus and the LMP Bus will be supplied by LM battery power only.

TABLE IV

LM Suit Loop Configuration

Pnl 16 INST: Sig Sensor - Close

ECS: Disp - Close

Verify Suit Press > 3.6 psia

Pnl 11 ECS: Suit Fan 1 - Close

Pnl 16 ECS: Suit Fan 2 - Close

Suit Fan ΔP- Close

Fwd Dump Vlv - Closed

Press Reg A & B - Egress

Suit Ckt Rlf - Auto

Diverter Vlv - Pull - Egress

Cabin Gas Return - Egress

Des O_2 - Open (Unstaged Only)

Asc 1 O_2 - Open (Staged Only)

Suit Fan - 1

After Crewman Connects to Suit Loop:

Suit Isol Vlv - Suit Flow

TELEMETRY HISTORY REPORT IN FORMATTED TABULATIONS (THRIFT)

1 AGS		1 PGNS		1 PROP	3 ECS	4 EMU	3 EPS
4305 LM TIME LOOPS	4330 ENG ON/OFF LOOP PAGE 1	4405 ATTITUDE - SM	4450 ISS	4200 DPS PROPULSION SHEET NO. 1	4100 LM SUIT LOOP AND CABIN PARAMETERS	4120 PLSS 1 PARAMETERS	4000 LM EPS BAT CURRENT PCT/QD TEMPS
4310 FAIL STATUS LOOP PAGE 1	4331 ENG ON/OFF LOOP PAGE 2	4410 ATTITUDE - FDAI PAGE 1	4455 PIPAS	4201 DPS PROPULSION SHEET NO. 2	4101 LM GLYCOL LOOP AND TEMP PARAMETERS	4121 PLSS 2 PARAMETERS	4001 LM EPS LOAD STATUS NO 2
4311 FAIL STATUS LOOP PAGE 2	4335 AGS DOWNLINK PAGE 1	4411 ATTITUDE - FDAI PAGE 2	4460 GYROS (VOLTS)	4202 DPS PROP PROJECTION PROGRAM	4102 LM OXYGEN SUPPLY PARAMETER		4002 LM EPS VOLTAGES/AC
4315 AGS STATUS PAGE 1	4336 AGS DOWNLINK PAGE 2	4415 RATES - BODY (DEG/SEC)	4465 RR OPERATE	4210 ASC PROPULSION SHEET NO. 1	4103 LM WATER SUPPLY PARAMETERS		4003 LM EPS AMPERE-HOURS
4316 AGS STATUS PAGE 2	4337 AGS DOWNLINK PAGE 3	4420 ERRORS - BODY	4470 RR ANT POS	4211 ASC PROPULSION SHEET NO. 2			4004 LM EPS CURRENT
4320 GDA LOOP	4340 ATCA LOOP	4425 DAP CONFIGURATION	4475 LR - VELOCITY (FPS)	4220 RCS SYSTEM A			4005 LM EPS ASCENT
4325 THROTTLE LOOP	4345 RCS JET TCP LOOP	4430 DSKY	4480 LR ALTITUDE (FT)	4221 RCS SYSTEM B			4006 LM INST TAB
		4435 LGC	4485 DELV/2 SEC	4230 PROPULSION TEMPERATURES			4007 LM EPS BUS CUR BILEVEL INDICATIONS
		4440 CHANNELS (OCTAL)	4490 DELTA V ACCUM/TORQUE TIMES	4240 RCS CONSUMABLES ANALYSIS 2			4008 LM EPS AVERAGE CURRENT
		4445 FLAGWORDS (OCTAL)		4241 PROP CONSUMABLE WT HIST SHEET NO. 1 2			4009 LM EPS BATTERY STATUS/MAL
				4242 PROP CONSUMABLE WT HIST SHEET NO. 2 2			4054 ** LM EPS DES/ ASC/TOTAL AVERAGE CUR
				4243 PROP CONSUMABLE WT HIST SHEET NO. 3 2			

NOTES:

1 UPDATED BY SMEK NO. 71

2 UPDATED BY SMEK NO. 67

3 UPDATED BY SMEK NO. 70

4 UPDATED BY SMEK NO. 79

5 IF A LETTER LISTED BELOW APPEARS TO THE RIGHT OF THE VALUE ON THE THRIFT PRINTOUT, THE CORRESPONDING MOST SIGNIFICANT DIGIT HAS BEEN TRUNCATED, i.e., 0.00E = 50.00

A = 1	D = 4	G = 7	T = 2 DIGITS TRUNCATED
B = 2	E = 5	H = 8	
C = 3	F = 6	I = 9	

6 THRIFT MICROFICHE GROUPINGS: LM TELMU FORMATS 4000-4121, LM PROP FORMATS 4200-4243, LM GNC FORMATS 4305-4490

** DENOTES PLOT - NOT UPDATED BY SMEK

S/C: LM
DATE: 3-1-72
REV: PCR-12
ORIGINATOR: R. Heselmeyer
APPROVAL:

TELMU Formats vs Parameters

ECS

4100 — IM SUIT LOOP AND CABIN PARAMETERS

LEM7802C	GET
GF3571	CAB P
GF1301	SUIT P
GF3591	U/H P
GF3592	F/H P
GF1521	CO2 PP
GF9999	SEP RT
GF4101	H20 ΔP
GF3071	REG A
GF3073	REG B
GF1201	CDR S
GF1202	LMP S
LEM4801L	SUIT RLF
GF1221	S DIV
LEM4802L	CAB RET
GF1241	CO2 SEL
GF3572	REPR ELEC

4101 — IM GLYCOL LOOP AND TEMPERATURE PARAMETERS

LEM7802C	GET
GF2921	SGLY P
GF9997	GLY P
GF2021	GLY ΔP
GF2936	P SW/O
GF9986	GLY LO
GF2531	G IN T
GF2581	G OUT
GF9998	GLY T
GF1281	SUIT T
GF4511	H20 T
GF1651	CAB T
[2]GL8275	RTG/ECA1
GF1083	FAN 1
GF1084	FAN 2
GB0541	MESA T
GB0542	MESA T
[1]GB0543	D2 H_2OT

4102 — IM OXYGEN SUPPLY PARAMETERS

LEM7802C	GET
GF3584	D1 02 P
LEM4602C	D1 02 LB
LEM4601C	D1 02 %
LEM4704C	D1 02 RT
GF0584	D1 02 P
LEM4616C	D2 02 LB
LEM4615C	D2 02 %
LEM4708	D2 02 RT
GF3582	A1 02 P
LEM4604C	A1 02 LB
LEM4705C	A1 02 RT
GF3583	A2 02 P
LEM4606C	A2 02 LB
LEM4706C	A2 02 RT

4103 — IM WATER SUPPLY PARAMETERS

LEM7802C	GET
GF4500	D1 H20 P
LEM4611C	D1 H20 LB
LEM4701C	D1 H20 RT
GF0500	D2 H20 P
LEM4617C	D2 H20 LB
LEM4707C	D2 H20 RT
GF4501	H20 P
GF4502	A1 H20 P
LEM4609C	A1 H20 LB
LEM4702C	A1 H20 RT
GF4503	A2 H20 P
LEM4610C	A2 H20 LB
LEM4703C	A2 H20 RT
LEM11201C	WC H20 RT

EMU

4120 — PLSS 1 PARAMETERS

LEM7802C	GET
GT8168	PGA P
GT8175	CO2 PP
GT8170	O2 T
GT8154	LCGT
GT8196	LCG ΔT
GT8110	FW P
LEM9310C	FW Q
GT8182	POS P
LEM9301C	POS Q
LEM7309C	POS QR
GT8140	CUR
GT8141	VOLT
LEM9304C	A-HR
GT8101	CAL 0
GT8102	CAL 5
GT8100	SYNC

4121 — PLSS 2 PARAMETERS

LEM7802C	GET
GT8268	PGA P
GT8275	CO2 PP
GT8270	O2 T
GT8254	LGC T
GT8296	LCG ΔT
GT8210	FW P
LEM9312C	FW Q
GT8282	POS P
LEM9305C	POS Q
LEM7310C	POS QR
GT8240	CUR
GT8241	VOLT
LEM9308C	A-HR
GT8201	CAL 0
GT8202	CAL 5
GT8200	SYNC

EPS/INST

4000 — IM EPS BATTERY CURRENT PERCENTAGE/ QD TEMPS

LEM7802C	SITE GET
LEM7802C	DEC GET
LEMEGMT	SITE GMT
LEM7401C	BAT 1 PCT
LEM7402C	BAT 2 PCT
LEM7407C	BAT L PCT
LEM7403C	BAT 3 PCT
LEM7404C	BAT 4 PCT
LEM7405C	BAT 5 PCT
LEM7406C	BAT 6 PCT
LEM4501C	TOT CUR
GR6004	QD 1 T
GR6003	QD 2 T
GR6002	QD 3 T
GR6001	QD 4 T

4001 — IM EPS LOAD STATUS NO. 2

LEM7802C	SITE GET
GF2021	GLY ΔP
GF2921	S GLY P
GF9999	H20 SEP
GH1230	A ARM
GP2010	A TCP
GH1348	D ARM
GQ6510	D TCP
LEM4867L	AGS STAT
GG1523	LGC OP
LGC4815L	LR STAT
LEM4866L	RR STAT
GG1513	IMU STBY
GG1201	IMU OPR
GF1462	P RT
LGC1503L	PROGRAM
LTGO	T GO

4002 — IM EPS VOLTAGES/ AC

LEM7802C	SITE GET
LEMEGMT	DEC GMT
LEMEGMT	SITE GMT
GC0201	B 1 V
GC0202	B 2 V
GC0207	B L V
GC0203	B 3 V
GC0204	B 4 V
GC0205	B 5 V
GC0206	B 6 V
GC0302	LMP V
GC0301	CDR V
GC0071	AC V
GC0155	AC F
GH1313	P GDA
GH1314	R GDA
[2]GL8275	RTG/ECA1T

4003 — IM EPS AMPERE-HOURS

LEM7802C	SITE GET
LEM7802C	DEC GET
LEMEGMT	DEC GMT
LEM4401C	B 1 AHC
LEM4402C	B 2 AHC
LEM4425C	B L AHC
LEM4403C	B 3 AHC
LEM4404C	B 4 AHC
LEM4407C	DAH CONS
LEM4405C	B 5 AHC
LEM4406C	B 6 AHC
LEM4408C	AAH CONS
LEM4409C	DAH RMNG
LEM4410C	AAH RMNG

4004 — IM EPS CURRENT

LEM7802C	SITE GET
LEM7802C	DEC GET
LEMEGMT	SITE GMT
GC1201	B 1 C
GC1202	B 2 C
GC1207	B L C
GC1203	B 3 C
GC1204	B 4 C
LEM4502C	DES CUR
GC1205	B 5 C
GC1206	B 6 C
LEM4503C	ASC CUR
LEM4501C	TOT CUR
LEM11411C	LMP BUS C
LEM11412C	CDR BUS C

4005 — IM EPS ASCENT

LEM7802C	SITE GET
GC0205	B 5 V
GC0302	LMP V
GC0206	B 6 V
GC0301	CDR V
GC1205	B 5 C
GC1206	B 6 C
LEM4503C	ASC CUR
LEM4405C	B 5 AHC
LEM4406C	B 6 AHC
LEM4818L	B 5 STAT
LEM4819L	B 6 STAT
LEM4415C	B 5 AV C
LEM4416C	B 6 AV C
LEM4506C	ASC AV C

4006 — IM INST TAB

LEM7802C	SITE GET
LEMEGMT	SITE GMT
GL0501	MET
GL0400	OSC 1
GL0422	OSC 2
GL0423	OSC 3
GL0401	CAL 85
GL0402	CAL 15
GL4054	CW PWR
GL4069	MA
GY0201	A K1-6
GY0202	B K1-6
GY0231	AK7-15
GY0232	BK7-15
GH1283	ABT SG

4007 — IM EPS BUS CURRENT BILEVEL INDICATIONS

LEM7802C	SITE GET
LEMEGMT	SITE GMT
LEM11401L	B1 ON LMP
LEM11402L	B2 ON LMP
LEM11403L	BL ON LMP
LEM11404L	B5 ON LMP
LEM11405L	B6 ON LMP
LEM11406L	BL ON CDR
LEM11407L	B3 ON CDR
LEM11408L	B4 ON CDR
LEM11409L	B5 ON CDR
LEM11410L	B6 ON CDR

4008 — IM EPS AVERAGE CURRENT

LEM7802C	SITE GET
LEM7802C	DEC GET
LEMEGMT	SITE GMT
LEM4411C	B1 AV C
LEM4412C	B2 AV C
LEM4423C	BL AV C
LEM4413C	B3 AV C
LEM4414C	B4 AV C
LEM4505C	DES AV C
LEM4415C	B5 AV C
LEM4416C	B6 AV C
LEM4506C	ASC AV C
LEM4504C	TOT AV C
[3]GN7563	LR/ECA2 T

4009 — IM EPS BAT STATUS/ MAL

LEM7802C	SITE GET
LEMEGMT	SITE GMT
LEM4803L	B1 STAT
GC4363	B2 STAT
LEM4869L	BL STAT
GC4365	B3 STAT
LEM4806L	B4 STAT
GC9961	B1 MAL
GC9962	B2 MAL
LEM4868L	BL MAL
GC9963	B3 MAL
GC9964	B4 MAL
GC9965	B5 MAL
GC9966	B6 MAL
GL4047	BAT MAL

4054 — IM EPS DES/ASC/TOT AVERAGE CUR

LEM4505C	DES AV CUR
LEM4504C	TOT AV CUR
LEM4506C	ASC AV CUR

NOTES:
1. GB0543 MESA T HAS BEEN REPLACED ON LM-11 BY GF0521 DES 2 H20 T; HOWEVER THE RTCC PROGRAM CONTINUES TO USE GB0543 AS THE MEASUREMENT NUMBER. THE REMOTE SITE PROGRAM USES GF0521.
2. OFFICIAL DOCUMENTATION INDICATES GL9401U SELECT RTG/ECA 1 TEMP IS ASSIGNED TO THE COMBINED MEASUREMENTS GL8275U RTG CASK T AND GC6201T ECA 1 TEMP. THE RTG CASK T BECOMES ECA 1 T AFTER LUNAR TOUCHDOWN UPON CREW SWITCHOVER; HOWEVER THE RTCC AND REMOTE SITE PROGRAMS USE ONLY GL8275U AS THE MEASUREMENT NUMBER.

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4200
DESCENT PROPULSION

LEM7802C - TIME GET
GQ3435 - SHE PR
GQ3015 - ST PR
GQ3018 - REG PR
GQ3025 - REG PR
GQ3611 - F IN P
GQ4111 - O IN P
GQ6806 - INJ POS
GQ6510 - CH PR
GH1348 - ENG ARM
GH1301 - DPS ON
GQ3603 - FU 1 Q
GQ3604 - FU 2 Q
GQ4103 - O 1 Q
GQ4104 - O 2 Q
LGC10200C - CALC Q
GQ4455 - LOW LV

4201
DESCENT PROPULSION

LEM7802C - TIME GET
LEM10701C - PROP REM
LEM10702C - DPS MAR
LEM10601C - FU MARGIN
LEM10602C - OX MARGIN
LGC11303C - LO LEV HT
LGC11304C - INST HT
LGC1503L - PROG
GI0001 × 0048 - VDX
LGC11000C - THRUST CAL

4202
DESCENT PROPULSION PROJECTION PROGRAM

LEM7802C - TIME GET
LEM10901C - TIME NOW
(PDI IGN - SEC)
LEM10902C - F1 P LL
LEM10903C - F2 P LL
LEM10904C - O1 P LL
LEM10905C - O2 P LL
LEM10910C - F1 CD SEC
LEM10911C - F2 CD SEC
LEM10912C - O1 CD SEC
LEM10913C - O2 CD SEC
LEM10914C - P PP CD
LEM10915C - LL CD SEC

4210
ASCENT PROPULSION

LEM7802C - TIME GET
GP0001 - HE 1 P
GP0041 - HE 1 P
GP0002 - HE 2 P
GP0042 - HE 2 P
GP0318 - R1 POS
GP0320 - R2 POS
GP0018 - REG P
GP0025 - REG P
GP1501 - F IN P
GP1503 - O IN P
GP2010 - TCP
GH1230 - ENG ARM
GH1260 - ENG ON
GP1408 - OX LO
GP0908 - FU LO
LGC10200C - CALC Q

4211
ASCENT PROPULSION

LEM7802C - TIME GET
LEM5806C - OX BTR
LEM5805C - FU BTR
LEM5802C - OX FL R
LEM5801C - FU FL R
GP2997 - A Δ P
GP2998 - B Δ P
LEM5423C - RCSA OQR
LEM5419C - RCSA FQR
LEM5424C - RCSB OQR
LEM5420C - RCSB FQR
LGC11000G - THRUST CAL

4220
RCS SYSTEM A

LEM7802C - TIME GET
GR1101 - HE PR
GR1201 - REG PR
GR9609 - MAIN P
GR2201 - FMP
GR3201 - O MP
GR1085 - PROP Q
LEM5415C - CAL OX
LEM5411C - CAL FU
GR9667 - 1A CMD
GR9665 - 2A CMD
GR9663 - 3A CMD
GR9661 - 4A CMD
GR9613 - X/F V
GR9641 - OX A/F
GR9631 - FU A/F

4221
RCS SYSTEM B

LEM7802C - TIME GET
GR1102 - HE P
GR1202 - REG P
GR9610 - MAIN P
GR2202 - F M P
GR3202 - O M P
GR1095 - PROP Q
LEM5416C - CALC OX
LEM5412C - CALC FU
GR9668 - 1B CMD
GR9666 - 2B CMD
GR9664 - 3B CMD
GR9662 - 4B CMD
GR9613 - X/F P
GR9642 - OX A/F
GR9632 - FU A/F

4230
PROPULSION TEMPERATURES

LEM7802C - TIME GET
GQ3718 - DF 1 T
GQ3719 - DF 2 T
GQ4218 - DO 1 T
GQ4219 - DO 2 T
GP0718 - A F T
GP1218 - A O T
GR2121 - RCS A FT
GR2122 - RCS B FT
GR6004 - Q 1 T
GR6003 - Q 2 T
GR6002 - Q 3 T
GR6001 - Q 4 T

4240
RCS CONSUMABLES ANALYSIS

LEM7802C - TIME GET
LPOSTORKU - +U TORQ
LNEGTORKU - -U TORQ
LPOSTORKV - +V TORQ
LNEGTORKV - -V TORQ
LPOSTORKP - +P TORQ
LNEGTORKP - -P TORQ
LEM4865L - DEADBAND
GH1621 - PGNS S
GH1643 - P AUTO
GH1644 - ATT H
LDBB15 - RATE C

4241
PROPULSION CONSUMABLE WEIGHT HISTORY

LEM7802C - TIME GET
LEM1101M - DRY W AS
LEM1102M - MISC W A
LEM5803C - APS F RM
LEM5804C - APS O RM
LEM5409C - RCS A F R
LEM5410C - RCS B F R
LEM5413C - RCS A O R
LEM5414C - RCS B O R
LEM6601C - ASC T W
LEM6603C - LM TOT W
LLMMASS - LGC MASS

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4242
PROPULSION CONSUMABLE WEIGHT HISTORY

LEM7802C - TIME GET
LEM1103M - DRY W DE
LEM5903C - D1 F REM
LEM5903C - D2 F REM
LEM5904C - D1 O REM
LEM5904C - D2 O REM
LEM4602C - DES O2 Q
LEM4611C - DD H2O Q
LEM6601C - AS TOT W
LEM6602C - D TOT W
LEM6603C - LM TOT W
LLMMASS - LGC MASS
LCMMASS - LGC MASS

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4243
PROPULSION CONSUMABLES WEIGHT HISTORY

LEM7802C - TIME GET
LGC10801C - QUAD 1 ON
LGC10802C - QUAD 2 ON
LGC10803C - QUAD 3 ON
LGC10804C - QUAD 4 ON
LEM4604C - ASC 1 O2 Q
LEM4606C - ASC 2 O2 Q
LEM4609C - ASC 1 H_2O Q
LEM4610C - ASC 2 H_2O Q

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P-8

4405 ATTITUDE - SM

LEM7802C - TIME GET
LEM5003C - RSVR X
LACDUX - ACDU X
AGS6102C - AGS X
LEM5001C - RSVR X
LACDUY - ACDU Y
AGS6103C - AGS Y
LEM5002C - RSVR Z
LACDUZ - ACDU Z
AGS6101C - AGS Z
LGC8601C - DEL ERR X
LGC8602C - DEL ERR Y
LGC8603C - DEL ERR Z
LCH 12B05 - ICDUZERO

4410 ATTITUDE - FDAI PAGE 1

LEM7802C - TIME GET
LGC5101C - ACDU F R
AGS5110C - AGS F R
LGC51054C - ICDU F R
LGC5113C - FCDU F R
LGC5103C - ACDU F P
AGS5112C - AGS F P
LGC5106C - ICDU
LGC5115C - FCDU F P
LGC5102C - ACDU F Y
AGS5111C - AGS F Y
LGC5105C - ICDU F Y
LGC5114C - FCDU F Y

4411 ATTITUDE - FDAI PAGE 2

LEM7802C - TIME GET
LEM5108C - RSVR X
LEM5109C - RSVR Y
LEM 510C - RSVR Z

4415 RATES - BODY (DEG/SEC)

LEM7802C - TIME GET
LOMEGAR - DESRATR
LBODYRATER - DAP RATE R
GH1463 - RGA R
AGS9712C - RATE R
LOMEGAQ - DES RATE P
LBODYRATEQ - DAP RATE P
GH1462 - RGA P
AGS9711C - RATE P
LOMEGAP - DES RATE Y
LBODYRATEP - DAP RATE Y
GH1461 - RGA Y
AGS9710C - RATE Y

4420 ERRORS - BODY

LEM7802C - TIME GET
LCH12B06 - IMU EEC
LEW0B15 - RTS/ERR
LFW0B04 - NEEDLES
LCH30B12 - ICDUFAIL
GG2279 - ROLL DAC
LEM11503C - PGNS R/E R
GI1457 - AGS ER R
GG2219 - PIT DAC
LEM11501C - PGNSR/E P
GH1456 - AGS ER P
GG2249 - YAW DAC
LEM11502C - PGNS R/E Y
GH1455 - AGSER Y

4425 DAP CONFIGURATION

LEM7802C - TIME GET
CH1621 - GUID
GH1643 - PGNS AUTO
CH1644 - ATT HOLD
LIM33B06 - NO DAP IMU
LGC4861L - DAP
LGC11100C - DAP LOAD
LDAPBOOLS - OCTAL
LCHANNEL31 - OCTAL
LCHANNEL32 - OCTAL
LCMMASS - CSM LBS
LLMASS - LM LBS
LEM6603
RTCC - LBS

4430 DSKY

LEM7802C - TIME GET
LGC1503L - PROG
LGC1502L - VERB
LGC1501L - NOUN
LCH11B06 - VBN FLSH
LGC1504L - REG 1
LGC1505L - REG 2
LGC1506L - REG 3
LSERVDURN - TLOSS
LGC9535C - DUMLOADS
LGC7900L - DWNLSTID
LCH5MASK - CH 5 MASK
LCH6MASK - CH 6 MASK
LCHWORK - CHANBKUB

4435 LGC

LEM7802C - TIME GET
GG9001 - LGC WARM
LCH33B14 - LGC WARN
LCHANNEL 77 - OCTAL
GG1523 - LGC OPR
LCH33B15 - OSC ALM
LREDOCNTR - RESTARTS
LDSPTAB+11 - DSKY LITES
LFAILREG - PROG
LFAILREG+1 - ALRM
LFAIL+2 - CODES
LCH33B12 - DWLNKRAT
LCH33B11 - UPLNKRAT

4440 CHANNELS (OCTAL)

LEM7802C - TIME GET
LCHANNEL - OCTAL
LCHANNEL12 - OCTAL
LCHANNEL13 - OCTAL
LCHANNEL14 - OCTAL
LCHANNEL30 - OCTAL
LIMODES30 - OCTAL
LCHANNEL31 - OCTAL
LCHANNEL32 - OCTAL
LCHANNEL33 - OCTAL
LIMODES33 - OCTAL
LFLAGWORD11 - OCTAL

4445 FLAGWORDS (OCTAL)

LEM7802C - TIME GET
LFLAGWORD0 - OCTAL
LFLAGWORD1 - OCTAL
LFLAGWORD2 - OCTAL
LFLAGWORD3 - OCTAL
LFLAGWORD4 - OCTAL
LFLAGWORD5 - OCTAL
LFLAGWORD6 - OCTAL
LFLAGWORD7 - OCTAL=
LFLAGWORD8 - OCTAL
LFLAGWORD9 - OCTAL
LFLAGWORD10 - OCTAL

4450 ISS

LEM7802C - TIME GET
GG1513 - IMU
LCH30B09 - IMU OPER
LCH30B14 - T/ON REO
LCH12B15 - T/ON CPT
GG9002 - ISS
LCH11B01 - WARN
LCH30B13 - IMU FAIL
LCH30B12 - ICDU FAIL
GG1331 - 3200 HZ
GG1201 - 800 HZ
GG1040 - 120 VDC
GG1110 - 2.5 VDC
LCH30B15 - TEMP CAUT
GG230 - PIPA T
GF9997 - GLY T

4455 PIPAS

LEM7802C - TIME GET
LCH33B13 - PIPA FAIL
GG2001 - P OUT XV
GG2021 - P OUT YV
GG2041 - P OUT ZV
LAPIPAX - CNTS X
LAPIPAY - CNTS Y
LAPIPAZ - CNTS Z
LGC8106C - PBIASX
LGC8107C - PBIASY
LGC8108C - PBIASZ
LGC8109C - OCTAL X
LGC8110C - OCTAL Y
LGC8111C - OCTAL Z
LTIME2TIME1 - TIME LGC

4460 GYROS (VOLTS)

LEM7802C - TIME GET
GG2172 - SIN X
GG2173 - COS X
GG2112 - SIN Y
GG2113 - COS Y
GG2142 - SIN Z
GG2143 - COS Z
LCHANNEL14 - OCTAL
GG2167 - SERVO X
GG2107 - SERVO Y
GG2137 - SERVO Z
LOGC - C CMD DEG
LIGC - Y CMD DEG
LMGC - Z CMD DEG
LCH12B04 - C/A CMD
LCH30B11 - CAGE CMD

4465 RR OPERATE

LEM7802C - TIME GET
GN7621 - NO TRK
LCH33B04 - DATA GOOD
LCH33B02 - RR MODE
LCH12B14 - TRACK EN
LRADARMODES - OCTAL
LCH33B03 - RNG SCALE
LRRANGE - RAW MN
LRRANGE RATE - RAW FPS
LRRRANGE - MARK TIME
LRRRANGERATE - MARK TIME
LDELTABETA - SHAFT BIAS
LDELTATHTA - TRUN VIAS

4470 RR ANT POS

LEM780C - TIME GET
LEM9804C - SHFT RSVR
LEM9802C - SHFT CDU
LEM9803C - TRUN RSVR
LEM9801C - TRUN CDU
LCH30B07 - RCDU FAIL
GG3304 - S/SIN
GG3305 - S/COS
GG3324 - T/SIN
GG3325 - T/COS
LCH12B02 - RR EEC EN
LCH12B08 - DID CMD
LRRSHFTERR - DRIVE RATE
LRRTRUNERR - DRIVE RATE
GN7723 - RR TEMP

4475 LR VELOCITY (FPS)

LEM7802C - TIME GET
GN7557 - VEL
LCH33B08 - DATA
LDT11B03 - LRVEL
LFW11B02 - LITE
LGC8001C - LRVX ANT
LGC8002C - LRVX ANT
LGC8003C - LRVZ ANT
LGC10302C - LRVX SM
LGC10303C - LRVY SM
LGC10304C - LRVZ SM
LGC10401C - PGNS DEL VX
LGC10403C - PGNS DEL VY
LGC10405C - PGNS DEL VZ

4480 LR - ALTITUDE (FT)

LEM7802C - TIME GET
LGC4815L - LR ANT POS
LCH12B13 - POS 2 CMD
LRADARMODES - OCTAL
GN7521 - RNG
LCH33B05 - DATA
LDT11B05 - LR ALT
LFW11B01 - LITE
LCH33B09 - RNG SCALE
LLRANGEDES - LR ALT
LDELTAH - LR PNGS
GI0001X0011 - AGS ALT
[3]GN7563 - LR/ECA2 T

4485 DELV/2 SEC

LEM7802C - TIME GET
LGC10001C - PGNS DELV X
GI0001X0020 - AGS DELV X
LGC9903 - ACT DELV X
LGC1002C - PGNS DELV Y
GI0001X0021 - AGS DELV Y
LGC10003C - PGNS DELV Z
GI0001X0022 - AGS DELV Z
LDELVX - DELVXS
LDELVY - DELVYS
LDELVZ - DELVZS
LCH33B13 - PIPA FAIL

4490 DELTA V ACCUM/TORQUE TIME

LEM7802C - TIME GET
LGC9901C - PGNS VEL
LDVTOTAL - LGC VEL
LGC9902C - AGS VEL
LGC9904C - ACT VEL
GI0001X0048 - ASA VEL X
GI0001X0049 - ASA VEL Y
LPOSTORKU - JET SEC
LNEGTORKU - JET SEC
LPOSTORKV - JET SEC
LNEGTORKV - JET SEC
LPOSTORKP - JET SEC
LNEGTORKP - JET SEC

NOTE: 3. Official documentation indicates GL9402U SELECT LR ANT/ECA 2 T is assigned to the combined measurements GN7563T LR ANT T and GC6202T ECA 2 TEMP. The LR ANT T becomes ECA 2 T after lunar touchdown upon crew switchover; however the RTCC and remote site programs use only GN7563T as the measurement number.

4305
LEM TIME LOOPS

LEM7802C - TIME GET
GL0501 - TIME MET
LTIME2TIME1 - TIME LGC
GI0001 × 4323 - TIME AGS
LKFACTORT - K FACTOR
LTIG - TIME OF IGN
LTGO - TIME TO GO
LTOFEVENT - EVENT TIME
LTTF8 - TIME IN PHS (SEC)
LEMEGMT - TIME GMT

4310
FAIL STATUS LOOP PAGE 1

LEM7802C - TIME GET
GL4069 - M ALARM
GL4026 - AC FL
GL4027 - DC FL
GL4028 - AGS FL
AGS01E - TEST FL
GI3301 - TEMP
GH1323 - P FAIL
GH1330 - R FAIL
LCH32B10 - TRM FL
LEM34E - CB2 FL
LEM35E - CB3 FL
LEM32E - CB37 FL
LEM33E - CB69 FL
LEM15E - CB80 FL

4311
FAIL STATUS LOOP PAGE 2

LEM7802C - TIME GET
LEM06E - AEA NO AUTO
LEM07E - ONLY AEA AUTO
LEM08E - AEA NO FU
LEM10E - NO AEA ABT
LEM11E - AEA CMD ABT
LEM14E - NO AEA D ON
LEM15E - ONLY AEA ON
LEM16E - NO AEA A ON
LEM17E - ONLY AEA A ON
LEM12E - NO A ABT STG
LEM13E - ONLY AEA AB STG
GC0071 - INV V

4315
AGS STATUS PAGE 1

LEM7802C - TIME GET
GI3305 - WARMUP
GI3306 - STBY
GI3301 - TEMP
GL4028 - AGS FL
AGS01E - TEST FL
DMFB06 - READOUT
DCFB06 - CLEAR
GI0001 × 0007 - DEDA ADDRESS
AGS1100L - REGISTER
GH1628 - R PLSD
GH1629 - P PLSD
GH1630 - Y PLSD

4316
AGS STATUS PAGE 2

LEM7802C - TIME GET
GH1603 - MIN DB
GH1896 - UNBAL CPLS
AGS4836L - WD44 S00
AGS4837L - AEA TEST
LEM4817L - AGS MODE
DW1B10 - AUTO
AGS4851L - WD15S10
DW1B09 - FOLLOWUP
GH1204 - OUT DET
LCH31B15 - OUT DET
LOBB12 - R CMD
LDBB15 - MINP

4320
GDA LOOP

LEM7802C - TIME GET
LCH32B09 - GDA PWR
GH1348 - DPS ARM
LMOMENTOFSTQ - P MNTO
LCG4834L - P TRIM
GH1313 - P POS
GH1323 - P FAIL
LMOMENTOFSTR - R MNTO
LCG4835L - R TRIM
GH1314 - R POS
GH1330 - R FAIL
LCH32B10 - TRIM FAIL
LDBB14 - GTS ALW

4325
THROTTLE LOOP

LEM7802C - TIME GET
GH1621 - GD SEL AGS
LCH30B05 - AUTO THL
GH1348 - DPS ARM
LCH14B04 - THR DRV
LGUIDTHRCMD - GUID TH CMD
LCMDSDECA - DECA CMDS
GH1331 - AUTO TH
GH1311 - MAN TH
GQ6806 - VAR ACT
LEM6002C - TCP × .909
GQ6510 - DPS TCP
LGC11000C - THRUST CAL

4330
ENG ON OFF LOOP PAGE 1

LEM7802C - TIME GET
LCH11B14 - ENG OFF
GH1217 - AUTO OFF
LCH30B03 - ENG ARM
LCH30B02 - STAGED
LDBB06 - ULLREQST
GI0001 × 0031 - ULLAGE
GH1893 - +X O/R
LCH11B13 - ENG ON
EOFB06 - ENG ON
GH1214 - AUTO ON
GH1286 - FIRE O/R

4331
ENG ON OFF LOOP PAGE 2

LEM7802C - TIME GET
GH1348 - DPS ARM
LCH30B01 - ABORT
DW1B13 - ABORT
GY0050 - ABORT
DW1B11 - DPS ON
GH1301 - DPS ON
LEM6002C - ENG THRUST
GH1230 - APS ARM
LCH30B04 - ABT STG
DW1B14 - ABT STG
GH1283 - ABT STG
DW1B12 - APS ON
GH1260 - APS ON
GP2010 - APS TCP

4335
AGS DOWNLINK PAGE 1

LEM7802C - TIME GET
DMFB06 - READOUT
AGS1100L - DEDA DATA
DCFB06 - CLEAR
GI0001 × 0004 - A11
GI0001 × 0005 - A12
GI0001 × 0006 - A13
GI0001 × 0007 - DEDA ADDRESS
GI0001 × 0008 - A31
GI0001 × 0009 - A32
GI0001 × 0010 - A33

4336
AGS DOWNLINK PAGE 2

LEM7802C - TIME GET
AGS4851L - WD15S10
GI0001 × 0020 - DELV X FPS
GI0001 × 0021 - DELV Y FPS
GI0001 × 0022 - DELV Z FPS
GI0001 × 4323 - TIME AGS
AGS9710C - WD24 Y DEG/SEC
AGS9711C - WD25 P DEG/SEC
AGS9712C - WD26 R DEG/SEC
GI0001 × 0027 - T BO OI SEC

4337
AGS DOWNLINK PAGE 3

LEM7802C - TIME GET
GI0001 × 0044 - S00
GI0001 × 0045 - DIS WD 1
GI0001 × 0048 - VDX
GI0001 × 0049 - VDY
GI0001 × 0050 - VDZ

4340
ATCA LOOP

LEM7802C - TIME GET
GH1240 - X TR CMD
GH1241 - Y TR CMD
GH1242 - Z TR CMD
GH1463 - R RATE
GH1457 - R ATT ERR
GH1249 - R ERR CMD
GH1462 - P RATE
GH1456 - P ATT ERR
GH1248 - P ERR CMD
GH1461 - Y RATE
GH1455 - Y ATT ERR
GH1247 - Y ERR CMD

4345
RCS JET TCP LOOP

LEM7802C - TIME GET
LCH32B06 - A1 CMD DISABLED | P-8
GR9667 - A1 CMD DISABLED | P-8
GH1430 - JD A1U
GR5043 - TCP A1U
GH1432 - JD A1F
GR5045 - TCP A1F
LCH32B05 - B1 CMD DISABLED | P-8
GR9668 - B1 CMD DISABLED | P-8
GH1431 - JD B1D
GR5044 - TCP B1D
GH1433 - JD B1L
GR5046 - TCP B1L
LCH32B08 - A2 CMD DISABLED | P-8
GR9665 - A2 CMD DISABLED | P-8
GH1427 - JD A2D
GR5040 - TCP A2D
GH1428 - JD A2A
GR5041 - TCP A2A
LCH32B07 - B2 CMD DISABLED | P-8
GR9666 - B2 CMD DISABLED | P-8
GH1426 - JD B2U
GR5039 - TCP B2U
GH1429 - JD B2L
GR5042 - TCP B2L
LCH32B02 - A3 CMD DISABLED | P-8
GR9663 - A3 CMD DISABLED | P-8
GH1422 - JD A3U
GR5035 - TCP A3U
GH1425 - JD A3R
GR5038 - TCP A3R
LCH32B04 - B3 CMD DISABLED | P-8
GR9664 - B3 CMD DISABLED | P-8
GH1423 - JD B3D
GR5036 - TCP B3D
GH1424 - JD B3A
GR5037 - TCP B3A
LCH32B01 - A4 CMD DISABLED | P-8
GR9661 - A4 CMD DISABLED | P-8
GH1419 - JD A4D
GR5032 - TCP A4D
GH1421 - JD A4R
GR5034 - TCP A4R
LCH32B03 - B4 CMD DISABLED | P-8
GR9662 - B4 CMD DISABLED | P-8
GH1418 - JD B4U
GR5031 - TCP B4U
GH1420 - JD B4F
GR5033 - TCP B4F

DISPLAY (D/TV)

MOCR/SSR REALTIME (R/T), PLAYBACK (P/B), AND UNIVERSAL PLOT (UP) DISPLAYS

CONTROL

R/T 1123 LM GUID, CONT AND PROP
P/B 1124

TELMU

R/T 1001 LM ECS, EPS AND PYRO/INSTR
P/B 1002

MOCR

SSR

PGNS/RADAR

R/T 1137 PGNS GNC
P/B 1138

R/T 1129 LGC BIT LOGIC
P/B 1130

AGS/CES

R/T 1127 LM AGS
P/B 1128

PROP

R/T 1125 LM PROP
P/B 1126

UNIVERSAL PLOTS*

1180 UP-35
1181 UP-36
1182 UP-37
1183 UP-38
1184 UP-39
1185 UP-40
1186 UP-41

EPS/INSTR

R/T 1091 LM ELEC/INSTR
P/B 1092

ECS

R/T 1051 ECS
P/B 1052

EMU

R/T 1314 ECS/EMU
P/B 1315

UNIVERSAL PLOTS*

1053 UP-28
1054 UP-29
1055 UP-30
1056 UP-31
1057 UP-32
1058 UP-33
1059 UP-34

COMPUTER DISPLAYS (NOT G&C DISPLAYS)

R/T 1222,1225,1228 COAST AND ALIGN

R/T 1231,1234,1237 LM RNDZ AND PRETHRUST

R/T 1240,1243,1246 LM POWERED PHASE

R/T 1261,1264 AGS INITIALIZATION /LM UPDATE

R/T 1280,1283, 1286,1289 AEA TM DOWNLINK

MOCR/SSR SUMMARIES

1139/1140/1141 LM GNC SUM 1
1142/1143/1144 LM GNC SUM 2
1145/1146/1147 LM GNC SUM 3
1148/1149/1150 LM GNC SUM 4
1151/1152/1153 LM GNC SUM 5
1154/1155/1156 LM GNC SUM 6
1157/1158/1159 LM GNC SUM 7
1160/1161/1162 LM GNC SUM 8
1163/1164/1165 LM GNC SUM 9
1166/1167/1168 LM GNC SUM 10
1169/1170/1171 LM GNC SUM 11
1172/1173/1174 LM GNC SUM 12

MOCR/SSR HISTORIES

1061/1062/1063 LM ELEC/INSTR HIST I
1071/1072/1073 LM ELEC/INSTR HIST II
1081/1082/1083 LM ELEC/INSTR HIST III
1084/1085/1086 LM ELEC/INSTR HIST IV

1011/1012/1013 LM ECS HIST I
1021/1022/1023 LM ECS HIST II
1031/1032/1033 LM ECS HIST III

1311/1312/1313 EMU/EVA HIST I
1321/1322/1323 EMU/EVA HIST II

P-11

OTHER

1007/1008/1009 CONS/WEIGHT UPDATE

R/T 2025 CONTROL TM CRIT ALARM LIMITS

MISCELLANEOUS DISPLAYS

0001 TV GUID
0047 FDO MISSION PLAN TABLE
0056 PRED SITE ACQ TABLE
0262 LM GUID MONITOR TABLE
0268 AGS SUPPORT DISPLAY
0289 LUNAR SURFACE ALIGN
1594 LGC MONITOR H/S
1599 LGC MONITOR II H/S
1625 LM MED VALUES
1628 LM MED VALUES
1636 THRIFT UPDATE RATE AND FORMAT
1637 SNAPSHOT PLOT FORMATS
2000 RTCC/PCS STATUS TABLE
2001 TM STATUS
2002 TM BIAS
2005 LM OPERATIONAL LIMITS

MISCELLANEOUS TV CHANNELS

0036 NTWK STATUS BOARD
0058 ECS TRENDS
0060 OVERALL MISSION TIMELINE
0064 PLSS TRENDS AND EPS POWER PROFILES

OTHER

R/T 2024 TELMU TM CRIT ALARM LIMITS

* SEE SCP GEN 1-10 FOR UNIVERSAL PLOT DETAILS

LM GNC SUM 1 (1139/1140/1141)

GG1523	LGC OPERATE
931C3009	IMU OPERATE
GG1513	IMU STBY/OFF
GG9001	LGC WARNING
GG9002	ISS WARNING
942C3315	OSC ALARM
931C3012	IMU CDU FAIL
931C3007	RR CDU FAIL
931C3013	IMU FAIL
942C3313	PIPA FAIL
502K1109	PROGRAM CAUTION
502K1106	GIMBAL LOCK
502K1108	TRACKER
502K1104	NO ATTITUDE
931C3015	TEMP IN LIMITS
441F1013	APS FLAG
431F0808	SURF FLAG
931C3002	STAGE VERIFY
	Σ ΔVX PGNS FPS
	Σ ΔVX AGS FPS
	Σ ΔVX ACT FPS

LM GNC SUM 2 (1142/1143/1144)

451-501	PROG
451-501	VERB
451-501	NOUN
451-501	R1
451-501	R2
451-501	R3
GG1201	28 V 800 HZ
GG1331	28 V 3.2 KHZ
GG1040	120 VDC
GG1110	2.5 V TM BIAS
GN7621	RR DATA GOOD
GN7521	LR DATA GOOD
GN7557	LR VEL GOOD
931C3011	IMU CAGE
912C1204	COARSE ALIGN
931C3014	TURN ON RQST
912C1215	TURN ON CMPT
931C3007	GUIDANCE
81213306	DAP DISABLE
642D0003	ACCEL N/G
932C3113	ATTITUDE HOLD
932C3114	ATTITUDE AUTO
LGC4861L	DAP ON/OFF
LGC4844L	MNVR RATE D/S

LM GNC SUM 3 (1145/1146/1147)

642D0004	DEADBAND
642D0006	ULLAGE
642D0007	RHC SCALING
642D0008	OFFSET
642D0009	LPD PHASE
642D0010	JET SYSTEM
642D0011	X-TRANS
642D0012	RATE CMD
642D0013	CSM DOCKED
642D0014	GTS
642D0015	MIN IMPULSE
FW0B15	NEEDL RATE
GG2219	P ATT ERR DEG
GH1456	P ATT ERR DEG
GG2279	R ATT ERR DEG
GH1457	R ATT ERR DEG
GG2249	Y ATT ERR DEG
GH1455	Y ATT ERR DEG
332	P BODY RT D/S
GH1462	P BODY RT D/S
341	R BODY RT D/S
GH1463	R BODY RT D/S
331	Y BODY RT D/S
GH1461	Y BODY RT D/S
2300	PIPA TEMP °F

LM GNC SUM 4 (1148/1149/1150)

GG2112	IG RSVR SIN
GG2113	IG RSVR COS
LM5001	IG RSVR CSM
LM5109	IG RSVR (FDAI)
LC5103	ACT CDU Y (FDAI)
AS5112	AGS CDU Y (FDAI)
LC5106	I CDU Y (FDAI)
LC5115	F CDU Y (FDAI)
GG2142	MG RSVR SIN
GG2143	MG RSVR COS
LM5002	MG RSVR CSM
LM5107	MG RSVR (FDAI)
LC5101	ACT CDU Z (FDAI)
AS5110	AGS CDU Z (FDAI)
LC5104	I CDU Z (FDAI)
LC5113	F CDU Z (FDAI)
GG2172	OG RSVR SIN
GG2173	OG RSVR COS
LM5003	OG RSVR (SM)
LM5108	OG RSVR (FDAI)
LC5102	ACT CDU X (FDAI)
AS5111	AGS CDU X (FDAI)
LC5105	I CDU X (FDAI)
LC5114	F CDU X (FDAI)

LM GNC SUM 5 (1151/1152/1153)

GG2107	IG SER ERR VRMS
GG2137	MG SER ERR VRMS
GG2167	OG SER ERR VRMS
GG2021	Y PIPA OUT VRMS
GG2001	X PIPA OUT VRMS
GG2041	Z PIPA OUT VRMS
GN7723	RR ANT TEMP °F
GN7563	LR ANT TEMP °F
	SHAFT RSVR DEG
	SHAFT LGC DEG
	TRUN RSVR DEG
	TRUN LGC DEG
131	RR RANGE STD NM
132	RNGE RTE STD F/S
091	RR RANGE NM
092	RANGE RATE F/S
LC8001	LR VEL X F/S
LC8002	LR VEL Y F/S
LC8003	LR VEL Z F/S
LC8004	LR RANGE FT
751	LR VEL X (ST) F/S
752	LR VEL Y (ST) F/S
761	LR VEL Z (ST) F/S
762	LR RANGE FT

LM GNC SUM 6 (1154/1155/1156)

931C3005	AUTO THRTL
991	CMD TO DECA %
GH1331	AUTO THRTL CMD %
GH1311	MAN THRTL CMD %
LM6001	CMD THRUST %
GQ6806	ACT POS %
281-781	GUID THR CMD %
LM6002	TCP (DPS) %
GH1286	ENG FIRE O/R
931C3003	ENG ARMED
911C1114	ENG OFF
GH1217	AUTO ENG OFF
31	ULLAGE COUNTS
1506	ENG ON (AGS)
911C1113	ENG ON
GH1214	AUTO ENG ON
GH1348	DPS ARM
4511	DPS ON
GH1301	DPS ON
GH1230	APS ARM
4512	APS ON
GH1260	APS ON
GP2010	APS TCP PSIA

LM GNC SUM 7 (1157/1158/1159)

23-43	AGS
	TIME
	AGS TAG
091	K
092	FACTOR
GY0050	ABORT CMD
GH1283	ABORT STAGE
931C3004	ABORT STAGE
GH1644	PGNS ATT HOLD
GH1643	PGNS AUTO
GH1603	SCS DEADBAND
GH1204	DETENT
932C3115	DETENT
45	MODE WORD S00
GH1628	ROLL ATT CNTL
GH1629	PTCH ATT CNTL
GH1630	YAW ATT CNTL
GH1896	COUPLES
GH1893	+X TRANS O/R
GH1240	X TRANS
GH1241	Y TRANS
GH1242	Z TRANS
GH1642	AGS ATT HOLD
GH1641	AGS AUTO

LM GNC SUM 8 (1160/1161/1162)

GH1247	Y ERR CMD VDC
GH1248	P ERR CMD VDC
GH1249	R ERR CMD VDC
GH1313	P GDA POS DEG
912B10	APP TRIM FAIL
931C3009	GIMBAL OFF
GH1323	P TRIM FAIL
GH1314	R GDA POS DEG
912B112	R TRIM
GH1330	R TRIM FAIL
941B10	APP GDA FAIL
941B09	GDA POWER
GL4026	CES AC PWR FL
GL4027	CES [illegible]
GL4028	AGS PWR FAIL
GI3305	AGS WARMUP
GI3306	AGS STANDBY
GI3301	ASA TEMP
1B6	DEDA READOUT FLAG
3B6	DEDA CLEAR FLAG
2	DEDA DATA WORD
7	DEDA OCTAL ADDRESS
LM10702	DPS MARGIN %
LM10602	OX MARGIN %
LM10601	FU MARGIN %

LM GNC SUM 9 (1163/1164/1165)

31B7-9	SELF TEST
GR9661	ISO 4A (DR)
941B1	ISO 4A (DR)
GR9662	ISO 4B (UF)
941B3	ISO 4B (UF)
GR9663	ISO 3A (UF)
941B2	ISO 3A (UR)
GR9664	ISO 3B (DA)
941B4	ISO 3B (DA)
GR9665	ISO 2A (DA)
941B8	ISO 2A (DA)
GR9666	ISO 2B (UL)
941B7	ISO 2B (UL)
GR9667	ISO 1A (UF)
941B6	ISO 1A (UF)
GR9668	ISO 1B (DL)
941B5	ISO 1B (DL)
961/2	DEL V X FPS
48	LM X VEL FPS
971/2	DEL V Y FPS
49	LM Y VEL FPS
981/2	DEL V Z FPS
50	LM Z VEL FPS

LM GNC SUM 10 (1166/1167/1168)

251/2	VGX
261/2	VGY
271/2	VGZ
141/2	T OF EVENT HR
	MIN SEC
001/2	T TO GO SEC
821/2	T OF IGN HR
	MIN SEC
27	T TO B/O SEC
RCS SYS A	
GR1101	HE PRESS PSIA
GR1201	REG PRESS PSIA
GR2121	FU TEMP °F
GR1085	PROP QTY %
	TOTAL REM A %
GR2201	FU MAN PR PSIA
GR3201	OX MAN PR PSIA
RCS SYS B	
GR1102	HE PRESS PSIA
GR1202	REG PRESS PSIA
GR2122	FU TEMP °F
GR1095	PROP QTY %
	TOTAL REM B %
GR2202	FU MAN PR PSIA

LM GNC SUM 11 (1169/1170/1171)

GR3202	OX MAN PR PSIA
GR6004	QUAD 1 TEMP °F
GR6003	QUAD 2 TEMP °F
GR6002	QUAD 3 TEMP °F
GR6001	QUAD 4 TEMP °F
GP0001	APS HE 1 P PSIA
GP0201	APS HE 1 T °F
GP0002	APS HE 2 P PSIA
GP0202	APS HE 2 T °F
GP0018	APS HE REG PSIA
GP0025	APS HE REG PSIA
GP0718	APS FU TEMP °F
GP1218	APS OX TEMP °F
GP1501	APS FU PR PSIA
GP1503	APS OX PR PSIA
GP2010	APS TCP PSIA
LM5801	APS FU W LB/SEC
LM5802	APS OX W LB/SEC
GQ3015	DPS TK PR PSIA
GQ3435	DPS HE PR PSIA
GQ3018	DPS HE REG PSIA
GQ3025	DPS HE REG PSIA
GQ3603	DPS FU QTY %
GQ3604	DPS FU QTY %
GQ4103	DPS OX QTY %
GQ4104	DPS OX QTY %

LM GNC SUM 12 (1172/1173/1174)

GQ3718	DPS FU 1 T °F
GQ3719	DPS FU 2 T °F
GQ4218	DPS OX 1 T °F
GQ4219	DPS OX 2 T °F
GQ3611	DPS FU PR PSIA
GQ4111	DPS OX PR PSIA
GQ6510	DPS TCP PSIA
GR9609	RCS MAIN A
GR9610	RCS MAIN B
GR9631	ASC FDA FU OPEN
GR9641	ASC FDA OX OPEN
GR9632	ASC FDB FU OPEN
GR9642	ASC FDB OX OPEN
GR9613	A/B X FEED
GP0318	APS HE 1
GP0320	APS HE 2
GP2997	A VLVS Δ POS
GP2998	B VLVS Δ POS
GP1408	OX LOW
GP0908	FU LOW
GQ7498	A/B VLVS Δ POS
GQ7499	C/D VLVS Δ POS
GQ4455	PROP LOW

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SCP NO. **GEN 1-15**

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: R. Legler
APPROVAL: James L. Hannigan

TITLE **CHART RECORDER FORMAT SELECTION**

PURPOSE : The SCP defines all LM chart recorder formats and the nominal times they are used. Medable formats are called up on an as required basis.

PROCEDURE: The following schedule defines the nominal selection of ground station formats on the Apollo 17 mission. Format changes are based on mission events and not on a specific GET; hence, the actual GET of switching may vary slightly even during a nominal mission. All format changes should be coordinated with all applicable MCC personnel.* All formats referenced herein are on PCM ground station Tape 4. P-8

A.

EVENT	APPROX GET	FORMAT	FORMAT TITLE
PRELAUNCH		IX	CSM/SLV
HK1 -15 min	40:05	V	ACT/PDI
IVT to CSM	42:00	(Release to CSM)	
HK2 -15 min	60:17	V	ACT/PDI
IVT to CSM	61:30	(Release to CSM)	
ACT - 15 min	107:45	V	ACT/PDI
TD/DPS VENT +5 min	113:18	VI	LUNAR SURFACE
EVA 1 -45 min	115:55	VII	LUNAR SURFACE + PLSS
EVA 1 term + 15	123:55	VI	LUNAR SURFACE P-14
EVA 2 -45 min	138:25	VII	LUNAR SURFACE + PLSS
EVA 2 term +15	146:25	VI	LUNAR SURFACE
EVA 3 -45 min	161:55	VII	LUNAR SURFACE + PLSS
EVA 3 TERM +15 min	169:55	VI	LUNAR SURFACE
Liftoff -10 min thru Impact	187:53	IV	STAGED
Impact	195:58		

B. FORMATS

CONSOLE 21L

Pen	Meas No.	Meas Desc	Pen	Meas No.	Meas Des
(FORMAT V, VI, VII)			(FORMAT IV)		
01	GF4500P	DES 1 H_2O P	01	GF4502P	ASC 1 H20 P P-8
02	GF3584P	DES 02 Press	02	GF3582P	ASC 1 02 Press
03	GF1521P	CO2 PP	03	GF1521P	CO2 PP
04	GF9999U	SEL H20 Sep Rt	04	GF9999U	SEL H20 Sep Rt
05	GF4101P	PRI H20 Reg ΔP	05	GF4101P	Pri H20 Reg ΔP
06	GF1301P	Suit Press	06	GF1301P	Suit Press
07	GF9997P	SEL Gly Pmp P	07	GF9997P	SEL Gly Pmp P
08	GF9998T	SEL Glycol T	08	GF9998T	SEL Glycol T

CONSOLE 29L

Pen	Meas No.	Meas Desc	Pen	Meas No.	Meas Des.
(FORMAT IX)			(FORMAT V)		
01	GC0302V	LMP Bus Volts	01	GH1314V	Roll GDA Pos
02	GC0301V	CDR Bus Volts	02	GG2279V	Roll DAC Out
03	GC1201C	Bat 1 Cur	03	GH1463V	RGA Roll Rate
04	GC1202C	Bat 2 Cur	04	GG2137V	MG Svo Err In Ø
05	GC1203C	Bat 3 Cur	05	GH1313V	Pitch GDA Pos
06	GC1204C	Bat 4 Cur	06	GH2219V	Pitch DAC Out
07	GC1205C	Bat 5 Cur	07	GH1462V	RGA Pitch Rate
08	GC1206C	Bat 6 Cur	08	GG2107V	IG Svo Err in Ø

Pen	Meas No.	Meas Desc
(FORMAT IV, VI, VII)		
01	GH1457V	Roll Att Err
02	GG2279V	Roll DAC Out
03	GH1463V	RGA Roll Rate
04	GG2137V	MG Svo Err in Ø
05	GH1456V	Pitch Att Err
06	GG2219V	Pitch DAC Out
07	GH1462V	RGA Pitch Rate
08	GG2107V	IG Svo Err in Ø

*See FCOH SOP 4.7 for medable chart recorder parameter change procedures. P-8

CONSOLE 30L

Pen	Meas No.	Meas Desc
(FORMAT V)		
01	GQ3435P	DPS HE Press
02	GH1311V	Man Thrust Cmd
03	GH1331V	Auto Thrust Cmd
04	GQ6806V	DPS VAR ACT
05	GQ6510P	DPS TCP
06	GG2249V	YAW DAC Out
07	GH1461V	RGA Yaw Rate
08	GG2167V	OG Svo Err in Ø

Pen	Meas No.	Meas Desc
(FORMAT IV, VI, VII)		
01	GG2167V	OG Svo Err in Ø
02	GP2010P	APS TCP
03	GP1501P	APS Fuel Press
04	GP1503P	APS OX Press
05	GH1455V	Yaw Att Err
06	GG2249V	Yaw DAC Out
07	GH1461V	RGA Yaw Rate
08	GN7723T	RR Ant Temp

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CONSOLE 31L

Pen	Meas No.	Meas Desc
(FORMAT VI, VII)		
01	GC0302V	LMP Bus Volts
02	GC0301V	CDR Bus Volts
03	GC1201C	Bat 1 Cur
04	GC1202C	Bat 2 Cur
05	GC1207C	Bat L Cur
06	GC1203C	Bat 3 Cur
07	GC1204C	Bat 4 Cur
08	GC0071V	AC Volts

Pen	Meas No.	Meas Desc
(FORMAT V)		
01	GC0302V	LMP Bus Volts
02	GC0301V	CDR Bus Volts
03	GC1201C	Bat 1 Cur
04	GC1202C	Bat 2 Cur
05	GC1203C	Bat 3 Cur
06	GC1204C	Bat 4 Cur
07	GC1205C	Bat 5 Cur
08	GC1206C	Bat 6 Cur

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Pen	Meas No.	Meas Desc
(FORMAT IV)		
01	GC0302V	LMP Bus Volts
02	GC0301V	CDR Bus Volts
03	GC0205V	Bat 5 Volts
04	GC0206V	Bat 6 Volts
05	GC1205C	Bat 5 Cur
06	GC1206C	Bat 6 Cur
07	GC0071V	AC Bus Volts
08	GC0155F	AC Bus Freq

CONSOLE 34R

Pen	Meas No.	Meas Desc
(FORMAT VII)		
01	GT8182P	PLSS 1 02 P
02	GT8168P	PGA 1 02 Press
03	GT8110P	PLSS 1 H20 P
04	GT8154T	LGC 1 H20 in T
05	GT8196T	LGC 1 H20 T
06	GT8170V	PLSS 1 02 Subl T
07	GT8141V	PLSS 1 Bat V
08	GT8140C	PLSS 1 Bat C

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C. MEDABLE FORMATS

CONSOLE 20 L

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Pen	Meas No.	Meas Desc	Pen	Meas No.	Meas Desc	
(MED Group 21A)			(MED Group 22A)			
01	GF4500P	DES 1 H20 P	01	GF4502P	ASC 1 H20 P	P-8
02	GF3584P	DES 1 02 P	02	GF3582P	ASC 1 02 Press	
03	GF1521P	CO2 PP	03	GF1521P	CO2 PP	
04	GF9999U	SEL H20 Sep Rt	04	GF9999U	SEL H20 Sep Rt	
05	GF4101P	Pri H20 Reg ΔP	05	GF4101P	Pri H20 Reg ΔP	
06	GF1301P	Suit Press	06	GF1301P	Suit Press	
07	GF9997P	SEL Gly Pmp P	07	GF9997P	SEL Gly Pmp P	
08	GF9998T	SEL Glycol T	08	GF9998T	SEL Glycol T	
(MED Group 23A)			(MED Group 24A)			
01	GF2531T	W/B Gly in T	01	GF3591P	U/H Rlf Press	
02	GF2581T	W/B Gly Out T	02	GF3592P	F/H Rlf Press	
03	GF9998T	SEL Glycol T	03	GF3571P	Cabin Press	
04	GF4511T	Pri W/B H20 T	04	GF1301P	Suit Press	
05	GF2021P	Pri Gly Pmp ΔP	05	GF4101P	Pri H20 Reg ΔP	
06	GF9997P	SEL Gly Pmp P	06	GF3584P	DES 1 02 P	P-8
07	GF4101P	Pri H20 Reg ΔP	07	GF0584P	DES 2 02 P	
08	GF4501P	DES H20 Press	08	GF1521P	CO2 PP	
(MED Group 25A)			(MED Group 26A)			
01	GF3584P	DES 1 02 P	01	GH1463V	RGA Roll Rate	P-8
02	GF0500P	DES 2 H20 P	02	GH1457V	Roll Att Err	
03	GF4500P	DES 1 H20 P	03	GH1249V	Roll Err Cmd	
04	GF4501P	DES H20 Press	04	GH1462V	RGA Pitch Rate	
05	GF4101P	Pri H20 Reg ΔP	05	GH1456V	Pitch Att Err	
06	GF9999U	SEL H20 Sep Rt	06	GH1248V	Pitch Err Cmd	
07	GF2531T	W/B Gly in T	07	GG2279V	Roll DAC Out	
08	GF1521P	CO2 PP	08	GG2219V	Pitch DAC Out	
(MED Group 27A)						
01	GF3584P	DES 1 02 P				P-8
02	GF0584P	DES 2 02 P				
03	GF3582P	ASC 1 02 Press				
04	GF3583P	ASC 2 02 Press				
05	GF4500P	DES 1 H20 P				
06	GF4501P	DES H20 Press				
07	GF4502P	ASC 1 H20 P				
08	GF4503P	ASC 2 H20 P				

CONSOLE 33R

Pen	Meas No.	Meas Desc	Pen	Meas No.	Meas Desc	
(MED Group 21B)			(MED Group 22B)			
01	GC0302V	LMP Bus Volts	01	GC0302V	LMP Bus Volts	
02	GC0301V	CDR Bus Volts	02	GC0301V	CDR Bus Volts	
03	GC1201C	Bat 1 Cur	03	GC0071V	AC Bus Volts	
04	GC1202C	Bat 2 Cur	04	GC1201C	Bat 1 Cur	
05	GC1203C	Bat 3 Cur	05	GC1202C	Bat 2 Cur	
06	GC1204C	Bat 4 Cur	06	GC1207C	Bat L Cur	P-8
07	GC1205C	Bat 5 Cur	07	GC1203C	Bat 3 Cur	
08	GC1206C	Bat 6 Cur	08	GC1204C	Bat 4 Cur	

CONSOLE 33R CONTINUED

Pen	Meas No.	Meas Desc
(MED Group 23B)		
01	GC0302V	LMP Bus Volts
02	GC0301V	CDR Bus Volts
03	GC0205V	Bat 5 Volts
04	GC0206V	Bat 6 Volts
05	GC1205C	Bat 5 Cur
06	GC1206C	Bat 6 Cur
07	GC0071V	AC But Volts
08	GC0155F	AC Bus Freq
(MED Group 24B)		
01	GC0207V	Bat L Volts
02	GC1203C	Bat 3 Cur
03	GC1204C	Bat 4 Cur
04	GC0155F	AC Bus Freq
05	GC0071V	AC Bus Volts
06	GH1313V	Pitch GDA Pos
07	GH1314V	Roll GDA Pos
08	GQ6510P	DPS TCP

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Pen	Meas No.	Meas Desc
(MED Group 25B)		
01	GC0201V	Bat 1 Volts
02	GC0202V	Bat 2 Volts
03	GC0203V	Bat 3 Volts
04	GC0204V	Bat 4 Volts
05	GC0205V	Bat 5 Volts
06	GC0206V	Bat 6 Volts
07	GC0301V	CDR Bus Volts
08	GC0302V	LMP Bus Volts
(MED Group 26B)		
01	GH1461V	RGA Yaw Rate
02	GH1455V	YAW Att Err
03	GH1247V	YAW Err CMD
04	GG2249V	YAW DAC Out
05	GG1040V	PLSS Torq Ref
06	GG2001V	X PIPA In Ø
07	GG2021V	Y PIPA In Ø
08	GG2041V	Z PIPA In Ø

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Pen	Meas No.	Meas Desc
(MED Group 27B)		
01	GT8282P	PLSS 2 02 P
02	GT8268P	PGA 2 02 Press
03	GT8210P	PLSS 2 H20 P
04	GT8254T	LGC 2 H20 in T
05	GT8296T	LGC 2 H20 Del T
06	GT8270T	PLSS 2 02 Sub T
07	GT8241V	PLSS 2 Bat V
08	GT8240C	PLSS 2 Bat C

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SCP NO. GEN 1-16

S/C: LM
DATE: 11-1-71
REVISION : PCN-11
ORIGINATOR: M. Perkins
APPROVAL: J. J. Hannigan

TITLE: EMERGENGY MISSION CONTROL CENTER (EMCC) ACTIVATION

PURPOSE: To define LM TELMU and CONTROL documentation required for transfer of mission operations to the EMCC.

PARTICIPATION: LM TELMU and CONTROL

A. In the event of EMCC activation, the following minimum documentation will be required by the LM participants.

1 copy each, of the following:

- LM Systems Handbook
- LM Console Handbook
- SODB Vol. 2 & 4
- LM AOH Vol. 1 & 2
- EMU AOH Vol. 1 & 2
- Mission Rules
- Checklist
- Flight Plan
- LM Operational Cal Curves
- LM Measurements Requirements and Configuration Data (LED 360-360)
- TDFCB (High Speed Data section)
- LM Propulsion Skinny Book
- THRIFT Printouts to date
- SPAN Requests and Answers to date
- EPS Consumables (SEENA Printout)
- LM Olivetti Programs
- LM Hewlett Packard Programs
- Console Logs

B. The following individuals will be notified of EMCC activation decision:

J. Hannigan	534-4292
D. Puddy	877-4787
R. Thorsen	488-3856
M. Merritt	665-0228
J. Wegener	488-4117
W. Peters	534-3264

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C. The following Manual Summaries will be generated by the remote site on request from EMCC:

- LM TELMU MANUAL SUMMARY
- LM PROPULSION MANUAL SUMMARY
- LM LGC/AEA MANUAL SUMMARY
- LM BILEVEL MANUAL SUMMARY

D. The following pages are the Manual Summary formats.

LM TELMU MANUAL SUMMARY

HRS: MIN: SEC:
DECIMAL PCM COUNT

____GROUND ELAPSED TIME		
____CABIN PRESS	GF3571	
____SUIT PRESS	GF1301	
____SUIT TEMP	GF1281	
____CO2 PART PRESS	GF1521	
____W/B GLY OUT TEMP	GF2581	
____W/B GLY IN TEMP	GF2531	
____GLY PUMP PRESS	GF9997	
____PRI GLY PUMP DELTA P	GF2021	
____GLY TEMP	GF9998	
____PRI H2O REG DELTA P	GF4101	
____H2O SEP RATE	GF9999	
____PRI W/B H2O TEMP	GF4511	
____DES 2 O2 PRESS	GF0584	P-8
____DES 1 O2 PRESS	GF3584	
____ASC 1 O2 PRESS	GF3582	
____ASC 2 O2 PRESS	GF3583	
____DES 2 H2O PRESS	GF0500	
____DES 1 H2O PRESS	GF4500	
____ASC 1 H2O PRESS	GF4502	P-8
____ASC 2 H2O PRESS	GF4503	
____AC BUS VOLT	GC0071	
____AC BUS FREQ	GC0155	
____CDR BUS VOLT	GC0301	
____LMP BUS VOLT	GC0302	
____BAT 1 CUR	GC1201	
____BAT 2 CUR	GC1202	
____BAT 3 CUR	GC1203	
____BAT 4 CUR	GC1204	
____BAT 5 CUR	GC1205	
____BAT 6 CUR	GC1206	
____BAT L CUR	GC1207	P-8
____BAT 1 VOLT	GC0201	
____BAT 2 VOLT	GC0202	
____BAT 3 VOLT	GC0203	
____BAT 4 VOLT	GC0204	
____BAT 5 VOLT	GC0205	
____BAT 6 VOLT	GC0206	
____BAT L VOLT	GC0207	P-8
____DES 2 H2O T	GF0521T	P-11

LM PROPULSION MANUAL SUMMARY

____	GROUND ELAPSED TIME	HRS: MIN: SEC:
____	RCS A HE PRESS	GR1101
____	RCS A REG PRESS	GR1201
____	RCS A FUEL TEMP	GR2121
____	RCS PROP A QTY	GR1085
____	A FUEL MFLD PRESS	GR2201
____	A OX MFLD PRESS	GR3201
____	RCS B HE PRESS	GR1102
____	RCS B REG PRESS	GR1202
____	RCS B FUEL TEMP	GR2122
____	RCS PROP B QTY	GR1095
____	B FUEL MFLD PRESS	GR2202
____	B OX MFLD PRESS	GR3202
____	QUAD 1 TEMP	GR6004
____	QUAD 2 TEMP	GR6003
____	QUAD 3 TEMP	GR6002
____	QUAD 4 TEMP	GR6001
____	APS HE 1 PRESS	GP0001
____	APS HE 1R PRESS	GP0041
____	APS HE 2 PRESS	GP0002
____	APS HE 2R PRESS	GP0042
____	APS HE REG PRESS 1	GP0018
____	APS HE REG PRESS 2	GP0025
____	APS FUEL TEMP	GP0718
____	APS OX TEMP	GP1218
____	APS FUEL PRESS	GP1501
____	APS OX PRESS	GP1503
____	VAR INJ ACT POS	GQ6806
____	AUTO THRUST CMD	GH1331
____	MAN THRUST CMD	GH1311
____	PITCH GDA POS	GH1313
____	ROLL GDA POS	GH1314
____	DPS START TANK PRESS	GQ3015
____	DPS HE PRESS	GQ3435
____	DPS HE REG PRESS 1	GQ3018
____	DPS HE REG PRESS 2	GQ3025
____	DPS FUEL 1 TEMP	GQ3718
____	DPS FUEL 2 TEMP	GQ3719
____	DPS OX 1 TEMP	GQ4218
____	DPS OX 2 TEMP	GQ4219
____	DPS FUEL PRESS	GQ3611
____	DPS OX PRESS	GQ4111

DECIMAL PCM COUNT

LM LGC/AEA MANUAL SUMMARY

____GROUND ELAPSED TIME		HRS: MIN: SEC:
____IMU 28 VAC 800	GG1201	DECIMAL PCM COUNT
____IRIG SUSP 3.2 KC	GG1331	
____PIPA TEMP	GG2300	
____ASA TEMP	GI3301	
____DISCRETE WORD ONE	GI0001X WORD 45	OCTAL
____S10 SWITCH/ENG ON	GI0001X WORD 15	
____SELF TEST/ULLAGE	GI0001X WORD 31	
____FUNCTION SEL SW	GI0001X WORD 44	
____LM MASS	GG0001X WORD 80A	
____FLAGWORD 0	GG0001X WORD 39A	
____FLAGWORD 1	39B	
____FLAGWORD 2	40A	
____FLAGWORD 3	40B	
____FLAGWORD 4	41A	
____FLAGWORD 5	41B	
____FLAGWORD 6	42A	
____FLAGWORD 7	42B	
____FLAGWORD 8	43A	
____FLAGWORD 9	43B	
____FLAGWORD 10	44A	
____FLAGWORD 11	44B	
____I MODES 30	81A	
____I MODES 33	81B	
____CHANNEL 11	91A	
____CHANNEL 12	91B	
____CHANNEL 13	92A	
____CHANNEL 14	92B	
____CHANNEL 30	93A	
____CHANNEL 31	93B	
____CHANNEL 32	94A	
____CHANNEL 33	94B	
____DSPTAB PLUS 11D	50B	
____RADMODES	64A	
____DAPBOOLS	64B	
____ACTUAL CDU X	37A	
____DESIRED CDU X	35A	
____ACTUAL CDU Y	37B	
____DESIRED CDU Y	35B	
____ACTUAL CDU Z	38A	
____DESIRED CDU X	36A	
____FINAL DESIRED CDU X	30B	
____FINAL DESIRED CDU Y	31A	
____FINAL DESIRED CDU Z	31B	

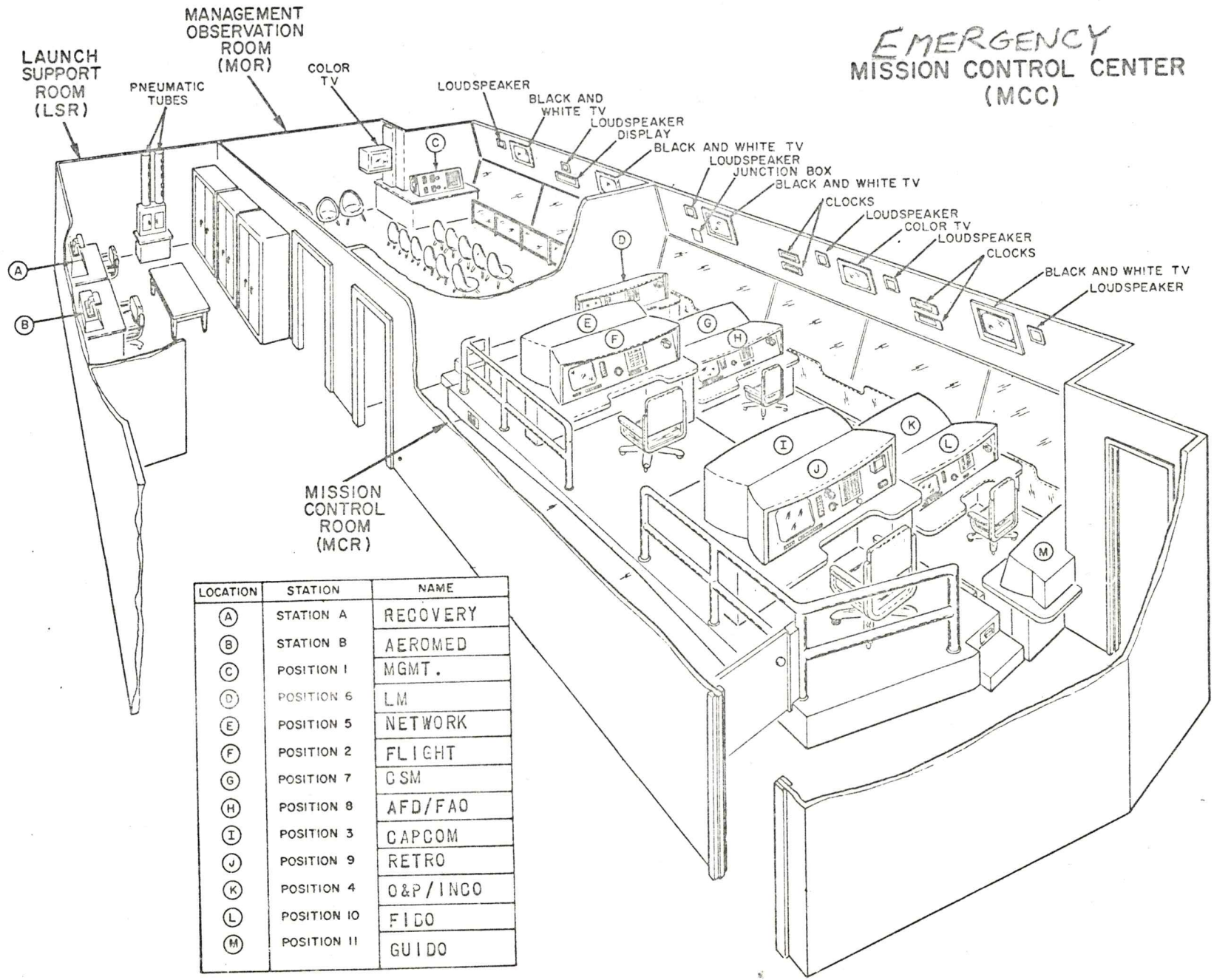
LM BILEVEL MANUAL SUMMARY

____GROUND ELAPSED TIME
____BL730
____BL742
____BL771
____BL772

____BL773
____BL774
____BL775
____BL776
____BL777

____BL778
____BL779
____BL781
____BL782
____BL783

HRS: MIN: SEC:
OCTAL



LOCATION	STATION	NAME
A	STATION A	RECOVERY
B	STATION B	AEROMED
C	POSITION 1	MGMT.
D	POSITION 6	LM
E	POSITION 5	NETWORK
F	POSITION 2	FLIGHT
G	POSITION 7	CSM
H	POSITION 8	AFD/FAO
I	POSITION 3	CAPCOM
J	POSITION 9	RETRO
K	POSITION 4	O&P/INCO
L	POSITION 10	FIDO
M	POSITION 11	GUIDO

SCP NO. **EPS 2-1**

S/C: LM
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: L. Nicholas
APPROVAL: William L. Titus

TITLE: **LM EPS AMPERE-HOUR(AH) CALCULATIONS**

PURPOSE: To explain the RTCC Real-Time (R/T) and Playback (P/B) AH calculations and the procedure for using them.

PROCEDURE:

A. R/T Calculation

Equation: $AH = (t_n - t_{n-1})(A + XA')$

1. t_n = time of present data frame (GMT-hours)
2. t_{n-1} = time of previous data frame (GMT-hours)
3. A = average current per battery, calculated by taking the average of the last ten data samples. This means that the AH's used during LOS will be averaged into the R/T calculation using the last nine current samples from the previous AOS and the first sample from the present AOS, then the last eight and the first two, et cetera. P-8
4. XA' = DA' or AA', Descent or Ascent current bias. These are MED quantities used to correct for obvious differences between actual currents and Current Monitor calibration curves.

B. P/B Calculation

Equation: $AH = (t_n - t_{n-1})(B + XA')$

1. t_n = time associated with present data frame (GMT hours) P-8
2. t_{n-1} = time associated with previous data frame (GMT hours)
3. B = instantaneous current per battery
4. XA' = DA' or AA', Descent or Ascent current bias. These will have the same numeric values as the R/T biases, but are separate MED quantities.

C. Comparison of R/T and P/B Calculations

1. Both R/T and P/B calculate AH's for each individual battery.
2. The R/T calculation uses average current and the P/B calculation uses instantaneous current.
3. The difference in the type of current used (average and instantaneous) will not affect the value of the current bias used. The same number should be used for both calculations.

D. Initial Conditions

The initial conditions for the battery calculations are:

1. All R/T calculations disabled
2. All P/B calculations enabled
3. AH used = 0
4. Descent AH available = 2075 P-8
5. Ascent AH available = 592
6. Descent and Ascent current bias (DA' and AA') = 0

E. Enabling and Disabling R/T and P/B Calculations

The battery AH calculation enable and disable functions are controlled by the SMEK.

1. To enable the R/T calculation:
   a. Depress desired battery calculation PBI's ("Battery No. 'X', X = 1, 2, ...6).
   b. Then depress the "BAT CALC" PBI.
   c. Then depress the "EXECUTE" PBI.
2. When the R/T battery calculation is enabled, the following data will be displayed:
   a. Average current
   b. The sums of average currents (Ascent, Descent, Total)
   c. The individual battery AH consumed (Bat 1, 2, ... 6)
   d. The sums of AH consumed (Ascent, Descent)
   e. The Ascent and Descent AH remaining (difference between initial AH and calculated AH consumed).

3. To disable the R/T calculation:
   a. Depress desired battery calculation PBI's ("Battery No. 'X', X = 1, 2, ... 6)
   b. Then depress the "BAT CALC" PBI.
   c. Then depress the "EXECUTE" PBI.
4. When the R/T battery calculation is disabled, the following data will be displayed:
   a. "M" (Missing) will be displayed for the affected average currents.
   b. The sums of the average currents will be that of the enabled battery calculations only.
   c. The individual battery AH affected will remain static at the last computed value.
   d. During periods of LOS, the D/TV display will remain static until the next sample of live data, at which time it will be updated to show the disabled status of the selected calculations. The battery calculation status lights indicate the actual status of the battery calculations at all times. P-3
5. All P/B battery calculations are enabled at the same time using the "BAT P/B COMP ENBL/DSBL" PBI, which works on an enable/disable flip-flop basis. Since the P/B calculations are enabled when the RTCC is initialized, depressing this PBI will disable the calculation. Subsequent depressions of the PBI will alternately enable and disable the P/B calculations. P-8
6. When the P/B calculations are enabled, the following data will be displayed:
   a. The individual battery AH consumed (Bat 1, 2, ... 6)
   b. The sums of the AH consumed (Ascent, Descent)
   c. IMET = time associated with initial data frame
   d. MET = time associated with present data frame
7. When the P/B calculations are disabled, all of the above displays will remain static except MET. P-8
8. The only other control over the P/B calculations is the "BAT P/B COMP ZERO" PBI. This PBI zeros the following parameters, after which they immediately start being updated again: P-8
   a. The individual battery AH consumed (Bat 1, 2, ... 6)
   b. The sums of AH consumed (Ascent, Descent)
   c. IMET P-8

F. Mission Data Management
1. Premission through TD&E (EPS SSR responsibility):
   a. The AH's consumed per battery from activation through TD&E should be hand calculated, based on the following data sources:
      (1) SODB power requirements and/or TM currents P-8
      (2) Observed percent battery sharing
      (3) Heater duty cycles observed prelaunch and at TD&E
      (4) Data received from SPAN
   b. The most accurate result as agreed upon and understood by all shifts should then be MED into the RTCC program just prior to the first LM powerup.
   c. The RTCC AH calculation will not be enabled prelaunch.
2. R/T Pass (EPS SSR responsibility)
   a. The following items should be logged in the console log book.
      (1) AOS GET, AH's used and average currents. P-8
      (2) LOS GET, AH's used and average currents.
   b. These data shall be used to verify that the RTCC program calculates the correct amp-hours for each LOS.

3. P/B Data (EPS SSR responsibility)

a. LM data is normally recorded by the CSM during periods of LOS, and is transmitted to a ground station. These data are not normally played back to MCC-H.

When time permits, the data should be played back at the 1/1 rate for accuracy. The 8/1 playback rate is acceptable when time is critical. There is no intention of using the 32/1 playback rate, but the capability does exist. P-8

If the 8/1 rate is used the numbers for amp-hours used must be multiplied by 8 to correct for the playback rate. A factor of 32 should be used for the 32/1 playback rate. The time used in the amp-hour calculations is R/T GMT and is not keyed to the playback rate.

b. Before P/B data is received, "zero" the P/B calculations.

c. Input "Tape P/B Request Form" to O&P, giving the following information:

(1) Site/REV
(2) PCM Playback (DSE)
(3) Vehicle
(4) Formats (HSD and MCC Events)
(5) Start/Stop Time (MET)
(6) P/B bit--set
(7) P/B speed

P-8

TIC will make all necessary arrangements and notify originator when P/B is ready, and will report when P/B is complete.

NOTE

It should be emphasized that P/B data should always be played with the P/B bit set at either the remote site or MCC. Otherwise P/B data will invalidate R/T AH calculations.

d. At the completion of P/B data, log the AH's used and the time covered by the P/B. P-8

e. There are no plans to use P/B data to correct R/T amp-hour calculations.

4. General

a. The R/T calculation will only be enabled after L/O and then immediately after the first acquisition of R/T data from the LM. P-3

b. During the LM power up sequences, there will be short periods of time during which the LM is on internal power with no TM data (R/T or P/B) available. For these instances, a hand-calculated AH available must be MED into the R/T calculation to account for the power used. This applies to both prelaunch and orbit phases.

c. The AH calculations in the R/T program can be disabled for an entire LOS period by disabling the R/T calculation anytime during the LOS period and enabling the R/T calculation after acquisition of R/T LM data. If the R/T AH calculations are disabled and enabled during the same LOS period, the AH will be computed for the entire LOS period. P-3

d. When a battery is turned off, the appropriate R/T calculation should be disabled to prevent noise from introducing inaccuracy into the total AH calculation (descent, ascent).

e. The P/B calculation will be disabled whenever someone requests a tape playback from which AH information is not wanted.

f. Whenever a MED is made or a R/T calculation is enabled or disabled the time and appropriate data must be entered in the EPS console log book. P-8

These pages deleted by PCN-8

SCP NO. **EPS 2-2**

S/C: LM
DATE: 11/1 /71
REVISION: PCN-11
ORIGINATOR: L. Nicholas
APPROVAL: William L. Peters

TITLE: CONTINGENCY TRANSLUNAR COAST LM BATTERY MANAGEMENT

PURPOSE: The purpose of this SCP is to describe the use of the LM descent batteries during translunar coast if power could not be supplied from the CSM.

PROCEDURE: As soon as possible after TD&E, a crewman should enter the LM and open the following circuit breakers:

CB (11) LTG: ANNUN/DOCK/COMPNT - OPEN
EPS: DES ECA - OPEN
DC BUS VOLT - OPEN

CB (16) LTG: FLOOD - OPEN
EPS: DC BUS VOLT - OPEN
DES ECA - OPEN

The LCA has 9 hour thermal constraint and the ECA's have a 31 hour thermal constraint.

After approximately 10 - 15 ampere-hours have been consumed from each battery 1 and 4, these batteries should be switched to high taps.

At GET of 58 hours, it is desirable to switch batteries 2 and 3 on and 1 and 4 off to keep the state of charge equal and to limit the temperature rise on batteries 1 and 4. Since there are no low taps available on batteries 2 and 3 to prevent over voltage at the bus, it is necessary to detusk these batteries. The LM will be powered up, batteries 2 and 3 switched on and 1 and 4 switched off. The LM will remain powered up until 10 - 15 ampere-hours are removed from each battery. The power up procedure is to use the PDI day portion of the activation checklist up through the ACTIVATION PWR UP CB charts.

Omit any descent battery switching in this checklist and the CDR and LMP CONNECT TO LM ECS. Batteries 2 and 3 are switched on at the end of this power up and 1 and 4 switched off. Thirty to forty minutes before power down water will be shut off to the sublimator. The LM will be powered down to the configuration at the beginning of this power up.

This sheet deleted by PCN-11

SCP NO. **PYRO 3-1**

S/C: LM
DATE: 3/1/72
REV: PCN 12
ORIGINATOR: Conwell/Heselmeyer
APPROVAL: William L. Peters

TITLE : MANUAL STAGING ON THE LUNAR SURFACE

REFERENCES:
1. MSC Internal Note No. 71-FM-198, "Manual Staging on the Lunar Surface for LM-10 and Subsequent Vehicles"
2. Memo FM 37 (71-90), "LM Attitude Constraints for Safe Manual Staging from the Lunar Surface and Equations for Interpreting Real-Time Data"

PURPOSE : To explain the constraints and procedures associated with manual staging on the lunar surface.

BACKGROUND: Manual staging on the lunar surface will be performed if one pyro system is lost because of the large number of possible single point failures in the remaining system that would preclude proper vehicle staging. If a problem with the staging sequence is discovered, corrective action can then be taken prior to lifting off the lunar surface.

The LM must be in a safe attitude before manual staging will be attempted. The constraint depends on vehicle attitude and the descent O_2 line pressure that appears at the high pressure interstage quick disconnect. The descent O_2 line pressure will be reduced, if required, to insure safe manual staging by means of a special vent adapter carried onboard in the right hand side stowage console.

PROCEDURE : Figures 1, 2, & 3 show the magnitude and direction of the LM tilt angles which are safe for manual staging with maximum pressure, 400 psi, and a depressurized high pressure O_2 line (200 psi constitutes a depressurized line). The LM tilt angle information is calculated by the LM PGNS SSR position immediately after touchdown using the Hewlett Packard 9100B computer and passed to the LM INSTR/PYRO SSR position, which is responsible for properly plotting the point on the attitude constraint chart (Figures 1, 2, & 3). P-12

The following assumptions are made pertaining to the tilt angle calculation:

a. The platform was aligned to be local vertical at the landing site.
b. The LM landed at the planned landing site.
c. The platform had no drift since the last alignment.

Using data from Apollo 11, 12, and 14, it was found that a 0.5° error in pitch or roll causes no greater error than $\pm 0.5^\circ$ in the magnitude and $\pm 7.0^\circ$ in the direction of the tilt angle. A 0.5° error in yaw causes no error in the magnitude and $\pm 0.5^\circ$ error in the direction of the tilt angle. In general, the maximum drift in each platform axis will be 0.1° which will cause a maximum error of $\pm 0.1^\circ$ in the magnitude and $\pm 1.4^\circ$ in the direction of the tilt angle. (After any P57, the Guidance Officer can project gimbal angles back to touchdown to give accurate touchdown angles if confidence was lost in the touchdown angles).

The Hewlett Packard Program is executed as follows:

1. Obtain gimbal angles in stable member coordinates from PGNS real-time D/TV display at touchdown or use angles supplied by the Guidance Officer after a P57.
2. Switch configuration for Hewlett Packard
   - o Degrees
   - o Fixed Point
   - o Power ON
   - o Run
   - o Printer ON with X, Y, and Z button depressed

3. Set decimal wheel to 5
4. Go to - 00
5. Enter side A of card No. 12
6. Go to - 00
7. Continue
8. Clear
9. Enter Roll
10. ↑
11. Enter Pitch
12. ↑
13. Enter Yaw
14. Continue
15. Printout will be as follows:

Roll
Pitch } Input
Yaw

Tilt Angle Magnitude
Tilt Angle Direction } Output
0

Should the LM tilt angle be such that manual staging cannot be safely performed with the high pressure O_2 line fully pressurized, then the line will be vented to the recommended tilt angle constraint. For a failed armed pyro system, any necessary venting will be performed as soon as practical and the lunar stay continued within the consumables capability. In this case, minimum O_2 venting is highly desirable, and the maximum tilt angle constraint will be used. If a better resolution than that provided by Figures 1, 2, or 3 on the O_2 line pressure for the particular vehicle attitude is required, MPAD will be requested to perform that analysis real-time via SPAN. Time for such an analysis is estimated to be a maximum of 2 hours. P-12

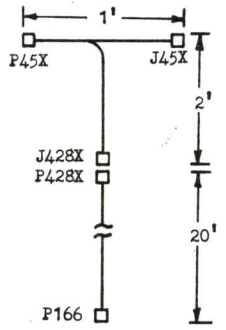
Manual staging due to the loss of a pyro system will be performed as close to liftoff as practical, while allowing sufficient time to verify staging. Three to five minutes before the planned liftoff is sufficient time for this verification. Any associated O_2 line venting required can be performed whenever it is convenient to do so. Figure 4 shows line pressure vs time to vent to that pressure. P-12

Only partial verification of the staging function can be accomplished. Those functions that can be monitored are:

a. ECI operation via the loss of descent parameters
b. Guillotine operation via Descent H_2O pressure decay (measured in the ascent stage)

Another possible cue could be a slight rise in the glycol pump pressure if the vehicle dynamics are such that the glycol interstage quick disconnects are separated and glycol no longer flows to the descent stage.

Verification of incomplete staging after the loss of a pyro system results in using the jumper cable provided for backing up the staging function as well as for an emergency ascent engine on capability. This jumper is configured as shown on the following page.

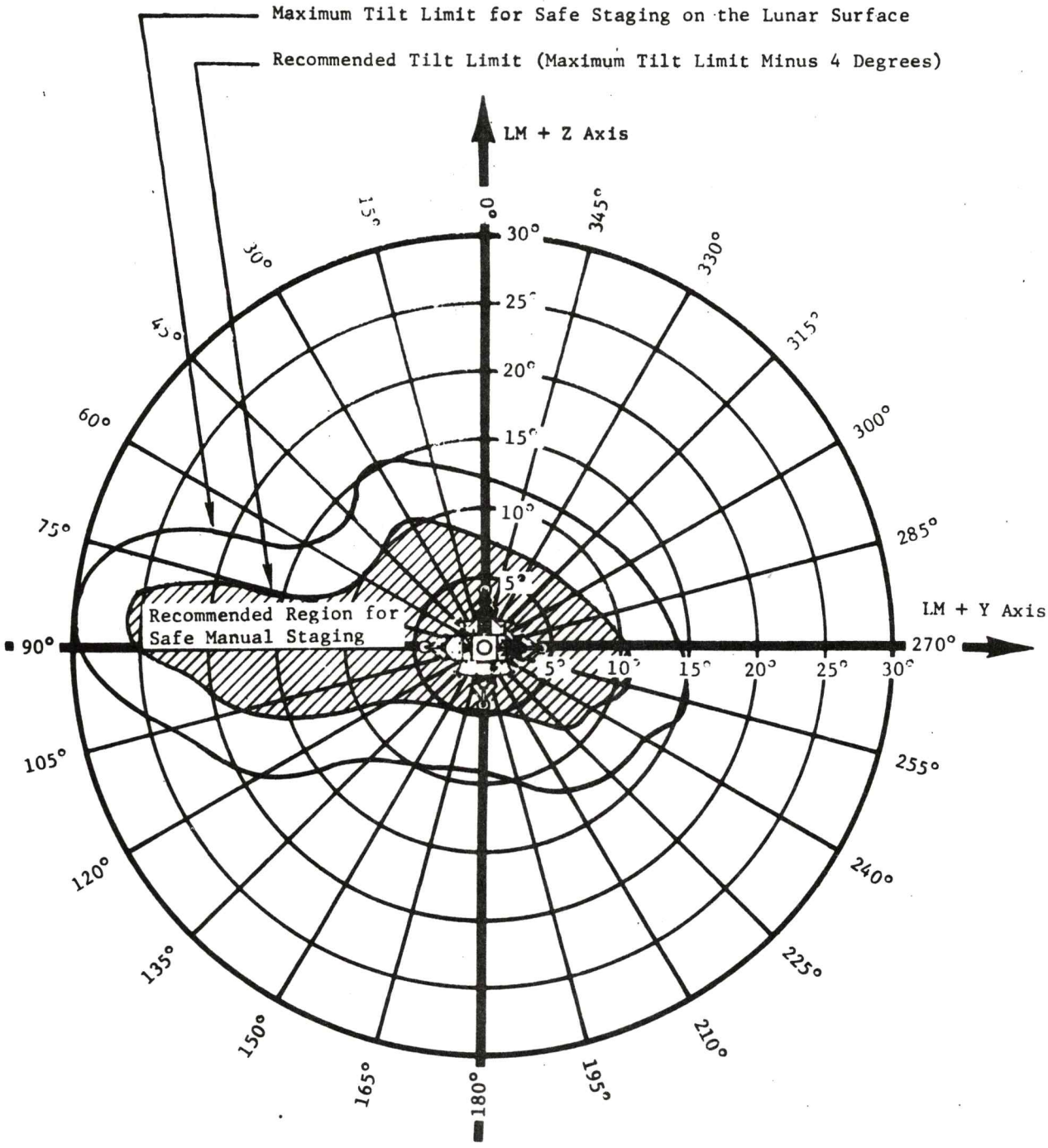


Both parts of the jumper are stowed in the left hand side midsection. For this purpose of backing up an incomplete staging the 20 foot portion of the jumper is used.

The special crew procedure for using this jumper is documented in the AOH, Volume II. In general, the 20 foot cable is connected from the LMP Bus GSE connector in the LM cabin to the GSE connector on top of the Pyro System A relay box in Quad IV of the descent stage (Ref. LSH DWG. 4.1.1).

This connection completes an electrical path from the LMP bus to Pyro Bus A, bypassing Pyro Battery A and the system A Master Arm relay. Staging may then be performed using the stage switch. The only failures for which this procedure is ineffective is the inability to close the Logic Power A circuit breaker or a stage switch failure that precludes energizing the System A stage relay. For those failures the staging sequence cannot be initiated by Pyro System A unless the jumper is spliced to each pyro function individually at the relay box.

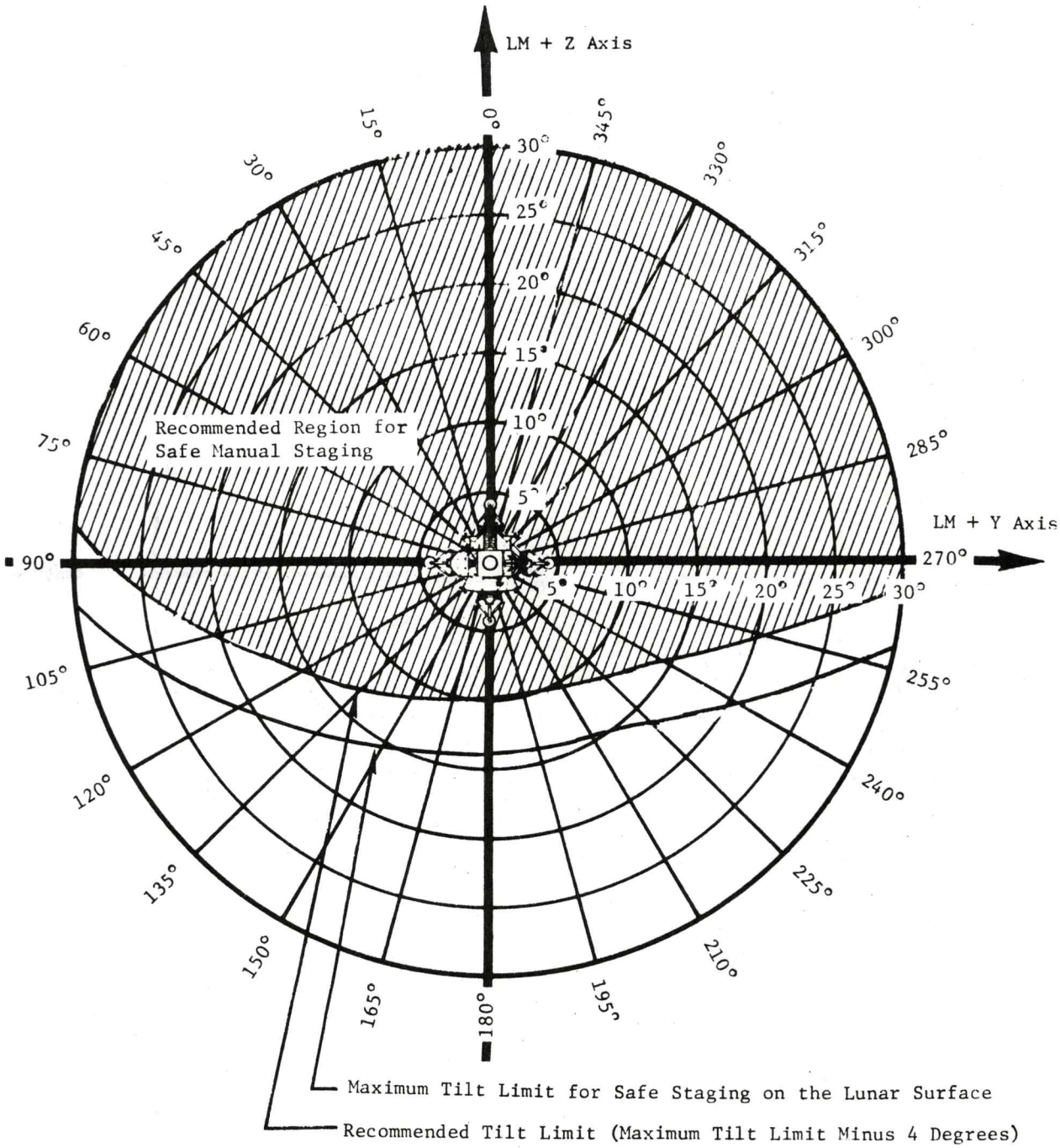
The jumper cable procedure cannot be used with Pyro System B because the System B relay box is inaccessible to the crew.



Tangential Coordinate: Azimuth of the Tilt Direction of the LM +X Axis, Measured Counterclockwise from the LM +Z Axis

Radial Coordinate: Total Rotation of the LM +X Axis Away from the Local Vertical

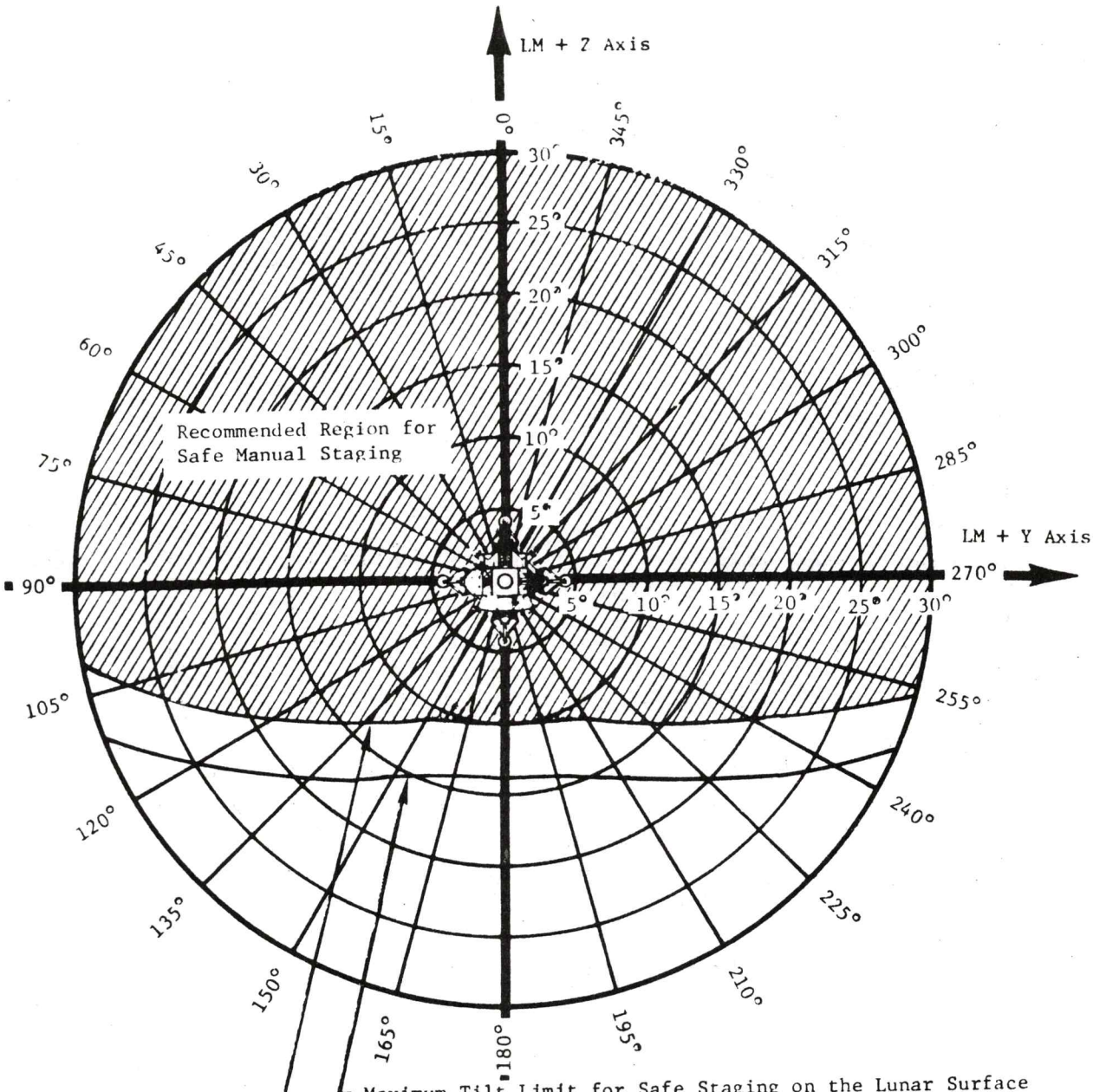
Figure 1. Lunar Surface Slope Limits for Safe Manual Staging; Fully Pressurized ECS Lines



Tangential Coordinate: Azimuth of the Tilt Direction of the LM +X Axis, Measured Counterclockwise from the LM +Z Axis

Radial Coordinate: Total Rotation of the LM +X Axis Away From the Local Vertical

Figure 2. Lunar Surface Slope Limits for Safe Manual Staging; 400 psi at Left Front ECS Fitting, Full Pressure at Right Rear Fitting



Tangential Coordinate: Azimuth of the Tilt Direction of the LM +X Axis, Measured Counterclockwise from the LM +Z Axis

Radial Coordinate: Total Rotation of the LM +X Axis Away from the Local Vertical

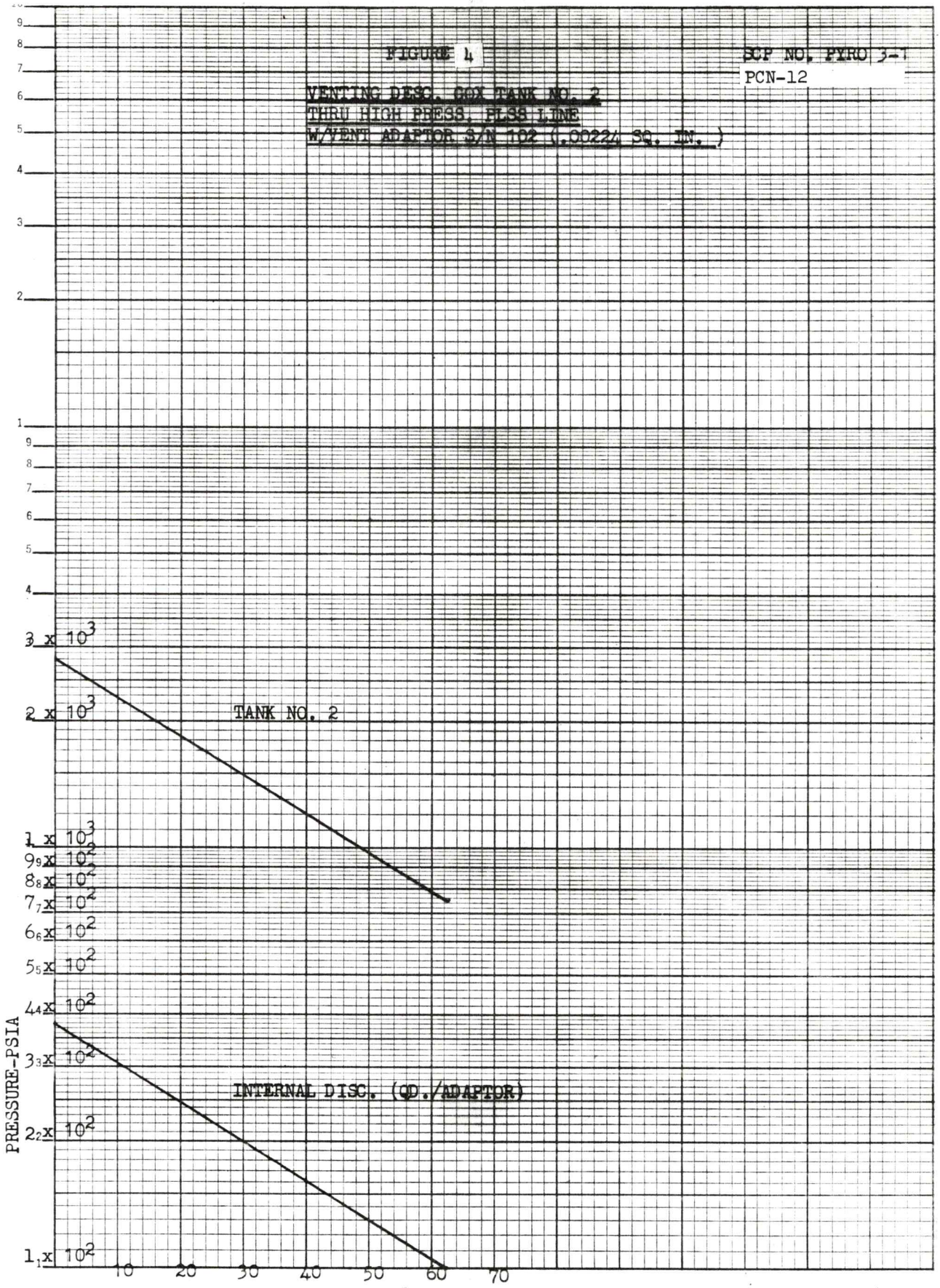
Figure 3. Lunar Surface Slope Limits for Safe Manual Staging; 200 psi at Left Front ECS Fitting, Full Pressure at Right Rear Fitting

P-12

FIGURE 4

SCP NO. PYRO 3-1
PCN-12

VENTING DESC. GOX TANK NO. 2
THRU HIGH PRESS. FLSS LINE
W/VENT ADAPTOR S/N 102 (.00224 SQ. IN.)



SEMI-LOGARITHMIC 46 5492
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

SCP NO. **PYRO 3-2**

S/C: LM
DATE: 11-1-71
REV: PCN-11/NEW
ORIGINATOR: H. Perkins
APPROVAL: William L. Peters

TITLE: PYROTECHNIC RELAY TROUBLESHOOTING PROCEDURES

INTRODUCTION: The purpose of this SCP is to clarify troubleshooting procedures pertaining to indications associated with an inadvertent closure of pyrotechnic relays K1 through K6.

BACKGROUND: The following are basic facts and assumptions which are pertinent to subsequent discussion of actions to be taken in the event a pyro relay failure is indicated.

A. Each pyro system is 100 percent redundant to the other in the ability to perform all required functions.

B. Each pyro system has 2 screened latching relays (K1 & K2). Each of these relays can be manually reset.

C. The remaining relays (K3, K4, K5, K5a, K6) in each system are nonlatching. There is no known failed closed failure mode of nonlatching relays.

D. In all pyro relays, separate contacts are used for the function and the instrumentation indication.

E. It is reasonable to assume that contamination within a relay will affect only one relay contact. For pyro relays, then, contamination affecting the instrumentation contacts is physically removed from the functional contacts, and the probability of the contamination bridging both the functional and instrumentation contacts is considered very small.

F. The functional actuation of each relay except K3 (STAGE SEQ.), K4 (GUILLOTINE), K5 and K5a (NUTS OR BOLTS) is verifiable should it occur inadvertently.

G. The telemetry and component caution lights are driven by the same signal. The ED RELAYS caution light is also driven by this signal but from a different signal conditioner location.

H. In general, no troubleshooting action will be taken if the action could result in a NO GO situation that could otherwise have been avoided.

I. The pyrotechnic systems will always be maintained so as to be able to withstand one more failure without catastrophic consequence.

J. Instrumentation indications of relay anomalies are insufficient to make a GO/NO GO decision. Anomalies must be confirmed by some action.

OPERATIONS:

A. Pre-PDI

1. Should telemetry and/or a STAGE SEQ. component caution light indicate inadvertent actuation of a relay without the ED RELAYS caution light, the following will be performed:
   (a) LAMP/TONE TEST SW - C/W 4 to verify ED RELAYS light bulb (also check CMPNT position if TM indication only to check comp light bulb).
   (b) Verify: CB ED: LOGIC PWR _____ - Closed
   MASTER ARM - Off
   (c) STAGE RELAY - Reset
   (d) Attempt a pyro function, if feasible, with the MASTER ARM SW - Off

The symptoms are indicative of an instrumentation problem (II-G), and steps (c) and (d) check for double failures only. The consequence of this failure is that the disarmed status of the applicable system will be functionally verified after the first time it is used to verify proper system operation. If the system were to remain armed, the mission would be NO GO.

2. If all applicable indications, i.e. the telemetry, the caution light, and the component light, show inadvertent acutation of a pyro relay, perform the following:
   (a) Verify: CB ED: LOGIC PWR ____ - Closed
   MASTER ARM - Off
   (b) STAGE RELAY - Reset

(c) Attempt a pyro function
(d) Ascent Bats 5 & 6 - On
Don helmets and gloves
MASTER ARM - On

The symptoms indicate that at least the instrumentation contacts on a relay have been closed. Step (c) above tests the functional contacts of K1. If closed, PDI is NO GO as documented in the mission rules. Step (d) tests the functional contacts of K2 & K6. If either is closed, the staging function or the ECI function will occur and PDI is impossible. This test is justified by the fact that if the functional contacts on either relay are closed, PDI is NO GO anyway. If the above procedure produces no function, then a problem with the instrumentation contacts of one of the pyro relays is assumed. This assumption is made in spite of the fact that the functional contacts K3, K4, K5 and K5a have not been verified, but this action is justified in view of the facts listed in paragraphs II-C, II-D, and II-E.

Again, the consequences of an instrumentation failure require verification of system disarming after the first time the system is used.

B. During Powered Descent

1. Same as III.A.1
2. With all three indications of a pyro relay closure:
   (a) Verify: CB ED: LOGIC PWR ____ - Closed
   MASTER ARM - Off
   (b) STAGE RELAY - Reset
   (c) Attempt a pyro function with the MASTER ARM SW - Off
   (d) CB ED: LOGIC PWR ____ - Open

This procedure manually resets the two K2 latching relays and tests the functional contacts of K1. For this mission phase, a test of the functional contacts of K2 - K6 (except for K3, K4, K5, & K5a - see II-F) is unacceptable because, if actually closed, the vehicle could stage without an ascent engine "ON" signal or descent engine control could be lost. Therefore, these functions cannot be tested. This situation is acceptable because the manual reset of the latching relays has been exercised, and the probability of functional contacts actually being closed is considered very small (Ref II-C, II-D, II-E).

Because of step (d), if abort staging is required for any reason, the additional step of closing this CB must be performed prior to the abort staging sequence.

After touchdown, DPS venting should be performed with the logic power CB in the questionable system open.

C. Lunar Stay

1. <u>LM within safe manual staging constraints</u> (Ref SCP PYRO 3-1)
   If the LM is within the landing attitude/descent oxygen tank pressure constraints that permit a safe manual (or inadvertent) staging, no troubleshooting is required and the mission will be continued. For this case inadvertent staging is the acceptable consequence of the next worst case failure.
2. <u>LM not within safe manual staging constraints</u> (Ref SCP PYRO 3-1)
   Troubleshooting should be performed as in III.A.1 or III.B.2 depending on the symptom. If K1 or K2 is confirmed closed and descent oxygen tank 2 can be vented to put the LM within the safe staging constraints, then the venting should be performed and the mission continued. With K1 or K2 closed and no possibility of getting within the safe staging constraints, lunar liftoff must be performed at the next best opportunity since the next worst case failure would be a catastrophic inadvertent staging

Note that no detectable pyro system failure will be cause for EVA termination. Even if the LM is not within the safe staging constraints, the probability of a second failure staging the vehicle before the EVA is terminated is considered acceptably small.

SCP NO. COMM 4-1

This SCP is deleted
by PCN-3

SCP NO. INST 5-1

S/C: LM
DATE: 4/14/69
REV: Original
ORIGINATOR: D. Whittle
APPROVAL: Donald R Puddy

TITLE: PCMTEA CAL VOLTAGE SHIFT

PURPOSE: The purpose of this SCP is to define the procedure to be followed if the PCMTEA calibration parameters GL0401V and GL0402V demonstrate a linear shift on the telemetry downlink.

Normal operating limits for subject parameters are:

GL0401V CAL 85 PCT 4.25(±one PCM cnt = .02 volts)

GL0402V CAL 15 PCT 0.75(±one PCM cnt = .02 volts)

PROCEDURE: Should the above parameters degrade beyond the given limits, the following action is recommended.

A. Choose a random sampling of analog parameters and ascertain if they are reading the expected normal for the particular phase of the mission the problem occurs. Suggested parameters would be:

GC0071	AC BUS VOLT
GC0155	AC BUS FREQ
GF4101	PRI H_2O ΔP
GF2021	GLY PUMP P
GF3582	ASC 1 O_2 PRESS
GF3583	ASC 2 O_2 PRESS
GH1311	MAN THRUST CMD
GP0001	APS HE 1 PRESS
GP0002	APS HE 2 PRESS
GP0025	APS HE REG PRESS
GP1501	APS FUEL PRESS
GP1503	APS OX PRESS
GQ3018	DPS HE REG PRESS
GQ3603	DPS FUEL 1 QTY
GQ3604	DPS FUEL 2 QTY
GQ4103	DPS OX 1 QTY
GQ4104	DPS OX 2 QTY
GR1085	RCS PROP A QTY
GR1095	RCS PROP B QTY

B. If the suggested parameters are reading normal, then there is a possibility that the calibrator reference power has deviated. The reference power is regulated via a zener diode within the calibrator box. A simple voltage divider provides the calibrator outputs. Therefore, no action is required to bias all analog parameters.

C. If the suggested parameters are not reading normal, then there is a very definite possibility that the coder has degraded. Two possibilities exist here. One is that reference current for the entire eight summing resistors has deviated. The action in this case would be to bias all analog parameters the appropriate plus or minus percent deviation from the expected normal. This bias will, of necessity, be a "best guess" and should be tied to the calibrator voltage output percent deviation. The second type of failure would be a summing resistor in the decoding lattice to open or shift value. In this case all analog parameters would be biased but by varying percentages depending upon the analog level being encoded. In this case, it would be impossible to determine the failure mode and the respective amount of shift in other analog measurements. The analog portion of the PCMTEA would be considered failed.

SCP NO. INST 5-2

This SCP is deleted
by PCN-3

SCP NO. **ECS 6-1**

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: J. Knight
APPROVAL:

TITLE: **H_2O/O_2 RATE CALCULATIONS**

PURPOSE: This SCP defines the time and method used for H_2O and rate calculations.

PROCEDURE: A. Time - H_2O and O_2 calculations will be hand calculated:

1. Anytime the ECS is initially turned ON
2. Before and after any engine burn

NOTE

Consumables predictions should be calculated in advance of engine burns and transferred to SSR PROP position for c.g. and burn time calculations.

3. Following staging
4. Following Demand Reg checks to determine amount required
5. Following PLSS fills to determine amount required
6. Following PGA integrity checks to determine the amount required
7. Following cabin repressurization

NOTE

Observations should be taken exactly on the PCM count change for maximum accuracy of rate computations. Consumables Sheet should be updated at least once every 30 minutes. If use rates are larger than expected, observation/notation rate shall be increased accordingly.

B. H_2O Rate Method

t_1 = Time Base Reference in minutes
t_2 = Time at which period ends in minutes
Q_1 = Quantity in lbs at T_1
Q_2 = Quantity in lbs at T_2

P-11

1. $\frac{Q_1 - Q_2}{t_2 - t_1} = \frac{\text{lbs}}{\text{min}}$

2. $\frac{\text{lbs}}{\text{min}} \quad (60) = \frac{\text{lbs}}{\text{hr}}$

C. O_2 Rate Method

t_1 = Time Base Reference in minutes
t_2 = Time at which period ends in minutes
P_1 = Pressure in psia at t_1
P_2 = Pressure in psia at t_2
W_1 = Quantity in lbs at t_1
W_2 = Quantity in lbs at t_2
V_1 = 2.985 ft^3 for descent tank
V_2 = 0.495 ft^3 for ascent tank
$R = 1544 \frac{\text{lb - ft}}{^{\circ}\text{R Mole}}$
M = 32 lb/Mole

T_R (°R) = Temperature °F + 460*

$\dot{W} = O_2$ lbs/hr

1. For Descent O_2

   a. $K = \frac{M}{R} V_1 = 8.9$ in^2 - °R

   b. $W_1 = \frac{P_1}{T_R} K =$ lbs

   c. $W_2 = \frac{P_2}{T_R} K =$ lbs

   d. $\dot{w} = \frac{W_1 - W_2}{t_2 - t_1} 60 =$ lbs/hr

2. For Ascent O_2

   a. $K = \frac{M}{R} V_2 = 1.48$ in^2 - °R

   b. Then proceed as steps b, c, and d above

*1. °F for pad operations = 70°.
2. °F for flight operations = 68°.
3. During cabin repress, the O_2 tank temperature will decrease to approximately 48°F and requires 2 to 3 hours to return to normal.

SCP NO. ECS 6-2

This SCP deleted by PCN-8

SCP NO. ECS 6-3

S/C: LM
DATE: 3/27/69
REV: Original
ORIGINATOR: Smith
APPROVAL: Donald K. Cuddy

TITLE: O_2 QUANTITY CALCULATIONS

PURPOSE: This SCP describes the method for determining O_2 quantities in pounds from telemetered pressure and temperature.

PROCEDURE: A. General - The mass of a body of gas can be determined by using the modified gas law formula

$$M = \frac{KP}{T_R Z}$$

where M = mass to be determined in pounds

K = 8.91 for descent tank

= 1.48 for a single ascent tank

P = Pressure in psia (GF3584P, GF3583P, GF3582P)

T_R = (70 + 460)

Z = Compressibility Factor obtained from Table 1 or from a chart of generalized compressibility factors. Z is inserted into the RTCC as a MED.

B. The LM ECS Engineer will insert the compressibility factor from TABLE 1 into the RTCC as required. The factor for 70°F is considered adequate for the expected range of temperatures.

TABLE 1 - O_2 QUANTITY CALCULATION INPUTS

	PRESSURE (PSIA)	QUANTITY (POUNDS) at 60°F	at 70°F	at 80°F	COMPRESSIBILITY (Z) at 70°F
DESCENT TANK	2900	53.92	52.44	51.47	0.930
	2700		48.83		0.930
	2500	46.48	45.16	43.85	0.931
	2300		41.42		0.934
	2100	38.75	37.73	36.64	0.936
	1900		33.99		0.940
	1700	31.00	30.22	29.38	0.946
	1500		26.44		0.954
	1300	23.39	22.77	22.24	0.960
	1100		19.15		0.966
	900	15.94	15.57	15.21	0.972
	700		12.00		0.981
	500	8.66	8.49	8.33	0.990
	300		5.05		0.998
	100	1.71	1.68	1.65	1.00

	PRESSURE (PSIA)	QUANTITY (POUNDS) at 60°F	at 70°F	at 80°F	COMPRESSIBILITY (Z) at 70°F
ASCENT TANK	900	2.64	2.58	2.52	0.972
	700		1.99		0.981
	500	1.44	1.41	1.38	0.990
	300		0.84		0.990
	100	0.28	0.28	0.27	1.00

S/C : LM
DATE : 11/1/70
REV : PCN-6/NEW
ORIGINATOR : Jack Knight
APPROVAL : [signature]

SCP NO. **ECS 6-4**

SUBLIMATED H_2O RATE CALCULATION

1. Subsequent to the LM-3 mission, the WQMD's in the LM water system began to experience accuracy problems and a method was sought to circumvent the loss of one of them.

2. A possible method is to measure the change in temperature across the coolant sublimator. This method makes use of the EPS bus voltage, glycol pump ΔP, and the estimated glycol bulk temperature to determine the glycol flow rate ($\dot{m}$) which, when multiplied by the specific heat of glycol (C_p) and the change in temperature (ΔT), produces the quantity of heat (Q) removed from the glycol:

$$Q = \dot{m} C_p \Delta T$$

Now, in a sublimator, about 1040 BTU are removed by 1 pound of H_2O. Therefore, the water usage rate (WR) is:

$$WR = \frac{Q}{1040} = \dot{m} \frac{C_p \Delta T}{1040}$$

3. An equation of this form with an additive constant has been loaded in the AS-509 RTCC program:

$$WR = \dot{m} K \Delta T + C$$

Where
$\dot{m}$ = MED, glycol flow rate ($\sim$290 LB/HR)
$K = \text{Constant} = \frac{C_p}{1040} = \frac{0.86}{1040} = 0.0008269$
C = MED, Constant

These MED constants will be modified and entered, as required, by the ECS SSR engineer. This latter constant, C, is initialized at zero; but may be used if one of the two temperatures (GF2531T, W/B inlet, and GF2581T, W/B outlet T) used to determine ΔT (= GF2531-GF2581) is in error. For example, if during the prelaunch count, one parameter indicates a temperature different from the other, then C should be chosen to be equal to, but opposite in sign from, the product of $\dot{m} \frac{C_p \Delta T}{1040}$ where ΔT is the static loop ΔT during this period.

Additionally, since the basic equation gives only the H_2O boiled, C may be further modified through use of the SODB information to account for the estimated water lost due to crew metabolic use (urine loss, etc.).

Suppose, for example, GF2531T and GF2581T are reading 75°F and 73.5°F respectively during prelaunch and we assume a metabolic load of 500 BTU/HR for the period under consideration. C, then, will be made up of two factors:

$C_1 = -\dot{m} K \Delta T = -290\ (0.0008269)(1.5) = -0.36$ LB/HR
$C_2 = (1.35 \times 10^{-4})(1000) = 0.135$ LB/HR SODB PAGE 4.3 -4 PAR 4.3.4.10

Therefore, $C = C_1 + C_2 = -0.225$ LB/HR

PLSS refills and water lost during EVA's must be accounted for by modifying the MED for water loaded (See paragraph 5 below) by the amount of PLSS refill and the product of 0.76 and the number of hours for the EVA.

4. The RTCC then, in effect, integrates this rate over time and displays the quantity of water consumed:

$$WC = \sum WR \cdot t$$

The computation operates any time live data is present, however, a PBI is provided to set WC to zero upon depression.

5. Finally, the RTCC performs a simple subtraction to display the water remaining:

$$W_{REM} = W_L - WC$$

Where W_L is an MED and is equivalent to the amount of water loaded in the tank (s) under consideration.

SCP NO. **ECS 6-5**

SPACECRAFT: LM
DATE : 11-1-71
REVISION : PCN-11
ORIGINATOR: Jack Knight
Approval :

CONVERSION OF LM WATER TANK PRESSURE TO QUANTITY

1. On LM-10 and subsequent, the water tank WQMD's will be replaced with pressure transducers to measure the N_2 gas pressure in the tank. These transducers have a range of 0 - 60 PSIA. Additionally, there is a 0 - 25 PSIA transducer in the H_2O line.

2. This means that the RTCC will act as the WQMD and has been programmed as such. This program is based on the following equation derivation:

V_T = Total water tank volume, cu. ft.
V_W = Volume of water in tank, cu. ft.
V_G = N_2 volume, cu. ft.
V_{GI} = Initial N_2 volume, cu. ft.
62.32 = Conversion of volume of H_2O to weight of H_2O, lbs/cu. ft.
P = N_2 pressure, psia
P_I = Initial N_2 pressure, psia
Q_G = N_2 quantity in tank, lbs.
T_G = Temperature of gas, ^oR
k = Constant ($= \frac{28(144)}{1546} = 2.608$)
W_W = Weight of H_2O, lbs.
A = Ratio of water volume to tank volume = $\frac{V_W}{V_T}$

P-11

The basis for these derivations is that the volume of water is equal to the difference between the volume of the tank and the volume of the gas.

$$V_w = V_T - V_G \quad \text{.....(1)}$$

where $V_G = \frac{Q_G \ T_G}{Pk}$ and $Q_G = \frac{P_I \ V_{GI} \ k}{T_{GI}}$

therefore, assuming $T_G = T_{GI}$ = constant,

$$V_G = \frac{P_I \ V_{GI}}{P} \quad \text{.....(2)}$$

and $$V_w = V_T - \frac{P_I \ V_{GI}}{P} \quad \text{.....(3)}$$

dividing by the volume of water loaded:

$$W_{\%} = \frac{1}{A} - (\frac{1}{A} - 1) \frac{P_I}{P} \quad \text{.....(4)}$$

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multiplying equation (3) by 62.32:

$$W_W = 62.32 \ V_T - \frac{62.32 \ P_I \ V_{GI}}{P} \quad \text{.....(5)}$$

The equation of the form $W_W = C_1 - \frac{C_2}{P}$, is loaded into the RTCC with C_1 and C_2 as MED's.

C_1 = 62.32 V_T where V_T = 7.13 for the descent tank and 0.910 for the ascent tanks
= 444.34 descent
= 56.71 ascent
C_2 = 62.32 (P_I V_{GI}) where P_I = initial pressure prior to use, V_{GI} = (1 - A) V_T

The above analysis is based on a constant temperature; the same as at launch. Although the tanks are not

insulated, there is a large mass of H_2O which tends to maintain the temperature within 5 or 10 R° of the predicted and the error involved in assuming constant temperature will be discussed below.

At any instant of time, the error in water volume due to pressure error is:

$$dV_{W_{T = \text{const}}} = \frac{P_I}{P} \frac{dP}{P} V_{GI} \quad \text{.....(6)}$$

Similarly, the error in water volume due to temperature error is:

$$dV_{W_{P = \text{const}}} = V_{GI} \frac{P_I}{P} \frac{dT}{T_I} \quad \text{.....(7)}$$

Applying an RSS technique:

$$dV_w = V_{GI} \frac{P_I}{P} \sqrt{\left(\frac{dP}{P}\right)^2 + \left(\frac{dT}{T_I}\right)^2} \quad \text{.....(8)}$$

The above represents the error equation (in terms of water volume vs gas pressure) applicable to a single tank or to the total water when using the 0 - 25 psia transducers. If both tanks are treated using their 0 - 60 psia transducers these must be RSS'd together.

$$dV_{wT} = \sqrt{(dV_{w1})^2 + (dV_{w2})^2} \quad \text{.....(9)}$$

From the above equations the water volume error clearly varies with the gas volume, i.e., the larger the gas volume, the lower the gas pressure and the larger the absolute error. As the gas eventually is to fill the entire tank, the worst case error is at the bottom of the tank. The most convenient format for this error is to graph the above equation (equation 8) after expressing it in percent error vs percent remaining. P-11

Dividing equation (8) by V_w and substituting $P = \frac{(\frac{1}{A} - 1)}{(\frac{1}{A} - W_\%)} P_I$ from equation (4):

$$\Delta W_\% = \frac{dV_w}{V_w} = \frac{V_{GI}}{V_w} \left(\frac{\frac{1}{A} - W_\%}{\frac{1}{A} - 1}\right) \sqrt{\left(\frac{dP/P_I}{\frac{1}{A} - 1}\right)^2 \left(\frac{1}{A} - W_\%\right)^2 + \left(\frac{dT}{T}\right)^2}$$

and since $\frac{V_{GI}}{V_w} = \frac{1}{A} - 1$; we obtain the equation on Figure 3. (The curves in Figure 3 are illustrative only and indicate the consequences of a 2 percent of full scale pressure error and a $5^\circ R$ temperature error.)

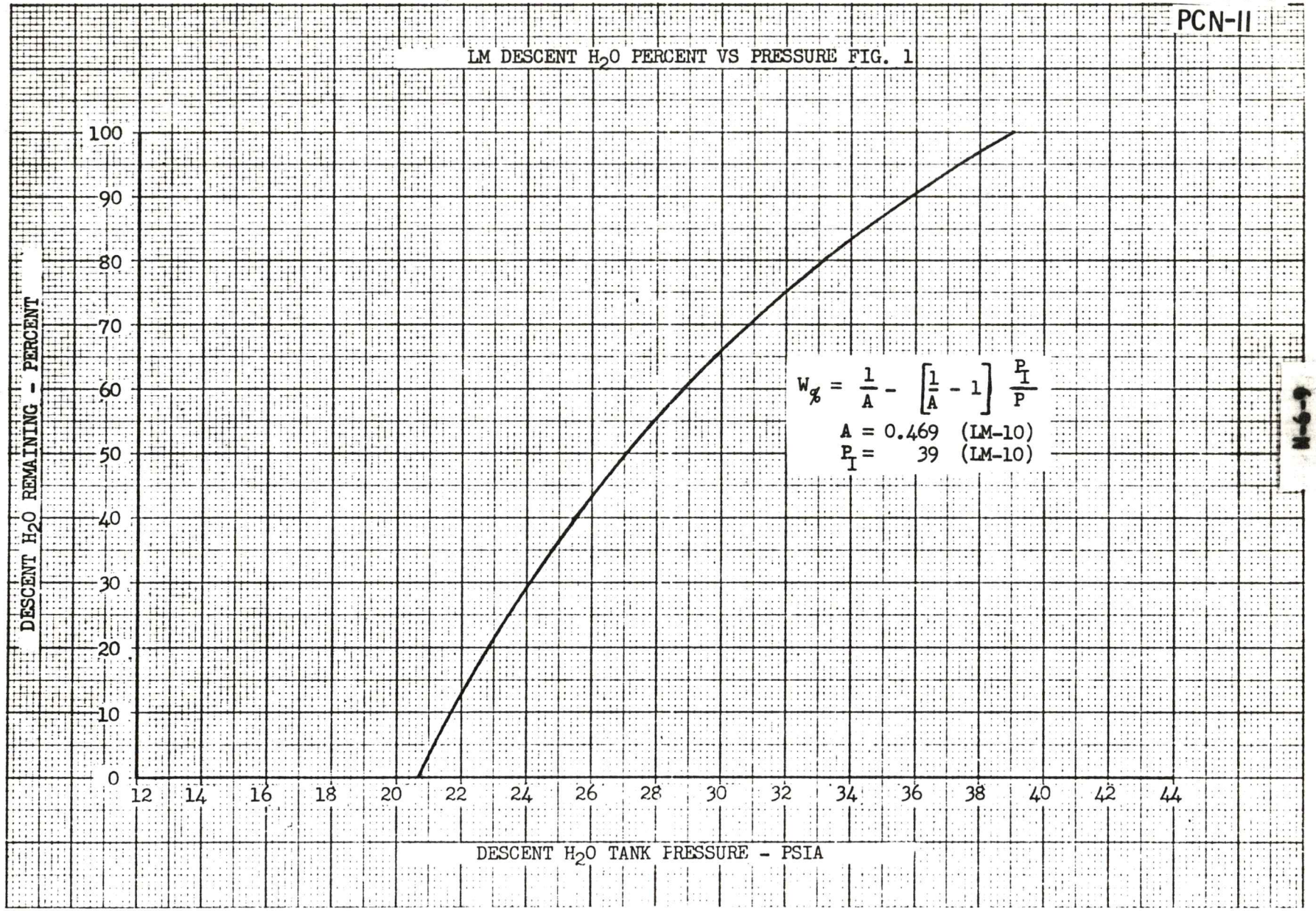
3. Now, should it become apparent that the temperature has in fact decayed, C_2 may be modified to account for this change. This modification may be accomplished simply by multiplying C_2 by the ratio of the present estimated temperature of the gas and the original temperature of the gas expressed in $^\circ R$, i.e., $\frac{T_G}{T_{GI}}$

4. The RTCC will also calculate the percentage of H_2O remaining relative to the initial loading.

$$W_\% = \frac{W_W}{W_L} \quad \text{where } W_\% = \text{percent } H_2O \text{ remaining}$$

W_L = amount of H_2O loaded (MED)

5. The onboard meter responds to a 0 - 5 volt input from the pressure transducers. This now corresponds to 0 - 60 psia but since the N_2 pressure in the H_2O tanks should not exceed 48 psia nor fall below 12 psia for an "A" ratio of 0.75 or 24 psi for an "A" ratio of 0.47, the corresponding maximum and minimum readings will be approximately 80% and 20% or 40%. Since the meter readout is linear with respect to pressure (see Figures 1 and 2), a special decal is constructed for overlay on the meter in the LM. P-11


LM DESCENT H_2O PERCENT VS PRESSURE FIG. 1
DESCENT H_2O REMAINING - PERCENT
100
90
80
70
60
50
40
30
20
10
0
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
DESCENT H_2O TANK PRESSURE - PSIA
$W_{\%} = \frac{1}{A} - \left[\frac{1}{A} - 1\right] \frac{P_I}{P}$
A = 0.469 (LM-10)
P_I = 39 (LM-10)

LM ASCENT H_2O PERCENT VS PRESSURE - FIG. 2

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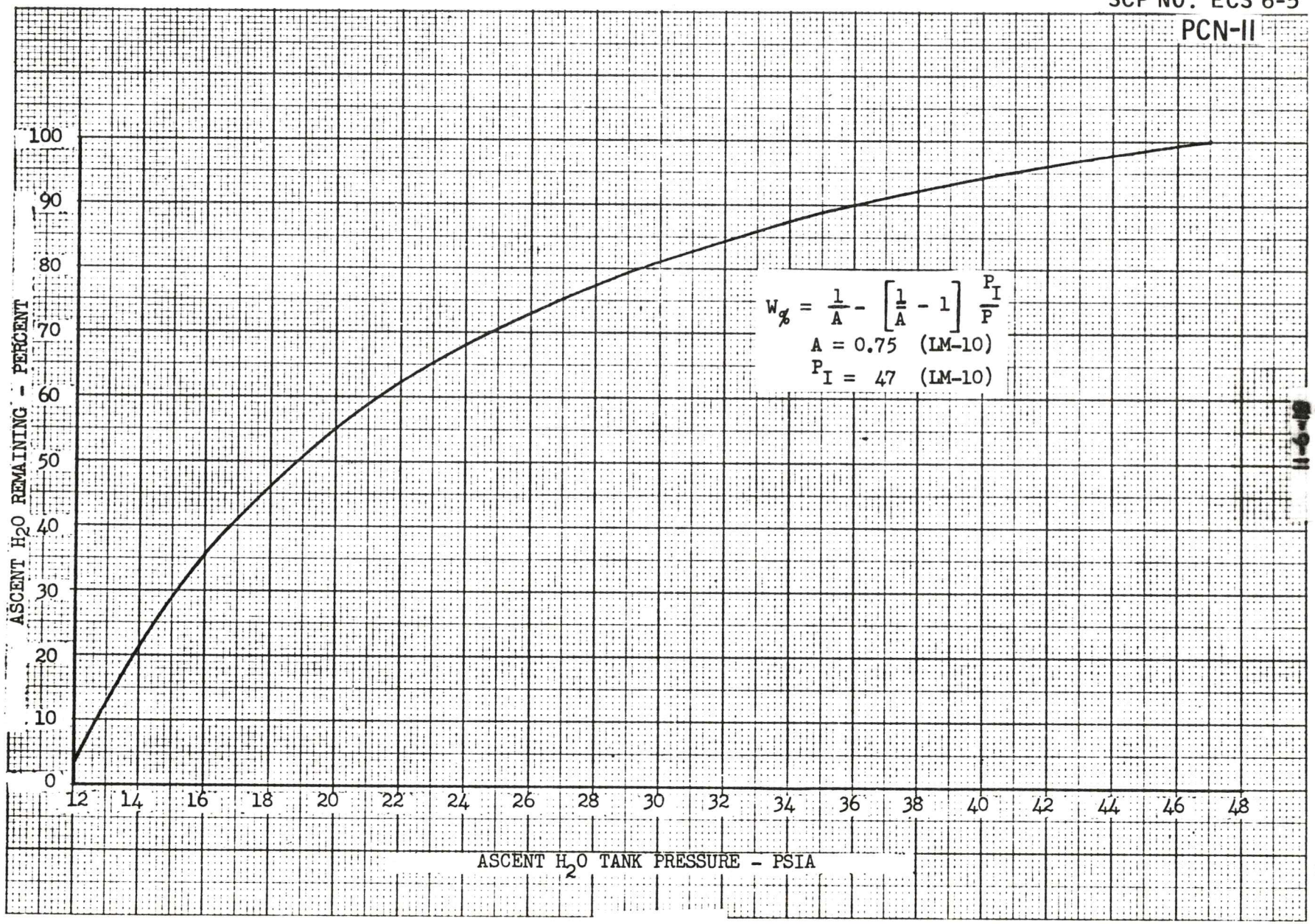
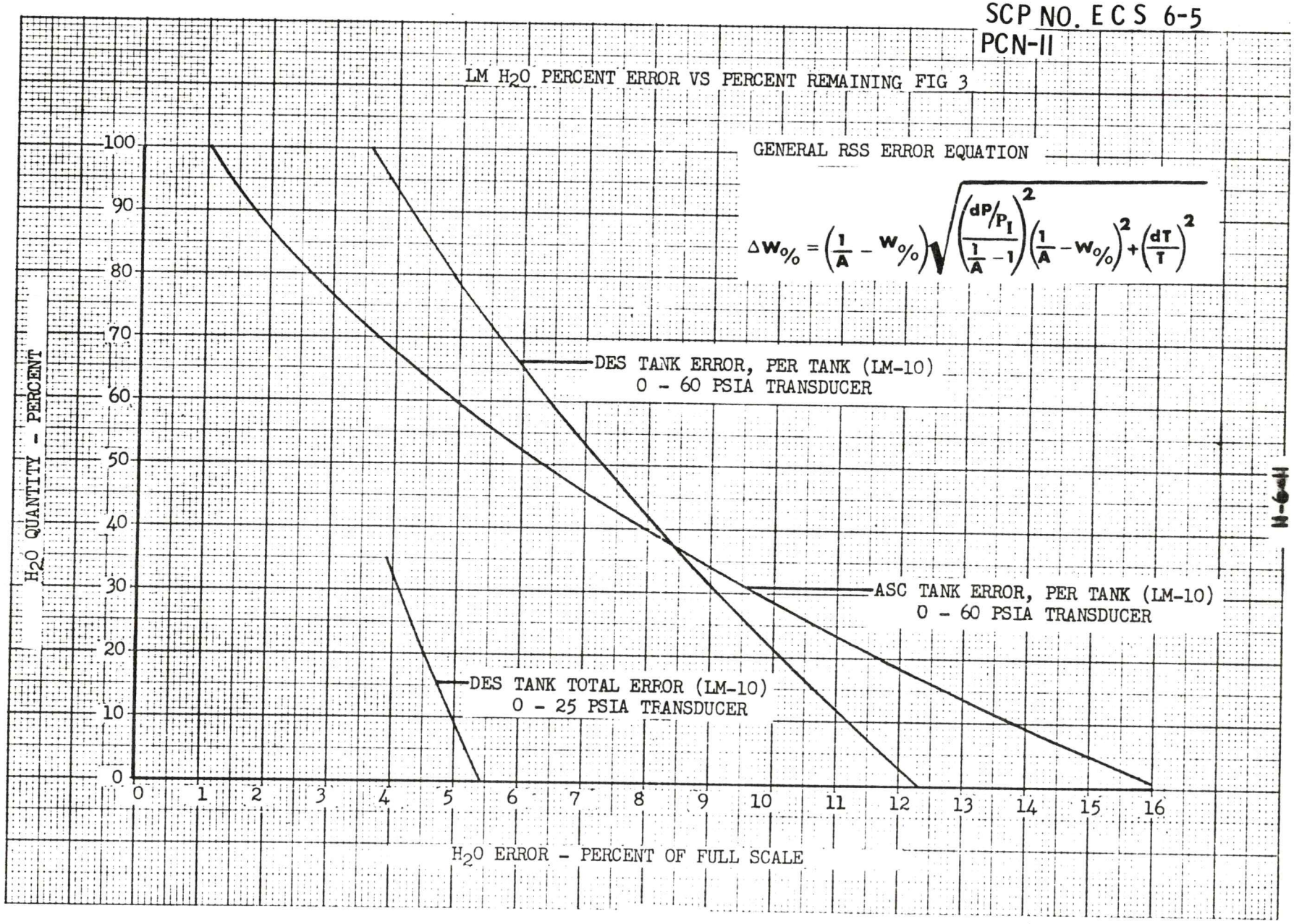
PCN-II



LM H_2O PERCENT ERROR VS PERCENT REMAINING FIG 3

GENERAL RSS ERROR EQUATION

$$\Delta W_{\%} = \left(\frac{1}{A} - W_{\%}\right)\sqrt{\left(\frac{dP/P_I}{\frac{1}{A}-1}\right)^2\left(\frac{1}{A} - W_{\%}\right)^2 + \left(\frac{dT}{T}\right)^2}$$



M-64H

S/C: LM
DATE: 11/1/71
REV: PCN-11
ORIGINATOR: J. Nelson
APPROVAL: Hanley A. Soler

SCP NO. **PGNS 7-1**

TITLE: **IRIG BIAS SHIFT DETERMINATION**

P-11

PURPOSE: The purpose of this SCP is to describe the Manual Irig Bias Shift Determination method using the SSR irig bias measurement log to record the data.

PROCEDURE: See SB PGNS 7-2 IRIG Bias Drift for a brief description of gyro drift. The use of the SSR Irig Bias Measurement Log (see page II-7-4) is described below:

COLUMN	DESCRIPTION
1	Contains the time (GET) of the second P-52 if the REFSMMAT option is selected by the astronaut.
2	Contains the time (GET) of the first P51 or P52.
3	Time between two alignments above in hours.
4, 5, & 6	Gyro torquing commands of the second alignment in R55: FL V06N93 R1 = X GYRO (OGC) XX.XXX Deg R2 = Y GYRO (IGC) XX.XXX Deg R3 = Z GYRO (MGC) XX.XXX Deg "PROCEED" enables torquing. OGC, IGC, MGC will count down to zero. These commands can be voiced down by the astronauts, copied from a DSKY display, or taken from any display which contains LGC downlink words 65, 66, and 67 (OGC, IGC, MGC). If site coverage is available during fine align, a good procedure is to update the LGC Summaries (1200 series) before gyro torquing begins. OGC, IGC, and MGC appear in COAST/ALIGN and LUNAR SURF ALIGN downlinks only.
7	Remarks (How torquing commands obtained)
8 thru 13	Bias shift calculated from torquing commands (DEG) divided by delta time (HRS). Also DEG/HR converted to MERU. (DEG/HR / .015 = MERU)
14 thru 19	If the bias shift exceeds mission rule values, new bias compensation values are calculated according to the following equations: $NBDX_{New} = NBDX_{Old}$ -X bias shift $NBDY_{New} = NBDY_{Old}$ -Y bias shift $NBDZ_{New} = NBDZ_{Old}$ +Z bias shift To convert the new NBD values to octal see attached OCTAL vs DRIFT conversion charts. Note that Table I is for positive NBD values and Table II is for negative values. If an update is to be made, an IRIG/PIPA BIAS UPDATE REQUEST must be filled out and sent to GUIDO. (See page II-7-5).
20	Time (GET) that new NBD terms were inserted into the LGC.

TABLE I

OCTAL UPDATE VS. GYRO DRIFT (POSITIVE)

For octal update of NBDX, Y, Z, (address 1460, 1461, 1462). NBD is scaled B-5 pulses per centisecond. One pulse = .61798 arc seconds.

MERU	(DEG/HR) (X 10-3)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		000	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5
00.	000	00000	00015	00031	00046	00063	00100	00114	00131	00146	00163
01.	15	00177	00214	00231	00245	00262	00277	00314	00330	00345	00362
02.	30	00377	00413	00430	00445	00461	00476	00513	00530	00544	00561
03.	45	00576	00613	00627	00644	00661	00675	00712	00727	00744	00760
04.	60	00775	01012	01026	01043	01060	01075	01111	01126	01143	01160
05.	75	01174	01211	01226	01242	01257	01274	01311	01325	01342	01357
06.	90	01374	01410	01425	01442	01456	01473	01510	01525	01541	01556
07.	105	01573	01610	01624	01641	01656	01672	01707	01724	01741	01755
08.	120	01772	02007	02024	02040	02055	02072	02106	02123	02140	02155
09.	135	02171	02206	02223	02240	02254	02271	02306	02322	02337	02354
10.	150	02371	02405	02422	02437	02453	02470	02505	02522	02536	02553
11.	165	02570	02605	02621	02636	02653	02667	02704	02721	02736	02752
12.	180	02767	03004	03021	03035	03052	03067	03103	03120	03135	03152
13.	195	03166	03203	03220	03235	03251	03266	03303	03317	03334	03351
14.	210	03366	03402	03417	03434	03451	03465	03502	03517	03533	03550
15.	225	03565	03602	03616	03633	03650	03665	03701	03716	03733	03747
16.	240	03764	04001	04016	04032	04047	04064	04100	04115	04132	04147
17.	255	04163	04200	04215	04232	04246	04263	04300	04314	04331	04346
18.	270	04363	04377	04414	04431	04446	04462	04477	04514	04530	04545
19.	285	04562	04577	04613	04630	04645	04662	04676	04713	04730	04744
20.	300	04761	04776	05013	05027	05044	05061	05076	05112	05127	05144
21.	315	05160	05175	05212	05227	05243	05260	05275	05312	05326	05343
22.	330	05360	05374	05411	05426	05443	05457	05474	05511	05525	05542
23.	345	05557	05574	04610	05625	05642	05657	05673	05710	05725	05741
24.	360	05756	05773	06010	06024	06041	06056	06073	06107	06124	06141
25.	375	06155	06172	06207	06224	06240	06255	06272	06307	06323	06340
26.	390	06355	06371	06406	06423	06440	06454	06471	06506	06523	06537
27.	405	06554	06571	06605	06622	06637	06654	06670	06705	06722	06737
28.	420	06753	06770	07005	07021	07036	07053	07070	07104	07121	07136
29.	435	07152	07167	07204	07221	07235	07252	07267	07304	07320	07335
30.	450	07352	07366	07403	07420	07435	07451	07466	07503	07520	07534
31.	465	07551	07566	07602	07617	07634	07651	07665	07702	07717	07734
32.	480	07750	07765	10002	10016	10033	10050	10065	10101	10116	10133
33.	495	10150	10164	10201	10216	10232	10247	10264	10301	10315	10332
34.	510	10347	10364	10400	10415	10432	10446	10463	10500	10515	10531
35.	525	10546	10563	10577	10614	10631	10646	10662	10677	10714	10731
36.	540	10745	10762	10777	11013	11030	11045	11062	11076	11113	11130
37.	555	11145	11161	11176	11213	11227	11244	11261	11276	11312	11327
38.	570	11344	11361	11375	11412	11427	11443	11460	11475	11512	11526
39.	585	11543	11560	11575	11611	11626	11643	11657	11674	11711	11726
40.	600	11742	11757	11774	12011	12025	12042	12057	12073	12110	12125
41.	615	12142	12156	12173	12210	12224	12241	12256	12273	12307	12324
42.	630	12341	12356	12372	12407	12424	12440	12455	12472	12507	12523
43.	645	12540	12555	12572	12606	12623	12640	12654	12671	12706	12723
44.	660	12737	12754	12771	13006	13022	13037	13054	13070	13105	13122

TABLE II

OCTAL UPDATE VS. GYRO DRIFT (NEGATIVE)

For octal update of NBDX, Y, Z (address 1460, 1461, 1462). NBD is scaled B-5 pulses per centisecond. One pulse = .61798 arc seconds.

MERU	(DEG/HR X 10-3)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		000	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5
-00.	-000	00000	77762	77746	77731	77714	77677	77663	77646	77631	77614
-01.	-15	77600	77563	77546	77532	77515	77500	77463	77447	77432	77415
-02.	-30	77400	77364	77347	77332	77316	77301	77264	77247	77233	77216
-03.	-45	77201	77164	77150	77133	77116	77102	77065	77050	77033	77017
-04.	-60	77002	76765	76751	76734	76717	76702	76666	76651	76634	76617
-05.	-75	76603	76566	76551	76535	76520	76503	76466	76452	76435	76420
-06.	-90	76403	76367	76352	76335	76321	76304	76261	76252	76236	76221
-07.	-105	76204	76167	76153	76136	76121	76105	76070	76053	76036	76022
-08.	-120	76005	75770	75753	75737	75722	75705	75671	75654	75637	75622
-09.	-135	75606	75571	75554	75537	75523	75506	75471	75455	75440	75423
-10.	-150	75406	75372	75355	75340	75324	75307	75272	75255	75241	75224
-11.	-165	75207	75172	75156	75141	75124	75110	75073	75056	75041	75025
-12.	-180	75010	74773	74756	74742	74725	74710	74674	74657	74642	74625
-13.	-195	74611	74574	74557	74542	74526	74511	74474	74460	74443	74426
-14.	-210	74411	74375	74360	74343	74326	74312	74275	74260	74244	74227
-15.	-225	74212	74175	74161	74144	74127	74112	74076	74061	74044	74030
-16.	-240	74013	73776	73761	73745	73730	73713	73677	73662	73645	73630
-17.	-255	73614	73577	73562	73545	73531	73514	73477	73463	73446	73431
-18.	-270	73414	73400	73363	73346	73331	73315	73300	73263	73247	73232
-19.	-285	73215	73200	73164	73147	73132	73115	73101	73064	73047	73033
-20.	-300	73016	73001	72764	72750	72733	72716	72701	72665	72650	72633
-21.	-315	72617	72602	72565	72550	72534	72517	72502	72465	72451	72434
-22.	-330	72417	72403	72366	72351	72334	72320	72303	72266	72252	72235
-23.	-345	72220	72203	72167	72152	72135	72120	72104	72067	72052	72036
-24.	-360	72021	72004	71767	71753	71736	71721	71704	71670	71653	71636
-25.	-375	71622	71605	71570	71553	71537	71522	71505	71470	71454	71437
-26.	-390	71422	71406	71371	71354	71337	71323	71306	71271	71254	71240
-27.	-405	71223	71206	71172	71155	71140	71123	71107	71072	71055	71040
-28.	-420	71024	71007	70772	70756	70741	70724	70707	70673	70656	70641
-29.	-435	70625	70610	70573	70556	70542	70525	70510	70473	70457	70442
-30.	-450	70425	70411	70374	70357	70342	70326	70311	70274	70257	70243
-31.	-465	70226	70211	70175	70160	70143	70126	70112	70075	70060	70043
-32.	-480	70027	70012	67775	67761	67744	67727	67712	67676	67661	67644
-33.	-495	67627	67613	67576	67561	67545	67530	67513	67476	67462	67445
-34.	-510	67430	67413	67377	67362	67345	67331	67314	67277	67262	67246
-35.	-525	67231	67214	67200	67163	67146	67131	67115	67100	67063	67046
-36.	-540	67032	67015	67000	66764	66747	66732	66715	66701	66664	66647
-37.	-555	66632	66616	66601	66564	66550	66533	66516	66501	66465	66450
-38.	-570	66433	66416	66402	66365	66350	66334	66317	77302	66265	66251
-39.	-585	66234	66217	66202	66166	66151	66134	66120	66103	66066	66051
-40.	-600	66035	66020	66003	65766	65752	65735	65720	65704	65667	65652
-41.	-615	65635	65621	65604	65567	65553	65536	65521	65504	65470	65453
-42.	-630	65436	65421	65405	65370	65353	65337	65322	65305	65270	65254
-43.	-645	65237	65222	65205	65171	65154	65137	65123	65106	65071	65054
-44.	-660	65040	65023	65006	64771	64755	64740	64723	64707	64672	64655

SSR IRIG BIAS MEASUREMENT LOG

MISSION _____ S/C _____ DATE _____

	PRELAUNCH (MERU)	IRIG BIAS (OCTAL)	ADDRESS
NBDX			1460
NBDY			1461
NBDZ			1462

BIAS SHIFT DETERMINATION

	GET 2ND P-52	GET 1ST P51/52	ΔT (HRS)	GYRO TORQUING CMDS			REMARKS
				X GYRO (OGC) (DEG)	Y GYRO (IGC) (DEG)	Z GYRO (MGC) (DEG)	
1							
2							
3							
4							
5							
6							

BIAS SHIFT $\frac{DEG}{HR} \div .015 = MERU$

BIAS COMPENSATION UPDATE

$NBDX, Y_{NEW} = NBDX, Y_{OLD} - OGC, IGC; NBDZ_{NEW} = NBDZ_{OLD} + MGC$

	X GYRO (OGC)		Y GYRO (IGC)		Z GYRO (MGC)		NBDX		NBDY		NBDZ		GET UPDATED
	$\frac{DEG}{HR}$	MERU	$\frac{DEG}{HR}$	MERU	$\frac{DEG}{HR}$	MERU	MERU	OCTAL	MERU	OCTAL	MERU	OCTAL	
1													
2													
3													
4													
5													
6													

SCP NO. PGNS 7-1

IRIG/PIPA BIAS UPDATE REQUEST

TO: GUIDO
INFO: LGC/CMC SUPPORT
FROM: CONTROL/GNC

GET ____: ____: ____
CONTROL/GNC _____

IRIG DRIFT COMPENSATION

	ADDRESS CMC	ADDRESS LGC	MERU	OCTAL		MERU
NBDX	1460	1460	____		$NBD_M X$	____
NBDY	1461	1461	____		$NBD_M Y$	____
NBDZ	1462	1462	____		$NBD_M Z$	____

PIPA BIAS

	ADDRESS CMC	ADDRESS LGC	PULSES/SEC	OCTAL		PUL/SEC
PBIASX	1452	1452	_____		ΔPBIASX	_____
PBIASY	1454	1454	_____		ΔPBIASY	_____
PBIASZ	1456	1456	_____		ΔPBIASZ	_____

NBDX (Y,Z) = REQUIRED COMPENSATION

$NBD_M X$ (Y,Z) = MEASURED DRIFT OF IRIG'S WITH PRESENT COMPENSATION

PBIASX (Y,Z) = NEW PIPA BIAS

ΔPBIASX (Y,Z) = DIFFERENCE BETWEEN PRESENT LOADED PIPA BIAS AND MEASURED PIPA BIAS

FEC/TSG Form 312 (Oct. 68)

SCP NO. PGNS 7-2

S/C: LM
DATE: 11/1/71
REV: PCN-11
ORIGINATOR: J. Nelson
APPROVAL: Harold A. Laton

TITLE: COASTING FLIGHT PIPA BIAS DETERMINATION

PURPOSE: The purpose of this SCP is to describe the manual and RTCC automated methods used to determine PIPA bias in freefall. P-11

PROCEDURE: I. Manual Method

Periodically, the PIPA bias terms (Bias X, Bias Y, and Bias Z) should be determined and compared to those presently stored in the LGC erasable memory locations for possible updating. The procedure is as follows (refer to the enclosed LM PIPA Bias Worksheet):

A. Record the X, Y, and Z PIPA counts at LGC time A.

B. Wait a minimum of 2 minutes and note any overflow of the PIPA counters that may occur.

C. Record the PIPA counts and time at LGC time B.

D. Calculate the new PIPA bias terms.

E. Calculate the delta bias terms from comparison of the new and previous PIPA bias terms.

F. If the delta bias terms exceed 0.100 cm/sec^2, use the IRIG/PIPA BIAS UPDATE REQUEST form (see SCP No. PGNS 7-1) to notify GUIDO of the required PIPA BIAS UPDATE. The enclosed tables (LM PIPA BIAS TO OCTAL) can be used to convert from cm/sec^2 (pulses/sec) to the LGC octal load.

G. Notify CONTROL and GUIDO of measured bias values and delta bias terms. Advise the Flight Director anytime that the absolute value of any bias term approaches the considered "broke" value of the PIPA of 5.0 cm/sec^2.

H. The capacity of the erasable memory locations for the PIPA bias terms is 12.5 cm/sec^2.

II. RTCC Automated Method

In order to speed up the PIPA bias computation time and limit computational errors, an RTCC program was developed to automatically calculate PIPA bias in basically the same manner as described in the manual method above.

A SMEK panel on the PROP console contains PBI's labeled PIPA BIAS, EXECUTE and CLEAR. These PBI's are used to start and stop the RTCC PIPA bias calculations. The output (PIPA bias in cm/sec^2 and equivalent octal values) is displayed on MSK 1137.

The procedure for using the RTCC method follows:

A. PIPA bias output on MSK 1137 must either be blank (computation not yet initiated) or contain values (previous computation completed) before a new PIPA bias computation can be initiated. P-11

B. The RTCC computation is started by depressing the PIPA BIAS PBI on the PROP SMEK panel followed by depressing the EXECUTE PBI. The execute causes the time and PIPA counts to be stored by the RTCC and M's to be displayed in the PIPA bias location on MSK 1137.

C. The CLEAR PBI should be depressed to disable the PIPA BIAS PBI so that an unintentional EXECUTE will not prematurely cause the PIPA bias computation to be completed.

D. After an appropriate length of time from the first execute (usually 2 to 5 min) the PIPA BIAS and EXECUTE PBI's are again depressed, causing the RTCC to again store time and PIPA counts.

E. The RTCC calculates X, Y, and Z PIPA bias (delta counts ÷ delta time) and displays PIPA bias in cm/sec^2 and equivalent octal on MSK 1137.

F. As in part I.F. above, if a PIPA bias update is required, the IRIG/PIPA BIAS UPDATE REQUEST form (see SCP No. PGNS 7-1) should be used.

LM PIPA BIAS WORKSHEET

LGC T	PIPA COUNTS
T_B ____ : ____ : ____	X____ Y____ Z____
T_A ____ : ____ : ____	____ ____ ____

ΔT ____ : ____ : ____ ΔX ____ ΔY ____ ΔZ ____

X3600 X60

____ + ____ + ____ = [ ] ΔT SECS

$BIAS_X = \frac{\Delta X}{\Delta T}$ ____ = ____ CM/SEC^2 [ ][ ][ ][ ][ ] 8

$BIAS_Y = \frac{\Delta Y}{\Delta T}$ ____ = ____ CM/SEC^2 [ ][ ][ ][ ][ ] 8

$BIAS_Z = \frac{\Delta Z}{\Delta T}$ ____ = ____ CM/SEC^2 [ ][ ][ ][ ][ ] 8

ΔBIAS = NEW BIAS VALUE - OLD BIAS VALUE

$\Delta BIAS_X$ = ____ − [ ] = ____ CM/SEC^2

$\Delta BIAS_Y$ = ____ − [ ] = ____ CM/SEC^2

$\Delta BIAS_Z$ = ____ − [ ] = ____ CM/SEC^2

TABLE I.- LM PIPA BIAS TO OCTAL (POSITIVE)

For octal update of PBIASX, Y, Z (address 1452, 1454, 1456). PBIAS is scaled B - 3 pulses per centisecond.

CM/SEC	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0	15	32	47	64	102	117	134	151	166
0.1	203	220	235	252	270	305	322	337	354	371
0.2	406	423	440	455	473	510	525	542	557	574
0.3	611	626	643	661	676	713	730	745	762	777
0.4	1014	1031	1047	1064	1101	1116	1133	1150	1165	1202
0.5	1217	1234	1252	1267	1304	1321	1336	1353	1370	1405
0.6	1422	1440	1455	1472	1507	1524	1541	1556	1573	1610
0.7	1626	1643	1660	1675	1712	1727	1744	1761	1776	2013
0.8	2031	2046	2063	2100	2115	2132	2147	2164	2201	2217
0.9	2234	2251	2266	2303	2320	2335	2352	2367	2405	2422
1.0	2437	2454	2471	2506	2523	2540	2555	2572	2610	2625
1.1	2642	2657	2674	2711	2726	2743	2760	2776	3013	3030
1.2	3045	3062	3077	3114	3131	3146	3164	3201	3216	3233
1.3	3250	3265	3302	3317	3334	3351	3367	3404	3421	3436
1.4	3453	3470	3505	3522	3537	3555	3572	3607	3624	3641
1.5	3656	3673	3710	3725	3743	3760	3775	4012	4027	4044
1.6	4061	4076	4113	4130	4146	4163	4200	4215	4232	4247
1.7	4264	4301	4316	4334	4351	4366	4403	4420	4435	4452
1.8	4467	4504	4522	4537	4554	4571	4606	4623	4640	4655
1.9	4672	4707	4725	4742	4757	4774	5011	5026	5043	5060
2.0	5075	5113	5130	5145	5162	5177	5214	5231	5246	5263
2.1	5301	5316	5333	5350	5365	5402	5417	5434	5451	5466
2.2	5504	5521	5536	5553	5570	5605	5622	5637	5654	5672
2.3	5707	5724	5741	5756	5773	6010	6025	6042	6060	6075
2.4	6112	6127	6144	6161	6176	6213	6230	6245	6263	6300
2.5	6315	6332	6347	6364	6401	6416	6433	6451	6466	6503
2.6	6520	6535	6552	6567	6604	6621	6637	6654	6671	6706
2.7	6723	6740	6755	6772	7007	7024	7042	7057	7074	7111
2.8	7126	7143	7160	7175	7212	7230	7245	7262	7277	7314
2.9	7331	7346	7363	7400	7416	7433	7450	7465	7502	7517
3.0	7534	7551	7566	7603	7621	7636	7653	7670	7705	7722
3.1	7737	7754	7771	10007	10024	10041	10056	10073	10110	10125
3.2	10142	10157	10175	10212	10227	10244	10261	10276	10313	10330
3.3	10345	10362	10400	10415	10432	10447	10464	10501	10516	10533
3.4	10550	10566	10603	10620	10635	10652	10667	10704	10721	10736
3.5	10754	10771	11006	11023	11040	11055	11072	11107	11124	11141
3.6	11157	11174	11211	11226	11243	11260	11275	11312	11327	11345
3.7	11362	11377	11414	11431	11446	11463	11500	11515	11533	11550
3.8	11565	11602	11617	11634	11651	11666	11703	11720	11736	11753
3.9	11770	12005	12022	12037	12054	12071	12106	12124	12141	12156
4.0	12173	12210	12225	12242	12257	12274	12312	12327	12344	12361
4.1	12376	12413	12430	12445	12462	12477	12515	12532	12547	12564
4.2	12601	12616	12633	12650	12665	12703	12720	12735	12752	12767
4.3	13004	13021	13036	13053	13071	13106	13123	13140	13155	13172
4.4	13207	13224	13241	13256	13274	13311	13326	13343	13360	13375
4.5	13412	13427	13444	13462	13477	13514	13531	13546	13563	13600
4.6	13615	13632	13650	13665	13702	13717	13734	13751	13766	14003
4.7	14020	14035	14053	14070	14105	14122	14137	14154	14171	14206
4.8	14223	14241	14256	14273	14310	14325	14342	14357	14374	14411
4.9	14427	14444	14461	14476	14513	14530	14545	14562	14577	14614
5.0	14632	14647	14664	14701	14716	14733	14750	14765	15002	15020
5.1	15035	15052	15067	15104	15121	15136	15153	15170	15206	15223
5.2	15240	15255	15272	15307	15324	15341	15356	15373	15411	15426
5.3	15443	15460	15475	15512	15527	15544	15561	15577	15614	15631
5.4	15646	15663	15700	15715	15732	15747	15765	16002	16017	16034

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TABLE I.- LM PIPA BIAS TO OCTAL (POSITIVE) - Concluded

For octal update of PBIASX, Y, Z (address 1452, 1454, 1456). PBIAS is scaled B - 3 pulses per centisecond.

CM/SEC	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
5.5	16051	16066	16103	16120	16135	16152	16170	16205	16222	16237
5.6	16254	16271	16306	16323	16340	16356	16373	16410	16425	16442
5.7	16457	16474	16511	16526	16544	16561	16576	16613	16630	16645
5.8	16662	16677	16714	16732	16747	16764	17001	17016	17033	17050
5.9	17065	17102	17117	17135	17152	17167	17204	17221	17236	17253
6.0	17270	17305	17323	17340	17355	17372	17407	17424	17441	17456
6.1	17473	17511	17526	17543	17560	17575	17612	17627	17644	17661
6.2	17676	17714	17731	17746	17763	20000	20015	20032	20047	20064
6.3	20102	20117	20134	20151	20166	20203	20220	20235	20252	20270
6.4	20305	20322	20337	20354	20371	20406	20423	20440	20455	20473
6.5	20510	20525	20542	20557	20574	20611	20626	20643	20661	20676
6.6	20713	20730	20745	20762	20777	21014	21031	21047	21064	21101
6.7	21116	21133	21150	21165	21202	21217	21234	21252	21267	21304
6.8	21321	21336	21353	21370	21405	21422	21440	21455	21472	21507
6.9	21524	21541	21556	21573	21610	21626	21643	21660	21675	21712
7.0	21727	21744	21761	21776	22013	22031	22046	22063	22100	22115
7.1	22132	22147	22164	22201	22217	22234	22251	22266	22303	22320
7.2	22335	22352	22367	22405	22422	22437	22454	22471	22506	22523
7.3	22540	22555	22572	22610	22625	22642	22657	22674	22711	22726
7.4	22743	22760	22776	23013	23030	23045	23062	23077	23114	23131
7.5	23146	23164	23201	23216	23233	23250	23265	23302	23317	23334
7.6	23351	23367	23404	23421	23436	23453	23470	23505	23522	23537
7.7	23555	23572	23607	23624	23641	23656	23673	23710	23725	23743
7.8	23760	23775	24012	24027	24044	24061	24076	24113	24130	24146
7.9	24163	24200	24215	24232	24247	24264	24301	24316	24334	24351
8.0	24366	24403	24420	24435	24452	24467	24504	24522	24537	24554
8.1	24571	24606	24623	24640	24655	24672	24707	24725	24742	24757
8.2	24774	25011	25026	25043	25060	25075	25113	25130	25145	25162
8.3	25177	25214	25231	25246	25263	25301	25316	25333	25350	25365
8.4	25402	25417	25434	25451	25466	25504	25521	25536	25553	25570
8.5	25605	25622	25637	25654	25672	25707	25724	25741	25756	25773
8.6	26010	26025	26042	26060	26075	26112	26127	26144	26161	26176
8.7	26213	26230	26245	26263	26300	26315	26332	26347	26364	26401
8.8	26416	26433	26451	26466	26503	26520	26535	26552	26567	26604
8.9	26621	26637	26654	26671	26706	26723	26740	26755	26772	27007

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TABLE II.- LM PIPA BIAS TO OCTAL (NEGATIVE)

For octal update of PBIASX, Y, Z (address 1452, 1454, 1456). PBIAS is scaled B - 3 pulses per centisecond.

CM/SEC	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-0.0	0	77762	77745	77730	77713	77675	77660	77643	77626	77611
-0.1	77574	77557	77542	77525	77507	77472	77455	77440	77423	77406
-0.2	77371	77354	77337	77322	77304	77267	77252	77235	77220	77203
-0.3	77166	77151	77134	77116	77101	77064	77047	77032	77015	77000
-0.4	76763	76746	76730	76713	76676	76661	76644	76627	76612	76575
-0.5	76560	76543	76525	76510	76473	76456	76441	76424	76407	76372
-0.6	76355	76337	76322	76305	76270	76253	76236	76221	76204	76167
-0.7	76151	76134	76117	76102	76065	76050	76033	76016	76001	75764
-0.8	75746	75731	75714	75677	75662	75645	75630	75613	75576	75560
-0.9	75543	75526	75511	75474	75457	75442	75425	75410	75372	75355
-1.0	75340	75323	75306	75271	75254	75237	75222	75205	75167	75152
-1.1	75135	75120	75103	75066	75051	75034	75017	75001	74764	74747
-1.2	74732	74715	74700	74663	74646	74631	74613	74576	74561	74544
-1.3	74527	74512	74475	74460	74443	74426	74410	74373	74358	74341
-1.4	74324	74307	74272	74255	74240	74222	74205	74170	74153	74136
-1.5	74121	74104	74067	74052	74034	74017	74002	73765	73750	73733
-1.6	73716	73701	73664	73647	73631	73614	73577	73562	73545	73530
-1.7	73513	73476	73461	73443	73426	73411	73374	73357	73342	73325
-1.8	73310	73273	73255	73240	73223	73206	73171	73154	73137	73122
-1.9	73105	73070	73052	73035	73020	73003	72766	72751	72734	72717
-2.0	72702	72664	72647	72632	72615	72600	72563	72546	72531	72514
-2.1	72476	72461	72444	72427	72412	72375	72360	72343	72326	72611
-2.2	72273	72256	72241	72224	72207	72172	72155	72140	72123	72105
-2.3	72070	72053	72036	72021	72004	71767	71752	71735	71717	71702
-2.4	71665	71650	71633	71616	71601	71564	71547	71532	71514	71477
-2.5	71462	71445	71430	71413	71376	71361	71344	71326	71311	71274
-2.6	71257	71242	71225	71210	71173	71156	71140	71123	71106	71071
-2.7	71054	71037	71022	71005	70770	70753	70735	70720	70703	70666
-2.8	70651	70634	70617	70602	70565	70547	70532	70515	70500	70463
-2.9	70446	70431	70414	70377	70361	70344	70327	70312	70275	70260
-3.0	70243	70226	70211	70174	70156	70141	70124	70107	70072	70055
-3.1	70040	70023	70006	67770	67753	67736	67721	67704	67667	67652
-3.2	67635	67620	67602	67565	67550	67533	67516	67501	67464	67447
-3.3	67432	67415	67377	67362	67345	67330	67313	67276	67261	67244
-3.4	67227	67211	67174	67157	67142	67125	67110	67073	67056	67041
-3.5	67023	67006	66771	66754	66737	66722	66705	66670	66653	66636
-3.6	66620	66603	66566	66551	66534	66517	66502	66465	66450	66432
-3.7	66415	66400	66363	66346	66331	66314	66277	66262	66244	66227
-3.8	66212	66175	66161	66143	66126	66111	66074	66857	66041	66024
-3.9	66007	65772	65755	65740	65723	65706	65671	65653	65636	65621
-4.0	65604	65567	65552	65535	65520	65503	65465	65450	65433	65416
-4.1	65401	65364	65347	65332	65315	65300	65262	65245	65230	65213
-4.2	65176	65161	65144	65127	65112	65074	65057	65642	65025	65010
-4.3	64773	64756	64741	64724	64706	64671	64654	64637	64622	64605
-4.4	64570	64553	64536	64521	64503	64466	64451	64434	64417	64402
-4.5	64365	64350	64333	64315	64300	64263	64246	64231	64214	64177
-4.6	64162	64145	64127	64112	64075	64060	64043	64026	64011	63774
-4.7	63757	63742	63724	63707	63672	63655	63640	63623	63606	63571
-4.8	63554	63536	63521	63504	63467	63452	63435	63420	63403	63366
-4.9	63350	63333	63316	63301	63264	63247	63232	63215	63200	63163
-5.0	63145	63130	63113	63076	63061	63044	63027	63012	62775	62757
-5.1	62742	62725	62710	62673	62656	62641	62624	62607	62571	62554
-5.2	62537	62522	62505	62470	62453	62436	62421	62404	62366	62351
-5.3	62334	62317	62302	62265	62250	62233	62216	62200	62163	62146
-5.4	62131	62114	62077	62062	62045	62030	62012	61775	61760	61743

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TABLE II.- LM PIPA BIAS TO OCTAL (NEGATIVE) - Concluded

For octal update of PBIASX, Y, Z (address 1452, 1454, 1456). PBIAS is scaled B - 3 pulses per centisecond.

CM/SEC	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-5.5	61726	61711	61674	61657	61642	61625	61607	61572	61555	61540
-5.6	61523	61506	61471	61454	61437	61421	61404	61367	61352	61335
-5.7	61320	61303	61266	61251	61233	61216	61201	61164	61147	61132
-5.8	61115	61100	61063	61045	61030	61013	60776	60761	60744	60727
-5.9	60712	60675	60660	60642	60625	60610	60573	60556	60541	60524
-6.0	60507	60472	60454	60437	60422	60405	60370	60353	60336	60321
-6.1	60304	60266	60251	60234	60217	60202	60165	60150	60133	60116
-6.2	60101	60063	60046	60031	60014	57777	57762	57745	57730	57713
-6.3	57675	57660	57643	57626	57611	57574	57557	57542	57525	57507
-6.4	57472	57455	57440	57423	57406	57371	57354	57337	57322	57304
-6.5	57267	57252	57235	57220	57203	57166	57151	57134	57116	57101
-6.6	57064	57047	57032	57015	57000	56763	56746	56730	56713	56676
-6.7	56661	56644	56627	56612	56575	56560	56543	56525	56510	56473
-6.8	56456	56441	56424	56407	56372	56355	56337	56322	56305	56270
-6.9	56253	56236	56221	56204	56167	56151	56134	56117	56102	56065
-7.0	56050	56033	56016	56001	55764	55746	55731	55714	55677	55662
-7.1	55645	55630	55613	55576	55560	55543	55526	55511	55474	55457
-7.2	55442	55425	55410	55372	55355	55340	55323	55306	55271	55254
-7.3	55237	55222	55205	55167	55152	55135	55120	55103	55066	55051
-7.4	55034	55017	55001	54764	54747	54732	54715	54700	54663	54646
-7.5	54631	54613	54576	54561	54544	54527	54512	54475	54400	54443
-7.6	54426	54410	54373	54356	54341	54324	54307	54272	54255	54240
-7.7	54222	54205	54170	54153	54136	54121	54104	54067	54052	54034
-7.8	54017	54002	53765	53750	53733	53716	53701	53664	53647	53631
-7.9	53614	53577	53562	53545	53530	53513	53476	53461	53443	53426
-8.0	53411	53374	53357	53342	53325	53310	53273	53255	53240	53223
-8.1	53206	53171	53154	53137	53122	53105	53070	53052	53035	53020
-8.2	53003	52766	52751	52734	52717	52702	52664	52647	52632	52615
-8.3	52600	52563	52546	52531	52514	52476	52461	52444	52427	52412
-8.4	52375	52360	52343	52326	52311	52273	52256	52241	52224	52207
-8.5	52172	52155	52140	52123	52105	52070	52053	52036	52021	52004
-8.6	51767	51752	51735	51717	51702	51665	51650	51633	51616	51601
-8.7	51564	51547	51532	51514	51477	51462	51445	51430	51413	51376
-8.8	50361	51344	51326	51311	51274	51257	51242	51225	51210	51173
-8.9	51156	51140	51123	51106	51071	51054	51037	51022	51005	50770

P-3

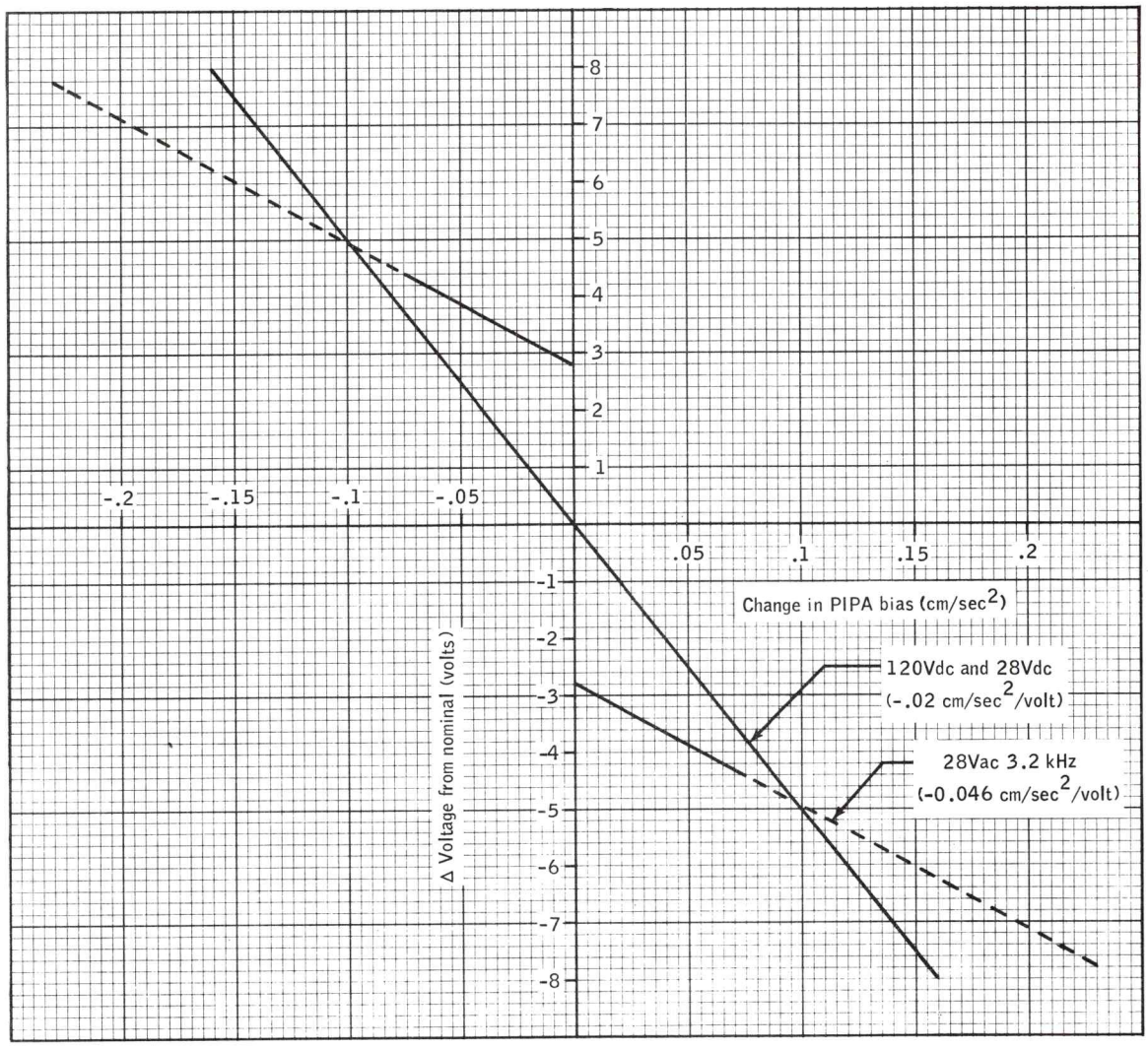


Figure 1. - Change in PIPA bias versus change in PGNS power supply voltages.

SCP NO. **PGNS 7-3**

S/C: LM
DATE: 11/1/70
REV: PGN-6
ORIGINATOR: J. Nelson
APPROVAL: H. A. Loden

TITLE: RESOLVER CONSTANTS/TM BIAS

PURPOSE: Describe resolver constants and TM bias as used by RTCC.

PROCEDURE: Resolver Constants

Rendezvous radar gimbal angles and ISS gimbal angles are calculated in the RTCC using the following equations:

ISS

$$\text{Sin } X = \frac{f_1 - C}{H_1}$$

$$\text{Cos } X = \frac{f_2 - C}{H_2}$$

where: $f_1 \rightarrow f_6 = \begin{bmatrix} GG2112, GG2113 \\ GG2142, GG2143 \\ GG2172, GG2173 \end{bmatrix}$

$H_1 \rightarrow H_6$ = resolver constants

C = TM bias

RR

$$\text{Sin } X = \frac{f_1 - K}{A_1}$$

$$\text{Cos } X = \frac{f_2 - K}{A_2}$$

where: $f_1 \rightarrow f_4 = \begin{bmatrix} GG3304, GG3305 \\ GG3324, GG3325 \end{bmatrix}$

$A_1 \rightarrow A_4$ = resolver constants

K = TM bias

For each sin and cos winding of the resolver, a value for H (ISS resolvers) and A (RR resolvers) is calculated from resolver angles versus voltage from the signal conditioner. The initial values presently used by the RTCC are $H_{1-6} = 3.26$ and $A_{1-4} = 3.26$. Prior to each mission, MCRB calculates these resolver constants and supplies them to the RTCC. If the occasion arises during a mission where the resolver angles differ by more than 3.5 degrees from CDU actual* and the TM bias is believed not to be the culprit, a MED update of the H or A constants may be in order.

The resolver constants may be calculated by using the above listed equations and letting C or K equal the current TM bias, letting f equal the resolver voltage output, and letting X be the appropriate resolver angle.

TM Bias

As noted above, GG1110V (TM bias) is used in RR and ISS gimbal angle calculations. TM bias is also used in a so called G&N bias calculation (TR170 6.4.69) which corrects the following TM parameters as shown:

$$Y = X + (128 - P)$$

where: P = GG1110V (TM bias) in PCM counts
X equals the following TM parameters:

GG1040
GG2001
GG2021
GG2041
GG2107
GG2137
GG2167
GG2219
GG2249
GG2279

P-6

After a parameter is corrected from any deviation in TM bias, calibration curves are employed to display values in engineering units. The three TM bias values used by RTCC (C for ISS Resolvers, K for RR resolvers, and P for other LM TM parameters) are initialized to zero which causes each of the above calculations to use the current value of GG1110 (TM bias). If the TM bias parameter is in error, a MED value for C, K and P can be made, in which case the MED value will be used rather than GG1110.

P-6

*The 3.5 degree value was arrived at by applying a 3 percent accuracy to the resolver voltage output from the signal conditioner.

*

SCP NO. **PGNS 7-4**

S/C: LM
DATE: 5/12/69
REV: PCN-1
ORIGNIATOR: B.A. Durand
APPROVAL: H.A. Lodon

TITLE: **PREDICTED PIPA READINGS**

PURPOSE: The purpose of these readings is to give to flight controllers, prior to any burn, the nominal maximum or average PIPA readings expected during that burn for comparison with actual readings.

PROCEDURE:

A. The maximum or average delta V (or PIPA) readings expected along the stable member X, Y, and Z axes can be obtained by using a navigation base to stable member transformation matrix with the following inputs:
   1. The maximum or average delta V for a 2 second period along the LM X body axis expected during a burn (which can be obtained from a nominal mission timeline prior to the mission or from the propulsion console position during the mission) in ft/sec.
   2. The actual inner and middle gimbal angles just prior to the burn.

B. Assuming all of the delta V is applied along the LM X body axis, the following equations perform the transformation:
   1. $VX_{SM} = VX_B$ Cos (IGA) Cos (MGA)
   2. $VY_{SM} = VX_B$ Sin (MGA)
   3. $VZ_{XM} = -VX_B$ Sin (IGA) Cos (MGA)

C. During the mission, a program card with brief but explicit directions will be provided so the Olivetti-Underwood Programma 101 Computer can be used for the above computations. The program will output the X, Y and Z stable member change in velocity, first in ft/sec, then in cm/sec.

SCP NO. PGNS 7-5

S/C: LM
DATE: 11/1/70
REV: PCN-6
ORIGINATOR: B. A. Durand
APPROVAL: H.A. Foden

TITLE : ATTITUDE MODEL OPERATION

PURPOSE : The purpose of this SCP is to describe the method in which the PGNS attitude model may be aligned in order to yield sun impingement angles and local horizontal/local vertical attitude of the LM with respect to the earth or moon.

PROCEDURE: A. For near earth operation:

1. Obtain from MSK 1222 (LM coast and Align Downlink Summary Page 1) the following REFSMMAT values: R_1C_1, R_1C_2, R_1C_3, R_2C_1, R_2C_2, R_2C_3. Use the AIR ALMANAC to determine the Greenwich Hour Angle (GHA) of the first point of Aries (the number of degrees west from the Greenwich Meridian). Use the REFSMMAT and GHA values as inputs to Hewlett Packard Program Card NO. 007. The program will output four values, LONGY, LATY, LONGZ, LATZ.
2. Place the +Y axis of the stable member (marked $+Y_{SM}$ on the outermost ring inside the globe) at LONGY (west if positive); then rotate $+Y_{SM}$ LATY degrees - north if LATY is positive, south if LATY is negative - and mark this point $+Y_{SM}$ on globe.
3. Holding $+Y_{SM}$ at the point just reached, rotate the stable member (outermost ring) until the +Z axis of the stable member (marked $+Z_{SM}$ on the outermost ring) is at LONGZ (west if positive). To check, $+Z_{SM}$ should be LATZ degrees north or south of the equator. (North if LATZ is positive). P-6
4. Rotate the central shaft (yaw), the innermost ring (roll), and the middle ring (pitch) until the appropriate outer, middle, and inner gimbal angles (respectively) are reached, as indicated by the pointers and compass roses.
5. To determine the local horizontal/local vertical attitude of the LM, mark a spot on the globe corresponding to present latitude and longitude of the LM and view the LM from the exact opposite point on the globe.
6. To determine sun impingement angles on the LM, mark the spot on the globe which the sun is directly overhead, and view the LM from that point. The AIR ALMANAC lists the GHA and DEC (declination) of the sun at any GMT. GHA is the number of degrees west of Greenwich Meridian, and DEC is the number of degrees north or south of the equator. If the present latitude/longitude of the LM is on the opposite side of the globe from the latitude/longitude of the sun, the LM, of course, is in the shade.

B. For near lunar operation:

1. Determine the lunar latitude and longitude of the lunar landing site and mark it on the globe.

2. Rotate the central shaft (yaw), the innermost ring (roll), and the middle ring (pitch) until the outer, middle, and inner gimbal angles (respectively) are zero, as indicated by the pointers and compass roses.
3. Holding the gimbal angles steady, rotate the stable member (outermost ring) until the top of the LM (+X axis) is directly underneath the landing site and the +Z axis is in the direction of the CSM orbital velocity (when over the landing site).
4. Now holding the stable member steady, enter the appropriate gimbal angles.
5. To determine the local horizontal/local vertical attitude of the LM, mark a spot on the globe corresponding to present latitude and longitude of the LM and view the LM from the exact opposite point on the globe.

SCP NO. **PGNS 7-6**

This SCP deleted by PCN-11

SCP NO. **PGNS 7-7a**

S/C: LM
DATE: 11/1/71
REV: PCN-11
ORIGINATOR: C. L. Gruby
APPROVAL: Harold G. Golden

TITLE : **LUNAR SURFACE PIPA BIAS CALCULATION (OLIVETTI METHOD)**

PURPOSE : The purpose of this SCP is to describe the method used to compute pipa bias on the lunar surface using Olivetti program 013A and B.

BACKGROUND : The amount of lunar gravity expected in each of the LM stable member axis is calculated by using the current landing site lunar gravity constant (GLS), IMU gimbal angles at the time of the measurement and the Guidance Officer's determination of local vertical attitude. The calculated value is then differenced from the measured value (obtained from the pipa counters) to determine pipa bias.

The equations for the computations are programed on an Olivetti Underwood Magnetic card (Card 013) and requires that both sides be used in the proper order.

DESCRIPTION: Card No. 013A

NAME: Lunar Surface Pipa Bias Calculation

INPUT: MGA ACTUAL CDU

MGA LOCAL VERTICAL

IGA LOCAL VERTICAL

IGA ACTUAL CDU

NOTES: Angle input must be 0 to $\pm 90^{\circ}$. For angles $> 270^{\circ}$, subtract from 360° and apply a minus (-) sign. (i.e., $359.1^{\circ} = 360.0 - 359.1 = -0.09^{\circ}$ P-11

CONSTANTS: D = 0.0174532925 (2 π/360 Deg to radius)

Card No. 013B

NAME: Continuation of Side 013A

INPUT: X Measured Pipa Bias

Y Measured Pipa Bias

Z Measured Pipa Bias

CONSTANTS: D/ GLS (from MPAD)

E 1 + SFEX

E/ PBIASX

F PBIASY

F/ PBIASZ

PROCEDURE :

1. Obtain Constants and record on form

(a) GLS = gravity at landing site (MPAD)

(b) 1 + SFEX, PBIASX, PBIASY and PBIASZ obtained premission from the eraseable load or in real time from "AGC Support".

2. Obtain local vertical attitude from GUIDO and record. If angle is $>270^{\circ}$, subtract from 360 and apply a minus (-) sign. Record final value in the parenthesis ( ). P-11

3. Obtain PIPA BIAS measurement from MSK 1137 and record.

4. Record GET

5. Obtain ACDU from MSK 1137 and record. If angle $>270^{\circ}$, subtract from 360 and apply a minus (-) sign. Record the final value in the parenthesis ( ). P-11

6. Transfer the data in the parenthesis ( ), obtained in 2. and 5. to the proper locations under "CARD 013A."

7. Turn on the Olivetti and GEN RESET.

8. Decimal Wheel = 8

9. Record Constants on side B by the following:

   Insert Side B

   ENTER: D/ GLS

   E 1 + SFEX

   E/ PBIASX

   F PBIASY

   F/ PBIASZ

   PUSH RECORD BUTTON

   INSERT SIDE B (data now recorded on Card 013B)

10. Push GEN RESET

11. Insert Side A

12. Follow the steps under Card 013A. Do not proceed to the next step until the computer activity light goes out. This will be apparent as the keyboard will be locked.

13. After doing subroutine Z and the computer activity light goes out, enter Side B and follow the steps.

14. After completing all of the steps under Card 013B, tape the printout to the form in the space provided. This will be retained as a permanent record and serve to annotate the printout.

PGNS LUNAR SURFACE PIPA BIAS COMP

(11)

LV ATTITUDE (2)

O_L _____

I_L _____ ( )

M_L _____ ( )

ACDU (1594) (5)

O_A _____ Δ ± _____

I_A _____ ( )

M_A _____ ( )

S/O LIMITS

X=37ft/s=1128cm/s
Y=50ft/s=152 cm/s
Z=24ft/s=731 cm/s

$Ts/o = \frac{1128}{X\ \Delta\ Bias} = \frac{1128}{\ } =$

$Ts/o = \frac{152}{Y\ \Delta\ Bias} = \frac{152}{\ } =$

$Ts/o = \frac{731}{Z\ \Delta\ Bias} = \frac{731}{\ } =$

MAX Δ BIAS cm/s^2
2.6
6.2
1.7

GLS _____ (1) D/

1+SFEX _____ E

PBIASX _____ E/

PBIASY _____ F

PBIASZ _____ F/

GET _____ : (4) : _____

CARD 013A
V
M_A _____
S
M_L _____
S
I_L _____
S
I_A _____
S
D/
W
Z (12)

CARD 013B
CV
Xmeas _____
S
Ymeas _____
S
Zmeas _____

$X_{meas\ comp} = (1+SFEX) \cdot X_{meas}$
$X_{cal} = GLS \cdot \cos(I_A - I_L) \cdot \cos(M_A - M_L)$
$X_{bias} = X_{meas\ comp} - X_{cal}$
$X\ \Delta\ bias = PBIASX - X_{bias}$

X_{meas} =
$X_{meas\ comp}$ =
X_{cal} =
X_{bias} =
$X\ \Delta\ bias$ =
(ft/s^2) =

$Y_{cal} = GLS \cdot \cos I_L \cdot \sin(M_A - M_L)$
$Y_{bias} = Y_{meas} - Y_{cal}$
$Y\ \Delta bias = PBIASY - Y_{bias}$

Y_{meas} =
Y_{cal} =
Y_{bias} =
$Y\ \Delta\ bias$ =
(ft/s^2) =

(13)

$Z_{cal} = GLS \cdot \sin(I_L - I_A)$
$Z_{bias} = Z_{meas} - Z_{cal}$
$Z\ \Delta bias = PBIASZ - Z_{bias}$

Z_{meas} =
Z_{cal} =
Z_{bias} =
$Z\ \Delta bias$ =
(ft/s^2) =

SCP NO. PGNS 7-7b

S/C: LM
DATE: 11/1/71
REV: PCN-11
ORIGINATOR: C. L. Gruby
APPROVAL: Harold A. Laden

TITLE : LUNAR SURFACE PIPA BIAS CALCULATION (H/P METHOD)

PURPOSE : The purpose of this SCP is to describe the method used to compute PIPA BIAS on the lunar surface using the Hewlett Packard 9100B computer.

BACKGROUND : The amount of lunar gravity expected in each of the LM stable member axes is calculated by using the current landing site lunar gravity constant (GLS), IMU gimbal angles at the time of the measurement and the Guidance Officer's determination of local vertical attitude. The calculated value is differenced from the measured value (obtained from the pipa counters) to determine pipa bias. The equations for the computations are programed on a Hewlett Packard 9100B MAGNETIC card and require that both sides be used in the proper order. The Hewlett Packard method is preferred over the Olivetti method in that the equations are exact and have not been reduced to meet the limited capability of the computer as in the case of the Olivetti.

DESCRIPTION : NAME: Lunar Surface Pipa Bias Calculation

INPUT: OL Outer gimbal angle (local vertical)
IL Inner gimbal angle (local vertical)
ML Middle gimbal angle (local vertical)
OA Outer gimbal angle (actual
IA Inner gimbal angle (actual)
MA Middle gimbal angle (actual) P-11
X Measured (X Pipa Counts)
Y Measured (Y Pipa Counts)
Z Measured (Z Pipa Counts)

CONSTANTS: + 9 = SFEX
+ 8 = SFEY
+ 7 = SFEZ
+ 6 = GLS
+ 5 = PBIASX
- f = PBIASY
- e = PBIASZ

PROCEDURE : The following procedure utilizes the PGNS LUNAR SURFACE PIPA BIAS WORKSHEET on page II-7-21 P-11

1. Obtain constants and record on worksheet

(a)(b)(c) SFEX, SFEY, SFEZ - obtained premission from the eraseable load or in real time from "AGC Support".

(d) GLS - Gravity at the landing site obtained both premission and real-time from MPAD

(e)(f)(g) PBIASX, PBIASY, PBIASZ - Obtained premission from the eraseable load or if updated during the mission, the PGNS log.

2. Obtain local vertical attitude from the Guidance Officer and record.
3. Obtain PIPA BIAS (PIPA COUNTS) Measurement from MSK1137 and record. P-11
4. Record GET
5. Obtain ACDU angles in stable member coordinates from MSK 1137
6. Switch Configuration

   Degrees

   Fixed Point

   Power ON

   Run

   Printer ON "X" BUTTON IN
7. Clear
8. Set Decimal wheel to 7
9. Go to ( ) ( ) - 00
10. Enter Side A and B
11. Load Constants as follows:

    SFEX X (→) + 9

    SFEY X (→) + 8

    SFEZ X (→) + 7

    GLS X (→) + 6

    PBIASX X (→) + 5

    PBIASY X (→) - f

    PBIASZ X (→) - e

    Go to ( )( ) - 00

    Insert Side A

    Record

    Insert Side B

    Record
12. Check Constants as follows:

    SFEX X (→) + 9 PRINT

    SFEY X (→) + 8 PRINT

    SFEZ X (→) + 7 PRINT

    GLS X (→) + 6 PRINT

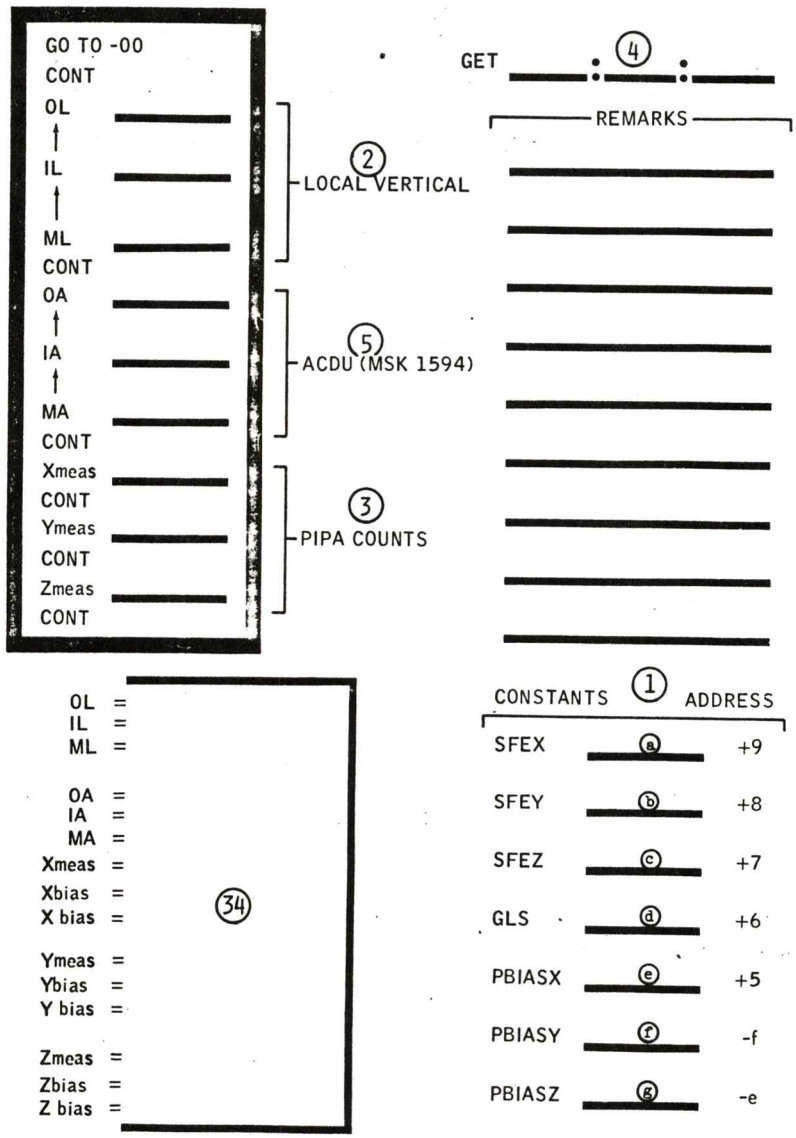
PBIASX X ( ) + 5 PRINT

PBIASY X ( ) - f PRINT

PBIASZ X ( ) - e PRINT

13. CONT
14. PRINTER X, Y & Z BUTTONS IN
15. ENTER OL
16. ↑
17. ENTER IL
18. ↑
19. ENTER ML
20. CONT
21. ENTER OA
22. ↑
23. ENTER IA
24. ↑
25. ENTER MA
26. CONT
27. PRINTER Y & Z BUTTONS OUT
28. ENTER X MEAS
29. CONT
30. ENTER Y MEAS
31. CONT
32. ENTER Z MEAS
33. CONT
34. TAPE THE PRINT OUT TO THE FORM FOR ANNOTATION AND TO MAINTAIN A PERMANENT RECORD.

PGNS LUNAR SURFACE PIPA BIAS WORKSHEET (HEWLETT PACKARD)



SCP NO. PGNS 7-8a

S/C: LM
DATE: 11/1/71
REV: PCN-11/New
ORIGINATOR: J. J. Conwell
APPROVAL: Harold A. Loden

TITLE: P52/P57 IRIG BIAS SHIFT DETERMINATION (HEWLETT PACKARD COMPUTER)

PURPOSE: The purpose of the SCP is to describe the P52/P57 method of calculating irig bias using the Hewlett Packard 9100B Computer. The LM irig bias worksheet (see page II-7-23) is used with this method.

BACKGROUND: There are two primary methods of IMU alignments; P52 and P57. P52 is used during coasting flight and P57 is used on the surface When the second P52 or P57 is complete, Noun 93 torquing angles are displayed on the DSKY. Using these angles and the time between alignments, the irig bias shift can be determined.

PROCEDURE: This procedure is the same for two P52's as it is for two P57's.

1. Switch configuration for Hewlett Packard degrees
   Fixed decimal point
   Program run switch to run
   Power ON
   Decimal wheel at 5
2. End
3. Enter side A and then B of card No. 10
4. End
5. Enter the following constants:
   NBDX → a
   NBDY → b
   NBDZ → c

   If these constants are loaded on the card then this step can be deleted.
6. Enter the time of first alignment as follows:
   Hours
   ↑
   Minutes
   ↑
   Seconds
7. Continue
8. Enter the time of second alignment as follows:
   Hours
   ↑
   Minutes
   ↑
   Seconds
9. Continue
10. N93X
    ↑
    N93Y
    ↑
    N93Z
11. Continue
12. Printout will be as shown on the right-hand side of LM irig drift worksheet.

IM IRIG DRIFT WORKSHEET

(HEWLETT PACKARD)

DECIMAL WHEEL 5

END

ENTER CARD 10 A & B

END

TIME 1 HRS _____

MIN _____

SEC _____

CONT

TIME 2 HRS _____

MIN _____

SEC _____

CONT

N93 X _____

Y _____

Z _____

CONT

TIME 1 HRS
MIN
SEC

TIME 2 HRS
MIN
SEC

ΔT HRS

N93X
DRIFT °/HR
DELTA DRIFT MERU
NBDX OLD
TOTAL DRIFT MERU
OCTAL

N93Y
DRIFT °/HR
DELTA DRIFT MERU
NBDY OLD
TOTAL DRIFT MERU
OCTAL

N93Z
DRIFT °/HR
DELTA DRIFT MERU
NBDZ OLD
TOTAL DRIFT MERU
OCTAL

CONSTANTS	ADDRESS
NBDX OLD _____	+a
NBDY OLD _____	+b
NBDY OLD _____	+c

S/C: LM
DATE: 3/1/72
REV: PCN-12
ORIGINATOR: J. J. Conwell
APPROVAL: Harold A. Loden

SCP NO. PGNS 7-8b

TITLE: SURFACE CDU/DOCKED NOUN 20 TORQUE ANGLE CALCULATION

PURPOSE: The purpose of this SCP is to describe the method used to calculate torquing angles for the IMU using the CDU method on the surface and using the Noun 20 method while the LM is docked to the CSM after an alignment has been performed. The surface/docked align torquing angles worksheet (see page II-7-26) and the Hewlett Packard 9100B computer are used with this method.

BACKGROUND: Reference MSC Internal Note No. 71-FC4-1 for the surface CDU method. On the lunar surface after the first P57 is performed, CDU angles are calculated for liftoff using present CDU angles. At a later time, using new CDU angles, a new liftoff attitude is calculated using the RTCC. Any difference between the liftoff attitude is due to drift of the platform. During the docked case, a similar method is used. The LM is aligned to the CSM using the same REFSMMAT. At a later time, LM and CSM CDU angles are compared at the same time. If the angles differ any, then it is due to a drifting LM platform considering that there is no drift in the CSM platform. The CDU angles are displayed on the DSKY under a Noun 20. These two methods give a set of torquing angles or Noun 93 angles which are indicative of drift. If the octal update was needed, these N93 angles and delta times could be used on the P52/P57 method described in PGNS 7-1A.

PROCEDURE 1: This procedure is for the Surface CDU Method.

1. Switch configuration
   degrees
   fixed decimal point
   Power ON
   Decimal wheel at 5
2. End
3. Enter side A & B Card No. 1
4. Continue
5. The LM PGNS position gives the Guidance Officer the first set of LM CDU angles. The Guidance Officer using these angles and RTCC calculates the first set of liftoff CDU angles. Enter first set of liftoff CDU angles as follows:
   OG or X
   ↑
   IG or Y
   ↑
   MG or Z
6. Continue
7. The LM PGNS position gives the Guidance Officer the second set of LM CDU angles. The Guidance Officer, using these angles and RTCC, calculates the second set of liftoff CDU angles.
   OG or X
   ↑
   IG or Y
   ↑
   MG or Z
8. Continue
9. Enter side A of Card No. 2
10. Continue

11. Enter side B of Card No. 2
12. Continue
13. Enter the time between the two sets of liftoff angles as follows:

    Hours
    ↑
    Minutes

14. Continue
15. Print out is shown on the right side of the Surface/Docked Align Torquing Angles worksheet.

PROCEDURE 2: This procedure is for the Docked N20 Method. The steps in this procedure will be exactly as in Procedure 1 except for the following steps:

5. The first set of angles to be entered are the CM CDU angles converted into LM CDU angles. These are obtained from AGC SUPPORT POSITION or from the astronauts.

   OG or X = 300 + RC - CMX
   ↑
   IG or Y = 180 + CMY
   ↑
   MG or Z = 360 - CMZ

7. The second set of angles are the LM CDU angles that are read at the same time as the CM angles are read. These are obtained from AGC SUPPORT POSITION or from the astronauts.

   OG or X
   ↑
   IG or Y
   ↑
   MG or Z

13. Tape printout to surface/docked align torquing angles worksheet.
14. Repeat steps 1 thru 13 with second set of N20 angles to obtain second set of N93 angles.
15. Subtract set 1 N93's from set 2 N93's to determine actual N93 angles. These angles can be used to determine drift using P52/P57 irig bias shift determination (Hewlett Packard) procedure. P-12

SURFACE CDU/DOCKED N20 TORQUING ANGLE CALCULATION

(HEWLETT PACKARD)

END

ENTER A&B CARD 1

CONT

REFERENCE

OL X _____ = 300 + _____ (RC) - _____ (CM X)

IL Y _____ = 180 + _____ (CM Y)

ML Z _____ = 360 - _____ (CM Z)

CONT

OL X _____

IL Y _____

ML Z _____

CONT

ENTER A CARD 2

CONT

ENTER B CARD 2

CONT

Δ HRS _____

Δ MIN _____

CONT

GET _____:_____:_____

GET REF _____:_____:_____

ΔT _____:_____:_____

REF OL / IL / ML

OL / IL / ML

N93 X O / Y I / Z M

ΔT HRS / MIN

TOTAL HRS

DRIFT

OG DEG/HR
MERU

IG DEG/HR
MERU

MG DEG/HR
MERU

SCP NO. PGNS 7-8c

S/C: LM
DATE: 11/1/71
REV: PCN-11/New
ORIGINATOR: J. Conwell
APPROVAL: Harold D. Golen

TITLE: NOUN 93 VENETIAN BLIND TABLE CALCULATION

REFERENCE: SCP No. 7-1

PURPOSE: The purpose of this SCP is to describe the method used to calculate the Noun 93 table.

BACKGROUND: After each P57 or P52, Noun 93's are displayed on the DSKY. Using these gyro drifts, the PGNS position computes the new NBD updates. The purpose of the Noun 93 table is as a check that the PGNS position has made the right computation. The CONTROL can use this table to determine the new update if he is given the N93 torquing angles and the time between alignments.

PROCEDURE:

1. Set decimal wheel at 1
2. Set degrees/radians switch to degrees
3. End
4. Enter sides A & B card No. 11
5. Enter desired parameters as follows:
   - NBDX - A
   - NBDY - B
   - NBDZ - C
   - START TIME (HRS) - -D
   - Δ TIME (HRS) - -C
   - STOP TIME (HRS) - -B
   - START N93 - -A
   - Δ N93 - -9
   - STOP N93 - -8
6. Set Print Y
7. End
8. Continue
9. Print out for each N93 for each time
   - Drift (MERU)
   - +X Update (OCTAL)
   - -X Update (OCTAL)
   - +Y Update (OCTAL)
   - -Y Update (OCTAL)
   - +Z Update (OCTAL)
   - -Z Update (OCTAL)
10. See next page for example of printout. If an update to any of the NBD values is made, then a new venetian blind table needs to be made. The following values were used to compute the table.
    - NBDX = 1.4
    - NBDY = 1.7
    - NBDZ = - 1.5
    - START TIME = 1 HR
    - Δ TIME = 1 HR
    - STOP TIME = 2 HRS
    - ORIGINAL N93 = .05
    - Δ N93 = .05
    - FINAL N93 = .30

N93 ↓	DRIFT (MERU)	3.3		1.7
	+X UPDATE	77411.		77736.
	-X UPDATE	1132.		606.
.05	+Y UPDATE	77460.		4.
	-Y UPDATE	1200.		654.
	+Z UPDATE	351.		25.
	-Z UPDATE	76630.		77155.
		6.7		3.3
		76541.		77411.
		2002.		1132.
.10		76607.		77460.
		2050.		1200.
		1221.		351.
		75760.		76630.
		10.0		5.0
		75671.		77065.
		2652.		1456.
.15		75737.		77134.
		2720.		1524.
		2071.		675.
		75110.		76304.
		13.3		6.7
		75021.		76541.
		3522.		2002.
.20		75067.		76607.
		3571.		2050.
		2741.		1221.
		74240.		75760.
		16.7		8.3
		74151.		76215.
		4373.		2326.
.25		74217.		76263.
		4441.		2374.
		3612.		1545.
		73370.		75434.
		20.0		10.0
		73300		75671.
		5243.		2652.
.30		73347.		75737.
TIME = 1 HR		5311.	TIME = 2 HR	2720.
		4462.		2071.
		72517.		75110.

SCP NO. **PGNS 7-8d**

S/C: LM
DATE: 11/1/71
REV: PCN-11/New
ORIGINATOR: J. J. Conwell
APPROVAL: Harold A. Loden

TITLE: **P52/P57 IRIG BIAS SHIFT DETERMINATION (OLIVETTI COMPUTER)**

PURPOSE: The purpose of this SCP is to describe the method used to determine gyro drift during coasting flight using the Olivetti **Desk** Computer. The SSR Irig Bias Worksheet (Olivetti Method) is used with this method (Page II-7-30).

PROCEDURE:

1. Turn on Olivetti and push General Reset
2. Set decimal wheel to 4
3. Record and Print button out
4. Load Card No. 18 Side A
5. Press V
6. Enter the following constants

   $NBDX_{old}$ - E

   $NBDY_{old}$ - E/

   $NBDZ_{old}$ - F

   If these constants are stored on the card then this step can be deleted.
7. Enter the following inputs

   ΔT { HOURS - B
   MINUTES - B/

   N93X - C
   N93Y - C/
   N93Z - D
8. Press S
9. Print out will be as in the box on the right on SSR Irig Bias Worksheet

SSR IRIG BIAS WORKSHEET
(OLIVETTI METHOD)

SCP NO. PGNS 7-8d
PCN-II/New

P5 _____ OPTION _____ A/T _____

TORQUE Δ'S ACCEPTED _____ N05 _____

$TIME_2$ _____ : _____

$TIME_1$ _____ : _____

ΔT _____ : _____

V B B/

CARD #018 A OR B

DELTA TIME		HRS
DELTA TIME		MIN
NOUN 93	X	DEG
	Y	DEG
	Z	DEG
BIAS SHIFT X		DEG/HR
BIAS SHIFT X		MERU
NBDX OLD		MERU
NBDX NEW		MERU
BIAS SHIFT Y		DEG/HR
BIAS SHIFT Y		MERU
NBDY OLD		MERU
NBDY NEW		MERU
BIAS SHIFT Z		DEG/HR
BIAS SHIFT Z		MERU
NBDZ OLD		MERU
NBDZ NEW		MERU

N93

C

$BIAS\ SHIFT_X$ = [ ] DEG / HR

C/

$BIAS\ SHIFT_Y$ = [ ] DEG / HR

D

$BIAS\ SHIFT_Z$ = [ ] DEG / HR

S

CONSTANTS

$NBDX_{NEW} = NBDX_{OLD} - BIAS\ SHIFT_X =$

E

= [ ] − _____ = _____ MERU OCTAL [ ][ ][ ][ ][ ]

$NBDY_{NEW} = NBDY_{OLD} - BIAS\ SHIFT_Y =$

E/

= [ ] − _____ = _____ MERU OCTAL [ ][ ][ ][ ][ ]

$NBDZ_{NEW} = NBDZ_{OLD} + BIAS\ SHIFT_Z =$

F

= [ ] + _____ = _____ MERU OCTAL [ ][ ][ ][ ][ ]

S/C: LM
DATE: 11/1/70
REV: PCN-11/New
ORIGINATOR: J. Conwell
APPROVAL: Harold A. Soden

SCP NO. **PGNS 7-9**

TITLE: **LOAD, MONITOR AND DISPLAY LGC STORAGE LOCATIONS**

REFERENCES:
A. MIT GSOP - Section 2
B. MIT GSOP - Section 4
C. MIT E-2260 Vol I (Jan 69)

BACKGROUND: Several methods are available to the astronauts and the ground to load, monitor, and display the values contained in various LGC erasable core locations. The purpose of this console procedure is to describe these methods and identify special applications and procedures associated with them.

A. LGC Program 27 (P27)

The primary means of loading or updating data contained in the LGC erasable core locations is through P27. This program may be entered via the DSKY in the LM or via uplink through MSFN. The program has four basic modes of operation dictated by the verb configuration associated with the program selection (Verb 70 to 73). The verb configuration specifies the type update capability which is desired. Associated with this program is the ability to monitor and validate the update data before it is actually loaded into the specified storage locations.

The following modes of operation are available via the specified verb configuration:

1. Verb 70 - To increment or decrement the LGC clock, LM and CSM State Vector times, and TEPHEM time.
2. Verb 71 - To update from 1 to 18 consecutive registers in the same bank (Contiguous Block Update). This verb is normally used to update state vectors and other E-memory location (i.e. REFSMMAT).
3. Verb 72 - To update from 1 to 9 nonconsecutive registers in the same or different memory banks (Scatter Update). (This format is described in detail in MIT-GSOP 557 Section 2, 2.1.3).
4. Verb 73 - To increment or decrement the LGC clock with a double precision octal time (see MIT GSOP 557, Section 2, 2.1.4).

The use of P27 by either the ground or the astronaut must conform to the following limitations:

a. LGC must be operating.
b. LGC must be in P00.
c. LM communication uplink must be configured with the "UP DATA LINK" C/B (Panel 11, Row 4) set and "UP DATA LINK" switch (Panel 12) set to the "DATA" position.

The program is entered by selecting P00 and entering the appropriate verb code for the desired mode of operation, e.g., V37E00EV70E.

B. Loading, Monitoring and Display LGC Values

Although P27 is the primary mode of updating LGC parameters and is the most efficient means of doing so for certain "standard" updates (LGC REFSMMAT, STATE VECTOR, etc.) mentioned previously, certain verb-noun instructions to the LGC permit modification and monitoring LGC storage values and are more operationally expeditious than through P27. The following matrix describes the various instructions available to load, monitor and display LGC parameters:

	OCTAL		DECIMAL	
	VERB	NOUN	VERB	NOUN
LOAD	21 to 25 25	01 to 03 07	-- --	-- --
DISPLAY	01 to 05	01 to 03	06-07	01 to 03
MONITOR	11 to 15	01 to 03	16-17	01 to 03

Various special operating instructions which may be used to update LGC storage parameters through the use of these verb-noun instructions are described below:

1. Erasable memory locations may be updated as follows:
   a. KEY V37E 00E
   b. KEY V21 N01E (Start update)
   c. KEY XXXXX E (ECADR address)
   d. KEY XXXXX E (update data; octal configuration of bits or scaled data, see paragraph 5 below)

   If more than one nonsequential address is to be loaded, perform step e and repeat steps c and d for each address to be loaded.

   e. KEY E (to reinitialize V21N01)

   If a number of sequential addresses are to be loaded, after the first data load:

   f. KEY N15E
   g. KEY XXXXX E E (update data, each component; the second E reinitializes V21N15)

2. To verify the update load:
   a. KEY V01N01E
   b. KEY XXXXXE (address)
   c. VERIFY DATA IN R1

   If a number of nonsequential addresses are to be monitored - Key ENTER and repeat step b and c.

   If the data in a number of sequential addresses is to be verified:

   d. KEY N15E
   e. VERIFY SECOND DATA WORD IN R1
   f. ENTER
   g. VERIFY THIRD DATA WORD IN R1, REPEAT f AND g AS DESIRED.

3. Procedure to isolate a single RCS jet is as follows:
   a. KEY V25N07E
   b. KEY 1257E to isolate $\pm$ (U-V) Jets
      1260E to isolate $\pm$ P Jets
   c. Verify R1 1257/1260
   d. KEY XXXE Octal Bit Configuration of Jet
   e. Verify R2 00XXX
   f. KEY 1E to isolate
      E to enable (NOTE: Cycling Jet thruster disable switches will also enable the desired jet).
   g. Verify R3 0000x
   h. KEY V48E
   i. Monitor FV01N46
   j. KEY PROCEED (Required to update the DAP)
   k. KEY V34E

OCTAL BIT CONFIGURATION OF JETS				Isolate A System
	± (U-V) Jets		± (P Jets)	1257E
A1U	100	A1F	4	146E
B1D	200	B1L	200	1E
B2U	20	A2A	10	1260E
A2D	40	B2L	20	154E
A3U	4	B3A	1	1E
B3D	10	A3R	40	Isolate B System
B4U	1	B4F	2	1257E
A4D	2	A4R	100	231E
				1E
				1260E
				223E
				1E

4. Procedure to configure specified bits in a specified erasable core address:
   a. KEY V25 N07E
   b. KEY XXXXE (ECADR of register)
   c. Verify ECADR in R1
   d. KEY XXXXXE ("1's" for bits to be changed, octal configuration)
   e. Verify bit configuration in R2
   f. KEY 1E (to set bits)
      or E (to reset bits)
   g. Verify bit changes in R3

5. Procedure to load output channels
   a. KEY V21N10E
   b. KEY XXE (Address of channel)
   c. KEY XXXXXE (Entire channel must be loaded)

   OR use procedure in 4. above.

6. To monitor input/output channels
   a. V11 N1DE
   b. KEY XXE (channel address)
   c. R1 equals octal contents of desired channel

7. The above procedures describe various means of loading or reconfiguring data in the LGC erasable core registers. It is necessary, however, to remain cognizant of the proper bit configuration and scaling of the binary information loaded into these registers.

   Fundamentally, the configuration of the LGC registers takes two basic forms: Unscaled, for bi-level type information, i.e., Flagwords and channels. Scaled, for registers which require the entire word (or possibly two or three words for double and triple precision) to define the information it contains.

   In the case of scaled registers, the desired value must be scaled to the proper register scaling and converted to octal before being loaded into the register.

   In some cases, a noun instruction is provided to accomplish this scaling process automatically in the LGC; thus the desired value may be loaded directly in decimal.

The following is a list of selected erasable core registers and their respective ECADR's:

SCALED REGISTERS	ECADR
PBIASX	1452
PBIASY	1454
PBIASZ	1456
PIPASCFX	1453
PIPASCFY	1455
PIPASCFZ	1457
NBDX	1460
NBDY	1461
NBDZ	1462
ADIAX	1463
ADIAY	1464
ADIAZ	1465
ADSRAX	1466
ADSRAY	1467
ADSRAZ	1470
HIASCENT	03000
DKDB	03011

UNSCALED REGISTERS	ECADR
RADMODES	0110
DAPBOOLS	0111
FLAGWORD 0	0074
FLAGWORD 1	0075
FLAGWORD 2	0076
FLAGWORD 3	0077
FLAGWORD 4	0100
FLAGWORD 5	0101
FLAGWORD 6	0102
FLAGWORD 7	0103
FLAGWORD 8	0104
FLAGWORD 9	0105
FLAGWORD 10	0106
FLAGWORD 11	0107
RCS FLGS	1262
CH5 MASK	1257
CH6 MASK	1260
IMODES 30	1277
IMODES 33	1300

8. The following procedure may be used to convert a decimal number to octal, scaled for direct input into E-memory by the methods described above:

1. Switch Configuration for 9100B Hewlett Packard Computer
   Power On
   Run Mode
   Fixed Decimal point
   Decimal wheel at 5
2. End
3. Enter side A and then B of Card No. 15
4. End
5. Continue
6. Enter decimal or octal number
7. ↑
8. Enter scale factor
9. If octal to decimal conversion then
   Continue
   If decimal to octal conversion then
   Press Set Flag
   Continue
10. Print out will be as follows:
    Scale Factor
    Original Number

    Converted Number

SCP NO. PGNS 7-10

S/C: LM
DATE: 11/1/71
REV: PCN-11/New
ORIGINATOR: C. L. Gruby
APPROVAL: Harold D. Loden

TITLE: EVALUATION OF TAPE METER INDICATED ALTITUDE WITH RESPECT TO VEHICLE PITCH AND ANTENNA POSITION

PURPOSE: To determine indicated altitude on the Altitude/Altitude Rate Meter as a function of actual altitude above the terrain and vehicle Pitch angle.

BACKGROUND: The LR altitude data displayed on the Altitude/Altitude Rate Meter does not represent true altitude for the following reasons:

1. The LR altitude beam is not positioned along the antenna X axis (20.33° aft)
2. LR antenna positions and mounting (X-axis)
   a. Pos 1 23.85° aft of LM X axis
   b. Pos 2 parallel with LM X axis
   c. Antenna rotated toward the LM + Y axis 6°
3. The Altitude/Altitude Rate Meter multiplies LR altitude data by the cosine of 15° (.96593)
4. Vehicle Pitch attitude varies the altitude beam impingment angle on the lunar surface.

To simplify the method of computation only vehicle pitch attitude was considered. The Yaw and Roll attitude were assumed to be zero. The antenna rotation toward the CM + Y axis was also neglected which introduces 0.5 percent error.

METHOD:

ALT BEAM $\measuredangle$ = 20.33°
ANT POS 1 $\measuredangle$ = 23.85°
ANT POS 2 $\measuredangle$ = 0.0°

TAPEMETER ALT = COS 15° (BEAM ALT)

TRUE ALT = COS (BEAM $\measuredangle$ + ANT POS $\measuredangle$ - PITCH $\measuredangle$) BEAM ALT

$$\text{BEAM ALT} = \frac{\text{TRUE ALT}}{\cos(\text{BEAM} \measuredangle + \text{ANT POS} \measuredangle - \text{PITCH} \measuredangle)}$$

$$\boxed{\text{TAPEMETER ALT} = \frac{\cos 15^\circ \text{ TRUE ALT}}{\cos(\text{BEAM} \measuredangle + \text{ANT POS} \measuredangle - \text{PITCH} \measuredangle)}}$$

Figures 1 through 4 are plots of tapemeter indicated altitude with respect to vehicle pitch angle. The curves are true altitude lines. Figures 1 & 2 represent antenna position 1 and Figures 3 & 4 represent position 2.

Figure 5 is a plot of vehicle pitch angle with respect to Tapemeter indicated altitude error expressed in percent. Antenna positions 1 and 2 are shown.

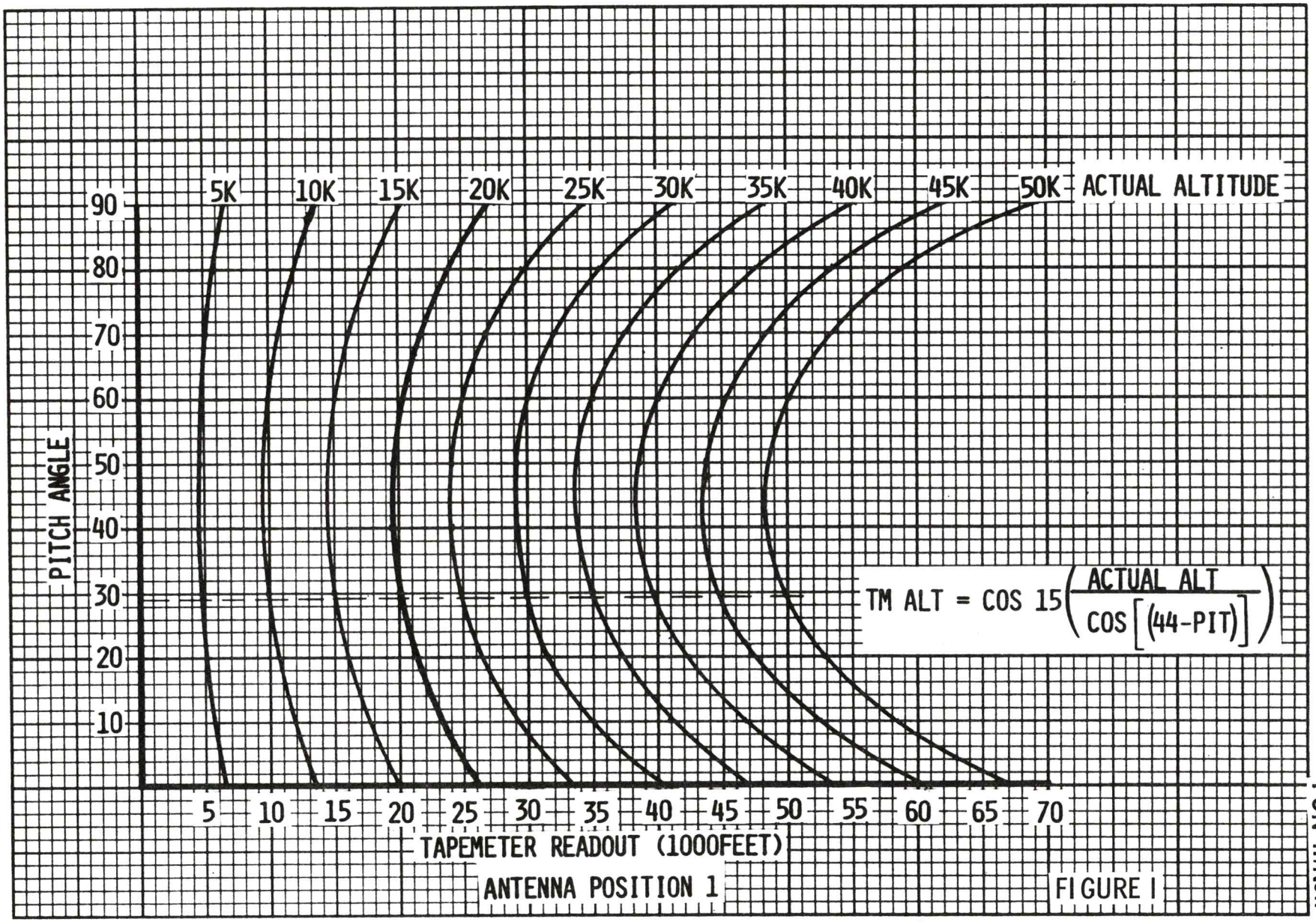

5K
10K
15K
20K
25K
30K
35K
40K
45K
50K
ACTUAL ALTITUDE
90
80
70
60
50
40
30
20
10
PITCH ANGLE
TM ALT = COS 15 (ACTUAL ALT / COS [(44-PIT)])
5
10
15
20
25
30
35
40
45
50
55
60
65
70
TAPEMETER READOUT (1000FEET)
ANTENNA POSITION 1

FIGURE I

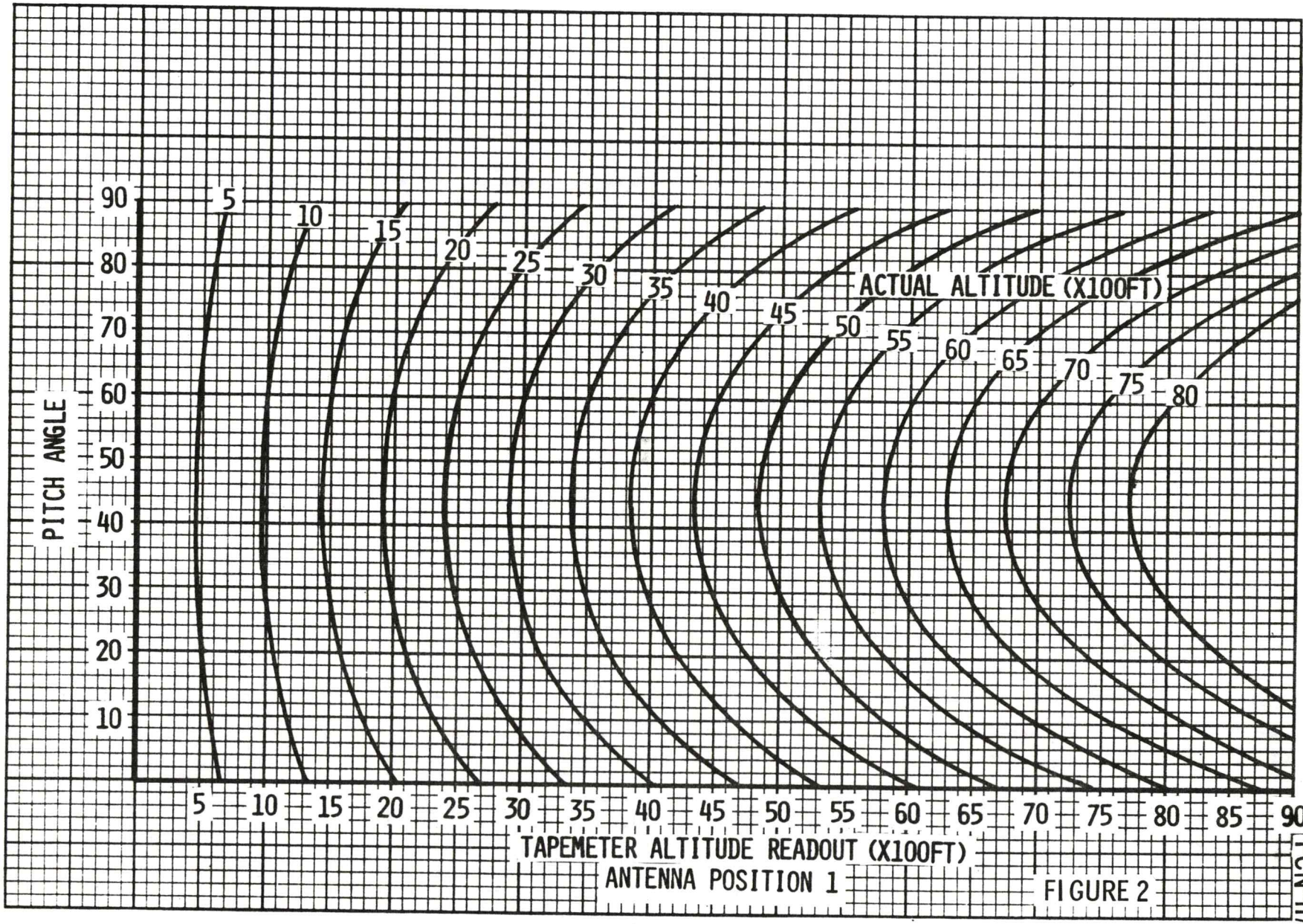

PITCH ANGLE
90
80
70
60
50
40
30
20
10
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
ACTUAL ALTITUDE (X100FT)
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
TAPEMETER ALTITUDE READOUT (X100FT)
ANTENNA POSITION 1

FIGURE 2

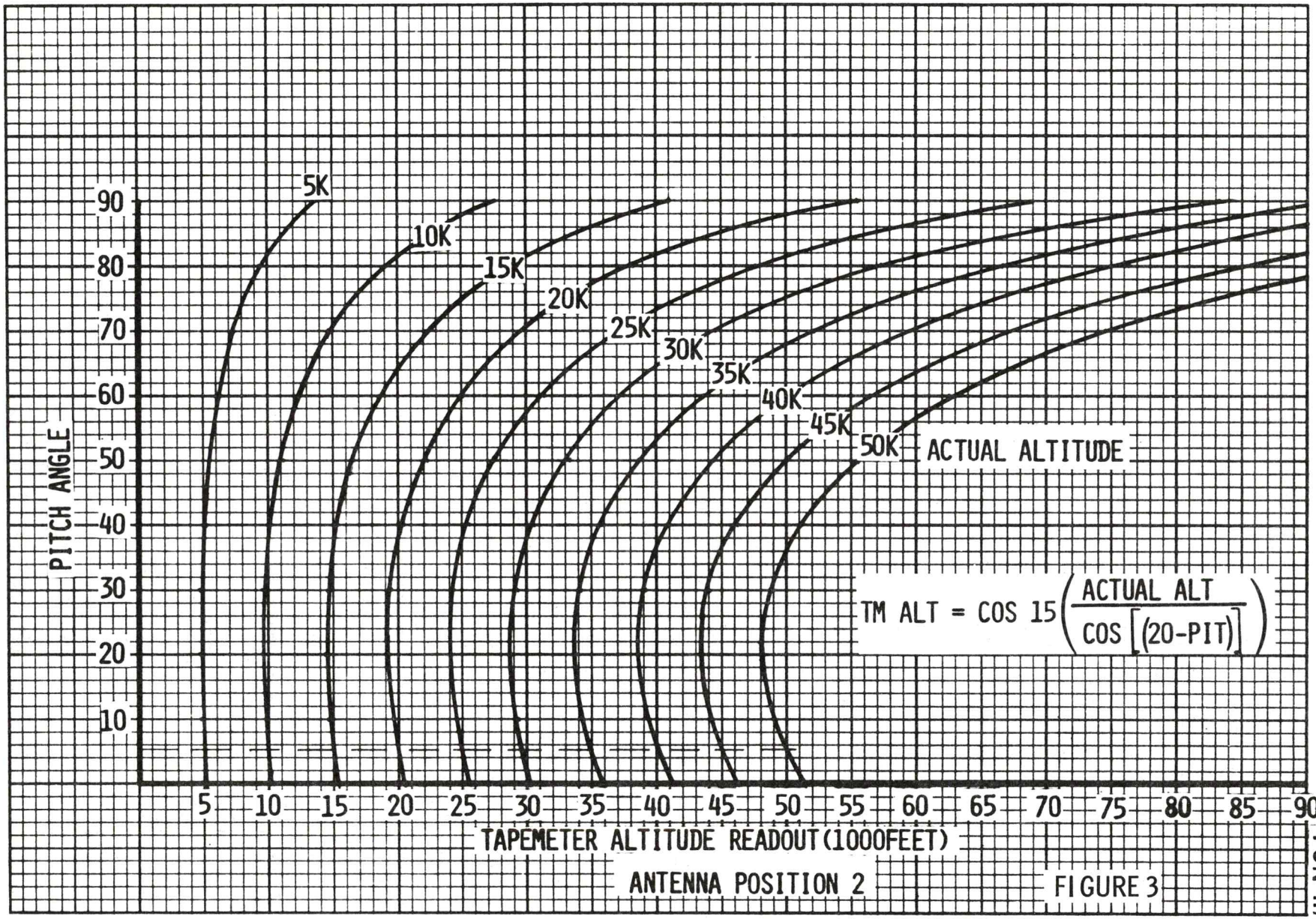

5K
10K
15K
20K
25K
30K
35K
40K
45K
50K
ACTUAL ALTITUDE
TM ALT = COS 15 (ACTUAL ALT / COS [(20-PIT)])
PITCH ANGLE
90
80
70
60
50
40
30
20
10
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
TAPEMETER ALTITUDE READOUT (1000 FEET)
ANTENNA POSITION 2

FIGURE 3

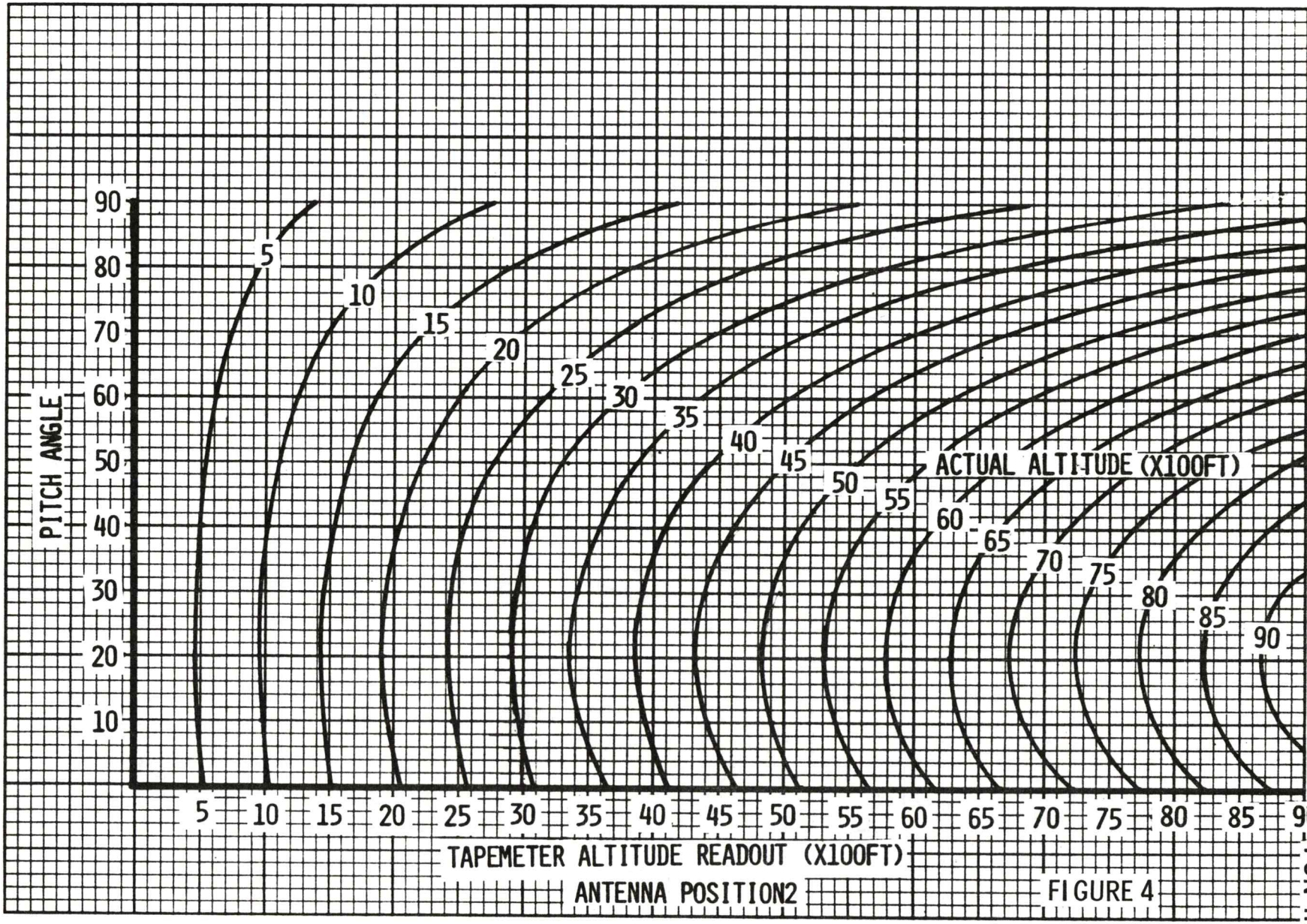

PITCH ANGLE
90
80
70
60
50
40
30
20
10
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
ACTUAL ALTITUDE (X100FT)
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
TAPEMETER ALTITUDE READOUT (X100FT)
ANTENNA POSITION2

FIGURE 4

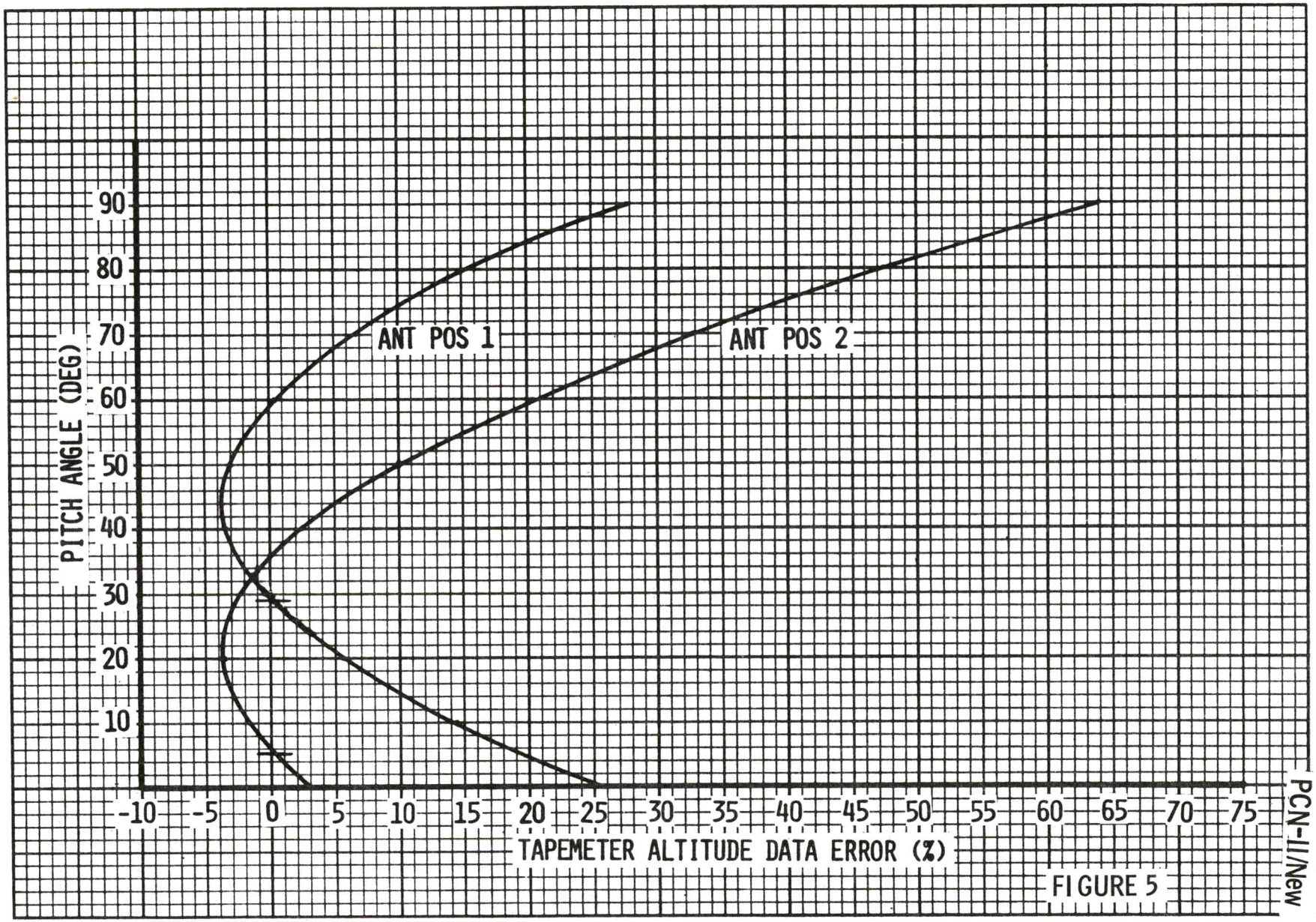

PITCH ANGLE (DEG)
90
80
70
60
50
40
30
20
10
ANT POS 1
ANT POS 2
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
TAPEMETER ALTITUDE DATA ERROR (%)

FIGURE 5

S/C: LM
DATE: 11/1/71
REV: PCN-11/New
ORIGINATOR: J. Conwell & J. Nelson
APPROVAL: Harold O. Golden

SCP NO. PGNS 7-11

TITLE: TEMPERATURE AND VOLTAGE EFFECTS ON IMU CONSTANTS WITH ATTENDANT VELOCITY AND ALIGNMENT ERRORS

PURPOSE: The purpose of this SCP is to show the effects of the IMU temperature changes and power supply changes on:

1. IRIG Constants
   (a) Acceleration Drift along the Spin Reference Axis (ADSRA)
   (b) Acceleration Drift along the Input Axis (ADIA)
   (c) Null Bias Drift (NBD)
2. PIPA Constants
   (a) PIPA bias
   (b) PIPA Scale Factor Error

PROCEDURE: 1. IRIG Constants

(a) ADSRA - Acceleration sensitive drift along the spin reference axis is affected by temperature. Figure 1 shows the change in ADSRA as the temperature varies about nominal. The slope of the curve is .5 MERU/g/^{o}F.

The maximum value on the graph is a change of 2.5 MERU/g for a 5°F change in temperature. This is one-half of the one sigma value of 5 MERU/g. If the entire ascent or descent burn were made in one stable member axis, then the following table would give the error caused in the platform alignment by a 1σ value and a 3σ value.

TYPE BURN	ADSRA ERROR	PLATFORM MISALIGNMENT
Descent	5 MERU/g (1σ)	.00468 deg
Descent	15 MERU/g (3σ)	.01404 deg
Ascent	5 MERU/g (1σ)	.00393 deg
Ascent	15 MERU/g (3σ)	.01176 deg

Table 1 could be used to update the ADSRA terms if a change in temperature occurred. An update would probably never be accomplished since the values are within the one sigma value. The table can also be used to check the values that are loaded in erasable storage in the LGC.

(b) ADIA - Acceleration sensitive drift along the input axis is affected by temperature. Figure 1 shows the change in ADIA as the temperature varies about nominal. The slope of the curve is .5 MERU/g/^{o}F. The maximum value on the graph is a change of 2.5 MERU/g for a 5°F change in temperature. This is within the one sigma value of 8 MERU/g. If the entire ascent or descent burn were made in one stable member axis, the following table gives the error caused in the platform alignment.

TYPE BURN	ADIA ERROR	PLATFORM MISALIGNMENT
Descent	8 MERU/g (1σ)	.00748 deg
Descent	24 MERU/g (3σ)	.02244 deg
Ascent	8 MERU/g (1σ)	.00627 deg
Ascent	24 MERU/g (3σ)	.01881 deg

Table 1 could be used to update the ADIA terms if a change in temperature occurred. An update would probably never be accomplished since the values are within the one sigma value.

(c) NBD - Normal bias drift changes with a change in temperature from nominal at the rate of .2 MERU^{o}/F as shown by Figure 1. Figure 2 shows NBD platform drift versus platform error versus time. If the temperature had changed by 5°F, the total NBD change would be 1 MERU. This is less than the one sigma NBD compensation value of 1.2 MERU. Therefore, this number would probably not be updated.

2. PIPA Constants

(a) PIPA Bias - Figure 3 shows change in PIPA bias with changes in the 120 VDC, 28 VDC and 28 VAC 3.2 KHZ power supplies. PIPA bias changes at the rate of -.046 cm/sec^{2}/volt for the 28 VAC 3.2 KHZ case. For the 120 VDC and 28 VDC case, the PIPA bias changes at the rate of $\approx$ .02 cm/sec/volt. PIPA bias does not change with PIPA temperature in the range of $\pm$ 4.5^{o}F about nominal PIPA temperature. Figure 3 also shows PIPA bias versus total accumulated velocity error for various burn times. Figure 4 is similar to Figure 3 and shows PIPA bias versus velocity error over a larger PIPA bias error range. PIPA bias shifts can be measured directly as described in SCP No. PGNS 7-2.

(b) PIPA Scale Factor Error - Figure 5 shows changes in PIPA bias scale factor with changes in the 120 VDC, 28 VDC, and 28 VAC 3.2 KHZ power supplies and PIPA temperature. Figure 5 also shows PIPA scale factor error versus percent accumulated velocity error. To find the total velocity error for any given burn, multiply the percent error by the total delta velocity expected for the burn maneuver. Table 2 is a PIPA scale factor to octal conversion chart that can be used for loading new scale factors in the LGC. Based on the small velocity errors caused by PIPA scale factor error, it is not expected that realtime updates will be necessary.

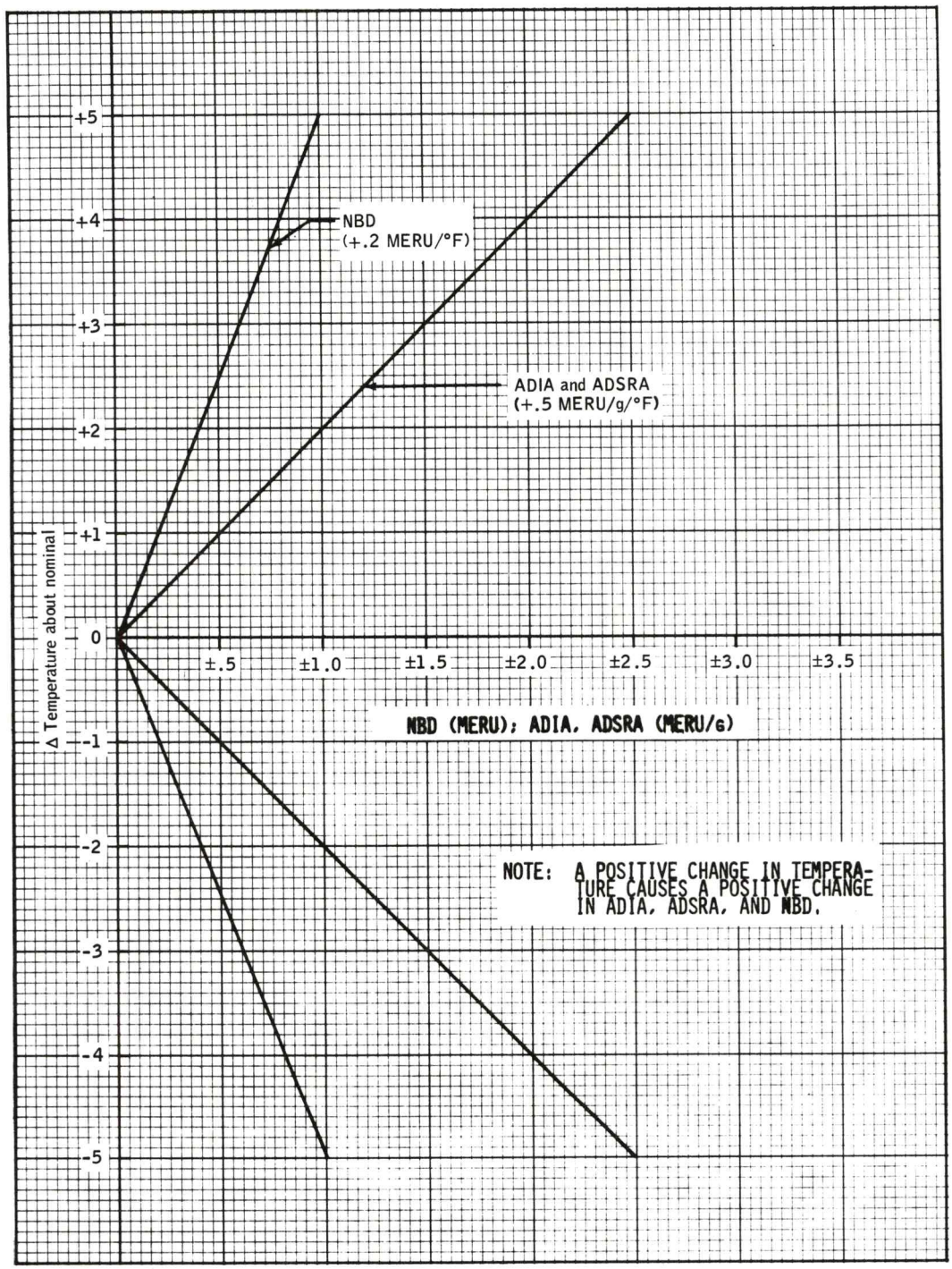


Figure 1. - Change in gyro drift terms vs change in temperature.

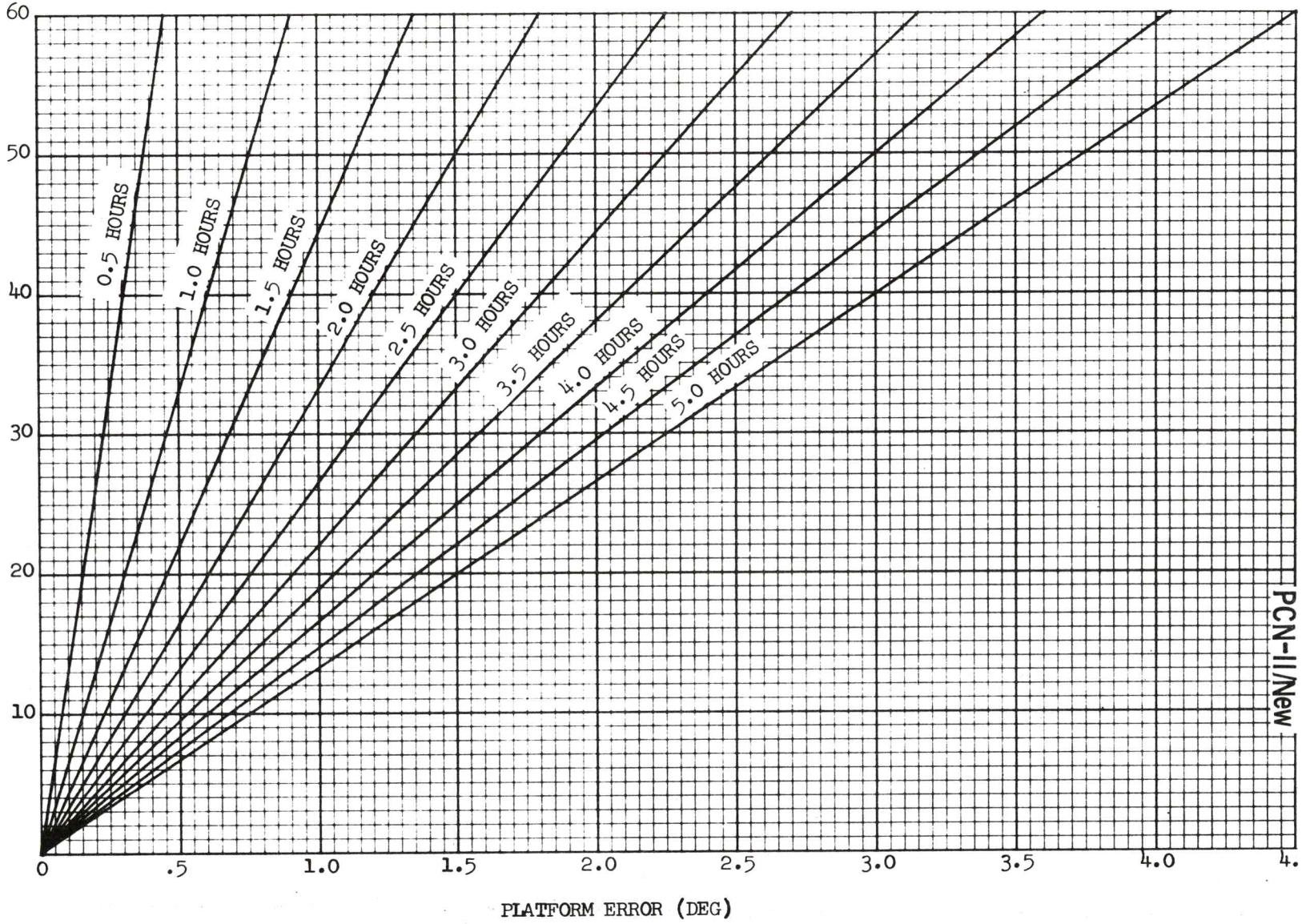


FIGURE 2: NBD PLATFORM DRIFT VS. PLATFORM ERROR

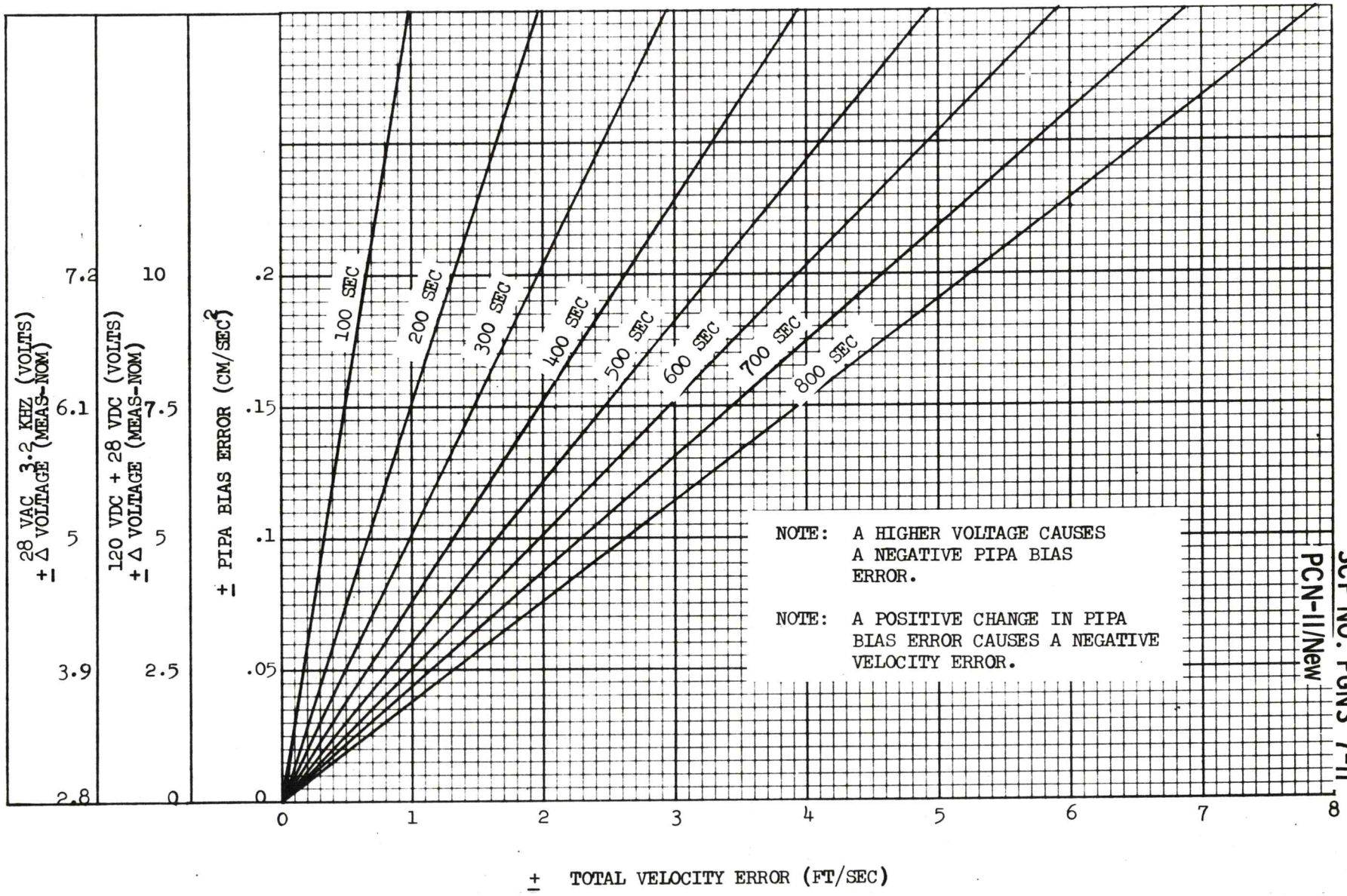


FIGURE 3: VOLTAGE VS. PIPA BIAS ERROR VS. TOTAL VELOCITY ERROR

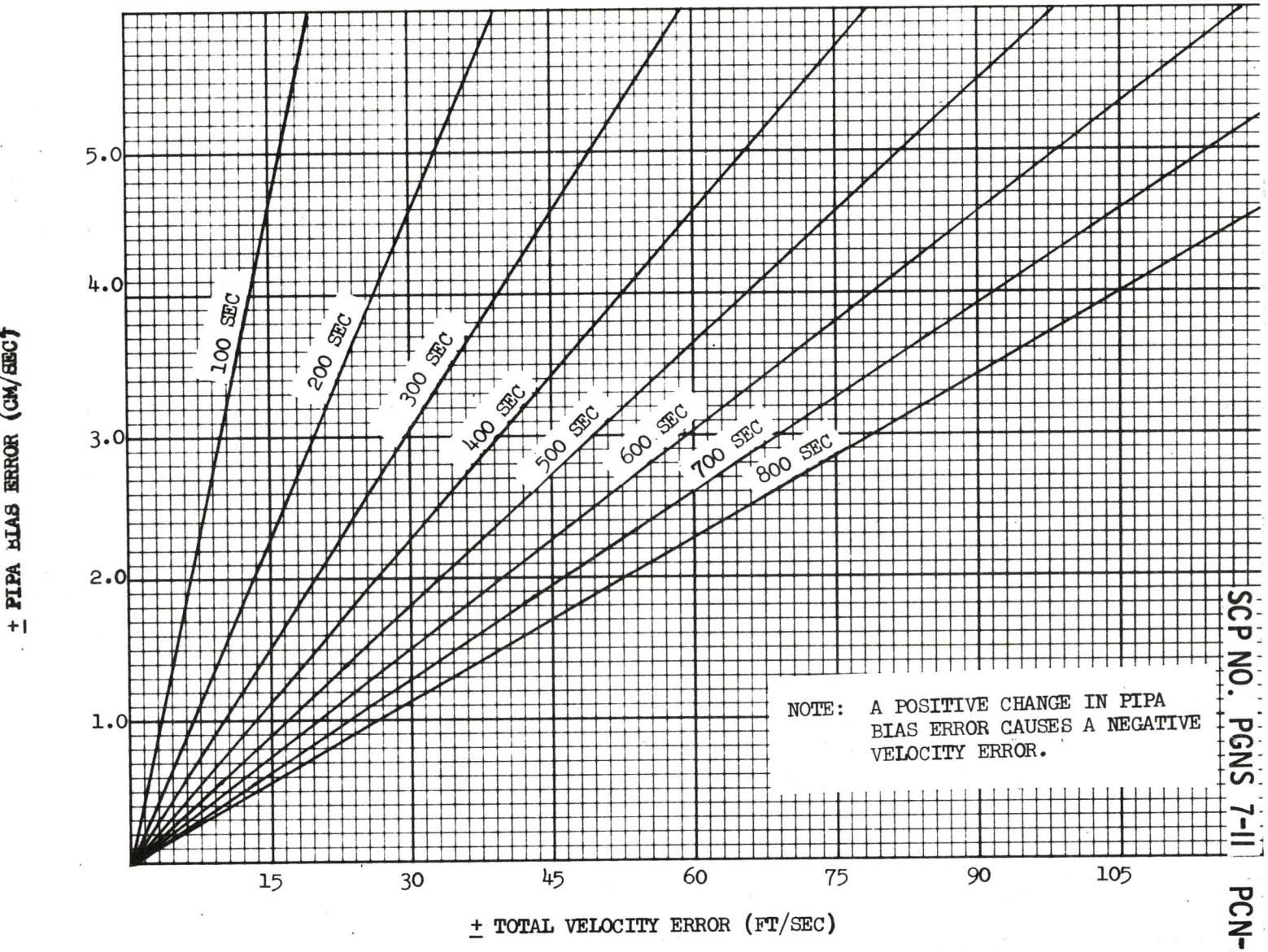


FIGURE 4: PIPA BIAS ERROR VS. TOTAL VELOCITY ERROR

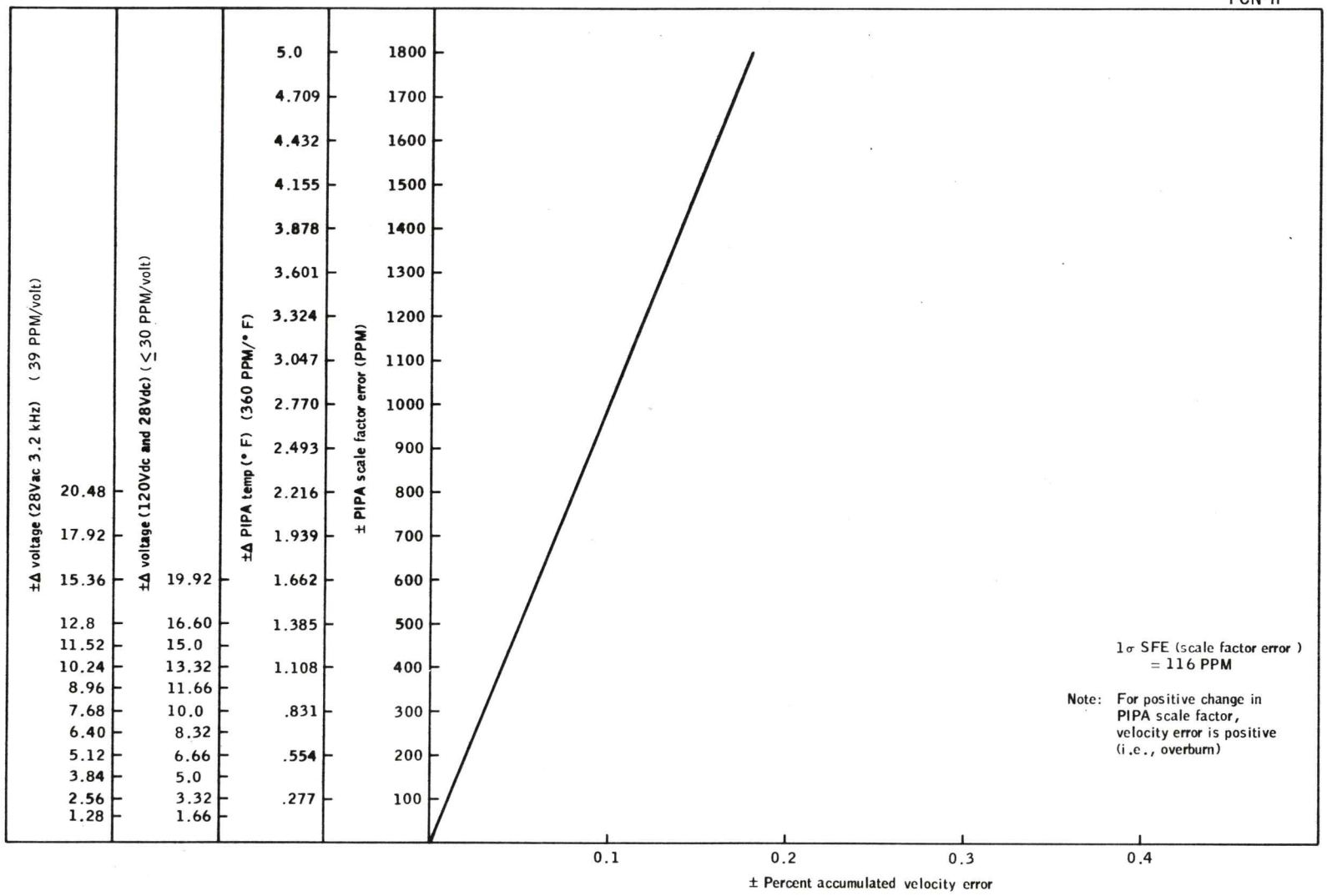


Figure 5. - PIPA scale factor error vs velocity error.

TABLE I.- LM ADIA AND ADSRA TO OCTAL

For octal update of ADIAX, Y, Z and ADSRAX, Y, Z (address 1463, 1464, 1465, 1466, 1467, 1470 respectively). ADIA and ADSRA are scaled B-6 gyro pulses/cm/sec^2.

MERU/g	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
0000.0	00000	00032	00064	00116	00150	00202	00234	00266	00320	00352
0010.0	00404	00436	00470	00522	00554	00606	00640	00672	00724	00756
0020.0	01010	01042	01074	01126	01160	01212	01244	01276	01330	01362
0030.0	01414	01446	01500	01532	01564	01616	01650	01702	01734	01766
0040.0	02020	02052	02104	02136	02170	02222	02254	02306	02340	02372
0050.0	02424	02456	02510	02542	02574	02626	02660	02712	02743	02775
0060.0	03027	03061	03113	03145	03177	03231	03263	03315	03347	03401
0070.0	03433	03465	03517	03551	03603	03635	03667	03721	03753	04005
0080.0	04037	04071	04123	04155	04207	04241	04273	04325	04357	04411
0090.0	04443	04475	04527	04561	04613	04645	04677	04731	04763	05015
0100.0	05047	05101	05133	05165	05217	05251	05303	05335	05367	05421
0110.0	05453	05505	05537	05571	05623	05655	05707	05741	05773	06025
0120.0	06057	06111	06143	06175	06227	06261	06313	06345	06377	06431
0130.0	06463	06515	06547	06601	06633	06665	06717	06751	07003	07035
0140.0	07067	07121	07153	07205	07237	07271	07323	07355	07407	07441
0150.0	07473	07525	07557	07611	07643	07675	07727	07761	10013	10045
0160.0	10077	10131	10163	10215	10247	10301	10333	10365	10417	10451
0170.0	10503	10535	10566	10620	10652	10704	10736	10770	11022	11054
0180.0	11106	11140	11172	11224	11256	11310	11342	11374	11426	11460
0190.0	11512	11544	11576	11630	11662	11714	11746	12000	12032	12064
0200.0	12116	12150	12202	12234	12266	12320	12352	12404	12436	12470
0210.0	12522	12554	12606	12640	12672	12724	12756	13010	13042	13074
0220.0	13126	13160	13212	13244	13276	13330	13362	13414	13446	13500
-0000.0	00000	77745	77713	77661	77627	77575	77543	77511	77457	77425
-0010.0	77373	77341	77307	77255	77223	77171	77137	77105	77053	77021
-0020.0	76767	76735	76703	76651	76617	76565	76533	76501	76447	76415
-0030.0	76363	76331	76277	76245	76213	76161	76127	76075	76043	76011
-0040.0	75757	75725	75673	75641	75607	75555	75523	75471	75437	75405
-0050.0	75353	75321	75267	75235	75203	75151	75117	75065	75034	75002
-0060.0	74750	74716	74664	74632	74600	74546	74514	74462	74430	74376
-0070.0	74344	74312	74260	74226	74174	74142	74110	74056	74024	73772
-0080.0	73740	73706	73654	73622	73570	73536	73504	73452	73420	73366
-0090.0	73334	73302	73250	73216	73164	73132	73100	73046	73014	72762
-0100.0	72730	72676	72644	72612	72560	72526	72474	72442	72410	72356
-0110.0	72324	72272	72240	72206	72154	72122	72070	72036	72004	71752
-0120.0	71720	71666	71634	71602	71550	71516	71464	71432	71400	71346
-0130.0	71314	71262	71230	71176	71144	71112	71060	71026	70774	70742
-0140.0	70710	70656	70624	70572	70540	70506	70454	70422	70370	70336
-0150.0	70304	70252	70220	70166	70134	70102	70050	70016	67764	67732
-0160.0	67700	67646	67614	67562	67530	67476	67444	67412	67360	67326
-0170.0	67274	67242	67211	67157	67125	67073	67041	67007	66755	66723
-0180.0	66671	66637	66605	66553	66521	66467	66435	66403	66351	66317
-0190.0	66265	66233	66201	66147	66115	66063	66031	65777	65745	65713
-0200.0	65661	65627	65575	65543	65511	65457	65425	65373	65341	65307
-0210.0	65255	65223	65171	65137	65105	65053	65021	64767	64735	64703
-0220.0	64651	64617	64565	64533	64501	64447	64415	64363	64331	64277

For Table I interpolation, add the octal number for positive ADIA or ADSRA values and subtract the octal number for negative values.

MERU/g	.05	.1	.2	.3	.4	.5	.6	.7	.8	.9
OCTAL NO.	1	3	5	10	12	15	20	22	25	27

TABLE II.- LM PIPA SCALE FACTOR TO OCTAL

For octal update of PIPASCFX, Y, Z (address 1453, 1455, 1457).
PIPASCF is scaled B-9 PIPA counts per PIPA count.

PPM	00.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
0000.0	00000	00124	00250	00374	00520	00643	00767	01113	01237	01363
0100.0	01507	01633	01757	02103	02226	02352	02476	02622	02746	03072
0200.0	03216	03342	03465	03611	03735	04061	04205	04331	04455	04601
0300.0	04725	05050	05174	05320	05444	05570	05714	06040	06164	06310
0400.0	06433	06557	06703	07027	07153	07277	07423	07547	07673	10016
0500.0	10142	10266	10412	10536	10662	11006	11132	11256	11401	11525
0600.0	11651	11775	12121	12245	12371	12515	12640	12764	13110	13234
0700.0	13360	13504	13630	13754	14100	14223	14347	14473	14617	14743
0800.0	15067	15213	15337	15463	15606	15732	16056	16202	16326	16452
0900.0	16576	16722	17046	17171	17315	17441	17565	17711	20035	20161
1000.0	20305	20430	20554	20700	21024	21150	21274	21420	21544	21670
1100.0	22013	22137	22263	22407	22533	22657	23003	23127	23253	23376
1200.0	23522	23646	23772	24116	24242	24366	24512	24636	24761	25105
1300.0	25231	25355	25501	25625	25751	26075	26221	26344	26470	26614
1400.0	26740	27064	27210	27334	27460	27603	27727	30053	30177	30323
1500.0	30447	30573	30717	31043	31166	31312	31436	31562	31706	32032
1600.0	32156	32302	32426	32551	32675	33021	33145	33271	33415	33541
1700.0	33665	34011	34134	34260	34404	34530	34654	35000	35124	35250
1800.0	35373	35517	35643	35767	36113	36237	36363	36507	36633	36756
1900.0	37102	37226	37352	37476	37622	37746				
-0000.0	00000	77653	77527	77403	77257	77134	77010	76664	76540	76414
-0100.0	76270	76144	76020	75674	75551	75425	75301	75155	75031	74705
-0200.0	74561	74435	74312	74166	74042	73716	73572	73446	73322	73176
-0300.0	73052	72727	72603	72457	72333	72207	72063	71737	71613	71467
-0400.0	71344	71220	71074	70750	70624	70500	70354	70230	70104	67761
-0500.0	67635	67511	67365	67241	67115	66771	66645	66521	66376	66252
-0600.0	66126	66002	65656	65532	65406	65262	65137	65013	64667	64543
-0700.0	64417	64273	64147	64023	63677	63554	63430	63304	63160	63034
-0800.0	62710	62564	62440	62314	62171	62045	61721	61575	61451	61325
-0900.0	61201	61055	60731	60606	60462	60336	60212	60066	57742	57616
-1000.0	57472	57347	57223	57077	56753	56627	56503	56357	56233	56107
-1100.0	55764	55640	55514	55370	55244	55120	54774	54650	54524	54401
-1200.0	54255	54131	54005	53661	53535	53411	53265	53141	53016	52672
-1300.0	52546	52422	52276	52152	52026	51702	51556	51433	51307	51163
-1400.0	51037	50713	50567	50443	50317	50174	50050	47724	47600	47454
-1500.0	47330	47204	47060	46734	46611	46465	46341	46215	46071	45745
-1600.0	45621	45475	45351	45226	45102	44756	44632	44506	44362	44236
-1700.0	44112	43766	43643	43517	43373	43247	43123	42777	42653	42527
-1800.0	42404	42260	42134	42010	41664	41540	41414	41270	41144	41021
-1900.0	40675	40551	40425	40301	40155	40031				

INTERPOLATION TABLE

PPM	0.5	1	2	3	4	5	6	7	8	9
OCTAL (for plus values add; for negative substract)	4	10	21	31	42	52	62	73	103	114

SCP NO. **PGNS 7-12**

S/C : LM
DATE : 11/1/71
REV. : PCN-11/New
ORIGINATOR : J. J. Conwell
APPROVAL : W. A. Foden

TITLE : LUNAR SURFACE TILT AND HEADING ANGLES FOR MANUAL STAGING

PURPOSE : The purpose of this SCP is to describe the method used to compute tilt and heading angles after touchdown.

BACKGROUND: On the lunar surface, it may sometimes be necessary to manually stage. The safety of the procedure depends upon the tilt and heading angles of the spacecraft. Once the tilt and heading angles are computed they are given to TELMU who then references MSC Internal Note No. 71-FM-198 to determine if manual staging is safe.

The following assumptions are made: the platform was aligned local vertical to the landing site, the LM landed at the landing site, and the platform had no drift. Using data from Apollo 11, 12 and 14, it was found that a 0.5° error in Pitch or Roll would cause no greater error than $\pm 0.5^{\circ}$ in tilt and ± 7.0 degrees in heading. A 0.5° error in yaw caused no error in tilt and $\pm 0.5^{\circ}$ error in heading. In general, the maximum error will be 0.1° in each axis which will cause a maximum error of $\pm 0.1^{\circ}$ in tilt and $\pm 1.4^{\circ}$ in heading

After the first P57, the guidance officer can project the angles back to touchdown to give good local vertical angles at touchdown if confidence was lost in the touchdown angles.

PROCEDURE:

1. Obtain gimbal angles in stable member coordinates from PGNS real-time console display at touchdown. (MSK 1137)
2. Switch configuration for Hewlett Packard.
   - o Degrees
   - o Fixed Point
   - o Power On
   - o Run
   - o Printer ON with X, Y, & Z button depressed.
3. Set decimal wheel to 5
4. GO TO + 00
5. Enter side A of card No. 12
6. GO TO - 00
7. Continue
8. Clear
9. Enter Roll
10. ↑
11. Enter Pitch
12. ↑
13. Enter Yaw
14. Continue
15. Printout will be as follows:

Roll Pitch Yaw	INPUT
Tilt Heading 0	OUTPUT

16. Give these angles to LM EPS

SCP NO. **PGNS 7-13**

S/C: LM
DATE:
REV: PCN-12
ORIGINATOR: J. Conwell
APPROVAL. Harold O. Loden

TITLE: PLATFORM PARKING ANGLES

PURPOSE: The purpose of this procedure is to describe the method used to calculate gimbal angles for parking the platform on the lunar surface using the Hewlett Packard 9100B computer.

BACKGROUND: On Apollo 15, a large shift was observed in the PIPA bias terms between power down and power up on the lunar surface. By parking the platform with all output axes of the accelerometer perpendicular to the gravity vector, the PIPA bias shift is expected to be reduced. The platform will be parked with the Y_{SM} input axis up and parallel to the gravity vector. Using the direction cosines of the gravity vector the gimbal angles for the platform can be computed.

$\vec{g}$ = gravity vector

$$-\vec{g} = \alpha\vec{X}_{NB} + \beta\vec{Y}_{NB} + \gamma\vec{Z}_{NB}$$

IGA = 0.00

$$MGA = \sin^{-1}\alpha$$

$$OGA = \begin{cases} \sin^{-1}\left(\frac{-\gamma}{\cos MGA}\right) \\ \cos^{-1}\left(\frac{\beta}{\cos MGA}\right) \end{cases}$$

PROCEDURE:

1. Obtain direction cosines α, β, and γ from MSK 1599 and record.
2. Switch configuration for Hewlett Packard
   X printer on
   Degrees
   Power On
   Run Mode
   Decimal wheel at 5
3. End
4. Enter Side A Card No. 16
5. End
6. Enter α
7. ↑
8. Enter β
9. ↑
10. Enter γ
11. Continue
12. Printout will be as follows:
    α
    β
    γ
    OGA
    IGA
    MGA

P-12

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: C. Gruby
APPROVAL: H. A. Loden

SCP NO RDR 8-1

TITLE: **RNDZ RADAR ANTENNA MODES**

PROCEDURE: The following equations are to be used to interpret the RR shaft and trunnion angles in terms of RR antenna line of sight azimuth and elevation angles:

MODE I

360° - Resolver trunnion angle = azimuth angle

Resolver shaft angle = elevation angle

MODE II

Resolver trunnion angle - 180 + X_1 = azimuth angle

Where: $X_1 = 0^\circ$

When: $180^\circ \leq$ Resolver trunnion angle $< 270^\circ$

Where: $X_1 = 360^\circ$

When: $90^\circ <$ Resolver trunnion angle $< 180^\circ$

X + Resolver shaft angle = elevation angle

Where: $X = 180^\circ$

When: $0^\circ \leq$ Resolver shaft angle $\leq 180^\circ$

and

Where: $X = -180^\circ$

When: $180^\circ <$ Resolver shaft angle $< 360^\circ$

Figure 1 represents graphical solutions of the above equations for trunnion and shaft respectively, in antenna modes I and II.

When communicating these angles to the astronauts, the sequence of presentation shall be first, azimuth (trunnion), and second, elevation (shaft).

Figures 2 and 3 show the software and hardware stops respectively. The software stops are those limits outside of which the LGC will reposition the antenna along the +Z (Mode I) or along the +X (Mode II) axis. The hardware stops show the mechanical limits beyond which the antenna cannot physically be positioned. P-11

RR COARSE ALIGN PROCEDURE (V41 N72)

CB(11) RR(2) - CLOSE
RR MODE - LGC
IF POSITIONING OUTSIDE OF SOFTWARE LIMITS SET NORRMON FLAG:
V25 N07E
101E, 10E, 1E
V41 N72E
F 21 73
R1 XXX.XX E LOAD TRUN
R2 XXX.XX E LOAD SHAFT

F 04 12
R1 00066 SPECIFY RR FUNCTION
R2 00001 LOCK ON CSM
00002 CONTINUOUS DESIGNATE
PRO
V41 (STATIC)
V16 N72E MONITOR ANTENNA DRIVING TO DESIRED POSITION FOR PARKING:
CB(11) RR(2) - OPEN
V44E TERMINATE

RR LOS AZIMUTH AND ELEVATION DISPLAY (V16 N56)

RNDZ RADAR SEL - LGC
V85E (RR LOS CALCULATION ROUTINE)
F 16 56
R1 AZIMUTH XXX.XX° + 000.00° TO 360.00° ABOUT + Z
R2 ELEVATION XXX.XX° + 000.00° TO 360.00° ABOUT + Y
R3 BLANK
TO TERMINATE
PRO

RR ANTENNA SLEW RATES

	HIGH	LOW
SHAFT UP	9.19°/SEC	1.05°/SEC
DOWN	9.19°/SEC	1.01°/SEC
TRUN RIGHT	9.22°/SEC	0.967°/SEC
LEFT	9.27°/SEC	1.04°/SEC

P-11

RR ANTENNA DRIFT RATES

	PRI	SEC
SHAFT	NOT MEASURED	------
TRUN	1.04°/MIN LEFT	0.58°/MIN LEFT

ALL VALUES ARE SUBJECT TO VARIATION BETWEEN DIFFERENT SERIAL NUMBERED RADARS. CHECK SODB FOR UPDATES.

POSITIONING RR ANTENNA FOR LOCK-ON DURING ASCENT ASSUMPTIONS:

A. Onboard and Ground TM readouts of RR position are unavailable during Ascent.
B. Desired RR lock-on time with CSM is known to obtain proper LOS angle.
C. Optimum RR antenna position for liftoff is:
SHAFT = 0°; TRUNNION = 180°
1. Rationale: Minimum antenna movement due to:
(a) Gas forces at staging
(b) Acceleration dynamics
2. Disadvantages:
(a) LGC cannot designate to the desired angles due to software limitations.

PROCEDURE (PRE-LIFTOFF)

A. Select secondary gyros for minimum trunnion drift.

B. Designate RR antenna (V41 N72) to:
SHAFT (R2) = 333° TRUNNION (R1) = 180°

C. Slew up (hi rate) for 3 seconds. Antenna should be at : TRUNNION = 180° SHAFT = 0°

D. Crew may read RR angles (ground also) if the NORRMON flag is set prior to P12.

PROCEDURE (ASCENT)

At liftoff + 4 minutes:

A. Slew up (hi rate) for 24 seconds. This will ensure antenna against + 68° hardstop (mechanical limitation).

B. Slew down (hi rate) for TBD seconds stopping short of desired LOS.
EX: (using Apollo 15 LOS for shaft = 275°)

$$\frac{360^\circ - 275^\circ + 68^\circ}{9.18} - 1 = 15.6 \text{ SEC} = 15 \text{ SEC at hi slew rate.}$$

C. Slew dn (low rate) until AGC meter indicates signal strength.

D. Maximize signal strength if desired then select auto track.

E. Possible trunnion drift error of:

57 SEC at 0.58°/Min = 0.5° error

P-11

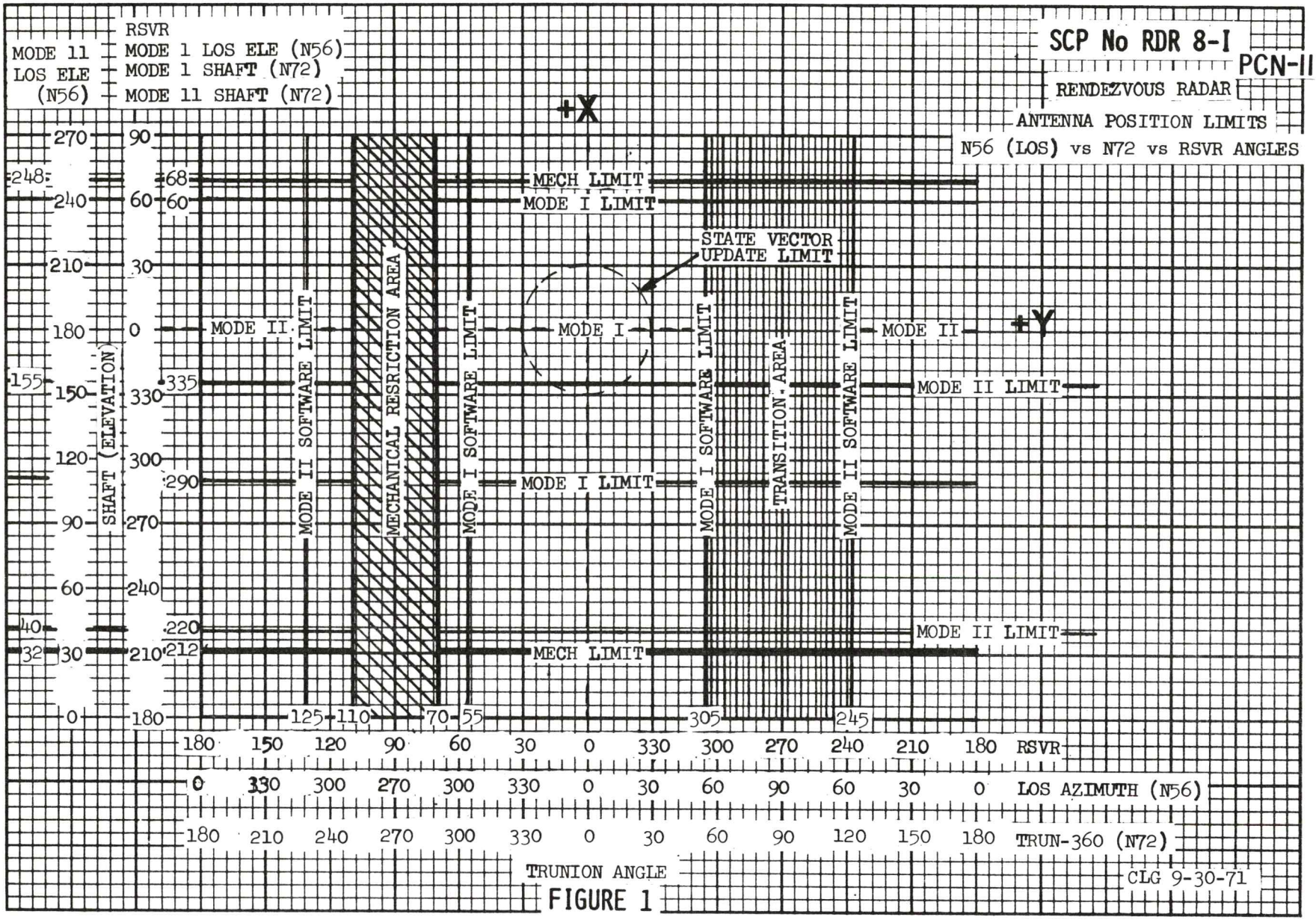
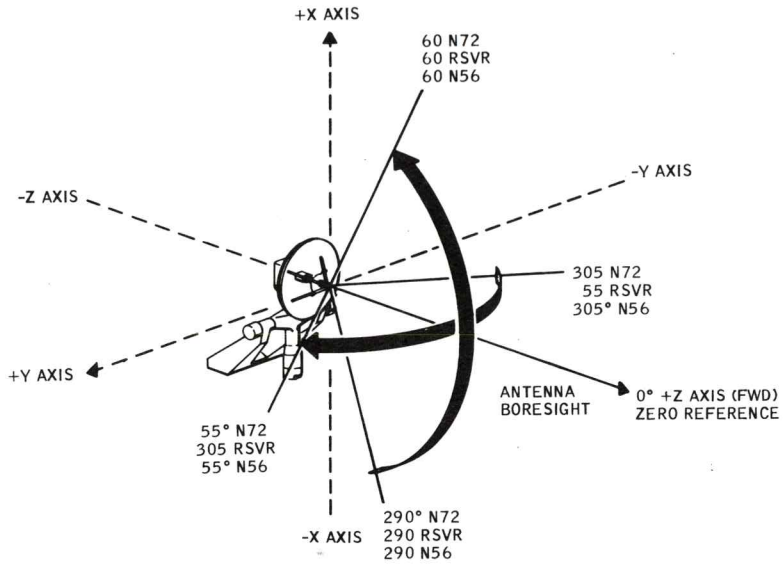
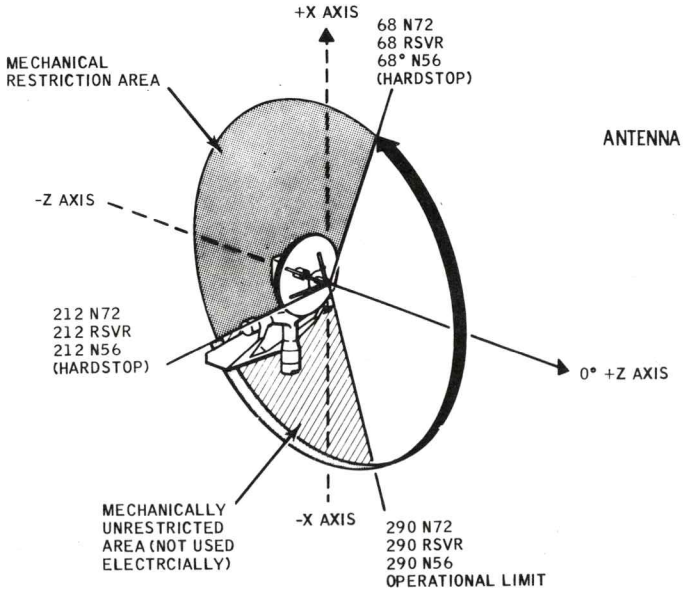

SCP No RDR 8-I
PCN-II
RENDEZVOUS RADAR
ANTENNA POSITION LIMITS
N56 (LOS) vs N72 vs RSVR ANGLES
RSVR
MODE II LOS ELE (N56)
MODE I LOS ELE (N56)
MODE I SHAFT (N72)
MODE II SHAFT (N72)
+X
+Y
MECH LIMIT
MODE I LIMIT
STATE VECTOR UPDATE LIMIT
MODE II
MODE I
MODE II
MODE II LIMIT
MODE I LIMIT
MODE II LIMIT
MECH LIMIT
MODE II SOFTWARE LIMIT
MECHANICAL RESTRICTION AREA
MODE I SOFTWARE LIMIT
MODE I SOFTWARE LIMIT
TRANSITION AREA
MODE II SOFTWARE LIMIT
SHAFT (ELEVATION)
270 248 240 210 180 155 150 120 90 60 40 32 30 0
90 68 60 30 0 335 330 300 270 240 220 212 210 180
125 110 70 55 305 245
180 150 120 90 60 30 0 330 300 270 240 210 180 RSVR
0 330 300 270 300 330 0 30 60 90 60 30 0 LOS AZIMUTH (N56)
180 210 240 270 300 330 0 30 60 90 120 150 180 TRUN-360 (N72)
TRUNION ANGLE
CLG 9-30-71

FIGURE 1

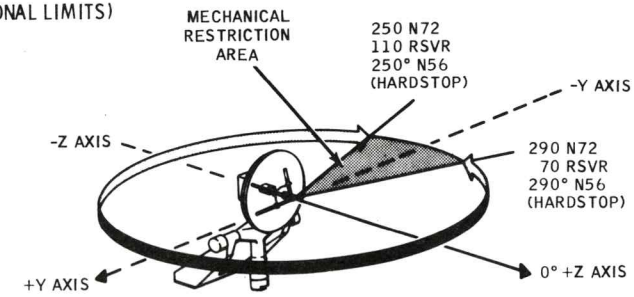
NOTES:
1. THE X, Y AND Z AXES SHOWN ARE THE LM AXIS.
2. ALL POSITIONS DEFINED IN DEGREES ARE THE ANTENNA RESOLVER, LOS (N56) AND THE N72 ANGLES.



ANTENNA BORESIGHT COVERAGE (OPERATIONAL LIMITS)



SHAFT

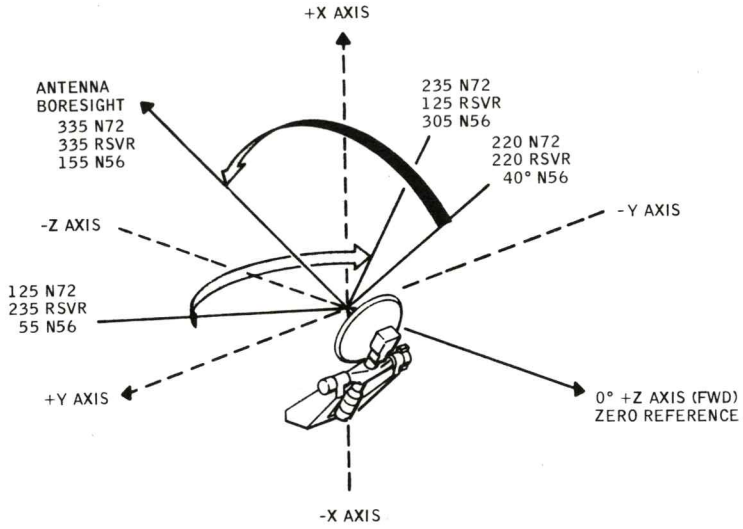


TRUNNION

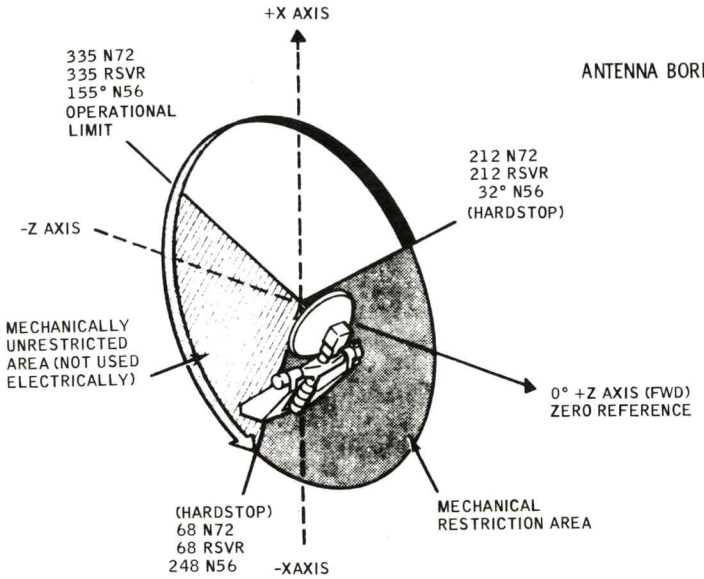
ANTENNA COVERAGE (MECHANICAL LIMITS)

FIGURE 2. - MODE I LIMITS.

NOTES:
1. THE X,Y AND Z AXES SHOWN ARE THE LM AXIS.
2. ALL POSITIONS DEFINED IN DEGREES ARE THE ANTENNA RESOLVER, LOS (N56) AND THE N72 ANGLES



ANTENNA BORESIGHT COVERAGE (OPERATIONAL LIMITS)



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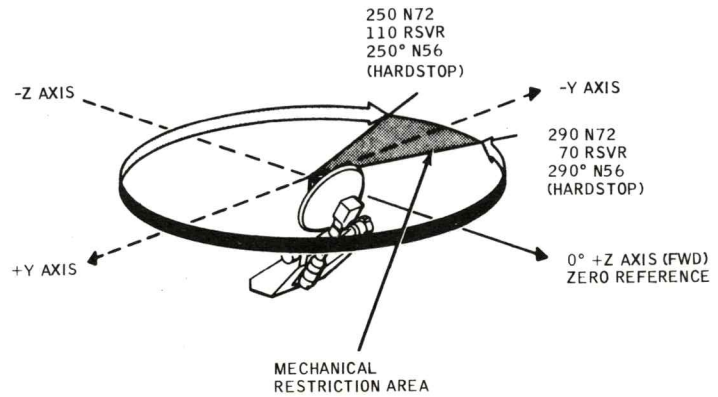


TRUNNION

ANTENNA COVERAGE (MECHANICAL LIMITS)

FIGURE 3. - MODE II LIMITS.

SCP NO. SCS 9-1

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: J. Conwell
APPROVAL: H. G. Loon

TITLE: **DPS GIMBAL TRIM ALIGNMENT**

PURPOSE: The purpose of this SCP is to give corrected inputs to the LGC gimbal trim routine (R03) to account for off nominal drive rates and hard stop position. Dependent on the equipment available, the inputs may be calculated by any of the following procedures: A. Olivetti Underwood Programma 101, B. Arithmetic, and C. Hewlett-Packard 9100B. P-11

PROCEDURE:

A.1. Use Olivetti "Bias of LM-_ DPS Gimbal Trim" program
2. Turn on Olivetti.
3. Set decimal wheel to 7.
4. Record and Print button out.
5. Push General Reset.
6. Enter side A or B.
7. Push Z for roll or Y for pitch.
8. Enter deg $\pm X^{\circ}$, push S. (Obtain desired gimbal trim angles from propulsion).
9. Read answer.

B.1. Obtain desired gimbal trim angles from LM propulsion $\pm P^{\circ}$ in pitch and $\pm R^{\circ}$ roll.
2. Obtain hard stop position Y (measured from center) and gimbal drive rate RATE from SODB.
3. Obtain corrected LGC trim input by: W°_{PIT} = new pitch entry = $\frac{.2}{RATE}\left[Y-(\pm P^{\circ})\right]$

$$W^{\circ}_{ROLL} = \text{new roll entry} = \frac{.2}{RATE}\left[Y-(\pm R^{\circ})\right]$$

4. Give W°_{PIT} and W°_{ROLL} to CONTROL for transmission to crew.
5. After crew inputs angles, check TM for roll and pitch within 0.5° for AGS GO.

For LM-_ Pitch Y = _____ Roll Y = _____ See SODB, LM-_ appendix
Rate = _____ Rate = _____ for this data. P-6

C.1. Use Hewlett-Packard Calculator 9100B Program card 6, GDA Angle Input from PROP INPUTS.
2. Switch positions: DEGREES, FIXED POINT, POWER ON, RUN, and DECIMAL DIGIT 6.
3. With ENTER switch, enter A and B, push CONT (program is now entered).
4. Set printer X and Y switches. P-11

NOTE

If negative number, use CHG SIGN on the desired gimbal trim angles from propulsion.

5. Push $\pm$ X.XXX (pitch angle), CONT
6. Push $\pm$ X.XXX (roll angle), CONT
7. Read answer.

SCP NO. **SCS 9-2**

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: D. Clark
APPROVAL: H.G. Loden

P-5

TITLE: **RCS INFLIGHT CHECKOUT TEST**

PURPOSE: The RCS checkout test is performed to:

A. Provide a PGNS and AGS TTCA cold fire check on the interface circuits between the thrust/translation controller assembly (TTCA) and the LGC/AGS-CES circuitry.

B. Provide a PGNS Rate Cmd cold fire check on the interface circuits between the attitude controller assembly (ACA) and the LGC.

C. Provide an AGS Rate Cmd and Pulse cold fire check on the interface circuits between the ACA and the CES circuitry.

D. Provide an end-to-end hot fire check of the RCS secondary coils, using 4-jet hardover.

E. Provide a hot fire test of the primary preamps and primary RCS coils via PGNS minimum impulse firings.

PROCEDURE: A. Vehicle configuration for test:

1. The RCS system has been pressurized.
2. CSM wide deadband and attitude hold.
3. Att-translation - 4 jets
4. Verify RCS Sys A and B Quad 1, 2, 3, 4 CB's - Open
5. Guid cont - PGNS Pin 100 not present
6. Mode Cont: PGNS - Att hold Pin 97
7. Mode Cont: AGS - Att hold Pin 99
8. Attitude Control (3) - Pulse
9. ACA/4-Jet (CDR) - Disable
10. TTCA/Transl - Enable
11. TTCA (Both) - Jets
12. Verify high bit rate with MSFN

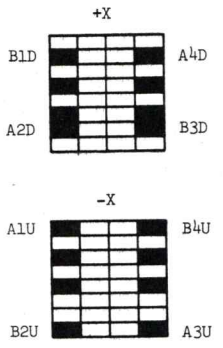
P-11

B. Perform PGNS and AGS TTCA cold fire check.

1. V76E Minimum Impulse
2. V11N10E, 5E Monitor Ch5 on DSKY
3. Deflect CDR TTCA:

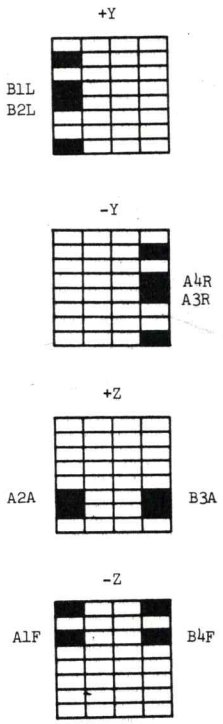
Commanded jet driver indication which provides jet driver indication of quad pair due to open QUAD TCA C/B.

Crew and PGNS SSR		AGS SSR		
Up (+X)	R1 00252	X Trans Cmd	GH1240	+10Vdc(H)
Down (-X)	R1 00125	X Trans Cmd	GH1240	-10Vdc(L)



4. Repeat step 3 for LMP TTCA.
5. E, 6E Monitor Ch6 on DSKY
6. Deflect CDR TTCA

Crew and PGNS SSR		AGS SSR		
Right (+Y)	R1 00220	Y Trans Cmd	GH1241	+10Vdc(H)
Left (-Y)	R1 00140	Y Trans Cmd	GH1241	-10Vdc(L)
Forward (+Z)	R1 00011	Z Trans Cmd	GH1242	+10Vdc(H)
Aft (-Z)	R1 00006	Z Trans Cmd	GH1242	-10Vdc(L)



P-11

C. Perform PGNS Rate Cmd cold fire check and AGS Pulse cold fire check.

1. CB(11) Att Dir Cont - Close pins 101, 102, 103 (PLSD) P-11
2. V77E Rate Command
3. V15N01E 42E Octal readout of roll, pitch, yaw counters
4. Deflect CDR ACA (to soft stop, pause 2 sec at null) Pin 64

Commanded jet driver indication which provides jet driver indication of quad pair due to open QUAD TCA C/B.

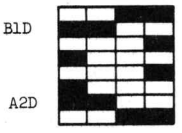
Crew and PGNS SSR		AGS SSR	
Roll right R3	00051	Roll Err Cmd (GH1249V) +2Vdc	ROLL RIGHT: B1D, B4U, A2D, A3U
Roll left R3	77726	Roll Err Cmd (GH1249V) -2Vdc	ROLL LEFT: A1U, A4D, B2U, B3D
Pitch up R1	00051	Pitch Err Cmd (GH1248V) +2Vdc	PITCH UP: B1D, A4D, B2U, A3U
Pitch down R1	77726	Pitch Err Cmd (GH1248V) -2Vdc	PITCH DOWN: A1U, B4U, A2D, B3D
Yaw right R2	77726	Yaw Err Cmd (GH1247V) -2Vdc	YAW RIGHT: B1L, B4F, A2A, A3R
Yaw left R2	00051	Yaw Error Cmd (GH1247V) +2Vdc	YAW LEFT: A1F, A4R, B2L, B3R

D. Perform AGS Rate Cmd cold fire test and RCS secondary coil hot fire test.

1. Verify CMC Mode - Free
2. Guid Control - AGS Pin 100
3. Att Control (3) - Mode Control Pins 101, 102, 103 not present
4. ACA/4-Jet (CDR) - Enable
5. CDR ACA (Deflect slowly to hardover, pause 2 sec at null) Pin 64
   (Quad flags and RCS TCA warning lights - ON) Pin 6 not present (Master Alarm)

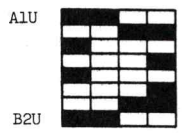
	GH1249V - Roll Err Cmd +13 Vdc (H)			
	GR5040	Jet A2D TCP	Pin 84	
Roll right -	GR5035	Jet A3U TCP	Pin 74	
	GR5031	Jet B4U TCP	Pin 66	
	GR5044	Jet B1D TCP	Pin 92	

ROLL RIGHT



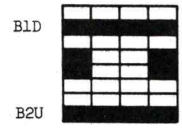
	GH1249V - Roll Err Cmd -13 Vdc (L)			
	GR5032	Jet A4D TCP	Pin 68	
Roll left -	GR5043	Jet A1U TCP	Pin 90	
	GR5039	Jet B2U TCP	Pin 82	
	GR5036	Jet B3D TCP	Pin 76	

ROLL LEFT



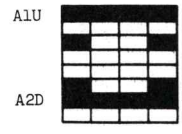
	GH1248V - Pitch Err Cmd +13 Vdc(H)			
	GR5032	Jet A4D TCP	Pin 68	
Pitch up -	GR5035	Jet A3U TCP	Pin 74	
	GR5039	Jet B2U TCP	Pin 82	
	GR5044	Jet B1D TCP	Pin 92	

PITCH UP



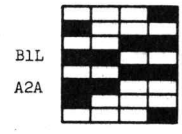
	GH1248V - Pitch Err Cmd -13 Vdc(L)			
	GR5040	Jet A2D TCP	Pin 84	
Pitch down -	GR5043	Jet A1U TCP	Pin 90	
	GR5031	Jet B4U TCP	Pin 66	
	GR5036	Jet B3D TCP	Pin 76	

PITCH DOWN



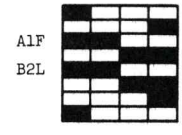
	GH1247V - Yaw Err Cmd -13 Vdc (L)			
	GR5033	Jet B4F TCP	Pin 70	
Yaw right -	GR5041	Jet A2A TCP	Pin 86	
	GR5038	Jet A3R TCP	Pin 80	
	GR5046	Jet B1L TCP	Pin 96	

YAW RIGHT



	GR1247V - Yaw Err Cmd +13 Vdc (H)			
	GR5034	Jet A4R TCP	Pin 72	
Yaw left -	GR5042	Jet B2L TCP	Pin 88	
	GR5037	Jet B3A TCP	Pin 78	
	GR5045	Jet A1F TCP	Pin 94	

YAW LEFT



P-11

E. Perform PGNS Minimum Impulse hot fire check and change DAP configuration

1. Guid Control - PGNS Pin 100 not present
2. V76E ↵ Minimum Impulse
3. CB(11) RCS Sys A: Quad TCA (4) - Close
4. CB(16) RCS Sys B: Quad TCA (4) - Close
5. CB(16) Inst: Cwea - Open and Close Pin 6
6. V11N10E, 31E R1 67777 ↵ Monitor CH31 on DSKY and R1 - Att Hold
7. CDR ACA (out of detent, 2.5°, pause 2 sec at null) Pin 64

P-11

Roll right - R1 27757

GR5040	Jet A2D TCP	Pin 84
GH1427	Jet A2D Driver	Pin 83
GR5035	Jet A3U TCP	Pin 74
GH1422	Jet A3U Driver	Pin 73

Roll left - R1 27737

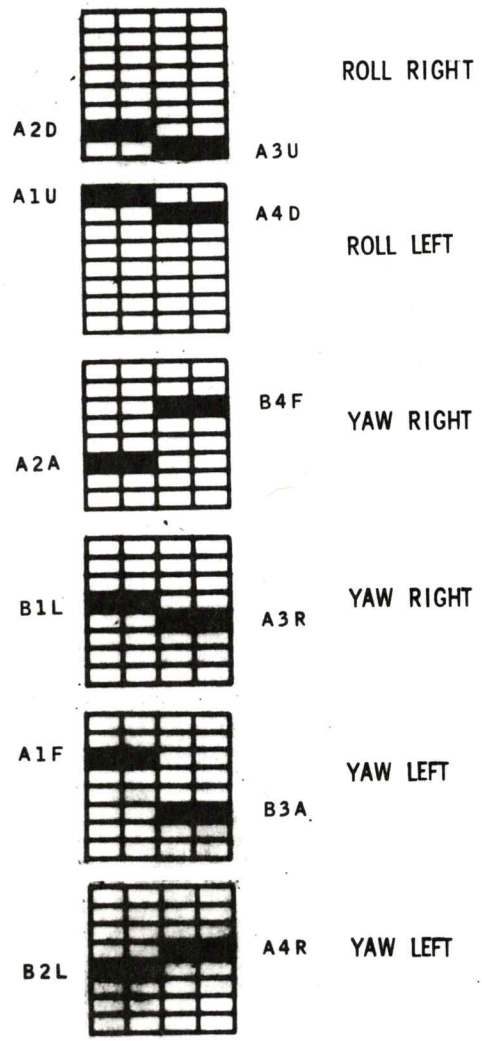
GR5043	Jet A1U TCP	Pin 90
GH1430	Jet A1U Driver	Pin 89
GR5032	Jet A4D TCP	Pin 68
GH1419	Jet A4D Driver	Pin 67

Yaw right (twice) - R1 27767

GR5041	Jet A2A TCP	Pin 86
GH1428	Jet A2A Driver	Pin 85
GR5033	Jet B4F TCP	Pin 70
GH1420	Jet B4F Driver	Pin 69
GR5046	Jet B1L TCP	Pin 96
GH1433	Jet B1L Driver	Pin 95
GR5038	Jet A3R TCP	Pin 80
GH1425	Jet A3R Driver	Pin 79

Yaw left (twice) R1 - 27773

GR5045	Jet A1F TCP	Pin 94
GH1432	Jet A1F Driver	Pin 93
GR5037	Jet B3A TCP	Pin 78
GH1424	Jet B3A Driver	Pin 77
GR5042	Jet B2L TCP	Pin 88
GH1429	Jet B2L Driver	Pin 87
GR5034	Jet A4R TCP	Pin 72
GH1421	Jet A4R Driver	Pin 71



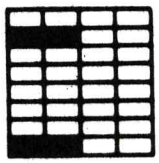
P-6

8. V48E, V21E, 31022E, PRO, V34E ← Selects Sys B jets.
9. V11N10E, 31E ← Monitor CH31 on DSKY
10. CDR ACA (out of detent, 2.5°, pause 2 sec at null) Pin 64

P-11

Pitch up - R1 27776

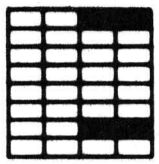
GR5044	Jet B1D TCP	Pin 92
GH1431	Jet B1D Driver	Pin 91
GR5039	Jet B2U TCP	Pin 82
GH1426	Jet B2U Driver	Pin 81



PITCH UP

Pitch down - R1 27775

GR5031	Jet B4U TCP	Pin 66
GH1418	Jet B4U Driver	Pin 65
GR5036	Jet B3D TCP	Pin 76
GH1423	Jet B3D Driver	Pin 75



PITCH DOWN

P-6

11. Notify CSM Hot Fire Checks Complete
CSM - WIDE Deadband ATT/HOLD

P-11

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: E. F. Marzano
APPROVAL H. A. Loden

SCP NO. **SCS 9-2a**

TITLE: **LUNAR SURFACE RCS CHECKOUT**

PURPOSE: The lunar surface RCS checkout is performed to:

A. Provide a hot fire test of the primary preamps and primary RCS coils via PGNS Rate Cmd.

B. Provide an end-to-end hot fire check of the RCS secondary coils, using 4-jet hardover coils, ACA cold fire CES voltage, minimum impulse check of CDR ACA to LGC.

PROCEDURE: A. Vehicle configuration for test:

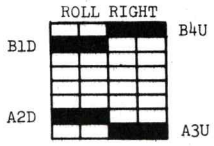
1. Att-translation - 4 jets
2. Verify RCS Sys A and B Quad TCA 1, 2, 3, 4 CB's Open
3. CB (16) inst: CWEA - Open and reclose
4. GUID CONT - PGNS — Pin 100 not present
5. MODE CONT: PGNS - ATT HOLD — Pin 97
6. MODE CONT: AGS - ATT HOLD — Pin 99
7. ATTITUDE CONT (3) MODE CONT — Pins 101, 102, 103 not present
8. ACA/4-jet (CDR) - Enable
9. Verify high bit rate with MSFN

P-11

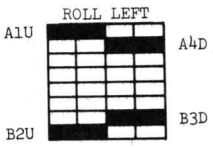
B. Perform PGNS Rate Cmd hot fire check ACA to jets:

1. V48, 12102, PRO, + XXXXX LM, PRO
2. V77E
3. V15N01E 42E - Rate Cmd hot fire check ACA to jets
4. CB (11 and 16) quad TCA (8) - Close
5. CDR ACA (out of detent, pause 2 sec at null) — Pin 64

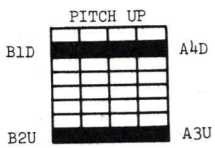
Roll right - R3 000XX	GR5040	Jet A2D TCP	Pin 84
	GH1427	Jet A2D Driver	Pin 83
	GR5035	Jet A3U TCP	Pin 74
	GH1422	Jet A3U Driver	Pin 73
	GR5044	Jet B1D TCP	Pin 92
	GH1431	Jet B1D Driver	Pin 91
	GR5031	Jet B4U TCP	Pin 66
	GH1418	Jet B4U Driver	Pin 65



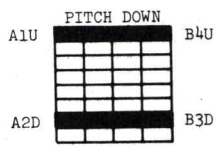
Roll left - R3 777XX	GR5043	Jet A1U TCP	Pin 90
	GH1430	Jet A1U Driver	Pin 89
	GR5032	Jet A4U TCP	Pin 68
	GH1419	Jet A4U Driver	Pin 67
	GR5039	Jet B2U TCP	Pin 82
	GH1426	Jet B2U Driver	Pin 81
	GR5036	Jet B3D TCP	Pin 76
	GH1423	Jet B3D Driver	Pin 75



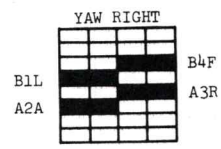
Pitch up - R1 000XX	GR5044	Jet B1D TCP	Pin 92
	GH1431	Jet B1D Driver	Pin 91
	GR5039	Jet B2U TCP	Pin 82
	GH1436	Jet B2U Driver	Pin 81
	GR5032	Jet A4U TCP	Pin 68
	GH1419	Jet A4U Driver	Pin 67
	GR5035	Jet A3U TCP	Pin 74
	GH1422	Jet A3U Driver	Pin 73



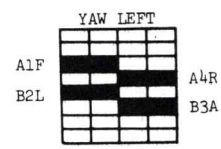
Pitch down - R1 777XX	GR5031	Jet B4U TCP	Pin 66
	GH1481	Jet B4U Driver	Pin 65
	GR5036	Jet B3D TCP	Pin 76
	GH1423	Jet B3D Driver	Pin 75
	GR5043	Jet A1U TCP	Pin 90
	GH1430	Jet A1U Driver	Pin 89
	GR5035	Jet A3U TCP	Pin 74
	GH1422	Jet A3U Driver	Pin 73



Yaw right - R2 777XX	GR5041	Jet A2A TCP	Pin 86
	GH1428	Jet A2A Driver	Pin 85
	GR5033	Jet B4F TCP	Pin 70
	GH1420	Jet B4F Driver	Pin 69
	GR5046	Jet B1L TCP	Pin 96
	GH1433	Jet B1L Driver	Pin 95
	GR5038	Jet A3R TCP	Pin 80
	GH1425	Jet A3R Driver	Pin 79



Yaw left - R2 000XX	GR5045	Jet A1F TCP	Pin 94
	GH1432	Jet A1F Driver	Pin 93
	GR5037	Jet B3A TCP	Pin 78
	GH1424	Jet B3A Driver	Pin 77
	GR5042	Jet B2L TCP	Pin 88
	GH1429	Jet B2L Driver	Pin 87
	GR5034	Jet A4R TCP	Pin 72
	GH1421	Jet A4R Driver	Pin 71



P-11

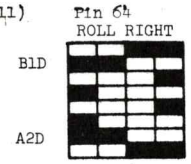
C. Perform minimum impulse check of CDR ACA to LGC, ACA cold fire CES Voltage, and RCS secondary coil hot fire using 4-jet in AGS

1. CB (11 & 16) QUAD TCA (8) - OPEN
2. V76E.
3. V11N10E, 31E, R1 67777
4. GUID CONT - AGS Pin 100
5. ATTITUDE CONT (3) - MODE CONT Pins 101, 102, 103 not present
6. CDR ACA (Deflect slowly to hardover, pause 2 sec at null) Pin 64

P-11

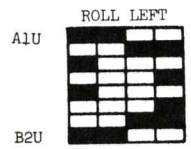
Roll right - R1 27757

GH1249V - Roll Err Cmd +13 Vdc
GR5040 Jet A2D TCP Pin 84
GR5035 Jet A3U TCP Pin 74
GR5031 Jet B4U TCP Pin 66
GR5044 Jet B1D TCP Pin 92



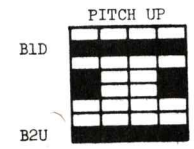
Roll left - R1 27737

GH1249V - Roll Err Cmd -13 Vdc
GR5032 Jet A4D TCP Pin 68
GR5043 Jet A1U TCP Pin 90
GR5039 Jet B2U TCP Pin 82
GR5036 Jet B3D TCP Pin 76



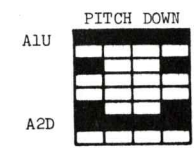
Pitch up - R1 27776

GH1248V - Pitch Err Cmd +13 Vdc
GR5032 Jet A4D TCP Pin 68
GR5035 Jet A3U TCP Pin 74
GR5039 Jet B2U TCP Pin 82
GR5044 Jet B1D TCP Pin 92



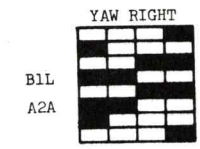
Pitch down - R1 27775

GH1248V - Pitch Err Cmd -13 Vdc
GR5040 Jet A2D TCP Pin 84
GR5043 Jet A1U TCP Pin 90
GR5031 Jet B4U TCP Pin 66
GR5036 Jet B3D TCP Pin 76



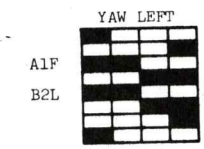
Yaw right - R1 27767

GH1247V - Yaw Err Cmd -13 Vdc
GR5033 Jet B4F TCP Pin 70
GR5041 Jet A2A TCP Pin 86
GR5038 Jet A3R TCP Pin 80
GR5046 Jet B1L TCP Pin 96



Yaw left - R1 27773

GH1247V - Yaw Err Cmd +13 Vdc
GR5034 Jet A4R TCP Pin 72
GR5042 Jet B2L TCP Pin 88
GR5037 Jet B3A TCP Pin 78
GR5045 Jet A1F TCP Pin 94



D. Reconfigure

1. Guidance control - PGNS Pin 100 not present
2. Mode control (AGS) - AUTO Pin 98, pin 99 not present
3. Cycle CB (16) CWEA.

P-11

SCP NO. **SCS 9-3**

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: W. Sturm
APPROVAL: Harold D. Sabo

TITLE: **DAP SET, GIMBAL DRIVE CHECK, AND THROTTLE TEST**

PURPOSE: The Dap Set, Gimbal Drive Check and Throttle Test is performed to provide the LM crew assurance that the descent engine gimbal trim system and manual throttle system will function properly during the descent engine burns. Due to an RCS impingement constraint, the RCS system U-V axis jets are inhibited during a docked descent engine burn. Hence, steering commands and vehicle attitude control are performed by the descent engine gimbal trim system during the burn, which means that this system is mandatory for performance of this type of burn. (See Figure 1 for gimbal dynamic information.) | P-5

PROCEDURE:

A. MCCH Test Setup Requirements

1. This test requires high speed data from the spacecraft in order that the SSR personnel can confirm satisfactory equipment performance. The LM crew does not have the onboard capability to confirm the position of the descent engine gimbals or the position of the throttle actuator valve.
2. The analog recorders are required to be in format VII for this test to be documented properly.
   a. Analog Recorder Console 29 left
      Pin 01 - Roll GDA Pos
      Pin 05 - Pitch GDA Pos
   b. Analog Recorder Console 30 left
      Pin 02 manual throttle cmd
      Pin 03 auto throttle cmd
      Pin 04 variable injector act pos

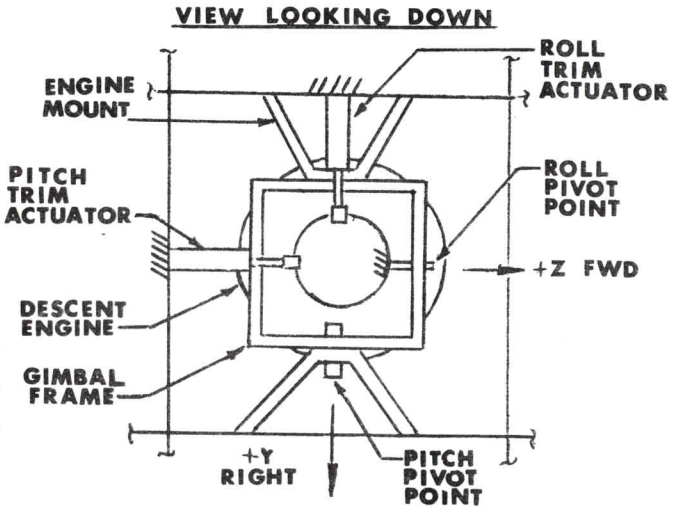
B. Spacecraft Configuration for Test

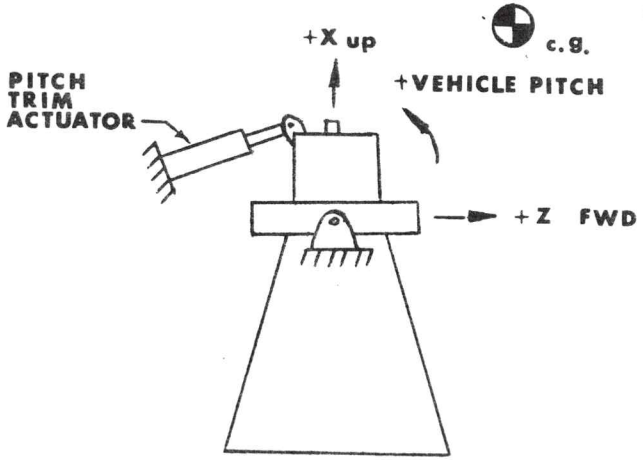
1. Verify RCS SYS A&B QUAD 1, 2, 3, 4 TCA CB's Open
2. Throttle control sw - manual
3. Manual throttle sw - CDR
4. TTCA (CDR) - Throttle (minimum position)
5. Verify mode control sw: PGNS - auto
6. Verify MSFN contact
7. Verify Engine gimbal sw - enable
8. V48E request DAP data load routine (R03)
   F0146 DAP configuration
   R1 32012
9. ENG ARM-DES
10. Proceed

C. SSR Responsibility during Test

1. LM PROP position uses SCP No. PROP 11-11, CG and DPS Gimbal Angle Determination, to calculate the roll and pitch descent engine gimbal positions for the present vehicle weight. | P-14
2. LM AGS position uses SCP No. SCS 9-1, DPS Gimbal Trim Alignment, to take the roll and pitch gimbal positions calculated by the PROP position and converts these into angles that the LM crew enters into the DSKY to drive the gimbals to their new location. The AGS position verifies at the completion of the test that the descent engine gimbal trim system has functioned satisfactorily. The AGS position also verifies that the descent engine has been dearmed at the completion of this test.
3. The LM PGNS position monitors the descent engine throttle portion of the test to confirm the manual throttle commands of minimum, softstop (53%), maximum, and minimum, agreeing with the throttle actuator position movement.
4. At completion of the test, a voice report to the LM crew that the equipment responded properly is required.

Trim Error	LGC CH 12	Actuator Movement	Engine Nozzle Movement	Resulting Vehicle Movement	RGA Test SW	AGS ATT ERR
Pitch down	Bit 9 = 1	Extend	Aft	+ Pitch up	Pitch neg Rt	+ Pitch
Pitch up	Bit 10 = 1	Retract	Fwd	- Pitch down	Pitch pos Rt	- Pitch
Roll Right	Bit 12 = 1	Extend	Left	- Roll left	Roll Pos Rt	- Roll
Roll Left	Bit 11 = 1	Retract	Right	+ Roll right	Roll Neg Rt	+ Roll





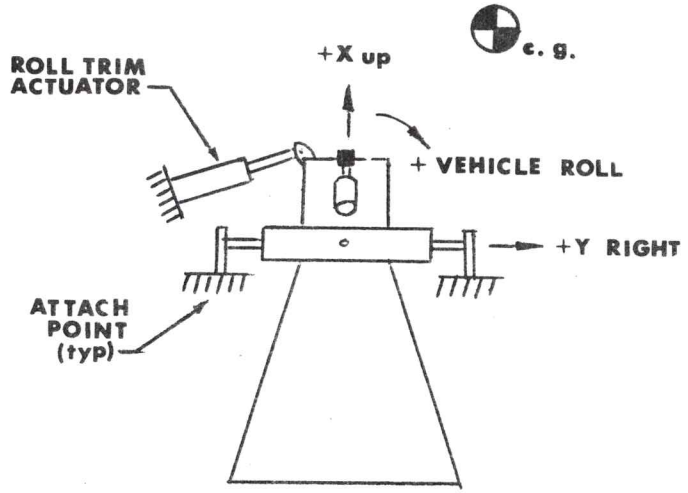


FIGURE 1. – GIMBAL DYNAMICS (descent engine trim gimbal).

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: D.E. Stamper
APPROVAL: Harold A. Loden

SCP NO. **SCS 9-6**

TITLE: RATE GYRO FLUCTUATIONS DURING LUNAR SURFACE RCS HOT FIRE

PURPOSE: This procedure is designed to verify the operational integrity of the Rate Gyro Assembly (RGA). This can be accomplished if the RGA senses jet firings during the lunar surface RCS hot fire. Two recording methods are to be used to verify an RGA detection of thruster activity. They are as follows:

A. A real-time recording of Format 30 Subformat 32

B. A near real-time delog of Format 30 Subformat 32

PROCEDURE:

A. MCC TEST SETUP REQUIREMENT

Approximately 10 minutes prior to the lunar surface RCS hot fire, CONTROL will verify that PROCEDURES has LM high speed Format 30 Subformat 32 entering MCC. CONTROL will also request that Subformat 32 data is placed on CRS-4 located in Rm. 311.

B. SSR RESPONSIBILITY DURING TEST

1. After verifying Subformat 32 is entering MCC, AGS will inform DISPLAY on his loop that analog recorders in Rm. 311 need to be adjusted for the required sensitivity and pen position.

2. The recorders that need adjustment are CRS-4 (analog channels 1-3 at 0.05 v/div, pen position center) 29L (pens 3 and 7 to 0.1 v/div, pen position at maximum) 30L (pen 7 to 0.1 v/div, pen position at maximum).

3. AGS will then inform TIC on the CCATS TM loop the hot fire test is upcoming and that TIC must coordinate the logging of Format 30 data during the hot fire.

4. AGS will inform TIC immediately prior to the hot fire to start his logging tape. The time at which AGS calls TIC will be copied down by TIC as a reference (GMT) for starting delog process.

5. On completion of the hot fire test, AGS will inform TIC to stop the logging tape. TIC will then inform the appropriate personnel to begin the delog process.

6. AGS will then advise the DISPLAY personnel to readjust the analog recorders and to strip the recording off SCR-1

7. At this time, AGS will inform CONTROL that Format 30 Subformat 32 is no longer required. CONTROL can then inform PROCEDURES of such and that CRS-4 can be reconfigured to its proper data source.

8. AGS will send a messenger to the TIC console to pick up the delog and return it to the AGS console in the Vehicle Systems SSR (Rm. 311).

SCP NO. AGS 10-1

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: Marzano
APPROVAL: H.A. Loden

TITLE: **DECIMAL TO OCTAL**

PURPOSE: To change decimal to DEDA octal for entry into DEDA.

PROCEDURE:

A. Turn on Olivetti.
B. Set decimal wheel to 7.
C. Record and Print button out.
D. Push General Reset.
E. Load "Decimal to AGS Octal" card, side A or B.
F. Push C W.
G. Enter number (0.XXXS). (NOTE: A zero must precede any number <1).
H. Enter scale factor (for B + X enter -X; for B - X enter XS).
I. If output is <1, proceed; if not, wrong scale factor is entered. Do not proceed; recycle to step F with correct SF.
J. Enter last Olivetti output, to 5 decimal places only. (XX.XXXXXS)
K. If in step G the number is positive, last output is answer; if negative, continue.
L. Do 8's complement (77777 - Nº + 1) = - XXXXX = answer
M. As a check, enter this number in the "AGS DEDA to Decimal" procedure.

SCP NO. AGS 10-2

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: Marzano
APPROVAL: H.A. Loden

TITLE: **DEDA OCTAL TO DECIMAL**

PURPOSE: To change DEDA octal to decimal.

PROCEDURE

A. Turn on Olivetti.
B. Set decimal wheel to 7.
C. Record and Print button out.
D. Push General Reset.
E. Load "AGS Octal to Decimal" cord, side A or B.
F. If negative, do 8's complement (77777 - Nº + 1).
G. Push C W.
H. Enter Nº (5 digit number) XXXXXS.
I. Enter scale factor (for B + X enter XS; for B - X enter -XS.
J. Output is decimal answer; number is negative if you did 8's complement in step F.
K. If red light appears, go back to step G and reduce decimal wheel one unit.
L. As a check enter this number in the "Decimal to DEDA Octal" procedure.

SCP NO. AGS 10-3

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: Marzano
APPROVAL: H.A. Sadow

TITLE: **DECIMAL TO DEDA OCTAL, HAND CALCULATION**

PURPOSE: Use in event of inability to use AGS 10-1.

PROCEDURE: A. Convert number to binary.

DECIMAL → Example - 1234.5678_{10}

$8\overline{)1234}$ 154 R=2
$8\overline{)154}$ 19 R=2
$8\overline{)19}$ 2 R=3
$8\overline{)2}$ R=2
2322_8

.5678 x8 = 4) .5424
x8 = 4) .3392
x8 = 2) .7136
x8 = 5) .7088
$.4425_8$

NOTE
Each time only multiply decimal part by 8.

OCTAL → 2 3 2 2 . 4 4 2 5 8

BINARY → 010 011 010 010 100 100 010 101 2

B. Scale binary number.
If binary scaling is positive, move decimal point to the left
If binary scaling is negative, move decimal point to the right
Example: B11 and our binary number from step A.
$10011010010 . 100100010_2$
Scale B11
$.1001101001010010001_2$

C. If number is negative do 2's complement. This is done by inverting all bits and adding 1 bit to the LSB.
Example: $.1001101001010010001_2$ ← Number
Complement: .0110010110101101110
+1
$-.0110010110101101111_2$ ← 2's Comp

D. Convert to DEDA octal.
$-.011\ 001\ 011\ 010\ 110\ 111\ 100_2$
$-.3\quad 1\quad 3\quad 2\quad 6_8$ — —

E. -31326 is the DEDA octal number for -1234.5678 sealed at B11.

Appendix D

Table of Powers of Two

2^n	n	2^{-n}
1	0	1.0
2	1	0.5
4	2	0.25
8	3	0.125
16	4	0.062 5
32	5	0.031 25
64	6	0.015 625
128	7	0.007 812 5
256	8	0.003 906 25
512	9	0.001 953 125
1 024	10	0.000 976 562 5
2 048	11	0.000 488 281 25
4 096	12	0.000 244 140 625
8 192	13	0.000 122 070 312 5
16 384	14	0.000 061 035 156 25
32 768	15	0.000 030 517 578 125
65 536	16	0.000 015 258 789 062 5
131 072	17	0.000 007 629 394 531 25
262 144	18	0.000 003 814 697 265 625
524 288	19	0.000 001 907 348 632 812 5
1 048 576	20	0.000 000 953 674 316 406 25
2 097 152	21	0.000 000 476 837 158 203 125
4 194 304	22	0.000 000 238 418 579 101 562 5
8 388 608	23	0.000 000 119 209 289 550 781 25
16 777 216	24	0.000 000 059 604 644 775 390 625
33 554 432	25	0.000 000 029 802 322 387 695 312 5
67 108 864	26	0.000 000 014 901 161 193 847 656 25
134 217 728	27	0.000 000 007 450 580 596 923 828 125
268 435 456	28	0.000 000 003 725 290 298 461 914 062 5
536 870 912	29	0.000 000 001 862 645 149 230 957 031 25
1 073 741 824	30	0.000 000 000 931 322 574 615 478 515 625
2 147 483 648	31	0.000 000 000 465 661 287 307 739 257 812 5
4 294 967 296	32	0.000 000 000 232 830 643 653 869 628 906 25
8 589 934 592	33	0.000 000 000 116 415 321 826 934 814 453 125
17 179 869 184	34	0.000 000 000 058 207 660 913 467 407 226 562 5
34 359 738 368	35	0.000 000 000 029 103 830 456 733 703 613 281 25
68 719 476 736	36	0.000 000 000 014 551 915 228 366 851 806 640 625
137 438 953 472	37	0.000 000 000 007 275 957 614 183 425 903 320 312 5
274 877 906 944	38	0.000 000 000 003 637 978 807 091 712 951 660 156 25
549 755 813 888	39	0.000 000 000 001 818 989 403 545 856 475 830 078 125

SCP NO. **AGS 10-4**

S/C: LM
DATE: 4/11/69
REV: Originator
ORIGINATOR: Marzano
APPROVAL: H.A. Loden

TITLE: **DEDA OCTAL TO DECIMAL HAND CALCULATION**

PURPOSE: Use in the event of inability to use AGS 10-2.

PROCEDURE: A. Convert to binary.

Example: -313268_8

$-.011\ C01\ 011\ 010\ 110_2$

B. Complement if negative.

$-.011\ 001\ 011\ 010\ 110_2$ Binary no.

$.100\ 110\ 100\ 101\ 001_2$ Complement of binary no.

+LSB +1

$-.100\ 110\ 100\ 101\ 010_2$ 2's complement of binary no.

C. Scale binary number.

$-.100\ 110\ 100\ 101\ 010_2$ B11

If binary scaling is positive, move decimal point to the right.

If binary scaling is negative, move decimal point to the left.

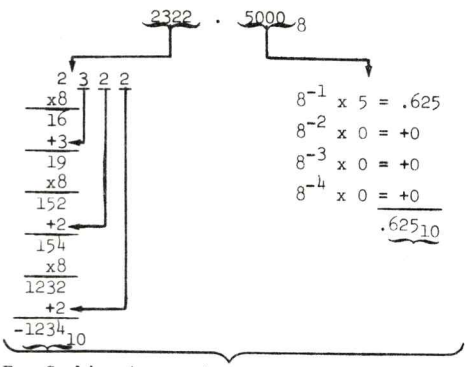
-100 110 100 10. 101 for B11 scaling.

D. Convert to octal.

$-\underline{010}\ \underline{011}\ \underline{010}\ \underline{010}\ .\ \underline{101}$

$-\ 2\quad 3\quad 2\quad 2\ .\ 5_8$

E. Convert to decimal.



F. Combine two parts.

-1234.625_{10}

$-1234.625_{10} = -313268_8$ B11

-1234.625 is the decimal value.

SCP NO. AGS 10-5

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: Marzano
APPROVAL: H.A. Loden

TITLE: AGS REFERENCE DRIFT DETERMINATION

PURPOSE: The purpose of this SCP is to determine the AGS inertial drift with reference to the PGNS inertial reference.

PROCEDURE:

A. Once per revolution on the CONUS pass during a non-thrusting non-maneuvering phase, make a hardcopy of 1127. (At least two separate passes are needed.)

B. Find the difference between roll, pitch, and yaw attitude per hour.

1. $Roll_{PGNS} - Roll_{AGS} = \Delta Roll_1$ ____

   @ GET #1

2. $Roll_{PGNS} - Roll_{AGS} = \Delta Roll_2$ ____

   @ GET #2

3. $\frac{\Delta Roll_1 - \Delta Roll_2}{(GET_2 - GET_1)_{hr}} = \Delta Roll°/hr =$ ____

4. Repeat for pitch and yaw.

   $\Delta Pitch°/hr =$ ____

   $\Delta Yaw°/hr =$ ____

C. If drift rate exceeds 2° per hr in any axis, recalibrate ASAP.

SCP NO. AGS 10-6

This SCP deleted by PCN-8

SCP NO. PROP 11-1

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: G. Watkins
APPROVAL: William L. Peters

TITLE: WEIGHT UPDATES, PROPELLANT REMAINING AND ΔV REMAINING DETERMINATION

PURPOSE: This SCP defines the method used in determining vehicle weight, propellant remaining, and ΔV remaining.

PROCEDURE:

A. Time - These calculations are performed whenever there is a significant change in vehicle weight (1% of total vehicle weight).

B. Method - Use the Olivetti Programma 101 program for "Vehicle Weight."

1. The inputs to this program are:***

b	W_I	(lb_m)	Initial weight prior to burn (**Total including propellant**)
*B	$\dot{\omega}_1$	(lb_m/sec)	Flow rate 1
*c	t_1	(sec)	Burn time at $\dot{\omega}_1$
*C	$\dot{\omega}_2$	(lb_m/sec)	Flow rate 2 (0 for APS)
*d	t_2	(sec)	Burn time at $\dot{\omega}_2$
D	P_R	(lb_m)	Prop at start of burn or initial loaded if no burn has yet been accomplished. (system being used)
e	PQMD	(on card)	RCS loaded (total)
**E	$PQMD_u$	(%)	% PQMD used since last weight update (use decimal, i.e., 10% = 0.10) (Average of systems A and B)
f	$PQMD_{rem}$	(%)	% usable remaining (total - unusable) (use decimal)
**F	$WATER_u$	(lb_m)	Water or other non-propulsive consumables used since last weight update.

The program is started by depressing "V."

When the PQGS method is applicable, the following changes to the inputs should be made.

B	W_L	(lb_m)	Total prop if PQGS could read 100% (18,642 lb)
c	$\%_{UDB}$	(%)	% of PQGS used during burn (use decimal, i.e., 10% = 0.10)
C	0		
d	0		

P-8

2. The outputs of this program are:

b ◊	New vehicle weight (lb_m)
B ◊	Propellant remaining (lb_m)
A ◊	RCS usable remaining (lb_m)

C. In order to get ΔV remaining, use the above outputs and the Olivetti Programma 101 program for "ΔV Remaining."****

1. The inputs to this program are:

****b	W_N	(lb_m)	New vehicle weight (from above)
****B	W_P	(lb_m)	Propellant remaining (from above) (must be input every time program is rerun)
c	Isp	(sec)	Specific impulse at FTP
E	K_1	(on card)	Constant
d	K_2	(on card)	Constant
D	K_3	(on card)	Constant
e	g	(on card)	Gravitational constant

The program is started by depressing "V."

2. The output of this program is:

ΔV remaining (ft/sec).

---

*The PQGS is sometimes more accurate than the flow rate times the time method. The PQGS method, as noted above, should be used if more than 30% of the propellant was consumed during the burn or if over four throttle changes were made during the burn.

**If more than one iteration of this program is used at one time (i.e., four throttle changes), input a zero for E and F until the last iteration.

***All numbers must be reinput except b, E, and e every time program is run.

****Depressing a "Z" and not clearing the vehicle weight program will automatically hold and input the new vehicle weight and propellant remaining in the ΔV Remaining program when it is inserted.

D. Input Variables

1. Vehicle Weight Program

QUANTITY	NOM VALUE	UPDATE VALUE	SOURCE	
13% Flow Rate	4.6			PCN-14
15% Flow Rate	5.4			
20% Flow Rate	7.2			
25% Flow Rate	9.0			
30% Flow Rate	10.7			
35% Flow Rate	12.5			
40% Flow Rate	14.3			
45% Flow Rate	16.0			
50% Flow Rate	18.0			
55% Flow Rate	20.0			
60% Flow Rate	21.5			
FTP	32.5			
APS $\dot{\omega}_1$	11.3			
PQMD (lb_m)	631.2			PCN-14
RCS (4 Jet)	1.47			

2. Delta V Remaining

QUANTITY	NOM VALUE	UPDATE VALUE	SOURCE	
DPS Isp (ave.)	305.8			PCN-14
DPS Isp 10%	298.5			
DPS Isp FTP	306.5			
APS Isp (with no RCS inter)	309.5			
APS Isp (with interconnect during depletion burn)	309.1			
RCS steady State I_{sp}	281.0			
K_1	2.0	None	In Prog	
K_2	0.666667	None	In Prog	
K_3	0.4	None	In Prog	
g (ft/sec)	32.17			

E. Special Cases

1. Staging - put the initial ascent weight (with full load RCS and water) in b_1, % PQMD used thus far in E, and total ascent water used thus far in f and calculate current ascent weight.
2. Interconnect - put 1 in C and number of pounds of APS used in inconnect in d and all other inputs should be their normal value.

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: R. S. Nance
APPROVAL: H. A. Loden

SCP NO. PROP 11-2

TITLE: **WEIGHT AND DELTA V REMAINING UPDATE TO RETRO**

PURPOSE: This SCP defines the procedure used in updating RETRO with vehicle weights and ΔV remaining.

PROCEDURE:

A. Time - These updates are performed whenever there is a significant change in vehicle weight (1% of total vehicle weight).

B. Method - Use SCP No. 11-1 to determine vehicle weight, propellant remaining and ΔV remaining. Use SCP No. 11-3 to determine APS burn time remaining. Enter these on FEC/TSC Form 199C (Rev Dec 67) making a copy for LM propulsion, LM consumables, and two copies for LM CONTROL. Send the two copies to LM CONTROL through the P-tube, and he will initial one copy and send it to RETRO. CONTROL and PROP will enter a note in the console log of weight update to RETRO. CONTROL will also maintain copies of all weight updates in a separate file.

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: R. S. Nance
APPROVAL: H. A. Loden

SCP NO. PROP 11-3

TITLE: **BURN TIME REMAINING DETERMINATION**

PURPOSE: This SCP defines the procedure used in determining burn time remaining for the APS.

PROCEDURE:

A. Time - These calculations are performed whenever there is a significant change in APS propellant remaining.

B. Method - Use SCP No. 11-1 to determine the APS propellant remaining and divide this by the average integrated flow rate of the APS yielding the burn time remaining.

C. INPUT VARIABLES

QUANTITY	NOM VALUE	UPDATE VALUE	SOURCE
APS Flow Rate (No interconnect)	11.3		
APS Flow Rate (Manned with interconnect)	11.5		
APS Flow Rate (Unmanned with interconnect)	11.7		

SCP NO. PROP 11-4

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: R. S. Nance
APPROVAL:

TITLE: DETERMINATION OF ΔV FOR A GIVEN TIME OF BURN

PURPOSE: This SCP determines a delta velocity for a given burn time.

PROCEDURE:

A. Time - A ΔV for a given burn time will be calculated by use of the Olivetti Programma 101 when any burn is accomplished that is not of a nominal burn time and a total ΔV accomplished is desired.

B. Method - Use the Olivetti Programma 101 program for "ΔV Program (given burn time)."

1. The inputs to this program are:

b	W_I	(lb_m)	Initial weight prior to burn
B	$\dot{\omega}$	(lb_m/sec)	Flow rate
c	t	(sec)	Time burned at flow rate
C	$K_{\Delta V}$	(sec x ft/sec)	Isp x g
d	K_1	On Card	Constant
D	K_2	On Card	Constant
e	K_3	On Card	Constant

The program is started by depressing "V."

2. The outputs of this program are:

$$E \lozenge \left(\frac{W_I}{W_I - \dot{\omega} t} \right)$$

$$F \lozenge \text{ LN } \left(\frac{W_I}{W_I - \dot{\omega} t} \right)$$

$$A \lozenge K_{\Delta V} \text{ LN } \left(\frac{W_I}{W_I - \dot{\omega} t} \right) = \Delta V \text{ ft/sec}$$

C. Input Variables

QUANTITY	NOM VALUE	UPDATE VALUE	SOURCE	
DES Flow Rate				
13%	4.6			
15%	5.3			
20%	7.0			
25%	8.7			
30%	10.4			
35%	12.1			P-8
40%	13.8			
45%	15.5			
50%	17.2			
55%	19.4			
60%	20.6			
FTP	32.3			P-14
APS Flow Rate (No interconnect)	11.3			
APS Flow Rate (Interconnect manned)	11.5			
APS Flow Rate (Interconnect unmanned)	11.7			
DES $K_{\Delta V}$ (Ave)	9,837.6			P-14
DES $K_{\Delta V}$ (13%)	9,602.7			
DES $K_{\Delta V}$ (FTP)	9860.1			
ASC $K_{\Delta V}$	9956.6			
ASC $K_{\Delta V}$ (Interconnect)	9943.7			
K_1	2.0	None	In Prog	
K_2	0.666667	None	In Prog	
K_3	0.4	None	In Prog	
RCS Flow Rate	1.47			
RCS Steady State I_{sp}	281.0			
RCS $K_{\Delta V}$	9039.77			

SCP NO. PROP 11-5

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: G. Watkins
APPROVAL: William L. Peters

TITLE: DETERMINATION OF A BURN TIME FOR A GIVEN ΔV

PURPOSE: This SCP determines a burn time for a given ΔV.

PROCEDURE:

A. Time - A burn time for a given ΔV will be calculated by use of the Olivetti Programma 101 when any burn is planned which is not a nominal burn.

B. Method - Use the Olivetti Programma 101 program for "Burn Time (given ΔV)."

1. The inputs to this program are:

b	W_I	(lb_m)	Weight of vehicle prior to burn
B	$\dot{\omega}$	(lb_m/sec)	Flow rate
c	ΔV	(ft/sec)	ΔV desired
C	$K_{\Delta V}$	(sec x ft/sec)	Isp x g
d	K_1	On Card	Constant
D	K_2	On Card	Constant
e	K_3	On Card	Constant

The program is started by depressing "V."

2. The outputs of this program are:

E ◊ $\frac{\Delta V}{K\ \Delta V}$

f ◊ Antilog of $\frac{\Delta V}{K_{\Delta V}}$

A ◊ Burn time required to achieve ΔV desired (sec)

C. Input Variables

QUANTITY	NOM VALUE	UPDATE VALUE	SOURCE
DES Flow Rate			
13%	4.6		
15%	5.3		
20%	7.0		
25%	8.7		
30%	10.4		
35%	12.1		
40%	13.8		
45%	15.5		
50%	17.2		
55%	19.4		
60%	20.6		
FTP	32.3		
APS Flow Rate (No interconnect)	11.3		
APS Flow Rate (Interconnect manned)	11.5		
APS Flow Rate Interconnect unmanned)	11.7		
DES $K_{\Delta V}$ (Ave)	9,837.6		
DES $K_{\Delta V}$ (13%)	9,602.7		
DES $K_{\Delta V}$ (FTP)	9,860.1		
ASC $K_{\Delta V}$	9,956.6		
ASC $K_{\Delta V}$ (Interconnect)	9,943.7		
K_1	2.0	None	In Prog
K_2	6.0	None	In Prog
K_3	120.0	None	In Prog
RCS Flow Rate	1.47		
RCS Steady State I_{sp}	281.0		
RCS $K_{\Delta V}$	9039.77		

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PCN-14

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SCP NO. **PROP 11-6**

S/C : LM
DATE : 11/1/70
REV : PCN 6
ORIGINATOR: G. Watkins
APPROVAL : Jaw

Title : RCS PROGRAM FOR OFFLINE RTCC USE

Purpose : This SCP defines the procedure to be followed in initiating the RCS Program to be run on the offline RTCC.

Procedure:

A. The LM RCS Budget Input Sheet is filled out.

B. Computer Command is informed that you are requesting an RCS run to be made.

C. The LM RCS Budget Input Sheet is submitted to Computer Command.

D. At the completion of the RCS run, Computer command informs the LM Prop SSR that the run is ready.

E. Specific procedures are as follows:

1. Time - These calculations are performed whenever it is desirable to develop an alternate mission plan and validate the RCS capabilities.

2. Method - This procedure utilizes the RTCC (Offline Computers) for all calculations. The inputs to this program are defined as follows:

   (a) Deck Number - deck found in alternate mission matrix in the LM Consumable book which matches the alternate mission more closely, ie. deck A-1.

   (b) Propellant Used Totals - The RCS System A and B, APS used through interconnect, and the APS and DPS propellants used previously to start of run.

   (c) GET of Run Initiation.

   (d) Variations of Timeline - deviations from deck noted in (1) such as ΔV's, maneuvers, deadbands, et cetera, or a completely new timeline if none of the decks in the alternate mission matrix are applicable.

   (e) Additional Comments - any additional instructions such as title changes or mass property constant changes.

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The information on this page
has been deleted by PCN-6

SCP NO. **PROP 11-7**

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: Hopkins
APPROVAL: H. a. Soden

TITLE: **WEIGHT DISPLAY UPDATE (SMEK DPS/APS CALC)**

PURPOSE: This SCP defines the method and procedure in validating the real-time weight display, MSK No. 1007/08/09

PROCEDURE:

A. Time - The vehicle weight shall be verified at the end of each burn or after any significant weight change (more than 50 pounds).

B. Method

1. Calculate the vehicle weight using SCP 11-1.
2. Determine if a discrepancy of greater than 1/2 of 1% exists between display and calcs. If no discrepancy exists, no further action is required.
3. If the calculated weight varies by more than 1/2% from the display, check all systems inputs as follows:
   a. DPS
   b. APS
   c. RCS
   d. Water
   e. O_2
4. Correct defective portion of weight computation in accordance with appropriate SCP.

SCP NO. PROP 11-8

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: G.W. WATKINS
APPROVAL: William L. Peters

TITLE : RTCC PROGRAM MED UPDATES

PURPOSE : This procedure establishes the method to be used in entering or changing propulsion RTCC program MED quantities update.

PROCEDURE: A. Any MED quantity changes during the mission shall be the responsibility of the SSR Propulsion position. All changes shall be sent to the RTCC Computer TM position. Five or less changes may be voiced to RTCC Computer TM using the RTCC TM communications loop. More than five changes should be written and sent to RTCC Computer TM via the pneumatic tube. Computer TM should be notified by voice prior to sending them in the pneumatic tube.

B. The MED quantities

1. APS Flow Rate Program

QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
K_F	0.086708		
K_o	0.109470		
Fu REM	1997.6		Usable Fuel
Ox REM	3181.0		Usable Oxidizer
LM PREDICTED L/O	183:00:00		

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2. LM DPS Propellant Quantities

QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
LM DPS MAS	18,642.0		
LM DPS QTY	104.5		
LM DPS MR	1.597		

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3. LM Vehicle Weights

QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
DW ASC	4661.5 LB		
MISC ASC	2.7 LB		
DW DES	5666.3 LB		

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4. RCS Ground Program

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QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
RCS A FU Temp	$0^{\circ}F$		
RCS A He Press	0 psi		
RCS A REG Press	188 psi		
RCS B FU Temp	$0^{\circ}F$		
RCS B REG Press	188 psi		
T_{s_a}	$530^{\circ}R$		
W_{fa}	107.4 LB		
W_{oa}	208.2 LB		
$*H_{ia}$	2975 psi		
M_{l_a}	1.93		
N_{fa}	0.9621		
N_{oa}	0.9652		
E_{oa}	12.55		
E_{fa}	6.45		
T_{sb}	$530^{\circ}R$		
W_{fb}	107.4 LB		
W_{ob}	208.2 LB		
$*H_{ib}$	2975 psi		
MR_{lb}	1.93		
N_{fb}	0.9621		
N_{ob}	0.9652		
E_{fb}	6.45		
E_{ob}	12.55		

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* The System A and System B programs will start calculating when these MED's are input the first time. These inputs should not be made until after pressurization.

5. DPS/APS Quantities

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QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
LM DPS Prop	17,192.9 LB		
DPS Prop M2	18,642 LB		

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6. RCS ON Time

QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
ULL A	0.0		
ULL B	0.0		
COOL T	100,000.0		

7. DPS Projection Program

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QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
PDI GET	112:47:00		
X	1		Number of Samples Discarded
Y	10		Number of Projections Averaged
Q_{LL}	5.795 percent		PQGS Reading at low level
CD Time	91 SEC		
DEL CD	14 SEC		

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8. Hover Time Program

QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
*DEL CD	14		
W_{INERT}	17,280.0 LBS		
W_{PROP}	945.5 LBS		
G_{LUNAR}	5.3152 FT/SEC^2		3σ Low Propellant at low level
A	− 0.00000006783		CONVERTS THRUST TO FLOW RATE
B	0.00377436		
C	− 0.7396739		
ABORT PAD	20 SEC		
TIME Δ	1 SEC		Time Δ which assumes a constant thrust for computing hover time remaining

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* Also used in projection program

9. Margin Plot

QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
A	- 0.021763		
B	0.068246		
C	0.013898		
D	0.135404		
E	7.4426633		
K_H	19.154		
A_{FF}	5.28034		
$ADOT_{FF}$	0.0431736		
ΔV_{FD}	- 77.0 FPS		
K_1	18642 LBS		
K_2	0		
EXVEL	- 9568.098		

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10. LM DPS Thrust

QUANTITY	NOM VALUE	UPDATE VALUE	NOTES
K_M	0		K_M is a bias (+ or -) value to correct the LGC mass

SCP NO. **PROP 11-9**

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: R. S. Nance
APPROVAL: H. A. Loden

TITLE: **DPS BLOWDOWN BURNS**

PURPOSE: This SCP defines the method used to predict DPS blowdown burns.

PROCEDURE: A. Time - This calculation should be made when a DPS burn in a blowdown mode becomes a possibility.

B. Method - Use the Olivetti Programma 101 programs "DPS Blowdown - 10% to 65%" and "DPS Blowdown - FTP." Every thrust level should be handled like a separate program. When the desired number of seconds in any thrust level has been accomplished, the program should be stopped by depressing the Reset button. Every time a new thrust level is desired, the data from the output of the previous thrust level program should be input to the new thrust level program.

1. The inputs to the "DPS Blowdown - 10% to 65%" are:

b		Thrust	Thrust in decimal percent (0-1.0)
B	P_u	psi	Ullage pressure
c	V_u	ft^3	Ullage volume
C	T	sec	Time after first ΔT
d	ΔT	sec	Time between output calculations
D	K_1	On Card	Constant (184)
e	K_2	On Card	Constant (43,190)
E	K_3	On Card	Constant (0.000566)

The program is started by depressing "V."

2. The outputs for the "DPS Blowdown 10% to 65%" are:

C◊ Time (sec)
B◊ P_u (ullage pressure in psi)
A◊ P_i (inlet pressure)
A◊ Thrust
c◊ V_u (ullage volume)

3. The inputs for the "DPS Blowdown - FTP" are:

b	K	0.021723	Constant
B	P_u	psi	Ullage pressure
c	V_u	ft^3	Ullage volume
C	T	sec	Time after first ΔT
d	ΔT	sec	Time between output calculations
D	K_1	On Card	Constant (0.5772)
e	K_2	On Card	Constant (43,872.3)
E	K_3	On Card	Constant (0.000349)

The program is started by depressing "V."

4. Outputs for the "DPS Blowdown - FTP" are:

C◊ Time (sec)
B◊ P_u (ullage pressure in psi)
A◊ P_i (inlet pressure)
A◊ Thrust
c◊ V_u (ullage volume)

SCP NO. **PROP 11-10**

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: R. S. Nance
APPROVAL: W.A. Tindall

TITLE: **APS BLOWDOWN WITH THRUST**

PURPOSE: This SCP defines the method used to predict APS blowdown burns.

PROCEDURE:

A. Time - This calculation should be made when a burn in a blowdown mode becomes a possibility.

B. Method - Use the Olivetti Programma 101 program for "APS blowdown with variable ΔT."

1. The inputs to this program are:

b	K	(0.0012)	Constant
B	P_u	(psi)	Ullage pressure
c	V_u	ft^3	Ullage volume
C	T	sec	Time after first ΔT
d	ΔT	Δ sec	Time between output calculations
D	K_1	On Card	Constant (22.575)
e	K_2	On Card	Constant (44,788)
E	K_3	On Card	Constant (0.000561)

The program is started by depressing "V."

2. The outputs of this program are:

C ◊ Time (sec)
B ◊ P_u (ullage pressure in psi)
A ◊ P_i (inlet pressure)
A ◊ Thrust (lb)
c ◊ V_u (ullage volume in ft^3)

C. The program will continue to iterate until P_u is less than zero unless the Reset button is depressed or the Print button is depressed. The Reset button will destroy the stored program and stored constants, and the Print button will only stop the calculation.

SCP NO. **PROP 11-11**

S/C: LM
DATE: 11/1/71
REV: PCN-11
ORIGINATOR: R. S. Nance
APPROVAL: [signature]

TITLE: **CG AND DPS GIMBAL ANGLE DETERMINATION**

PURPOSE: This SCP defines the methods used in determining cg location and/or DPS GDA gimbal angle position.

PROCEDURE: A. Time - A cg location and gimbal angle position is required prior to each DPS burn to insure proper alignment of the DPS gimbal and prior to either an APS or RCS burn to calculate predicted RCS consumption during the burn.

B. Method One - This method is designed for use on the Olivetti Programma 101. It is constrained to LM/CSM docking angles of 0 to 90 degrees. Step 1 converts cg from CSM coordinates to LM coordinates. It allows conversion of CSM cg in CSM coordinates to LM coordinates which can be used in Step 2 to calculate docked cg. Step 2 corrects nominal LM cg in LM coordinates for abnormal weight distribution and docked configuration. For docked configuration, the CSM cg obtained from Step 1 is handled as an additional delta weight. Step 3 converts vehicle cg to GDA pitch and roll gimbal angles. Step 4 alters the GDA pitch and roll gimbal angles to account for structural compliance. These steps are as follows: P-11

1. Conversion of CSM cg in CSM coordinates or docked cg in CSM coordinates to LM coordinates. Use Olivetti Programma 101 program entitled "CSM Coord Transformation to LM Coord."

   a. Inputs*:

b	(in.)	X cg (CSM or docked cg in CSM coord)
B	(in.)	Y cg (CSM or docked cg in CSM coord)
c	(in.)	Z cg (CSM or docked cg in CSM coord)
C	(degrees)	θ (Angle between LM -Z axis and CSM +Z axis)
d	(0.166666)	Constant (On Card)
D	(0.008333)	Constant (On Card)
e	(57.29577)	Constant (On Card)
E	(in.)	CSM Docking Interface Station No. plus LM Interface (1422.75 in.) (On Card)
f	(90.0)	Constant (On Card)

   This program is initiated by depressing "V."

   b. Outputs:

A◊	X cg in LM coord (in.)
A◊	Z cg in LM coord (in.)
A◊	Y cg in LM coord (in.)

   *Every time this program is rerun, all registers must be input (b - f), of if card is re-input constants (d - f) will be restored.

2. LM cg calculation for delta weight changes from nominal. Docked cg can be calculated by using nominal LM cg and using CSM cg in LM coord (obtained from Step 1). Use Olivetti Programma 101 program for "cg calculation."

   a. Inputs:

b	(in.)	Nominal X cg
B	(in.)	Nominal Z cg
c	(in.)	Nominal y cg
C	(lb)	Total LM Weight (include all delta weights)
d	(lb)	Delta Weight (+ for additional weight, - for less weight)

D	(in.)	Y cg of ΔW
e	(in.)	Z cg of ΔW
E	(in.)	X cg of ΔW
f	On Card	Constant (154)

This program is initiated by depressing the "V" button.

b. Outputs:

b◊	New X cg (in.)
B◊	New Z cg (in.)
c◊	New Y cg (in.)

After all delta weights are taken account, if the operator desires a DPS gimbal angle corresponding to this new cg depress "Z" and the new cg will be stored for the Gimbal Angle program in Step 3. After "Z" is depressed do not depress any buttons until after the Gimbal Angle program is inserted.

3. GDA gimbal angles can be calculated by using the Olivetti Programma entitled "Gimbal Angles."

a. Inputs:

*b	(in.)	(X cg - 154) distance from gimbal axis to cg
*B	(in.)	Z cg (must be input every time program is rerun)
*c	(in.)	Y cg (must be input every time program is rerun)
E	On Card	Constant (0.333333)
d	On Card	Constant (0.2)
D	On Card	Constant (0.14285)
e	On Card	Constant (57.29577)

This program is activated by pressing the "V" button.

b. Outputs:

A◊	Pitch Angle (degrees)
A◊	Roll Angle (degrees)

*These will automatically be stored in the Olivetti from step 2 if "Z" is depressed and transferred when the Gimbal Angle program card is inserted. Otherwise, they must be put in just like any other number.

4. Structural compliance of the DPS engine mount results in a change in thrust vector direction and can be calculated by using the Olivetti programma entitled "GDA Conversion Due to Structural Torquing."

a. Inputs:

b	(degrees)	GDA pitch angle
B	(degrees)	GDA roll angle
C	(percent)	Thrust (0-100)
d	(On Card)	Constant (0.105)
D	(On Card)	Constant (0.033229)

This program is activated by pressing the "V" button.

b. Outputs:

C◊	Thrust (percent)
A◊	Compliance corrected GDA pitch angle position
A◊	Compliance corrected GDA roll angle position

C. Method Two - This method is designed for use on the Hewlett-Packard Calculator. There is no constraint on the LM/CSM docking angle. Step 1 converts a cg from CSM coordinates to LM coordinates through the appropriate docking angle. Step 2 corrects the nominal LM cg in LM coordinates for abnormal weight distribution and docked configuration. For docked configurations, the CSM cg obtained from Step 1 is handled as an additional delta weight. This step can also be used to calculate a CSM cg in CSM coordinates prior to performing Step 1. Step 3 converts vehicle cg to GDA pitch and roll gimbal angles. Step 4 alters the GDA pitch and roll gimbal angles to account for structural compliance and calculates the proper DAP load for the GDA.

The Hewlett-Packard Program "CSM ROTATION, C.G., GDA, GDA with COMPLIANCE and DAP LOAD" is loaded in the Hewlett-Packard calculator by selecting run and depressing "GO TO, +, 0, 0" and entering side A and B.

1. Conversion of CSM cg in CSM coordinates or docked cg in CSM coordinates to LM coordinates.
   Enter the data as follows:

DATA	UNITS	PROGRAM INSTRUCTION
INPUTS		
		END
		CONT
X_{cg} CSM	XXX.XX in.	CONT
Y_{cg} CSM	X.XX in.	CONT
Z_{cg} CSM	X.XX in.	CONT
θ (docking angle)	XXX.X degrees	CONT
OUTPUTS		
X_{cg} IN LM COORDINATES		
Y_{cg} IN LM COORDINATES		
Z_{cg} IN LM COORDINATES		

2. LM or CSM cg calculation for delta weight changes from nominal. Docked cg can be calculated by using nominal LM cg and using CSM cg in LM coordinates as obtained from Step 1. Enter the data as follows: P-11

DATA	UNITS	PROGRAM INSTRUCTION
INPUTS		
		GO TO
		+
		6
		0
		CONT
X_{cg} LM	XXX.XX in.	CONT
Y_{cg} LM	X.XX in.	CONT
Z_{cg} LM	X.XX in.	CONT
WEIGHT ON LM	XXXXX lb.	CONT
*WEIGHT OF Δ WT.	XXXXX lb.	CONT
X_{cg} ΔW	XXX.XX in.	CONT
Y_{cg} ΔW	X.XX in.	CONT
Z_{cg} ΔW	X.XX in.	CONT

DATA	UNITS	PROGRAM INSTRUCTION
OUTPUTS		
$X_{cg\ LM} + \Delta W$		
$Y_{cg\ LM} + \Delta W$		
$Z_{cg\ LM} + \Delta W$		

*Program will loop back to this point for additional Δ weights.

3. GDA gimbal angles.

a. If coming from Step 2, use the following:

DATA	UNITS	PROGRAM INSTRUCTION
INPUTS		
		GO TO
		-
		4
		5
		CONT
OUTPUTS		
PITCH GDA		
ROLL GDA		

b. If **not** coming from Step 2, use the following inputs:

DATA	UNITS	PROGRAM INSTRUCTION
INPUTS		
$X_{cg\ LM}$	XXX.XX in.	X → ( ) f
$Y_{cg\ LM}$	X.XX in.	X → ( ) e
$X_{cg\ LM}$	X.XX in.	X → ( ) d
		GO TO
		-
		4
		5
		CONT
OUTPUTS		
PITCH GDA		
ROLL GDA		

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4. Structural compliance of the DPS engine mount and DAP LOAD.

a. If coming from Step 3, use the following inputs:

DATA	UNITS	PROGRAM INSTRUCTION
INPUTS		
*THRUST	XX.X PERCENT	CONT

OUTPUTS

Pitch GDA with compliance
Pitch DAP Load
Roll GDA with compliance
Pitch DAP Load

*Program will loop back to this point for alternate thrust inputs.

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b. If not coming from Step 3, use the following inputs:

DATA	UNITS	PROGRAM INSTRUCTION
INPUTS		
PITCH GDA	X.XX°	X → ( ) a
ROLL GDA	X.XX°	X → ( ) b
		GO TO - 7 2
*THRUST	XX.X PERCENT	CONT

OUTPUTS

Pitch GDA with compliance
Pitch DAP Load
Roll GDA with compliance
Pitch DAP Load

*Program will loop back to this point for alternate thrust inputs.

SCP NO. **PROP 11-12**

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: R.S. Nance
APPROVAL: William L. Peters

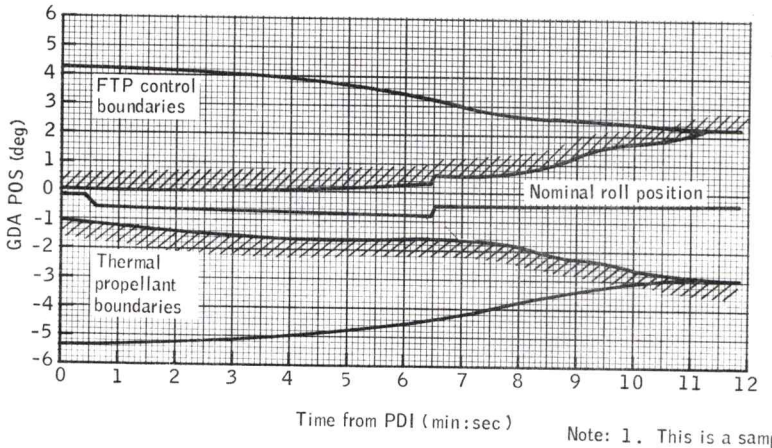
TITLE: MONITORING GDA FAILURES

PURPOSE: To define methods to be used in monitoring GDA failures.

PROCEDURE: A. Time - Whenever a GDA failure occurs, it is necessary to determine if the mission can be completed or must be aborted.

B. Method - The initial analysis and monitoring of a GDA failure is broken down into the following steps:

1. When the GDA fails, the time of the failure and the failed position in degrees will be recorded and plotted on a curve similar to the example curve given below. There will be two such curves; one for pitch as well as one for roll. These curves will be updated for each specific mission using data from the SODB, Vol II and III. P-14

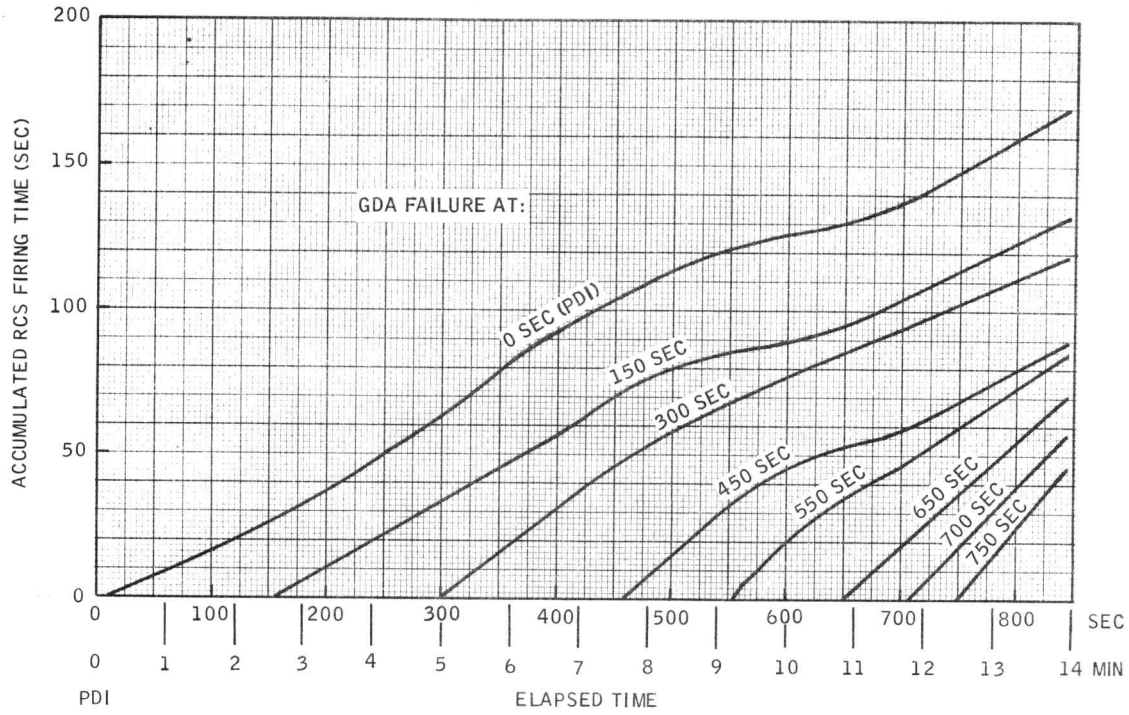


Note: 1. This is a sample curve for demonstration only
2. There will be two such curves; one for pitch and one for roll.

2. If the failed GDA position falls outside the boundaries indicated on the SODB curve, then either a thermal boundary, propellant usage boundary, or FTP control boundary has been violated. Violation of this boundary means the nominal MDC can not be completed. Before an abort is requested by MSFN, a secondary cue showing that a landing is impossible must be obtained. (Secondary cues will be discussed later.)

If the GDA position fails within the acceptable boundary, then the nominal mission can be completed; however, continued evaluation must be maintained to reassess that the capability to land still exists. This continuous evaluation is conducted by application of SODB Figure 4.8 - 89. An example of this curve appears on the next page.

Note: This is a sample curve.



3. Each curve on the above graph represents predicted accumulated RCS firing time for a GDA failure on the boundary line of the first graph. Each curve also corresponds to a GDA failure at a given time into powered descent. For real-time application, the accumulated RCS firing time can be obtained from the LM propulsion display and plotted on the curve. A new point should be plotted every thirty seconds using the worst case accumulated on time number with its corresponding time into powered descent. If the data points fall below the curve under consideration, then powered descent may continue. But if the point falls above the curve, then a thermal or propellant boundary will be exceeded before landing and an abort will be requested. After aborting, an overlay is available which can be placed over Figure 4.8 - 89 and used to calculate the duty cycle of the RCS to determine if any impingement constraints are being violated (see SODB Section 4.8.6 for impingement constraints).
4. Additional methods of monitoring the duty cycle are available and listed as follows:
   a. Use of a stop watch and on times from propulsion display can give a very accurate calculation of the RCS duty cycle over a measured interval.
   b. An on-time plot of 10 minutes duration is also available. Accumulated RCS firing time for thrusters B1D and B3D are plotted versus time. This provides a pictorial history of particular jet firings and can be used in determining past and present duty cycles.

Pages below were reserved for figures
to be added, which are now no longer
applicable to this SCP.

SCP NO. **PROP 11-13**

S/C: LM
DATE: 4/11/69
REV: Original
ORIGINATOR: R. S. Nance
APPROVAL: Ed. A. Soden

TITLE: **ΔV REMAINING DETERMINATION FOR BLOWDOWN BURNS**

PURPOSE: This SCP defines the method used in determining ΔV remaining in blowdown modes.

PROCEDURE: A. Time - These calculations are performed whenever there is a requirement to calculate a ΔV remaining in blowdown.

B. Method - Use Olivetti Programma 101 program for "$AX^2 + BX + C$ curve fit."

1. The inputs to this program are:

b	Y_1	(lb)	Thrust at a point 1
B	X_1	(sec)	Time at a point 1
c	Y_2	(lb)	Thrust at a point 2
C	X_1	(sec)	Time at a point 2
d	Y_3	(lb)	Thrust at a point 3
D	X_3	(lb)	Time at a point 3

This program is started by depressing "V."

2. The outputs to this program are

e ◇ A
D ◇ B
c ◇ C

Next use the Olivetti program titled "ΔV for blowdown."

3. The inputs to this program are:

b	A		A from previous output
B	B		B from previous output
c	C		C from previous output
C	T_{final}	(sec)	Time at end of blowdown
d	$T_{initial}$	(sec)	Time at start of blowdown
D	ISP_{nom}	(sec)	Nominal ISP
e	W_i	(lb)	Weight at $T_{initial}$
E	(On Card)		32.2
f	(On Card)		3

This program is started by depressing "V."

4. The outputs to this program are:

b ◇ (lb_f X sec)
A ◇ ΔV in ft/sec

C. If several thrust levels are desired, i.e. DPS, then each thrust level will have to be handled separately.

D. Note that for ΔV remaining calculations, the blowdown calculations are valid only until the minimum inlet pressure or maximum ullage volume (propellant depletion) is reached.

SCP NO. **PROP 11-14**

S/C : LM
DATE : 10-1-72
REVISION : PCN-14
ORIGINATOR: G. W. Watkins
APPROVAL : William L. Peters

TITLE : **INITIATION OF SMEK CONTROLLED PROPULSION FUNCTIONS**

PURPOSE : This SCP defines the procedure to be used in initializing SMEK-controlled propulsion functions.

BACKGROUND: A. General

1. Two SMEK panels are provided for LM CONTROL and LM PROP use. One is located at the CONTROL position in the MOCR, and the other is located at the PROPULSION position in the SSR. The following functions are provided on the PROPULSION SMEK:

   a. APS CALC START/STOP

   b. ON TIME START/STOP

   c. PGGS PROG START/STOP

   d. GQ3603Q INHIBIT, GQ3604Q INHIBIT, GQ4103Q INHIBIT, and GQ4104Q INHIBIT P-6

   e. LO LVL CD ARM/DEARM

   f. UP-35 THRU 41 START PLOTS P-14

2. A brief description of these functions is discussed below. The CONTROL SMEK does not contain the functions listed above. The CONTROL SMEK does contain many other functions which will not be discussed in this SCP.

B. Description of Prop Functions

1. APS Calc Start/Stop - Initial depression/execution will enable the computer to calculate APS flow rate and burn time. Subsequent depression/execution will disable these computations.
2. On Time Start/Stop - Initial depression/execution will enable the computer to calculate the firing time on each down firing RCS thruster. Subsequent depression/execution will disable these calculations. P-11

3. PQGS PROG Start/Stop - Initial depression/execution will enable the computer to calculate the point when the DPS low level should be reached. The second SMEK depression/execution will stop and hold the last good data point. The next SMEK depression/execution will reinitialize the program and start it over.

4. GQ3603Q Inhibit, GQ3604Q Inhibit, GQ4103Q Inhibit, GQ4104 Inhibit - Initial depression/execution of any of the above SMEKS will inhibit that parameter from being used in the DPS Propellant Margin Plot program and the DPS PQGS Program. A second SMEK depression/execution would allow that parameter to be used in the DPS Propellant Margin Plot program and the DPS PQGS Program. P-6

5. LO LVL CD ARM/DEARM - Initial depression/execution will arm the low level countdown, the PQGS Projection Program countdown, and the hover time countdown. The second depression/execution will stop the programs and hold the last data. The next depression/execution will reinitialize and arm the countdown programs. P-14

6. UP-35 THRU 41 START PLOTS - Each individual universal plot can be started by initial depression/execution of its associated SMEK. The plot will continue to plot up to the max capability (180 points) unless a second depression/execution is made, which sets the plot back to zero and restarts the plot. P-14

PROCEDURES: A. General

1. The SSR Propulsion position will be responsible for initialization of the APS Calc, On Time, PQGS Prog, GQ3603Q Inhibit, GQ3604Q Inhibit, GQ4103Q Inhibit, GQ4104Q Inhibit, LO LVL CD, and UP-35 thru 41 PLOTS. P-14

2. The clear PBI must be depressed immediately after each SMEK Execution.

3. Those SMEK functions which are time critical will be "set up" not sooner than one minute prior to required execution and cleared immediately after execution.

4. LM Propulsion will advise CONTROL when he has "set up" these functions. P-8

B. Specific

1. APS Calc Start/Stop

a. The Start function will be executed at the initiation of each APS burn to enable calculation of APS flow rate and quantity. The SMEK status light will illuminate when the calculations are being performed. P-6

b. The Stop function will be executed at the termination of each APS burn. The SMEK status light will go out when the APS calculations are stopped.

2. On Time Start/Stop

   a. The start function will be executed at the initiation of each main propulsion burn.

   b. The stop function will be executed at the termination of each main propulsion burn. The On Time plot will also be reinitialized during PDI if a DPS engine gimbal problem arises.

3. PQGS PROG Start/Stop

   a. The start function will be executed at 12 percent PQGS quantity. The first projection point will not be displayed for one to ten seconds depending on the value of MED (y). P-14

   b. The stop function can be executed after the DPS low level point has been reached. If the stop function is executed after the hover time countdown has started, the countdown will not be affected. The SMEK status light will go out when the stop function is executed.

4. Inhibit SMEKS for GQ3603Q, GQ3604Q, GQ4103Q, and GQ4104Q.

   During PDI, if anyone of the DPS PQGS quantities are malfunctioning, then it should be inhibited by its appropriate SMEK. Once an Inhibit SMEK is executed, then a SMEK status light is illuminated for the associated parameter. P-6

5. LO LVL CD ARM/DEARM

   a. The arm function will be executed at 9 percent PQGS quantity.

   b. The dearm function can be performed anytime after the DPS low level has been reached. The SMEK status light goes out when the dearm function is executed.

6. UP-35 THRU 41 START PLOTS

   At the initiation of a DPS burn, the following universal plots should be started: - UP 35 (DPS/APS TCP and GDA), UP 36 (DPS/APS HELIUM PLOT), UP 37 (PERCENT MARGIN PLOT) - UP 39 (ACCUM ON TIME, UP 40 (RCS QTY/DPS INLETS), UP 41 (RPY PGNS/AGS ERRS). At approximately 12 percent PQGS quantity, UP 38 should be initialized. The following universal plots should be started at the initiation of an APS burn: - UP 36, UP 38, UP 39, and UP 40. P-14

SCP NO. **PROP 11-15**

S/C: IM
DATE: 7/26/71
REV: PCN-10
ORIGINATOR: R. S. Nance
APPROVAL: HQ for J.A. Wigner

TITLE : DPS PQGS/LOW LEVEL MONITORING PROCEDURES

PURPOSE : To define the realtime procedures used in evaluating the propellant available during all phases of powered descent

PROCEDURE: A. Time - These procedures should be initiated at the start of powered descent and continued until a safe landing is accomplished.

B. Definition and abbreviations -

1. Definitions:

Margin Plot to P64 - This is a realtime program which predicts the propellant margin in PQGS percent (propellant available at any instant minus propellant required for an automatic landing from this instant) at touchdown. This program is valid during the Braking Phase (P63).

Margin Plot in P64 - This is the realtime program which predicts the propellant margin in PQGS percent at touchdown. This program is valid during the approach phase (P64).

Proj. Prog. - The PQGS projection program smooths the PQGS data and predicts when the low level discrete (GQ4455X) will occur.

LL CD ARM - The low level countdown is a series of realtime clocks which countdown from the low level point. One clock counts down from the low level discrete (GQ4455), another clock counts down from the first time the projection program reaches the predicted low level point. Still another clock counts down from a valid low level discrete or a valid projection program low level (if the low level discrete came on early) and corrects for manual throttle.

Bingo - The point in powered descent where 20 sec of hover time remains and the crew must assess whether they can land or use the remaining propellant for an abort.

2. Abbreviations:

MR - Mixture Ratio
LL CD - Low Level Countdown
PP CD - Projection Program Countdown
HT - Hovertime Remaining to Bingo based on program that takes manual throttle into account.

C. Flow -

(Continued on next page)

SCP NO. **PROP 11-18**

S/C: LM
DATE: 11/1/71
REVISION: P-11/New
ORIGINATOR: R. Nance
APPROVAL:

TITLE: DETERMINATION OF RCS CAPABILITY TO PERFORM LM TWEAK

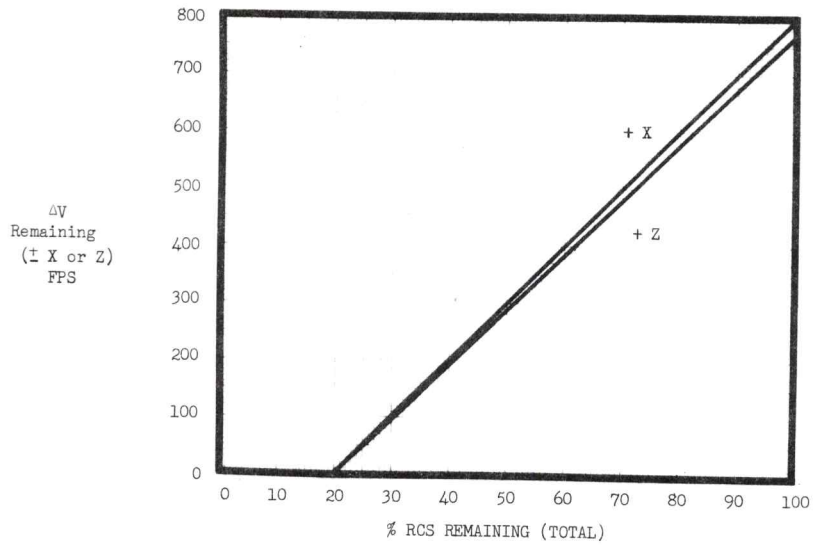
PURPOSE: This SCP defines the method used in determining the capability of the LM RCS to perform a TWEAK maneuver. The procedure is designed so that this determination can be made rapidly so a "GO" or "NO GO" can be made prior to the maneuver.

PROCEDURE:

A. Time - This procedure should be performed immediately upon ascent insertion.

B. Method - Immediately upon insertion the delta velocity available for TWEAK is calculated using a curve of ΔV remaining versus RCS remaining. An example of this curve is given below. There are two curves: one for ± X maneuvers and one for ± Z maneuvers. The curves are shown on the same graph below.

ΔV REMAINING AS A FUNCTION OF RCS REMAINING



The above curves have already taken out sufficient RCS to perform LOS to Docking, Docking, 2.5% OPS Reserve and unusable propellants. The curves also assumes a nominal insertion weight. Should an abnormal condition exist where the weight was off nominal, there are similar curves for this condition.

The user averages the RCS System A and B propellant remaining together and reads off the delta velocity available. The LM Propulsion Flight Controller should report the Delta V available in ± X and ± Z to the LM CONTROL Flight Controller. It should be made clear that the Delta V available is either XXX FPS ± X or XXX FPS ± Z.

The LM CONTROL should pass the above data to FIDO if either number is less than 60 FPS, and FIDO will determine whether the TWEAK exceeds the LM RCS capability.

SCP NO. **PROP 11-19**

S/C: LM
DATE: 10-1-72
REVISION: PCN-14
ORIGINATOR: W. Stephens
APPROVAL: William L. Peters

TITLE: DETERMINATION OF DPS ENGINE EROSION

REFERENCES: 1. SODB, Vol II, Part I

2. LSB Note of Interest: LM-10 Non-Throttle Region, July 12, 1971

PURPOSE: This SCP establishes the procedures for monitoring DPS erosion resulting from off-nominal operation.

PROCEDURE:

A. TIME

This procedure will be applicable if the DPS operates in the non-throttling range, or if excessive engine erosion occurs.

B. Method

The procedures used by LM PROP for monitoring and determining engine erosion are divided into two groups: (1) excessive engine erosion from other than operation in the non-throttling range (Throttle Actuator Nominal) and (2) operation in the non-throttleable region (Throttle Actuator OFF-Nominal). These two groups will be discussed below.

1. Excessive engine erosion from other than operation in the non-throttling range

(a) When excessive engine erosion is suspected, the thrust chamber pressure (TCP) will be noted and monitored for decay. Correspondingly, the thrust will also be monitored as an indication of throat erosion. PROP malfunction analysis for GQ65l0P gives procedures for detecting throat erosion.

(b) If the excessive erosion is noticed while at full throttle position (FTP), the decaying TCP will be compared to the TCP noted at the start of FTP.

(1) The decaying TCP will be plotted as a function of FTP on a figure similar to Figure 1. Figure 1 is a typical curve of chamber pressure versus thrust (percent of 10,500 lbs), and is obtained for each vehicle from the appropriate vehicle appendix of the Spacecraft Operational Data Book (SODB), Vol II, Part I.

(2) As TCP is plotted at a thrust of 92.5 percent (FTP), the approximate throat erosion can be determined by interpolating between the NO THROAT EROSION (0.0 percent) curve and the MAXIMUM ALLOWABLE THROAT EROSION (52 percent) curve.

(3) The TCP decay will continue to be monitored to insure the TCP doesn't drop below the MAXIMUM ALLOWABLE THROAT EROSION (52 percent) curve. From the typical curves in Figure 1, it can be seen at a chamber pressure of approximately 74 psia for 92.5 percent, 52 percent erosion is predicted. However, to complete the nominal PDI mission duty cycle with 52 percent erosion, a TCP decay of only 23 psia can be permitted (not shown on Figure). | P-14

(c) Also after FTP throttledown, chamber pressure and thrust will be the key to the amount of engine erosion sustained, and will be monitored in the following way:

(1) Plot TCP as a function of percent thrust on Figure 1.

(2) Determine approximate amount of erosion by interpolating between no erosion curve and 52 percent erosion curve for the plotted TCP points.

(3) Continue to monitor TCP and verify 52 percent erosion is not exceeded using Figure 1.

2. Operation in the non-throttleable region

(a) When the DPS has been confirmed to be operating in the non-throttleable region, the time of failure or entry into the non-throttling range will be recorded.

(b) With the time from ignition, the maximum allowable time for DPS non-throttling operation is determined from a curve similar to Figure 2. This time is the maximum time the DPS can be operated in the non-throttling region without exceeding 52 percent erosion. As shown in Figure 2, two curves are given. The curve labeled throttle actuator greater than 80 percent will be used should operation in the non-throttleable region be caused by loss of manual command voltage from the DECA. The second curve will be used for all other failures. Erosion rates used in the derivation of these curves are also given.

(c) While operating in the non-throttling range, DPS performance (thrust, TCP, throttle actuator position, etc.) will be analyzed, and the time in the range monitored. Depending on whether non-throttling occurs during Descent or alternate mission aborts, the non-throttling time which will allow mission completion may be less than maximum allowable time discussed in paragraph B.2.b. These non-throttling times are outlined as follows:

(1) For aborts, the time in the non-throttling region may be equal to the maximum time in Figure 2.

(2) To complete the nominal mission duty cycle, however, the permitted time must be less than the maximum time, and is dependent on the reason for non-throttling operation. For the case of loss of 10 percent manual command voltage, approximately 295 seconds can be sustained at the non-throttling range. But for all other cases, only approximately 177 seconds can be allowed and still complete powered Descent. These times are applicable for the LM-11 DPS engine, but are only typical for LM-12. The permissible time in the non-throttleable region is evaluated for each engine based on engine ablative characteristics. P-14

(d) During Descent, the following steps will be followed if throttle recovery (FTP operation) or automatic throttle down prior to high gate target conditions can be achieved within the times mentioned above which will allow mission completion. It should be mentioned, however, that guidance constraints could be exceeded by the low DPS thrust prior to these times being reached.

(1) At FTP throttledown, the TCP will be compared with the TCP noted at start of FTP. A TCP decay of 23 psi corresponds to the maximum allowable throat erosion of 52 percent for the nominal mission duty cycle. P-14

(2) The procedures discussed under paragraph B.1.c will also be followed.

(e) For alternate mission DPS burns (e.g. LOI aborts) if throttle recovery is obtained prior to exceeding 52 percent erosion, monitoring procedures will simply consist of noting chamber pressure decay. Again this procedure consists of using Figure 1 as an indication of throat erosion. DPS operation will be continued if the MAXIMUM ALLOWABLE THROAT EROSION (52 percent) curve is not exceeded.

(f) If throttle recovery can not be achieved and continued engine operation is required to support an abort (PDI or LOI), DPS operation will be permitted for the maximum allowable time determined from Figure 2 (as discussed in paragraph b above).

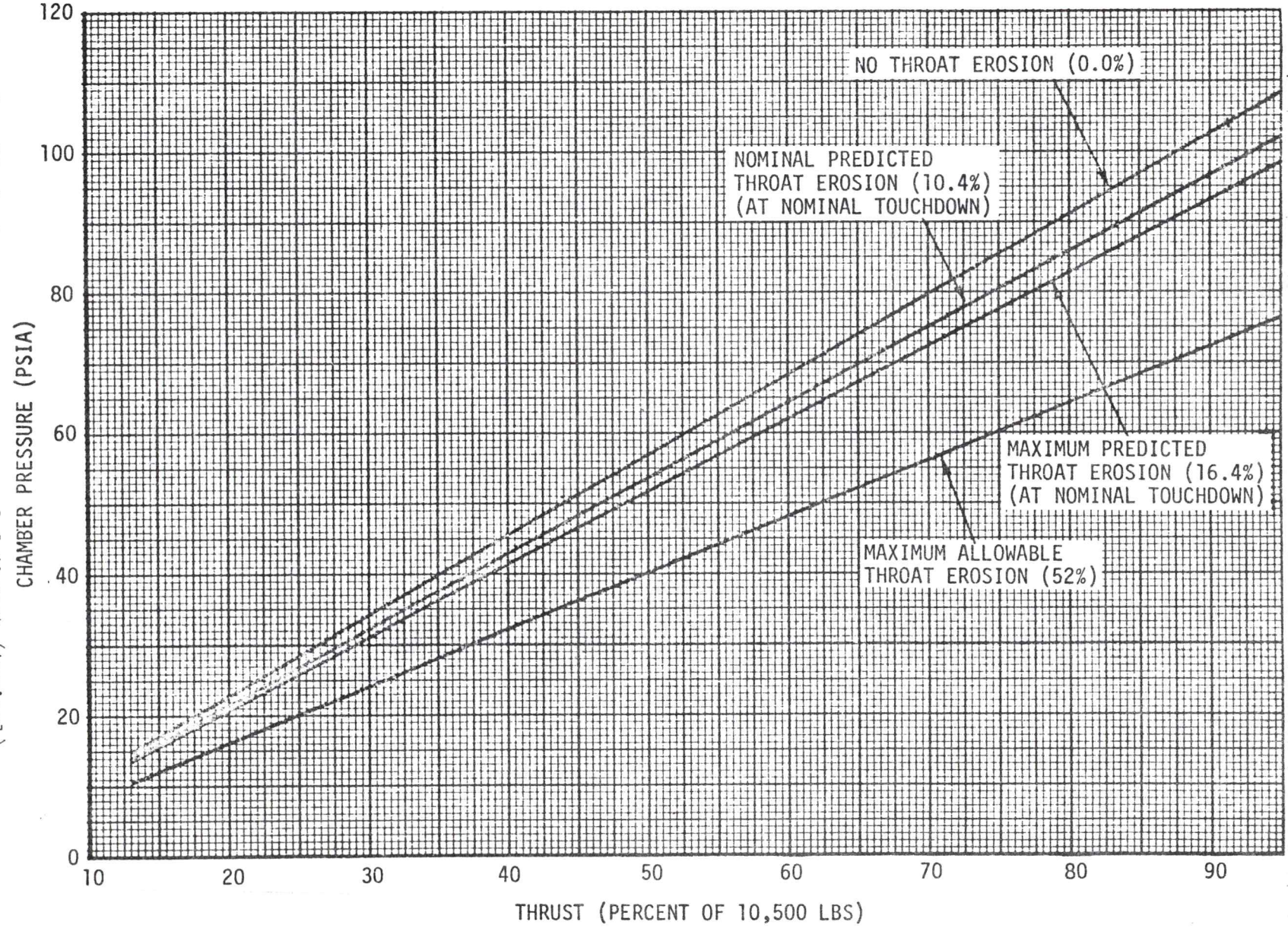


FIGURE 1: DPS chamber pressure vs. commanded thrust (typical)

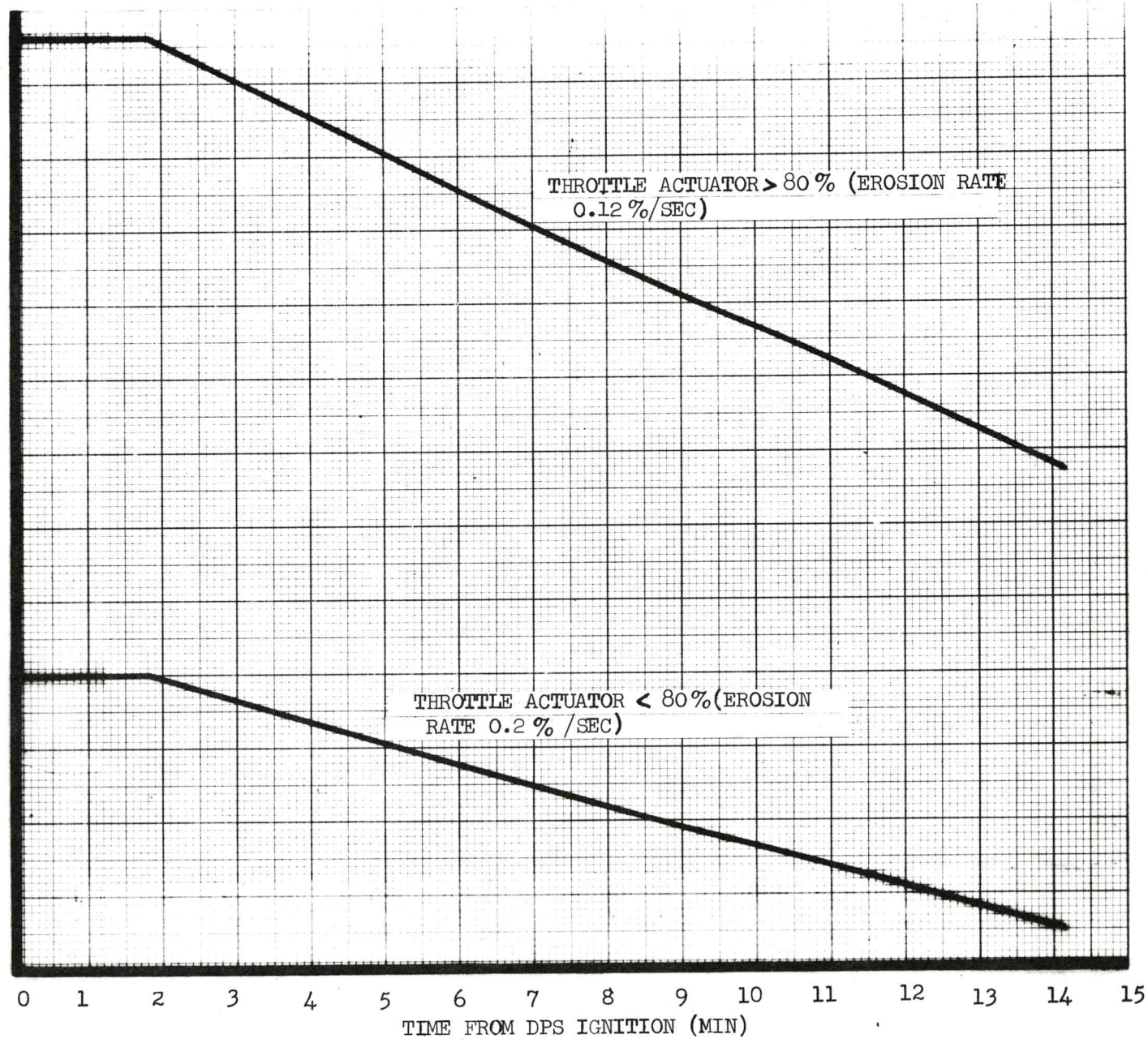


FIGURE 2: MAX ALLOWABLE NON-THROTTLING TIME

MAXIMUM ALLOWABLE TIME IN NON-THROTTLE REGION (MIN)

SCP NO. **PROP 11-20**

S/C: LM
DATE: 3-1-72
REV: PCN-12
ORIGINATOR: E. Keesler
APPROVAL: J. A. Hagener

TITLE: APS PROPELLANT LEAK

PURPOSE: This SCP defines the method of determining APS propellant leak rate and time vehicle may remain on the surface before insertion capability is lost.

PROCEDURE:

A. TIME

Lunar Stay

B. CHARTS

A fuel and oxidizer chart are provided, by LM Propulsion, showing delta v remaining and lbs. propellant lost vs percent initial inlet pressure.

C. METHOD

1. Leak Rate

(a) Determine the time required for inlet pressure to drop 3 to 5 percent of initial inlet pressure.

(b) Use propellant lost vs percent initial inlet pressure curve to determine propellant lost.

(c) Leak rate = propellant lost $\div$ time.

2. ΔV required for insertion.

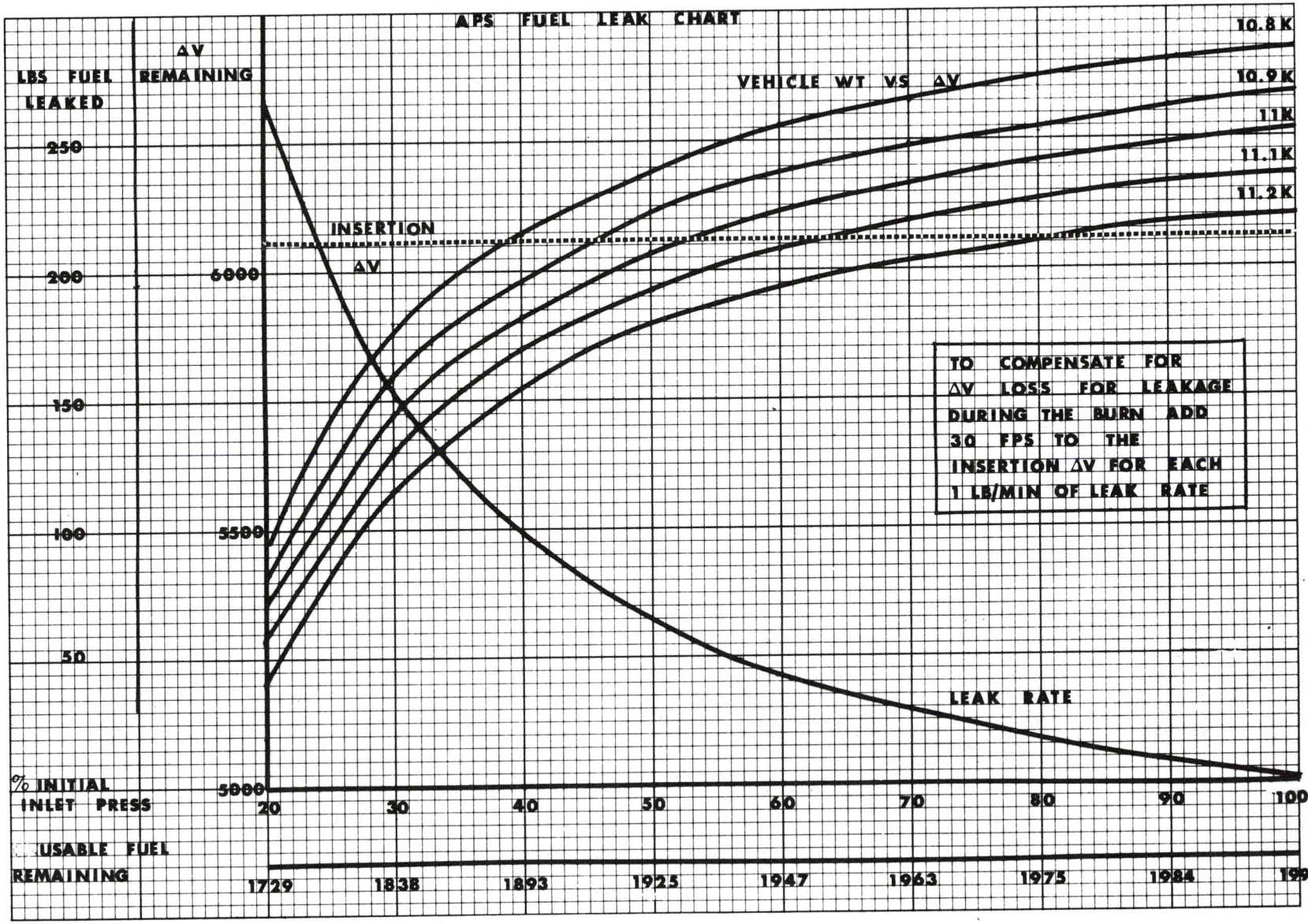
(a) ΔV required for insertion line on the charts assumes no leak rate during flight.

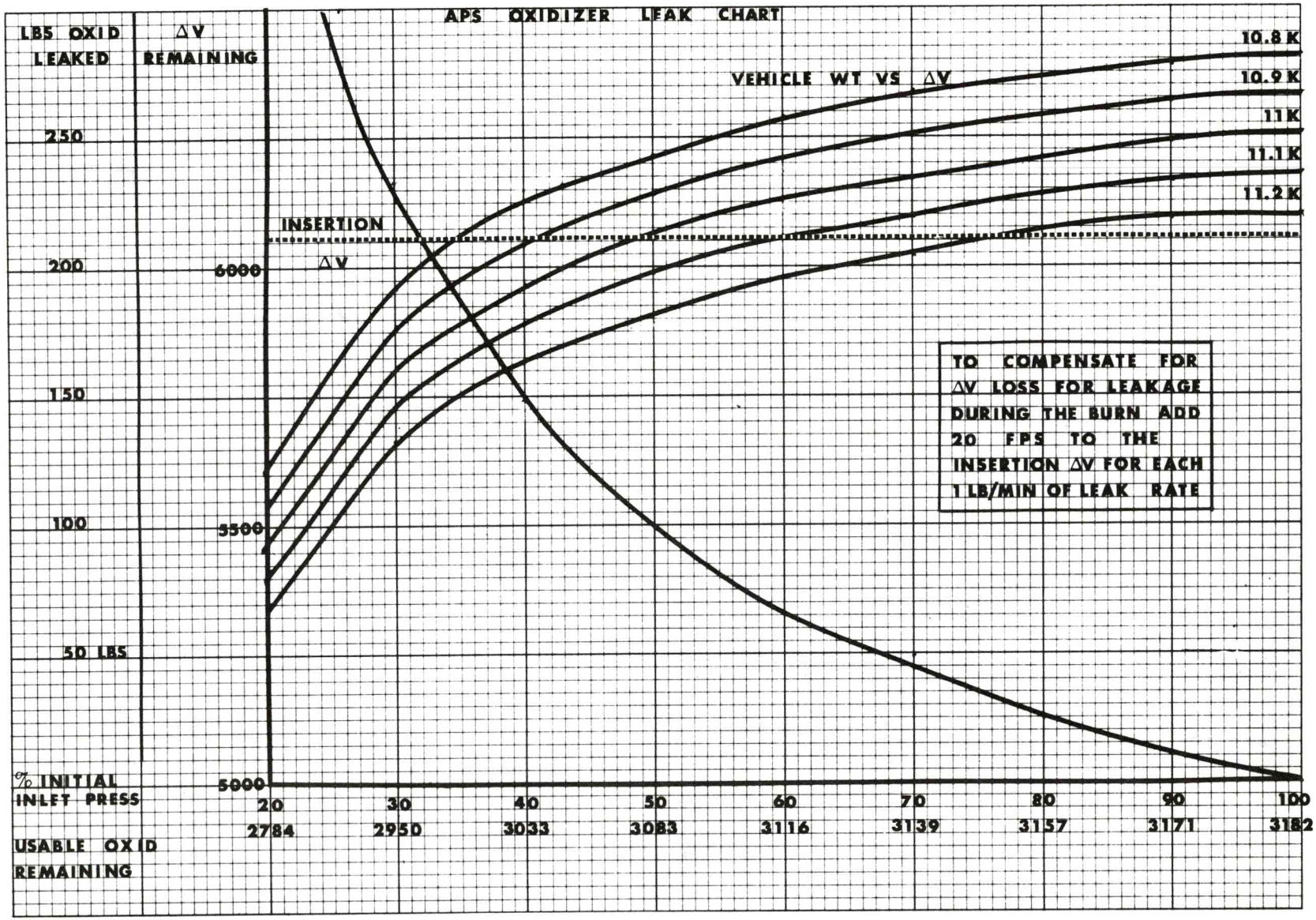
(b) For each 1-lb per min leak rate add 30 feet per second for fuel and 20 feet per second for oxidizer to the insertion ΔV line.

3. Time remaining on surface.

(a) Use weight curve that represents weight of vehicle when leak started. Find the point where weight line crosses new insertion ΔV line. Read percent initial inlet pressure and weight of propellant remaining. This is the lowest percent of initial inlet pressure where insertion capability exists.

(b) Subtract propellant remaining at insertion point from propellant remaining now. Divide by leak rate to determine time, vehicle may remain on surface.


APS FUEL LEAK CHART
LBS FUEL LEAKED
ΔV REMAINING
VEHICLE WT VS ΔV
10.8K
10.9K
11K
11.1K
11.2K
INSERTION ΔV
250
200
150
100
50
6000
5500
5000
TO COMPENSATE FOR ΔV LOSS FOR LEAKAGE DURING THE BURN ADD 3.0 FPS TO THE INSERTION ΔV FOR EACH 1 LB/MIN OF LEAK RATE
LEAK RATE
% INITIAL INLET PRESS
20
30
40
50
60
70
80
90
100
USABLE FUEL REMAINING
1729
1838
1893
1925
1947
1963
1975
1984
1991


APS OXIDIZER LEAK CHART
LBS OXID LEAKED
ΔV REMAINING
VEHICLE WT VS ΔV
10.8K
10.9K
11K
11.1K
11.2K
INSERTION ΔV
250
200
150
100
50 LBS
6000
5500
5000
TO COMPENSATE FOR ΔV LOSS FOR LEAKAGE DURING THE BURN ADD 20 FPS TO THE INSERTION ΔV FOR EACH 1 LB/MIN OF LEAK RATE
% INITIAL INLET PRESS
USABLE OXID REMAINING
20 2784
30 2950
40 3033
50 3083
60 3116
70 3139
80 3157
90 3171
100 3182

SCP NO. **PROP 11-21**

S/C: LM-11
DATE: 11/1 /71
REV: PCN-11 /New
ORIGINATOR: G. Watkins
APPROVAL: Gaw

TITLE: RCS P/V, PQMD CONVERSION

PURPOSE: The purpose of this SCP is to define conversion and bias techniques between onboard and ground systems for determining RCS propellant available.

BACKGROUND: The LM RCS propellant is gaged by two independent systems (ground and onboard). The ground system is the RCS P/V (pressure/volume) ground computer program. The onboard system is the PQMD (reference SB PROP 11-6). A conversion technique is needed because the two programs differ in several aspects. The aspects are as follows: The RCS P/V ground program calculates total propellant remaining in terms of percent, the PQMD measures RCS tanked propellant remaining in terms of percent. A bias technique is needed for the following reasons: The PQMD can have an initial error or bias, also the PQMD assumes a mixture ratio whereas the P/V ground program can correct for a mixture ratio change.

PROCEDURE: A. TIME:

This procedure should be followed anytime the ground interfaces with the crew for the following RCS consumables updates: nominal, GO/NO GO's, and Redlines.

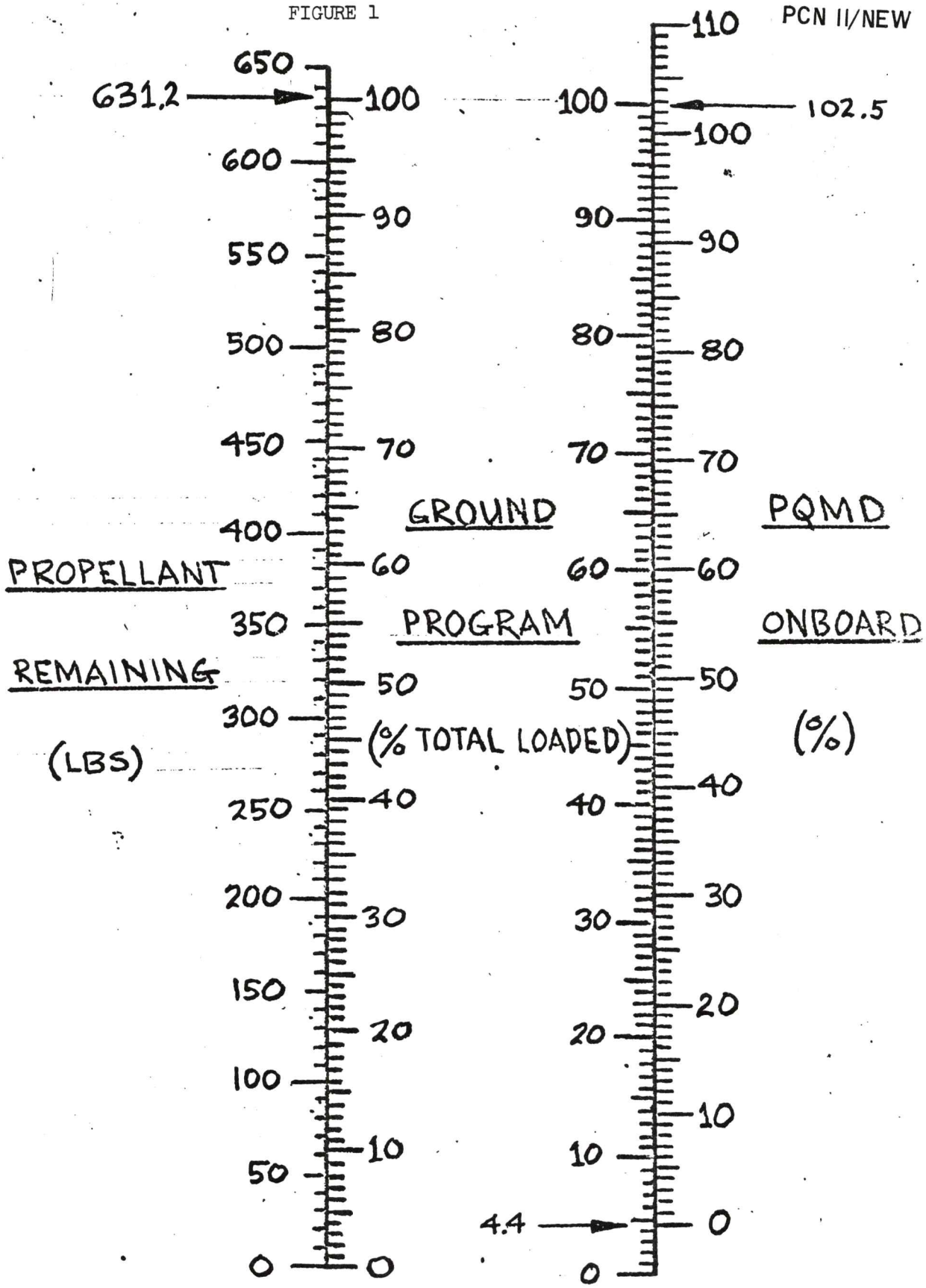
B. METHOD:

Figure 1 (RCS Conversion Chart) is used for conversion between the RCS P/V ground program and the PQMD. For example, a reading of 90 percent on the RCS P/V ground program would correspond to a reading of 92 percent on the PQMD using the right-hand vertical scale. The left-hand scale will convert the percent reading to total pounds remaining. If the PQMD reading does not correspond to the converted value from Figure 1, then a bias (plus or minus) is present. Therefore, the bias must be taken into account when using the PQMD real-time. To get the actual reading for a known bias you must subtract a positive bias or add a negative bias from the telemetered PQMD value. To convert an actual value to an expected reading, the opposite is true, you must add a positive bias to the actual value and subtract a negative bias from the actual value.

RCS CONVERSION CHART

SCP NO. II-21
PCN II/NEW

FIGURE 1



S/C: LM
DATE: 11-1-71
REV: PCN-11/New
ORIGINATOR: E. L. Keesler
APPROVAL: J. A. Wegener

SCP NO. PROP 11-22

TITLE: **RCS CAPABILITY AFTER A HELIUM OR PROPELLANT LEAK**

PURPOSE: This SCP defines the method of determining RCS capability after substaining either a helium or propellant leak.

PROCEDURE: A. Time

Pre-Press or Post-Press.

B. Data

Helium Tank Volume at 3000 PSIA = 920 $in.^3$

Fuel Tank including line volume at 185 PSIA = 3307 $in.^3$

Oxid tank including line volume at 185 PSIA = 4117 $in.^3$

Fuel ullage volume (initial) = 164 $in.^3$

Oxid ullage volume (initial) = 281 $in.^3$

Volume Fuel trapped in tank at Depletion = 65 $in.^3$

Volume Oxid trapped in tank at Depletion = 77 $in.^3$

Helium Pressure required to expel all propellant = 2200 PSIA

Fuel Density 56.3 lb/ft^3

Oxid Density 90.24 lb/ft^3

C. Method Prior to Press

1. Helium Source Leak

a. Use H.P. leak program to predict time for pressure to decrease to 2200 PSIA. At this point capability to expel total propellant is lost. RCS blowdown capability may be created after pressurization. (Ref. D.l.d.).

2. Leak between SQUIB valves and main SOVS.

a. Leak may be either propellant or helium. Assume a propellant leak and determine leak rate. System must be pressurized to isolate leak to either helium or propellant.

b. $\frac{P_1 V_1}{P_2} = V_2$

Where: P_1 = initial Reg. Pressure

V_1 = initial ullage volume

P_2 = Reg pressure now

V_2 = Volume Now

c. $\frac{(V_2 - V_1)d}{T}$ = leak rate

Where: d = density

T = Time

3. Leaks downstream of main SOVS must be analized after Press.

D. Method - Post Press.

1. Helium Source Pressure decreasing

a. Leak may be either helium or propellant upstream of main SOV.

b. First consider the worst case which is a Fuel or Oxid leak. Use Figure 1 which plots PQMD reading against actual percent propellant remaining to determine depletion quantity PQMD reading and leak rate.

Leak rate = $\frac{\%\text{propellant leaked}}{\text{Time}}$ X lbs/%

c. If the leak is propellant the source pressure will stabilize when propellant is depleted. Use, Figure 2, Plot of PQMD reading when leak starts vs. source press at propellant depletion to verify if leak is propellant or helium.

d. If leak is helium, some blowdown capability exists. The amount of propellant available in blowdown varies with the propellant remaining at the start of blowdown. Figure 3 is a plot of percent of total useable propellant in blowdown vs. propellant remaining at start of blowdown.

Figure 4 is a plot of percent of total useable propellant in blowdown vs. propellant remaining at the start of blowdown, for the special case where a reg has failed open and the initial ullage pressure is 212 PSIA.

2. Propellant leak downstream of main SOVS.

Use Figure 1, Actual percent remaining vs. PQMD reading to determine PQMD reading where propellant will deplete if leak continues. This will be conservative. Since any system usage during leak will lower depletion point.

System may be conserved by opening main SOV only during Critical Control Periods.

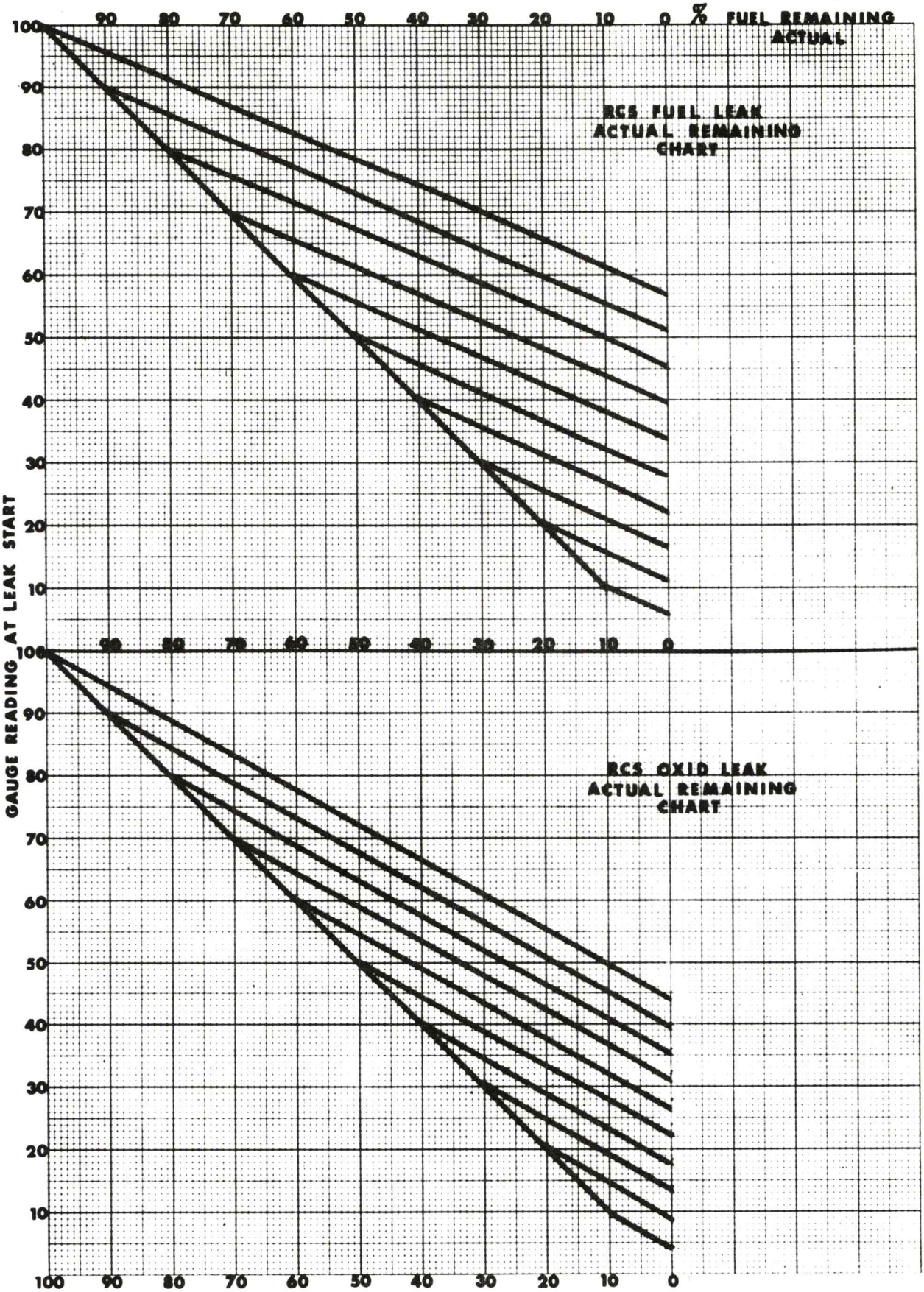

% FUEL REMAINING ACTUAL
RCS FUEL LEAK ACTUAL REMAINING CHART
RCS OXID LEAK ACTUAL REMAINING CHART
GAUGE READING AT LEAK START
BEE 20X20 TO INCH
100 90 80 70 60 50 40 30 20 10 0

FIGURE 1

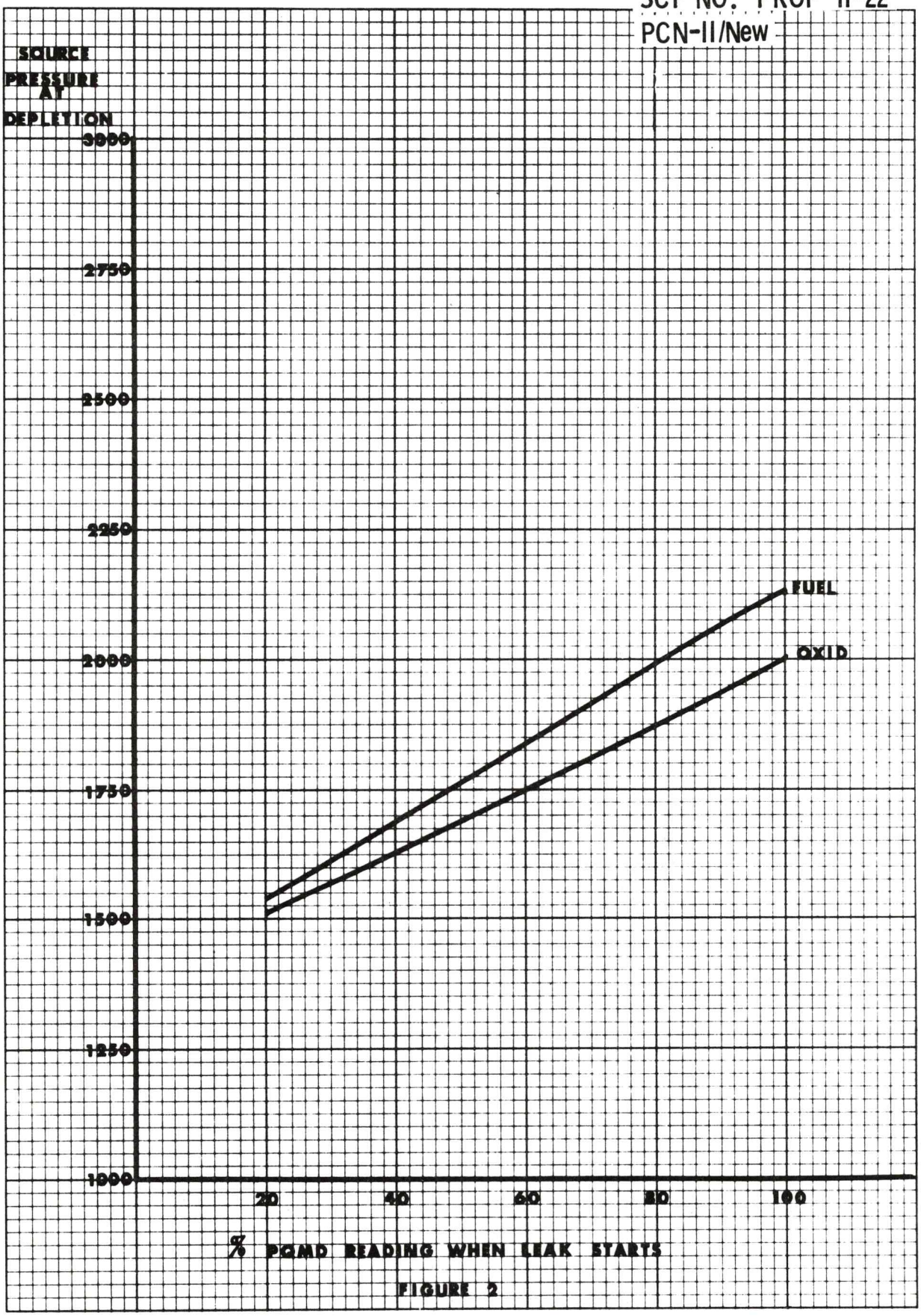

SOURCE PRESSURE AT DEPLETION
3000
2750
2500
2250
2000
1750
1500
1250
1000
FUEL
OXID
20
40
60
80
100
% PCMD READING WHEN LEAK STARTS

FIGURE 2

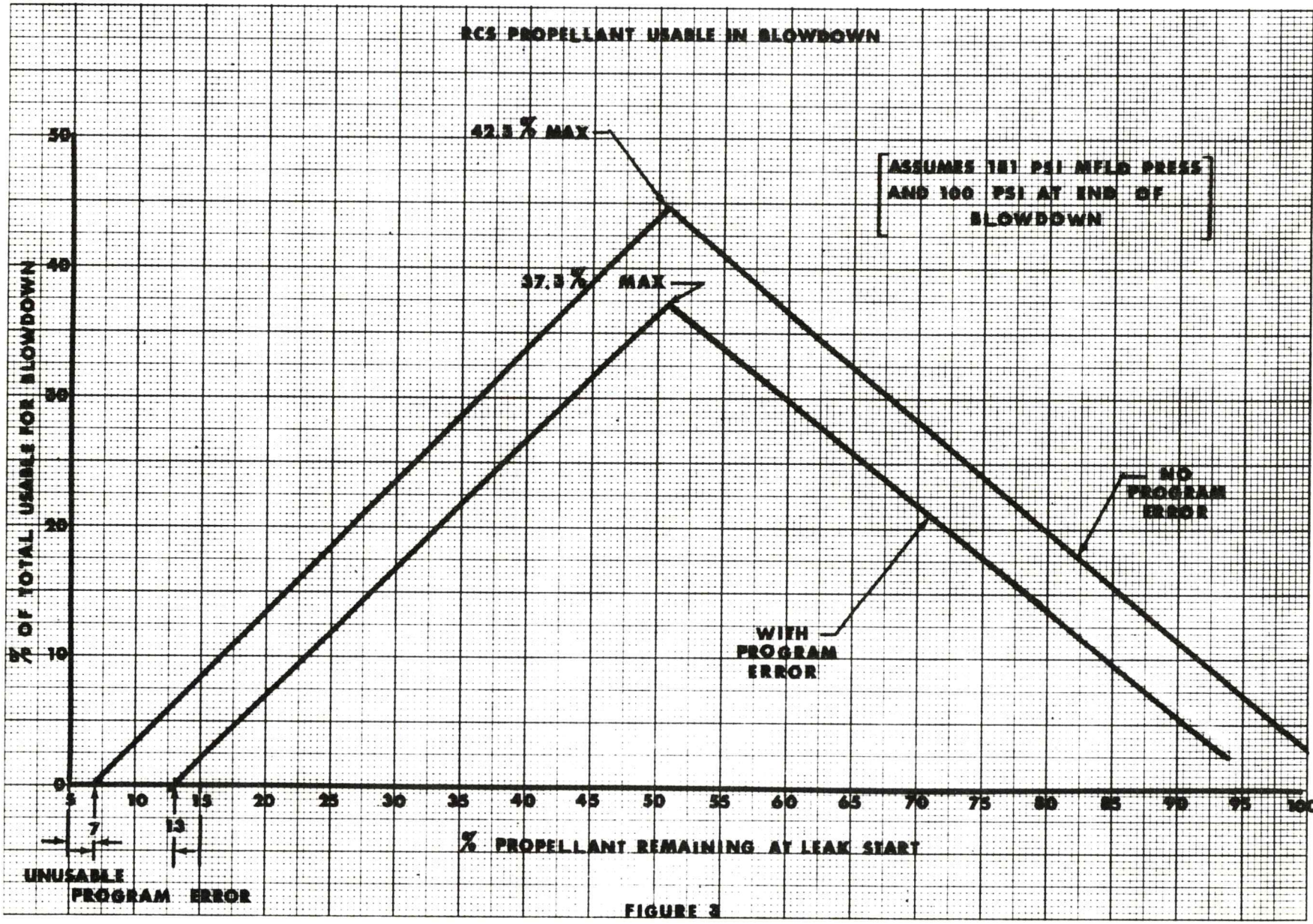

RCS PROPELLANT USABLE IN BLOWDOWN
42.5 % MAX
37.5 % MAX
ASSUMES 181 PSI MFLD PRESS AND 100 PSI AT END OF BLOWDOWN
NO PROGRAM ERROR
WITH PROGRAM ERROR
% OF TOTAL USABLE FOR BLOWDOWN
0
10
20
30
40
50
5
7
10
13
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
% PROPELLANT REMAINING AT LEAK START
UNUSABLE PROGRAM ERROR

FIGURE 3

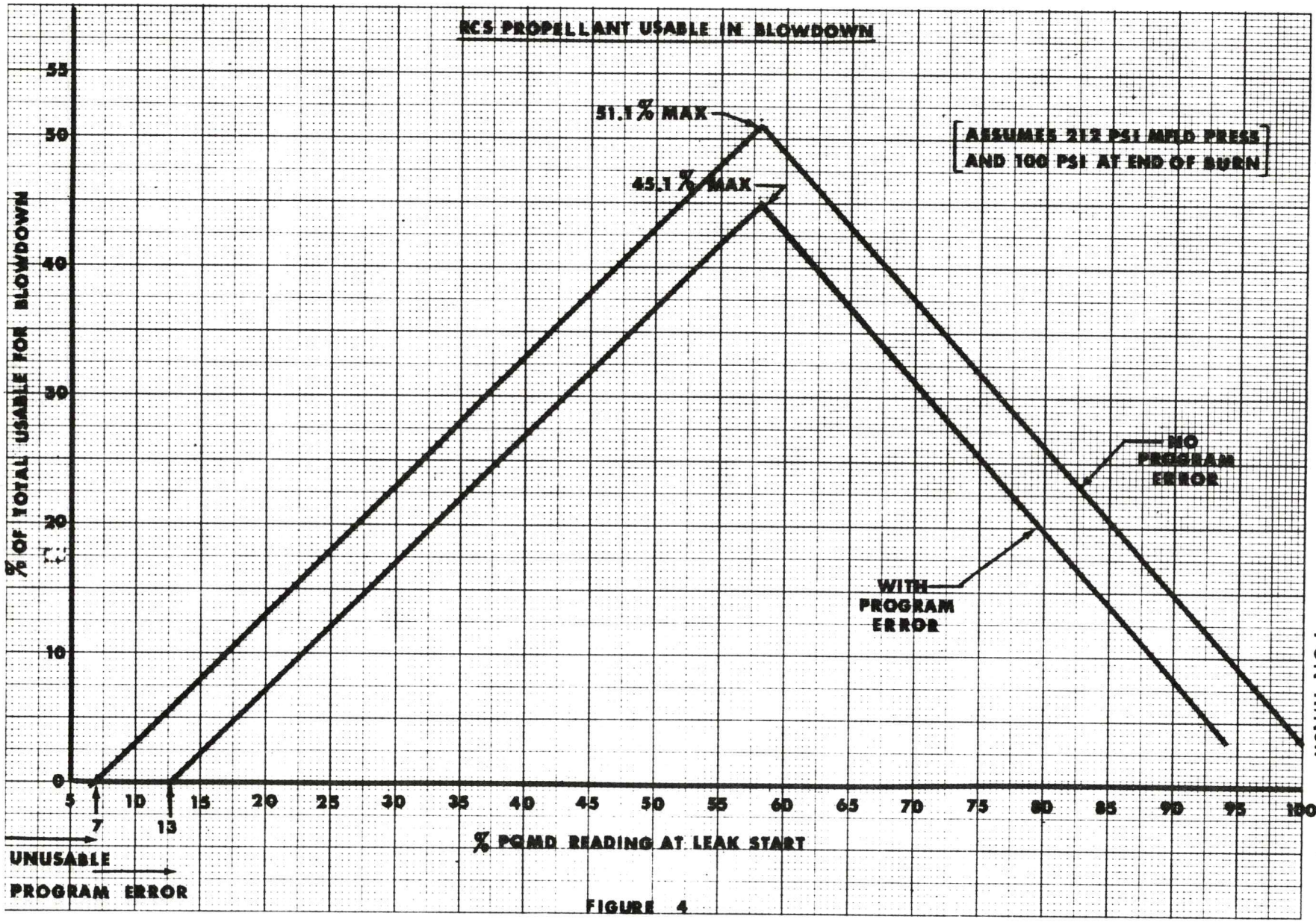

RCS PROPELLANT USABLE IN BLOWDOWN
51.1% MAX
45.1 % MAX
ASSUMES 212 PSI MFLD PRESS AND 100 PSI AT END OF BURN
NO PROGRAM ERROR
WITH PROGRAM ERROR
% OF TOTAL USABLE FOR BLOWDOWN
0
10
20
30
40
50
55
5
7
10
13
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
% PGMD READING AT LEAK START
UNUSABLE
PROGRAM ERROR

FIGURE 4

S/C: LM
DATE: 11/1/71
REV: PCN-11/New
ORIGINATOR: R. Nance
APPROVAL: John Wegener

SCP NO. PROP 11-23

TITLE: OPTIMUM LM ASC STAGE/CSM DOCKING ANGLE DETERMINATION

PURPOSE: This SCP defines the method used in determining the optimum LM Ascent Stage/CSM docking angle to minimize RCS propellant consumption.

PROCEDURE: A. Time - This procedure should be performed if there is a situation where sufficient RCS or Ascent propellant is not available to control a docked APS burn.

B. Method - Two steps of the Hewlett-Packard program "CSM ROTATION, C.G, GDA, GDA with Compliance and DAP LOAD" are used for this procedure. The procedures for the use of these steps are described in SCP PROP 11-11 under Method Two. Step 1, "Conversion of CSM cg in CSM coordinates", and Step 2, "LM or CSM cg calculation for delta weight changes from nominal", are used. The two steps should be used in an iteration process to solve for the docking angle that makes the docked Y cg in LM coordinates go to zero and has a positive docked Z cg in LM coordinates. The CSM is rotated in step one and added to the LM in step 2. If the proper conditions are not met, another docking angle is chosen and the docked cg is recalculated. By using pre-mission curves, the approximate optimum docking angle can be located to facilitate this process.

P-11

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: G. Watkins
APPROVAL: William L. Peters

SCP NO. PROP 11-24

TITLE: ASCENT LIMIT WEIGHT DETERMINATION

PURPOSE: The purpose of this SCP is to establish a method of determining the ascent limit weight margins in real time and to determine the effect of trading off ascent feed and/or balance couples during ascent.

BACKGROUND: DEFINITION

The ascent limit weight is defined as the maximum weight that will allow the ascent stage to achieve insertion orbit utilizing APS propellant. The following assumptions are defined pre-mission by the Apollo Spacecraft Program Office (ASPO) affecting propellant utilization.

1. APS propellant will be allocated for the TPI burn.
2. The LM will be required to perform a $1/2^{o}$ plane change.
3. Three sigma dispersions on performance will be considered in the propellant budget.
4. APS propellant will be utilized for moment control by ascent feeding the RCS for the duration of the burn.
5. An APS engine valve pair malfunction will be considered.
6. The RCS engines will be assumed to operate in the balance couple mode for controlling attitude during the insertion burn. This means that the RCS will contribute nothing towards the ΔV during the burn.
7. A pad (99.999 percent probability of propellant nondepletion) will be considered for the propellant budget.
8. Unusable and propellant allocated for outage will not be considered available for the APS engines to burn.
9. A nominal ΔV of 6055 is assumed for insertion.
10. Nominal lunar sample return and stowage is assumed.

Feasibility of Exceeding Limit Weight

Even under nominal conditions the ascent limit weight could be exceeded for some periods. Also, the EVA's are getting longer which allows more time to collect additional rock samples. This can cause the lunar surface weight to increase. Lower than expected RCS usage during descent can drive the lunar surface weight up. These factors make it more feasible that the ascent limit weight can be exceeded.

Premission Determination of Ascent Limit Weight Margins

Prior to each mission, Mission Planning and Analysis Division (MPAD), utilizing the ASPO defined assumptions, publishes a memo establishing the ascent limit weight margins for various phases on the lunar surface. These phases include touchdown abort, before and after each EVA, as well as the nominal liftoff. These pre-mission margins are valid unless the vehicle mass properties change "real-time" and/or any of the assumptions are changed.

TIME: This procedure is to be used anytime on the lunar surface that the ascent center of gravity changes from the nominal, or different assumptions are made for ascent feed or balance couple operation as outlined in the definition. Either of these conditions requires a new ascent limit weight determinations.

SCP NO. PROP 11-24

PROCEDURE: ASCENT LIMIT WEIGHT CALCULATION

When the ascent limit margin is negative, certain assumptions can be traded off to increase the limit weight. These trade off items and their priority are covered by an ASPO memo (Ascent Limit Weights, PD12/241-71, dated November 18, 1971). the value of the trade off items (1, 2, and 7) is determined by the pre-mission ascent limit weight memo published by MPAD. If the margin is still negative, it may be desireable to consider trading off items 4 and 6. The following procedure will outline how to determine the ascent limit weight as a function of vehicle cg. The method of determining the trade off value of items 4 and 6 (ascent feed and balance couple) will also be discussed.

1. Changes to Ascent Weight

   Any changes to the expected lunar surface weight or stowage is monitored and reported per FCOH SOP 2.16 (Lunar Surface Weight Updates).

2. Vehicle Weight and "wet cg"

   Ascent vehicle weight and "wet cg" is determined per FCOH 2.5 (S/V Weight Updates). LM Prop runs a parallel determination of "wet cg" utilizing LM Console Handbook SCP PROP 11-11 (cg and DPS Gimbal Angle Determination). The "wet cg" represents the cg of the ascent stage with the APS and RCS propellant.

   The following steps (3 thru 6) are to be performed after the new cg is determined. Data that is used in these steps is found in the SODB Vol. II RCS Section.

3. Determine the "dry CG"

   The "wet cg" is transformed into the "dry cg" of the vehicle utilizing the SODB curve entitled Ascent Wet to Dry CG Conversion and found in the SODB Vol. II RCS Section. The "dry cg" represents the cg of the ascent stage with the APS propellant and tanked RCS propellant removed.

4. Determine the "Delta Limit Weight"

   The "dry cg" is used for the limit weight curve to determine the effects of balance and unbalance couple operation as well as ascent feed. Four curves for the following conditions are listed in the SODB Vol. II RCS Section under Delta Ascent Limit Weight during Moment Control. versus dry vehicle cg.

   (a) Balance couple with ascent feed (nominal configuration)
   (b) Balance couple without ascent feed
   (c) Unbalance couple with ascent feed
   (d) Unbalance couple without ascent feed

   Entering these curves with the Y and Z "dry CG" coordinates will yield a positive or negative number for the configuration desired termed the ascent stage delta limit weight. Curve (a) represents the nominal configuration and is normally used in determining the ascent stage delta limit weight. To determine trade off capability for no ascent feed and/or balance couples off, curves (b), (c), and (d) are used.

5. Determine the New Ascent Stage Limit Weight

   After the ascent stage delta limit weight for the configuration desired is determined from step (4), it is added (positive or negative value) to the value used for the reference limit weight, which is defined in the specific vehicle appendix of the SODB. Therefore, the new ascent stage limit weight for the configuration desired = $\pm$ ascent stage delta limit weight + ascent stage reference limit weight.

6. Determination of Trade Off Value

   Trade off value of ascent feed and/or balance couple operation is determined as follows:

SCP NO. PROP 11-24 (cont)

(a) Balance Couple Trade Off

Determine the limit weight for the nominal configuration (balance couple with ascent feed open), and subtract that value from the case for unbalance couple with ascent feed. This difference is the trade off value for balance couple.

(b) Ascent Feed Effect

Determine the limit weight for the nominal configuration (balance couple and ascent feed open), and subtract that value from the case for balance couple and ascent feed closed. This difference is the trade off value for ascent feed.

(c) Balance Couple and Ascent Feed

Determine the limit weight for the nominal configuration (balance couple and ascent feed open) and subtract that value from the case for unbalance couple and ascent feed closed. This difference is the trade off value for balance couple and ascent feed.

S/C: EMU
DATE:
REV: PCN-14
ORIGINATOR: L. Minter
APPROVAL: H. H. Merritt

SCP NO. EMU 12-1

TITLE: APOLLO 17 EVA TRAVERSE CONSTRAINTS

PURPOSE: The purpose of this SCP is to explain Apollo 17 EVA traverse constraints and the technique employed in updating and utilizing these constraints in real-time. Prior to an EVA, traverse constraint profiles will be constructed to assure that the crewmen have sufficient consumables (OPS O_2, PLSS O_2, electrical power, and feedwater) to allow a safe return to the LM in case of a PLSS or LRV failure at any time during a traverse. Following is an explanation of typical constraint curves and how they are constructed pre-mission and updated in real-time. Also attached are some typical calculations using present consumable values (reference enclosure 1).

PROCEDURE: I. EVA Constraint Line Definitions (reference Figure 1).

1. The LRV/BSLSS/OPS(L) limit line ($D_{ROPS(L)}$) is drawn at the maximum LRV traverse distance for which a safe LRV return can be conducted utilizing the BSLSS, OPS (low flow), and LRV, considering a PLSS failure. This line is found by multiplying the return travel time (as afforded by the OPS) by the LRV contingency rate. Below is the equation for this line:

(1) LRV/BSLSS/OPS(L) = $D_{ROPS(L)}$ = $\left[\frac{\text{(OPS Loading - Residual) (lbs)}}{\text{(OPS Low Flow Rate) (lbs/hr)}}\right.$ - 100 M Walkback to LRV Time (hrs) - BSLSS Hookup Time (hrs) - Ingress Time (hrs)$\left.\right] \cdot \left[\text{LRV Contingency Rate (km/hr)}\right]$

Inserting present values into equation (1) gives:

$$D_{ROPS(L)} = \left(\frac{5.55 \text{ lbs}}{3.9 \text{ lbs/hr}} - 0.025 \text{ hr} - 0.083 \text{ hr} - 0.217 \text{ hr}\right) \cdot \left(7.3 \frac{\text{km}}{\text{hr}}\right) = \left(1.098\right) \cdot \left(7.3 \frac{\text{km}}{\text{hr}}\right) = 8.01 \text{ km}$$

Assuming the OPS lifetime has not changed, a new OPS low flow limit line can be determined for any LRV contingency rate by multiplying that rate by 1.098 hr.

2. If the BSLSS is not available (such as on a one-man EVA) or is inoperable for some reason, then the OPS must be used for crewman heat removal in the event of a PLSS failure. This results in the LRV/OPS (L,H) constraint of Figure 1. For this case the OPS low flow is used for 2 minutes to return to the LRV (133 meters), 2 minutes for LRV prep, and the LRV return drive time. OPS high flow is used for the ingress time. An arbitrary 10 minute pad is subtracted from the available drive time.

The equation for this line is:

(2) LRV/OPS(L,H) = $D_{ROPS(L,H)}$ = $\left[\frac{\text{(OPS Loading - High Flow Residual) (lbs) - (Ingress Time) (hrs)} \cdot \text{(OPS High Flow Rate) (lbs/hr)}}{\text{(OPS LOW Flow Rate) (lbs/hr)}}\right.$ - (Return to LRV and LRV Prep Time + Pad) (hrs)$\left.\right] \cdot \left[\text{LRV Contingency Rate (km/hr)}\right]$

Inserting present values gives:

$$D_{ROPS(L,H)} = \left[\frac{5.37 \text{ lbs} - (.217)\ (7.55) \text{ lbs}}{3.9 \text{ lbs/hr}} - 0.233 \text{ hr}\right] \cdot \left[7.3 \text{ km/hr}\right]$$

$$D_{ROPS(L,H)} = (0.723 \text{ hr})\ (7.3 \text{ km/hr}) = 5.28 \text{ km}$$

3. The Walking/BSLSS/OPS(L) constraint is applicable if the LRV is inoperable. For this walking traverse, the constraint is found by simply multiplying the contingency walk rate by the available OPS time in low flow.

(3) WALKING/BSLSS/OPS(L) = $D_{WOPS(L)}$ = $\left[\frac{\text{(OPS Loading - Residual) (lbs)}}{\text{(OPS Low Flow Rate) (lbs/hr)}} - \text{BSLSS Hookup time (hrs)} - \text{Ingress Time(hrs)}\right] \cdot \left[\text{Contingency Walk Rate}\right]$

Inserting present values, we have:

$D_{WOPS(L)} = (1.123 \text{ hr}) \cdot (3.6 \text{ km/hr}) = 4.04 \text{ km}$

4. The Walking/OPS(H) constraint line is to be used if both the LRV and the BSLSS are inoperable. The limiting factor for the WALKING/OPS(H) constraint is crewman heat storage instead of OPS lifetime. Considering an initial heat storage of 100 BTU and a maximum heat storage of 300 BTU, the $D_{WOPS(H)}$ line is at 0.9 km.

5. The PLSS Consumable Constraint line is drawn to assure the crewmen will have sufficient PLSS consumables (oxygen, electrical power, feedwater) to conduct a contingency walkback to the LM in case of an LRV failure, allowing time for LRV equipment assembly and LM ingress. (There are actually three consumable constraint lines although only one is indicated). The method for determining the consumable constraint line is as follows:

   (a) First find the constraint line intersection with the absissa (T_{max}).

   The equation for T_{max} is as follows:

   T_{max} (hrs) = $\frac{Q}{\dot{M}_N}$ (hrs) - LRV Equipment Assy Time (hrs) - Ingress time (hrs)

   Where Q = Consumable quantity usable for EVA

   $\dot{M}_N$ = Normal average consumable usage rate

   (b) Next find the slope of the consumable constraint line.

   Slope (km/hr) = $\left(\frac{\dot{M}_N}{\dot{M}_{CW}}\right) \cdot$ (Contingency Walk rate)

   Where $\dot{M}_{CW}$ = Contingency walking consumable usage rate (see (d)).

   (c) Next find the time at which the consumable constraint line intersects the LRV/BSLSS/OPS(L) line (T_I).

   T_I (hrs) = T_{max} (hrs) - $\frac{D_{ROPS(L)} \text{ (km)}}{\text{Slope (km/hr)}}$.

   (d) The constraint line is now found by drawing a straight line between the intersection (T_I) and T_{max}. If the crewmen are less than 1 hour walk time from the LM, their average contingency walk rate will be higher because of less fatigue (3.6 km/hr versus 2.7 km/hr). This causes the change of slope in the PLSS Consumable Constraint line. As seen in Figure 1, the upper portion of the PLSS Consumable Constraint line intersects the abissa at T_{max}. The slope and intersection point of the lower portion are found by the same equations as above ("b" and "c"), but by using the contingency walk and metabolic rates for walk times less than 1 hour, and substituting 3.6 km for $D_{ROPS(L)}$.

6. For the LRV/BSLSS/OPS(L) distance, the crewmen may walk only 100 m from the LRV since only 1½ minutes is included for walking back to the LRV in case of a PLSS failure. For progressively closer distances to the LM, the crewmen may traverse farther from the LRV, up to the LCRU communications range (approximately 1 km). This is illustrated by the Walking/LRV constraint line of Figure 1. If the distance from the LRV is greater than 670 meters, the BSLSS must be carried by the crewmen to insure not exceeding 300 BTU stored heat by a crewman operating in OPS low flow. To construct this line, $D'_{ROPS(L)}$ is found, and a line drawn between this point and the LRV/BSLSS/OPS(L) line for the specific LRV contingency return rate being considered. The equation for $D'_{ROPS(L)}$ is

$D'_{ROPS(L)}$ = $\left(\text{LRV Contingency Rate}\right) \cdot \left(\text{Usable OPS time} - \frac{1 \text{ km}}{\text{Contingency Walk Rate}}\right)$

After the Walking/LRV Constraint line is determined, the distance the crew can be away from the LRV is simply read from this line as a function of LRV distance from the LM (see Figure 1).

II. Real Time Constraint Line Updates

During Apollo 17 EVA's, PLSS Consumables (PC) will construct real-time plots of feedwater remaining, oxygen remaining, and amp-hours remaining versus EVA elapsed time. The profiles will enable PC to predict the possible EVA time remaining as constrained by consumables. If the real-time consumable plots indicate an abnormal consumable usage rate, PC will update the premission PLSS Consumable Constraint lines. The procedure used to accomplish this will now be discussed.

1. Considering the planned activities, PC will extend the real-time plot for the most constraining consumable to obtain the predicted EVA termination time (see Figure 2).

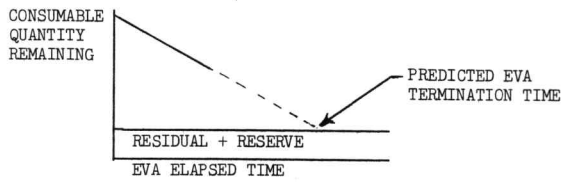


Figure 2: Real-time PLSS Consumable Projection

2. Subtracting 0.167 hour (10 minutes) for LRV equipment assembly and 0.217 hour (13 minutes) for LM ingress from the predicted EVA termination time gives the new T_{max} (see Figure 3).

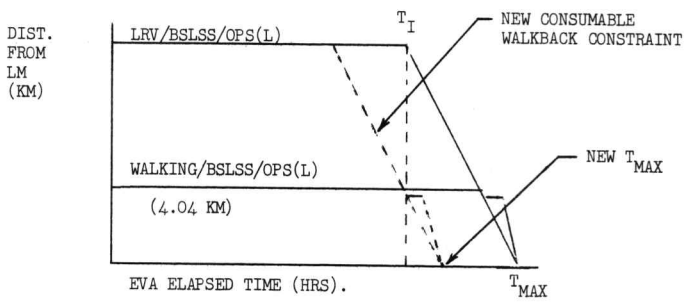


Figure 3: Altered Traverse Constraint Curve

3. The remainder of the constraint lines can now be constructed using the equations in Section I, paragraph 5.

A. Using example values, the PLSS O_2 walkback constraint line for EVA 1 can be calculated as follows:

(1) $\dot{M}_{NO2}$ = Normal O_2 usage rate (lb/hr)

$= \left(1.627 \times 10^{-4}\right) \cdot$ (Average Met Rate) + Leakage

$= \left(1.627 \times 10^{-4} \frac{lb}{BTU}\right) \cdot \left(984 \frac{BTU}{hr}\right) + 0.020$ lb/hr

$\dot{M}_{NO2}$ = 0.18 lb/hr

(2) $\dot{M}_{CO2}$ = Contingency O_2 usage rate (lb/hr)

$= \left(1.627 \times 10^{-4}\right) \cdot (1290) + 0.02$

$\dot{M}_{CO2}$ = 0.23 lb/hr for 2.7 km/hr

(3) $T_{max(O_2)} = \frac{Q_{O2}}{\dot{M}_{NO2}}$ - LRV Equip. Assy Time - Ingress Time

$= \frac{1.403 \text{ lb}}{0.18 \text{ lb/hr}} - 0.167 \text{ hr} - 0.217 \text{ hr}$

$T_{max(O_2)}$ = 7.42 hr = 7 hr 25 min

(4) $\text{Slope}_{(>1 \text{ hr})} = \frac{\dot{M}_{NO2}}{\dot{M}_{CO2}}$ (Contingency Walk Rate for walk time greater than 1 hr)

$= \left(\frac{0.18}{0.23}\right) \cdot (2.7)$

$\text{Slope}_{(>1 \text{ hr})}$ = 2.113 km/hr

(5) $T_{IO2} = T_{maxO2} - \frac{D_{ROPS(L)}}{\text{Slope}}$

$= 7.42 \text{ hr} - \frac{8.01 \text{ km}}{2.113 \text{ km/hr}}$

T_{IO2} = 3.63 hr = 3 hr 38 min

(6) Now the PLSS O2 walkback constraint for distances less than an hour away from the LM must be found

$\dot{M}_{CO2} = \left(1.627 \times 10^{-4}\right) \cdot (1560) + 0.02 = 0.274$ lb/hr

Contingency walk rate for walk time <1 hr = 3.6 km/hr

$\text{Slope}_{(<1 \text{ hr})} = \left(\frac{\dot{M}_{NO2}}{\dot{M}_{CO2}}\right) \cdot$ (Contingency Walk rate)

$= \left(\frac{0.18}{0.274}\right) \cdot (3.6 \text{ km/hr})$

$\text{Slope}_{(<1 \text{ hr})}$ = 2.365 km/hr

(7) For 3.6 km (1 hour walk time),

$$T'_{IO2} = T_{maxO2} - \frac{3.6 \text{ km}}{\text{Slope } (< 1 \text{ hr})}$$

$$= 7.42 \text{ hr} - \frac{3.6 \text{ km}}{2.365 \text{ km/hr}}$$

$$= 7.42 \text{ hr} - 1.52 \text{ hr}$$

$$T'_{IO2} = 5.9 \text{ hr} = 5 \text{ hr } 54 \text{ min}$$

B. The distance the crew can be away from the LRV is determined as follows:

(1) Given a distance from the LRV of 1000 meters, $D_{ROPS(L)}$ is found by,

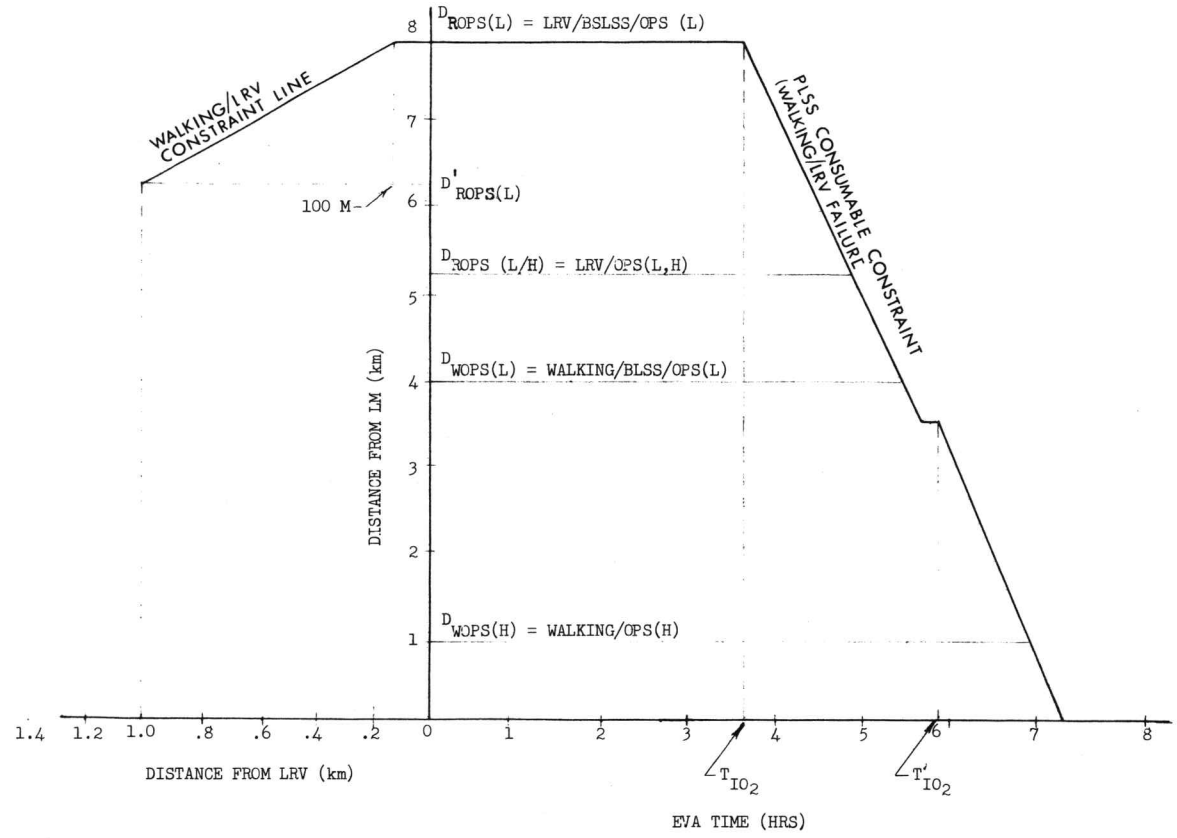
$$D'_{ROPS(L)} = \left[\text{LRV Contingency Rate}\right] \cdot \left[\frac{\text{(OPS Loading - Residual) (lbs)}}{\text{(OPS Low Flow Rate) (lbs/hr)}} - \text{BSLSS Hookup Time (hrs) - Ingress Time (hrs)} - \frac{\text{Distance from LRV}}{\text{Contingency Walk Rate}}\right]$$

$$D'_{ROPS(L)} = (7.3 \text{ km/hr}) \cdot \left(1.123 \text{ hr} - \frac{1.0 \text{ km}}{4.0 \text{ km/hr}}\right)$$

$$= (7.3)(0.873) \text{ km}$$

$$D'_{ROPS(L)} = 6.37 \text{ km}$$

(2) Now using the Walking/LRV Constraint line and assuming an LRV distance of 7.0 km from the LM, the distance the crew can be away from the LRV is 670 meters (from curve).


$D_{ROPS(L)}$ = LRV/BSLSS/OPS (L)
WALKING/LRV CONSTRAINT LINE
100 M
$D'_{ROPS(L)}$
$D_{ROPS\ (L/H)}$ = LRV/OPS(L,H)
$D_{WOPS(L)}$ = WALKING/BLSS/OPS(L)
$D_{WOPS(H)}$ = WALKING/OPS(H)
PLSS CONSUMABLE CONSTRAINT (WALKING/LRV FAILURE)
DISTANCE FROM LM (km)
DISTANCE FROM LRV (km)
EVA TIME (HRS)
T_{IO_2}
T'_{IO_2}
8
7
6
5
4
3
2
1
1.4 1.2 1.0 .8 .6 .4 .2 0 1 2 3 4 5 6 7 8

SCP NO. **PLSS 13 -1**

S/C: LM
DATE: 11/1/71
REVISION: PCN-11/New
ORIGINATOR: Larry Minter
APPROVAL:

TITLE: PLSS FEEDWATER REMAINING AND RATE CALCULATION

PROCEDURE: PLSS feedwater remaining and water usage rates are calculated in the RTCC utilizing the output from the metabolic rate computation, which is based on the LCG inlet and delta temperatures. These computations will be controlled from the SSR Aeromed console. PLSS Consumables (PC) will verify the MEDS for the initial feedwater quantities (LEM3811M/LEM3812M) and the heat leaks (LEM3815M/LEM3816M) with SURGEON/BTU. PC will also update the feedwater remaining trends for televiewer display on channel 64. Equations for usage rate and feedwater remaining are as follows:

FEEDWATER USAGE RATE (lbs/hr) (LEM9309C/LEM9311C)

$$\dot{M}_{fw} = \frac{(1.26) \cdot (MR) + EP + HL}{1038} \quad \frac{lbs}{hr}$$

FEEDWATER REMAINING (lbs) (LEM9310C/LEM9312C)

$$FW\ REM = FW_i - \left[(1.26) \cdot (MR) + EP + HL\right] \cdot \left[\frac{\Delta t}{3600 \cdot 1038}\right] \quad lbs,$$

where:

1. FW_i = initial feedwater quantity (lbs) (LEM3811M/LEM3812M). The first valid FW REM computed will become FW_i for the next FW REM computation. This same process will continue for the successive feedwater computations.
2. 1.26 = constant to account for heat generated by LiOH, which is based on a respiratory quotient of 0.90.
3. MR = crewman metabolic rate (BTU/hr) (LEM7305C/LEM7306C).
4. EP = PLSS battery electrical power = (battery current) · (battery voltage) · (3.413) BTU/hr (LEM9313C/LEM9314C).
5. HL = EMU heat leak rate (BTU/hr) (LEM3815M/LEM3816M).
6. Δt = computation update interval (sec) (AMD3000M). This Δt is the same as that used for computing metabolic rates.
7. 3600 = time conversion factor (sec/hr).
8. 1038 = heat removal capability of water (BTU/lb), assuming 85 percent sublimation and 15 percent vaporization.

SCP NO. PLSS 13-1b

This SCP deleted by PCN-8

SCP NO. **PLSS 13-2**

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: W. Bates
APPROVAL:

TITLE : **PLSS O_2 QUANTITY AND RATE CALCULATION**

PROCEDURE : PLSS 1/2 will verify the initial O_2 temperature (^oF) MED input with TELMU and request implementation by voice to COMPUTER TM on the RTCC TM loop. PLSS 1/2 will verify that TELEMU has SMEK initiated the RTCC special processing which includes the PLSS O_2 Quantity Calculation. PLSS CONSUMABLES will follow up with the standard MED change request form via P-tube to COMPUTER TM (Station 31). PLSS 1/2 will verify the initial change in pressure ΔM (PSIA) MED input with BTU. SURGEON/BTU will have complete control over SMEK initiation and termination of the PLSS O_2 Rate Calculation RTCC special processing. P-6 P-6

PLSS 1/2

C11Q/C21Q PLSS O_2 QTY (LEM 9301C/LEM 9305C)

1. Calculated values

   WO_2R = mass of O_2 remaining (lbs)

2. Telemetered inputs

   P = GT8182P/GT8282P PLSS O_2 PRESS (psi) P-6

3. Constants

   R = Gas constant = $48.28 \frac{ft - lb_f}{lb_m - {}^oR}$ P-6

   Z = Compressibility factor = $1.006-3.7(10^{-5})P$ (psi) P-8

   V = O_2 bottle volume (0.214 ft^3)

4. MED values

   T = Temperature (^oF) (LEM3801M/LEM3806M)

   K = Equation constant ($ft^2 - {}^oR$) (LEM3802M/LEM3807M)

   Equation for 1, 2, 3, and 4.

$$WO_2R = \frac{P_f V}{ZRTo_R} = \frac{P_f K}{ZTo_R}$$ P-11

   Conversion before computation:

   P_f (lbs/ft^2) = (144) P (psi)

   To_R = 459.69 + T (^oF)

C12Q/C22Q PLSS O_2 Consumption (LEM 7309C/LEM 7310C)

1. Calculated Values

WO_2 = Mass flow rate (lbs/hr) P-8

Z = Compressibility Factor = $1.006-3.7(10^{-5})P$ (psi)

ΔT = Elapsed time between average pressure computations (seconds)

ΔP = Difference in averaged pressures (PSIA)

P_B = Pressure base - basic average allocation for comparison (PSIA) updated each time computation updates.

2. Telemetered Inputs

P = GT8182P/GT8282P PLSS O_2 PRESS (PSIA)

3. Constants

C_1 = Conversion from PSIA to LBS MASS (1.23×10^{-3})

C_2 = Conversion of time from seconds to hours $\left(\frac{1}{3600}\right)$

4. MED Values

ΔM = Pressure difference used for regulating computation update rate (PSIA) (LEM 5521M)

5. SMEK Operations

To = Initial GET from MET * RATE * START * EMU 1/MET * RATE * START * EMU 2 (HR:MIN:SEC) P-6

Equation for 1 through 5

$$P_B = \frac{\sum P_i}{10 \text{ sec.}} \quad \text{at } T_B \text{ (LEM 7311C/LEM7312C)}$$

Where $\sum P_i$ = the summation of pressure values from PLSS O_2 PRESS telemetry information (GT8182P/GT8282P), and

P_B = initial pressure average based on a 10 second time frame, and

T_B = GET at which P_B is calculated.

Each P_i, where P_i = individual inputs from GT8182P/GT8282P, is then compared to P_B by the following:

$$|P_B - P_i| < 3\ \Delta M \qquad (\Delta M \text{ initially} = 15.0 \text{ PSIA})$$

The P_i's that satisfy $|P_B - P_i| < 3\ \Delta M$ in a 10 second period are used to calculate P_C, the current pressure average, and T_C, the GET corresponding to P_C.

When P_C and T_C are calculated, then $\Delta P = P_B - P_C$ is computed and compared to ΔM.

When $\Delta P \geq \Delta M$ (ΔM = LEM 5521M)

then $T_C - T_B = \Delta T$

Each time $\Delta P \geq \Delta M$ and ΔT is determined, P_B is replaced with the value of the current P_C and T_B is replaced with the value of the current T_C. P-6

From this information,

$$\dot{W}O_2 = \frac{C_1 \Delta P C_2}{Z \Delta T} = \frac{1.23 \times 10^{-3} (\Delta P) 3600}{\left[1.006 - 3.7 \times 10^{-5} (P_c)\right] \Delta T} \text{ (LEM 7309C/LEM 7310C)}$$ P-8

An additional check is provided on this output as only those values ≤ 0.66 LB/HR are utilized to update the real-time displays. P-6

NOTE

All MED values may be referenced on MSK 1628.

*

SCP NO. PLSS 13-3

S/C: EMU
DATE: 11/1/70
REV: PCN-6
ORIGINATOR: J. A. Joki
APPROVAL:

TITLE: **BATTERY AMP-HR CALCULATIONS**

PURPOSE: This SCP defines the procedure for determining the amp-hr remaining by special processing.

PROCEDURE:

A. PLSS 1/2 will verify the amp-hr MED input with TELMU and request implementation by voice to COMPUTER TM on the RTCC TM loop. PLSS 1/2 will verify that TELMU has SMEK initiated the RTCC special processing. PLSS 1/2 will follow up with the standard MED change request form via P-tube to COMPUTER TM (Station 31). P-3

B. PLSS 1/2 will update consumable trends for televiewer display on channel 64.

C. C16Q/C26Q AMP-HR REM (LEM9304C/LEM9308C)

1. Calculated values

   AH_R = AMP HR-REM (amp-hrs)

2. Telemetered inputs

   A = GT8140C/GT8240C PLSS BAT CUR (amp)

3. Constants - None P-3

4. MED values

   AH_T = AMP-HRS TOTAL (amp-hrs) (LEM3805M/LEM3810M-LIVE) (LEM3813M/LEM3814M-P/B)

5. SMEK operations

   t_o = Initial GET from EMU 1 * CALC * START or EMU 2 * CALC * START (hrs)**

Equation for 1, 2, 3, 4, and 5

$$AH_R = AH_T - (A)(\Delta t)$$

The value for AH_T is updated once per second by replacing it with the previous (one second earlier) value for AH_R [i.e., $AH_T(N+1) = AH_R(N)$].

NOTE

All MED values may be referenced on MSK 1628. P-6

**Δt = .0002783 hrs GET (1 second).

S/C: CSM 114
DATE: 11/1/72
REVISION: PCN-14/New
ORIGINATOR: L. Hirsh
APPROVAL: Paul M. Lowrey

SCP NO. CORO 16-1

TITLE: HEAT FLOW AND CONVECTION (HF AND C) INFLIGHT DEMONSTRATION

PURPOSE: The purpose of this SCP is to specify an operational support plan for the Apollo 17 HF&C Inflight Demonstration and present a single source reference of operational data.

BACKGROUND: The Apollo 14 HF&C Demonstration performed during January 1971 resulted in identifying surface tension-driven convection in one test, and apparent convection in a heated gas. The Apollo 17 HF&C Demonstration is designed to provide qualitative data which can be used to characterize the convection observed in the previous demonstration. Improved hardware, control and instrumentation are used on the Apollo 17 HF&C to achieve the qualitative information.

1. Operational Concept

The Apollo 17 HF&C Demonstration will be performed during translunar coast by the CMP. The primary test sequence, prior to PTC, is presently flight planned for 42:50 GET. The spacecraft rates will be nulled in all three axes ($\leq$ 0.005 degrees per second) in the manner normally accomplished prior to setting up PTC. The telemetry will be configured in the HBR mode and the high gain antenna (HGA) will be used. The HF&C hardware will be mounted to the left of panel 122 on the lower equipment bay along the X axis of the CM using bungee straps. The HF&C power cable will be connected to the utility outlet on panel 100 and the CM 16 mm Maurer DAC power cable will be connected to the utility outlet on panel 16. Preparation and performance of the primary test will take approximately 50 minutes and will be completed by 43:40 GET.

The secondary test sequence, during PTC, is flight planned from 45:20 to 46:00 GET. The test set-up is essentially the same as the primary test sequence. It is highly desirable to obtain HBR data during the HF&C Demonstration during PTC. INCO has agreed to accomplish this by using the 210 ft antenna at GDS to acquire HBR or using the DSE during the demonstration and later dumping the data. HBR is required to obtain high sample rate data on the SCS Body Rates and associated systems data for post mission data reduction.

The 150 ft, 16 mm sequenced film magazine and the small reference tab of liquid crystals taped to it will be stowed in the CM for return and it is planned to off-load the HF&C in the LM prior to LM jettison.

2. Constraints

1. Prior to PTC (attitide hold) - Spacecraft rates $\leq$ 0.005 degrees per sec.
2. Liquid dumps inhibited
3. RCS jets inhibited
4. Crew motion minimized

PROCEDURES:

1. The HF&C prime MOCR operator will be TELMU.
2. The HF&C prime SSR operator call sign will be INFLIGHT DEMO.
3. The SSR personnel will be located in the vehicle systems SSR at Console 33 (Booster Support Specialist Console)
4. The SSR personnel will use CCS positions 3084 and 3085 on Console 33 and will communicate with TELMU on either SSR*VEH SYS*2 or LM 1*TELCOM 1.
5. PI support personnel will be located at Console 33 also, and will be available to support the prime SSR operator.
6. Select MSK 690 to monitor CDU Body Rates.

7. Timeline

20:00 GET, 1653 CST - INFLIGHT DEMO, check with TELMU on next days flight activities with reference to HF&C on the flight plan.
36:00 GET, 0853 CST - INFLIGHT DEMO and PI support personnel - on console.
42:50 GET, - *Perform HF&C primary test
45:20 GET, - *Perform HF&C secondary test
47:00 GET, 1953 CST - INFLIGHT DEMO and PI obtain release from TELMU

*Follow crew checklists and monitor GOSS CONF

SYSTEMS DESCRIPTION: The HF&C demonstration concept is to observe the thermal behavior of fluids in specially selected "cell" configurations in low gravity by time-lapse photography. Each cell contains a small electric heater to heat the fluid being tested. Power for heating is obtained from the 28VDC spacecraft system. Data will be recorded by the onboard 16 mm DAC attached to the unit operating at a rate of one frame per second.

1. Radial Test Cell

The radial cell is a circular cell filled with argon gas used to test radial heat flow. The cell is a cylindrical dish with a small electric heater mounted in its center and the cell is covered by a plastic film coated with a liquid crystal material that changes color as it is heated. This film is divided into eight sectors, and different sectors are sensitive in different temperature ranges. The changing color patterns indicate the temperature distribution as it develops and is recorded by the camera.

2. Flow Pattern Test Cell

The flow pattern cell is designed to test the convective flow pattern induced in an oil film by thermally caused changes in surface tension. The cell consists essentially of a shallow aluminum dish with a heated bottom, into which thin layers of heavy oil, called Krytox, is introduced. The oil contains a suspension of aluminum powder which enable the oil flow patterns to be viewed. The window to this cell is opened during the tests so that the heat from the oil can be dissipated into the spacecraft atmosphere. The cell contains special baffles to properly distribute the fluid in a uniform layer over the pan.

3. Lineal Test Cell

The lineal cell on the right side of the unit is a transparent cyclinder with an electric heating element located in the end of the cylinder. This cell also contains Krytox. Strips with liquid crystal materials are located along the cylinder. The presence or absence of convection will be determined by the changing color pattern observed in the strips as heat flows in both directions from the heated zone. A few small particles are immersed in the Krytox for indication of any flow patterns that occur in the cell.

OPERATIONAL DATA:

1. Mechanical

	SN 002 (FLIGHT)	SN 003 (BACKUP FLIGHT)
SIZE	9" x 9" x 3.8"	9" x 9" x 3.8"
WT.	7 lb 14 oz.	7 lb 13.25 oz.

2. Electrical (characteristics the same for SN002 and 003) Ref: HF&C - ATP

A. HF&C Equipment

EXP/HEAT SELECT ROTARY POSITION	CURRENT (AMPS) AT 28 VDC	POWER (WATTS) AT 28 VDC
Light 1	0.183 ± 10 percent	5.13 ± 10 percent
Light 2	0.183 ± 10 percent	5.13 ± 10 percent
Light 3	0.183 ± 10 percent	5.13 ± 10 percent
Radial and Lineal	1.05 ± 10 percent*	29.40 ± 10 percent
Light 4	0.183 ± 10 percent	5.13 ± 10 percent
Flow Patt Lo	0.413 ± 10 percent	11.60 ± 10 percent
Flow Patt Hi	0.473 ± 10 percent	13.30 ± 10 percent
Light 5	0.183 ± 10 percent	5.13 ± 10 percent
Light 6	0.183 ± 10 percent	5.13 ± 10 percent

*Initial value - current decreases to 0.89 ± 10 percent after 5 minutes heating, power - 24.90 watts.

B. DAC Load - 0.6 amps at 28 VDC, REF: ODB

C. Panel 100 - UTILITY OUTLET - 2A breaker - MB

D. Panel 16 - UTILITY OUTLET - 2A breaker - MA

3. Temperature - Liquid Crystal Sensors

A. Cabin Temp

1	2
3	4

TEMP RANGE °C	CODE NO.
16.5 - 21.5	1
21 - 28	2
20 - 23	3
23 - 25.75	4

B. Panel Temp

1	2	3	4

TEMP RANGE °C	CODE NO.
16.5 - 21.5	1
21 - 28	2
20 - 23	3
23 - 25.75	4

C. Lineal Unit

1		2
3		
4	5	6
7	8	9

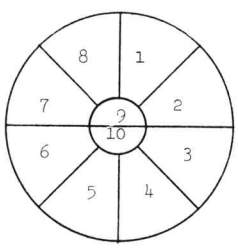
TEMP RANGE °C	CODE NO.
27 - 30	1
23 - 25.75	2
29.5 - 36.25	3
35 - 44	4
27 - 30	5
24 - 28.5	6
40 - 46.5	7
34.75- 37.75	8
32 - 35	9

D. Radial Unit

CASE

1	2	3	4

GAS



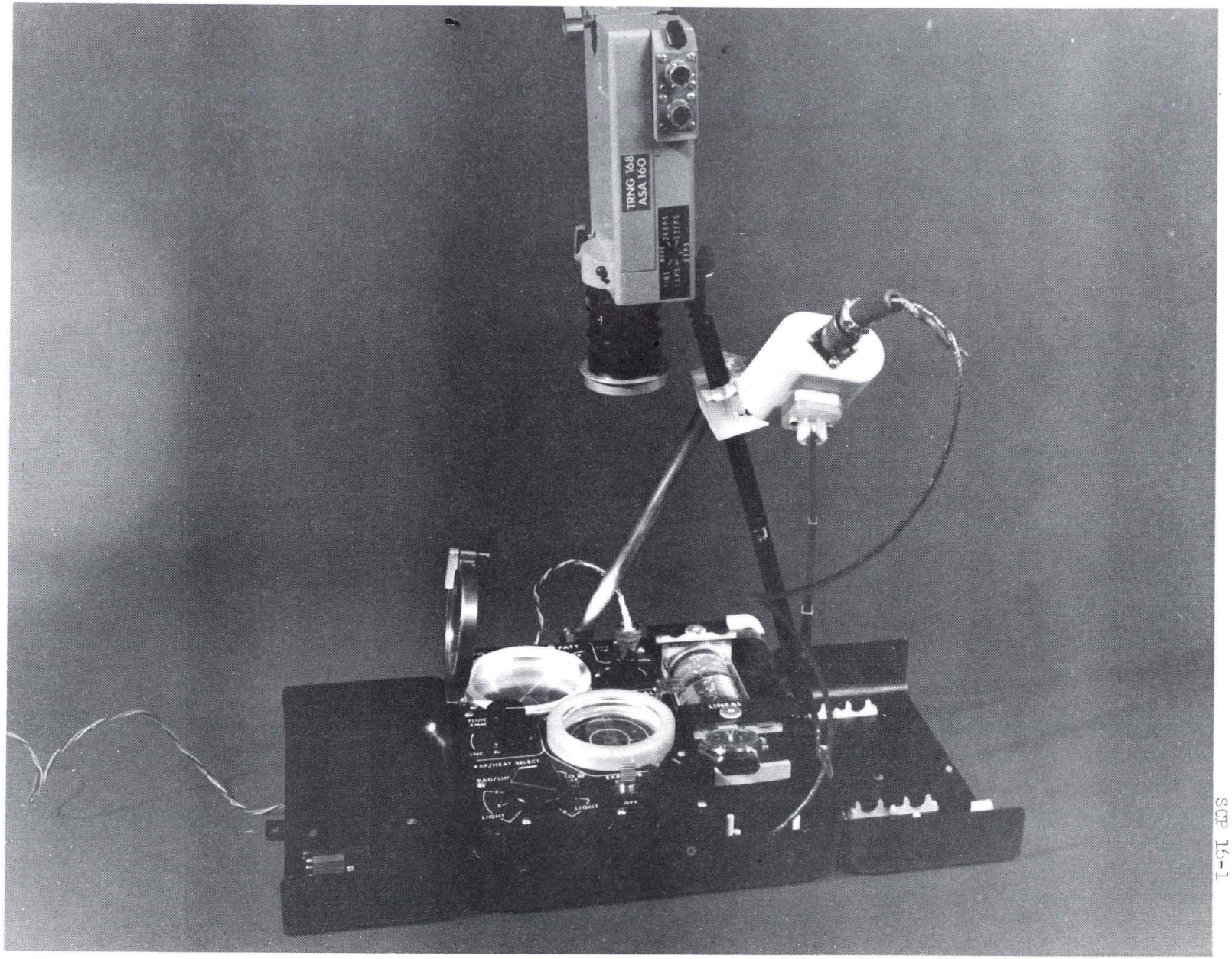
TEMP RANGE °C	CODE NO.
16.5 - 21.5	1
21 - 28	2
29.5 - 36.25	3
35 - 44	4
23 - 25.75	1
34.75 - 37.75	2
24 - 28.5	3
27 - 30	4
32 - 35	5
34.75 - 37.75	6
35 - 44	7
40 - 46.5	8
29.5 - 36.25	9
40 - 46.5	10

E. Flow Patt

CASE

1	2	3	4

TEMP RANGE °C	CODE NO.
16.5 - 21.5	1
21 - 28	2
29.5 - 36.25	3
35 - 44	4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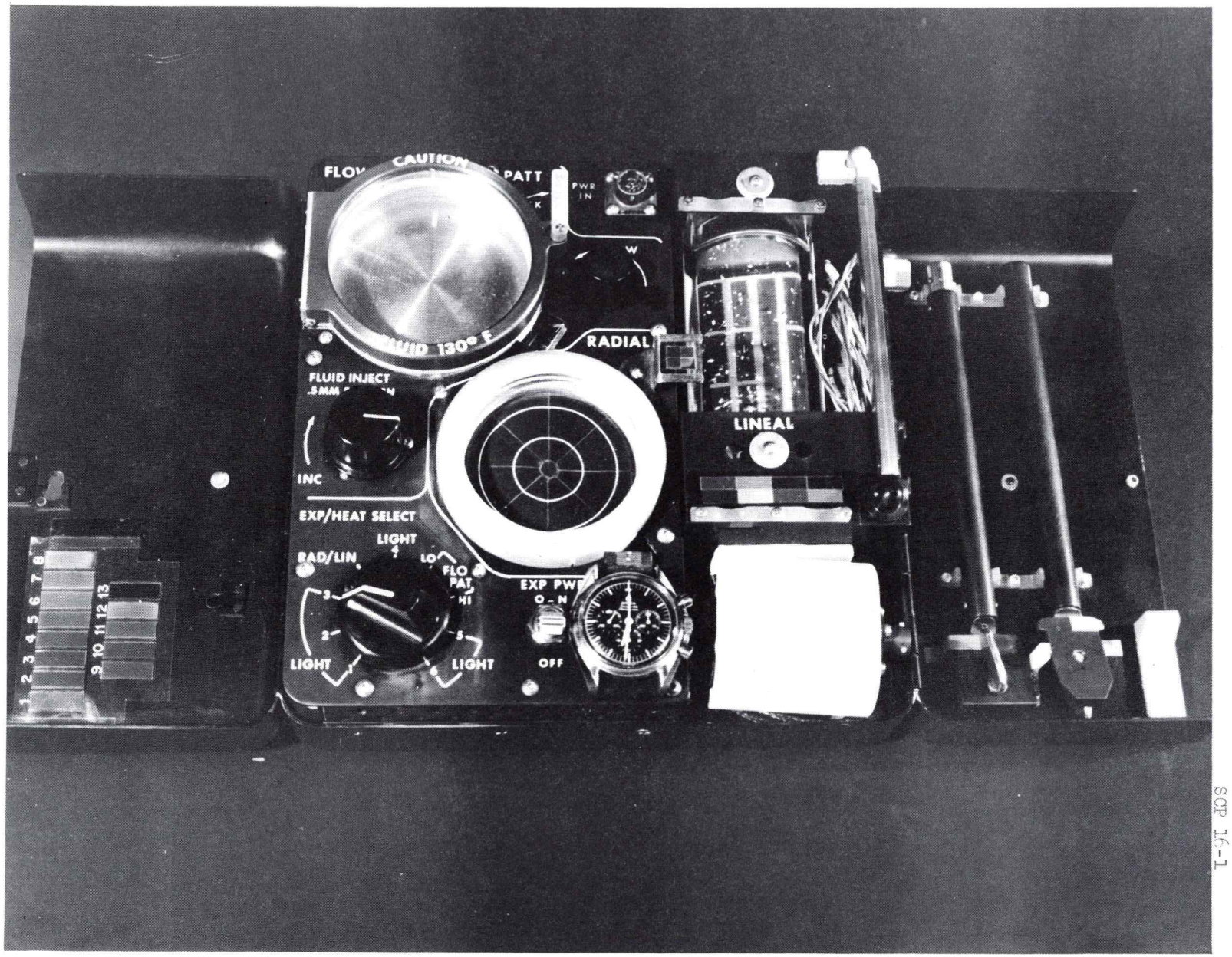
ASA 160
EXP/HEAT SELECT
RAD/LIN
LIGHT
LIGHT
OFF


CAUTION
PATT
PWR IN
W
RADIAL
FLUID INJECT
INC
LINEAL
EXP/HEAT SELECT
LIGHT
RAD/LIN
LO
FLO PAT
HI
EXP PWR
O - N
LIGHT
LIGHT
OFF
1 2 3 4 5 6 7 8 9 10 11 12 13

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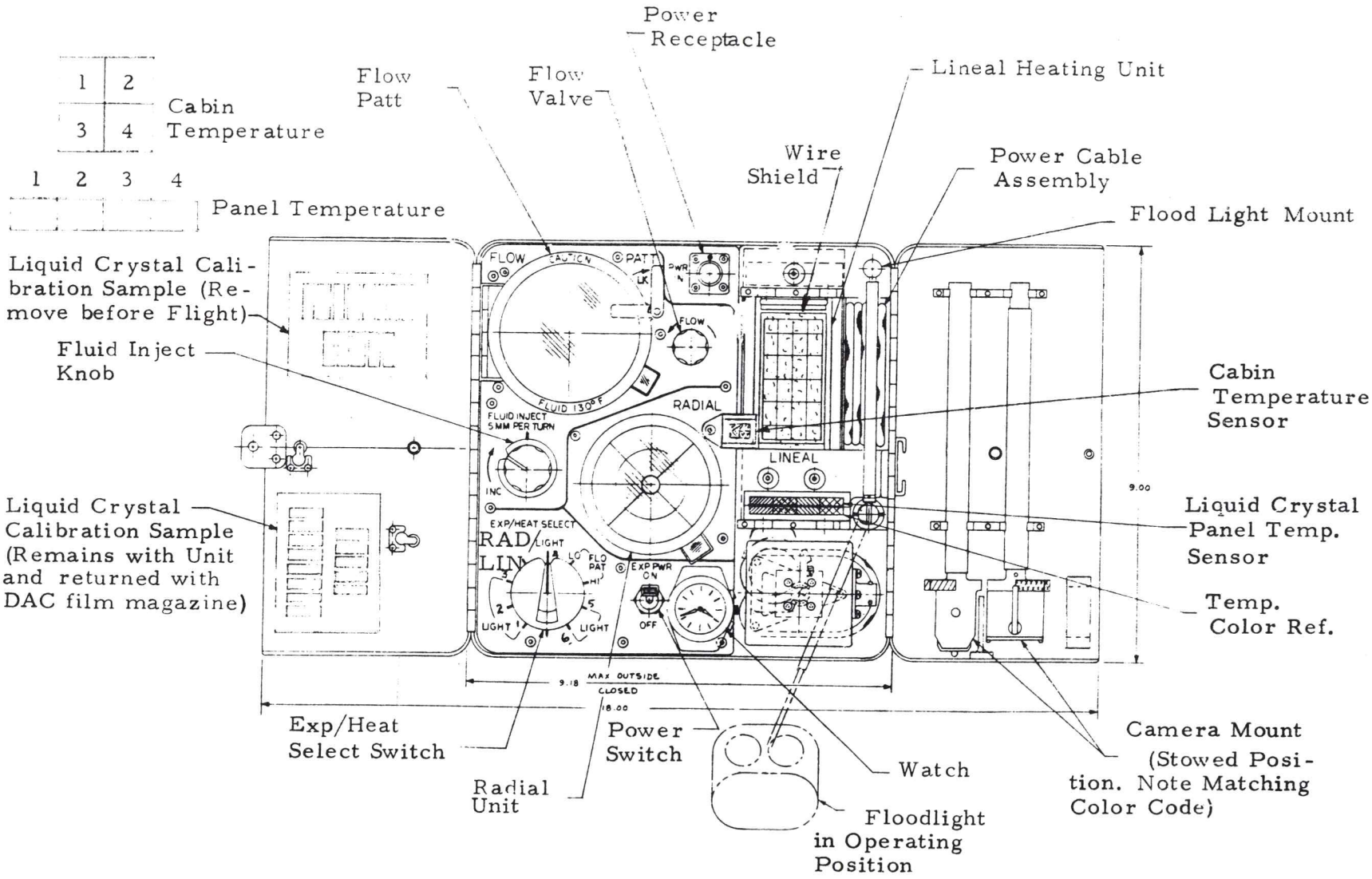

Fig. 2 - Panel Face of Heat Flow and Convection Apparatus (Apollo 17)

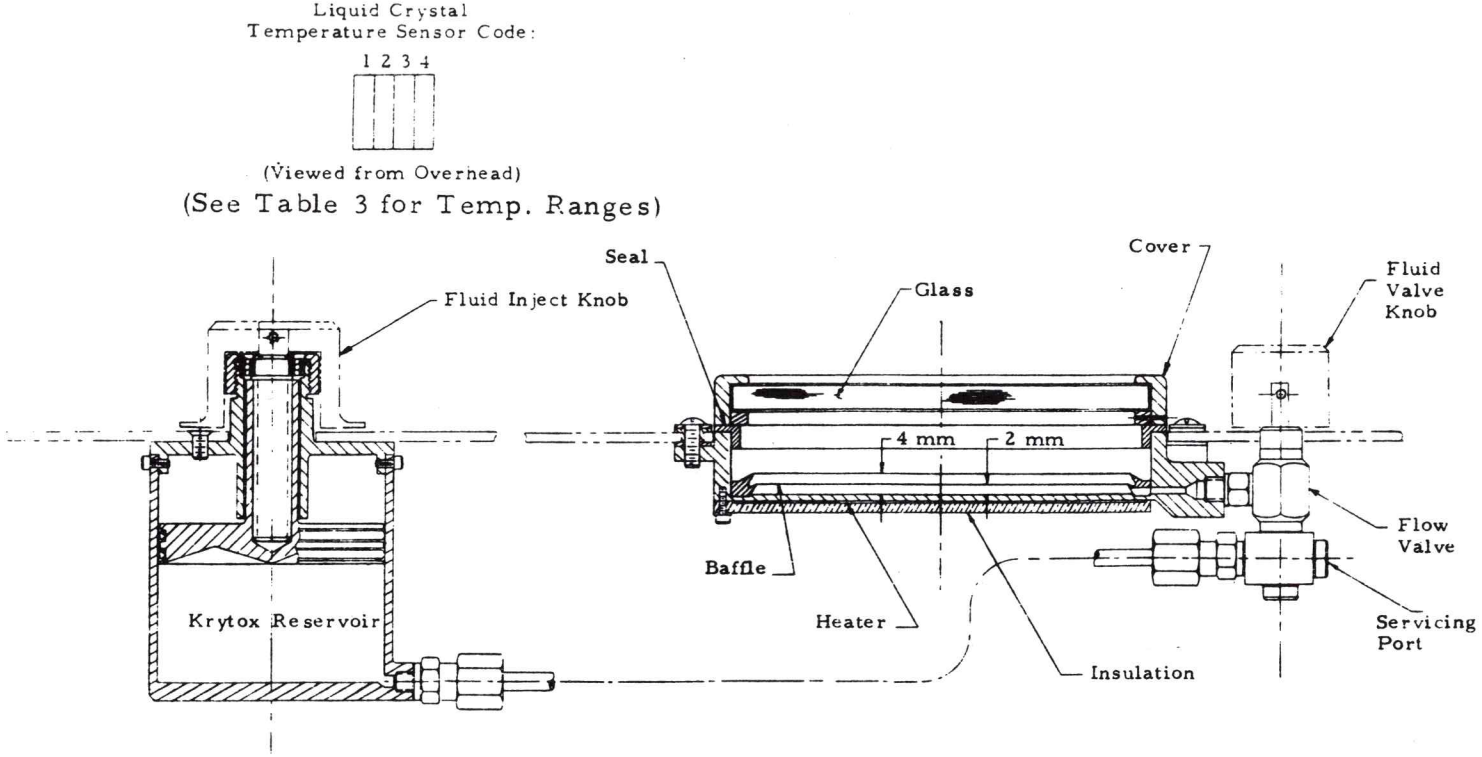

Fig. 3 - Flow Pattern Unit (Apollo 17)

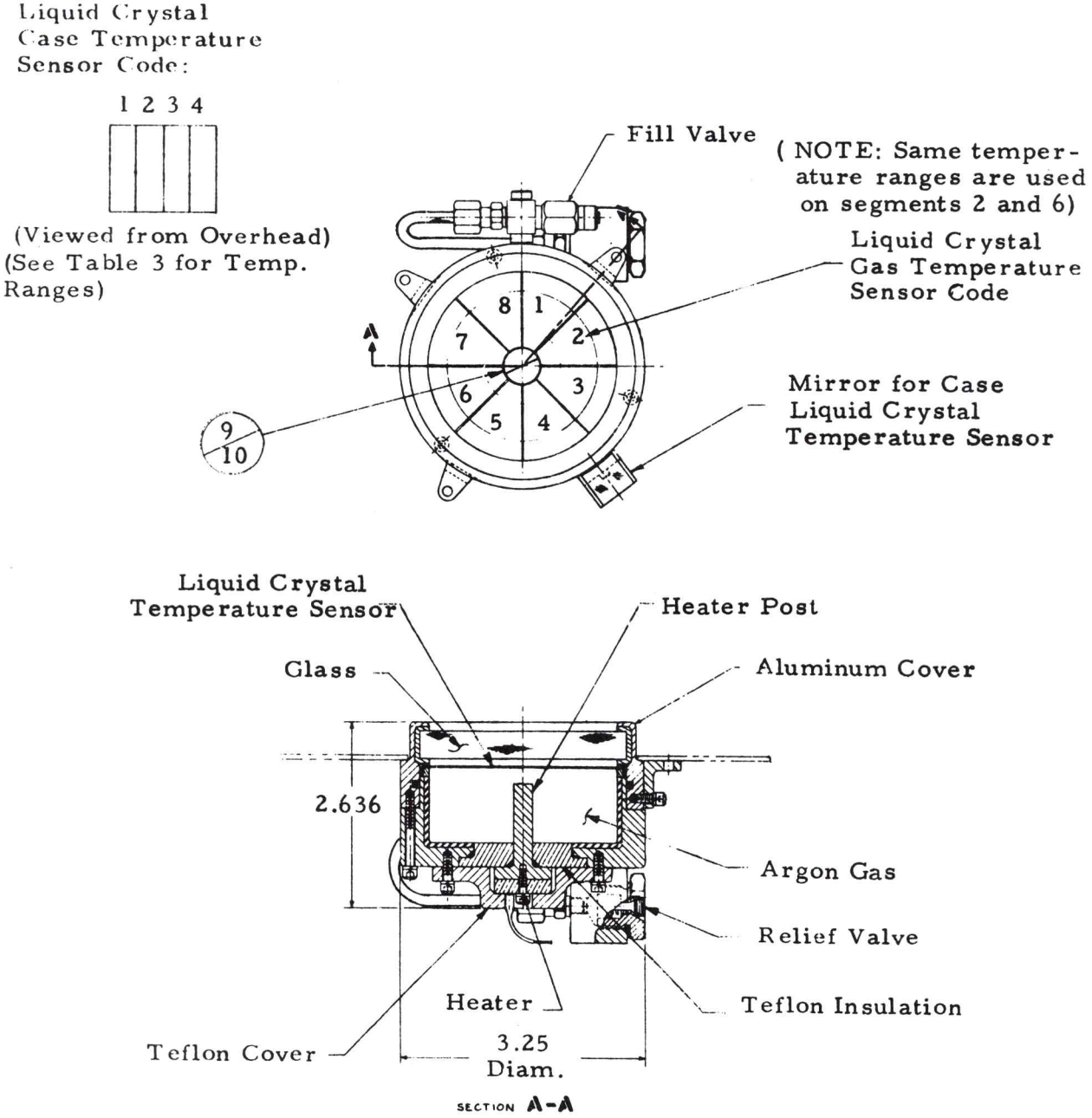

Fig. 4 - Radial Heating Unit (Apollo 17)

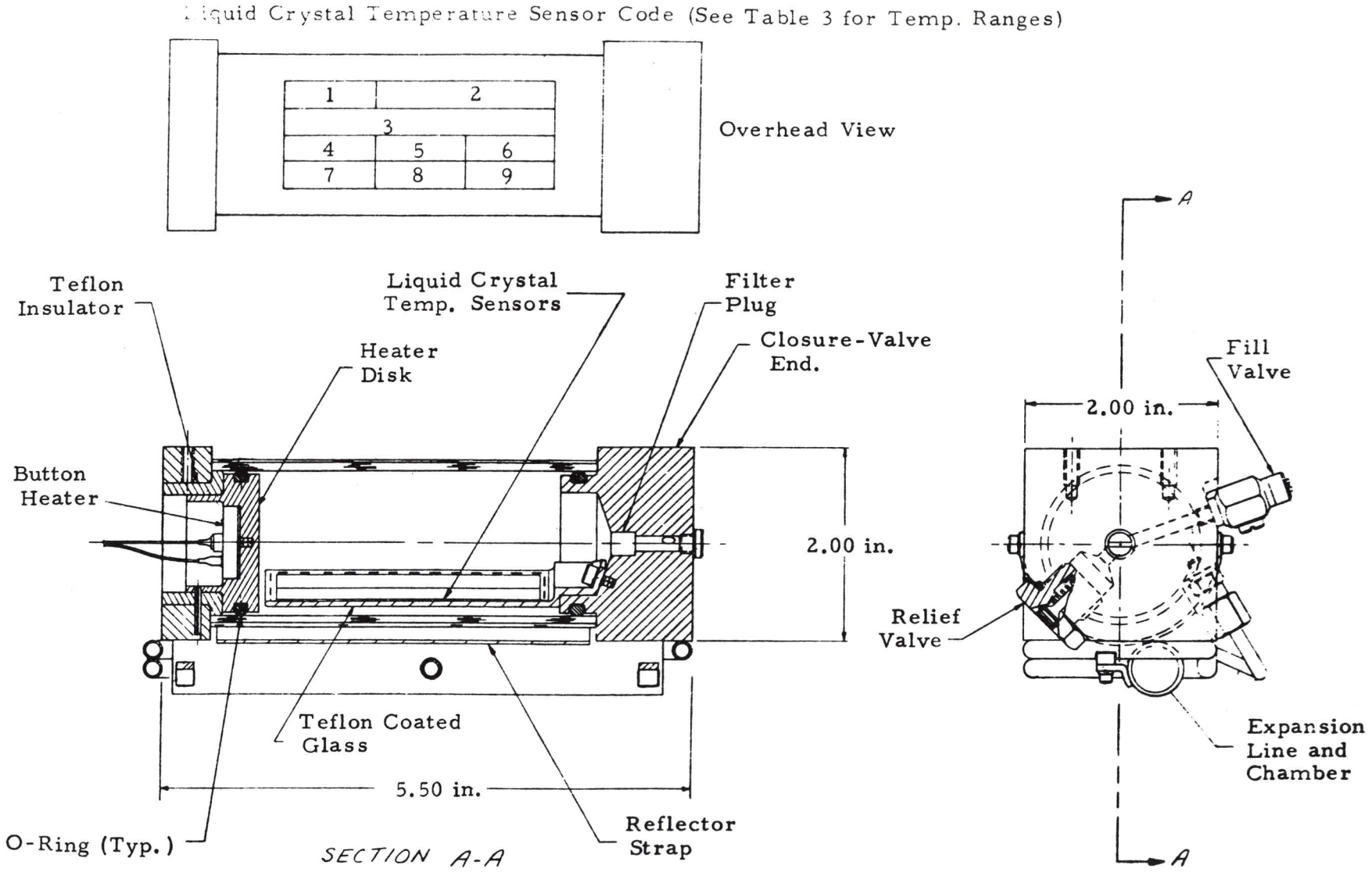

Fig. 5 - Lineal Uniting Unit (Apollo 17)

NASA — MSC

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			/1/71
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SB NO. **GEN 1-1**

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: J. Knight
APPROVAL: James E. Hannigan

TITLE : **TELMU CONSUMABLES**

REFERENCE : Descent Battery Spec: LSP 390-22B, 8-25-66

Ascent Battery Spec: LSP 390-21B, 8-29-66

BACKGROUND: A. Electrical Power P-6

1. Total Loaded:

   a. Descent - Each descent battery shall be capable of a discharge of 25 amps at 28.0 volts minimum for 16.6 hours at 80°F, or 415 ampere-hours total. With five descent batteries, the total minimum guaranteed descent power is 2075 ampere-hours. P-8

   b. Ascent - Each ascent battery shall be capable of a discharge of 50 amps at 28.0 volts minimum for 5.92 hours at 80°F, or 296 ampere-hours. With two ascent batteries, the total minimum guaranteed ascent power is 592 ampere-hours.

   c. Data pertaining to the variations of descent and ascent battery capacity due to different discharge rates and temperatures is available in the SODB.

2. Unusables:

Because the ampere-hours consumed are calculated on the ground from the TM currents, there is an inherent source of error which is the TM inaccuracy of the current measurement.

There are two factors which must be considered when computing descent ampere-hour unusables which are attributed to TM inaccuracy. These two factors are the current measurement range and the internal ECA temperature. The TM inaccuracy associated with individual descent batteries is 0.3 amperes in the 3-12 ampere range for an internal ECA temperature of less than 75° F, and 0.55 amperes in the 3-12 ampere range for an internal ECA temperature of greater than 75° F. The TM inaccuracy is 0.95 amperes for any measurement outside the 3-12 ampere range regardless of the ECA temperature. The TM inaccuracy associated with the individual ascent battery is 1.9 amperes. P-12

The descent and ascent TM inaccuracies are computed independently by RSSing the individual TM inaccuracy based on the number of descent and/or ascent batteries on line. The TM inaccuracy for each configuration is shown in Table I.

TABLE I - DESCENT TM INACCURACY

No. of Descent Batteries on line	TM Inaccuracy (3-12 Ampere Range) <75°F	>75°F	TM Inaccuracy Outside 3-12 amp range
1	0.3	0.55	0.95
2	0.42	0.78	1.34
3	0.52	0.95	1.64
4	0.60	1.10	1.90

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Ascent TM Inaccuracy

No. of Ascent Batteries on line	TM Inaccuracy
1	1.9
2	2.69

The descent and ascent unusable is determined by multiplying the TM inaccuracy for each battery configuration by the number of hours in the respective configuration.

MSC Form 887A (Mar 65)

3. Example calculation for unusable:

		DAH
a.	1 hour with 2 descent batteries on line - 1 X 0.42 =	0.42
b.	48 hours with 3 descent batteries on line - 48 X 0.52 =	24.96
c.	30 hours with 4 descent batteries on line - 30 X 0.60 =	18.00
	TOTAL	43.38

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		AAH
d.	8 hours with 2 ascent batteries on line - 8 X 2.69 =	21.52
e.	1 hour with 1 ascent battery on line - 1 X 1.9 =	1.90
	TOTAL	23.42

4. Margin:

It is undesirable to plan use of the entire expected available electrical power since there are other factors which affect the mission requirements. While extreme effort is exercised to detail the Flight Plan and Crew Checklists, there are frequent deviations from the planned timeline due to a variety of unforeseen circumstances. These factors result in delays and additional time is devoted to a portion of the checklist, and in some instances a specific phase may be completed earlier to permit additional time for another phase of the mission, i.e., reduce the rest period to allow for more EVA preparation time. A margin of approximately 10% of total electrical energy is utilized in mission planning to allow for deviations. There is no fixed margin constraint and each mission plan is individually judged adequate or inadequate.

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B. Environmental Control

1. Total Loaded

a. Descent

(1) The descent H_2O tanks will be loaded to predetermined values to provide water for crew consumption, evaporative cooling, fire fighting, and PLSS resupply. The exact amount loaded is mission dependent and is based on MPAD mission analysis.

(2) The descent GOX tanks will be loaded to approximately 45 pounds each.

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b. Ascent

(1) Each of the two ascent H_2O tanks will be loaded with 42.5 pounds of H_2O for a total of 85.0 pounds of ascent H_2O.

(2) Each of the two ascent GOX tanks will be loaded with 2.4 pounds of O_2, for a total of 4.8 pounds of ascent O_2.

2. Unusables

The unusables for H_2O consist of tank residuals, loading error and TM inaccuracy, of which the latter two are mission dependent. The unusables for O_2 are residuals and TM inaccuracy with an additional possible unusable based on spec tank leakage. These values are shown below.

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TABLE II - H_2O and O_2 UNUSABLES

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	DESCENT TOTAL		ASCENT TOTAL	
	H_2O	O_2	H_2O	O_2
Loading Error		-----	0.72	-----
Residual	8.07 lbs	1.68 lbs	1.7 lbs	0.28
TM Inaccuracy	**	*1.09 lbs/tank	*4.8 lbs	0.114 lbs
Tank Leakage	----	2.64 lbs	-----	0.34 lbs

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* RSS values: to obtain single tank value, divide by 1.414.
** See SCP 6-5 for descent H_2O TM inaccuracy.

3. Dispersion

For premission planning computations, an arbitrary 5 percent of the total O_2 and H_2O used is considered necessary to account for high metabolic loads, inflight checkouts of pressure regulators, slightly high leak rates, and for unexpected structural/thermal loads.

4. LM/EMU Consumables

Table II gives a detailed breakdown of LM ECS/EMU consumables.

TABLE II. - LM/EMU ECS CONSUMABLES

CONSUMABLE	LOCATION	VOLUME /TANK	DESIGN LOADED /TANK	NORMAL LOADED /TANK	TM ERROR	UNUSABLE (TM + RESIDUAL)	USABLE	FLOW RATE	TM
OXYGEN (O_2)	2 DESCENT TANKS QUAD 3, QUAD 4 LUNAR MODULE	2.981 FT^3	3000 PSIA	46.7 LBS EACH AT 2610 PSIA, 70° F	1.09 LBS/TANK	1.93 LBS/TANK	44.77 LBS	CABIN MODE 0.25 TO 0.37 LB/HR EGRESS MODE 0.25 LB/HR	GF0584P GF3584P
	2 ASCENT TANKS AFT EQUIPMENT BAY LUNAR MODULE	0.495 FT^3	1000 PSIA	2.43 LBS AT 854 PSIA, 70° F	0.057 LBS/TANK	.257 LBS/TANK AT 50 PSIA	2.17 LBS/TANK	CABIN MODE 0.25 TO 0.37 LB/HR EGRESS MODE 0.25 LB/HR	GF3582P GF3583P
	PRIMARY OXYGEN SUBSYSTEM (POS) ⊙ PLSS	0.219 FT^3	1410 ±30 PSIA	1.860 LBS AT 1420 PSIA, 70° F / LM RECHARGE: 1.810 LBS AT 1395 PSIA, 70° F	0.060 LBS 48 PSIA AT 70°F	0.240 LBS AT 193 PSIA 70° F	⑨ EVA 1 = 1.498 LBS EVA 2 and 3 = 1.448 LBS	EMU 0.07 TO 2.0 LBS/HR (REGULATED) 0.18 LBS/HR NOMINAL	GT8182P GT8282P
WATER (H_2O)	2 DESCENT TANKS QUAD 2, QUAD 4 LUNAR MODULE	7.13 FT^3	GN_2 PRECHARGE - 50 PSIA AT 100°F H_2O - 333LB	△	△	△ + 4.04 LBS/TANK	△	3-8 LBS/HR	GF0500P GF4500P
	2 ASCENT TANKS I R/H 2 L/H LUNAR MODULE	0.91 FT^3	GN_2 PRECHARGE - 50 PSIA AT 100°F H_2O - 42.5 LB	42.5 LBS	3.39 LBS/TANK 4.8 LBS TOTAL RSS	4.24 LB/TANK 6.5 LBS TOTAL RSS	38.26 LB/TANK 78.5 LBS TOTAL	3-8 LBS/HR	GF4502P GF4503P
	PLSS FEED WATER ⊙ SUPPLY	0.191 FT^3 (0.136 + 0.055)	12.05 ±0.25 LBS	12.2 LBS MAX ③ / 12.2 LBS ⑦	NA	1.04 LBS ⑩ / 0.91 LBS	11.16 LBS ③ / 11.59 LBS	0.75 TO 3.0 LBS/HR 1.4 LB/HR NOMINAL	GT8110 GT8210
LIOH	LM PRIMARY CARTRIDGE	NA	NA	5.25 LBS	NA	NA	CO_2 EXTRACTION LIFETIME - 41 MAN-HRS	NA	GF1521P CO_2 PARTIAL PRESS LEVEL
	LM SECONDARY/ PLSS CARTRIDGE	NA	3.25 ±0.13LBS	3.22 LBS	NA	NA	CO_2 EXTRACTION LIFETIME LM - 18 MAN-HRS PLSS 8.5 HRS AT 1050 BTU	NA	LM SECONDARY SELECT GF1241X GT8175P GF1521P GT8275P
OXYGEN PURGE SYSTEM	SRC STOWAGE COMPARTMENT	0.186 FT^3	5880 ± 500 PSIA	5.78 LBS AT 5880 PSIA, 70° F	0.312 LBS 300 PSIA (GAGE ERROR)	0.106 LBS ⑤ / ④ 0.353 LBS / 0.166 LBS ⑧	5.61 LBS / ④ 5.37 LBS ⑤ / 5.55 LBS ⑧	≥ 240 LBS/HRS / ⑥ 0.07 TO 8.0 LBS/HR (REGULATED)	NA

CONFIGURATION	VOLUME	NORMAL PRESSURE	LEAK RATE	REPRESSURIZATION TIME	DEPRESSURIZATION TIME	METABOLIC CONSUMPTION	METABOLIC RATE	NORMAL TEMPERATURE	TM
CABIN MODE	195.0 FT^3	4.8 ±.2 PSIA	0.20 LB/HR SPEC	0 TO 4.6 PSIA 2 MIN > 350 PSIA (DESCENT O_2 TANKS ONLY)	*ONE VALVE 240 SEC TWO VALVES 105 SEC *FILTER	0.085 LBS/MAN-HR	520 BTU/MAN-HR	55° - 70° F	GF1651T GF3571P
SUIT LOOP	0.58 FT^3 W/O SUITS 2.9 FT^3 W/SUITS	LM EGRESS MODE 3.8 ±.2 PSIA / EMU 3.7± .3 PSIA	SUIT LOOP 0.01 LBS/HR / SUITS 0.035 LBS/HR-SUIT	SUIT CIRCUIT <2 MIN (MAX) ONE REGULATOR	NA	SUIT O_2 FLOW EGRESS MODE 30 LB/HR CABIN MODE 42 LB/HR	520-560 BTU/MAN-HR *1050 BTU/MAN-HR *EVA	55° - 70° F	GF1281T GF1301P

△ - MISSION DEPENDENT

⊙ - RECHARGE STATION LM CABIN FLOOR

① I DELETE ALLOWANCE FOR VENTING
② DELETED

③ PLSS TOTAL H_2O AVAILABLE IS 12.5 LBS WHICH INCLUDES 0.3 LB LEFT OVER SLAVE H_2O

④ MAKE UP (100 PSIA AT 70°F)

⑤ HIGH PURGE MODE 500 PSIA AT -40°F (SPEC)

⑥ UNRESTRICTED (OPS) FLOW AT 5880 PSIA

⑧ LOW PURGE MODE 300 PSIA AT -40°F (SPEC)

⑦ DUE TO VENTING 12.8 LBS RECHARGE H_2O IS REQUIRED FROM LM

⑨ 0.122 LBS (95 PSIA) HAS BEEN SUBTRACTED FOR EMU PRESSURIZATION (70 PSIA) AND LM REPRESS (25 PSIA)

⑩ 1.04 LBS INCLUDES 0.13 LBS TRANSPORT LOOP MAKEUP FOR EVA 1.

PCN-14

PCN-14

SB NO. GEN 1-1
PCN 14

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S/C : LM
DATE : 11/1/70
REV : PCN -6/NEW
ORIGINATOR: Jack Knight
APPROVAL :

SB NO. GEN 1-2

PRESSURE DEFINITIONS

1. All enclosed volumes which are to be subjected to delta pressure environments are tested to pressure envelopes based on the maximum expected operating pressure (MEOP) or, as sometimes referred to, maximum working pressure.

2. There are several terms which are associated with the testing of these vessels:

a. MEOP or Maximum Working Pressure - The maximum pressure the vessel (tank, pipe, regulator, etc) will be subjected to during ground testing and flight.

b. Proof Pressure - Generally, but not always equal to 1.33 times the MEOP. Some components have proof pressures of anywhere from 1.5 to 20 times the MEOP. This value is imposed on the components during acceptance testing prior to flight. Proof pressure is generally maintained for 1 to 2 minutes and does not result in any deformation of the component.

c. Burst or Ultimate Pressure - Generally, but not always equal to 2 times the MEOP. Some components have burst pressures of anywhere from 1.5 to 35 times the MEOP. This value is imposed on one or more of a type of component; it means only that the component may be deformed; structural failure at this pressure is not acceptable. These vessels are not, of course, used for flight purposes.

3. Examples

SUIT CIRCUIT ASSEMBLY	MEOP	PROOF PRESSURE	BURST PRESSURE
Gas	4.8 PSIG	6.4 PSIG	9.6 PSIG
H_2O	7.2 PSIG	10.6 PSIG	14.5 PSIG
GLYCOL	47.5 PSIG	60.0 PSIG	90.0 PSIG
O_2	1100.0 PSIG	1465.0 PSIG	2200.0 PSIG
GLYCOL LOOP	47.5 PSIG	60.0 PSIG	90.0 PSIG
GOX TANK			
Ascent	1000.0 PSIG	1330.0 PSIG	1500.0 PSIG
Descent	3000.0 PSIG	4120.0 PSIG	4700.0 PSIG
H_2O TANK			
Ascent	50.0 PSID	64.0 PSID	96.4 PSID
Descent	50.0 PSID	64.0 PSID	96.4 PSID
CABIN	4.8 PSIG	7.8 PSIG	11.6 PSIG
DPS			
SHe	1710 PSIG	2274 PSIG	3420 PSIG
Ambient He	1750 PSIG	2325 PSIG	2622 PSIG
Prop	253 PSIG	360 PSIG	405 PSIG
APS			
He	3250 PSIG	4660 PSIG	5250 PSIG
Prop	203 PSIG	333 PSIG	375 PSIG
RCS			
He	3500 PSIG	4655 PSIG	7000 PSIG
Prop	194 PSIG	333 PSIG	375 PSIG

4. Fracture Mechanics is also a term frequently encountered in discussions of proof and burst pressures. Briefly, fracture mechanics consider an assumed flaw size in the vessel, the specific fluid contained in the vessel, the number of pressure cycles imposed on the vessel (Vessel History), and statistically relates these with a pressure-temperature relationship to predict the point at which the tank will fail. The examples given above are specification values at ambient or near-ambient temperatures (up to 160°F) and therefore do not necessarily reflect fracture mechanics limits.

SB NO. **EPS 2-1**

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: R. Heselmeyer
APPROVAL: William L. Peters

TITLE: **LM INVERTER CONFIGURATION AND LOADS**

REFERENCES:
A. EPS Level III Drawings: LDW 390-54000
B. ASPO-RQAD Problem Tracking List 1/12/68
C. Inverter Spec: LSP 390-6D 11/4/66
D. FCR J-11 1/26/66
E. LLR 390-91 6/6/66
F. LSP-370-2H 9-4-70
G. LSP-350-201C 5-5-67
H. LSP-350-401C 12-16-66
I. LSP-350-307D 9-24-67

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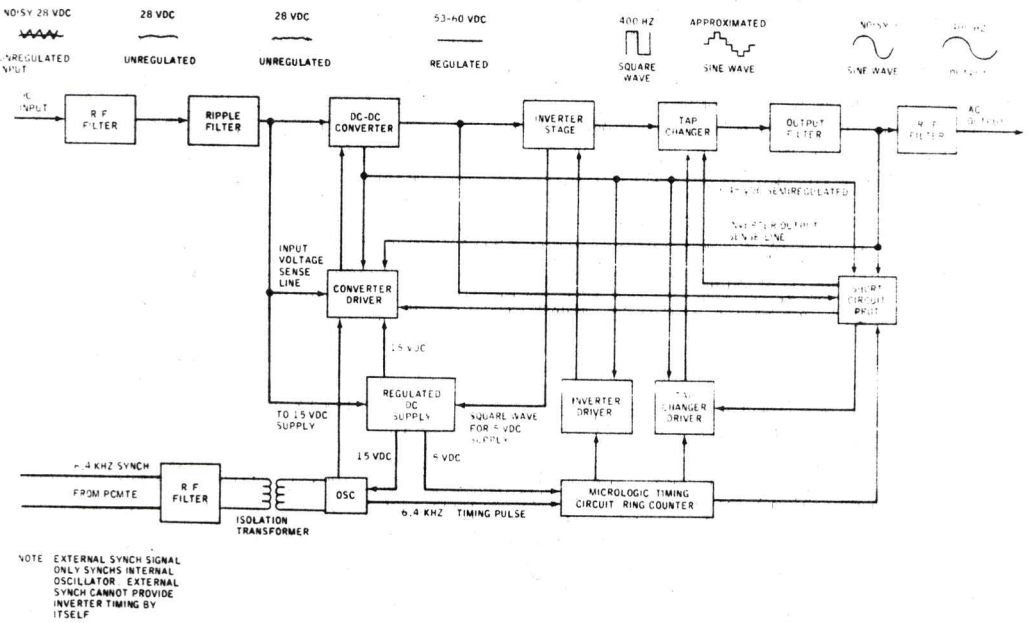
BACKGROUND:
A. Every LM has two identical, independent inverters onboard. Either Inverter 1, powered from the CDR Bus, or Inverter 2, powered from the LMP Bus, can be selected by the Inverter Switch on Panel 14 to power the split ac buses. Both inverters, however, cannot be selected simultaneously. Each inverter accepts a 28 Vdc input and is capable of supplying 117 Vac, 400 Hz to a 350-watt continuous load, or 525 watts for 10 minutes. The inverters will also automatically limit the maximum current to a short circuit to approximately 10 amps for 20 seconds without internal damage. Maximum warmup time is 5 seconds; however, testing has shown nominal outputs immediately after an inverter has been placed online.

B. Also supplied as an input is a 6.4 kHz timing pulse from the PCMTEA to sync an oscillator in each inverter. With this timing signal present, the output frequency will be 400 Hz ± 0.1 percent. If the timing signal is lost, the oscillator will be in the free running mode, and the output frequency may vary as much as 400 ± 10 Hz. Test results indicate, however, that in general the frequency in the free running mode will be 400 ± 1 Hz.

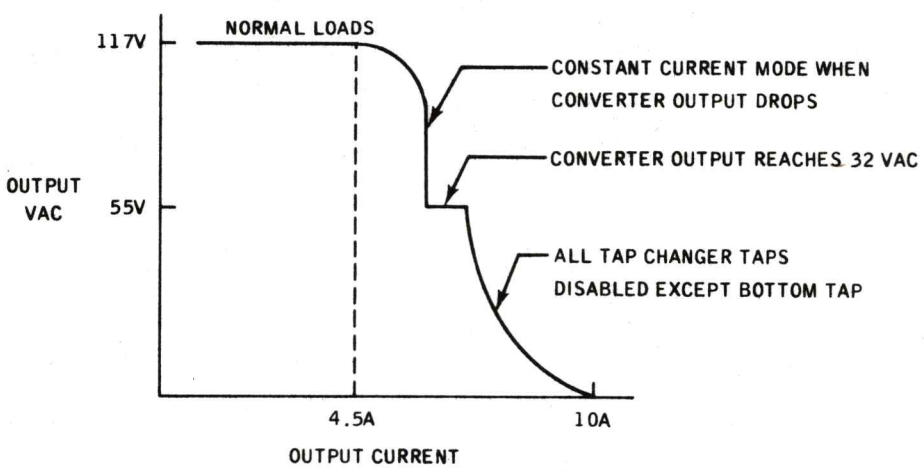
C. A block diagram of an inverter is shown below.



NOTE EXTERNAL SYNCH SIGNAL ONLY SYNCHS INTERNAL OSCILLATOR EXTERNAL SYNCH CANNOT PROVIDE INVERTER TIMING BY ITSELF

INVERTER - BLOCK DIAGRAM

1. RF Filters - Used to eliminate RF noise. The dc and synch inputs, and the ac output interface with the inverter at the same physical location. The three RF filters shown are actually located in the same housing. RF filters have experienced numerous quality control failures during testing due to capacitors with high dissipation losses. This problem has been corrected, and all inverters now have acceptable filters.
2. Ripple Filter - Consists of a high series and low shunt impedance. Its function is to prevent the 6.4 kHz converter ripple current from appearing on the dc input lines.
3. Dc-dc Converter - The dc input is switched on and off into an L-C circuit at a basic rate of 6.4 kHz which produces a regulated output of from 53 Vdc to 60 Vdc. The 39-45 Vdc semi-regulated output is tapped off of the coil in the dc-dc converter. In the past, the dc-dc converter has experienced failures, resulting in an output of approximately 90 V peak. In these cases the converter failed to boost the input voltage to the proper 53-60 Vdc level, and the 28 Vdc bus voltage resulted in the 90 V peak output. These failures have also been corrected.
4. Converter Driver - Compares the input and output voltages of the inverter to determine the exact switching rate of the dc-dc converter. Basic timing is supplied by the oscillator. The 15 Vdc and 39-45 Vdc drive the control circuitry.
5. Inverter Stage - The dc input is switched back and forth across the primary of a transformer to produce a 400 Hz square wave.
6. Inverter Driver - Drives the switching in the inverter stage at exactly 400 Hz through its input from the timing circuit. The 39-45 Vdc drives the associated circuitry.
7. Tap Changer - Samples the secondary of the transformer in the inverter stage at predetermined levels in an exact sequence resulting in an approximated 400 Hz sine wave.
8. Tap Changer Driver - Drives the tap changer through its input from the timing circuitry. The 39-45 Vdc drives the associated circuitry.
9. Output Filter - Smoothes the simulated sine wave output by the tap changer.
10. Oscillators - The free-running unijunction oscillator is synched to the timing signal from the PCMTE and provides the basic timing pulse for the timing circuitry. The 15 Vdc is used to drive the associated circuitry.
11. Micrologic Timing Circuit - Two ring counters in series used to count down the 6.4 kHz timing pulse to 400 Hz.
12. Regulated dc Supply - Uses the input dc voltage to supply a regulated 15 Vdc; and a sample of the inverter stage square wave which is rectified to produce a regulated 5 Vdc used for driving the timing circuitry.
13. Short Circuit Protection - Monitors the inverter output for a heavy overload condition. When such a condition exists, the normal constant voltage mode of the inverter maintained by the converter driver is overridden by a constant current mode of operation maintained by the short circuit protection. Normal tap changer operation is disabled, and a portion of the tap changer is driven directly by the short circuit protection. The output VI characteristic is shown below.



D. The inverter loads are configured such that they are tied to one of two split ac buses, "A" or "B". Bus A loads are primarily associated with PGNS operation, and Bus B loads with AGS operation. The loads, according to bus, are as follows:

AC Bus A	Watts	AC Bus B	Watts
Integral Lighting	46.2	Numeric Lighting	4.0
Rendz Radar	13.8	He/PQGS Display	6.7
DECA	82.6	S-Bnd Antenna	3.5
DSEA	2.7	AGS	3.5
CDR FDAI	4.0	LMP FDAI	4.0
AOT Lamp	9.3	AOT Lamp	9.3
CDR Window Htr	61.8	LMP Window Htr	61.8
GASTA	12.5	ORDEAL	3.5
Range/Alt Mtr	10.5		
AC Voltmeter	--		

The maximum load for Bus A alone is 241 watts, and for Bus B, 96.3 watts. The maximum possible ac load, with all equipment on at the same time, is 328 watts. (The AOT lamp was considered a load for both individual bus totals; for the total combined load, therefore, 9.3 watts must be subtracted.) During nominal operation, therefore, the inverter should be well within its operating limits. The only load unique to burn phases is the DECA. The remaining loads are periodic, depending on mission phase or necessity. P-8

E. The two ac buses are tied together through three different paths, each path having two circuit breakers in series, as shown in Figure 2.

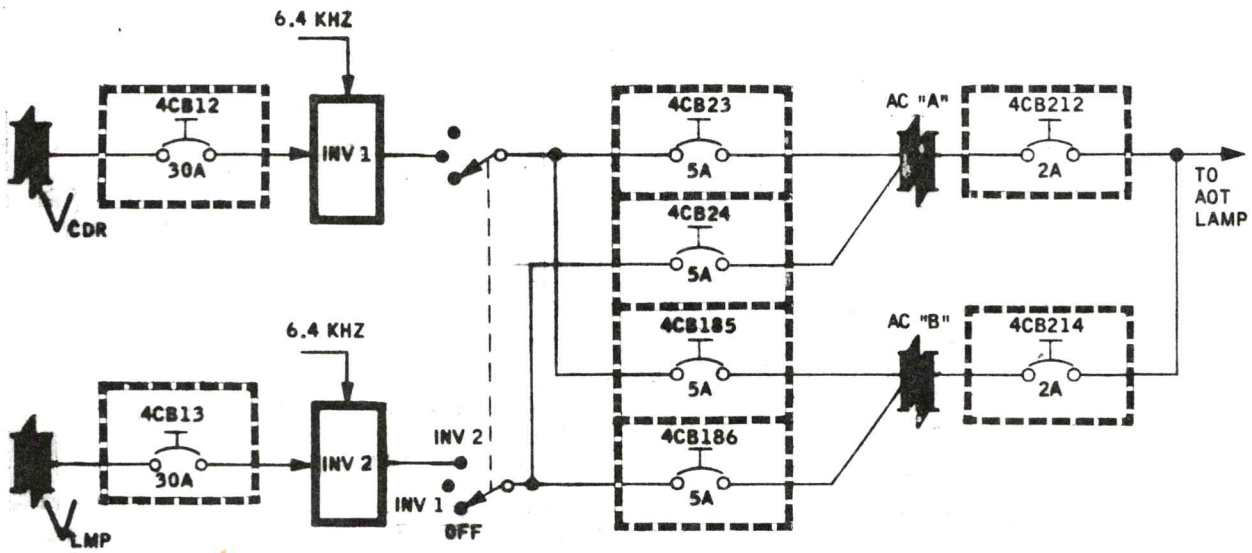


FIGURE 2.- INVERTER CIRCUIT BREAKER CONFIGURATION.

All four circuit breakers between the inverters and ac buses are normally closed. Therefore, to completely isolate the ac buses from each other, at least two circuit breakers must be pulled. The AOT lamp is the only ac load supplied by both ac buses. This was done to optimize power to a crew safety device in the event of an ac bus failure; however, there is only one feeder to the lamp, and several single point failures in the lamp assembly itself. Normally only one AOT lamp breaker will be closed at one time.

MALFUNCTION DETECTION:

A. On the ground, two PCM parameters monitor inverter activity: GC0071V AC Bus Volt, and GC0155F AC Bus Freq. Both of these parameters are measured on AC Bus A only. Onboard, GC0071V is displayed on a meter when the "AC" position is selected by the POWER/TEMP MONITOR switch on Panel 14. In addition, the Inverter caution light will illuminate for: 398>F>402 Hz and V<112 Vac.

B. On LM-1 it was noted that during DECA operation the ac voltage varied from 112 to 124.5 Vac without detrimental effect to the equipment. Subsequent investigation of this problem revealed that the signal conditioning calculates the average dc voltage of the rectified ac output. This calculation,

$$V_{AVE} = V_{PEAK} \left(\frac{2}{\pi} - \frac{4}{3\pi} \text{Cos } 2\ \omega t - \frac{4}{15\pi} \text{Cos } 4\ \omega t - \ldots.\right)$$

allows harmonics to distort the final dc output. Also, the pulsed input to the gimbal drive motors caused very short duration (<300 ms) voltage spikes on the inverter output which could have been sampled by the signal conditioning, thus giving a false impression of the overall value of the output voltage. It has been postulated that these were the causes of the fluctuating voltage reading on LM-1. Tests have shown that heavier ac loading on LM-3 will alleviate this spiking, and the flight performance of the LM-3 inverters verified that the problem no longer exists.

In the event of the loss of the ac parameters, equipment characteristics must be used as an indication of off-nominal inverter output. A brief summary of ac equipment and the effect of voltage and frequency variations on that equipment follows:

	Circuit Breaker 4 CB	Equipment	Critical Limits Vac Low	Vac High	Hz Low	Hz High	Failure Mode	
Bus A	27	AC BUS VOLTS MEAS AC BUS FREQ MEAS	NONE		NONE		NONE - THIS IS PARAMETER SENSE LINE.	
	144	CDR WINDOW HTR	112.5	117.5	390	410	LOSS OF CDR WINDOW HTR.	
	201	GASTA	112.5	117.5	390	410	LOSS OF FDAI ATTITUDE INDICATIONS.	
	202	DSEA	112.5	117.5	390	410	LOSS OF DSEA.	
	204	RNG/ALT METER	112.5	117.5	390	410	LOSS OF TAPE DRIVE MOTOR. THEREFORE, LOSS OF RNG/ALT METER.	P-11
	206	RENDZ RDR	112.5	117.5	399.6	400.4	LOSS OF GYRO SPIN MOTORS AND SOME REFERENCE VOLTAGES. SEVERE DEGREDATION OF RENDZ RDR PERFORMANCE.	P-11
	207	DECA GIMBAL	REF SB NO SCS 9-2		TBD		REF SB NO SCS 9-2	P-6
	209	CDR FDAI	112.5	117.5	390	410	LOSS OF SPHERE DRIVE MOTOR.	
	211	INTGL LTG	15	117.5	390	410	DEGRADED OR LOST INTEGRAL LIGHTING.	
	212	AOT LAMP	TBD		TBD		LOSS OF USE OF AOT (4CB214 IS REDUNDANT).	
Bus B	34	S-BAND ANT	103.5	126.5	360	440	LOSS OF SLEW CAPABILITY OF S-BAND ANT.	
	152	SE WINDOW HTR	112.5	117.5	390	410	LOSS OF SE WINDOW HTR.	
	169	HE/PQGS DISP	112.5	117.5	390	410	LOSS OF 10M1 and 10M5 - DPS HE PRESS AND PROP QTY, AND APS HE TEMP AND PRESS.	P-11
	200	NUMERIC LTG	20	117.5	390	410	DEGRADED OR LOST NUMERIC LIGHTING.	
	203	AGS	TBD		TBD		LOSS OF SIN AND COS ATTITUDE SIGNALS TO FDAI's AND ORDEAL.	
	210	SE FDAI	112.5	117.5	390	410	LOSS OF SPHERE DRIVE MOTOR.	
	214	AOT LAMP	TBD		TBD		LOSS OF USE OF AOT (4CB212 IS REDUNDANT).	
	226	ORDEAL	112.5	117.5	390	410	LOSS OF ORDEAL.	

C. Should a short circuit occur on the ac distribution system, the inverter output is automatically limited to 10 amps maximum by the short circuit protection (see Background, C.13). The distribution system is configured such that these 10 amps will be divided between the parallel 5 amp circuit breakers. These circuit breakers could take an hour or more to open, depending on their temperature. Therefore, the problem can be detected via the inverter light and trouble-shooting can be completed before the circuit breakers open.

D. The inverters are mounted on a cold rail in the aft equipment bay, and will operate safely at all glycol temperatures between 35 and 112°F. Inverter thermal problems will be impossible to detect because the inverters will malfunction due to overheating long before enough heat is given off to the glycol to be reflected in the glycol temp measurement.

MISSION IMPACT:

A. Normally, Inverter 2 will be used to supply ac power to the vehicle at all times except for DPS burns. The use of Inverter 2 has the advantage of powering the ac loads from the normally more lightly loaded LMP Bus. For DPS burns, however, using Inverter 1 avoids shutting down the engine if the LMP Bus is lost. Should either inverter fail during the mission, the other inverter may be switched online immediately and the normal mission continued. If both inverters fail, LM solo flight will have to be curtailed due to difficulties associated with flying the LM without any ac equipment.

B. Loss of either ac bus may require modifying certain mission phases, depending on the mission phase and equipment required.

C. In the event that there is a loss of cooling, the inverters can safely supply a 350-watt load for approximately 25 minutes. Since the ac load should never be this high, inverter life can be extended indefinitely by switching inverters every 30-40 minutes.

D. There is no constraint against powering the inverter and the AC loads at the same time via the DC inverter circuit breaker (reference SPAN chit 66-Apollo 13).

CORRECTIVE ACTION:

A. Other than switching the other inverter online in the event of a failed inverter, no corrective action can be taken.

B. It should be noted that in the event of a failed open inverter bus tie circuit breaker, the affected ac bus will be powered from the other ac bus with no interruption of power. This is due to the fact that all applicable circuit breakers are normally closed. For example, if Inverter 2 is on and 4CB186 fails open, AC Bus B will be powered from AC Bus A through 4CB23 and 4CB185 in series. Even during maximum nominal ac loading there is no danger of the bus tie breakers opening, because the current demands of both ac buses do not exceed the circuit breaker ratings.

SB NO. **EPS 2-2**

S/C: LM
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: W. D. Reeves
APPROVAL: William L Peters

TITLE: CM/LM POWER INTERFACE

REFERENCE: MH01-05273-414, MH01-05048-116, MH01-05059-216, V28-420107, V28-420108, V34-945523, LDW 390-53000, AOH Volume 2, and EPS, SA&I and equipment lines groups at GAC, Bethpage.

BACKGROUND: A. The CM/LM power interface supplies power to the LM from the CM via a pair of electrical umbilicals from TD&E until LM activation in lunar orbit.

The electrical umbilicals consist of two separate cables, each having nineteen 22-gauge wires. Eighteen of these wires are used in each cable, leaving the others as spares. Eight of the wires in each cable are for electrical power transfer between the CM and LM. The remaining ten active wires in each cable connect the CM pyrotechnic system through the LM to LM/SLA separation devices on the LM outriggers and the LM/SLA umbilical guillotine.

The cables are stowed in the LM docking tunnel area and are held to the walls of the tunnel by velcro strips. In the stowed position, the ends of the cables that are to be attached to the CM are plugged into two dummy receptacles located near two of the drogue mounts, between the drogue periphery and the LM tunnel walls. Upon docking the LM and CM, a crewman can crawl partially into the docking tunnel, unplug the cables from their stowage receptacles, and plug them into the receptacles in the CM. These receptacles have covers which are opened when connecting the umbilicals, then closed over the plugs to prevent them from being disconnected accidentally upon IVT. This can all be done without removing the probe or drogue and without the use of any tools.

B. The plugs have 19 pins with only 18 being used. They also have a master key to align them in their receptacles, each one being keyed differently so that it will fit only its respective socket in the CM. This precludes the possibility of connecting the wrong cable and socket. Each plug and socket is painted universal orange 180° around its circumference such that when a plug is inserted in its socket, there will be one continuous orange line. The plugs themselves are of the type that lock upon pushing them into their receptacles, and they must be turned approximately 30° before they can be disengaged. They require a maximum of 20 pounds of force to engage or disengage them.

C. Upon connecting the umbilicals, there will be no power on them due to the OFF position of the LM PWR switch in the CM. By placing this switch in the CSM position, power will be transferred from the CM main DC bus to the LM CDR's bus via three wires in each umbilical (see Figure 2). Simultaneously, power will be applied via one wire in each umbilical to the descent battery reset coils to turn the descent batteries off. The five descent batteries may be left in any configuration other than batteries 1, 2, 3, and 4 on high voltage taps prior to performing this switchover to prevent a relay race between relays 4K3, 4K4, and the descent battery reset coils, possibly resulting in CSM power and LM batteries being paralleled. Three negative return leads are also provided in each umbilical which connect the LM translunar bus to the CM Negative DC bus. In addition to this function, the negative return wires pass through a LM power shunt connected to a signal conditioner in the CSM, permitting monitoring of the current to the LM both on TM and onboard (CC2962 LM HTR Current). The onboard meter and TM have a range of 0 to 10 amps. The LM translunar ground is a negative return isolated from the LM structure ground. Without this isolation, the electrical return when on CM power would be made via the structure, thus causing the current monitoring technique to become ineffective. This would prevent detecting loss of any critical heaters in the LM or abnormal heater cycling which could result in loss of LM activities. P-8

Prior to switching from internal LM power to CM power, the loads on in the LM will be the RR HTR, LR HTR, IMU HTR, S-BAND ANT HTR, MESA HTR, DES ECA's, docking light, meter power fail lights, C/W PWR caution light, and lighting on the DEDA and DSKY panels. The heaters are cyclic loads and should not all be on at once (reference the XLUNAR LOADS TABLE in the SODB Vol II appendices for P-11

peak loads and average loads due to cycling per vehicle). The other loads listed above amount to an extra 1.63 amps, most of which is due to the docking lights (1.07amps). When relays 4K3 and 4K4 are operated at power switchover, all of the loads listed above are turned off except the heater loads, the floodlights, and relays 4K3 and 4K4. If all of the heaters should be on at once with the floodlights, the total load would be 333 watts. Based on 28 Vdc, this requires a current of 11.5 amps, which is divided between two 7.5 amp breakers in the CM and among three 22 gauge wires in each umbilical. It also flows through the switch contacts of the LM PWR switch and through the parallel relay contacts of 4K3 and 4K4 in the LM (see Figure 2). The LM PWR switch is capable of supplying 23 amps continuously; the contacts of 4K3 and 4K4 are rated at 10 amps each; and a 22-gauge wire is rated at 11.7 amps in a vacuum. The wire ratings are based on the amount of steady current necessary to raise the wire temperature to 400°F. Based on these data, the trip limits of the breakers in the CM are being approached; however, this is for the unrealistic worst case condition of all heaters on at once. Also, with a nominal 28 Vdc on the CSM bus, approximately 25 Vdc will appear at the LM bus due to line losses in the umbilicals. Therefore, the current drawn by these loads will be less than that based on 28 Vdc, and it may be concluded that the CM will be capable of supplying the LM power. The current should be approximately the same as it has been in past missions which is shown in Figure 1. The ASA HTR has been turned off during the TLC since a heater failed on during prelaunch testing on Apollo 14 and it was discovered that it was not necessary during TLC. The ASA heater is composed of two heater systems, a fine temperature control heater and a fast warm up heater. The fine temperature control heater is always on during LM active phases to maintain the ASA temperature at its operating level of 120 $\pm$ 1.2°F while the fast warm up heater is a 200 watt heater which comes on any time the temperature of the ASA falls below 116 $^{+2}_{-1}$°F. P-11 P-11

D. At the time of LM activation, the LM batteries 1 and 4 will be put back on the LM bus by use of the LM PWR switch in the CM. There is one wire in each umbilical which supplies power to the LM descent battery 1 and 4 low voltage set coils upon placing the LM PWR switch in the RESET position and maintaining it for a minimum of 300 miliseconds. Whenever the low voltage contacts close, the CM power is removed from the LM bus by relays in the LM which prevent the LM and CM power from being on the LM bus simultaneously. During power switchover, the transient voltage limits will be 21 to 32 volts with recovery to steady state within one second. The LM will be placed on internal power after manning the LM, then switched to CSM power prior to IVT back to the CSM. P-8 P-8

E. On LM 10 and subsequent, the capability has been incorporated to allow CSM/LM power transfer after staging. This was accomplished by making a wiring modification such that upon firing the electrical circuit interrupters at staging, the circuit from the CSM interface to 4K3 and 4K4 is completed (see Figure 2). P-8

MALFUNCTION DETECTION and MISSION IMPACT

A. There exist two areas of single point failure in the CM/LM electrical interface. First, a failed open contact of either relay 4K3 or 4K4 in the descent battery reset line would prevent the descent batteries from being turned off, therefore preventing switchover. Should this occur, the switchover could be performed from within the LM. The procedure would be as follows:

1. CB(16) EPS: EPS DISP - close
   DES ECA CONT - close
   X LUNAR BUS TIE - close
   CROSS TIE BAL LOAD - open
   INST: SIG CONDR 2 - close

2. NOTE
   The next step will cause a momentary loss of lighting
   LMP BAT 1 HI VOLT - OFF/RESET then ON, tb - HI
   CDR BAT 4 LO VOLT - OFF/RESET; tb - BP

3. Coordinate power transfer with CSM crewman
   LM POWER - CSM

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4. NOTE:
   The next step will cause loss of vehicle lighting until step 5.
   LMP BAT 1 HI VOLT - OFF/RESET, tb - BP
5. CB(16) EPS: CROSS TIE BAL LOAD - close
   INST: SIG CONDR 2 - open
   EPS: DISP - open
   DES ECA CONT - open
   XLUNAR BUS TIE - open

P-14

Second, if any of the low voltage relay contacts in the line to power relays 4K3 and 4K4 fail to close when the descent batteries are turned off (see Figure 2), power switchover from the CM cannot be performed unless the vehicle is staged.

P-8

B. Inability to connect at least one umbilical would result in a shorter alternate mission, for it would be impossible to remove the LM from the SLA or to supply power to the LM from the CSM.

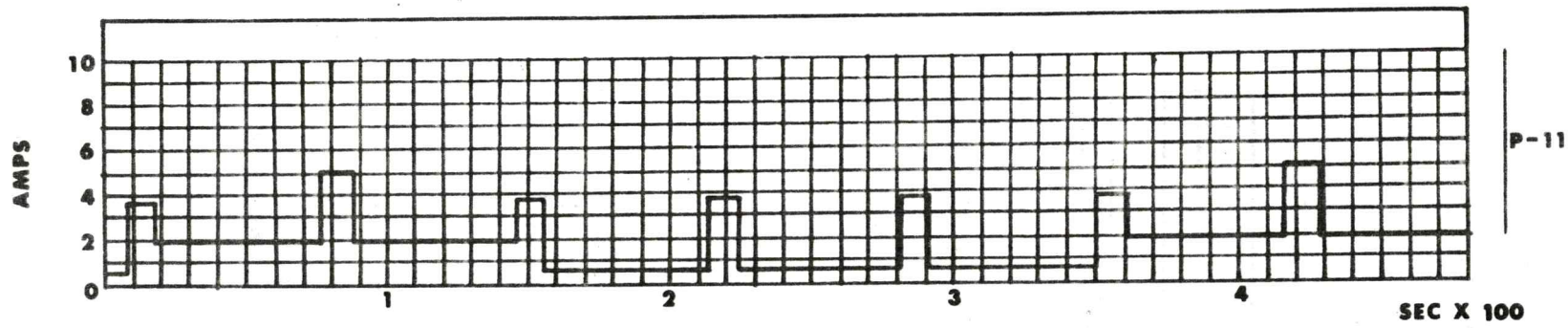


Figure 1. LM Heater current Vs Time

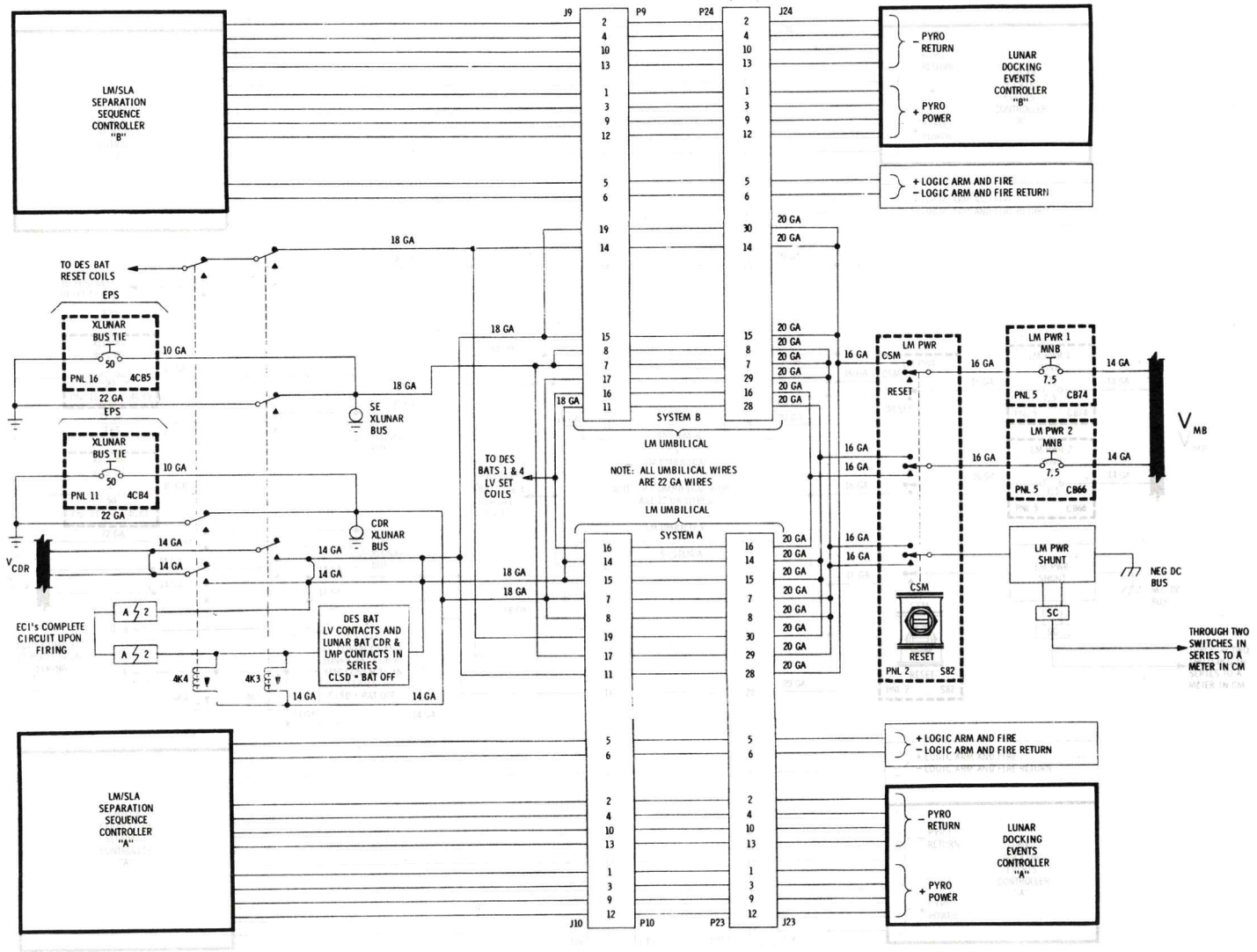


FIGURE 2. - CM/LM POWER INTERFACE (LM 10 AND SUBSEQUENT).

SB NO. EPS 2-3

S/C: LM
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: L. Nicholas
APPROVAL: William L. Peters

TITLE: EPS OVERCURRENT PROTECTION

BACKGROUND: A. The sections of this brief cover:

1. EPS behavior under short-circuit conditions.
2. The feeder system maximum current rating.
3. Circuit breaker ratings.

B. Short Circuits

For the three possible EPS dc circuit configurations, the following would occur under short-circuit conditions.

1. Balanced load cross tie circuit breakers closed (30A).
   a. If a short occurred on either bus or either bus feeder, one of the cross tie breakers would open and the ECA's associated with the shorted bus or feeder would trip. The battery feed tie circuit breakers would not open.
   b. If a short occurred on the cross tie, both cross tie circuit breakers would open. No other circuit breakers or ECA's would trip.
2. Bus cross tie circuit breakers closed (100A).
   It is not possible to definitely predict what would open first under short-circuit conditions because of the ratings of the circuit breakers and ECA's. It is possible that one of the cross tie breakers would open, and all ECA's would open leaving the entire vehicle unpowered.
3. All cross tie circuit breakers open.
   If a short occurred on the bus or feeder, the ECA's associated with the bus or feeder would trip. The battery feed tie circuit breakers would not open.

C. Maximum loads

The maximum load on a bus is limited by the current rating of the feeder. A feeder for a bus consists of two number 6 wires. The current carrying capacity of each wire is limited to 45 amps because at this current, the wire reaches its maximum design temperature of 212°F. Therefore, the load on a bus is limited to 90 amps. The cross tie wire consists of one number 4 wire. The maximum current for a number 4 wire is 62 amps with the same maximum design temperature.

D. Circuit Breaker Ratings

1. Circuit breakers will trip at varying percentage values of the nameplate rating depending on the breaker's environmental temperature and pressure. Specifically,
   a. A breaker is designed to carry 115 percent of nameplate rating at an external temperature of 77°F and atmospheric pressure, and
   b. A breaker is designed to carry 60 percent of nameplate rating at an external temperature of 180°F and 10^{-4} mm Hg.

   Derating occurs for normal operation because of temperature and pressure conditions prevalent in orbit, that is, approximately 70 to 180°F structural temperature and either 5 psia or vacuum pressure.
2. LM circuit breakers are thermally activated and are therefore effected by the environment's ability to increase, decrease, or sustain heat loads. A circulating atmosphere or even a stagnant atmosphere will transfer enough heat away from the breaker to greatly effect the rating. Since the bi-metallic strips or "hot wires" in the circuit breakers are heated by the current passing through them, it follows that a higher current operates a breaker more rapidly than a lower current. Even when the current just barely reaches the breaker trip level, the time to trip should not be over 60 seconds for the largest breakers and much less time for the smaller breakers.

MALFUNCTION DETECTION, MISSION IMPACT, AND CORRECTIVE ACTION

A. The astronaut can observe the condition of the DC BUS warning light, DC FEEDER fault light, BATTERY caution light, flood lights, and display power fail lights to determine if a short has occurred in the EPS feeder/bus system. The EPS voltmeter can be used to verify the bus and battery voltages and the battery flag indicators can be used to determine if the batteries are on or off.

B. If the CDR bus has failed because of a short, the Master Alarm, DC BUS warning, BATTERY caution, DC FEEDER fault, CDR cross-pointer and Thrust display power fail lights will come on. The batteries associated with the CDR bus will be off and the cross tie breakers will be open.

C. If the LMP bus has failed because of a short, the DC BUS warning, BATTERY caution, DC FEEDER fault and RCS, ECS, PROP PRESS LMP and cross-pointer display power fail lights will come on. The batteries associated with the LMP bus will be off and the cross tie breakers will be open. P-8

D. Once it has been determined the short has occurred on a feeder/bus system by verifying the battery voltages are normal, the short can be isolated to the bus or feeder. Verify the batteries on the affected bus are off then open the EPS BAT FEED TIE circuit breakers for that bus. If the DC FEEDER FAULT light is on, the feeder is shorted; if the light is off, the bus is shorted. If the bus was not shorted, the bus can be powered from the other bus by closing the EPS BUS CROSS TIE circuit breakers (100A).

E. If a bus is shorted, then all equipment utilizing this bus as the only source of power will be inoperative. The caution and warning lights associated with this equipment may not necessarily be operational.

The crew malfunction procedures should be consulted for exact details of malfunction analysis.

S/C: LM
DATE: 11/1/70
REV: PCN-6
ORIGINATOR: William Reeves
APPROVAL: William L. Peters

SB NO. EPS 2-4

TITLE: LM/GSE AND LM/SLA INTERFACE

REFERENCE: A. MH01-05136-124, MH01-05601-224, MH01-05213-124, MH01-05074-124, LED-561-5

B. Discussion with EPS and ECS groups at Cape Kennedy.

BACKGROUND: A. The LM/GSE interface from approximately T-7 hours to liftoff consists solely of the LUT fly-away umbilical which is made up of three dc electrical cables and one gaseous nitrogen (GN_2) hose. Table I gives a complete listing of the wires and their functions which are routed through this umbilical. Some of these functions include electrical power transfer, PCM data transfer, and all switching from GSE. The GN_2 hose is a safety requirement for purging the aft equipment bay after the loading of propellants.

B. The LUT umbilical connects via quick disconnects to a plate located on the SLA just above the panel hinge points on the +Y side of the LM. A swing-arm device (Figure 1B) on the inside of the panel carries the three cables and the GN_2 hose of the LUT umbilical from the SLA panel to a junction box on the LM. The junction box is located on the right, aft, main structural strut of the LM connecting the ascent and descent stages. The GN_2 hose is connected to a plate in this junction box using a quick disconnect; however, the electrical cables pass through a pyrothechnic guillotine located on the end of the swing arm and into the LM through the junction box mentioned above.

C. At liftoff, the LUT umbilical is unplugged and pulled away as the launch vehicle leaves the pad. If the PCM equipment should happen to be on at this time, it would automatically be turned off when the umbilical is unplugged.

D. The signal for CSM/S-IVB separation will be manually sent from the CSM as scheduled in the Flight Plan. This signal ignites a CDF (Confined Detonating Fuse) which in turn causes three events to occur. First, it ignites an MDF (Mild Detonating Fuse) which burns around each of the SLA panels separating them from each other and from the CSM allowing the panels to deploy. Second, the CDF initiates an exploding plug on the umbilical between the CSM and S-IVB, completely separating the CSM from the S-IVB. And third, the CDF initiates the pyrotechnic guillotine, mentioned earlier, on the swing-arm device between the SLA panel and the LM. This cuts all of the electrical cables to the LM which were used for LM/GSE functions. At the same time, this cutter cuts a cable between the swing arm and the LM allowing a reel device on the SLA panel to reel in this arm as the SLA panels deploy. The LM is now attached to the bottom part of the SLA by a hold-down device on each of the four LM outriggers (Figure 1C). There is also a LM/SLA umbilical running down the +Y outrigger of the LM through a pyrotechnic guillotine bolted to the SLA wall below the hinge point, and into the lower SLA area. This umbilical carries several wires for LM/SLA pyrotechnic functions.

E. After the CSM has gone through transposition and docking, the two CM/LM umbilicals are connected between the CSM and LM.* The LM/SLA separation signal is then sent via a switch in the CSM. This signal passes down through the LM, down the +Y outrigger, through the pyrotechnic guillotine on the SLA wall to the LM/SLA Separation Sequence Controller (LSSC) in the SLA. The LSSC directs this signal to the hold-down devices on the four outriggers of the LM releasing them. Then after a 30-millisecond delay the signal fires the pyrotechnic guillotine in the SLA severing the last connection between the LM and SLA.

MALFUNCTION DETECTION AND MISSION IMPACT: A. For CSM/S-IVB separation there is a CSM TM event SS0140X, SLA/CM SEP A (there is no SLA/CM SEP B); however, for SLA panel deploy which occurs at the same time, there is no TM and it will have to be detected visually by the astronauts. Three other parameters in the CSM, CD0132 EDS ABORT VOTE 1, CD0133 EDS ABORT VOTE 2, and CD0134 EDS ABORT VOTE 3, are part of the emergency detection system and may be used to verify CSM/S-IVB separation. Accompanying CSM/S-IVB separation and SLA panel deployment, the docking lights on the LM will come on verifying proper deployment of

*Refer to System Brief "EPS 2-2, CM/LM Pwr Interface".

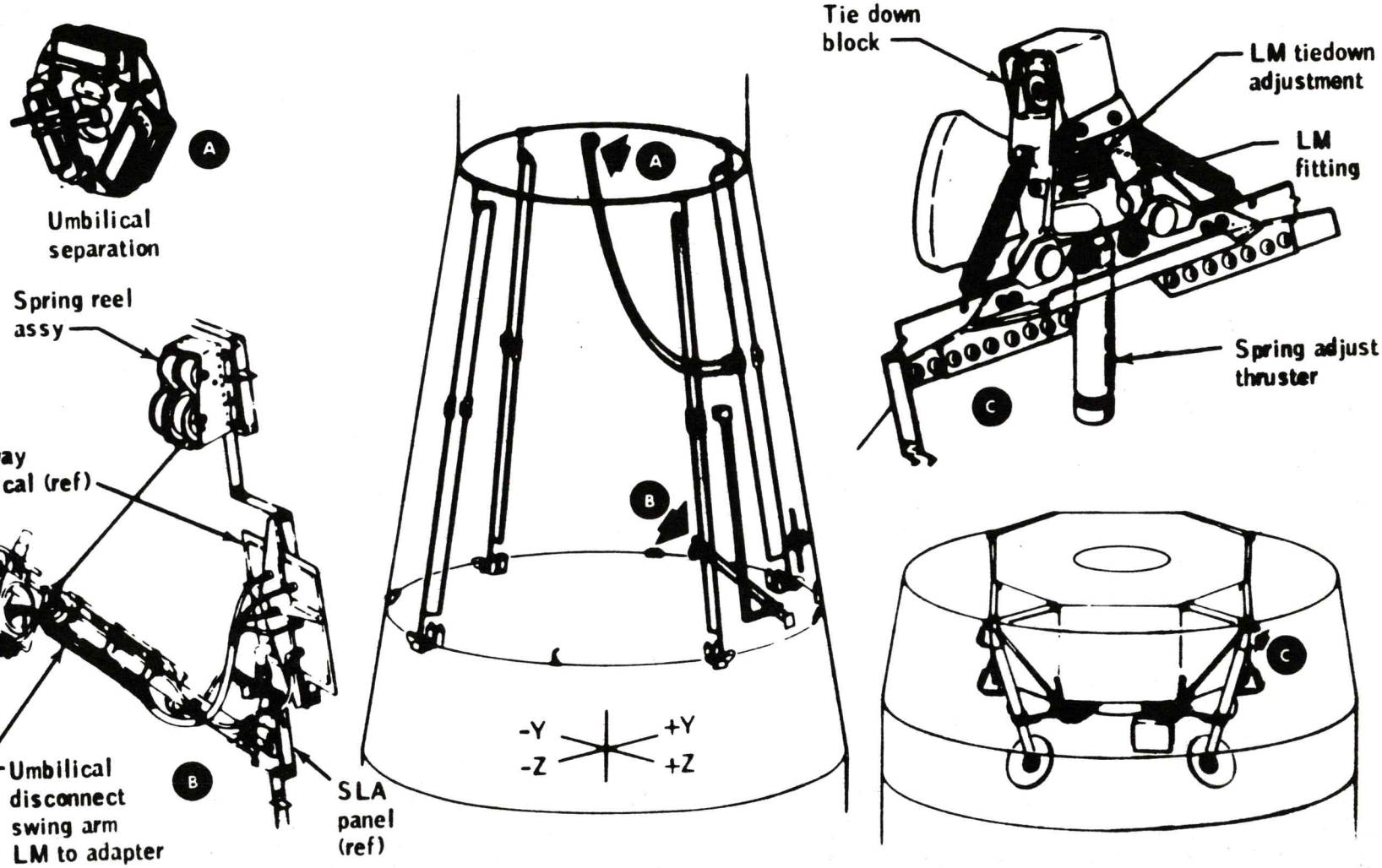


Figure 1. - Adapter separation system.

the swing-arm device between the SLA panel and the LM. If for any reason CSM/S-IVB separation cannot be achieved, the mission will have to be altered, and should CSM/SLA separation occur without proper deployment of the SLA, an alternate mission must be followed using solely the CSM.

B. LM/SLA separation will be a visually detected event by the crew since LM telemetry will be turned off at this time. If this cannot be achieved, an alternate mission will be required.

TABLE I.- MAKE-UP OF THE LUT UMBILICAL | P-6

PLUG	PIN	WIRE	MEASUREMENT	WIRE FUNCTION
J92	4	P120	JC9515V	GSE DC POWER TO THE LM
	5	P120	JC9515V	GSE DC POWER TO THE LM
	10	P120	JC9515V	GSE DC POWER TO THE LM
	31	P120	JC9515V	GSE DC POWER TO THE LM
	15	P119		GSE DC POWER RETURN
	16	P119		GSE DC POWER RETURN
	21	P119		GSE DC POWER RETURN
	22	P119		GSE DC POWER RETURN
J93	12	D4190		51.2/1.6 KBIT SYNC FROM DATA XFER BUFFER
	34	D4236		51.2/1.6 KBIT SYNC RETURN
	17	D4192		512 KHZ SYNC FROM DATA XFER BUFFER
	37	D4191		512 KHZ SYNC RETURN
	6	D4194		1 P/SEC SYNC FROM DATA XFER BUFFER
	28	D4193		1 P/SEC SYNC RETURN
	1	D4189		PCM HARDLINE RZ DATA
	25	D4235		PCM HARDLINE RZ DATA RETURN
	50	D6000		SCHIELD GROUND
J95	29	D4187		HARDLINE RZ DATA ENABLE (9.5 VDC)
	30	D4188		HARDLINE RZ DATA ENABLE RETURN (9.5 VDC)
	6	P400	JL9793	POWER TO RELAY 4K6 TO TURN PCM ON
	5	P224	JC9891	DES BATS LV/HV COIL RESET CONTROL
	4	P125	JC9892	DES BATS LV TAPS ON CONTROL
	1	P121	JC9893	* LDA AND LDR RELAYS SET CONTROL
	2	P122		LDA AND LDR RELAYS CONTROL RETURN
	25	P123	JC9894	LDR AND LDA RELAYS RESET CONTROL
	28	P124	GC9520	GSE POWER MONITOR
	56	P443	GC0020	LUT UMBILICAL RELEASE MONITOR
	57	P443		UMBILICAL RELEASE MONITOR RETURN
	27	W813	GG9006	IMU TEMP OUT OF LIMITS MONITOR

* LDR ENABLES GSE DC POWER TO BE DELIVERED TO THE LM. LDA ENABLES THE VOLTAGE MONITORING OF GSE POWER TO THE LM.

NOTE

Any wires and pins in the LUT umbilical not mentioned above are spares. | P-6

SB NO. **EPS 2-5**

S/C: LM
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: W. D. Reeves
APPROVAL: William L. Peters

TITLE: **ASCENT BATTERY PARALLELING REQUIREMENTS AND PROCEDURES**

REFERENCE:

A. Test Report for Ascent Battery Transient Test: LTR 396-86, 10-2-67.
B. Ascent Battery - G & N Interface Transient Voltage Test: LTR 390-87, 10-20-67.
C. LM Ascent Battery Parametric Tests: LTR 390-104, 2-21-68.
D. Ascent Battery Transient Test: LTR 390-128, 10-10-69.
E. LM-8 Bus Inrush Current Test: LTR 390-128, 7-20-69.
F. PGNS Prime Power Requirements and Characteristics: LTS 390-10002, Rev A, 8-2-65.
G. IRN LIS 390-10002A to Reference E.
H. Note of Interest: A Couple of Mission Rules About Descent, by G. D. Griffin
I. Apollo Engineering Memorandum, AP-71-00251, April 27, 1971: Variations of X Accelerometer Characteristics vs +28 VDC on the G&N Learner System for Apollo 14.

BACKGROUND:

The stage and abort stage functions were originally incorporated into the LM design to provide the capability of instantaneously separating the ascent and descent stages at any time during a mission. This capability, however, has been severely restricted because the ascent batteries cannot, at any arbitrary time, assume the entire LM electrical load. The batteries must first be preconditioned by placing them on line with the descent batteries for a sufficient period of time to condition the plates chemically and allow them to warm up for efficient battery performance. Preconditioning time is dependent on the amount of step load expected which varies for the four possible staging conditions; two-ascent battery abort stage from powered descent, one-battery/two-bus abort stage from powered descent, two-ascent battery lunar lift-off, and one-ascent battery/two-bus lunar liftoff. Should proper preconditioning not be performed and the ascent batteries subjected to the step load at staging, severe voltage transients occur which could be detrimental to LM equipments. The most critical equipments are the LGC, IMU, and AEA. These equipments all have a critical input voltage below which degraded operation or total failure occurs (see figures 1-4). P-8

Violation of the LGC input voltage will cause the LGC to perform a restart. This simply means that when the voltage recovers, the LGC will retreat back in the program it was in at the time of the transient and re-enter the program at the nearest built-in restart point. The LGC will have lost track of what happened during the transient, but will become updated when it restarts. The LM Systems Branch, Flight Control Division G & N personnel state that the program is believed to be restart protected in the burn programs but as a very worst case failure during a voltage transient, the LGC may lose track of where it was in a program resulting in loss of the LGC for that burn.

The failure mode of the IMU for violation of the input critical voltage limit is a biasing of the PIPA's and GYRO's. This was believed to cause a permanent shift in these components but recent tests, prior to and during the Apollo 14 mission, indicate that (1) no drastic attitude changes may come about due to low voltage, (2) no large drift rates of attitude will be noted, (3) both accelerometer and stab servo loops remain closed, and (4) observable and significant changes of accelerometer bias and scale factor do occur; however, the changes are not permanent and seem to correct themselves when the voltage is restored.

If the AEA critical voltage is violated, the AEA memory may either be dropped or scrambled. In any case, the AEA will be lost.

Factors other than transient voltages also affect the amount of preconditioning time such as ascent consumable redlines. At all times, each ascent battery is required to have enough energy remaining to be capable of performing a one-battery/two-bus lift-off and rendezvous. Excessive and unnecessary preconditioning

is prohibited for this reason. Crew reconfiguration time and the particular reconfiguration of the system also affect the amount of preconditioning required when considering an abort stage. For example, if one ascent battery has been lost and both buses are to be maintained after staging, then obviously more preconditioning must be performed than would have to be done should only one bus be required.

Now that the general requirements for preconditioning have been discussed the specific conditions must be considered. The first case is in preparation for a two-ascent battery/two-bus abort stage from powered descent. The buses will be isolated at this time and staging occurs following an Abort and DPS burn to depletion. The step load seen by each ascent battery will be caused by dropping from three batteries per bus to one battery with the loads changing from a burning DPS to ascent stage only operation with a burning APS; however, in the sequence of events beginning with initiation of an abort stage, the DPS shutdown occurs first, immediately followed by the turn-off of the descent batteries. Therefore; considering worst case in determining the precondition time, the time between these events is considered negligible and the step load which will be considered is as if the switchover to ascent power occurred while the DPS was burning. With the assumption that all batteries share equally when paralleled, and the above assumptions, the step load on LMP BAT 5 will be 7.5 to 32.4 amps and on CDR BAT 6, it will be 13.8 to 51.5 amps. In the step loads just mentioned, 10 amps have been added to the step on each bus to account for the very likely possibility of two thrusters per bus and maybe a heater coming on at staging. Many battery tests have been performed using flight ascent batteries under simulated flight conditions to determine if the LGC, IMU, and AEA fail voltages can be avoided when the battery with various amounts of preconditioning is subjected to the above steps. Figure 1 presents the data obtained from one of the tests which best fits the conditions under investigation. As can be seen, the battery on the LMP bus feeding the AEA could pass the AEA fail voltage with zero amp-hours out; however, with 2.5 amp-hours the voltage response is much more stable. The battery feeding the CDR bus with the IMU and LGC must have at least 5.0 amp-hours removed prior to staging to prevent violation of the IMU critical voltage. As mentioned previously, the IMU is believed to be capable of tolerating lower voltages than this ICD voltage as a result of testing during the Apollo 14 mission. P-8

The second case to investigate is the one-battery/two-bus abort stage. Voltage transients at the guidance equipment vary slightly depending on the configuration of the remaining ascent battery. That is, whether the two buses are fed directly via the normal and backup feeds of the remaining battery, or whether the remaining battery feeds one bus directly and the other via the crossties. There is less voltage drop when both buses are fed directly through the normal and backup feeds; therefore, this configuration has been chosen as the best method to use after loss of one ascent battery. The step load associated with staging now becomes 12.78 amps to 83.9 amps or a 71.12 amp step. This includes the same assumptions used in the previous case where all batteries share evenly before staging; however, now the step is from five batteries to one. Figures 2 and 3 show the voltages expected at the guidance equipment for this step load and various amounts of preconditioning. As demonstrated by the curves, the IMU appears to be the piece of equipment whose critical voltage is most seriously threatened and this is for 5 amp-hours removed. A point of interest here is the behavior of the batteries at this large a current step versus discharge. For high states of charge (0, 2.5, and 5 amp-hours removed), the voltage is bad, but at 10 amp-hours removed, it becomes satisfactory; at 15 amp-hours, it becomes bad again and at 20 amp-hours, good again. One test was carried out to 45 amp-hours removed in 5 amp-hour increments and this inconsistant battery performance continued making it virtually impossible to predict how much preconditioning is required to protect the IMU for this current step. However, as mentioned earlier, testing prior to and during Apollo 14 indicated that the IMU critical voltage as stated in the ICD, LIS 390-10002, could be violated without drastically affecting the vehicle. With the type voltage responses expected as shown in the figures and the newly acquired data on the IMU, it appears that the errors in the IMU would be acceptable with 2.5 amp-hours removed from the ascent battery. Voltage conditions could be improved even more by turning descent batteries off one at a time to decrease the current step on the ascent battery if crew reconfiguration time permits.

The third case is that of the normal two-ascent battery lunar lift-off. The step for this case if allowed to occur at staging without turning any descent batteries off first would be from 8.0 to 36.9 amps on battery five and 7.7 to 35.9 amps on battery six. Figure 4 presents the data from one of the battery tests which best represents the case under discussion. With no conditioning at all, the voltage response was marginal; however, by removing 2.5 amp-hours the response was very satisfactory. To improve the response even further, the descent batteries are manually stepped off two at a time with approximately 15 minutes between switchings, thus reducing the current step seen by the ascent batteries even further. The step is then from two batteries to one per bus or 12 to 36.9 amps for battery five and 11.6 to 35.9 amps on battery six.

The fourth and final case to analyze is that of a one-battery/two-bus lunar lift-off. The current step seen by the one-ascent battery would now come from switching from five batteries to one if the switchover occurred at staging. This means the current step would be from 9.4 to 72.8 amps or a 63.4 amp step. The test data which simulates best the above conditions is presented in Figures 2 and 3. As can be seen, this is the same data used for case 2 which demonstrated the inconsistent battery behavior for various discharges at this large a current step. However, for this particular case, the current step can be reduced by manually stepping off the descent batteries such that the largest step appears on the ascent battery when the last descent battery is turned off, 28 amp step from 28 to 56 amps, and at ignition, a 16.8 amp step from 56 to 72.8 amps. Figure 4 displays the test data supporting this step load and indicates 2.5 amp-hours is sufficient with 5 amp-hours being very conservative.

MISSION IMPACT AND CORRECTIVE ACTION:

A. Two-ascent battery/split bus abort stage from powered descent. Remove 2.5 amp-hours from the battery on the LMP bus (normally battery 5) and 5 amp-hours from the battery on the CDR bus (normally battery 6) immediately prior to abort staging. To insure that these preconditioning requirements have been met in the event of an abort stage from powered descent, it will be standard procedure to satisfy them prior to PDI by paralleling the ascent and descent batteries for a sufficient amount of time. In the event an ascent battery fails just after staging, the capability of tieing the buses together does not exist because of very large inrush currents to the dead bus. These inrush currents, based on test data, are several orders of magnitude larger than the normal bus steady state load and if subjected to the remaining ascent battery would seriously affect the only remaining guidance system by dropping the input voltage. P-8

B. One-ascent battery/two-bus abort stage from powered descent. This is the most complex and controversial of the abort stage situations due to the high activity period under discussion and the many possible actions which could be taken. Basically, powered descent is separated into three phases: PDI to descent insertion capability (DIC), DIC to high gate, and high gate to touchdown. During PDI to DIC, the LM still has descent engine insertion capability and presents no great problem. The second phase, DIC to high gate, requires an abort stage to attain insertion; however, it is felt that there will be sufficient time to detect and verify a failed ascent battery and configure the vehicle properly for a one-battery/two-bus abort stage. Therefore, an abort will be initiated for an ascent battery failure during this phase. The third phase, high gate to touchdown, is the controversial one. The problem arises because to get into this situation, an ascent battery must fail after high gate, be detected and verified as a failed battery, the landing must be aborted due to some reason other than the battery failure because this alone will not abort the landing, the vehicle must be reconfigured to one-battery/two-bus operation, and the abort stage initiated. As can be seen, this is a great deal to do especially while trying to fly the vehicle during the last two minutes of the burn. Also, based on all data and testing to date there is no reasonable amount of battery preconditioning which can be performed to completely protect the guidance equipment without stepping the descent batteries off one at a time. The whole issue was finally settled by program management and the Apollo 14 crew based on what the crew felt they would have time to do and what risks management felt were acceptable. The outcome was as follows:

For an ascent battery failure after high gate, the crew will configure the vehicle by opening the Panel 11, DES ECA cb and closing the Cross-Tie Bus (100A) cb's. This means that a landing will be attempted with both electrical buses in the LM tied together subjecting the LM to a single point short which would be catastrophic; however, management felt the probability of a short at this time is much less than having to abort for some other reason where two buses would be preferred. Also, after high gate the crew will seldom have time to confirm a battery loss; therefore, the best thing to do is to put the vehicle in the best configuration for a subsequent abort should the cause arise, and continue the landing. In the event a subsequent abort becomes necessary, the crew must open the Panel 16 DES ECA cb to prevent the failed ascent battery from being placed on a bus automatically at staging. If time permits, the crew will attempt to place the remaining ascent battery also on its backup feedpath and turn the descent batteries off one at a time with a five-second interval between each switch action to decrease the step load on the remaining ascent battery prior to staging. If time does not permit, the chance will be taken on a low bus voltage transient and its effect on the guidance systems.

C. Two-ascent battery lunar lift-off or staging during coasting flight. Remove 2.5 amp-hours from each ascent battery immediately prior to staging. Any combination of ascent and descent battery paralleling is acceptable as long as the 2.5 amp-hours criterion is met. Nominally, the ascent batteries will be placed on line and two descent batteries taken off-line approximately 30 minutes before staging, followed by the other two descent batteries taken off-line 15 minutes before staging. Should a battery fail after staging, certain key circuit breakers on the unpowered bus must be pulled prior to tieing the buses together because of the large inrush currents described previously. The worst current step seen by each ascent battery during the above switching of batteries occurs when the last descent battery is switch off of each bus. P-8

D. Lunar lift-off or staging during coasting flight with one ascent battery/two-bus operation. The remaining ascent battery should be placed on both normal and backup feeds with the crosstie circuit breakers closed and all descent batteries turned off five seconds apart except one. When five amp-hours have been removed from the ascent battery, approximately 10 to 15 minutes, the last descent battery may be removed and staging performed.

K&E SEMI-LOGARITHMIC 46 6463
7 CYCLES X 60 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

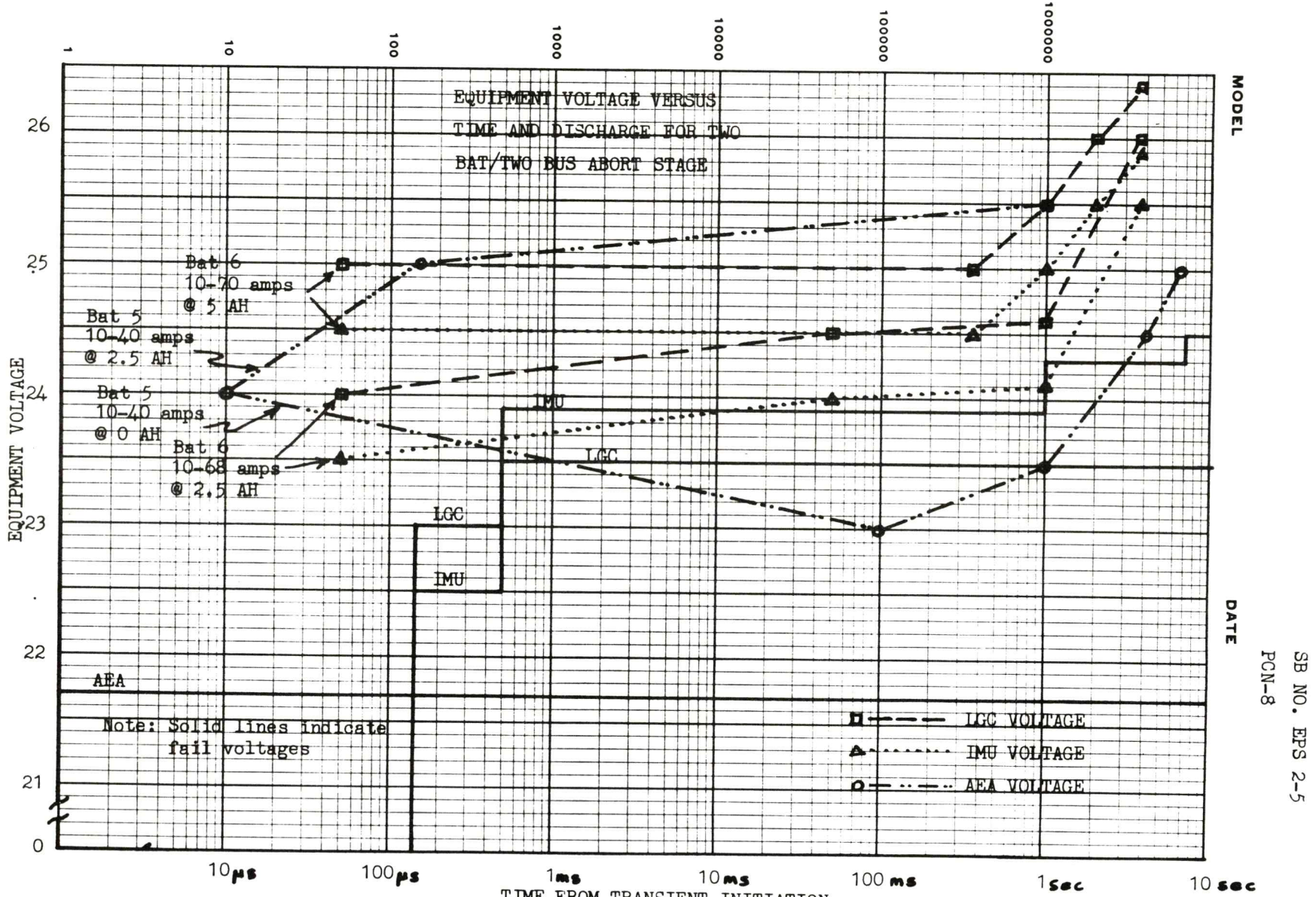


FIGURE 1

K+E SEMI-LOGARITHMIC 46 6463
7 CYCLES X 60 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

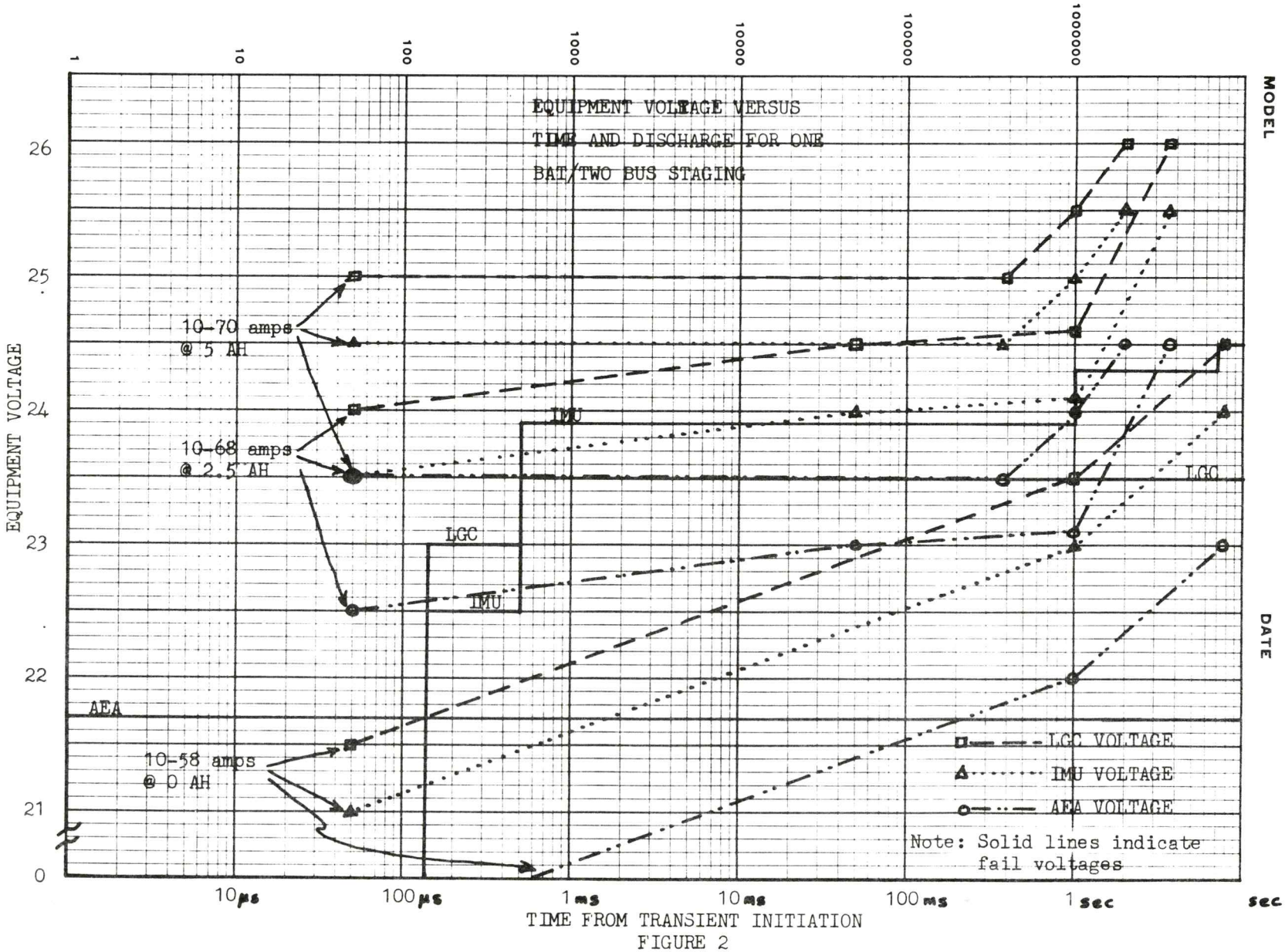


FIGURE 2

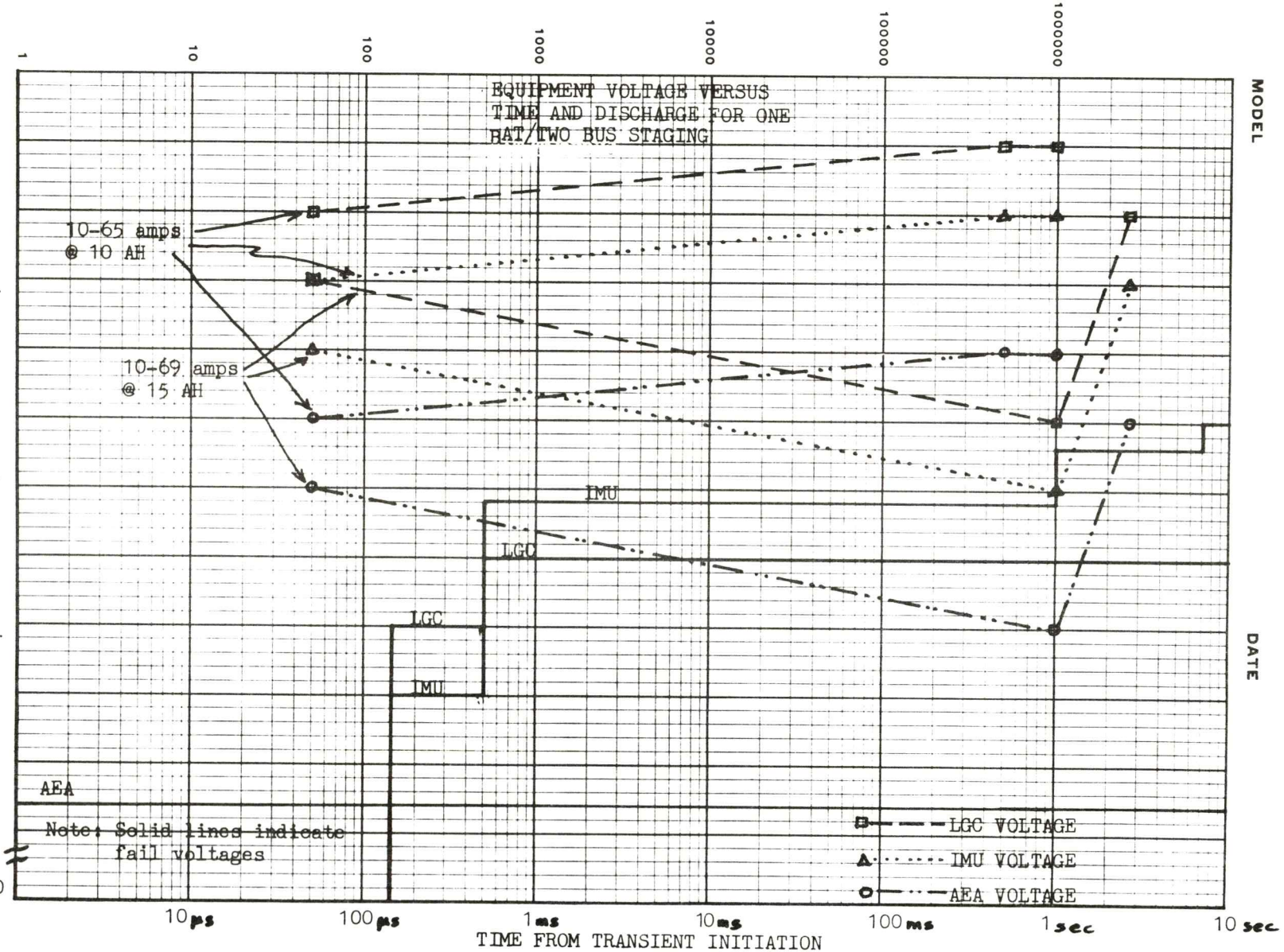

EQUIPMENT VOLTAGE VERSUS
TIME AND DISCHARGE FOR ONE
BAT/TWO BUS STAGING
MODEL
DATE
EQUIPMENT VOLTAGE
26
25
24
23
22
0
10-65 amps
@ 10 AH
10-69 amps
@ 15 AH
IMU
LGC
LGC
IMU
AEA
Note: Solid lines indicate
fail voltages
LGC VOLTAGE
IMU VOLTAGE
AEA VOLTAGE
1
10
100
1000
10000
100000
1000000
10 μs
100 μs
1 ms
10 ms
100 ms
1 sec
10 sec
TIME FROM TRANSIENT INITIATION

FIGURE 3

SB NO. EPS 2-5
PCN-8

K+E SEMI-LOGARITHMIC 46 6463
7 CYCLES X 60 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

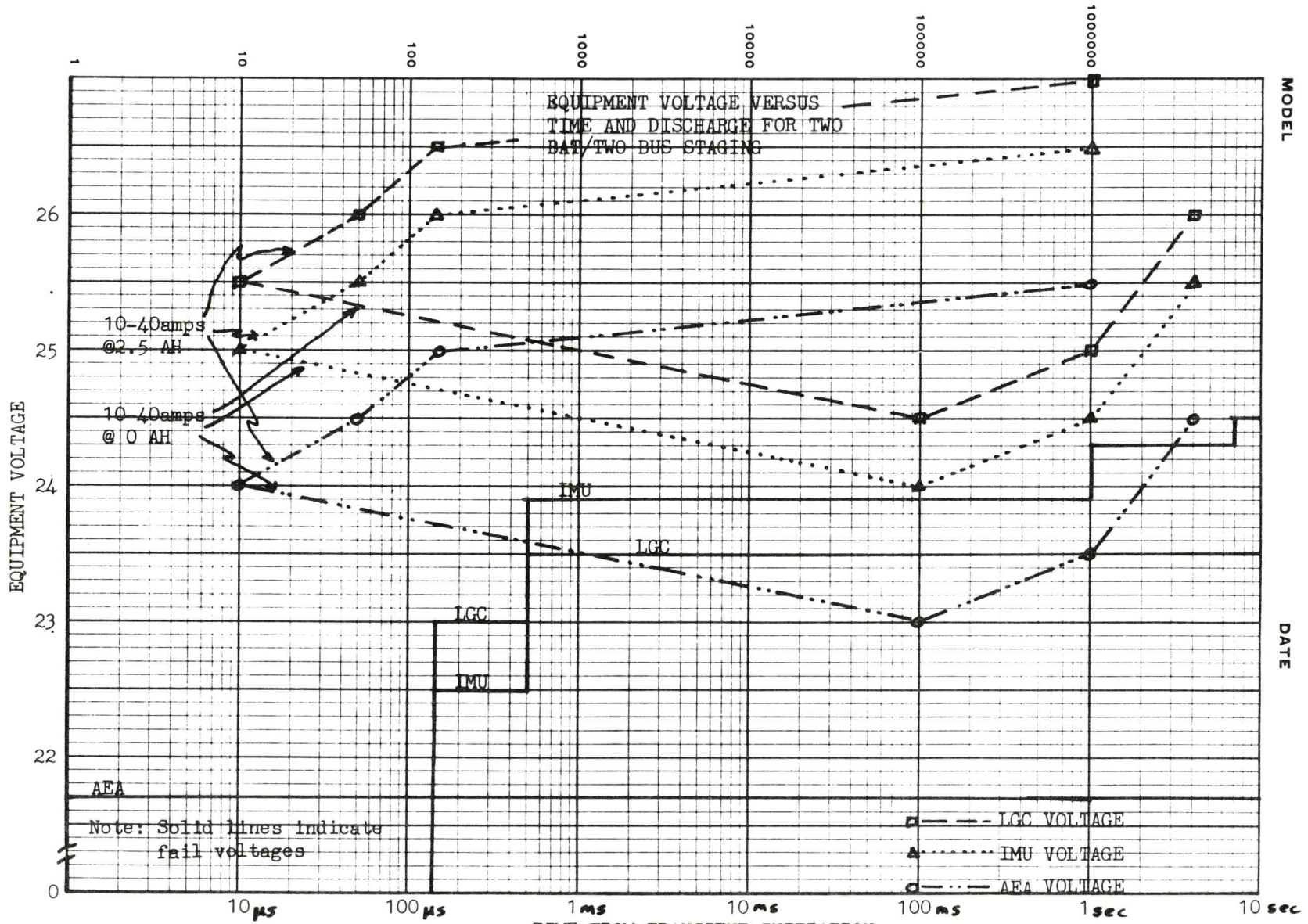


FIGURE 4

SB NO. **EPS 2-6**

S/C: LM
DATE: 6/1/71
REV: PCN-8/New
ORIGINATOR: R. Legler
APPROVAL: William L. Peters

TITLE: LM DESCENT BATTERY SWITCHING GROUNDRULES

REFERENCES: ASPO Memo, subject: LM Emergency Oxygen Smoke Masks dated 12 March 1971

BACKGROUND:

A. Purpose

There is a need to establish ground rules for LM descent battery switching to insure proper battery management with a minimum impact to crew activities. The battery management plan attempts to maintain state-of-charge divergence between any two descent batteries to less than 100 ampere-hours and to reach equal battery state-of-charges at the end of the planned mission.

B. Ground Rules and Rationale

1. Keep the state-of-charge of all five descent batteries as equal as practical:
   This ground rule minimizes the worst failure case of ampere-hour capacity loss should a battery be lost for any reason. Maintaining the state-of-charge relatively equal tends to limit the divergence of batteries connected to different feeders but supplying power to common loads.
2. Battery pair 1 and 2 or battery pair 3 and 4 will be switched on and off in pairs:
   Switching in pairs maintains the same battery temperatures and state-of-charge for batteries on the same feeder. If the battery temperature and state-of-charge were different when two batteries were connected to the same feeder, the state-of-charge would probably become more divergent.
3. The lunar battery will be used only on lunar surface.
   Crew activities may be too high to do battery switching prior to touchdown and it is not necessary to discharge the lunar battery at this time to maintain relative state-of-charge at a satisfactory level.
4. The LMP bus will not be operated with only one battery connected with the crossties open unless the crew is in the cabin and awake or secondary S-band xmtr/rcvr is selected.

   If the one battery should become disconnected from the LMP bus, there would be no audible indication to the crew that the bus had failed and no communications would exist with the ground. (The master alarm, PMP and primary S-Band are connected to the LMP bus).
5. Crossties will be closed whenever possible but always closed during EVA.

   Keeping crossties closed tends to balance the discharge of batteries. During EVA this will maintain redundant power sources to each bus when there is no crewman to correct single point failures which cause a loss of power.
6. Do not perform EPS switching immediately before or after a sleep period or pre-EVA while the crew is working with the PLSS's.

   Wherever possible, switching will not be accomplished within 30 minutes before or after an EVA or sleep period to reduce the interruptions to these sequences.
7. Battery switching will be accomplished while the crew is suited, when possible.

   This procedure is consistent with the desire to reduce electrical transitions and potential ignition sources while the crew is unsuited.

SB NO. **EPS 2-7**

S/C : LM
DATE : 11/1/71
REVISION : PCN-11/New
ORIGINATOR: W. Reeves
APPROVAL : William L. Peters

TITLE: ABNORMAL ASCENT BATTERY GO/NO GO CONSIDERATIONS

REFERENCES:

A. NASA Memorandum, PE-DMC-M11-71, March 2, 1971: LM Ascent Battery Anomaly, Apollo 14
B. Test Report, Battery Testing In Support of LM-8 Ascent Battery Anomaly: LMO 390-1370, 3-15-71
C. Note of Interest: Minimum LM Electrical Power Requirements Necessary to Accomplish a Short Rendezvous
D. Thermochemical Test Branch, Power and Propulsion Division, NASA MSC Test Data
E. LM Console Handbook, Systems Brief EPS 2 - 5, Ascent Battery Paralleling Requirements and Procedures

BACKGROUND:

As a result of a suspected bad cell in one ascent battery on Apollo 14, a study was launched to determine under what abnormal ascent battery conditions a mission could be continued. Three questions were answered:

1. What type of failure exists in the battery and can be identified in flight, eg. one or more cells shorted or a light short on the whole battery?
2. Can a battery with such a condition satisfy all possible transient conditions with normal preconditioning?
3. Can a battery with such a condition support the full mission and a lunar liftoff and rendezvous assuming the good ascent battery is subsequently lost?

The method of detection and analysis of an ascent battery problem in flight is to monitor the open circuit voltage (OCV). Nominally unused ascent batteries should read 37.0 or 37.2 VDC and definitely should not read any less than their installation OCV. A decreasing OCV is indicative of either a parasitic load draining the whole battery or one or more cells having developed internal shorts. As a result of discharge tests at various rates on a limited number of test cells, a family of voltage versus time curves was generated, (Figure 1). A suspected short in a battery can be approximated by utilizing this graph. A drop in OCV of greater than 1.85 VDC indicates more than one cell is affected since this is the voltage of one cell. Any OCV drop of less than 1.85 VDC is very obscure and requires several data points to distinguish between one or more cell shorts or a parasitic load on the battery. Obviously, the more readings which can be obtained the closer the approximation.

To best explain how to utilize Figure 1, an example will be followed. The assumptions used are:

(a) The short occurred immediately prior to its detection (to provide worst case).
(b) The magnitude of the short will not change.

For an example, assume the first abnormal ascent battery OCV of 36.8 VDC occurred at the first housekeeping around 34 hours GET. Because of the digital nature of the LM telemetry system, a reading of 36.8 VDC could represent an actual battery voltage of from 36.759 VDC to 36.917 VDC which reflects a one cell OCV from 1.609 VDC to 1.767 VDC. These two cell voltages are then plotted on Figure 1 at time zero. The next set of data points are obtained at the second housekeeping around 56 hours GET. Assuming this reading is still 36.8 VDC, and plotting the same data points at 22 hours on Figure 1, it can be seen that the current must be greater than 0.5 amps and less than 1.0 amp. The next data point is at activation around 96:40 GET. Assume the OCV has dropped another data bit to 36.7 VDC which could reflect a cell voltage of 1.451 to 1.609 VDC. Plotting these data points on Figure 1 at 64 hours, it appears that the problem was a single cell short and a GO will be given since this is an acceptable condition. If the last reading at 96:40 GET had been 36.8 VDC, the short could not have been in a single cell because no curve of Figure 1 fits the data points. However, by splitting the voltage drop between two cells it can be seen that the short appears to be 0.5 amps in two cells. Docking occurs at 175:13 GET and the short occurred at 34:00 GET resulting in (175:13 - 34:00) (0.5) =

70.6 AH lost to the 0.5 amp short. Based on the aforementioned assumptions, this too is a GO condition because sufficient consumables, greater than 119 AH, will remain in the bad battery to perform a liftoff and rendezvous should the good battery fail. The above procedures have been followed for most cases and the results are presented in Table I.

There is one additional case which must be covered and that is an OCV reading of exactly 35.1 VDC. This reading could be indicative of any of the conditions listed in Table II. As can be seen for six or more lightly shorted cells, their voltage is very near the monoxide plateau and could have almost any state of charge on this plateau. Therefore, a stable reading of 35.1 OCV could be indicative of either one cell completely discharged to zero volts or six or more cells lightly shorted. However, a load of approximately 25 amps can be placed on the battery and the load voltage will be pulled down by 1.5 to 1.9 VDC if one cell is dead; whereas, if the failure was six or more cells lightly shorted, there will be no detectable voltage suppression under load.

A limited number of experiments have been performed to determine the characteristics of an ascent battery with a failed cell. Figure 2 presents data at various discharges of such batteries showing what happens to the voltage across the dead cell. It can be seen that the voltage reverses immediately and stabilizes at approximately -0.4 VDC for a period of time which will cause the overall battery voltage to be down by -1.9 VDC (-1.5 VDC due to loss of the loaded cell voltage plus -0.4 VDC cell reversal). This loss of battery voltage immediately brings up the question of "Can a battery with a dead cell support all of the staging transients it is required to meet with normal preconditioning?" To answer this, reference the systems brief EPS 2 - 5, Ascent Battery Paralleling Requirements and Procedures. By biasing all of the curves of Figures 1 through 4 of that brief by -1.9 VDC for the dead cell, the voltages at the guidance equipment may be determined. Tables III and IV of this brief summarize the findings and it can be seen that the only case which must be altered is a one battery, two bus abort stage from PDI. An extra 5 AH must be removed for this case to achieve the best conditions and even then the IMU ICD will be violated. Further preconditioning does not improve the situation. A battery with more than one bad cell will not meet any of the transient situations.

Continuous use of a battery with one bad cell results in the bad cell being driven more and more negative causing the battery voltage to drop as demonstrated in Figure 2. The criteria for continuing a mission with such a battery is that the ascent battery with one dead cell must be capable of maintaining good bus voltage throughout lunar liftoff and rendezvous, should the one good battery be lost. Tests were run under these conditions and recorded in enclosure (4) of LMO 390-1370. The conclusion was that a one battery/two bus liftoff and rendezvous could be completed with one cell dead in the ascent battery and still maintain the voltage at the PGNS equipment above 25.5 VDC. These tests assumed worst case where the bad cell was completely dead at liftoff. A note of interest dated June 9, 1971 titled, "Minimum LM Electrical Power Requirements Necessary To Accomplish A Short Rendezvous," lists several alternate equipment configurations for rendezvous which decrease the power level. These configurations improve the voltage at the bus throughout the rendezvous.

MISSION IMPACT AND CORRECTIVE ACTION

Several important points which anyone using the above methods of battery capacity prediction should be aware of is that the whole scheme is based on the assumption that the short within the battery will remain constant. Testing at GAC and Boeing have shown that in some instances the short has increased in magnitude and in others has decreased. In no instance has the short remained unchanged. Also, Figure 1 is not a statistical representation but rather a total compilation of all cells run to date, two for each current level. All of the tests were run at room temperature rather than flight simulated conditions and it is well known that temperature drastically affects cell performance. In addition, once a GO is given on an abnormal battery and it is placed on line, all further use of the OCV to determine the nature of the battery problem is lost. Considering all of the above uncertainties, management has decided all of the risks are acceptable and the procedures to be used follow.

Open circuit voltage readings of the ascent batteries will be obtained during the first housekeeping period early in translunar coast. Should there be an abnormal reading, the additional readings obtained at the second housekeeping and LM activation with the long time duration in between will permit determination of the nature of the battery problem. In order to continue the mission, it must be confirmed that only one cell in the battery is bad or that it is a parasitic load small enough such that the ascent battery consumable redline will not be violated.

If the first abnormal OCV occurs at LM activation and is less than 35.1 VDC, the mission will be terminated because more than one cell is bad. For readings between 35.1 and 36.8 VDC, a hold will be called and the LM powered down somewhat to conserve consumables. The OCV of the affected battery will be monitored for a voltage change in order to use Table I, Table II and Figure 1 to determine the particular battery problem. Should the OCV hold at exactly 35.1 VDC for two hours, then the load check described earlier must be applied to distinguish one bad cell from six or more shorted cells. The amount of time available to do this checkout is limited in order to meet sun angle and trajectory constraints for landing.

K+E SEMI-LOGARITHMIC 46 5492
KEUFFEL & ESSER CO.

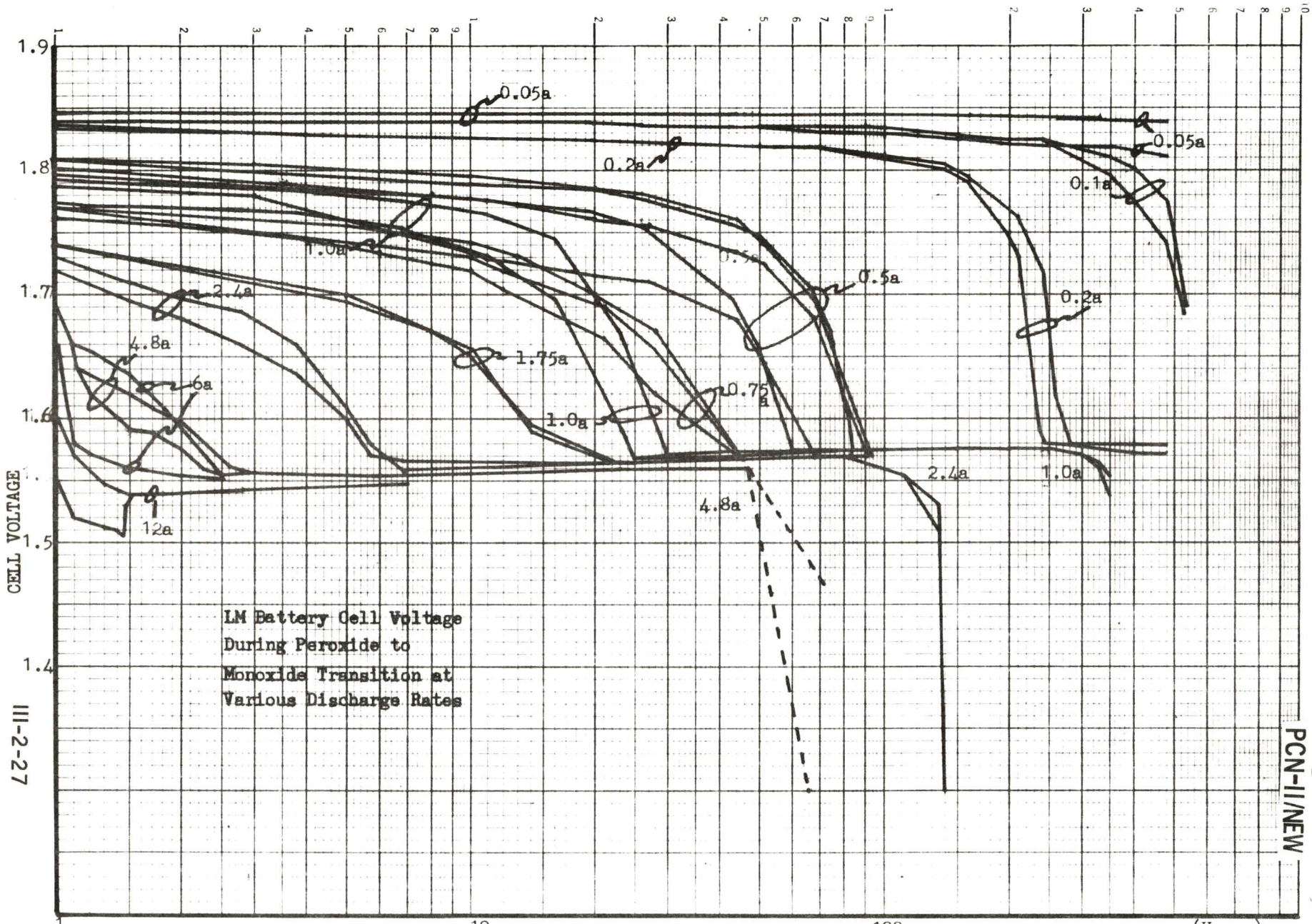


Figure 1

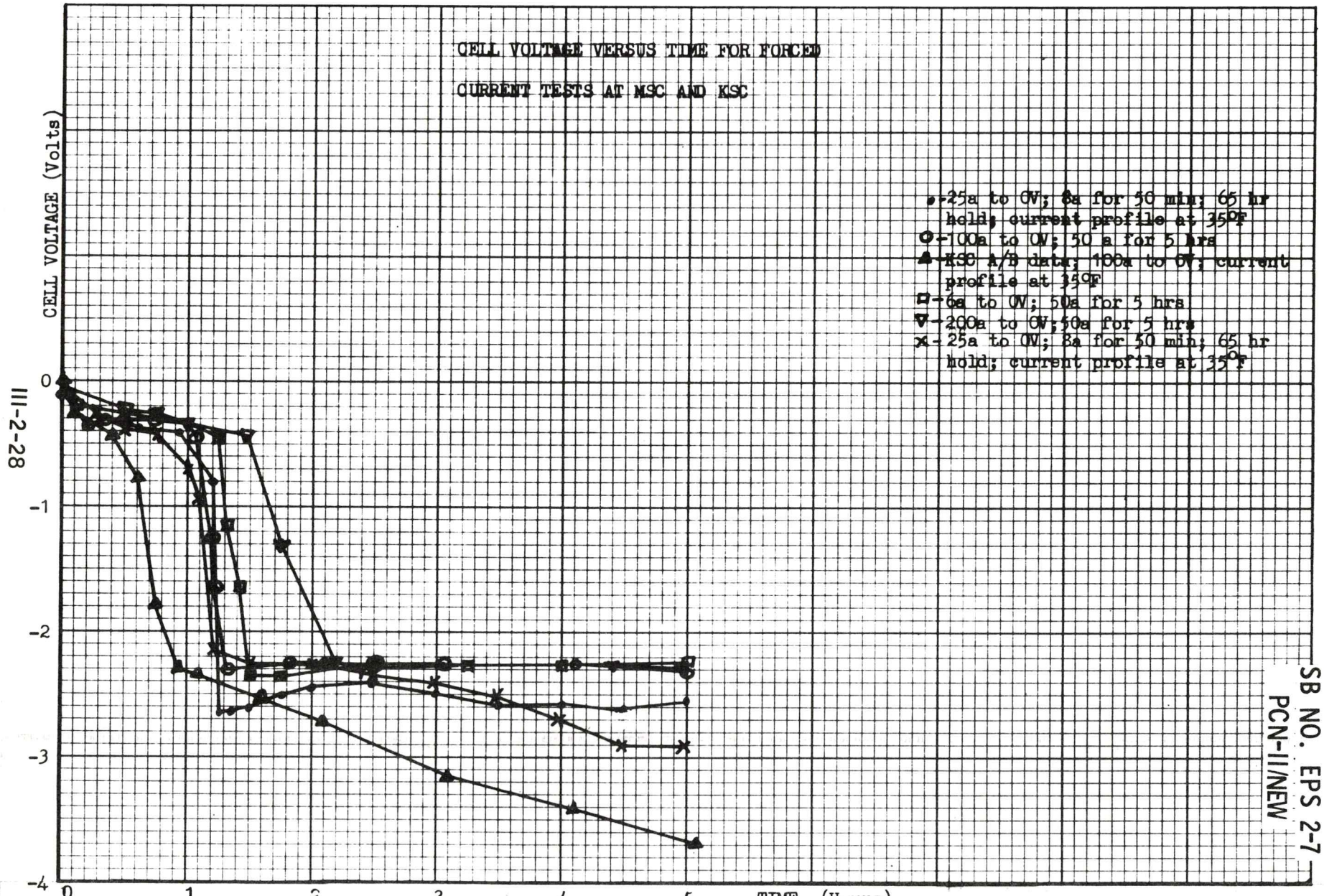


Figure 2

SB NO. EPS 2-7
PCN-II/NEW

TABLE I

EFFECTS OF CELL SHORT CIRCUITS ON

LM ASCENT BATTERY OCV READINGS

* THIS TABLE TO BE PROVIDED AT A LATER UPDATE

TABLE II

CAUSE AND EFFECTS OF 35.1 VDC OCV OF AN ASCENT BATTERY

NO. OF CELLS SHORTED	EACH SHORTED CELL's VOLTAGE TO PROVIDE 35.1 VDC OCV	MINIMUM TIME IN MINUTES FOR THE NEXT BIT DROP IN OCV
1	0	∞
2	0.925	10
3	1.233	20
4	1.39	60
5	1.48	$90 < t < 120$
≥ 6	≥ 1.54	$>> 120$

TABLE III

NOMINAL ASCENT BATTERY PRECONDITIONING

General Considerations:

- Ascent and descent batteries share equally
- Voltage drops from the battery

  to LGC = 1.5V
  to IMU = 2.0V
  to AEA = 3.0V

CONDITION	LGC	IMU	AEA	ASSUMPTIONS
Two-Bat/Two-Bus Abort Stage 2.5 AH from Bat 5 5.0 AH from Bat 6	Passes ICD	Passes ICD	Passes ICD	o Split bus configuration o Bat 5 (LMP) Step = 7.5 to 32.4 amps Bat 6 (CDR) Step = 13.8 to 51.5 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used for Bat 5 10 - 70 amp step data @ 40°F and 5 AH used for Bat 6 o Step is from 3 Bats (2 des, 1 asc) to 1 asc plus 10 amps/bus for RCS thrusters and cyclic loads.
One-Bat/Two-Bus Abort Stage 2.5 AH Removed	Passes ICD	Fails ICD Between 500 μs to 15 ms and between 1 sec and 1.5 sec. Lowest V = 23.5 at 50 μs.	Passes ICD	o Battery connected on both normal and backup feed paths o Bat Step Load = 12.78 amps to 83.9 amps o 10 - 70 amp step data @ 40°F and 2.5 AH used o Step is from 4 des and 1 asc to 1 asc plus 10 amps/bus

TABLE III Cont'd

CONDITION	LGC	IMU	AEA	ASSUMPTIONS
One-Bat/Two-Bus Abort Stage 5 AH Removed	Passes ICD	Passes ICD	Passes ICD	o Same assumptions as previous case except 10 - 70 amp step data @ 40°F and 5.0 AH used.
Two-Bat/Two-Bus Lunar Liftoff 2.5 AH from Bat 5 2.5 AH from Bat 6	Passes ICD	Passes ICD	Passes ICD	o Split bus configuration o Bat 5 (LMP) Step = 12.56 to 25.13 amps Bat 6 (CDR) Step = 10.08 to 20.15 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used. o Step occurs when last descent is removed from each bus. Time permits turning Des Bats off one at a time.
One-Bat/Two-Bus Lunar Liftoff 2.5 AH Removed	Passes ICD	Passes ICD	Passes ICD	o Battery connected on both normal and backup feedpaths with 100-amp crosstie C/B's closed. o Same assumptions as previous case except step is from 22.64 to 45.28 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used.

TABLE IV

ASCENT BATTERY PRECONDITIONING IF ONE CELL FAILED

General Considerations:

- Ascent battery carries 11% of total load when paralleled with one or more descent batteries if polarity has reversed.
- Voltage drops from the battery to guidance equipments same as for nominal battery.
- Voltage drop due to loss of one cell considered to be 1.9 VDC
- Battery/bus configuration and rationale for steps same as for nominal battery.

CONDITION	LGC	IMU	AEA	ASSUMPTIONS
Two-Bat/Two-Bus Abort Stage 2.5 AH from Bat 5 5.0 AH from Bat 6	Fails ICD from 150 μ sec to 2 sec Lowest voltage is 22.6 50 μ sec	Fails ICD from 500 μ sec to approx 3 sec Lowest voltis 23.1 at 50 μ sec.	Passes ICD	o Bat 5 (LMP) step 7.5 to 32.4 amps Bat 6 (CDR) step 13.8 to 51.5 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used for Bat 5 o 10 - 70 amp step data @ 40°F and 5 AH used for Bat 6
One-Bat/Two-Bus Abort Stage 5 AH Removed	Fails ICD Same as previous step	Fails ICD Same as previous step	Fails ICD between 50 μ sec and 500 ms. Lowest voltage is 21.6 at 50 μ sec.	o Step load = 7.0 amps to 83.9 amps o 10 - 70 amp data @ 40°F and 5 AH used
One-Bat/Two-Bus Abort Stage 10 AH Removed	Passes ICD	Fails ICD between 500 μ sec - 10 ms and between 1 sec unknown. Lowest voltage is 24.1 at 50 μ sec.	Passes ICD	o Same assumptions as previous case except 10 - 70 amp step data @ 40°F and 10 AH used.

TABLE IV CONT'D

CONDITION	LGC	IMU	AEA	ASSUMPTIONS
Two-Bat/Two-Bus Lunar Liftoff 2.5 AH from Bat 5 2.5 AH from Bat 6	Passes ICD	Passes ICD	Passes ICD	o Bat 5 step = 2.76 to 25.13 amps Bat 6 step = 2.22 to 20.15 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used.
One-Bat/Two-Bus Lunar Liftoff 2.5 AH Removed	Passes ICD	Passes ICD	Passes ICD	o Same assumptions as previous case except step is from 4.98 to 45.28 amps. o 10 - 40 amp step data @ 40°F and 2.5 AH used.

S/C: LM
DATE: 11-1-71
REV: PCN-11/New
ORIGINATOR: R. D. Legler
APPROVAL: William P. Peters
APPROVAL: Gerald W. Linden

SB NO. **EPS 2-8**

TITLE: MINIMUM LM ELECTRICAL POWER REQUIREMENTS TO ACCOMPLISH A RENDEZVOUS

PURPOSE: The purpose of this systems brief is to define the minimum LM electrical power requirements using the various acceptable combinations of G & N Systems needed for a rendezvous.

BACKGROUND: The basic philosophy adopted by Data Priority is that one primary onboard TPI solution is required to select the direct rendezvous. The acceptable combinations of G & N systems needed for a rendezvous are defined below. Loss of all three of these techniques will result in execution of the coelliptic sequence rendezvous.

REQUIRED G&N SYSTEMS NEEDED FOR DIRECT RENDEZVOUS					
PRIMARY RENDEZVOUS NAVIGATION TECHNIQUE	SYSTEMS REQUIREMENTS				
	COMPUTER	SENSOR/OPTICS	SENSOR/COMPUTER INTERFACE SUPPLYING:	TRACKER LIGHT	PLATFORM
LGC/RR	LGC	RENDEZVOUS RADAR	RANGE, RANGE RATE, SHAFT and TRUNNION ANGLES		LM IMU
AGS/RR	AEA	RENDEZVOUS RADAR LM COAS	TAPEMETER: RANGE and RANGE RATE	CSM	ASA
CMC/SEXTANT	CMC	USEABLE SEXTANT	SEXTANT SHAFT and TRUNNION ANGLES	LM	CSM IMU

The Apollo 15 SEENA program was used as a basis for these alternate G & N combinations and typical ascent battery requirements are as follows:

	BAT 5	BAT 6	AAH
Pre-PDI to Lunar Surface PWR down	14	10	24
ASC Bats on to Liftoff	12	10	22
Liftoff to Insertion	3	3	6
Insertion to Docking	51	40	91
	80	63	143

For the purposes of developing additional power profiles, the total ampere-hours of 6 from liftoff to insertion and 91 from insertion to docking will be used as a reference.

G & N OPTIONS: The following combinations of G & N Systems have been selected as options for an electrical power contingency case:

1. LGC with RR, Direct Rendezvous.
2. AGS with RR, Direct Rendezvous.
3. CMC with Sextant, Direct Rendezvous, with LM track light
4. CMC with Sextant, coelliptic rendezvous, with LM track light.
5. CMC with Sextant, coelliptic rendezvous, with VHF ranging.

ASSUMPTIONS:
1. In all options, the LM will be fully powered up with both PGNS and AGS through insertion.
2. Cabin fan is on at insertion.
3. Suit fan is turned off at insertion plus 10 minutes.
4. If PGNS is to be used, the AGS will be turned off at insertion.
5. If AGS is to be used, the PGNS and GASTA will be turned off at insertion.

6. The track light will be on only during the dark side (approximately 50 minutes) and then only when the CMC with Sextant is used for the solution.
7. All floodlights will be turned off at insertion.
8. VHF voice Vox Mode with CSM has been retained without ranging for all solutions.
9. Eight ampere-hours is assumed for the preconditioning of the remaining ascent battery prior to liftoff.
10. The computations below are made by taking the deltas from the following numbers:

one battery pre-conditioning	5
DES BATS off to L/O	3
L/O to Insertion	6
Insertion to Docking	91
	105

11. If the ampere-hours during powered descent are to be considered, 14 AH must be added to the 105 giving a total reference of 119 AH.
12. S-Band PA and transceiver will be turned off during lunar LOS.

OPTIONS:

1. LGC with RR, direct rendezvous

	EQUIPMENT OFF	AH DELTA
After Insertion	Floodlights	-4.32
	AGS	-9.63
Insertion + 10 minutes	Suit Fan	-9.36
During Lunar LOS	S-Band	-3.22
Not Required	Track Light	-4.07
	VHF XMTR A VC/RNG	-2.51
		-33.11

105 AH minus 33 = 72 AH Pre-liftoff through docking.

2. AGS with RR, direct rendezvous

	EQUIPMENT OFF	AH DELTA
After Insertion	PGNS	-19.03
	Floodlights	- 4.32
	GASTA	- 1.19
Insertion + 10 minutes	Suit Fan	- 9.36
During Lunar LOS	S-Band	- 3.22
Not Required	Track Light	- 4.07
	VHF XMTR A VC/RNG	- 2.51
	TOTAL	-43.70

105 AH minus 44 = 61 AH pre-liftoff through docking

3. CMC with SEXTANT, DIRECT RENDEZVOUS with LM TRACK LIGHT:
The LM is configured to the Apollo 13 power down (11.3 amperes) after insertion except that RCS heaters would be enabled (no power would be required for RCS heaters, since temperatures would be elevated from ascent thruster activity). The LM track light is required during the dark side only. From insertion through docking 24 AH are required which includes 4 AH for the LM track light.

Pre-liftoff	8 AH
L/O to insertion	6 AH
Insertion to docking	24 AH
	38 AH pre-liftoff through docking

4. CMC with SEXTANT, COELLIPTIC RENDEZVOUS with LM TRACK LIGHT:
If a coelliptic rendezvous is required, 23 AH must be added to the above case or a total of 61 AH required for pre-liftoff through docking.
5. VHF Ranging may be substituted in lieu of the tracklight when using the CMC with sextant on a coelliptic rendezvous. VHF tracking is required for CSI, TPI, MCC/TPF and results in 1 AH saving for a total of 60 AH pre-liftoff through docking.

SUMMARY:

1.	LGC with RR, Direct Rendezvous	72 AH
2.	AGS with RR, Direct Rendezvous	61 AH
3.	CMC with SEXTANT, direct rendezvous, LM track light	38 AH
4.	CMC with SEXTANT, coelliptic rendezvous, LM track light	61 AH
5.	CMC with SEXTANT, coelliptic rendezvous, VHF Ranging	60 AH

Fourteen ampere-hours must be added to the above totals for ascent battery usage during powered descent.

SB NO. **EPS 2-9**

S/C: LM
DATE: 3-1-72
REV: PCN 12/NEW
ORIGINATOR: R. Legler/ W. Reeves
APPROVAL: William K. Peters

TITLE: LM ELECTRICAL CONFIGURATION FOR THE LOSS OF ONE ASCENT BATTERY

REFERENCE:
A. Test Report for Ascent Battery Transient Test: LTR 396-86, 10-2-67
B. Ascent Battery - G & N Interface Transient Voltage Test: LTR 390-87, 10-20-67
C. LM Ascent Battery Parametric Tests: LTR 390-104, 2-21-68
D. Ascent Battery Transient Test: LTR 390-128, 10-10-69
E. Apollo Data Submittals: GAEC-S-57, 2-6-69, GAEC-S-61, 4-14-69
F. IRN LIS 390-10002A to Reference E
G. Memorandum No. E68-69-359

BACKGROUND: The subject, "loss of one ascent battery", is an extremely controversial topic which has been discussed in great detail, since the loss of the remaining ascent battery capability would be catastrophic. The battery and bus configuration affects the susceptibility to different types of failures. This system configuration is contained in the mission rules, malfunction procedures, and other documentation, all of which must be changed each time this configuration is modified. The various configurations and their merits will be discussed in this systems brief. The ultimate goal of this systems brief is to establish the best configuration and to insure that all mission documentation are in agreement.

CONSIDERATIONS:

Some of the factors that must be considered when establishing the most desired configuration are:

1. Effect on EPS system as a result of a short on a feeder or bus:
   a. Will short isolate itself?
   b. Can short be isolated manually?
2. Are there any single point failures that can be bypassed in another configuration?
3. Will the configuration result in reduced capability or reduced protection to voltage sensitive equipment under static and transient conditions?

SWITCHING CAPABILITIES:

1. Place battery on NORMAL FEED only.
2. Place battery on BACKUP FEED only.
3. Place battery on both NORMAL and BACKUP FEEDS.
4. Close CROSSTIE BAL LOAD (30 amp) circuit breakers.
5. Close CROSSTIE BUS (100 amp) circuit breakers.
6. Leave both BATTERY FEED TIE (100 amp) circuit breakers closed on LMP bus.
7. Open one BATTERY FEED TIE (100 amp) circuit breaker on LMP bus.
8. Leave both BATTERY FEED TIE (100 amp) circuit breakers closed on CDR bus.
9. Open one BATTERY FEED TIE (100 amp) circuit breaker on CDR bus.

CONFIGURATIONS

Assuming that both buses are to be fed from the remaining battery, there are four different configurations which may be used (see attached schematics):

1. Connect remaining battery via the NORMAL FEED with the CROSSTIE BUS circuit breakers closed.
2. Connect remaining battery via the BACKUP FEED with the CROSSTIE BUS circuit breakers closed.
3. Connect remaining battery via both the NORMAL and BACKUP FEED with the CROSSTIE cbs open.
4. Connect remaining battery via both the normal and backup feeds with the CROSSTIE cbs closed.
5. Several minor variations have been considered but they are less desirable:
   a. One variation ties the buses via the CROSSTIE BAL LOAD (30A) cb's VICE the CROSSTIE BUS (100A) cb's. The disadvantage is that a BAL LOAD cb may open under normal rendezvous bus current

if an open developed in a feed path.

b. Another variation opens one BATTERY FEED TIE cb on a feeder. This configuration results in a loss of redundancy. It could result in an unpowered LM in some configurations if the other BATTERY FEED TIE cb opened, VICE a CROSSTIE BUS cb, as a consequence of a short.

FAILURES: Three types of failures have been identified - Controlled Shorts, Hard Shorts and Open Circuits.

1. Controlled Short - is generally considered to be a short whereby the current is limited such that it will not be automatically isolated and does not cause an alarm or serious degradation of the voltage (< 115 amps). This type of short is power consuming but does not create an emergency situation. The crew must take action to clear them as soon as practical. This type of short is not considered to be a likely prospect.
2. Hard Short - is generally considered to be extremely high currents that would normally cause an alarm and automatically be isolated if both buses were independently powered. If only one ascent battery is powering both buses, it may or may not be automatically isolated. A hard short requires immediate action by the crew, if it does not automatically isolate itself, since it is an emergency situation causing serious voltage degradation and possible damage to wiring or equipment. In the case of the LM being powered by one ascent battery, it could easily result in a voltage reduction that would render all equipment inoperative. Furthermore, if the short were on a feeder, it could result in voltage degradation to the point that it would be impossible to operate the reset coils of the ECA main and backup feed relays.
3. Open Circuit - This type of failure could result in a completely unpowered LM. The only open circuit considered possible when on ascent power is for an ECA contact to open because all feeders and Bat feed tie circuit breakers are redundant.

VOLTAGE DROP:

The loss of one ascent battery is a critical failure, but a LM active rendezvous may be performed under nominal conditions. However, there would be little margin in the power available to complete a rendezvous. Failure to successfully complete a burn, at the specified time, could require a LM power down and a CSM rescue. The risk of a computer problem, due to a low voltage transient, is primarily during these critical maneuver periods. Therefore, every possible precaution should be taken to protect against low voltage transient during this critical situation.

The voltage drop between buses, when feeding one bus via the crosstie during normal coasting flight, is approximately 0.2 volts with a bus current of 20 - 30 amperes. This is based on a crosstie resistance of approximately 7 milliohms. During thruster and engine firings, in conjunction with the other transient loads, the voltage drop could be several times this amount. The voltage drop can be kept to a minimum by feeding both buses directly vice feeding one bus via the crossties.

To analyze the voltage conditions that will exist at the PGNS and AGS computers, a worst case condition of an APS abort at T1 with one ascent battery two bus operation has been assumed. Figure 1 exhibits the circuit used in this analysis with all resistances as set forth in the Apollo Data Submittals GAEC-S-57 and GAEC-S-61, dated February 6, 1969 and April 14, 1969 respectively. The currents used were derived from the LM SEENA Program for a nominal lunar landing mission and the battery voltage response from the LM Ascent Battery Voltage Transient tests (LTR 390-128).

Three different battery/bus configurations were analyzed using the following assumptions:

1. Step load seen by battery due to APS ignition is from 46.4 to 52 amps.
2. Assume four thrusters come on adding 16 amps to the step, making it 46.4 to 68 amps.
3. Run No. 11 of LTR 390-128 best represents the battery transient.

The results of the analysis are presented in Tables I, II, and III. It should be noted, that all of the above figures were hand calculated and no transients other than those mentioned were considered.

By comparing Tables I, II, and III, it can be seen that maximum voltage protection is afforded by feeding both buses directly with the crossties closed.

FAILURE RESULTS:

For purpose of this section a short is considered to be a hard short. The following steps taken after a failure are functionally correct; however, the malfunction procedures describe the entire sequence. (See the attached schematics for configurations and cases).

CONFIGURATION 1 - Battery on NORMAL FEED with CROSSTIE BUS cb's closed and BATTERY FEED TIE cb's open on the opposite feeder.

CASE 1 - A short on the opposite bus would be isolated by the CROSSTIE BUS cb opening. The voltage on the adjacent bus probably would drop below the critical level until a CROSSTIE BUS cb opened. The voltage would return to normal resulting in a one-bus operation.

CASE 2 - A short on the opposite feeder is already isolated since the BATTERY FEED TIE cb's were opened during configuration.

CASE 3 - A short on the adjacent bus would result in the voltage on both buses dropping below the critical level until the BATTERY FEED TIE circuit breakers opened, at which time the LM would be unpowered. Power could be restored to the opposite bus by opening the CROSSTIE BUS cb's, closing the BATTERY FEED TIE cb's on the opposite feeder and placing the battery on BACKUP FEED. Then the NORMAL FEED should be turned off. This would permit a one-bus operation.

CASE 4 - A short on the adjacent feeder or battery terminal would cause the voltage to drop below the critical level and could not be isolated. Hence the LM would essentially be unpowered and the crew would be unable to isolate the short.

CASE 5 - An open in the crosstie cabling would result in a temporary loss of the opposite bus which could be recovered by placing the battery on BACKUP FEED and closing the BATTERY FEED TIE circuit breakers.

CASE 6 - An open in the feed path being used would result in an unpowered LM until the crew placed the battery on BACKUP FEED and closed the BATTERY FEED TIE cb's which would permit recovery of both buses.

CASE 7 - An open on the battery terminal would result in an unpowered LM and is an unrecoverable situation.

CASE 8 - Closed contacts in the overcurrent relay may result in the battery being removed from the line and the LM would be unpowered until the crew placed the battery on BACKUP FEED and closed the BATTERY FEED TIE cb's.

CONFIGURATION 2 - Battery on BACKUP FEED with CROSSTIE BUS cb's closed and BATTERY FEED TIE cb's open on opposite feeder.

Results would be identical with the battery on NORMAL FEED with the crossties closed except the overcurrent relay does not interrupt the BACKUP FEED (See Case 8, configuration 1).

CONFIGURATION 3 - Battery on both NORMAL and BACKUP FEEDS with the CROSSTIE BUS circuit open and all BATTERY FEED TIE cb's closed.

CASE 1 - A short on either bus would cause both bus voltages to drop below the critical limit until the BATTERY FEED TIE circuit breakers on the faulted bus open, at which time the nominal voltage would be restored to the good bus.

CASE 2 - A short on either feeder would result in the voltage dropping below the critical limit and the LM would be essentially unpowered since the crew would be unable to isolate the short.

CASE 3 - An open in either feed path would result in the loss of one bus; however, the opposite bus would still be functional. The other bus could be recovered by closing the CROSSTIE BUS cb's.

CASE 4 - An open on the battery terminal would result in an unpowered LM, and is an unrecoverable situation.

CONFIGURATION 4 - Battery on both NORMAL and BACKUP FEEDS with the CROSSTIE BUS circuit breakers closed.

CASE 1 - A short on either bus would cause the bus voltages to drop below the critical limit, one CROSSTIE BUS cb would open, and then the BATTERY FEED TIE cb's would open. This would isolate the short and the voltage on the good bus would return to normal.

CASE 2 - A short on either feeder would result in the bus voltages dropping below the critical limit and one CROSSTIE cb would open. However, the short could not be isolated and the LM would be essentially unpowered.

CASE 3 - An open in either feed path would not result in loss of a bus since the bus is fed alternately via the CROSSTIE BUS cb.

COMPARATIVE ADVANTAGES/DISADVANTAGES:

CONFIGURATION 1 - Battery on NORMAL FEED with CROSSTIE BUS cb's closed, and BATTERY FEED TIE cb's open on the opposite feeder:

a. Advantages:

A short on the opposite feeder does not affect the vehicle, since the BATTERY FEED TIE cb's and the ECA relays are open.

b. Disadvantages:

(1) An open on the adjacent feed path would result in an unpowered LM until the crew could close the BATTERY FEED TIE cb's on the opposite feeder and place the battery on BACKUP FEED.

(2) The voltage drop during transients may be several volts which could lead to a computer problem.

(3) Closed contacts in overcurrent relay possibly could trip the battery off-line.

CONFIGURATION 2 - BATTERY on BACKUP FEED with CROSSTIE cb's closed, and BATTERY FEED TIE cb's open on the opposite feeder. The characteristics are the same as with the battery on NORMAL FEED except that the overcurrent relay does not interrupt the BACKUP FEED path.

CONFIGURATION 3 - BATTERY on both NORMAL and BACKUP FEED with the CROSSTIE BUS cb's open:

a. Advantages:

(1) The voltage drop on both buses would be minimal since both buses are fed directly.

(2) An open on either feed path would interrupt power to only one BUS.

b. Disadvantages:

(1) A short on either feeder results in a condition wherein the short can not be isolated and is a catastrophic failure. (Note: In configurations 1 and 2, a short on the powered feeder would have similar results).

(2) An open on either feed path would interrupt power to one bus.

CONFIGURATION 4 - Battery on both NORMAL and BACKUP FEEDS with the CROSSTIE BUS cb's closed:

The characteristics are the same as for configuration 3 except that additional voltage transient protection is offered by closing the CROSSTIE BUS cb's, and an open on either feed path will not interrupt power to either bus.

SUMMARY:

In summary, two configurations appear to be most advantageous (No. 2 and No. 4):

Battery on BACKUP FEED with the CROSSTIE BUS cb's closed and the BATTERY FEED TIE cb's open on the unused feeder (configuration 2).

Battery on NORMAL and BACKUP FEEDS with the CROSSTIE BUS cb's closed (configuration 4).

TRADE OFF:

In Configuration 2 - a short on the unpowered feeder will not result in a catastrophic situation.

VERSUS

In Configuration 4 - an open in either feed path does not interrupt power to either bus. Both buses are fed directly which reduces the voltage drop; thereby, lessening the possibility of a voltage transient causing a computer problem.

CONCLUSION:

The LM E & ISS is of the opinion that the additional protection from a shorted feeder, afforded in configuration 2, does not warrant the risk of a computer problem due to a voltage transient or the loss of a bus due to an open feed path. Hence, our recommendation is to plan use of configuration 4 - Battery on NORMAL and BACKUP FEEDS with the CROSSTIE BUS cb's closed.

TABLE I

Voltage Response for T1 Liftoff for one Ascent Battery Feeding LMP Bus directly and CDR Bus via Crossties.

TIME FROM STEP	0-100 μs	100-500 μs	After 500 μs
Bat Voltage	26.5	26.75	27.3
CDR Bus Voltage	25.927	26.177	26.727
LGC Voltage	25.645	25.895	26.445
*LGC Fail Voltage	0	23.00	23.85
LMP Bus Voltage	26.208	26.458	27.008
AEA Voltage	24.152	24.402	24.952
*AEA Fail Voltage	21.7	21.7	21.7

TABLE II

Voltage Response for T1 Liftoff for one Ascent Battery Feeding CDR Bus directly and LMP Bus via Crossties.

TIME FROM STEP	0-100 μs	100-500μs	After 500 μs
Bat Voltage	26.5	26.75	27.3
CDR Bus Voltage	26.21	26.458	27.008
LGC Voltage	25.928	26.176	26.726
*LGC Fail Voltage	0	23.00	23.85
LMP Bus Voltage	25.976	26.224	26.774
AEA Voltage	23.92	24.168	24.718
*AEA Fail Voltage	21.7	21.7	21.7

TABLE III

Voltage Response for T1 Liftoff for One Ascent Battery Feeding both Buses directly with the Crossties Closed.

TIME FROM STEP	0-100 μs	100-500 μs	After 500 μs
Bat Voltage	26.5	26.75	27.3
CDR Voltage	26.391	26.64	27.187
LGC Voltage	26.109	26.358	26.905
*LGC Fail Voltage	0	23.00	23.85
LMP Bus Voltage	26.409	26.658	27.206
AEA Voltage	24.353	24.602	25.150
*AEA Fail Voltage	21.7	21.7	21.7

* The LGC fail voltage was derived from ICD NO. LIS 390-10002, REV A and the AEA fail voltage from memorandum NO. EG8-69-359.

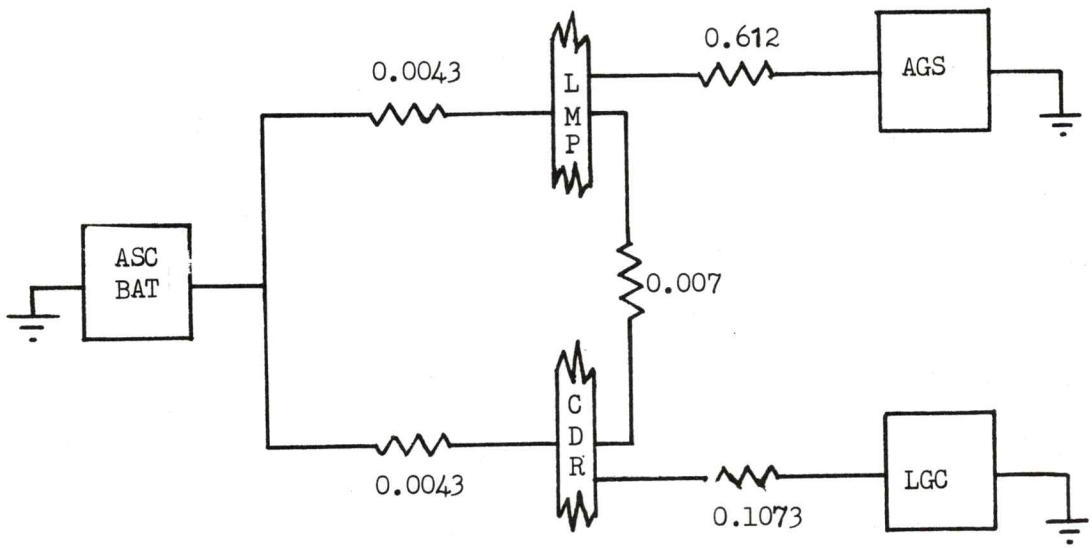
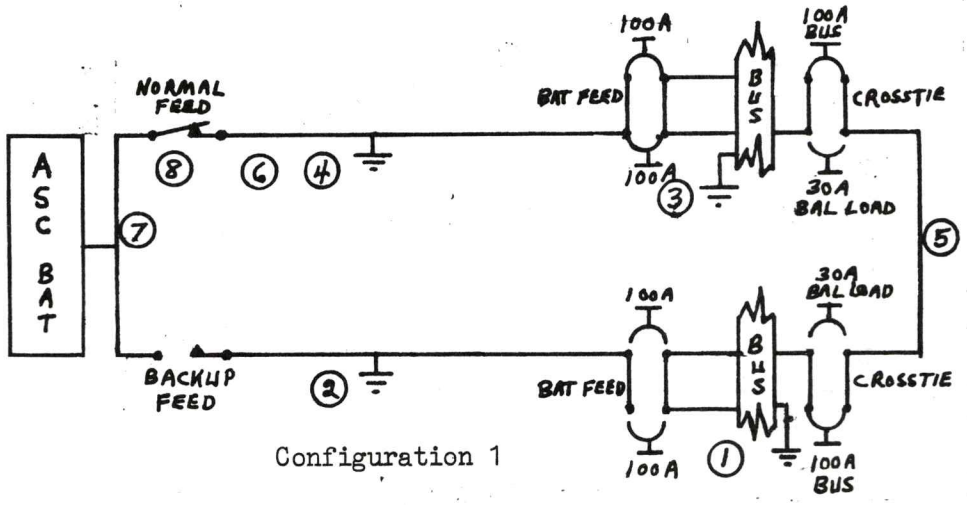


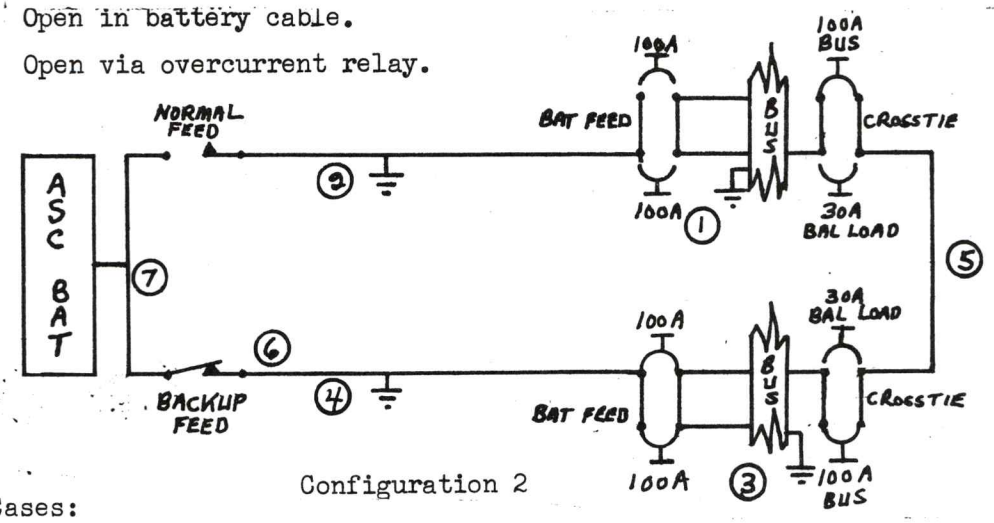
FIGURE 1.



Configuration 1

Cases:

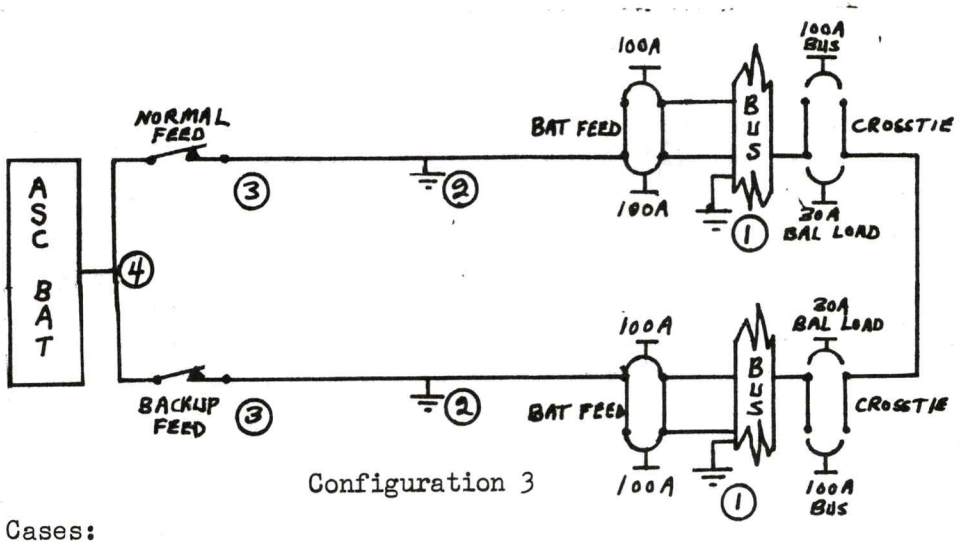
1. Short on opposite bus.
2. Short on opposite Feeder.
3. Short on adjacent bus.
4. Short on adjacent feeder.
5. Open in crosstie cabling.
6. Open in adjacent feeder.
7. Open in battery cable.
8. Open via overcurrent relay.



Configuration 2

Cases:

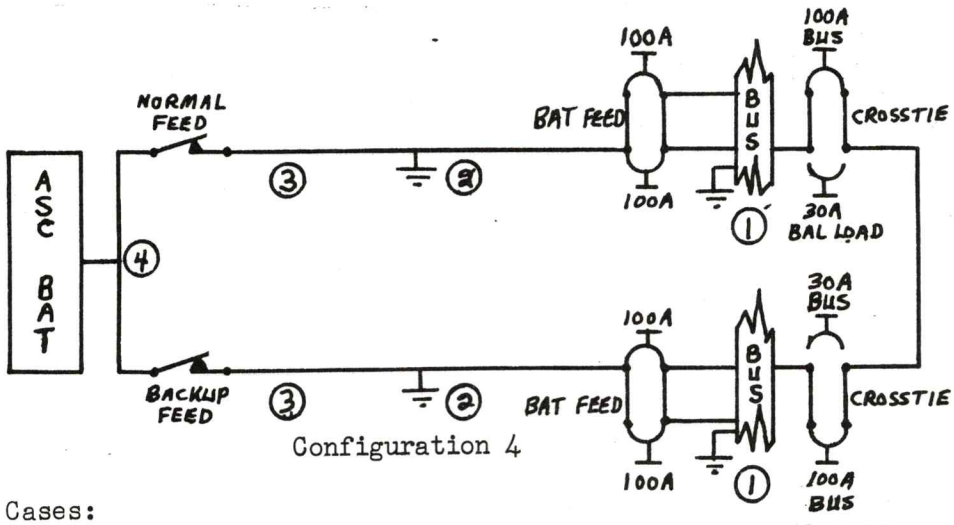
1. Short on opposite bus.
2. Short on opposite feeder.
3. Short on adjacent bus.
4. Short on adjacent feeder.
5. Open in crosstie cabling.
6. Open in adjacent feeder.
7. Open in battery cable.



Configuration 3

Cases:

(1) Short on either bus.
(2) Short on either feeder.
(3) Open in either feeder.
(4) Open in battery cable.



Configuration 4

Cases:

(1) Short on either bus.
(2) Short on either feeder.
(3) Open in either feeder.
(4) Open in battery cable.

SB NO. **EPS 2-10**

S/C: LM
DATE: 3-1-72
REV: PCN-12/NEW
ORIGINATOR: R. Heselmeyer
APPROVAL: W. Wm. L. Peters

TITLE: DESCENT COOLING VALVE AND ECA TEMP VEHICLE MODIFICATIONS

PURPOSE: Explanation of the total effect of the glycol shutoff valve and ECA temperature vehicle modifications on the spacecraft, crew procedures, and ground operations.

BACKGROUND: After the Apollo 15 mission a series of descent battery discharge tests revealed that the batteries were not delivering their rated capacity. Of the several possible causes of this problem (including wet stand time, discharge rate, negative plate limiting), the test data shows that battery temperature is a major factor in determining battery capacity. Based on this data the decision was made to install a valve in the glycol line to provide the capability of limiting or stopping glycol flow to the descent batteries. Thus the capability is provided of increasing the descent battery temperatures to help increase capacity should it become necessary.

The new glycol valve is located behind some netting in the extreme rear corner of the LM cabin on the LMP side. Rerouting of the glycol line was required to interface with the valve, resulting in two new cabin pressure vessel penetrations. With respect to glycol flow, the valve is located downstream of the equipment cooled in the descent stage.

The valve itself is the same as the Suit Temp Control Valve, which is a three port valve. Flow cannot be completely stopped between the inlet and the outlet ports, but can be stopped between the inlet and heat exchanger ports. For this application the inlet and heat exchanger ports will be used with the outlet port capped to enable completely shutting off glycol flow. The additional capability of modulating glycol flow is also available. Figures 1 through 4 show information pertinent to glycol loop operation with the valve installed.

All equipment on the cold rails in the descent stage is affected by the new valve. This equipment is all descent batteries, the descent ECA's, the battery control relay assembly (BCRA), and the Pyro System A battery. A recent test conducted by GAC indicates that the battery and ECA temperature rise rates without cooling, at 7 amps per battery, are approximately 3.4 and 3.9 degrees per hour respectively. Because the maximum allowable nominal operating temperature of the batteries is 100°F and the critical ECA temperature is 132°F, it is questionable whether the batteries or ECA's will reach their temperature limit first. Pertinent results of this and subsequent tests will be documented in the SODB. Figure 5 shows battery temperature versus coolant flow, and is based on current SODB information.

To protect against overheating the most critical equipment when glycol flow is shut off, a temperature transducer has been added to the flange of each ECA. These two temperatures have been wired to a newly installed switch in Quad II of the descent stage. The existing RTG Cask temperature and Landing Radar Antenna temperature measurements have been rewired through this same switch. With this configuration the RTG Cask temperature will be received on telemetry and the Landing Radar Antenna temperature will be available onboard and on telemetry exactly as in previous missions until sometime during the first EVA. At that time a crewman will throw the switch, and in so doing will replace the RTG Cask and Landing Radar Antenna temperatures with the two ECA temperatures. The ECA 1 temperature uses the same instrumentation path previously used by the RTG Cask temperature, and will therefore be available on telemetry. Likewise the ECA 2 temperature uses the same instrumentation path used by the Landing Radar Antenna temperature and will therefore be available on telemetry and onboard on the temperature meter on panel 3 when the "LDG" position is selected with the Temp Monitor switch, also on panel 3.

MISSION IMPACT:

Several alternate methods for using the glycol valve have been considered. These included a modulated but constant glycol flow, an on/off duty cycling of the valve, or normal flow until late in the lunar stay when flow would be inhibited for the remainder of the stay. The first two methods are unacceptable because of systems or procedural considerations. If required, the last method will be implemented with cooling terminated approximately 16 hours before battery depletion. Use of the valve must be carefully placed in the crew timeline because of its relative inaccessibility. Use of the valve should not be required when the location of crew equipment (PLSS's, OPS, PGA's) is such that easy access is prohibited.

Officially the new ECA temperature measurement numbers are GC6201T and GC6202T for ECA's 1 and 2 respectively. The RTG Cask and Landing Radar Antenna temperature measurement numbers, GL8275U and GN7563T, still apply to those measurements. However, since these measurements are now switchable such that the same instrumentation path is used by each pair of parameters, new measurement numbers have been assigned for the combined measurements. The displayed measurements, onboard and on telemetry, are GL9401U, Sel RTG/ECA 1 Temp, and GL9402U, Sel LR/ECA 2 Temp. Because the transducers used for the ECA 1 and RTG Cask temperatures are the same, and the transducers used for the ECA 2 and Landing Radar Antenna temperatures are the same, one calibration curve can be used for each of these measurements. This configuration eliminates the need to switch calibration curves in the RTCC when the parameters are switched. The applicable curves will be published under the combined parameter numbers, GL9401U and GL9402U.

Because the ECA temperatures, GC6201T and GC6202T apply from the temperature transducers to the switch only, they will not appear in documentation pertaining to onboard and telemetry displayed information, and are mentioned here for information only. Normally the same would be true for the RTG Cask and the Landing Radar Antenna temperatures. However, constraints associated with ground processing prevent incorporation of the new combined measurement numbers, GL9401U and GL9402U, and therefore the RTG Cask and Landing Radar Antenna temperature numbers, GL8275U and GN7563T, must be used when information is requested from ground processing personnel, both at Houston and at the sites.

A minor operational implication of the glycol modification is the increase in descent ECA measurement inaccuracy at higher operating temperatures. The TM inaccuracy associated with individual descent batteries is 0.3 amps in the 3 - 12 amp range for an internal ECA temperature of less than 75°F, and 0.55 amps in the 3 - 12 amp range for an internal ECA temperature of greater than 75°F. (The TM inaccuracy is 0.95 amps for any value outside the 3 - 12 amp range regardless of ECA temperature). This change in ECA measurement inaccuracy will not be a factor when formulating the glycol valve management plan.

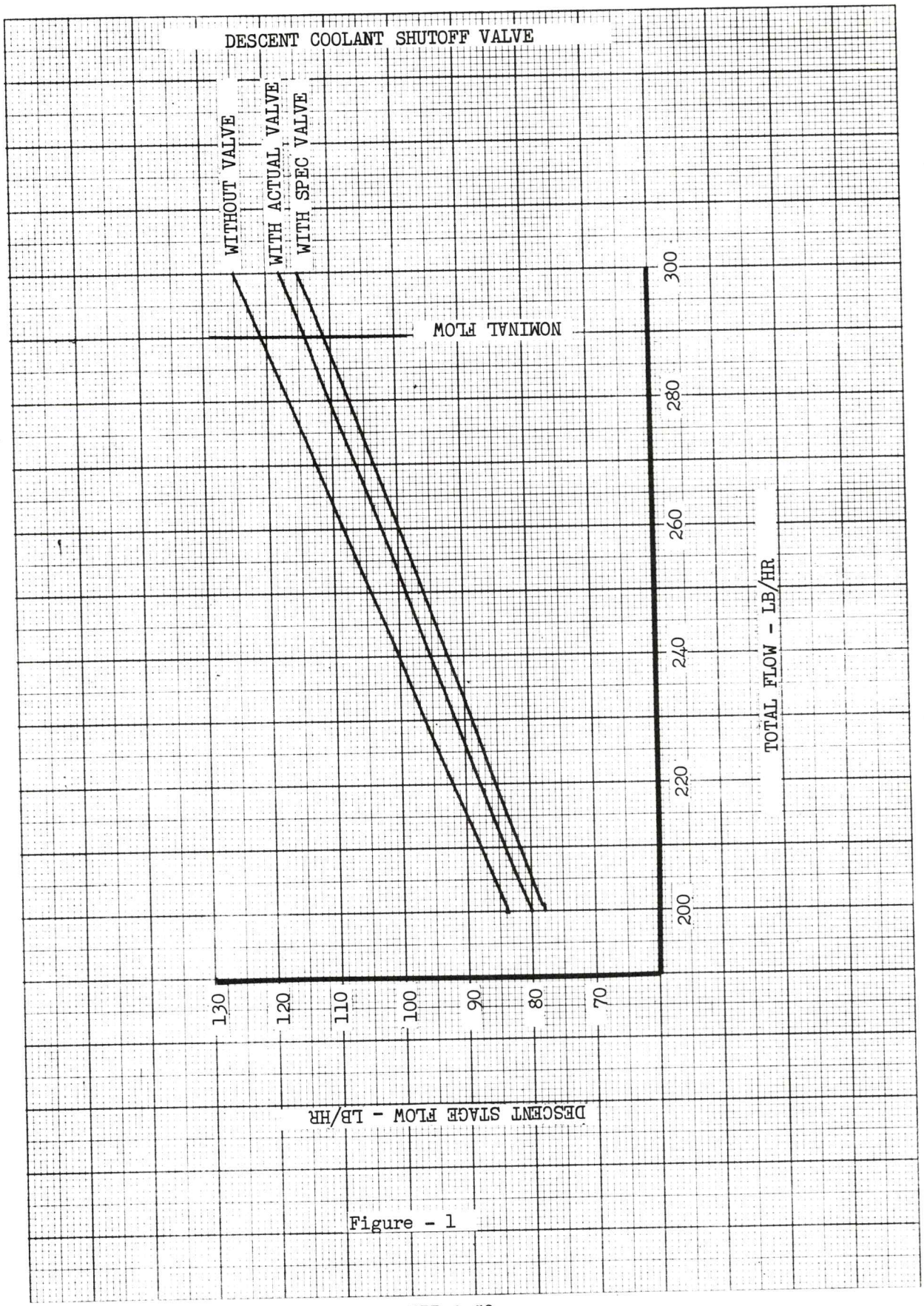


Figure - 1

BEE 20x20 TO INCH

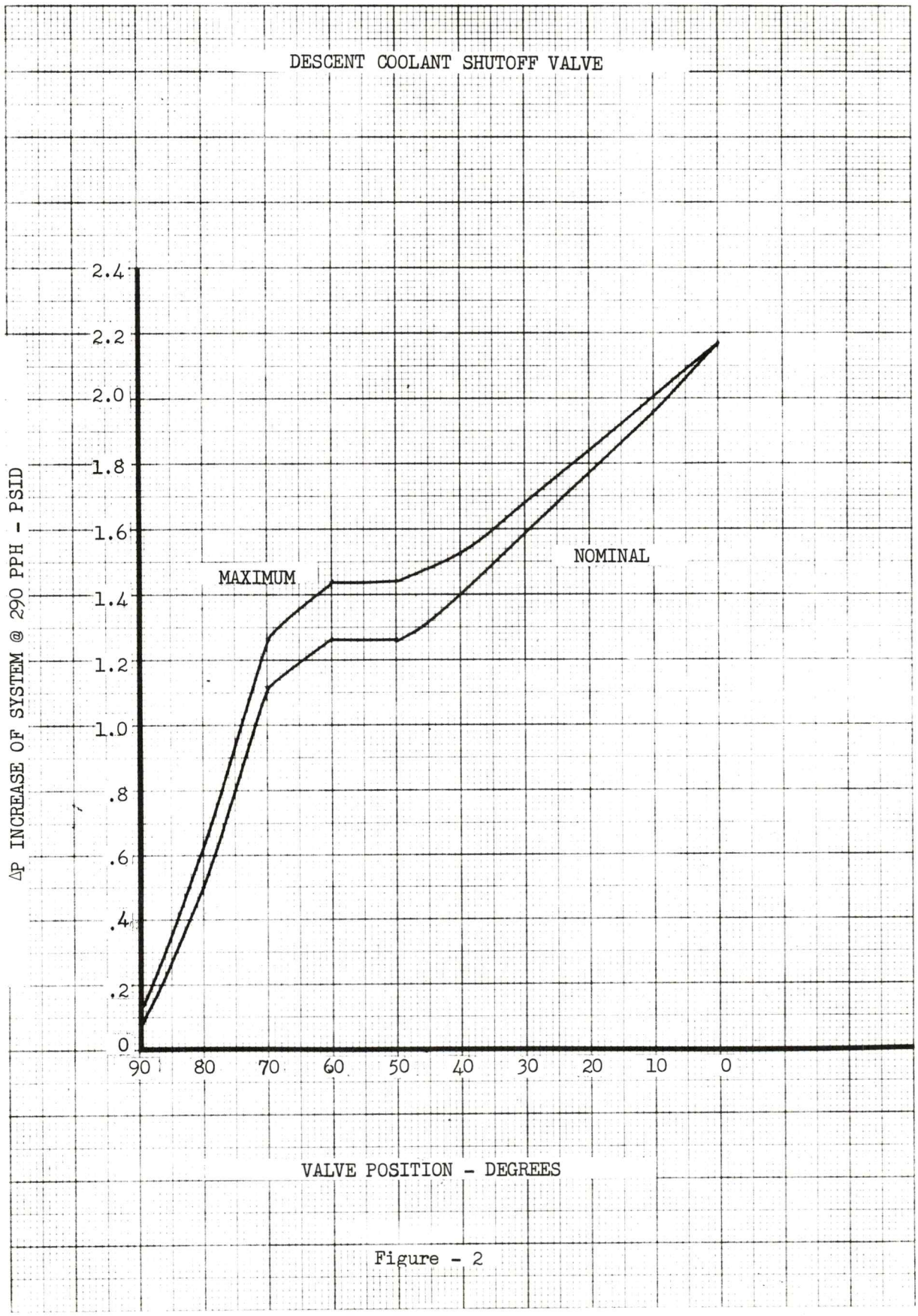


Figure - 2

BEE 20x20 TO INCH

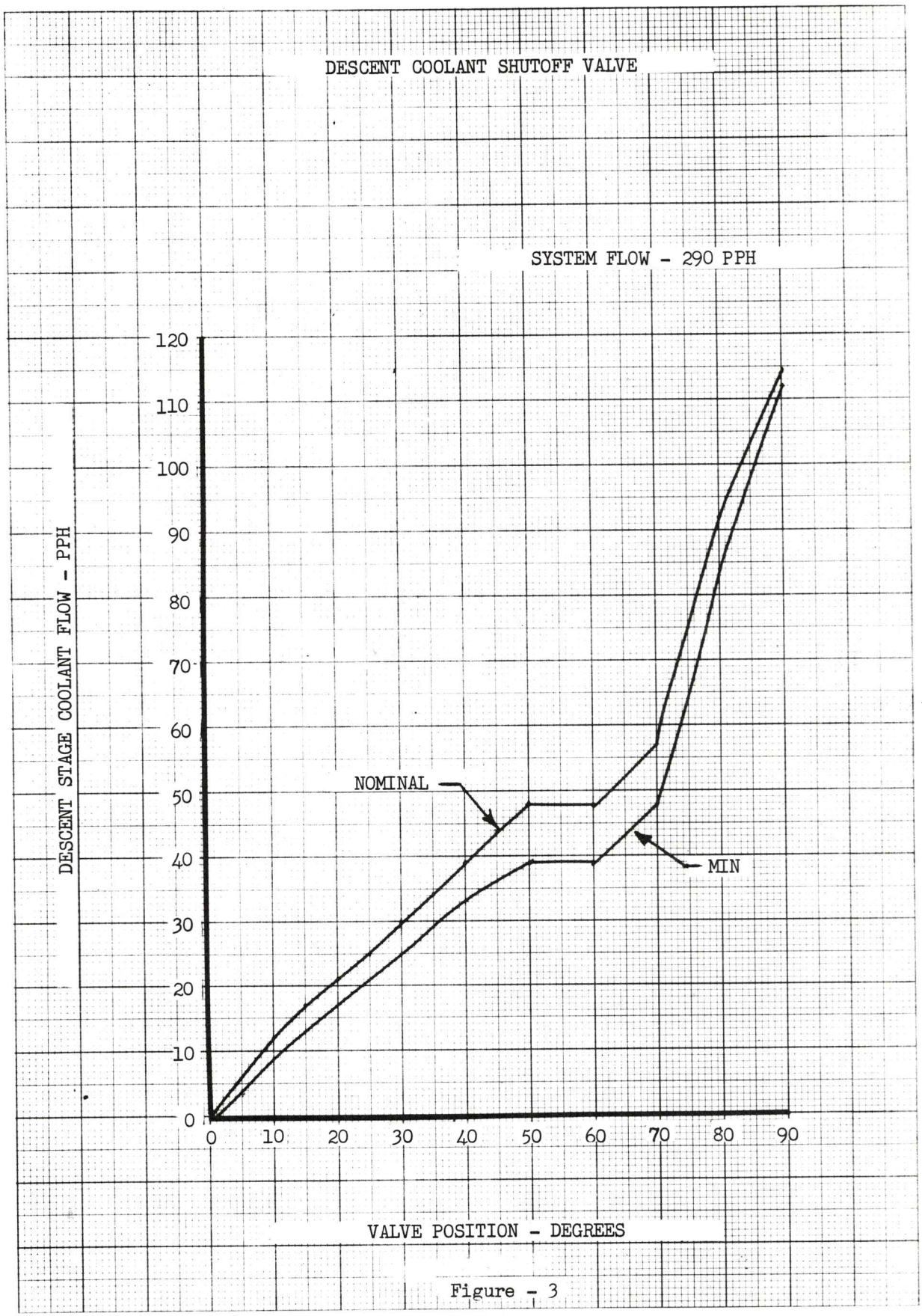


Figure - 3

BEE 20x20 TO INCH

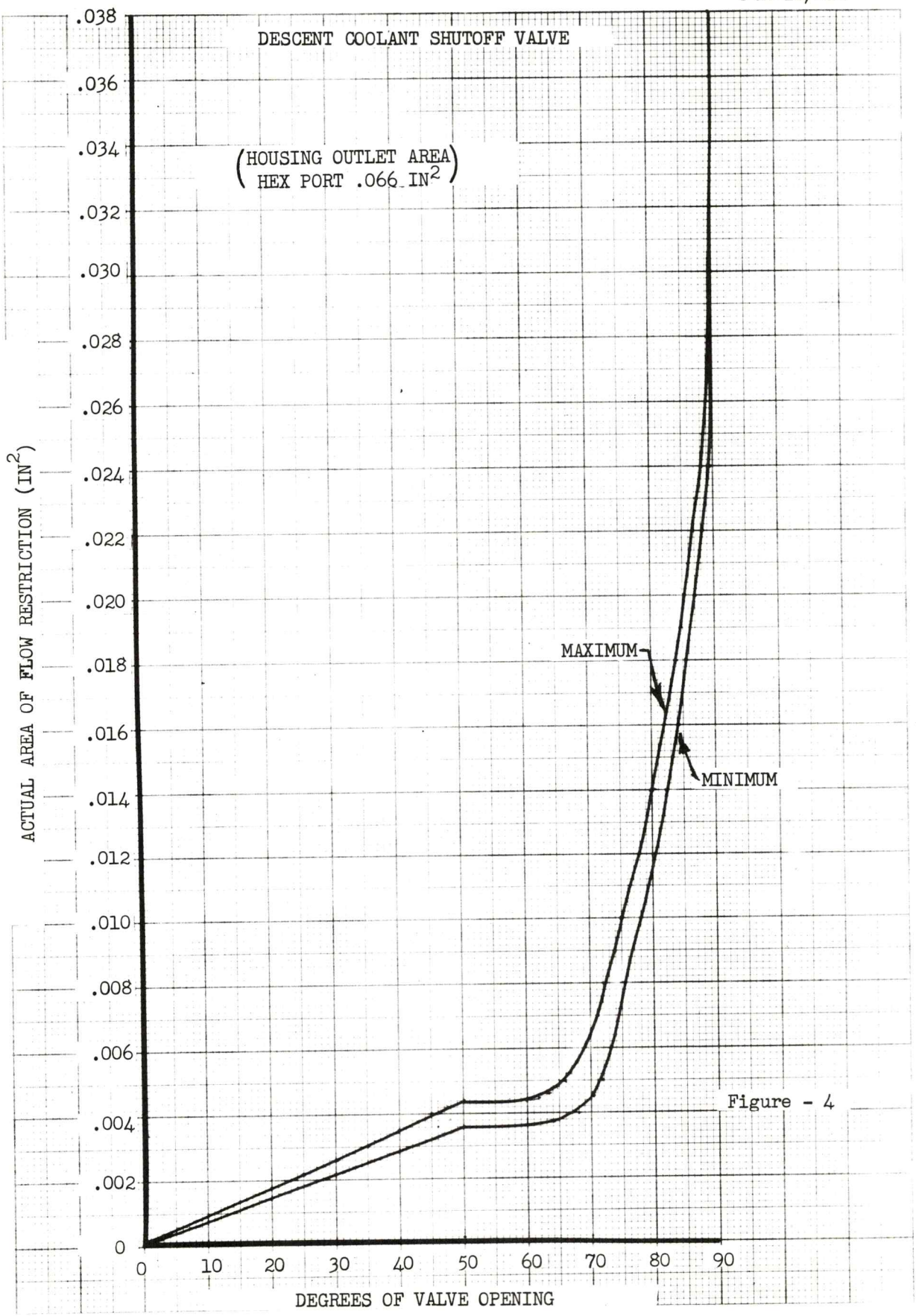


Figure - 4

BEE 20X20 TO INCH

BEE 20x20 TO INCH

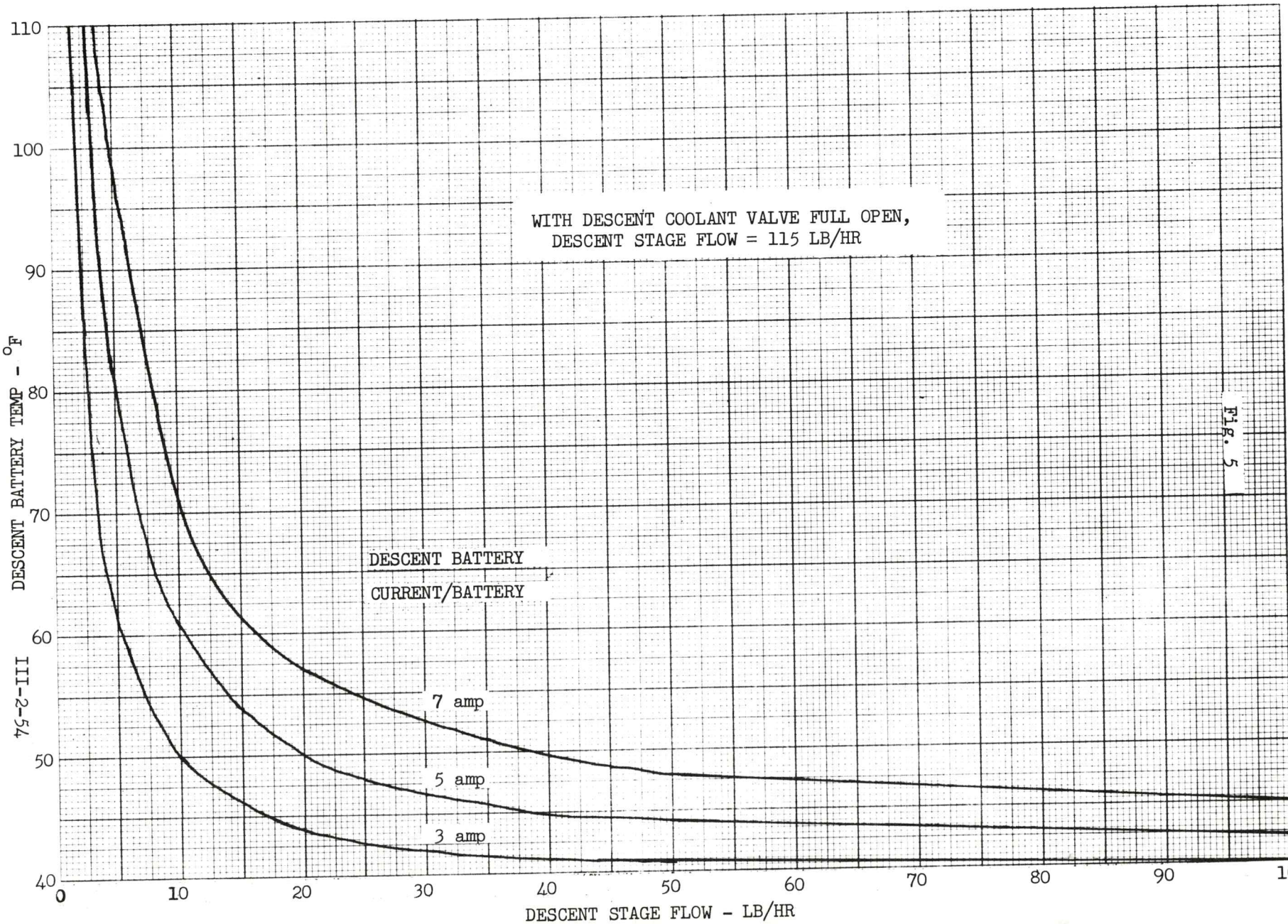


Fig. 5

III-2-54

SCB NO. EPS 2-10
PCN-12/NEW

SB NO. **EPS 2-11**

S/C: LM
DATE: 3-1-72
REV: PCN-12/NEW
ORIGINATOR: D. R. Puddy
W. D. Reeves
APPROVAL: William L. Peters

TITLE: EVERYTHING YOU WANTED TO KNOW ABOUT ASCENT BATTERIES BUT WERE AFRAID TO ASK

REFERENCE:
A. Test Report for Ascent Battery Transient Test: LTR 396-86, 10-2-67
B. Ascent Battery - G & N Interface Transient Voltage Test: LTR 390-87, 10-20-67
C. LM Ascent Battery Parametric Tests: LTR 390-104, 2-21-68
D. Ascent Battery Transient Test: LTR 390-128, 10-10-69
E. Apollo Data Submittals: GAEC-S-57, 2-6-69, GAEC-S-61, 4-14-69
F. IRN LIS 390-10002A to Reference E
G. Memorandum No. EG8-69-359
H. Battery Testing In Support of LM-8 Ascent Battery Anomaly: LMO 390-1370, 3-15-71

BACKGROUND: This systems brief summarizes available data concerning the ascent battery testing that resulted from an investigation of the Apollo 14 inflight anomaly (decrease in ascent battery 5 OCV of 0.3 VDC). The specific subjects that will be covered are as follows:

Summary of Ascent Battery Testing
Battery Load Voltage Response with One Cell Shorted
PGNS and AGS Voltage Sensitivities
Ascent Battery Preconditioning
Summary

We emphasize that this Systems Brief is based on our understanding of test data and the assumptions listed herein. Any disagreement in these areas probably invalidates the conclusions.

Summary of Ascent Battery Testing - Listed below are the ascent battery test conclusions. Table I gives a more detailed description of the tests.

a. GAC Tests

A stabilized voltage of 36.7 VDC could not be maintained with a total load in the range of 4.2 to 10 milliamps.

An ascent battery with one depleted cell will share approximately 11% to 20% of the total current when paralleled with one or two descent batteries.

Exposing the intercell connector area of a battery to free electrolyte can result in battery shorting and possible battery loss.

b. KSC Tests

A typical silver zinc battery with one dead cell is capable of supporting a substantial constant load.

An ascent battery with one dead cell will cause the IMU ICD voltage limit of 24.5 VDC to be violated by 0.8 VDC at docking during a nominal 1½-hour rendezvous.

c. Eagle-Picher Tests

If one cell is depleted and current is continually drained from an ascent battery, the battery voltage will eventually be 4.0 volts less than nominal. This voltage drop is made up of 1.5 VDC due to loss of cell potential and approximately 2.5 VDC due to polarity reversal.

Oxygen and hydrogen are generated at explosive mixture ratios at any load and independent of cell polarity.

d. Boeing Tests

A cracked cell can result in a significant short.

Cell shorts as a result of cracked cells tend to stay small and variable but runaway shorts have been observed.

Significant heating occurs in the area of a cracked cell short which can result in cell case melting.

Battery Load Voltage Response with One Cell Shorted - Figure 1 is a curve showing cell voltage response with respect to time at a constant drain of 50 amps. Of interest is the amount of time required to move from 0 VDC potential to less than 0.4 VDC reverse polarity. This occurs when approximately 25 - 50 amp-hours have been removed from the battery.

PGNS and AGS Voltage Sensitivities - ICD values of PGNS and AGS voltage sensitivities are shown in Figures 2 through 5. Prior to Apollo 14, test data was requested on PGNS equipments at lower voltages. The results of these tests are summarized below:

The computer would restart at the 20.3 ± 0.3 volt level. Since the burn programs are restart protected, a restart results in the loss of delta V accumulated calculations during the time of the restart.

No drastic loss of attitude would be noticeable during the whole time of ascent.

IRIG drifts would be negligible during the time of ascent.

Accelerometer bias and scale factor changes would be insignificant at steady state voltages greater than 23.5 VDC, but would increase at lower values. At a steady state voltage of 22.5 VDC, scale factor errors would be ≈ +6450 PPM and bias would have increased to ≈+5.081 cm/sec^2. Even with these errors, insertion conditions are acceptable. Transients, while causing the same affects as steady state voltages, do not result in permanent errors. Return to nominal value will occur as the voltage returns to normal.

Ascent Battery Preconditioning - Battery preconditioning requirements are based on providing acceptable voltage responses for the guidance equipments at the current step loadings for the following conditions:

Two-battery/two-bus abort staging
One-battery/two-bus abort staging
Two-battery/two-bus lunar liftoff
One-battery/two-bus lunar liftoff

An evaluation of the critical guidance equipments for each of these conditions is shown in Tables 2 and 3.

SUMMARY:

a. An ascent battery with an open circuit voltage ≥36.7 VDC either has a very small short which may clear itself or only one cell is shorted and has been discharged to its monoxide plateau. The latter case is the most likely especially if 36.7V is maintained for a long period of time. A large short would be distinguishable in that the voltage would continuously degrade.

b. An open circuit voltage ≥35.1 VDC but < 36.7 could represent a multitude of failures. The only way to discern anything about such a battery would be to wait until the voltage dropped to 35.1 VDC and stabilized for a couple of hours. At this time, the battery should be placed on a bus alone supplying at least 25 amps. The voltage reading thus obtained should be compared to the reading obtained by placing the good ascent battery under the same load. If the load voltage of the battery with the bad OCV is suppressed ≥1.5 VDC from the good battery it can be concluded that only one cell is shorted. A smaller voltage suppression indicates more than one cell affected.

c. An open circuit voltage reading < 35.1 VDC indicates that several cells of the battery are shorted.

d. A battery with a single shorted cell is considered acceptable since testing has indicated that it is still capable of supporting the entire spacecraft load alone throughout a 1.5 hour direct rendezvous. The voltage will be lower than nominal assuming the shorted cell was completely dead at liftoff. Referring to Figure 1, it can be seen that the voltage would first fall off by 1.9 V, 1.5 V due to loss of the cell plus 0.4 V due to the first plateau of the reversal. As the discharge continued, the voltage would fall off by a total of 4.0 V, 1.5 V due to loss of the cell plus 2.5 V due to the second plateau of the reversal. At docking, the battery voltage should be down to approximately 25.7 V which will still meet the voltage constraints of the guidance equipment. However, because of the voltage constraints on the guidance equipment ten amp-hours must be removed from this battery prior to PDI to provide maximum voltage protection to the guidance equipment in the event of an abort stage from powered descent.

TABLE I

NO.	DATE	LOCATION	DOCUMENT	TEST DESCRIPTION	TEST RESULTS
1	8-24-70	GAC	LTR 390-136	The cell tops and terminals of a descent battery were wet with 20 cc's of KOH to attempt to produce an internal short. A current shunt was placed between the negative terminal and case to detect leakage current.	Within 4 hours after KOH introduction, current spikes between 0.1 and 1.0 amp, lasting a few miliseconds, and repeating every 10 to 20 seconds appeared. After 10 hours, the spikes were between 7.3 and 10 amps with a steady 0.6 to 0.9 amp between spikes. At 23.2 hours, the spikes increased to 18 amps; at 24.2 hours, the spikes were 44 to 48 amps; and at 24.8 hours, they were 100 to 140 amps. By 25 hours, the battery 20th cell terminal strap to HV terminal fused open.
2	6-8-70	MSC	MSC 03894	Two stainless steel plates were separated by a 1/16" thick teflon plate with a 1/4" square window cut in it. This window was filled with a KOH solution and 28 volts applied between the plates.	When the voltage was applied to a 36% KOH solution, the current initially surged to between 35 and 50 amps and decayed to zero in 30 to 40 milliseconds.
3	7-23-71	Boeing	5-2710-HOU-515	A silver electrode was placed next to a magnesium plate and a voltage applied between them. The voltage was varied and the current monitored.	Lowest current seen was 0.002 amp at 1.0 volt and the highest was 2.54 amps at 5.0 volts. There was a steady increase in current as the voltage increased.
3a	7-23-71	Boeing	5-2710-HOU-515	Same as No. 3, except a zinc electrode was used.	Lowest current seen was 0.004 amp at 1.0 volt and the highest was 0.045 amp at 6.0 volts. The current bounced up and down inconsistently as voltage was steadily increased to 37 volts.
4	7-23-71	Boeing	5-2710-HOU-515	A simulated 2.1" long, 0.012" gap crack was cut in a cell. A 2.4" x 0.43" magnesium plate was placed over the crack. The voltage varied by a power supply connected between the negative terminal of the cell and the magnesium plate.	The lowest current was 0.040 amp at 1.0 volt and the highest was 1.40 amps at 25.0 volts. The current steadily increased as the voltage increased up to 25.0 volts then decreased slightly when the voltage was increased from 25 to 30 and 35 volts. The cell was warm at test completion (30-minute test).
5	7-23-71	Boeing	5-2710-HOU-515	Same No. 4 except the magnesium plate was 0.2" x 0.2".	The lowest current was 0.008 amp at 2.0 volts. The current steadily increased as the voltage inceased to 25.0 volts and fell to 0.7 amp when the voltage was increased from 25 to 30 volts. At test completion, the cell was hot and the case crazed and melted locally.
6	7-23-71	Boeing	5-2710-HOU-515	The corner of a cell was sawed off and the cell placed in close proximity to a small unprotected patch of magnesium. A voltage was applied between the cell negative and the magnesium patch. The voltage was varied and then maintained at 15 volts.	The current increased as the voltage was increased to 25 volts then decreased when the voltage was increased further. When the voltage was held steady the current continued to vary with the lowest reading =0 and the highest = 2.6 amps. The test lasted about 35 minutes and the cell case was melting.
7	7-23-71	Boeing	5-2710-HOU-515	This test is similar to test No. 3 except the magnesium is exposed through a slit 0.1 inches long penetrating the insulation and located over the simulated cell crack.	While the voltage was varied the current did not appear to follow any particular pattern. When the voltage was held constant at 15 volts, the current steadily increased for about 18 hours then decreased for 4 hours before the test was terminated. Zinc was deposited at the slit on the magnesium. Highest current seen was 0.06 amp and lowest was 0.011 amp.

TABLE I (Continued)

NO.	DATE	LOCATION	DOCUMENT	TEST DESCRIPTION	TEST RESULTS
8	7-23-71	Boeing	5-2710-HOU-515	A simulated crack was made in a cell case and this crack placed adjacent to a Magnesium case with a simulated defect. The defect was a pinhole in the Magnesium simulated by drilling a small hole. The power supply was connected between the cell and Magnesium and the voltage varied.	As the voltage was increased the current increased in the milliamp region. The highest current was .78 Ma at 38 volts. The voltage was then held constant at 15 v for 20 hours and the current steadily increased from 0.39 ma to 5.5 ma. The voltage was then varied again and the current increased with increased voltage. After this the voltage was held constant at 4.0 V and the current increased steadily from 0.7 amps to 4.5 amps when the test was terminated.
9	7-23-71	GAC	TELECON NOTES	A .040" diameter hole was drilled in the center of two cells and they were placed in contact with bare magnesium with KOH in the interface. Leakage current and cell voltage were monitored for 24 hours.	Cell No. 1 had an initial leakage. Current of 1.2 milliamps which decayed to zero in 21 hours. Occasionally, the current spiked to 1.8 milliamps. Cell No. 2 has an initial leakage of 0.18 milliamps, but decayed to zero in an hour. In both tests cell voltage remained at 1.85 volts.
10	7-23-71	GAC	TELECON NOTES	Same set up as test No. 9 but an "O" ring was placed between the cell and magnesium plate to contain KOH spillage. A power supply was placed in series and set at 16.7 volts to simulate a crack in Cell No. 10.	Initial current was 0.2 milliamps; current after 1 hour was 0.2 milliamps; current after 24 hours was 0.05 milliamps.
11	7-23-71	GAC	TELECON NOTES	Same set up as Test No. 10 but magnesium plate was finished with Dow 7 and PT 401 paint. This coating was then damaged with a center punch in "O" ring area.	Initial current was 0.5 milliamps; current at 1 hour was 0.56 milliamps; current at 24 hours, was 0.92 milliamps.
12	7-23-71	GAC	TELECON	Same set up as Test No. 11 except instead of a hole drilled in the cell, a crack was cut in it $1\frac{1}{2}$" long.	Initial current was 100 milliamps; current after 1 hour was 19 miliamps; current after 24 hours was 5.6 milliamps.
13	7-23-71	GAC	TELECON NOTES	Same set up as Test No. 12 except the negative plate was damaged accidentally in preparation.	Initial current was 50 milliamps; current after 3 minutes was 3 amps. Test was terminated early.
14	3-15-71	GAC	LMO 390-1370	A potentiometer was used to attempt to set a discharge rate which would stabilize the voltage of an ascent battery 0.3 vdc below OCV.	No stabilized voltage could be attained.
15	3-15-71	GAC	LMO390-1370	An ascent battery with a depleted cell was placed in parallel with two descent batteries and subjected to a powered descent profile.	The ascent battery shared 20% of the total load.
16	3-15-71	GAC	LMO390-1370	An ascent battery with a depleted cell was placed in parallel with the descent batteries, then one, and then alone to simulate a one battery one bus abort.	The ascent battery shared 17% of the load with two descent and 11.5% with one ascent. Once the depleted cell reversed, the voltage was 25.45amps under 26.5 amp load.
17	3-15-71	KSC	LMO 390-1370	An ascent battery with a depleted cell was subjected to a one battery two bus powered ascent abort.	The voltage at the battery remained above 25.5 V through docking.

TABLE I (Continued)

NO.	DATE	LOCATION	DOCUMENT	TEST DESCRIPTION	TEST RESULTS
18	3-15-71	KSC	LMO 390-1370	A descent battery with a depleted cell was subjected to a continuous 35 amp load.	Approximately 11 hours into the test the voltage dropped to 25.0 v and to 24.0 v one hour later
19	3-15-71	KSC	LMO 390-1370	18 depleted ascent battery cells had current forced through them at 25 and 50 amp rates.	All cells went through a polarity reversal and after 8 hours had reached -2.23 v to -2.55 v.

TABLE II

NOMINAL ASCENT BATTERY PRECONDITIONING

General Consideration:

- o Ascent and descent batteries share equally
- o Voltage drops from the battery
  - to LGC = 1.5V
  - to IMU = 2.0V
  - to AEA = 3.0V

CONDITION	LGC	IMU	AEA	ASSUMPTIONS
Two-Bat/Two-Bus Abort Stage 2.5 AH from Bat 5 5.0 AH from Bat 6	Passes ICD	Passes ICD	Passes ICD	o Split bus configuration o Bat 5 (LMP) Step = 7.5 to 32.4 amps Bat 6 (CDR) Step = 13.8 to 51.5 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used for Bat 5 10 - 70 amp step data @ 40°F and 5 AH used for Bat 6 o Step is from 3 Bats (2 des, 1 asc) to 1 asc plus 10 amps/bus for RCS thrusters and cyclic loads.
One-Bat/Two-Bus Abort Stage 2.5 AH Removed	Passes ICD	Fails ICD Between 500μs to 15 ms and between 1 sec and 1.5 sec. Lowest V = 23.5 at 50μs	Passes ICD	o Battery connected on both normal and back-up feed paths o Bat Step Load = 12.78 amps to 83.9 amps o 10 - 70 amp step data @ 40°F and 2.5 AH used o Step is from 4 des and 1 asc to 1 asc plus 10 amps/bus
One-Bat/Two-Bus Abort Stage 5 AH Removed	Passes ICD	Passes ICD	Passes ICD	o Same assumptions as previous case except 10 - 70 amp step data @ 40°F and 5.0 AH used.
Two-Bat/Two-Bus Lunar Liftoff 2.5 AH from Bat 5 2.5 AH from Bat 6	Passes ICD	Passes ICD	Passes ICD	o Split bus configuration o Bat 5 (LMP) Step = 12.56 to 25.13 amps Bat 6 (CDR) Step = 10.08 to 20.15 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used. o Step occurs when last descent is removed from each bus. Time permits turning Des Bats off one at a time.
One-Bat/Two-Bus Lunar Liftoff 2.5 AH Removed	Passes ICD	Passes ICD	Passes ICD	o Battery connected on both normal and back-up feedpaths with 100 - amp crosstie C/B's closed. o Same assumptions as previous case except step is from 22.64 to 45.28 amps. o 10 - 40 amp step data @ 40°F and 2.5 AH used.

TABLE III

ASCENT BATTERY PRECONDITIONING IF ONE CELL FAILED

General Considerations:

- Ascent battery carries 11% of total load when paralleled with one or more descent batteries if polarity has reversed.
- Voltage drops from the battery to guidance equipments same as for nominal battery.
- Voltage drop due to loss of one cell considered to be 1.9 VDC.
- Battery/bus configuration and rationale for steps same as for nominal battery.

CONDITION	LGC	IMU	AEA	ASSUMPTIONS
Two-Bat/Two-Bus Abort Stage 2.5 AH from Bat 5 5.0 AH from Bat 6	Fails ICD from 150 μ sec to 2 sec Lowest voltage is 22.6 50 μ sec.	Fails ICD from 500 μ sec to approx 3 sec Lowest voltis 23.1 at 50 μ sec.	Passes ICD	o Bat 5 (LMP) step 7.5 to 32.4 amps Bat 6 (CDR) step 13.8 to 51.5 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used for Bat 5 o 10 - 70 amp step data @ 40°F and 5 AH used for Bat 6
One Bat/Two-Bus Abort Stage 5 AH Removed	Fails ICD Same as previous step	Fails ICD Same as previous step	Fails ICD between 50 μ sec and 500 ms. Lowest voltage is 21.6 at 50 μ sec.	o Step load = 7.0 amps to 83.9 amps o 10 - 70 amp data @ 40°F and 5 AH used
One-Bat/Two-Bus Abort Stage 10 AH Removed	Passes ICD	Fails ICD between 500 sec - 10 ms and between 1 sec unknown.	Passes ICD	o Same assumptions as previous case except 10 - 70 amp step data @ 40°F and 10 AH used.
Two-Bat/Two-Bus Lunar Liftoff 2.5 AH from Bat 5 2.5 AH from Bat 6	Passes ICD	Passes ICD	Passes ICD	o Bat 5 step = 2.76 to 25.13 amps Bat 6 step = 2.22 to 20.15 amps o 10 - 40 amp step data @ 40°F and 2.5 AH used.
One-Bat/Two-Bus Lunar Liftoff 2.5 AH Removed	Passes ICD	Passes ICD	Passes ICD	o Same assumptions as previous case except step is from 4.98 to 45.28 amps. o 10 - 40 amp step data @ 40°F and 2.5 AH used.

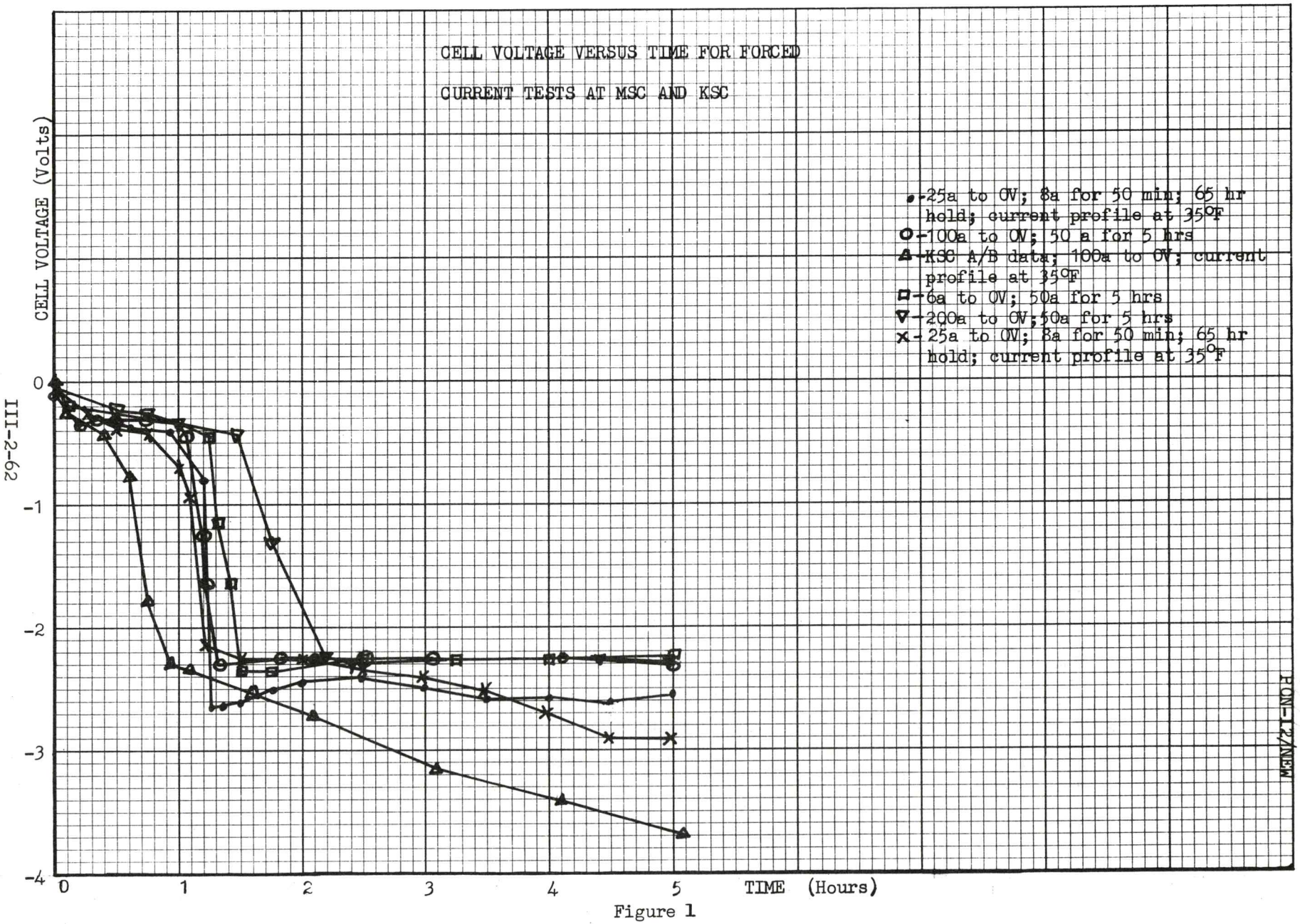

CELL VOLTAGE VERSUS TIME FOR FORCED
CURRENT TESTS AT MSC AND KSC
CELL VOLTAGE (Volts)
0
-1
-2
-3
-4
0
1
2
3
4
5
TIME (Hours)
•-25a to 0V; 8a for 50 min; 65 hr hold; current profile at 35°F
O-100a to 0V; 50 a for 5 hrs
Δ-KSC A/B data; 100a to 0V; current profile at 35°F
□-6a to 0V; 50a for 5 hrs
▽-200a to 0V; 50a for 5 hrs
x-25a to 0V; 8a for 50 min; 65 hr hold; current profile at 35°F

Figure 1

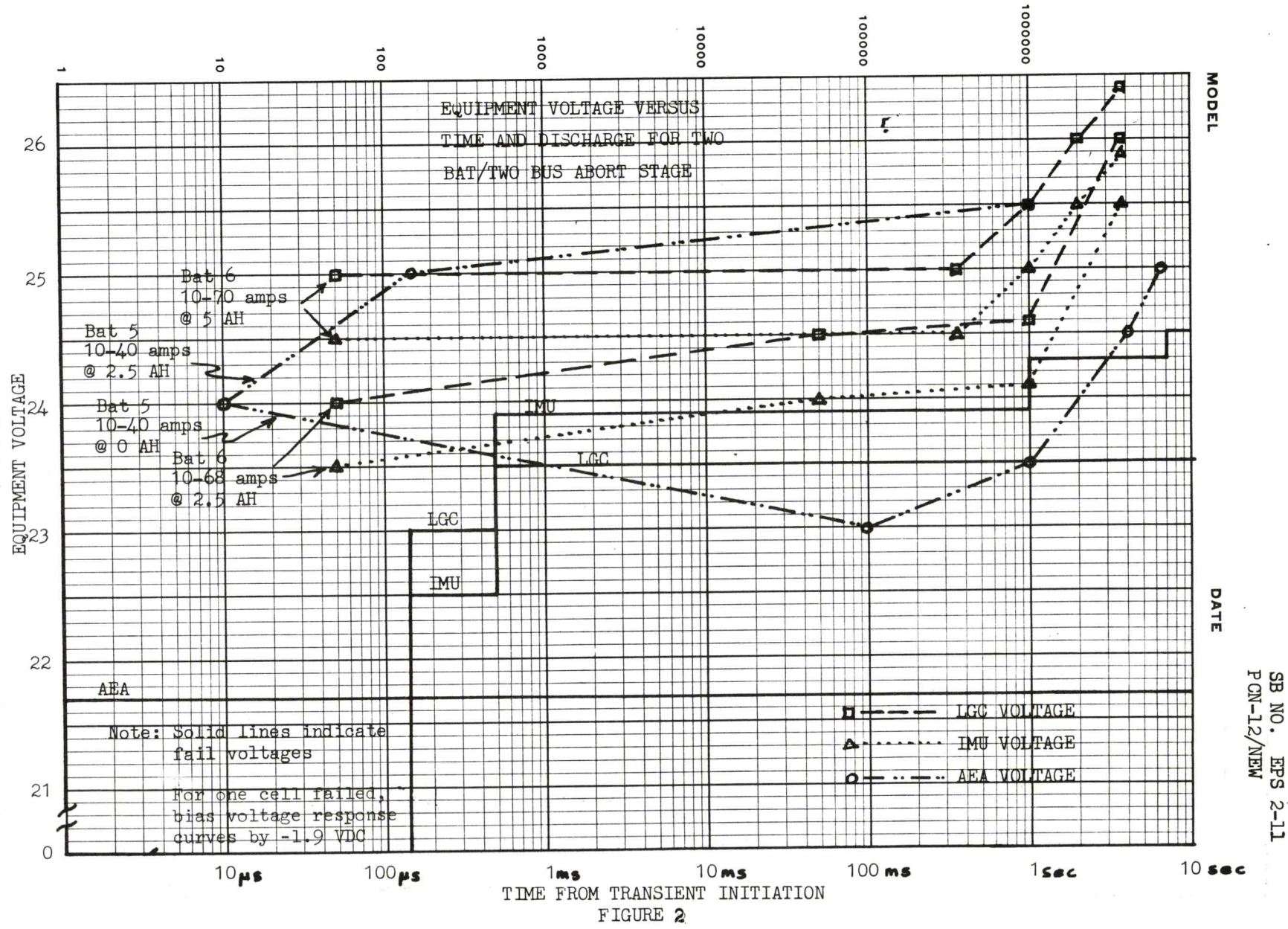


FIGURE 2

SB NO. EPS 2-11
PCN-12/NEW

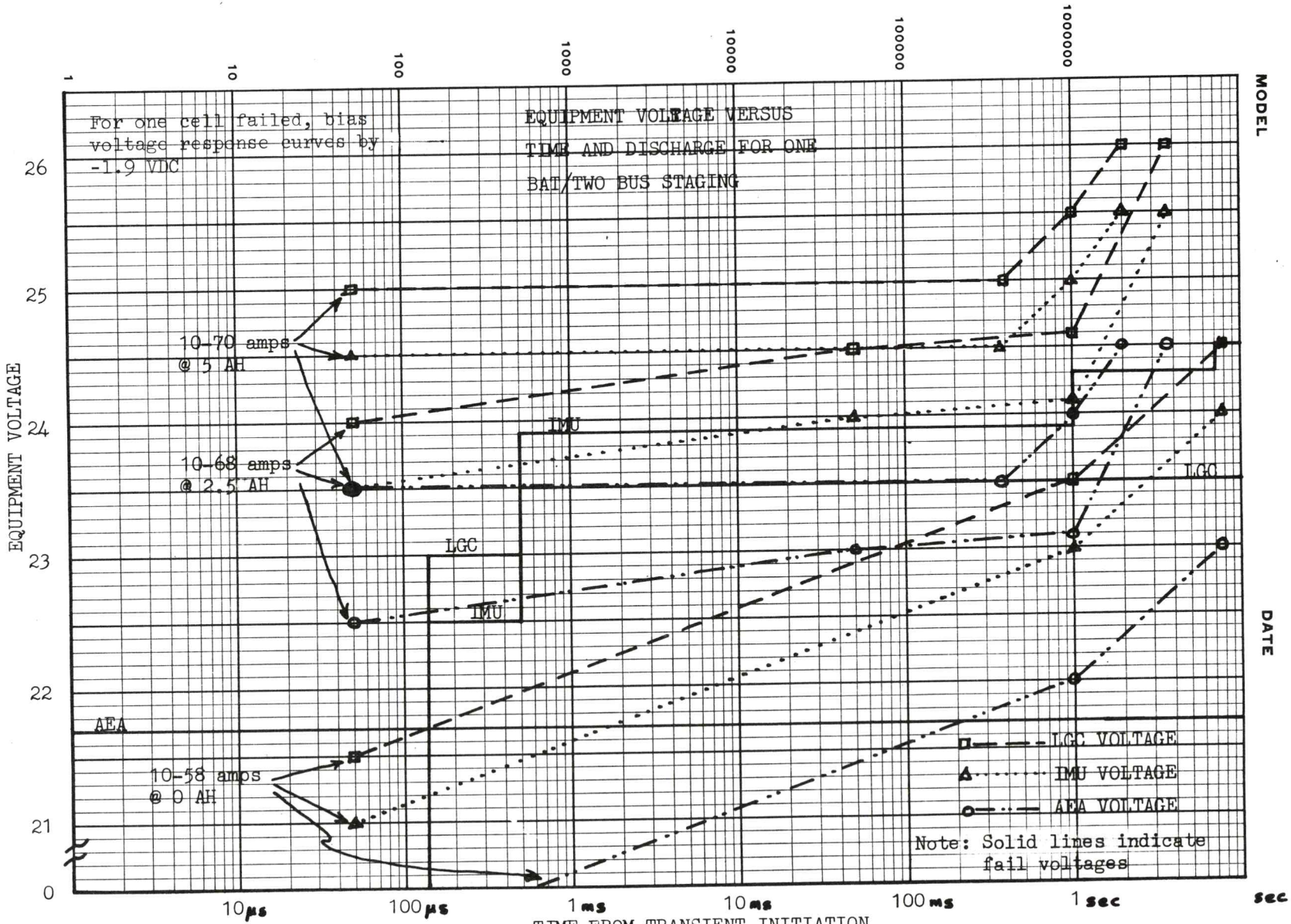

EQUIPMENT VOLTAGE VERSUS
TIME AND DISCHARGE FOR ONE
BAT/TWO BUS STAGING
For one cell failed, bias voltage response curves by -1.9 VDC
10-70 amps
@ 5 AH
10-68 amps
@ 2.5 AH
10-58 amps
@ 0 AH
LGC
IMU
AEA
LGC VOLTAGE
IMU VOLTAGE
AEA VOLTAGE
Note: Solid lines indicate fail voltages
EQUIPMENT VOLTAGE
TIME FROM TRANSIENT INITIATION
MODEL
DATE
sec

FIGURE 3

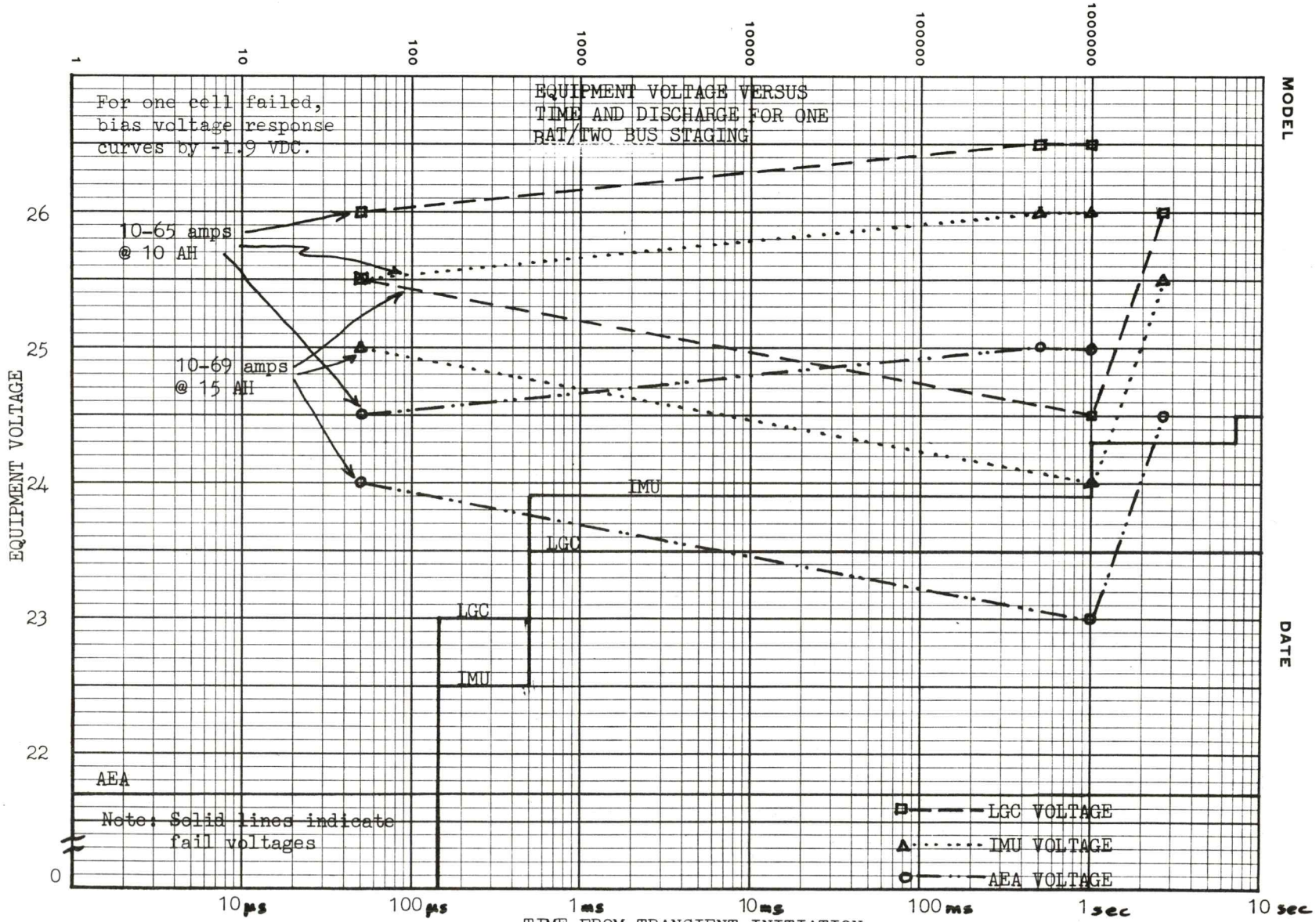

EQUIPMENT VOLTAGE VERSUS
TIME AND DISCHARGE FOR ONE
BAT/TWO BUS STAGING
For one cell failed,
bias voltage response
curves by -1.9 VDC.
10-65 amps
@ 10 AH
10-69 amps
@ 15 AH
IMU
LGC
LGC
IMU
AEA
Note: Solid lines indicate
fail voltages
LGC VOLTAGE
IMU VOLTAGE
AEA VOLTAGE
EQUIPMENT VOLTAGE
26
25
24
23
22
0
1
10
100
1000
10000
100000
1000000
10 μs
100 μs
1 ms
10 ms
100 ms
1 sec
10 sec
TIME FROM TRANSIENT INITIATION
MODEL
DATE

FIGURE 4

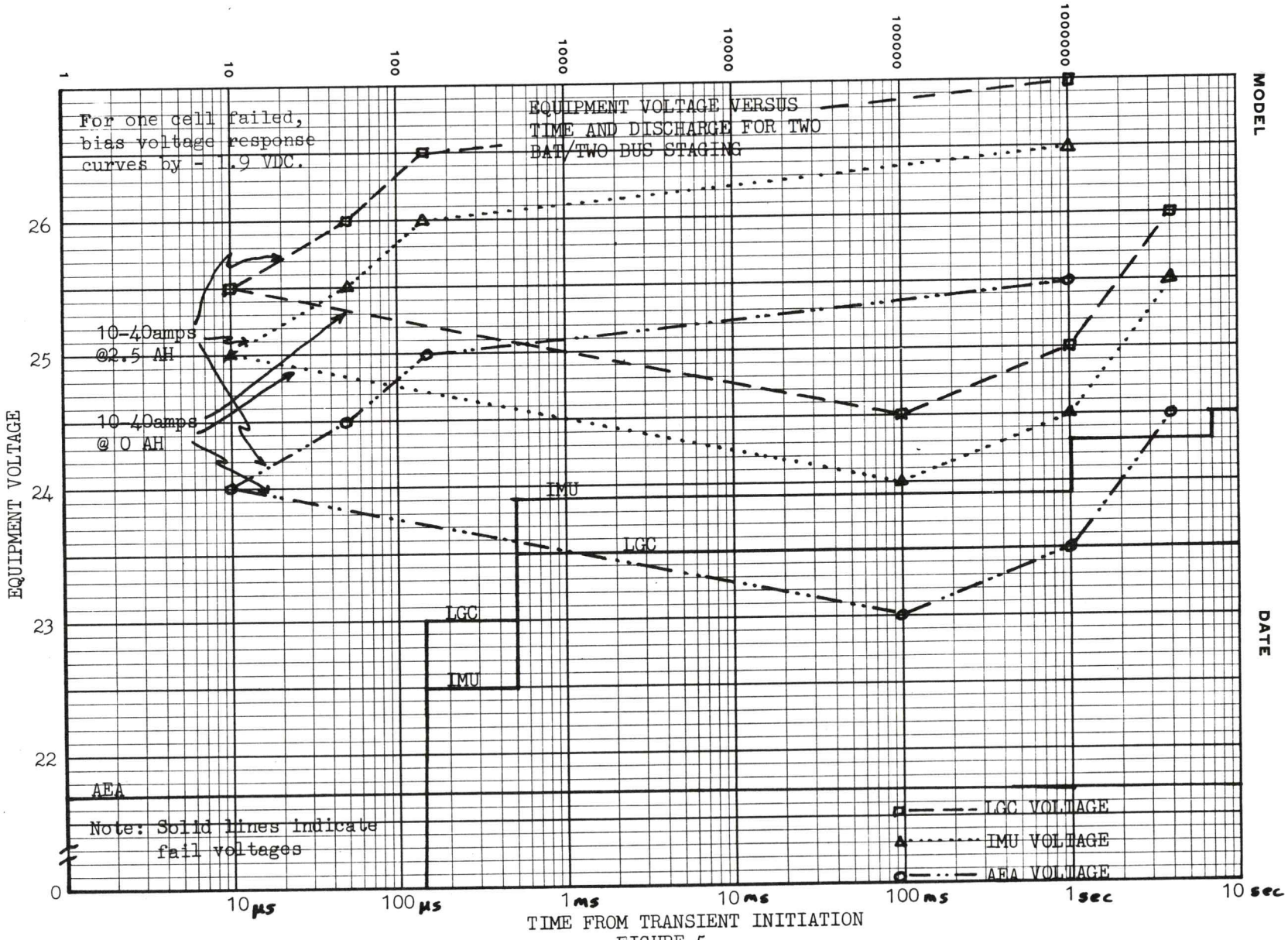

EQUIPMENT VOLTAGE VERSUS
TIME AND DISCHARGE FOR TWO
BAT/TWO BUS STAGING
For one cell failed,
bias voltage response
curves by - 1.9 VDC.
10-40amps
@2.5 AH
10-40amps
@ 0 AH
IMU
LGC
LGC
IMU
AEA
Note: Solid lines indicate
fail voltages
LGC VOLTAGE
IMU VOLTAGE
AEA VOLTAGE
EQUIPMENT VOLTAGE
26
25
24
23
22
0
1
10
100
1000
10000
100000
1000000
10 μs
100 μs
1 ms
10 ms
100 ms
1 sec
10 sec
TIME FROM TRANSIENT INITIATION
MODEL
DATE

FIGURE 5

SB NO. **EPS 2-12**

S/C: LM
DATE: 3-1-72
REV: PCN-12/NEW
ORIGINATOR: L. E. Nicholas
APPROVAL: William L. Peters

TITLE: MAXIMUM ELECTRICAL POWER RENDEZVOUS LIFETIMES FOR ASCENT BATTERIES

REFERENCES:
1. MSC Memorandum FM64 (72-5), "Maximum Available LM Ascent Stage Lifetime with a Failed Ascent Battery, dated, 1-24-72
2. System Brief EPS 2 - 8, dated 11-1-71

BACKGROUND: This study was performed to establish the maximum electrical rendezvous lifetimes for one and two ascent batteries. Of the three G & N configurations studied, two were LM active and one was CSM active. Maximum electrical lifetimes were computed for each G & N configuration using two different suit fan duty cycles. When determining one lifetime, the suit fan was operated continuously and when determining the other lifetime the suit fan was operated 20% of the time after insertion plus 10 minutes. The cases for two batteries were analyzed to provide a maximum lifetime guide line when performing an off nominal rendezvous other than a T1 or T2 liftoff.

The following G & N configurations were used in performing this study:

1. LM active - LGC with Rendezvous Radar
2. LM active - AGS with Rendezvous Radar
3. CSM active - CMC with Sextant, VHF Ranging and LM tracking light.

LM spacecraft current levels for configurations 1 & 2 were determined by the LM - SEENA computer program. The LM current level for configuration 3 was determined by Apollo 13 real-time data. A list of assumptions used in performing this study may be found in Table 1.

Ascent power usage prior to insertion + 10 minutes is itemized in Table 2. For the one battery case, 26.4 ampere-hours are consumed at insertion + 10 minutes and the unusable due to telemetry inaccuracy is 2.1 A-H. Using a one battery capacity of 286 A-H leaves 257.5 A-H usable after this point. For the two battery case, 31.9 ampere-hours are consumed at insertion + 10 minutes and unusable due to telemetry inaccuracy is 3 A-H. Using a capacity of 296 A-H per battery leaves 557.1 A-H total usable after this point. Note that the time from liftoff to insertion + 10 minutes is 17 minutes.

Table 3 & 4 presents the maximum lifetime data, average current and amp-hours consumed for one and two ascent battery cases respectively. Table 3 also indicates the margins for a one ascent battery rendezvous and a liftoff time at T1 or T2.

MISSION IMPACT:

This study indicates adequate power is available from one or two ascent batteries to perform a T1 liftoff for all G & N and suit fan configurations which have been presented here. This abort requires 5.5 hours from liftoff to docking.

With the suit fan operating continuously, the power available from one ascent battery is marginal to perform a T2 liftoff and rendezvous operating in the PGNS/RR configuration. All other T2 cases have adequate margins. This abort requires 7.5 hours from liftoff to docking.

The maximum lifetime for two batteries varies from 16 hr 8 min to 36 hr 39 min.

TABLE 1

1. All rendezvous cases are coelliptic.
2. The single ascent battery capacity is 286 A-H.
3. The usable amp-hours is zero at docking
4. The tracking light and VHF ranging were not used for configurations 1 and 2.
5. The VHF B data mode was never used.
6. All floodlights were off after insertion.
7. The S-Band equipment was off during LOS periods.
8. TM unusables were computed using a telemetry measurement uncertainty of 1.9 amperes for the one battery cases and 2.69 amperes for the two battery cases.
9. For the PGNS/RR configuration, the AEA and ASA were turned off after insertion.
10. For the AGS/RR configuration, the LGC, DSKY, IMU and GASTA were turned off after insertion.
11. The rendezvous radar was operated a total of 2 hours during the latter part of the rendezvous for configuration 1 and 2.
12. No LM platform was used after insertion for configuration 3.
13. For configuration 3 the VHF ranging was used from insertion to CSI minus 45 minutes and the tracking light was used from then to docking during each dark side pass.
14. The cabin fan was not used.
15. The buses were tied together for the one and two battery cases.

TABLE 2

Summary of LM Ascent Power Usage Prior to Insertion + 10 min.

Event	Relative Time	Total Ascent A -H	A - H BAT 5	A - H BAT 6
Ascent Batts Parallel	PDI - 28	1.4	.7	.7
PDI	PDI + 0	11.1	6.5	4.6
Bat 6 Failed	PDI + 6	13.8	8.3	5.5
Touchdown	PDI + 12	15.5	10.0	5.5
Liftoff	PDI + 21	18.7	13.2	5.5
Insertion	PDI + 28	24.8	19.3	5.5
Insertion + 10 min.	PDI + 38	31.9	26.4	5.5

TABLE 3

ONE ASCENT BATTERY MAXIMUM LIFETIME

Configuration	% Operation of Suit Fan	Max Time L/O to Dock	Insertion + 10 min to Docking				T1 Margin	T2 Margin
			Max Time Ins +10 min To Dock	AVG Current	Amp-Hour Used	TM Unusable		
1. PGNS/RR	20%	8hr 58min	8hr 41min	27.77	240.9	16.6	3hr 28min	1hr 28min
	100%	7hr 46min	7hr 29min	32.45	243.2	14.3	2hr 16min	0hr 16min
2. AGS/RR	20%	11hr 18min	11hr 1min	21.46	236.5	21.0	5hr 48min	3hr 48min
	100%	9hr 28min	9hr 11min	26.14	240.0	17.5	3hr 58min	1hr 58min
3. CMC/SXT	20%	17hr 59min	17hr 42min	12.63	223.7	33.8	12hr 29min	10hr 29min
	100%	13hr 41min	13hr 24min	17.31	231.9	25.6	8hr 11min	6hr 11min

TABLE 4

TWO ASCENT BATTERY MAXIMUM LIFETIME

Configuration	% Operation of Suit Fan	Max Time L/O To Dock	Insertion + 10 min to Docking			
			Max Time Ins +10 min to Dock	AVG CURRENT	Amp-Hour Used	TM Unusable
1. PGNS/RR	20%	18 hr 34 min	18 hr 17 min	27.77	507.9	49.2
	100%	16 hr 8 min	15 hr 51 min	32.45	514.5	42.6
2. AGS/RR	20%	23 hr 21 min	23 hr 4 min	21.46	495.0	62.1
	100%	19 hr 36 min	19 hr 19 min	26.14	505.1	52.0
3. CMC/SXT	20%	36 hr 39 min	36 hr 22 min	12.63	459.3	97.8
	100%	28 hr 8 min	27 hr 51 min	17.31	482.2	74.9

SB NO. **PYRO 3-1**

S/C: LM
DATE: 11/1/71
REVISION: PCN-11/New
ORIGINATOR: D. Whittle
APPROVAL: William L. Peters

TITLE: PYRO BATTERY OPEN CIRCUIT VOLTAGE (OCV) ANALYSIS

BACKGROUND: Discharge tests run on pyro batteries have demonstrated that the magnitude of parasitic battery loads can be approximated by analysis of the terminal voltage rate of decrease during the transitition from the peroxide to the monoxide plateau. The time on the peroxide plateau is greatly dependent upon the charge cycle of the batteries after their formation discharge (part of the activation process). When batteries have been charged together, their discharge characteristics will be very similar. Figure 1 shows the discharge curve for 4 batteries that went through their charge cycle together. Two of the batteries had a 1200 OHM load (27.5 and 31.0 ma), one had a 600 OHM load (63 ma), and one had a 300 OHM load (120 ma). These curves fall as expected in that the greater the load current the less time the battery stays on the peroxide plateau, the greater the initial voltage suppression, and the faster the transition between plateaus. Figure 2 demonstrates the same relationship between 3 more batteries which were charged together. Loads on these batteries were 300 OHMs (93 ma), 450 OHMs (80 ma) and 600 OHMs (48.7ma). Two marked differences between these batteries and the 4 batteries of Figure 1 are: (1) greater voltage suppression and (2) less energy on the peroxide plateau. Figure 3 shows dv/dt vs. time for the batteries whose voltage characteristics are shown in Figures 1, & 2. These curves were plotted using data points gathered every hour during discharge to simulate what might be a realistic inflight data frequency. The result for the dv/dt vs. time curve results in an interesting comparison for the four discharge rates. As expected the peak of the dv/dt curve falls in the center of the battery's transition from peroxide to monoxide plateau. The distinguishing characteristics are that as the discharge rate increases the peak of the dv/dt curve becomes greater and the general shape of the curve narrows. Exactly where the dv/dt peak falls on the time scale is a function of energy on the peroxide plateau and not important in comparing batteries from different charge cycles. Figure 4 shows the dv/dt vs. time curves for the batteries whose discharge curves are shown in Figures 1 & 2 with 30 minute data rates. As a comparison with Figure 3 will show, the greater data rate more clearly defines the curve peak, but the general curve shape peak position in time remain relatively the same. The conclusion from these curve comparisons is that although a 30 minute data rate is best for curve resolution a 60 minute data rate would probably be sufficient for pyro battery load estimations.

Once a pyro battery has reached the monoxide plateau an accurate estimate of the battery load current is impossible based on data gathered thus far. Similarly once a battery has begun to roll off its monoxide plateau the energy remaining in the battery and therefore time remaining is unpredictable, as shown in Figure 5.

To estimate an unknown load requires that a dv/dt plot of the battery voltage be calculated (see APP. A) and then a curve peak and shape comparison be made with the seven known battery discharges. If, for instance, the unknown curve's peak is less than that of SN304 and if the general curve shape is more broad in nature than that of SN304 then the unknown current is probably less than the 120 ma of battery SN304. Similarly if the unknown curve's peak is greater than that of SN288 and the general curve shape is more narrow in nature, then the unknown load is probably greater than the 27.5 ma of battery SN288. Using the above described technique a general estimate of the battery's discharge rate may be attained.

Without sufficient data to define the dv/dt curve peak an estimate of the batteries' load could be in gross error. In general, confidence is maintained in this technique only when enough data is available to define the curve peak as well as a general curve shape. The dv/dt curve peak has in the past come when the terminal voltage is in the 32 - 34 volt region, therefore if the voltage is 32 volts when data is initially gathered, it is unlikely sufficient data will be available for a load estimation. It is obvious from looking at the data in Figures 1 & 2 that if the terminal voltage reaches the mono-

oxide plateau in less than 3 hours the terminal load is probably greater than 100 ma resulting in a battery life of less than the 25 hours expected with a 100 ma short. Similarly if the terminal voltage falls to the monoxide level in greater than 16 hours then the drain is probably less than 25 ma and expected lifetime probably greater than 100 hours.

The following table is based on the seven data points in this brief and lists acceptable parasitic loads as a function of when the problem was discovered and minimum Lunar Stay Times. These values also assume that the parasitic load remains constant in value, and that TD occurs at approximately 100:00 GET.

TIME PROBLEM DISCOVERED	MINIMUM LUNAR STAYTIME	
	10 HR	24.5 HR
1st Housekeeping Assumes Problem Developed LM Cabin Closeout (-29:30)	None Acceptable	None Acceptable
2nd Housekeeping Assumes Problem Developed Immediately after 1st Housekeeping (≈36:00 GET)	31 ma Maximum (S/N 289)	31 mA Maximum (S/N 289)
Activation Assumes Problem Developed Immediately after 2nd Housekeeping (≈60:00GET)	63 ma Maximum Based on in- terpolation of S/N 289 and S/N 299	31 MA Maximum (S/N 289)

APPENDIX A

Given a Table of Data Points evenly spaced in Time such as:

V_1	T_1
V_2	T_2
V_3	T_3
V_4	T_4
.	.
.	.
.	.

Where V_1 = Pyro Battery OCV reading

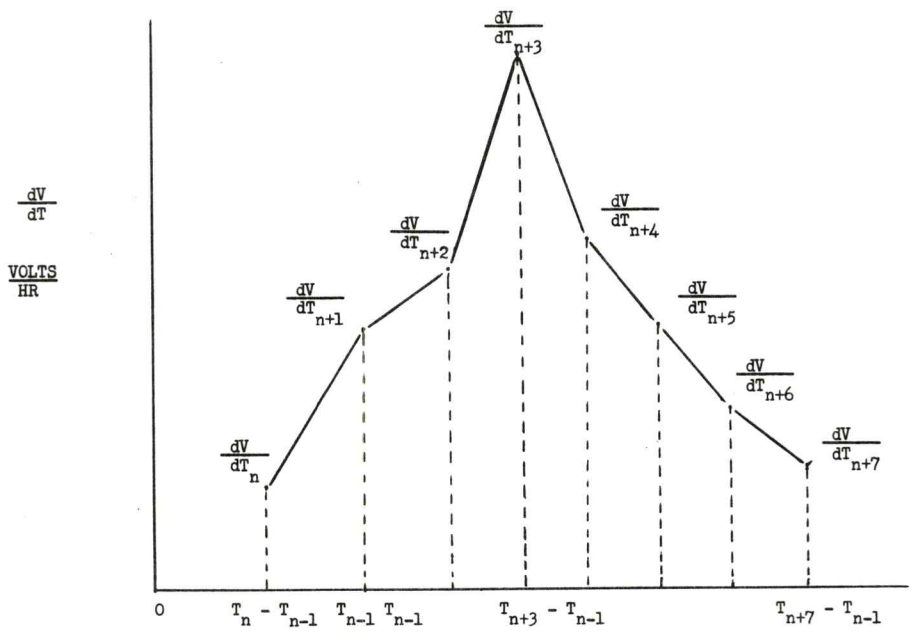
T_1 = Time of OCV reading in hours

And n = The number of the Data Point in the series of Points 1 through X

Then $$\frac{dV}{dT_n} = \frac{\left(V_{n-1} - V_{n+1}\right)}{\left(T_{n+1} - T_{n-1}\right)}$$

(note that this calculation cannot be performed for the first and last data points in the series)

Plotting this data will take the form:



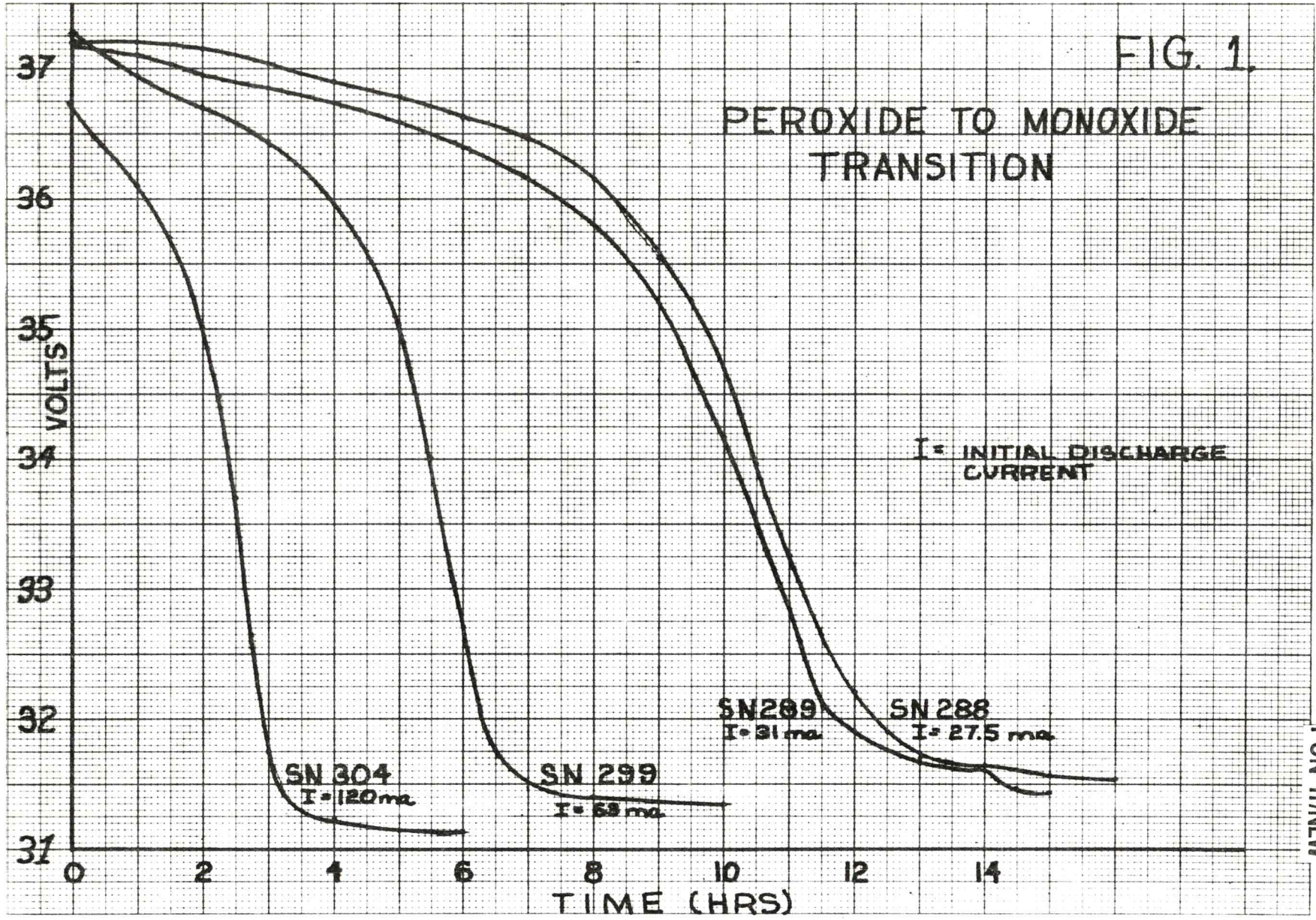


FIG. 1.
PEROXIDE TO MONOXIDE TRANSITION
37
36
35
34
33
32
31
VOLTS
0
2
4
6
8
10
12
14
TIME (HRS)
I= INITIAL DISCHARGE CURRENT
SN 304
I=120ma
SN 299
I=69 ma
SN289
I=31 ma
SN 288
I=27.5 ma

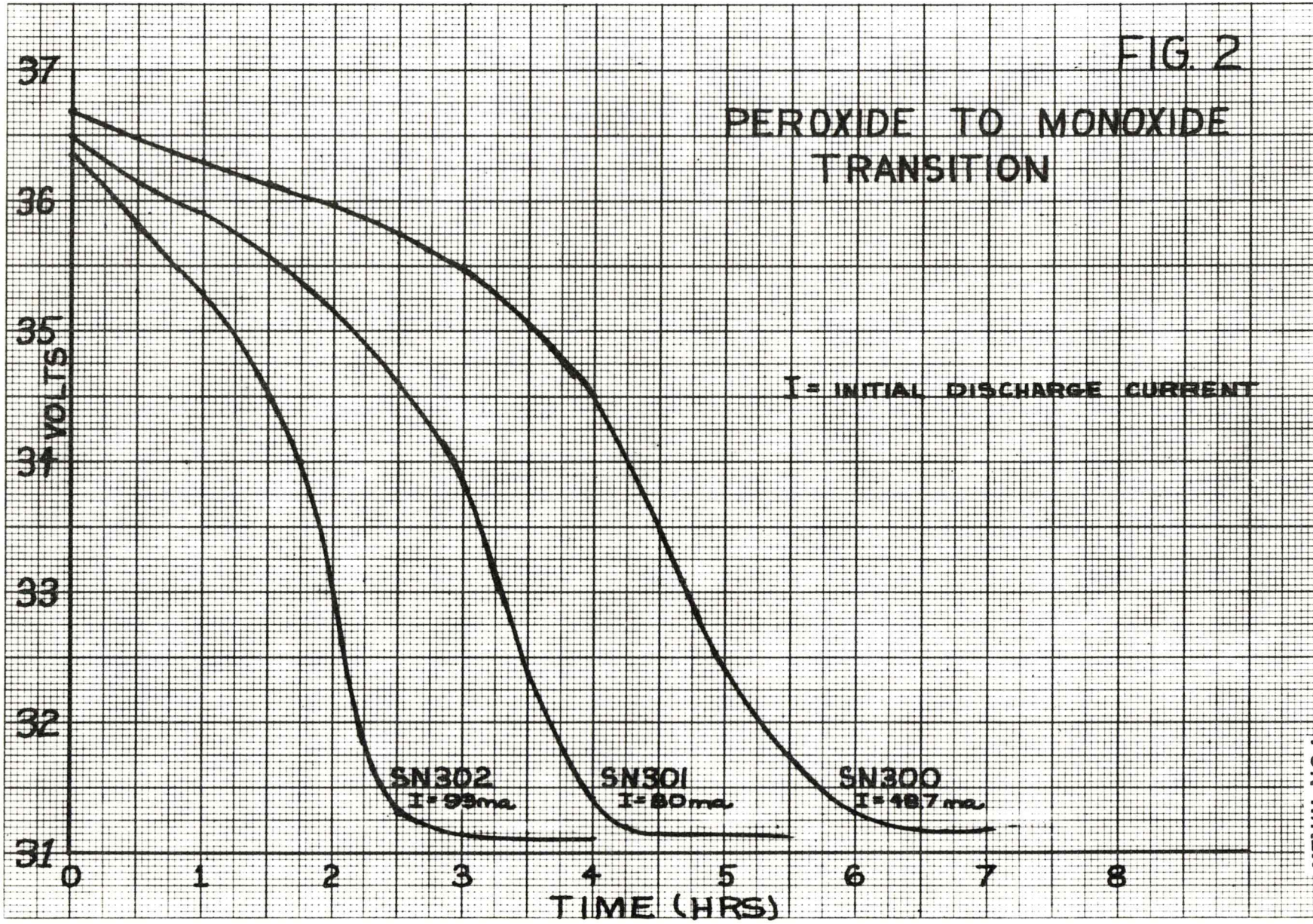
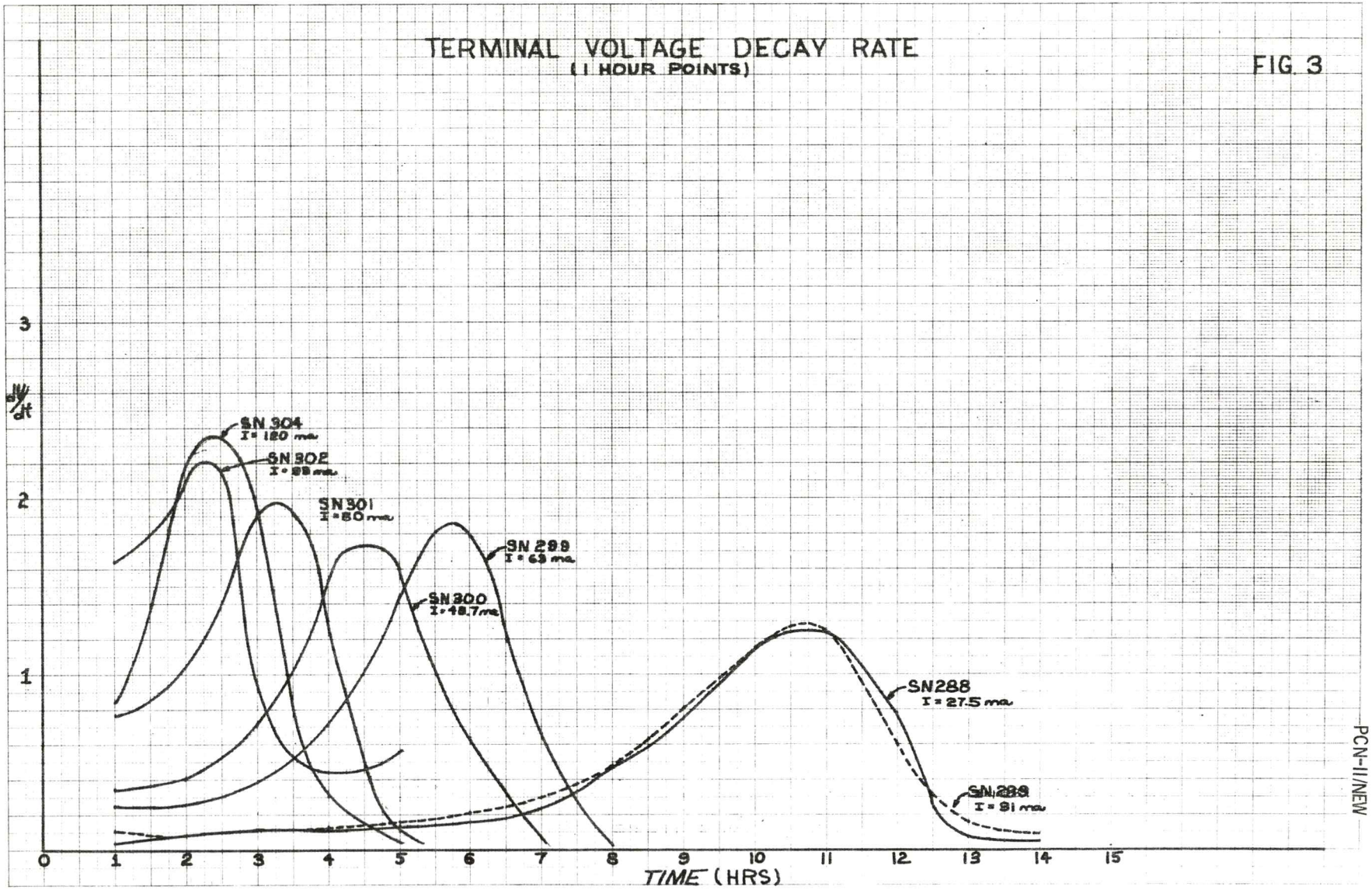
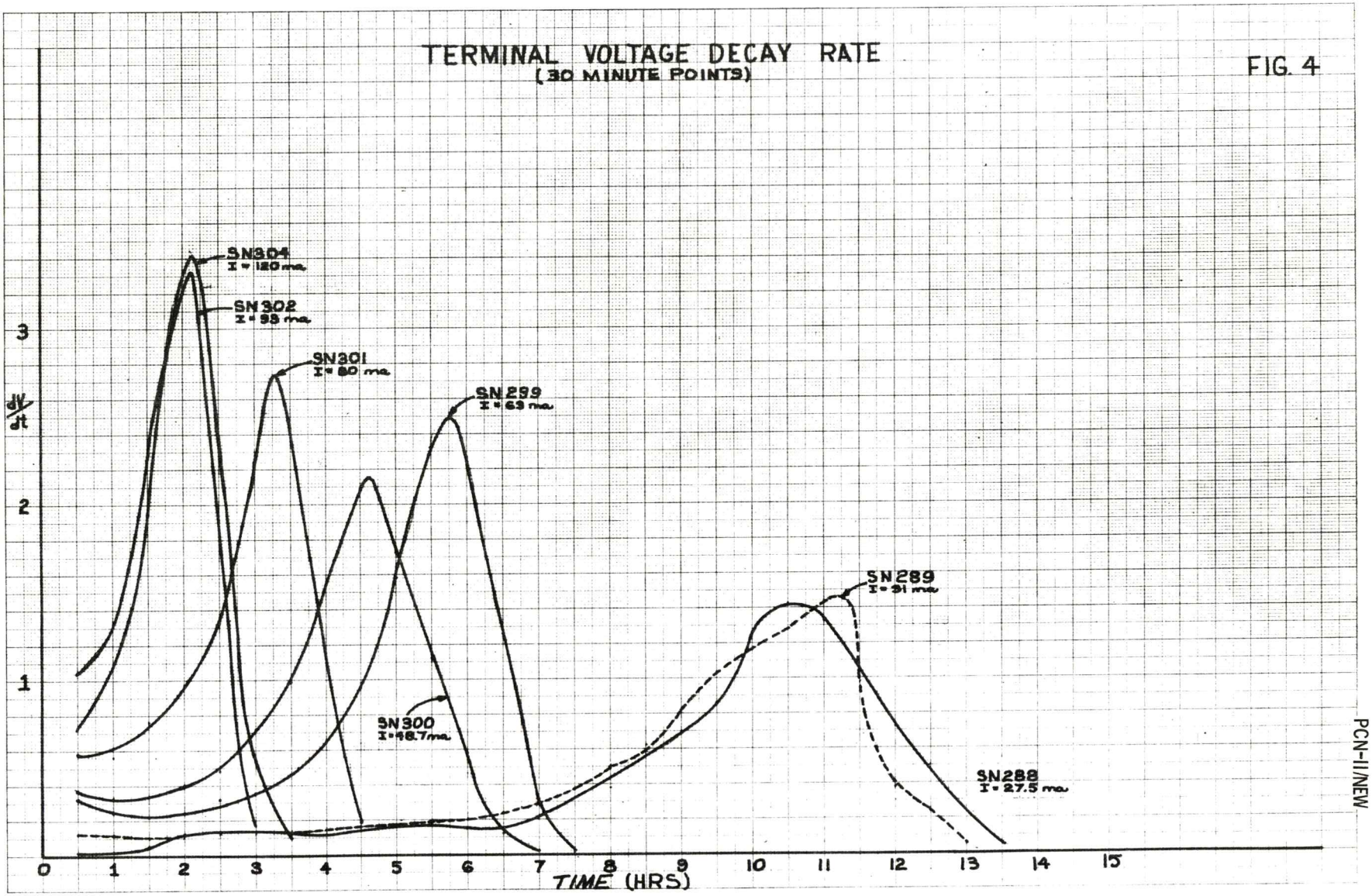


FIG 2
PEROXIDE TO MONOXIDE TRANSITION
I = INITIAL DISCHARGE CURRENT
37
36
35
34
33
32
31
VOLTS
SN302
I = 93ma.
SN301
I = 80ma.
SN300
I = 48.7 ma.
0
1
2
3
4
5
6
7
8
TIME (HRS)


TERMINAL VOLTAGE DECAY RATE
(1 HOUR POINTS)
FIG. 3
dV/dt
3
2
1
SN 304
I = 120 ma
SN 302
I = 88 ma
SN 301
I = 80 ma
SN 299
I = 63 ma
SN 300
I = 48.7 ma
SN 288
I = 27.5 ma
SN 289
I = 21 ma
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
TIME (HRS)

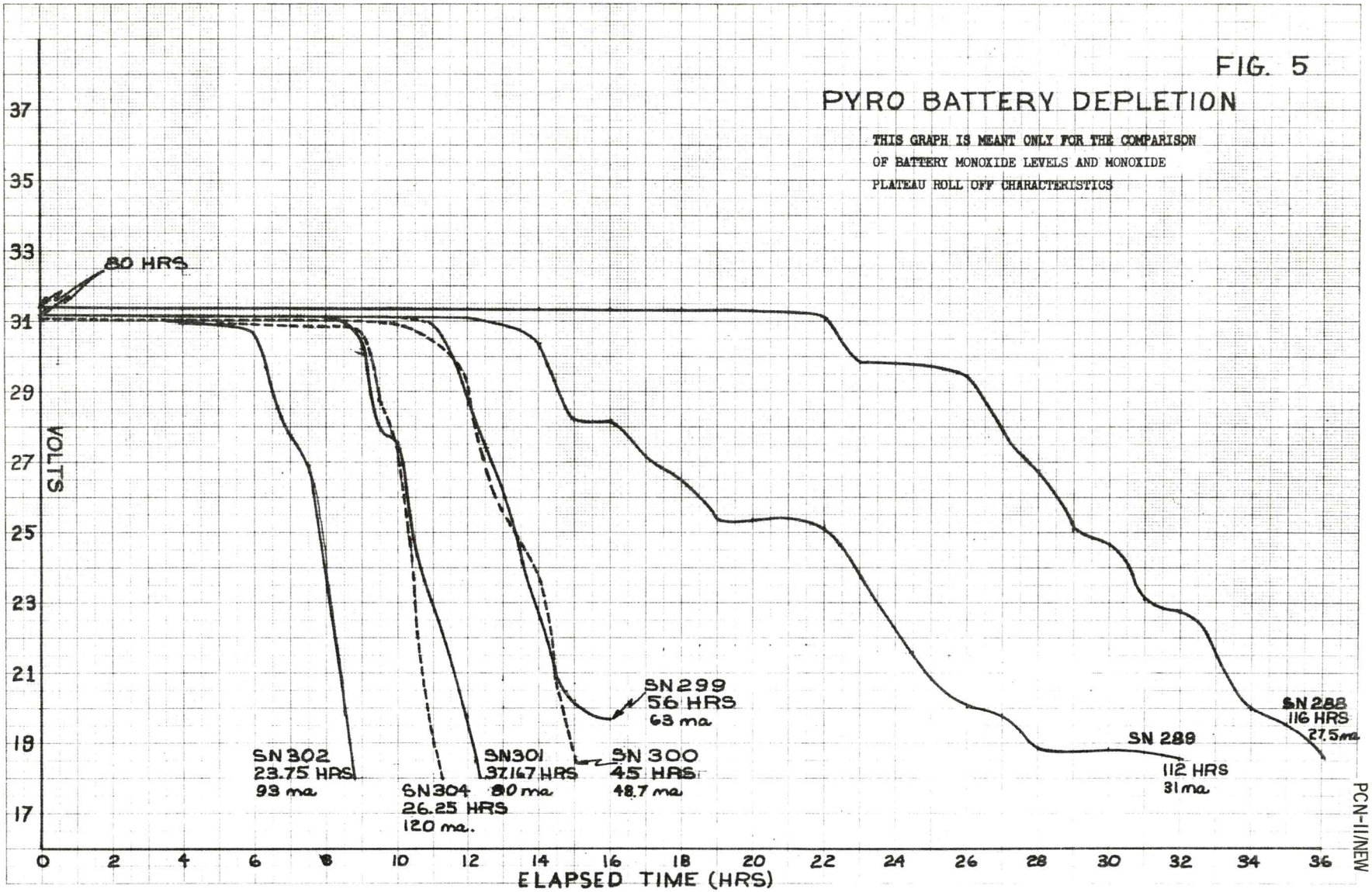


10 X 10 TO THE CENTIMETER 47 1510

FIG. 5

PYRO BATTERY DEPLETION

THIS GRAPH IS MEANT ONLY FOR THE COMPARISON
OF BATTERY MONOXIDE LEVELS AND MONOXIDE
PLATEAU ROLL OFF CHARACTERISTICS



SB NO. COMM 4-1,4-2,4-3

All Communications SB'S
are deleted by PCN-3

SB NO. **INST 5-1**

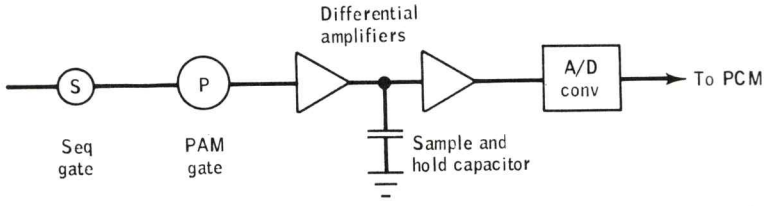
S/C: LM
DATE: 3/1/72
REV: PCN 12
ORIGINATOR: D. WHITTLE
APPROVAL: James E. Hannigan

TITLE: PCMTEA CROSSTALK

BACKGROUND:

A. For telemetry purposes, crosstalk occurs whenever information on one telemetry channel appears on another telemetry channel by virtue of some unintended means. Inductive or capacitive coupling may both give rise to a crosstalk situation. Due to the possibility of improper impedance matching in the analog multiplexer, PCM crosstalk is a possibility. In instances where the MIT signal conditioning has been powered down, PCM crosstalk has been seen on LM-3. With this type of crosstalk, the information is transferred only to adjacent channels in the bit stream.

B. The diagram below shows basically how the analog-to-digital conversion is accomplished.



The problem occurs in the sample and hold circuitry. The differential amplifier forces the sample and hold capacitor to the voltage level sampled by the PAM gate. This capacitor then holds this voltage level for the A/D converter to work with until a new sample of data forces the capacitor to some new value corresponding to a different measurement. In order for the voltage impressed upon the sample and hold capacitor to be an accurate representation of the sampled voltage, the sampled channel should have a purely resistive impedance of 5K ohms.

C. Due to the sampling characteristics of the sequencer gates, should the impedance seen in a particular gate become capacitive in nature, then that channel will tend to track the previously sampled analog channel. The degree of tracking depends on the sample rate of the channel. For a 1 s/s channel, the bleed-off between measurements is about 50 percent, for a 200 s/s channel, the bleed-off is only 27 percent of the previously sampled level.

D. Presently there are two ways that the afore-described conditions may exist. Should a wire to an analog channel be broken or opened, the capacity of the cabling and harnessing is such that this crosstalk could occur. The second method is for the MIT signal conditioning to be turned off. This equipment, in the off configuration, is such that the impedance it presents is almost purely capacitive.

MALFUNCTION DETECTION: In most cases PCM crosstalk can be recognized in real time. A measurement which is affected by crosstalk will not under normal circumstances retain a value in the region it would normally be in; therefore, an abnormal reading of the affected channel would indicate that a problem was present. Then a check to see if the measurement in the bit stream previous to the effected measurement is an analog measurement, and if so, if the effected measurement tracks the previous measurement at some percentage lower value. If tracking is taking place, then crosstalk is occurring. Table 1 (PCM Crosstalk Matrix) lists all analog parameters preceded by an analog parameter in the bit stream. This should be a useful real-time tool for spoting crosstalk.

MISSION IMPACT: For PCM crosstalk to occur, either a channel wire is broken so the measurement is lost anyway or the MIT signal conditioner is powered down, in which case the flight controller is not worried about the readout of these parameters. Crosstalk should be readily recognized in real time; however, there is a remote possibility that crosstalk could be of such a value so as to elude immediate real time evaluation.

CORRECTIVE ACTION: None

TABLE 1 - PCM CROSSTALK MATRIX

MEASUREMENT IDENTIFICATION		PRIM OR SEC	PRECEDING PARAMETER
GB0541	MESA TEMP 1		FRAME COUNT
GB0542	MESA TEMP 2		FRAME COUNT
GC0071	AC BUS VOLT		GH1455 YAW ATT ERR
GC0155	AC BUS FREQ	S	GP0041 APS He 1R P
GC0155	AC BUS FREQ	P	IN SH
GC0201	BAT 1 VOLT		DISCRETE
GC0202	BAT 2 VOLT		GH1456 PITCH ATT ERR
GC0203	BAT 3 VOLT		GH1456 PITCH ATT ERR
GC0204	BAT 4 VOLT		DISCRETE
GC0205	BAT 5 VOLT		GH1331 AUTO THRUST CMD
GC0206	BAT 6 VOLT		GG2142 MG RSVR OUT SIN
GC0207	BAT L VOLT		GL0501 MET
GC0301	CDR BUS VOLT		GH1247 YAW ERR CMD
GC0302	LMP BUS VOLT	P	IN SH
GC0302	LMP BUS VOLT	S	GG2249 YAW DAC OUT
GC1201	BAT 1 CUR	P	OPEN
GC1201	BAT 1 CUR	S	GH1247 YAW ERR CMD
GC1202	BAT 2 CUR	P	GH1455 YAW ATT ERR
GC1202	BAT 2 CUR	S	GL0402 CAL 15 PCT
GC1203	BAT 3 CUR	P	GH1455 YAW ATT ERR
GC1203	BAT 3 CUR	S	DISCRETE
GC1204	BAT 4 CUR	P	GH1247 YAW ERR CMD
GC1204	BAT 4 CUR	S	IN SH
GC1205	BAT 5 CUR	S	GH1455 YAW ATT ERR
GC1205	BAT 5 CUR	P	GL0402 CAL 15 PCT
GC1206	BAT 6 CUR	P	IN SH
GC1206	BAT 6 CUR	S	GL0402 CAL 15 PCT
GC1207	BAT L CUR	P	GG3324 RR TRUN SIN
GC1207	BAT L CUR	S	FRAME COUNT
GF0500	DES 2 H_2O PRESS		GH1455 YAW ATT ERR
GF0521	DES 2 H_2O TEMP		GG2142 MG RSVR OUT SIN
GF0584	DES 2 O_2 PRESS		GG3324 RR TRUN SIN
GF1281	SUIT TEMP	S	GL0501 MET
GF1281	SUIT TEMP	P	FRAME COUNT
GF1301	SUIT PRESS	P	GG2219 PITCH DAC OUT
GF1301	SUIT PRESS	S	GL0402 CAL 15 PCT
GF1521	CO_2 PART PRESS	P	GG2142 MG RSVR OUT SIN
GF1521	CO_2 PART PRESS	S	FRAME COUNT
GF1651	CABIN TEMP		FRAME COUNT
GF2021	PRI GLY PUMP ΔP	P	GP0041 APS He 1R P
GF2021	PRI GLY PUMP ΔP	S	GH1456 PITCH ATT ERR
GF2531	W/B GLY IN T		GL0501 MET
GF2581	W/B GLY IN T		GL0402 CAL 15 PCT
GF2921	SEC GLY PRESS	P	FRAME COUNT
GF2921	SEC GLY PRESS	S	GG3324 RR TRUN SIN
GF3571	CABIN PRESS	S	GP0041 APS He 1R P
GF3571	CABIN PRESS	P	GG2249 YAW DAC OUT
GF3582	ASC 1 O_2 PRESS	S	GH1331 AUTO THRUST CMD
GF3582	ASC 1 O_2 PRESS	P	FRAME COUNT
GF3583	ASC 2 O_2 PRESS	S	GL0501 MET
GF3583	ASC 2 O_2 PRESS	P	FRAME COUNT
GF3584	DES 1 O_2 PRESS	S	GH1455 YAW ATT ERR
GF3584	DES 1 O_2 PRESS	P	DISCRETE
GF3591	U/H RLF PRESS		IN SH
GF3592	F/H RLF PRESS		GG2249 YAW DAC OUT
GF4101	PRI H_2O REG ΔP	P	GL0402 CAL 15 PCT
GF4101	PRI H_2O REG ΔP	S	GH1456 PITCH ATT ERR
GF4500	DES 1 H_2O PRESS	P	GL0501 MET
GF4500	DES 1 H_2O PRESS	S	FRAME COUNT
GF4501	DES H_2O PRESS		GG2219 PITCH DAC OUT

MEASUREMENT IDENTIFICATION		PRIM OR SEC	PRECEDING PARAMETER
GF4502	ASC 1 H_2O PRESS	P	GL0501 MET
GF4502	ASC 1 H_2O PRESS	S	FRAME COUNT
GF4503	ASC 2 H_2O PRESS	P	GG3324 RR TRUN SIN
GF4503	ASC 2 H_2O PRESS	S	FRAME COUNT
GF4511	PRI W/B H_2O TEMP	P	IN SH
GF4511	PRI W/B H_2O TEMP	S	GG2249 YAW DAC OUT
GF4585	ASC 1 H_2O TEMP	P	DISCRETE
GF4585	ASC 1 H_2O TEMP	S	GG2219 PITCH DAC OUT
GF4586	ASC 2 H_2O TEMP	P	GH1314 ROLL GDA POS
GF4586	ASC 2 H_2O TEMP	S	FRAME COUNT
GF9997	SEL GLY PUMP P	S	GH1247 YAW ERR CMD
GF9997	SEL BLY PUMP P	P	DISCRETE
GF9998	SEL GLY TEMP	S	GH1314 ROLL GDA POS
GF9998	SEL GLY TEMP	P	FRAME COUNT
GF9999	SEL H_2O SEP RATE		GH1455 YAW ATT ERR
GG1040	PLS TORQ REF	P	GP0041 APS He 1R P
GG1040	PLS TORQ REF	S	GL0402 CAL 15 PCT
GG1110	2.5 VDC TM BIAS	S	GH1314 ROLL GDA POS
GG1110	2.5 VDC TM BIAS	P	FRAME COUNT
GG1201	IMU 28 VAC 800		GG3324 RR TRUN SIN
GG1331	28VAC 3.2KHZ		GG3324 RR TRUN SIN
GG2001	X PIPA OUT IN Ø	P	GG2021 Y PIPA OUT IN Ø
GG2001	X PIPA OUT IN Ø	S	GQ6806 DPS VAR INJ ACT POS
GG2021	Y PIPA OUT IN Ø		IN SH
GG2041	Z PIPA OUT IN Ø	P	GG2001 X PIPA OUT IN Ø
GG2041	Z PIPA OUT IN Ø	S	GG2001 X PIPA OUT IN Ø
GG2107	IG SVO ERR IN Ø	P	DISCRETE
GG2107	IG SVO ERR IN Ø	S	GQ3603 DPS FUEL 1 QTY
GG2112	IG RSVR OUT SIN		DISCRETE
GG2113	IG RSVR OUT COS		GH1457 ROLL ATT ERR
GG2137	MG SVO ERR IN Ø	P	OPEN
GG2137	MG SVO ERR IN Ø	S	IN SH
GG2142	MG RSVR OUT SIN	P	GH1241 Y TRANS CMD
GG2142	MG RSVR OUT SIN	S	GH1455 YAW ATT ERR
GG2143	MG RSVR OUT COS	S	GQ6806 DPS VAR INJ ACT POS
GG2143	MG RSVR OUT COS	P	GG2249 YAW DAC OUT
GG2167	OG SVO ERR IN Ø	P	IN SH
GG2167	OG SVO ERR IN Ø	S	IN SH
GG2172	OG RSVR OUT SIN		GG2279 ROLL DAC OUT
GG2173	OG RSVR OUT COS	S	DISCRETE
GG2173	OG RSVR OUT COS	P	GG2249 YAW DAC OUT
GG2219	PITCH DAC OUT		GH1463 RGA ROLL RATE
GG2249	YAW DAC OUT		GG2112 IG RSVR OUT SIN
GG2279	ROLL DAC OUT		GP0042 APS He 2R P
GG2300	PIPA TEMP	S	GH1247 YAW ERR CMD
GG2300	PIPA TEMP	P	GG2249 YAW DAC OUT
GG3304	RR SHFT SIN		GQ6806 DPS VAR INJ ACT POS
GG3305	RR SHFT COS		GG2142 MG RSVR OUT SIN
GG3324	RR TRUN SIN		GG3305 RR SHFT COS
GG3325	RR TRUN COS		GH1461 RGA YAW RATE
GH1240	X TRANS CMD		GQ6806 DPS VAR INJ ACT POS
GH1241	Y TRANS CMD		DISCRETE
GH1242	Z TRANS CMD		DISCRETE
GH1247	YAW ERR CMD	P	GG2172 OG RSVR OUT SIN
GH1247	YAW ERR CMD	S	GH1456 PITCH ATT ERR
GH1248	PITCH ERR CMD	P	GG3304 RR SHFT SIN
GH1248	PITCH ERR CMD	S	DISCRETE
GH1249	ROLL ERR CMD	P	GT0441 DUA STATUS
GH1249	ROLL ERR CMD	S	DISCRETE
GH1311	MAN THRUST CMD		FRAME COUNT

PCN-12

MEASUREMENT IDENTIFICATION		PRIM OR SEC	PRECEDING PARAMETER
GH1313	PITCH GDA POS	S	GH1462 RGA PITCH RATE
GH1313	PITCH GDA POS	P	GH1456 PITCH ATT ERR
GH1314	ROLL GDA POS	S	GH1313 PITCH GDA POS
GH1314	ROLL GDA POS	P	GL0402 CAL 15 PCT
GH1331	AUTO THRUST CMD	S	GG3325 RR TRUN COS
GH1331	AUTO THRUST CMD	P	GH1247 YAW ERR CMD
GH1455	YAW ATT ERR	S	GH1463 RGA ROLL RATE
GH1455	YAW ATT ERR	P	GG2113 IG RSVR OUT COS
GH1455	YAW ATT ERR	S	GG2249 YAW DAC OUT
GH1456	PITCH ATT ERR	S	GL0401 CAL 85 PCT
GH1456	PITCH ATT ERR	P	IN SH
GH1456	PITCH ATT ERR	S	GH1456 PITCH ATT ERR
GH1457	ROLL ATT ERR	S	DISCRETE
GH1457	ROLL ATT ERR	P	GG2143 MG RSVR OUT COS
GH1457	ROLL ATT ERR	S	DISCRETE
GH1461	RGA YAW RATE	P	GH1242 Z TRANS CMD
GH1461	RGA YAW RATE	S	GH1456 PITCH ATT ERR
GH1462	RGA PITCH RATE	P	GG2173 OG RSVR OUT COS
GH1462	RGA PITCH RATE	S	DISCRETE
GH1463	RGA ROLL RATE	P	GH1457 ROLL ATT ERR
GH1463	RGA ROLL RATE	S	GH1248 PITCH ERR CMD
GI3301	ASA TEMP	S	GH1314 ROLL GDA POS
GI3301	ASA TEMP	P	FRAME COUNT
GL0401	CAL 85 PCT	S	GQ6806 DPS VAR INJ ACT POS
GL0401	CAL 85 PCT	P	DISCRETE
GL0402	CAL 15 PCT	P	DISCRETE
GL0402	CAL 15 PCT	S	GL0401 CAL 85 PCT
GL0422	PCM OSC FAIL 2		DISCRETE
GL0423	PCM OSC FAIL 3		GH1331 AUTO THRUST CMD
*GL9401	SEL RTG/ECA 1 T		FRAME COUNT
**GL9402	SEL LR/ECA 2 T	S	GH1314 ROLL GDA POS
**GL9402	SEL LR/ECA 2 T	P	FRAME COUNT
GN7723	RR ANT TEMP	P	GP0041 APS He 1R P
GN7723	RR ANT TEMP	S	FRAME COUNT
GN7723	RR ANT TEMP	S	GG2142 MG RSVR OUT SIN
GP0001	APS He 1 PRESS	S	GG2142 MG RSVR OUT SIN
GP0001	APS He 1 PRESS	P	GH1456 PITCH ATT ERR
GP0002	APS He 2 PRESS	P	GG2142 MG RSVR OUT SIN
GP0002	APS He 2 PRESS	S	FRAME COUNT
GP0018	APS He REG PRESS		GH1314 ROLL GDA POS
GP0025	APS He REG PRESS		IN SH
GP0041	APS He 1R P		OPEN
GP0042	APS He 2R P		GQ6806 DPS VAR INJ ACT POS
GP0718	APS FUEL TEMP		IN SH
GP1218	APS OX TEMP	S	GH1314 ROLL GDA POS
GP1218	APS OX TEMP	P	FRAME COUNT
GP1501	APS FUEL PRESS	P	GG3324 RR TRUN SIN
GP1501	APS FUEL PRESS	S	FRAME COUNT
GP1503	APS OX PRESS	S	GH1331 AUTO THRUST CMD
GP1503	APS OX PRESS	P	FRAME COUNT
GP2010	APS TCP	P	GQ6510 DPS TCP
GP2010	APS TCP	S	GP0041 APS He 1R P
GP2010	APS TCP	S	GG2142 MG RSVR OUT SIN
GQ3015	DPS START TANK P		GP0041 APS He 1R P
GQ3018	DPS REG PRESS		FRAME COUNT
GQ3025	DPS He REG PRESS		FRAME COUNT
GQ3435	DPS He PRESS	P	GH1455 YAW ATT ERR
GQ3435	DPS He PRESS	S	GL0402 CAL 15 PCT
GQ3603	DPS FUEL 1 QTY	S	GL0501 MET
GQ3603	DPS FUEL 1 QTY	S	FRAME COUNT
GQ3603	DPS FUEL 1 QTY	P	DISCRETE
GQ3604	DPS FUEL 2 QTY	S	GG3324 RR TRUN SIN
GQ3604	DPS FUEL 2 QTY	P	OPEN
GQ3604	DPS FUEL 2 QTY	S	FRAME COUNT
GQ3611	DPS FUEL PRESS	S	IN SH
GQ3611	DPS FUEL PRESS	S	DISCRETE
GQ3611	DPS FUEL PRESS	P	IN SH
GQ3718	DPS FUEL TEMP	S	GH1331 AUTO THRUST CMD
GQ3718	DPS FUEL TEMP	P	FRAME COUNT
GQ3719	DPS FUEL 2 TEMP	P	GL0501 MET
GQ3719	DPS FUEL 2 TEMP	S	FRAME COUNT
GQ4103	DPS OX 1 QTY	S	GH1331 AUTO THRUST CMD
GQ4103	DPS OX 1 QTY	S	FRAME COUNT
GQ4103	DPS OX 1 QTY	P	IN SH
GQ4104	DPS OX 2 QTY	P	OPEN
GQ4104	DPS OX 2 QTY	S	GG2142 MG RSVR OUT SIN
GQ4104	DPS OX 2 QTY	S	FRAME COUNT
GQ4111	DPS OX PRESS	P	GH1247 YAW ERR CMD
GQ4111	DPS OX PRESS	S	GQ3611 DPS FUEL PRESS
GQ4111	DPS OX PRESS	S	GQ3611 DPS FUEL PRESS
GQ4218	DPS OX 1 TEMP	S	GH1247 YAW ERR CMD
GQ4218	DPS OX 1 TEMP	P	GH1456 PITCH ATT ERR
GQ4219	DPS OX 2 TEMP	S	IN SH
GQ4219	DPS OX 2 TEMP	P	DISCRETE
GQ6510	DPS TCP	P	GQ4111 DPS OX PRESS
GQ6510	DPS TCP	S	GH1247 YAW ERR CMD
GQ6510	DPS TCP	S	DISCRETE
GQ6806	DPS VAR INJ ACT POS	S	GG2142 MG RSVR OUT SIN
GQ6806	DPS VAR INJ ACT POS	S	GG2041 Z PIPA OUT IN Ø
GQ6806	DPS VAR INJ ACT POS	P	IN SH
GR1085	RCS PROP A QTY	P	GH1455 YAW ATT ERR
GR1085	RCS PROP A QTY	S	DISCRETE
GR1095	RCS PROP B QTY	P	GH1247 PITCH ERR CMD
GR1095	DPS PROP B QTY	S	GH1456 PITCH ATT ERR
GR1101	RCS A He PRESS	P	GH1331 AUTO THRUST CMD
GR1101	RCS A He PRESS	S	FRAME COUNT
GR1102	RCS B He PRESS	S	GH1331 AUTO THRUST CMD
GR1102	RCS B He PRESS	P	FRAME COUNT
GR1201	RCS A REG PRESS	S	GG2219 PITCH DAC OUT
GR1201	RCS A REG PRESS	P	FRAME COUNT
GR1202	RCS B REG PRESS		FRAME COUNT
GR2121	RCS A FUEL TEMP		GH1331 AUTO THRUST CMD
GR2122	RCS B FUEL TEMP		GG2142 MG RSVR OUT SIN
GR2201	A FUEL MFLD PRESS	P	GG2219 PITCH DAC OUT
GR2201	A FUEL MFLD PRESS	S	GG2249 YAW DAC OUT
GR2202	B FUEL MFLD PRESS	S	GH1455 YAW ATT ERR
GR2202	B FUEL MFLD PRESS	P	OPEN
GR3201	A OX MFLD PRESS	P	GP0041 APS He 1R P
GR3201	A OX MFLD PRESS	S	OPEN
GR3202	B OX MFLD PRESS	S	GG2219 PITCH DAC OUT
GR3202	B OX MFLD PRESS	P	DISCRETE
GR6001	QUAD 4 TEMP		FRAME COUNT
GR6002	QUAD 3 TEMP		FRAME COUNT
GR6003	QUAD 2 TEMP		FRAME COUNT
GR6004	QUAD 1 TEMP		FRAME COUNT
GT0441	DUA STATUS		DISCRETE
GT0454	S-BAND ANT TEMP		GL0402 CAL 15 PCT
GT0625	VHF B AGC	P	GG2219 PITCH DAC OUT
GT0625	VHF B AGC	S	GG2249 YAW DAC OUT
GT0992	S-BAND ST PH ERR	P	GH1331 AUTO THRUST CMD
GT0992	S-BAND ST PH ERR	S	GH1240 X TRANS CMD
GT0993	S-BAND XMTR PO		DISCRETE
GT0994	S-BAND RCVR SIG	S	GG3324 RR TRUN SIN
GT0994	S-BAND RCVR SIG	P	FRAME COUNT

PCN-12

* THIS PARAMETER REPLACES GL8275 RTG CASK TEMP

** THIS PARAMETER REPLACES GN7563 LR ANT TEMP

NOTE

ALL GG PARAMETERS ARE MIT SIGNAL-CONDITIONED.

P INDICATES PRIMARY LOADING SLOT
S INDICATES SECONDARY LOADING SLOT

SB NO. INST 5-2

S/C: LM
DATE: 11/1/71
REV: PCN-11
ORIGINATOR: H. Perkins
APPROVAL: William E. Peters

TITLE: LM CALIBRATION CURVES

REFERENCES:
A. Operational Calibration Curves MSC
B. General Electric Technical Info Release 580-5-574-6147
C. LM Calibration Data

DISCUSSION:

A. General - Calibration data are available in the FCD at T-90 days or upon spacecraft delivery to KSC, whichever occurs first. Updated information is provided at T-60, T-30, and T-20 days. Commencing at T-20 days until liftoff, calibration updates will be provided to Computation and Analysis Division (CAD) on an "as-occurred" basis from KSC. Upon receipt of this information, the CAD will immediately make it available to the FCD and the ASPO Test Division to update calibration documents and RTCC tapes.

B. Data Definitions

1. Linear Analog Measurements - Calibration data derived from the design control specification that define a theoretical straight line representing zero output at low scale and full scale output at the high scale input. Hardware identification is not mandatory for these measurements since component replacement can be accomplished without affecting the calibration.
2. Non-Linear Analog Measurements - Calibration data derived from the design control specification that describe the curve over the operating measurement range. Hardware identification is not mandatory for these measurements.
3. Associate Contractor (AC) Measurements - Calibration data supplied to GAEC by AC Electronics. All GGXXXX measurements are in this category. Hardware identification is mandatory for these measurements since the data are derived from tests on specified hardware components.
4. Raw Data Measurements - Calibration data which are derived from observed tests. All GTXXXX measurements are in this category. Hardware identification is mandatory for these measurements since the data is derived from tests on specific hardware components.

C. Calibration Curve Format - Figure 1 is a typical calibration curve format. The letters in the circle are described as follows:

1. Vehicle Number - The numeric number assigned to the vehicle.
2. Measurement Name - The measurement name or description is GAEC assigned brief title given to each measurement. Standard abbreviation is used where applicable.
3. Calibration Date - Approximate vehicle shipment date. If measurement is recalibrated at KSC, the date is the latest calibration date.
4. Hardware Calibration Number - Not applicable.
5. Serial Number - The NASA, Vendor, or GAEC serial number is used for tracibility of the particular instrument. If only one number appears, this is the sensor or transducer serial number and no signal conditioning is required. If a second number appears below the first, this is the serial number of the signal conditioning hardware.
6. Document Reference - Section of the Calibration Data Book in which the parameter appears.
7. Range - The range of the input valve (Y-axis) in engineering units (EU).
8. Equation Coefficients - The polynominal equation coefficients denoted by (A_0, A_1, A_2, A_3, A_4, A_5) which determine the curve as follows:
$$Y = A_0 + A_1 X + A_2 X^2 + A_3 X^3 + A_4 X^4 + A_5 X^5$$
In this equation, X is in volts dc, and Y is the equivalent value in engineering units determined by the Vdc entry into the equation.

NOTE

E 01 is the computer coding for positioning of the decimal point.

9. AL DEV (allowed deviation percent) - represents the maximum allowable deviation of a data point from the best fit curve expressed as a percentage of the absolute range. This value is always 0.5 percent. P-11

10. MAX D/Range - This is the greatest deviation of any data point from the best fit curve expressed as a presentage of the absolute range.

NOTE

On some older calibration formats, the word "Sigma" may appear in place of MAX D.

11. Measurement Number - The unique number assigned to a particular location of the vehicle where the measurement is taken. The measurement number is ten characters long. The first character (module code) is a letter which designates the measurement location by spacecraft. The second character (functional system code) is a letter which denotes the system within which the measurement originates. Characters three through six are numbers assigned sequentially or grouped for clarity within each system. The seventh character, a letter, denotes measurement classification. Character eight is a dash, and characters nine and ten denote the number of times the measurement has been calibrated (example: GQ3719T - 01).

12. Measurement Loading Number - The measurement loading number gives all the information required to process and locate the data.

1 0 31 037 1 5

- 5 — Link associated with GSE and flight response equipment (always 5 for operational TM).
- 1 — Interleaver channel number (always 1 for operational TM).
- 037 — First word position (time slot) within the first frame it appears.
- 31 — First frame where measurement appears (1-50).
- 0 — Number of zeros that follows the first digit in sample rate.
- 1 — First digit of sample rate.

13. DC Volts Output - The PCM output in Vdc. Zero Vdc corresponds to 1 PCM count, and 5 Vdc corresponds to 254 counts.

14. Percent of Full Scale - The PCM output in PFS. Zero PFS corresponds to 1 PCM count, and 100 PFS corresponds to 254 PCM counts.

15. Engineering Units - The EU value of a parameter corresponding to the volts/PFS intersection of the curve.

16. PFS/EU - PFS values with the corresponding computed EU values in increments of 10 percent.

NOTE

E 01 is the computer code for positioning the decimal point.

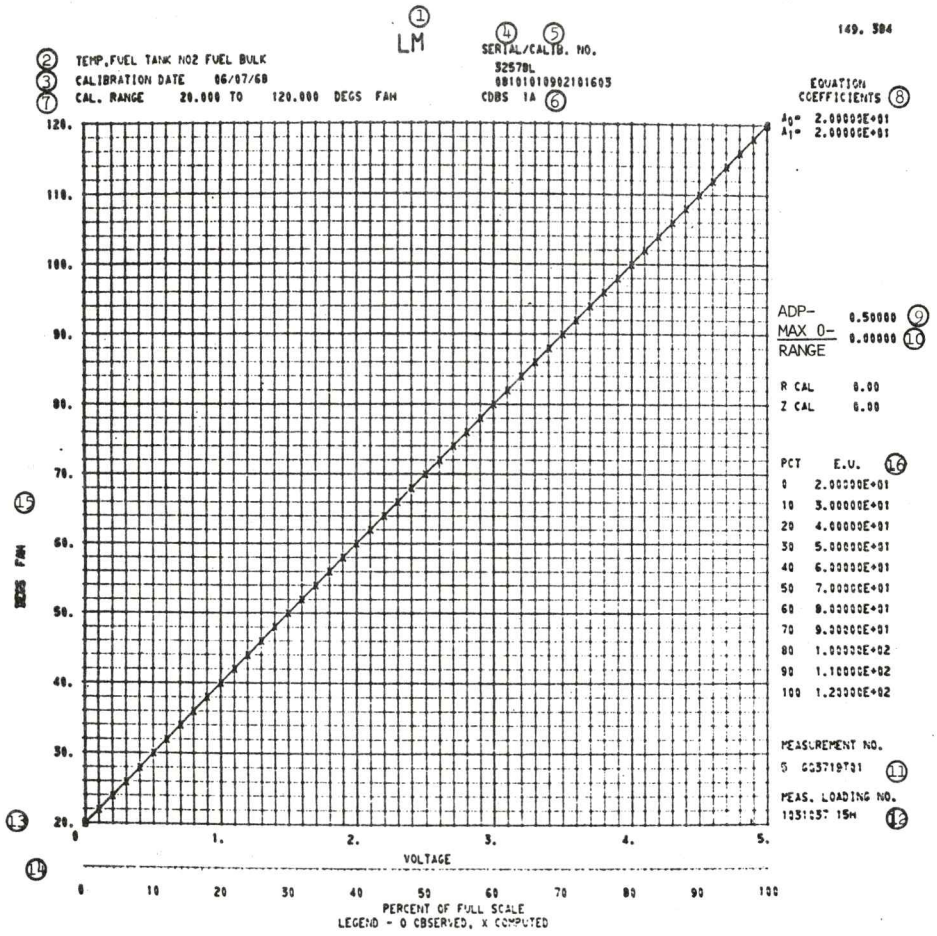


Figure 1.- Sample cal curve.

D. Measurement Accuracy

1. Normalized Curves

Measurement accuracies are listed in the Measurement Requirement and Configuration Data Book LED 360-318 and Measurements List LED 360-22 (LM-3) and for normalized calibration curves is derived from the following "Root Sum Square" (RSS) equation.

$$ACC = \sqrt{(T)^2 + (SC)^2 + (PCM)^2 + \left(\frac{MAX\ D}{RANGE}\right)^2}$$

Where: T = Specification Transducer Accuracy

SC = Specification Signal Conditioner Accuracy

PCM = PCM Encoding Accuracy

MAX D/Range = Greatest deviation of any data point from the best fit curve

The true maximum inaccuracy of a measurement is the sum of all inaccuracies in the measurement link; that is, Transducer + Signal Conditioner + PCM Encoding + Curve Fit. RSS is a method which takes into account the high probability that errors will not be maximum or in the same direction and defines an error band about the computed calibration curve which is considerably smaller than if the errors were numerically summed. Since the distribution of errors within the specification values for the transducers and signal conditioners are not known, no degree of certainty or guarantee can be attached to the error bands connected with normalized calibration curves.

2. Actual Curves:

GAEC will provide so called actual calibration data on 24 FCD selected parameters (see measurements below) with an 89% certainty that the actual measurement will remain within the error band throughout the range; that is, 0 to 100 PFS. This error band could conceivably be larger than the error that is derived for the same measurement using specification values.

The method for generating an actual calibration curve is quite complex; but basically a calibration curve and error band are statistically generated for the transducer stage of a measurement using appropriate actual data. This data is then married with the signal conditioner and PCM encoding spec data to form an end-to-end or actual calibration curve and associated error band.

The accuracy of a transducer is established by taking data from calibration runs and statistically establishing an error band. If there is a limited number of runs or if the repeatability of runs is poor, the statistical approach will probably cause the error band to increase. In some cases this will cause the actual curve to have a larger error band than the specification error band for the same measurement.

The inaccuracies of the signal conditioner cannot be reduced by statistical methods due to the lack of test data. Likewise the inaccuracy of the PCM cannot be reduced due to the nature of its operation.

a. Actual calibrations are provided on the following parameters:

GC1201	BAT 1 CUR	GP1501P	APS FU PRESS
GC1202	BAT 2 CUR	GP1503P	APS OX PRESS
GC1203	BAT 3 CUR	GP2010P	APS TCP
GC1204	BAT 4 CUR	GQ3025P	DPS He REG PRESS
GC1207	BAT L CUR	GQ3603Q	DPS FU 1 QTY
GF3582P	ASC 1 O_2 PRESS	GQ3604Q	DPS FU 2 QTY
GF3584P	DES O_2 PRESS	GQ4103Q	DPS OX 1 QTY
GF4501P	DES H_2O PRESS	GQ4104Q	DPS OX 2 QTY
GF4502P	ASC 1 H_2O PRESS	GQ3611P	DPS FU PRESS
GF4503P	ASC 2 H_2O PRESS	GQ4111P	DPS OX PRESS
GF9997U	GLY PUMP PRESS	GR2201P	A FU MFLD PRESS
GF9998U	GLY TEMP	GR2202P	B FU MFLD PRESS
GP0001P	APS He 1 PRESS	GR3201P	A OX MFLD PRESS
GP0002P	APS He 2 PRESS	GR3202P	B OX MFLD PRESS
GP0025P	APS He REG PRESS		

P-11

SB NO. ECS 6-1

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: J. Knight
APPROVAL:

TITLE: CO_2 BUILDUP

REFERENCES:
A. Atmosphere In Space Cabins and Closed Environments, Karl Kammermeyer, 1966
B. GAEC FMEA LED-550-37B, March 21, 1966
C. GAEC LED-360-318, October 13, 1967
D. MPAD Memo 68-FM74-464, Lunar Module CO_2 Study

BACKGROUND:

A. Toxic gases are normally present only in small amounts and represent both a nuisance and a potential hazard in long-time exposure. The removal of CO_2, which is the most lethal of these toxic gases, may be accomplished by the following methods:
   1. Algae systems, which are presently in the developmental stage.
   2. Gaseous diffusion, for which the power and area requirements still appear excessive.
   3. Regenerable absorbents, which are suitable for medium-duration flights using space vacuum for regeneration of absorbent.
   4. Absorption, which for short flights is the best available method.

B. The latter method, using lithium hydroxide as the absorbent, is the system used in LM spacecraft. It can be shown mathematically that when a steady-state has been achieved, and the rate of contaminant disposal is equal to the rate of contaminant generation, the cabin will accumulate a contaminant concentration given in parts-per-million (PPM) by

$$PPM = (10^6)\ (R_G/R_L)\ (M_M/M_C)$$

where R_G is the contaminant generation rate in pounds-per-hour, R_L the rate of gas mixture leakage to space, M_M the mixture molecular weight, and M_C the contaminant molecular weight. Thus when the leakage rate is sufficiently high with respect to the contaminant generation rate, a low concentration of contaminant is sustained.

C. Although the primary purpose of the lithium hydroxide is to remove the carbon dioxide produced within the spacecraft, it is also effective in absorbing certain acid gases present in trace quantities. In operation, the cabin and/or suit atmosphere is circulated through a bed of solid, anhydrous lithium hydroxide granules, where the carbon dioxide is chemisorbed:

$$CO_2 + 2\ LiOH = Li_2\ CO_3 + H_2O$$

Lithium hydroxide has a capacity in most applications approaching the stoichemetric value of 0.917 pounds of carbon dioxide per pound of lithium hydroxide. Once its capacity has been attained, however, it cannot be regenerated practicably. Activated charcoal is used in the cartridges to remove those toxic gases and odors not removed by either leakage or the lithium hydroxide. Many such contaminants are removed by physical absorption on the extended surface of the charcoal.

D. The LM has three large cartridges and seven smaller cartridges. Filtering provisions are provided to prevent the escape of LiOH and/or activated charcoal. Both cartridges are similar in construction and operation; however, the larger contains approximately 5.2 pounds of LiOH and 0.5 pounds of charcoal providing 41 man-hours before requiring replacement. The smaller cartridge contains 3 pounds of LiOH and 0.3 pounds of activated charcoal providing a maximum endurance of 16 man-hours at 520 Btu per man-hour when used in the LM vehicle. There is a non-linear relationship between the lifetimes of the PLSS cartridges since they operate at different temperatures when used in the PLSS versus when used in the LM. The lifetime versus maximum operating temperature is an exponential curve which has a significant slope change at the anticipated PLSS operating temperature. The LM canister operates at approximately 30°F below the PLSS canister. The cartridges consist of a perforated inner tube, surrounded by concentric layers of activated charcoal, screening, lithium hydroxide, and orlon felt. The gas enters the cartridge at the end of the perforated tube which passes through the center of the cartridge. The gas flows radially through the holes in the tube, passes over the bed of activated charcoal, through a screen, the lithium hydroxide, orlon felt, and out of the assembly via elongated slots cut in the outer shell. P-11

E. For average metabolic loads, CO_2 builds up at a rate of 5.0 mmHg per hour. The crew can tolerate 19 mmHg for periods up to approximately 3 hours. The normal CO_2 level is maintained at <7.6 mmHg. P-11

Under normal metabolic load (500/700 Btu), the CO_2 meter should read almost zero for approximately 10 hours. The reading will then exponentially increase until reaching 7.6 mmHg, at which time the canister should be changed. In comparison, the stressed CO_2 level is 7.6 to 15 mmHg, and the emergency CO_2 level is approximately 40 mmHg. The effect of a high CO_2 level is to suppress the respiration control centers in the brain such that the crewmen will pass out and subsequently stop breathing.

MALFUNCTION DETECTION: The indications provided for CO_2 buildup detection are the CO_2 component caution light and CO_2 partial pressure indicator. The latter readout is telemetered as GF1521P. In addition, there is an input to Caution and Warning which will trigger the ECS caution light when the level of CO_2 is 5.3 to 12.6 mmHg @ 3.7 psia and 4.2 to 9.2 mmHg @ 5.0 psia.

CORRECTIVE ACTION: In the event a high level of CO_2 is indicated, the crewmen should go to "SEC" position on the canister select handle. This will allow uninterrupted suit flow while the large canister is replaced. Following replacement, the handle is returned to the "PRIM" position. Evidence that this procedure has decreased the CO_2 level is by visual observation of the extinguished Caution and Warning light and the component caution light. Also, the meter reading will have returned to zero.

MISSION IMPACT:

A. In the event the procedure is successful, there is a negative mission impact; however, if unsuccessful, it is advised that the mission be terminated due to the possibility of loss of the crew.

B. As a last resort, crew members could remove their helmets and "breath the cabin down." It takes approximately 4 hours to build up to a 20 mmHg level after a cabin "blowdown."

|P-11

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: Q. Patin
APPROVAL:

SB NO. **ECS 6-2**

TITLE: **TORN SUIT PROTECTION**

REFERENCES:

BACKGROUND:

A. The LM ECS provides for protection of the crew in the event of an unexpected cabin, suit loop (ARS), or PGA depressurization. The torn suit protection section of the ECS is a completely automatic system once the necessary valves and circuit breakers are configured properly. With the descent stage attached and at least 540 psia in the descent oxygen tank, corresponding to approximately 20 percent (10 pounds) O_2 quantity, the cabin will be repressurized within 90 seconds. Due to the very small total ascent O_2 quantity available (approximately 4.4 pounds), this latter feature is not provided during ascent stage operation. P-5 P-3

B. The following table depicts the valve and circuit breaker configuration for staged and unstaged torn suit protection. It assumes both hatches are closed.

	UNSTAGED	STAGED
DES O_2 shutoff vlv	OPEN	CLOSE
CABIN REPRESS vlv	AUTO	CLOSE
CABIN REPRESS cb	CLOSE	CLOSE
SUIT/FLOW CONT cb	CLOSE	CLOSE

P-5

C. Reference Figure 1 for the electrical schematic demonstrating this automatic circuitry.

D. UNSTAGED OPERATION - "CABIN PRESSURIZED" P-5

If the ECS is configured to the cabin mode and cabin pressure drops below 4.07 ± 0.37 psia (these and other figures below are spec bands; individual vehicles may vary slightly), any 2 of 3 baro switches closing will provide a ground path for the CABIN REPRESS valve automatic solenoid operation. The solenoid opens the valve allowing O_2 at 900 ± 25 psia into the cabin at approximately 4 pounds per minute. This flow will stop automatically when the cabin pressure rises above 4.70 ± 0.30 psia or the **CABIN REPRESS** C/B is opened. In addition, the CABIN warning light will illuminate and the SUIT DIVERTER valve will move to the EGRESS position. Should the leak be of a magnitude that the suit loop pressure drops below 2.9 psia, the actions described below will occur. P-3 P-5

E. UNSTAGED OPERATION - "CABIN DEPRESSURIZED" P-5

1. This assumes the hatches are closed, the cabin is depressurized, the CABIN REPRESS valve is closed and the CABIN REPRESS C/B is open. P-5
2. If the suit loop pressure as sensed by the suit loop pressure switch, which is a 2-of-3 voting logic aneroid switch, falls below 2.9 psia, the SUIT ISOLATION valve solenoids are energized thereby allowing the SUIT ISOLATION valve solenoids to actuate and return to the SUIT DISC position, isolating both suits from the suit loop.
3. If the PGA's are isolated from the suit loop (assuming the crew is suited), the cognizant crewman should immediately configure for cabin mode by depressing the CABIN REPRESS circuit breaker. In addition, there will be about 1 minute to reconfigure the SUIT ISOLATION valve to regain O_2 flow before CO_2 level in the helmet builds to dangerous levels. P-5

F. STAGED OPERATION

Staged operation is identical to unstaged operation except the CABIN REPRESS valve is manually closed such that no repressurization can occur. P-5

MALFUNCTION DETECTION: The circuitry is all automatic and triggers on cabin pressure below 4.07 ± 0.37 psia. The CABIN and/or SUIT/FAN warning lights will illuminate to indicate this malfunction. P-5

MISSION IMPACT

A. There are several single-point failures which could cause actuation of this circuitry:
1. Temporary cabin leak
2. Temporary suit loop/PGA leak
3. Cabin puncture

4. Suit loop puncture (depressurized cabin)
5. Torn PGA (depressurized cabin)

B. Failures 1 and 2 will not compromise the mission. Failures 3, 4, and 5 would compromise the mission.

CORRECTIVE ACTION: Corrective action is dependent on the failure mode. Reference ECS 2, 2a, and 4, AOH malfunction procedures for specific procedures.

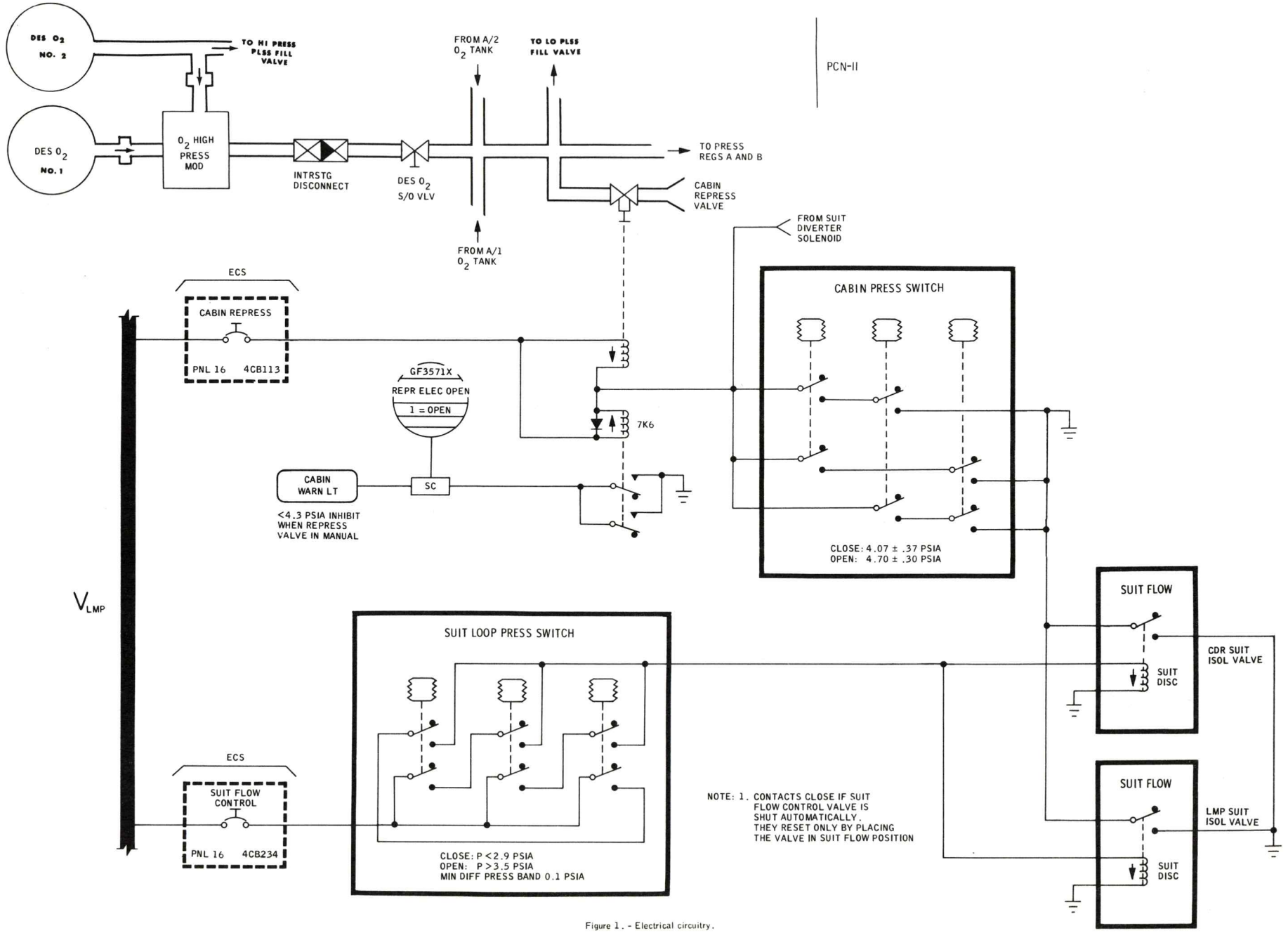


Figure 1. - Electrical circuitry.

SB NO. **ECS 6-3**

S/C: LM
DATE: 10/24/69
REV: PCN-3
ORIGINATOR: F. Frere
APPROVAL: Donald A Ruddy

TITLE: **WATER SUBLIMATOR/EVAPORATOR**

REFERENCE: HSER 2997 Porous-Plate Water Boiler Design Study, Phase II Report, May 25, 1964

BACKGROUND:

A. The LM ECS uses a porous-plate sublimator as the heat sink for the glycol loop. The porous-plate sublimator cools the glycol through the sublimation of ice and/or the evaporation of water.

B. The sublimator is constructed of four center sections and two end sections. A center section is sandwich construction which consists of a porous plate, a finned water passage, a finned glycol passage, another finned water passage, and another porous plate. The water side is separated from the glycol passage by a metal plate but is exposed to the vacuum of space through the porous plate. An end section is similar to a center section except that there is only one porous plate and one water passage.

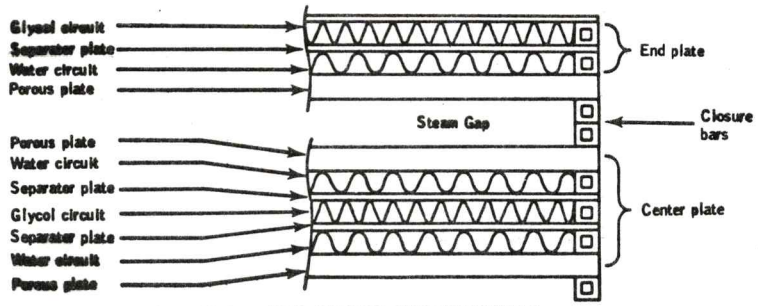


FIGURE 1 - SUBLIMATOR CONSTRUCTION

C. The thermodynamic cycle of the sublimation/evaporation process is based upon the fact that the water is exposed to an environment where the pressure drops below the "triple point" pressure (defined as the combination of pressure and temperature which permits the existence of all three states - liquid, solid, and gas -- of a substance simultaneously). See Figure 2. For water, the triple point pressure is 0.0885 psia, and temperature is 32°F. To properly treat the thermodynamic cycle, we must define the property of water called enthalpy. For our purposes, it may be defined as the inherent heat energy of a pound of water; the pound is chosen as a unit since we are to speak in terms of Btu's. The enthalpy of water in various states is given below:

1. Enthalpy of water at 32°F, 0.0885 psia = h_f = 0.00 Btu
2. Enthalpy of water at 67°F, 5 psia = h_{fl} = 35 Btu
3. Enthalpy of ice at 32°F, 0.0885 psia = h_{fi} = -143 Btu
4. Enthalpy of steam at 32°F, 0.0885 psia = h_{fs} = 1075 Btu

D. There are several factors which influence the mechanism of the heat removal process: sublimator heat load, porous-plate hole size, vapor pressure drop across the porous plate, and water pressure on the inlet side of the plate (2.5 to 8.5 psia). Let us assume that all these factors are properly balanced for normal operation. Since the porous plate has holes of varying sizes, it has been found that under medium or high heat loads, the sublimator will operate in both the sublimative and the evaporative modes. Therefore, there are two mechanisms in operation to remove heat. To properly define the operation, boundary conditions are established as follows:

1. Water at inlet to sublimator is 67°F, 5 psia.
2. Ice at porous plate is 32°F.
3. Steam exhausted at vacuum side of porous plate is 32°F.
4. Water at porous plate is 32°F, 0.0885 psia.

E. Observing that the enthalpy of steam is 1075 Btu, the question is where did the energy originate? The only sources, excluding external structural heat, is from the water itself and the glycol. Assuming the evaporation mode to be in effect, we must first decrease the temperature of the incoming water to 32°F. This requires the removal of some 35 Btu ($h_{fl} - h_f$) from the water. The hot glycol therefore

must provide another 1040 Btu which is sufficient when added to the 35 Btu from the incoming water to change the water at 32°F, 0.0885 psia, to steam at the same temperature and pressure ($h_{fs} - h_f$ = 1075 Btu). Now, assuming the sublimation mode is in effect, we will arrive at the same conclusion but by a more torturous route. Again we begin with water at 67°F, 5 psia, and reduce it to 32°F, 5 psia, for a net heat transfer of 35 Btu ($h_{f1} - h_f$). Next, there is another transfer of heat energy as the water changes state to ice of 143 Btu ($h_f - h_{fi}$). Since we are postulating a sublimation mode, all the previous discussion has taken place on the pressurized side of the ice layer. On the vacuum side of the ice layer, we are faced with the problem of adding 1218 Btu ($h_{fs} - h_{fi}$) to the ice to change it to steam. We have available the 178 Btu resulting from the previously discussed changes and, again, 1040 Btu from the glycol loop is required. Therefore, regardless of the mode of operation, that is, sublimation or evaporation, the efficiency is about the same. That is, 1 pound of water will remove approximately 1040 Btu from the glycol loop.

F. There are two possible failure modes of the sublimator: freezeup and breakthrough. The former is basically a result of too low a heat load (<800 Btu on the LM primary, and 755 Btu on the secondary). The latter may result from either too great a water feed pressure, too high a heat load, too high a pressure on the steam vent side, or too high a water flow at startup. Assuming no mechanical failures, these are rather remote possibilities with the present hardware.

G. A related failure which produces similar results is loss of water feed. This may be caused by:

1. A primary regulator failing closed
2. A leak in the water system
3. The water feedlines becoming blocked
4. The water regulator reference pressure (suit loop) dropping to a value <1.5 psia.

P-3

H. Sublimator Operations

1. Initial Conditions:

a.	Suit Temp	65 - 70 deg
b.	Glycol Temp	69 deg
c.	W/B H_2O Temp	65 - 70 deg
d.	PRI W/B GLY IN Temp	68 - 70 deg
e.	PRI W/B GLY OUT Temp	68 - 70 deg
f.	PRI H_2O REG	ΔP - off scale high

2. Activation

a. Initial indication of PRI FLOW NO. 1 to "Open"; PRI, H_2O REG ΔP drops from OFF scale high to OFF scale low for 30 seconds, at which time it should return to 0.75 ± .25 psi. If this indication goes off scale high again and remains there for > 120 seconds, the primary regulators have failed open.

3. Postactivation

a.	PRI W/B Glycol Inlet Temp increase to	74°
b.	PRI W/B Glycol Outlet Temp decrease to	36° - 42°
c.	Glycol Temp	40° - 46°
d.	Suit Temp	48° - 52°
e.	W/B H_2O Temp	67° - 71°

MALFUNCTION DETECTION:

A. A frozen sublimator may crack and result in loss of glycol. Should this occur, the result will be reflected in a glycol low discrete and a drop in pump pressure and ΔP.

B. A sublimator experiencing breakthrough will manifest itself in a high water usage rate and an oscillation in glycol temperature. The cyclical nature of the temperature is a function of the causation factors and may have cycles as short as 3 minutes or as long as 20 minutes. Occasionally, the sublimator will appear to recover and the oscillations will dampen but it is unrealistic to assume the problem has disappeared if the causation factors have not been removed.

C. Loss of water feed can be detected by an otherwise unexplained rise in glycol temperature accompanied by a rise in primary sublimator water temperature and perhaps a drop in H_2O ΔP. Loss of the reference pressure will result in at least severely restricted water feed to the sublimator.

MISSION IMPACT: Loss of the primary loop, worst case. Rapid depletion of consumables may be experienced if breakthrough should occur.

CORRECTIVE ACTION: A frozen water sublimator is difficult to detect with present instrumentation. Therefore, little can be done to correct it; however, if sufficient heat load is maintained, there is little probability of this failure.

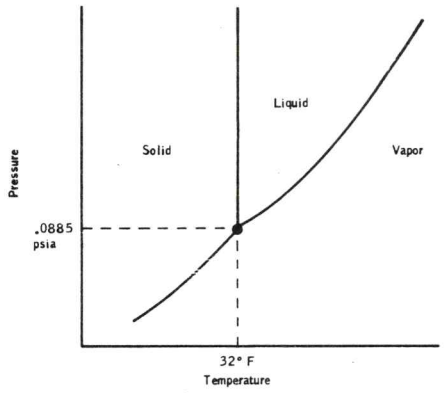


FIGURE 2.- EQUILIBRIUM PHASE DIAGRAM FOR WATER.

SB NO. ECS 6-4

This SB deleted by PCN-8

SB NO. **PGNS 7-1**

S/C: LM
DATE: 3/27/69
REV: Original
ORIGINATOR: B. Durand
APPROVAL: H. A. Soden

TITLE: COORDINATE SYSTEMS

REFERENCES:

BACKGROUND: In general the LM attitude is determined by reference to the inertial platform (stable member), which in turn may be aligned or referenced to one of several available coordinate systems. The LM attitude is displayed to the astronaut by the "8 Ball" which is mechanized to use a unique coordinate system called the FDAI coordinate system. Since the astronaut normally reads 8-ball coordinates, ground processing is also implemented to display spacecraft attitudes in the FDAI 8-ball coordinates. The following will define the method for interpreting the FDAI coordinate system and its application to the various other coordinate systems.

A. Introduction and Earth-Centered Coordinate System

1. In order for the LGC to continually and accurately update the spacecraft state vector it must have an original position and an original velocity vector, and then keep track of the changes in these vectors via the changes in the IMU resolver and PIPA readings. To facilitate this "tracking" procedure the computer resolves all vectors into one coordinate system - the earth-centered coordinate system which is shown in Figure 1 and defined as follows:

   The Z-axis of this system is parallel to the spin axis of the earth and is positive in the direction from the center of the earth to the north celestial pole on the celestial sphere. The X-axis lies in the plane defined by the celestial equator and is positive in the direction from the center of the earth to the first point of Aries on the celestial sphere. The Y-axis also lies in the plane of the celestial equator and completes the right-hand orthogonal system.

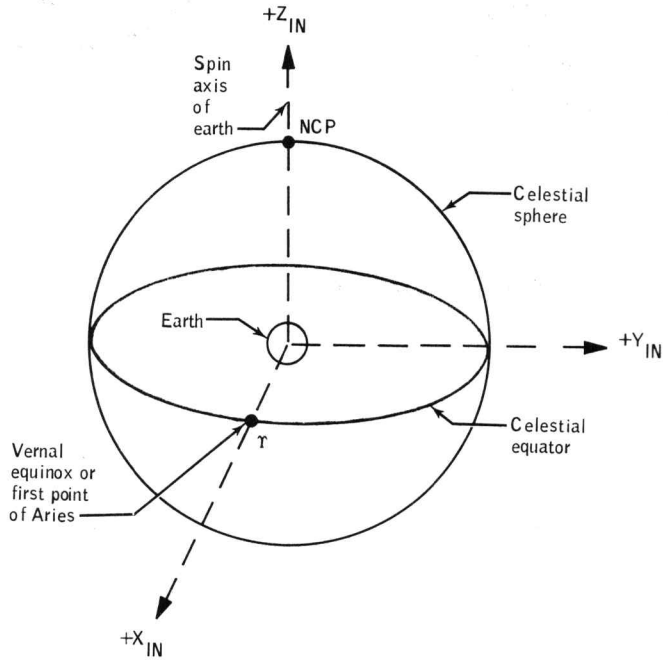


FIGURE 1 - EARTH-CENTERED COORDINATE SYSTEM

2. Now, no matter which orientation the IMU stable member axes are aligned or referenced to - nominal, preferred, landing site, or any other "known" orientation - a vector in stable member coordinates can be transformed into a vector in reference coordinates via REFSMMAT (the reference to stable member transformation matrix).

B. Spacecraft Coordinate System

In this system the X-axis is defined by the line joining the point formed by the crossed diagonals of the landing pads (gear extended) and the center point of the docking hatch, positive up. The Z-axis extends perpendicular from the X-axis through the center point of the forward hatch, positive forward. The +Y-axis completes the right-hand orthogonal system.

C. FDAI Coordinate System and Method for Interpreting the FDAI Total Attitude

1. The FDAI coordinate system may be better understood by considering that the three angles in this system are constrained by the manner in which the 8 ball is mechanized. Figure 2 shows the front and back of the 8 ball.

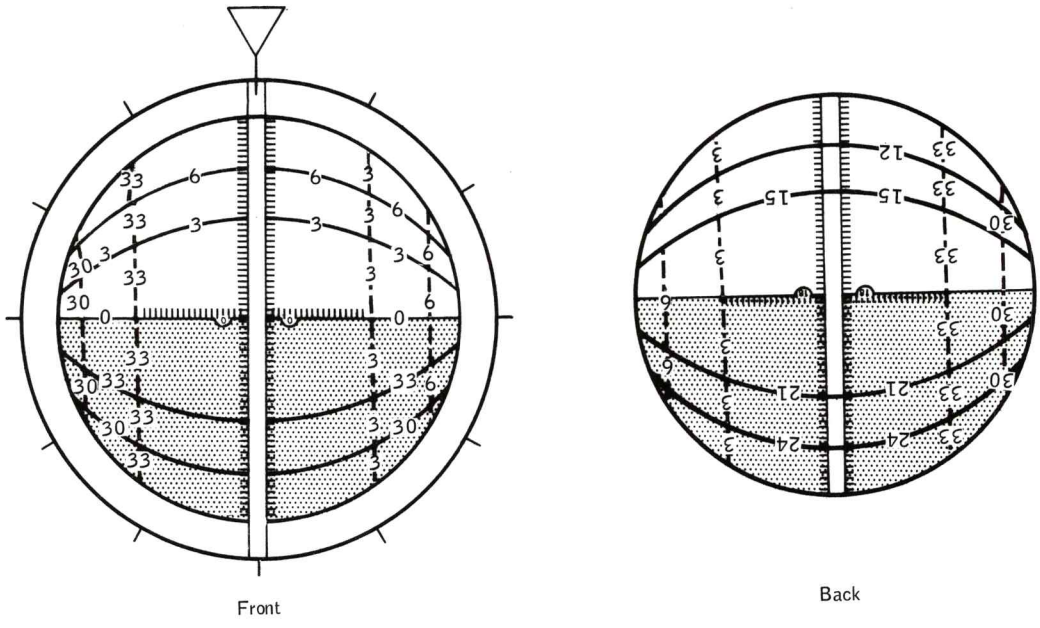


FIGURE 2 - EIGHT BALL

As can be seen from the above figure, the 8-ball yaw angle is limited to ±90 degrees (270 degrees < yaw < 90 degrees). The amount of roll is indicated by the position of the roll bug.

2. The FDAI coordinate system has three uses:

   a. Displays the spacecraft attitude with respect to the IMU stable member axes,

   b. Displays the spacecraft attitude with respect to a local horizontal/local vertical reference system,

   c. Communicates to the astronaut a desired orientation or line-of-sight with respect to the present spacecraft orientation (Body Coordinate System).

   If the IMU is aligned to some specific orientation, such as nominal, preferred, or landing site (i.e., the IMU stable member axes are parallel to the specific coordinate system axes), then the FDAI will display the spacecraft attitude with respect to that coordinate system. If the IMU is aligned to a "known" but not specific orientation (i.e., REFSMMAT), then the FDAI merely displays the spacecraft attitude with respect to the stable member. If ORDEAL is in operation, then the FDAI displays the spacecraft attitude with respect to a rotating local horizontal/local vertical coordinate system.

3. The astronaut may interpret the FDAI angles in the following manner: Consider himself to be in the center of a sphere and pointing the +Z spacecraft axis at a point on the sphere defined by the three FDAI angles. When pointing at the 0,0,0 point of the sphere, 90 degrees pitch is straight up and

270 degrees straight down, 90 degrees yaw directly right and 270 degrees directly left, and positive roll clockwise. Although only two parameters are necessary to define a point on a sphere, a third parameter is necessary to define rotation about the line joining the center of the sphere and a point on its surface. From the 0,0,0 orientation, a plus vehicle yaw (left) will cause the 8-ball to move right as viewed by the astronaut; a plus vehicle pitch (up) will cause the ball to move down; a plus vehicle roll (clockwise) will cause the ball (and the roll bug) to rotate counterclockwise. In the latter cases, the 8-ball readings will increase from 0 through 90 and 270 to 360 degrees for a complete one-axis rotation. For a positive vehicle yaw the 8-ball readings would decrease from 0 through 315 to 270 degrees. At this point the ball will quiver momentarily, and the roll bug will flip to the 180-degree position. The yaw readings will now increase from 270 through 0 up to 90 degrees and the pitch reading, since we are now on the back side of the ball, will read 180 degrees. At the 90-degree yaw reading (270 degrees of vehicle plus yaw) the roll bug will flip back up to the 0-degree position, and the yaw will decrease down through 45 to 0 degrees and the pitch reading, since we are again on the front of the ball, will be 0 degrees.

D. Four coordinate systems to which the IMU stable member axes can be aligned are:

1. Nominal

In this system the IMU stable member axes are aligned as follows:

$$+X_{SM} = \text{Unit } (\overline{R})$$

$$+Y_{SM} = \text{Unit } (\overline{V} \times \overline{R})$$

$$+Z_{SM} = \text{Unit } (\overline{X}_{SM} \times \overline{Y}_{SM})$$

Where $\overline{R}$ = the geocentric (earth orbit) or selenocentric (lunar orbit) radius vector at time T (align) selected by the astronaut, and $\overline{V}$ = the velocity vector at time T (align). This orientation may be chosen by the astronaut for any in-plane burn and facilitates the monitoring of the FDAI Total Attitude Display (e.g., a 0,0,0 reading) and the avoidance of possible gimbal lock during that burn.

2. Preferred

This system is used with the IMU aligned to an orientation calculated and stored by a previously selected program. This is an optimum orientation for any particular maneuver considering the avoidance of gimbal lock and ease of monitoring the FDAI angles.

3. Landing Site

In this system the IMU stable member axes are aligned as follows:

$$+X_{SM} = \text{Unit } (\overline{R}_{LS})$$

$$+Y_{SM} = \text{Unit } (\overline{Z}_{SM} \times \overline{X}_{SM})$$

$$+Z_{SM} = \text{Unit } (\overline{H}_{CSM} \times \overline{X}_{SM})$$

Where the origin is the center of the moon, $\overline{R}_{LS}$ = the position vector of the LM on the lunar surface at a landing site and a time T (align) selected by the crew, and $\overline{H}_{CSM}$ = the angular momentum vector of the CSM ($\overline{R}_{CSM} \times \overline{V}_{CSM}$) at time T (align). This system will give the crew FDAI angles of 0,0,0 at the time of touchdown when T (align) is equal to T (land).

4. REFSMMAT

The IMU stable member axes are initially aligned to an arbitrary orientation, and then this orientation with respect to the celestial sphere is determined by star sightings and a REFSMMAT computed (if the IMU stable member axes are parallel to the earth-centered coordinate system axes then REFSMMAT will be a unity matrix). This arbitrary orientation will thereafter be called the REFSMMAT orientation. Thus, any "known" orientation is a REFSMMAT orientation, and the nominal, preferred, and landing site orientations of the IMU stable member are special cases of a REFSMMAT orientation.

E. Local Horizontal/Local Vertical Coordinate System

The X-axis of this system is defined by the line joining the center of the earth (or moon) and the vehicle, and is positive in the direction from the earth or moon center up through the vehicle. The Z-axis is perpendicular to the X-axis, lies in the orbital plane, and is positive in the direction of the vehicle velocity. The Y-axis completes the right-hand orthogonal system. When in circular orbit and using ORDEAL (orbital rate display, earth and lunar), a pitch rate will be input to the FDAI 8 ball to compensate for the pitch rate due to the orbit (thus providing the astronaut with a local horizontal reference). The ORDEAL is used after obtaining the IM attitude with respect to the local horizontal from the LGC, and then slewing the selected FDAI to this angle.

F. Body Coordinate System

This coordinate system is used to convey directions relative to an instantaneous spacecraft position (e.g., to tell the astronaut where to look to see the CSM). The angles given to the astronaut are in terms of an FDAI coordinate system coincident with the spacecraft axes. The angles are always given in the sequence roll, pitch, yaw to define an external point with respect to the spacecraft. The astronaut will always consider himself to be in the center of the FDAI coordinate system sphere and pointing at the 0,0,0 point. For example, in order to communicate to the astronaut a point directly behind him (i.e., 180-degree vehicle yaw) we would give the angles 180, 180, 0 degrees (roll, pitch, yaw).

SB NO. **PGNS 7-2**

S/C: LM
DATE: 11/1/71
REV: PCN-11
ORIGINATOR: J. Nelson
APPROVAL: Harold A. Loden

TITLE: **IRIG BIAS DRIFT**

REFERENCES: A. MSC Internal Note No. 71-FC4-1 | P-11
B. AG 852-66-(MIT)
C. EG41-32-68-87
D. SODB, Vol II, Paragraoh 4.5.1
E. MIT/IL Systems Test Group Memo No. 1220, Rev 1
F. MIT/IL Systems Test Group Memo No. 1231, Rev A
G. MIT/IL Systems Test Group Memo No. 1256

BACKGROUND: There are three primary types of gyro drift associated with the three X, Y, Z IRIG's (inertial reference integrating gyros). Two of the drifts are G sensitive; these are (1) IRIG acceleration sensitive drift along the input axis (ADIA), and (2) IRIG acceleration sensitive drift along the spin reference axis (ADSRA). The non-G sensitive drift is (3) normal bias drift (NBD).

ADIA and ADSRA cannot be measured in flight but are calculated prelaunch. ADIA, ADSRA, and NBD bias compensation are applied to the IRIG's every 2 seconds during a burn as called by the Servicer program. Only NBD compensation is applied to the IRIG's during coast.

Of primary concern to flight controllers is the non-G sensitive drift, NBD. NBD shifts can be caused by restraint type torques, external magnetic fields, temperature, wear, and contamination or failure in peripheral electronics. Contamination and peripheral electronics problems will cause abrupt shifts in NBD.

NBD IRIG compensation is accomplished via routine SVCT3 every 81.93 seconds as called by waitlist control if FW2 bit 15 (IRIFTFLG) = 1. One gyro torquing pulse is equal to .617981 seconds of arc of rotation (.003 milliradians) at the gyro gimbal. It should be noted that the sign convention used to display the torquing commands (OGC and IGC) displayed to the astronaut in the gyro torquing routine R55 is opposite to that used for NBDX and NBDY. MGC and NBDZ are of the same sign convention. Therefore, the following equations should be used for calculations of new NBD values.

$$NBDX_{new} = NBDX_{old} - OGC$$

$$NBDY_{new} = NBDY_{old} - IGC$$

$$NBDZ_{new} = NBDZ_{old} + MGC$$

A discussion of the methods used for calculating gyro drift follows:

A. P52/P57 alignments

Two consecutive P52 or P57 alignments are the primary means for calculating Irig drift. Table 1 shows two sigma alignment accuracies for various alignment methods. Also included in Table 1 is the root sum square of alignment accuracies for two consecutive alignments of the same technique. The 2 sigma drift measurement accuracy for any two consecutive alignments can be calculated using the following equations: | P-11

COASTING FLIGHT

$$\text{2 Sigma X, Y, Z IRIG drift accuracy} = \frac{\sqrt{\left(\begin{matrix}2\sigma \text{ alignment accuracy} \\ \text{for 1st alignment}\end{matrix}\right)^2 + \left(\begin{matrix}2\sigma \text{ alignment accuracy} \\ \text{for 2nd alignment}\end{matrix}\right)^2}}{\text{time between alignments}}$$

LUNAR SURFACE

$$\text{2 Sigma X IRIG drift accuracy} \sqrt{\left(\frac{\sqrt{\left(\begin{matrix}2\sigma \text{ alignment accuracy} \\ \text{for 1st alignment}\end{matrix}\right)^2 + \left(\begin{matrix}2\sigma \text{ alignment accuracy} \\ \text{for 2nd alignment}\end{matrix}\right)^2}}{\text{time between alignments}}\right)^2 + (\text{ADIAX error})^2}$$

where 2σ ADIAX error = 16 MERU/earth g = .04 deg/HR/lunar g

2 Sigma Y, Z IRIG drift accuracy = same as for coasting flight above

The above equations can be used to calculate mission rule update limits above the 5 MERU minimum. SCP No's 7-1A, 1B, ID, and IE describe procedures used to calculate IRIG drift between P52 and P57 alignments.

B. Lunar Surface CDU method/N20

The method used for prelaunch gyro null bias drift (NBD) calculations utilizes the first P57 alignment as a baseline, thereafter using CDU angles to periodically calculate gyro drift. Basically, the drift calculation involves the following procedure which has been compared to a P57 Option 0. P-11

CDU METHOD	COMPARISON WITH P57 OPTION 0
1. Immediately after completion of a P57, CDU angles and time are recorded.	1. Store LM position vectors in moon fixed coordinates during last good P57 alignment.
2. Projecting the post P57 CDU angles forward in time to liftoff, a set of reference liftoff gimbal angles is obtained NOTE: The CDU angles can be projected to any time. The only constraint is that the next set of CDU angles be projected to the same time as the first set. Projection to liftoff was chosen as nominal for the CDU method since the surface PIPA bias calculation also uses liftoff angles.	2. Start of P57 Option 0: Rotate the two previously stored position vectors to the present P57 time and transform to stable member coordinates.
3. At an appropriate time, (e.g. one hour intervals) CDU angles and time are again read and projected forward to liftoff obtaining a new set of liftoff gimbal angles.	3. Read the present CDU angles and transform to stable member coordinates.
4. Using the reference liftoff gimbal angles (first set taken) and the new set of liftoff gimbal angles, N93 torquing angles are calculated using the same equations as P57 Option 0.	4. Calculate N93 torquing angles by calculating the angles required to rotate the present angles into the reference angles.
5. Using the N93 torquing angles and the time between the two CDU readings, gyro drift is calculated.	5. Using the N93 torquing angles and the time between the two P57's, gyro drift is calculated.

Assuming no spacecraft movement, the primary error source of the CDU method is CDU granularity (.011 degrees). Table 2 contains drift measurement accuracies for various times between CDU readings. Y and Z axes drift accuracy is equal to the RSS of the 2 σ CDU granularity value (.022 deg) divided by the time between CDU readings. X axis drift accuracy is the RSS of the drift accuracy (as in Y and Z above) and the ADIAX 2 sigma accuracy ($.04^{o}$/hr/lunar g).

The CDU method can be used on the surface anytime the IMU is aligned to a known reference. Its primary use is during launch prep between the P57 alignments. Care must be taken not to make drift measurements over periods that contain cabin depress/repress, crew egress/ingress or P57 alignment operations. The following sequence may be used for launch prep alignments 2 hours apart.

1. Read CDU angles and time immediately after 1st P57 and obtain 1st set of reference liftoff angles.
2. Wait until Z CDU angle changes or approximately 10 minutes and read a second set of CDU angles and obtain 2nd set of reference liftoff angles.
3. Thirty minutes after the P57, obtain a 3rd set of liftoff angles.
4. Use 1st and 3rd set of angles to get rough check on gyro drift.
5. One hour after the P57, obtain a 4th set of liftoff angles.
6. One hour and 10 minutes after the P57, obtain a 5th set of liftoff angles.
7. Use sets 1 & 4 and 2 & 5 to calculate two sets of drift values.
8. Average the above two sets to determine if a change in a gyro drift compensation term is required. P-11
9. Use 2nd P57 N93 torquing angles to calculate drift. If the P57 values verify the CDU method values, update the LM computer with the CDU values. If the P57 values do not verify the CDU values the P57 values will be considered good and a new update will be made if necessary.

The present program was written primarily to support lunar surface operations. However, Part 2 of the program (reference SCP No. 7-1) can also be used to calculate LM torquing angles for a docked alignment. Basically, Part 2 calculates the amount of LM platform torquing (Noun 93 torquing angles) required to rotate one set of gimbal angles into another set of reference gimbal angles. In the docked align case, CSM CDU angles are the reference gimbal angles which are transferred to the LM coordinate system with the following equations:

$$OG = 300 + \text{Docking Angle} - CSMOG$$
$$IG = 180 + CSMIG$$
$$MG = 360 - CSMMG$$

The LM gimbal angles read at the same time as the CSM angles are the second set of inputs to the program. LM N93 torquing angles result. The capability is pointed out here to indicate that CONTROL can back up GUIDANCE in the business of docked alignments if the LM platform is to be aligned to the same REFSMMAT as the CSM. Also, it is possible to take CDU angles simultaneously from the CSM and LM downlinks and make rough docked drift checks without requiring crew participation.

SCP No. 7-1B describes the procedures used to calculate IRIG drift using the surface CDU method and the docked CDU method. Reference A contains the equations used in the CDU method.

FIGURE 1. LM NOUN 05 AND ALIGNMENT ACCURACY

SIGHTING VECTORS	INSTRUMENT[f]	3σ NOUN 05 ACCURACY[a] (DEG)	2σ ALIGNMENT ACCURACY[a] PER AXIS (DEG)	2σ RSS OF THE ALIGNMENT ACCURACIES[a] FOR TWO CONSECUTIVE ALIGNMENTS OF THE SAME ALIGN TECHNIQUE (DEG)
STAR/STAR	AOT (INFLIGHT) AOT (SURFACE) COAS	.117 .103 .707	.119 .116 .422	.168 .164 .597
STAR/PLANET	AOT (INFLIGHT) AOT (SURFACE) COAS	.212 .205 .729	.148 .146 .431	.209 .206 .610
STAR/SUN	AOT (SURFACE)	.103 (.105)	.116 (.117)	.164 (.165)
STAR/EARTH	AOT (INFLIGHT)	.130 (.164)[b] (.132 to 1.384)[c]	.122 (.137)[b] (.123 to .215)[c]	.173 (.194)[b] (.174 to .304)[c]
SUN/MOON	AOT (INFLIGHT)	.130 (.164 to 5.501)[b] (.132)[c]	.122 (.137 to .223)[b] (.123)[c]	.173 (.194 to .316)[b] (.174)[c]
g/STAR	AOT (SURFACE)	.095	X .082, Y .031, Z .049	X .116, Y .044, Z .069
g/SUN	AOT (SURFACE)	.095 (.098)	.082 (.083), .031, .049	.116 (.117), .044, .069
g/PLANET	AOT (SURFACE)	.130	.093, .031, .049	.132, .044, .069
g/Z-BODY	AOT (SURFACE)[d] AOT (SURFACE)[e]	.218 .184	.195, .031, .049 .118, .031, .049	.275, .044, .069 .167, .044, .069

[a]The numbers in parenthesis represent accuracies with onboard computed vectors when they differ from ground values.

[b]Earth reference near lunar sphere-of-influence.

[c]Moon reference near lunar sphere-of-influence.

[d]for alignment with landing stored azimuth.

[e]for alignment with stored azimuth that was updated from a two star alignment.

[f]Inflight AOT alignments may be either cursor/spiral or X/Y mark alignments.

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TABLE 2 DRIFT ACCURACY USING CDU METHOD

DELTA TIME (HRS)	2σ DRIFT MEASUREMENT ACCURACY (DEG/HR)			(MERU)		
	X	Y	Z	X	Y	Z
0.5	.073	.062	.062	4.92	4.14	4.14
0.75	.057	.041	.041	3.83	2.76	2.76
1.0	.050	.031	.031	3.37	2.07	2.07
1.5	.045	.020	.020	3.00	1.38	1.38
2.0	.043	.015	.015	2.86	1.03	1.03
2.5	.042	.012	.012	2.79	.83	.83
3.0	.041	.010	.010	2.75	.69	.69

This Page Deleted by PCN-11

S/C: IM
DATE: 11/1/71
REV: PCN-11
ORIGINATOR: J. Nelson
APPROVAL: Harold A. Sodin

SB NO. **PGNS 7-3**

TITLE: **OPERATION OF THE PGNS FOR VARIOUS BATTERY BUS VOLTAGES** P-11

REFERENCES:
1. LIS-390-10002-PGNS Prime Power Requirements and Characteristics - GAEC
2. AG 133-68, Change to the 28V Failure Detection Leak (V-Fail), MIT/IL
3. EG 44-68-41, The Effects of Transient Low Voltage on G&N Operation and Performance, 2/5/68
4. AG 44-67, The Effects of Transient Low Voltage on G&N Operation and Performance, MIT/IL, 2/1/68
5. STG 1107, The Effects of Transient Low Voltage on G&N Operation and Performance, 1/31/68
6. AP-71-00251, Variations of X Accelerometer Characteristics vs + 28 VAC, 4/27/71
7. TR-039-1, Relay-Electric Magnetic Test, 2/3/66 P-11

BACKGROUND: The PGNS is known to exhibit different behavior with reduced S/C battery bus voltages. This brief describes the behavior due to constant low voltage and low voltage transients. P-11

Table I lists the various units and their bus voltage ranges where interface control documents (ICD) requirements are met.

TABLE I

PGNS	EQUIPMENT VOLTAGE (From interface control documents)	BUS VOLTAGE
Inertial Subsystem: IMU, PSA, CDU	Operate 23.5 to 32.5 Vdc	24.0 → 32.5
Computer Subsystem: DSKY, Computer	23.5 to 32.5 Vdc 20.3 ± .3 Voltage Fail Detection	24.0 → 32.5

The inertial and computer subsystems are unaffected (in operation) by high voltages up to 34 Vdc. However, it is expected that some finite limit near 34 Vdc may exist where a sudden malfunction would occur rather than a slow degradation of operation. No testing beyond 34 Vdc has been reported.

The computer and display keyboard (DSKY) have a definite lower voltage where all effective action of the computer can be expected to be ceased. This is the level at which the voltage fail (Vfail) signal is generated within the computer. The Vfail signal is generated when the prime power decreases below 20.3* ± .3 volts. After Vfail is generated and persists for 146 to 258 microseconds, the caution and warning integrator in turn generates a "restart" signal. "Restart" then zeros or initializes a number of registers in the computer and resumes operation in a program near where it had left off after the voltage had gone above the Vfail limit. It also temporarily interrupts the DAP. This describes a single restart in the computer and is typical of a voltage transient. For the case where the voltage remains below the Vfail limit for a long time, the operation is slightly different. If the bus voltage continues to remain at the low level threshold of Vfail, the LGC will become locked in a "continual-restart" condition and will not be able to resume normal operation until the voltage rises above the Vfail limit. P-11 P-6

Some level of safety margin still exists within the computer to assure that fixed and erasable memory cannot be altered in a random manner (reference MIT/IL memorandum AG 133-68). This margin is at a level somewhat below 16 Vdc of prime power.

*This value may vary depending upon LGC characteristics.

At the level of 17 VDC, the drop out point of the normally energized relay in the DSKY, which issues the LGC warning and the PTA inhibit, is being approached. If the level of dropout voltage of the relay and relay driver combination is reached, no operation, proper or otherwise, will allow the LGC warning to be removed until voltage is restored above 17 volts.

The inertial subsystem (IMU, PSA, and CDU's) is unaffected by voltage drops at the equipment interface to a lower limit of 23.5 volts (Ref. AP-71-00251). At lesser voltages, errors are induced in the PIPA's and IRIG's due to exceeding their operational limits. The bias shift and scale factor errors exhibited by the PIPA's are significant and could cause the PGNS to perform unsatisfactorily.The IRIG's, exhibit an uncompensated drift which would probably be acceptable for a reasonable short period of time. Although these characteristics would also appear in transient cases, it is expected that the PGNS would recover and be available as a prime system. One additional consideration for transient cases is the possibility of losing the IMU turn on relay. Tests have shown that the drop out voltage is approximately 3.1 Vdc with an average time delay of 9.1 milli-seconds. P-11

PAGES III-7-11THROUGH III-7-26a DELETED BY PCN-12

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SB NO. **PGNS 7-8**

S/C: LM
DATE: 10/3/69
REV: PCN-3/New
ORIGINATOR: B. A. Durand
APPROVAL: H. O. Loden

TITLE: **RANGE/RANGE RATE METER**

REFERENCES: Range Indicator Technical Analysis Report - March 1968
G.A.E.C. P.O. 3-63413
LSH (LM-5) Dwg 10.4.4 - Range/Range Rate Meter
MIT GSOP R567, Section 5

DISCUSSION: The range/range rate meter is a vertical scale indicator which displays on two motor driven tape scales either landing radar, rendezvous radar, LGC or AGS values for range and range rate (altitude or altitude rate).

A. Method of Operation - The meter has two sources of power, 28 Vdc (tape motor power) and 115 volt-400 Hz (logic power), which are applied to the meter via CB activation. To prevent the tape meter from random cycling during the turn ON/OFF sequence, the dc power must be applied after the ac power during power up, and prior to removal of the ac power during power down.

Selection of LR, RR, LGC or AGS data is accomplished by two switches located on panel 1, the RNG/ALT monitor switch and the MODE select switch. The RNG/ALT monitor switch accomplishes the switching of range/range rate or altitude/altitude rate signals to the meter. Selection of either type of signal via the RNG/ALT MON switch will illuminate the integral lighting at the top of the display to indicate the mode of operation, range/range rate or altitude/altitude rate. The RNG/RNG RT position of this switch routes RR data directly to the meter while the ALT/ALT RT position routes the information that is selected via the MODE select switch. This switch allows either LR, LGC or AGS altitude/altitude rate data to be displayed on the meter. Thus, there are a total of eight signals that can be introduced to the meter in four separate switched modes of operation depending upon crew choice. Figure 1 illustrates these modes. The following discussion defines each of the signals and the form in which they are sent to the meter electronics:

1. RR Range: An 18-bit digital word which is equivalent to the raw range between the LM and CSM. The LSB of this word is worth 9.38 ft.
2. RR Range Rate: A continuous pulse train with frequency proportional to the change in velocity between the LM and CSM along the LOS. The scale factor of this data is 19.9 pps/fps.
3. LR Altitude: A continuous pulse train with frequency proportional to the slant range from the LM along beam 4 of the LR antenna to the lunar surface. The scale factor of this data is 2.316 pps/ft for altitudes greater than 2500 ft and 11.583 pps/ft for an altitude less than 2500 ft.
4. LR Altitude Rate: A continuous pulse train with frequency proportional to the LM velocity with respect to the lunar surface along the antenna X-axis. (NOTE: In antenna position 1, the antenna X-axis is displaced 24° rearward from the LM body X-axis. In position 2, the antenna X-axis is coincident with the LM X-axis). The scale factor of this data is 19.439 pps/fps.
5. LGC Altitude: A 15-bit digital word with a value equivalent to the estimated local altitude above the lunar surface, which is the difference between the current position state vector and the magnitude of the landing-site radius. The magnitude of the LSB is 2.345 ft.
6. LGC Altitude Rate: A 15-bit digital word equivalent to the LM's velocity along the local vertical direction as computed from LGC state vectors. The magnitude of the LSB is .5 ft/sec.
7. AGS Altitude: A 15-bit digital word equal to the estimated local altitude above the lunar surface. The magnitude of the LSB is .2925 ft.
8. AGS Altitude Rate: A 15-bit digital word equivalent to the LM's velocity along the local vertical direction. The magnitude of the LSB is 1/16 ft/sec.

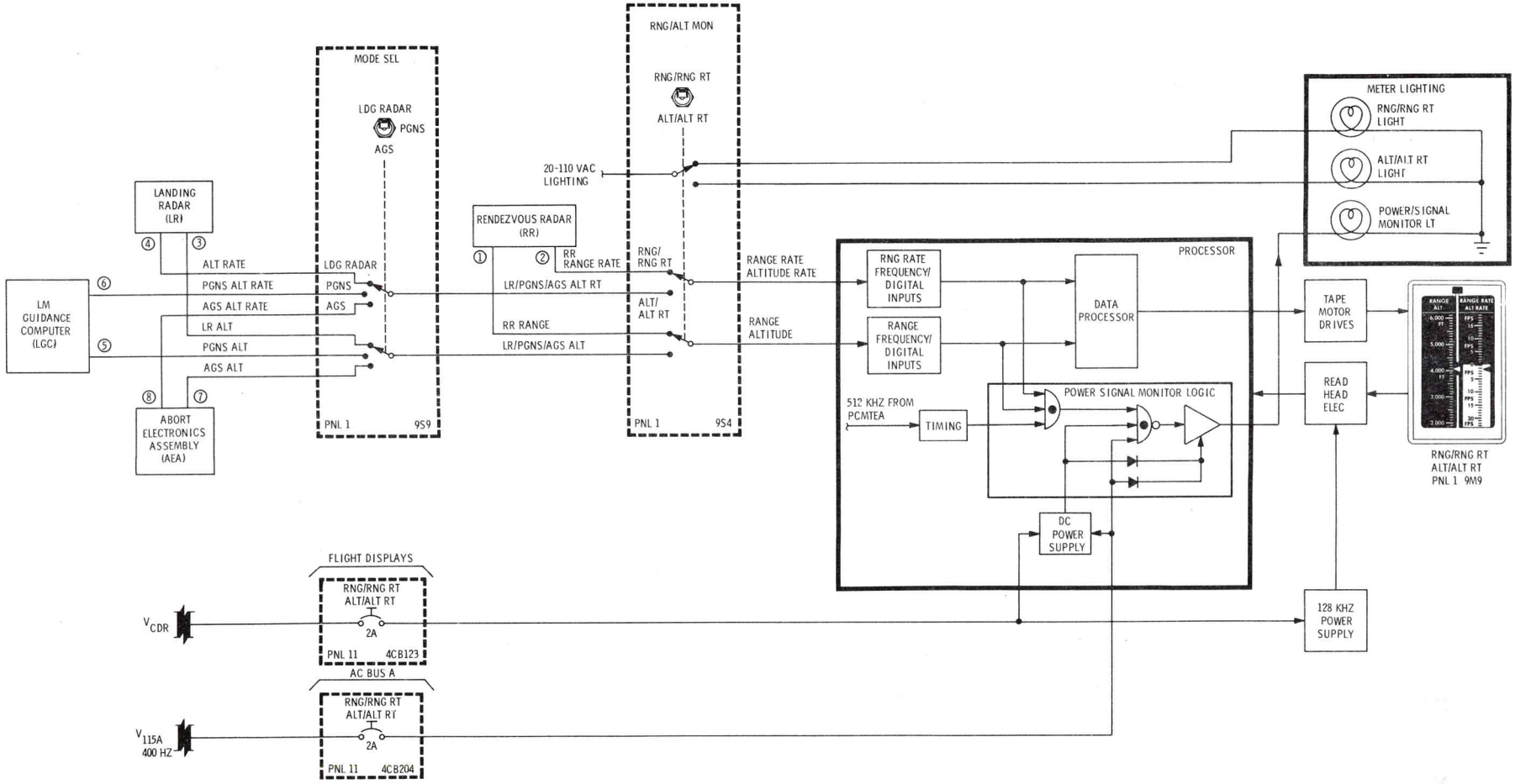


Figure 1. - Range/range rate meter switched modes of operation.

The information sent to the meter by either the radars, the LGC, or the AGS is displayed on two tape meters. One tape displays either range or altitude dependent upon the mode selected by the crew. The range/altitude tape is divided into three sections each graduated as follows:

1. 0 - 1000 ft with 5 ft graduations.
2. 1000 - 60,500 ft (10 n.mi) with 100 ft graduations.
3. 10 n.mi. - 405 n.mi. with 2 n.mi. increments.

One point of interest is the landing radar altitude readout on the tape meter. The input received from the LR is multiplied by the cos 15° within the meter to give the crew a more accurate indication of true altitude. It should also be noted that a comparison cannot be made between the LR and the computer values of altitude since from the previous definitions:

$$\text{LV ALTITUDE (COMPUTED)} \neq \text{(LR SLANT RANGE) Cos } 15^\circ$$

Also, comparison of LR altitude on the meter with raw LR altitude on the DSKY (V16N66) will differ since:

$$\text{LR SLANT RANGE (DSKY)} \neq \text{(LR SLANT RANGE) Cos } 15^\circ$$

The second tape meter displays either range rate or altitude rate, depending upon the mode selected, and is divided into two halves:

1. WHITE - 0 to 700 ft/sec, indicating an opening velocity located on the bottom half of the tape with 0 fps being the separation point.
2. BLACK - 0 to -700 ft/sec, indicating a closing velocity on the top half of the tape.

The graduations are consistant over the entire tape with a spacing of ± 1 ft/sec.

Care should be exercised in comparisons of LR data with computed velocity data. When the LR antenna is in position one, the LR altitude rate is the velocity sensed along the antenna X-axis, which is 24° offset from the vehicle X-axis, whereas the computed data is the velocity of the vehicle with respect to the local vertical. In antenna position two, the altitude rate is along the body X; however if the vehicle X-axis is not along the local vertical, there will not be an exact comparison between the two sources.

Internal to the meter is a power failure circuit which will indicate to the crew that a malfunction has occurred either in the meter or at its interface. This circuit continuously monitors for one set of input data as well as the AC and DC voltage inputs. In addition, the circuit monitors the presence of a 512 kc signal (G.A.E.C.) that is used in the circuitry to detect loss of data at the input registers of the meter. Loss of any of these inputs causes a red light to be illuminated at the top of the meter. The internal logic of the circuit is designed to detect a delay greater than 700 milliseconds between the processing of successive groups of information. The duration of the illuminated light is dependent upon the time in excess of the 700 millisecond threshold. Loss of any input (data, power, sync) will cause the light to illuminate indefinitely due to this circuit. One feature of the circuit is worthy of notice. At low values of range rate/altitude rate from the radars (0 to ± 5 ft/sec), the fail light will begin to flash with increasing frequency until zero rate is input; then the light will stay illuminated.

B. Theory of Operation - The meter is basically a zero-nulling digital servo system. Input information arrives at the meter input in two forms: digital (e.g., 15-bit binary word) or continuous pulse train (frequency dependent). This information is scaled and processed as digital information into a holding register which is updated with new data every 100 milliseconds. Every 4 milliseconds, the hold register is read of its contents by a comparator which compares this input with the present value displayed on the tape meter. The difference in these two values is sent to the tape step-motor which either increments or decrements. The tape, which has a metallic binary code on its backside (equivalent to the readings on the front side), is read by a capacitive sensing read-head. This reading is converted to a digital word and sent to the comparator. When the reading is equivalent to the value received from the hold register, the drive signal to the tape is nulled and the tape displays the required reading.

C. Accuracy - The following discussions are intended to describe the accuracy of the tape meter as compared to the true value and to a comparable DSKY readout of the identical parameter:

1. RR Range - As mentioned previously the range tape meter is divided into three sections each with different graduations. In addition, the meter drops off a number of low order bits from the input word depending upon the magnitude of the range. The effect of this action is to change the scale factor at discrete values of range/altitude. The following table illustrates the accuracy for each range with the total error (RSS) taking into account the reading error:

Range	LSB	Reading Error	RSS Error
0 - 900.5 ft	9.38 ft	±2.5 ft	±9.7 ft
900.5 - 1000 ft	18.76 ft	±2.5 ft	±19 ft
1000 - 1200.64 ft	18.76 ft	±50 ft	±53.2 ft
1200.64 - 38420.5 ft	37.52 ft	±50 ft	±62.5 ft
38420.5 - 57630.7 ft	300.16 ft	±50 ft	±305 ft
57630.7 - 60500 ft (10 n.mi.)	1200.60 ft	±50 ft	±1201 ft
10 - 12.64 n.mi.	1200.64 ft	±1 n.mi.	±1.01 n.mi.
12.64 - 404.4 n.mi.	2401.28 ft	±1 n.mi.	±1.07 n.mi.

   The RR range readouts of the meter will differ from those readout on the DSKY (R04) display. The basic reason for this is the scale factor differences between the LGC and the meter. The data sent to the LGC has a bit weight of 9.38 ft for ranges less than 50.58 n.mi. and 75.08 ft/bit for greater ranges. Thus the data displayed on the DSKY is more accurate in all cases as listed above.

2. LR Range - The LR data sent to the meter is scaled at 2.316 pps/ft above 2500 ft and at 11.583 pps/ft below this altitude. The range meter however utilizes a scale factor of 2.32 pps/ft and 11.6 pps/ft which introduces an error of .2% and .15% respectively with the meter reading low. In addition to the round off error, the altitude tape meter is truncated in the same manner as illustrated for the RR Range with the exception of the first range. At 0-900.5 ft., the LSB is worth 2.345 ft. The error inherent in these readings as compared with DSKY readings will be masked by the multiplication factor .96 (cos 15°) that is performed within the meter. Thus the meter would read low by:

   $$\underline{(\text{LR ALTITUDE})\ (\cos 15^\circ)} - \underline{(\text{LR ALTITUDE})\ (.002)}$$

3. RR Range Rate - The meter receives RR data scaled at 19.9 pps/fps and applies a scale factor of 20.0 pps/fps. This introduces an error of 0.5% low from both the true value and the comparable DSKY readout (R04). In addition, the tape motor steps at intervals of .5 ft/sec, and readout inaccuracy is ±.5 ft/sec. The sum of these errors as a function of range rate is shown in Figure 2a.

4. LR Altitude Rate - As with the RR range rate, a round off error occurs at the interface of the tape meter. The input scaled at -19.41 pps/fps is read as -20 pps/fps giving an error of 2.95% low at every value of altitude rate. As with range rate the meter has an inherent error of ±1 fps. Figure 2b illustrates the meter accuracy with respect to altitude rate.

   There are also a few cases when the tape meter data must be interpreted based on a knowledge of the relative position and velocity of the CSM with respect to the LM:

   a. If range should increase beyond 405 n.mi., the tape will recycle and start at zero; thus a reading of 5 n.mi. is equal to a true value of 410 n.mi.

   b. If range rate should increase beyond 700 fps, the tape meter will remain static until the range rate exceeds 1000 fps. The tape will then return to zero and start over. Thus a reading of 100 fps would be equivalent to 1100 fps (2,100, 3,100, or 4,100 fps would also be possible).

   c. If digital data should become lost at any time during operation, the meter will stop with the tape displaying the last valid data. The crew will be aware of this malfunction by the power fail light being illuminated.

   d. If continuous pulse data (frequency input) is lost, the meter will interpret this as 0 cps equivalent to 0 fps or 0 ft and the tape will be driven to zero. Again a secondary indication of this failure will be the power fail light.

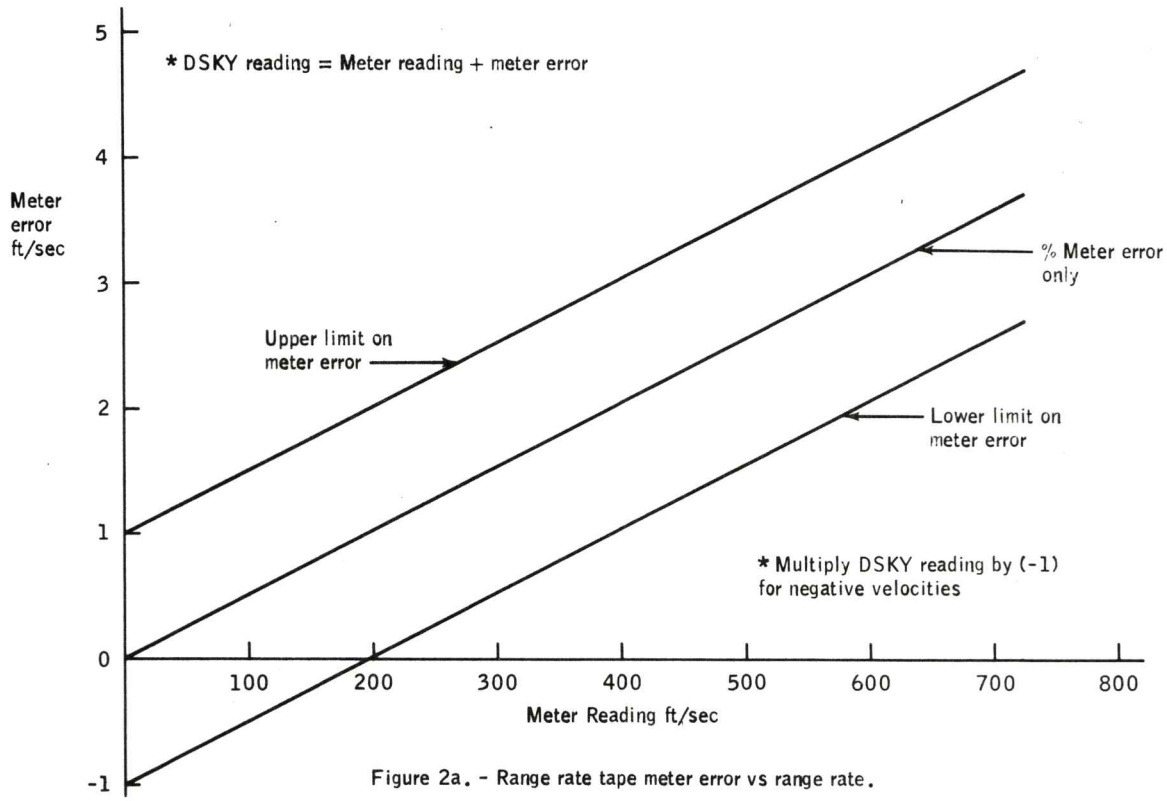


Figure 2a. - Range rate tape meter error vs range rate.

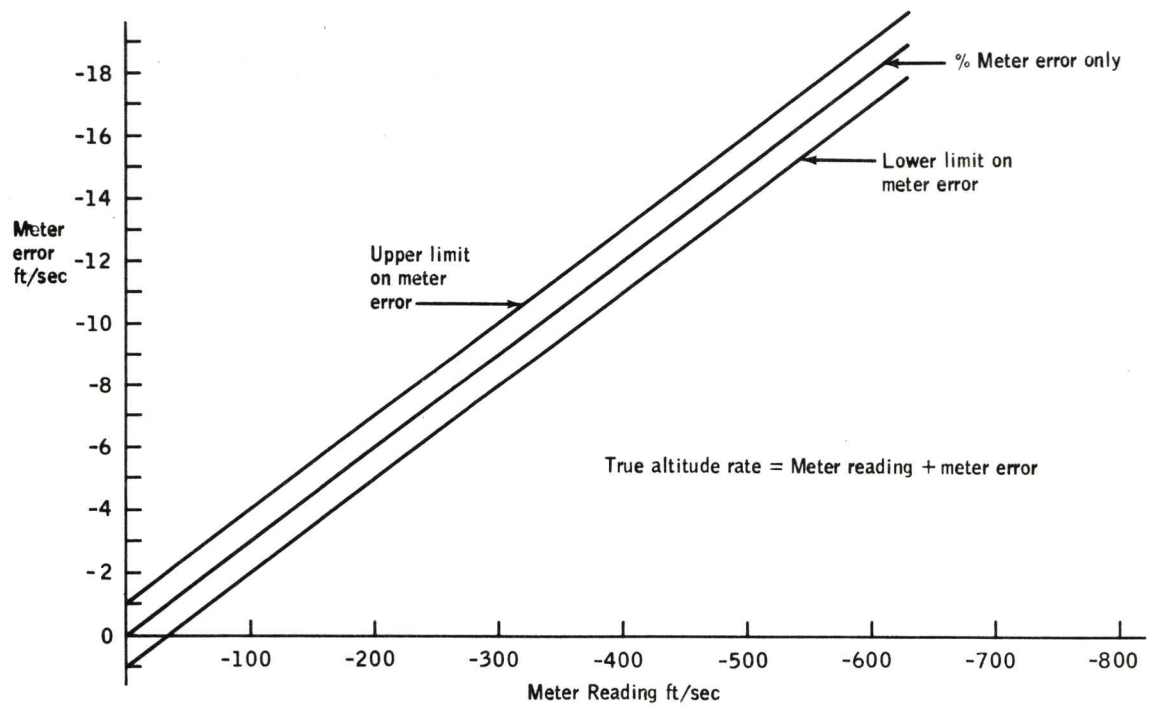


Figure 2b. - Altitude rate tape meter error vs altitude rate.

SB NO. **PGNS 7-9**

S/C: LM
DATE: 11/1/70
REV: PCN-6/New
ORIGINATOR: C. L. Gruby
APPROVAL: H.G. Loden

TITLE : **LUNAR SURFACE PIPA BIAS CALCULATION**

REFERENCES : Guidance System Operations Plan R567

Section 3 Rev 3 Page 3.7.6

Apollo Eng Memorandum AP70-0033 9 January 1970

BACKGROUND : The following describes the method used to measure pipa bias while the LM is on the Lunar surface. The amount of lunar gravity expected in each of the LM stable member axes is calculated by using the current landing site lunar gravity constant (GLS), IMU gimbal angles at the time of the measurement and the Guidance Officer's determination of local vertical attitude. The calculated value is then differenced from the measured value, obtained from the pipas, to determine pipa bias.

DEFINITIONS:

I = INNER GIMBAL

O = OUTER GIMBAL

M = MIDDLE GIMBAL

A = ACTUAL CDU ANGLE

L = LOCAL VERTICAL ANGLE

GLS = LUNAR GRAVITY AT LANDING SITE (CM/S^2)

GSM = GRAVITY COMPONENT ALONG x, y or z SM AXIS

GIVEN :

LOCAL VERTICAL SM GIMBAL ANGLES

SM GIMBAL ANGLES AT TIME (t)

GLS = 162.615 CM/S^2 (MATH PHYSICS BRANCH, MPAD)

EQUATIONS :

(1) $[GSM] = [NBSM]_A [SMNB]_L [GLS]_L$

(2)
$$\begin{bmatrix} GSM_x \\ GSM_y \\ GSM_z \end{bmatrix} = \begin{bmatrix} C_1 & C_2 & C_3 \\ C_4 & C_5 & C_6 \\ C_7 & C_8 & C_9 \end{bmatrix}_A \begin{bmatrix} C_1 & C_4 & C_7 \\ C_2 & C_5 & C_8 \\ C_3 & C_6 & C_9 \end{bmatrix}_L \begin{bmatrix} GLS \\ 0 \\ 0 \end{bmatrix}_L$$

C_1 = COS I COS M

C_2 = - COS I SIN M COS O + SIN I SIN O

C_3 = COS I SIN M SIN O + SIN I COS O

C_4 = SIN M

C_5 = COS M COS O

C_6 = - COS M SIN O

C_7 = - SIN I COS M

C_8 = SIN I SIN M COS O + COS I SIN O

C_9 = - SIN I SIN M SIN O + M COS O

(3) Multiplying through the matrix, $GSM_{x, y \& z}$ take the following form:

(a) GSM_x = GLS [COS IA COS MA COS IL COS ML
+ (-COS IA SIN MA COS OA + SIN IA SIN OA) (-COS IL SIN ML COS OL + SIN IL SIN OL)
+ (COS IA SIN MA SIN OA + SIN IA COS OA) (COS IL SIN ML SIN OL + SIN IL COS OL)]

(b) GSM_y = GLS [SIN MA COS IL COS ML
+ COS MA COS OA (-COS IL SIN ML COS OL + SIN IL SIN OL)
- COS MA SIN OA (COS IL SIN ML SIN OL + SIN IL COS OL)]

(c) GSM_z = GLS [- SIN IA COS MA COS IL COS ML
+ (SIN IA SIN MA COS OA + COS IA SIN OA) (-COS IL SIN ML COS OL + SIN IL SIN OL)
- (SIN IA SIN MA SIN OA + COS IA COS OA) (COS IL SIN ML SIN OL + SIN IL COS OL)]

(4) Using trigonometric identities to simplify, $GSM_{x, y \text{ and } z}$ are reduced to the following:

(a) GSM_x = GLS [COS IA SIN MA COS IL SIN ML (COS OA - OL)
+ COS IA COS MA COS IL COS ML
+ COS IA SIN MA SIN IL (SIN OA - OL)
+ SIN IA SIN IL (COS OA - OL)
+ SIN IA COS IL SIN ML (SIN OL - OA)]

(b) GSM_y = GLS [SIN MA COS IL COS ML
- COS MA COS IL SIN ML COS (OA - OL)
- COS MA SIN IL SIN (OA - OL)]

(c) GSM_z = GLS [- SIN IA SIN MA SIN IL SIN (OA - OL)
- SIN IA SIN MA COS IL SIN ML COS (OA - OL)
- COS IA COS IL SIN ML SIN (OA - OL)
+ COS IA SIN IL COS (OA - OL)
- SIN IA COS MA COS IL COS ML]

(5) Actual pipa bias and Δ bias calculation is accomplished in real time on the Hewlett Packard 9100B using the equations (4a), (4b) and (4c) and the measured pipa bias.

(a) G measured = $\frac{\Delta \text{ PIPA COUNTS}}{T_2 - T_1}$ = CM/SEC^2

(b) X Bias = X measured (1-SFEX) - GSM_x

(c) XΔ Bias = X Bias - PBIASX

(d) Y Bias = Y measured (1-SFEY) - GSM_y

(e) YΔ Bias = Y Bias - PBIASY

(f) Z Bias = Z measured (1-SFEZ) - GSM_z

(g) ZΔ Bias = Z Bias - PBIASZ

(6) By making the following assumptions, GSM_x, $_y$ and $_z$ can be reduced to allow computations to be performed on the olivetti computer.

For GSM_x, $_y$ and $_z$ let: $\cos(OA - OL) = 1$

$\sin(OA - OL) = 0$

For GSM_x let: $\sin IA \sin IL \left[1 - \cos(MA - ML)\right] = 0$

$\sin(OL - OA) = 0$

For GSM_z let: $\cos(MA - ML) = 1$

Then:

(a) $GSM_x = GLS \left[\cos(IA - IL) \cos(MA-ML)\right]$

(b) $GSM_y = GLS \left[\cos IL \sin(MA - ML)\right]$

(c) $GSM_z = GLS \left[\sin(IL - IA)\right]$

(7) The actual bias and Δ bias calculation is accomplished in real time on the olivetti using the equations (6a), (6b) and (6c) and the measured pipa bias.

(a) G measured = $\frac{\Delta \text{ PIPA COUNTS}}{T_2 - T_1}$ CM/S^2

(b) X Bias = X measured (1-SFEX) - $GLS \left[\cos(IA - IL) \cos(MA-ML)\right]$

(c) X Δ Bias = X Bias - P Bias X

(d) Y Bias = Y measured - $GLS \left[\cos IL \sin(MA - ML)\right]$

(e) Y Δ Bias = Y Bias - P Bias Y

(f) Z Bias = Z measured - $GLS \left[\sin(IL - IA)\right]$

(g) Z Δ Bias = Z Bias - P Bias Z

NOTES:

(1) SFEX, P BIAS X, P BIAS Y, P BIAS Z are LGC eraseable memory locations.

(2) Scale factor error was included into the X Bias computation due to the fact that almost all of lunar gravity is sensed by that PIPA. Y and Z scale factor errors have virtually no effect on the calculation of Y and Z Bias.

8. SUMMARY: Equations (5a), (5b), and (5c) represent the exact solutions to GSM_x, $_y$ and $_z$ but are too lengthy and cumbersome to be used in real time. Equations (6a), (6b) and (6c) will be used during mission time with only one constraining factor and that is the magnitude of the outer gimbal Δ angle (OA - OL). These equations remain accurate with a Δ outer gimbal angle of less than $\pm 1.0^\circ$.

SB NO. **PGNS 7-10**

S/C: LM
REV: PCN-11/New
DATE: 11/1/71
ORIGINATOR: R. A. Thorson
APPROVAL: Hans O. Loben

TITLE: **PGNS OPERATION WITHOUT COOLING ON THE LUNAR SURFACE**

BACKGROUND: The following brief is an outline of contingency PGNS procedures for the loss of cooling on the lunar surface. The purpose of these procedures is to allow a PGNS direct ascent and RNDZ while maintaining PGNS reliability.

Although the PGNS is known to be temperature sensitive, performance degradation vs time had not been experienced until Apollo 11. Prior to this time, temperature analysis of the PGNS had been performed only via computer simulations. This data which indicated a PGNS lifetime of approximately one hour was based on violating equipment redlines. Apollo 11, however, indicated that the initial degradation did not occur to approximately 3 hours after cessation of cooling. Due to lack of telemetry on the PGNS equipment, it can only be speculated as to the exact temperatures of the various PGNS equipment. The one measurement that could be correlated is the PIPA temperature: After a quiesent period of approximately 1.3 hours from coolant turn-off, the PIPA temperature rose at approximately 5°/hr vs a prediction (computer simulation) of $\approx 6^{\circ}$/hr. The following table illustrates the predicted redline values vs the Apollo 11 systems failures:

TIME FROM GLYCOL FAILURE (HOURS)	PREDICTED COMPONENT FAILURE	PROBABLE SYMPTOM	APOLLO 11 DATA
0.9	PTA	PIPA/IMU FAIL	
1.1	PSA	PIPA/IMU FAIL	
1.15	IMU	PIPA/IMU FAIL	
1.5	PIPA	PIPA TEMP CAUT	
1.7	LGC	LGC WARN	
1.75			PIPA TEMP CAUT.
2.5	PIPA	PIPA OFF SCALE HI	
3.2	CDU	CDU FAIL	PIPA TEMP OFF SEAL
3.4			CDU FAIL
4.25			PIPA FAIL
6.25			IMU FAIL
6.9			PLATFORM TUMBLE
7.1			LGC WARN

It is significant that of the predicted component failures only the CDU fail was verified on LM-5 (Apollo 11). It should again be emphasized, however, that the predicted failures were based on redline values and true failures would be dependent upon individual components (e.g., the failure history of the PGNS indicates that failures have been caused by degraded components).

PGNS accuracies under degraded conditions have been looked at by MIT and G&C division with the following conclusions:

With temperature deviations of $\pm 6^{\circ}$F, PIPA bias and scale factor errors cause small variations in ascent perilune of $\approx$.1 n.m. Apolune figures are somewhat larger in the neighborhood of $\pm$ 10 n.m. per $\pm 6^{\circ}$F. These figures are acceptable since it is not expected that the PIPA temperature will be greater than $\pm 1^{\circ}$F off nominal at liftoff.

Based on the above data, a successful PGNS ascent and RNDZ is possible with proper management of PGNS operation times. Basically, the contingency timeline follows this sequence.

Initial Conditions: Secondary glycol loop has failed; the crew is on EVA and one hour's traveling distance from the LM when the primary loop fails.

*T-3 hours	Ground informs crew of failure and to return to LM
*T-2 hours	Crew enters LM and deactivates PGNS heaters
T- :45 min	Crew begins emergency checklist
T- :30 min	PGNS powered up and aligned
T- :15 min	AGS powered up and aligned
Post-insertion	Power down AGS
TPI- :10 min	Power up AGS and align to PGNS

*These figures are approximate as it may be 1 3/4 to 3 3/4 hours for the proper phasing to be achieved for a direct RNDZ sequence.

*

SB NO. SCS 9-1

S/C: LM
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: D. Clark
APPROVAL:

TITLE: **ENGINE THRUST METER**

REFERENCES: A. OPERATIONAL CALIBRATION CURVES VOL II (LM-7 & SUB) P-8
B. LSP-350-801D METERS, D'ARSONVAL
C. LSC-350-80145 METERS, D'ARSONVAL
D. LSC-360-601A TRANSDUCER PRESSURE-ABSOLUTE
E. LSH (DWG 10.23 DES ENG THROTTLE SIGNAL FLOW, DWG 3.1 LIGHTING SYSTEMS) P-8

DISCUSSION: A. The engine thrust meter is made up of two identical movements. Each uses the "servometric" concept, employing a closed loop rebalancing principle to position a pointer in accordance with an input signal. An output from a feedback transducer mounted on the pointer is compared with the input signal (see Figure 2). Because there is no spring attached to the meter pointer, when power is removed from the driving elements of the meter, the pointers will hold their last position due to bearing and potentiometer friction. Therefore, a warning light is above the meter indicating such a failure. The meter accuracy has been specified at 2 percent of full scale under all environmental conditions. Experience (Honeywell) has shown 0.8 percent (±0.04 volts) of full scale can easily be maintained. Figure 3 shows meter movement versus dc volt input.

B. The engine thrust meter (9M7 PNL I) displays two parameters:

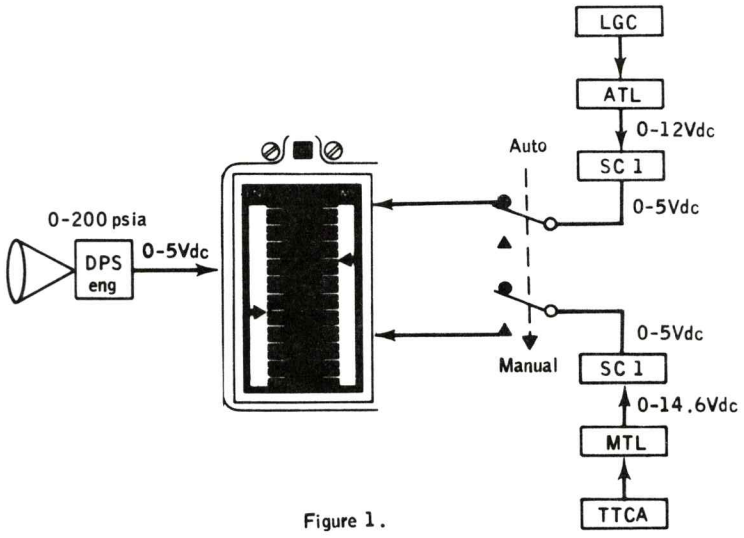


Figure 1.

1. Descent chamber pressure in percent (0-100); meter was designed for maximum pressure at 110 psia.
2. Commanded thrust, auto or manual, in percent (0-100).

The left side of the meter displays descent engine thrust as supplied by a pressure transducer on the DPS engine (see Figure 1). The pressure transducer measures 0 to 200 psia and outputs a linear 0-5 Vdc (volts dc) over this range. Since the maximum pressure at FTP of the DPS chamber is 106 psia, the maximum transducer output is 2.65 Vdc. The signal goes directly to the left side of the thrust meter where 0 to 2.75 Vdc causes full scale deflection (0 to 100 percent thrust, see Figure 3).

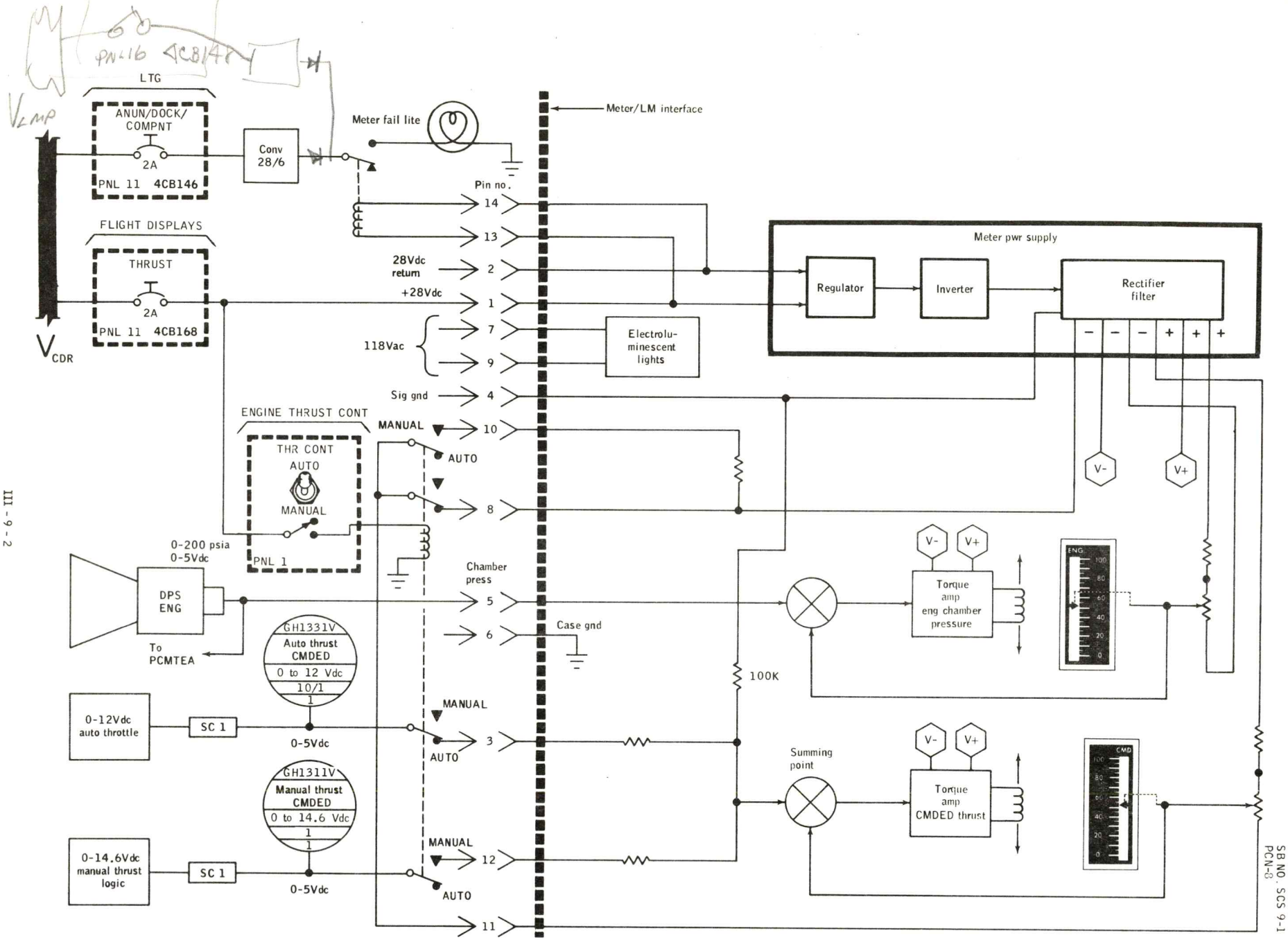


Figure 2. - Engine thrust meter schematic diagram.

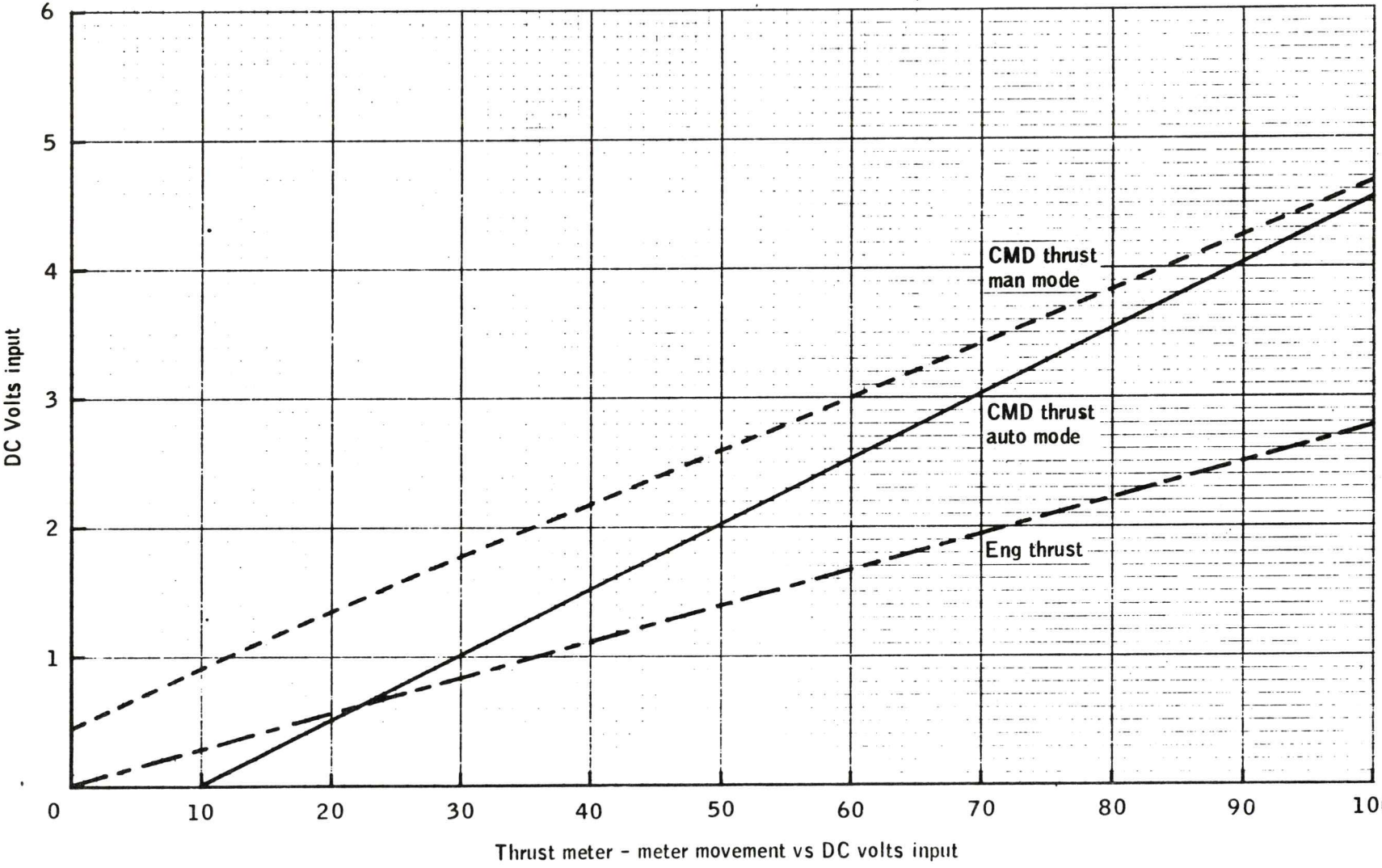
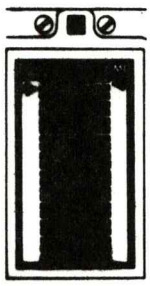
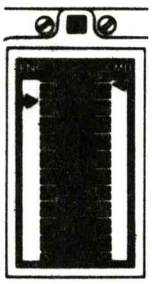


Figure 3. - Thrust meter readiness percent vs input (LSC 350 - 80145-14).

A few interesting points to consider when using this side of the meter include: Throat erosion of the DPS (descent propulsion system) nozzle causes a drop in TCP (thrust chamber pressure).



100% thrust before erosion



100% thrust with full erosion

Figure 4

The drop is from 106 psia with no erosion to 100 psia with total erosion (see Figure 4). This means that when the pressure drops, the engine thrust indication will drop. For example, at FTP (full throttle position) when the chamber pressure is 106 psia, the meter will read 97 percent. When the throat erodes during a long burn, the pressure will fall to 100 psia and the meter will read 91 percent.

The thrust on the DPS is limited mechanically to approximately 92.5 percent of its full descent engine capability (106 psia) due to engine optimization. The meter shows 97 percent (due to design scale of 110 psia). P-8

C. The right side of the meter (9M7 PNL I) displays the thrust commanded. There are two modes of display on this meter:

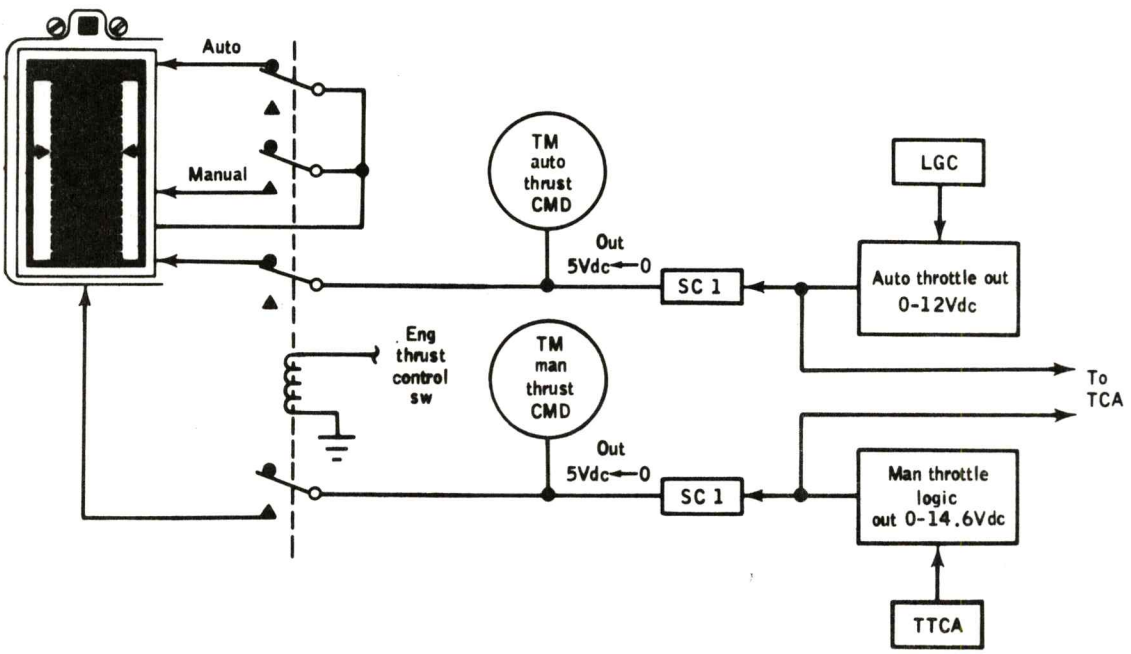


Figure 5.

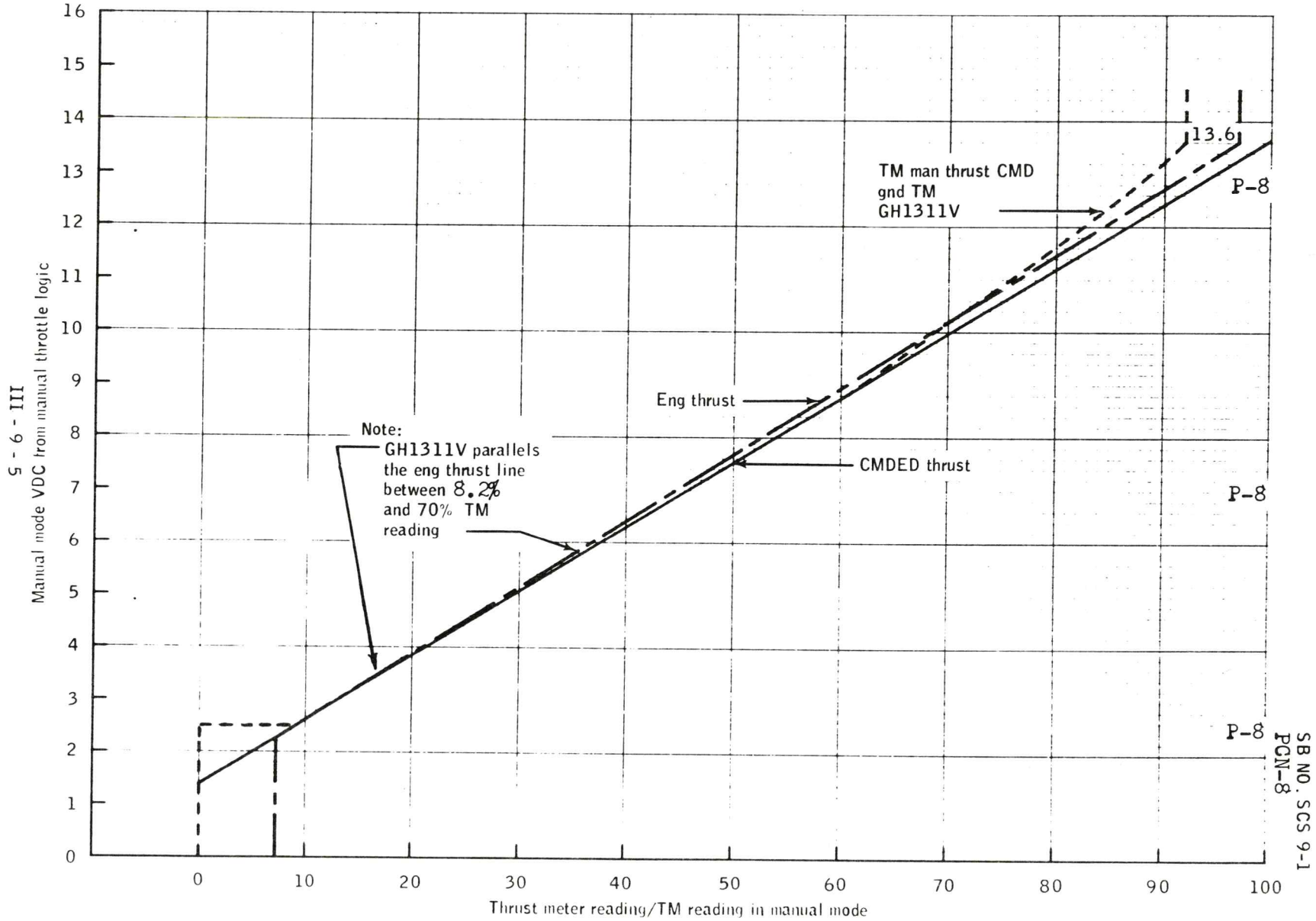


Figure 6. - Thrust meter and TM readout vs manual thrust CMD from manual throttle logic.

1. The Manual Mode

When the "THRUST CONTROL SW" 1511 PNL I is switched to "MANUAL", the biasing is such that the meter will read 0 with a 0 to 1.4V manual throttle input - 0 to 100 percent for a 1.4 to 13.6 Vdc - and 100 percent for a 13.6 to 14.6 Vdc input (see Figure 6).

Since the voltage from the manual throttle is 0 to 14.6 Vdc, the manual throttle signal is routed through the TM Signal Conditioner No. 1, where it is sent to PCMTEA (pulse code modulation timing electronics assembly) and to the commanded thrust meter as a 0 to 5 volt signal. In the manual mode 4.65 Vdc will cause full scale deflection (100 percent, see Figure 3). Full movement of the TTCA provides 5 Vdc, which is more than necessary to position the commanded thrust meter to 100 percent. A failure in the manual mode such as a loss of the TTCA (thrust and translation control assembly) voltage will cause the command side of the meter to drop to zero and the engine side of the meter to drop to 7.5 percent. When in the manual mode, the auto throttle is totally isolated from throttle control as well as the thrust meter.

2. Auto Mode

When the "THRUST CONTROL SW" PNL I is switched to "AUTO", the bias is such that the meter reads from 10 to 100 percent as the auto throttle circuit outputs 0 to 11 Vdc and 100 percent when the auto circuit puts out 11 to 12 Vdc (see Figure 8).

The 0 to 12 Vdc is routed to the Signal Conditioner No. 1 (see Figure 5) where it is changed to a 0 to 5 Vdc signal. The signal is then routed to PCMTEA and to the commanded thrust portion of the meter which in the auto mode reads 10 to 100 percent with a 0 to 4.58 Vdc input (4.58 Vdc out of SC No. 1 equals 11 Vdc from the auto throttle circuit). Because 12 Vdc auto throttle circuits equal 5 Vdc SC No. 1 output, the auto throttle circuit can give more than enough to give full scale deflection. However, the command thrust meter has a built-in bias which assumes that there is 10 percent (2.6 Vdc) being summed with the TTCA. If this 10 percent from the TTCA is lost in the auto mode, the commanded thrust will still read 100 percent, but the engine thrust meter will drop to 85.5 percent due to the fact that the 12 Vdc from auto throttle circuit will not give the necessary voltage needed (13.6 Vdc) for maximum throttle without the 2.6 Vdc supplied by the manual throttle (see Figure 7).

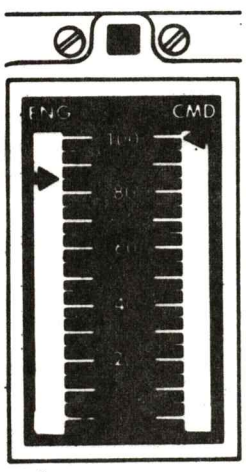


Figure 7.- Meter in auto mode with 100% commanded and a manual throttle input failure.

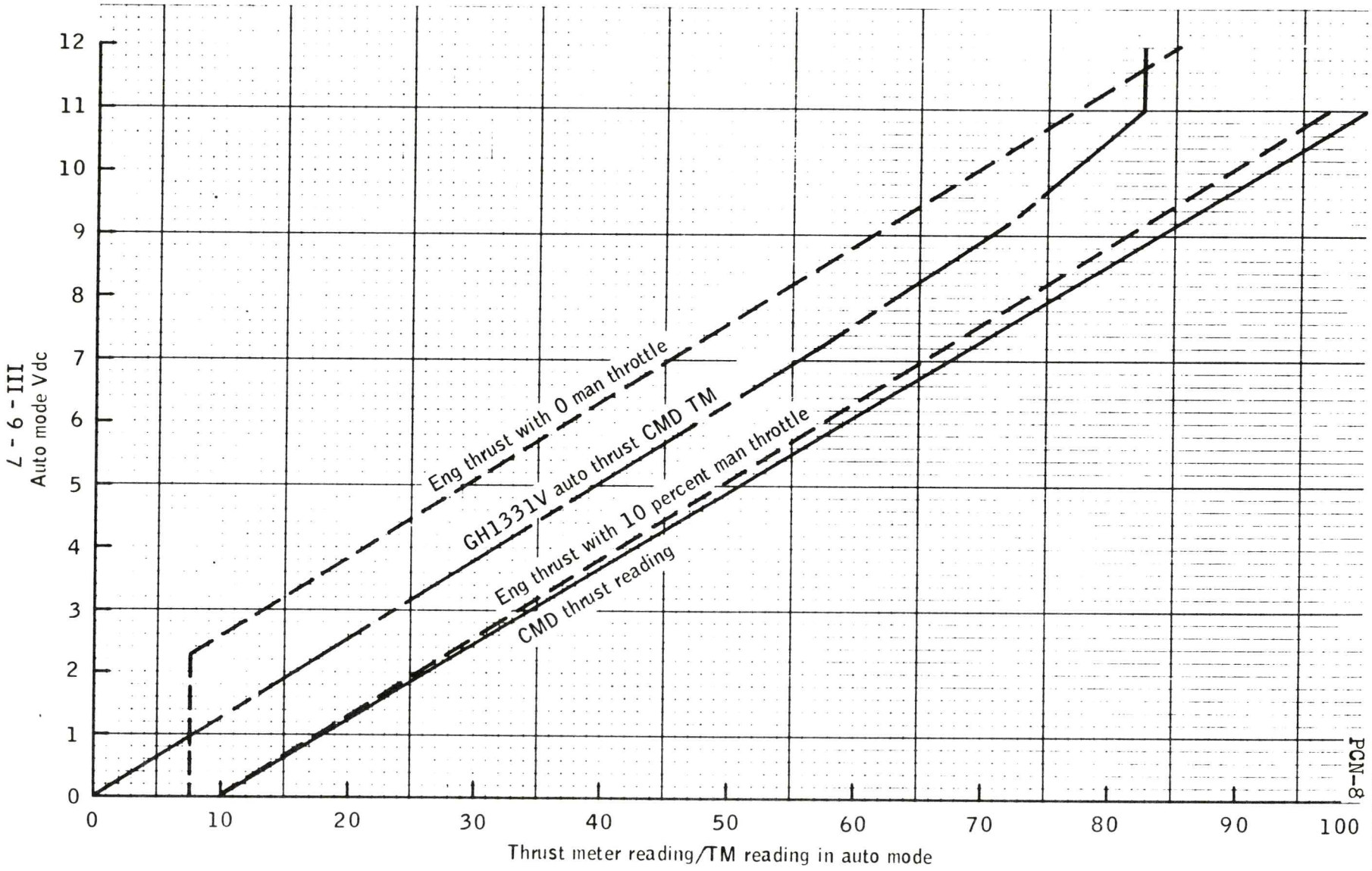


Figure 8. - Thrust meter and TM readout vs auto thrust CMD from auto throttle logic.

The results of losing the manual throttle voltage and the effect on the thrust meter can be seen in Figure 8. For example if 40 percent thrust was being commanded, it can be seen from Figure 8 that 3.6 Vdc is being outputted by the auto throttle and the remaining 2.6 Vdc is being supplied by the manual throttle. Both engine and commanded thrust read 40 percent. Now if the manual throttle input fails, the auto throttle will immediately respond by printing out the difference (2.6 Vdc) which will now show 40 percent on the engine thrust and 62 percent on the commanded thrust portion of the meter (see Figure 9).

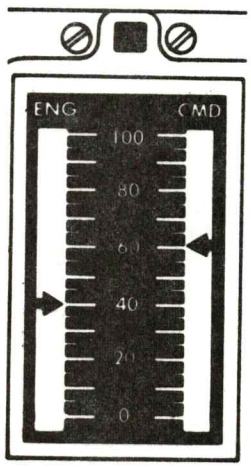


Figure 9.- Thrust meter in auto mode with manual input failure at 40% thrust.

Another interesting point is that in the auto throttle mode, any input above 10 percent by the manual throttle will cause the auto throttle to output that same amount less. Therefore, if while at 40 percent the manual throttle were raised to 20 percent throttle, the commanded thrust meter would drop to 30 percent (another 10 percent is being supplied by the manual throttle) while the engine thrust meter would remain at 40 percent (see Figure 10).

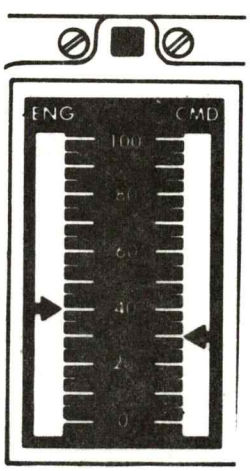


Figure 10.- Thrust meter in auto mode with manual throttle in 20% position while auto is commanding 40%.

SB NO. SCS 9-2

S/C: LM
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: D. E. Stamper
APPROVAL: W. A. Tindall

P-8

TITLE : OPERATIONAL ASPECTS OF DECA K26

REFERENCES :

A. CES Level III Drawings: LDW 300-56003

B. DECA Production Model Design Report

LDR (B) - 6200 - 14 15 December 1965

Amendment 1 15 September 1967

C. Design Control Specification for DECA

LSP 300 - 13E 8 January 1968

D. Red-line Survey of DECA Parameters

CR-68-588-47 16 December 1968

BACKGROUND : The function of DECA K26 is to remove ATCA DC voltages (± 15 and + 4.3) from the DECA Power Supply whenever these ATCA voltages are out-of-tolerance. This condition is determined in the DECA Pwr Supply by comparing the ATCA voltages against DECA DC voltages which are generated with AC power delivered through the DECA GIMBAL CB. If the inverter AC is subjected to variations, the DECA DC voltages will also vary which could cause K26 to energize.

MALFUNCTION DETECTION : The failure detection methods used to detect a K26 failure must then consider the overall system responses to both the ATCA DC voltages and the inverter voltage. The ATCA DC voltages are used in the DPS gimballing and throttling control circuits and also in AGS attitude control and Auto Ascent Engine On circuits. The inverter voltage is also used for lighting, displays, slew and track capability of the RR, and slew capability of the S-Band in addition to its use as descent engine gimbal motor power. However, sufficient secondary cues exist to determine which voltage supply has failed. The ATCA DC voltages (± 15 and + 4.3) are monitored by the CES DC warning light and the inverter outputs by the INVERTER caution light.

Since the comparison electronics are enabled only when the DPS is armed, there are only two times during the nominal lunar mission which K26 can become energized--during the DPS throttle check or during PDI. If K26 became energized during the throttle check, the result would be that the throttle actuator would move to its FTP position. If it energized during PDI, the results would be: the GDA's locked in their last commanded position; the throttle actuator at FTP; and the commanded auto thrust at 10 percent on the THRUST meter and at 0 percent on TM.

The AC voltage and ATCA DC voltages necessary to cause K26 to energize are dependent upon which DECA S/N is flown. The ATCA voltage required to trip K26 are found in SODB paragraph 4.5.3.2.2.1. The following table shows the relationship between the AC voltage, the state of K26 and the effects of the state of K26 for all DECA's.

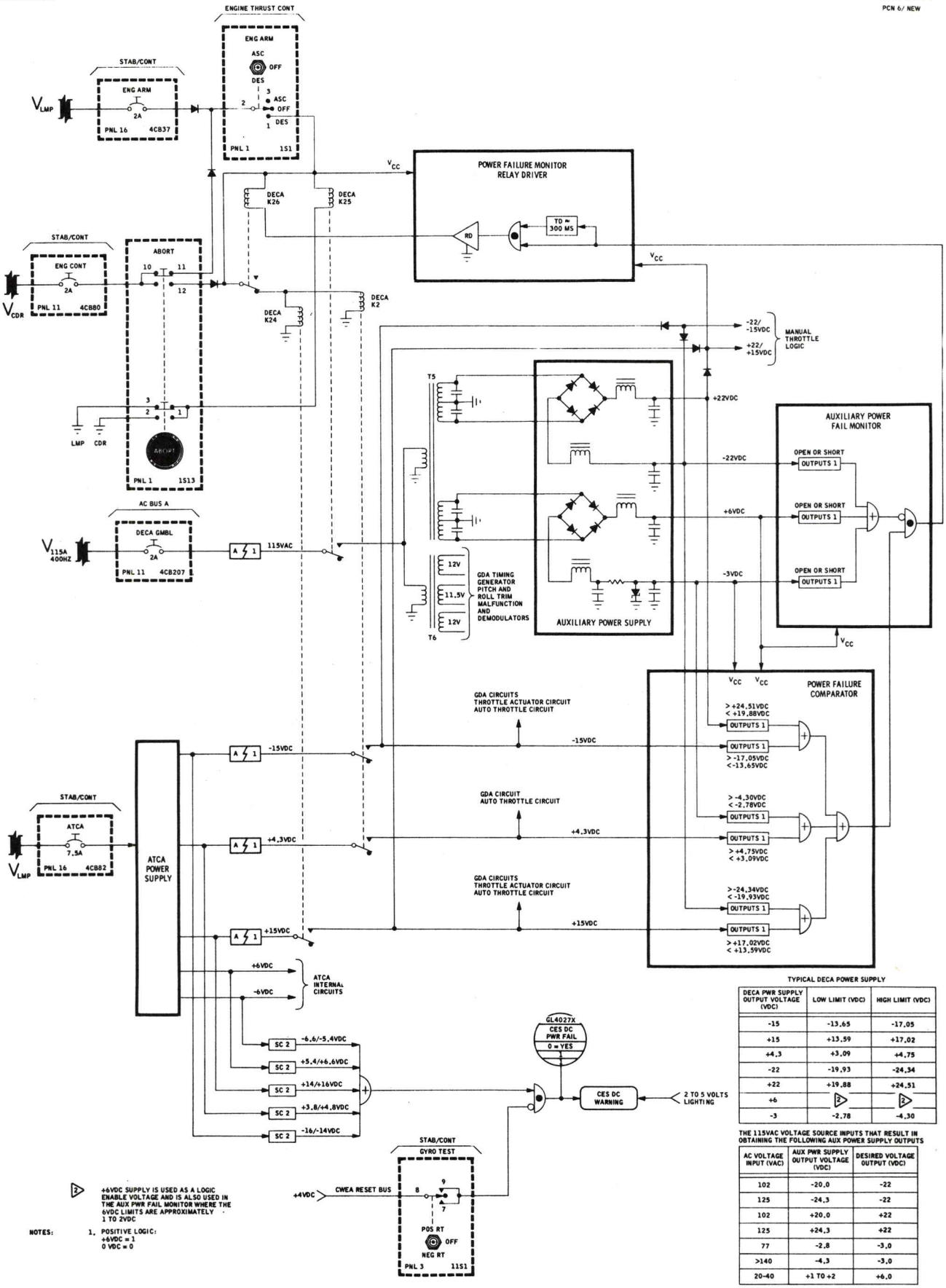
AC VOLTAGE AT DECA	STATE OF K26	EFFECTS
100 < VAC < 103 for > 300 msec	may be energized	may lock GDA's and may cause throttle to go max thrust
55< VAC <100 for > 300 msec	energized	locks GDA's and throttle to max thrust
30 < VAC < 55 for > 300 msec	may oscillate	locks GDA's and may cause oscillations in thrust
VAC < 30	de-energized	locks GDA's but throttle fully operational

MISSION IMPACT
CORRECTIVE ACTION: The following table should be used if K26 is energized during PDI. The table represents the various verification procedures which should be used if the actual thrust is at FTP and the commanded auto thrust is at 10 percent on the THRUST meter and the GDA's locked. The table assumes that the THRUST meter reading is valid.

CES DC WARNING	INVERTER CAUTION	VERIFICATION PROCEDURE	FAILURE CAUSING K26 TO ENERGIZE
NO	NO	A. Cycle DECA GMBL CB	A. Transient AC volt.
		B. No effect, pull DECA GMBL CB	B. K26 failure
NO	YES	Switch to other inverter	AC out-of-tolerance
YES	NO	Pull DECA GMBL CB	DC out-of-tolerance
		I. If actual thrust at FTP and commanded auto at 10 percent	I. + and/or - 15 vdc supply failed
		II. If actual thrust at commanded manual thrust and commanded auto thrust at 10 percent	II. + 4.3 vdc supply failed

The loss of DECA GMBL CB power will cause the loss of DPS gimballing. The loss of the + 15 vdc supply will cause the loss of DPS gimballing and throttling control, Auto Ascent Engine ON, and AGS attitude control. The loss of the - 15 vdc supply will cause the loss of gimballing and throttling control and AGS attitude control. The loss of the + 4.3 vdc supply will cause the loss of gimballing control, auto throttle control, Auto Ascent Engine On, and AGS attitude control. Mission Rules will determine the required actions for the loss of these functions.

The following figure is a logical representation of the internal DECA circuits which cause K26 to energize.



TYPICAL DECA POWER SUPPLY

DECA PWR SUPPLY OUTPUT VOLTAGE (VDC)	LOW LIMIT (VDC)	HIGH LIMIT (VDC)
-15	-13.65	-17.05
+15	+13.59	+17.02
+4.3	+3.09	+4.75
-22	-19.93	-24.34
+22	+19.88	+24.51
+6	[2]	[2]
-3	-2.78	-4.30

THE 115VAC VOLTAGE SOURCE INPUTS THAT RESULT IN OBTAINING THE FOLLOWING AUX POWER SUPPLY OUTPUTS

AC VOLTAGE INPUT (VAC)	AUX PWR SUPPLY OUTPUT VOLTAGE (VDC)	DESIRED VOLTAGE OUTPUT (VDC)
102	-20.0	-22
125	-24.3	-22
102	+20.0	+22
125	+24.3	+22
77	-2.8	-3.0
>140	-4.3	-3.0
20-40	+1 TO +2	+6.0

[2] +6VDC SUPPLY IS USED AS A LOGIC ENABLE VOLTAGE AND IS ALSO USED IN THE AUX PWR FAIL MONITOR WHERE THE 6VDC LIMITS ARE APPROXIMATELY 1 TO 2VDC

NOTES: 1. POSITIVE LOGIC:
+6VDC = 1
0 VDC = 0

FIGURE 1. - DECA POWER SUPPLY.

SB NO. **SCS 9-3**

S/C: LM
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: STURM
APPROVAL: H.A. Loden

TITLE: ASCENT ENGINE ADAPTER CABLE IGNITION

REFERENCES: A. AOH VOL II, PARAGRAPHS 5.4.23, 24, & 25
B. SCP NO. PYRO 3-1, MANUAL STAGING ON THE LUNAR SURFACE

DISCUSSION: A. NORMAL ASCENT ENGINE IGNITION

The ascent engine was designed with two methods available to the crew for ignition. The first method is an automatic start sequence driven by either the PGNS or AGS guidance system. The second method is a manual start sequence performed by the crew. Both of these methods are subject to single point failures in preventing ignition, but it would require a double failure to prevent ignition on the lunar surface because the automatic method is used and backed up by the manual method.

B. ADAPTER CABLE ASCENT ENGINE IGNITION

With the loss of automatic and manual start capability in the past the crew would have had to go into the spacecraft wiring and try rewiring equipment to start the ascent engine. Now an adapter cable has been fabricated that will allow the crew to start the engine much easier. The above mentioned reference contains a step by step procedure for using this cable.

The adapter cable consists of twelve wires, ten of which are used to maintain existing functions and two wires provide +28 VDC power directly to the ascent engine system A pre-valve assembly bypassing all engine control logic. Starting the ascent engine via the adapter cable will not automatically stage the vehicle so a manual staging sequence must be performed first.

The ascent engine firing adapter cable is plugged into the ED power adapter cable and that is plugged into the GSE connector on either the LMP bus or the CDR bus. The bus used has to be powered down, the cables connected, and then the ascent engine is started and stopped by powering up and down the specific bus via the battery feed tie circuit breakers. Thus, the insertion burn would be made with one guidance system working. If the PGNS system is operational the LMP's bus will be used, but if the PGNS system is degraded then the CDR's bus will be used. Reference LSH Dwg 4.1.1 for electrical drawing. | P-11

SB NO. PROP 11-1

S/C: LM
DATE: 4/1/69
REV: Original
ORIGINATOR: Wegener
APPROVAL: H. A. Loden

TITLE: **THROTTLE ACTUATOR CONTROL ASSY**

REFERENCES:
A. TRW LM Descent Engine Characteristics Report
B. NASA Memo

BACKGROUND:
A. The throttle actuator is an electromechanical, linear-motion servoactuator which moves the throttle linkage in response to an electrical input command. The motion of the throttle simultaneously positions the flow control valve pintles and the injector sleeve. Changing the position of the flow control valve pintles varies the amount of fuel and oxidizer metered into the engine and thus changes the magnitude of the engine's thrust.

B. When the DPS engine is **not** armed (i.e., 28V power removed from the throttle actuator motors) the throttle actuator is driven to a null position by the hydraulic loads imposed on the flow control valves and by the action of a set of compensating springs designed to minimize the actuation force requirements. The expected position of the throttle actuator during an orbit coast is approximately 40 to 75 percent. The null position at sea level is higher than that under vacuum conditions due to differential pressures acting upon the flow control valves and throttle actuator bellows assemblies. At sea level, the expected throttle actuator position is approximately 50 to 100 percent.

C. When the engine is armed, the throttle actuator will drive to the position of commanded thrust (auto-commanded thrust plus manual-commanded thrust). The response time of the throttle actuator is approximately 0.6 seconds from 10 percent thrust to max thrust or from max thrust to 10 percent thrust.

D. The instrumentation readout from GQ6806H, throttle actuator position, provides a valid indication of actual throttle position at all times regardless of DPS arm power or ATCA power. The actuator will indicate commanded position only when the DPS engine is armed.

SB NO. PROP 11-2

S/C: LM
DATE: 4/1/69
REV: Original
ORIGINATOR: Fleming
APPROVAL: H. A. Loden

TITLE: **RCS/APS INTERCONNECT**

REFERENCES:

BACKGROUND:
A. The APS/RCS interconnect is designed to allow APS propellants to be used in the two RCS systems during periods of +X thrusting (within limits specified in SODB) Eight solenoid valves are used to control propellant flow between the APS and RCS. There are two valves in series to each of the RCS System A fuel, System A oxidizer, System B fuel and System B oxidizer manifolds. These valves are controlled by four three-position momentary switches located in Panel 2. Each of these switches controls one fuel and one oxidizer valve in parallel for either System A or System B. Valve position is indicated by four talkbacks (flags) also on Panel 2 and by four operational TM discretes to MSFN. It should be noted that these valve position indications are not a reflection of switch position history, as each indicator is displaying the status of two fuel or two oxidizer valves in series in either System A or System B. Each talkback will display a barberpole indication and the TM discrete will be a "0" if either one or both valves in the pair are closed. Each talkback will display a gray indication and the TM discrete will be a "1" only when both valves in the pair are open.

B. Normally the upstream (closest to APS) fuel and oxidizer valve in each system will be closed while the downstream valves will be open. Thus the normal indication will be barberpole on the talkback and a "0" on TM. This same indication would be displayed if both valves were closed or if power were removed from the indicator circuits.

SB NO. **PROP 11-3**

S/C: LM
DATE: 1/26/70
REV: PCN-5
ORIGINATOR: R. Nance
APPROVAL: James E. Hannigan

TITLE: **RCS THRUSTER HEATERS**

REFERENCES:

BACKGROUND:

A. Ground testing of RCS thrusters has shown that explosions result when thrusters are operated at low thruster flange temperatures. To maintain thruster flange temperatures above the critical level each of the 16 RCS thrusters is equipped with two electrical heaters attached to the outboard side of the thruster mounting flange. Each heater has a built-in thermostat. Electrical power for the heaters in each quad is supplied through two circuit breakers.

1. One circuit breaker draws power from the CDR Bus and supplies it to one heater on each thruster direct.
2. The other circuit breaker draws power from the LMP Bus and supplies it to the other heater on each thruster through the "Heaters System A/B" switch for that quad located on Panel 3.

This switch has three positions, "Off", "Man" and "Auto". The "Off" position interrupts power to the heater assembly. The "Man" position bypasses the integral thermostat and supplies power direct to the heater coil. The "Auto" position supplies power through the thermostat to the heater coil.

B. Thruster flange temperature is not directly sensed. However, each quad has a temperature transducer attached to the thruster mounting frame common to all four thrusters. This measurement must be used to infer that thruster flange temperature is above the critical limit.

C. Thruster mount (quad) temperature is displayed to the crew, one at a time, on a meter located on Panel 3, through a rotary switch. P-5

D. All four thruster mount (quad) temperatures are telemetered directly and simultaneously to MSFN.

SB NO. **PROP 11-4**

S/C: LM
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: G. W. WATKINS
APPROVAL: W.A. for J.A. Wagner

TITLE: **SUPERCRITICAL HELIUM**

REFERENCES:

BACKGROUND:

A. The supercritical helium system provides the means to pressurize and feed propellants for descent engine operation. The system consists of four major components.

1. Supercritical helium tank
2. Fuel/helium heat exchanger
3. Internal heat exchanger
4. Pressure relief system.

B. The supercritical helium tank provides storage for approximately 51 pounds of helium. The fuel/helium heat exchanger functions as a heat source to the cold helium for helium pressure development. Within the supercritical helium tank the internal heat exchanger inputs heat gained from the fuel/helium heat exchanger to the helium mass. The capability of relieving excessively high helium tank pressure is provided by the pressure relief system, which consists of two burst disks in series with an internal bleed valve. P-8

C. Upon initiation of the first descent engine burn the supercritical helium system begins to provide propellant pressurization. Helium leaves the storage tank and flows through the fuel/helium heat exchanger. Heat is picked up from the flowing fuel and returned to the storage tank via the internal heat exchanger. The heat given off to the bulk helium increases both temperature and pressure. The helium then leaves the internal heat exchanger and returns to the fuel/helium heat exchanger where it is warmed by the fuel and the pressure and temperature is further increased. At this point the helium leaves the supercritical system and is routed to the regulators where it pressurizes and feeds the propellants to the descent engine.

SB NO. PROP 11-5

S/C: LM
DATE: 4/1/69
REV: Original
ORIGINATOR: Nance
APPROVAL: H. A. Lodes

TITLE: FLOW CONTROL VALVES

REFERENCES:

BACKGROUND:

A. The throttleable LM descent engine utilizes variable area Venturi valves to meter the propellants and provide mixture ratio control.

B. The valves have two distinct modes of operation: cavitating and non-cavitating.

1. The cavitating region extends from the zero-stroke position to approximately the 67-percent stroke position.

2. The non-cavitating region extends from approximately the 67-percent stroke position to the fixed-throttle position.

C. While in the cavitating mode of operation, propellant consumption is strictly controlled by the flow control valves, dependent only on the upstream valve pressure and the temperature of the propellant. The flow control valves decouple or isolate the feed system from the thrust chamber while in this mode. This enables the propellant consumption to be accurately maintained regardless of chamber pressure fluctuations and changes in injector or system pressure differentials.

D. In the non-cavitating mode of operation propellant consumption is dependent on the hydraulic characteristics of the total engine system, of which the variable area valve is only one component.

S/C: LM
DATE: 3/1/72
REV: PCN-12
ORIGINATOR: G. W. WATKINS
APPROVAL:

SB NO. PROP 11-6

TITLE: **RCS PROPELLANT QUANTITY**

REFERENCES: PQMD Design and Operational Manual LED 360-427

BACKGROUND: A. General

The RCS Propellant Quantity Measuring Device (PQMD) calculates the nominal design usable RCS propellant quantity remaining using the helium source pressure/temperature ratio, the ideal gas laws, and known RCS system constants. This quantity is displayed on a meter onboard and telemetered to the ground. The PQMD does not measure propellant quantity directly. The PQMD consists of a temperature compensated pressure transducer, computer/signal conditioner electronics, and connecting cables.

B. Operating Principle

Each RCS system is a liquid bipropellant rocket system using helium gas to feed propellants to eight combustion chambers. The helium gas is stored at high pressure in a common source, regulated down, and supplied at constant pressure to both the fuel and oxidizer tanks. Propellants used are displaced by an equal volume of helium, thereby lowering the helium source pressure. The temperature compensated pressure transducer senses helium source pressure, compensates for helium gas temperature, and transmits this ratio to the PQMD computer. The PQMD computer uses this data, the ideal gas laws, and the following assumed system constants to calculate propellant remaining:

1. Helium source volume
2. Initial helium pressure and temperature loaded
3. Initial propellant quantity loaded (616 pounds)
4. Propellant tank pressures (177.5 psia)
5. Propellant temperature (70°F)
6. Propellant mixture ratio (2.0)
7. Propellant tank volumes
8. Main solenoid valves closed and propellant lines below main solenoid valves evacuated to a vacuum.

NOTE

Propellant will be loaded in the lines downstream of the main solenoid valves to the thrusters.

P-6
P-8

9. Trapped and unexpellable propellant quantity (28 pounds)

The design usable quantity remaining is then transmitted to the onboard meter for display and to the PCM TEA to be telemetered to the ground.

C. System Limitations

1. Calculated propellant quantity is not valid until after pressurization, and the helium source pressure is reduced to that pressure corresponding to the design full tank quantity of 616 pounds (approximately 2920 psia at 70°F).
2. Fuel and oxidizer are not measured directly or individually.
3. Indicated propellant quantity will be lower than actual for up to 30 minutes after high usage periods due to measured helium temperature lagging the actual gas temperature. The higher and longer the usage, the longer the period of inaccuracy.
4. Helium leaks after pressurization appear as loss of propellant.
5. The PQMD indicates percent of "Nominal Design Usable Propellant Remaining". Design Usable Propellant Remaining (588 pounds) is the Design Nominal Loaded (616 pounds) less the Design Trapped and Unexpellable (28 pounds). In actual practice, the PQMD does not indicate usable propellant due to the system variables described in paragraph D.

D. System Variables

1. Instrumentation tolerances - The temperature compensated pressure transducer tolerances are 4 percent of full scale (100 percent).
2. Process variations - Helium does not precisely follow the ideal gas laws. The following assumed constants do vary:
   a. Helium source volume
   b. Propellant tank pressures
   c. Propellant temperature
   d. Propellant mixture ratio
   e. Propellant tank volumes

   In addition, the PQMD electronic component tolerances contribute some variation. The total process error amounts to 3 percent of full scale (100 percent).
3. Loading variations - The following assumed contants do vary due to loading equipment and process tolerances:
   a. Initial helium pressure and temperature loaded
   b. Initial propellant quantity loaded

   These tolerances amount to 3 percent of full scale (100 percent).

   In addition, any loading other than the Nominal Design Loading, (616 pounds with the main solenoid valves closed and propellant lines below main solenoid valves evacuated to a vacuum) will make the PQMD inaccurate until the nominal conditions are reached.
4. Transmission and display tolerances - The onboard meter has a mechanism tolerance of 1 percent of full scale (100 percent). Crew viewing error is estimated to be 2 percent of full scale (100 percent).

   Telemetry downlink and ground display is negligable due to the transmission and dis ay method.

PQMD INDICATED QUANTITY VS. NOMINAL PROPELLANT QUANTITY

P-6

	Nominal Propellant Quantity (Lb)	Nominal PQMD Indication	
		TM to Ground	Onboard
Nominal Loaded	631.2	108%	Off Scale High
Post Pressurization	631.2	103%	Off Scale High
Design Nominal Loaded (PQMD Design Full Tank)	616	100%	100%
Design Nominal Trapped and Unexpellable (PQMD Design Empty Tank)	28	0%	0%
Preload Empty Tank	0	Off Scale Low	Off Scale Low

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PQMD TOLERANCES

	Instrumentation	Process	Loading	*RSS ERROR	Transmission and Display	Total
Onboard	2%	4%	2%	5%	3%	8%
Ground	2%	4%	2%	5%	0%	5%

P-12

*RSS error subject to loading within helium loading envelope and being calibrated. RSS error could be 6% without CAL data.

SB NO. PROP 11-7

This SB is deleted
by PCN-6

S/C: LM
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: G. W. WATKINS
APPROVAL: W.K. for J.A. Wagner

SB NO. **PROP 11-9**

TITLE: **MAGNETIC LATCHING SOLENOID (PARKER) VALVE**

BACKGROUND: A. The Magnetic Latching Solenoid (Parker) Valve is used to control liquids in the following places on the LM vehicle:

1. RCS Propellant Tank Main Outlets (4, normally open)
2. RCS Crossfeed between Systems A and B (2, normally closed)
3. Ascent to RCS Interconnect (8, normally closed)
4. Descent Propellant Tank Lunar Dump (2, normally closed)

P-8

B. This valve is a two-way, electromagnetically operated magnetic latching valve with valve position sensed by a magnetically operated reed switch.

Two fixed electromagnets with series connected coils are located in the upper and middle portions of the valve. Between these are two permanent magnets attached to the upper end of the shaft. A bellows and poppet assembly attached to the lower end of the shaft is the closure mechanism. A decoupling spring on the shaft takes up dimensional variations to enable uniform contact between the poppet and seat. The inlet port, outlet port, and seat are in the lower portion of the valve. The reed switch is located in a tube outside the valve body beside the upper electromagnet. The moving contact and one fixed contact of the switch are made of low magnetic retention ferrous material while the other fixed contact is made of non-ferrous material. The moving contact is spring loaded against the non-ferrous contact. (Reference cutaway drawing, Figure 1.)

C. The valve is opened by applying power of the correct polarity to <u>both</u> electromagnet coils. The upper electromagnet attracts the upper permanent magnet and the lower electromagnet repels the lower permanent magnet, lifting the poppet off its seat until the two upper magnets are in contact. With power on, the magnetic force of attraction between the fixed and moving ferrous contacts of the reed switch will be strong enough to overcome the spring load and attract the moving contact to the fixed ferrous contact. The valve position indicator circuit will be interrupted for normally open valves and completed for normally closed valves. When power is removed, residual magnetism will maintain the upper magnets and the reed switch contacts in this position.

The valve is closed by applying power of reverse polarity to <u>both</u> coils. The upper electromagnet repels the upper permanent magnet and the lower electromagnet attracts the lower permanent magnet, pulling the poppet back on its seat. The shaft continues to move, compressing the decoupling spring, until the lower magnets are in contact. As long as electrical power is on, the reed switch will remain in its former position because the magnetic force generated by the upper electromagnet is great enough to overcome the spring load. <u>As long as electrical power is applied, valve position indications may not be valid.</u> When power is removed, residual magnetism will maintain the lower magnets in contact. The residual magnetic force will no longer be great enough to hold the reed switch moving ferrous contact against the fixed ferrous contact. The spring load will pull the moving contact against the non-ferrous contact. The valve position circuit will be completed for normally open valves and interrupted for normally closed valves. (See Figures 2 and 3.)

If the valve changes position without the application of power to the electromagnets, the reed switch will respond as it would when the valve is operated normally and power is removed, giving a valid valve position indication.

P-8

D. Tests at GAEC on this valve have shown that a large high pressure (≈150 psi or greater) liquid source upstream and a large volume under vacuum downstream produce high-velocity flow across the valve seat. This high-velocity flow causes a low pressure region to form between the valve seat and poppet. Due to the resulting ΔP, the valve will not remain open. As long as power is maintained, the valve will cycle rapidly open and closed, destroying the valve seat.

These conditions can occur in orbit in the DPS Lunar Dump Circuit due to the unpredictable location of the liquid propellant under zero gravity. Therefore the DPS Lunar Dump valves cannot be relied upon to relieve DPS propellant tank pressure in orbit. The valves in the RCS are not affected because the necessary conditions do not occur during normal systems operation. P-8

MAGNETIC LATCHING SOLENOID (PARKER) VALVE

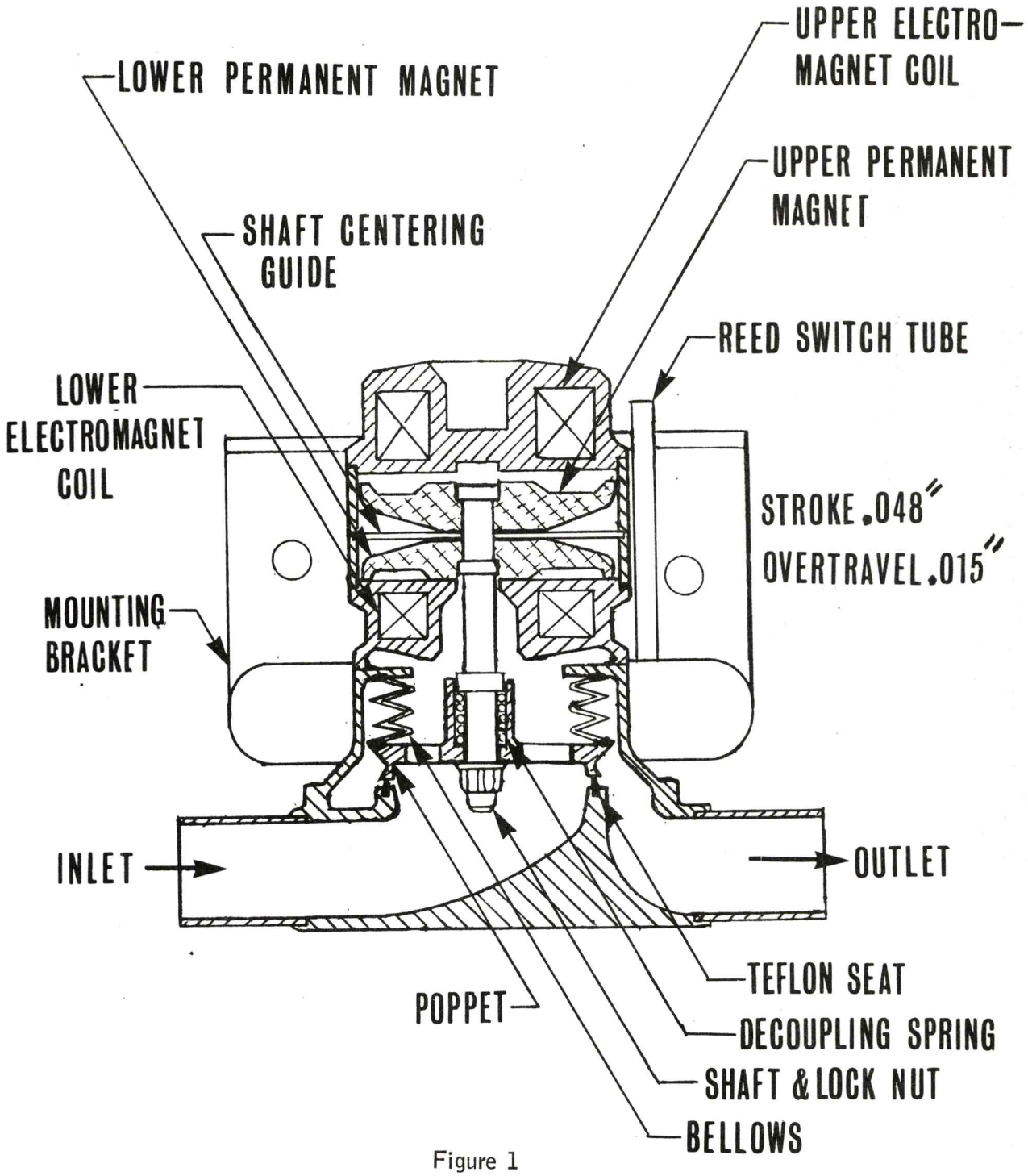

Figure 1

VF 2-5-69

SCHEMATIC FOR NORMALLY CLOSED VALVE INSTALLATION

(RCS CROSSFEED; ASCENT INTERCONNECT AND DESCENT LUNAR DUMP)

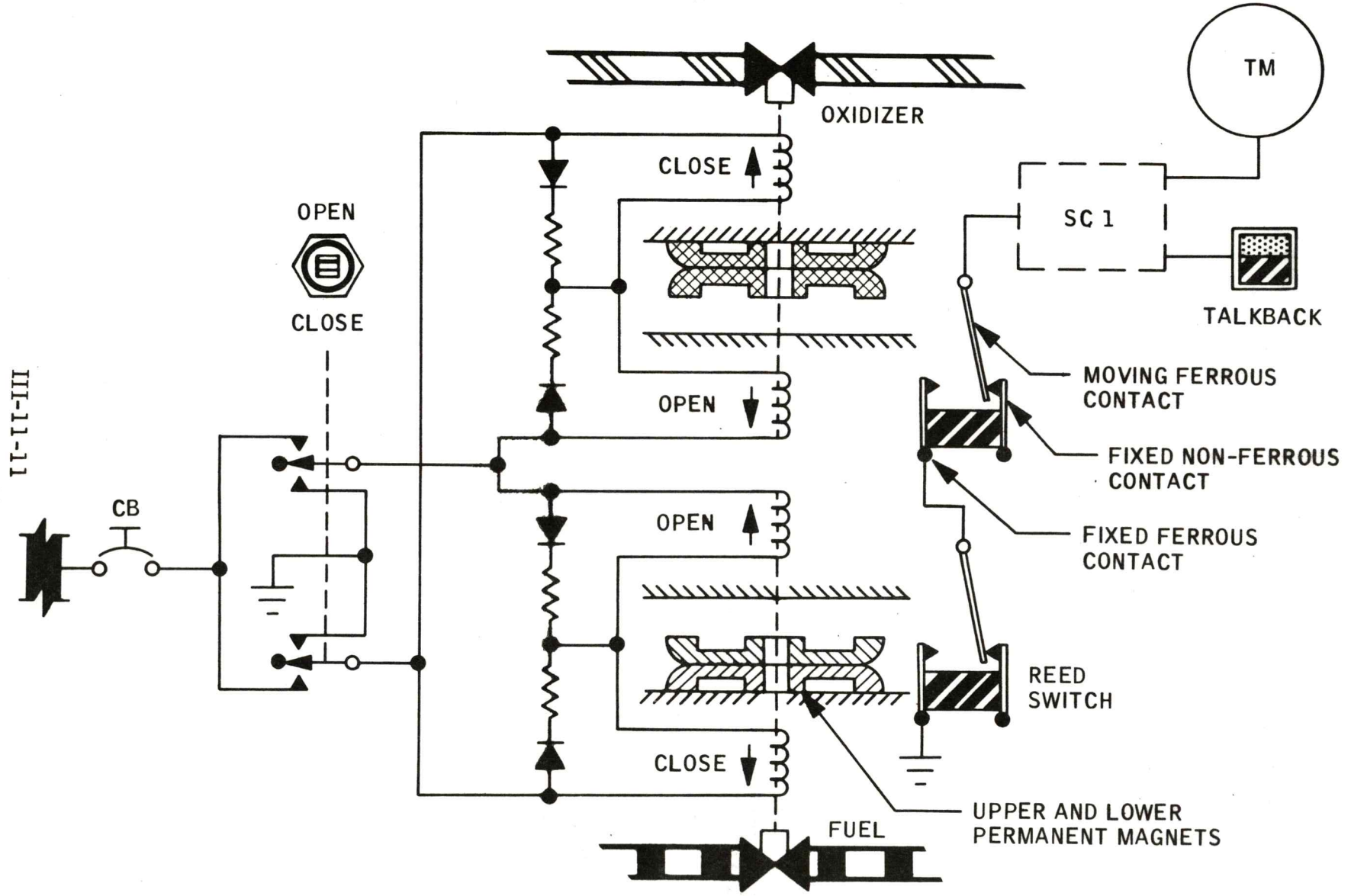

Figure 2

SCHEMATIC for NORMALLY OPEN VALVE INSTALLATION

(RCS MAIN)

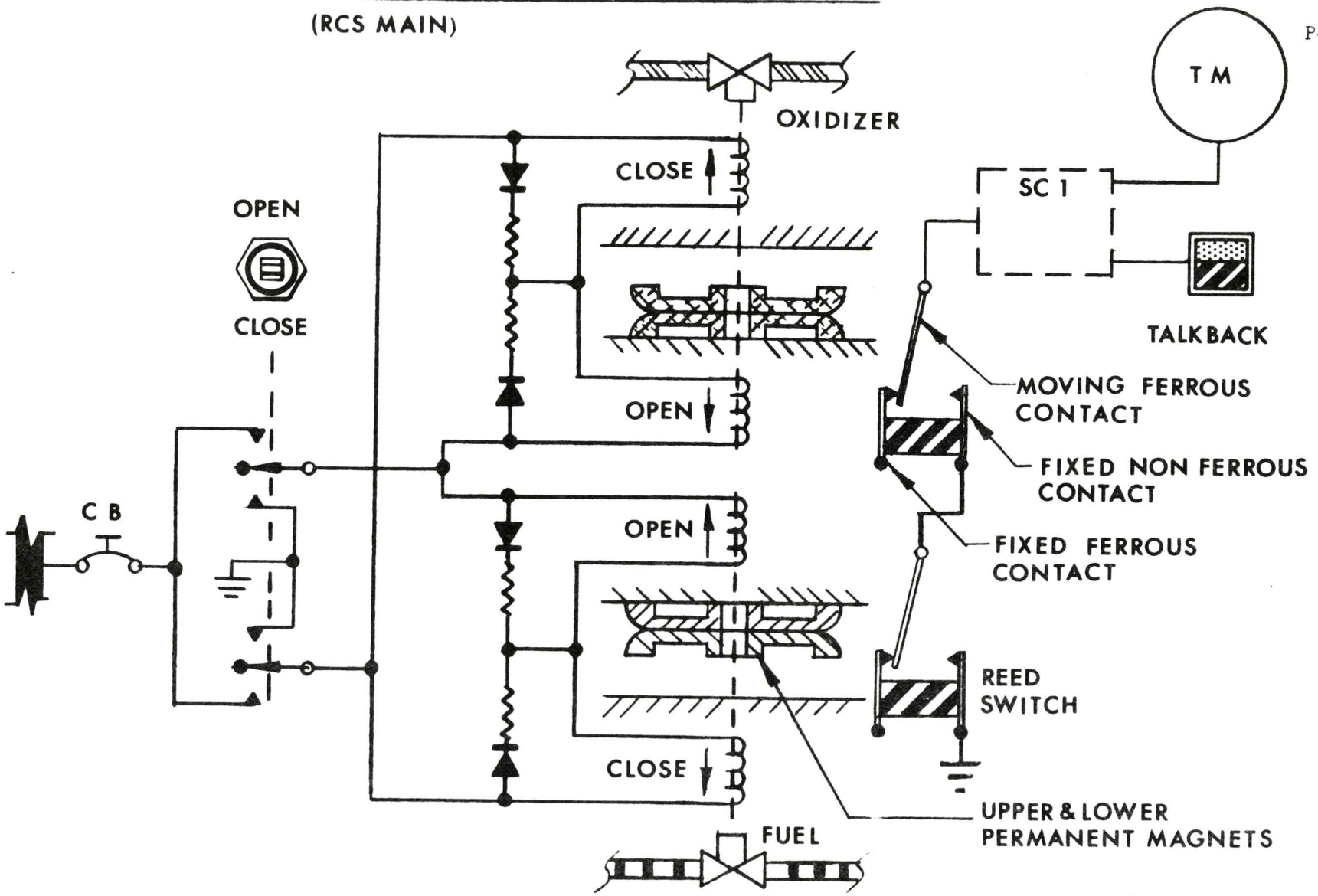

Figure 3

VA 2-11-69

SB NO. PROP 11-10

This SB is deleted
by PCN-6

SB NO. **EMU 12-1**

S/C: EMU
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: W. W. Bates
APPROVAL: [signature]

TITLE: **DOCUMENTATION**

ITEM NO.	COMPONENT	DWG NO.	SERIAL NO. IMP/CDR	SPECIFICATION	DVT/QUAL	
	EMU					
	EXTRAVEHICULAR MOBILITY UNIT	SEB13100045B		CSD-A-096		
	EXTRAVEHICULAR COMMUNICATIONS SYSTEM	8358750-503		8553518/8553517		
	PLSS/EVCS	SEB11100066-301				
	PLSS/EVCS	SEB11100066-302				
	PGA					
	EV PRESSURE GARMENT ASSEMBLY	A7LB-100006-04		CP3001		
	EV GLOVE ASSEMBLY	A7LB-203034-3/4		CP3001		
	LIQUID COOLING GARMENT	A6L-400000-17		CP1002		P-8
	FECAL CONTAINMENT SYSTEM	A6L-501000-05		CD1015		
	PRESSURE HELMET ASSEMBLY	A7LB-102053-03		CP3001		
	URINE COLLECTION AND TRANSFER ASSEMBLY	14-0108-2		CSD-A-650		
	COMMUNICATIONS CARRIER	16536G-4				
	PURGE VALVE ASSEMBLY	A6L-505000-05		CD1018		P-8
	BIOINSTRUMENTATION	SEB42100083-306				
	PGA RELIEF VALVE	A7LB-109049-01		CP3001		
	SUIT ELECTRICAL HARNESS	A7LB-109040-01		CP3001		
	BIOMED HARNESS	A7LB-109043-01		CP3001		P-8
	LUNAR EXTRAVEHICULAR VISOR ASSEMBLY	A6L 205000-07		CP2004		
	LUNAR BOOTS	A7LB-106062-3/4		CP3001		
		DWG NO. (SV)		SPECIFICATION (SVHS)	DVT/QUAL (SVHSER)	
100	MOUNTED HARDWARE					
113	PGA MULTIPLE WATER CONNECTOR	710830		3309		
116	URINE TRANSFER CONNECTOR	710904		3328		
141-4	PGA URINE CONNECTOR	714153		3306		
144	INTERNAL URINE TRANSFER CONNECTOR	714152		3307		
183	PGA PRESSURE TRANSDUCER	714171		3291, 3380		
184	PGA LOW PRESSURE WARNING SWITCH	714170		3392, 3381		
200	PLSS	706100-7		3003C	5149	
				4968	5575	P-8
					5719	
201-209, 230-239	DISPLAY AND SENSORS					
201	CARBON DIOXIDE SENSOR	723670-4		3999B		P-8
202	VENTILATION FLOW SENSOR	721730-2		4100	5170	
203	PGA PRESSURE TRANSDUCER	714171-4		3291, 3380 4311	5053 5327	
204	PGA LOW PRESSURE WARNING SWITCH	714170-5		3381, 3292 4312	5113 5269	
205	LCG INLET WATER TEMP TRANSDUCER	730324		4149	5055	
206	WARNING INDICATORS	721724		4256	5264	

ITEM NO.	COMPONENT	DWG NO. (SV)	SERIAL NO. LMP/CDR	SPECIFICATION (SVHS)	DVT/QUAL (SVHSER)	
207	OXYGEN QUANTITY INDICATOR	701830-2		3226, 3282		
208	RCU LIGHTING	723601		4265		
231	EXPENDABLE H_2O QUANTITY SENSOR	707460		3231A		
232	PRIMARY OXYGEN PRESSURE TRANSDUCER	714168-2		3226		
233	TEMPERATURE TRANSDUCER	714167-2		3225		
234	BATTERY CURRENT SENSOR	701788-2		3229A		
235	OXYGEN FLOW SENSOR	701088-5		3013A		
236	WATER DIFFERENTIAL TEMP TRANSDUCER	713085-4-200 713085-4-201		3224A		
237	OXYGEN/WATER QUANTITY INDICATOR	710972		3282		
238-1-4	FEEDWATER FLOW INDICATOR	723439-2				P-8
238-2	RESERVE FEEDWATER FLOW INDICATOR	723121-1				
239	FEEDWATER PRESSURE TRANSDUCER & SWITCH	718788		3302C, 3867	5158	
210	EVCS AND POWER					
211	EVCS	710980-6		3221, 3223B		
213	MAIN POWER SUPPLY	722862-1		3221, 3302C 3382A	5177	P-8
	MAIN BATTERY CABLE	713821-2				
	BRANCHED WIRE HARNESS	715458-2 713083-2 731719-2				
215	TERMINAL BOXES A-1 A-2	715500-9 726873-7		4159, 4302 4159, 4302		P-8
216	EMI SUPPRESSORS	707413 730219		3302C	5209	
220	ELECTRICAL CONTROLS & SWITCHES					
221	VOLUME CONTROL POTENTIOMETER	710951-3		3016A	5058	
221-1	VOLUME CONTROL POTENTIOMETER	723603		4255		
222	MODE SELECTOR SWITCH	717514-4		3137A	5058 5240	
222-1	MODE SELECTOR SWITCH	723602		4262		
223	TIME DELAY MODULE	726451		3835	5052	
224	PUSH TO TALK SWITCH	721728-2		4171A	5576	P-8
225	PUMP SWITCH	715949-2		3302C	5058	
226	FAN SWITCH	712948-2		3302C	5058	
	CONTROL PACKAGE	721722-2				
227	ALARM GENERATOR	721722-3		3302C, 4154A	5570	
228	PLSS ELECTRICAL UMBILICAL	713812-8		3302C	5056	P-8
229	CURRENT LIMITERS	730307-7		3302C	5182	
240	OXYGEN VENTILATION LOOP					
241	CONTAMINANT CONTROL ASSEMBLY					
241-1	LITHIUM HYDROXIDE CANISTER	706160-12		3230A		P-8
241-2	LITHIUM HYDROXIDE CARTRIDGE	710854-11		3364, 2836B	5156 5225	
241-3	LITHIUM HYDROXIDE CONTAINER	718783-4		2369		
242	WATER SEPARATOR	706120-5		3135A		P-8
243	FAN MOTOR ASSEMBLY	710974-6		3273A	5207	
243-1	FAN MOTOR	712964-6		3218A	4865	

ITEM NO.	COMPONENT	DWG NO. (SV)	SERIAL NO. LMP/CDR	SPECIFICATION (SVHS)	DVT/QUAL (SVHSER)	
244-1	OXYGEN INLET CONNECTOR	713097-3		3822A, 33088	5180	
244-2	OXYGEN OUTLET CONNECTOR	713844-3		3822A, 3308B	5180	
245	BACK FLOW CHECK VALVE	721915-5		4284	5173	P-8
246	CO_2 SENSOR FLOW RESTRICTOR	723425-1				
250	FEEDWATER LOOP					
251	SUBLIMATOR	705119-4		3130C	5204	
252	FEEDWATER RESERVOIR	706160-12		3230B		P-8
253	WATER SHUTOFF AND RELIEF VALVE	715484-4		3140C	5147	
253-2	WATER SHUTOFF AND RELIEF VALVE			4350		
254	WATER FILL CONNECTOR	706140-7		2700A, 3141A		
255	WATER DRAIN CONNECTOR	706141-4		3141A, 3142A		
256	RESERVOIR VENT CONNECTOR	718720				
256-1	RESERVE RESERVOIR VENT CONNECTOR	718720				
257	SUBLIMATOR FLOW LIMITER	713601-2		3150		P-8
258	RESERVE FEEDWATER RESERVOIR	723145		4349		
259	RESERVE FEEDWATER RESERVOIR SHUTOFF & RELIEF VALVE	723147				
260	LIQUID TRANSPORT LOOP					
261	ACCUMULATOR	706180		3134A	5208	
262	PUMP/MOTOR ASSEMBLY	713867-6 710975		3318A 3272	5208 5181	P-8
263	WATER DIVERTER VALVE	715486-2		3133A		
264	MULTIPLE WATER CONNECTOR	718776-5		3128E, 3309 3310	5183	P-8
265	PLSS WATER FILL CONNECTOR/DRINK WATER GUN	706140		2700A		
266	TRANSPORT LOOP RELIEV VALVE ASSEMBLY	723610-1		4282	5208	
267	CHECK VALVE	723206-1				P-8
268	GAS SEPARATOR	742108-2		4736		
270	PRIMARY OXYGEN SUBSYSTEM					
274	PRIMARY OXYGEN BOTTLE	723145		3122A		
275	PRIMARY OXYGEN FILL CONNECTOR	723020		3138, 3322		P-8
276	PRIMARY OXYGEN REGULATOR ASSEMBLY	707844-3		3127A		
280	PACKAGING					
281	PLSS COVER AND CLOSURE	718730-7 718756-3				P-8
282	THERMAL INSULATION COVER	718800-9		2260, 3017		P-8
283-1	INLET GAS CONNECTOR STOWAGE PLATE	713845-3		3308B		
283-2	OUTLET GAS CONNECTOR STOWAGE PLATE	713846-3		4196, 3308B		
286	MULTIPLE WATER CONNECTOR STOWAGE PLATE	710921-2		3128E	5154	
287-1	PLSS ELECTRICAL UMBILICAL STOWAGE PLATE	718745-2				
287-2	PLSS ELECTRICAL UMBILICAL STOWAGE PLATE (PGA)	723509-1				P-8
288	MAIN POWER SUPPLY STOWAGE PLATE	718765				
289	REMOTE CONTROL UNIT	721783-8		3302C, 4288		
	CAMERA MOUNTING BRACKET	742170-2				
300	LCG MOUNTED HARDWARE					
302	LCG MULTIPLE WATER CONNECTOR	710832		3310		
400-406	DELETE					P-8

ITEM NO.	COMPONENT	DWG NO. (SV)	SERIAL NO. LMP/CDR	SPECIFICATION (SVHS)	DVT/QUAL (SVHSER)	
500	OXYGEN PURGE SYSTEM	730101-3		4039	5150 5265	P-8
510	OXYGEN SYSTEM					
511-2	1 OPS BOTTLE	730103		4049	5153	
512-2	OPS SHUTOFF VALVE	730111-5		4044, 4046		
512-3	OPS FILL FITTING	730111-5		4046		
512-4	OPS HEATER AND REGULATOR	730111-9		4046	5221	P-8
513	OPS OXYGEN CONNECTOR	718775-9				
520	ELECTRICAL CONTROLS AND POWER					
521	1 OPS POWER SUPPLY	730107-4		4184, 4042A	5178	
522	OPS HEATER CONTROLLER	730106-2		4153	5171	
523	OPS POWER ON-OFF SWITCH	730108-2		4171A	5205	
524						
524-1	OPS CHECKOUT SWITCH	731784		3302, 4171A	5201	
524-2	OPS CHECKOUT LAMP	730303		3302C	5201	
525	OPS TERMINAL BOX AND FERRULES			4159	5152	
526	OPS TEMPERATURE SENSOR	731901		4206	5110	
527	OPS BATTERY CABLE	731720		3302C		
530	PACKAGING					
531	OPS COVER ASSEMBLY	731816-4/-5				P-8
532	OPS THERMAL COVER	731814-4				
533	OXYGEN CONNECTOR STOWAGE PLATE	721760-2		4196		
534	ACTUATING CABLE AND LEVER	723734-3		4044	5206	P-8
534-1	REMOTE CONTROL ACTUATOR	721920-5				
535	PLSS ANTENNA	713932-4		3385, 3227		
536	OPS REGULATOR CHECKOUT PRESSURE GAUGE	731716		4205	5179	
537	BREAST PLATE	723238				
	SHOULDER HARNESS	723239				
	WAIST HARNESS	723241				P-8
	LOWER HARNESS MOUNTING	723244				
	UPPER HARNESS MOUNTING	723242				
800	VEHICLE ASSOCIATED EMU COMPONENTS					
831	VEHICLE H_2O RECHARGE CONNECTOR	710911-3		3141A, 3325A	5322	
832	VEHICLE WASTE CONNECTOR	710908-4		3327A	5326	
833-1	VEHICLE INLET OXYGEN CONNECTOR	713065		3330		
833-2	VEHICLE OUTLET OXYGEN CONNECTOR	713842		3330		
834	OXYGEN RECHARGE CONNECTOR	714121		3322		
837-1	VEHICLE OXYGEN CONNECTOR STOWAGE PLATE	713883		3300		
	PLSS SUPPORT HARNESS	718793-4 718794-3			5141 5146	
	EMU SYSTEM FAILURE MODE AND EFFECT ANALYSIS	706100-6/-7 730101-2				
	COMPONENT IGNITION POTENTIAL TEST				5184	
	PLSS OUTGASSING AND ODOR TEST				5176	

SB NO. EMU 12-2

S/C: EMU
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: W. V. Bates
APPROVAL:

TITLE: EMU WEIGHTS

				(Lbs_m)	
A.	EVA Configuration				
1.	EV PGA with ITMG (including IV gloves, pressure helmet assembly and comm carrier)	EV PGA with ITMG and auxiliary components	66.3	47.27	P-8
2.	Liquid cooling garment (LCG)			4.9	P-5
3.	Fecal containment subsystem (FCS)			0.5	
4.	Urine collection and transfer assembly (UCTA)			0.53	P-8
5.	Biobelt assembly			0.2	
6.	Bioinstrumentation assembly			1.1	
7.	EV gloves			2.5	
8.	Lunar extravehicular visor assembly (LEVA)			4.4	P-5
9.	Lunar overshoes			4.9	
10.	Purge valve			0.63	P-6
11.	PLSS, dry with EVCS, thermal cover, and harness	PLSS	100.21	63.79	P-8
12.	Remote control unit (RCU)[1]			5.95	P-6
13.	PLSS battery			10.5	
14.	PLSS LiOH cartridge			5.02	P-8
15.	PLSS oxygen			1.80	
16.	PLSS liquid transport loop			1.25	P-5
17.	PLSS feedwater			11.9	P-8
18.	Oxygen purge system (OPS) without oxygen	OPS	35.00	29.22	P-6
19.	OPS oxygen			5.78	P-5
20.	BSLSS			10.65	P-6
			Total	212.79	P-8
B.	IVA Configuration				
1.	IV PGA with IVCL (including IV gloves, pressure helmet assembly and comm carrier)			35.7	
2.	Constant wear garment (CWG)			0.9	P-5
3.	Fecal containment subsystem (FCS)			0.5	
4.	Urine collection and transfer assembly (UCTA)			0.53	
5.	Biobelt assembly			0.2	
6.	Bioinstrumentation assembly			1.1	
7.	Helmet protective shield			0.8	
			Total	39.73	
C.	EMU Maintenance Kit			0.5	P-5
D.	Inflight Coverall Garment (ICG)			4.4	

[1] The weight of the RCU includes the weight of the RCU camera bracket(5.391bs. + 0.561bs.). P-6

SB NO. EMU 12-3

THIS SB IS DELETED

BY PCN-8

SB NO. EMU 12-4

This SB deleted by PCN-8

SB NO. EMU 12-5

S/C: EMU
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: W. V. Bates
APPROVAL:

TITLE: THERMAL CONTROL

BACKGROUND: The EMU must provide sufficient thermal control to satisfy the design metabolic expenditure superimposed upon the extremes of external thermal environment. The responsibility for thermal control for the EMU is divided between the oxygen ventilation loop (OVL) and the liquid transport loop (LTL) in conjunction with the liquid cooling garment (LCG). The oxygen ventilation loop heat loads include respiration latent, suit sensible, perspiration, fan/motor, LiOH sensible and latent. The liquid transport loop heat load includes metabolic (less respiration and suit sensible), heat leak, EVCS, pump, battery, and fan/motor cooling jacket.

The following symbols are used in the text:

$\dot{Q}$ = heat transfer rate, Btu/hr
C_p = specific heat, Btu/lb-°F
$\dot{m}$ = mass flow rate of H_2O, lbs/hr
T = temperature, °F
T_{db} = dry bulb temperature, °F (i.e., the measured temperature of a gas mixture)
T_{wb} = wet bulb temperature, °F (i.e., the adiabatic saturation temperature of the mixture)
P = pressure, psia
R = gas constant, 48.3 $\frac{ft\text{-}lb_f}{lb_m\text{-}°R}$
ν = specific volume, ft^3/lb
ω = humidity ratio, lb water vapor/lb dry air
ϕ = relative humidity, percent
h_{fg} = enthalpy of evaporation, Btu
h_g = enthalpy of a saturated vapor, Btu
h_f = enthalpy of a saturated liquid, Btu
q = heat, Btu
M_{da} = mass flow rate of dry air, lb/hr
M_{in} = mass flow rate of ambient air, lb/hr

Subscripts:

a = dry air
in = inlet parameter
out = outlet parameter
m = mixture of vapor and dry gas
v = water vapor parameter
g = saturator vapor parameter

The LTL/LCG transfers heat to the sublimator by conduction. Heat rejection by the LTL at the sublimator is defined by the following equation:

$$\dot{Q} = \dot{m}C_p\,(T_{in} - T_{out})$$

where $C_p = 1.0$
$T_{in} - T_{out}$ = differential temp across the sublimator

For a 2000 Btu/hr metabolic load, plus equipment load, the LCG/LTL removes approximately 2140 Btu/hr.

$$\dot{Q} = (1)(4.2)(60)(53.5 - 45) = 2142.0 \text{ Btu/hr}$$ P-3

The OVL utilizes natural forced convection, radiation, and evaporation to transfer heat to the sublimator for heat rejection.

Sublimator Inlet	Sublimator Outlet
$T_{db_{in}} = 120.5°F$	$T_{db_{out}} = 52°F$
$T_{wb_{in}} = 88.3°F$	$T_{wb_{out}} = 52°F$
$P_{m_{in}} = 3.70$ psia	$P_{m_{out}} = 3.67$ psia

P-6

where: $P_{m_{in}}$ = total atmospheric press at inlet

$P_{m_{out}}$ = total atmospheric press at outlet

Complete adiabatic saturation pressure at 88.3°F is 0.66 psia (steam tables). Therefore, the pressure of the dry gas at the sublimator inlet is:

$$P_{a_{in}} = P_{m_{in}} - P_v = 3.7 - 0.66 = 3.04 \text{ psia}$$

The specific volume (ν_a) of the inlet dry gas for complete saturation is:

$$\nu_a = \frac{R_a T_{in}}{P_a} = \frac{(48.3)(460 + 88.3)}{(3.04)(144)} = 60.5 \text{ ft}^3/\text{lb}$$

and the relative humidity ratio (ω_a) for complete saturation at 88.3°F is:

$$\omega_a = \frac{\nu_a}{\nu_g}\phi = \frac{60.5}{493.7}(1.0) = 0.123$$

Application of the first law to adiabatic saturation results in the humidity ratio (ω_{in}) for the sublimator inlet:

$$\omega_{in} = \frac{C_{p_a}(T_2 - T_1) + \omega_a h_{fg_a}}{h_{g_{in}} - h_{f_a}} = 0.1149 \text{ lb water vapor/lb dry air}$$

where: $C_{p_a} = 0.24$ Btu/lb-°F

$T_1 = 120.5°F$

$T_2 = 88.3°F$

P-3

From the steam tables, at 88.3°F:

h_{fg_a} = latent heat of evaporization (1042 Btu)

$h_{g_{in}}$ = saturation vapor (1100 Btu)

h_{f_a} = saturation liquid (56 Btu)

The inlet relative humidity (ϕ_{in}) can be determined from the following expression:

$$\phi_{in} = \frac{\nu_g}{\nu_a}\omega_{in}(100) = \frac{200.35}{60.5}(0.1149)(100) = 38.05\%$$

where: $\nu_g = 200.35$ ft^3/lb at 120.5°F

and $P_g = 1.712$ psia at 120.5°F

The dew point is the saturation temperature corresponding to P_v.

where: $P_v = \phi P_g = (.3805)(1.712) = 0.6514$ psia

dew point = 87.9°F

The gas mixture leaving the sublimator will be saturated and must have the same humidity ratio (ω) as the mixture in the desired final condition. This saturation temperature of 52°F corresponds to a final vapor pressure (P_v) of 0.2 psia.

$$P_a = P_m - P_v = 3.67 - 0.2 = 3.47 \text{ psia}$$

$$\nu_a = \frac{R_a T_a}{P_a} = \frac{(48.3)(480 + 52)}{(3.47)(144)} = 51.424 \text{ ft}^3/\text{lb}$$

$$\phi = 100\%$$

$$\omega_{out} = \frac{v_a}{v_g}\,\phi = \frac{(51.424)\ (1.0)}{1588.2} = 0.0324 \text{ lb/lb}$$ P-3

where: $v_g = 1588.22 \text{ ft}^3/\text{lb}$ for 52°F

The sublimator must, therefore, cool the gas from 120.5°F to 52°F. During the latter part of this cooling process, water is removed. Application of the first law to the sublimator in which work = 0, $\Delta KE = 0$, and the flow is steady state:

$$q_{out} = h_{a_{in}} + \omega_{in}\, h_{v_{in}} - h_{a_x} - \omega_x\, h_{v_x} - (\omega_{in} - \omega_{out})\, h_{f_x}$$

Assume that all condensate leaves at the temperature T_x (52°F). Noting that $\omega_x = \omega_{out}$, $h_v = h_g$ at the same temperature, and $\Delta h_a = C_{p_a}\,\Delta T$.

$$q_{out} = C_{p_a}\,(T_{in} - T_x) + \omega_{in}\, h_{g_{in}} - \omega_{out}\, h_{g_{out}} - (\omega_{in} - \omega_{out})\, h_{f_{out}}$$

From the steam tables, at 52°F:

$h_{g_{out}} = 1061$ Btu P-3

$h_{f_{out}} = 20$ Btu

$$q_{out} = 0.24\ (120.5 - 52) + 0.1149\ (1100) - 0.0324\ (1061) - (0.1149 - 0.0324)\ (20)$$ P-3

$q_{out} = 106.84$ Btu/lb at dry air

Where mass flow rate of dry gas into the sublimator is:

$$M_{da} = \frac{M_{in}}{1 + \omega_{in}}$$

where: $M_{in} = 7.65$ lb/hr

$$M_{da} = \frac{7.65}{1 + 0.1149} = 6.86 \text{ lb/hr}$$ P-3

The rate of heat removed by the oxygen ventilation loop at the sublimator is:

$$\dot{Q} = M_{da}\, q_{out} = 6.86\ (106.84) = 733.1 \text{ Btu/hr}$$

Total sublimator heat load rejection for 2000 Btu/hr metabolic plus equipment loads:

Oxygen ventilation loop = 733.1 Btu/hr
Liquid transport loop = 2142 Btu/hr P-3
Total load = 2875.1 Btu/hr

or approximately 2900 Btu/hr

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Figure 12-5a

SB NO. EMU 12-6a

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SB NO. EMU 12-6b

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S/C: EMU
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: W. Bates
APPROVAL:

SB NO. EMU 12-7

TITLE: **EMU PRESSURE REGULATORS**

BACKGROUND: The PLSS primary O_2 and OPS pressure regulators are both single stage regulators (Figure 12-7a) referenced to ambient pressure. The outlet pressure of the regulator is maintained by the force balance existing across the bellows (i.e., lower regulator valve spring plus PGA pressure versus bellows calibration spring and ambient pressure). As oxygen is consumed, the PGA pressure decreases, causing an imbalance and displacement of the bellows. This displacement modulates the regulator flow metering ball valve, re-establishing the force balance by increasing the PGA pressure. The PLSS primary O_2 pressure regulator maintains the PGA pressure at 3.85 $\pm$ 0.15 psid for flow rates of 0.07 to 0.7 lb/hr and 3.75 $\pm$ 0.25 psid for flow rates of 0.7 to 2.0 lb/hr. The OPS pressure regulator maintains the PGA pressure at 3.7 $\pm$ 0.3 psid for flow rates ranging from 0.07 to 8.4 lb/hr. P-14

For a lower regulator valve spring failure, the regulator would fail open. If the PLSS primary O_2 pressure regulator fails open, a flow limiting orifice restricts the flow to a maximum of 3.98lb/hr for an upstream pressure of 1500 psia. The PGA pressure relief valve is capable of P-11 accommodating the flow from the failed open PLSS primary O_2 pressure regulator, preventing over-pressurization. For a full primary O_2 supply (POS), approximately 70 minutes lifetime is P-11 available. If the OPS pressure regulator failed open, the flow would be in excess of 200 lbs/hr, rupturing the PGA by overpressurization. Since the OPS is a backup system, an upstream shutoff valve prohibits this from occurring when not in use.

If either of the regulators' bellows calibration spring fails, the respective regulator will fail closed. If either of the regulators' bellows ruptures, the respective regulator will fail open. P-6

In the event of a bellows failure, the POS would escape through the ambient reference port and the PGA pressure relief valve. Once the POS is depleted, an orifice in the ambient reference port limits any further oxygen ventilation loop O_2 losses to 0.7 lb/hr at 3.9 psia. P-11

If the OPS pressure regulator bellows fails while the shutoff valve is open, the entire O_2 supply will escape to vacuum within a few seconds. P-14

During LM cabin repressurization to 5 psia, a POS source pressure of 150 psia will prevent the PGA from receiving negative pressures. To maintain proper PGA pressure regulation during repressurization (100 sec), either a minimum POS pressure of 527 psia or a reduced cabin repressurization rate is required. P-6 P-5

In the absence of a flow restriction at the OPS outlet, the entire OPS source pressure can be dumped in approximately 4 minutes at an initial flow rate of 240 lbs/hr at a source pressure of 5880 psia. P-6 P-5

The OPS pressure regulator will maintain properly regulated pressures down to a minimum source pressure of 500 psia at 8 lbs/hr in a vacuum, and 300 psia at 4 lbs/hr in a vacuum. P-11

At 5 psia ambient, the OPS regulated pressure falls to 3.4 psid between a source pressure of 600 to 800 psia, and to 2.5 psid at a source pressure between 400 and 600 psia.

SB NO. **EMU 12-8**

S/C: EMU
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: L. Wible
APPROVAL:

TITLE: CMP EVA

BACKGROUND: The CMP EVA on Apollo 17 is required for retrieval of the two film cassettes (one each) from the pan camera and the mapping camera along with the lunar sounder, located in the SIM bay of the SM. These cameras are for lunar surface photography. The CMP assisted by the LMP, positioned at the CM side hatch, will conduct the film cassette retrieval, utilizing the wrist tether retrieval system. P-14

The EVA is currently scheduled after TEI. The SIM bay orbital experiments have been active since LM jettison and SIM bay door ejection. The total EVA, including preparation and post activities, will encompass approximately 2.5 to 3.0 hours of which 45 minutes (approx.) will be EVA time (cabin depress to cabin repress). P-14

The CMP's EVA equipment shall consist of an extravehicular pressure garment assembly (A7L-B-CMP EV-PGA), an open loop, umbilical supplied, primary life support system (with crewman restraint capabilities) and a portable, nonrechargable, open loop, emergency life support system.

The primary life support system consists of an EVA oxygen umbilical, a Suit Control Unit (SCU), and a Pressure Control Valve (PCV). The SCU contains an ON-OFF valve, a low pressure warning switch which activates between 3.1 and 3.4 psia, and a low flow warning switch which activates at 6.0 lbs/hr with a tone audible to the CMP only. The PCV, located at the PGA outlet, back pressures the PGA by means of a relief valve to provide downstream pressure regulation at 3.85 $\pm$ .15 psia between PGA inlet flow rates of 10-12 lbs/hr. The CSM provides an O_2 supply at 900 $\pm$ 35 psia to the EVA/IVA demand regulator which reduces the pressure to 100 $\pm$ 5 psia before entering the EVA umbilical. The emergency life support system consists of a helmet-mounted Oxygen Purge System (OPS) and a two-position PGA purge valve. This system provides a minimum of 30 minutes regulated O_2 supply based on a fully charged system. P-14

The CDR and LMP, during the EVA, shall be configured in the CDR and LMP lunar surface extravehicular pressure garment assemblies (LMP/CDR A7L/B EV-PGA) while connected to the Command Module Environmental Control System (CM-ECS).

SB NO. **PLSS 13-1**

S/C: EMU
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: W. V. Bates
APPROVAL:

TITLE: **CONTAMINANT CONTROL ASSEMBLY**

REFERENCES: SVHS 3230A; 2369; 2826B; SVHSER 5156; 5225; 5390; 5411

P-5

BACKGROUND: A lithium hydroxide cartridge is used for contaminate control in the oxygen ventilation loop of the PLSS. The cartridge provides a means of removing CO_2 and trace contaminants from the recirculating oxygen. The contaminated gases (O_2, CO_2) enter the center of the perforated titanium annulus from one end of the PLSS cartridge (Figure 13-1a). From the annulus, the gases flow radially outward through a 200 mesh stainless steel screen which is used to prevent LiOH back dusting, and into a bed of activated charcoal (0.3 to 0.32 lbs) for odor removal. From the charcoal bed, the gases pass through a separation screen and into the monohydrate LiOH bed (3.12 to 3.38 lbs) where the CO_2 removal occurs. The O_2 then passes through the teflon felt filter and out of the assembly through elongated slots cut in the outer titanium shell.

P-8

The cartridge performance is dependent upon stowage temperature, stowage pressure, gas flow rate, operating temperature, relative humidity, inlet CO_2 PP, and LiOH structure. The PLSS cartridge operates in a relatively low flow, low humidity, low temperature, and high CO_2 environment. Under these severe conditions, the cartridge utilizes a monohydrate (4 to 8 percent H_2O) LiOH structure to accomplish the design mission without exhibiting breakthrough (>15 mm Hg).

P-5

P-5

The monohydrate structure increases the surface area of LiOH granules, providing a greater number of sites of activation for diffusion and CO_2 absorption. The cartridge initially scrubs both moisture and CO_2 and generates heat and water as a by-product. This total moisture, in conjunction with the inlet CO_2 PP, comprises the driving force that further propagates the reaction and controls cartridge lifetime. After 1-1/2 to 2 hours of operation, the LiOH structure reaches a sufficient hydration level and starts dumping the excess moisture, increasing the outlet dew point. The net exchange of moisture within the cartridge over its lifetime is negligible. The monohydrate LiOH bed reacts with CO_2 in the following basic reaction:

P-3

$$CO_2 + 2LiOH \longrightarrow Li_2CO_3 + H_2O + \Delta Q$$

P-6

A. **Gram Molecular Weight Determination**

CO_2 = 12.011 + 32.000 = 44.011 gms = .097 lbs

2 LiOH = 2(6.939 + 16.000 + 1.000) = 47.878 gms = 0.105 lbs

Li_2CO_3 = 13.878 + 12.011 + 48.000 = 73.889 gms = 0.163 lbs

H_2O = 2.000 + 16.000 = 18.000 gms = 0.040 lbs

If 100 percent efficiency is considered:

3.00 lbs LiOH will react with and remove 2.77 lbs of CO_2 and generate 1.14 lbs of H_2O and 3626.5 Btu's

P-3

If 34 percent efficiency is considered:

3.00 lbs LiOH will react with and remove 0.940 lbs of CO_2 and generate 0.39 lbs of H_2O and 510.6 Btu's

P-3

For a 3-hour mission profile, the cartridge outlet CO_2 partial pressure must not exceed 10 mm Hg. The 4800 Btu metabolic production corresponds to a total CO_2 generation of 0.94 lbs. The removal of 0.94 lbs of CO_2 corresponds to a cartridge efficiency of approximately 34 percent (Figure 13-1b). Nominally, the cartridge is at least 50 percent efficient.

B. Vacuum Degradation

The minimum allowable ambient pressure for the LiOH cartridge is 0.5 psia to prevent vaporization of cartridge moisture. If the cartridge is exposed to an ambient pressure of less than 0.5 psia, the maximum time for EMU use is 60 minutes.

C. Cold and Hot Soak

Cartridges exposed to 5°F for 48 hours completed the 3-hour 4800-Btu mission profile with margins of 41 and 51 minutes. Cartridges exposed to 30°F for 72 hours completed the 3-hour 4800-Btu profile with margins of 57 and 70 minutes. Cartridges exposed to 130°F for 130 hours failed to maintain an outlet CO_2 partial pressure of less than 10.00 mm Hg for the required 3-hour mission profile.

P-5

The high temperature exposure changes the granular structure (monohydrate LiOH) into a crystaline structure (anhydrous LiOH), reducing the surface area for diffusion and absorption.

D. Performance in Mission Profile

The increase in dew point (relative humidity) from 65°F to 75°F increases the CO_2 absorption rate and cartridge performance by a factor of 1/2. The low dew point profile had margins at 20 to 28 minutes where the high dew point profile had margins at 110 to 150 minutes. However, direct liquid injection in excess of 100 grams would glaze (oversaturate) the granules, reducing the surface area and activation sites for CO_2 absorption. A partially consumed cartridge stowed within the PLSS in excess of 12 hours absorbs the residual water in the OVL, saturating the LiOH. P-3 P-5

A 4500 Btu/hr metabolic rate, even for a minute duration, is detrimental to sustained cartridge performance and would require a shortened mission.

Fluorel foam end pads, which are preloaded to 140 psi, prevent possible LiOH channeling by keeping a constant compressive load on the bed, thereby resisting the formation of fissures and channels. P-5

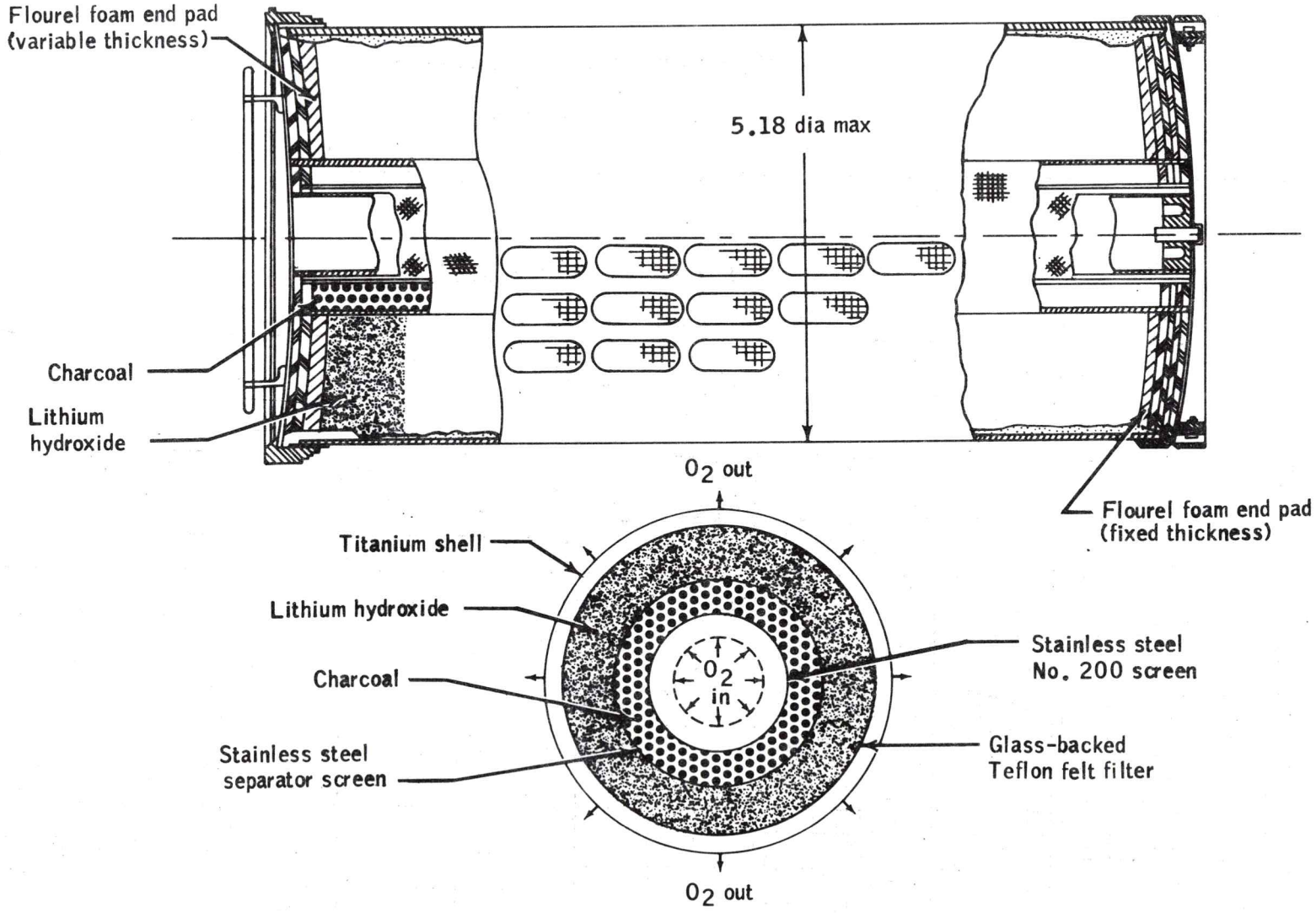


Figure 13-1a. - LiOH canister.

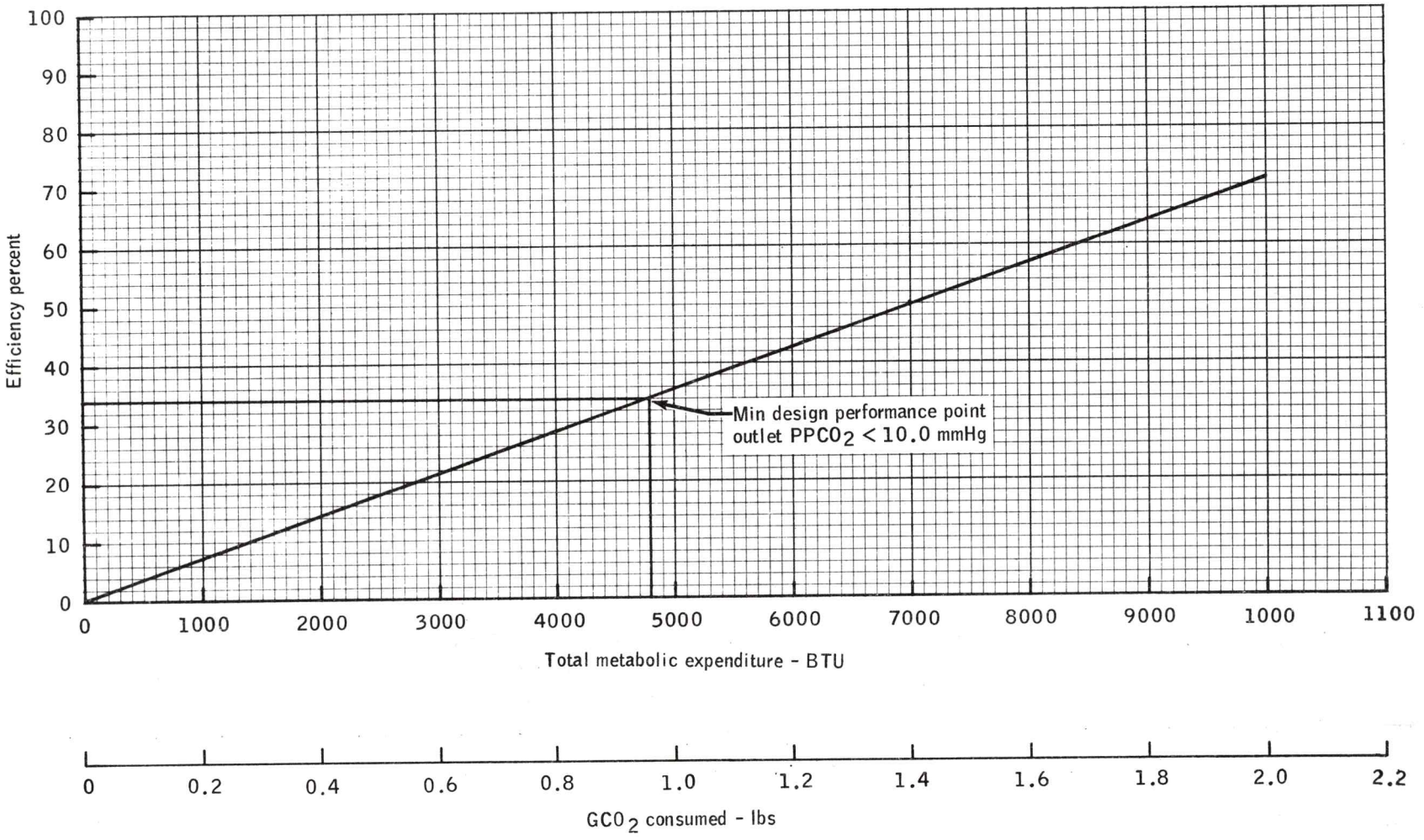


Figure 13-1b. - LiOH cartridge efficiency.

SB NO. **PLSS 13-2**

S/C: EMU
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: W. V. Bates
APPROVAL:

TITLE: **PLSS SUBLIMATOR**

REFERENCES: SVHS 3130C; SVHSER 5204

BACKGROUND: The PLSS utilizes a sintered-nickel, porous plate sublimator operating at triple point as a heat sink for the liquid transport loop (LTL) and the oxygen ventilation loop (OVL) (Figure 13-2a). The respective loops' cooling passages transfer heat by conduction to the feedwater loop cooling passages. The heat contained in these passages is then dissipated by a mixed mode of sublimation/vaporization of feedwater.

At triple point, the PLSS sublimator rejects heat by a mixed mode of operation (sublimation/vaporization). This mixed mode of operation is defined by the feedwater pressure and the rate of heat transfer and vapor pressure drop across the porous plate, the latter being a function of the plate porosity.

A vaporization mode of operation (h_{fg}) exists when the pressure and/or temperature at the inner surface of the porous plate exceeds the defined triple point. The retention of water in absence of a solid ice layer is achieved by maintaining the combination of vapor pressure of water and surface tension in excess of the feedwater sublimator inlet pressure. (The pressure differential which a pore can retain by surface tension is inversely proportional to the equivalent radius of the restriction, i.e., the smaller pores begin the vaporization process before the larger pores as the heat load increases.) Sublimation (h_{ig}) occurs when the pressure and/or temperature on the inner surface of the porous plate drops below the defined triple point conditions. The thickness of the ice layer formed is governed by the rate of heat transfer and sublimation temperature corresponding to the local vapor pressure at the inlet face of the porous plate. As a result of the random variation in pore radii, the PLSS rejects heat simultaneously by sublimation and vaporization establishing a 32° F heat sink at a vapor pressure of 0.0885 psia (Figure 13-2b).

During startup (Figure 13-2c), provisions are necessary to insure that the sublimation mode is established prior to feedwater pressure buildup. If feedwater pressure (GT8110P/GT8210P) is allowed to build in combination with high initial thermal loads prior to establishing an ice layer, feedwater breakthrough would occur. (Breakthrough results when a pore cannot maintain feedwater pressure by the combination of its surface tension and characteristic vapor pressure.) To prohibit breakthrough, a feedwater flow limiting orifice (visojet) has been placed in the line at the sublimator inlet to prevent high initial feedwater pressure. This flow limiter produces a sufficient line pressure drop to allow formation of the ice layer. The pressure drop across the flow limiter becomes negligible during steady state operation as relatively small flows are required. The maximum feedwater pressure for sublimation is 6.0 psia with any pressure above this resulting in sublimator breakthrough. P-6

The entire thermodynamic cycle (startup, ice layer formation, and operation) is illustrated in Figure 13-2b. Startup is characterized by a pure vaporization mode (h_{fg}). As the feedwater enters the sublimator at startup, its maximum temperature will be approximately 109° F and its pressure will simply be the vapor pressure of water at this temperature (Figure 13-2d), 1.2422 psia, plus the ΔP characteristic of the porous plate, 0.0097 psia (500 microns), for a total back pressure of 1.2519 psia. (The fact that the pressure is a function only of these two sources is due to the ΔP vs flow characteristics of the flow limiter.) The rate decrease of enthalpy is given by the equation for the latent heat of vaporization $h_{fg} = h_g - h_f$, where h_f and h_g are defined as follows: P-5 P-3

Enthalpy of water at 109° F and 3.5 psia = h_f = 76 Btu/lb
Enthalpy of steam at 109° F and 1.2519 psia = h_g = 1109 Btu/lb (Figure 13-2d)
Enthalpy of water at 32° F and 0.0885 psia = h_f = 0.00 Btu/lb
Enthalpy of steam at 32° F and 0.0885 psia = h_g = 1076 Btu/lb P-5

The value of h_{fg} will range from 1033 Btu/lb to 1076 Btu/lb as the feedwater decreases its temperature from 109° F to 32° F. As the temperature of the feedwater approaches very close to 32° F, the high rate of decrease of the enthalpy together with variations of pore radii results in the formulation of an ice layer. The sublimator is completely filled with an ice layer formation in approximately 4 minutes.

The thickness of the ice layer increases with a further decrease in temperature slowly decreasing the amount of vaporization and, hence, localized pressure until an equilibrium state is reached. This equilibrium state occurs at a temperature of 32°F and a pressure of 0.0885 psia (triple point) P-3
resulting from localized vaporization due to the nonhomogeneity of the porous plate. (Figure 13-2b) P-5

The sublimator, which is now at triple point, has established its ice layer and is in the nominal mode of operation of approximately 85 percent sublimation and 15 percent vaporization. The inlet feedwater pressure now stabilizes at a pressure corresponding to the feed H_2O flow rate and sublimator heat load. The change in enthalpy of the feedwater at triple point, Δh_{Tpt}, is given by $\Delta h_{Tpt} = 0.85(h_{ig}) + 0.15(h_{fg})$ where the following quantities are defined: P-3

Enthalpy of water at 32°F and 0.0885 psia = h_f = 0.00 Btu/lb
Enthalpy of ice at 32°F and 0.0885 psia = h_{fi} = -143 Btu/lb
Enthalpy of steam at 32°F and 0.0885 psia = h_{fg} = 1076 Btu/lb
Latent heat of sublimation at 32°F and 0.0885 psia = h_{ig}

where $h_{ig} = h_g - h_i = h_{fg} - h_{fi}$ = 1219 Btu/lb or
Δh_{Tpt} = 0.85(1219 Btu/lb) + 0.15(1076 Btu/lb) P-3
Δh_{Tpt} = 1197 Btu/lb

This is the amount of enthalpy the sublimator is capable of removing in the mixed mode of operation. The enthalpy content in the liquid transport loop and the oxygen ventilation loop will have to be reduced to effectively cool the crewman. There will also have to be additional decreases in enthalpy of the feedwater itself. The enthalpy of the sublimator structure has been increased by the lowering of temperature of the inlet feedwater from 109° F (startup) down to its 32° F triple point value. This P-5
addition of enthalpy will be at the rate of 1.0 Btu/lb-°F, the specific heat of water. Once the P-3
feedwater has reached the 32°F level, the enthalpy of the sublimator structure is again increased by the physical change of approximately 85 percent of the incoming feedwater to ice. As this will not effect a change in temperature of the feedwater, the increase in enthalpy of the sublimator structure will be the latent heat of fusion or 143.0 Btu/lb. The combination of these two increases in enthalpy must also be removed to effectively cool the crewman. Therefore, the amount of decrease in enthalpy that may be utilized for the oxygen ventilation loop and liquid transport loop will equal the capability of the sublimator less the combination of the latter described system increases or:

(Startup at 109° F) 1197 Btu/lb - 77 Btu/lb - 0.85 (143 Btu/lb) = 957 Btu/lb P-5
(Nominal operating at 70° F) 1197 Btu/lb - 38 Btu/lb - 0.85 (143 Btu/lb) = 1038 Btu/lb P-6

It should be noted that the efficiency of the sublimator increases with a decrease in temperature of the inlet feedwater. Although the sublimator heat removal rate is approximately the same whether in a pure vaporization mode, pure sublimation mode, or a mixed mode, the mixed has the advantage of being self regulating.

The back vented sublimator may operate at a maximum heat rejection level of approximately 8750 Btu/hr without suffering breakthrough. The limiting performance factor for the sublimator is the physical size of the viscojet. For high feedwater flow rates and corresponding high pressure drops across the viscojet, the downstream pressure eventually approaches the saturation pressure of the feedwater flowing through the flow limiter. When this phenomenon occurs (approximately 1.75 psia), boiling and subsequent vapor blanketing of the sublimator plenum results in degraded sublimator performance.

The sublimator has sustained minimum heat loads for 2 hours of operation without suffering degradation. However, complete termination of liquid transport loop flow in excess of 10 minutes will result in sublimator freeze-up.

The minimum total heat load for the sublimator is 390 Btu/hr which consists of 140 Btu/hour for the oxygen ventilation loop (OVL) and 250 Btu/hr for the liquid transport loop (LTL). When the heat load on either of these loops drops below these respective values, freezing will occur in that portion of the sublimator. P-5

In the event of pump failure, or other loss of liquid transport loop flow, the oxygen ventilation loop can continue to provide cooling, since only the liquid transport section of the sublimator will freeze. At an OVL flow of 8.0 lbs/hr and a loop pressure of 3.7 psia, a crewman would have 40 minutes of operation at a metabolic rate of 900 Btu/hr before reaching a heat storage limit of 340 Btu. P-5

Degradation in cooling can result from either air inclusion in the liquid transport loop (LTL) or by flow restriction (crimping of the LGC lines). In the maximum diverter valve position, evolved air not entrapped by the gas separator continually circulates through the LTL/LCG, causing flow reduction and a reduced rate of thermal exchange between the LCG and sublimator. In the minimum and intermediate diverter valve positions, air collects in the sublimator because it is the highest point in the loop and exhibits the maximum pressure drop. As a result of the air collection in the sublimator, the pump performance returns to normal operation. However, this entrapment of air restricts flow through the sublimator, degrading the rate of heat rejection and the heat rejection level. In the minimum diverter valve position, termination of flow through the sublimator due to restriction occurs at an approximate total flow rate of 1.5 lbs/min. This reduction is identified by the erratic response of LCG H_2O ΔT (GT8196T/GT8296T) on telemetry. In the intermediate or maximum diverter valve positions, complete termination of flow through the sublimator cannot be achieved by restriction.

The depletion of the feedwater reservoir is identified by the characteristic rise, then fall, in feedwater pressure (GT8110P/GT2110P) over a period of 10 to 20 minutes. This occurrence represents the passage of the water vapor bubble through the flow limiting orifice. When the feedwater pressure drops sufficiently to activate the low feedwater pressure flag and warning tone (1.2 to 1.7 psia), a residual cooling capacity of approximately 0.6 lbs of feedwater remains downstream of the H_2O shutoff and relief valve to provide an additional 700 Btu's of degraded cooling. P-8 P-5

Inability to close the water shutoff and relief valve prior to LM repressurization results in eventual breakdown of the sublimator ice layer and loss of feedwater to the cabin. However, if the PGA pressure (feedwater reservoir reference pressure) approaches cabin ambient pressure during repressurization, insufficient ΔP across the PLSS exists to expel feedwater. On a subsequent depressurization with H_2O shutoff and relief valves closed, 140 cc of entrapped water in the sublimator will be extruded through the porous plates in the form of fine hairline filaments of ice.

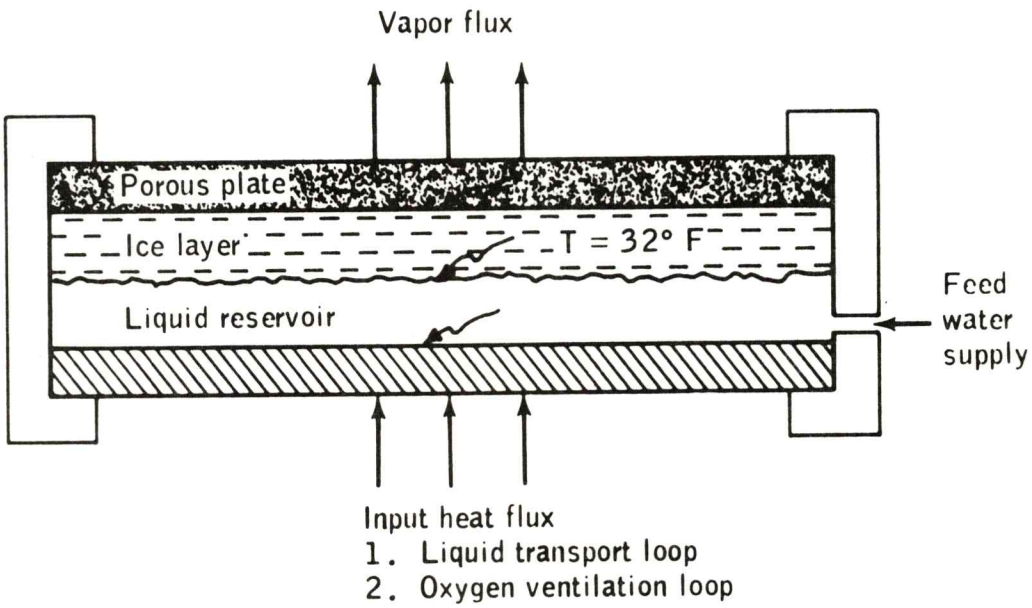
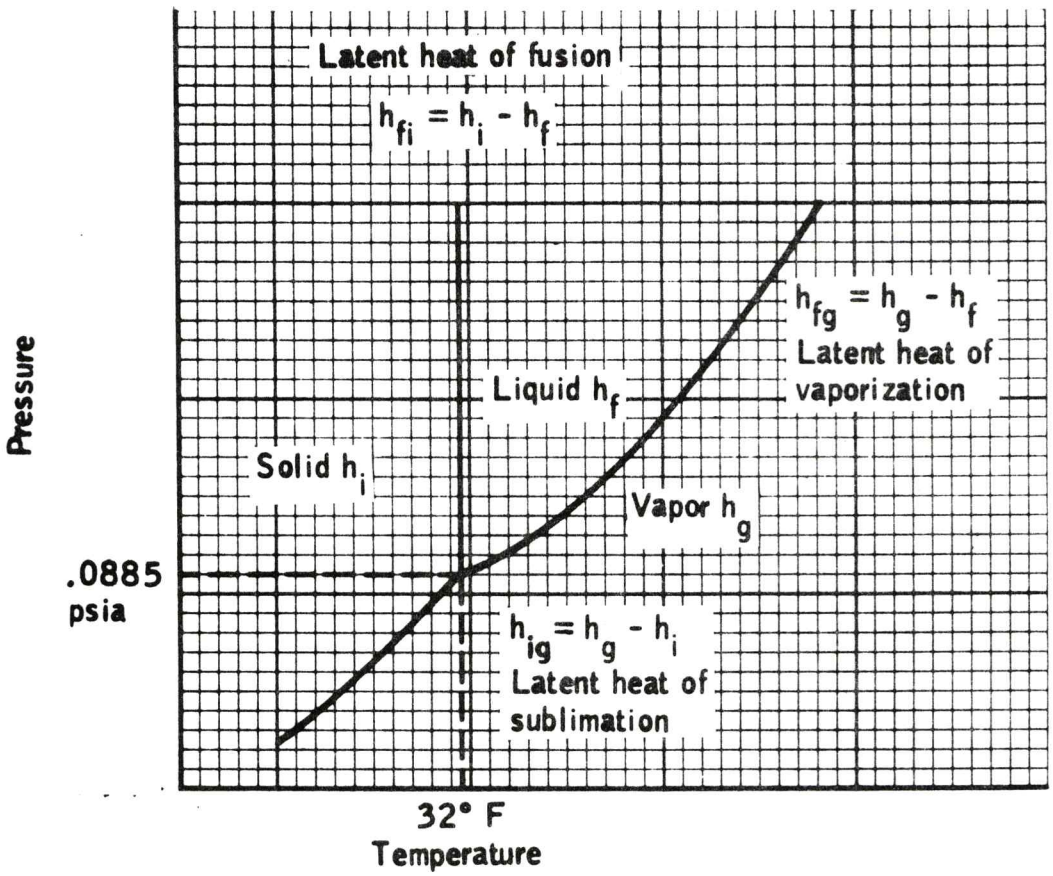


Figure 13-2a. - Porous plate sublimator operation.



Boundary conditions:

1. Water at inlet to sublimator 32° to 109° F, 0.0885 to 6.0 psia
2. Ice at porous plate 32° F
3. Steam exhausted at vacuum side of porous plate is 32° F (additional heat from conduction)
4. Water at porous plate is 32° F, 0.0885 psia

Figure 13-2b. - Pressure vs temperature of water.

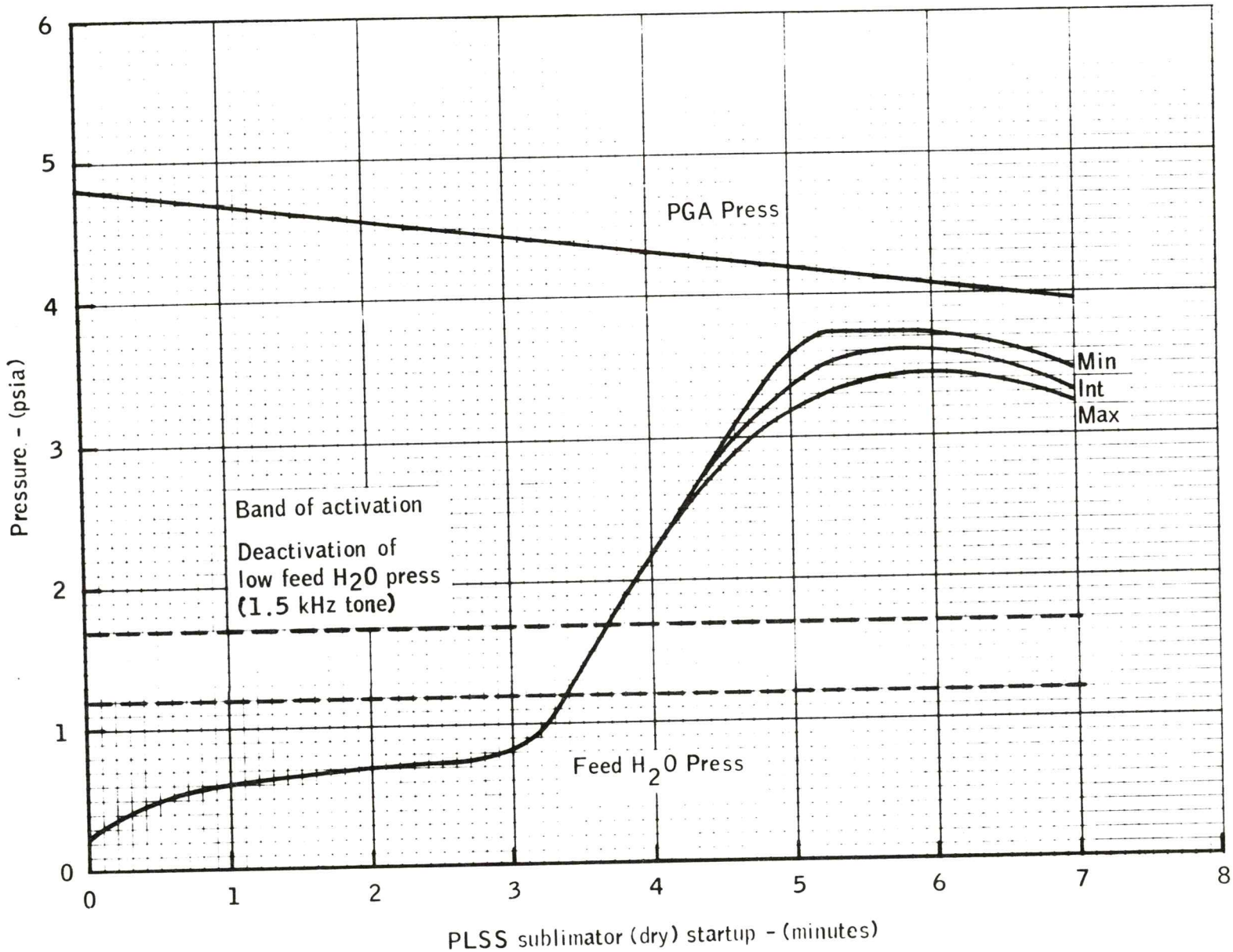


Figure 13-2c. - Sublimator startup.

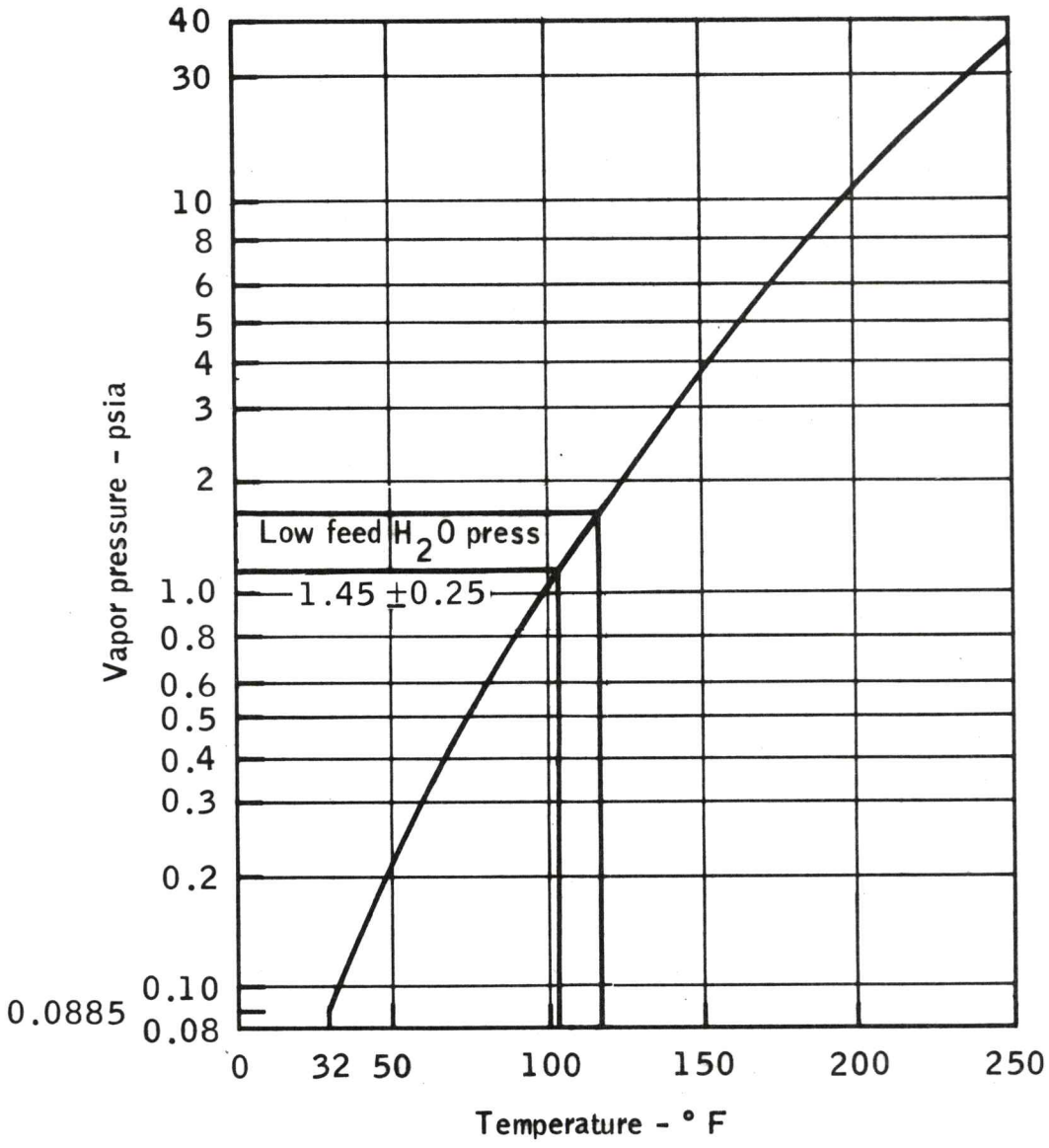


Figure 13-2d. - Vapor pressure of water.

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SB NO. **PLSS 13-3**

S/C: EMU
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: W. Bates
APPROVAL:

TITLE: **PLSS PUMP/MOTOR ASSEMBLY**

REFERENCES: SVHS - 3318A
SVHSER - 5208; 5410

BACKGROUND: The pump/motor assembly consists of the pump, torque motor (multivibrator), and inverter assembly operating between 15.7 and 20.5 Vdc. The positive displacement pump generates a pressure rise of 5.7 ± 1.0 psid, producing a flow rate of 4.0 ± 0.4 lbs/min through the PLSS liquid transport loop (LTL) or the LM ECS LCG coolant loop. P-11

A. Inverter Assembly

The solid state inverter assembly (flip-flop) generates a square wave ac signal having a frequency of 32 to 40 Hz. An EMI filter on the inverter power line reduces the level of broad band conductive interference. In addition, two zener diodes on the power line further reduce the susceptibility to transient pulses which manifest themselves by gating the power transistors, resulting in an open circuit. A failed open inverter power transistor inhibits pump startup. P-3
Due to the inverter assembly EMI susceptibility, a high-speed switching diode was also placed in parallel with the fan/motor assembly to limit startup transients to -2.25 to +25 Vdc. Maximum pump/motor assembly startup current is less than 2.0 amps. P-5

B. Torque Motor

The torque motor consists of an electromagnetic coil within the magnetic flux field of a permanent magnet. The material for the magnets is initially magnetized with high flux, then demagnetized to limit operational aging. The armature or core for the electromagnetic coil is a cross configuration with a pivot point at the center of the cross. As magnetic couples are produced in one end of the armature about this pivot point, a reaction couple is transmitted to the pump diaphrams at the other end of the armature through the actuation arm. When the armature magnetic polarity reverses, couples reverse and the pump diaphrams are displaced in the opposite direction. The reversing field of the electromagnet is generated by the inverter assembly. Bumper pads on the armature aid damping while a torsion bar at the pivot point restores the armature to a neutral position. The efficiency of the motor depends on the symmetry and consistency of the armature air gap within the motor. Since the armature is supported by the torsion bar, any misalignment results in an asymmetrical condition. An asymmetric armature air gap acts as a shunt across the pole faces, which increases the magnetic leakage between field poles. This in turn decreases the working flux density and increases the power consumption. The performance of the low impedance motor is directly related to the input voltage. The motor is designed to withstand operation at 25 percent above rated frequency of oscillation for a minimum of 5 minutes under rated load conditions without failure or impairment of function.

C. Pump

The pump is of the double-acting positive displacement type. The midsection of the pump contains the actuation arm of the torque motor and is isolated from the water compartments on each side of the midsection by diaphrams. Each of the two diaphrams is a pump chamber with an inlet and outlet check valve to control the water flow direction through the pump. The oscillating motion of the actuation shaft simultaneously compresses the diaphram of one chamber, expelling water, and expands the chamber capacity of the other diaphram, resulting in water induction. The cycle reverses with the motion of the actuation arm. Improper seating of the pump check valves results in reduced performance at nominal power consumption. Working against an incompressible fluid, the pump demands a surge of power during each compression stroke. This 40 Hz EMI ripple (noise) has been eliminated from the telemetered battery current with the installation of a low pass filter. However, the ripple is still apparent on the telemetered battery voltage. From a LM feedwater recharge, the 40 psia N_2 aerated H_2O will release

approximately 0.20 cc of N_2 per 1.0 cc of recharge H_2O at 3.5 psia. When the PLSS liquid transport loop drops below 3.5 psia and requires over 200 cc of makeup H_2O, the evolved air will exceed the capacity of the gas separator and degrade the pump to complete cavitation ($\Delta P = 0$). This condition can either be caused by a leakage or stretching of the LCG (cold flow), creating a larger volume which necessitates additional coolant.

There are no constraints associated with the operation of the PLSS pump in a deadheaded condition. P-3

During PLSS sublimator operations, the pump may be cycled off for a period not to exceed 10 minutes without suffering degradation to the liquid transport loop (freezeup).

The pump performance (ΔP) and PLSS internal resistance are the two parameters which control the PLSS liquid transport loop pressure rise. The minimum allowable performance (pressure drop) is 1.9 psid at 3.7 lbs/min (including a 0.53 psi pressure drop from the PGA multiple water connector). P-5

SB NO. PLSS 13-4

S/C: EMU
DATE: 2/25/70
REV: PCN-5
ORIGINATOR: J. A. Joki
APPROVAL: R. J. Carlton

TITLE: FAN/MOTOR ASSEMBLY

REFERENCES: SVHS 3273A; 3218A
SVHSER 4865; 5207

BACKGROUND: The fan/motor assembly supplies the pressure rise required to circulate oxygen between the PLSS and the PGA for proper ventilation. The assembly consists of a volute and impeller assembly, and a water cooled inductive inverter type brushless dc motor.

A. Motor

The principle of operation of this motor is identical to the conventional rotor/stator dc motor. A torque is produced when the rotor and stator assemblies generate two electromagnetic fields with a relative angle between them. The commutation operation is derived by a switching function that changes motor polarity by reversing electromagnetic fields.

The motor and its electrical circuits (printed circuit board) are sealed off from the oxygen ventilation loop by epoxy potting to reduce the possibility of condensation entering the electronics and shorting electrical components. These circuits provide directional starting and speed control.

In the starting mode (current spike of 5.75 amps), the electrical circuit phase 2 switching transistors generate an approximate square wave, producing a motor operating frequency of 80 to 120 Hz. Auxiliary windings of the directional starting circuit provide additional induction during startup and prevent the impeller from rotating in the reverse direction. A high-speed switching diode limits fan startup transient voltages between -2.25 Vdc and +25 Vdc, providing PLSS EMI protection. P-5 P-3 P-5

Two seconds after startup, the phase 1 (normal operating phase) switching transistors increase the motor operating frequency to 200 to 300 Hz. After 8 to 10 seconds, the starting circuit provides an RC timing pulse to switch the directional starting circuitry off (auxiliary windings). After 15 to 30 seconds, the motor is operating at full speed at 350 Hz on both phase 1 and 2 windings. The speed control circuitry utilizes phase drive feedback to the phase 1 and 2 windings to compensate for any changes in loading.

A degradation in the speed control circuit will manifest itself by higher power consumption, lower running speed under load, and overheating of components. The bias level of switching transistors will be decreased, and phase 1 windings (normal operating phase) will not share the motor load equally with phase 2 windings.

The failure to switch off the starting circuit results in the motor operating at a lower speed and higher power consumption (i.e., 10,000 to 12,000 vs 18,000 rpm and 3.0 to 3.5 vs 1.3 amps). Phase 2 windings and the auxiliary windings will carry the entire load, eventually overheating. P-5

A loss of the directional starting circuit results in the possibility of the motor starting in reverse direction (1.8 inches of H_2O vs 4.9 inches of H_2O).

The motor performance is dependent upon the loading (in-oz) and operating voltage level. The motor speed becomes unstable at the breakover point, approximately 0.9 in-oz at 15.7 Vdc. The operation of the motor in an environment of higher density results in a proportionally higher power consumption.

This motor is capable of being operated without cooling indefinitely without suffering degraded operation.

A short or open in either rotor or stator windings will render the motor inoperative.

Bearing stiction, high breakaway torque attributed to the lubricant, increases power consumption and reduces fan efficiency. Rotor stall current is 3.75 amps. P-5

Volute and Impeller Assembly

The fan performance (ΔP) and PLSS internal resistance are the two parameters which control the PLSS oxygen ventilation loop pressure rise. The maximum pressure rise (deadheading) corresponds to the minimum volumetric flow. This condition of no flow results in low torque and current loading and high rpm. The fan can operate deadheaded with no time limit, and with oxygen ventilation loop pressure up to 12 psia. A minimum pressure rise corresponds to maximum volumetric flow. This condition of maximum mass flow results in high torque and current loading and low rpm.

To satisfy proper PLSS CO_2 washout and ventilation, the following design performance criteria have been identified for the fan, motor, and PLSS.

The minimum requirement for fan performance under dry conditions (sublimator and LiOH cartridge not functioning) is a 1.046 pressure ratio at 0.472 lbs/min corrected weight flow (equivalent to 4.98 inches of H_2O at 5.5 acfm at 17 Vdc). The minimum requirement for motor performance is 18,000 rpm at 0.635 in-oz at 15.7 Vdc. The minimum PLSS performance requirement for a dry system is 2.85 inches of H_2O at 5.5 acfm. P-5 P-5

The PLSS wet condition performance requires a minimum of 1.82 inches of H_2O at 6.0 acfm (1.5 inches of H_2O plus an additional 0.32 inches of H_2O resulting from the PLSS gas connector's internal check valves).

The fan/motor assembly has successfully been subjected to water injection without suffering any degradation.

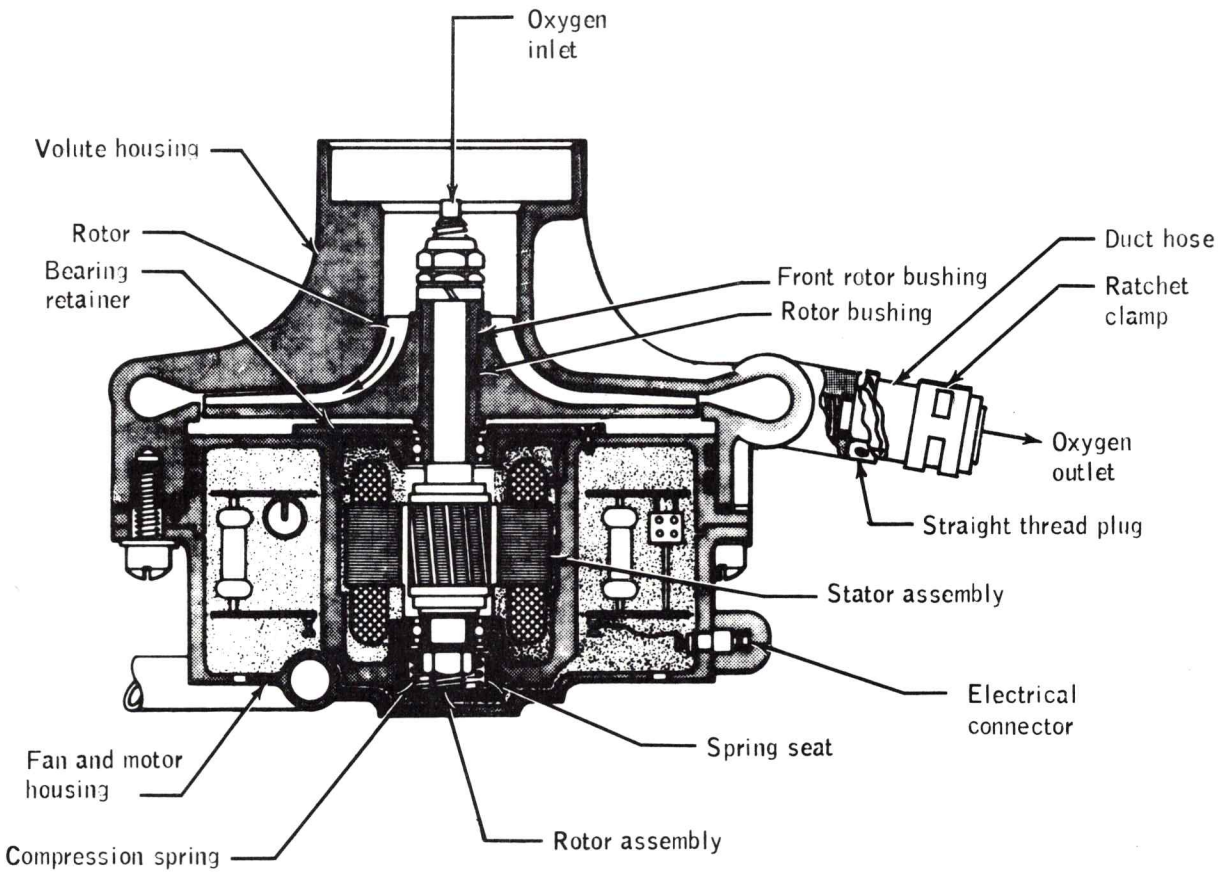

Figure 13-4a. - Fan/motor assembly.

SB NO. PLSS 13-5

S/C: EMU
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: W. Bates
APPROVAL:

TITLE: PLSS BATTERY

REFERENCES: SVHS 4968
SVHSER 5719

BACKGROUND: The PLSS battery, consisting of 11 series connected cells with approximately 1.53 Vdc per cell, will deliver 16.8 ± 0.8 Vdc. For 20.5 Vdc, each cell's potential will be 1.86 Vdc. Each cell, as well as the battery case, has a relief valve. The relief and reset pressure for each cell is 4 - 25 psid. The battery case relieves at 8.0 psid max and reseats at 3.0 psid min. To maintain a proper voltage (16.8 Vdc - 1.5 Vdc = 15.3 Vdc), none of the cells can be lost. The battery can be stored 3 years as a dry-charged unit and 17 days as an activated unit. P-14

The PLSS battery was designed for a 7-hour EVA at approximately 3.5 amps or a total power capacity of 25.7 amp-hrs or 432 watt-hrs at a nominal voltage of 16.8 ± 0.8 Vdc. For mission planning a current of 2.94 amps (2.70 amp load plus 0.243 amp measurement inaccuracy) yields an 7.70 hour EVA time excluding checkout and post EVA reserve.

At hot startup, no more than 20.5 Vdc is expected, which will then rapidly decay, overshooting 16.8 Vdc but never below 16.0 Vdc. At cold startup, slower startup voltage and less overshooting is expected. The plateau voltage is between 16.6 and 17.0 Vdc for either cold or hot starts. A battery voltage below 16.0 Vdc may be experienced momentarily during the peak current load(5.75 amp) associated with fan startup. P-5

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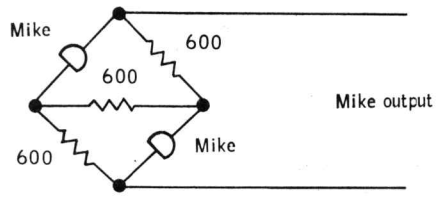
SB NO. PLSS 13-7

S/C: EMU
DATE: 11/1/70
REV: PCN-6
ORIGINATOR: W. Bates
APPROVAL:

TITLE: MICROPHONES AND EARPHONES

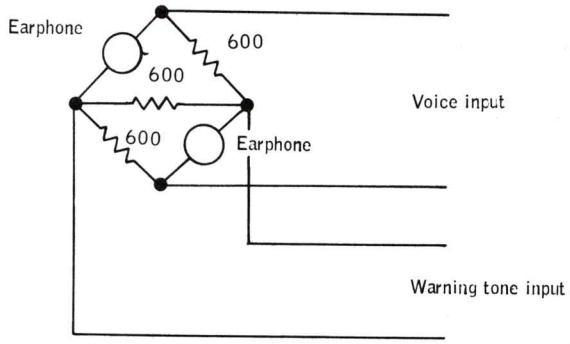
MICROPHONES

The two comm carrier microphones are hooked up in a bridge configuration with three 600 ohm resistors. The bridge configuration allows one microphone to fail without complete communication failure.



In the event of a microphone failure, only a 6 db drop will be noticed. If the diagonal resistor shorts, complete failure of communications occurs. But if the diagonal resistor opens, no effect will be noticed. With either one of the two leg resistors open, a 3 db drop will be noticed because the two microphones will be in series with each other.

The two comm carrier earphones are hooked up in a bridge configuration with three 600-ohm resistors. The bridge configuration allows one earphone to fail without complete communication failure. P-6



If the diagonal resistor shorts, complete failure of communications occur. But if the diagonal resistor opens, there will be a 3 db drop. With either one of the two leg resistors open, loss in the redundancy of the warning tones occur. If either one of the two leg resistors shortens, however, an increase in the audio output can be noticed.

*

SB NO. PLSS 13-8

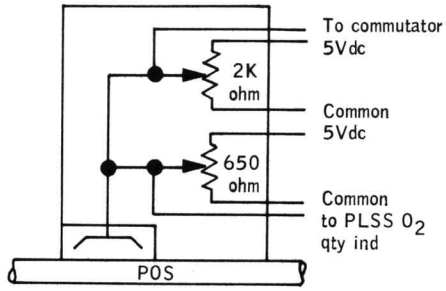
S/C: EMU
DATE: 10-1-72
REV: PCN-14
ORIGINATOR: W. Bates
APPROVAL: R. M. Merritt

TITLE: INSTRUMENTATION

BACKGROUND: A. Transducers

1. PLSS O_2 Press (GT8182P/GT8282P) P-11

The PLSS O_2 pressure transducer is a Bourdon tube pressure sensor that is mechanically coupled to the wiper contacts of two separate potentiometers. The 2 k ohm potentiometer provides a 0 to 5 Vdc input to the telemetry channel. The 650 ohm potentiometer drives the PLSS O_2 quantity indicator.



The transducer's characteristics are:

a. Range: 0 to 1500 psia when excited by 0 to 5 Vdc P-11

b. Power: approximately 0.05 watts

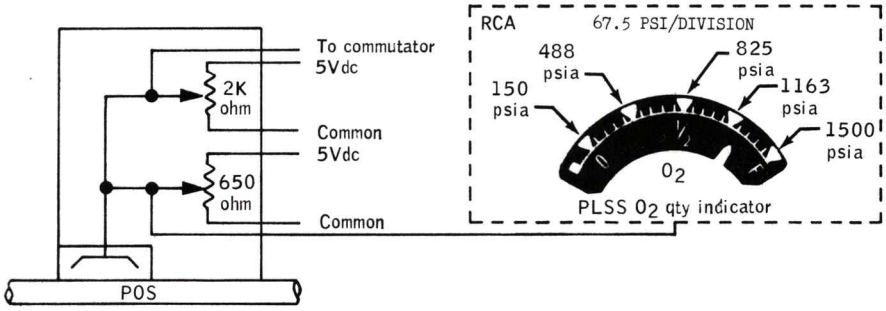
c. Weight: 0.34 pounds

d. Location: between the primary O_2 bottle and the primary O_2 shutoff valve

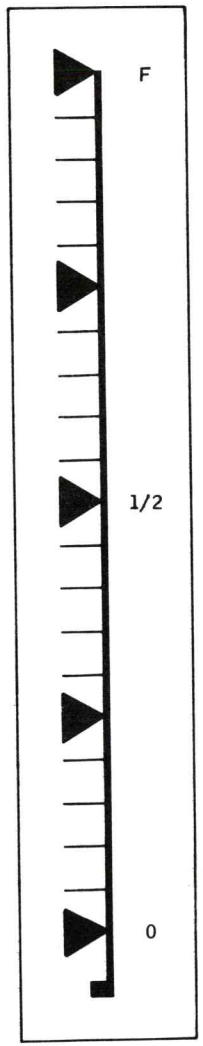
e. Source: 5 Vdc

2. PLSS O_2 Quantity Indicator (See Table I)

The output from the PLSS O_2 pressure transducer's 650 ohm potentiometer drives the PLSS O_2 quantity indicator. The indicator is a dc milliampere meter using the D'arsonval movement. The PLSS O_2 quantity indicator is astronaut monitored. It is mounted on the remote control unit (RCU) and provides a visual indication of the O_2 quantity remaining in the primary O_2 bottle.



P-11



100 %	1500 PSIA
95 %	1433 PSIA
90 %	1365 PSIA
85 %	1298 PSIA
80 %	1230 PSIA
75 %	1163 PSIA
70 %	1095 PSIA
65 %	1028 PSIA
60 %	960 PSIA
55 %	893 PSIA
50 %	825 PSIA
45 %	758 PSIA
40 %	690 PSIA
35 %	623 PSIA
30 %	555 PSIA
25 %	488 PSIA
20 %	420 PSIA
15 %	353 PSIA
10 %	285 PSIA
5 %	218 PSIA
0 %	150 PSIA

TABLE I. - PLSS O_2 QUANTITY INDICATOR

1%	164 PSIA	36%	636 PSIA	71%	1109 PSIA
2%	177 PSIA	37%	650 PSIA	72%	1122 PSIA
3%	191 PSIA	38%	663 PSIA	73%	1136 PSIA
4%	204 PSIA	39%	677 PSIA	74%	1149 PSIA
5%	218 PSIA	40%	690 PSIA	75%	1163 PSIA
6%	231 PSIA	41%	704 PSIA	76%	1176 PSIA
7%	245 PSIA	42%	717 PSIA	77%	1190 PSIA
8%	258 PSIA	43%	731 PSIA	78%	1203 PSIA
9%	272 PSIA	44%	744 PSIA	79%	1217 PSIA
10%	285 PSIA	45%	758 PSIA	80%	1230 PSIA
11%	299 PSIA	46%	771 PSIA	81%	1244 PSIA
12%	312 PSIA	47%	785 PSIA	82%	1257 PSIA
13%	326 PSIA	48%	798 PSIA	83%	1271 PSIA
14%	339 PSIA	49%	812 PSIA	84%	1284 PSIA
15%	353 PSIA	50%	825 PSIA	85%	1298 PSIA
16%	366 PSIA	51%	839 PSIA	86%	1311 PSIA
17%	380 PSIA	52%	852 PSIA	87%	1325 PSIA
18%	393 PSIA	53%	866 PSIA	88%	1338 PSIA
19%	407 PSIA	54%	879 PSIA	89%	1352 PSIA
20%	420 PSIA	55%	893 PSIA	90%	1365 PSIA
21%	434 PSIA	56%	906 PSIA	91%	1379 PSIA
22%	447 PSIA	57%	920 PSIA	92%	1392 PSIA
23%	461 PSIA	58%	933 PSIA	93%	1406 PSIA
24%	474 PSIA	59%	947 PSIA	94%	1419 PSIA
25%	488 PSIA	60%	960 PSIA	95%	1433 PSIA
26%	501 PSIA	61%	974 PSIA	96%	1446 PSIA
27%	515 PSIA	62%	987 PSIA	97%	1460 PSIA
28%	528 PSIA	63%	1001 PSIA	98%	1473 PSIA
29%	542 PSIA	64%	1014 PSIA	99%	1487 PSIA
30%	555 PSIA	65%	1028 PSIA	100%	1500 PSIA
31%	569 PSIA	66%	1041 PSIA	0%	150 PSIA
32%	582 PSIA	67%	1055 PSIA		
33%	596 PSIA	68%	1068 PSIA		
34%	609 PSIA	69%	1082 PSIA		
35%	623 PSIA	70%	1095 PSIA		

The indicator's characteristics are:

a. Range: 0 to full (150 to 1500 psia) |P-11

b. Pointer deflection: 100° rotation

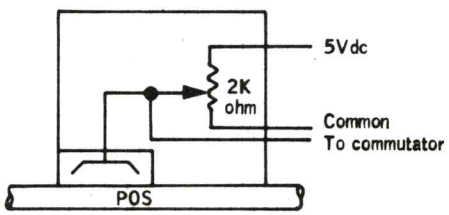
c. Response time: 63 percent of full scale in 2 seconds

d. Location: on RCU

e. Source: 5 Vdc

3. PGA Press (GT8168P/GT8268P)

The PGA pressure transducer's linear resistive potentiometer is varied by a pressure sensing element. The transducer senses differential pressure. A 0 to 5 Vdc output signal, for a 2.5 to 5 psid input pressure, is applied to the telemetry commutator.



The transducer's characteristics are:

a. Weight: approximately 0.16 pounds |P-11

b. Power: approximately 0.05 watts

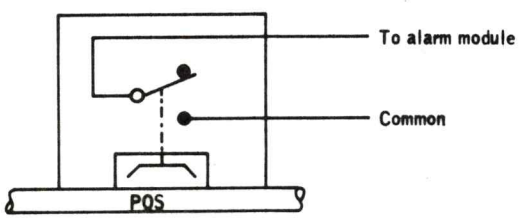
c. Range: 2.5 to 5.0 psid

d. Location: between the low PGA pressure transducer and the interface with the 0_2 ventilation loop

e. Source: 5 Vdc

4. Low PGA Press

The low PGA pressure transducer contains differential pressure sensing element and an SPST switch. The switch closes at 3.4 to 3.10 psid giving the astronaut a 1.5 kHz tone and flag indicator. |P-11



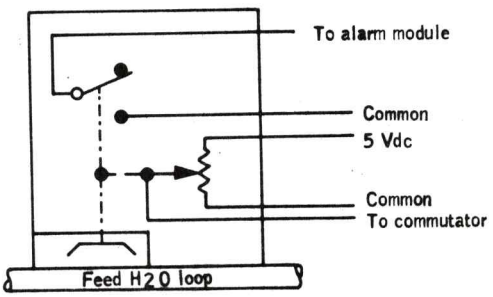
The transducer's characteristics are:

a. Weight: approximately 0.16 pounds |P-11

b. Location: between the high 0_2 flow sensor and the PGA press transducer

5. Feedwater Press (GT8110P/GT8210P) and Low Feedwater Press

The feedwater pressure transducer senses the pressure in the feedwater loop; the pressure actuates a 2 k ohm potentiometer, which produces a 0 to 5 Vdc output signal for a 0 to 5 psia input pressure. The output signal is then applied to the TM commutator. The low feedwater pressure switch actuates at 1.2 to 1.7 psia. P-8

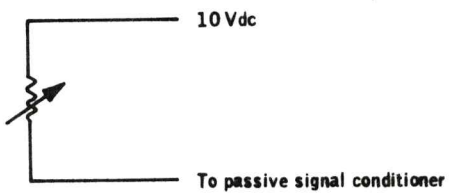


The transducer's characteristics are:

a. Weight: approximately 0.36 pounds
b. Range: 0 to 5 psia
c. Source: 5 Vdc from regulator B
d. Location: between the feedwater flow limiter and the sublimator

6. Subl O_2 Out Temp (GT8170T/GT8270T)

The sublimator O_2 outlet temperature transducer is a resistance temperature sensing element (thermistor) whose resistance varies logarithmically with temperature. Using this transducer, the sublimator performance can be determined. The output is fed through a passive signal conditioner. The 0 to 5 Vdc signal from the signal conditioner, representing -4 to 90°F, is applied to the telemetry commutator. P-11

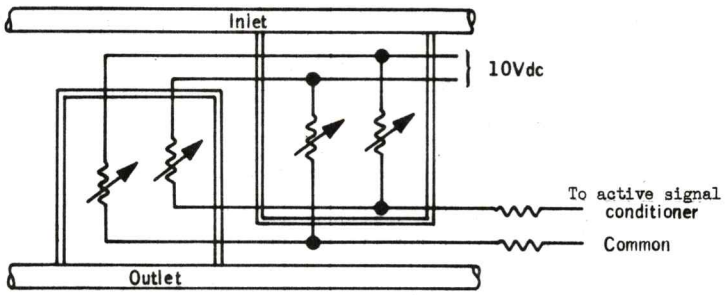


The transducer's characteristics are: P-11

a. Range: -4 to 90°F
b. Source: 10 Vdc
c. Power: approximately 0.7 milliwatts
d. Weight: approximately 0.1 pounds
e. Location: between the sublimator and the fan/motor assembly

7. LCG H_2O ΔT (GT8196T/GT8296T)

The LCG H_2O ΔT transducer consists of four resistance temperature elements. Two sense the inlet temperature, and two the outlet temperature. When all four sensing elements are connected, they form a bridge network which is connected to an active signal conditioner. A 0 to 5 Vdc signal from the signal conditioner, representing 0 to 15°F, is applied to the telemetry commutator. P-6



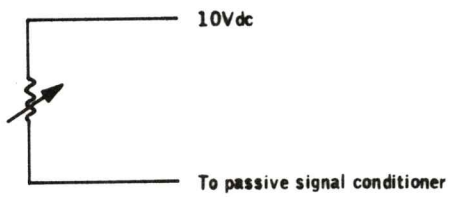
P-11

The transducer's characteristics are:

a. Range: 0 to 15°F
b. Source: 10 Vdc
c. Weight: approximately 0.3 pounds
d. Power: approximately 10 milliwatts
e. Location: inlet and outlet of the liquid transport loop

8. LCG H_2O Temp (GT8154T/GT8254T)

The LCG water inlet temperature transducer is a resistance temperature sensing element (thermistor) whose resistance varies logarithmically with temperature. Using the inlet temperature transducer in conjunction with the delta temperature transducer, the astronaut's metabolic rate and the PLSS performance can be determined. The output is fed through a passive signal conditioner. The 0 to 5 Vdc signal from the signal conditioner, representing -4 to 90°F, is applied to the telemetry commutator. P-11

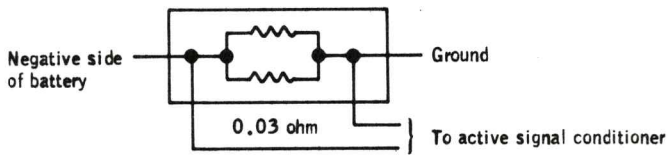


The transducer's characteristics are:

a. Range: 40 to 90°F
b. Source: 10 Vdc
c. Power: approximately 0.7 milliwatts
d. Weight: approximately 0.3 pounds P-11
e. Location: between the H_2O diverter valve and the PLSS multiple water connector

9. PLSS Bat Cur (GT8140C/GT8240C)

The battery current transducer consists of two precision nichrome resistors in parallel. The total resistance of 0.03 ohm ± 1 percent produces a 0 to 300 millivolt output over a 0 to 10 amp current range. The transducer output is fed into an active signal conditioner. The output out of the signal conditioner is in the 0 to 5 Vdc range which is applied to the telemetry commutator.



The transducer's characteristics are:

a. Weight: 0.022 pounds
b. Power (maximum): 3 watts
c. Power (nominal): approximately 0.25 watts
d. Range: 0 to 10 amps
e. Location: on terminal box A-1

10. PLSS CO_2 PP (GT8175P/GT8275P) P-6

The CO_2 sensor consists of a mechanical housing containing the electronics and sensing elements. The housing also provides attachment points to mount on the PLSS and connect the gas lines. The P-11 sensing element and preamplifier may be calibrated or removed and reinstalled without removing the sensor assembly from the PLSS.

The sensing element is basically a pH sensing assembly consisting of a glass electrode immersed in an electrolyte contained by a semipermeable membrane. The pH of the sensing element is a function of the partial pressure of CO_2. The change in pH as a result of the change in hydrogen ion concentration is detected as a change in potential between two electrodes, one of which is a glass capsule containing an electrolyte at a fixed pH.

The electronics consists of a preamplifier which is permanently coupled to the sensing element to form the replaceable portion of the sensor. The preamplifier feeds into a buffer amplifier which provides a 0 to 5 Vdc telemetry output. The circuit also includes a dc to dc converter and a voltage regulator to control power to the preamp and buffer amplifier. P-11

The transducer's characteristics are:

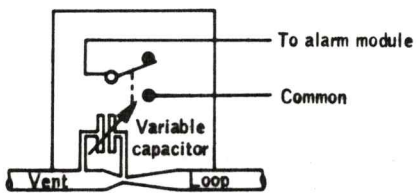
a. Storage life: 1 year
b. Operational life (protective cap removed): 1000 hours
c. Range: 0.1 to 30 mm Hg partial pressure CO_2
d. Output: 0 to 5 Vdc, proportional to the $\log_{10}$ P CO_2 P-11

e. Temperature range: 35°F to 120°F
f. Power: 1 watt
g. Source: 10 Vdc
h. Weight: 1.3 pounds
i. Total pressure range: 10^{-4} to 21 psia (Note: may not be subjected to vacuum for more than one hour cumulative.)
j. Location: A bypass line containing the sensor is tied into a point upstream of the fan and upstream of the checkvalve.

11. Low Vent Flow

The low vent flow sensor consists of a calibrated low loss venturi flow tube and a variable capacitance differential pressure sensor. As the capacitance of the sensors is varied with the flow rate through the venturi, the switch closes when the flow rate falls below 5.3 to 4.0 acfm. This actuates the 1.5 kHz warble tone for 10 seconds and the flag on the RCU (remote control unit) is activated while the switch is closed. P-11

The low vent flow sensor is sensitive to humidity, pressure, and voltage. With a pressure increase due to bending of the arms, et cetera, the flow will decrease, actuating the tone. This problem has been solved by a 5-second delay in the time delay module. Humidity and the decrease in voltage still affect the sensor. Abnormal LM environment or PLSS operation causes the actuation band to shift to 3.5 to 5.4 acfm. For a 1-volt decrease, there is a 0.1 to 0.2 acfm decrease in ventilation flow rate and an 0.07acfm upward shift for the sensor's switch point. (See Note 1. Page III-13-36) P-11



The transducer's characteristics are:
a. Weight: approximately 1 pound maximum
b. Range: 4.0 to 5.3 cfm actuation band
c. Source: 16.8 Vdc
d. Location: between the fan/motor assembly and the primary O_2 line

12. High O_2 Flow

The high O_2 flow circuit operates on the "Hot Wire Anemometer" principle. Two thermistors are installed at different points in the O_2 flow path. The downstream thermistor is heated by an electric heater whose current is controlled by the temperature difference between the two thermistors, a bridge circuit, and a heater driver. The heated downstream thermistor (hot wire equivalent) is mounted in the O_2 line where the O_2 flow velocity (rate) can exert the maximum temperature change effect. However, the upstream thermistor is installed in the O_2 tubing wall where it reflects the gas temperature flowing in the line. The closed loop circuit,

from thermistors to heater, maintains a preset temperature differential of 1°C. A change in O_2 flow rate creates a temperature differential greater than 1°C and unbalances the bridge circuit. The bridge unbalance generates an error signal that is applied to a differential amplifier, is amplified by two additional stages, and finally governs the downstream heater current. As the oxygen flow increases, the differential temperature causes the heater current to increase. When the heater current reaches a predetermined value, equivalent to a 0.5 to 0.65 lb/hr flow rate, a flow level detector causes a transistor switch to close. The signal generated from the switch closure is applied to the alarm module after passing through the 5-second time delay module. This activates the 1.5 kHz alarm generator and flag, which alerts the astronaut to a hazardous condition. (See Note 1. Page III-13-36) P-11

The transducer's characteristics are:

a. Regulator: a precision, temperature compensated, zener-referenced regulator provides the voltage for all stages.
b. Transistor switch: CLOSED = 100 ohms maximum
c. Impedance: OPEN = 100,000 ohms minimum
d. Power consumption: OPEN = 0.1 watt CLOSED = 0.41 watt
e. Weight: 0.56 pounds P-11
f. Source: 16.8 Vdc
g. Location: between the primary O_2 pressure regulator and the low PGA pressure transducer

B. Transducer Excitation

1. Regulators provide precise excitation voltage to signal transducers by compensating for variations in line voltage, temperature, and load. The regulators in the PLSS/EVCS (extravehicular communications system) are series-shunt types consisting of integrated circuit operational amplifiers, temperature compensated zener diode references, and series transistors. A total of five transducer regulators are used in the EVCS with three different output ratings:
   a. Three 5-volt at 25 mA
   b. One 10-volt at 50 mA
   c. One 10-volt at 200 mA: this unit has an additional pass transistor which shares the load current and increases the reliability.
2. The regulator design includes the following:
   a. Overload protection
   b. Temperature compensation
   c. Short circuit protection
   d. An idling current of 2 mA nominal
3. Specifications of the three regulator types are listed below:
   a. 5-volt regulator (25 mA)
      (1) Output voltage: +5 ± 0.5 percent
      (2) Regulation: ± 25 millivolts over the line voltage input range
      (3) Temperature stability: ± 0.005 percent per deg F
      (4) Output current: 0 to 25 mA rating
      (5) Ripple: 15 millivolts peak to peak
      (6) Overload protected to limit current to less than three times rated load (75 mA)
   b. 10-volt regulator (50 mA)
      (1) Output voltage: + 10 ± 0.25 percent
      (2) Temperature stability: ± 0.005 percent per deg F
      (3) Output current: 0 to 50 mA rating
      (4) Overload protected to limit current to less than three times rated load (150 mA)
   c. 10-volt (200 mA)
      (1) Output voltage: + 10 ± 0.25 percent
      (2) Regulation: ± 25 millivolts over the line voltage input range
      (3) Temperature stability: ± 0.005 percent per deg F
      (4) Output current: 0 to 200 mA rating
      (5) Ripple: 25 millivolts peak to peak
      (6) Overload protected to limit current to less than three times rated load (600 mA)

4. The five regulators are designated A, B, C, D, and E. Transducer assignments are as follows:
   a. A - 5.0 volts at 25 mA
      PGA Press GT8168P/GT8268P
   b. B - 5.0 volts at 25 mA
      (1) PLSS O_2 Press GT8182P/GT8282P
      (2) Feed H_2O Press GT8110P/GT8210P
   c. C - 10.0 volts at 50 mA
      LCG H_2O ΔT GT8196T/GT8296T
   d. D - 5.0 volts at 25 mA
      Primary O_2 Quantity Indicator (meter)
   e. E - 10.0 volts at 200 mA
      (1) Subl O_2 Out Temp GT8170T/GT8270T
      (2) LCG H_2O Temp GT8154T/GT8254T
      (3) PLSS CO_2 PP GT8175P/GT8275P

C. Signal Conditioning

1. Some PLSS/TM transducers require signal conditioning before they are fed into the TM commutator. Two methods are used: active conditioning and passive conditioning.
   a. Active signal conditioning is used for low level signals to provide the amplification necessary for deviating the VCO's (voltage controlled oscillators) 0 to 5 volts. The battery current measurement (GT8140C/GT8240C) and the LCG H_2O delta temperature (GT8196T/GT8296T) require active signal conditioning. The battery current conditioning is provided by a simple, single ended, operational amplifier with a gain of 16.67 and an input impedance of 6 k ohms. The LCG H_2O delta temperature requires a differential input amplifier with a gain of 167.
      (1) The battery current signal conditioner's characteristics are:

(a)	Input signal	0 to 300 mV single ended and referenced to ground
(b)	Output signal	0 to 5 V $\pm$ 25 mV
(c)	Input impedance	6 k ohms $\pm$ 10 percent
(d)	Output impedance	Less than 1 k ohm
(e)	Offset	Less than 25 mV
(f)	Temperature stability	Offset - less than 25 mV change over the temperature range of 20° to 140°F. Gain change less than 1 percent over the same temperature range.
(g)	Power	-7 to -10 volts at 3 mA +7 to +10 volts at 3 mA

      (2) The LCG H_2O delta temperature signal conditioner's characteristics are:

(a)	Input signal	0 to 30 mV differential
(b)	Output signal	0 to 5 V $\pm$ 25 mV
(c)	Offset signal	Less than 25 mV
(d)	Input impedance	Greater than 900 k ohms
(e)	Output impedance	Less than 1 k ohm
(f)	DC common mode	50,000 to 1 minimum at 5 volts
(g)	Temperature stability	Offset - less than 25 mV change over the temperature range of +20° to +140°F. Gain change less than 1 percent over the above temperature change.

   b. Passive signal conditioning consists primarily of resistive elements. The signals conditioned are greater than 5 volts and require reduction to within the 0 to 5 volt range for driving the VCO's. The transducers involved are Bat Volt (GT8141V/GT8241V), LCG H_2O Temp (GT8154T/GT8254T) and Subl O_2 Out Temp (GT8170T/GT8270T). The important facts about the passive signal conditioning are outlined below:

(1) Thermistors: The LCG H_2O In Temp (GT8154T/GT8254T) and the Subl O_2 Out Temp (GT8170T/GT8270T) thermistor sensors are the most complex of the passive signal conditioning circuits since each measurement requires linearization and reduction in order to obtain the proper output voltage. In addition, the linearizing and voltage dropping circuits increase the output impedance to 63 k ohms.

(2) External resistors: The PLSS O_2 quantity indicator (meter) uses a 4,840 ohm ± 0.25 percent precision metal film resistor to set the meter full scale range to 1.0 mA.

(3) Current limiting resistors: The LCG H_2O Delta Temp (GT8196T/GT8296T) differential bridge uses a 4,430 ohm ± 0.25 percent precision metal film resistor in each leg to limit the bridge current to 1.0 mA, which increases the bridge sensitivity.

(4) Zener diode buffer: The PLSS Bat Volt (GT8141V/GT8241V) measurement is accomplished with a 12-volt zener diode to reduce the line voltage in order to increase the measurement sensitivity. Use of the temperature compensated zener (0.01 percent per degree centigrade) increases the measurement resolution approximately 2.5 to 1 over the pure resistive voltage divider. The 40 cps ripple generated by the positive displacement pump will result in a noisy telemetry readout.

D. Voltage Controlled Oscillators (VCO)

1. Two VCO's are used in each EVCS (extravehicular communications system) to provide the analog FM subcarrier requirements. Standard IRIG frequencies are used which cover channels 9, 10, 11, and 12. The channel assignments are as follows:

EVC-1 Channel 10 (5.4 kHz) - deviation = ±7.5 percent; GT8124J PLSS 1 EKG
Channel 12 (10.5 kHz) - deviation = ±7.5 percent; PLSS 1 PAM data

EVC-2 Channel 9 (3.9 kHz) - deviation = ±7.5 percent; GT8224J PLSS 2 EKG
Channel 11 (7.35 kHz) - deviation = ±7.5 percent; PLSS 2 PAM data

2. Each VCO consists of three basic blocks: regulator, frequency generator (multivibrator), and a band limiter (active filter).

a. Regulator - The regulator is an integrated circuit, temperature compensated, zener-shunt type which provides 0.33 percent dBW line voltage stability to the VCO and B+ line voltage isolation.

b. Frequency generator - The frequency generator is a multivibrator which uses a hybrid module and discrete components for timing and temperature compensation (NPO capacitors and metal film resistors).

c. Filter - The filter is an active low-pass and notch combination unit which provides 20 dB rejection for the second harmonic, 36 dB for the third harmonic, and 40 dB for all other harmonics.

d. VCO characteristics are:

(1) Input impedance: 750 k ohms.

(2) Source impedance sensitivity: Less than ±1 percent of bandwidth change in zero input frequency with a source impedance change from short circuit to open circuit.

(3) Linearity: Within 0.15 percent of bandwidth from the best straight line.

(4) Output impedance: 1 k ohm nominal.

(5) Output voltage: Minimum of 3.0 volts peak to peak into a 10 k load (min).

(6) Subcarrier distortion: Less than 1 percent at any frequency in the band.

(7) Amplitude distortion: Less than 5 percent.

(8) Temperature stability: Maximum of ±1 percent dBW change in frequency from 20° to 140°F with 75°F as ambient reference.

(9) Sensitivity stability - Less than 1 percent dBW change over the temperature range of 20°F to 140°F.

(10) B+ stability: (system power 14.5 to 20.5 volts) Frequency is stable within 0.33 percent dBW over the above voltage range. The VCO operates on 9.9 to 10.1 volts from the regulator.

(11) Controls: None. Output frequency and sensitivity are preset with fixed resistors to within ±1 percent dBW of IRIG.

(12) Power: 6 mA nominal.

E. EVCS Commutator (See Figure 13-8a)

The EVCS commutator is an IRIG PAM solid state multiplexer which provides 30 samples 1-1/2 times per second by acting as an electronic switching device with a common "OR" gate output. A series of "AND" gates, activated by an electronic clock and digital counter, feeds the common "OR" gate output. All input gates, counters, and decoders are MOSFET integrated circuits. Basically, the commutator consists of a power supply, clock, counters, decoders, analog gates, and an output format unit.

The power supply is composed of regulators and a dc to dc converter. The following voltages are provided by the power supply:

1. -1 Vdc to pedestal
2. -8 Vdc to logic circuitry
3. -16 Vdc to counter
4. +3 Vdc to logic circuitry
5. +5 Vdc to synch and cal level for channel 2
6. +6 Vdc to clock
7. +10 Vdc to VCO (7.35 or 10.5 kHz)

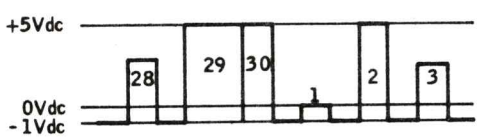
In addition to the prime function of line voltage regulation, a preregulator serves as an input line noise filter and prevents the dc to dc converter noise from entering the 16.8 Vdc line. This input voltage reduction improves the output regulation. P-8

The clock is a hybrid multivibrator whose frequency is preset by fixed resistors and temperature compensated with diodes. The sampling rate provided by the clock is 45 samples per second.

The counters count the clock pulses in binary coded decimal (BCD). The first counter counts to 10 and the carry is counted up to 3 in the second counter for a total count of 30 (3 x 10 = 30). The counters then reset to "0" for the next cycle. Outputs of the counters are fed to the decoders, which are binary coded decimal-to-decimal converters. The outputs of the first counter are decoded into 10 signals and the outputs of the second counter are decoded into 3 signals. Both decoder outputs are connected to analog gates and are used to switch the analog inputs. Both decoder outputs are combined to form the output signal format.

The analog gates are MOSFET devices which provide low "ON" resistance and low leakage and require decoded BCD signals for activation. With any input signal in excess of 167 percent, the analog gates are overdriven, causing other TM readings to shift.

The commutator output format is a 50-50 duty cycle continuous wavetrain signal with a negative 1-volt pedestal. The signal is generated by a chopper type switch which is driven by the clock negative phase. The synch signal of one and one-half channels "ON" and one-half channel "OFF" is derived by decoding channel 29 and by-passing the 50-50 duty cycle switch.



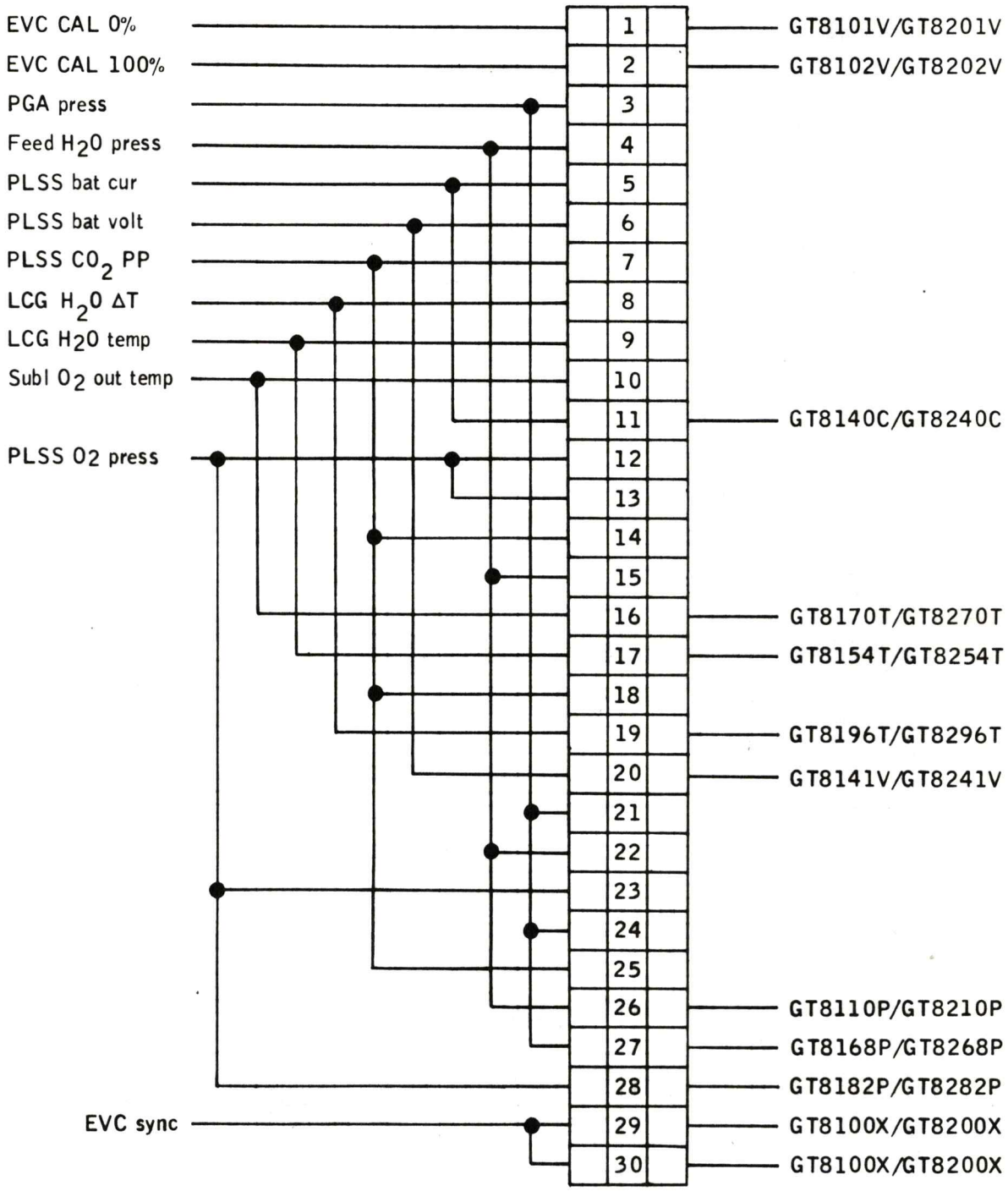


Figure 13-8a. - PLSS/EVCS commutator channel selection.

TABLE II.- HSD TM AND MCC PCMGS ANALOG FORMAT SELECTION

A. MSFN HSD FORMATS

MEAS NO.	SHORT TITLE	CHANNEL LOADING		FM 4	FM 5	FM 6	FM 10
		IRIG	PAM				
GT8100X	EVC SYNC	12	(29), (30)	---	---	---	---
GT8101V	EVC CAL 0 VDC	12	(1)	0.1	0.1	0.1	1.0
GT8102V	EVC CAL 5 VDC	12	(2)	0.1	0.1	0.1	1.0
GT8110P	FEED H_2O PRESS	12	4,15,22, (26)	0.5	1.0	0.5	1.0
GT8124J	PLSS EKG	10	---	---	---	---	---
GT8140C	PLSS BAT CUR	12	5, (11)	1.0	1.0	1.0	1.0
GT8141V	PLSS BAT VOLT	12	6, (20)	0.2	0.5	0.2	1.0
GT8154T	LCG H_2O IN TEMP	12	9, (17)	0.5	1.0	0.2	1.0
GT8168P	PGA PRESS	12	3, 21,24, (27)	1.0	1.0	1.0	1.0
GT8170T	SUBL O_2 OUT TEMP	12	10, (16)	0.2	0.5	0.1	1.0
GT8175P	PLSS CO_2 PP	12	7, 14, 18, (25)	0.1	0.1	0.1	1.0
GT8182P	PLSS O_2 PRESS	12	12,13, 23, (28)	0.2	0.5	0.2	1.0
GT8196T	LCG H_2O ΔT	12	8, (19)	0.5	1.0	0.5	1.0
GT8200X	EVC SYNC	11	(29), (30)	---	---	---	---
GT8201V	EVC CAL 0 VDC	11	(1)	0.1	0.1	0.1	1.0
GT8202V	EVC CAL 5 VDC	11	(2)	0.1	0.1	0.1	1.0
GT8210P	FEED H_2O PRESS	11	4,15,22, (26)	0.5	1.0	0.5	1.0
GT8224J	PLSS EKG	9	---	---	---	---	---
GT8240C	PLSS BAT CUR	11	5, (11)	1.0	1.0	1.0	1.0
GT8241V	PLSS BAT VOLT	11	6, (20)	0.2	0.5	0.2	1.0
GT8254T	LCG H_2O IN TEMP	11	9, (17)	0.5	1.0	0.2	1.0
GT8268P	PGA PRESS	11	3, 21,24, (27)	1.0	1.0	1.0	1.0
GT8270T	SUBL O_2 OUT TEMP	11	10, (16)	0.2	0.5	0.1	1.0
GT8275P	PLSS CO_2 PP	11	7, 14, 18, (25)	0.1	0.1	0.1	1.0
GT8282P	PLSS O_2 PRESS	11	12,13, 23, (28)	0.2	0.5	0.2	1.0
GT8296T	LCG H_2O ΔT	11	8, (19)	0.5	1.0	0.5	1.0
SPC EMUST*	PLSS EVC SYNC ST	---	---	0.5	1.0	0.5	1.0

P-9

NOTE: (O) - LOADED INTO RSDP.

*(PCM DECOM SYNC) BIT 1 GT8100 BIT 5 GT8200 ("1" SYNC, "0" OUT OF SYNC)
THESE PARAMETERS MAY BE MONITORED ON D/TV PAGE MSK 1709.

B. MCC PCMGS ANALOG FORMAT

CONSOLE 34R (FORMAT 7)			CONSOLE 33R (MEDABLE FORMAT 27-B)		
PEN NO.	SHORT TITLE	MEAS NO.	PEN NO.	SHORT TITLE	MEAS NO.
1	PLSS O_2 PRESS	GT8182P	1	PLSS O_2 PRESS	GT8282P
2	PGA PRESS	GT8168P	2	PGA PRESS	GT8268P
3	FEED H_2O PRESS	GT8110P	3	FEED H_2O PRESS	GT8210P
4	LCG H_2O TEMP	GT8154T	4	LCG H_2O TEMP	GT8254T
5	LCG H_2O ΔT	GT8196T	5	LCG H_2O ΔT	GT8296T
6	SUBL O_2 OUT TEMP	GT8170T	6	SUBL O_2 OUT TEMP	GT8270T
7	PLSS BAT VOLT	GT8141V	7	PLSS BAT VOLT	GT8241V
8	PLSS BAT CUR	GT8140C	8	PLSS BAT CUR	GT8240C

P-8

P-6

Table II deleted by PCN-11

F. Alarm Indicators (Flags)

The alarm indicators provide the astronauts with a visual indication of the specific malfunction and inform them of the action to take when the warning tone is activated. The four indicators are: P-6

Malfunction	Action
H_2O (Low feedwater press)	A (abort)
O_2 (High O_2 flow)	O (actuate OPS)
Pres (Low PGA press)	O (actuate OPS)
Vent (Low vent flow)	P (actuate OPS and purge)

P-6

As the warning tone is activated, an electromagnet causes a white flag to disappear and expose a white letter (A, O, or P) on a black background. The alarm indicators are illuminated by Beta lights. Activation of the electromagnet is accomplished by a 10 Vdc signal at 80 milliamps from the alarm module. (See Note 1. Page III-13-36) P-11

G. Tone Generator

The tone generator produces a 1.5 kHz tone that is modulated at a 15 Hz rate in order to increase the tone perception. An alarm is generated when specific critical operating parameters exceed preset upper or lower limit settings, and the 10-second alarm tone in conjunction with a flag indicator alerts the astronaut to an abnormal condition and indicates which system is at fault.

The tone generator uses two IC (integrated circuit) astable multivibrators, a one-pole filter, an output driver, and an isolation transformer. Voltage regulation is not required, so the B+ (line voltage) is applied directly to the first astable 15 Hz multivibrator and the output driver stage. No power is consumed until a common ground is received from the alarm module.

When a ground is applied, the 15 Hz astable multivibrator generates a 15 Hz square wave (7.5 to 11.0 volts.) that is used as B+ for the 1.5 kHz astable multivibrator whose output is fed through a one-pole RC (resistor-capacitor) filter. The filter eliminates the square wave's sharp leading and trailing edges, provides a 6 dB per octave response, and a 3 dB attenuation at 2.0 kHz. The filtered output is applied to an FET (field effect transistor) source follower and through the output transformer which provides an isolated balanced output to a 300 ohm load. The alarm tone generator characteristics are:

1. Frequency: 1.5 kHz ±3 percent. P-6
2. Modulation: Amplitude modulated at least 90 percent at a frequency of 15 ± 3 Hz.
3. Control: Activated by a remote switch closure impedance of 250 ohms maximum with a 10 mA current referenced to the system common; deactivated when the remote switch impedance is 0.1 megohm or greater at 20.5 Vdc referenced to the system common.
4. Adjustments: None. The frequency and output amplitude are controlled by fixed resistors. P-6
5. Output impedance: Transformer isolated with 300 ohm output impedance.
6. Output level: 2 ± 0.5 milliwatts into a 300 ohm balanced load.

H. Alarm Module

The alarm module triggers the warning tone generator through a common line output and drives 4 FLAG type warning indicators through separate output lines. A solid state five input "OR" gate provides a 10 ± 2 second -10 Vdc pulse to virtual ground in order to activate the warning tone generator for the same time span when any of four critical limit settings have been exceeded: Low PGA Pressure; Low Vent Flow; High O_2 Flow; or Low Feedwater Pressure. (See Note 1. Page III-13-36) P-11

In addition to triggering the warning tone, the "OR" gate provides separate output lines to the four warning indicator drivers. The indicator remains energized while the malfunction exists. P-6
Should a second malfunction occur while the common line is active, the indicator associated with the second malfunction will be energized but the timed warning tone will not be affected. P-6
A change in position of the mode selector switch with a fault present results in the reinitiation of the common output and warning tone on the Low Vent Flow, High O_2 Flow and Low Feedwater Pressure inputs. This characteristic is not true of the Low PGA Pressure input. P-11

The alarm module's characteristics are:

1. Power: 15 to 21 Vdc; input current <50 mA quiescent over a temperature range of $0^{\circ}F$ to $140^{\circ}F$ over the supply voltage range under nominal input/output loading conditions.
2. Current: <300 mA under nominal loads for all states of activation.
3. Inputs: Five Channels:
   a. Channel 1 - contact type closure: CLOSED <10 ohms to input signal common; OPEN >100 k ohms to input signal common.
   b. Channel 2 - same as Channel 1.
   c. Channel 3 - NPN grounded emitter transistor switch: CLOSED <150 ohms to input signal common; OPEN >100 k ohms to input signal common.
   d. Channel 4 - same as Channel 3.
   e. Channel 5 - same as Channel 3.
4. Input criteria
   a. ≥9 mA dc to the transducer circuit under any condition.
   b. ≤9 Vdc to the transducer circuit when it is in the OPEN state >100 k ohms.
   c. Must respond to an input signal greater than 1 millisecond duration and less than 1 millisecond leading edge fall time.
5. Outputs
   a. Five output lines to the warning indicators (FLAGS) capable of supplying 10 Vdc at 80 mA for each indicator.
   b. One common output line that provides a 10 ± 2 second -10 Vdc pulse to energize the warning tone generator.
   c. All output lines contain open short circuit protection.

NOTE 1: If an input signal from the discrete flow switches is present at the 5 second time delay module for greater than 1.5 seconds, the 10 ± 2 second warning tone is activated. (The warning flag is not activated unless the input signal duration is greater than 5 seconds.) This discrepancy is due to the design of the EMI filter in the 5 second time delay circuitry. P-14

SB NO. PLSS 13-9

S/C: EMU
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: W. Bates
APPROVAL:

TITLE: H_2O SEPARATOR

BACKGROUND: The water separator (Figure 13-9a) removes entrained water condensed from water vapor during the cooling of the oxygen in the sublimator. This sheet of water leaving the trailing edge of the sublimator cooling fin passages becomes unstable and finally collapses into drops as a result of surface tension. The size of the drop formed increases with increases in liquid surface tension, viscosity, and mass flow and decreases with increases in gas velocity, gas density, liquid density, coefficient of friction, sublimator/condensor width, number of fins per inch, and number of stacks. The collector section captures and collects the condensed water by directing the airstream flow through three 90° turns, producing forced impingement upon the nylon wick. Toluene is utilized as the wick wetting agent to reduce surface tension and improve absorption.

The return section containing two dacron pads and a fused glass bead plug transfers condensed water from the collection section by diffusion and capillary action.

As the feedwater flows out of the reservoir bladder, a pressure differential forms across the glass beads, extracting the condensation from the pads. The water in the glass beads then transfers to the drain tube in the form of large drops. The separated water is accumulated in the space left between the bladder and the reservoir housing as the bladder empties. The backside of the reservoirs have an actual storage capacity of 5353 cc (min). During a single recharge of feedwater reservoirs (Primary and auxiliary), a maximum of 1318 cc of condensate will be discharged (2.91 lb). P-11

The maximum water separation rate is 0.508 lbs/hr at a feed H_2O usage rate of 3.0 lbs of H_2O/hr. The separator is capable of separating slugs of water ranging in volume up to 5 cubic inches.

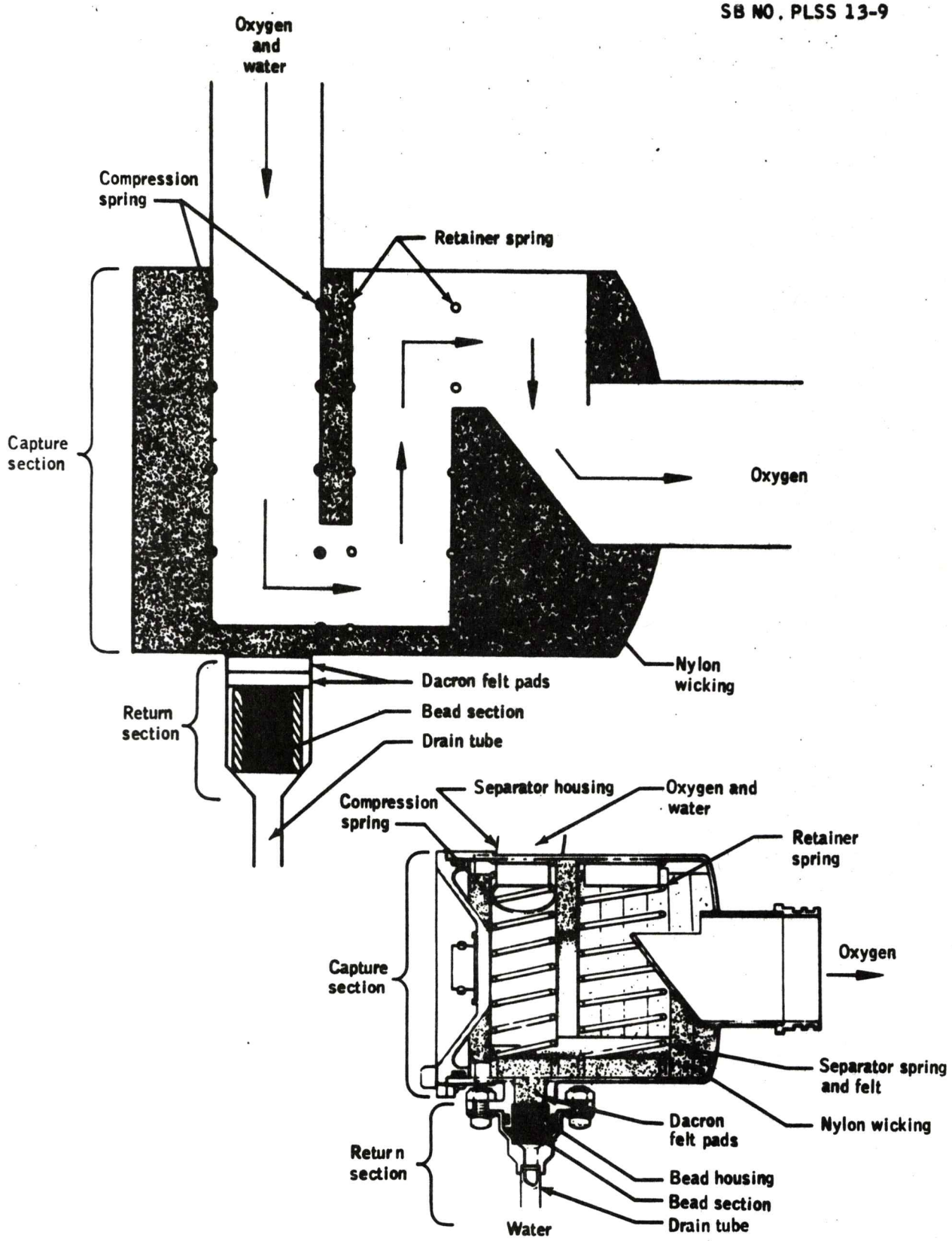


Figure 13-9a. - Schematic - water separator.

S/C: EMU P-3
DATE: 9/29/69
REV: PCN-3
ORIGINATOR: J. A. Joki
APPROVAL: James L. Hannigan

SB NO. OPS 14-1

TITLE: OPS THERMAL CONTROL

BACKGROUND: During OPS purge operation, the crewman's entire thermal control is dependent upon the heat removal capacity of gas ventilation in the PGA. As the body increases in heat storage, the heat removal capacity of the gas stream increases. The limit on this increase is saturation of the gas stream and an outlet temperature approaching skin temperature. At initial activation of purge, the PGA inlet pressure drops to 3.64 psia with an inlet gas temperature of 80°F and dew point of 32°F. The purge valve outlet pressure corresponds to 3.60 psia with an outlet gas temperature of 95°F and dew point of 95°F.

The following symbols are used in the text:

$\dot{Q}$ = heat transfer rate, Btu/hr
Cp = specific heat, Btu/lb-°F
T = temperature, °F
Tdb = dry bulb temperature, °F (i.e., the measured temperature of a gas mixture)
P = pressure, psia
R = gas constant, 48.3 $\frac{ft\text{-}lb_f}{lb_m - {}^\circ R}$
ν = specific volume, ft^3/lb
ω = humidity ratio, lb water vapor/lb dry air
ϕ = relative humidity, percent
h_{fg} = enthalpy of evaporation, Btu
h_g = enthalpy of a saturated vapor, Btu
h_f = enthalpy of a saturated liquid, Btu
q = heat, Btu
M_{da} = mass flow rate of dry air, lb/hr
M_{in} = mass flow rate of ambient air, lb/hr

Subscripts:

a = dry air
in = inlet parameter
out = outlet parameter
m = mixture of vapor and dry gas
v = water vapor parameter
g = saturator vapor parameter

PGA Inlet	PGA Outlet
$P_{m_{in}}$ = 3.64 psia	$P_{m_{out}}$ = 3.6 psia
$T_{db_{in}}$ = 80°F	$T_{db_{out}}$ = 95°F
Dew point$_{in}$ = 32°F	Dew point$_{out}$ = 95°F

From the steam tables, the saturation pressure (P_g) for water vapor at 80°F is 0.5069 psia.

The dew point is the saturation temperature corresponding to P_v.

From the steam tables:

Inlet dew point at 32°F: $P_{v_{in}}$ = 0.08854 psia

Outlet dew point at 95°F: $P_{v_{out}}$ = 0.8126 psia

P-3

Inlet Conditions	Outlet Conditions
$\phi_{in} = \frac{P_v}{P_g}(100) = \frac{0.08854}{0.5069}(100) = 17.5\%$	$\phi_{out} = 100\%$
$P_{a_{in}} = P_{m_{in}} - P_{v_{in}} = 3.64 - 0.5069 = 3.13$ psia	$P_{a_{out}} = P_{m_{out}} - P_{v_{out}} = 3.6 - 0.8126 = 2.787$ psia
$\nu_{a_{in}} = \frac{R_a T_{in}}{P_{a_{in}}} = \frac{(48.3)(540)}{(3.13)(144)} = 57.87$ ft^3/lb	$\nu_{a_{out}} = \frac{(48.3)(555)}{2.787\ (144)} = 66.79$
$\nu_{g_{in}} = 633.1$ ft^3/lb at 80°F	$\nu_{g_{out}} = 404.7$ ft^3/lb at 95°F
$\omega_{in} = \frac{\nu_{a_{in}}}{\nu_{g_{in}}}\phi_{in} = \frac{(57.87)(.175)}{633.1} = 0.016$ lb/lb	$\omega_{out} = \frac{\nu_{a_{out}}}{\nu_{g_{out}}}\phi_{in} = \frac{(66.79)(1)}{404.7} = 0.165$ lb/lb

P-3

The mass flow rate for dry air into the PGA

$$M_{da} = \frac{M_{in}}{1.0 + \omega_{in}} = \frac{8}{1.016} = 7.87 \text{ lbs/hr}$$

P-3

Where: $M_{in} = 8.0$ lb/hr

The mass flow rate of water removal is

$$M_w = M_{da}(\omega_{in} - \omega_{out}) = 7.87(-0.150) = -1.18 \text{ lbs/hr}$$

P-3

The gas leaving the PGA is assumed saturated. Applying the first law of thermodynamics, work = 0, $\Delta KE = 0$, and steady flow conditions.

$$q_{out} = Cp_a(T_{in} - T_{out}) + \omega_{out} h_{g_{out}} - (\omega_{in} - \omega_{out}) h_{f_{out}}$$

Obtaining the appropriate data from the steam tables:

$$q_{out} = 0.24(80 - 95) + (0.165)(1038.5) - (0.016 - 0.165)(63.1)$$

$$q_{out} = -3.6 + 171.35 + 9.4 = 177.15 \text{ Btu/lb dry air}$$

P-3

The rate of heat removal

$$\dot{Q} = M_{da}\, q_{out} = (7.87)(177.15) = 1394.17$$

P-3

From empirical calculations, the OPS, operating at saturation point at the outlet gas stream, has an approximate maximum heat removal capacity of 1400 Btu/hr.

From test data, the maximum purge flow heat removal is 600 Btu (20 Btu/min) for the 30 minute OPS lifetime. The limiting factor in the use of the OPS is the crewman's capability to store heat. The crewman should not plan to store more than 150 Btu including that accumulated prior to use of the OPS.

P-3

For orbital contingencies, the maximum sustaining work rate may not exceed 1200 Btu/hr with a maximum metabolic expenditure of 750 Btu.

Work Rate (1200 Btu/hr for 30 minutes)	= 600 Btu	750 Btu Total Metabolic Expenditure
Stored Heat	150 Btu	
PGA Heat Load	0 Btu	
Total Heat Load	750 Btu	

P-3

For lunar surface operations using the OPS exclusively, the maximum sustained work rate is 1000 Btu/hr with a total metabolic expenditure of 600 Btu.

Work Rate (1000 Btu/hr for 30 minutes)	= 500 Btu	600 Btu Total Metabolic Expenditure
Stored Heat	= 100 Btu	
PGA Heat Leak	= 150 Btu	
Total Heat Load	750 Btu	

P-3

SB NO. OPS 14-2

This SB deleted by PCN-8

SB NO. OPS 14-3

This SB deleted by PCN-8

SB NO. PGA 15-1

S/C: EMU
DATE: 11-1-71
REV: PCN-11
ORIGINATOR: W. Bates
APPROVAL:

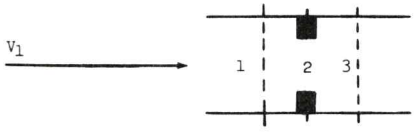
TITLE: **ORIFICE AND NOZZLE FLOW**

BACKGROUND: As a compressible fluid passes through a nozzle, a drop in pressure and simultaneous increase in velocity results. Assuming adiabatic reversible flow, it is possible to calculate from the continuity equation ($M = \rho VA$) the required area for the cross section of the nozzle at any point. From this calculation, it is found that for all compressible fluids the nozzle form must first be converging, but eventually, if the pressure drops sufficiently, a point is reached where to accommodate the increased volume due to the expansion, the nozzle must become diverging in form. The smallest cross section of the nozzle is called the throat, and the pressure at the throat is the critical flow pressure p_2. For gases when the ratio of critical to inlet pressure (p_2/p_1) is ≤ 0.53, the flow is sonic or choked.

The following items are used in the derivation:

A_1 = upstream cross sectional area, ft^2
A_2 = orifice cross sectional area, ft^2
C = empirically determined coefficient of discharge
g_c = dimensional constant
h = enthalpy, Btu/lb
M = mass flow, rate of ambient air; lbs/hr
J = 778.3 Btu
C_p = specific heat for constant volume, Btu/lb-°F
C_v = specific heat for constant pressure, Btu/lb-°F
$k = C_p/C_v$
p_1 = upstream pressure, psia
p_2 = orifice pressure, psia
P_m = critical flow pressure
ρ = density, lbs/ft^3
V = mean velocity at the given section, ft/sec
v_1 = upstream specific volume
v_2 = orifice specific volume
R = gas constant, $48.3 \frac{ft\text{-}lb_f}{lb_m\text{-}°R}$

The general fundamental relation for orifice flow is given by the energy balance $(V_2^2 - V_1^2)/2g_c = J(h_1 - h_2)$. Referring to the figure below,



Let section 2 be taken at the orifice; section 3 is somewhat beyond the orifice on the downstream side; and section 1 is before the orifice on the upstream side. Then solving for V_2,

$$V_2 = C\sqrt{2g_cJ(h_1 - h_2)} \Bigg/ \sqrt{1 - \left(\frac{A_2}{A_1}\right)^2 \left(\frac{V_1}{V_2}\right)^2}$$

where C is the coefficient of discharge factor. The volume of gas passing through the orifice is V_2A_2 ft^3 per sec, and the quantity is $V_2A_2\rho$. For ideal gases, assuming adiabatic expansion through the orifice, a pressure ratio $(p_2/p_1) \geq 0.53$ results in subsonic flow. For subsonic orifice flow, the flow rate is dependent upon the upstream/downstream pressure relationship.

$$V_2 = C \sqrt{2g_c p_1 V_1 \frac{k}{k-1} \left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}}\right]} \Bigg/ \sqrt{1 - \left(\frac{A_2}{A_1}\right)^2 \left(\frac{p_2}{p_1}\right)^{\frac{2}{k}}}$$

$$M = 3600\, CA_2p_2 \sqrt{\frac{2g_c}{RT_1} \frac{k}{k-1} \left(\frac{p_1}{p_2}\right)^{\frac{k-1}{k}} \left[\frac{p_1}{p_2}^{\frac{k-1}{k}} - 1\right]} \Bigg/ \sqrt{1 - \left(\frac{A_2}{A_1}\right)^2 \left(\frac{p_2}{p_1}\right)^{\frac{2}{k}}} = \text{lbs/hr}$$

V_1 is ofetn small compared with V_2, and under these conditions, the denominators in the preceding equations become approximately equal to unity.

For ideal gases when $\frac{p_2}{p_1} < 0.53$, the flow rate through the throat is sonic (choke flow).

$$M = CA_2p_1 \sqrt{\frac{g_c}{RT_1} k \left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} = f(p_1) \text{ lbs/hr}$$

For choke flow conditions, the flow rate becomes independent of the downstream pressure.

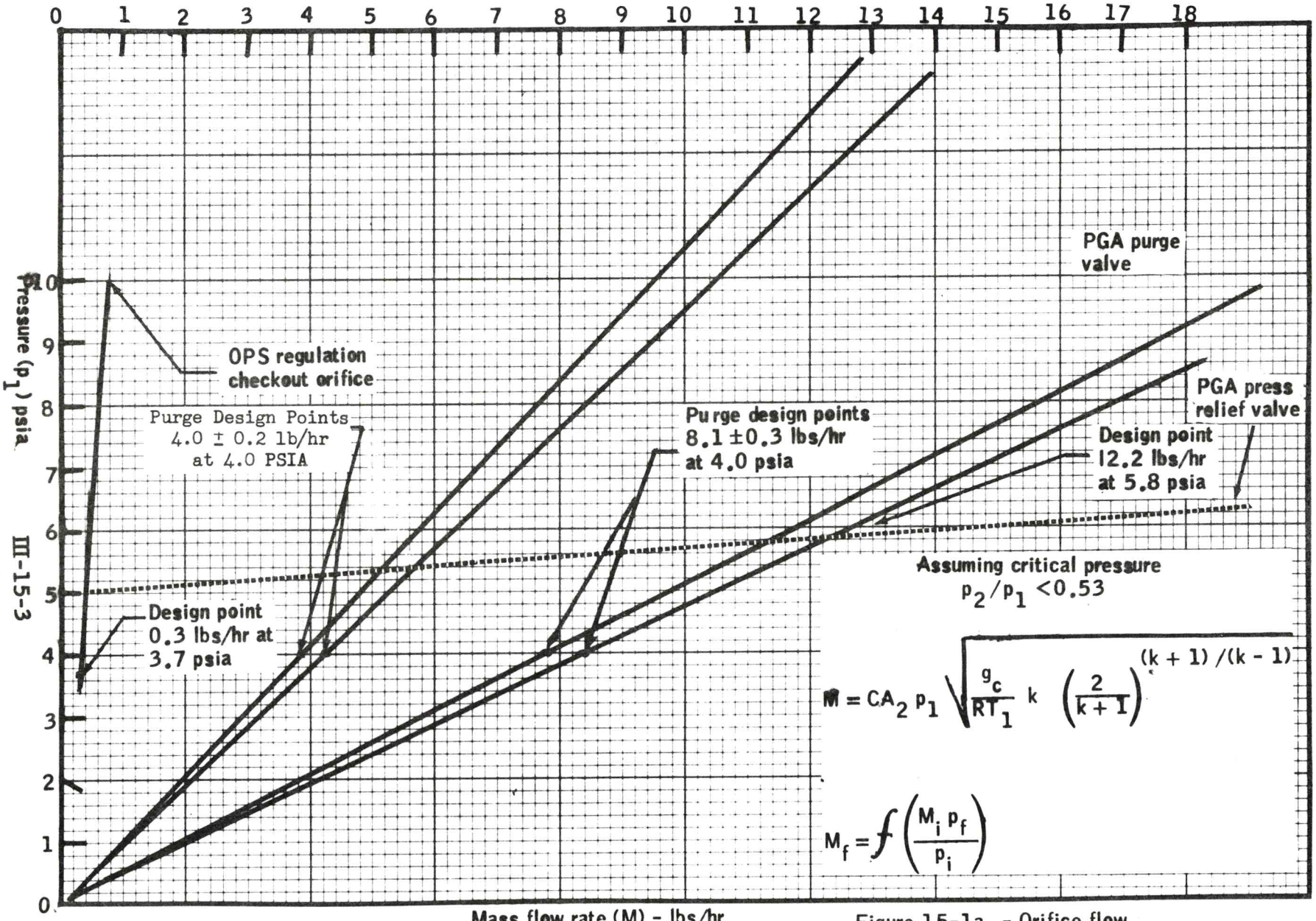
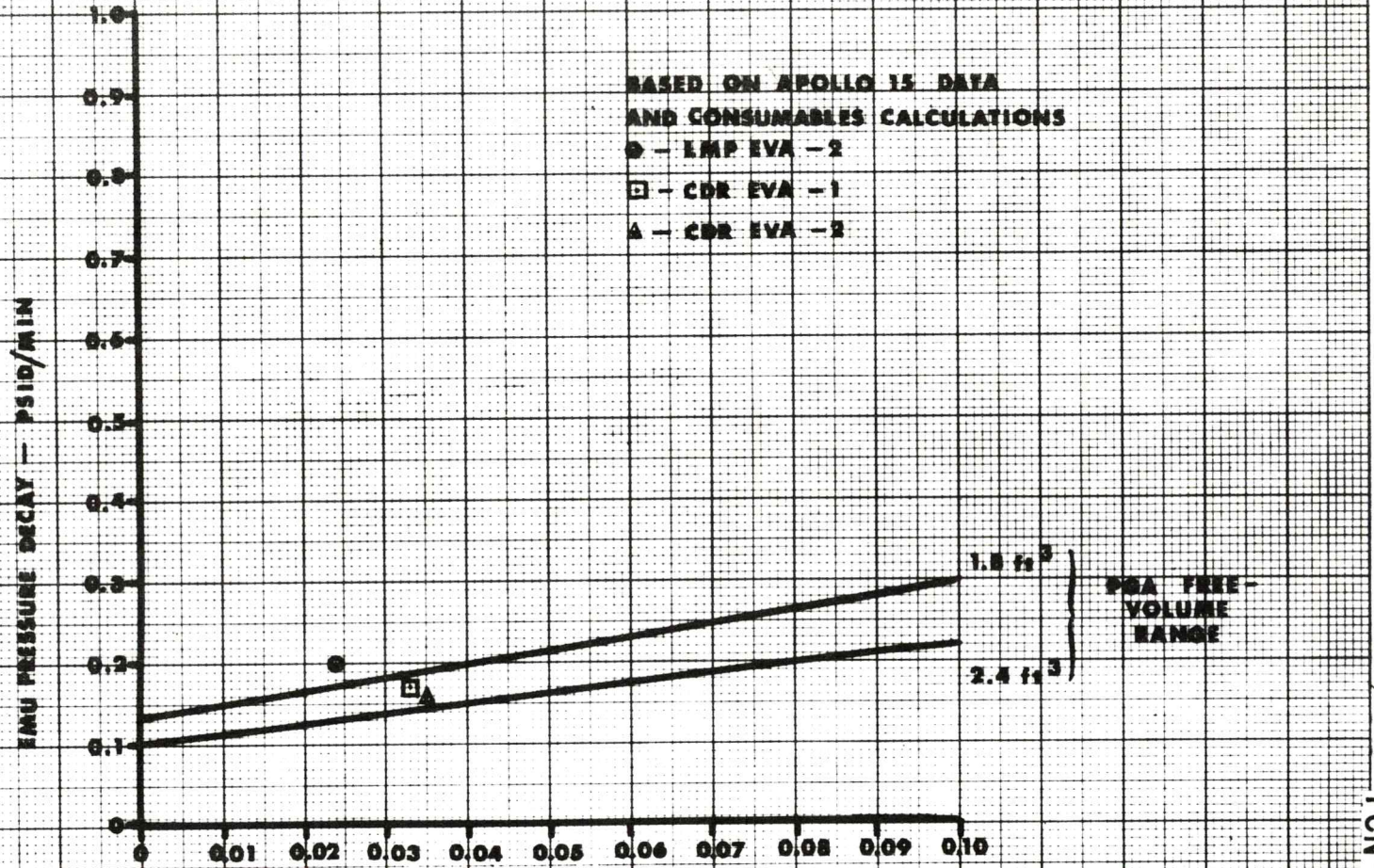


Figure 15-1a. - Orifice flow.



ASSUMED CREWMAN METABOLIC RATE – 500 BTU/HR – 0.082 LB/HR

FIGURE 15-b EMU PRESSURE DECAY

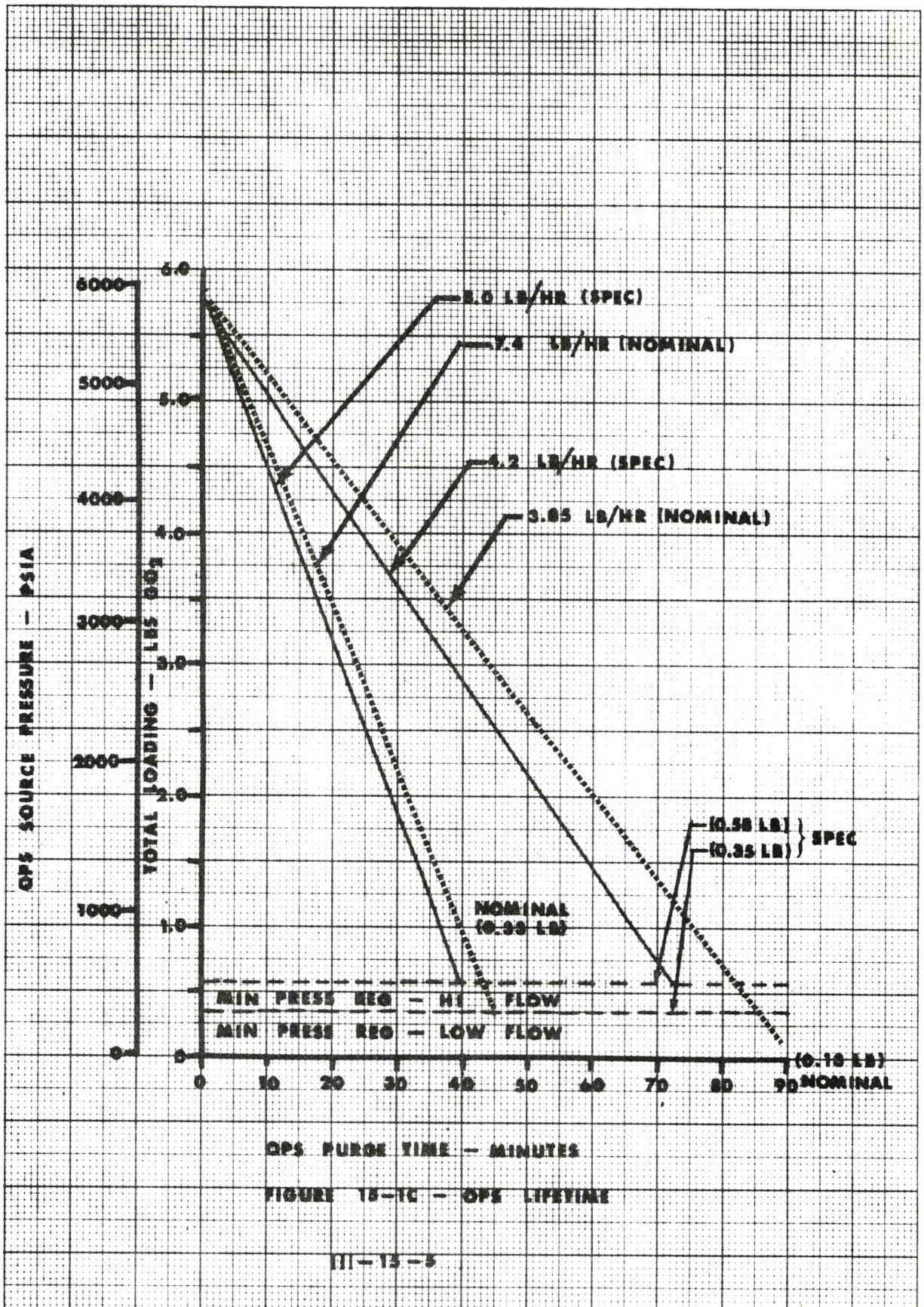


FIGURE 15-1C – OPS LIFETIME

BEE 20x20 TO INCH

Figure 15-1d deleted by PCN-11

SB NO. PGA 15-2

This SB deleted by PCN-8

SB NO. **PGA 15-3**

S/C: EMU
DATE: 6/1/71
REV: PCN-8
ORIGINATOR: L. V. Minter
APPROVAL:

TITLE: A7LB AND A7LB-CMP PGA's

BACKGROUND: Two types of extravehicular PGA's will be utilized for the Apollo J-missions: (1) the A7LB-CMP PGA will be worn by the Command Module Pilot (CMP); (2) the A7LB PGA will be worn by the Commander (CDR) and the Lunar Module Pilot (LMP). The A7LB-CMP PGA is a modified A7L PGA designed to be worn EV by the CMP during the CMP EVA. The CMP does not require liquid cooling, so the A7LB-CMP PGA does not contain a water connector, and the CMP does not wear a liquid cooling garment (LCG). The A7LB PGA utilizes an LCG in conjunction with gas ventilation cooling with both the LM ECS and PLSS.

The main differences between the A7L and A7LB PGA's were designed to afford greater mobility and durability with the A7LB PGA. A waist joint was added allowing a normal sitting position capability, improving downward visibility and improving center of gravity control. No torso tiedown straps are required. A neck joint was added improving visibility, reducing neck fatigue, and allowing for an adjustable neutral position. Elimination of hardware interference at the shoulder and neck ring improved overhead reach and reduced operating torque Grasping capability and comfort were improved by increasing the glove thumb extension. Also, the wrist disconnect diameters were increased for improved donning, doffing, and comfort. The A7LB glove has peripheral ducting as opposed to a single duct for improved ventilation.

The A7LB zipper goes from the upper left chest area, down to the waist, and across the back to the right front waist area. For both PGA's, the restraint layer is outside of the bladder layer, but the A7LB pressure sealing zipper is behind the restraint zipper instead of being the outside zipper as on the A7L and the A7LB-CMP PGA's. Due to the A7LB zipper path, the ventilation system was rerouted, creating a different connector configuration. Due to the relocated water connector, the LCG connector manifold was redesigned. An improved clamp and strain relief for the tubing connections account for better reliability.

P-8

The A7LB PGA durability was increased via the addition of a nylon scuff layer on the bladder and convolutes and construction of a more durable ITMG. More spacer layers were added and gridded Kapton film was used to improve flammability characteristics.

Unchanged items are the maintenance kit, helmet shield, LEVA, FCS, communications carrier, bio harness, lunar boots, neck dam, CWG electrical harness, purge valve (dual orifice type), and the UCTA.

Some of the improved design items of the A7LB PGA were utilized on the A7LB-CMP. As previously mentioned, the A7LB-CMP torso is basically the same as the A7L torso less the water connector. The arms and legs are the A7LB configuration which standardizes dipped convolutes and improves abrasion resistance by an additional scuff layer. The boot bladders are laminated for improved structural integrity and increased abrasion resistance. The ITMG is the A7L EV configuration with a teflon outer layer for improved abrasion resistance. The helmet is the A7LB configuration containing teflon covered vent pad for improved abrasion resistance. The gloves are the A7LB configuration with the large wrist rings. The A7LB-CMP PGA also has improved shoulder cable swages, stainless steel pulley assemblies, and is equipped with the A7LB type pockets.

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LSB NOTES OF INTEREST

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September 28, 1972

NOTE OF INTEREST: LM Tracking Versus Telemetry Matrix for Descent/Ascent

The enclosed three matrices detail the onboard LM switching procedures for obtaining tracking or telemetry for a failure of the LM PM subcarrier voice and telemetry prior to Descent and Ascent. Each matrix has been reviewed by the appropriate MOCR positions on the Ascent and Descent teams.

Alan C. Glines

3 Enclosures

Distribution:
CB/E. A. Cernan/H. H. Schmitt/J. W. Young/C. M. Duke/C. G. Fullerton
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FC73/ACG:dbp:2267

I. DESCENT

A. DESCENT CONFIGURATION

TIME	DATA	CREW ACTION
PDI - 5 MIN TO PDI + 1:30	TRACKING (VOICE)	PM, SEC, PRIM, DN VOICE BU, PCM, BIOMED OFF, HI
PDI + 1:30 TO PDI + 2:00	VOICE/TM	S-BAND FUNCTION/VOICE TO VOICE S-BAND MODULATE TO FM
PDI + 2:00 TO PDI + 4:00	TRACKING (VOICE)	S-BAND MODULATE TO PM S-BAND FUNCTION/VOICE TO DN VOICE BU
PDI + 4:00 TO TOUCHDOWN	VOICE/TM	S-BAND FUNCTION/VOICE TO VOICE S-BAND MODULATE TO FM

B. DESCENT ABORT CONFIGURATION

- ONE GOOD GUIDANCE SYSTEM AVAILABLE (EITHER PNGS OR AGS) - TRACK FROM ABORT INITIATE TO INSERTION.
- TWO GOOD GUIDANCE SYSTEMS AVAILABLE (PNGS AND AGS) - REMAIN ON TLM FROM ABORT INITIATE TO INSERTION.

II. ASCENT

A. PNGS/AGS BOTH GO FOR NAV

TIME	DATA	CREW ACTION
LIFTOFF - 5 MIN	TRACKING (VOICE)	PM, SEC, PRIM, DN VOICE BU, PCM, BIOMED OFF, HI
LIFTOFF - 4 MIN 30 SEC	VOICE/TM	S-BAND FUNC/VOICE TO VOICE S-BAND MOD TO FM
LIFTOFF + 1 MIN 30 SEC	TRACKING (VOICE)	S-BAND MOD TO PM S-BAND FUNC/VOICE TO DN VOICE BU
LIFTOFF + 4 MIN	VOICE/TM	S-BAND FUNC/VOICE TO VOICE S-BAND MOD TO FM
LIFTOFF + 5 MIN	TRACKING (VOICE)	S-BAND MOD TO PM S-BAND FUNC/VOICE TO DN VOICE BU
LIFTOFF + 6 MIN	VOICE/TM	S-BAND FUNC/VOICE TO VOICE S-BAND MOD TO FM
LIFTOFF + 6 MIN 30 SEC	TRACKING (VOICE)	S-BAND MOD TO PM S-BAND FUNC/VOICE TO DN VOICE BU
CUTOFF + 30 SEC (ONLY IF VOICE NOT AVAILABLE WITH TRACKING)	VOICE/TM TO PASS TWEAK	S-BAND FUNC/VOICE TO VOICE S-BAND MOD TO FM

II. ASCENT

B. PNGS OR AGS NO GO FOR BOTH NAV/GUIDANCE

TIME	DATA	CREW ACTION
LIFTOFF - 5 MIN	TRACKING (VOICE)	PM, SEC, PRIM, DN VOICE BU, PCM, BIOMED OFF, HI
LIFTOFF - 4 MIN 30 SEC	VOICE/TM	S-BAND FUNC/VOICE TO VOICE S-BAND MOD TO FM
LIFTOFF + 1 MIN 30 SEC	TRACKING (VOICE)	S-BAND MOD TO PM S-BAND FUNC/VOICE TO DN VOICE BU
LIFTOFF - 1 MIN 30 SEC	VOICE/TM	S-BAND FUNC/VOICE TO VOICE S-BAND MOD TO FM
LIFTOFF + 2 MIN 30 SEC	TRACKING (VOICE)	S-BAND MOD TO PM S-BAND FUNC VOICE TO DN VOICE BUS
LIFTOFF + 5 MIN	VOICE/TM	S-BAND FUNC/VOICE TO VOICE S-BAND MOD TO FM
LIFTOFF + 6 MIN	TRACKING (VOICE)	S-BAND MOD TO PM S-BAND FUNC/VOICE TO DN VOICE BU
CUTOFF + 30 SEC (ONLY IF VOICE NOT AVAILABLE WITH TRACKING)	VOICE/TM TO PASS TWEAK	S-BAND FUNC/VOICE TO VOICE S-BAND MOD TO FM

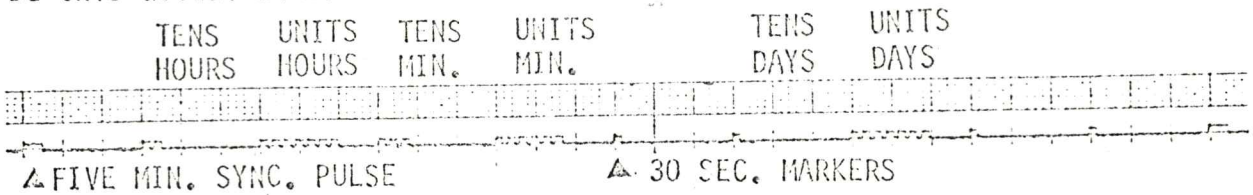
April 4, 1972

INTERESTING NOTE: New Chart Recorder Timing

1. Two new timing codes have been added to the Apollo chart recorders. This modification will allow chart recorder operation at slow paper speeds while retaining legible timing marks. Unmodified recorders cannot be operated slower than 10 millimeters per second (MPS) because the timing code marks become extremely compressed and illegible. The modified recorders can be operated at paper speeds as slow as 0.25 MPS.

2. The new codes are called EXPANDED CTE and EXPANDED MET and have been added to the right timing selector switch. The new codes can be selected to the right timing pen only. The EXPANDED CTE/MET time word is longer than the standard CTE/MET by a factor of 30. The standard CTE/MET time word is 10 sec. long and output every multiple of 10 sec. The EXPANDED CTE/MET time word is five min. long and output every multiple of five min. (00, 05, 10, 15 min. etc.).

3. The format of EXPANDED CTE/MET is identical to the standard CTE/MET format. At a paper speed of one MPS an expanded time word would be 30 cm long. At a paper speed of 0.5 MPS the expanded time word would be this actual size:



expressing the time 06:16:25:00 or 160:25:00 at the start of the five min. sync pulse. This modification is an addition only. The right timing selector swtich still has the old positions along with the new positions. The left selector swtich has not been modified in any manner.

4. Due to the five min. length of the time code word, EXPANDED CTE/MET will be effected by poor quality telemetry more than the standard CTE/MET 10 sec. time word. This effect has not presented any serious difficulties during tests. One MPS and 0.5 MPS have been found to be the most useful

paper speeds.

Richard B. Ramsell

EIF

CSH

Distribution:
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PM-MO-F/R. S. Hammer

NOTE OF INTEREST

Leon Vick
October 13 1972

SUBJECT: LM 12 COMM PLANS

Attached are a revised LM 12 Comm Plan for the T-0 (Dec. 6) launch, and a new plan for the T+24 (Dec. 7) launch.

The T-0 plan has been modified to accomodate usage of the 210 ft antenna at Parkes, Australia. The only procedural change resulting from Parkes usage is deletion of the power amplifier at ~147:30 (post EVA-2) This period is now within 210 ft. (Parkes) coverage.

Another change in the T-0 plan is the battery configuration in the period from ~147:30 to ~171:30. The revised configuration, resulting from analysis of battery usage, provides a much better balance of amp-hrs consumed.

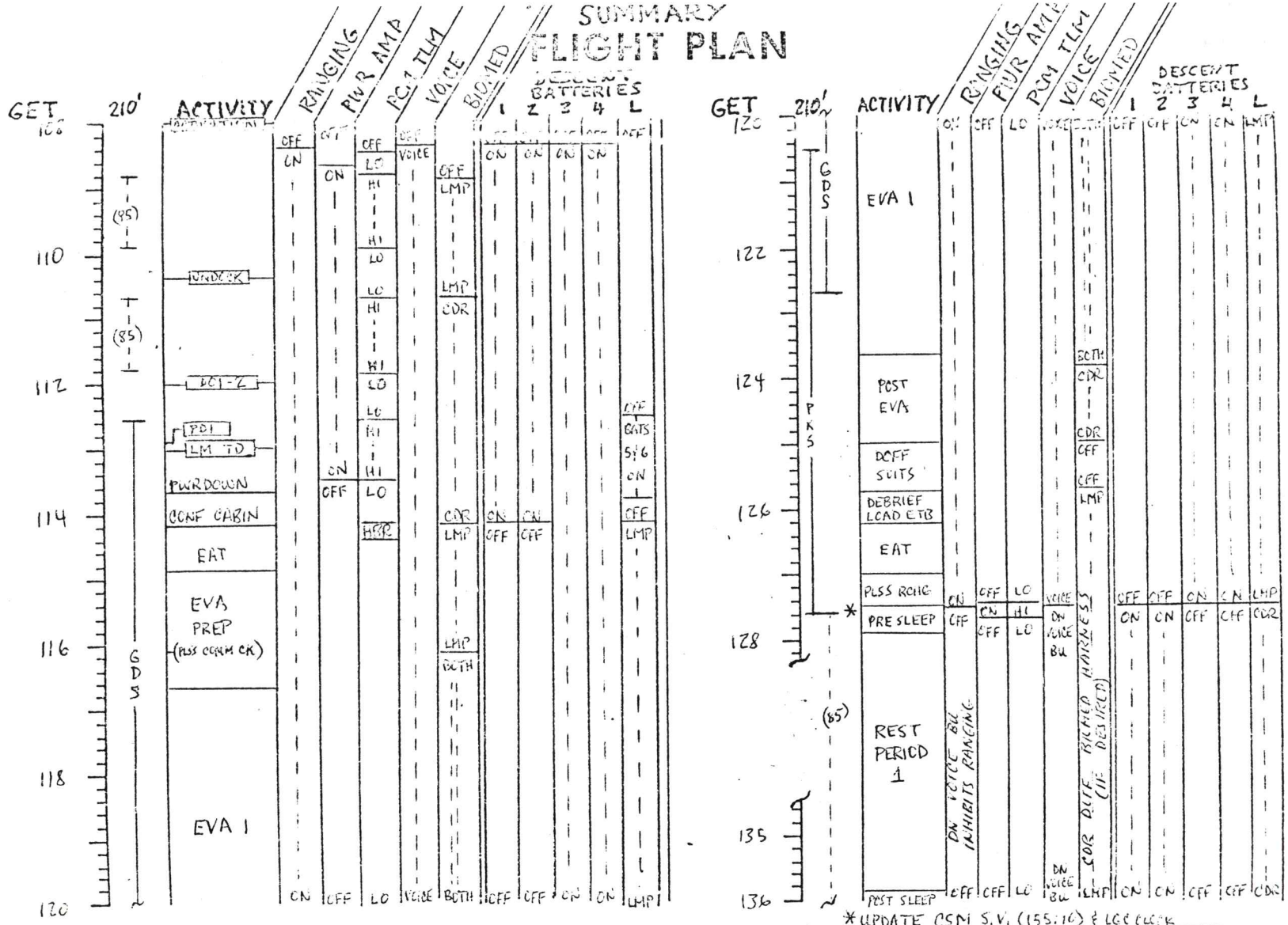
The T+24 plan reflects the use of a clock sync during translunar coast such that the lunar stay is all at the same GET as on the nominal mission. However, the GMT's of these activities are ~18 hrs later than for T-0 Thus, 210 ft. station coverage is shifted by this delta causing modification of power amplifier usage as follows:

~147:30	(Post EVA-2)	PWR AMP-ON
~161:10	(Pre EVA-3)	PWR AMP-OFF
~170:50	(Post EVA-3)	PWR AMP-ON

All other Comm/Battery functions are configured the same on the T+24 and T-0 plans.

Leon Vick

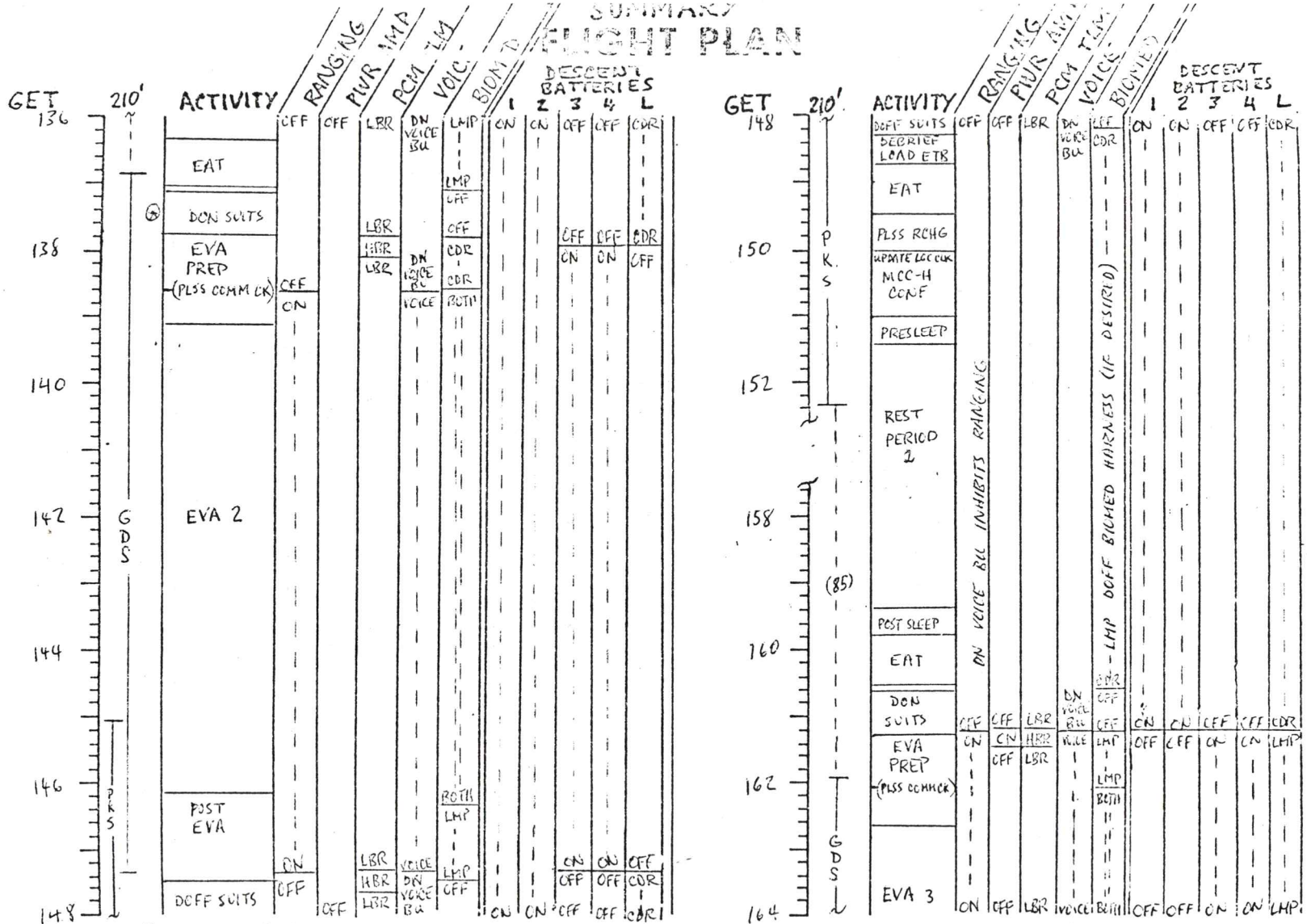
SUMMARY FLIGHT PLAN



MISSION	EDITION	DATE	TIME	DAY/REV	PAGE
APOLLO 17	LM COMM PLAN	12 OCT 72 REV A 1 AUG 72	LUNAR SURFACE	—	1 of 3

MSC Form 1077 OT (Mar 69) FLIGHT PLANNING BRANCH

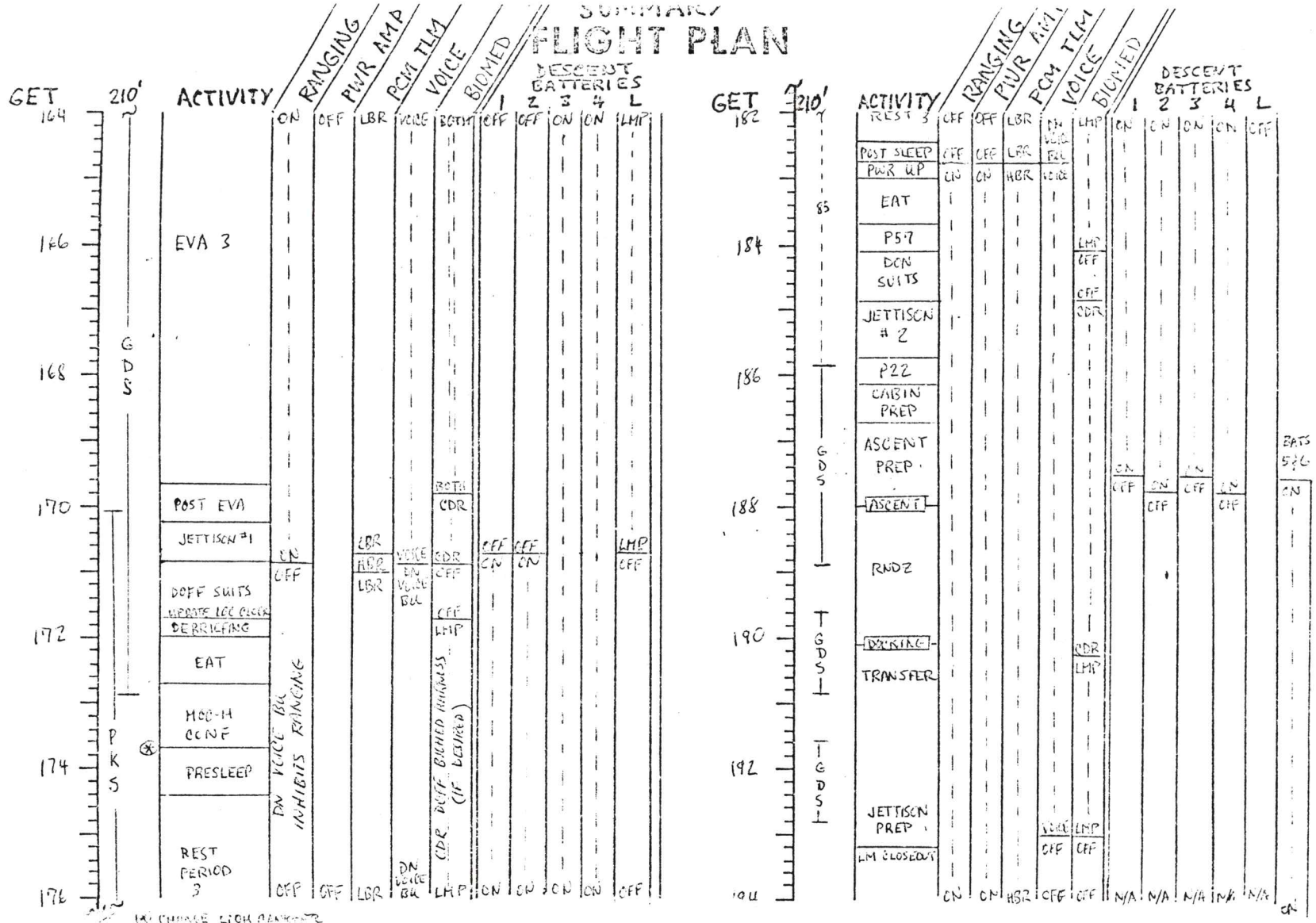
SUMMARY FLIGHT PLAN



MISSION	EDITION	DATE	TIME	DAY/REV	PAGE
APOLLO 17	LM COMM PLAN	12 OCT 72 REV A 1 AUG 72	LUNAR SURFACE	—	2 of 3

FLIGHT PLANNING BRANCH

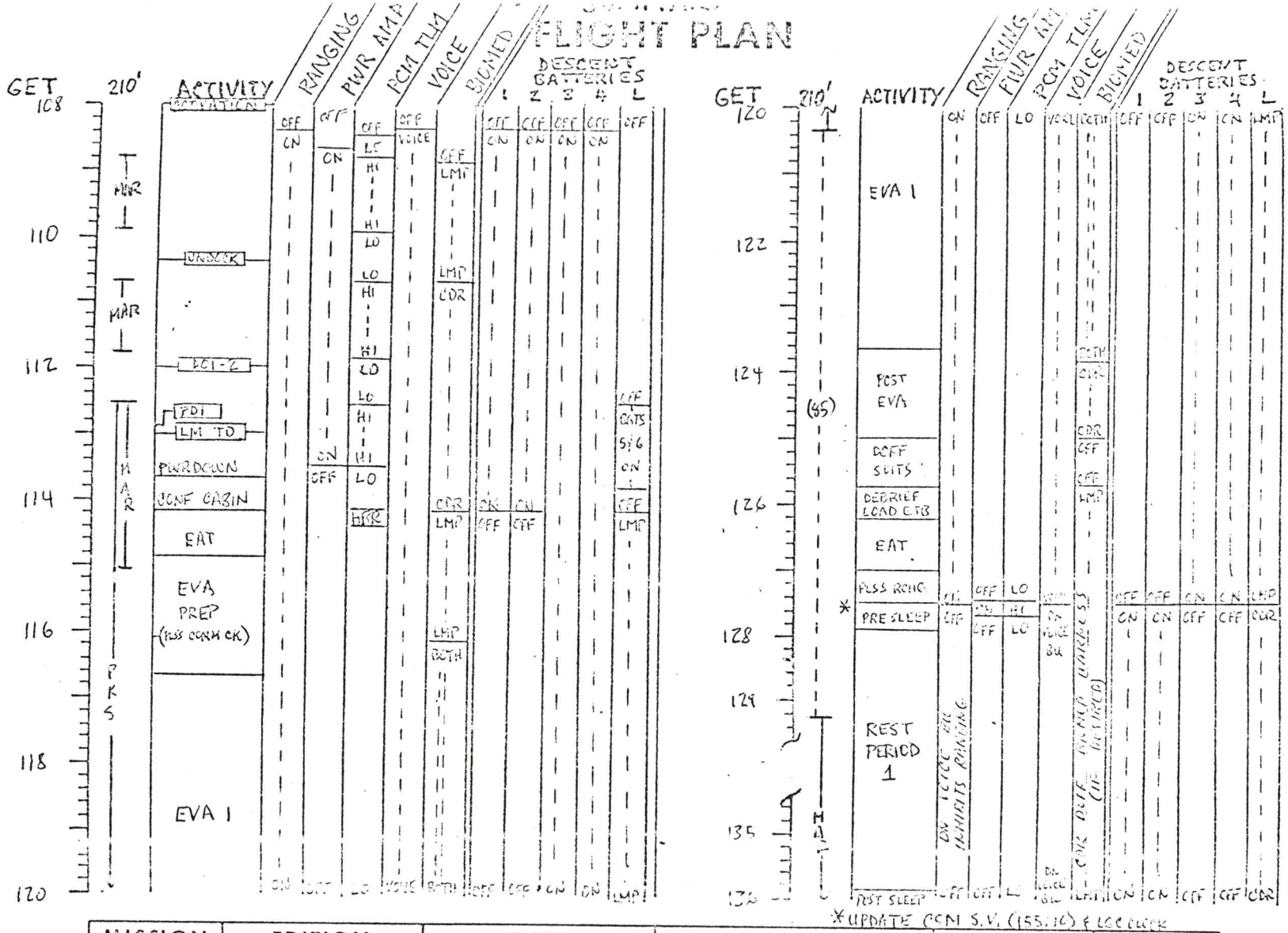
SUMMARY FLIGHT PLAN



MISSION	EDITION	DATE	TIME	DAY/REV	PAGE
APOLLO 17	LM COMM PLAN	1 AUG 72	LUNAR SURFACE	—	3 of 3

MSC Form 1077 OT (Mar 69) FLIGHT PLANNING BRANCH

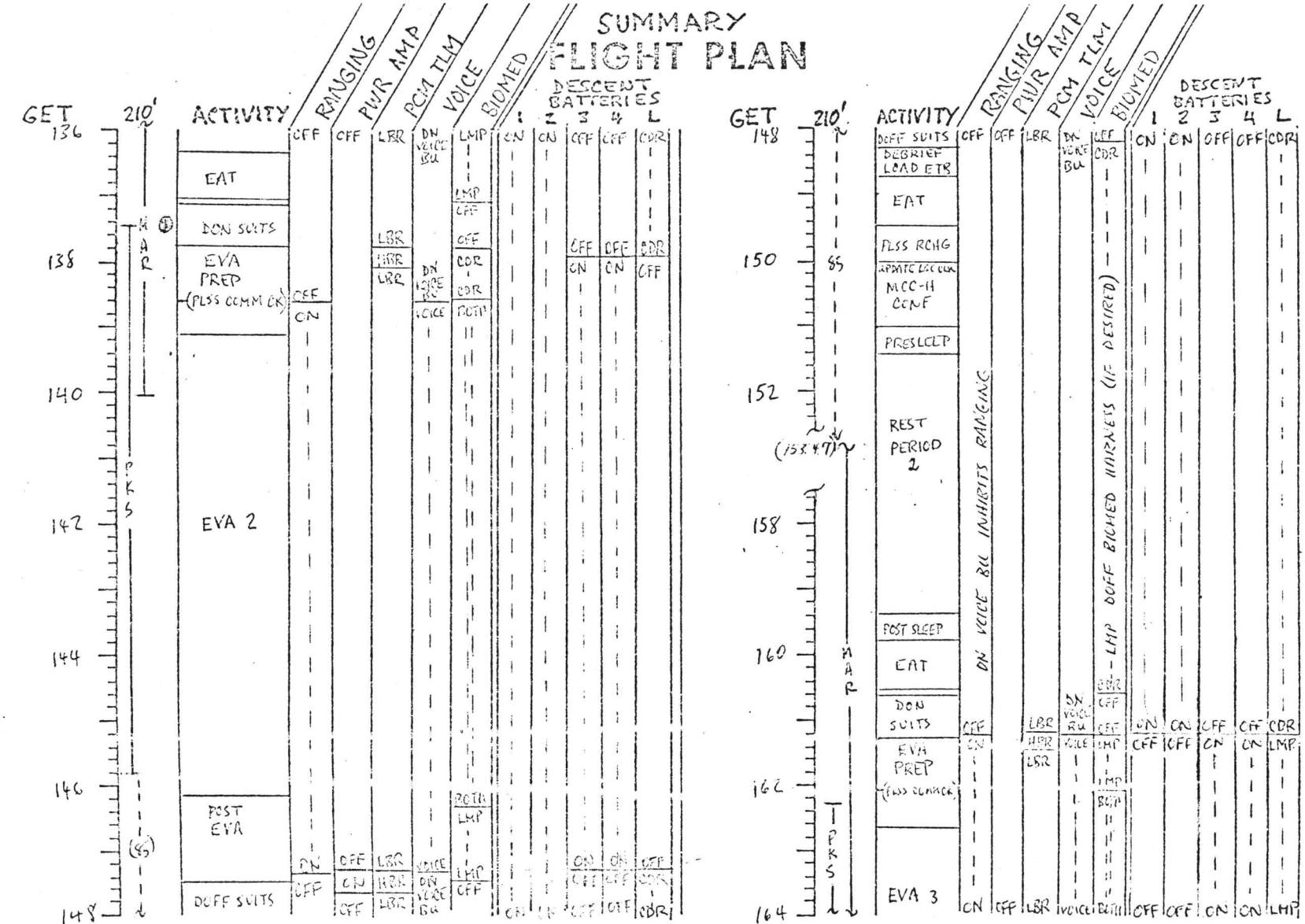
FLIGHT PLAN



MISSION	EDITION	DATE	TIME	DAY/REV	PAGE
APOLLO 17	T+24 LM COMM PLAN	OCT 12, 1972	LUNAR SURFACE	—	1 of 3

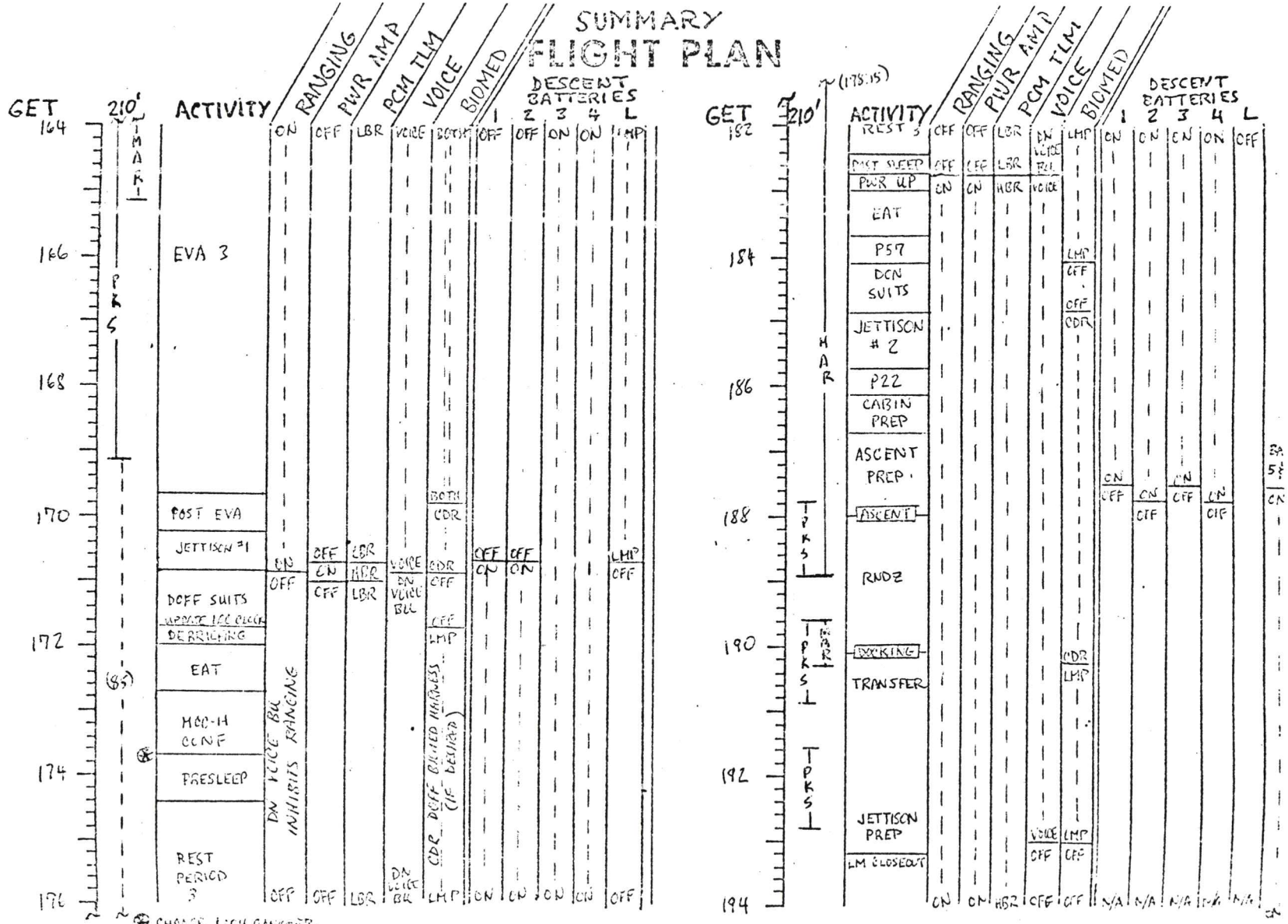
MSC Form 1057 OT (Mar 69) FLIGHT PLANNING BRANCH

SUMMARY FLIGHT PLAN



MISSION	EDITION	DATE	TIME	DAY/REV	PAGE

SUMMARY FLIGHT PLAN



OCT 10 1972

NOTE OF INTEREST: Lunar Surface Contingency Lift-off Procedures

1. For the previous Apollo missions, a procedure for "no PGNS auto ignition" for lunar lift-off has existed, which was designed to meet the following two constraints:

a. To provide for redundant APS-ON signals if possible.

b. To lift-off within 10 seconds of nominal Tig in order to achieve a direct rendezvous.

After the Apollo 16 LM jettison attitude control problem, another constraint evolved which is inconsistent with current procedures. This new constraint, that of checking the attitude control circuitry via a hot-fire after an attitude control configuration change, has caused Apollo 17 checklists to be modified to perform the PGNS portion of the lunar surface hot-fire test last. Another constraint change which impacts the existing procedure is that the 10-second limitation for the direct rendezvous has been relaxed to 30 seconds. This allows more time to execute an alternate procedure as will be examined below.

2. Several options are available which could change the existing procedure to ensure attitude control at lift-off. In some cases, however, this is at the expense of the other constraints. These options and the advantages and disadvantages are as follows:

a. "Safe" the vehicle and wait one rev.

Although this action has the advantage of not hurrying, troubleshooting, and lifting off in the best possible configuration, it causes a powerdown and reconfiguration problem. Also, waiting another two hours on the surface subjects the vehicle to additional failure risks.

b. Immediate manual ignition via START p.b.

An immediate manual start in PGNS does prevent the risk of lifting off in AGS with possibly no attitude control, and obviously can be accomplished in time to make a direct rendezvous. However, the constraint of providing for a redundant APS-ON signal, if possible, would be ignored, and is the main objection to this procedure.

c. Modify original procedure to include Hot-Fire checks after Switching between PGNS and AGS.

Since the original procedure conforms to all constraints except verifying AGS attitude control prior to an AGS auto ignition, it can be modified to include a quick hot-fire check via the ACA prior to ignition. Switching to AGS in the lift-off configuration should cause an auto-on command to be issued and therefore, the AGS would need to be "safed" prior to switching to AGS. This can be accomplished by

already having the AGS MODE CONT switch in ATT HOLD or switching to ATT HOLD, or resetting the ABORT STAGE p.b. prior to selecting AGS. After the crew's assessment of a quick hot-fire check, auto ignition could be allowed via the opposite "safing" action, i.e., switching to AUTO or pushing the ABORT STAGE p.b. This procedure should be able to be performed within the new 30-second time constraint for the direct rendezvous. Although both methods of safing the AGS for the hot-fire check would be acceptable, resetting the ABORT STAGE seems to adhere best to the constraints. Performing the hot-fire in the AGS ATT HOLD does have a slight disadvantage of changing the attitude control configuration after the test by switching to AUTO. This switching causes enable power to the abort preamps to be switched between two contacts of the AGS MODE CONT switch. However, resetting the ABORT STAGE p.b. allows the attitude control circuitry which will be used for the ascent to be checked end-to-end. Both methods require action to safe the AGS prior to its selection unless the AGS MODE CONT switch was placed in ATT HOLD prior to the final countdown. However, this would cause several checklist changes altering normal procedures for a possible contingency. Also, both methods are subject to a single point contact failure which would fail to remove the appropriate inbit to the AEA and cause ignition when AGS was selected.

3. As can be seen from analyzing the above options, arguments can be made for and against each. If the constraints of verifying attitude control and providing for redundant APS-ON are to be met, then safing the AGS for a hot-fire best meets these requirements. Resetting the ABORT STAGE p.b. is recommended over the AGS ATT HOLD method simply because it performs an end-to-end attitude control check and requires no attitude control configuration changes for ascent.

Larry W. Strimple

JEH
HAL
RAT

October 5, 1972

NOTE OF INTEREST: Failed LM Circuit Breaker Critical Bus Cases

"If a DC bus is determined to be critical (loss of the bus results in a catastrophic situation due to other systems failures), the ascent batteries will be configured split bus on backup feed paths (normal feed off) for ascent and descent if time permits."

The above mission rule defines the term "critical bus" and states the battery reconfiguration action. This note of interest defines:

1. The protected catastrophic situations.
2. The procedures to be used for battery/bus reconfiguration.
3. The circuit breaker failure cases which would place the LM in a critical bus situation and the action to be taken on a phase by phase basis.

The catastrophic situations protected against are:

1. Descent engine shutdown
2. Ascent engine shutdown
3. Loss of attitude control
4. Loss of staging capability

The loss of both computer systems is not protected since a manual profile may be flown for ascent or any PDI abort case. Attitude control failures which could use the secondary coils as a backup are protected since the mission rules do not consider secondary coils as an adequate control system.

The action taken is the same for either critical bus case in either the staged or the unstaged configuration. The procedure is as follows:

CB (16) EPS: ASC ECA CONT - Close
Bat 5 Backup CDR Feed - ON; tb-gray
Bat 6 Backup LMP Feed - ON; tb-gray
Bat 5 Normal LMP Feed - OFF/Reset; tb-b/p
Bat 6 Normal CDR Feed - OFF/Reset; tb-b/p
Verify Bat 5 & 6 current prior to staging
CB (16) EPS: ASC ECA CONT - OPEN

There are many specific failures and combinations of failures which place the LM in a critical bus situation. Some of these systems failures are identified on the cue cards. The attached chart defines those critical bus situations brought about by a circuit breaker failure and the action to be taken on a phase by phase basis.

William L. Peters

William L. Peters

Enclosure

RAT RAP
JK
JEH

CRITICAL BUS CIRCUIT BREAKER FAILURE CASES

BUS AND CB	PRE PDI	PDI to 6:10	6:10 to HI-GATE	HI-GATE to T.D.	SURFACE	ASCENT
CDR BUS						
*QUAD 1,2,3,4 TCA	NO GO	C - A	C - A	C - O	C - NBO	C
*ATCA (PGNS)	NO GO	C - A	C - A	C - O	C - NBO	C
AELD	NO GO	A	C	C	C - NBO	C
ENG CONT	C	C	C	C	-	-
ENG START OVRD	NO GO	A	C	C	C - NBO	C
LOGIC PWR A	NO GO	A	C	C	MS-NBO	-
*LGC/DSKY	NO GO	C - A	C - A	C	C - NBO	C
*IMU OPR	NO GO	C - A	C - A	C	C - NBO	C
LMP BUS						
QUAD 1,2,3,4 TCA	NO GO	C - A	C - A	C - O	C - NBO	C
LOGIC PWR B	NO GO	A	C	C	MS-NBO	-
ENG ARM	NO GO	A	C	C	C - NBO	-
AELD	NO GO	A	C	C	C - NBO	C
ATCA	NO GO	C - A	C - A	C - O	C - NBO	C
ATCA (AGS)	NO GO	C - A	C - A	C - O	C - NBO	C
DES ENG OVRD	C	C	C	C	-	-

C - Configure for Critical Bus

A - Abort

O - Crew Option to Abort or Land

NBO-Liftoff next best opportunity

MS- Manual Stage

*- If secondary coils are considered a valid attitude control mode, loss of these circuit breakers will not create a critical bus condition.

NOTE OF INTEREST: Lunar L/O through Impact on One Ascent Battery for Apollo 17.

The nominal ascent battery energy usage at LM impact is 400 A-h (including TM unusable). The guaranteed battery capacity in the single ascent battery configuration is 286 A-h. Therefore, the ascent power requirement at impact must be reduced 114 A-h if impact is to be performed with a failed ascent battery.

The possible methods of reducing the power requirement at impact are as follows:

1. Power down all unnecessary equipment shortly after docking

2. Power down some unnecessary equipment after insertion and some after docking

3. Power down LM after docking and power up before jettison

4. Shorten liftoff to docking time

Option 1 was selected as having the minimum impact on the nominal mission. The power requirements for such a plan and the nominal mission are shown in Table 1. The equipment operating after power down are shown in Table 2. The timeline book changes which achieve these power levels are shown in Table 3.

Although the margin at impact is essentially zero, experience has shown that the ascent battery capacity greatly exceeds the rated capacity.

V. Scott Ritchey

3 Enclosures

FM7:VSRitchey:lad:10/31/72:4581

CWP WLP JEH

TABLE 1 - ASCENT BATTERY REQUIREMENTS THROUGH IMPACT

From Event	To Event	From GET	To GET	Delta Time	Nominal Amps	Nominal Amp-Hr	Powered Down Amps	Powered Down Amp-Hr
Pre PDI ASC Batts On	Lunar Surface ASC Batts Off	112:15	113:10	0 + 55	From SEENA	20	From SEENA	13*
Liftoff Prep	Liftoff	187:28	188:03	0 + 35	From SEENA	22	Req'd Precondition	5
Liftoff	Docking	188:03	190:05	2 + 02	From SEENA	106	From SEENA	106
Docking	Open Hatch	190:05	190:30	0 + 25	44.0	18	44.0	18
Open Hatch	Nominal Power Down Time	190:30	192:53	2 + 23	44.0	105	23.0	55
Nominal Power Down Time	Jettison	192:53	193:58	1 + 05	33.2	36	22.7	25
Jettison	Burn	193:58	195:33	1 + 35	34.2	54	22.7	36
Burn	Impact	195:33	195:58	0 + 25	34.2	14	22.7	9
TM Unusable					2.69	25	1.9	18
Total				9 + 25	----	400	----	285

* Worst Battery

TABLE 2

COMPONENTS BEING POWERED AT 190:30

Equipment	Amps
S Band Antenna (DC)	0.030
S Band Antenna (AC)	0.123 (at 28v)
S Band Power Amp-Pri	2.570
S Band XMTR/RCVR - Sec	1.290
PMP	0.150
DUA - Data	0.430
CDR Audio	0.150
SE Audio	0.150
EPS Disp	0.084
ASC ECA	0.360
Glycol Pump 1	1.090
CO2 Sensor	0.040
ATCA	1.930
LGC + DSKY	2.630
IMU Operate	6.765
IMU Heater	0.893
SCEA 1	0.490
PCMTEA	0.390
C + WEA	0.490
SCEA 2	0.370
Sensors	0.380
RCS HTRS	0.714
Invertor	1.450
	22.97

TABLE 3

LM TIMELINE BOOK CHANGES REQUIRED TO
ACCOMMODATE LM IMPACT WITH A FAILED ASCENT BATTERY

NOTE: The remaining ascent battery is configured on both normal and backup feed paths and all crosstie circuit breakers are closed before liftoff.

Change to P 3-1

ADD:

190:30

Hatch Open to CSM

Configure CB's to charts (P 3-4, 3-5)

CB (11) AC BUS B: AGS - Open

Comm: CDR Audio - Close

CB (16) RCS Sys B: PQGS/Disp - Open

LTG: Flood - Open

Track - Open

STAB/CONT: AEA - Open

ASA - Open

ATCA (AGS) - Open

Comm: VHF A XMTR - Open

VHF B XMTR - Open

DELETE:

CB(16) Comm: Disp - Close

Change to P 3-2

DELETE:

Configure AGS

1 404 + 0

405 + 0

406 + 0

470R

Change to P 3-3

DELETE:

2 VHF A: XMTR - Voice/Range
RCVR - Off
VHF B: XMTR - Off
RCVR - On

6 Configure CB's per chart

Change to P 3-6

DELETE:

1 Exterior LTG - Track
Bat 5 + 6 backup feed - on; tb(2) - gray

10/31/72

11-1-71

NOTE OF INTEREST: Pyro Battery Information

The LM pyro batteries are of silver-zinc construction as are the LM primary batteries. In the past, a pyro battery has been considered to be failed if its open circuit terminal voltage fell below 35 VDC. The reasoning behind this 35 VDC selection was that it represented a failure of more than one of the batteries 20 cells and thus a questionable battery state. Apollo 14 primary battery problems coupled with a desire to lower the 35 VDC redline on the pyro batteries resulted in a number of pyro battery tests performed at GAC. (Ref LTP 390-143). In general, these tests consisted of demonstrating the battery's capability to handle the staging functions with numerous cell failures and under various states of discharge.

The results of these tests demonstrated that the pyro battery is capable of performing the staging function numerous times with a terminal voltage of 18 VDC. Only when the terminal voltage falls below 15 VDC does the ability to perform staging become questionable. Since the LM voltmeter only reads from 20 VDC to 40 VDC, a value greater than 20 VDC must be selected in setting a pyro battery redline. Twenty-five VDC was arbitrarily selected as a value which would substantially reduce the previous 35 VDC redline and at the same time provide ample margin between the redline and offscale low on the voltmeter.

The pyro battery discharge characteristics are as shown in Figure 1.

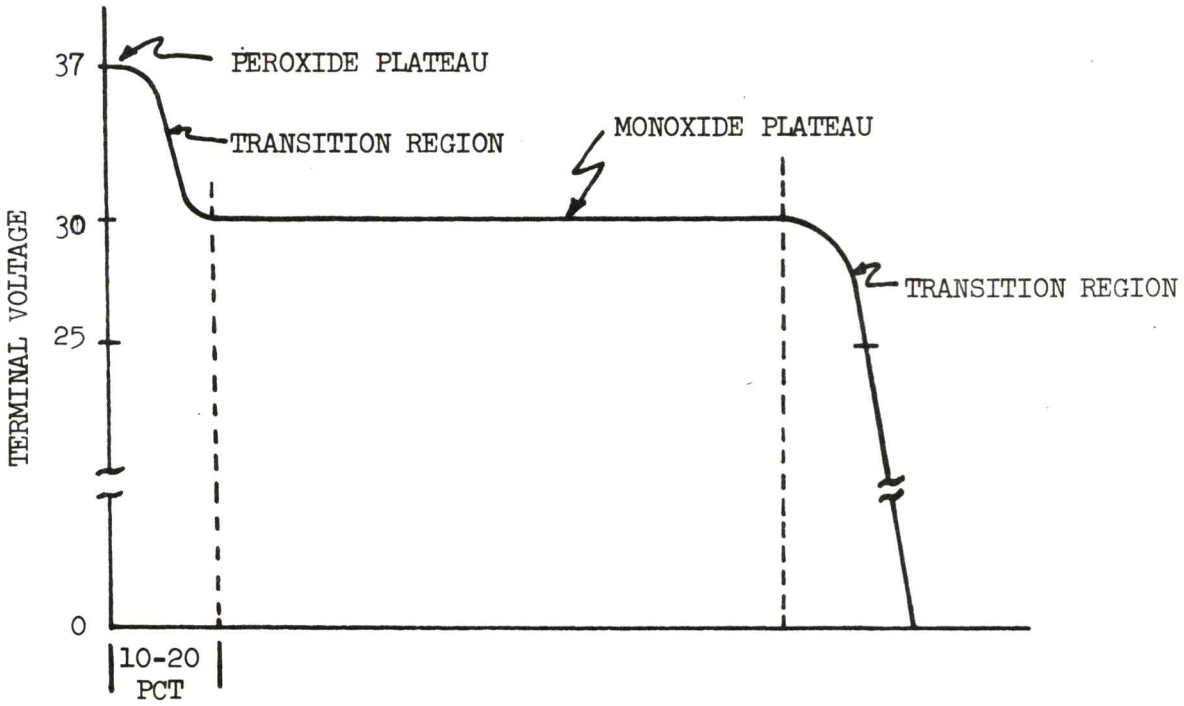


FIGURE 1

Due to the fact that while on the monoxide plateau the battery terminal voltage is relatively constant, it is impossible to determine, with the instrumentation available, exactly where on the discharge curve the battery might be. Thus with a terminal voltage in the vicinity of 30 VDC, the battery might have 90 percent of its capacity remaining or only 10 percent remaining. For this reason, a pyro battery is considered NO-GO if it is holding in the region of the monoxide plateau.

for Robert Haslage
Dave Whittle

Updated 11-1-71
1-11-71

NOTE OF INTEREST

SUBJECT: Stay on the lunar surface with a single point failure allowing inadvertent staging

1. Present mission rules call for a mission abort anytime the pyrotechnic system(s) cannot be disarmed. The basic reason for the abort is that one more single point failure will cause the vehicle to stage. Should in advertent staging occur during powered flight or at lunar touchdown, a catastrophic event may occur by shutting down the DPS with no APS on signal or the ascent stage may topple off the descent stage at touchdown. These events are serious enough that this portion of the mission rule should remain unchanged. However, once on the lunar surface and the pyrotechnic failure exists, a different set of consequences must be observed. This paper will show that the consequences of an inadvertent staging on the lunar surface is not catastrophic and that the normal mission profile should be continued rather than a next best opportunity liftoff.

2. With the crew either in the cabin or out on an EVA, the following uncomfortable situations will exist with an inadvertent staging:

a. Loss of descent H_2O
b. Water boiler freezeup in 1 hour
c. Loss of descent O_2
d. Loss of PLSS recharge capability
e. Loss of CABIN REPRESS capability
f. Loss of descent batteries
g. Temporary loss of vehicle power
h. Temporary loss of communications and telemetry
i. Descent batteries are shorted via the guillotine blade
j. Pyrotechnic devices are actuated in presence of crew (EVA only)

3. Although the list above seems quite formidable, each one is recoverable as follows:

a. Select ascent H_2O
b. Water boiler will not freeze up if glycol loop circulation is restored in 1 hour. This requires one EVA crewman to remain within 1 hour of the LM.
c. Use ascent O_2 for metabolic requirements.
d. At the end of a normal EVA there is always a 30-minute O_2 reserve remaining in the PLSS which could be used for contingency transfer.
e. The cabin can be repressurized with one OPS plus a small amount out of one ascent O_2 tank. This action will not violate redlines but a subsequent depress and repress to dump material on the lunar surface will not be allowed.
f. Select ascent batteries.
g. Vehicle power will be restored when ascent batteries are placed on line.

h. Communications and telemetry will be restored when vehicle power is restored.

i. Tests performed on descent batteries show that a dead short raises current of approximately 2100 amperes for a short time until the intercell connectors burn open. The batteries may vent but will not endanger an EVA crewman. The batteries will not explode.

j. All LM pyrotechnic devices by design specification will not produce shrapnel; i.e., they are self-contained and have blast deflectors which contain any particles.

4. In view of the non-catastrophic results described above, plus the low probability of occurrence, it seems prudent to accept the single point failure possibility and continue the mission on the lunar surface. Should inadvertent staging occur, the crew has adequate procedures to recover on ascent consumables and perform a next best opportunity liftoff. The above discussion is contingent on the capability of the LM to safely manually stage on the lunar surface. In attitude envelopes where manual staging is unsafe, the present mission rule of liftoff at the next best opportunity should be followed; however, if manual staging is allowable then the lunar surface stay should be continued if the pyrotechnic system(s) cannot be disarmed.

William L. Peters

Willim L. Peters/FC4

Approved: J. E. Hannigan/Chief FC4

August 7, 1970

NOTE OF INTEREST: Calibration Curves

1. Conversion of measurement system outputs into meaningful engineering units is accomplished by using calibration curves. There are many types of calibration curves, and terminology used by industry to identify curve types has led to much confusion. The problem facing aircraft and spacecraft manufacturers is the selection of an adequate curve within the bounds of accuracy, flexibility, and cost. The following calibration code definitions are meant to clarify the existing confusion as well as provide some concrete definitions for further discussion. In order of descending accuracy, curves shall be defined as End to End, Actual, Hybrid, and Normalized.

2. End to End Calibration Curves:

The end to end calibration curve is the most accurate curve available. This curve is generated by physically stimulating the transducer with a known stimuli and then recording the resultant output of the flight hardware. Obviously the generated curve is directly related to the specific equipments involved. (i.e. transducer, signal conditioning, & signal encoding equipment) the attainable accuracy is limited only by the accuracy of the components involved and the calibrating equipment. Generally the end to end calibration is employed only where extreme accuracy is necessary. Measurements requiring accuracy of this fine a tolerance normally comprise only a fraction of the total number of parameters on a vehicle, and even then they are generally developmental type measurements. Additionally, end to end calibration curves require the establishment of calibration facilities to perform re-calibrations. The end to end calibration is specific equipment sensitive. This means that the calibration is destroyed by equipment replacement.

3. Actual Calibration Curve:

The actual calibration curve is a mathematical entity. It emerges from the mathematical marriage of the actual performance curves of each element in the data chain. Actual calibrations can be maintained without a calibration facility if manufacturer's data is acceptable; however, most aircraft manufacturers do not accept the hardware manufacturers data, but recalibrate all items inhouse. Accuracy sacrificed by using an actual as opposed to an end to end curve is a function of the type measurement (e.g. press, temp) as well as the accuracy of the individual components. Typically, this accuracy error would be so small as to be unnoticeable, except in the most critical of applications. Most signal conditioning and encoding equipment can be easily manufactured to such small tolerances that the resultant curve is that of the transducer alone. The actual curve is equipment sensitive.

4. Hybrid Calibration Curve:

Like the actual curve, the hybrid calibration curve is the result of a mathematical manipulation. The hybrid curve uses specification values for one or more of the equipments in the data chain. These specification values are mathematically combined with the actual curves on the rest of the involved equipment. Typically, actual curves from the transducer are combined

with specification values for the signal conditioning and encoding equipment. The hybrid curve is only partially equipment sensitive which allows some equipment replacement without curve impact. Again accuracy sacraficed is minimal, and is still a function of measurement type and component. Some manufacturers refer to these curves as actual curves. (i.e. Grumman Aerospace Corp and North American Rockwell)

5. Normalized Calibration Curves:

The normalized calibration curve results from the mathematical marriage of specification values on each element in the data chain. It has the distinct advantage of being insensitive to equipments. Accuracies on the order of 2% are readily attainable with the normalized technique. Some manufacturers refer to normalized curve as a standard or spec curve.

A review of U.S. manned spacecraft launched to-date reveals a mixture of hybrid and normalized curves during the Mercury and Gemini programs. The initial calibration curves were normalized; however, before flight a check was run on each measurement based on the actual transducer installed in the vehicle. If the check revealed a deviation greater than 1%, then the curve was updated with a hybrid curve. For the Apollo program, North American Rockwell (NAR) uses 100% normalized curves for inhouse checkout and 100% hybrid curves for Cape checkout and for flight. Gruman Aerospace Corporation (GAC) supplies 100% normalized curves and up to 20% hybrid curves on request. Further discussion with Lockheed, Boeing, and aircraft related elements of GAC and NAR indicate a mixture of the various calibration curve techniques depending upon cost, application, accuracy, and various other influencing factors. Aircraft flight tests, for example, are strictly developmental in nature and as such require special characteristics not found in operational measurements. In addition, the small number of transducers required to satisfy a flight test program make reliable normalized curves not feasible. Other considerations make a concrete recommendation of the type of calibration curve for future spacecraft premature at this time. Further research and interface with various aircraft manufacturers combined with an intensive study of future spacecraft requirements should precipitate such a recommendation.

David Whittle

David Whittle

WLP 8/7/70

DWW:jm

NOV 25 1970

NOTE OF INTEREST

SUBJECT : Explanation of the PCMTEA loading as presented on the Instrumentation Interface drawings.

Sample rate: The number used to represent the samples per second is a code devised for use in some instrumentation documentation. In this code the first digit corresponds to the first digit of the actual sample rate. The second digit indicates how many zeros follow the first digit. Therefore, 10 = 1s/s, 11 = 10 s/s, 22 = 200 s/s, etc.

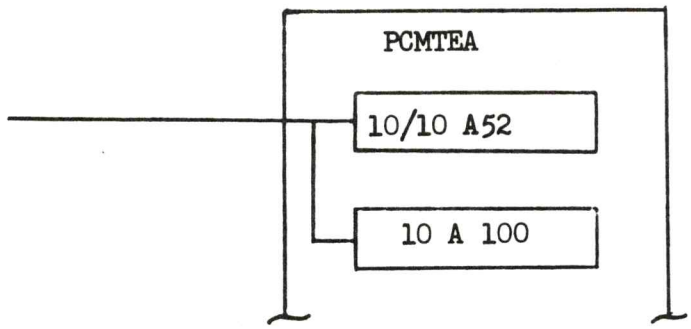
High Bit Rate (HBR)/Low Bit Rate (LBR): If a parameter location is on HBR only, then only one sample rate number will be shown. Should the location be on HBR and LBR, then two sample rates will be shown divided by a slash. If a parameter is on LBR, it is also always on HBR.

Analog/Events: Following the appropriate sample rate and HBR/LBR combination, an "A" "E", or in a few cases a "D" is shown to indicate whether the parameter is an analog, event, or digital eight bit word, respectively. "Digital words" are used to downlink such things as time and the code for the DUA status. For some analog parameters the "A" will be followed by an "H". The "H" no longer signifies anything and should be ignored.

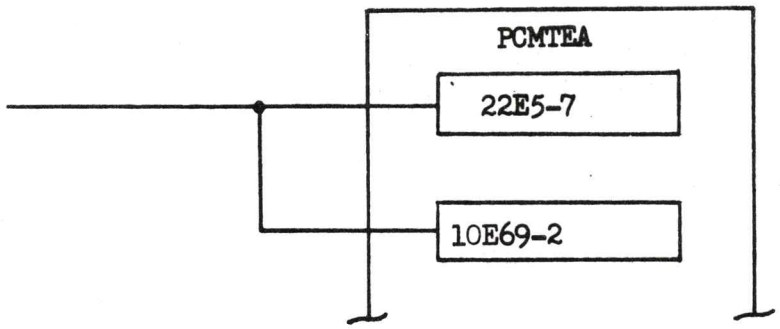
Analog/Event Location: The last number shown is the channel assignment for the parameter. For events this number will be followed by a dash and another number which indicate the assigned bit for the parameter.

Redundancy: If a parameter is in more than one location then more than one block will be shown for it. Each parameter will have one block per location. If the parameter is redundantly loaded the prime location, or the location used as the source of data at the MCC, is listed first. The parameter is internally redundant if the line connecting the different locations is drawn inside of the "PCMTEA" block. External redundancy is indicated if the line connecting the different location is drawn outside of the "PCMTEA" block.

EXAMPLES:



Internally redundant 1 s/s analog with channel 100 HBR only and channel 52 on HBR and LBR.



Externally redundant event on HBR only with channel 5, bit 7 sampled 200 times per second and channel 69, bit 2 sampled 1 time per second.

Robert Heselmeyer

Robert Heselmeyer

wlp 11/25/70

Distribution:

All LSB Personnel

27 October 1971

NOTE OF INTEREST: CONSTRAINTS ASSOCIATED WITH USE OF THE SECONDARY COOLANT LOOP ON THE LUNAR SURFACE FOR BATTERY MANAGEMENT

1. Due to recent modifications to the construction and fill procedures of the descent batteries, their capacity has been suspect and, in several cases, has been less than specification. One possible workaround to increase the performance is to raise the battery operating temperatures; a suggestion has been made to accomplish this by terminating primary glycol loop flow and using the secondary glycol loop for cooling while on the lunar surface. There are several consequences associated with this:

a. Time must be allotted to dryout the primary sublimator (≈55 minutes).

b. No active cooling to the following equipment: DSEA, LGC, LCA, IMU, GASTA, PTA, and all the equipment located in the descent stage.

c. No cooling to crew's liquid cooling garment (LCG) during Prep for EVA's.

d. Secondary loop has a single pump, therefore no redundancy or switchover capability in loop.

e. No capability for monitoring the secondary H_2O ΔP or secondary W/B inlet temperature. No CWEA is associated with secondary loop.

f. Unknown temperature rise rate of descent batteries operating without active cooling.

g. Special procedures must be observed when recharging PLSS H_2O.

h. Continuous suit fan operation is required during EVA while on secondary loop. Approximately 126 amp-hours must be budgeted for this.

i. The water feed configuration has never been tested before.

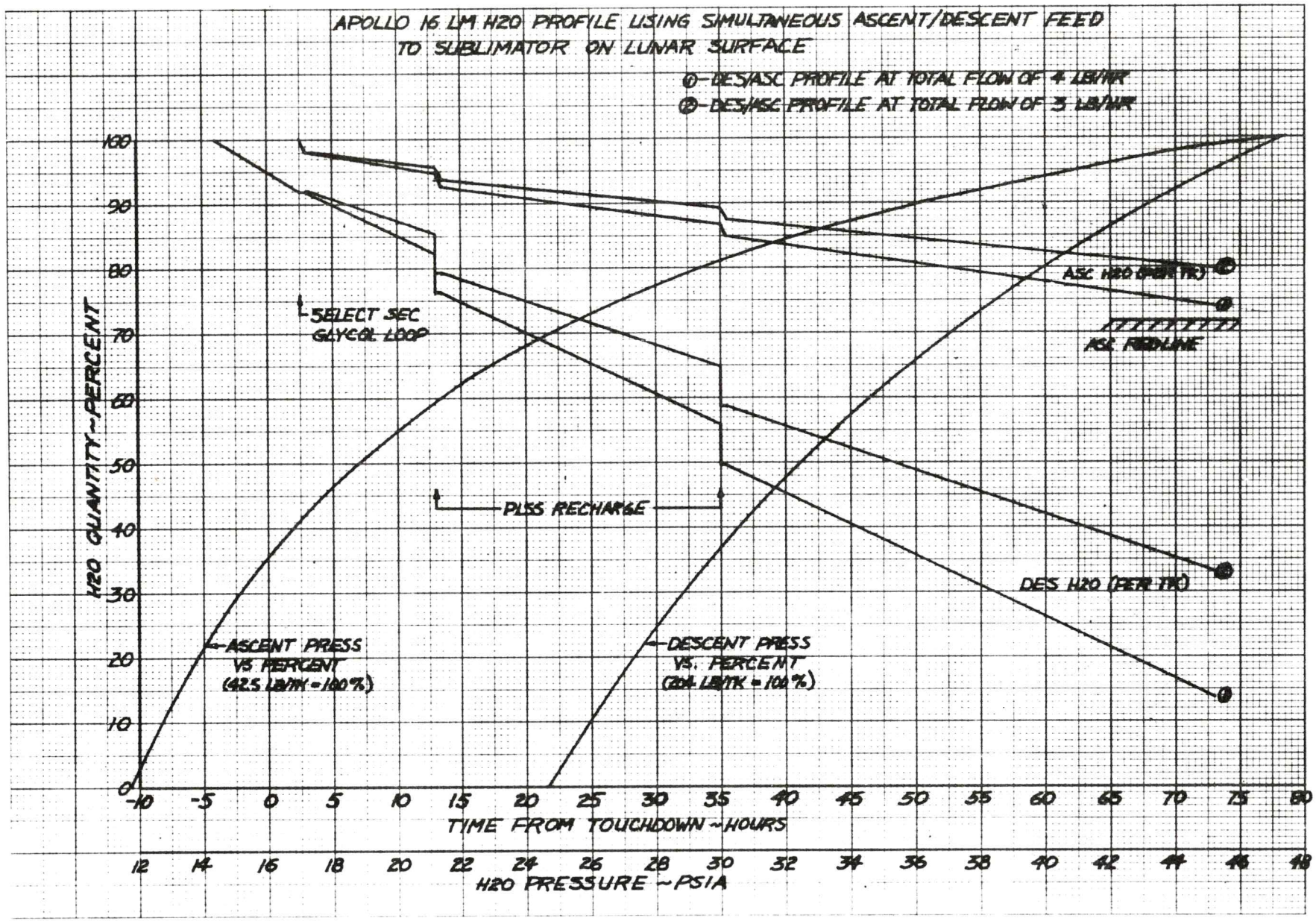
2. The enclosed plot represents an estimated H_2O usage profile for secondary loop operations. The critical consumable during the secondary loop is ascent H_2O of which about 12 lbs/tank would be available. The total stay time is relatively unaffected by the time of activation of the secondary loop, however, the time without cooling to the descent batteries is longer the earlier the secondary loop is activated.

3. Although the profile indicates the feasibility of performing this consumable management, the additional procedures required and the additional amp-hours used by the suit fan during the EVA's would overly complicate the procedures and partially negate any additional amp-hour performance obtained from the descent batteries; therefore, we do not recommend this approach to increase descent battery performance.

WMM/JEH

Q. Patin/FC46

BEE 20x20 TO INCH



NOTE OF INTEREST May 13, 1971

SUBJECT: CMP EVA without OPS

1. It is the position of the LM Systems Branch that a CMP EVA (nominal or otherwise) should not be attempted without the availability of a functional OPS.

2. Single point failures which could result in catastrophic end results without OPS capabilities, during an EVA, are as follows:

a. Any supply failure upstream of the CM EVA/IVA panel demand regulator (to either the SM or CM portion of the system) resulting in loss of O_2 flow (ventilation) to the crewman.

b. Similarly, a failed closed EVA/IVA demand regulator.

c. Similarly, a sever or restriction of the EVA umbilical.

Any of the above, which would result in reverse flow from the PGA through the suit control unit (SCU) and overboard, would require closure (if possible) of the SCU mounted shut-off valve (SOV) immediately upon detection by the crewman. Prior to SOV closure, the PGA pressure could reduce from 4.0 psia to 3.0 psia in 82 seconds at an initial flowrate of 7.2×10^{-3} lb/hr. From the time of loss of O_2 ventilation, the crewman would have approximately 3 minutes (at a low metabolic rate - 500 BTU/hr) of activity time before he would exhibit definite effects on mobility due to CO_2 buildup. Reference Enclosure 2 which correlates suit helmet CO_2 partial pressure buildup without ventilation with CO_2 effects on crewman. Since this type of situation would dictate immediate termination of all EVA activity, coupled with transfer and ingress, the crewman's work rate would greatly increase (approximately 2000 BTU/hr), proportionally reducing the amount of time available before CO_2 buildup affects were incurred (approximately one minute to reach 30 mm Hg).

3. A crewman's emergency ingress time for a vacuum ECS transfer is dependent on distance of travel and LMP clearing of hatch area along with umbilical relocation. Minimum time for this activity is about 45 seconds; subsequent CM ECS hook-up time and O_2 initiation is about 45 seconds--resulting in a minute and a half total. Emergency repress requires additional camera/pole removal and stowage, hatch closure, and hatch locking (approximately one minute). Current procedures require a 15 - 20 second manual closing of the CM dump valve (prior to cabin repress). Whether or not a vacuum ECS transfer is completed, an emergency CM repress can be accomplished in approximately one minute facilitating the three one-pound bottles and the 3.75-pound surge tank. Therefore, the total time from failure to cabin repress is 3 minutes, 5 seconds minimum; and 3 minutes, 50 seconds maximum (depending on CM ECS hook-up). These time estimates are based on available crew procedure guidelines. Reference Activity Time Chart (enclosure 1).

4. Single point failures which would result during checkout in not performing an EVA without OPS capabilities are as follows:

a. A failed closed PCV would not permit PGA pressure regulation, resulting in increasing (if SCU mounted shut-off valve open and flowing) suit pressure to the point of pressure relief valve operation.

b. A failed open or closed SCU mounted shut-off valve would not permit PGA pressure isolation in event of upstream flow loss or the inability to provide flow into the PGA.

OPS backup capabilities in these instances would provide the backup system should an EVA be necessary.

5. Throughout the Apollo program, it has been the philosophy never to subject a crew to a situation without an adequate backup system, if possible, when a single point failure could be catastrophic. In summary, it is felt that the time available to return and connect to the CM ECS from the EV station would not be of sufficient backup due to the increased CO_2 buildup as previously indicated.

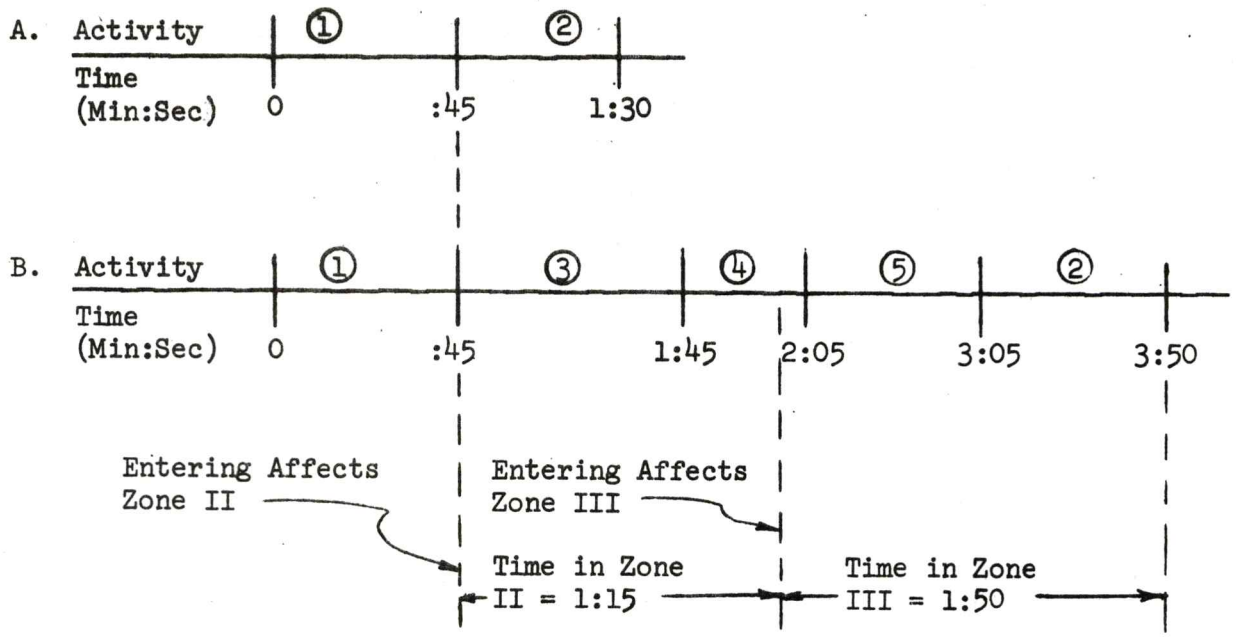
Lee A. Wible

Lee A. Wible

2 Enclosures

WMM/JHH

ACTIVITY/TIME CHART



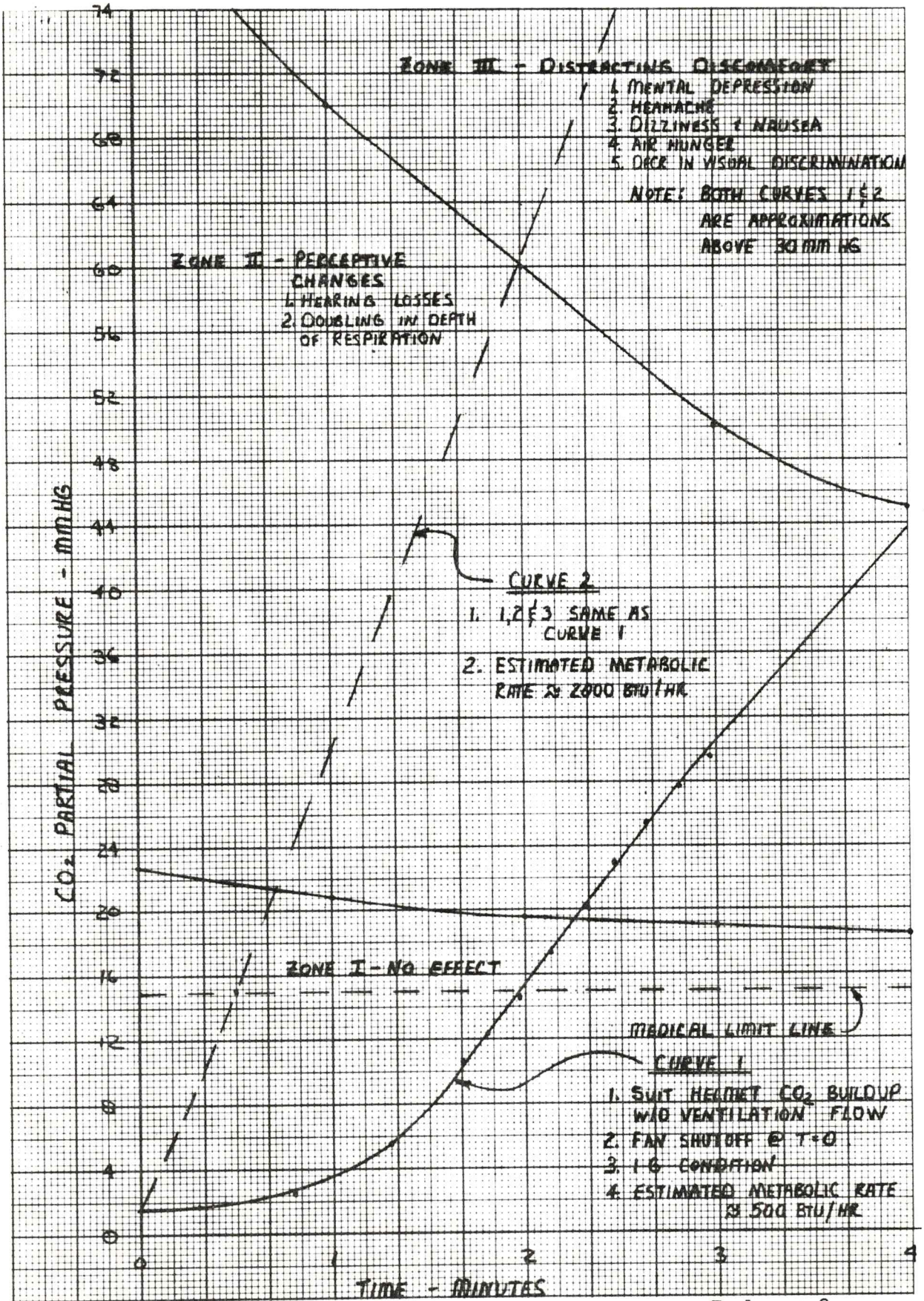
A. Vacuum ECS Transfer

B. ECS Transfer in Pressurized Cabin

Activity Definition:

1. Transfer and ingress CM
2. Transfer to CM ECS
3. Camera removal, hatch closure and lock
4. CM dump valve closure
5. Emergency repress

Enclosure 1


ZONE III - DISTRACTING DISCOMFORT
1. MENTAL DEPRESSION
2. HEADACHE
3. DIZZINESS & NAUSEA
4. AIR HUNGER
5. DECR IN VISUAL DISCRIMINATION
NOTE: BOTH CURVES 1 & 2 ARE APPROXIMATIONS ABOVE 30 MM HG
ZONE II - PERCEPTIVE CHANGES
1. HEARING LOSSES
2. DOUBLING IN DEPTH OF RESPIRATION
CURVE 2
1. 1,2 & 3 SAME AS CURVE 1
2. ESTIMATED METABOLIC RATE ≥ 2000 BTU/HR
ZONE I - NO EFFECT
MEDICAL LIMIT LINE
CURVE 1
1. SUIT HELMET CO_2 BUILDUP W/O VENTILATION FLOW
2. FAN SHUTOFF @ T+0
3. 1 G CONDITION
4. ESTIMATED METABOLIC RATE @ 500 BTU/HR
CO_2 PARTIAL PRESSURE - MM HG
TIME - MINUTES
74
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
0
1
2
3
4

Enclosure 2

July 19, 1971

NOTE OF INTEREST

SUBJECT: Crew Unsuited Configuration While on the Lunar Surface

Apollo 15 and subsequent missions require the LM crew to doff their PGA's (Pressure Garment Assembly) during sleep periods on the Lunar Surface; in previous lunar stays only the helmets and gloves were doffed and in the event cabin pressure dropped below 4.03 ± .37 PSIA, the Cabin Repress valve (AUTO) would maintain cabin pressure while the crewmen donned helmets and gloves and configured to CLOSED SUIT LOOP mode.

Obviously, without the suits donned, the time to reach a safe configuration is much greater and there are certain large cabin leaks that we cannot stand. In order to minimize these potential problems we investigated all ECS valves and switches which, if inadvertently actuated, could have direct effects or lead to potential problems, and have determined that the Lunar Surface Checklist provides adequate safeguards against these potential problems.

Enclosed is an investigation of the critical LM ECS circuit breakers and valves.

Q. Patin FC/46

Approved JSH

1 Enclosure

FC46:Q. Patin:mk:7-19-71:4576

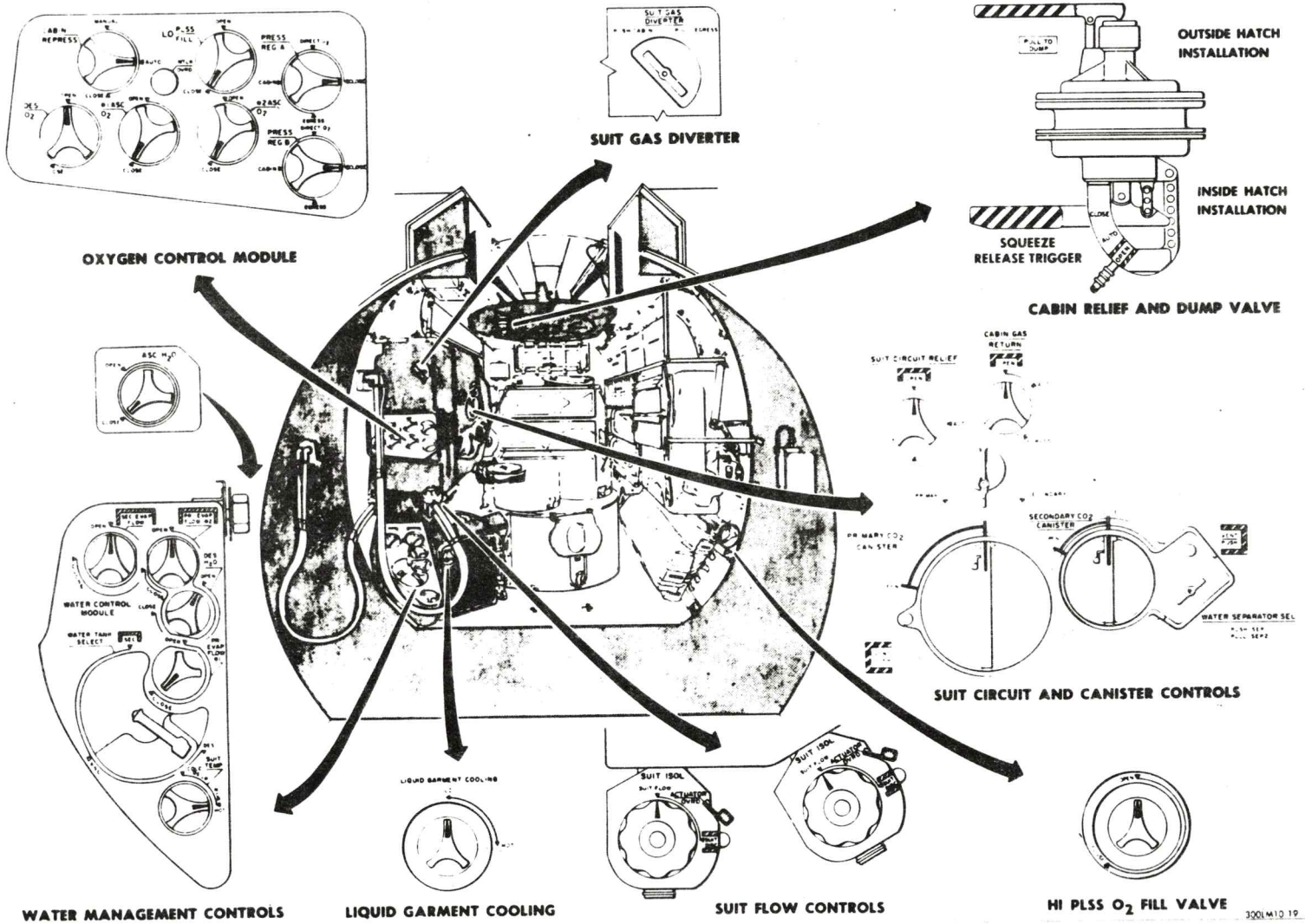
TYPE	FUNCTIONAL DESCRIPTION	POSSIBLE INADVERTENT ACTUATION	TOTAL EFFECT S/C - CREW
DES O_2 SHUTOFF VALVE	-Two position, manually operated shutoff valve controls O_2 flow into the OXYGEN CONTROL MODULE. There are OPEN and CLOSE positions, with mechanical stops on the handle to prevent overtravel.	Displacement of valve to CLOSE position.	Inadvertent closure of this valve does not present immediate danger. However, O_2 is not available for cabin puncture protection or for make-up oxygen to maintain the nominal cabin pressure via the DEMAND Regulators. If the valve remains in the CLOSE position for an extended time the cabin pressure decay will cause an onboard Master Alarm via the cabin pressure switch. Crew may re-open the Descent O_2 valve and allow the cabin repress valve to bring the cabin pressure back to the normal range. Ground monitoring can determine lack of cabin makeup within 0.5 - 1.0 hr.
DEMAND REGULATORS A and B	-Two regulators work in parallel to regulate oxygen from upstream O_2 tanks to the downstream suit loop. Each valve must be manually selected to the required mode. CABIN - 4.8 $\pm$.2psia EGRESS - 3.8 $\pm$.2psia DIRECT - 7.0#/hr (FULL FLOW) CLOSE - NO FLOW	Displacement of a DEMAND Regulator to DIRECT position.	Initiates a continuous High O_2 Flow (7 #/hr) to the suit loop and via the suit circuit relief valve to the cabin. A cabin pressure buildup to 5.4 psid will automatically dump overboard through the F/H or U/H Dump valve, if placed in AUTO. Crew action requires reselecting the appropriate regulator's CABIN position. Detectable via ground monitoring
H_2O SEPARATOR SELECTOR VALVE	-Two position manually operated flapper-type valve that enables selection of either water separator. Positions are: PUSH: SEP 1 PULL: SEP 2	Displacement of the valve selector handle to a position between completely in and completely out.	May result in split air flow to both separators with neither attaining sufficient speed to eject the condensed water; eventually results in 100% humidity and possible cabin condensation.

TYPE	FUNCTIONAL DESCRIPTION	POSSIBLE INADVERTENT ACTUATION	TOTAL EFFECT S/C - CREW
CABIN REPRESS VALVE	-Three position solenoid valve with manual override -		
	MANUAL - permits continuous oxygen flow (≈6.0 - 8.0 lbs/min) into cabin if Descent O_2 valve open.	Displacement of valve to MANUAL position.	If cabin pressure exceeds 5.4 psia, venting will occur via U/H and F/H dump valves. Immediate corrective action by crew should be taken to re-position valve to AUTO.
	CLOSE - inhibits oxygen flow.	Displacement of valve to CLOSE position.	No immediate danger. However, cabin puncture protection is lost if valve remains in CLOSE position while crew is unsuited. Undetectable via ground monitoring.
	AUTO - permits oxygen flow into cabin (≈6.0 - 8.0 lbs/min) if valve solenoid is energized via CABIN REPRESS C/B and cabin pressure switch closing at < 4.07 ± 0.37 psia.		
PLSS O_2 RECHARGE VALVES ~~HI PRESS~~ LO PRESS	-Two position manually operated shutoff valves control O_2 flow to the PLSS for O_2 recharge only. There are OPEN and CLOSE positions with mechanical stops on the handles to prevent overtravel.	Displacement of valve(s) from CLOSE position.	Down stream of both PLSS O_2 recharge valves are Q.D.'s which are designed to maintain line seals under full pressures of 1500 and 1000 psia respectively. However, a single point failure possibility is introduced to leak O_2 to cabin which U/H or F/H valves would relieve.

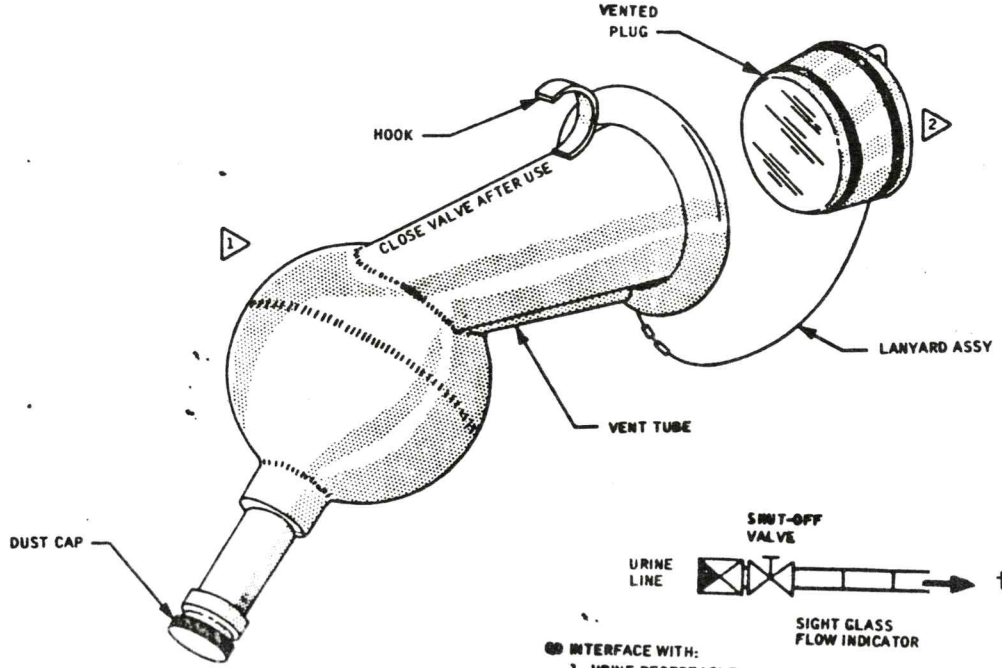
TYPE	FUNCTIONAL DESCRIPTION	POSSIBLE INADVERTENT ACTUATION	TOTAL EFFECT S/C - CREW
UPPER and FORWARD HATCH CABIN DUMP VALVE	-Three position valves		
	CLOSE - Isolates press contained in the cabin.	Displacement of valve to CLOSE position	Inhibits cabin pressure from relieving overboard in the event pressure exceeds normal operations of 4.8 $\pm$.2 psia. Undetectable via ground monitoring.
	OPEN - Permits cabin pressure to vent O/B if valve remains in this position. (Max full flow >11.1 lb/min at 5.4 psia)	Displacement of valve to OPEN position	Immediately begins to dump cabin more rapidly than cabin repress valve can make up. Crew must immediately return valve to AUTO or CLOSE position. Prior to doffing suits crew should verify both dump valves has been safely locked out from the OPEN detent.
	AUTO - Permits automatic cabin venting whenever pressure exceeds 5.4 psid.		
	NOTE: Valve handle must be squeezed before valve position can be manually changed. Also, a safety latch is provided to prevent movement from CLOSE or AUTO to OPEN if properly positioned.		
URINE DUMP VALVE and ASSEMBLY	Petcock type 360° rotational valve permitting urine/water waste material to be vented to the waste container assembly in the descent stage, when rotated to open position. Positions are unmarked; however, line indicating blocked or unblocked flow is available to indicate valve status.	Displacement of valve to OPEN position.	If the urine valve remains in the open position with the urine receptacle attached cabin oxygen will vent overboard via the waste container vent valve at rate 2.25 #/hr. Demand regulators can provide sufficient flow to prevent decay in cabin pressure. Immediately after use, the crew should close the shutoff valve and disconnect the urine receptacle from the urine line.

TYPE	FUNCTIONAL DESCRIPTION	POSSIBLE INADVERTENT ACTUATION	TOTAL EFFECT ON S/C - CREW
CABIN REPRESS C/B	Panel 16 C/B providing power to permit the cabin pressure switch to actuate the Cabin Warning Light and the Cabin Repress valve (if in AUTO)	Circuit breaker opens	Loss of Function. Undetectable via ground monitoring; however, ground can detect cabin pressure decay and SUIT/FAN warning light is actuated at 3.12 psia.
SUIT FANΔP C/B	Panel 16 C/B providing power to actuate Caution & Warning if a suit fan fails.	Circuit breaker opens	Loss of Function. Suit fan failure eventually detectable via slowing of H_2O separator RPM and resulting ECS caution light.

ECS AFT BULKHEAD CONTROLS



URINE RECEPTABLE ASSEMBLY



URINE RECEPTACLE

to WASTE CONTAINER ASSEMBLY
DESCENT STAGE
QUAD IV

@ INTERFACE WITH:
1. URINE RECEPTACLE
2. SUIT
3. PLSS DRAIN LINE

FROM: H. Smith

SUBJECT: Note of Interest April 30, 1971

LRV DEPLOYMENT MECHANISM
SPACE SUPPORT EQUIPMENT (SSE)

The information presented was extracted from Boeing documents presented for a DCR at Washington D.C.; the drawings were accomplished by FCD. These are Fig. 13-3, sheets 1 and 2 of the LM Systems Handbook.

PERFORMANCE

The LRV Deployment Mechanism is required to support and restrain the stowed LRV in the Quadrant I stowage bay of the LM during earth-lunar transit, and to deploy the stowed vehicle to the lunar surface. The SSE is required to deploy the LRV within 15 minutes with the LM tilted up to 14-1/2 degrees in any direction and with the bottom of the descent stage 14 to 62 inches above the lunar surface. LRV deployment manual acitvity is normally performed by both crewmen.

EQUIPMENT DESCRIPTION

The Deployment Mechanism consists of two basic subsystems of hardware, the structural support subsystem and the deployment hardware subsystem. The function of the structural support subsystem is to structurally support the LRV in the LM during launch boost, earth-lunar transit and landing. The function of the deployment hardware subsystem is to deploy the LRV from the LM to the lunar surface after landing.

The structural support subsystem includes two steel support spools at the lower (left and right) sides of the LM quadrant. The spools are bolted to LM attach fittings. Aluminum tube tripod structure attached to the LRV center chassis terminate in left and right tripod apex fittings which attach to the steel spools. The apex fitting halves are pinned together and clamped to the spools to support the LRV. The LRV is restrained against outboard rotation by an aluminum strut (the upper support arm) in the upper center of the LM, connecting the inboard

quadrant corner structure to an LRV center chassis standoff with a pin.

The deployment hardware system (fig. 13-3, sheet 1) consists of bell-cranks, linkages and pins to release the LRV from the structural subsystem, thus allowing the LRV to deploy from the LM. It also consists of braked reels, braked reel operating tapes, braked reel deployment cables, LRV rotation initiating push-off spring, telescopic tubes, chassis latches, release pin mechanisms, and LRV rotation support points, all of which operate in the following manner and sequence.

The deployment of the LRV from the LM to the lunar surface consists of five basic steps or phases.

Phase I - Deployment from the stowed position of both braked reel operating tapes and the deployment lanyard.

Phase II - Operating the D-ring to disconnect the LRV from the structural support subsystem.

Phase III - Operating the outer braked reel to unfold the LRV and lower the aft chassis wheels to the lunar surface.

Phase IV - operating the inner braked reel to lower the forward chassis wheels to the lunar surface.

Phase V - Disconnecting the deployment hardware from the LRV after all four wheels are on the surface.

Phase I - This phase consists of deployment of the two braked reel operating tapes and the deployment lanyard from their stowed positions. The outer braked reel operating tape is stowed in a nylon bag attached to the lower right support arm by velcro tape. The inner braked reel operating tape is stowed on the left side of the LRV center chassis in a nylon bag attached to the lower left support arm by velcro tape. (sheet 1, K/2). The deployment lanyard is stowed on the left side of the LRV center chassis by teflon clips. The deployment lanyard is used to assist deployment of the LRV if it stops during any phase of the deployment.

Phase II - At the completion of Phase I, the astronaut pulls the D-ring, which is located on the right side of the porch. The first 5-6 inches of travel of the D-ring removes the two lower release pins (Detail -C) from the apex fittings, releasing the lower halves and allowing them to fall away immediately or during deployment rotation. The apex fittings are now configured to lift off the spools when required. The last segment of travel of the D-ring removes the upper release pin (Detail -A). When the upper release pin is removed, the push-off spring rotates the LRV out from the LM approximately 4°, taking up the slack in the outer deployment cables.

Phase III - The LRV is now released from the LM and is ready to be deployed to the lunar surface. During the entire Phase III operations, the astronaut operates the outer braked reel operating tape. The braked reel is a worm and wheel gear arrangement. When the operating tape is pulled, the cable storage drum is rotated, thus releasing (feeding off) cable from the drum (Detail-B) The cable is attached to the LRV center chassis and, as the LRV rotates outboard due to gravity, resists the motion of the LRV. However, as the drum is rotated, feeding out cable, the LRV is allowed to rotate and deploy. For the first 15° of rotation, the LRV rotates on the apex fittings. At 15° rotation, the support arm is engaged by the LRV and the point of rotation shifts from the apex fittings to the support arm, at which point the apex fitting lifts off the support spools. The deployment cable may or may not be required at this time, depending on the landing attitude of the LM.

The LRV continues to rotate about the support arm. At 35° rotation, the lower telescopic tubes ratchets are engaged, preventing any reverse rotation of the telescopic tube assembly about its lower pivot points. The telescopic tube assembly consists of a pair of three telescoped aluminum tubes, hinged to the LM structure (lower center of the LM quadrant) and connected at the top by the saddle. The aluminum saddle fits to the forward section of the forward chassis, held by two dowel pins and a ball-lock pin clevis joint. The saddle carries the pulleys, cables and pin mechanisms whereby the forward and aft LRV chassis are

unlocked from the stowed (folded) LRV position. As the LRV moves outboard, the 45° cable tightens, and rotates the saddle pulley (Detail E). This rotation actuates (rotates) two additional pulleys, each with a steel cable and ball-lock pin. The two ball-lock pins lock the connection between forward and aft chassis to the console post mounted on the center chassis. If either the aft or forward chassis latch pin fails to pull, the deployment lanyard may be pulled to help accomplish this action.

The telescopic tubes and forward chassis stops at 45° due to the 45° cable (chassis latch actuating cable) becoming taut, then by counteracting forces of the LRV forward chassis hinge torsion spring, the telescopic tubes and forward chassis return to the 35° position (stop due to the telescopic tube ratchet). The center chassis and aft chassis continue to deploy. After it is unlocked, the aft chassis fully deploys (unfolds) automatically due to the aft chassis hinge torque bars, until it latches with the center chassis.

The wire mesh LRV wheels are held in the stowed position by four wheel lock struts. One end of each strut is held by a steel pin to the aft or forward chassis structure. The other end of each strut is held by a wheel hub by a pin (in the hub). The wheel lock strut pins are pulled by a steel cable so linked as to pull the pins as the aft or forward chassis opens approximately 170°. When the pins are pulled, the spring-loaded wheels deploy to the operational position. As the wheels rotate outboard to the deployed position, a mechanism within the wheel hub retracts the pin retaining the wheel strut. The strut is thus freed at both ends, and falls free during wheel deployment movement. Each strut is retained by a 1/8 inch diameter mylar tether.

The LRV center/aft chassis continues outboard rotation, pivoting around the lower support arm latch. During LRV outboard roatation, the telescopic tubes extend (lengthen). Before 72° LRV rotation an anti-collapse telescopic tube latch in each tube engages to prevent shortening (but permit elongation of tubes.

At approximately 73° center chassis angle, the cam on the forward sides of the center chassis strut (engaged in the lower support arm latch) strikes the steel latch arm (Detail -D). As the chassis rotates, the cam forces the latch lock arm down out of a safety retaining spring, and unlocks the latch. The center/aft chassis continues to rotate until the aft chassis wheels are on the surface. The wheels are locked with the emergency hand brake, therefore must slide on the surface. Depending on the landing attitude of the LM and the condition of the surface, the wheels might not slide on the lunar surface, therefore use of the deployment lanyard by the astronaut would be required. The astronaut continues to actuate the outer braked reel operating tape to allow the forward chassis hinge to deploy by virtue of the forward chassis hinge torsion spring. Concurrently, the center/aft chassis move outboard, away from the LM. At this point in the sequence, the 45° cable becomes taut due to the outboard movement of the entire LRV. The center chassis continues to move down but is driven outboard by the forward chassis springs. As the angle between forward and center chassis approaches 170°, the forward wheel lock strut pins in the forward chassis release, and the forward wheels deploy as did the aft wheels. The astronaut then pulls the pins that attach the two outer braked reel deployment cables to the center chassis.

Phase III - is complete (motion ceases) with the aft wheels on the lunar surface, with forward and aft chassis locked to the center chassis, all wheels deployed, all four wheel struts free and hanging from their tethers, the outer braked reel deployment cables released, and with the forward chassis held up by the telescopic tube assembly and the 45° cable.

Phase IV - This phase of the deployment consists of the astronaut actuating the inner braked reel operating tape, thus allowing the forward wheels to lower to the surface. Again, the deployment lanyard may be required at this point if the aft wheels will not slide on the surface.

Phase V - This phase consists of releasing the deployment hardware from the LRV. The astronaut pulls up on the saddle release cable

located on the left rear side of the forward chassis. This operation releases a ball-lock pin which holds the saddle on the forward chassis (Detail -F). When the saddle is released the following hardware goes with it:

1. Telescopic tube assembly.
2. Forward and aft chassis lock release pins.
3. Forward chassis wheel lock struts and tethers.

The astronaut then pulls a ball-lock pin, located on the aft center of the aft chassis. This releases the deployment lanyard and the aft chassis wheel lock struts (Detail -G).

At this point, the deployment of the LRV from the LM to the lunar surface is complete.

23 February 1970

Note of Interest - LM Attitude Control Modes during PDI

1. Of the many LM attitude control modes, four are acceptable for performing undocked powered maneuvers. In order of priority, these are: PGNS Auto, AGS Auto, PGNS Rate Cmd, and AGS Rate Cmd. However, for PDI, AGS Auto is not considered a valid control mode except for an abort case. The remaining modes, PGNS minimum impulse, AGS pulse, AGS direct (3-axis), and hardover are deemed unacceptable for powered maneuvers.

2. For PDI, a philosophy has been adopted which states that any failure that leaves only one acceptable control mode such that one more failure would require use of an unacceptable control mode, an abort will be requested to insure crew safety. Based on this philosophy, there are a number of failure modes which may occur that will allow for continuation of the mission. A number of examples follow: (Enclosure 1 defines the control modes, their components/interfaces, and disabling failures.)

3. The present mission rules require PGNS Auto/Rate Cmd and AGS Rate Cmd for initiation and continuation of PDI. If a failure occurs in the PGNS auto mode such that PGNS rate cmd in uneffected (e.g., mode control switch failure), the two remaining control modes, PGNS Rate Cmd and AGS Rate Cmd, share no point of commonality except jet drivers for which one failure has no effect on crew safety. The same logic is true for a loss of PGNS Rate Cmd independent of PGNS Auto. In these cases continuation of the mission would be the recommended course of action. It should be pointed out that loss of either mode may cause a change in the crew landing procedures. For example, loss of PGNS Auto would cause the crew to manually fly the FDAI error needles until touchdown. This would not allow automatic velocity nulling using auto-P66. Loss of PGNS Rate Cmd would necessitate flying in PGNS Auto or switching to AGS Rate Cmd for manual-P66 capability and switching back to PGNS for Auto-P66 velocity nulling.

4. A failure which causes loss of both PGNS Auto/Rate Cmd would leave only AGS Rate Cmd as an acceptable control mode. A subsequent failure (CES AC fail, which disables all three RGA's and loss of AGS Auto) would result in an abort utilizing one or more of the unacceptable control modes. Thus a failure common to both PGNS Auto/Rate Cmd would require an abort.

5. The loss of AGS Rate Cmd would leave the crew dependent on PGNS Auto/Rate Cmd. This is undesirable since a single failure could remove total PGNS capability; however, consideration for continuing the mission with loss of AGS Rate Cmd would be given if the failure is independent of AGS Auto since this would be a valid mode for an abort if required. The partial loss of AGS Rate Cmd (loss of one RGA) is considered an acceptable mode with the crew using AGS direct (secondary coils) in the effected axis. Based on this, a one-axis failure on AGS Rate Cmd will allow continuation of the mission.

6. Loss of AGS Auto would not constitute loss of AGS Rate Cmd in all cases since the crew may have rate dampening capability (no attitude hold). Thus, this failure may not be cause for abort unless AGS Rate Cmd is also disabled. In addition, loss of any of the unacceptable modes of control (secondary coils, etc.) also is an allowable event until only one acceptable control mode exists at which time an abort must be performed.

7. The statements above reflect the intent and interpretation of the current 3-axis control mission rules. It should be pointed out that inherent in these rulings is the availability of PGNS guidance steering for either automatic steering or for providing steering information to the crew (FDAI error needles). The loss of this capability above hi-gate is cause for an abort. However, below hi-gate manual landing at the crew's option may be attempted with loss of guidance steering. The rationale for this decision is that the problem may be recoverable upon landing and that time for ground evaluation during this time frame is minimal. Thus, in accordance with this statement, landing may be attempted after hi-gate (at the crew's option) with a violation of the 3-axis control philosophy stated earlier, since the failure of guidance steering may be common with PGNS Auto/Rate Cmd. Of course, an obvious unrecoverable failure would be cause for an abort and would be so recommended during this time frame.

Richard A. Thorson

Enclosure

HAL/JEH

Control Mode	Components/Interfaces	Ruling
PGNS Auto	Operational ISS	Loss of mode[1]
	Operational LGC	Loss of mode[1]
	Valid Navigation	Loss of mode
	Primary Pre-amps	Loss of mode[2]
	CES-LGC Interface	Loss of mode[2]
PGNS Rate Cmd	Operational ISS	Loss of mode[1]
	Operational LGC	Loss of mode[1]
	Primary Pre-amps	Loss of mode[2]
	ACA	c/m with loss of one
	ACA-LGC Interface	Loss of mode
	CES-LGC interface	Loss of mode[2]
AGS Rate Cmd	Operational AEA	c/m[3]
	Operational ASA	c/m[3]
	3 RGA's	c/m with loss of one[4]
	ACA	c/m with loss of one
	Abort pre-amps	Loss of mode[2]
	ATCA	Loss of mode
	CES-AEA interface	Loss of mode[2]
AGS Auto	Operational AEA	Loss of mode
	Operational ASA	Loss of mode
	3 RGA's	c/m with loss of one[4]
	Abort pre-amps	Loss of mode[2]
	ATCA	Loss of mode
	CES-AEA Interface	Loss of mode[2]

1. A permanent loss of either the ISS or LGC will disable both PGNS Auto and Rate Cmd. A temporary loss of the ISS or LGC will disable only PGNS Auto (cause a loss of guidance steering) leaving PGNS Rate Cmd as an acceptable mode.

2. Although these components and interfaces are common to each mode, there are specific failures associated with each that may disable only one of the two modes.

3. Loss of the AEA or ASA functions would cause a loss of the attitude hold function of AGS Rate Cmd. This would only effect AGS Rate Cmd if erroneous outputs were introduced to the ATCA. A zero output would permit retention of AGS Rate Cmd as an acceptable control mode.

4. Loss of one RGA would disable rate dampening in the effected axis only. By using AGS direct in this axis, AGS Auto/Rate Cmd remains an acceptable mode.

Enclosure 1

July 27, 1971

NOTE OF INTEREST: A Follow-up on CDU Failures and PDI

1. A number of static CDU failure cases have been run on the Houston LMS to determine procedures for the continuation of PDI (reference note of interest - CDU Failures and PDI, dated July 2, 1971). The resultant conclusions from these runs vary depending on the type of CDU failure (i.e., pitch, roll, or yaw) experienced.

2. The LMS runs proved that the pitch CDU failure was the most critical, although a technique was developed to reach the visibility phase (hi-gate). It was in fact a "manual" technique, flying to chart values of altitude and altitude rate. Since landing radar could not be incorporated into the LGC, it was decided that this failure presented an abort case should it occur during powered descent.

3. Static roll CDU failures were acceptable; however, initial out-of-plane position dispersions caused problems with landing radar updates. The techniques required for this failure are straight forward provided a limited amount of out-of-plane steering is required. The Apollo 15 crew has agreed to continue with this failure provided a concurrence from the ground is received, based on analysis of the trajectory dispersions.

4. The yaw case represents a situation where the techniques are similar to existing procedures. One exception is to ensure a zero yaw angle while following the pitch and roll attitude error needles, thus allowing incorporation of landing radar data. The procedures for the roll and yaw failure cases are presented in enclosure 1.

5. Although the crew is familiar with the techniques presented in enclosure 1, and have demonstrated the yaw technique in descent simulations (July 16, 1971), it should be understood that a single static CDU failure is highly unlikely. Dynamic failures or static failure of all CDU's is more realistic. In view of this, MIT has developed an E-memory program which could conceivably be used for all cases of CDU failures. However, there are two constraints to this approach. First, the IMU platform must be aligned and time must exist for uplinking the E-memory program prior to PDI. Secondly, multiple failures or dynamic failures violate existing redundant 3-axis attitude control mission rules.

6. From the preceding discussions it should be apparent that only in the case of static CDU failures do acceptable procedures exist. However, this conclusion is probably academic due to the nature of the failure.

Richard A. Thorson

Richard A. Thorson

1 Enclosures

FC42:RAThorson:dh:4717:7-27-71

HAL:JEH

CDU FAILURES

1. For dynamic (changing) types of failures or static pitch CDU failures during PDI, the PGNS is no go as a navigation system, and we have an abort situation.

2. For single axis yaw or roll CDU failures statically, the PGNS is go for nav, go for control with the failed axis being flown like accel CMD (no rate damping or deadbanding). The following proposal permits continuing descent and maintaining PGNS abortability utilizing AGS attitude hold as the primary control mode.

STATIC YAW OR ROLL CDU FAIL

Descent Techniques

Primary Control Mode: AGS att hold
Yaw to zero
VxxN20E, E; xx is 21 for Yaw, 23 for Roll
Follow N22 pitch and roll or error needles (if N22 is used with a roll CDU failure, the roll sign represents an attitude error vice desired attitude).
Maintain zero yaw on ball
V57 at ΔH OK

NOTE:

1. Error needles will be valid after N20 loading.
2. Use auto throttle until visibility, landing phase.
3. Use manual throttle in visibility, landing phase.

Aborts or Ascent

1. Use AGS Auto
2. Second preference

   PGNS att hold
   Follow N22 pitch and roll or error needles (see above).
   Maintain zero yaw on ball (N77 can be called late for cutoff backup)

May 24, 1971

NOTE OF INTEREST: PDI Procedure for LR Antenna Switching

The question of what's the best procedure for an LR antenna out of proper position has arisen again. In this note, I will present some background on the subject, our conclusion, and rationale.

BACKGROUND:

The following facts are pertinent to the discussion:

1. PDI is nominally initiated with the LR antenna in position 1 (24° angular offset from the X axis).

2. LR position 2 (vertical position) is automatically commanded at P64.

3. The H and $\dot{H}$ at P64 is 7030 ft and - 162 ft/sec.

4. The LR can be driven manually to either position 1 or position 2.

5. It takes the antenna approximately 8-10 seconds to drive from one position to another.

6. The LGC must recognize either position 1 or position 2 in order to process LR data through the proper matrix.

7. The worst thing that can happen is to have an antenna/antenna position indication mismatch, i.e., the antenna actually in position 2 but indicating position 1, or vice versa. (The LGC processes LR data through the wrong matrix.)

8. If the LR antenna is actually stuck in position 1 during the vertical phase, the tapemeter readout of raw LR data will be approximately 10 percent in error.

9. LR dropouts may occur if the LR is in position 1 during the vertical phase.

DISCUSSION:

The following situations could theoretically occur at antenna switchover time (64):

1. The antenna could fail to move from position 1 (with the position 1 discrete still indicated to the LGC).

2. The antenna could physically move to position 2, properly indicate position 2, but the position 1 discrete not go away.

3. The antenna could move to position 2 but fail to send the position 2 discrete to the LGC.

4. The antenna could drive to an intermediate position where neither position discrete were indicated. (Cases 3 and 4 would appear the same).

For Cases 2 and 3, it is clear that the proper action is to command the antenna manually back to position 1 (LDG ANT: DES). For Case 4, it's not quite as clear, but since Cases 3 and 4 appear the same, I think the thing to do is to manually command position 1 where the LR was working properly before. For Case 1 there are some systems reasons that say that manually commanding position 2 may not hurt the situation and may indeed get us the desired position where the LR works best. There is also a philosophy which says to "leave well enough alone" - if the LR is working properly in position 1, don't mess with it. If you couple this philosophy with the fact that at LR switchover time we are descending at a rate of -160 ft/sec and at an altitude of 7000 feet, and the fact that it takes 8-10 seconds for the LR to drive, we arrive at our conclusion.

CONCLUSION:

It is concluded that the proper action for any of the 4 situations is to manually command LR position 1 (LDG ANT:DES). Even for case 1, we want to command LDG ANT: DES in order to insure that we remain in position 1. There just isn't enough time to do anything else. If for case 1 we chose to manually attempt to drive to position 2 and were unsuccessful, we would then have to command the antenna back to position 1. Data delays, drive times and recognition time would eat up 40-50 seconds (~4000-5000 ft) altitude. We procedurally start a stop watch at P64. If we do not reach position 2 within 15 seconds, we will call LDG ANT: DES. If we fail to lose position 1 within ~5 seconds after P64, we will also call LDG ANT: DES. Should the crew ever get a 511 alarm (LR not in position 2 or repositioning) they should procedurally command position 1.

John A. Wegener
John A. Wegener
LM Control

JEH

June 9, 1971

ADDENDUM - NOTE OF INTEREST: PDI Procedure for LR Antenna Switching

Publication of this note was delayed pending an analysis by LAB of the extent of data dropouts for the LR failed in Position 1. The results of the run are as follows:

ALTITUDE (FT)	
39,700 - 6,600	LOCK
6,600 - 900	LOST LOCK
900 - 200	LOCK
200 - 130	LOST LOCK

These results were discussed with the Guidance Officer and it was mutually agreed that the actions and procedures delineated in the basic note of interest are acceptable.

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November 1, 1971

NOTE OF INTEREST: Lunar Surface Operation of the PGNS and AGS without Active Cooling

1. On Apollo 15, the mission rule for loss of secondary glycol was changed to reflect a continue mission ruling on the lunar surface. The rationale for this change was based primarily on the ability of the PGNS to perform a direct rendezvous in the event of a primary glycol failure, i.e., an ascent/direct RNDZ on an uncooled and possibly degraded PGNS. The following note is intended to clarify the management of the PGNS and AGS for a no-cooling contingency.

2. Although the PGNS and AGS are known to be temperature sensitive, performance degradation vs time from loss of cooling has been debated since Apollo 11. Prior to this time, temperature analysis of the PGNS had been performed only via computer simulations. This data indicated that the PGNS lifetime was approximately one hour which was based on violating various equipment redlines. Apollo 11, however (in lunar orbit), indicated that the initial equipment degradation did not occur until approximately 3 hours after cessation of cooling (AGS did not degrade as it was operating on the active secondary loop). Due to lack of telemetry on the PGNS equipment, it can only be speculated as to the exact temperature of the various PGNS equipment. The one measurement that can be correlated was the PIPA temperature, which after a quiescent period of approximately 1.3 hours from coolant turn-off, rose at approximately 5°/hr vs computer simulation data of approximately 6°/hr. The following table illustrates the predicted failures (redline limits) vs the Apollo 11 systems failures:

TIME FROM GLYCOL FAILURE (HOURS)	PREDICTED COMPONENT FAILURE	PROBABLE SYMPTOM	APOLLO 11 DATA
0.9	PTA	PIPA/IMU FAIL	
1.1	PSA	PIPA/IMU FAIL	
1.15	IMU	PIPA/IMU FAIL	
1.5	PIPA	PIPA TEMP CAUTION	
1.7	LGC	LGC WARNING	
1.75			PIPA TEMP CAUTION
2.5	PIPA	PIPA OFF SCALE HI	
3.2	CDU	CDU FAIL	PIPA TEMP OFF SCALE HI
3.4			CDU FAIL
4.25			PIPA FAIL
6.25			IMU FAIL
6.9			PLATFORM TUMBLE
7.1			LGC WARNING

It is significant that of the predicted component failures only the CDU fail was verified on LM-5 (Apollo 11). It should be emphasized however, that these predicted failures were based on specification values rather than actual expected failure levels.

3. Prior to the Apollo 11 test, the PGNS was considered reliable for one hour from loss of coolant. Thus, our rules were written for a T-1 or T-2 liftoff if the failure occured at touchdown or late in descent. For a loss of the secondary coolant loop, a next best opportunity ascent was scheduled ($\leq$ two hours). For an any time loss of the primary loop, ascent would have been planned within forty-five minutes if the PGNS was to be the prime system.

4. With MIT, G&C Division and FCD's re-evaluation of the Apollo 11 data and subsequent simulations, it seemed practical to desensitize our position on uncooled PGNS reliability. First, with the PGNS unpowered, the initial heat into the system will be less than on Apollo 11. Second, by minimizing PGNS operating time prior to liftoff, a direct RNDZ on the PGNS ($\approx$ 1 3/4 hr) seemed practical based on the available data. In addition, the computer simulation data indicates that the AGS can be used as a PGNS backup for insertion, turned off, and used again from TPI until docking. The following is a brief summary of the PGNS and AGS accuracies under uncooled conditions as determined by MIT and G&C Division:

With temperature deviations, PIPA bias and scale factor errors cause small variations in the ascent trajectory of $\approx$0.01 n.m./^{o}F in perilune and $\approx$ 1.4 n.m./^{o}F in apolune. Since the PIPA temperature should not be greater than $\pm$ 1°F at liftoff, these dispersions are acceptable. AGS performance is also acceptable provided the AGS is turned off after insertion. AGS errors are expected to be .1°/hr/^{o}F gyro bias and 22 X 10^{-6} g/^{o}F accelerometer uncertainty.

5. Based on these considerations, the mission rule for loss of the secondary loop (which does not affect either PGNS or AGS provided the primary loop is available) allows a stay ruling on the lunar surface. Loss of the primary loop (the PGNS is not on the secondary loop) requires a next best short RNDZ opportunity. For this latter case, predictable temperatures can be maintained by following the timeline below:

*T-3 hours	Ground informs crew of failure and crew returns to LM (Assumes worst case condition of crew EVA and approximately 1 hour traveling time from the LM).
*T-2 hours	Crew enters LM and deactivates LGC and PGNS heaters (AGS heaters if secondary loop has failed).
T- :45 min	Crew begins emergency liftoff checklist (pp 19-1, Lunar Surface Checklist).
T- :30 min	Begin PGNS power up and alignment.

T-	:15 min	Begin AGS power up and alignment.
Post-insertion		Power down AGS (If secondary loop failed).
TPI-	:10 min	Power up AGS and align to PGNS (if secondary loop failed).

*These figures are approximate as it may be 1 3/4 to ≈ 3 3/4 hours to enable the proper phasing to be achieved for a direct Ascent/RNDZ sequence. However, with the heaters deactivated, the time required to obtain proper phasing is immaterial. The small rise in structural temperature that occurs with the loss of all vehicle cooling will have a negligible effect on PGNS or AGS temperatures during the times considered.

Richard A. Thorson

Richard A. Thorson

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FEB 25 1972

Note of Interest - LM Platform Drift

In the past couple of weeks, several items concerning LM platform drift have been reviewed. These items are LM activation drift check comparison and onboard crew chart for gyro compensation. The following is to present the problem addressed, the considerations discussed, and the end agreements derived:

a. Drift checks - The last LM activation sim pointed out a weakness in the flight controller philosophy of comparing the two drift checks. The problem presents itself when the V06N20 docked drift check differs greatly from the P52 alignment drift check. In the case where there is no reason to suspicion either method, some criteria has to be applied to select the data used to evaluate gyro compensation. This criteria is to avoid a one-rev slip in PDI to obtain an additional P52 drift check. The circumstances which could lead to a large difference were first considered. These are obscure sighting errors and gyro bias shifts. Data input and calculation errors were disregarded, since these could be doublechecked. The P52 display of N05 star angle difference provides a check on sighting accuracy. However, a sighting error out of the plane of the two star vectors does not appear in the N05 value. Thus it is possible, though remote, for a sighting error to pass the N05 check and degrade the N93 torque angles. A gyro drift bias can change or shift because of instrument contamination. An example of possible contamination is bubble entrapment around the gyro float. A bias shift not only causes the two drift-check methods to disagree, but allows both methods to indicate a drift other than actually exists.

(1) Numerous theoretical cases were studied assuming one of the error sources. An attempt was made to apply a voting or weighting logic to select the best drift data. After much headscratching, it became apparent that all cases could not be protected by a given logic. As a result, the alternate approach to apply a reasonability limit was considered. The theoretical uncertainties in each drift check method can be combined to give an expected tolerance on the comparison. Any difference exceeding this tolerance, plus an additional pad, would indicate a hidden error in one or both methods. For the nominal timeline, the two-sigma uncertainties in the N20 and P52 checks are 4.3 meru and 5.6 meru, respectively. For a comparison uncertainty, the RSS sum of the above individual values is used. This comparison value is 7.08 meru. A detailed description of the various error sources considered in the uncertainty values are contained in enclosure 1.

(2) The selection of the absolute tolerance limit was just a matter of adding an arbitrary pad to the uncertainty. In discussing the drift-check problem with the Apollo 16 Activation/Descent flight director, the tolerance philosophy was accepted and a limit of 12 meru selected. The limit is approximately one half the allowable drift about the y axis to maintain abortability during descent. Thus in summary, the results of the N20 and P52 drift checks will be compared. If the values agree within 12 meru, the P52 data will be used to update gyro compensation.

If the values disagree by more than 12 meru and there is no indication of error in either method, PDI will be slipped a rev to allow another P52 to be performed. For further discussion, questions should be directed to Mr. J. Nelson/FC4, extension 4717, or Mr. W. Presley/FC5, extension 3268.

b. Gyro Compensation Chart - Concern has again been expressed over crew usage of the onboard gyro compensation chart. The necessary scratch-pad calculations and chart entries allow much room for error. Even though it is unlikely the crew will ever be required to use the chart (late P52 completed after LOS on rev 12), the chart is still considered a necessary evil. However, the indicated drift level requiring usage of the chart has been reevaluated. For previous missions, this level has been 5 meru or greater. To increase this limit, the landing errors resulting from various drift levels were investigated.

(1) The drifts were applied to the Apollo 16 timeline from LOS rev 12 to nominal PDI. The position errors resulting from the misalignment assumed no LR velocity updates. The maximum allowed error was selected as the redesignation capability at 6,000 ft requiring 60 fps DPS propellant usage. These errors are $\pm$ 4100 ft crossrange and +2100 ft downrange. Crossrange errors result from x and z axis drifts; the x being the most sensitive. A drift rate of approximately 15 meru about x results in the allowable dispersion. Downrange errors are caused by y axis drifts. The drift rate required to cause the allowable downrange dispersion, however, far exceeds the abortability constraint. The limiting level about the y axis is selected as one half the abortability value or approximately 16 meru. As a result, the acceptable uncompensated drift level is increased to 10 meru. The new value has been submitted for update in the LM Data Card Book for Apollo 16.

(2) In the process of reevaluating the update criteria, the idea of altering the compensation chart format was considered. A change was suggested to make the onboard chart similar to a special flight controller quick-look format. The format change eliminates all arithmetic steps. The variable chart entries are N93 torque angle and the time interval between alignments. The output is the new gyro compensation in scaled octal form. A sample format is contained as enclosure 2. The new format assumes a known value for the old or previous compensation. If the prelaunch compensation values change, then the chart must be modified accordingly. This is not considered a problem since the gyro characteristics are usually stabilized well before the final cut-off data for the onboard data file.

(3) The new format was shown to the crew of Apollo 17. The crew opinion was favorable, and as a result, the format will be submitted as a change to the Apollo 17 LM Data Card Book. The idea was rejected for Apollo 16 as being too close to launch for a change of this nature. For

further discussion, questions should be directed to Mr. R. Thorson/FC4, extension 4717, or Mr. W. Presley/FC5, extension 3268.

Will S. Presley
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CBP JCB

2 Enclosures

FC551/WSPresley:phc:2/17/72:3268

I. P52/N20 GYRO DRIFT MEASUREMENT ACCURACY

P52

The two sigma alignment accuracy of an AOT inflight P52 alignment using two stars is 0.119 degrees.[1] Since two P52 alignments are required to measure gyro drift, the RSS of the alignment accuracy for each P52 is used to determine drift measurement accuracy as follows:

2σ accuracy of 1st P52	$.119^\circ$
2σ accuracy of 2nd P52	$.119^\circ$
RSS	$.168^\circ$

$$\text{Drift measurement accuracy} = \frac{.168^\circ}{\text{time between alignments (HR)}}$$

Apollo 16/~~2σ~~ P52 Drift measurement accuracy = $\frac{.168^\circ}{2 \text{ HR}} = \pm .084^\circ/\text{HR} = \pm 5.6$ MERU

NOTE: To simplify decisions real-time, if the N93 torquing angles of the second P52 are less than $.168^\circ$, no gyro drift update will be made since the torquing angle is less than the two sigma accuracy of two consecutive alignments.

N20

The LM IMU to CSM IMU mechanical interface uncertainties which adversely affect the accuracy of a N20 alignment do not affect the N20 drift check if the N20 sets are taken at the same attitude. Since the N20 drift check uses the difference between two N20 alignments, the LM/CSM mechanical uncertainties drop out.

The N20 gyro drift check accuracy is calculated using the following error sources and assumes that both N20 sets are taken at the same attitude:

1. Gimbal uncertainty - 23 arc sec (0.0063 deg) for both the CSM and LM.[2]

2. CSM uncompensated drift - The CSM mission rule limit for gyro drift updates is 1 MERU (0.15°/hr) for the first update and 3 MERU ($.045^\circ$/hr) thereafter. For the purposes of the N20 drift accuracy calculation, a two sigma CSM drift accuracy of 3 MERU will be used.

NOTE: Due to the length of time that the CSM platform has been operating prior to the docked alignment period, the CSM platform drift is well known. Furthermore, the CSM does a P52 alignment and drift check approximately 2 hours prior to the first LM P52.

[1]SODB (Spacecraft Operational Data Book) Vol II, Table 4.5-3 "LM Noun 05 and alignment accuracy"

[2]MSC Internal Note 70-FM-219, Apollo G&N Contingency Alignment Accuracy Update, AGS Gravity Alignment and RTCC LM IMU Orientation Determination Accuracy, Page 7.

3. Crew marking accuracy - For a heavy CSM/LM (98,047 lbs) a 2 jet minimum impulse jet firing will cause a rate of 0.02 deg/sec about the X body axis and 0.0022 deg/sec about the Y and Z axes. Assuming a crew DSKY marking accuracy on the V06N20's of 0.5 seconds and a worse case spacecraft rate of 0.02 deg/sec a marking accuracy of 0.01 degrees is obtained.

Assuming the above three error sources are the primary errors associated with a N20 drift check, the two sigma N20 drift measurement accuracy can be calculated as follows:

Accuracy of a single N20 set

SOURCE	ERROR (DEG)
LM Gimbal uncertainty	0.0063
CSM Gimbal uncertainty	0.0063
LM crew marking accuracy	0.01
CSM crew marking accuracy	0.01
RSS	0.0167 deg

Accuracy of two N20 sets

Accuracy of 1st N20 set	0.0167 deg
Accuracy of 2nd N20 set	0.0167 deg
RSS	0.0236 deg
2σ	0.0472

Based on the Apollo 16 nominal time between N20 sets of one hour, the 2σ accuracy for two N20 sets and the 2σ CSM uncompensated drift value of 3 MERU, the drift measurement accuracy is calculated as follows:

$$\text{Apollo 16 N20 drift measurement accuracy} = \sqrt{3^2 + \left(\frac{0.0472^\circ}{1\ \text{HR}} \div \frac{0.015^\circ}{\text{MERU}}\right)^2}$$

$$= \sqrt{3^2 + (3.14)^2}$$

$$\text{Apollo 16 } \overset{2\sigma}{\text{N20}} \text{ drift measurement accuracy} = \pm 4.34 \text{ MERU}$$

Using the P52 and N20 drift measurement accuracies, a combined accuracy for comparing the N20 drift check with the P52 drift check is 7.1 MERU.

APOLLO 14 AND 15 DATA

Apollo 14 and 15 drift checks were similar to Apollo 16 in that N20 drift checks were made and compared to P52 drift checks. However, Apollo 15 N20 mark data was taken both by the crew and the ground. The following table contains the difference between N20 and P52 drift values for Apollo 14 and 15. Subscripts indicate which consecutive alignments were used for the drift calculations.

	DIFFERENCE BETWEEN N20 AND P52 DRIFT VALUES (MERU)		
	X	Y	Z
Apollo 14 $N20_{1-2}$ - $P52_{1-2}$	.5	.35	1.12
Apollo 15* $N20_{1-3}$ - $P52_{1-2}$	.18	1.12	.95
$N20_{1-3}$ - $P52_{2-3}$	1.31	3.90	3.56

*Some of the data taken by the ground was erroneous and was not used in the above table.

II. P52/N20 ALIGNMENT COMPARISON UNCERTAINTY

The following table lists error sources associated with N20 alignments and shows P52/N20 N93 comparison accuracies.

N20 ALIGNMENT UNCERTAINTY

ERROR SOURCE	(DEG) X	Y	Z
LM Gimbal Uncertainty[1]	0.0063	0.0063	0.0063
CM Gimbal Uncertainty	0.0063	0.0063	0.0063
LM Crew Marking Uncertainty[2]	0.01	0.01	0.01
CM Crew Marking Uncertainty	0.01	0.01	0.01
Hardware Alignment Uncertainty[3]			
X (.264 deg)	0.0638	0.0001	0.2561
Y (.067 deg)	0.057	0.034	0 014
Z (.068 deg)	0.033	0.059	0.008
RSS	0.093	0.070	0.257
2σ	0.186	0.140	0.514

P52/N20 ALIGNMENT COMPARISON UNCERTAINTY

		(DEG) X	Y	Z
2σ	P52 Alignment Uncertainty[4]	0.119	0.119	0.119
2σ	N20 Alignment Uncertainty	0.186	0.140	0.514
2σ	P52/N20 Comparison Uncertainty	0.221	0.184	0.527

1 & 2 See previous Part I for discussion.

3 Spacecraft Operational Data Book (SOBD) Vol II, Table LM10/4.5.1-2; Also note that propagation of the hardware uncertainties into the platform axes is dependent on attitude. The above uncertainties were computed using a CSM attitude of 0° roll, 104° pitch, 0° Yaw.

4 Spacecraft Operational Data Book (SODB) Vol II, Table 4.5-3

In addition to the above N20 alignment uncertainty, a N20 alignment is affected by known hardware misalignments between the LM IMU and CSM IMU. Hardware misalignments are listed in Table 4.5.1-2 of the appropriate LM vehicle SODB appendix. The X axis misalignment is corrected with the docking angle bias. Presently the Y & Z hardware misalignments are not included in the N20 alignment and therefore the N20 Y & Z axes alignment uncertainties should include the known hardware misalignments. Capability to propagate the Y & Z CSM & LM misalignments into the LM platform axes does not presently exist. Arrival of the LM11 misalignment data must be obtained before a total picture of the N20 alignment accuracy can be obtained.

April 10, 1972

NOTE OF INTEREST: Ascent Guidance and Control Modes, Their Priority and Selection

Recent discussions have illustrated the need to discuss established ascent flight control modes relative to navigation and guidance sources as set down by Data Priority. Although the combinations set forth by Data Priority are valid during powered flight, the sequential cockpit switching required is of concern to some people. It is this concern which is addressed by this memo.

Before continuing, it will be convenient to review the definitions of navigation, guidance and control and their relation to the established ascent guidance and control modes:

1. Navigation - The capability to measure a change in the vehicle state with a subsequent state vector update. To perform the navigation function, requires an operational IMU or reference that is correctly aligned for measurement purposes (i.e., working PIPA's) and a functional computer (LGC, AGS) to perform the necessary computations for state vector updates.

2. Guidance - The ability to compute and generate commands that guide the vehicle along a desired path or towards a desired end point. Thus, in addition to attitude measurements (i.e., gyros, CDU's), guidance is dependent upon valid navigation. Also, guidance must be able to control the vehicle via attitude commands or it must supply these commands to the crew (error needles) such that they may act on them. In this vein, guidance is considered as guidance steering.

3. To perform the guidance steering function requires one of a number of acceptable control modes. These are: PGNS auto, AGS auto, PGNS attitude hold, and AGS attitude hold.

From these definitions, it is possible to view the established guidance and control mode priorities and the rationale used in their selection. These modes are listed below in their order of priority:

CONTROL MODES	GUIDANCE MODES
1. PGNS auto	1. PGNS auto (Nav, guidance, control)
2. AGS auto	2. AGS auto (Nav, guidance, control)
3. PGNS attitude hold	3. PGNS error needles (Nav, guidance)
4. AGS attitude hold*	4. AGS error needles (Nav, guidance)*
5. Manual	5. FDAI (H if possible) (Nav)
	6. Overhead window

*AGS error needles and auto shutdown are not available in AGS attitude hold.

As noted above, the order of these modes is based on the desirability of an automatic sequence. The selection of PGNS attitude hold as the third priority is based on two facts. First, an auto shutdown is possible if PGNS guidance is valid and second, PGNS needles are available (AGS attitude hold does not allow for error needles or an auto guidance shutdown).

Although these priorities are valid for powered ascent, the possibility of a switch failure when switching control modes brings up the question of gain vs risk during powered flight. In talks with Phil Shaffer, he has stated that it is acceptable during ascent for the crew to down mode (i.e., PGNS auto to PGNS attitude hold) control modes to an acceptable system following loss of the prime mode. Thus ground attempts to upgrade control modes are not necessary provided the crew's configuration insures a safe insertion. This reasoning accepts the fact that a manual shutdown and subsequent tweak may be necessary, and that the subsequent gain of an auto shutdown is not worth the risk of additional guidance control switching in which a number of relays are exercised. It should be emphasized that the above argument does not supercede the recognized ground procedure of requesting a guidance switch to AGS auto for trajectory dispersions.

A typical example of the above rationale is the case where PGNS auto is declared NO-GO on the lunar surface. Although PGNS attitude hold and guidance may be available, the ascent would be performed on AGS auto as per data priority agreements. In contrast, if PGNS auto should fail during ascent, AGS auto would be preferred; however, PGNS attitude hold (if available) flying PGNS or AGS error needles would be acceptable. Similarly, if AGS auto should fail after an AGS liftoff, AGS attitude hold flying PGNS error needles would be preferred to switching to PGNS attitude hold.

The point of this discussion is that the ground must make clear to the crew their capabilities such that they have at their option the most desirable control mode available should a subsequent failure cause them to change their guidance source. This will minimize the powered flight use of the guidance control switch.

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FC42:RAT:drd:4/10/72:4717

RAT:

April 11, 1972

NOTE OF INTEREST: Change to the RR Antenna Parking Position on the Lunar Surface

GAC has recently concluded that the present lunar surface RR antenna position is inadequate for a coelliptic RNDZ sequence. Although the current antenna position does not impact a direct RNDZ, it is predicted that the RR temperature will exceed the RR thermal limits during a coelliptic sequence.

To preclude exceeding the antenna thermal limits, it is currently planned to reposition the antenna after the initial P57 alignment on ascent day. This technique will lower the antenna temperature sufficiently to prevent subsequent thermal problems. Currently, the recommended position is 30° shaft and 0° trunnion. The appropriate change will be made via real time checklist update.

Richard A. Thorson

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FC42:RAT:drd:4/11/72:4717

HAL:JEH

July 7, 1971

NOTE OF INTEREST: Analysis of Vehicle Dynamics resulting from Isolation of Critical Jet Failed On During Powered Descent

If one LM vertical jet has failed during Powered Descent and has been isolated pulling the TCA circuit breaker associated with that pair, a subsequent failed on vertical jet in the diagonal quad in the opposite direction will cause the GDA to drive to some new location to counteract the torque induced by that failed on jet. For simplicity, we will call that jet the critical jet.

This note of interest addressees itself to what happens when the failed on jet is isolated during PDI. The isolation of the critical jet leaves the GDA out from the C.G. by over a degree and no jets to counteract the torque it is introducing. The GDA drives back seeking the C.G. but a large excursion occurs in the meantime. A mathematical simulation of this dynamics problem was made and some of the results can be seen in figures 1 and 2. Figure 1 represents the case where the critical jet failure occurs at PDI + 0:30 and figure 2 depicts the dynamic response at PDI + 12:00. The different lines on each figure represent the response as a function of the reaction time of the crew to isolate the critical jet. As a check on the math model data, several runs were made at the Grumman FMES simulator and that data is shown by small circles in figures 1 and 2. The FMES data correlated very close to the math model data.

The following conclusions were reached from this study:

1. During FTP operation (PDI + 0:26 to PDI + 7:24), the critical jet can always be isolated without loss of control of the vehicle even if the crew's reaction time allows the GDA to stabilize ($\approx$ 6 sec) with sufficient offset to overcome the failed on jet.

a. The worst case angular deviation from the flight path angle is 41° which gives an effective thrust of 7600 lbs. along the flight path.

b. The later the isolation occurs in FTP, the less the excursion. (concluded from data not shown).

2. During hover (i.e. lower thrust which requires the GDA to move out farther than at FTP to counteract a critical failed on jet) the vehicle is unstable if the critical jet is isolated after it stabilizes.

3. When the critical jet is not isolated prior to throttle down, the data showed there would be a 7° excursion at throttle down.

Robert S. Nance Jr.

Robert S. Nance
LM Propulsion Section

Attachments

JAW/JEH

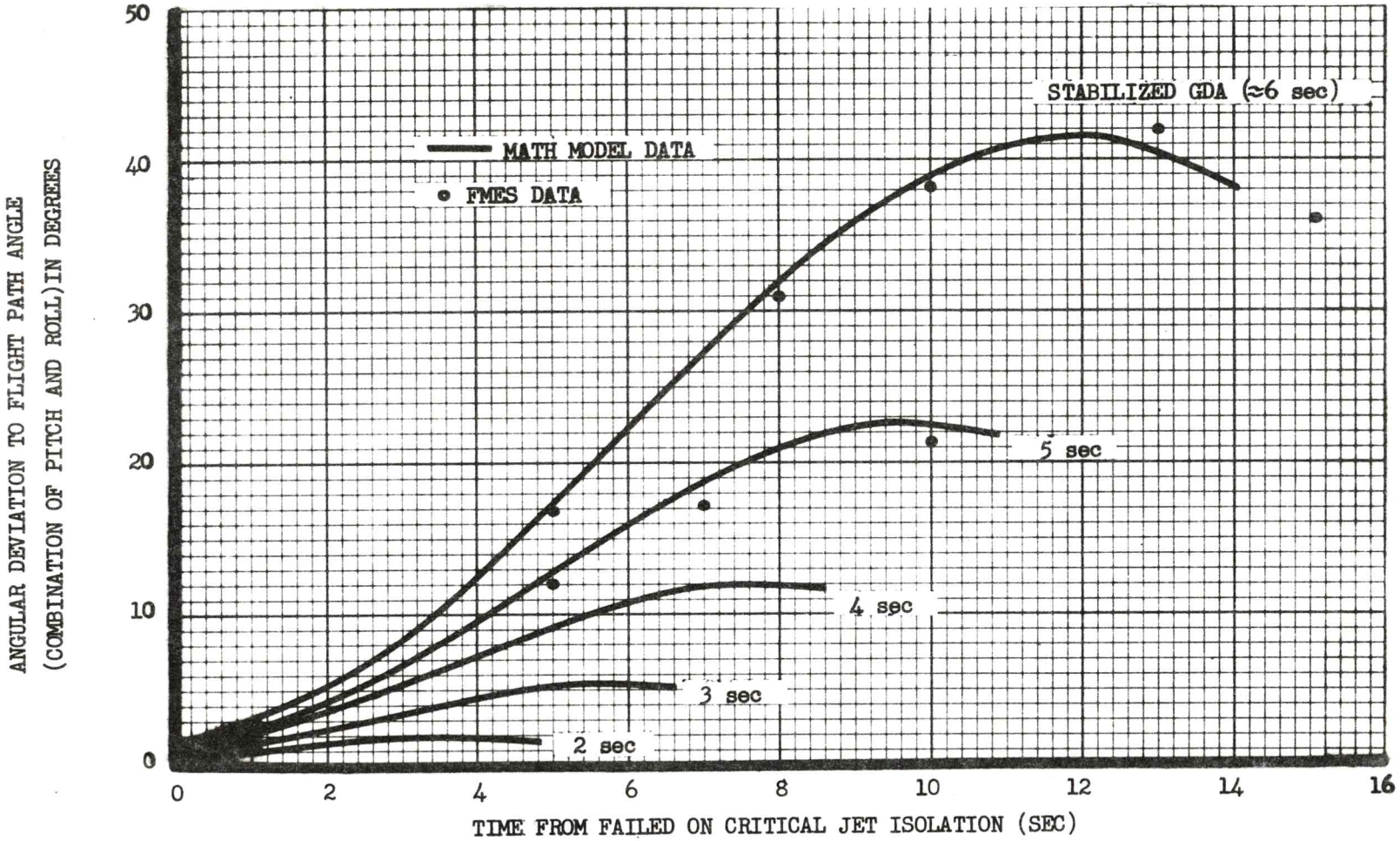
Figure 1

LM-10 VEHICLE DYNAMICS WHEN GDA IS RECOVERING FROM ISOLATION OF A FAILED ON CRITICAL JET (DIAGONAL PAIR ISOLATED)

ASSUMPTIONS:

A. FAILED ON CRITICAL JET OCCURS AT PDI + 0:30.

B. TIME REQUIRED TO ISOLATE CRITICAL JET IS NOTED WITH EACH CURVE



R.S. NANCE
6/24/71

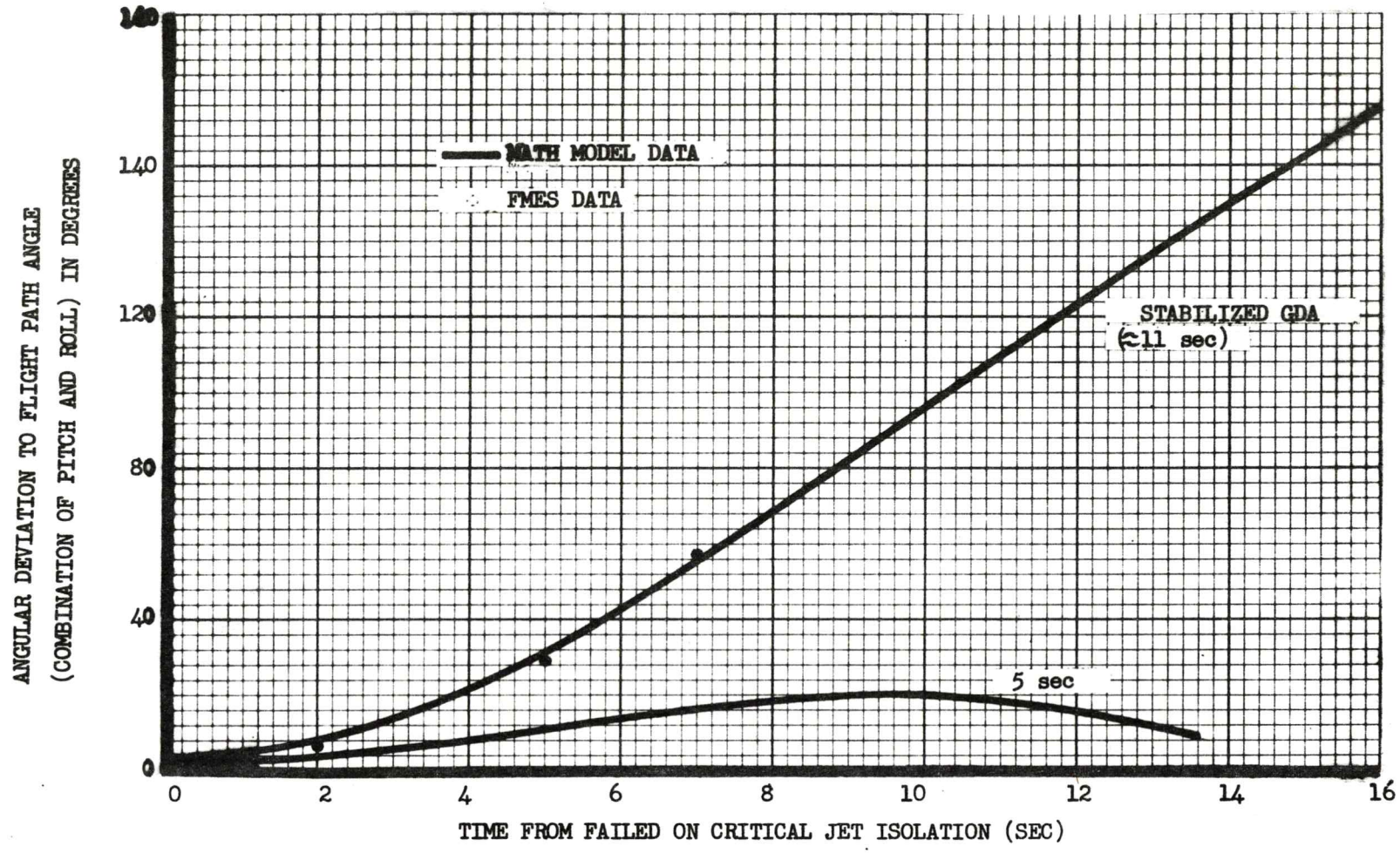
Figure 2

LM-10 VEHICLE DYNAMICS WHEN GDA IS RECOVERING FROM ISOLATION OF A FAILED ON CRITICAL JET (DIAGONAL PAIR ISOLATED).

ASSUMPTIONS:

A. FAILED ON CRITICAL JET OCCURS AT PDI + 12:00

B. TIME REQUIRED TO ISOLATE CRITICAL JET IS NOTED WITH EACH CURVE



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6/24/71

July 7, 1971

NOTE OF INTEREST: Monitoring Techniques for a Failed APS Inlet Pressure Transducer

A question has been raised as to the course of action if an APS inlet pressure transducer failed during the mission.

Background - The APS fuel and ox tanks are isolated by squibs prior to pressurization. The ground has two inlet pressure transducers (ox and fuel) for monitoring propellant leaks prior to pressurization. The crew has ullage pressure transducers (ox and fuel) which provide redundant instrumentation for monitoring leaks.

Monitoring Techniques - If an APS inlet pressure transducer fails, the crew, as long as they are not EVA, can use the redundant ullage pressure for monitoring APS propellant leaks. However, once on the lunar surface several options are available for a failed APS inlet pressure transducer. These options or techniques are discussed below:

1. One-man EVA - EVA could be constrained to one man. This would allow the other crew member to monitor the onboard ullage pressure for a leak. This, of course, would change and limit the lunar surface experiments and timeline.

2. Pressurize one APS helium tank - By pressurizing with one APS helium tank, a propellant leak would show up as a decrease in APS helium pressure. This provides a monitoring technique, but a leak would be much greater under a pressurized condition. This technique is considered unacceptable.

3. Ascent feed - Opening up the ascent feed and closing the mains to one RCS system would allow monitoring of the APS inlets via the RCS manifold pressures. This would allow ground monitoring capability but exposes the APS to more plumbing which could leak.

4. Establish confidence in system integrity and proceed nominally - If the APS is able to take the launch and boost vibration as well as the shock of landing without developing a leak, system integrity has been established. The crew would monitor ullage pressure to confirm no leaks after touchdown until EVA time. After this confidence was established by onboard monitoring, a "GO" would be given with no other perturbations to the system.

Conclusion - All of the above options have been considered for a failed inlet pressure transducer by the LM Propulsion Section, LM CONTROLS, and Lead Flight Director. Option four is considered the best technique available to handle an APS inlet pressure transducer failure. We feel that option four can give confidence of a "tight" APS without any of the disadvantages of the other three options.

Glenn W. Watkins

Glenn W. Watkins
LM Propulsion Section

JAW/JEH:dh:7-7-71

NOTE OF INTEREST: RCS Management with a Critical Thruster stuck on.

BACKGROUND: After high gate should a critical jet fail on,(second failure after diagonal opposing jet has failed) the crew will go on and land with the failed jet firing. This is done because isolation by pulling the circuit breaker would cause the vehicle to spin up and crash.

The purpose of this note of interest is to present the proper RCS propellant management for ascent if this condition can not be corrected on the surface.

The first case considered is where the horizontal jet in the critical pair fails on right after high gate. The nominal RCS remaining at touchdown is 76% for both system A and B but the stuck on horizontal jet and the jets to oppose it would drop the RCS to 66% in one system and 45% in the other system. It is assumed that the failure is either electrically isolated or mechanically isolated by closing the RCS main SOVs upon touchdown. In order to safely ascent without losing control, the failed jet may have to be re-enabled just prior to ascent. The amount of RCS required would be 50% for the failed jet and the jets to oppose it and 10% normal moment control. Since the amount of RCS at touchdown averaged 55% (AVE of 45% & 66%) and 13% is unusable there would be only 42% usable RCS remaining. The 60% required would dictate that some ascent feed would be required. If both RCS systems were used down to 20% i.e. 35% used during ascent and the remaining 25% came from ascent feed, approximately 300 fps ΔV margin would remain in the APS at insertion. This ΔV margin is possible because the vehicle is several hundred pounds lighter due to the high RCS usage. The ascent feed would last about 4 minutes.

The second case considered is if the vertical jet in the critical pair fails on right after high gate. In this case the GDA will overcome the failed on jet and the RCS at touchdown will average 65% (one system at 55% and one at 76%). Due to the complex nature of a vertical failed on jet during ascent, the RCS data for this case was run on the

FMES at Grumman and with John Young in the Houston LMS. An upward firing jet was selected to be failed on since it negates 100 pounds of thrust of the APS engine and is a worst case situation. It was found that the APS could make orbit if 2½ minutes of ascent feed was used at the start of the burn and the RCS used for the remainder of the burn. This leaves the RCS at about 20 - 25% (7% - 12% usable) at insertion.

John Young tried electrically isolating the failed jet during ascent and supplementing PGNS auto with direct coils which saved a lot of propellant. He said it was not too difficult, particularly around the time of pitch crossover.

CONCLUSIONS:

1. If a horizontal jet in a critical pair is required during ascent, ascent feed should be used during the first four minutes of ascent and RCS for the remainder of the burn. The RCS should be managed with the crossfeed to keep both systems above 20%.

2. If a vertical jet in a critical pair is failed on during ascent, ascent feed should be used during the first two and a half minutes of ascent and RCS for the remainder of the burn. The RCS should be managed with the crossfeed to keep both systems above 20%.

3. After ascent pitchover, at crew option, the failure can be isolated and the crew can supplement the attitude control with the direct coils. Should the crew have difficulty controlling the vehicle, the failed on jet should be reenabled.

Robert S. Nance Jr.
Robert S. Nance FC/42

JAW/JRH

FC42:RS Nance:mhk:4717:7-24-71

July 7, 1971

NOTE OF INTEREST: RCS Thruster Failures and Apollo 15 *

RCS thrusters can fail in many different ways. They can fail mechanically off or on, or electrically off or on. Electrical failures can be via primary preamps, abort preamps, or jet drivers. Considerable discussion has again arisen over what types of thruster failures constitute violation of redundant 3-axis attitude control. The attachments define how RCS thruster failures will affect Apollo 15. Attachment 1 generalizes how thruster failures will affect mission continuation. Attachment 2 specifies for single thruster failures per jet and per phase what mission action will be taken. Attachment 3 specifies mission action required for multiple thruster failures. It should be noted that a single vertical thruster failed off with a subsequent specific D.C. power failure or specific RCS system failure will result in the loss of attitude control. **These two specific failures are not considered in the attachments.**

John A. Wegener
IM Control

Attachments

JEH

* REVISED 7-13-71

ATTACHMENT 1

THRUSTER FAILURES

Single Thruster Failure

1. Single vertical thrusters mechanically failed off or failed off via the jet driver (can't be fired via PGNS or AGS) will violate redundant 3-axis attitude control and no go PDI.

2. Any single horizontal or vertical thrusters mechanically failed on will violate redundant 3-axis attitude control (RCS system must be isolated), will no go PDI, and will be cause for abort from PDI to HI GATE.

Multiple Thruster Failures (Critical Jets)

An abort will be performed from PDI to HI GATE for the following combinations of thruster failures:

1. Any combination of horizontal and/or vertical thrusters failed on* in critical quads which require isolation.

2. Confirmed failed off vertical thrusters in critical quads.

   NOTE: To provide confirmation, a PGNS ATT HOLD check will be performed when the critical vertical thruster is suspected to be failed off.

3. Any horizontal or vertical thrusters failed on (requiring isolation)* and the critical vertical thruster failed off.

4. Any 2 adjacent pairs isolated* and loss of GDA.

5. Any 3 pair isolated.

* Isolation of a thruster failed electrically on is accomplished by opening the affected quad TCA circuit breaker.

MISSION RULE ACTION FOR FIRST JET FAILURE

	PRE PDI	PDI TO HG	HG TO TD	LUNAR SURFACE
MECH OFF				
HORIZONTAL	GO 1	—	—	STAY 1
VERTICAL	NO GO 2	—	—	STAY 2
MECH ON *				
HORIZONTAL	NO GO 5	NO GO 5	GO 1	STAY 5
VERTICAL	NO GO 5	NO GO 6	GO 1	STAY 6
ELEC ON				
JET DRIVER (H or V)	GO 3	GO 3	GO 3	STAY 3
PRIME PREAMPS	GO 3	GO 3	GO 3	STAY 3
ABORT PREAMPS	GO 4	-o- 4	-o- 4	STAY 4
ELEC OFF				
JET DRIVER				
HORIZONTAL	GO 1	—	—	STAY 1
VERTICAL	NO GO 2	—	—	STAY 2
PRIME PREAMPS				
HORIZONTAL	GO 1	—	—	STAY 1
VERTICAL	GO 2	—	—	STAY 2
ABORT PREAMPS	GO 1	—	—	STAY 1

* May appear as an RCS leak if only one valve fails open.
— A single thruster failed off during PDI cannot be confirmed.
-o- Abort preamps failed on could only be detected in AGS.

CONFIGURATION AFTER FIRST THRUSTER FAILURE

1. Take no action
2. Disable thruster in LGC (optional) V25 N07
3. Isolate thruster
   PANEL_____(11 or 16)
   RCS SYS_____(A or B)
   QUAD_____(1 - 4) TCA - OPEN
   (remainder optional)
   RCS SYSTEM_____(A or B)
   LGC THRUSTER PAIR CMDS
   QUAD_____(1 - 4) - DISABLE
4. If AGS selected,
   PANEL_____(11 or 16)
   RCS SYS_____(A or B)
   QUAD_____(1 - 4) TCA - OPEN
5. Isolate System
   a. PANEL_____(11 or 16)
      RCS SYS_____(A or B)
      QUAD 1 thru 4 TCA - OPEN
   b. RCS SYS_____(A or B)
      LGC THRUSTER PAIR CMDS
      QUAD 1 thru 4 DISABLE
   c. RCS MAIN SOV
      SYS_____(A or B) - CLOSE
6. Isolate system prior to staging
   a. PANEL_____(11 or 16)
      RCS SYS_____(A or B)
      QUAD 1 - 4 TCA - OPEN
   b. RCS SYS_____(A or B)
      LGC THRUSTER PAIR CMDS
      QUAD 1 thru 4 DISABLE
   c. RCS MAIN SOV
      SYS_____(A or B) - CLOSE

GENERAL NOTE: First Failed ON jets after high gate MAY be isolated (Time Permitting).

7-13-71
JAW/RSN

MISSION RULE ACTION FOR CRITICAL THRUSTER FAILURES PRIOR TO HIGH GATE

	SECOND FAILURE											
FIRST FAILURE	HORIZONTAL OFF			HORIZONTAL ON			VERTICAL OFF(I)			VERTICAL ON		
HORIZONTAL OFF	J.D.	P.P.	A.P.	J.D.	P.P.	A.P.	J.D.	P.P.	A.P.	J.D.	P.P.	A.P.
J.D.	-	-	-	G1	G1	-o-	-	-	-	G1	G1	-o-
PRIME PRE	-	-	-	G1	G1	-o-	-	-	-	G1	G1	-o-
ABORT PRE	-	-	-	G1	G1	-o-	-	-	-	G1	G1	-o-
HORIZONTAL ON												
J.D.(ISOLATED)	-	-	-	A2	A3	-o-	A7	A3	-	A7	A3	-o-
PRIME PRE(ISOLATED)	-	-	-	A5	A4	-o-	A4	A4	-	A5	A4	-o-
ABORT PRE	-	-	-	G1	G1	-o-	-	-	-	G1	G1	-o-
VERT OFF(I)												
J.D.(II)	-	-	-	A2	A3	-o-	A2	A3	-	A2	A3	-o-
PRIME PRE	-	-	-	A6	A4	-o-	A3	A3	-	A6	A3	-o-
ABORT PRE	-	-	-	G1	G1	-o-	-	-	-	G1	G1	-o-
VERT ON												
J.D.(ISOLATED)	-	-	-	A2	A3	-o-	A8	A3	-	A2	A3	-o-
PRIME PRE(ISOL)	-	-	-	A5	A4	-o-	A4	A4	-	A5	A4	-o-
ABORT PRE	-	-	-	G1	G1	-o-	-	-	-	G1	G1	-o-

\- A single thruster failed off during PDI cannot be confirmed.

-o- Abort preamps failed on could only be detected in AGS.

G Continue Mission

A Abort PDI to HI GATE then perform AGS check to determine maximum controlability.

(I) Vertical thrusters suspected to be failed off will be verified via PGNS RATE CMD check when the second vertical thruster becomes suspect.

(II) PDI will not be initiated with a confirmed vertical thruster failed off via jet driver.

1-8 See attached sheet.

NOTE: It is recognized that a vertical thruster failed off with subsequent specific loss of DC power or specific RCS System loss results in loss of control.

GENERAL NOTE: Second Jet Failed ON after High Gate will NOT be isolated.

7-13-71
JAW/RSN

CONFIGURATION AFTER CRITICAL THRUSTER FAILURE

1. Isolate second failure
   PANEL_____(11 or 16)
   RCS SYS_____(A or B)
   QUAD_____(1 - 4) TCA - OPEN
   (remainder optional)
   RCS SYS_____(A or B)
   LGC THRUSTER PAIR CMDS
   QUAD_____(1 - 4) - DISABLE
2. After AGS check take no action on second failure and select PGNS *
3. After AGS check take no action on second failure and stay in AGS.
4. After AGS check, stay in AGS and enable first failure
   PANEL_____(11 or 16)
   RCS SYS_____(A or B)
   QUAD_____(1 - 4) TCA - CLOSE
5. After AGS check, stay in AGS and enable first failure and isolate second failure
   FIRST FAILURE
   PANEL_____(11 or 16)
   RCS SYS_____(A or B)
   QUAD_____(1 - 4) TCA -CLOSE
   SECOND FAILURE
   PANEL_____(16 or 11)
   RCS SYS_____(B or A)
   QUAD_____(1 - 4) TCA - OPEN
6. After AGS check, stay in AGS and isolate second failure
   PANEL_____(11 or 16)
   RCS SYS_____(A or B)
   QUAD_____(1 - 4) TCA - OPEN
7. After AGS check, select PGNS, enable first failure and isolate second failure
   FIRST FAILURE:
   PANEL_____(11 or 16)
   RCS SYS_____(A or B)
   QUAD_____(1 - 4) TCA - CLOSE
   (If first failure disabled in LGC)
   RCS SYS_____(A or B)
   LGC THRUSTER PAIR CMDS
   QUAD_____(1 - 4) - ENABLE
   SECOND FAILURE:
   PANEL_____(16 or 11)
   RCS SYS_____(B or A)
   QUAD_____(1 - 4) TCA - OPEN
   (Remainder optional)
   RCS SYS_____(A or B)
   LGC THRUSTER PAIR CMDS
   QUAD _____(1 - 4) - DISABLE
8. After AGS check take no action on second failure, select PGNS and enable first failure prior to staging.
   PANEL_____(11 or 16)
   RCS SYS_____(A or B)
   QUAD_____(1 - 4) TCA - OPEN

*Assumes Direct and Hardover available if required.

7-13-71
JAW/RSN

NOTE OF INTEREST: APS TPI and Depletion

References: LMO 271-947, Helium Ingestion Testing of the Ascent Engine, dated November 23, 1970

EP22-5-71, WSTF Helium Ingestion Testing on the Ascent Engine, dated January 22, 1971

FC44 (71-137), APS Propellant Level Detector (PLD) Failures, dated September 3, 1971

The intent of this note of interest is to show the development of a philosophy which precluded an APS TPI burn to depletion for Apollos 14 and 15 to a philosophy that allows APS TPI burn to depletion for Apollo 16.

When the direct rendezvous was proposed for the Apollo 14 mission, GAC expressed much concern over the short APS TPI burn (~4 sec nominally). Their primary concern was that the relatively small mass quantities remaining after insertion would rebound and slosh when ullage was applied for the APS TPI burn. This, GAC maintained, would result in helium ingestion to the APS beyond the level of confidence of testing. GAC proposed an RCS TPI (~42 sec nominally). ASPO, on the other hand, had no qualms about the ability of the ascent engine to withstand helium ingestion, but subsequently agreed that additional helium ingestion testing would increase their level of confidence significantly. An APS TPI for Apollo 14 was agreed on pending the results of these tests. FCD, at that time, established a philosophy that we would never "knowingly" burn the APS to depletion even though this depletion constraint had long since been removed from the SODB.

The helium ingestion tests designed to set up the conditions caused by rebounding propellants, were performed at WSTF as planned. Of the seven tests which were conducted with three types of helium ingestion (entrained flow, slug flow, and interrupted flow), there was no evidence of any detrimental effects to the engine or its operation. Entrainment flow involves the injection of a low volumetric flow (approximately one standard cubic foot per minute, SCFM) of helium into the engine feedlines. Slug flow is cycled ON in one-half second intervals while interruption flow is ON continuously for 2 to 5 seconds. For each of the flow conditions, the gas was ingested into the oxidizer and fuel feedlines at different times and simultaneously. Despite over seventy seconds of gas ingestion testing during which large pressure oscillations were induced, the engine continued to operate satisfactorily. No signs of structural damage to the engine or the supporting structures were noted following the test.

In spite of the results of these extremely severe tests (these test conditions are similar but worse than those expected for a depletion burn), we maintained our philosophy for Apollo 14 to never knowingly commit to an APS depletion. We had established procedures by which the APS low level discretes were compared with the engine OFF discrete to determine APS TPI capability. Prior to Apollo 15, however, I began to question, in view of the overwhelming supporting data, whether we were needlessly penalizing our APS capability. What bothered me specifically was the comparison technique was no better than four seconds accurate (sensor error plus 1 sample/second data on discretes). Since we subtracted the four-second uncertainty, this meant we could no go APS TPI when the capability might really exist. Still, we maintained a conservative philosophy with regard to APS depletion for Apollo 15.

When Apollo 16 data priorities began to crank up, Phil Shaffer approached me as to whether the APS could be taken to depletion for TPI. He was concerned about RCS deorbit ΔV for certain situations and proposed an APS/RCS hybrid TPI, if required. I concluded, after verifying it with the APS subsystem manager, that there was no reason not to burn the APS to depletion.

I felt that an APS depletion burn was justified for the following reasons:

a. The potential conditions induced by rebounding and sloshing APS propellants during the nominal TPI are worse than the conditions induced by a depletion burn. The helium ingestion tests showed that the APS engine could withstand these worse case conditions. If we are not concerned about the nominal APS TPI, we should not be concerned about depletion burns.

b. There have been five APS ground tests to depletion and two flight tests to depletion. There is no SODB constraint against burning the APS to depletion.

c. The uncertainty in the technique for determining APS remaining could preclude APS TPI when the capability really exists.

d. The crew (I talked with C. Duke) did not object to the procedures required by the hybrid burn, i.e., it is really normal trim procedures.

I recommended, and I still recommend, that we no longer adhere to the old philosophy which precludes burning the APS to depletion.

I would also like to clarify that the retention of the APS low level detector (ground TM) for Apollo 16 was not defended based on the determination of APS TPI capability, but rather an abort situation where a certain ΔV capability must be guaranteed in order to commit to a LM-active or a CSM-active maneuver.

John A. Wegener
John A. Wegener

JEH 12-1-71

April 3, 1972

NOTE OF INTEREST: Ascent Limit Weight

Attached is the procedure that will determine the ascent limit weight "real time". Also included are the curves that will appear in the SODB for the ascent limit weight. This procedure will be contained in the LM Console Handbook for Apollo 16.

Glenn W. Watkins

Glenn W. Watkins

FC44:GWWatkins:drd:4/3/72:4717

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S/C: LM
DATE: 4/1/72
REV: PCN-13/New
ORIGINATOR: G. Watkins
APPROVAL: L. Wegner

SCP NO. PROP 11-24

TITLE: ASCENT LIMIT WEIGHT DETERMINATION

PURPOSE: The purpose of this SCP is to establish a method of determining the ascent limit weight margins in real time and to determine the effect of trading off ascent feed and/or balance couples during ascent.

BACKGROUND: DEFINITION

The ascent limit weight is defined as the maximum weight that will allow the ascent stage to achieve insertion orbit utilizing APS propellant. The following assumptions are defined pre-mission by the Apollo Spacecraft Program Office (ASPO) affecting propellant utilization.

1. APS propellant will be allocated for the TPI burn.
2. The LM will be required to perform a $1/2^{\circ}$ plane change.
3. Three sigma dispersions on performance will be considered in the propellant budget.
4. APS propellant will be utilized for moment control by ascent feeding the RCS for the duration of the burn.
5. An APS engine valve pair malfunction will be considered.
6. The RCS engines will be assumed to operate in the balance couple mode for controlling attitude during the insertion burn. This means that the RCS will contribute nothing towards the ΔV during the burn.
7. A pad (99.999 percent probability of propellant non-depletion) will be considered for the propellant budget.
8. Unusable and propellant allocated for outage will not be considered available for the APS engines to burn.

9. A nominal ΔV of 6055 FPS is assumed for insertion.

10. Nominal lunar sample return and stowage is assumed.

Feasibility of Exceeding Limit Weight

Even under nominal conditions the ascent limit weight could be exceeded for some periods. Also, the EVA's are getting longer which allows more time to collect additional rock samples. This can cause the lunar surface weight to increase. Lower than expected RCS usage during descent can drive the lunar surface weight up. These factors make it more feasible that the ascent limit weight can be exceeded.

Premission Determination of Ascent Limit Weight Margins

Prior to each mission, Mission Planning and Analysis Division (MPAD), utilizing the ASPO defined assumptions, publishes a memo establishing the ascent limit weight margins for various phases on the lunar surface. These phases include touchdown abort, before and after each EVA, as well as the nominal liftoff. These pre-mission margins are valid unless the vehicle mass properties change "real time" and/or any of the assumptions are changed.

TIME: This procedure is to be used anytime on the lunar surface that the ascent center of gravity changes from the nominal, or different assumptions are made for ascent feed or balance couple operation as outlined in the definition. Either of these conditions requires a new ascent limit weight determination.

PROCEDURE: ASCENT LIMIT WEIGHT CALCULATION

When the ascent limit margin is negative, certain assumptions can be traded off to increase the limit weight. These trade off items and their priority are covered by a ASPO memo (Ascent Limit Weights, PD12/241-71, dated November 18, 1971). The value of the trade off items (1, 2, and 7) is determined by the pre-mission ascent limit weight memo published by MPAD. If the margin is still negative, it may be desireable to consider trading off items 4 and 6. The following procedure will outline how to determine the ascent limit weight as a function of vehicle cg. The method for determining the trade off value of items 4 and 6 (ascent feed and balance couple) will also be discussed.

1. Changes to ascent weight

   Any changes to the expected lunar surface weight or stowage is monitored and reported per FCOH SOP 2.16 (Lunar Surface Weight Updates).

2. Vehicle Weight and "wet CG"

   Ascent vehicle weight and "wet cg" is determined per FCOH 2.5 (S/V Weight Updates). LM Prop runs a parallel determination of "wet cg" utilizing LM Console Handbook SCP PROP 11-11 (cg and DPS Gimbal Angle Determination). The "wet cg" represents the cg of the ascent stage with the APS and RCS propellant.

   The following steps (3 thru 6) are to be performed after the new cg is determined. Data that is used in these steps is found in the SODB Vol. II RCS Section.

3. Determine the "dry CG"

The "wet cg" is transformed into the "dry cg" of the vehicle utilizing the SODB curve entitled Ascent Wet to Dry CG Conversion and found in the SODB Vol. II RCS Section. The "dry cg" represents the cg of the ascent stage with the APS propellant and tanked RCS propellant removed.

4. Determine the "Delta Limit Weight"

The "dry cg" is used for the limit weight curve to determine the effects of balance and unbalance couple operation as well as ascent feed. Four curves for the following conditions are listed in the SODB Vol. II RCS Section under Delta Ascent Limit Weight during Moment Control versus dry vehicle cg.

A. Balance couple with ascent feed (nominal configuration)

B. Balance couple without ascent feed

C. Unbalance couple with ascent feed

D. Unbalance couple without ascent feed

Entering these curves with the Y and Z "dry CG" coordinates will yield a positive or negative number for the configuration desired termed the ascent stage delta limit weight. Curve (A) represents the nominal configuration and is normally used in determining the ascent stage delta limit weight. To determine trade off capability for no ascent feed and/or balance couples off, curves (B, C, and D) are used.

5. Determine the New Ascent Stage Limit Weight

After the ascent stage delta limit weight for the configuration desired is determined from step (4), it is added (positive or negative value) to the value used for the reference limit weight, which is defined in the specific vehicle appendix of the SODB. Therefore, the new ascent stage limit weight for the configuration desired = ± ascent stage delta limit weight + ascent stage reference limit weight.

6. Determination of Trade Off Value

Trade off value of ascent feed and/or balance couple operation is determined as follows:

A. Balance Couple Trade Off

Determine the limit weight for the nominal configuration (balance couple with ascent feed open), and subtract that value from the case for unbalance couple with ascent feed. This difference is the trade off value for balance couple.

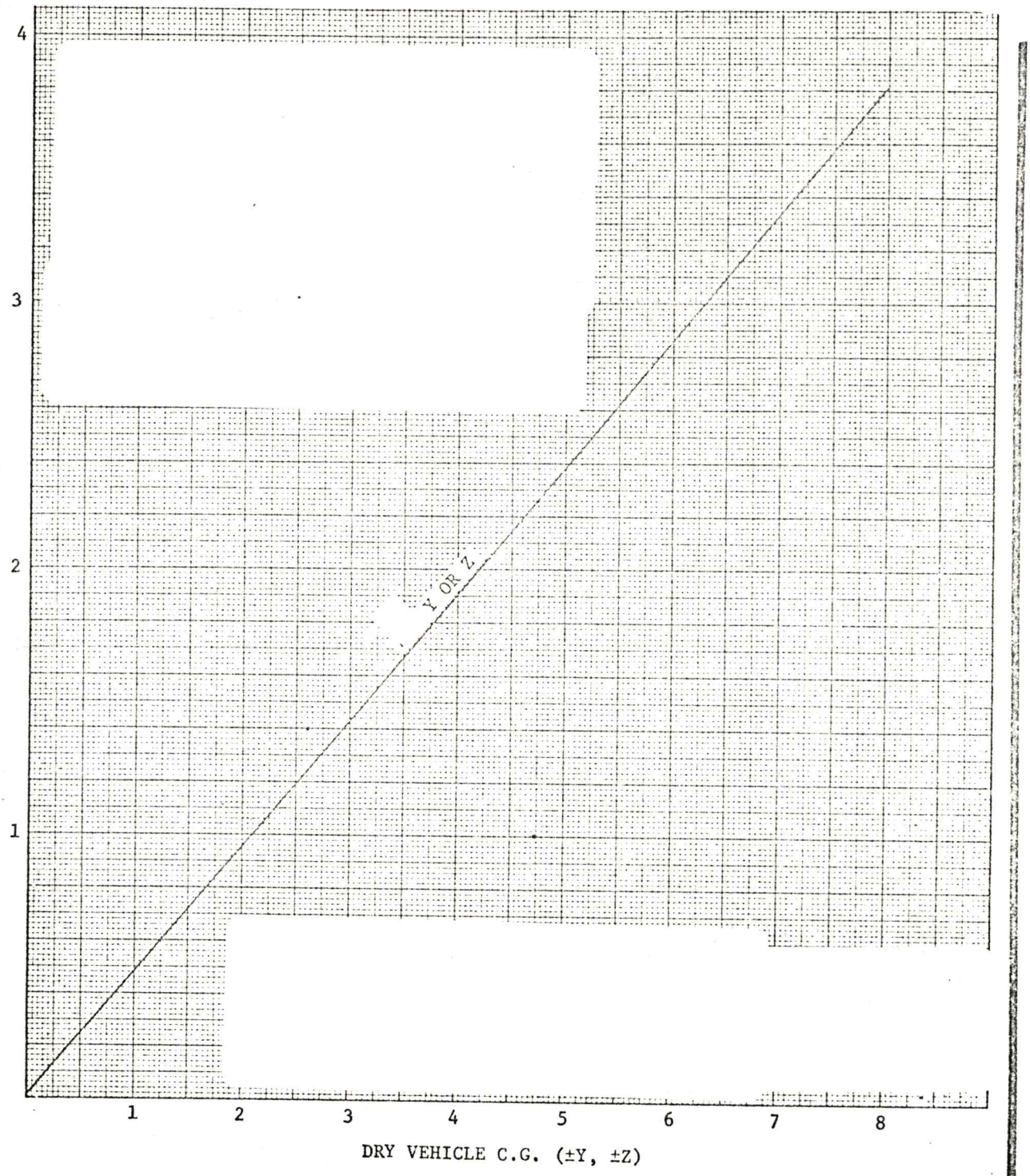
B. Ascent Feed Effect

Determine the limit weight for the nominal configuration (balance couple and ascent feed open) and subtract that value from the case for balance couple and ascent feed closed. This difference is the trade off value for ascent feed.

C. Balance Couple and Ascent Feed

Determine the limit weight for the nominal configuration (balance couple and ascent feed open) and

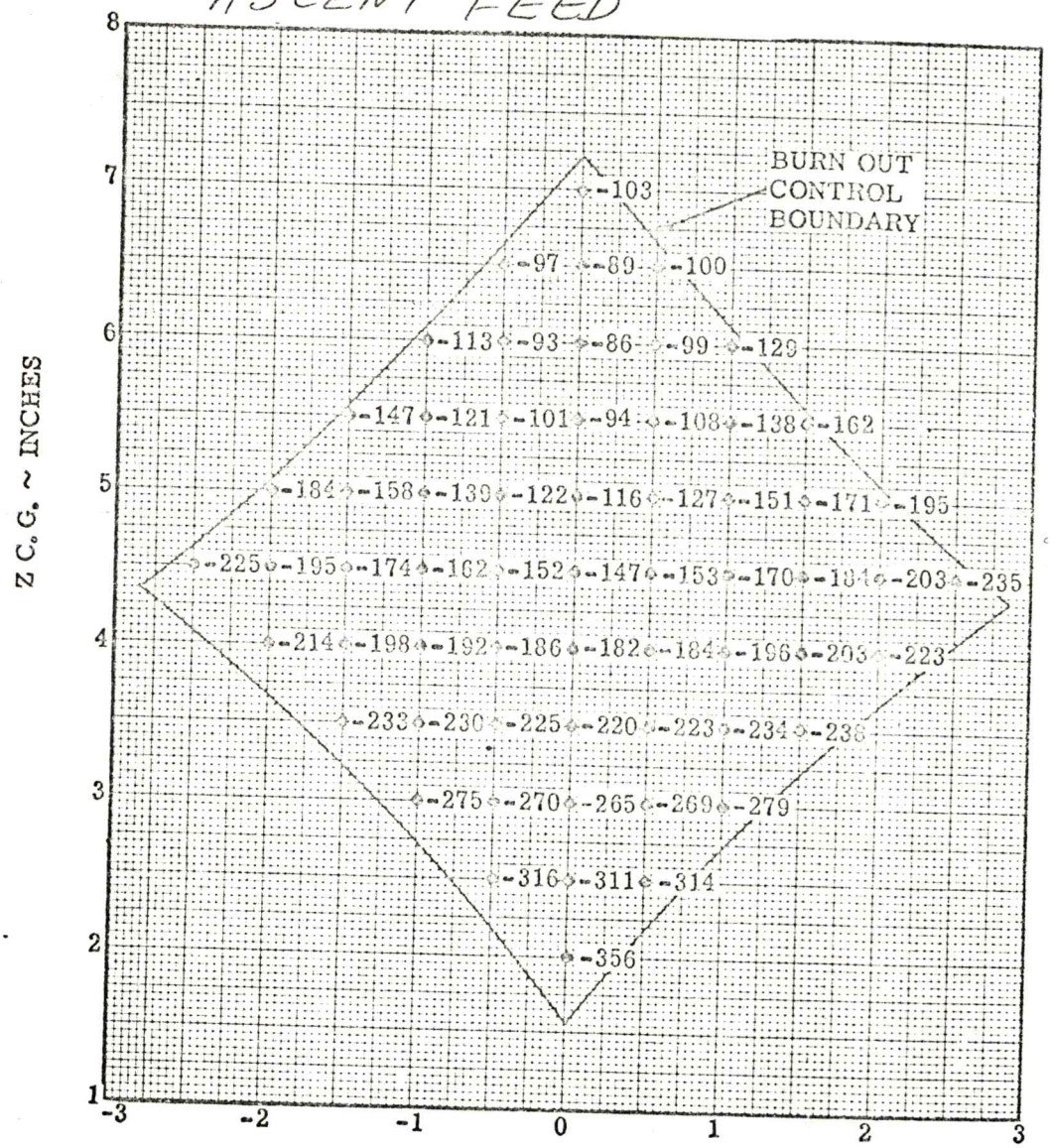
subtract that value from the case for unbalance couple and ascent feed closed. This difference is the trade off value for balance couple and ascent feed.



*Note: The above figure should not be used to convert dry C.G. to wet vehicle C.G.

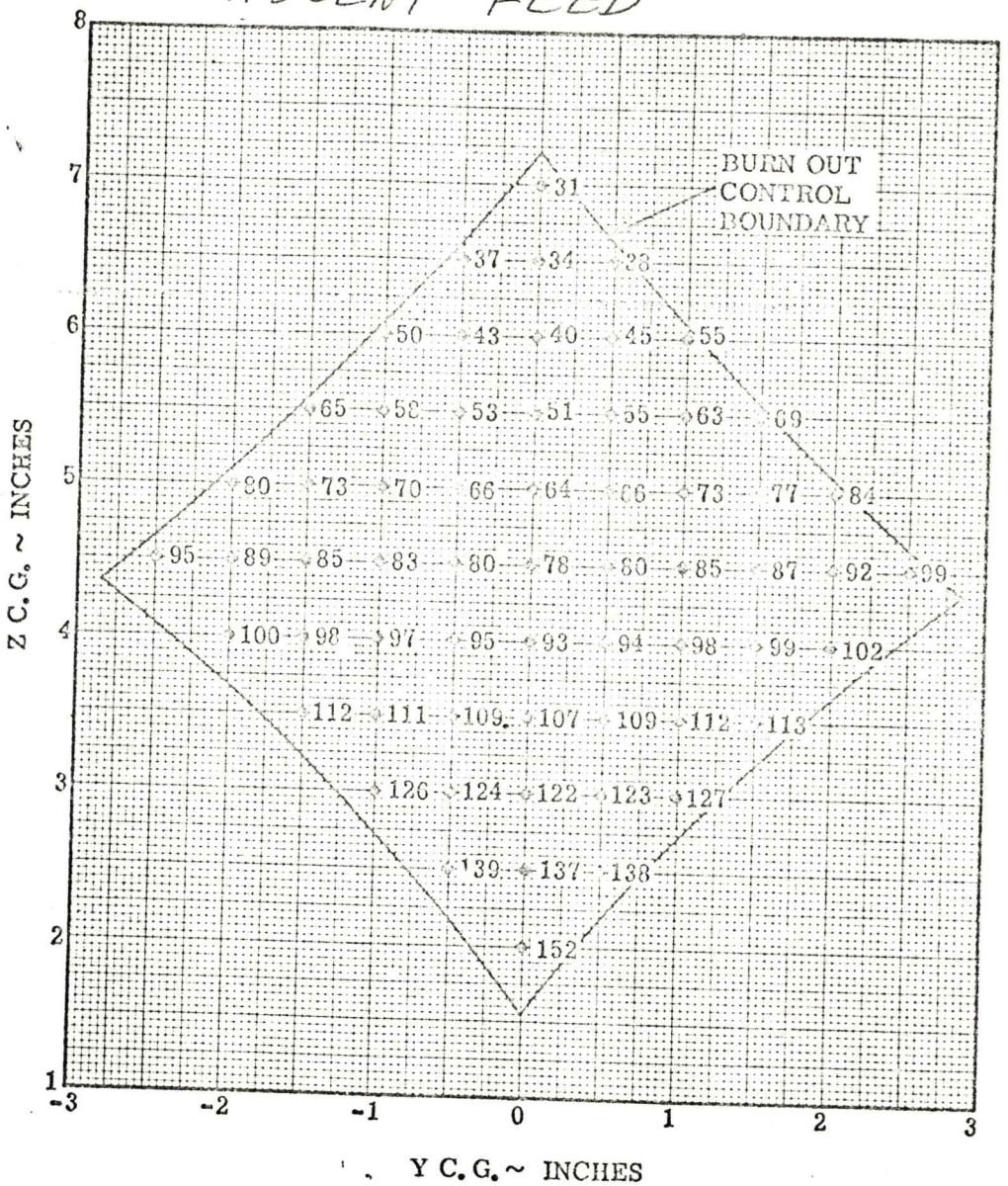
Figure 4.8-30.4. Ascent Wet to Dry C.G. Conversion
(See Para. 4.8.1.4)

BALANCE COUPLE
WITH
ASCENT FEED



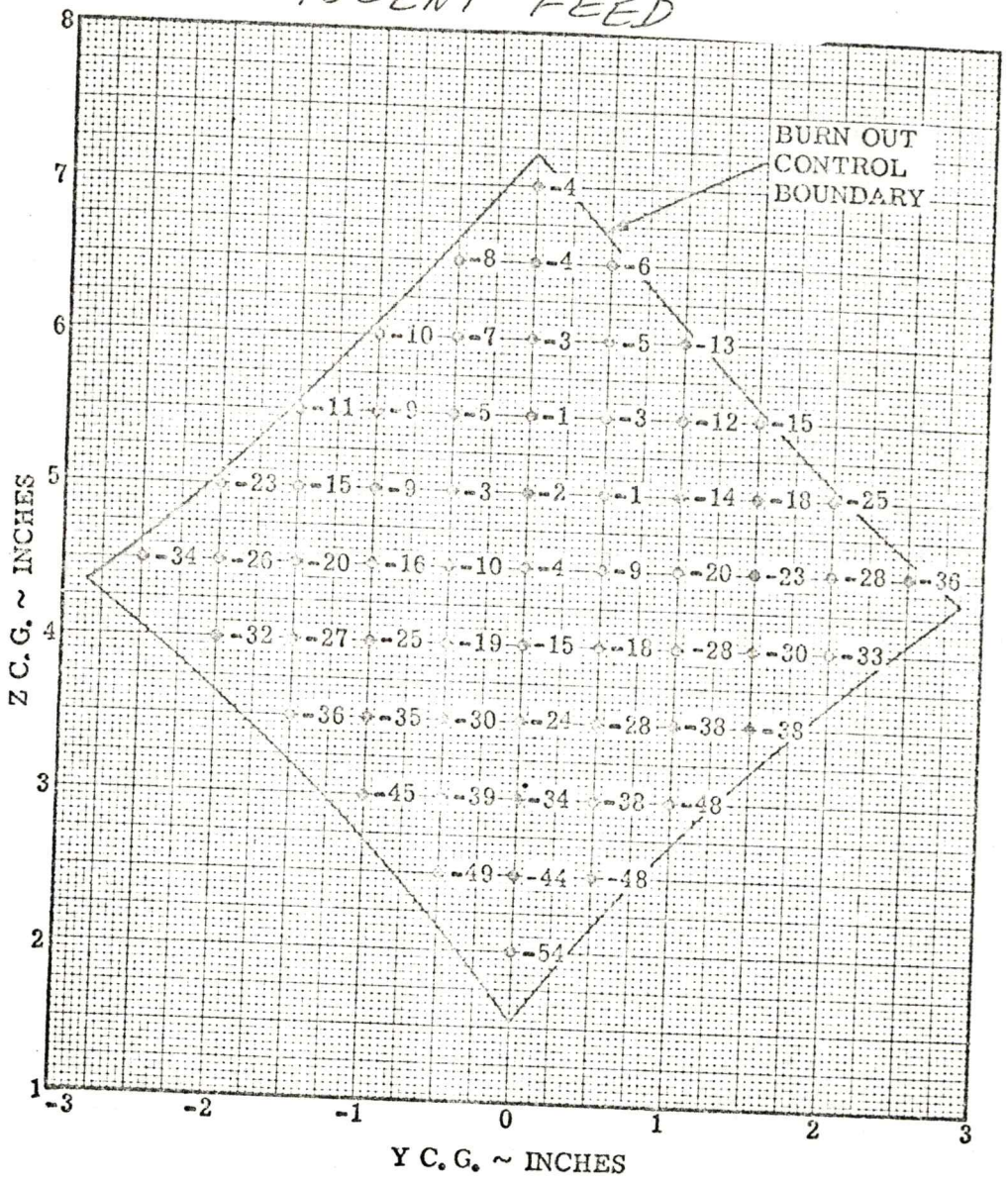
REFERENCE LIMIT WEIGHT = 11,003 LBS

BALANCE COUPLE
WITHOUT
ASCENT FEED



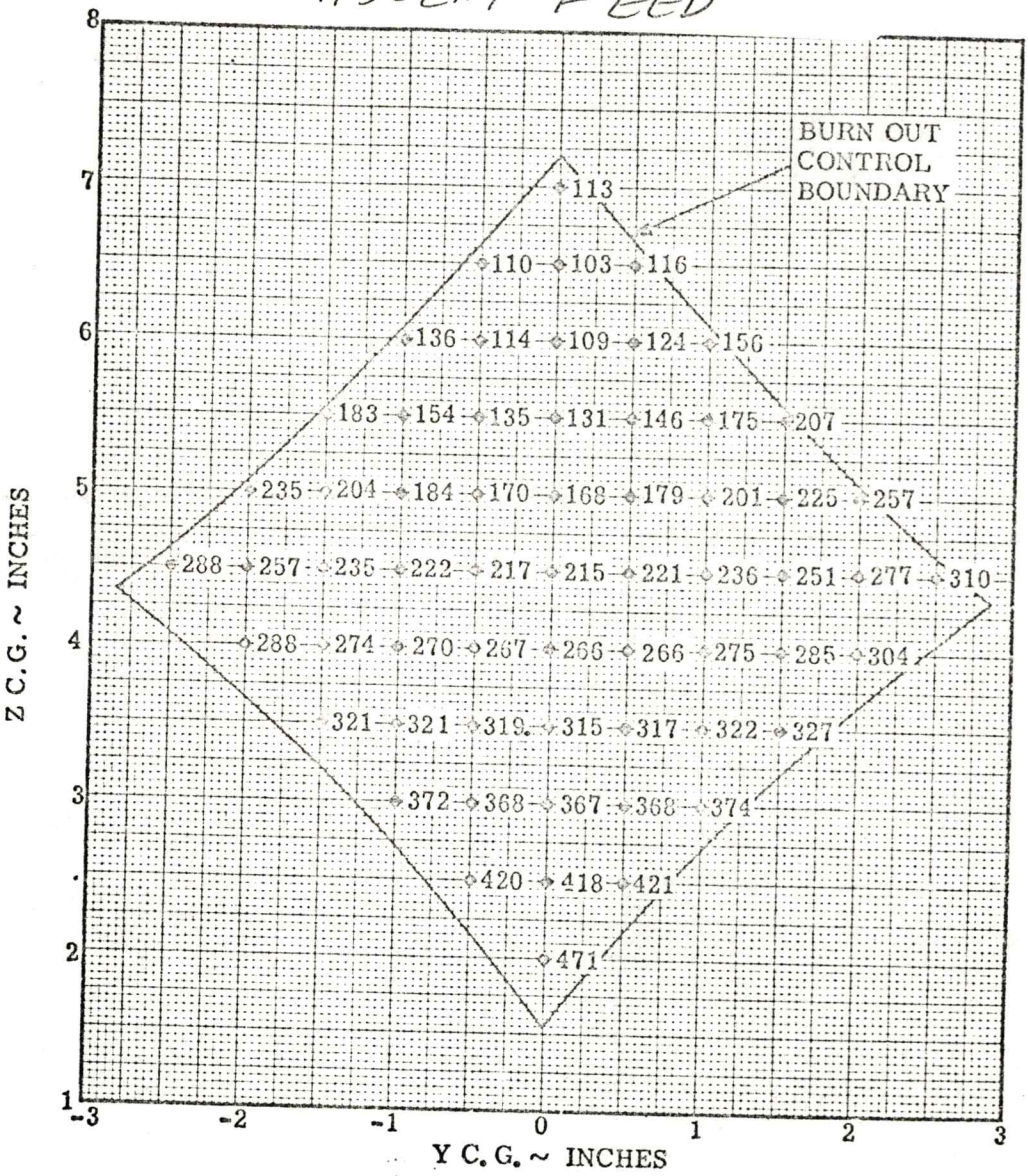
REFERENCE LIMIT WEIGHT = 11,083 LBS

UNBALANCE COUPLE
WITH
ASCENT FEED



REFERENCE LIMIT WEIGHT = 11,003 LBS

UNBALANCE COUPLE
WITHOUT
ASCENT FEED



REFERENCE LIMIT WEIGHT = 11,003 LBS

DATE: 10/1/72
REV: PCN-14
APPROVAL William L. Peters

PROP MALFUNCTION ANALYSIS INDEX

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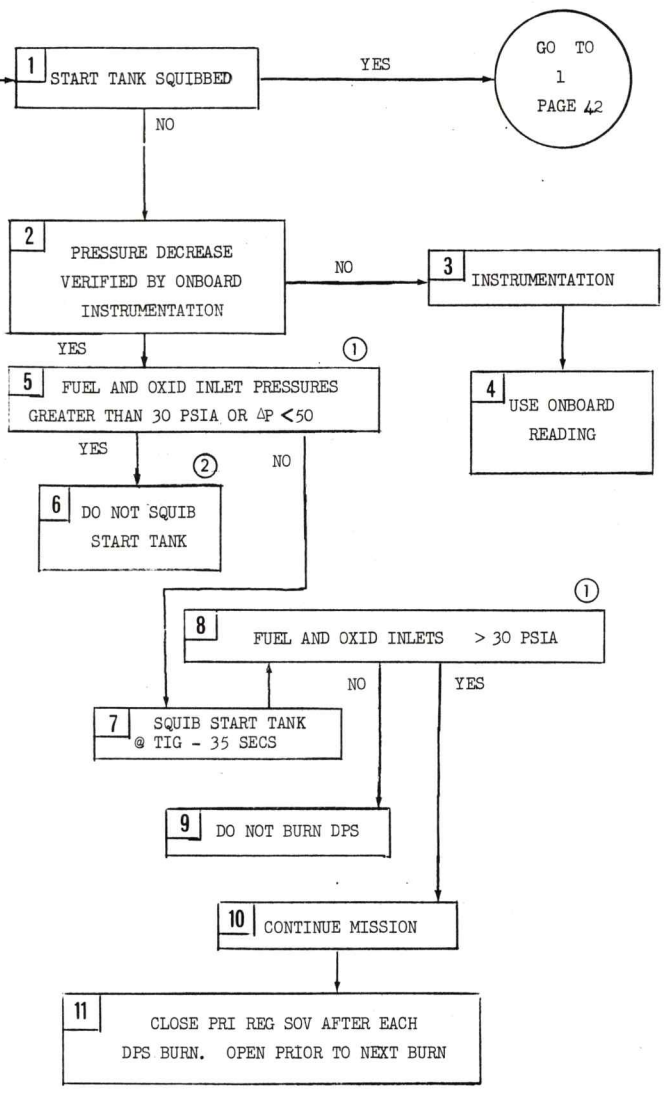
SYMPTOM	PROCEDURE	REMARKS
GQ3015 START TANK PRESSURE ABNORMAL ABNORMAL IS DEFINED AS A 2 PCM COUNT SHIFT FROM THE NORMAL TEMPERATURE PRESSURE PROFILE. 2 PCM COUNT IS 13.84 PSIA		① 30 PSI IS MINIMUM INLET PRESSURE AT WHICH DPS MAY BE STARTED. ② SQUIBBING START TANK WOULD OPEN ENTIRE SYSTEM TO LEAK. INLETS ARE HIGH ENOUGH TO OPERATE ENGINE WITHOUT START TANK.

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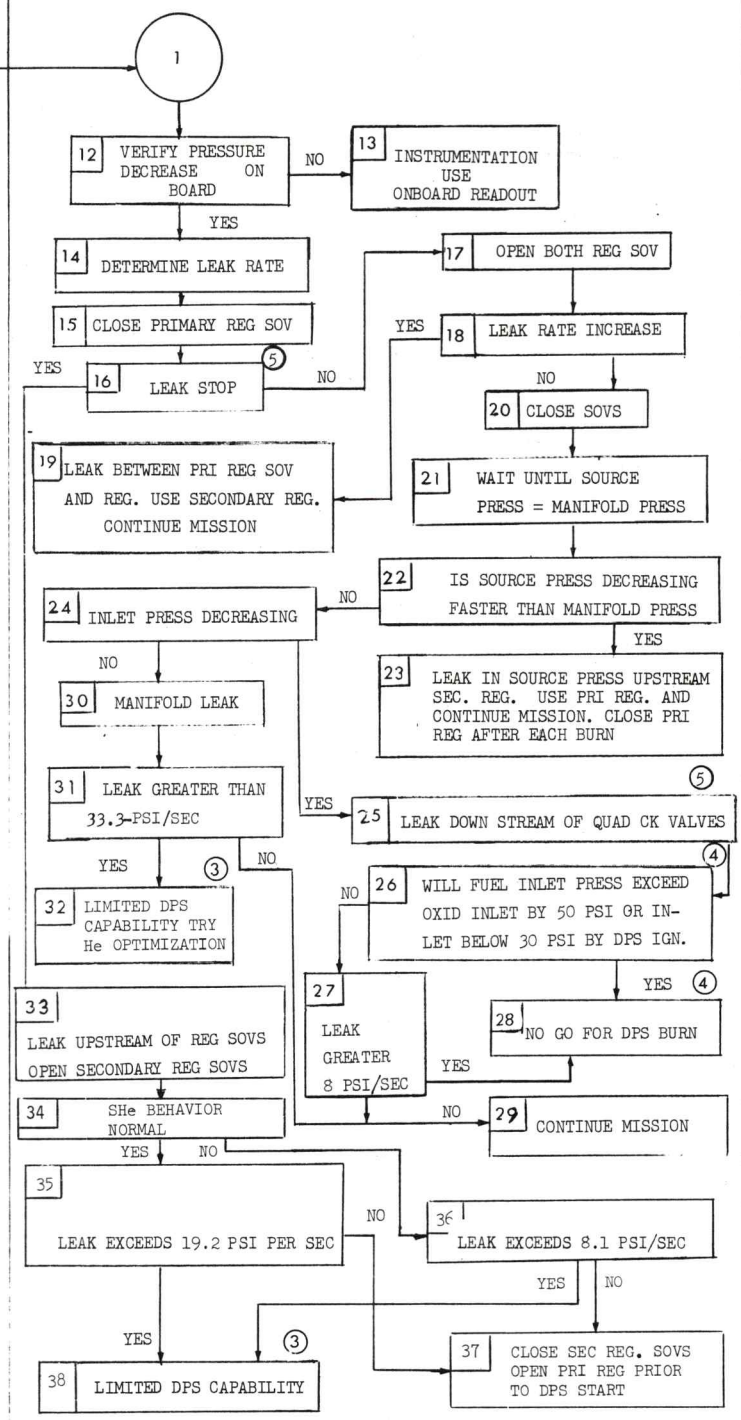
SYMPTOM	PROCEDURE	REMARKS
(CONTINUED) GQ3015P START TANK PRESSURE ABNORMAL (TANK SQUIBBED)		(3) INSUFFICIENT HELIUM TO EXPEL ALL DPS PROPELLANTS WITHOUT VIOLATING ENG. LIMITS (4) ENG MAY NOT BE STARTED WHEN FUEL PRESSURE EXCEEDS OXIDIZER INLET PRESSURE BY 50 PSI OR WHEN INLET PRESSURE IS BELOW 30 PSI. P-12 (5) FURTHER LEAK ISOLATION MAY BE POSSIBLE BY CLOSING FUEL AND OXIDIZER VENT VALVES P-14

P-12
P-14
P-14
P-12
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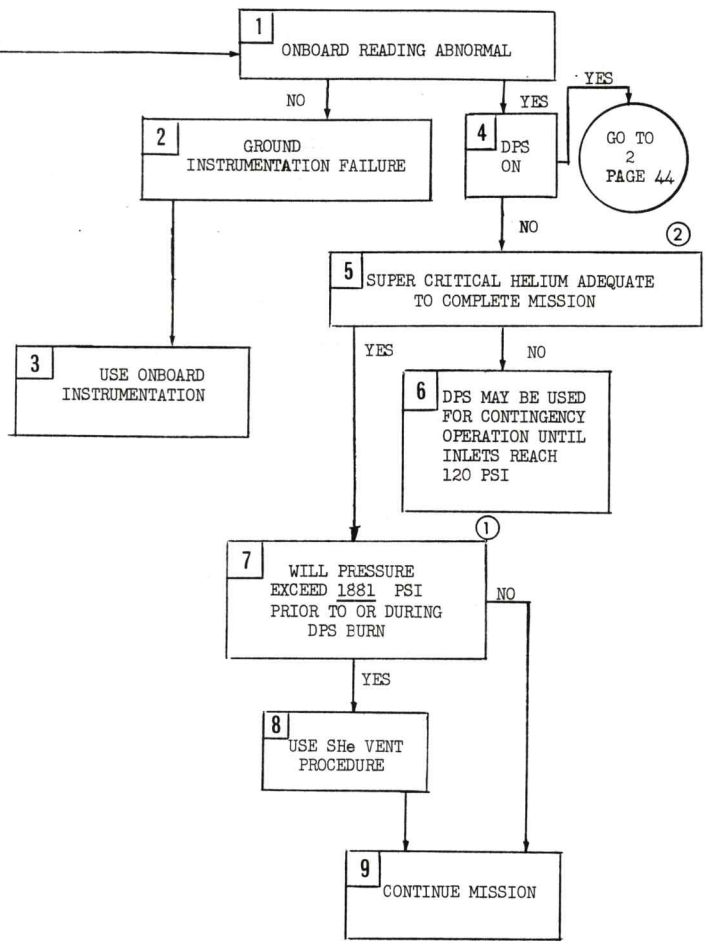
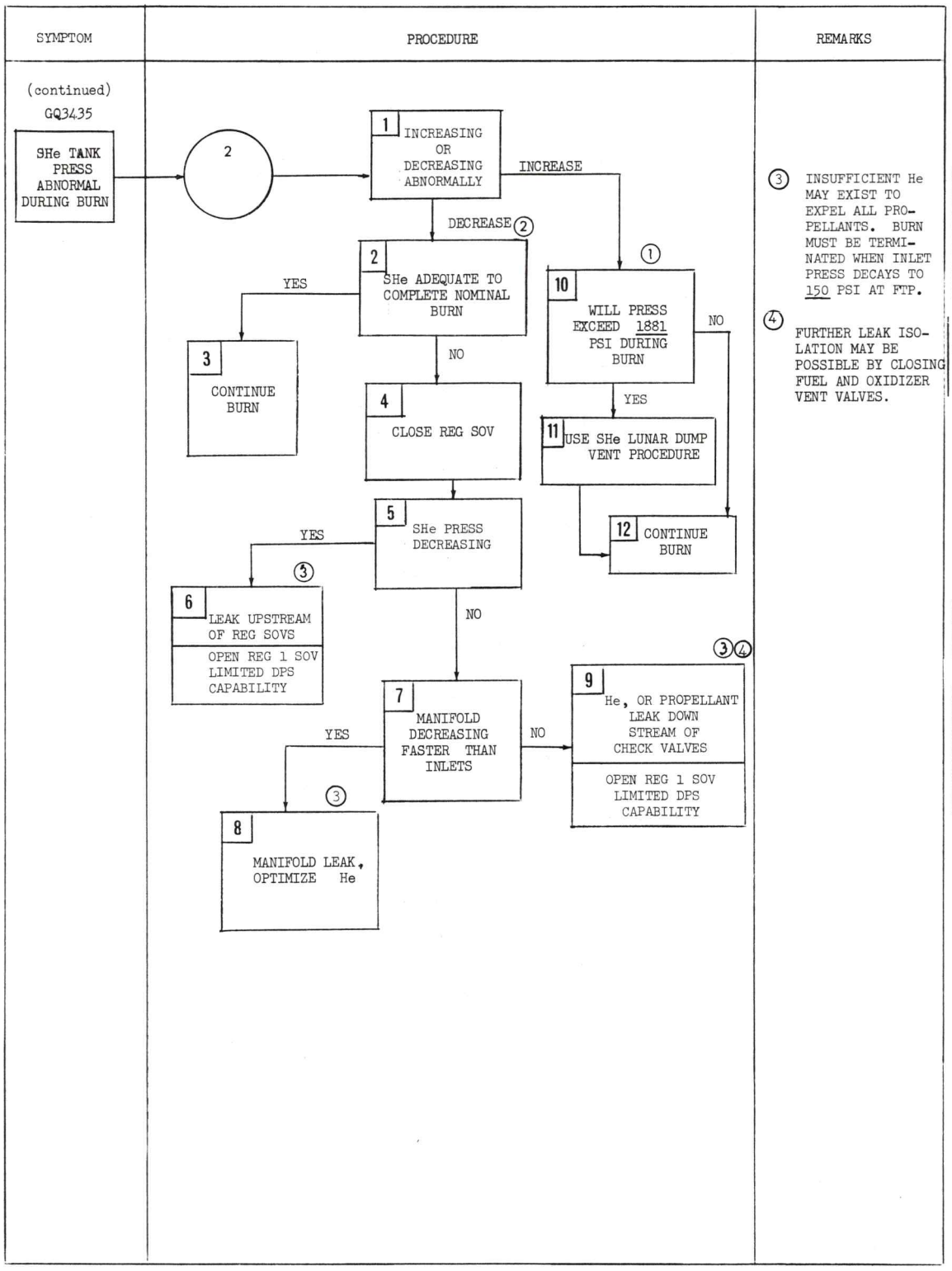
SYMPTOM	PROCEDURE	REMARKS
GQ3435 SHe TANK PRESS ABNORMAL ABNORMAL IS DEFINED AS A 2 PCM COUNT SHIFT FROM THE NORMAL TEMPERATURE PRESSURE PROFILE. 2 PCM COUNT IS 15.8 PSIA		① EXCEEDING 1881 PSI MAY CAUSE BURST DISK TO RUPTURE AND VENT SHe OVERBOARD. ② IF LESS THAN 34% PROPELLANT REMAINING WHEN ENGINE STARTS BLOW DOWN OPERATION SUFFICIENT He IS AVAILABLE TO EXPEL ALL PROPELLANTS.

P-12

P-12


SYMPTOM
PROCEDURE
REMARKS
(continued)
GQ3435
SHe TANK PRESS ABNORMAL DURING BURN
2
1 INCREASING OR DECREASING ABNORMALLY
INCREASE
DECREASE (2)
2 SHe ADEQUATE TO COMPLETE NOMINAL BURN
YES
NO
3 CONTINUE BURN
4 CLOSE REG SOV
5 SHe PRESS DECREASING
YES
(3)
6 LEAK UPSTREAM OF REG SOVS
OPEN REG 1 SOV LIMITED DPS CAPABILITY
NO
7 MANIFOLD DECREASING FASTER THAN INLETS
YES
NO
(3)
8 MANIFOLD LEAK, OPTIMIZE He
(3)(4)
9 He, OR PROPELLANT LEAK DOWN STREAM OF CHECK VALVES
OPEN REG 1 SOV LIMITED DPS CAPABILITY
(1)
10 WILL PRESS EXCEED 1881 PSI DURING BURN
NO
YES
11 USE SHe LUNAR DUMP VENT PROCEDURE
12 CONTINUE BURN
(3) INSUFFICIENT He MAY EXIST TO EXPEL ALL PROPELLANTS. BURN MUST BE TERMINATED WHEN INLET PRESS DECAYS TO 150 PSI AT FTP.
P-12
(4) FURTHER LEAK ISOLATION MAY BE POSSIBLE BY CLOSING FUEL AND OXIDIZER VENT VALVES.
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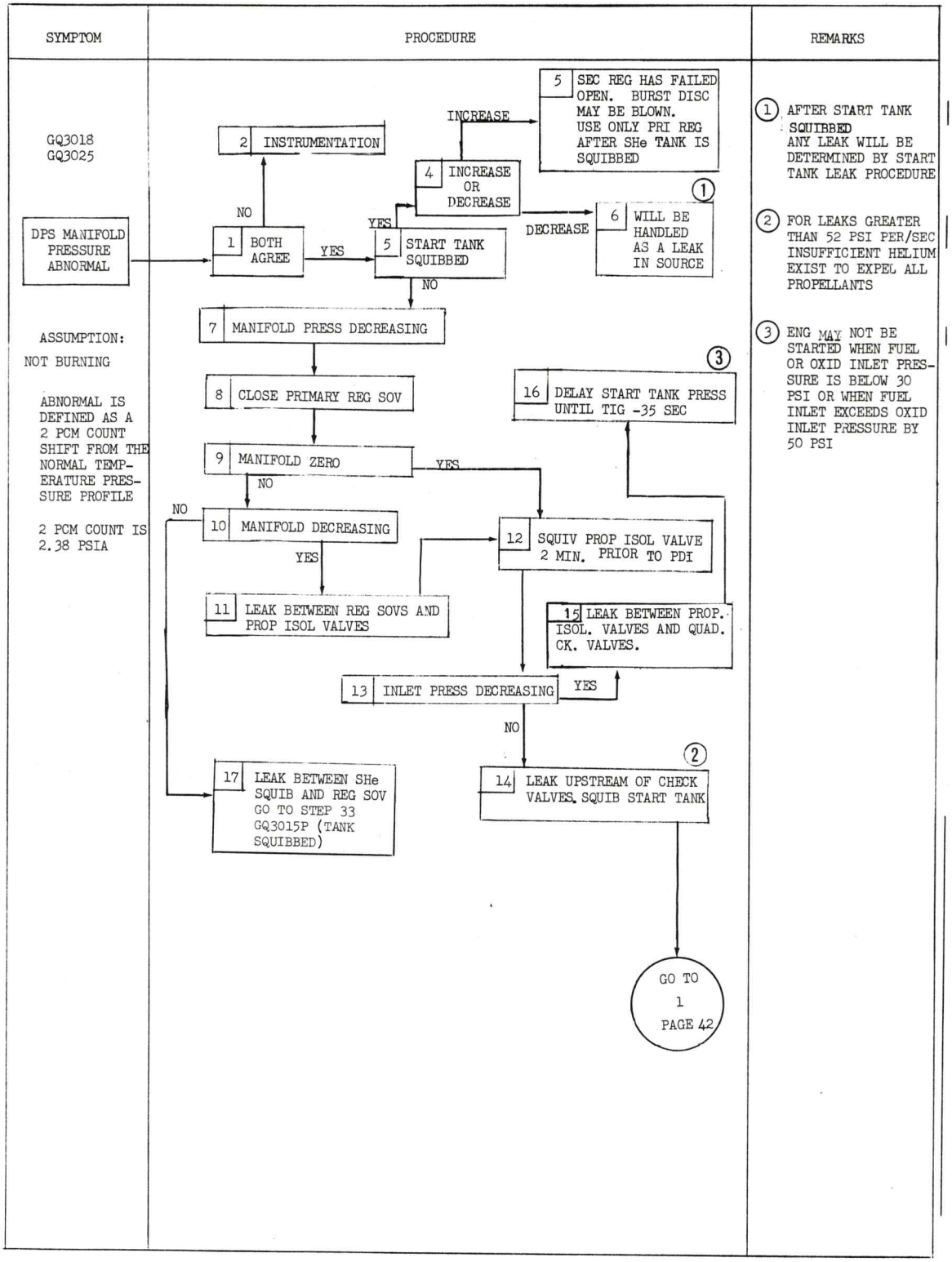
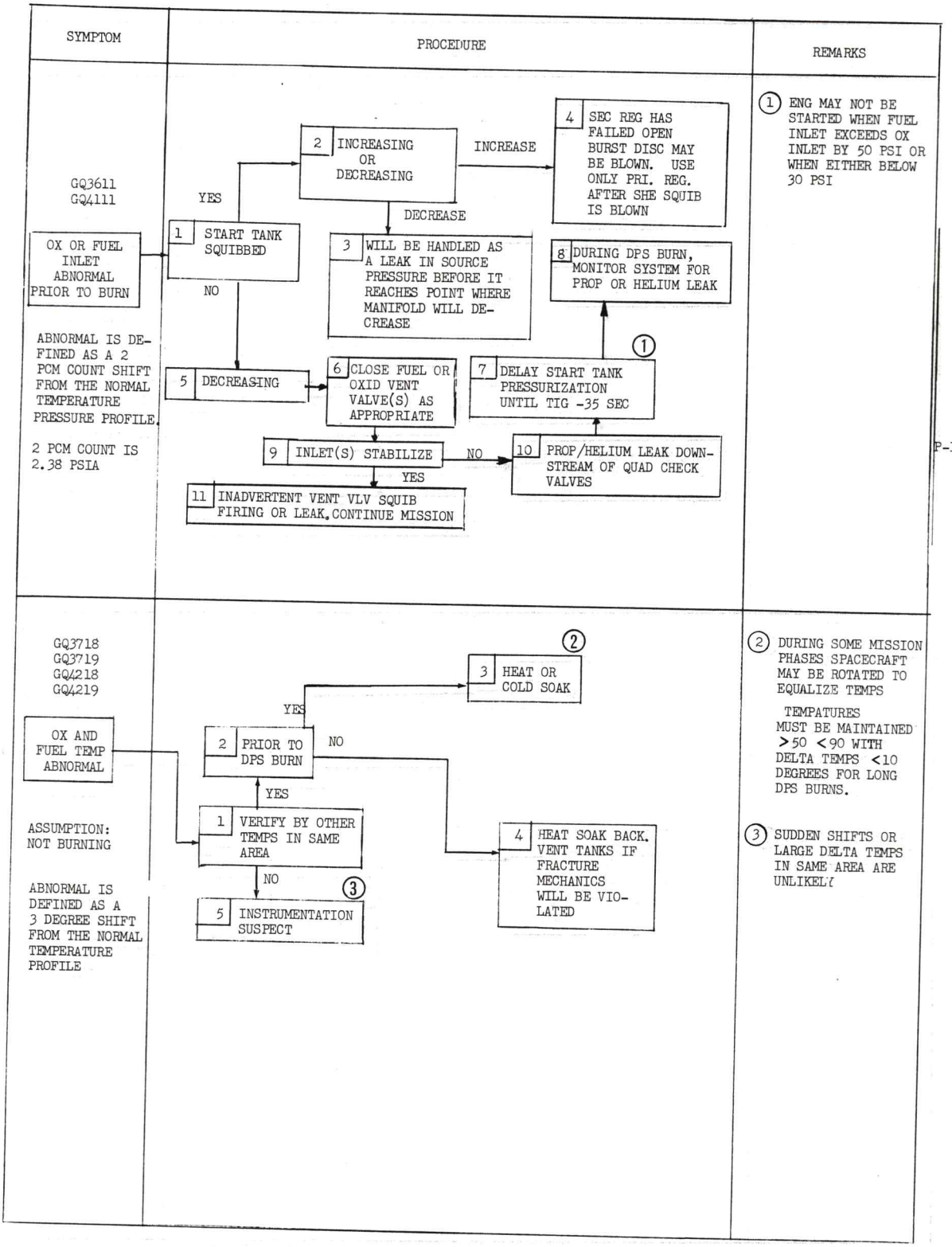

SYMPTOM
PROCEDURE
REMARKS
GQ3018
GQ3025
DPS MANIFOLD PRESSURE ABNORMAL
ASSUMPTION:
NOT BURNING
ABNORMAL IS DEFINED AS A 2 PCM COUNT SHIFT FROM THE NORMAL TEMP-ERATURE PRES-SURE PROFILE
2 PCM COUNT IS 2.38 PSIA
1 BOTH AGREE
2 INSTRUMENTATION
4 INCREASE OR DECREASE
5 SEC REG HAS FAILED OPEN. BURST DISC MAY BE BLOWN. USE ONLY PRI REG AFTER SHe TANK IS SQUIBBED
5 START TANK SQUIBBED
6 WILL BE HANDLED AS A LEAK IN SOURCE
7 MANIFOLD PRESS DECREASING
8 CLOSE PRIMARY REG SOV
9 MANIFOLD ZERO
10 MANIFOLD DECREASING
11 LEAK BETWEEN REG SOVS AND PROP ISOL VALVES
12 SQUIV PROP ISOL VALVE 2 MIN. PRIOR TO PDI
13 INLET PRESS DECREASING
14 LEAK UPSTREAM OF CHECK VALVES. SQUIB START TANK
15 LEAK BETWEEN PROP. ISOL. VALVES AND QUAD. CK. VALVES.
16 DELAY START TANK PRESS UNTIL TIG -35 SEC
17 LEAK BETWEEN SHe SQUIB AND REG SOV GO TO STEP 33 GQ3015P (TANK SQUIBBED)
GO TO 1 PAGE 42
YES
NO
INCREASE
DECREASE
1 AFTER START TANK SQUIBBED ANY LEAK WILL BE DETERMINED BY START TANK LEAK PROCEDURE
P-12
2 FOR LEAKS GREATER THAN 52 PSI PER/SEC INSUFFICIENT HELIUM EXIST TO EXPEL ALL PROPELLANTS
P-12
3 ENG MAY NOT BE STARTED WHEN FUEL OR OXID INLET PRES-SURE IS BELOW 30 PSI OR WHEN FUEL INLET EXCEEDS OXID INLET PRESSURE BY 50 PSI
P-12
P-12


SYMPTOM
PROCEDURE
REMARKS
GQ3611
GQ4111
OX OR FUEL INLET ABNORMAL PRIOR TO BURN
ABNORMAL IS DEFINED AS A 2 PCM COUNT SHIFT FROM THE NORMAL TEMPERATURE PRESSURE PROFILE.
2 PCM COUNT IS 2.38 PSIA
1 START TANK SQUIBBED
YES
NO
2 INCREASING OR DECREASING
INCREASE
DECREASE
4 SEC REG HAS FAILED OPEN BURST DISC MAY BE BLOWN. USE ONLY PRI. REG. AFTER SHE SQUIB IS BLOWN
3 WILL BE HANDLED AS A LEAK IN SOURCE PRESSURE BEFORE IT REACHES POINT WHERE MANIFOLD WILL DE-CREASE
8 DURING DPS BURN, MONITOR SYSTEM FOR PROP OR HELIUM LEAK
5 DECREASING
6 CLOSE FUEL OR OXID VENT VALVE(S) AS APPROPRIATE
7 DELAY START TANK PRESSURIZATION UNTIL TIG -35 SEC
1
9 INLET(S) STABILIZE
NO
10 PROP/HELIUM LEAK DOWN-STREAM OF QUAD CHECK VALVES
YES
11 INADVERTENT VENT VLV SQUIB FIRING OR LEAK. CONTINUE MISSION
1 ENG MAY NOT BE STARTED WHEN FUEL INLET EXCEEDS OX INLET BY 50 PSI OR WHEN EITHER BELOW 30 PSI
GQ3718
GQ3719
GQ4218
GQ4219
OX AND FUEL TEMP ABNORMAL
ASSUMPTION: NOT BURNING
ABNORMAL IS DEFINED AS A 3 DEGREE SHIFT FROM THE NORMAL TEMPERATURE PROFILE
2
3 HEAT OR COLD SOAK
YES
2 PRIOR TO DPS BURN
NO
YES
1 VERIFY BY OTHER TEMPS IN SAME AREA
NO
3
5 INSTRUMENTATION SUSPECT
4 HEAT SOAK BACK. VENT TANKS IF FRACTURE MECHANICS WILL BE VIO-LATED
2 DURING SOME MISSION PHASES SPACECRAFT MAY BE ROTATED TO EQUALIZE TEMPS
TEMPATURES MUST BE MAINTAINED >50 <90 WITH DELTA TEMPS <10 DEGREES FOR LONG DPS BURNS.
3 SUDDEN SHIFTS OR LARGE DELTA TEMPS IN SAME AREA ARE UNLIKELY

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DATE: 10/1/72
REV: PCN-14
APPROVAL: Harold A. Fabon

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
GG9002X ISS WARNING 1 = ON 0 = OFF (CONT'D)		1.C. ISS CDU FAIL WHICH MAY BE CAUSED BY ONE OF THE FOLLOWING: • CDU FINE ERROR >1.0 VRMS. (.7°). • CDU COARSE ERROR >2.0 VRMS. (30°). • UPLINE COUNTER FREQ. > 160 CPS. • COS (θ-φ) < 2.0V (66.4°). • +14 VDC SUPPLY < 8 VDC.	1.C. IMU CDU FAIL C30B12 = 0.	1.C. LOSS OF INERTIAL REFERENCE TO THE LGC PLATFORM GOOD FDAI IS VALID.	1.C. EFFECT LOSS OF INERTIAL REFERENCE TO THE LGC. ACTION USE AGS FOR BURNS AND ATTITUDE CONTROL, PGNS MIN IMP GOOD. P-12
		1.D. LGC INTERFACE FAILURE.	1.D. CH33B13 = 1, NO PIPA FAIL CH30B13 = 1, NO IMU FAIL CH30B12 = 1, NO ICDU FAIL	1.D. LOSS OF CREW INDICATION OF ISS WARN.	1.D. EFFECT LOSS OF CREW INDICATION OF ISS WARN. P-12 ACTION CREW MUST RELY ON PROG CAUT AND ASSOCIATED ERROR CODES FOR WARNING OF ISS FAILURES.
	2. GG9002X = 0 NO ISS WARN AND CH11B1 = 0 NO ISS WARN.	2. LGC INTERFACE FAILURE.	2. PROG CAUT AND ERROR CODE INDICATE IMU FAIL, ICDU FAIL AND/OR PIPA FAIL WHILE THRUSTING. ALSO WILL GET ONE OR MORE OF THE FOLLOWING: CH30B13 = 0 IMU FAIL CH30B12 = 0 ICDU FAIL CH33B13 = 0 PIPA FAIL (IF THRUSTING).	2. LOSS OF PART OF THE ISS DEPENDING ON FAILURE. REF. APPROPRIATE CHANNEL BIT MALFUNCTION ANALYSIS.	2. EFFECT LOSS OF PART OF ISS DEPENDING ON FAILURE. ACTION REF. APPROPRIATE CHANNEL BIT MALFUNCTION ANALYSIS.
	3. GG9002X = 1 ISS WARN AND CH11B1 = 0 NO ISS WARN.	3. RELAY CONTACT SHORTED	3. CH33B13 = 1, NO PIPA FAIL CH30B13 = 1, NO IMU FAIL CH30B12 = 1, NO ICDU FAIL	3. LOSS OF CREW INDICATION OF ISS WARN.	3. EFFECT LOSS OF CREW INDICATION OF ISS WARN. P-12 ACTION CREW MUST RELY ON PROG CAUT AND ASSOCIATED ERROR CODES FOR WARNING OF ISS FAILURES. P-14
	4. WRONG INDICATION FOR PRESENT STATUS OF ISS.	4. TM FAILURE.	4. SCERA 2 LOCATION 3	4. NONE.	4. EFFECT REF. LSH TABLE 9-IV. ACTION ADVISE INSTRUMENTATION OF FAILURE.

LM SYSTEMS FAILURE ANALYSIS

GN7521X LR RANGE BAD (PAGE 1 OF 2) PCN-9

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
GN7521X LR RNG DATA BAD 1 = LR RNG DATA BAD 0 = LR RNG DATA GOOD AND CHAN 33 BIT 5 LR RNG DATA GOOD 1 = LR RNG DATA BAD 0 = LR RNG DATA GOOD	1. CHAN 33B5 = 1 (LR RNG BAD) AND GN7521X = 1 (LR RNG DATA BAD)	1.A. VELOCITY TRACKER 1 OR 2 NOT LOCKED ON BECAUSE OF 1.A.1 OR 1.A.2. BELOW. 1.A.1. VELOCITY TRANSMITTER INOPERATIVE.	1.A. CHAN 33B8 = 1 (VEL DATA BAD) GN7557X = 1 (VEL DATA BAD) VEL LIGHT ON. 1.A.1. ONBOARD VEL XMTR POWER OUTPUT BELOW NOMINAL.	1.A. VELOCITY TRACKER LOCK ON OR BEAMS 1 AND 2 ARE REQUIRED TO ENABLE A RANGE DATA GOOD. WITH NO RANGE DATA GOOD, NO RANGE DATA WILL BE PROCESSED. 1.A.1. POSSIBLE TRANSMITTER ARCING (SEE 1.A. ABOVE).	1.A. EFFECT LOSS OF LR DATA. ACTION (SEE 1.A.1 AND 1.A.2. BELOW). 1.A.1. EFFECT LOSS OF LR DATA. ACTION ATTEMPT TO RESTORE POWER OUT, CYCLE CB (11) PGNS LR. P-12
		1.A.2. ZERO DOPPLER FOR AT LEAST 1/2 SEC ON VELOCITY BEAMS 1 AND/OR 2.	1.A.2. CYCLING OF ALT & VEL LIGHTS AND ALSO GN7521X AND GN7557X TO A "1" INTERMITTENTLY AND SIMULTANEOUSLY.	1.A.2. SPACECRAFT VELOCITY & ATTITUDE IN COMBINATION WITH TERRAIN IRREGULARITIES MAY CAUSE ZERO DOPPLER, WHICH MOMENTARILY MAY CAUSE DATA DROPOUTS.	1.A.2. EFFECT MOMENTARY DATA LOSS. ACTION NONE.
		1.B. ALTITUDE MODE SWITCH SET TO LO SCALE ABOVE 2500 FT ALTITUDE.	1.B. CHAN 33B9 = 0 (RNG LO SCALE FACTOR) CHAN 33B8 = 1 (VEL DATA BAD) GN7557X = 1 (VEL DATA BAD) VEL LIGHT- ON.	1.B. THE ALTITUDE MODE SWITCH SWITCHES THE VELOCITY AND RANGE FREQUENCY TRACKER'S FILTERS TO LOW PASS WHICH FILTERS OUT THE HIGH DOPPLER FREQUENCIES WHICH ARE PRESENT UNTIL MUCH OF THE FORWARD VELOCITY IS DISSIPATED. ALSO THE ALTIMETER MODULATION SWEEP RANGE IS LIMITED TO 12,000 FT, THUS PREVENTING ALTITUDE LOCK ABOVE THAT ALTITUDE. POSITIONING THE LR ANT TO DES WILL INHIBIT THE LO SCALE FUNCTION. CYCLING CB(11) PGNS LR WILL REINITIALIZE THE LO SCALE CIRCUITRY TO HIGH SCALE.	1.B. EFFECT LATE ACQUISITION OF LR DATA. ACTION LDG ANT SWITCH - HOVER WAIT 10 SEC. LDG ANT SWITCH - DESC IF ATTEMPT TO RESET LO SCALE UNSUCCESSFUL: CB(11) PGNS LR - OPEN WAIT 4 SECONDS CB(11) PGNS LR - CLOSE
		1.C. ALTITUDE TRANSMITTER INOPERATIVE.	1.C. ONBOARD ALT XMTR POWER OUTPUT BELOW NOMINAL ALT, LIGHT ON.	1.C. POSSIBLE TRANSMITTER ARCING. PROVIDED THAT LR VELOCITY TRANSMITTER IS NOT EFFECTED, VELOCITY DATA WILL BE AVAILABLE AND CAN BE ACCEPTED FOR STATE VECTOR UPDATES.	1.C. EFFECT LOSS OF LR ALTITUDE DATA. ACTION ATTEMPT TO RESTORE POWER OUT. CYCLE CB(11) PGNS LR.
		1.D. FAILURE OF RANGE DATA GOOD RELAY TO BOTH LGC AND TM.	1.D. ALT LIGHT ON. RANGE DATA ON DOWNLINK AND TAPE METER APPEARS LOCKED UP. ΔH VALUE WILL BE STATIC.	1.D. LGC WILL CONTINUE TO READ ALTITUDE AND ALTITUDE RATE BUT WILL NOT UPDATE THE STATE VECTOR WITH ALTITUDE DATA. DELTA HEIGHT ON THE DSKY WILL BE STATIC. TAPE METER AND CROSS POINTER DATA WILL BE VALID.	1.D. EFFECT LOSS OF ALTITUDE UPDATES IN LGC. ACTION CREW MUST RELY ON MSFN ASSESSMENT OF ΔH.

LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 6 DID REQUEST	THIS BIT IS NO LONGER CHECKED BY THE LUMINARY PROGRAM.				

LM SYSTEMS FAILURE ANALYSIS

CHAN 30 BIT 7 RCDU FAIL (PAGE 1 OF 1) PCN-9

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 7 RCDU FL 0 = RCDU FL 1 = NO RCDU FL	1. "0" RCDU FAIL.	1.A. LGC INTERFACE CIRCUIT FAIL OR RCDU FAIL LOGIC MALFUNCTION.	1.A. DSKY TRACKER LIGHT, NO RESOLVER/CDU DELTAS IN LGC MODE, IF IN LGC MODE WILL GET 515 ALARM (RR CDU FAIL). IF IN P20/22 AND LOCKED ON WILL NOT GET 525 ALARM (DELTA THETA GREATER THAN 3 DEGREES. DSKY PROG LIGHT (P20/22).	1.A. FAILURE CAN BE VERIFIED BY EVALUATING THE RCDUS/RESOLVERS, WITHIN ACCEPTABLE LIMITS, WITH RR IN LGC MODE. IF THE INDICATION IS FALSE, THE RR ANT RESOLVER/LGC INTERFACE (RCDUS) IS STILL OPERATIONAL. LR/RR READ (R20) CHECKS RADMODES B7 WHICH IS RESET WHEN THE RCDU FAIL OCCURS. THIS KEEPS R20 FROM READING DATA. THE SOFTWARE THEN SEQUENCES AS FOLLOWS: LR/RR READ (R20) → RR DATA READ (R22) → P20→ RR DESIGNATE (R21). P20 CAN BE USED TO LOCK ON AND THEN SWITCH TO AUTO TRACK TO KEEP LOCK. SOFTWARE WORKAROUND WILL BE NECESSARY TO UPDATE STATE VECTORS.	1.A. EFFECT LOSS OF P20 STATE VECTOR UPDATE CAPABILITY. ACTION LOCK ON WITH P20 & THEN SWITCH TO AUTO TRACK OR USE EMP. P-14
		1.B RCDU FAIL.	1.B. RESOLVER/RCDU DELTAS IN LGC MODE, TRACKER LIGHT ON, IF IN LGC MODE WILL GET NO 515 ALARM (RR CDU FAIL). IF IN P20/22 AND LOCKED ON POSSIBLE 525 ALARM (DELTA THETA GREATER THAN 3 DEGREES).	1.B. RCDU FAILURE PRECLUDES THE USE OF RCDUS. RR IS OPERATIONAL IN AUTO TRACK AND SLEW BUT P20/22 IS UNUSEABLE.	1.B. EFFECT RCDU FAIL. ACTION USE RR MODES SLEW AND AUTO TRACK.
	2. "1" NO RCDU FAIL.	2. LGC INTERFACE CIRCUIT FAIL. OR CDU FAIL LOGIC MALFUNCTION.	2. RESOLVER/RCDU DELTAS IN LGC MODE, IF IN P20/22 AND LOCKED ON POSSIBLE 525 ALARM (DELTA THETA GREATER THAN 3 DEGREES).	2. SAME AS 1.B. EXCEPT THAT FAILURE OF THIS INBIT WILL MASK ACTUAL RCDU FAILURE AND REQUIRE THE EVALUATION OF RESOLVER/RCDU DELTAS.	2. EFFECT RR UNUSEABLE IN LGC MODE. ACTION USE RR MODES SLEW AND AUTO TRACK.

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T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 9 IMU OPERATE 0 = OPR 1 = NOT IN OPR (CONT)				2.C P51 AND P57 WILL CAUSE PROG CAUT 00210 AND TRANSFER TO POOH (FLASHING V37). A DSKY PROCEDURE WILL HAVE TO BE USED TO AVOID ROUTINE IMUCHK IN P51 AND P57 NOTE: IF IMU OPR BIT FAILS OFF AFTER TURN ON HAS BEEN ACHIEVED T4RUPT IMUMON DOES THE FOLLOWING 2C1 SET IM30B9 = IMU OFF 2C2 SET IM33B6 = 1 DAP OFF 2C3 FW1B5 = 0 TRACKING NOT ALLOWED 2C4 FW2B15 = 0 DRIFT FLAG (NO GYRO COMP) 2C5 FW3B13 = 0 REFSMFLG (NO REFSMMAT) 2C6 IF FWOB8 = 1 (IMU IN USE) PROG CAUT 00214 2C7 SET FWOB8 & B7 = 0 (IMU NOT IN USE, P20 NOT RUNNING) DSKY PROCEDURE WILL HAVE TO BE USED TO SWITCH BITS 2C2 - 2C7. AFTER THE SWITCHING HAS BEEN ACCOMPLISHED EFFECT OF FAILURE WILL BE THE SAME AS ABOVE.	

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LM SYSTEMS FAILURE ANALYSIS

CHAN 30 BIT 10 G/N CONTROL OF S/C (PAGE 1 OF 2) PCN-9

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 10 G&N CONTROL OF S/C 0 = PGNS 1 = AGS	1. "1" (AGS) WHEN SWITCHING FROM AGS TO PGNS	1.A. OPEN BETWEEN CONTACTS 2 AND 3 OF GUID CONT SW 9S6 ON PANEL 1.	1.A. GH1621X = 1 AGS SELECTED; AGS WD45 BIT 9 = 1 AGS NOT IN FOLLOW UP.	1.A. LOSS OF LGC-CES INTERFACE. AGS WILL BE IN CONTROL OF SPACECRAFT. DAP WILL REMAIN ON AND PGNS RCS, GDA & ENG ON/OFF COMMANDS GENERATED BUT DISABLED TO CES. IF SWITCH BACK TO PGNS IS EFFECTED THE DAP WILL BE INITIALIZED. PGNS ATTITUDE ERRORS STILL AVAILABLE ON FDAI. ONBOARD ISS & LGC WARN INHIBITED.	1.A. EFFECT LOSS OF REDUNDANT (PGNS) 3-AXIS ATTITUDE CONTROL ACTION LET AGS CONTROL S/C OR CONTROL MANUALLY USING PGNS ATTITUDE ERROR NEEDLES.
		1.B. CB (11) STAB/CONT, ATCA (PGNS) OPEN.	1.B. PREAMPS CAUTION LIGHT 6DS30 ON PANEL 2 ON; GH1621X = 1 AGS SELECTED; AGS WD 45 BIT 9 = 1 AGS NOT IN FOLLOWUP.	1.B. SEE IM CB FAILURE ANALYSIS OF 4CB81. NOTE: PGNS ATTITUDE ERRORS STILL AVAILABLE ON FDAI.	1.B. EFFECT LOSS OF REDUNDANT (PGNS) 3-AXIS ATTITUDE CONTROL ACTION ,ATTEMPT TO RESET CB. SWITCH TO AGS IF NOT EFFECTIVE.
	2. "1" (AGS) ANYTIME	2. MICRO-LOGIC CIRCUIT FAILURE IN LGC OR FAILURE OF RELAY CONTACT CA2 K7.	2. GH1621X = 0 PGNS SELECTED; AGS WD45 BIT 9 = 0 AGS IN FOLLOW UP.	2. DAP WILL REMAIN ON AND THE S/C WILL REMAIN IN PGNS CONTROL. ALTHOUGH AUTOMATIC GUIDANCE STEERING IS STILL GOOD, AUTOMATIC ATTITUDE MANEUVERS WILL NOT BE POSSIBLE (CHECKLIST CODE 203 WILL APPEAR IN BURN PROGRAMS BUT CAN BE BYPASSED WITH AN ENTER).	2. EFFECT AUTOMATIC MANEUVERS NOT POSSIBLE ACTION MANEUVER IN ATTITUDE HOLD OR AGS.
	3. "1" (AGS) AFTER A SUCCESSFUL SWITCH FROM AGS TO PGNS	3. SHORT BETWEEN CONTACTS 4 AND 5 OF GUID CONT SW 9S6 ON PANEL 1.	3. GH1621X = 1 AGS SELECTED; AGS WD 45 BIT 9 = 1 AGS NOT IN FOLLOWUP.	3. SAME AS 1.A. A SWITCH BACK TO PGNS CAN BE EFFECTED BY CYCLING GUID CONT SW TO AGS AND BACK TO PGNS. IF SHORT IS INTERMITTENT CB (16) STAB/CONTROL ATCA (AGS) SHOULD BE OPENED TO PREVENT ANY RECURRENCE.	3. EFFECT TEMPORARY LOSS OF PGNS CONTROL ACTION CYCLE GUID CONT SW AND OPEN 4CB230 ATCA (AGS). SEE MALFUNCTION ANALYSIS OF 4CB230 FOR FUNCTIONS LOST.
	4. "0" (PGNS) WHEN SWITCHING FROM PGNS TO AGS	4.A. OPEN BETWEEN CONTACTS 4 AND 5 OF GUID CONT SW 9S6 ON PANEL 1.	4.A. GH1621X = 0 PGNS SELECTED; AGS WD 45 BIT 9 = 0 AGS IN FOLLOWUP.	4.A. LOSS OF AGS USE OF PRIMARY COILS, GDA AND ENGINE ON/OFF INTERFACE WITH CES. PGNS WILL BE IN CONTROL OF SPACECRAFT. HARDOVER AND DIRECT WILL STILL BE AVAILABLE, AS WELL AS AGS ATTITUDE ERRORS.	4.A. EFFECT LOSS OF REDUNDANT (AGS) 3-AXIS ATTITUDE CONTROL ACTION USE PGNS CONTROL
		4.B. CB (16) STAB/CONT, ATCA (AGS) OPEN.	4.B. GH1621X = 0 PGNS SELECTED; AGS WD 45 BIT 9 = 0 AGS IN FOLLOWUP.	4.B. SEE IM CB FAILURE ANALYSIS OF 4CB230. NOTE: AGS ATTITUDE ERRORS STILL AVAILABLE ON FDAI.	4.B. EFFECT LOSS OF REDUNDANT (AGS) 3-AXIS ATTITUDE CONTROL ACTION ATTEMPT TO RESET CB. IF NOT EFFECTIVE SWITCH TO PGNS.

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 10 (CONT)	5. "0" (PGNS) ANYTIME	5. MICRO-LOGIC CIRCUIT FAILURE IN LGC OR FAILURE OF RELAY CONTACT CA2K7.	5. GH1621X = 1 AGS SELECTED AGS WD 45 BIT 9 = 1 AGS NOT IN FOLLOWUP.	5. THE DAP WILL REMAIN ON BUT RCS, GDA AND ENGINE ON/OFF COMMANDS WILL BE DISABLED TO THE SCS. WHEN SWITCHING BACK TO PGNS A LARGE ATTITUDE MANEUVER MAY RESULT SINCE THE LACK OF AN AGS INDICATION WILL PREVENT A DAP INITIALIZATION. THE BURN PROGRAMS CHECK ON THIS DISCRETE WILL NOT RESULT IN CHECKLIST CODE 203 AS IT SHOULD WHEN THE S/C IS NOT IN PGNS CONTROL.	5. EFFECT POSSIBLE LARGE UNEXPECTED ATTITUDE MANEUVER WHEN SWITCHING BACK TO PGNS ACTION TURN DAP OFF VIA MODE CONTROL SW OR SELECT ATT HOLD MIN IMPULSE BEFORE SWITCHING TO PGNS CONTROL. P-14
	6. "0" (PGNS) AFTER A SUCCESSFUL SWITCH FROM PGNS TO AGS	6. SHORT BETWEEN CONTACTS 2 AND 3 OF GUID CONTROL SW 9S6 ON PANEL 1.	6. GH1621X = 0 PGNS SELECTED; AGS WD45 BIT 9 = 0 AGS IN FOLLOW UP.	6. SAME AS 4.A. A SWITCH BACK TO AGS CAN BE EFFECTED BY CYCLING GUID CONT SW TO PGNS AND BACK TO AGS. IF SHORT IS INTERMITTENT CB (11) STAB/CONT, ATCA (PGNS) COULD BE OPENED TO PREVENT RECURRENCE.	6. EFFECT TEMPORARY LOSS OF AGS CONTROL ACTION CYCLE GUID CONT SW AND OPEN 4CB81 ATCA (PGNS). SEE MALFUNCTION ANALYSIS OF 4CB81 FOR FUNCTIONS LOST. P-14

LM SYSTEMS FAILURE ANALYSIS

CHAN 30 BIT 13 IMU CAGE (PAGE 1 OF 2) PCN-9

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 11 IMU CAGE 0 = IMU CAGE 1 = NO IMU CAGE	1. "0" IMU CAGE	1A. LGC INTERFACE FAILURE	1A. IM30B11 = 0 RSVRS DO NOT INDICATE THAT THE PLATFORM IS CAGED. CREW WILL GET NO ATT LIGHT AND DSTAB11 BIT 4 = 1 "NO ATTITUDE." IM33B6 - 1 "DAP DISABLE"	1A. PLATFORM REMAINS ALIGNED AND INERTIAL ALTHOUGH DRIFT COMPENSATION IS NOT BEING ACCOMPLISHED. THE DAP IS DISABLED. THE FOLLOWING MUST BE ACCOMPLISHED TO NEGATE THE EFFECTS OF THE CAGE DISCRETE: 1. SET DSPTAB11B4 = 0 NO ATT OFF 2. SET CH12B5 = 1 ZERO IMU CDU 3. SET CDUX, Y, Z = 0 4. SCHEDULE UNZ2 ROUTINE	1A. EFFECT T4RUPT INITIALIZES SOME BITS IN WRONG STATE ACTION CORRECT T4RUPT ACTION NOTE: SUBSEQUENT POWER UP WILL REQUIRE REPEAT OF ABOVE ACTION
		1B. SHORTED DIODE BETWEEN IMU TURN-ON RELAY AND CAGE CMD TO THE LGC.	1B. IM30B11 = 0 IMU CAGE RSVR'S AND CDU'S INDICATE PLATFORM IS CAGED.	1B. PLATFORM WILL BE CAGED DUE TO THE ENERGIZED CAGE RELAY. THE ISS CANNOT BE USED AS AN ATTITUDE REFERENCE. MINIMUM IMPULSE IS THE ONLY PGNS CONTROL MODE AVAILABLE.	1B. EFFECT LOSS OF PGNS, DAP MINIMUM IMPULSE ONLY PGNS CONTROL MODE ACTION SWITCH TO AGS.
		1C. SHORT ON IMU CAGE SWITCH.	1C. SAME AS 1B, EXCEPT CAGE INDICATION WILL DISAPPEAR WHEN CB:PGNS:IMU STBY IS OPEN.	1C. SAME AS 1B WITH CB:PGNS:IMU STBY CLOSED. CAGE CONDITION WILL BE TERMINATED IF CB:PGNS:IMU STBY IS OPENED. PLATFORM IS USABLE EXCEPT IMU HEATER POWER IS REMOVED WITH OPEN IMU STBY CB AND PIPA TEMP WILL DECREASE TO GLYCOL TEMP. PIPA'S WILL BE LOST AFTER 1/2 HOUR TO 1 HOUR. IRIG'S WILL BE STABLE AT THE GLYCOL TEMP ALTHOUGH MAY GET SIZEABLE DRIFT RATES (0 TO 30 MERU).	1C. SAME AS 1B WITH CB:PGNS:IMU STBY CLOSED WITH CB;PGNS:IMU STBY OPEN EFFECT LOSS OF PIPA'S AFTER 1/2 HOUR TO 1 HOUR. PLATFORM IS DEGRADED. ACTION USE PGNS UNTIL PIPA'S ARE LOST. THEN SWITCH TO AGS OR CLOSE CB:PGNS:IMU STBY TO REGAIN NOMINAL IMU TEMPERATURE.
	2. "0" IMU CAGE (MOMENTARILY) MSFN PROBABLY WILL NOT BE ABLE TO SEE FAILURE SYMPTOM.	2. SHORTED DIODE BETWEEN CAGE RELAY AND CAGE AND TO LGC. (CAN OCCUR DURING IMU TURN-ON ONLY)	2. IM30B11 = 0 IMU CAGE OCCURS MOMENTARILY. FAILURE CAUSES TURN-ON RELAY TO BE ENERGIZED THUS REMOVING BOTH THE CAGE CMD AND THE T/O REQUEST. WILL GET PROG CAUT 00207 "ISS TURN-ON REQUEST NOT PRESENT FOR 90 SEC" AND IM30B2 = 1 TURN ON SEQUENCE FAILED.	2. PLATFORM MAY NOT BE CAGED BEFORE GOING INTO AN INERTIAL MODE. NO FURTHER S/C EFFECT.	2. EFFECT POSSIBLE NON-NOMINAL TURN-ON SEQUENCE ACTION NONE.

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 11 (CONT'D)	3. "1" (NO IMU CAGE) WITH IMU CAGE SWITCH IN ON POSITION	3A. OPEN 4CB161 (IMU STBY)	3A. SEE 4CB161 ANALYSIS	3A. SEE 4CB161 ANALYSIS	3A. SEE 4CB161 ANALYSIS
		3B. CAGE SWITCH FAILED	3B. IMODES 30 BIT 11 = 1 (IMU CAGE NOT REQUESTED)	3B. UNABLE TO CAGE IMU VIA CAGE SWITCH (3S1) ON PANEL 1	EFFECT 3B. UNABLE TO CAGE IMU VIA CAGE SWITCH ACTION CAN CAGE VIA TURN-ON OR DSKY INPUT
		3C. LGC INTERFACE FAILURE	3C. SAME AS 3B. EXCESSIVE ATTITUDE EXCURSIONS IF DAP IS ON. ALSO IMU FAIL C30B13 = 0 ICDU FAIL C30B12 = 0 CREW WOULD SEE PROG CAUT AND ISS WARN.	3C. THE LGC WILL NOT BE AWARE OF THE CAGING PROCESS AND THUS NOT INHIBIT THE DAP OR IMU AND ICDU FAILS, OR RESET THE TRACK, DRIFT, AND REFSMMAT FLAGS (F1B5, F2B15, F3B13). IF THE DESIRED ATTITUDE OF THE SPACECRAFT (AS "KNOWN" BY THE DAP) IS ANYTHING OTHER THAN CLOSE TO ZERO, THE DAP WILL INTERPRET THE CAGING PROCESS AS AN ATTITUDE ERROR AND FIRE JETS TO CORRECT FOR IT. NOTE: IF USE OF CAGE SWITCH IS DESIRED THE DAP CAN BE TURNED OFF.	3C. EFFECT POSSIBLE UNSTABLE VEHICLE DUE TO EXCESSIVE JET FIRINGS. ACTION STABILIZE VEHICLE; RE-ESTABLISH INERTIAL REFERENCE.

LM SYSTEMS FAILURE ANALYSIS

CHAN 30 BIT 12 ISS CDU FAIL (PAGE 1 OF 1) PCN-9

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 12 ISS CDU FAIL 0 = ISS CDU FAIL 1 = NO ISS CDU FAIL	1. "0" ISS CDU FAIL.	1.A. LGC INTERFACE FAIL OR CDU FAIL LOGIC MALFUNCTION.	1.A. NO RESOLVER/CDU DELTAS, ISS WARNING (PNL 1), 3777 ALARM.	1.A. FAILURE CAN BE VERIFIED BY EVALUATING CDU/RESOLVER DELTAS. IF THE INDICATION IS DETERMINED TO BE FALSE ISS CDU INTERFACE IS STILL OPERATIONAL. ISS WARNING CAN BE MASK BY INTERNALLY SETTING CH11 B01. (G&N DICTIONARY PG1-68) SUCCEEDING T4RUPT CYCLES WILL BYPASS CHECK FOR THIS DISCRETE. IF ANOTHER FAILURE OCCURS, CH30 CK IN T4RUPT WILL LIGHT ISS WARNING. IMU RESOLVER/CDU DELTAS MUST BE MONITORED CLOSELY AS THIS FAILURE WILL MASK AN ACTUAL ICDU FAILURE.	1.A. EFFECT FALSE ICDU FAIL. ACTION CONTINUE MISSION AND RESET CH11 B01 TO CLEAR ISS WARNING. P-14 P-14
		1.B. I CDU FAILURE, COARSE ERROR TOO GREAT, FINE ERROR TOO GREAT, COUNTER FREQUENCY TOO LARGE, 14 VDC CDU POWER SUPPLY FAILURE.	1.B. RESOLVER/CDU DELTAS, ISS WARNING, 3777 ALARM.	1.B. LOSS OF INERTIAL REFERENCE TO THE LGC. THE RESOLVER ANGLES & FDAI TOTAL ATTITUDE ARE STILL CORRECT. DAP WILL FIRE JETS BECAUSE IT THINKS THE SPACECRAFT IS OUT OF THE DEADBAND. TURN DAP OFF & SWITCH TO AGS. PGNS MIN IMPULSE IS STILL AVAILABLE. A SOFTWARE WORKAROUND IS AVAILABLE FOR CERTAIN FAILURES. REF EMP 103 A, P, DESCENT WITH FAILED CDU'S.	1.B. EFFECT LOSS OF CDU'S, PLATFORM IS STILL AVAILABLE, & MIN IMPULSE IS AVAILABLE. ACTION SWITCH TO AGS OR USE SOFTWARE WORKAROUND. P-14
	2. "1" NO ISS. CDU FAIL.	2. LGC INTERFACE FAIL. CDU FAIL LOGIC MALFUNCTION.	2. RESOLVER/CDU DELTAS NO ISS WARNING (PNL 1), NO 3777 ALARM.	2. FAILURE MUST BE VERIFIED BY EVALUATING RESOLVER/CDU DELTAS. THIS FAILURE PREVENTS USE OF IMU FOR LOGIC ATTITUDE REFERENCE. FDAI TOTAL ATT. IS STILL AVAILABLE FOR ATT. REF. VIA RESOLVERS AND GASTA. NOTE: IN EITHER 1A OR 2 FAILURE CASE, ICDU FAIL MONITOR CAPABILITY IS LOST.	2. SAME AS 1.B. P-14

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 13 IMU FAIL (CONT)	2. "1" NO IMU FAIL	2. LGC INPUT FAILURE OR FAILURE IN IMU FAIL DETECTION CIRCUITRY.	2. WILL NOT GET ISS WARN OR PROG CAUT BUT ONE OF THE FOLLOWING WILL BE OUT OF LIMITS. GG1201V 800 HZ PWR < 14 VOLTS GG1331V 3.2 KHZ PWR < 14 VOLTS GG2107, 37, 67, IG, MG, OG SERVO ERRORS > 3 VRMS FOR 2 SEC.	2. CREW WILL NOT BE WARNED OF IMU FAILURE. SEE APPROPRIATE TM MALFUNCTION ANALYSIS FOR FUNCTION EFFECTS OF FAILURE.	EFFECT 2. VALID IMU FAIL CONDITION - LOSS OF IMU LOSS OF CREW IMU FAIL WARNING VIA ISS WARN LIGHT. ISS WARN LITE IS VALID FOR FAILURES OTHER THAN IMU FAIL. ACTION PGNS MIN IMP STILL GOOD OTHERWISE USE AGS

LM SYSTEMS FAILURE ANALYSIS

CHAN 30 BIT 14 ISS TURN ON REQUEST (PAGE 1 OF 2)

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 14 ISS TURN-ON REQUEST 0 = T/O REQUEST 1 = NO T/O REQUEST	1. "0" T/O REQUEST	1A. LGC INTERFACE FAILURE. NOTE: UNLIKELY FAILURE SINCE 28 VDC PWR IS NEEDED TO ACTIVATE LGC INPUT CIRCUITRY	1A. IM 30 BIT 14 = 0	1A. T/O SEQUENCE WILL BE NOMINAL WITH EXCEPTION THAT T/O SEQUENCE FAILURE (IM30B2 = 1) WILL NOT BE CHECKED AND PROG CAUT 00207 COULD NOT BE ISSUED IN CASE OF A SEQUENCE FAILURE. IM30B14 WOULD AGREE WITH CH30B14 THROUGHOUT THE MISSION. NOTE: IF FAILURE GOES AWAY SUBSEQUENT TO TURN-ON, WILL GET IM30B14 = 1 WITH IM30B2 = 1 (T/O SEQUENCE FAILED) AND PROG CAUT 00207 (ISS T/O REQUEST NOT PRESENT FOR 90 SEC). TO AVOID PROBLEMS WITH ROUTINE ENDTNON DURING FUTURE IMU TURN-ON'S, IM30B2 SHOULD BE SET TO ZERO.	EFFECT 1A. LOSS OF PROG CAUT 00207 ACTION NONE
		1B. LOSS OF POWER TO IMU T/O RELAY. CAUSED BY FAILURE OF DIODE OR TRANSISTOR ON DELAY COMPLETE LINE. FAILURE OF CH12B15 ISS T/O DELAY COMPLETE.	1B. SAME AS 1A. ALSO PTA INHIBIT CAUSES 120 VDC PTA PWR SUPPLY (GG1040) OFF SCALE LOW. PIPA FAIL CH33B13 = 0 PROG CAUT 00212.	1B. CYCLE IMU CAGE SWITCH TO COMPLETE TURN ON SEQUENCE.	EFFECT 1B. NON-NOMINAL TURN ON. ACTION CYCLE IMU CAGE SWITCH TO ALLOW PLATFORM TO GO INERTIAL.
		1C. FAILED IMU TURN ON RELAY OR CONTACT SHORTED TO 28 VDC POWER.	1C. SAME AS 1B.	1C. LOSS OF IMU. IMU WILL REMAIN CAGED. CONSIDER POWERING DOWN THE IMU.	EFFECT 1C. LOSS OF PGNS ATTITUDE REFERENCE. ACTION SWITCH TO AGS. PGNS MIN IMPULSE STILL GOOD.
	2. "1" NO T/O REQUEST (DURING TURN-ON SEQUENCE)	2A. LGC INTERFACE FAILURE	2A. IM30B14 = 1 PLATFORM WILL BE CAGED.	2A. THE FOLLOWING SEQUENCE WILL HAVE TO BE FOLLOWED TO ACHIEVE A TURN-ON. 1. CLOSE IMU OPR CB 2. SET IM30B7 = 1 (FIRST TURN-ON SAMPLE) WITH DSKY PROCEDURE. NO FURTHER ACTION REQUIRED.	EFFECT 2A. LOSS OF NOMINAL IMU T/O SEQUENCE. ACTION USE ALTERNATE METHODS.

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 14 ISS TURN-ON REQUEST 0 = T/O REQUEST 1 = NO T/O REQUEST	2. "1" NO T/O REQUEST. (DURING TURN-ON SEQUENCE)	2B. LOSS OF IMU OPR CB	2B. SEE IMU OPR CB MALFUNCTION ANALYSIS.	2B. SEE IMU OPR CB MALFUNCTION	2B. SEE IMU OPR CB MALFUNCTION.
		2C. SHORTED DIODE BETWEEN CAGE RELAY AND CAGE CMD TO LGC.	2C. IM30B11 = 0 IMU CAGE OCCURS MOMENTARILY. WILL GET PROG CAUT 00207 "ISS TURN-ON REQUEST NOT PRESENT FOR 90 SEC" AND IM30B2 = 1 TURN-ON SEQUENCE FAILED.	2C. PLATFORM MAY NOT BE CAGED BEFORE GOING INTO AN INERTIAL MODE. NO FURTHER S/C EFFECT. CAGE USING DSKY PROCEDURE IF DESIRED. FAILURE CAUSES TURN-ON RELAY TO BE ENERGIZED THUS REMOVING BOTH THE CAGE CMD AND THE T/O REQUEST.	EFFECT 2C. LOSS OF NOMINAL TURN-ON SEQUENCE. ACTION NONE. PCN-9
		2D. OPEN CONTACT ON IMU T/O RELAY	2D. PLATFORM WILL BE INERTIAL WITHOUT BEING CAGED & IM30B14 = 1 PTA INHIBIT WILL CAUSE 120 VDC GG1040 OFF SCALE LOW.	2D. TO REMOVE PTA INHIBIT SET IM30B7 = 1 (FIRST TURN ON SAMPLE) WITH DSKY PROCEDURE OR CYCLE IMU CAGE SWITCH.	2D. EFFECT PLATFORM WILL BE INERTIAL WITHOUT GETTING RID OF THE PTA INHIBIT. ACTION FINISH TURN ON SEQUENCE USING DSKY METHOD OR CYCLE IMU CAGE SWITCH. P-14

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CHAN 30 BIT 14 ISS TURN ON REQUEST (PAGE 2 OF 2)

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 30 BIT 15 TEMP IN LIMITS 1 = TEMP OUT OF LIMITS 0 = TEMP IN	1. "1" TEMP OUT OF LIMITS.	1.A. LGC INPUT FAILURE.	1.A. GG2300T PIPA TEMP WILL READ $< 134 \pm .2^{\circ}F$ OR $> 126 \pm .2^{\circ}F$.	1.A. CREW WILL GET TEMP LIGHT ON DSKY ILLUMINATED.	1.A. EFFECT LOSS OF CREW WARNING OF IMU TEMPERATURE. ACTION LIGHT ON DSKY CAN BE EXTINGUISHED BY SETTING CH11 BIT 4 = 0.
		1.B. TEMPERATURE CONTROL FAILURE.	1.B. GG2300T PIPA TEMP WILL READ $> 134 \pm .2^{\circ}F$ OR $< 120 \pm .2^{\circ}F$.	1.B. REF. GG2300T FAILURE ANALYSIS.	1.B. REF. GG2300T FAILURE ANALYSIS.
	2. "0" TEMP IN LIMITS	2. LGC INPUT FAILURE.	2. GG2300T PIPA TEMP READS $> 134 \pm .2^{\circ}F$ OR $< 120 \pm .2^{\circ}F$.	2. CREW HAS LOST ABILITY TO SEE TEMPERATURE PROBLEM. SEE GG2300T PIPA TEMP MALFUNCTION ANALYSIS FOR TEMP OUT OF LIMITS FUNCTION EFFECTS.	2. EFFECT LOSS OF CREW WARNING OF IMU TEMPERATURE PROBLEM. ACTION CREW CONSULT MSFN FOR STATUS OF IMU.
NOTE: THE TEMP CAUT INDICATION TO THE CREW IS VALID WHEN THE LGC IS IN THE STANDBY MODE.					

CHAN 31 BITS 1 - 6 2½ DEGREE SWITCHES (PAGE 1 OF 3) PCN-9

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 31 BIT 1-6 2 1/2 DEGREE SWITCHES BIT 1 + PITCH MIN IMPULSE, + EL (LPD) BIT 2 -PITCH MIN IMPULSE, - EL (LPD) BIT 3 + YAW MIN IMPULSE BIT 4 - YAW MIN IMPULSE BIT 5 +ROLL MIN IMPULSE, + AZ (LPD) BIT 6 - ROLL MIN IMPULSE, - AZ (LPD) 0 = ON 1 = OFF	1. "0" (ON)	1A. 2½ DEGREE SWITCH IN ACA SHORTED.	1A. WITH APPROPRIATE ATTITUDE CONTROL SW IN PULSE, CORRESPONDING ERROR COMMAND = +2 ±.1V; C31B15 = 1 ACA IN DETENT. NOTE: GH1247/48/49 = YAW, PITCH, ROLL ERROR COMMANDS RESPECTIVELY.	1A. • PARTIAL LOSS OF MINIMUM IMPULSE CAPABILITY. THE ± YAW MIN IMP CMDS (CHAN 6) ARE PROCESSED INDEPENDENTLY OF THE ± PITCH AND ± ROLL CMDS (CHAN 5) AND A FAILURE IN ONE CHANNEL DOES NOT AFFECT THE OTHER CHANNEL. THE SHORT CAN BE ISOLATED COMPLETELY BY UNPLUGGING THE DEFECTIVE ACA AND INSERTING THE SHORTING PLUG, OR PARTIALLY VIA THE ATTITUDE CONTROL SWITCHES. PLACING THE APPROPRIATE ATTITUDE CONTROL SW TO PULSE WOULD DISABLE THE SHORT AND NOT FIRE JETS AS LONG AS GUID CONT SW WAS IN PGNS. (PLACING IT TO DIRECT WOULD FIRE JETS IF CB(11) STA B/CONT, ATT DIR CONT WAS CLOSED.) FOR PITCH AND ROLL IF THE + SW IS SHORTED THE -CAPABILITY IS LOST BUT ONE + PULSE COULD BE OBTAINED WITH EVERY CYCLING OF THE APPROPRIATE ATTITUDE CONTROL SW. IF THE -SW IS SHORTED, ONE -PULSE CAN BE OBTAINED WITH EVERY CYCLING OF THE ATT CONT SW AND ONE + PULSE WITH EVERY CYCLING OF THE ATT CONT SW WHILE THE ACA IS DEFLECTED IN THE + DIRECTION. FOR YAW THE FAILURE MODES ARE JUST THE OPPOSITE OF PITCH AND ROLL, I.E. IF THE -SW IS SHORTED, THEN THE +CAPABILITY IS LOST. • THE + PITCH AND + ROLL COMMANDS ARE ALSO USED FOR ± AZ AND + ELEVATION LPD CMDS. THE AZ AND EL CMDS CAN ALSO BE ISOLATED VIA THE ROLL & PITCH ATTITUDE CONTROL SWITCHES, RESPECTIVELY. EITHER ONE + OR ONE - PULSE CORRESPONDING TO THE SHORTED SW CAN BE OBTAINED WITH EACH CYCLING OF THE ATT CONT SW, BUT CAPABILITY IN THE OPPOSITE DIRECTION (- OR +) IS LOST. AFTER THE CREW HAS PROCEEDED IN P64 TO ENABLE LPD CAPABILITY, AN ON FAILURE OF THE LPD BITS STARTS A MONITOR WHICH RUNS UNTIL THE NEXT V37 OR RESTART OR ISOLATION OF THE SHORT VIA THE ATT CONT SW AND CAUSES 3 TO 4 PERCENT T LOSS.	EFFECT 1A. PARTIAL LOSS OF LPD AND/OR MINIMUM IMPULSE CAPABILITY ACTION ISOLATE FAILURE COMPLETELY VIA ACA SHORTING PLUG OR PARTIALLY VIA ATTITUDE CONTROL SWITCH MANAGEMENT, OR USE RATE COMMAND OR AUTO FOR MANEUVERS. FOR LPD WORK-AROUND, SEE NOTE.**

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 31 BIT 1 - 6 (CONT'D)		1B. MICRO-LOGIC CIRCUIT FAILURE IN LGC.	1B. WITH APPROPRIATE ATTITUDE CONTROL SWITCH IN PULSE, CORRESPONDING ERR CMD = 0; C31B15 = 1 ACA IN DETENT.	1B. PARTIAL LOSS OF ±YAW MIN IMP CMDS OR ±PITCH AND ±ROLL MIN IMP CMDS AND ±AZ AND ±E1 LPD CMDS. THE ±YAW MIN IMP CMDS (CHAN 6) ARE PROCESSED INDEPENDENTLY OF THE ±PITCH AND ±ROLL CMDS (CHAN 5) AND A FAILURE IN ONE CHANNEL DOES NOT AFFECT THE OTHER CHANNEL. FOR A FAILED ON -YAW BIT, ONE -YAW PULSE COULD BE OBTAINED FOR EVERY OFF AND ON CYCLING OF THE DAP MODE CONTROL SWITCH, BUT +YAW CAPABILITY IS LOST. FOR A FAILED ON +YAW BIT, ONE +YAW PULSE COULD BE OBTAINED FOR EVERY OFF AND ON CYCLING OF THE DAP AND ONE −YAW PULSE FOR EVERY OFF AND ON CYCLING OF THE DAP WHILE THE ACA IS DEFLECTED IN THE -YAW DIRECTION. SIMILARLY, THE ± PITCH AND ± ROLL BIT FAILURES CAN BE MASKED WITH THE ORDER HERE BEING +PITCH, −PITCH, +ROLL, −ROLL; THUS FOR A FAILED+PITCH BIT, −PITCH AND +ROLL CAPABILITY IS LOST; FOR A FAILED −ROLL BIT, NO CAPABILITY IS LOST WHEN COUPLED WITH SIMULTANEOUS ACA DEFLECTION. IF ANY OF THE FOUR (±AZ OR ±E1) LPD BITS ARE FAILED ON, ALL NORMAL LPD CAPABILITY IS LOST. TIME PERMITTING A SOFTWARE WORKAROUND COULD BE UTILIZED. IF LPD IS ENABLED A MONITOR WILL BE STARTED WHICH CAUSES 3 TO 4 PERCENT T LOSS.	EFFECT 1B. TOTAL LOSS OF LPD CAPABILITY AND/OR PARTIAL LOSS OF MIN IMP CAPABILITY. ACTION ISOLATE MIN IMP FAILURES PARTIALLY BY MODE CONTROL SWITCH MANAGEMENT, OR USE RATE COMMAND OR AUTO OR AGS FOR MANEUVERS. FOR LPD WORK-AROUND SEE NOTE. **
	2. "1" (OFF)	2A. FAILED OPEN 2½ DEGREE SWITCH IN ONE OF THE ACA'S.	2A. WITH APPROPRIATE ATTITUDE CONTROL SWITCH IN PULSE AND ACA DEFLECTED, CORRESPONDING ERR CMD = 0.	2A. LOSS OF MIN IMP AND POSSIBLY LPD CAPABILITY FOR ONE OF THE ACA'S FOR APPROPRIATE FAILED BIT.	EFFECT 2A. PARTIAL LOSS OF LPD AND/OR MIN IMP CAPABILITY FOR ONE ACA ACTION USE REMAINING ACA.**
		2B. MICRO-LOGIC CIRCUIT FAILURE IN LGC OR OPEN BETWEEN CONTACTS 1 AND 2 (FOR −) OR 13 AND 14 (FOR +) OF APPROPRIATE ATTITUDE CONTROL SWITCH (11S3, 4, 5) ON PANEL 13.	2B. THE OPPOSITE (+ OR −) PGNS MIN IMP CMD AVAILABLE AND BOTH + AND − AGS PULSE CMDS AVAILABLE IN AFFECTED AXIS.	2B. LOSS OF ONE (+ OR − IN ONE AXIS ONLY) PGNS MIN IMP CMD AND (IF BIT 1, 2, 5, OR 6) ONE LPD CMD.	2B. EFFECT PARTIAL LOSS OF LPD AND/OR MIN IMP CAPABILITY ACTION USE RATE COMMAND OR AUTO OR AGS FOR MANEUVERS.**

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 31 BIT 1 - 6 (CONT'D)		*2C. OPEN BETWEEN CONTACTS 1, 2, 3 AND 4 (FOR −) OR 13, 14, 15, AND 16 (FOR +) OF APPROPRIATE ATTITUDE CONTROL SW.	2C. THE OPPOSITE (+ OR −) PGNS MIN IMP CMD AVAILABLE AND THE OPPOSITE (+ OR −, BUT NOT BOTH) AGS PULSE CMD AVAILABLE IN AFFECTED AXIS.	2C. LOSS OF ONE (+ OR − IN ONE AXIS ONLY) PGNS MIN IMP CMD, AGS PULSE CMD, AND (IF BIT 1, 2, 5 OR 6) LPD CMD. FURTHER, ONLY ONE JET DIRECT CONTROL IS AVAILABLE IN CORRESPONDING DIRECTION (+ OR − BUT NOT BOTH).	EFFECT 2C PARTIAL LOSS OF LPD AND/OR PGNS MIN IMP AND AGS PULSE AND DIRECT CAPABILITY ACTION USE RATE COMMAND OR AUTO FOR MANEUVERS.**
		*2D. OPEN BETWEEN CONTACTS 5 AND 6 OF APPROPRIATE ATTITUDE CONTROL SW.	2D. NEITHER + OR − PGNS MIN IMP CMD AVAILABLE BUT BOTH + AND − AGS PULSE CMDS AVAILABLE IN AFFECTED AXIS.	2D. LOSS OF PGNS MIN IMP CONTROL AND LPD CAPABILITY (IF BITS 1, 2, 5 OR 6) IN ONE AXIS.	2D. EFFECT LOSS OF LPD AND/OR MIN IMP CAPABILITY IN ONE AXIS ACTION USE RATE COMMAND OR AUTO OR AGS FOR MANEUVERS.**
		*2E. OPEN BETWEEN CONTACTS 5, 6, 7, AND 8 OF APPROPRIATE ATTITUDE CONTROL SWITCH.	2E. NEITHER + OR − PGNS MIN IMP NOR AGS PULSE CMDS AVAILABLE IN AFFECTED AXIS.	2E. LOSS OF PGNS MIN IMP CONTROL AND LPD CAPABILITY (IF BITS 1, 2, 5, OR 6) AND AGS PULSE COMMANDS IN ONE AXIS. FURTHER ONLY ONE JET DIRECT CONTROL IS AVAILABLE IN AFFECTED AXIS (+ AND −).	2E. EFFECT LOSS OF LPD AND/OR PGNS MIN IMP AND AGS PULSE CAPABILITY AND PARTIAL LOSS OF DIRECT CAPABILITY IN ONE AXIS. ACTION USE AUTO OR RATE COMMAND FOR MANEUVERS.**
					**NOTE: A SOFTWARE WORK-AROUND IS AVAILABLE TO ENABLE REDESIGNATIONS, TIME PERMITTING, BY WRITING INTO THE E-MEMORY REGISTERS AZ1NCR1 AND/OR EL1NCR1 DIRECTLY VIA THE DSKY, OR BY USING THE STANDARD N69 UPDATE.

*CAPABILITY REMAINING MATRIX FOR FAILURES 2B, C, D, E

OPEN CONTACTS	MIN IMP	AGS PULSE	DIRECT
1, 2 (−)	+	+/−	2 JET +/−
13, 14 (+)	−	+/−	2 JET +/−
1, 2, 3, 4 (−)	+	+	2 JET +, 1 JET −
13,14,15,16 (+)	−	−	1 JET +, 2 JET −
5, 6		+/−	2 JET +/−
5, 6, 7, 8			1 JET +/−

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CHAN 31 BITS 7 - 12 TRANSLATION COMMANDS (PAGE 1 OF 3) PCN-9

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 31 BITS 7-12 TRANSLATION COMMANDS BIT 7 +X TRANS BIT 8 -X TRANS BIT 9 +Y TRANS BIT 10 -Y TRANS BIT 11 +Z TRANS BIT 12 -Z TRANS 0 = ON 1 = OFF	1. "0" (ON)* *NOTE: FAILED ON TRANSLATION COMMANDS WILL NOT AFFECT ATTITUDE CONTROL AS ROTATION TAKES PRECEDENCE IN DAP.	1A. SHORTED SW IN ONE OF THE TTCA'S.	1A. RCS JET DRIVERS AND TCP'S CORRESPONDING TO FAILED TRANSLATION COMMANDS. SEE TABLE 2. POSSIBLE GH1240, 41, 42 = ± 10V, AGS ± X, ± Y, ± Z TRANSLATION COMMANDS.	1A. DAP EXECUTES ERRONEOUS TRANSLATION COMMAND. THE TRANSLATION CAN BE STOPPED BY PLACING BOTH TTCA/TRANSL SWITCHES TO DISABLE. THE AFFECTED TTCA CAN BE DETERMINED BY ENABLING EACH TTCA SEPARATELY AND THEN LEAVING THAT ONE OFF. IF THE AGS TRANSLATION SW WAS NOT SHORTED ALSO (GH1240, 41, 42) THEN TTCA USE IN AGS COULD BE REGAINED BY TURNING THE DAP OFF AND RE-ENABLING AFFECTED TTCA.	1A. EFFECT UNWANTED TRANSLATION OCCURS ACTION ISOLATE APPROPRIATE TTCA VIA TTCA/TRANSL SW.
		1B. MICRO-LOGIC CIRCUIT FAILURE IN LGC.	1B. RCS JET DRIVERS AND TCP'S CORRESPONDING TO FAILED TRANSLATION COMMANDS GH1240, 41, 42 = 0. NO AGS TRANSLATION COMMANDS.	1B. DAP EXECUTES ERRONEOUS TRANSLATION COMMAND. THE TRANSLATION CAN BE STOPPED BY TURNING THE DAP OFF VIA MODE CONTROL SW OR SWITCHING TO AGS. TO MAKE THE PGNS USEABLE AGAIN, TWO JET PAIRS MUST BE ISOLATED IN THE LGC VIA THE LGC THRUSTER PAIR CMD SWITCHES OR TWO JETS VIA THE DSKY. REFERENCE TABLE 1. THIS WILL RESULT IN A PROGRAM CAUTION AND ALARM CODE 2001 OR 2002 EVERY DAP CYCLE AND THUS EFFECTIVE LOSS OF PROGRAM CAUTION AND ALARM CODE MONITORING.*	1B. EFFECT UNWANTED TRANSLATION OCCURS ACTION ISOLATE APPROPRIATE JETS VIA LGC THRUSTER PAIR CMD SWITCHES OR THE DSKY. REFERENCE TABLE 1 TO DETERMINE WHICH JETS TO ISOLATE AND TRANSLATION CAPABILITY LOST DUE TO ISOLATION. P-14
	2. "1" (OFF)	2A. OPEN SWITCH IN ONE OF THE TTCA'S.	2A. NO RCS JET DRIVERS AND TCP'S FOR CORRESPONDING TTCA DEFLECTION; POSSIBLE GH1240, 41, 42 = ± 10V, AGS ± X, ± Y, ± Z TRANSLATION COMMANDS.	2A. LOSS OF ONE TRANSLATION COMMAND FOR PGNS AND/OR AGS, DEPENDING ON WHETHER ONE OR BOTH CONTACTS HAVE FAILED.	2A. EFFECT PARTIAL LOSS OF TRANSLATION CAPABILITY FOR ONE TTCA. ACTION USE OTHER TTCA.
		2B. MICRO-LOGIC CIRCUIT FAILURE IN LGC.	2B. NO RCS JET DRIVERS AND TCP'S FOR CORRESPONDING TTCA DEFLECTION; GH1240, 41, 42 = ± 10V, AGS ±X, ±Y, ±Z TRANSLATION COMMAND CORRESPONDING TO TTCA DEFLECTION.	2B. LOSS OF ONE TRANSLATION COMMAND FOR PGNS, BUT NO EFFECT ON AGS TRANSLATION CAPABILITY. +X TRANSLATION CAN ALSO BE ACCOMPLISHED BY SETTING DAPBOOLS BIT 6 VIA THE DSKY AS THE BURN PROGRAMS DO. THUS NO LOSS OF AUTOMATIC ULLAGE FOR FAILURE OF +X TRANSLATION BIT.	2B. EFFECT PARTIAL LOSS OF PGNS TRANSLATION CAPABILITY ACTION PERFORM DESIRED TRANSLATION WITH AGS, OR +X TRANSLATION WITH +X TRANS BUTTON OR VIA THE DSKY.
		2C. OPEN BETWEEN CONTACTS 2 AND 3 IN TTCA/TRANSL SW (1S20, 22) ON PANEL 4.	2C. NO RCS JET DRIVERS AND TCP'S FOR CORRESPONDING TTCA DEFLECTION; GH1240, 41, 42 = ±10V, AGS ±X, ±Y, ±Z TRANSLATION COMMAND CORRESPONDING TO TTCA DEFLECTION.	2C. LOSS OF ALL PGNS TRANSLATION CAPABILITY WITH ONE TTCA DUE TO LOSS OF LGC COMMON VOLTAGE FOR ALL 6 TRANSLATION SWITCHES.	EFFECT 2C. TOTAL LOSS OF PGNS TRANSLATION CAPABILITY WITH ONE TTCA. P-14 ACTION USE OTHER TTCA

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LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 31 BITS 7-12 (CONT'D)	2. "1" (OFF) (CONT'D)	2D. FAILED OPEN ±X TRANS DISABLE CLUTCH	2D. NO RCS JET DRIVERS AND TCP'S FOR CORRESPONDING ±X TRANSLATION TTCA DEFLECTION; GH1240 = 0 NO AGS ±X TRANSLATION COMMAND	2D. LOSS OF ±X TRANSLATION IN PGNS AND AGS FOR ONE TTCA. *IF A BIT IS STUCK ON THEN TRANSLATION CAPABILITY VIA PGNS IN THE OTHER DIRECTION IS LOST FOR ± Y & ± Z. FOR ± X TRANS IF + X IS ON THEN - X IS LOST, IF -X IS ON THEN +X IS STILL AVAILABLE.	2D. EFFECT LOSS OF X TRANSLATION FOR ONE TTCA ACTION USE OTHER TTCA

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TABLE 1

PAIRS ISOLATED	MANEUVERS DISABLED									
	+X	-X	+Y	-Y	+Z	-Z	+U	-U	+V	-V
B1, A2	•		•		•		•			
B3, A4	•			•	•				•	
B3, A2	•				•		•		•	
A4, B1	⊙									
A1, B2		•	•			•				•
B2, A3		⊙								
A3, B4		•		•		•		•		
B4, A1		•				•		•		•
B1, B2			⊙				⊙			⊙
B1, B4			•			⊙				•
B2, B3			•		⊙		•			
A3, A4				⊙				⊙	⊙	
A3, A2				•	⊙				•	
A4, A1				•		⊙		•		

⊙ INDICATES BEST PAIR ISOLATION FOR ANY GIVEN MANEUVER

TABLE 2

CHAN 31 BITS 7 - 12 TRANSLATION COMMANDS (PAGE 3 OF 3) PCN-9

TRANSLATION JETS	JET DRIVERS	TCP
+Y		
PURE / TRANS B1L	GH1433V	GR5046X
PURE / TRANS B2L	GH1429V	GR5042X
A1F	GH1432V	GR5045X
B3A	GH1424V	GR5037X
B4F	GH1420V	GR5033X
A2A	GH1428V	GR5041X
-Y		
PURE / TRANS A3R	GH1425V	GR5038X
PURE / TRANS A4R	GH1421V	GR5034X
A1F	GH1432V	GR5045X
B3A	GH1424V	GR5037X
A2A	GH1428V	GR5041X
B4F	GH1420V	GR5033X
+Z		
PURE / TRANS B3A	GH1424V	GR5037X
PURE / TRANS A2A	GH1428V	GR5041X
A3R	GH1425V	GR5038X
B1L	GH1433V	GR5046X
A4R	GH1421V	GR5034X
B2L	GH1429V	GR5042X

TRANSLATION JETS	JET DRIVERS	TCP
-Z		
PURE / TRANS A1F	GH1432V	GR5045X
PURE / TRANS B4F	GH1420V	GR5033X
A3R	GH1425V	GR5038X
B1L	GH1433V	GR5046X
B2L	GH1429V	GR5042X
A4R	GH1421V	GR5034X
+X		
B1D	GH1431V	GR5044X
A2D	GH1427V	GR5040X
B3D	GH1423V	GR5036X
A4D	GH1419V	GR5032X
-X		
A1U	GH1430V	GR5043X
B2U	GH1426V	GR5039X
A3U	GH1422V	GR5035X
B4U	GH1418V	GR5031X

LM SYSTEMS FAILURE ANALYSIS

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 33 BIT 8 LR VEL DATA GOOD 0 = LR VEL DATA GOOD 1 = LR VEL DATA BAD	REF. GN7557X FAILURE ANALYSIS.				

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LM SYSTEMS FAILURE ANALYSIS

CHAN 33 BIT 9 LR RNG LO SCALE (PAGE 1 OF 1) PCN-9

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 33 BIT 9 LR RNG LO SCALE 1 = RNG HI SCALE 0 = RNG LO SCALE	1. "0" (RNG LO SCALE) WHEN ABOVE 2500 FT.	1.A. ALTITUDE MODE SWITCH FAILURE.	1.A. POSSIBLE LOSS OF LOCK ON DEPENDING ON ALTITUDE. CHAN 33 B5 = 1 (LR RNG BAD) GN7521 = 1 (LR RNG BAD) ALT LIGHT ON CHAN 33 B8 = 1 (LR VEL BAD) GN7551 = 1 (LR VEL BAD) VEL LIGHT ON.	1.A. THE ALTITUDE MODE SWITCH SWITCHES THE VELOCITY AND RANGE FREQUENCY TRACKER'S FILTERS TO LOW PASS WHICH TENDS TO FILTER OUT THE HIGH DOPPLER FREQUENCIES WHICH ARE PRESENT UNTIL MUCH OF THE FORWARD VELOCITY IS DISSIPATED. ALSO THE ALTIMETER TRANSMITTER MODULATION SWEEP RANGE IS LIMITED TO 12,000 FEET, THUS PREVENTING ALTITUDE LOCK ABOVE THAT ALTITUDE.	1.A. EFFECT LATE RR LOCK-ON. ACTION ATTEMPT TO RESET THE LO SCALE: LDG ANT - HOVER WAIT 10 SEC LDG ANT - DESC IF UNSUCCESSFUL CB(11) PGNS LR OPEN WAIT 4 SECONDS CB(11) PGNS LR - CLOSE
		1.B. LGC INPUT FAILURE.	1.B. ΔH EXCESSIVE AND NOT CONVERGING.	1.B. DATA INPUT TO THE LGC WILL BE IMPROPERLY SCALED. SCALING IS: >2500 FT 1.07746 FT/BIT < 2500 FT 5.3873 FT/BIT WHEN THE LGC RECEIVES AN INDICATION OF RANGE LO SCALE NOT SET, IT MULTIPLIES THE ALTITUDE DATA BY 5. TAPE METER ALTITUDE DATA WILL BE VALID.	1.B. EFFECT POSSIBILITY OF UPDATING STATE VECTOR WITH INCORRECTLY SCALED ALTITUDE DATA. NO VALID LR ALTITUDE DATA WILL BE AVAILABLE FOR STATE VECTOR PRIOR TO 2500 FEET. ACTION DO NOT INCORPORATE LR DATA UNTIL ΔH APPEARS REASONABLE. IF ENABLED, INHIBIT STATE VECTOR UPDATE V58E.
	2. "1" RNG HI SCALE WHEN BELOW 2500 FEET	2.A. ALTITUDE MODE SWITCH FAILS TO SWITCH TO LO SCALE.	2.A. NONE.	2.A. ALTITUDE DATA WOULD NOT BE AFFECTED ABOVE 2500 FEET AND WOULD SUFFER AN INACCURACY OF APPROXIMATELY 5% BELOW 2500 FEET. FREQUENCY TRACKER FILTERS WOULD SWITCH TO LOW BAND PASS BASED ON THE RECEIPT OF LOW DOPPLER DATA AND WOULD OPERATE NORMALLY.	2.A. EFFECT SLIGHT INACCURACY IN ALTITUDE DATA. ACTION NONE.
		2.B. LGC INPUT FAILURE.	2.B. NONE.	2.B. SAME AS ABOVE EXCEPT THE ALTITUDE MODE SWITCH WOULD SWITCH ALL BAND PASS FILTERS NOMINALLY BELOW 2500 FEET. DATA WILL BE SCALED INCORRECTLY. NEED A V58E TO INHIBIT STATE VECTOR UPDATES.	2.B. EFFECT INCORRECTLY SCALED DATA WILL UPDATE STATE VECTOR INCORRECTLY. P-14 ACTION INHIBIT STATE VECTOR UPDATES VIA V58E.

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T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 12 BIT 4 COARSE ALIGN ENABLE 1 = COARSE ALIGN ENABLE 0 = COARSE ALIGN NOT ENABLED	1. "1" (ENABLE) WITH ISS ERROR COUNTERS NOT ENABLED. (CHAN 12 BIT 6 = 0)	1. MICRO LOGIC FAILURE WITHIN THE LGC	GG2107V/37V/67V IG, MG, OG SERVO ERRORS WILL BE STATIC AT ZERO VOLTAGE. NOTE: DURING COARSE ALIGN AND CAGE THE SERVO ERROR IS A 800 HZ SIGNAL. THE SIGNAL CONDITIONER HAS A 3.2 KHZ REFERENCE, THEREFORE THE SERVO ERRORS ALTHOUGH HIGH WILL APPEAR ON TM AS NULL. LGC ACTUAL GIMBAL ANGLES WILL BE STATIC.	1. IMU IS LOST. ISS CDU READ COUNTERS ARE INHIBITED. THE COARSE ALIGN ENABLE WILL CAUSE THE COARSE ALIGN RELAY IN THE PSA TO BE ENERGIZED, THUS ROUTING COARSE ALIGN SIGNALS FROM THE ISS CDU'S TO THE ISS SERVO LOOP. SINCE THE ERROR COUNTERS ARE NOT ENABLED, NO COARSE ALIGN COMMANDS WILL BE INTRODUCED INTO THE SERVO LOOP. PRESENCE OF A COARSE ALIGN DISCRETE AND ABSENCE OF AN ERROR COUNTER ENABLE DISCRETE IN THE CDU CAUSES THE ISS CDU READ COUNTERS TO BE INHIBITED, THUS CAUSING THE LGC GIMBAL ANGLE COUNTERS TO BE STATIC. WITH STATIC CDU ACTUALS, THE DAP WILL EITHER FIRE CONTINUALLY IF THE S/C IS OUT OF THE DEADBAND OR IT WILL NOT FIRE AT ALL IF THE S/C IS WITHIN THE DEADBAND. NOTE: DUE TO AN INHIBITED READ COUNTER, A CHANGE IN S/C ATTITUDE (IF DETECTED BY THE IMU) WILL CAUSE AN ICDU FAIL (CH30 B12) AND AN ISS WARN (CH11 B1) WHEN THE DIFFERENCE BETWEEN THE READ COUNTER (Ψ) AND THE GIMBAL (Θ) ARE $>.7^{\circ}$ FINE ERROR.	1. EFFECT IMU LOST, DAP EITHER FIRING CONTINUALLY OR NOT AT ALL. ACTION SWITCH TO AGS FOR AUTO CONTROL OF S/C.
	2. "1" (ENABLE) WITH ISS ERROR COUNTER ENABLED (CH12 B6 = 1) ALSO WITH CAGE RELAY NOT ENERGIZED	2. MICRO-LOGIC FAILURE WITHIN THE LGC.	2. GG2107V/37/67 IG, MG, OG SERVO ERRORS WILL INDICATE HIGH ERRORS.	2. IMU IS LOST. ROLL, PITCH, YAW ATTIUTDE ERRORS WILL BE ROUTED TO SERVO LOOP. THIS WILL CAUSE THE GIMBALS TO BE DRIVEN SO THAT THE ERROR IS NULLED. THE DAP MAY FIRE TO COUNTER THE RATE AT WHICH THE GIMBALS ARE BEING DRIVEN.	2. EFFECT LOSS OF S/C ATTITUDE AND IMU. ACTION SWITCH TO AGS FOR AUTO CONTROL OF S/C.
	3. "0" (NOT ENABLED)	3. MICRO-LOGIC FAILURE WITHIN THE LGC	3. LGC DOWNLINK. IMU WILL NOT RESPOND TO V41.	3. LOSS OF IMU COARSE ALIGN OPERATIONS. STAB LOOP WILL BE LOCKED IN FINE ALIGN MODE. CAGE OPERATION IS POSSIBLE.	3. EFFECT LOSS OF IMU COARSE ALIGN OPERATION. ACTION ALIGN IMU VIA FINE ALIGN ROUTINE (V42). NOTE: THE Δ GYRO ANGLES MUST BE LIMITED SO AS NOT TO DRIVE THE MG INTO GIMBAL LOCK.

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LM SYSTEMS FAILURE ANALYSIS

CHAN 12 BIT 5 ZERO IMU CDU'S (PAGE 1 OF 1)

T/M NUMBER	FAILURE SYMPTOM	POSSIBLE CAUSE	FAILURE VERIFICATION METHOD	EQUIP/FUNCTION EFFECTS AND NOTES	TOTAL S/C EFFECT/ACTION
CHAN 12 BIT 5 ZERO IMU CDU'S 1 = CDU ZERO 0 = NO CDU ZERO	1. "1" (CDU ZERO)	1. MICRO-LOGIC FAILURE WITHIN THE LGC	1. IG, MG, OG CDU ACTUAL ANGLES IN THE LGC WILL BE ZERO. ISS CDU FAIL (CH30 B12 = 0) ISS WARN (CH11 B1 = 1)	1. LOSS OF ISS ANGLE INFORMATION TO THE LGC. DAP WILL ASSUME LARGE ATTITUDE ERRORS WHICH IT WILL FIRE TO CORRECT. COARSE ALIGN CAPABILITY WILL BE LOST. STATIC GIMBAL ANGLES OF ZERO DEGREES WILL BE SENT TO THE LGC AND THE AEA. THE ISS CDU ERROR COUNTERS CAN STILL BE USED TO DISPLAY ATTITUDE ERRORS.	1. EFFECT LOSS OF PGNS ATTITUDE CONTROL AND IMU. ACTION SWITCH TO AGS FOR ATTO ATTITUDE CONTROL. P-14 PCN-9
	2. "0" (NO CDU ZERO)	2. MICRO-LOGIC FAILURE WITHIN THE LGC	2. CHAN 12 BIT 5 WILL NOT RESPOND TO V40 N20 (ZERO ISS CDU'S) SHOULD BE A Δ BETWEEN CDU'S & RESOLVERS IF SPACECRAFT IF NOT AT 0, 0, 0 ATT.	2. LOSS OF CDU ZERO CAPABILITY. LOSS OF LGC KNOWLEDGE OF ATT REFERENCE. LGC WOULD READ 0, 0, 0 & THE RESOLVERS & READ COUNTERS WOULD READ THE ACTUAL ANGLES. THE CDU ANGLES DISPLAYED WOULD BE THE LGC'S KNOWLEDGE OF THE SPACECRAFT & SINCE THE READ COUNTER WOULD NEVER COUNT UP THEN THE LGC WOULD ASSUME THAT THE SPACECRAFT WAS AT 0, 0, 0. DAP WILL SEE LARGE ATT ERRORS & WILL FIRE JETS TO CORRECT IT.	2. EFFECT LOSS OF AGS INITIALIZATION CAPABILITY. AGS GUIDANCE MAY BE DEGRADED. DAP WILL FIRE JETS BECAUSE IT IS OUT OF DEADBAND. P-14 ACTION SWITCH TO AGS & FLY TO 0, 0, 0 THEN DO ANOTHER CDU ZERO TO COARSE ALIGN PGNS, THEN REALIGN.

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June 21, 1971

NOTE OF INTEREST: PGNS Automatic Control of GDA's for DPS Thirty Minute Burns

1. Certain modes of LOI aborts require the DPS to be burned at LOI ignition plus thirty minutes. At present, the only technique available in the Contingency Checklist for performing this burn is the manual AGS procedure using the TTCA's for controlling pitch and roll. Since the assumption for LOI aborts has always been that no LM failures exist or will occur during the burn, this single-point failure sensitive procedure has never been questioned. However, this assumption is not valid, and a need for another less sensitive procedure exists. Therefore, a procedure for the burn to be performed in PGNS with automatic control of the GDA's was developed.

2. In the current thirty minute activation listed in the Contingency Checklist, both PGNS and AGS are aligned to 0, 0, 0 at the burn attitude. The AGS is then configured for performing the burn, and the PGNS is set up for monitoring in P47. Changing this configuration to perform a PGNS burn, plus the addition of a few DSKY entries will allow a manual PGNS burn with automatic GDA attitude control. Thus, no manual TTCA control for pitch and roll is required.

3. Required checklist changes include monitoring the PGNS on the FDAI's vice the AGS, disabling U-V jets via a V65E, and changing the switch configuration for a PGNS-Auto burn. In addition, the following DSKY entries must be accomplished:

a. Set DV counter to "POSMAX" to allow the burn to be started manually at the crew's leisure without an ENG FAIL alarm when DV Monitor Routine is enabled:

V21 N01E
3515E
37777E

b. Set DV THRUST for GDA Trim allow to the docked constant of 12 cm/sec.

V21 N01E
1250E
14E

c. Start DV Monitor Routine:

V25 N07E
103E
100E
0E

d. Reset DRIFTBIT to cause DAP to compute offset accelerations for GDA Trimming:

V25 N07E
111E
200E
0E

Engine ignition and shutdown procedures remain as per the checklist. Also, selecting P00 after the burn clears all flags.

4. Burning with this technique has the following advantages:

a. PGNS automatically controls GDA's for roll and pitch stabilization (no TTCA manual control necessary).

b. RCS propellant saved, as only jets fired are for yaw control.

c. Horizontal jet failures no longer cause attitude control problems (horizontal jets are used by TTCA's for controlling pitch and roll in the manual AGS procedure).

d. GDA problems during the burn can be controlled by disabling the GDA's and using the TTCA's in PGNS.

e. Normal AGS TTCA Technique available for backup in case of PGNS failure. Thus, no alternate procedures to read-up during time critical situation.

5. Although this procedure has been run on the LMS and checked out on the FMES at GAC, the crew has already trained to the current LOI abort techniques and all LOI abort simulations have been completed. Therefore, the procedure will not be incorporated into the Apollo 15 Checklist, but will be available on the ground if required. Every effort will be made to include it in the Apollo 16 Checklist as the primary method of performing DPS thirty minute burns.

Larry W. Strimple

HAL: JEH

February 9, 1972

NOTE OF INTEREST: Planned Operation of the LM Descent Cooling Valve

The planned use of the LM descent cooling valve would allow glycol flow to the descent stage in normal fashion until late in the LM battery discharge cycle when flow would be terminated. This technique would allow the batteries to warm up near the end of their discharge and theoretically produce more power. Constraining this plan are the battery and ECA temperature limits. The purpose of this note of interest is to explain the method of determining the time of glycol flow termination which affords maximum temperature rise in the batteries without damaging them or the ECA's. The many factors that affect this time and their nominal values are listed below.

FACTOR	NORMAL VALUE
a. Battery Starting Temp	45°F internal
b. ECA Starting Temp	40°F internal
c. Battery Temp Rise Rate	3.4°F/hr*
d. ECA Temp Rise Rate	3.9°F/hr*
e. Battery Temp limit	100°F Nominal, 130°F Contingency
f. ECA Temp limit	132°F Flange
g. Total Battery Capacity	2075 Amp-hrs
h. Battery Management Plan	
i. Predicted Mission Current Profile	

*These temperature rise rates are actually exponential and can be used for approximations only.

The number of hours prior to battery depletion that glycol flow is terminated is based on a temperature constraint defined by either the battery or the ECA. A rough approximation of the earliest time the valve can be closed without violating any temp constraints may be obtained by inserting the parameters for each equipment in the following equation and taking the smallest generated number.

$$Tc = \frac{\text{Temp limit } ^\circ\text{F} - \text{Start Temp } ^\circ\text{F}}{\text{Temp rise rate } ^\circ\text{F/hr}}$$

In practice, these limiting numbers will be determined graphically by extrapolating actual test data. Results obtained from LMO 510-1903 "ECA/Battery

Control Relay Assembly No-Coolant Test-Quick Look Report" are listed below:

CASE	TIME TO REACH CONSTRAINT (Tc)
100°F Battery Constraint (Nominal)	16.2 hours
130°F Battery Constraint (Contingency)	24.5 hours
132°F ECA Constraint	23.5 hours

In order to relate the "Tc" to the GET, it is necessary to know the current profile and battery management plan both before and after the descent cooling valve is shut off. The battery management plan calls for 4 descent batteries to be on line for the last 15 hours of the lunar stay which allows for equal heat distribution. Ampere hours consumed relative to GET in conjunction with the following equation establish the time of glycol shut off.

$$\text{Amp-hours consumed at descent cooling valve cutoff } (AH_{C.O.}) = \text{Total Bat Capacity} - (\text{Avg amps for Tc} \cdot \text{Tc})$$

Knowing Tc to be 16.2 hours, the average current for the last 16.2 hours of descent battery operation was determined to be 23.1 amperes. Substituting in the equation gives:

$$AH_{C.O.} = 2075 - (23.1 \cdot 16.2) = 1701 \text{ ampere hours}$$

Since the planned Apollo 16 mission will use only 1665 ampere hours, it is obvious that the descent cooling valve is not required to be shut off in the nominal case. Should the 100°F battery constraint be raised to the contingency 130°F level, the ECA temperature constraint will become the limiting factor yielding an $AH_{C.O.}$ of 1532 ampere hours or approximately 4 hours prior to liftoff. Should one descent battery be lost, the $AH_{C.O.}$ would be 1286 ampere hours or approximately 16 hours prior to liftoff.

In summary, the descent cooling valve need not be operated for the nominal mission but should some contingency arise which may require additional battery capacity, the valve could be operated in accordance with the guidelines described in this note of interest.

William L. Peters

William L. Peters

FC43:WLPeters:drd:4576:2/11/72

JEH

Clark

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

REPLY TO ATTN OF: FC43 (72-49)

APR 14 1972

MEMORANDUM FOR RECORD

FROM: FC4/Chief, LM Systems Branch

SUBJECT: Electrical Power Management Procedures for Total Loss of One LM Descent Battery for Apollo 16

1. The total loss of one LM descent battery prior to its delivery of any energy could result in a reduction of lunar stay time unless positive action is taken. Several approaches to the problem, such as reduction in power consumption, may be taken in order to complete the nominal mission. The electrical energy budget for Apollo 16 is shown below:

	Ampere-hours
Mission Required	1642
TM unusable	43
Contingency revolution	63
Total required	1748
Total available (4 Bats)	1660
Excess capacity required	88

2. One method of obtaining the needed power to complete the nominal mission would be to adjust the predicted power usage after a period of time on the lunar surface based on real-time power usage. Past missions have demonstrated that premission predictions on power consumption have always been high--7.5%, 10.8%, 1.8%, and 8.9% on Apollo's 11, 12, 14, and 15, respectively. Experience on these missions has also shown that the error between predicted and actual current levels can be determined after one sleep and one EVA period. The problem with this approach is that by the time an adjusted profile can be generated, it is too late to manage the load profile.

3. Ascent electrical energy could be used to cover the contingency revolution on the surface with the realization that one ascent battery would be adequate for rendezvous and docking, but not for lunar impact. In this particular case, the descent batteries would be run to depletion before switchover to ascent power. The increase of ampere-hour capacity of the remaining four descent batteries will be attempted by closing the descent cooling valve during the latter hours of lunar stay time. The procedure for valve operation is covered in the current flight mission rules and an FC4 note of interest dated February 9, 1972, subject: Planned Operation of the LM Descent Cooling Valve.

4. The above methods of obtaining a nominal mission depend strongly on all the 3-sigma dispersions falling in the good direction. A more reliable method of obtaining the objective is to manage the electrical power profile. The electrical loads powered during activation and descent are all required and there are only two loads that may be eliminated or duty cycled during the lunar stay, the LGC standby power, and the inverter. The consequence of powering down the LGC completely is the stopping of the LGC clock. The CSM state vector can still be updated every 20 hours as planned and any emergency liftoff on PGNS is delayed only by the key strokes required to update the time. The LGC will be completely powered down at the nominal equipment power down time after touchdown. The inverter is kept powered up on the lunar surface to prevent S-band steerable antenna sag and subsequent loss of communications and telemetry. In order to develop a plan for inverter cycling several assumptions must be made.

a. The MARS 210' antenna is scheduled to cover all LM activity.

b. The Parks 210' antenna will be called up as required to extend the MARS antenna coverage.

c. The combination of a 210' antenna and a LM omni antenna is an acceptable LBR mode.

d. PLSS data relayed through the LM must be via the LM steerable. A test will be performed to determine if the S-band steerable antenna does sag as advertized when AC power is removed. If it does not sag, the inverter will only be powered when the crew is not in the LM and the steerable is required. The crewman in the cockpit can always correct a sagging antenna by powering the inverter. If the antenna does sag, the inverter must be powered whenever the steerable is required. The steerable will be required when there is no 210' antenna coverage or PLSS data is to be relayed through the LM. Reference figure 1 for the planned inverter duty cycle. Power saved is as follows:

	Ampere-hours saved with no antenna sag	Ampere-hours saved with antenna sag
LGC standby OFF	58	58
Inverter Cycle	76.5	23.1
Total	135.5	81.1

5. In summary, if the LM descent battery is lost prior to its use, the nominal Apollo 16 mission can be performed with some fairly minimal equipment duty-cycling. At power down on the lunar surface, the LGC will be completely powered down and the inverter will begin a regulated duty cycle. The mission will be continued in this mode until the

adjusted predicted profile produces an adequate ampere-hour pad at which time the inverter will return to a continuous duty cycle, and the LGC will be powered up, updated, then returned to normal checklist standby mode. The descent cooling valve will be closed according to the mission rules and the referenced note of interest on that subject. If all the 3-sigma dispersions work against the above plan, the difference of the excess capacity required (88 AH) and the ampere-hours saved in the worst case (81.1 AH) can be obtained from the ascent batteries without any loss in capability in normal or contingency modes.

6. Any questions or comments concerning this memorandum should be directed to W. L. Peters, extension 4576.

James E. Hannigan
Enclosure
FC43:WDReeves/RDLegler:dh:4576:4-13-72

cc:
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CG5/T. W. Holloway
DD3/J. F. Zieglschmid
EG7/J. Hanaway
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FM2/F. V. Bennett
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FM7/D. Nelson
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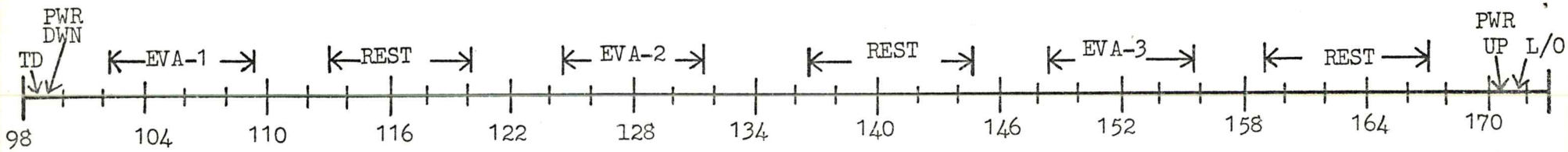
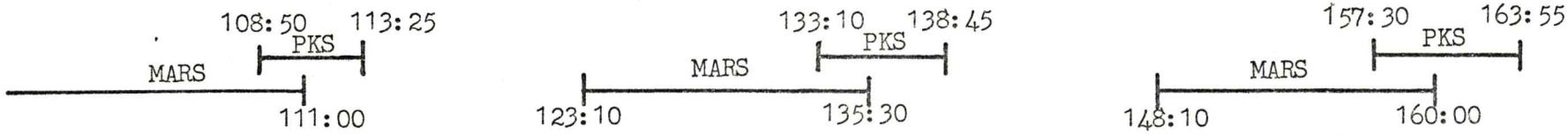
NOMINAL TIMELINE

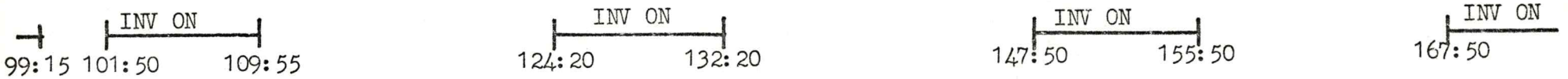


GET

210' ANTENNA COVERAGE IF MARS AND PKS ARE BOTH CALLED UP:



a. INVERTER OFF WHEN CREW IN CABIN, NO STEERABLE SAG:



b. INVERTER OFF DURING 210' ANT COVERAGE DURING PERIODS OF NO PLSS DATA:

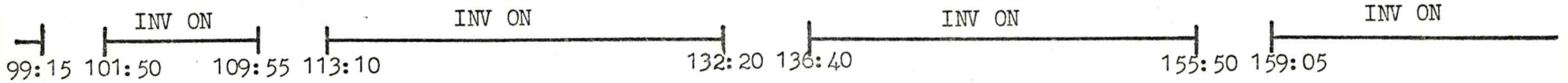
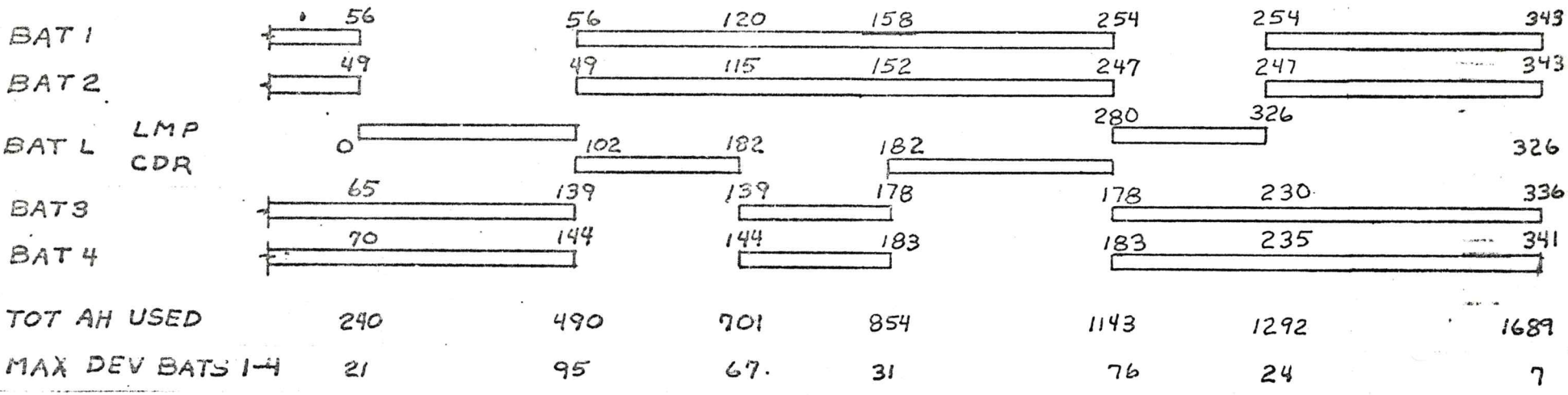


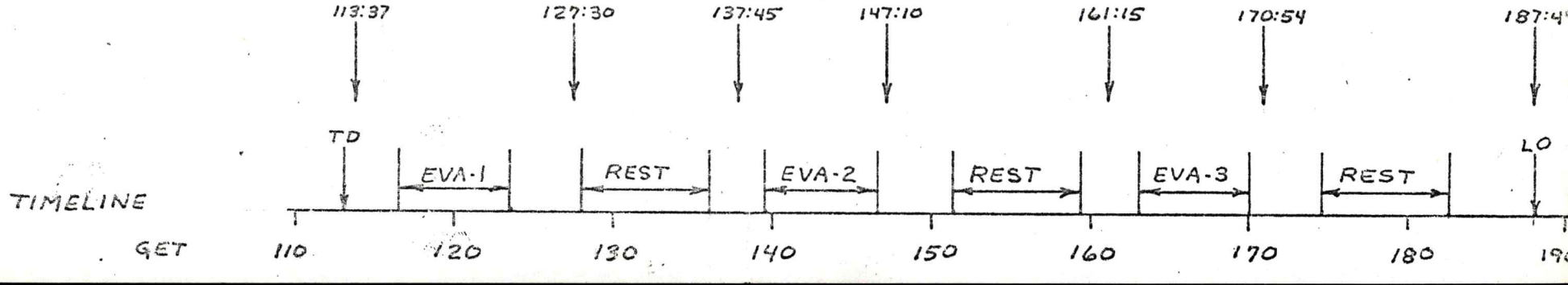
FIGURE 1

LM-12 BATTERY MANAGEMENT PLAN
OCTOBER 2, 1972

LUNAR SURFACE STAY TIME = 75HR
THREE EVA 7-7-7 HR

BASED ON SEENA





[redacted]EN: [redacted] PYRO BATTERY VO[redacted]GE READOUT AT PL[redacted]+4 MI[redacted]

<37.1 VOLTS WITH ALL PRIOR READINGS GOOD

SINGLE POINT FAILURE POSSIBILITIES:

A) VOLTAGE > 35.3 VOLTS – SINGLE CELL SHORT OR EXTERNAL LOAD ON BATTERY. IF ONE CELL, VOLTAGE WILL STEADY AT 35.3 VOLTS WHEN CELL DEPLETED; IF LOAD ON WHOLE BATTERY, VOLTAGE WILL DECAY TO 30.5-31.5 VOLTS UNTIL BATTERY IS DEPLETED THEN DECAY FURTHER.

B) VOLTAGE <35.3 VOLTS – LOAD ON WHOLE BATTERY; VOLTAGE WILL DECAY TO 30.5-31.5 VOLTS WHERE IT WILL REMAIN UNTIL BATTERY DEPLETED.

RECOMMENDATIONS:

A) FOR CASE A) ABOVE, A <u>CONTINUE MISSION</u> DECISION PERMITS BATTERY VOLTAGE TO SETTLE OUT AT 35.3 VOLTS WHICH IS A CONTINUE MISSION CASE UNDER PRESENT WRITTEN RULES. RISK IS THAT VOLTAGE WILL CONTINUE TO DECAY AND MAY REQUIRE MANUAL STAGING BEFORE A $\overline{T_3}$ LIFTOFF

B) <u>ABORT</u> SINCE NO POSSIBILITY OF A FRUITFUL LUNAR STAY IS FELT TO EXIST

ATTACHMENT 9-II

FLIGHT CONTROLLERS' CHECKLIST

Note: The Flight Controllers' checklist includes MCC, SSR's, CCATS, RTCC, RTACF.

ITEM		ACCOMPLISHED
A.	Discontinue Commanding	_____
	Discontinue commanding as directed by the Flight Director.	
B.	Mission Contingency or Possible Mission Contingency	_____
	If a contingency appears imminent or has occurred, insure that logs are current. Monitor equipment closely and restrict all voice communication to only that which is necessary.	
C.	Log Mission Contingency Time	_____
	Log in GMT and GET the time a mission contingency was declared.	
D.	RTCC-Log a Time for Delog (O&P)	_____
	The O&P will request RTCC to log a time for a delog of display.	
E.	Terminate all Telephone Calls	_____
	Terminate all telephone calls unless specifically authorized by current directives.	
F.	Hardcopy D/TV Displays	_____
	(Only if a display has a bearing on the mission contingency.)	
G.	Crew Recovery	_____
	Any possible efforts toward crew recovery will receive the highest priority. Further checklist items will not restrict crew recovery efforts.	

Benson DB
Dauch RR
Hal

NOV 2 1972

Note of Interest - Apollo 17 Rendezvous Techniques When VHF Comm Has Gone Away

During an Ascent sim debriefing on October 26, 1972, White flight volunteered me to write this note of limited interest. It concerns how we will handle terminal phase, most of which occurs on the lunar backside, when we have lost VHF comm between the vehicles. The plan we came up with is straightforward, with the variables being tied to malfunctions in the rendezvous sensors.

Since the only insurmountable problem created by failed VHF comm occurs when we lose STDN coverage, the plan is constant until LOS. In all cases we still want the LM to execute TPI. So as long as the RR is working, it's ops normal with MSFN Relay providing for intra-vehicle communications. When the RR is not working, the only sure solutions are the CMC (w/Sextant tracking) and the ground. Depending on the nature of the VHF problem, normal or intermittent VHF ranging could provide a marginal solution in the AGS and an even more marginal solution from the charts. The CMC solution has the highest priority, followed by the ground, and then whatever else is available. The main consideration here is how to get the best solution to the LM. The most accurate technique would be for the ground to take the final comp CMC vectors, compute a LM - active TPI solution with those vectors, and have that solution voiced to the LM. An acceptable backup to this technique is for the CMP to voice his solution (which is computed CSM - active) to the LM where the LM crew will apply the correction biases (-1 fps in ΔVx, +2 fps in ΔVz). This would provide an acceptable solution, but does insure small midcourse corrections since these biases are rounded off numbers and assume circular orbits.

If there is an agreement between the CMC and ground solutions, no other comparison efforts need be made. If they disagree, then we can obtain another ground solution, using 10 to 15 minutes of post-insertion tracking, which should be adequate to break the tie. (The prime ground solution is based on the final Powered Flight Processor vector from Ascent.) The marginal solutions available from intermittent VHF ranging could also be used. Confidence in the CMC solution will be related to the observed vector behavior during the mark schedule. Things like N49's, number of marks, solution behavior, etc., all provide valuable clues about the validity of that solution. The point is that even when the only two "good" solutions disagree we can usually deduce which one is better.

The post-TPI plan will vary depending on sensor availability. As long as the RR is working, we will continue with a LM - active rendezvous. Although the CSM won't have good solutions after the LM executes a MCC, by P76'ing his own computed MCC (with the sign changes) onto his LM vector, he should stay in the ball park. Regardless, if they get off a good TPI and the RR keeps working, we're home free.

For the no RR case, after the LM executes TPI we will revert to CSM - active terminal phase midcourses and braking. The rationale for this decision is

obvious, since the LM has no way of computing good midcourses or the actual closing rates during braking. The CSM on the other hand will be good navigation (Sextant) for the midcourses and will have the best relative state estimates at braking. The actual braking techniques vary with the available tools. If VHF ranging is available, things are essentially nominal for the CMP. If not, his N54 range rate is the best data available, and should be adequate to get him close when coupled with his visual techniques. The LGC and AGS states, which probably were not that great to start with, have not incorporated the midcourses the CSM executed, and would be too inaccurate to solve the close-in rendezvous problem.

In summary, we have arrived at three basic ground rules for this remote VHF comm failure case:

a. The LM will remain active for TPI, regardless of the status of the rendezvous sensors. If the RR is unavailable, the ground is prime for computation of the TPI solution, with the CMC vectors having the highest priority.

b. As long as the RR is available, the LM will remain active for MCC computation, execution, and braking.

c. If the RR is unavailable, the CSM will go active for MCC computation, execution, and braking.

If there are any questions or comments you can contact Bill Stoval, extension 2538.

Bill Stoval

Bill Stoval

ELP JCB

FC54/WMS:phc:10/31/72:2538

Neibauer

LM-EPS Minimum Requirements Resulting
From Meeting of all LM-EPS Personnel
On 1 December 1972

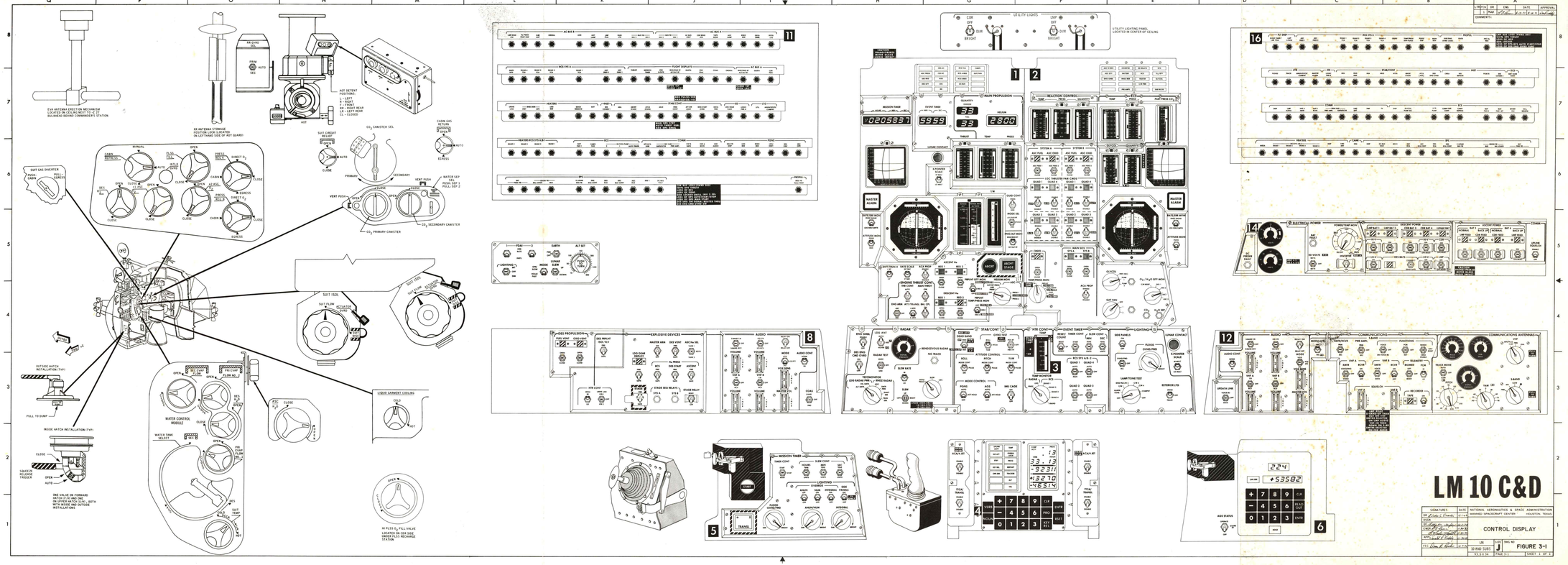
A. From undocking to touchdown, the minimum requirements are based on the time to complete a landing, a 24.5 hour lunar stay with 1 EVA (4 hrs), a 2 hr surface contingency, ascent, and a 2 hr rendezvous through crew transfer, a 2 hour orbital contingency, and redundant ascent EPS sources for the rendezvous.

The time to complete the landing and the 24.5 hr lunar stay may be supported by any combination of descent and ascent consumables. In addition, each ascent battery must contain the consumables required for liftoff and a 2.0 hr rendezvous through crew transfer. The 2 hr orbital contingency is considered to be satisfied by the redundancy requirement.

B. For the remainder of the lunar stay, the minimum descent and ascent stage requirements are based on the consumables required for the scheduled activities during each defined phase, a 2 hour surface reserve and a 2 hour orbital reserve. If the descent batteries are depleted on the surface and the IM power requirements are being supplied solely by the ascent stage, each ascent battery must have sufficient energy remaining at the scheduled liftoff for a 2 hour surface reserve, a liftoff, and a 2 hour rendezvous. If the descent batteries have sufficient energy to complete the lunar stay, each ascent battery must have sufficient energy remaining for preconditioning, a liftoff, a 2 hr rendezvous, and crew transfer. The sur-

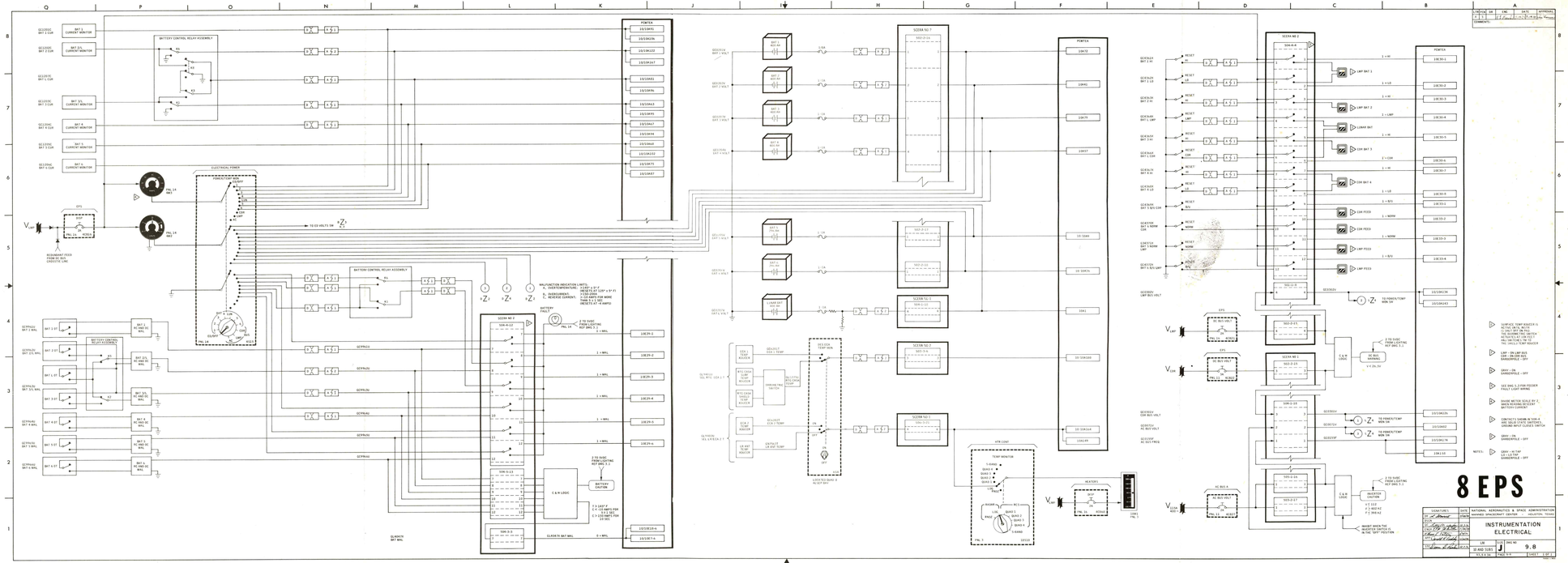
face reserve may be satisfied by either the ascent or descent batteries while the orbital contingency is satisfied by the redundancy requirement.

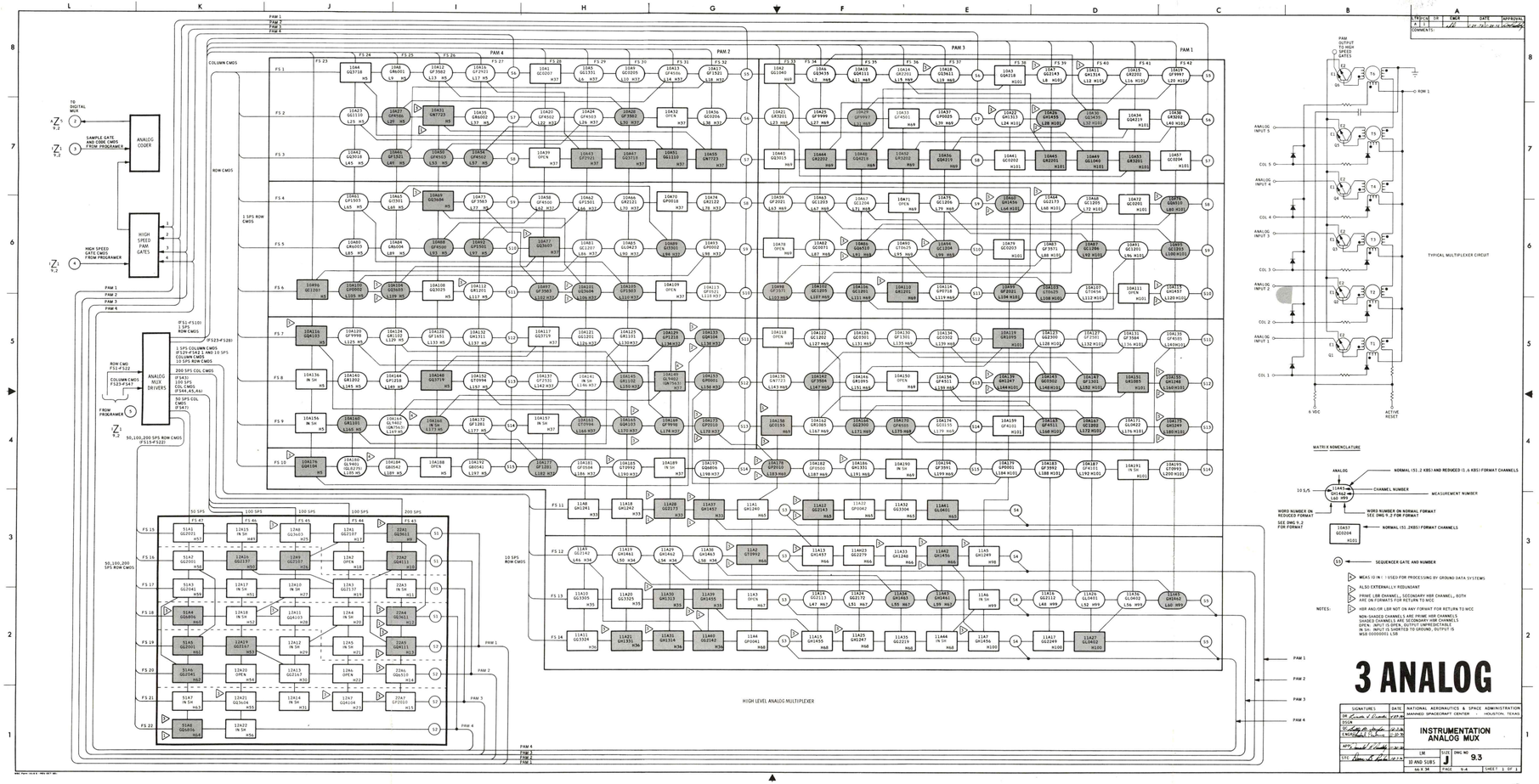
C. For the rendezvous the minimum requirement is the energy required to complete a LM active rendezvous through crew transfer. Should these minimum requirements be violated the LM will be powered down while the CSM becomes the active vehicle. However, the LM will be powered up to perform braking with sufficient consumables being retained for this purpose.



LM 10 C&D

SIGNATURES	DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION
CDR		MANNED SPACECRAFT CENTER — HOUSTON, TEXAS
LMP		
CONT		CONTROL DISPLAY
FLT DIR		LM: 10 AND SUBS — DWG NO
		93.3.4.14 — PAGE 3-1 — FIGURE 3-1 — SHEET 1 OF 1


8 EPS
INSTRUMENTATION
ELECTRICAL
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS
LM
10 AND 11/81
9.8
SHEET 1 OF 4
PANEL 9.8
BATTERY CONTROL RELAY ASSEMBLY
ELECTRICAL POWER
BATTERY CHARGER
BATTERY CONTROL
C & W LOGIC
INVERTER CONTROL
EPS
AC BUS A
AC BUS B
HTR CONT
HEATERS
TEMP MONITOR
SCERA NO 2
SCERA NO 1
SCERA NO 7
SCERA NO 8
SCERA NO 5
SCERA NO 6
PCM/TEA
SURFACE TEMP SOURCE (1 OF 2 SHOWN) TO ONE OF THE FOLLOWING ACTUATES AT 178 ±11°F RISING AND 168 ±11°F FALLING
LMP - ON LAMP BUS ON - ON ZERO BUS BARBERPOLE - OFF
GRAY - ON BARBERPOLE - OFF
SEE SHT. 2.3 FOR FEEDER FAULT LIGHT WIRING
GAGE METER SCALE BY 2 WHEN READING DESCENT BATTERY CURRENT
CONTACT 5 SHOWN IN SHT. 4 ARE SOLID STATE SWITCHES, GROUND INPUT CLOSES SWITCH
GRAY - ON BARBERPOLE - OFF
GRAY - HI TAP ON LIGHTING BARBERPOLE - OFF
NOTE 5:
WHEN INVERTER SWITCH IS IN THE "OFF" POSITION


3 ANALOG
INSTRUMENTATION
ANALOG MUX
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER - HOUSTON, TEXAS
HIGH LEVEL ANALOG MULTIPLEXER
TYPICAL MULTIPLEXER CIRCUIT
MATRIX NOMENCLATURE
NOTES:
ANALOG CODER
HIGH SPEED FAM GATES
ANALOG MUX DRIVERS
SAMPLE GATE AND CODE CMDS FROM PROGRAMMER
HIGH SPEED GATE CMDS FROM PROGRAMMER
TO DIGITAL MUX
COLUMN CMOS
ROW CMOS
1 SPS ROW CMOS
10 SPS ROW CMOS
50,100,200 SPS ROW CMOS
200 SPS COL CMOS
50 SPS COL CMOS
6 VDC
ACTIVE RESET
PAM 1
PAM 2
PAM 3
PAM 4

2 DIGITAL

PCMTEA DIGITAL MULTIPLEXER

CHANNEL/FRAME WORD CROSS REFERENCE

LBR (REVISED 3, 4 KBS) FORMAT

HBR (51.2 KBS) FORMAT

CHANNEL ASSIGNMENT FOR HBR (51.2) FRAME

CHANNEL ASSIGNMENT FOR LBR (51.2) FRAME

PCMTEA DATA TRANSFER BUFFERS

PCMTEA FORMATTER

PCMTEA TIMING REFERENCE

PCMTEA OUTPUT REGISTER

PCMTEA DATA TRANSFER BUFFERS

PCMTEA PROGRAMMER

DIODE GROUP 241

DIODE GROUP 242

DIODE GROUP 243

DIODE GROUP 244

DIODE GROUP 245

DIODE GROUP 246

DIODE GROUP 247

DIODE GROUP 248

DIODE GROUP 249

DIODE GROUP 250

DIODE GROUP

TABLE 9-V. - TELEMETRY VERSUS PAM AND SEQUENCER GATES

PAM 1						PAM 2						PAM 3						PAM 4					
SEQ	CHANNEL (S)	ELEC/ COMM	ECS	GNC	PROP	SEQ	CHANNEL (S)	ELEC/ COMM	ECS	GNC	PROP	SEQ	CHANNEL(S)	ELEC/ COMM	ECS	GNC	PROP	SEQ	CHANNEL (S)	ELEC/ COMM	ECS	GNC	PROP
1	22A1 (22A4) (EX) 12A1 (12A9) 12A8 (EX) 12A15 51A1			GG2107 GG2021	GQ3611 GQ3603	1	22A2 (22A5) (EX) 12A2 12A9 (12A1) 12A16 (12A3) 51A2 (51A5)	--	--	-- GG2107 GG2137 GG2001	GQ4111 --	1	22A3 12A3 (12A16) 12A10 (12A18) 12A17 51A3 (51A6)			GG2137 GG2041		1	22A4 (22A1) (EX) 12A4 (12A12) 12A11 12A18 (12A10) 51A4 (EX)				GQ3611 GQ4103 GQ6806
2	22A5 (22A2) (EX) 12A5 12A12 (12A4) 12A19 (12A13) 51A5 (51A2)			 GG2167 GG2001	GQ4111	2	22A6 (EX) 12A6 12A13 (12A19) 12A20 51A6 (51A3)	-- --	-- --	-- GG2167 -- GG2041	GQ6510 -- --	2	22A7 (EX) 12A7 12A14 12A21 51A7				GP2010 GQ4104 GQ3604	2	12A22 51A8(EX)				GQ6806
3	11A1 11A8 11A18 11A28 (EX) 11A37 (11A13) (EX)			GH1240 GH1241 GH1242 GG2173 GH1457		3	11A2 (EX) 11A9 (11A40) 11A19 (11A43) 11A29 (11A45) 11A38 (11A34)	GT0992		*GG2142 *GH1461 *GH1462 *GH1463		3	11A3 11A10 11A20 11A30 (EX) 11A39 (11A15) (EX)	--	--	-- GG3305 GG3325 GH1313 GH1455	--	3	11A4 11A11 11A21 (EX) 11A31 (EX) 11A40 (11A9)			GG3324 GH1331 GH1314 *GG2142	GP0041
4	11A12 (EX) 11A22 11A32 11A41 (11A26)	GL0401		GG2143 GG3304	GP0042	4	11A5 (EX) 11A13 (11A37) (EX) 11A23 11A33 (EX) 11A42 (11A7) (EX)			GH1249 GH1457 GG2279 GH1248 GH1456		4	11A6 (11A44) 11A14 11A24 11A34 (11A38) 11A43 (11A19)			*GG2113 *GG2172 *GH1463 *GH1461		4	11A7 (11A42) (EX) 11A15 (11A39) (EX) 11A25 (EX) 11A35 11A44 (11A6)			GH1456 GH1455 GH1247 GG2219	
5	10A3 (10A48) 10A7 (EX) 10A11 (EX) 10A15 (10A44) 10A19 (10A29)		 *GF9997	*GG2143 *GH1314	GQ4218 *GR2202	5	10A1 10A5 10A9 10A13 (10A27) 10A17 (10A46)	GC0207 *GC0205	-- *GF4586 *GF1521	-- *GG1331	--	5	11A16 11A26 (11A41) 11A36 (11A27) 11A45 (11A29)	*GL0401 *GL0402		*GG2112 ^GH1462		5	11A17 11A27 (11A36)	GL0402		GG2249	
6	10A22 (EX) 10A26 (EX) 10A30 (10A6) 10A34 (10A56) 10A38 (10A52)			*GH1313 *GH1455	 *GQ3435 GQ4219 *GR3202	6	10A20 (10A54) 10A24 (10A50) 10A28 (10A12) 10A32 10A36	 -- *GC0206	*GF4502 *GF4503 *GF3582 --	 --	 --	6	10A2 (10A49) 10A6 (10A30) 10A10 (EX) 10A14 (10A45) 10A18 (EX)			GG1040	 *GQ3435 *GQ4111 *GR2201 *GQ3611	6	10A4 (10A47) 10A8 10A12 (10A28) 10A16 (10A43)	 --	 *GF3582 *GF2921	 --	GQ3718 *GR6001 --
7	10A41 10A45 (10A14) 10A49 (10A2) 10A53 (10A21) 10A57	GC0202 GC0204		GG1040	GR2201 GR3201	7	10A39 10A43 (10A16) 10A47 (10A4) 10A51 (10A23) 10A55 (10A31) (EX)	--	-- GF2921	-- GG1110 GN7723	-- GQ3718	7	10A21 (10A53) 10A25 10A29 (10A19) 10A33 10A37		*GF9999 *GF9997 GF4501		*GR3201 *GP0025	7	10A23 (10A51) 10A27 (10A13) 10A31 (10A55) (EX) 10A35		*GF4586	*GG1110 GN7723	 *GR6002
8	10A60 (EX) 10A64 (EX) 10A68 (10A102) 10A72 10A76 (10A86) (EX)	*GC1205 GC0201		*GH1456 *GG2173	 *GQ6510	8	10A58 (10A88) 10A62 (10A92) 10A66 10A70 10A74		*GF4500		*GP1501 *GR2121 GP0018 *GR2122	8	10A40 10A44 (10A15) 10A48 (10A3) 10A52 (10A38) 10A56 (10A34)				GQ3015 GR2202 GQ4218 GR3202 GQ4219	8	10A42 10A46 (10A17) 10A50 (10A24) 10A54 (10A20)		*GF1521 *GF4503 *GF4502		*GQ3018
9	10A79 10A83 (10A98) 10A87 (10A75) 10A91 (10A106) 10A95 (10A63)	GC0203 *GC1206 *GC1201 *GC1203	*GF3571			9	10A77 (10A104) (EX) 10A81 (10AH96) 10A85 10A89 (10A65) 10A93 (10A100)	*GC1207 GL0423		*GI3301	GQ3603 *GP0002	9	10A59 (10A99) 10A63 (10A95) 10A67 (10A94) 10A71 10A75 (10A87)	*GC1203 *GC1204 -- *GC1206	*GF2021 --	 --	 --	9	10A61 (10A105) 10A65 (10A89) 10A69 (10A101) (EX) 10A73 (10A97)		 *GF3583	*GI3301	*GP1503 GQ3604
10	10A99 (10A59) 10A103 (10A90) 10A107 10A111 10A115 (EX)	GT0454 --	*GF2021 --	 *GH1457	 --	10	10A97 (10A73) 10A101 (10A69) (EX) 10A105 (10A61) 10A109 10A113	 --	*GF3583 -- *GF0521	 --	*GQ3604 *GP1503 --	10	10A78 10A82 10A86 (10A76) (EX) 10A90 (10A103) 10A94 (10A67)	-- *GC0071 *GC1204	-- GT0626	--	*GQ6510	10	10A80 10A84 10A88 (10A58) 10A92 (10A62)		 *GF4500		*GR6003 *GR6004 *GP1501
11	10A119 (10A146) 10A123 (10A166) 10A127 10A131 (10A142) 10A135 (10A170)		*GF2581 *GF3584 *GF4585	*GG2300	GR1095	11	10A117 (10A148) 10A121 10A125 (10A160) 10A129 (10A144) 10A133 (10A176) (EX)			*GG1201	GQ3719 *GR1101 *GP1218 *GQ4104	11	10A98 (10A83) 10A102 (10A68) 10A106 (10A91) 10A110 10A114	*GC1205 ^GC1201	*GF3571		 GR1201 *GP0718	11	10A96 (10A81) 10A100 (10A93) 10A104 (10A77) (EX) 10A108 10A112 (EX)	GC1207			*GP0002 *GQ3603 GQ3025 *GR1201
12	10A139 (EX) 10A143 (10A134) 10A147 (10A130) 10A151 (10A162) 10A155 (EX)	*GC0302	*GF1301	*GH1247 *GH1248	 GR1085	12	10A137 10A141 (10A168) 10A145 (10A124) 10A149 (10A164) 10A153 (10A179)	GL9402	*GF2531 *GF4101	(GN7563)[1]	*GR1102 *GP0001	12	10A118 10A122 (10A167) 10A126 (EX) 10A130 (10A147) 10A134 (10A143)	-- *GC1202 *GC0301 *GC0302	-- *GF1301	--	--	12	10A116 (10A165) (EX) 10A120 (10A169) 10A124 (10A145) 10A128 10A132		*GF9998 *GF1651	^GH1311	GQ4103 *GR1102
13	10A159 (EX) 10A163 (10A154) 10A167 (10A122) 10A171 10A175 (EX)	-- *GC1202 *GL0422	GF4101 *GF4511	-- *GH1249	-- --	13	10A157 10A161 (10A152) 10A165 (10A116) (EX) 10A169 (10A120) 10A173 (10A178) (EX)	-- *GT0994	-- *GF9998	-- --	-- *GQ4103 *GP2010	13	10A138 (EX) 10A142 (10A131) 10A146 (10A119) 10A150 10A154 (10A163)	 --	*GF3584 -- *GF4511	*GN7723 --	*GR1095 --	13	10A136 10A140 10A144 (10A129) 10A148 (10A117) 10A152 (10A161)	-- *GT0994	--	--	-- *GR1202 *GP1218 GQ3719
14	10A179 (10A153) 10A183 10A187 (EX) 10A191 10A195	 *GT0993	*GF3592 *GF4101		*GP0001	14	10A177 (10A172) 10A181 10A185 (EX) 10A189 10A193 (EX)	*GT0992	*GF1281 *GF0584		 *GQ6806	14	10A158 10A162 (10A151) 10A166 (10A123) 10A170 (10A135) 10A174 (EX)	GC0155 *GC0155	 *GF4585	*GG2300	*GR1085	14	10A156 10A160 (10A125) 10A164 (10A149) 10A168 (10A141) 10A172 (10A177)	-- *GL9402	-- *GF4101 *GF1281	-- ^GN7563[1]	-- *GR1101
												15	10A178 (10A173) (EX) 10A182 10A186 (EX) 10A190 10A194	--	*GF0500 -- *GF3591	*GH1331 --	^GP2010 --	15	10A176 (10A133) (EX) 10A180 10A184 10A188 10A192	*GL9401 -- -- --	(*GL8275[1] ^GB0542 -- *GB0541	-- -- --	GQ4104 -- -- --

* LBR
( ) INTERNAL REDUNDANT CHANNEL
(EX) EXTERNAL REDUNDANT CHANNEL

[1]. MEAS ID IN ( ) USED FOR PROCESSING BY GROUND DATA SYSTEMS

LETTER	ENG	DATE	APPROVAL
A, PCN-1		12-12-72	

TABLE 9-VI.- LM VEHICLE TM CONVERSION

BINARY	DEC EQV	VOLTS	MILLI-VOLTS	% FS	OCTAL
00000000	0	*	*	*	0
00000001	1	0.000	0.00	0.00	1
00000010	2	0.020	0.08	0.40	2
00000011	3	0.040	0.16	0.79	3
00000100	4	0.059	0.24	1.19	4
00000101	5	0.079	0.32	1.58	5
00000110	6	0.099	0.40	1.98	6
00000111	7	0.119	0.47	2.38	7
00001000	8	0.138	0.55	2.77	10
00001001	9	0.158	0.63	3.16	11
00001010	10	0.178	0.71	3.56	12
00001011	11	0.198	0.79	3.96	13
00001100	12	0.217	0.87	4.34	14
00001101	13	0.237	0.95	4.74	15
00001110	14	0.257	1.03	5.14	16
00001111	15	0.277	1.11	5.54	17
00010000	16	0.296	1.19	5.92	20
00010001	17	0.316	1.27	6.32	21
00010010	18	0.336	1.34	6.72	22
00010011	19	0.356	1.42	7.12	23
00010100	20	0.376	1.50	7.52	24
00010101	21	0.395	1.58	7.90	25
00010110	22	0.415	1.66	8.30	26
00010111	23	0.435	1.74	8.70	27
00011000	24	0.455	1.82	9.10	30
00011001	25	0.474	1.90	9.48	31
00011010	26	0.494	1.98	9.88	32
00011011	27	0.514	2.06	10.28	33
00011100	28	0.534	2.13	10.68	34
00011101	29	0.553	2.21	11.06	35
00011110	30	0.573	2.29	11.46	36
00011111	31	0.593	2.37	11.86	37
00100000	32	0.613	2.45	12.16	40
00100001	33	0.632	2.53	12.64	41
00100010	34	0.652	2.61	13.04	42
00100011	35	0.672	2.69	13.44	43
00100100	36	0.692	2.77	13.84	44
00100101	37	0.711	2.85	14.22	45
00100110	38	0.731	2.93	14.62	46
00100111	39	0.751	3.00	15.02	47
00101000	40	0.771	3.08	15.42	50
00101001	41	0.791	3.16	15.82	51
00101010	42	0.810	3.24	16.20	52
00101011	43	0.830	3.32	16.60	53
00101100	44	0.850	3.40	17.00	54
00101101	45	0.870	3.48	17.40	55
00101110	46	0.890	3.56	17.80	56
00101111	47	0.909	3.64	18.18	57
00110000	48	0.929	3.72	18.58	60
00110001	49	0.949	3.79	18.98	61
00110010	50	0.968	3.87	19.36	62
00110011	51	0.988	3.95	19.76	63
00110100	52	1.008	4.03	20.16	64
00110101	53	1.028	4.11	20.56	65
00110110	54	1.047	4.19	20.94	66
00110111	55	1.067	4.27	21.34	67
00111000	56	1.087	4.35	21.74	70
00111001	57	1.107	4.43	22.14	71
00111010	58	1.127	4.51	22.54	72
00111011	59	1.146	4.59	22.92	73
00111100	60	1.166	4.66	23.32	74
00111101	61	1.186	4.74	23.72	75
00111110	62	1.206	4.82	24.12	76
00111111	63	1.225	4.90	24.50	77

BINARY	DEC EQV	VOLTS	MILLI-VOLTS	% FS	OCTAL
01000000	64	1.245	4.98	24.90	100
01000001	65	1.265	5.06	25.30	101
01000010	66	1.285	5.14	25.70	102
01000011	67	1.304	5.22	26.08	103
01000100	68	1.324	5.30	26.48	104
01000101	69	1.344	5.38	26.88	105
01000110	70	1.364	5.45	27.28	106
01000111	71	1.383	5.53	27.76	107
01001000	72	1.403	5.61	28.06	110
01001001	73	1.423	5.69	28.46	111
01001010	74	1.443	5.77	28.86	112
01001011	75	1.463	5.85	29.26	113
01001100	76	1.482	5.93	29.64	114
01001101	77	1.502	6.01	30.04	115
01001110	78	1.522	5.09	30.44	116
01001111	79	1.542	6.17	30.84	117
01010000	80	1.561	6.25	31.22	120
01010001	81	1.581	6.32	31.62	121
01010010	82	1.601	6.40	32.02	122
01010011	83	1.621	6.48	32.42	123
01010100	84	1.640	6.56	32.80	124
01010101	85	1.660	6.64	33.20	125
01010110	86	1.680	6.72	33.60	126
01010111	87	1.700	6.80	34.00	127
01011000	88	1.719	6.88	34.38	130
01011001	89	1.739	6.96	34.78	131
01011010	90	1.759	7.04	35.18	132
01011011	91	1.779	7.12	35.58	133
01011100	92	1.798	7.19	35.96	134
01011101	93	1.818	7.27	36.36	135
01011110	94	1.838	7.35	36.76	136
01011111	95	1.858	7.43	37.16	137
01100000	96	1.878	7.51	37.56	140
01100001	97	1.897	7.59	37.94	141
01100010	98	1.917	7.66	38.34	142
01100011	99	1.937	7.75	38.74	143
01100100	100	1.957	7.83	39.14	144
01100101	101	1.976	7.91	39.52	145
01100110	102	1.996	7.98	39.92	146
01100111	103	2.016	8.06	40.32	147
01101000	104	2.036	8.14	40.72	150
01101001	105	2.055	8.22	41.10	151
01101010	106	2.075	8.30	41.50	152
01101011	107	2.095	8.38	41.90	153
01101100	108	2.115	8.46	42.30	154
01101101	109	2.134	8.54	42.68	155
01101110	110	2.154	8.62	43.08	156
01101111	111	2.174	8.70	43.48	157
01110000	112	2.194	8.78	43.88	160
01110001	113	2.214	8.85	44.28	161
01110010	114	2.233	8.93	44.66	162
01110011	115	2.253	9.01	45.06	163
01110100	116	2.273	9.09	45.46	164
01110101	117	2.293	9.17	45.86	165
01110110	118	2.312	9.25	46.24	166
01110111	119	2.332	9.33	46.64	167
01111000	120	2.352	9.41	47.04	170
01111001	121	2.372	9.49	47.44	171
01111010	122	2.391	9.57	47.82	172
01111011	123	2.411	9.64	48.22	173
01111100	124	2.431	9.72	48.62	174
01111101	125	2.451	9.80	49.02	175
01111110	126	2.470	9.88	49.40	176
01111111	127	2.490	9.96	49.80	177

BINARY	DEC EQV	VOLTS	MILLI-VOLTS	% FS	OCTAL
10000000	128	2.510	10.04	50.20	200
10000001	129	2.530	10.12	50.60	201
10000010	130	2.549	10.20	50.98	202
10000011	131	2.569	10.28	51.38	203
10000100	132	2.589	10.36	51.78	204
10000101	133	2.609	10.44	52.18	205
10000110	134	2.628	10.51	52.56	206
10000111	135	2.648	10.59	52.96	207
10001000	136	2.668	10.67	53.36	210
10001001	137	2.688	10.75	53.76	211
10001010	138	2.708	10.83	54.16	212
10001011	139	2.727	10.91	54.54	213
10001100	140	2.747	10.99	54.94	214
10001101	141	2.767	11.07	55.34	215
10001110	142	2.787	11.15	55.74	216
10001111	143	2.806	11.23	56.12	217
10010000	144	2.826	11.30	56.52	220
10010001	145	2.846	11.38	56.92	221
10010010	146	2.866	11.46	57.32	222
10010011	147	2.885	11.54	57.70	223
10010100	148	2.905	11.62	58.10	224
10010101	149	2.925	11.70	58.50	225
10010110	150	2.945	11.78	58.90	226
10010111	151	2.965	11.86	59.30	227
10011000	152	2.984	11.94	59.68	230
10011001	153	3.004	12.02	60.80	231
10011010	154	3.024	12.10	60.48	232
10011011	155	3.044	12.17	60.88	233
10011100	156	3.063	12.25	61.26	234
10011101	157	3.083	12.33	61.66	235
10011110	158	3.103	12.41	62.06	236
10011111	159	3.123	12.49	62.46	237
10100000	160	3.142	12.57	62.84	240
10100001	161	3.162	12.65	63.24	241
10100010	162	3.182	12.73	63.64	242
10100011	163	3.202	12.81	64.04	243
10100100	164	3.221	12.89	64.42	244
10100101	165	3.241	12.96	64.82	245
10100110	166	3.261	13.04	65.22	246
10100111	167	3.281	13.12	65.62	247
10101000	168	3.300	13.20	66.00	250
10101001	169	3.320	13.28	66.40	251
10101010	170	3.340	13.36	66.80	252
10101011	171	3.360	13.44	67.20	253
10101100	172	3.380	13.52	67.60	254
10101101	173	3.399	13.60	67.98	255
10101110	174	3.419	13.68	68.38	256
10101111	175	3.439	13.76	68.78	257
10110000	176	3.459	13.83	69.18	260
10110001	177	3.478	13.91	69.56	261
10110010	178	3.498	13.99	69.96	262
10110011	179	3.518	14.07	70.36	263
10110100	180	3.538	14.15	70.76	264
10110101	181	3.557	14.23	71.14	265
10110110	182	3.577	14.31	71.54	266
10110111	183	3.597	14.39	71.94	267
10111000	184	3.617	14.47	72.34	270
10111001	185	3.636	14.55	72.72	271
10111010	186	3.656	14.62	73.12	272
10111011	187	3.676	14.70	73.52	273
10111100	188	3.696	14.78	73.92	274
10111101	189	3.715	14.86	74.30	275
10111110	190	3.735	14.94	74.70	276
10111111	191	3.755	15.02	75.10	277

BINARY	DEC EQV	VOLTS	MILLI-VOLTS	% FS	OCTAL
11000000	192	3.775	15.10	75.50	300
11000001	193	3.795	15.18	75.90	301
11000010	194	3.814	15.26	76.28	302
11000011	195	3.834	15.34	76.68	303
11000100	196	3.854	15.42	77.08	304
11000101	197	3.875	15.49	77.48	305
11000110	198	3.893	15.57	77.86	306
11000111	199	3.913	15.65	78.26	307
11001000	200	3.933	15.73	78.66	310
11001001	201	3.953	15.81	79.06	311
11001010	202	3.972	15.89	79.44	312
11001011	203	3.992	15.97	79.84	313
11001100	204	4.012	16.05	80.24	314
11001101	205	4.032	16.13	80.64	315
11001110	206	4.051	16.21	81.02	316
11001111	207	4.071	16.28	81.42	317
11010000	208	4.091	16.36	81.82	320
11010001	209	4.111	16.44	82.22	321
11010010	210	4.131	16.52	82.62	322
11010011	211	4.150	16.60	83.00	323
11010100	212	4.170	16.68	83.40	324
11010101	213	4.190	16.76	83.80	325
11010110	214	4.210	16.84	84.20	326
11010111	215	4.229	16.92	84.58	327
11011000	216	4.249	17.00	84.98	330
11011001	217	4.269	17.08	85.38	331
11011010	218	4.289	17.15	85.78	332
11011011	219	4.308	17.23	86.16	333
11011100	220	4.328	17.31	86.56	334
11011101	221	4.348	17.39	86.96	335
11011110	222	4.368	17.47	87.36	336
11011111	223	4.387	17.55	87.74	337
11100000	224	4.407	17.63	88.14	340
11100001	225	4.427	17.71	88.54	341
11100010	226	4.447	17.79	88.94	342
11100011	227	4.466	17.87	89.32	343
11100100	228	4.486	17.94	89.72	344
11100101	229	4.506	18.02	90.12	345
11100110	230	4.526	18.10	90.52	346
11100111	231	4.546	18.18	90.92	347
11101000	232	4.565	18.26	91.30	350
11101001	233	4.585	18.34	91.70	351
11101010	234	4.605	18.42	92.10	352
11101011	235	4.625	18.50	92.50	353
11101100	236	4.644	18.58	92.88	354
11101101	237	4.664	18.66	93.28	355
11101110	238	4.684	18.74	93.68	356
11101111	239	4.704	18.81	94.08	357
11110000	240	4.723	18.89	94.46	360
11110001	241	4.743	18.97	94.86	361
11110010	242	4.763	19.05	95.26	362
11110011	243	4.783	19.13	95.66	363
11110100	244	4.802	19.21	96.04	364
11110101	245	4.822	19.29	96.44	365
11110110	246	4.842	19.37	96.84	366
11110111	247	4.862	19.45	97.24	367
11111000	248	4.882	19.53	97.74	370
11111001	249	4.901	19.60	98.02	371
11111010	250	4.921	19.68	98.42	372
11111011	251	4.941	19.76	98.82	373
11111100	252	4.961	19.84	99.22	374
11111101	253	4.980	19.92	99.60	375
11111110	254	5.000	20.00	100.00	376
11111111	255	***	***	***	377

*LESS THAN 0.00 VOLTS (0.00 MILLIVOLTS) UNDERSCALE.

***GREATER THAN 5.000 VOLTS (20.0 MILLIVOLTS) OVERSCALE.

LETTER	ENG	DATE	APPROVAL
A		11/30/70	

TABLE 9-IV. - SIGNAL CONDITIONING MEASUREMENT ASSIGNMENTS

SCERA 1

SCERA LOCATION AND TYPE	ELEC/COMM	ECS	GNC	PROP	MEASUREMENT FIELD TITLES	C&W	PCM	DISP
LOC-1 GSE CHECKOUT								
LOC-2 SIGNAL ISOLATION DISCRETE BUFFER 504-2	GY0050X		GH1426V GH1427V GH1428V GH1429V GH1430V GH1431V GH1433V GH1432V		JD B2U OUTPUT JD A2D OUTPUT JD A2A OUTPUT JD B2L OUTPUT JD A1J OUTPUT JD B1D OUTPUT JD B1L OUTPUT JD A1F OUTPUT ABORT CMD OPEN	X X X X X X X X X X	X X X X X X X X X X	
LOC-3 SIGNAL ISOLATING DISCRETE BUFFER 504-2			GH1603X GH1230X GH1348X GH1893X	GR5041X GR5042X GR5043X GR5044X GR5045X GR5046X	MIN DEADBAND APS ARM RCS TCP A2A RCS TCP B2L RCS TCP A1U RCS TCP B1D RCS TCP A1F RCS TCP B1L DPS ARM X TRANS OVRD	X X X X X X X	X X X X X X X X X X	
LOC-4 SIGNAL ISOLATING DISCRETE BUFFER 504-2		GI3232X GH1418V GH1420V GH1419V GH1421V GH1422V GH1423V GH1424V GH1425V			TEST MODE FAIL OPEN JD B4U OUTPUT JD B4F OUTPUT JD A4D OUTPUT JD A4R OUTPUT JD A3U OUTPUT JD B3D OUTPUT JD B3A OUTPUT JD A3R OUTPUT	X X X X X X X X X X	X X X X X X X X	
LOC-5 SIGNAL ISOLATING ANALOG BUFFER 504-1	GT0994V	GF1301P GF1521P GF9999U			SUIT PRESS CO_2 PP SEL H_2O SEP RT S-BAND RCVR AGC	1 1 1 1	X X X X	X
1. MEASUREMENT NOT SIGNAL CONDITIONED IN SCERA								
LOC-6 SIGNAL ISOLATING ANALOG BUFFER 504-1				GR1101P GR1102P GR1201P GR1202P	RCS A HE PRESS RCS B HE PRESS RCS A REG PRESS RCS B REG PRESS	1 1 1 1	X X X X	X X X X
1. MEASUREMENT NOT SIGNAL CONDITIONED IN SCERA								
LOC-7 SIGNAL ISOLATING ANALOG BUFFER 504-1	GY0703U	GF3582P GF3583P GF4500P			ASC 1 O_2 P ASC 2 O_2 P DES 3 H_2O P SEL ED BAT V	1 1 1	X X X	X X X
1. MEASUREMENT NOT SIGNAL CONDITIONED IN SCERA								
LOC-8 SIGNAL ISOLATING ANALOG BUFFER 504-1		GF4502P GF4503P		GP0025P GP0001P	ASC 1 H_2O P ASC 2 H_2O P APS HE REG P APS HE 1 PRESS	1 1 1 1	X X X X	X X X
1. MEASUREMENT NOT SIGNAL CONDITIONED IN SCERA								
LOC-9 RESISTANCE TO DC CONVERTER 506-3			GQ3718T GQ3719T GP0718T GP1218T		DPS 1 FU T DPS 2 FU T APS FUEL TEMP APS OX TEMP		X X X X	X X X X
LOC-10 RESISTANCE TO DC CONVERTER 506-3		GF9998U GI3301T	GQ4218T GQ4219T		SEL GLYCOL T ASA TEMP DPS 1 OX T DPS 2 OX T	X	X X X X	X X X
LOC-11 SIGNAL ISOLATING DISCRETE BUFFER 504-2			GR5031X GR5032X GR5033X GR5034X GR5035X GR5036X GR5037X GR5038X GR5039X GR5040X		RCS TCP B4U RCS TCP A4D RCS TCP B4F RCS TCP A4R RCS TCP A3U RCS TCP B3D RCS TCP B3A RCS TCP A3R RCS TCP B2U RCS TCP A2U	X X X X X X X X X X	X X X X X X X X X X	

SCERA LOCATION AND TYPE	ELEC/COMM	ECS	GNC	PROP	MEASUREMENT FIELD TITLES	C&W	PCM	DISP
LOC-12 SIGNAL ISOLATING DISCRETE BUFFER 504-4	GY0201X GY0202X				GR9609U GR9610U GR9641U GR9642U GP0318X GP0320X GR9609U GR9610U	X X X X	 X X X X X X X X	 X X X X X X X X
LOC-13 SIGNAL ISOLATING DISCRETE BUFFER 504-4	GM5000U				GR9661U GR9662U GR9663U GR9664U GR9665U GR9666U GR9667U GR9668U GR9631U GR9632U GR9613U		X X X X X X X X X X X X	X X X X X X X X X X X X
LOC-14 SIGNAL ISOLATING DISCRETE BUFFER 504-5	GY0231X GY0232X GY0201X GY0202X				GR9661U GR9662U GR9663U GR9664U GR9665U GR9666U GR9667U GR9668U

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE DWG/FIG	REFERENCE ZONE
GB0541T	MESA TEMP 1	1L	4-15	2-6	20 200 DEG F	3.9	.710				13-1	B-6
GB0542T	MESA TEMP 2	1L	4-15	2-6	20 200 DEG F	3.9	.710				13-1	B-6
GC0071V	AC BUS VOLTS	1L	3-10	1-18/1-17	0 125 VRMS	1.59	.494	C	63 126 VAC	2.9	5.4	C-3
GC0155F	AC BUS FREQ	1-1L	3-14	1-18/1-16	380 420 HZ	.68	.158	C			5.2	C-3
GC0201V	BAT 1 VOLTS	1	1-8	2-16	0 40 VDC	.45	.158		20 40 VDC	.9	5.2	S-5
GC0202V	BAT 2 VOLTS	1	1-7	2-16	0 40 VDC	.45	.158		20 40 VDC	.9	5.2	G-4
GC0203V	BAT 3 VOLTS	1	1-9	2-16	0 40 VDC	.45	.158		20 40 VDC	.9	5.2	G-4
GC0204V	BAT 4 VOLTS	1	1-7	2-16	0 40 VDC	.45	.158		20 40 VDC	.9	5.2	S-4
GC0205V	BAT 5 VOLTS	1L	2-5	2-17	0 40 VDC	.45	.158		20 40 VDC	.9	5.3	H-4
GC0206V	BAT 6 VOLTS	1L	2-6	2-18	0 40 VDC	.45	.158		20 40 VDC	.9	5.3	R-4
GC0207V	BAT L VOLTS	1	2-5	1-18	0 40 VDC	.51	.158		20 40 VDC	.9	5.2	G-4
GC0301V	CDR BUS V	1L	3-12	1-18/1-15	0 40 VDC	.51	.158	W	20 40 VDC	.9	5.3	G-3
GC0302V	LMP BUS V	1L-1L	3-12/1-12	2-8/2-15	0 40 VDC	.60	.158	W	20 40 VDC	1.0	5.3	G-3
GC1201C	BAT 1 CUR	1L-1L	1-9/3-11		0 60 AMPS	.95	.237		0 60 AMP	1.5	5.2	S-5
GC1202C	BAT 2 CUR	1L-1L	3-12/1-13		0 60 AMPS	.95	.237		0 60 AMP	1.5	5.2	F-4
GC1203C	BAT 3 CUR	1L-1L	3-9/1-9		0 60 AMPS	.95	.237		0 60 AMP	1.5	5.2	F-4
GC1204C	BAT 4 CUR	1L-1L	3-9/3-10		0 60 AMPS	.95	.237		0 60 AMP	1.5	5.2	S-5
GC1205C	BAT 5 CUR	1L-1L	1-8/3-11		0 120 AMPS	1.9	.474		0 120 AMP	3.0	5.3	N-5
GC1206C	BAT 6 CUR	1L-1L	3-9/1-9		0 120 AMPS	1.9	.474		0 120 AMP	3.0	5.3	R-4
GC1207C	BAT L CR	1-1L	2-9/4-11		0 60 AMPS	.95	.237		0 60 AMP	1.5	5.2	F-4
GC4361X	BAT 1 HI	1	10E30-2A1	2-4			HI		FLAG		5.2	S-5
GC4362X	BAT 1 LO	1	10E30-2A1	2-4			LO		FLAG		5.2	S-5
GC4363X	BAT 2 HI	1	10E30-2A1	2-4			HI		FLAG		5.2	F-7
GC4364X	BAT L LMP	1	10E30-2A1	2-4			LMP		FLAG		5.2	G-6
GC4365X	BAT 3 HI	1	10E30-2A1	2-4			HI		FLAG		5.2	F-5
GC4366X	BAT L CDR	1	10E30-2A1	2-4			CDR		FLAG		5.2	F-6
GC4367X	BAT 4 HI	1	10E30-2A1	2-4			HI		FLAG		5.2	S-5
GC4368X	BAT 4 LO	1	10E30-2A1	2-4			LO		FLAG		5.2	S-5
GC4369X	BAT 5 CDR B	1	10E33-3A1	2-4			B/U		FLAG		5.3	P-4
GC4370X	BAT 6 CDR N	1	10E33-3A1	2-4			NORM		FLAG		5.3	Q-4
GC4371X	BAT 5 LMP N	1	10E33-3A1	2-4			NORM		FLAG		5.3	O-4
GC4372X	BAT 6 LMP B	1	10E33-3A1	2-4			B/U		FLAG		5.3	Q-4
GC4391X	DEADFACE OPEN								FLAG			
GC4411X	BUS FAULT								COMP CAUT			
GC9961U	BAT 1 MAL	1	10E29-2A1	2-12/2-13			MAL	C			5.2	S-5
GC9962U	BAT 2/L MAL	1	10E29-2A1	2-12/2-13			MAL	C			5.2	F-5
GC9963U	BAT 3/L MAL	1	10E29-2A1	2-12/2-13			MAL	C			5.2	F-4
GC9964U	BAT 4 MAL	1	10E29-2A1	2-12/2-13			MAL	C			5.2	S-5
GC9965U	BAT 5 MAL	1	10E29-2A1	2-12/2-13			MAL	C			5.3	G-4
GC9966U	BAT 6 MAL	1	10E29-2A1	2-12/2-13			MAL	C			5.3	G-5

A

[a] S/S AND LBR (SAMPLES/SECOND AND LOW BIT RATE)
Example: 1L, ONE S/S AND ON LBR
1-1L, REDUNDANT ONE S/S WITH ONE LOCATION ON LBR
1L-1L, REDUNDANT ONE S/S WITH BOTH LOCATIONS ON LBR

[b] PAM AND SEQ/GT AND DIODE (PAM AND SEQUENCER GATE FOR ANALOG PARAMETERS/GATE AND DIODE FOR BILEVEL PARAMETERS)

[c] 1 PCM CNT (ENGINEERING WEIGHT OF ONE PCM COUNT)

LETTER	ENG	DATE		APPROVAL
A	Herschel Pickering	4-30-71	4-30-71	Donald K. Slayton

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Continued

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE DWG	REFERENCE ZONE
GF0500P	DES 2 H_2O P	1L	3-15		0 60 PSIA	1.18	.237		0 100 PCT	2.8	6.2	Q-9
GF0521T	DES 2 H_2O T	1L	2-10	2-21	20 200 DEG F	1.5	.710				6.2	S-9
GF0584P	DES 2 O_2 P	1L	2-14		0 3000 PSIA	63.6	11.9		0 100 PCT	2.9	6.1	S-4
GF1083X	SUIT FAN 1 MAL	1L-1L	10E5-5A1	2-3			FAIL	C			6.1	F-4
GF1084X	SUIT FAN 2 MAL	1L-1L	10E5-5A1	2-3			FAIL	W			6.1	F-4
GF1087X	SEL FAN FAIL								COMP CAUT		6.1	F-3
GF1201X	CDR SUIT DISC	1L-1L	10E3-3A1	2-5			DISC				6.1	J-7
GF1202X	LMP SUIT DISC	1L-1L	10E3-3A1	2-5			DISC				6.1	J-4
GF1211X	SUIT RLF CLSD	1L-1L	10E5-5A1	2-5			CLSD				6.1	H-7
GF1212X	SUIT RLF OPEN	1L-1L	10E5-5A1	2-5			OPEN				6.1	H-7
GF1221X	SUIT DIV EGR	1L-1L	10E5-5A1	2-5			EGR				6.1	G-6
GF1231X	CABIN RET EGR	1L-1L	10E4-4A1	2-5			CLSD				6.1	E-7
GF1232X	CABIN RET OPEN	1L-1L	10E4-4A1	2-5			OPEN				6.1	E-7
GF1241X	SEC CO_2 SEL	1L-1L	10E5-5A1	2-5			SEC				6.1	D-4
GF1281T	SUIT TEMP	1L-1L	4-14/2-14	1-21	20 120 DEG F	1.75	.395		40 100 DEG	1.6	6.1	M-7
GF1301P	SUIT PRESS	1L-1L	3-12/1-12	1-5	0 10 PPSIA	.26	.040	W	0 10 PSI	.33	6.1	G-8
GF1521P	CO_2 PP	1L-1L	2-5/4-8	1-5	0 30 MMHg	3.00	.118	C			6.1	K-5
GF1522P	CO_2 PP								0 30 MMHg		6.1	K-6
GF1651T	CABIN TEMP	1L	4-12	1-21	20 120 DEG F	2.77	.395		40 100 DEG	2.0	6.1	L-7
GF2021P	PRI GLY PMP ΔP	1L-1L	3-9/1-10		0 50 PSID	1.28	.198				6.2	J-8
GF2531T	W/B GLY IN T	1L	2-12	2-20	20 120 DEG F	2.77	.395				6.2	M-1
GF2581T	W/B GLY OUT T	1L	1-11	2-20	20 120 DEG F	2.77	.395				6.2	O-1
GF2681T	PRI GLY PUMP IN T								20 120 DEG		6.2	M-3
GF2921P	SEC GLY PRESS	1-1L	4-6/2-7		0 60 PSIA	1.12	.237		0 60 PSI	1.9	6.2	H-4
GF2935X	GLY PUMP FAIL			2-13			FAIL	C			6.2	L-7
GF2936X	GLY PUMP SW/O	1L-1L	10E4-4A1	2-12			FAIL		COMP CAUT		6.2	H-6
GF3071X	DMD REG A CLSD	1L-1L	10E4-4A1	2-5			CLSD				6.1	M-4
GF3073X	DMD REG B CLSD	1L-1L	10E4-4A1	2-5			CLSD				6.1	N-4
GF3571P	CABIN PRESS	1L-1L	1-9/3-11		0 10 PSIA	.26	.040		0 10 PSI	.32	6.1	F-8
GF3572X	REPR ELEC OPEN	1L-1L	10E3-3A1	2-3			OPEN	W			6.1	N-4
GF3582P	ASC 1 O_2 P	1L-1L	4-6/2-6	1-7	0 1000 PSIA	19.6	3.95	C	0 100 PCT	2.8	6.1	Q-6
GF3583P	ASC 2 O_2 P	1L-1L	4-9/2-10	1-7	0 1000 PSIA	19.6	3.95	C	0 100 PCT	2.8	6.1	R-4
GF3584P	DES 1 O_2 P	1L-1L	1-11/3-13	2-8	0 3000 PSIA	63.6	11.9	C	0 100 PCT	2.9	6.1	R-4
GF3591P	U/H RLF PRESS	1L	3-15		0 25 PSIA	.47	.099				6.1	C-3
GF3592P	F/H RLF PRESS	1L	1-14		0 25 PSIA	.47	.099				6.1	D-2
GF4101P	PRI H_2O REG ΔP	1-1L	1-14/1-13		0 2 PSID	.06	.008				6.2	P-6
GF4500P	DES 1 H_2O P	1L-1L	2-8/4-10	1-7	0 60 PSIA	1.18	.237		0 100 PCT	2.8	6.2	Q-9
GF4501P	DES H_2O PRESS	1	3-7		0 25 PSIA		.099				6.2	R-7
GF4502P	ASC 1 H_2O P	1L-1L	2-6/4-8	1-8	0 60 PSIA	1.18	.237		0 100 PCT	2.8	6.2	P-9
GF4503P	ASC 2 H_2O P	1L-1L	2-6/4-8	1-8	0 60 PSIA	1.18	.237		0 100 PCT	2.8	6.2	Q-9
GF4511T	PRI W/B H_2O T	1L-1L	3-13/1-13	2-6	20 160 DEG F	3.32	.554				6.2	N-2
GF4585T	ASC 1 H_2O T	1L-1L	1-11/3-14	2-21	-200 200 DEG F	6.86	1.59				6.2	Q-8
GF4586T	ASC 2 H_2O T	1L-1L	2-5/4-7	2-21	-200 200 DEG F	6.86	1.59				6.2	Q-8
GF9986U	SEL GLY LO LVL	1L-1L	10E3-3A1	2-3				C			6.2	M-5
GF9993U	CO_2 COMP CAUT								COMP CAUT		6.3	L-2

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Continued

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE DWG	REFERENCE ZONE
GF9997U	SEL GLY PMP P	1L-1L	1-5/3-7		0 60 PSIA	1.12	.237		0 60 PSI	1.9	6.2	K-5
GF9998U	SEL GLYCOL T	1L-1L	4-12/2-13	1-10	20 120 DEG F	2.77	.395		20 80 DEG	3.2	6.2	L-5
GF9999U	SEL H_2O SEP RT	1L	3-7	1-5	0 3600 RPM	77.4	14.2	C	COMP CAUT		6.1	K-4
GG0001X	PGNS DOWNLINK	50									9.11	K-8
GG0117H	ALT POS								0 60500 FT			
GG0118L	ALT RATE VEL								-700 700 F/S			
GG0119L	FORWARD VEL								-200 200 F/S			
GG0120L	LATERAL VEL								-200 200 F/S			
GG1040V	PLS TORQ REF	1-1	3-6/1-7	PB8-III	85 135 VDC		.198				10.7	D-4
GG1110V	2.5VDC TM BIAS	1-1L	4-7/2-7	PU-I	0 5 VDC		.020				10.12	F-4
GG1201V	28VAC 800HZ	1L	2-11	PU-I	0 31 VRMS		.125				10.7	E-8
GG1331V	26VAC 3.2KHZ	1L	2-5	PU-II	0 31 VRMS		.125				10.7	E-9
GG1513X	IMU STBY	1L-1L	10E6-1A1	PD-I			STBY				10.7	K-6
GG1523X	LGC OPERATE	1L-1L	10E6-1A1	PD-I			OPR				10.7	S-8
GG2001V	X PIPA OUT INØ	50-50	2-1/1-2	PB3.2-II	-2.5/2.5 VRMS		.020				10.11.1	O-9
GG2021V	Y PIPA OUT INØ	50	1-1	PB3.2-II	-2.5/2.5 VRMS		.020				10.11.1	M-7
GG2041V	Z PIPA OUT INØ	50-50	3-1/2-2	PB3.2-II	-2.5/2.5 VRMS		.020				10.11.1	N-7
GG2107V	1G SVO ERR INØ	100-100	1-1/2-1	PB3.2-II	-3 3 VRMS		.024				10.11.1	J-1
GG2112V	1G RSV OUT SIN	10L	3-5	PB8-IV	-20 20 VRMS		.158				10.11.1	D-7
GG2113V	1G RSV OUT COS	10L	3-4	PB8-IV	-20 20 VRMS		.158				10.11.1	D-7
GG2122V	1G RSV OUT SIN								-90 90 DEG PITCH			
GG2123V	1G RSV OUT COS								-90 90 DEG PITCH			
GG2137V	MG SVO ERR INØ	100-100	3-1/2-1	PB3.2-II	-3 3 VRMS		.024				10.11.1	J-1
GG2142V	MG RSV OUT SIN	10L-10	2-3/4-3	PB8-IV	-20 20 VRMS		.158				10.11.1	D-6
GG2143V	MG RSV OUT COS	10-1L	1-5/1-4	PB8-IV	-20 20 VRMS		.158				10.11.1	D-6
GG2152V	MG RSV OUT SIN								-180 180 DEG ROLL			
GG2153V	MG RSV OUT COS								-180 180 DEG ROLL			
GG2167V	OG SVO ERR INØ	100-100	2-2/1-2	PB3.2-II	-3 3 VRMS		.024				10.11.1	I-1
GG2172V	OG RSV OUT SIN	10L	3-4	PB8-IV	-20 20 VRMS		.158				10.11.1	D-4
GG2173V	OG RSV OUT COS	10-1L	1-8/1-3	PB8-IV	-20 20 VRMS		.158				10.11.1	D-4
GG2182V	OG RSV OUT SIN								0 360 DDEG YAW			
GG2183V	OG RSV OUT COS								0 360 DEG YAW			
GG2217V	PITCH ATT ERR											
GG2219V	PITCH DAC OUT	10	4-4	PB8-I	-5 5 VRMS		.040				10.11.2	F-5
GG2247V	ROLL ATT ERR											
GG2249V	YAW DAC OUT	10	4-5	PB8-I	-5 5 VRMS		.040				10.11.2	F-5
GG2277V	YAW ATT ERR											
GG2279V	ROLL DAC OUT	10	2-4	PB8-I	-5 5 VRMS		.040				10.11.2	G-5
GG2300T	PIPA TEMP	1L-1L	1-11/3-14	PU-I	120 140 DEG F		.080				10.11.1	I-7
GG3304V	RR SHFT SIN	10	1-4	PB8-III	-20 20 VRMS		.158				10.14	B-3
GG3305V	RR SHFT COS	10	3-3	PB8-III	-20 20 VRMS		.158				10.14	B-3
GG3324V	RR TRUN SIN	10	4-3	PB8-III	-20 20 VRMS		.158				10.14	C-3
GG3325V	RR TRUN COS	10	3-3	PB8-III	-20 20 VRMS		.158				10.1	C-3

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Continued

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE	
											DWG	ZONE
GG9001X	LGC WARNING	1L-1L	10E2-2A1	2-3			WARN	W			10.13.2	B-6
GG9002X	ISS WARNING	1L-1L	10E2-2A1	2-3			WARN	W			10.13.2	C-8
GH1204X	OUT OF DETENT	1	10E31-3A1	2-14			OUT				10.20	R-7
GH1214X	AUTO ON	1L	10E23-1A1	2-14			ON				10.21	S-9
GH1217X	AUTO OFF	1	10E31-3A1	2-14			OFF				10.21	S-7
GH1230X	APS ARM	1	10E41-1A2	1-3			ARM				10.24	K-5
GH1240V	X TRANS CMD	10	1-3	2-17	-10 10 VDC		.080				10.20	K-4
GH1241V	Y TRANS CMD	10	1-3	2-17	-10 10 VDC		.080				10.20	K-5
GH1242V	Z TRANS CMD	10	1-3	2-17	-10 10 VDC		.080				10.20	K-6
GH1247V	YAW ERR CMD	10-1L	4-4/1-12	2-18	-13 13 VDC		.103				10.20	K-7
GH1248V	PITCH ERR CMD	10-1L	2-4/1-12	2-18	-13 13 VDC		.103				10.20	M-7
GH1249V	ROLL ERR CMD	10-1L	2-4/1-13	2-18	-13 13 VDC		.103				10.20	M-3
GH1260X	APS ON	50L-50L	51E1-1A2	2-2			ON				10.24	E-6
GH1283X	ABORT STG CMD	50L-50L	51E1-1A2	2-14			STG				10.24	S-4
GH1286X	ENG FIRE OVRD	1	10E31-3A1	2-14			ON				10.21	N-3
GH1301X	DPS ON	1L	10E23-1A1	2-3			ON				10.21	E-6
GH1311V	MAN THRUST CMD	1L	4-12	1-15	0 92.5 PCT		.471		0 100 PCT		10.23	I-4
GH1313V	PITCH GDA POS	10-1L	1-6/3-3	2-9	-6 6 DEG		.047				10.22	I-3
GH1314V	ROLL GDA POS	10-1L	4-3/1-5	2-9	-6 6 DEG		.047				10.22	I-5
GH1323X	P TRIM FAIL	1L	10E23-1A1	2-3			FAIL	C			10.22	B-2
GH1330X	R TRIM FAIL	1L	10E23-1A1	2-3			FAIL	C			10.22	B-6
GH1331V	AUTO THRUST CMD	10-1L	4-3/3-5	1-15	0 82.5 PCT		.387		0 100 PCT		10.23	I-4
GH1348X	DPS ARM	1	10E41-1A2	1-3			ARM				10.21	L-6
GH1401V	RGA A-B 800 HZ			2-7				W				
GH1402V	RGA B-C 800 HZ			2-7				W				
GH1403V	RGA C-A 800 HZ			2-7				W				
GH1405V	RGA XCIT 800 HZ			1-17				W				
GH1406V	+15 VDC			2-19				W				
GH1407V	-15 VDC			2-19				W				
GH1408V	+4.3 VDC			2-8				W				
GH1418V	JD B4U OUTPUT	100-100	12E1-4A2	1-4			ON	W			10.20	F-8
GH1419V	JD A4D OUTPUT	100-100	12E1-4A2	1-4			ON	W			10.20	F-8
GH1420	JD B4F OUTPUT	100	12E4-3A2	1-4			ON	W			10.20	F-8
GH1421V	JD A4R OUTPUT	100	12E4-3A2	1-4			ON	W			10.20	F-8
GH1422V	JD A3U OUTPUT	100-100	12E1-4A2	1-4			ON	W			10.20	F-8
GH1423V	JD B3D OUTPUT	100-100	12E1-4A2	1-4			ON	W			10.20	F-8
GH1424V	JD B3A OUTPUT	100	12E4-3A2	1-4			ON	W			10.20	F-8
GH1425V	JD A3R OUTPUT	100	12E4-3A2	1-4			ON	W			10.20	F-8
GH1426V	JD B2U OUTPUT	100-100	12E1-4A2	1-2			ON	W			10.20	F-8
GH1427V	JD A2D OUTPUT	100-100	12E1-4A2	1-2			ON	W			10.20	F-8
GH1428V	JD A2A OUTPUT	100	12E4-3A2	1-2			ON	W			10.20	F-8
GH1429V	JD B2L OUTPUT	100	12E4-3A2	1-2			ON	W			10.20	F-8
GH1430V	JD A1U OUTPUT	100-100	12E1-4A2	1-2			ON	W			10.20	F-8

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Continued

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE	
											DWG	ZONE
GH1431V	JD BID OUTPUT	100-100	12E1-4A2	1-2			ON	W			10.20	F-8
GH1432V	JD A1F OUTPUT	100	12E4-3A2	1-2			ON	W			10.20	F-8
GH1433V	JD B1L OUTPUT	100	12E4-3A2	1-2			ON	W			10.20	F-8
GH1455V	YAW ATT ERR	10-10-1L	4-4/3-3/ 1-6	2-9	-3.5 3.5 VRMS		.028				10.20	S-6
GH1456V	PITCH ATT ERR	10-10-1L	4-4/2-4/ 1-8	2-9	-3.5 3.5 VRMS		.028				10.20	S-4
GH1457V	ROLL ATT ERR	10-10-1L	2-4/1-10/ 1-3	2-10	-3.5 3.5 VRMS		.028				10.20	S-2
GH1461V	RGA YAW RATE	10L-10L	2-3/3-4	2-10	-25 25 DEG/SEC		.198				10.20	T-5
GH1462V	RGA PITCH RATE	10L-10L	2-3/3-5	2-10	-25 25 DEG/SEC		.198				10.20	T-4
GH1463V	RGA ROLL RATE	10L-10L	2-3/3-4	2-10	-25 25 DEG/SEC		.198				10.20	T-2
GH1488V	PRIME -4.7 VDC			2-15				C				
GH1489V	B/U -4.7 VDC			2-15				C				
GH1493V	+6 VDC SUPPLY			2-19				W				
GH1494V	-6 VDC SUPPLY			2-19				W				
GH1497V	YAW RGA SIG								-25 25 DEG/SEC		10.20	S-5
GH1498V	PITCH RGA SIG								-25 25 DEG/SEC		10.20	S-3
GH1499V	ROLL RGA SIG								-25 25 DEG/SEC		10.20	S-1
GH1603X	MIN DEADBAND	1	10E41-1A2	1-3			WIDE				10.20	Q-1
GH1621X	AGS SELECT	1L	10E23-1A1	2-3			AGS				10.20	T-1
GH1628X	ROLL PLS/DIR	1	10E27-2A1	2-13			ON				10.20	O-3
GH1629X	PITCH PLS/DIR	1	10E27-2A1	2-13			ON				10.20	O-5
GH1630X	YAW PLS/DIR	1	10E27-2A1	2-13			ON				10.20	L-8
GH1641X	AGS AUTO	1	10E31-3A1	2-12			ON				10.20	S-9
GH1642X	AGS ATT HOLD	1	10E31-3A1	2-12			ON				10.20	R-9
GH1643X	PGNS AUTO	1	10E31-3A1	2-14			ON				10.20	J-8
GH1644X	PGNS ATT HOLD	1	10E31-3A1	2-14			ON				10.20	J-8
GH1893X	+X TRANS OVRD	1	10E41-1A2	1-3			OFF				10.20	Q-9
GH1896X	UNBAL COUPLES	1	10E31-3A1	2-14			ON				10.20	F-9
GI0001X	AGS DOWNLINK	50									10.19	D-5
GI3151V	ALPHA SIN								-180 180 DEG		10.19	C-2
GI3152V	ALPHA COS								-180 180 DEG		10.19	C-2
GI3153V	BETA SIN								0 360 DEG		10.19	C-2
GI3154V	BETA COS								0 360 DEG		10.19	C-2
GI3155V	GAMMA SIN								-90 90 DEG		10.19	C-2
GI3156V	GAMMA COS								-90 90 DEG		10.19	C-2
GI3166V	YAW ATT ERR								-15 15 DEG		10.18	F-5
GI3167V	PITCH ATT ERR								-15 15 DEG		10.18	F-5
GI3168V	ROLL ATT ERR								-15 15 DEG		10.18	F-5
GI3203H	ALT POS								0 50,000 FT		10.18	F-2
GI3204L	ALT VEL RATE								-700 700 FFT/SEC		10.18	F-2
GI3205L	LAT VEL								-200 200 FT/SEC		10.18	G-4

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Continued

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE	
											DWG	ZONE
GI3214V	ASA +28 VDC			2-15				W			10.17	J-6
GI3215V	ASA +12 VDC			1-15				W			10.17	J-6
GI3232X	TEST MODE FAIL			1-4				W			10.17	J-6
GI3233F	ASA 400 HZ			1-16				W			10.17	J-6
GI3301T	ASA TEMP	1L-1L	4-9/2-9	1-10	20 200 DEG F						10.17	J-6
GI3305X	AGS WARMUP	1	10E27-2A1	2-2			WMUP				10.17	O-6
GI3306X	AGS STANDBY	1	10E27-2A1	2-13			STBY				10.17	O-7
GL0300X	FRAME SYNC & ID	50L									9.1	E-4
GL0302X	FORMAT ID	1L									9.1	E-4
GL0400X	PCM OSC FAIL 1	1L-1L	10E7-2A1				FAIL				9.1	H-6
GL0401V	CAL 85 PCT	10L-10	3-5/1-4		0 5 VDC		.020				9.1	H-2
GL0402V	CAL 15 PCT	10L-10	3-5/4-5		0 5 VDC		.020				9.1	H-2
GL0422V	PCM OSC FAIL 2	1L	1-13		0 5 VDC		.020				9.1	H-6
GL0423V	PCM OSC FAIL 3	1L	2-9		0 5 VDC		.020				9.1	H-6
GL0501W	MET	10L			0 40 DAYS						9.1	E-6
GL4022X	ASC PRESS WARN							W				
GL4023X	DES REG WARN							W				
GL4024X	DES QTY WARN							W				
GL4026X	CES AC PWR FAIL	1L-1L	10E7-2A1	2-2			GOOD	W			10.17	G-4
GL4027X	CES DC PWR FAIL	1L-1L	10E7-2A1	2-2			GOOD	W			10.17	G-4
GL4028X	AGS PWR FAIL	1L-1L	10E7-2A1	2-2			GOOD	W			10.17	O-7
GL4029X	LGC WARNING							W				
GL4030X	ISS WARNING							W				
GL4031X	RCS TCA WARN							W				
GL4032X	RCS REG A WARN							W				
GL4033X	RCS REG B WARN							W				
GL4034X	DC BUS WARN							W				
GL4036X	CABIN WARN							W				
GL4037X	SUIT/FAN WARN							W				
GL4041X	ASC REG CAUT							C				
GL4042X	ASC QTY CAUT							C				
GL4043X	ENG GMBL CAUT							C				
GL4046X	INVERTER CAUT							C				
GL4047X	BAT MAL	1L-1L	10E7-2A1	2-3			GOOD	C			9.6	I-4
GL4048X	RNDZ RDR CAUT							C				
GL4050X	PRE AMPS CAUT							C				
GL4051X	ED RELAYS CAUT							C				
GL4052X	RCS CAUT							C				
GL4053X	HEATER CAUT							C				
GL4054X	C/W PWR FAIL	1L-1L	10E7-2A1	2-12			GOOD	C			9.4	E-4
GL4056X	ECS CAUT							C				
GL4057X	O_2 QTY CAUT							C				
GL4058X	GLYCOL CAUT							C				

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Continued

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE DWG	REFERENCE ZONE	
GL4059X	WATER QTY CAUT							C					
GL4060X	S-BD RCVR CAUT							C					
GL4069X	MASTER ALARM	1L-1L	10E7-2A1	2-2			OFF				9.4	C-8	
GL4070X	RECORDER ON								FLAG				
GL8275U	USED FOR PROCESSING BY GROUND DATA SYSTEMS. REF. GL9401U FOR VEHICLE DATA												P-1
GL9001U	BATTERY FAULT								COMP CAUT				
GL9011W	MISSION TIME								0 1000 HRS				
GL9012W	EVENT TIME								0 60 MIN				
GL9013A	THRUST/WEIGHT								FLAG				
GL9401U	SEL RTG/ECA 1T	1L	4-15	2-6	-200 500 DEG F		2.77						
GL9402U	SEL LR/ECA 2T	1-1L	4-14/2-12	1-21	-200 200 DEG F		1.58		-100 200 DEG F				P-1
GL9501U	TCA PR 4A FAIL								FLAG				
GL9502U	TCA PR 4B FAIL								FLAG				
GL9503U	TCA PR 3A FAIL								FLAG				
GL9504U	TCA PR 3B FAIL								FLAG				
GL9505U	TCA PR 2A FAIL								FLAG				
GL9506U	TCA PR 2B FAIL								FLAG				
GL9507U	TCA PR 1A FAIL								FLAG				
GL9508U	TCA PR 1B FAIL								FLAG				
GM2435U	LUNAR CONTACT								LUNAR CONT				
GM5000U	LAND GEAR DPLY	1	10E40-1A2	1-13			DPLY		FLAG		4.1	D-6	
GN7521X	LR RNG BAD	1L-1L	10E1-1A1	2-2			BAD				10.16.2	C-6	
GN7523L	LR VXA								-700 700 FT/SEC				
GN7524L	LR VYA								-200 200 FT/SEC				
GN7525L	LR VZA								-200 200 FT/SEC				
GN7527H	LR RANGE								0 60500 FT				
GN7545E	VEL XMTR PWR								0 500 MW				
GN7546E	ALT XMTR PWR								0 500 MW				
GN7557X	LR VEL BAD	1L-1L	10E1-1A1	2-2			BAD				10.16.1	F-3	
GN7563T	USED FOR PROCESSING BY GROUND DATA SYSTEMS. REF. GL9402U FOR VEHICLE DATA												P-1
GN7609H	RR SHFT ANGLE								-70 155 DEG				
GN7610R	RR SHFT RATE								-10 10 DEG/SEC				
GN7611H	RR TRUN ANGLE								-70 70 DEG				
GN7612R	RR TRUN RATE								-10 10 DEG/SEC				
GN7613H	RR RANGE								0 400 N.MI				
GN7614L	RR RANGE RATE								-700 700 FT/SEC				
GN7621X	RR NO TRACK	1L-1L	10E1-1A1	2-2			NO TRACK	C	COMP CAUT		10.14	K-2	
GN7642E	RR PWR OUT								0 500 MW				
GN7644V	ATM TRUN OUT								0 5 VDC				
GN7646V	ATM SHAFT OUT								0 5 VDC				
GN7648V	ATM AGC								0 5 VDC				A
GN7723T	RR ANT TEMP	1-1-1L	2-7/3-13/4-7	1-21	-200 200 DEG F		1.58	C	-100 200 DEG		10.14	T-3	
GP0001P	APS He 1 PRESS	1L-1L	1-14/2-12	1-8	0 4000 PSIA		15.8	W	0 4000 PSI		11.2	P-2	
GP0002P	APS He 2 PRESS	1L-1L	2-9/4-11	1-19	0 4000 PSIA		15.8	W	0 4000 PSI		11.2	O-6	
GP0018P	APS He REG P	1	2-8		0 300 PSIA		1.19				11.2	K-7	

LETTER	ENG	DATE	APPROVAL
A,PCN-1	[signature]	1-24-72	1-24-72 [signature]

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Continued

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE	
											DWG	ZONE
GP0025P	APS He REG P	1L	3-7	1-8	0 300 PSIA		1.19	C			11.2	K-2
GP0041P	APS He 1R P	10	4-3		0 4000 PSIA		15.8		0 4000 PSI		11.2	O-3
GP0042P	APS He 2R P	10	1-4		0 4000 PSIA		15.8		0 4000 PSI		11.2	O-6
GP0318X	APS He 1 CLSD	1	10E43-2A2	1-12			CLSD		FLAG		11.2	M-3
GP0320X	APS He 2 CLSD	1	10E43-2A2	1-12			CLSD		FLAG		11.2	M-6
GP0501P	FU ULLAGE P								0 300 PSI		11.2	I-7
GP0718T	APS FUEL TEMP	1L	3-11	1-9	20 120 DEG F		.395		40 100 DEG		11.2	I-6
GP0908X	APS FUEL LO	1L	10E24-1A1	2-2			LO				11.2	H-6
GP1001P	OX ULLAGE P								0 300 PSI		11.2	I-2
GP1218T	APS OX TEMP	1L-1L	4-13/2-11	1-9	20 120 DEG F		.395		40 100 DEG		11.2	I-2
GP1408X	APS OX LO	1L	10E24-1A1	2-2			LO				11.2	H-2
GP1501P	APS FU PRESS	1L-1L	2-8/4-10	1-19	0 250 PSIA		.990				11.2	G-7
GP1503P	APS OX PRESS	1L-1L	4-9/2-10	1-19	0 250 PSIA		.990				11.2	G-2
GP2010P	APS TCP	200-1L-1L	2-2/3-13/ 3-15		0 150 PSIA		.592				11.2	B-5
GP2997U	APS VLV A ΔPOS	1	10E32-3A1	2-14			ΔPOS				11.2	B-3
GP2998U	APS VLV B ΔPOS	1	10E32-3A1	2-14			ΔPOS				11.2	B-3
GQ3015P	DPS STRT TNK P	1	3-8		0 1750 PSIA		6.92		0 1750 PSI		11.1	T-7
GQ3018P	DPS REG P	1L	4-8	1-19	0 300 PSIA		1.19	W			11.1	Q-3
GQ3025P	DPS He REG P	1	4-11		0 300 PSIA		1.19				11.1	Q-6
GQ3309X	DES He REG 1								FLAG			
GQ3310X	DES He REG 2								FLAG			
GQ3435P	DPS He PRESS	1L-1L	3-6/1-6		0 2000 PSIA		7.90				11.1	H-7
GQ3436P	DPS He PRESS								0 1750 PSI		11.1	H-7
GQ3500X	FU VENT OPEN								FLAG		11.1	K-6
GQ3501P	DPS FU ULL P											
GQ3603Q	DPS FU 1 QTY	100-1-1L	1-1/4-11/ 2-9		0 95 PCT		.375				11.1	L-6
GQ3604Q	DPS FU 2 QTY	100-1-1L	3-2/2-10/ 4-9		0 95 PCT		.375				11.	L-6
GQ3605Q	DPS FU QTY SEL								0 95 PCT		1.1	L-5
GQ3611P	DPS FU PRESS	200-200-1L	3-6/1-1/ 4-1		0 300 PSIA		1.19				11.1	G-2
GQ3718T	DPS 1 FU T	1-1	4-6/2-7	1-9	20 120 DEG F		.395		40 100 DEG		11.1	J-3
GQ3719T	DPS 2 FU T	1-1	2-11/4-13	1-9	20 120 DEG F		.395		40 100 DEG		11.1	J-1
GQ4000X	DPS OX VENT								FLAG			
GQ4001P	DPS OX ULL P								0 300 PSI		11.1	K-3
GQ4103Q	DPS OX 1 QTY	100-1-1L	4-1/2-13/ 4-12		0 95 PCT		.375				11.1	K6
GQ4104Q	DPS OX 2 QTY	100-1-1L	3-2/2-11/ 4-15		0 95 PCT		.375				11.1	K-6
GQ4105Q	DPS OX QTY SEL								0 95 PCT		11.1	L-5
GQ4111P	DPS OX PRESS	200-200-1L	3-6/2-1/ 1-2		0 300 PSI		1.19				11.1	G-2
GQ4218T	DPS 1 OX T	1-1	1-5/3-8	1-10	20 120 DEG F		.395		40 100 DEG		11.1	J-3
GQ4219T	DPS 2 OX T	1-1	1-6/3-8	1-10	20 120 DEG F		.395		40 100 DEG		11.1	J-1
GQ4455X	DPS PROP LO	1	10E32-3A1	2-12			LOW	W			11.1	L-5
GQ6510P	DPS TCP	200-1L-1L	2-2/1-8/ 3-10		0 200 PSIA		.790		0 100 PCT		11.1	C-3

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Continued

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE	
											DWG	ZONE
GQ6806H	DPS VAR ACT	50-50-1L	2-14/4-1/4-2		0 100 PCT		.395				11.1	E-3
GR1085Q	RCS PROP A QTY	1-1L	3-14/1-12		0 108 PCT		.425		0 100 PCT		12.1	H-9
GR1095Q	RCS PROP B QTY	1-1L	3-13/1-11		0 108 PCT		.425		0 100 PCT		12.1	H-9
GR1101P	RCS A He PRESS	1L-1L	2-11/4-14	1-6	0 3500 PSIA		13.8	C	0 3500 PSI		12.1	J-8
GR1102P	RCS B He PRESS	1L-1L	4-12/2-12	1-6	0 3500 PSIA		13.8	C	0 3500 PSI		12.1	G-8
GR1201P	RCS A REG PRESS	1-1L	4-11/3-11	1-6	0 350 PSIA		1.38	W	0 350 PSI		12.1	I-6
GR1202P	RCS B REG PRESS	1L	4-13	1-6	0 350 PSIA		1.38	W	0 350 PSI		12.1	G-6
GR2121T	RCS A FU TEMP	1L	2-8	2-20	20 120 DEG F		.395		20 120 DEG		12.1	J-5
GF2122T	RCS B FU TEMP	1L	2-8	2-20	20 120 DEG F		.395		20 120 DEG		12.1	G-5
GR2201P	A FU MFLD PRESS	1-1L	3-6/1-7		0 350 PSIA		1.38		0 350 PSI		12.1	I-3
GR2202P	B FU MFLD PRESS	1-1L	1-5/3-8		0 350 PSIA		1.38		0 350 PSI		12.1	G-4
GR3201P	A OX MFLD PRESS	1-1L	3-7/1-7		0 350 PSIA		1.38		0 350 PSI		12.1	I-4
GR3202P	B OX MFLD PRESS	1-1L	1-6/3-8		0 350 PSIA		1.38		0 350 PSI		12.1	H-4
GR5031X	RCS TCP B4U	200	22E1a-3A2	1-11			ON	W			12.1	C-2
GR5032X	RCS TCP A4D	200	22E1a-3A2	1-11			ON	W			12.1	N-1
GR5033X	RCS TCP B4F	200	22E1a-3A2	1-11			ON	W			12.1	B-1
GR5034X	RCS TCP A4R	200	22E1a-3A2	1-11			ON	W			12.1	N-2
GR5035X	RCS TCP A3U	200	22E1a-3A2	1-11			ON	W			12.1	N-4
GR5036X	RCS TCP B3D	200	22E1a-3A2	1-11			ON	W			12.1	C-3
GR5037X	RCS TCP B3A	200	22E1a-3A2	1-11			ON	W			12.1	C-4
GR5038X	RCS TCP A3R	200	22E1a-3A2	1-11			ON	W			12.1	N-3
GR5039X	RCS TCP B2U	200	22E1b-3A2	1-11			ON	W			12.1	C-7
GR5040X	RCS TCP A2D	200	22E1b-3A2	1-11			ON	W			12.1	N-5
GR5041X	RCS TCP A2A	200	22E1b-3A2	1-3			ON	W			12.1	N-6
GR5042X	RCS TCP B2L	200	22E1b-3A2	1-3			ON	W			12.1	C-5
GR5043X	RCS TCP A1U	200	22E1b-3A2	1-3			ON	W			12.1	N-9
GR5044X	RCS TCP B1D	200	22E1b-3A2	1-3			ON	W			12.1	C-8
GR5045X	RCS TCP A1F	200	22E1b-3A2	1-3			ON	W			12.1	N-7
GR5046X	RCS TCP B1L	200	22E1b-3A2	1-3			ON	W			12.1	C-9
GR6001T	QUAD 4 TEMP	1L	4-6	1-20	-60 260 DEG F		1.26		-60 260 DEG		12.1	C-2
GR6002T	QUAD 3 TEMP	1L	4-7	1-20	-60 260 DEG F		1.26		-60 260 DEG		12.1	D-4
GR6003T	QUAD 2 TEMP	1L	4-10	1-20	-60 260 DEG F		1.26		-60 260 DEG		12.1	D-6
GR6004T	QUAD 1 TEMP	1L	4-10	1-20	-60 260 DEG F		1.26		-60 260 DEG		12.1	D-8
GR9609U	RCS MAIN A CLSD	1L-1L	10E10-1A2	1-12			CLSD		FLAG		12.1	F-5
GR9610U	RCS MAIN B CLSD	1L-1L	10E10-1A2	1-12			CLSD		FLAG		12.1	K-5
GR9613U	A/B X FEED OPN	1L-1L	10E10-1A2	1-13			OPEN		FLAG		12.1	I-2
GR9631U	ASC FD A FU	1L-1L	10E10-1A2	1-13			OPEN		FLAG		12.1	H-2
GR9632U	ASC FD B FU	1L-1L	10E10-1A2	1-13			OPEN		FLAG		12.1	K-2
GR9641U	ASC FD A OX	1L-1L	10E10-1A2	1-12			OPEN		FLAG		12.1	F-2
GR9642U	ASC FD B OX	1L-1L	10E10-1A2	1-12			OPEN		FLAG		12.1	G-2
GR9661X	THR PR 4A CMD	1	10E42-1A2	1-13/1-14			CMD		FLAG		12.1	M-2
GR9662X	THR PR 4B CMD	1	10E42-1A2	1-13/1-14			CMD		FLAG		12.1	D-2
GR9663X	THR PR 3A CMD	1	10E42-1A2	1-13/1-14			CMD		FLAG		12.1	M-4
GR9664X	THR PR 3B CMD	1	10E42-1A2	1-13/1-14			CMD		FLAG		12.1	D-2
GR9665X	THR PR 2A CMD	1	10E42-1A2	1-13/1-14			CMD		FLAG		12.1	M-6

TABLE 9-III.- TELEMETERED AND DISPLAYED PARAMETERS - Concluded

MEAS ID	MEASUREMENT DESCRIPTION	S/S AND LBR[a]	PAM AND SEQ/ GT AND DIODE[b]	SCERA AND LOC	TM RANGE	TM ACC EU	1 PCM CNT[c]	C&W	ONBOARD RANGE	O/B ACC EU	REFERENCE	
											DWG	ZONE
GR9666X	THR PR 2B CMD	1	10E42-1A2	1-13/1-14			CMD		FLAG		12.1	D-6
GR9667X	THR PR 1A CMD	1	10E42-1A2	1-13/1-14			CMD		FLAG		12.1	M-8
GR9668X	THR PR 1B CMD	1	10E42-1A2	1-13/1-14			CMD		FLAG		12.1	D-8
GT0441X	DUA STATUS	50	51D2-4A1								8.4	K-7
GT0451H	Y POS GIMB OUT								-75 255 DEG		8.3	B-7
GT0452H	X POS GIMB OUT								-75 75 DEG		8.3	B-7
GT0454T	S-BND ANT TEMP	1L	1-10	2-21	-200 200 DEG F		1.59		-100 200 DEG		8.3	B-5
GT0504V	S-BND RCVR AGC								0 5 VDC		8.3	I-7
GT0625V	VHF B AGC	1L-1L	3-10/1-10		-97 -27 DBM		.276				8.3	P-1
GT0992B	S-BND ST Ø ERR	10-1L	2-14/2-3		-200 +200 KHZ		1.59				8.3	J-6
GT0993E	S-BND XMTR PO	1L	1-14		0 1.2 W		.020				8.3	H-5
GT0994V	S-BND RCVR AGC	1L-1L	4-13/2-13	1-5	-135 -50 DBM		.020	C			8.3	J-7
GT9999J	EKG 1/2											
GY0050X	ABORT CMD	1L-1L	10E11-2A2	1-2			ON				10.21	S-4
GY0201X	ED RLY A K1-6	1L-1L	10E11-2A2	1-12/1-14			ARM	C	COMP CAUT		4.1	D-5
GY0202X	ED RLY B K1-6	1L-1L	10E11-2A2	1-12/1-14			ARM	C	COMP CAUT		4.1	C-5
GY0231X	ED RLY A K7-15	1L-1L	10E11-2A2	1-14			SAFE				4.1	D-3
GY0232X	ED RLY B K7-15	1L-1L	10E11-2A2	1-14			SAFE				4.1	C-3
GY0703U	SEL ED BAT V			1-7					20 40 VDC		4.1	R-2
					PLSS DATA							
GT8100X	EVC 1 SYNC	1.5										
GT8101V	EVC 1 CAL 0	1.5			0 5 VDC							
GT8102V	EVC 1 CAL 100	1.5			0 5 VDC							
GT8110P	PLSS 1 H_2O P	1.5			0 5 PSIA	.18			FLG/TONE		7.1	Q-2
GT8124J	PLSS EKG 1	FM 5.4 kHz			0 5 VDC						7.1	I-6
GT8140C	PLSS 1 BAT CUR	1.5			0 10 AMPS	.243					7.1	S-9
GT8141V	PLSS 1 BAT V	1.5			12 20.5 VDC	.316					7.1	P-5
GT8154T	LCG 1 H_2O IN T	1.5			-4 90 DEG F	4.51					7.1	L-3
GT8168P	PGA 1 O_2 PRESS	1.5			2.5 5 PSID	.11			F/T2.5/6 PSI	0.1	7.1	N-4
GT8170T	PLSS 1 O_2 SUBL T	1.5			-4 90 DEG F	4.51					7.1	P-2
GT8175P	PLSS 1 CO_2 PP	1.5			.1 30 MMHg	1.0					7.1	N-3
GT8182P	PLSS 1 O_2 P	1.5			0 1500 PSIA	47			O/FULL	70	7.1	T-4
GT8196T	LCG 1 H_2O ΔT	1.5			0 15 DEG F	.57					7.1	L-2
GT8200X	EVC 2 SYNC	1.5										
GT8201V	EVC 2 CAL 0	1.5			0 5 VDC							
GT8202V	EVC 2 CAL 100	1.5			0 5 VDC							
GT8210P	PLSS 2 H_2O P	1.5			0 5 PSIA	.18			FLG/TONE		7.1	R-2
GT8224J	PLSS EKG 2	FM 3.9 kHz			0 5 VDC						7.1	I-7
GT8240C	PLSS 2 BAT CUR	1.5			0 10 AMPS	.243					7.1	S-9
GT8241V	PLSS 2 BAT V	1.5			12 20.5 VDC	.316					7.1	O-5
GT8254T	LCG 2 H_2O IN T	1.5			-4 90 DEG F	4.51					7.1	L-3
GT8268P	PGA 2 O_2 PRESS	1.5			2.5 5 PSID	.11			F/T2.5/6 PSI	0.1	7.1	M-4
GT8270T	PLSS 2 O_2 SUBL T	1.5			-4 90 DEG F	4.51					7.1	P-2
GT8275P	PLSS 2 CO_2 PP	1.5			.1 30 MMHg	1.0					7.1	M-3
GT8282P	PLSS 2 O_2 P	1.5			0 1500 PSIA	47			O/FULL	70	7.1	T-4
GT8296T	LCG 2 H_2O ΔT	1.5			0 15 DEG F	.57					7.1	L-2

TABLE IV.- LUNAR MODULE TELEMETRY DATA SUMMARY

Measurement					Loading number	MSFN format Sample rates, S/S										Summary TWX number	PCM analog tabs and plots		Strip chart record setup number	Primary MSK number
Number	Title	Unit	Range			1	2	3	4	5	6	7	8	9	10		STD	SP		
			Low	High																
GC0071V	AC BUS VOLT	VRMS	0	120	1022069	1			.2	.2	.2					70	21B		LP-1	1001, 1002, 1071, 1091, 1127
GC0155F	AC BUS FREQ	HZ	380	420	1041069	1			.2	.2	.2					70	21B		LP-1	1001, 1002, 1091, 1127
GC0201V	BAT 1 VOLT	VDC	0	40	1019101	1			.2	.2	.2					70	21A		LP-1	1001, 1002, 1061
GC0202V	BAT 2 VOLT	VDC	0	40	1011101	1			.2	.2	.2					70	21A		LP-1	1001, 1002, 1061
GC0203V	BAT 3 VOLT	VDC	0	40	1021101	1			.2	.2	.2					70	21A		LP-1	1001, 1002, 1061
GC0204V	BAT 4 VOLT	VDC	0	40	1015101	1			.2	.2	.2					70	21A		LP-2	1001, 1002, 1061
GC0205V	BAT 5 VOLT	VDC	0	40	1003037	1			.2	.2	.2					70	21B		LP-2	1001, 1002, 1061
GC0206V	BAT 6 VOLT	VDC	0	40	1010037	1			.2	.2	.2					70	21B		LP-2	1001, 1002, 1061
GC0301V	CDR BUS VOLT	VDC	0	40	1033069	1			1	1	1					70	21B		LP-2	1001, 1002, 1061, 1091
GC0302V	SE BUS VOLT	VDC	0	40	1035069	1			1	1	1					70	21A		LP-2	1001, 1002, 1061, 1091
GC1201C	BAT 1 CUR	AMP	0	60	1024101	1			1	1	1					70	21A		LP-1	1001, 1002, 1071
GC1202C	BAT 2 CUR	AMP	0	60	1032069	1			1	1	1					70	21A		LP-1	1001, 1002, 1071
GC1203C	BAT 3 CUR	AMP	0	60	1017069	1			1	1	1					70	21A		LP-1	1001, 1002, 1071
GC1204C	BAT 4 CUR	AMP	0	60	1018069	1			1	1	1					70	21A		LP-2	1001, 1002, 1071
GC1205C	BAT 5 CUR	AMP	0	120	1018101	1			1	1	1					70	21B		LP-2	1001, 1002, 1071
GC1206C	BAT 6 CUR	AMP	0	120	1020069	1			1	1	1					70	21B		LP-2	1001, 1002, 1071
GC4361X	BAT 1 HI TAP		OFF	ON	1035098H												41			
GC4362X	BAT 1 LOW TAP		OFF	ON	1005098G												41			
GC4363X	BAT 2 HI TAP		OFF	ON	1035098F												41			
GC4364X	BAT 2 LOW TAP		OFF	ON	1035098E	1			.2	.2	.2						41			
GC4365X	BAT 3 HI TAP		OFF	ON	1035098D	1			.2	.2	.2						41			
GC4366X	BAT 3 LOW TAP		OFF	ON	1035098C	1			.2	.2	.2						41			
GC4367X	BAT 4 HI TAP		OFF	ON	1035098B	1			.2	.2	.2						41			
GC4368X	BAT 4 LOW TAP		OFF	ON	1035098A	1			.2	.2	.2						41			
GC4369X	BAT 5 B/U CDR		OFF	ON	1039098H	1			1	1	.5						41			
GC4370X	BAT 6 NORM CDR		OFF	ON	1039098G	1			1	1	.5						41			
GC4371X	BAT 5 NORM SE		OFF	ON	1039098F	1			1	1	.5						41			
GC4372X	BAT 6 B/U SE		OFF	ON	1039098E	1			1	1	.5						41			
GC9961U	BAT 1 MAL		ABS	PRS	1034100H	1			.2	.2	.2						41			1001, 1002, 1081
GC9962U	BAT 2 MAL		ABS	PRS	1034100G	1			.2	.2	.2						41			1001, 1002, 1081
GC9963U	BAT 3 MAL		ABS	PRS	1034100F	1			.2	.2	.2						41			1001, 1002, 1083
GC9964U	BAT 4 MAL		ABS	PRS	1034100E	1			.2	.2	.2						41			1001, 1002, 1081
GC9965U	BAT 5 MAL		ABS	PRS	1034100D	1			.2	.2	.2						41			1001, 1002, 1081
GC9966U	BAT 6 MAL		ABS	PRS	1034100C	1			.2	.2	.2						41			1001, 1002, 1081
GF1083X	SUIT FAN 1 MAL		NO	YES	1007098H	1			.2	.2	.2						42			1001, 1002, 1021, 1051, 1310
GF1084X	SUIT FAN 2 MAL		NO	YES	1007098G	1			.2	.2	.2						42			1001, 1002, 1021, 1051, 1310
GF1201X	CDR SUIT DISC		FLOW	DISC	1004098H	1			1	.1	.5						42			1001, 1002, 1021, 1051, 1310
GF1202X	SE SUIT DISC		FLOW	DISC	1004098G	1			1	.1	.5						42			1001, 1002, 1021, 1051, 1310
GF1211X	SUIT RLF CLSD		NOT CLOSED	CLOSED	1007098F	1			.2	.2	.2						42			1021, 1051
GF1212X	SUIT RLF OPEN		NOT OPEN	OPEN	1007098E	1			.2	.2	.2						42			1021, 1051
GF1221X	SUIT DIV EGRESS		CAB	EGR	1007098D	1			.2	.2	.2						42			1021, 1051, 1310
GF1231X	CABIN RET CLSD		NOT CLOSED	CLOSED	1005098H	1			.2	.2	.2						42			1021, 1051
GF1232X	CABIN RET OPEN		NOT OPEN	OPEN	1005098G	1			.2	.2	.2						42			1021, 1051
GF1241X	SEC CO2 SEL		PRI	SEC	1007098C	1			.2	.2	.2						42			1001, 1002, 1021, 1051, 1310
GF1281T	SUIT TEMP	°F	20	120	1045005	1			.1	.1	.1					70	22A		LP-4	1001, 1002, 1011, 1051
GF1301P	SUIT PRESS	PSIA	0	10	1034069	1			1	1	1					70	22A		LP-4	1001, 1002, 1011, 1051, 1310
GF1521P	CO2 PART PRESS	MMHG	0	30	1005037	1			.1	.1	.1					70	22A		LP-4	1001, 1002, 1011, 1051, 1310
GF1651T	CABIN TEMP	°F	20	120	1034005	1			.1	.1	.1					70	22A		LP-3	1001, 1002, 1011, 1051
GF2021P	PRI GLY PMP DEL P	PSID	0	50	1016069	1			.1	.1	.1					70	22C		LP-5	1001, 1002, 1011, 1051, 1310
GF2531T	MAIN W/B GLY IN	°F	20	120	1036037	1			.2	.2	.2					70	22B		LP-5	1001, 1002, 1021, 1051, 1310
GF2581T	MAIN W/B GLY OUT	°F	20	120	1033101	1			.2	.2	.2					70	22B		LP-5	1021, 1051, 1310
GF2921P	REDUN PMP PRESS	PSIA	0	60	1005005	1			.1	.1	.1						22B		LP-3	1001, 1002, 1011, 1051, 1310
GF2936X	SEL GLY PMP FAIL		NO	YES	1005098B	1			.2	.2	.2						42			1001, 1002, 1011, 1051, 1310
GF3070X	DMD REG A EGR/CLSD		NO	YES	1005098E	1			.2	.2	.2						42			1051
GF3071X	DMD REG A CLSD		NO	YES	1005098F	1			.2	.2	.2						42			1051
GF3073X	DMD REG B CLSD		NO	YES	1005098D	1			.2	.2	.2						42			1021, 1051
GF3075X	DMD REG B EGR/CLSD		NO	YES	1005098C	1			.2	.2	.2						42			1021, 1051
GF3571P	CABIN PRESS	PSIA	0	10	1022101	1			1	1	1					70	22A		LP-3	1001, 1002, 1011, 1051
GF3572X	REPR ELEC OPEN		NO	YES	1004098	1			1	1	.5						42			1001, 1002, 1021, 1052, 1310
GF3582P	ASC 1 02 PRESS	PSIA	0	1000	1004005	1			.2	.2	.2					70	22B		LP-4	1001, 1002, 1011, 1031, 1051, 1310
GF3583P	ASC 2 02 PRESS	PSIA	0	1000	1020005	1			.2	.2	.2					70	22B		LP-4	1001, 1002, 1011, 1031, 1051
GF3584P	DES 02 PRESS	PSIA	0	3000	1034101	1			.2	.2	.2					70	22B		LP-4	1001, 1002, 1011, 1031, 1051
GF3589P	02 MANIFOLD PRESS	PSIA	0	1400	1024069	1			.2	.2	.2					70	22A		LP-4	1001, 1002, 1011, 1051
GF3591P	U/H PLF PRESS	PSIA	0	25	1050069	1			.2	.2	.2					70	22B		LP-3	1001, 1002, 1021, 1051

TABLE IV.- LUNAR MODULE TELEMETRY DATA SUMMARY - Continued

Measurement					Loading number	MSFN format Sample rates, S/S										Summary TWX number	PCM analog tabs and plots		Strip chart record setup number	Primary MSK number
Number	Title	Unit	Range			1	2	3	4	5	6	7	8	9	10		STD	SP		
			Low	High																
GF3592P	F/H RLF PRESS	PSIA	0	25	1047101	1			.2	.2	.2					70	22B		LP-3	1001, 1002, 1021, 1051, 1310
GF4101P	PRI H2O REG DEL P	PSID	0	2	1037037	1			.2	.2	.2					70	22C		LP-3	1001, 1002, 1011
GF4501P	DESCENT H2O PRESS	PSID	0	60	1009065												22A		LP-3	1001
GF4511T	PRI W/B H2O TEMP	°F	20	260	1040069	1			.1	.1	.1					70	22C		LP-3	1001, 1002, 1011, 1351
GF4581Q	DES H2O QTY	PCT	0	100	1016037	1			.2	.2	.2					70	22C		LP-5	1001, 1002, 1011, 1031, 1310
GF4582Q	ASC 1 H2O QTY	PCT	0	100	1006037	1			.2	.2	.2					70	22C		LP-5	1001, 1002, 1011, 1031, 1310
GF4583Q	ASC 2 H2O QTY	PCT	0	100	1007037	1			.2	.2	.2					70	22C		LP-5	1001, 1002, 1011, 1031, 1310
GF9986U	GLY ACCUM LL		NORM	LOW	1004098	1			1	1	.5						42			1001, 1002, 1011, 1051
GF9997U	GLY PUMP PRESS	PSIA	0	60	1005101	1			.2	.2	.2					70	22C		LP-5	1001, 1002, 1011, 1051
GF9998U	GLY TEMP	°F	20	120	1032005	1			.2	.2	.2					70	22C		LP-5	1001, 1002, 1011, 1051, 1310
GF9999U	H2O SEP RATE	RPM	0	3600	1007069	1			.1	.1	.1					70	22C		LP-4	1001, 1002, 1011, 1051, 1310
GG0001X	PGNS DOWN LINK		DIG	CODE	5101121	1	.2				.1	.1								1125
GG1040V	PLS TORQ REF	VDC	84.3	134.5	1001069	1			.2	.1	.2						23A		LP-6	1133, 1137, 1142
GG1110V	2.5 VDC TM BIAS	VDC	0	5	1007005	1			.2	.1	.2						23A		LP-6	1137, 1142
GG1201V	IMU 28 VAC 800	VRMS	0	30.75	1032037	1			.2	1	.2					71	23A		LP-6	1133, 1135, 1137, 1142
GG1331V	IRIG SUSP 3.2 KC	VRMS	0	31.34	1002037	1			.2	1	.2					71	23A		LP-6	1133, 1135, 1137, 1142
GG1513X	IMU STBY		OFF	ON	1008098	1			1	1	.5						45			1133, 1139
GG1523X	LGC OPR		OFF	ON	1008098	1			1	1	.5						45			1133, 1139
GG2001V	X PIPA OUT IN PH	VRMS	-2.69	2.65	5101058	1			.2	.2	.2							30D	LO-3	1133, 1151
GG2021V	Y PIPA OUT IN PH	VRMS	-2.68	2.63	5101057	1			.2	.2	.2							30D	LO-3	1133, 1151
GG2041V	Z PIPA OUT IN PH	VRMS	02.7	2.65	5101059	1			.2	.2	.2							30D	LO-3	1133, 1151
GG2107V	IG SVO ERR IN PH	VRMS	-2.93	2.88	1201017	10			1	5	1							30D	LO-3	1133, 1135, 1151
GG2112V	IG RSVR OUT SIN	VRMS	-21.11	20.69	1102099	1			1	1	1							30E	LO-3	1133, 1148, 1475
GG2113V	IG RSVR OUT COS	VRMS	-21.15	20.91	1102067	1			1	1	1							30E	LO-3	1133, 1148
GG2137V	MG SVO ERR IN PH	VRMS	-2.92	2.96	1201019	10			1	5	1							30D	LO-3	1133, 1135, 1151
GG2142V	MG RSVR OUT SIN	VRMS	-21.91	20.70	1102034	1			1	1	1							30E	LO-3	1133, 1135, 1475
GG2143V	MG RSVR OUT COS	VRMS	-20.94	20.71	1002101	1			1	1	1							30E	LO-3	1133, 1135
GG2167V	OG SVO ERR IN PH	VRMS	-2.97	2.92	1201030	10			1	5	1							30D	LO-3	1133, 1135, 1151
GG2172V	OG RSVR OUT SIN	VRMS	-20.74	20.60	1103067	1			1	1	1							30E	LO-3	1133, 1148, 1475
GG2173V	OG RSVR OUT COS	VRMS	-21.35	21.02	1017101	1			1	1	1							30E	LO-3	1133, 1148
GG2219V	PITCH ATT ERR	VRMS	-20.00	19.70	1104068	4			3	3	1							30B	LO-1 LO-2	1123, 1127, 1137, 1145
GG2249V	YAW ATT ERR	VRMS	-20.5	20.10	1102100	4			3	3	1							30B	LO-1 LO-2	1123, 1127, 1137, 1145
GG2279V	ROLL ATT ERR	VRMS	-20.10	19.70	1103066	4			3	3	1							30B	LO-1 LO-2	1123, 1127, 1137, 1145
GG2300T	PIPA TEMP	°F	119.0	139.7	1032101	1			1	1	1					71	23A		LP-7	1133, 1137, 1145
GG3304V	RR SHFT SIN	VRMS	-23.05	22.63	1104065	1			1	1	.5							30D	LP-7 LO-3	1131
GG3305V	RR SHFT COS	VRMS	-22.39	21.95	1102035	1			1	1	.5							30D	LP-7 LO-3	1131
GG3324V	RR TRUN SIN	VRMS	-22.39	22.03	1102036	1			1	1	.5							30E	LP-7 LO-3	1131
GG3325V	RR TRUN COS	VRMS	-22.63	22.22	1103035	1			1	1	.5							30E	LP-7 LO-3	1131
GG9001X	LGC WARNING		ABS	PRS	1003098H	1			1	1	.5						45	30E	LP-7	1135, 1139
GG9002X	ISS WARNING		ABS	PRS	1003098G	1			1	1	.5						45			1135, 1139
GH1204X	OUT DET		NO	YES	1037098H	1			1	1	.5						44		LO-1	1127, 1157
GH1214X	AUTO ON		NO	YES	1020908	1			1	1	.5						44			1154
GH1217X	AUTO OFF		NO	YES	1037098G	1			1	1	.5						44			1123, 1125, 1154
GH1230X	APS ARM		NO	YES	1047098H	1			1	1	.5						44			1154
GH1240V	X TRANS CMD	VDC	-10	10	1101065	1			1	1	.5						43	30C	LP-8	1127, 1157
GH1241V	Y TRANS CMD	VDC	-10	10	1102033	1			1	1	.5						43	30C	LP-8	1127, 1157
GH1242V	Z TRANS CMD	VDC	-10	10	1103033	1			1	1	.5						43	30C	LP-8	1127, 1157
GH1247V	YAW LC IMPUT ERR	VDC	-12	12	1036101	4			1	1	1					71		30A	LO-1	1123, 1127, 1160
GH1248V	PITCH LC INPUT ERR	VDC	-12	12	1040101	4			1	1	1					71		30A	LO-1	1123, 1127, 1160
GH1249V	ROLL LC INPUT ERR	VDC	-12	12	1045101	4			1	1	1					71		30A	LO-1	1123, 1127, 1160
GH1260X	APS ON		OFF	ON	5101024H	1			1	1	.5						44		LO-2	1125, 1127, 1154
GH1283X	ABORT STAGE		NO	YES	5101024	1			1	1	.5						44			1001, 1002, 1081, 1091, 1127, 1157
GH1286X	ENG FIR OVERRIDE		NO	YES	1037098	1			1	1	.5						44			1123, 1127, 1154
GH1301X	DPS ON		OFF	NO	1029098	1			1	1	.5						44		LO-2	1125, 1127, 1154
GH1311V	MAN THRUST CMD	PCT	0	9.25	1035005	1			1	1	1					71		30C	LO-2	1123, 1127, 1137, 1154
GH1313V	PITCH GDA POS	VRMS	-15	15	1006101	1			1	1	1					71		30C	LO-2	1001, 1002, 1071, 1091, 1123, 1127, 1160
GH1314V	ROLL GDA POS	VRMS	-15	15	1003101	1			1	1	1					71		30C	LO-2	1001, 1002, 1071, 1091, 1123, 1124, 1160
GH1323X	R TRM FAIL		NO	YES	1029098F	1			1	1	.5						44			1001, 1002, 1021, 1123, 1127, 1160
GH1330X	R TRM FAIL		NO	YES	1029098E	1			1	1	.5						44			1001, 1002, 1021, 1123, 1330, 1160
GH1331V	AUTO THRUST CMD	PCT	0	0.25	1048069	1			1	1	1					71		30C	LO-2	1071, 1123, 1127, 1137, 1154
GH1348X	DPS ARM		OFF	ON	1047098	1			1	1	.5						44			1001, 1002, 1091, 1123, 1125, 1154
GH1418V	JDB4U OUTPUT		OFF	ON	1201008A												43		LO-1,2 LO-5	

TABLE IV.- LUNAR MODULE TELEMETRY DATA SUMMARY - Continued

Measurement					Loading number	MSFN format Sample rates, S/S										Summary TWX number	PCM analog tabs and plots		Strip chart record setup number	Primary MSK number
Number	Title	Unit	Range			1	2	3	4	5	6	7	8	9	10		STD	SP		
			Low	High																
GH1419V	JDA4D OUTPUT		OFF	ON	1201008												43		LO-1,2 LO-4	
GH1420V	JDB4F OUTPUT		OFF	ON	1201048A												43		LO-1,2 LO-5	
GH1421V	JDA4R OUTPUT		OFF	ON	1201048B												43		LO-1,2 LO-4	
GH1422V	JDA3U OUTPUT		OFF	ON	1201008C												43		LO-1,2 LO-4	
GH1423V	JDB3D OUTPUT		OFF	ON	1201008D												43		LO-1,2 LO-5	
GH1424V	JDB3A OUTPUT		OFF	ON	1201048C												43		LO-1,2 LO-5	
GH1425V	JDA3B OUTPUT		OFF	ON	1201048D												43		LO-1,2 LO-4	
GH1426V	JDB2U OUTPUT		OFF	ON	1201008E												43		LO-1,2 LO-5	
GH1427V	JDA2D OUTPUT		OFF	ON	1201008F												43		LO-1,2 LO-4	
GH1428V	JDA2A OUTPUT		OFF	ON	1201048E												43		LO-1,2 LO-4	
GH1429V	JDB2L OUTPUT		OFF	ON	1201048F												43		LO-1,2 LO-5	
GH1430V	JDA1U OUTPUT		OFF	ON	1201008G												43		LO-1,2 LO-4	
GH1431V	JDB1D OUTPUT		OFF	ON	1201008H												43		LO-1,2 LO-5	
GH1432V	JDA1F OUTPUT		OFF	ON	1201048G												43		LO-1,2	
GH1433V	JDB1L OUTPUT		OFF	ON	1201048H												43		LO-1,2 LO-5	
GH1455V	YAW ATT ERR	DEG	-11.67	11.67	1007101	4			2	3	.5					71		30B	LO-1	1123, 1127, 1137, 1145
GH1456V	PITCH ATT ERR	DEG	-11.56	11.67	1016101	4			2	3	.5					71		30B	LO-1	1123, 1127, 1137, 1145
GH1457V	ROLL ATT ERR	DEG	-11.67	11.67	1030101	4			2	3	.5					71		30B	LO-1	1123, 1127, 1137, 1145
GH1461V	RGA YAW RATE	DEG/ SEC	-25.00	25.00	1103034	10			3	5	1					71		30A	LO-1,2 LO-4,5	1123, 1127, 1137, 1145
GH1462V	RGA PITCH RATE	DEG/ SEC	-25.00	25.00	1104034	10			3	5	1					71		30A	LO-1,2 LO-4,5	1123, 1127, 1137, 1145
GH1463V	RGA ROLL RATE	DEG/ SEC	-25.00	25.00	1105034	10			3	5	1					71		30A	LO-1,2 LO-4,5	1123, 1127, 1137, 1145
GH1603X	WIDE DBND SEL		NAR	WIDE	1047098F	1			1	1	.5						44		LO-1	1137, 1145
GH1621X	AGS SEL		PGNS	AGS	1029098D	1			1	1	.5						44		LO-1,2	1127, 1137
GH1628X	ROLL PLSD/DIR		OUT	IN	1033098H	1			1	1	.5						44			1123, 1127, 1157
GH1629X	PITCH PLSD/DIR		OUT	IN	1033098G	1			1	1	.5						44			1123, 1127, 1157
GH1630X	YAW PLSD/DIR		OUT	IN	1033098F	1			1	1	.5						44			1123, 1127, 1157
GH1641X	AGS MODE AUTO		OFF	ON	1037098A	1			1	1	.5						44			1123, 1157
GH1642X	AGS MODE ATT HOLD		OFF	ON	1037098B	1			1	1	.5						44			1123, 1157
GH1643X	PGNS MODE AUTO		OFF	ON	1037098E	1			1	1	.5						44			1123, 1137, 1157
GH1644X	PGNS MODE ATT HLD		OFF	ON	1037098D	1			1	1	.5						44			1123, 1137, 1157
GH1893X	X TRANS OVERRIDE		ON	OFF	1047098E	1			1	1	.5						44			1127, 1157
GH1896X	UNBAL CPLS		NO	YES	1037098C	1			1	1	.5						44			1127, 1157
GI0001X	AGS COMPUTER WORDS		DIG	CODE	5101126	1			.5	.1	.1					64				1123
GI3301T	ASA TEMP	°F	20	200	1018005	1			.2	.2	.2					71	23A		LP-8	1127, 1160
GI3305X	AGS WARMUP		OFF	ON	1033098E	1			1	1	.5						45			1127, 1160
GI3306X	AGS STBY		OFF	ON	1033098D	1			1	1	.5						45			1127, 1160
GL0400X	OSC FAIL DETCT		NO	YES	1009098A	1			.2	.2	.2						46			1081, 1091
GL0401V	CAL 85 PCT	VDC	0	5.0	1103099	1			.1	.1	.1					70	24A		LP-9	1081, 1091
GL0402V	CAL 15 PCT	VDC	0	5.0	1104099	1			.1	.1	.1					70	24A		LP-9	1001, 1081, 1091
GL0422V	OSC FAIL DETCT 2	VDC	0	5.0	1044101	1			.2	.2	.2						24A		LP-9	1081, 1091
GL0423V	OSC FAIL DETCT 3	VDC	0	5.0	1023037	1			.2	.2	.2						24A		LP-9	1081, 1091
GL4026X	CES AC POWER FAIL		NO	YES	1001098H	1			1	1	.5						46			1127, 1160
GL4027X	CES DC PWR FAIL		NO	YES	1009098G	1			1	1	.5						46			1127, 1160
GL4028X	AGS PWR FAIL		YES	NO	1009098F	1			1	1	.5						46			1127, 1160
GL4047X	EPS BATTERY CAUT		YES	NO	1009098C	1			.2	.2	.2						46			1001, 1081, 1091
GL4054X	C W PWR FAIL		YES	NO	1009098E	1			1	1	.5						46			1001, 1081, 1091
GL4069X	MASTER ALARM ON		YES	NO	1009098D	1			1	1	.5					70	46			1001, 1081, 1091, 1468
GL8275T	RTG CASK SHLD TEMP	°F	-200	500	1047005	1			.1	.1	.1					70	24A		LP-9	1021, 1310
GM5000X	LAND GEAR DEPLOY		NO	YES	1045098H	1			1	1	.5						46			1001, 1002, 1021
GN7521X	LR RANGE BAD		NO	YES	1002098H	1			1	1	.5						46			1031, 1135, 1142
GN7557X	LR VEL BAD		NO	YES	1002098G	1			1	1	.5						46			1131, 1135, 1142
GN7563T	LR ANT TEMP	°F	-200	200	1043005	1			.1	.1	.1						25A		LP-10	1131, 1137, 1151
GN7621X	RR NO TRACK		TRK	NTRK	1002098	1			1	1	.5						46			1137, 1145
GN7723T	RR ANT TEMP	°F	-200	200	1009005	1			.1	.1	.1					71	25A		LP-10	1131, 1137, 1151
GP0001P	APS HE 1 PRESS	PSIA	0	4000	1040037	1			.2	.2	.2					71	26A	31A	LP-11	1123, 1125, 1169
GP0002P	APS HE 2 PRESS	PSIA	0	4000	1025037	1			.2	.2	.2					71	26A	31A	LP-11	1123, 1169
GP0018P	APS HE REG PRESS	PSIA	0	300	1019037	1			.2	.2	.2					71	26A	31A	LP-11	1125, 1169
GP0025P	APS HE REG PRESS	PSIA	0	300	1010069	1			.2	.2	.2					71	26A	31A	LP-11	1123, 1125, 1169
GP0201T	APS HE 1 TEMP	°F	-200	200	1035101	1			.1	.1	.1					71	26B		LP-11	1169
GP0318X	APS HE 1 CLSD		OPEN	CLSD	1049098H	1			.1	.1	.1						47			1123, 1125, 1172
GP0320X	APS HE 2 CLSD		OPEN	CLSD	1049098G	1			.1	.1	.1						47			1123, 1125, 1172
GP0718T	APS FUEL TEMP	°F	20	120	1030069	1			.1	.1	.1					71	26B		LP-12	1125, 1169
GP0908X	APS FUEL LOW		NORM	LOW	1029100	1			.1	.1	.1						47			1123, 1125, 1172
GP1218T	APS OX TEMP	°F	20	120	1034037	1			.1	.1	.1					71	26B		LP-12	1125, 1169
GP1408X	APS OX LOW		NORM	LOW	1029100	1			1	1	.5						47			1123, 1125, 1172
GP1501P	APS FUEL PRESS	PSIA	0	250	1017037	1			1	1	1					71	26A	31A	LP-12	1123, 1125, 1169

TABLE IV.- LUNAR MODULE TELEMETRY DATA SUMMARY - Continued

Measurement					Loading number	MSFN format Sample rates, S/S										Summary TWX number	PCM analog tabs and plots		Strip chart record setup number	Primary MSK number
Number	Title	Unit	Range			1	2	3	4	5	6	7	8	9	10		STD	SP		
			Low	High																
GP1503P	APS OX PRESS	PSIA	0	250	1017005	1			1	1	1					71	26A	31A	LP-12	1123, 1125, 1169
GP2010P	APS TCP	PSIA	0	150	1045037	1				5						71		31B	LP-12	1001, 1002, 1091, 1123, 1125, 1127, 1169
GP2997U	APS DELTA POS A		CLD/OPN	MID	1038098F	1			.1	.1	.1						48			1071, 1154, 1172
GP2998U	APS DELTA POS B		CLD/OPN	MID	1038098E	1			.1	.1	.1					71	48 27A	32A	LP-13	1172
GQ3015P	DPS START TANK P	PSIA	0	1750	1011069	1			.2	.2	.2					71	27A	32A	LP-13	1123, 1125, 1169
GQ3018P	DPS HE REG PRESS	PSIA	0	300	1012005	1			.2	.2	.2					71	27A	32A	LP-13	1123, 1125, 1169
GQ3025P	DPS HE REG PRESS	PSIA	0	300	1029005	1			.2	.2	.2					71	27A	32A	LP-13	1123, 1125, 1169
GQ3435P	DPS HE PRESS	PSIA	0	200	1002069	1			.2	.2	.2						27C		LP-14	1123, 1125, 1169
GQ3603Q	DPS FUEL 1 QTY	PCT	0	95	1028005	1			.2	.2	.2						27C		LP-14	1123, 1125, 1169
GQ3604Q	DPS FUEL 2 QTY	PCT	0	95	1027027	1			.2	.2	.2					71		32A	LP-13	1123, 1125, 1169
GQ3611P	DPS FUEL PRESS	PSIA	0	300	1005069	1			1	1	1					71	27B		LP-14	1123, 1125, 1172
GQ3718T	DPS FUEL 1 TEMP	°F	20	120	1002005	1			.1	.1	.1					71	27B		LP-14	1125, 1172
GQ3719T	DPS FUEL 2 TEMP	°F	20	120	1031037	1			.1	.1	.1						27C		LP-14	1125, 1172
GQ4103Q	DPS OX 1 QTY	PCT	0	95	1043037	1			.2	.2	.2						27C		LP-14	1123, 1125, 1169
GQ4104Q	DPS OX 2 QTY	PCT	0	95	1035037	1			.2	.2	.2					71		32A	LP-13	1123, 1125, 1169
GQ4111P	DPS OX PRESS	PSIA	0	300	1003069	1			1	1	1					71	27B		LP-14	1123, 1125, 1172
GQ4218T	DPS OX 1 TEMP	°F	20	120	1001101	1			.1	.1	.1					71	27B		LP-14	1125, 1172
GQ4219T	DPS OX 2 TEMP	°F	20	120	1009101	1			.1	.1	.1					71				1125, 1172
GQ4455X	DPS PROP LOW		NORM	LOW	1038098G												47			1123, 1125, 1172
GQ6510P	DPS TCP	PSIA	0	200	1020101				.2	.5	.2					71		32B	LP-13	1071, 1091, 1123, 1125, 1172
GQ6806H	VAR INJT ACT POS	PCT	0	100	1050037	1			1	1	1					71		32B	LP-13	1123, 1125, 1127, 1137, 1154
GR1085Q	RCS PROP A QTY	PCT	0	103.5	1042069	1			.2	.2	.2						48			1123, 1125, 1166
GR1095Q	RCS PROP B QTY	PCT	0	103.5	1038069	1			.2	.2	.2						48			1166
GR1101P	RCS A HE PRESS	PSIA	0	3500	1033037	1			.2	.2	.2					71	28A		LP-15	1123, 1125, 1166
GR1102P	RCS B HE PRESS	PSIA	0	3500	1033005	1			.2	.2	.2					71	28A		LP-15	1123, 1125, 1166
GR1201P	RCS A REG PRESS	PSIA	0	350	1030005	1			.2	.2	.2					71	28A		LP-15	1123, 1125, 1166
GR2121T	RCS A FUEL TEMP	°F	20	120	1018037	1			.1	.1	.1					71	28A		LP-15	1125, 1166
GR2122T	RCS B FUEL TEMP	°F	20	120	1020037	1			1	1	1					71	28A		LP-15	1125, 1166
GR2201P	A FUEL MFLD PRESS	PSIA	0	350	1004069	1			1	1	1					71	28C		LO-4 LP-15	1123, 1166
GR2202P	B FUEL MFLD PRESS	PSIA	0	350	1004101	1			1	1	1					71	28C		LO-5 LP-16	1123, 1166
GR3201P	A OX MFLD PRESS	PSIA	0	350	1006069	1			1	1	1					71	28C		LO-4 LP-16	1123, 1125, 1166
GR3202P	B OX MFLD PRESS	PSIA	0	350	1010101	1			1	1	1					71	28C		LO-5 LP-16	1123, 1125, 1169
GR5031X	RCS TCP B4U		OFF	ON	2201006A	SPECIAL PROCESSING											43		LO-5	1091
GR5032X	RCS TCP A4D		OFF	ON	2201006B	SPECIAL PROCESSING											43		LO-4	1091
GR5033X	RCS TCP B4F		OFF	ON	2201006C	SPECIAL PROCESSING											43		LO-5	1091
GR5034X	RCS TCP A4R		OFF	ON	2201006D	SPECIAL PROCESSING											43		LO-4	1091
GR5035X	RCS TCP A3U		OFF	ON	2201006E	SPECIAL PROCESSING											43		LO-4	1091
GR5036X	RCS TCP B3D		OFF	ON	2201006F	SPECIAL PROCESSING											43		LO-5	1091
GR5037X	RCS TCP B3A		OFF	ON	2201006G	SPECIAL PROCESSING											43		LO-5	1091
GR5038X	RCS TCP A3R		OFF	ON	2201006H	SPECIAL PROCESSING											43		LO-4	1091
GR5039X	RCS TCP B2U		OFF	ON	2201007A	SPECIAL PROCESSING											43		LO-5	1091
GR5040X	RCS TCP A2D		OFF	ON	2201007B	SPECIAL PROCESSING											43		LO-4	1091
GR5041X	RCS TCP A2A		OFF	ON	2201007C	SPECIAL PROCESSING											41		LO-4	1091
GR5042X	RCS TCP B2L		OFF	ON	2201007D	SPECIAL PROCESSING											43		LO-5	1091
GR5043X	RCS TCP A1D		OFF	ON	2201007E	SPECIAL PROCESSING											43		LO-4	1091
GR5044X	RCS TCP B1D		OFF	ON	2201007F	SPECIAL PROCESSING											43		LO-5	1091
GR5045X	RCS TCP A1F		OFF	ON	2201007G	SPECIAL PROCESSING											43		LO-4	1091
GR5046X	RCS TCP B1L		OFF	ON	2201007H	SPECIAL PROCESSING											43		LO-5	1091
GR6001T	QUAD 4 TEMP	°F	20	200	1003005	1			.1	.1	.1					71	28B		LP-16	1091, 1123, 1125, 1169
GR6002T	QUAD 3 TEMP	°F	20	200	1010005	1			.1	.1	.1					71	28B		LP-16	1123, 1125, 1169
GR6003T	QUAD 2 TEMP	°F	20	200	1022005	1			.1	.1	.1					71	28B		LP-16	1123, 1125, 1169
GR6004T	QUAD 1 TEMP	°F	20	200	1023005	1			.1	.1	.1					71	28B		LP-16	1123, 1125, 1169
GR9609U	RCS MAIN A CLSD		OPEN	CLSD	1013098F	1			.1	.1	.1						49			1123, 1125, 1172
GR9610U	RCS MAIN B CLSD		OPEN	CLSD	1013098E	1			.1	.1	.1						49			1123, 1125, 1172
GR9613U	A/B XFEED OPEN		CLSD	OPEN	1013098B	1			.1	.1	.1						49			1123, 1125, 1172
GR9631U	FUEL INCNT A OPN		CLSD	OPEN	1013098D	1			.1	.1	.1						49			1123, 1125, 1172
GR9632U	FUEL INTCNT B OPN		CLSD	OPEN	1013098C	1			.1	.1	.1						49			1123, 1125, 1172
GR9641U	OXID INTCNT A OPN		CLSD	OPEN	1013098H	1			.1	.1	.1						49			1123, 1125, 1172
GR9642U	OXID INTCNT A OPN		CLSD	OPEN	1013098G	1			.1	.1	.1						49			1123, 1125, 1172
GR9661U	4A ISO CLSD		OPEN	CLSD	1048098H	1			.1	.1	.1						49			1127, 1163
GR9662U	4B ISO CLSD		OPEN	CLSD	1048098G	1			.1	.1	.1						49			1127, 1163
GR9663U	3A ISO CLSD		OPEN	CLSD	1048098F	1			.1	.1	.1						49			1127, 1163
GR9664U	3B ISO CLSD		OPEN	CLSD	1048098E	1			.1	.1	.1						49			1127, 1163
GR9665U	2A ISO CLSD		OPEN	CLSD	1048098D	1			.1	.1	.1						49			1127, 1163
GR9666U	2B ISO CLSD		OPEN	CLSD	1048098C	1			.1	.1	.1						49			1127, 1163
GR9667R	1A ISO CLSD		OPEN	CLSD	1048098B	1			.1	.1	.1						49			1127, 1163
GR9668U	1BISO CLSD		OPEN	CLSD	1048098A	1			.1	.1	.1						49			1127, 1163
GT0441X	DUA STATUS				5101097	60											50			1091
GT0454T	ST ANT ELEC ASSY	DEG	-200	200	1028101	1			.1	.1	.1						29A		LP-17	1001, 1002, 1071, 1091, 1468
GT0992B	S-BND ST PH ERROR	DEG	-90	90	1048037	1			.1	.1	.1					70	29A		LP-17	1001, 1002, 1081, 1091, 1468
GT0993B	S-BND XMTR PO	KHZ	1130	1250	1050101	1			.1	.1	.1					70	29A		LP-17	1001, 1002, 1081, 1091, 1468

TABLE IV.- LUNAR MODULE TELEMETRY DATA SUMMARY - Concluded

Measurement					Loading number	MSFN format Sample rates, S/S										Summary TWX number	PCM analog tabs and plots		Strip chart record setup number	Primary MSK number
Number	Title	Unit	Range			1	2	3	4	5	6	7	8	9	10		STD	SP		
			Low	High																
GT0994V	S-BND RCVR SIG	VDC	0	5	1040005					1						70	29A		LP-17	1001, 1002, 1081, 1091, 1468
GY0050X	ABORT CMD		NO	YES	1014098H	1			1	1	.5						50			1001, 1002, 1081, 1091, 1127, 1157
GY0201X	ED SYS A REL XFER		NO	YES	1014098C	1			1	1	.5						50			1001, 1002, 1081, 1091
GY0202X	ED SYS B REL XFER		NO	YES	1014098B	1			1	1	.5						50			1001, 1002, 1081, 1091
GY0231X	SYS A FED REL CLSD		OPEN	CLSD	1014098E	1			1	1	.5						50			1001, 1002, 1081, 1091
GY0232X	SYS B FED REL CLSD		OPEN	CLSD	1014098D	1			1	1	.5						50			1001, 1002, 1081, 1091
GT8101V	EVCS 1 CAL 0 PCT	VDC	0	5					.1	.1	.1									1310
GT8102V	EVCS 1 CAL 100 PCT	VDC	0	5					.1	.1	.1									1310
GT8110P	PLSS FEED NO 1 H2O	PSIA	0	5					.5	1	.5						34A		LP-18	1302, 1310
GT8124J	EKG NO 1	VDC	0	5															LP-20	1310
GT8140C	PLSS BATTERY CURRENT NO 1	AMP	0	10					1	1	1						34A		LP-18	1310, 1316
GT8141V	PLSS NO 1 BATTERY	VDC	12	20.5					.2	.5	.2						34A		LP-18	1310, 1316
GT8154T	LCG H2O INLET NO 1	°F	40	90					.5	1	.2						34B		LP-18	1310
GT8168P	PGA O2 NO 1	PSIA	2.5	5.0					1	1	1						34B		LP-18	1310
GT8170T	PLSS 1 SUB O2 OUT	°F	40	90					.2	.5	.1						34B		LP-18	1310
GT8182T	PLSS O2 SUPPLY NO 1	PSIA	0	1110					.2	.5	.2						34A		LP-18	1301, 1310
GT8196T	LCG H2O DELTA T	°F	0	15					.5	1	.5						34B		LP-18	1310
GT8201V	EVCS 2 CAL 0 PCT	VDC	0	5					.1	.1	.1									1310
GT8202V	EVCS 2 CAL 100 PCT	VDC	0	5					.1	.1	.1									1310
GT8210F	PLSS NO 2 FEED H2O	PSIA	0	5					.5	1	.5						34A		LP-19	1302, 1310
GT8224J	EKG NO 2	VDC	0	5															LP-20	1310
GT8240C	PLSS BATTERY CURRENT NO 2	AMP	0	10					1	1	1						34A		LP-19	1310, 1326
GT8241V	PLSS NO 2 BATTERY	VDC	12	20.5					.2	.5	.2						34A		LP-19	1310, 1326
GT8254T	LCG H2O INLET NO 2	°F	40	90					.5	1	.2						34B		LP-19	1310
GT8268P	PGA O2 NO 2	PSIA	2.5	5.0					1	1	1						34B		LP-19	1310
GT8270T	PLSS 2 SUB O2 OUT	°F	40	90					.2	.5	.1						34B		LP-19	1310
GT8282P	PLSS O2 SUPPLY NO 2	PSIA	0	1110					.2	.5	.2						34A		LP-19	1301, 1310
GT8296T	LCG H2O DELTA T	°F	0	15					.5	1	.5						34B		LP-19	1310

TABLE V.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY

Measurement					Loading number	MSFN format Sample rates, S/S										Summary TWX number	PCM analog tabs and plots		Strip chart record setup number	Primary MSK number
Number	Title	Unit	Range			1	2	3	4	5	6	7	8	9	10		STD	SP		
			Low	High																
CA1820T	TEMP CREW HS ABL SUR LOC 1A	°F	-300.0	+850.0	1022084	1	.2	-	-	.1	.1	-	.1	.1	.1	3	1A		CP-1	404
CA1821T	TEMP CREW HS ABL SUR LOC 4A	°F	-300.0	+850.0	1024052	1	.1	-	-	.1	.1	-	.1	.1	.1	3	1A		CP-1	404
CA1822T	TEMP CREW HS ABL SUR LOC 7A	°F	-300.0	+850.0	1025084	1	.1	-	-	.1	.1	-	.1	.1	.1	3	1A		CP-1	404
CA1823T	TEMP CREW HS ABL SUR LOC 10A	°F	-300.0	+850.0	1027052	1	.1	-	-	.1	.1	-	.1	.1	.1	3	1A		CP-1	404
SA1830T	TEMP SM SKIN SURF LOC 1A	°F	-109.0	+264.0	1014052	1	-	-	-	.5	.1	-	.1	.1	.5	3	2A		CP-2	
SA1831T	TEMP SM SKIN SURF LOC 4A	°F	-109.0	+264.0	1048084	1	-	-	-	.5	.1	-	.1	.1	.5	3	2A		CP-2	
SA1832T	TEMP SM SKIN SURF LOC 7A	°F	-109.0	+264.0	1014084	1	-	-	-	.5	.1	-	.1	.1	.5	3	2A		CP-2	
SA1833T	TEMP SM SKIN SURF LOC 10A	°F	-109.0	+264.0	1049052	1	.1	-	-	.1	.1	-	.1	.1	.1	3	2A		CP-2	
SA2377T	TEMP BAY 2 OX TANK SURFACE	°F	-100.0	+200.0	1048052	1	.1	-	-	.1	.1	-	.1	.1	.1	3,5	2A		CP-2	674, 884
SA2378T	TEMP BAY 3 OX TANK SURFACE	°F	-100.0	+200.0	1046084	1	.1	-	-	.1	.1	-	.1	.1	.1	3,5	2A		CP-2	674, 884
SA2379T	TEMP BAY 5 FUEL TANK SURFACE	°F	-100.0	+200.0	1047052	1	.1	-	-	.1	.1	-	.1	.1	.1	3,5	2A		CP-2	674, 884
SA2380T	TEMP BAY 6 FUEL TANK SURFACE	°F	-100.0	+200.0	1047084	1	.1	-	-	.1	.1	-	.1	.1	.1	3,5	2A		CP-2	674, 884
SC0030Q	QUANTITY H2 TANK 1	PCT	.0000	100.0	1047116	1	.1	-	-	.1	.1	-	.1	.5	.1	4	4B		CP-6	554, 613
SC0031Q	QUANTITY H2 TANK 2	PCT	.0000	100.0	1048116	1	.1	-	-	.1	.1	-	.1	.5	.1	4	4B		CP-6	554, 613
SC0032Q	QUANTITY 02 TANK 1	PCT	.0000	100.0	1049116	1	.1	-	-	.1	.1	-	.1	.5	.1	4	4B		CP-6	554, 613
SC0033Q	QUANTITY 02 TANK 2	PCT	.0000	100.0	1014116	1	.1	-	-	.1	.1	-	.1	.5	.1	4	4B		CP-6	554, 613
SC0037P	PRESS 02 TANK 1	PSIA	0	1100	1050116	1	.2	-	-	.2	.2	-	.5	.5	.2	4	4B		CP-6	554, 613
SC0038P	PRESS 02 TANK 2	PSIA	0	1100	1022116	1	.2	-	-	.2	.2	-	.5	1.0	.2	4	4B		CP-6	554, 613
SC0039P	PRESS H2 TANK 1	PSIA	0	350	1012116	1	.2	-	-	.2	.2	-	.5	1.0	.2	4	4B		CP-6	554, 613
SC0040P	PRESS H2 TANK 2	PSIA	0	350	1013116	1	.2	-	-	.2	.2	-	.5	1.0	.2	4	4B		CP-6	554, 613
SC0041T	TEMP 02 TANK 1	°F	-325.0	+80.00	1018116	1	.1	-	-	.1	.2	-	.1	.5	.1	4	4E		CP-9	554, 613
SC0042T	TEMP 02 TANK 2	°F	-325.0	+80.00	1019116	1	.1	-	-	.1	.1	-	.1	.5	.1	4	4E		CP-9	554, 613
SC0043T	TEMP H2 TANK 1	°F	-425.0	-200.0	1020116	1	.1	-	-	.1	.1	-	.1	.5	.1	4	4E	22AA	CP-9	554, 613
SC0044T	TEMP H2 TANK 1	°F	-425.0	-200.0	1021116	1	.1	-	-	.1	.1	-	.1	.5	.1	4	4E		CP-9	554, 613
CC0175T	TEMP STATIC INVERTER 1	°F	+32.00	+248.0	1029084	1	.1	-	-	.1	.1	-	.1	.5	.1	3	3A		CP-3	443, 524
CC0176T	TEMP STATIC INVERTER 2	°F	+32.00	+248.0	1030052	1	.1	-	-	.1	.1	-	.1	.5	.1	3	3A		CP-3	443, 524
CC0177T	TEMP STATIC INVERTER 3	°F	+32.00	+248.0	1030084	1	.1	-	-	.1	.1	-	.1	.5	.1	3	3A		CP-3	443, 524
CC0200V	AC VOLTAGE MAIN BUS 1 PHASE A	VAC	0.0	+150.0	1105011	5	.2	-	-	.2	.5	-	.2	1.0	.2	3	3B	22AA	CP-4	443, 518, 524
CC0203V	AC VOLTAGE MAIN BUS 2 PHASE A	VAC	0.0	+150.0	1102074	5	.2	-	-	.2	.5	-	.2	1.0	.2	3	3B		CP-4	443, 518, 524
CC0206V	DC VOLTAGE MAIN BUS A	VDC	0.0	+45.00	1102075	5	.2	-	-	.2	.5	-	.2	1.0	.2	3	3B		CP-4	443, 518, 524, 544, 574, 584, 594
CC0207V	DC VOLTAGE MAIN BUS B	VDC	0.0	+45.00	1102076	5	.2	-	-	.2	.5	-	.2	1.0	.2	3	3B		CP-4	443, 518, 524, 544, 574, 584, 594
CC0210V	DC VOLTAGE BAT-TERY BUS A	VDC	0.0	+45.00	1103073	5	.2	-	-	.2	.5	-	.2	1.0	.2	3	3B		CP-4	443, 518, 524
CC0211V	DC VOLTAGE BAT-TERY BUS B	VDC	0.0	+45.00	1103075	5	.2	-	-	.2	.5	-	.2	1.0	.2	3	3B		CP-4	443, 518, 524
CC0215C	DC CURRENT BATT CHARGER OUT	AMP	0.0	+5.000	1103009	5	.1	-	-	.2	.1	-	.2	1.0	.2	3	3A		CP-3	518, 524
CC0222C	DC CURRENT BATTERY A	AMP	0.0	+100.0	1103010	5	.1	-	-	.2	.1	-	.2	1.0	.2	3	3A		CP-3	443, 518, 524
CC0223C	DC CURRENT BATTERY B	AMP	0.0	+100.0	1104009	5	.1	-	-	.2	.1	-	.2	1.0	.2	3	3A		CP-3	443, 518, 524
CC0224C	DC CURRENT BATTERY C	AMP	0.0	+100.0	1104010	5	.2	-	-	.2	.2	-	.2	1.0	.2	3	3A		CP-3	443, 518, 524
CC0232V	DC VOLTAGE BAT-TERY RELAY BUS	VDC	0.0	+45.00	1103011	5	.2	-	-	.2	.2	-	.2	1.0	.2	3	3B		CP-4	443, 518, 524
SC2060P	N2 PRESSURE FC 1 REGULATED	PSIA	0.0	75.00	1101106	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4C		CP-7	443, 518, 544, 574
SC2061P	N2 PRESSURE FC 2 REGULATED	PSIA	0.0	75.00	1101107	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4C		CP-7	443, 518, 544, 584
SC2062P	N2 PRESSURE FC 3 REGULATED	PSIA	0.0	75.00	1101123	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4C		CP-7	443, 518, 544, 594
SC2066P	02 PRESSURE FC 1 REGULATED	PSIA	0.0	75.00	1102108	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4C		CP-7	518, 574
SC2067P	02 PRESSURE FC 2 REGULATED	PSIA	0.0	75.00	1102113	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4C		CP-7	518, 584
SC2068P	02 PRESSURE FC 3 REGULATED	PSIA	0.0	75.00	1102121	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4C		CP-7	518, 594
SC2069P	H2 PRESSURE FC 1 REGULATED	PSIA	0.0	75.00	1102122	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4C		CP-7	518, 574
SC2070P	H2 PRESSURE FC 2 REGULATED	PSIA	0.0	75.00	1102123	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4C		CP-7	518, 584
SC2071P	H2 PRESSURE FC 3 REGULATED	PSIA	0.0	75.00	1102124	1	.2	-	-	.2	.1	-	.2	1.0	.2	3	4D		CP-8	518, 594

FLIGHT DIR MISSION LOG	DAY	REV	PG

SITE/ACQ/LOS	FLIGHT EVENTS/HISTORY/BRIEFING
12/6 4PM	LM INST ON-MAN All Inst OK
	OFF 6:20 ON 8:10 -40:00
	-28:18 Init Prior
	-07:20 Last Data
	Recycle ±00:30
	LOX prepress SAB Press to recycle to -22:00
	(swing arm)
9 14	Data back
	to pick up -22:00 at 9:45 (4/0 +1:15)
	4/0 11:53:00 (+2:40)
	cut-off 11:42 (-5 sec)

MSC FORM 1441 (APR 66)

NASA — MSC

FLIGHT DIRECTOR'S MISSION LOG

FLIGHT DIR MISSION LOG	DAY	REV	PG

SITE/ACQ/LOS	FLIGHT EVENTS/HISTORY/BRIEFING

MSC FORM 1441 (APR 66)

FLIGHT DIRECTOR'S MISSION LOG

FLIGHT DIR MISSION LOG	DAY	REV	PG

SITE/ACQ/LOS	FLIGHT EVENTS/HISTORY/BRIEFING

MSC FORM 1441 (APR 66)

NASA — MSC

FLIGHT DIRECTOR'S MISSION LOG

FLIGHT DIR MISSION LOG	DAY	REV	PG

SITE/ACQ/LOS	FLIGHT EVENTS/HISTORY/BRIEFING

MSC FORM 1441 (APR 66)

FLIGHT DIRECTOR'S MISSION LOG