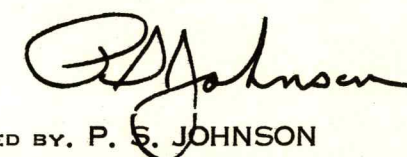


FAULT ISOLATION GUIDE

MCDONNELL DOUGLAS 
FLORIDA TEST CENTER

FAULT ISOLATION GUIDE

SATURN S-IVB STAGE

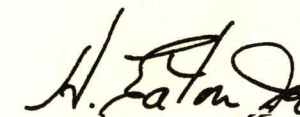


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SATURN S-IVB PROGRAM

REVISION A

1.0 PREFACE

<u>ORIGINAL PAGE NO.</u>	<u>UPDATED YES/ NO</u>	<u>DESCRIPTION</u>	<u>REVISED FIG CONTAINS PAGE NO.</u>	<u>REV</u>
1-0	YES	COVER SHEET	1.0	A
1-1	YES	APPROVAL PAGE	1-1	A
1-1.1	YES	TBL OF CONTENTS	1-1.1	A
1-1.2	YES	TBL OF CONTENTS	1-1.2	A
1-1.3	YES	TBL OF CONTENTS	1-1.3	A
		TBL OF CONTENTS	1-1.4	NEW
		TBL OF CONTENTS	1-1.5	NEW
1-2.1	YES	NARRATIVE	1-4	A
1-2.2	YES	NARRATIVE	1-5	A

2.0 LEGEND

<u>ORIGINAL PAGE NO.</u>	<u>UPDATED YES/ NO</u>	<u>DESCRIPTION</u>	<u>REVISED FIG CONTAINS PAGE NO.</u>	<u>REV</u>
2-1	NO	SCHEM SYMBOLS	2-1	ORIG
2-2	NO	SCHEM SYMBOLS	2-2	ORIG
2-3	NO	SCHEM SYMBOLS	2-3	ORIG
2-4	NO	SCHEM SYMBOLS	2-4	ORIG

3.0 POWER DISTRIBUTION SUBSYSTEM

<u>ORIGINAL PAGE NO.</u>	<u>UPDATED YES / NO</u>	<u>DESCRIPTION</u>	<u>REVISED FIG CONTAINS PAGE NO.</u>	<u>REV</u>
3-1	NO	NARRATIVE	3-1	ORIG
3-2	YES	SCHEMATIC	3-2	A
3-3	YES	NARRATIVE	3-3	A
3-4	NO	NARRATIVE	3-4	ORIG
3-5	YES	NARRATIVE	3-5	A
3-6	YES	NARRATIVE	3-6	A
3-7	YES	NARRATIVE	3-7	A
3-9	YES	SCHEMATIC	3-9	A
3-10	YES	SCHEMATIC	3-10	A
3-11	YES	SCHEMATIC	3-11	A
3-12	YES	SCHEMATIC	3-12	A
3-13	YES	SCHEMATIC	3-13	A
3-13.1	YES	SCHEMATIC	3-13.1	A
3-14	YES	SCHEMATIC	3-14	A
3-15	YES	SCHEMATIC	3-15	A
3-16	YES	SCHEMATIC	3-16	A
3-17	YES	SCHEMATIC	3-17	A
3-18	NO	SCHEMATIC	3-18	ORIG
3-19	YES	SCHEMATIC	3-19	A
3-20	YES	SCHEMATIC	3-20	A
3-21	YES	SCHEMATIC	3-21	A
3-22	NO	SCHEMATIC	3-22	ORIG
3-23	NO	SCHEMATIC	3-23	ORIG
3-24	YES	SCHEMATIC	3-24	A
3-25	YES	SCHEMATIC	3-25	A
3-26	YES	SCHEMATIC	3-26	A
3-35	YES	LOGIC DIAG	3-35	A
3-36	YES	LOGIC DIAG	3-36	A
3-37	YES	LOGIC DIAG	3-37	A
3-38	YES	LOGIC DIAG	3-38	A
3-39	YES	LOGIC DIAG	3-39	A

REV. A

1-1.1

4.0 PCM DDAS SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
4-1	NO	NARRATIVE
4-2	NO	NARRATIVE
4-3	NO	NARRATIVE
4-4	YES	NARRATIVE
4-5	YES	NARRATIVE
4-6	YES	NARRATIVE
4-7	NO	NARRATIVE
4-8	NO	NARRATIVE
4-9	NO	NARRATIVE
4-10	YES	BLOCK DIAG
4-11	NO	BLOCK DIAG
4-12	NO	SCHEMATIC
4-13	YES	BLOCK DIAG
4-14	NO	BLOCK DIAG
4-15	NO	SCHEMATIC
4-16	NO	SCHEMATIC
4-17	NO	SCHEMATIC
4-18	NO	BLOCK DIAG
4-35	NO	SCHEMATIC
4-36	NO	DIAGRAM
4-37	NO	SCHEMATIC
4-38	NO	DIAGRAM
4-39	NO	DIAGRAM
4-40	YES	SCHEMATIC
4-41	YES	SCHEMATIC
4-42	YES	TABLE
4-43	YES	TABLE
4-44	YES	TABLE
4-48	YES	SCHEMATIC
4-49	YES	SCHEMATIC
4-50	YES	SCHEMATIC

5.0 EBW SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
5-1	YES	NARRATIVE
5-2	YES	SCHEMATIC
5-3	YES	SCHEMATIC
5-4	YES	LOGIC DIAG

REVISED FIG CONTAINS

PAGE NO.	REV
4-1	ORIG
4-2	ORIG
4-3	ORIG
4-4	A
4-5	A
4-6	A
4-7	ORIG
4-8	ORIG
4-9	ORIG
4-10	A
4-11	ORIG
4-12	ORIG
4-13	A
4-14	ORIG
4-15	ORIG
4-16	ORIG
4-17	ORIG
4-18	ORIG
6-35	ORIG
6-36	ORIG
6-37	ORIG
4-38	ORIG
4-39	ORIG
4-40	A
4-41	A
4-42	A
4-43	A
4-44	A
4-48	A
4-49	A
4-50	A

6.0 RANGE SAFETY SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
6-1	YES	NARRATIVE
6-2	YES	NARRATIVE
6-4	NO	SCHEMATIC
6-5	YES	SCHEMATIC
6-6	YES	SCHEMATIC
6-7	YES	SCHEMATIC
6-8	YES	SCHEMATIC
6-9	YES	SCHEMATIC
6-10	YES	SCHEMATIC
6-11	YES	SCHEMATIC

7.0 PROPELLANT UTILIZATION SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
7-1	YES	NARRATIVE
7-2	YES	NARRATIVE
7-3	YES	SCHEMATIC
7-4	YES	SCHEMATIC
7-6	YES	LOGIC DIAG

8.0 HELIUM SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
8-1	YES	NARRATIVE
8-2	YES	NARRATIVE
8-3	YES	NARRATIVE
8-4	YES	MEASUREMENTS
8-5	YES	MEASUREMENTS
8-6	YES	DIAGRAM
8-7	YES	SCHEMATIC
8-8	YES	SCHEMATIC
8-9	YES	SCHEMATIC
8-11	YES	LOGIC DIAGRAM
8-12	NO	LOGIC DIAGRAM

REVISED FIG CONTAINS

PAGE NO.	REV
6-1	A
6-2	A
6-4	ORIG
6-5	A
6-6	A
6-7	A
6-8	A
6-9	A
6-10	A
6-11	A

REVISED FIG CONTAINS

PAGE NO.	REV
7-1	A
7-2	A
7-3	A
7-4	A
7-6	A

REVISED FIG CONTAINS

PAGE NO.	REV
8-1	A
8-2	A
8-3	A
8-4	A
8-5	A
8-5.1	NEW
8-6	A
8-7	A
8-7.1	NEW
8-7.2	NEW
8-7.3	NEW
8-7.4	NEW
8-7.5	NEW
8-8	A
8-8.1	NEW
8-8.2	NEW
8-8.3	NEW
8-8.3.1	NEW
8-8.4	NEW
8-9	A
8-11	A
8-12	A

9.0 O2H2 BURNER SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
9-1	YES	NARRATIVE
9-2	YES	NARRATIVE
9-3	YES	NARRATIVE
9-4	YES	SCHEMATIC
9-5	YES	SCHEMATIC
9-6	YES	SCHEMATIC
9-7	YES	SCHEMATIC
9-8	YES	LOGIC DIAGRAM

REVISED FIG CONTAINS

PAGE NO.	REV
9-1	A
9-2	A
9-3	A
9-4	A
9-5	A
9-6	A
9-7	A
9-8	A

10.0 LOX TANK PRESSURIZATION SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
10-1	YES	NARRATIVE
10-2	YES	NARRATIVE
10-3	YES	NARRATIVE
10-4	YES	NARRATIVE
10-5	NO	NARRATIVE
10-6	YES	NARRATIVE
10-7	YES	SCHEMATIC
10-8	YES	SCHEMATIC
10-9	YES	SCHEMATIC
10-10	YES	SCHEMATIC

REVISED FIG CONTAINS

PAGE NO.	REV
10-1	A
10-2	A
10-3	A
10-4	A
10-5	ORIG
10-6	A
10-7	A
10-8	A
10-9	A
10-10	A

11.0 LH2 SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
11-1	YES	NARRATIVE
11-2	YES	NARRATIVE
11-3	YES	NARRATIVE
11-4	YES	NARRATIVE
11-5	YES	NARRATIVE
11-6	NO	NARRATIVE
11-7	YES	NARRATIVE
11-8	NO	NARRATIVE
11-9	NO	NARRATIVE
11-10	NO	NARRATIVE
11-11	NO	NARRATIVE
11-12	YES	SCHEMATIC
11-13	YES	SCHEMATIC
11-14	YES	SCHEMATIC
11-15	YES	SCHEMATIC
11-16	YES	SCHEMATIC

REVISED FIG CONTAINS

PAGE NO.	REV
11-1	A
11-2	A
11-3	A
11-4	A
11-5	A
11-6	ORIG
11-7	A
11-8	ORIG
11-9	ORIG
11-10	ORIG
11-11	ORIG
11-12	A
11-13	A
11-14	A
11-15	A
11-16	A

12.0 J-2 ENGINE SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
12-1	YES	NARRATIVE
12-2	YES	NARRATIVE
12-3	NO	NARRATIVE
12-4	YES	NARRATIVE
12-5	NO	SCHEMATIC
12-6	YES	SCHEMATIC
12-8	YES	SCHEMATIC
12-9	YES	SCHEMATIC
		SCHEMATIC
12-10	YES	SCHEMATIC
		SCHEMATIC
12-11	YES	SCHEMATIC
12-13	NO	SCHEMATIC

REVISED FIG CONTAINS

PAGE NO.	REV
12-1	A
12-2	A
12-3	ORIG
12-4	A
12-5	ORIG
12-6	A
12-8	A
12-9	A
12-9.1	NEW
12-10	A
12-10.1	NEW
12-11	A
12-13	ORIG

13.0 HYDRAULIC SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION
13-1	YES	NARRATIVE
13-2	YES	NARRATIVE
13-3	YES	NARRATIVE
13-4	YES	SCHEMATIC
13-5	YES	DIAGRAM
13-6	YES	LOGIC DIAG

REVISED FIG CONTAINS

PAGE NO.	REV
13-1	A
13-2	A
13-3	A
13-4	A
13-5	A
13-6	A

14.0 AUXILIARY PROPULSION SUBSYSTEM

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION	REVISED FIG CONTAINS PAGE NO.	REV
14-1	NO	NARRATIVE	14-1	ORIG
14-2	NO	NARRATIVE	14-2	ORIG
14-3	NO	NARRATIVE	14-3	ORIG
14-4	NO	NARRATIVE	14-4	ORIG
14-5	NO	NARRATIVE	14-5	ORIG
14-6	NO	NARRATIVE	14-6	ORIG
14-7	NO	NARRATIVE	14-7	ORIG
14-8	NO	NARRATIVE	14-8	ORIG
14-9	NO	NARRATIVE	14-9	ORIG
14-10	YES	NARRATIVE	14-10	A
14-11	NO	DIAGRAM	14-11	ORIG
14-12	NO	DIAGRAM	14-12	ORIG
14-13	YES	SCHEMATIC	14-13	A
14-14	YES	SCHEMATIC	14-14	A
14-15	YES	SCHEMATIC	14-15	A
14-16	YES	SCHEMATIC	14-16	A
14-17	YES	SCHEMATIC	14-17	A
14-18	YES	MEASUREMENTS	14-18	A
14-19	YES	MEASUREMENTS	14-19	A
14-20	YES	SCHEMATIC	14-20	A

15.0 PROPELLANT TANKING SYSTEM (P.T.C.S.)

ORIGINAL PAGE NO.	UPDATED YES / NO	DESCRIPTION	REVISED FIG CONTAINS PAGE NO.	REV
NOT APPLICABLE		NARRATIVE	15-1	NEW
↓		NARRATIVE	15-2	NEW
		NARRATIVE	15-3	NEW
		NARRATIVE	15-3A	NEW
		DIAGRAM	15-4	NEW
		NARRATIVE	15-5	NEW
		NARRATIVE	15-6	NEW
		NARRATIVE	15-7	NEW
		DIAGRAM	15-8	NEW
		NARRATIVE	15-9	NEW
		SYMBOLS	15-9A	NEW
		SCHEMATIC	15-10	NEW
		SCHEMATIC	15-11	NEW
		SCHEMATIC	15-12	NEW
		SCHEMATIC	15-13	NEW
		SCHEMATIC	15-14	NEW
		SCHEMATIC	15-15	NEW
		SCHEMATIC	15-16	NEW
		SCHEMATIC	15-17	NEW
		SCHEMATIC	15-18	NEW
		SCHEMATIC	15-19	NEW
		SCHEMATIC	15-20	NEW
		SCHEMATIC	15-21	NEW
		SCHEMATIC	15-22	NEW
		SCHEMATIC	15-23	NEW
		SCHEMATIC	15-24	NEW
		SCHEMATIC	15-25	NEW
		SCHEMATIC	15-26	NEW
		SCHEMATIC	15-27	NEW
		SCHEMATIC	15-28	NEW
		SCHEMATIC	15-29	NEW
		SCHEMATIC	15-30	NEW
		LOGIC DIAG	15-31	NEW
		LOGIC DIAG	15-32	NEW
		LOGIC DIAG	15-33	NEW
		LOGIC DIAG	15-34	NEW
		LOGIC DIAG	15-35	NEW
		LOGIC DIAG	15-36	NEW
		LOGIC DIAG	15-37	NEW
		LOGIC DIAG	15-38	NEW
		LOGIC DIAG	15-39	NEW
		LOGIC DIAG	15-40	NEW
		LOGIC DIAG	15-41	NEW
		LOGIC DIAG	15-42	NEW
		LOGIC DIAG	15-43	NEW

1.0

INTRODUCTION

AS WITH ALL COMPLEX ELECTRO-MECHANICAL SYSTEMS, THERE IS A NEED FOR DETAILED PRE-PLANNED FAULT ANALYSIS. THIS ANALYSIS TAKES PLACE IN MANY WAYS AND IS REFLECTED IN MANY DOCUMENTS. FOR EXAMPLE, IN THE BASIC DESIGN OF THE SYSTEM, FAULT ANALYSIS LOGIC IS PERFORMED IN ORDER TO FULFILL THE SPECIFIC OVERALL OBJECTIVES OF END ITEM DESIGN CRITERIA. SUCH AS, "NO SINGLE MALFUNCTION WILL RESULT IN CATASTROPHIC FAILURE." ADDITIONAL FAULT ANALYSIS IS PERFORMED IN THE ESTABLISHMENT OF RELIABILITY MATH-MODELS AND HARDWARE CRITICALITY VALUES. ALSO, MANY INDIVIDUAL AND INDEPENDENT INVESTIGATIONS ARE CONDUCTED AS A RESULT OF THE FUNDAMENTAL APPROACH OF HUNDREDS OF ENGINEERS INVOLVED IN THE DEVELOPMENT OF SOFTWARE PROGRAMS UTILIZED IN CHECKOUT AND LAUNCH ACTIVITY.

HOWEVER, THE STUDIES AND INVESTIGATIONS CONDUCTED THUS FAR DO NOT PROVIDE AN ADEQUATE END-TO-END FAULT ISOLATION AND ANALYSIS TOOL FOR THE S-IVB VEHICLE AND ASSOCIATED LAUNCH COMPLEX ESE SYSTEMS. IT IS FOR THE PURPOSE OF CREATING SUCH A TOOL THAT THIS DOCUMENT WAS PREPARED.

IN ORDER TO EFFICIENTLY ANALYZE A MALFUNCTION AND CONDUCT THE NECESSARY TROUBLESHOOTING OPERATIONS, THE TEST ENGINEER MUST BE EQUIPPED WITH AS MUCH TECHNICAL BACKGROUND AND INFORMATION AS POSSIBLE UNDER ONE COVER. SYSTEM DESCRIPTIONS, SYSTEM SCHEMATICS, AND LOGIC DIAGRAMS IS THE INFORMATION REQUIRED TO PROCEED RAPIDLY THROUGH THE PROCESS OF DETECTION, PROTECTION, ISOLATION, CORRECTION, AND VALIDATION IS PRESENTED IN A CONCENTRATED FORMAT.

THE INTENDED EMPHASIS OF THIS DOCUMENT HAS BEEN PLACED ON FAULT ISOLATION WHEREBY THE TEST ENGINEERS MAY UTILIZE SUBSYSTEM OR COMPONENT DRAWINGS TO AFFECT TROUBLESHOOTING AFTER THE PROBLEM HAS BEEN SUFFICIENTLY ANALYZED TO THAT LEVEL. HOWEVER, IT IS HOPED THAT THIS DOCUMENT WILL ALSO PROVIDE ADDITIONAL BENEFITS AVAILABLE THROUGH EXPANSION OF THE TECHNIQUES AND DISCIPLINES USED IN ITS CREATION. THESE ADDITIONAL BENEFITS ARE LEFT TO THE PURVIEW OF EACH READER AND S-IVB ORGANIZATIONAL ELEMENT.

1.1

PURPOSE

THE PURPOSE OF THIS DOCUMENT IS TO PROVIDE A COMPACT SOURCE OF INFORMATION SUFFICIENT TO GAIN SYSTEM KNOWLEDGE OF THE S-IVB VEHICLE AND GSE AND TO PRESENT A GUIDE FOR THE FAULT ISOLATION OF CRITICAL S-IVB STAGE AND GSE MALFUNCTIONS.

1.2

SCOPE

THIS DOCUMENT CONTAINS SYSTEM DESCRIPTIONS, SYSTEM SCHEMATICS AND LOGIC DIAGRAMS FOR USE IN THE PRE-PLANNED STUDY OF CRITICAL S-IVB STAGE AND GSE MALFUNCTIONS. THIS DOCUMENT MAY ALSO BE USED AS A TRAINING AID TO NEWLY ASSIGNED ENGINEERING PERSONNEL, OR BY ENGINEERS DESIRING INFORMATION IN A FIELD OUTSIDE OF THEIR WORK EXPERIENCE, FURTHERMORE, THIS DOCUMENT MAY BE UTILIZED BY TEST MANAGEMENT TO TRACK TROUBLESHOOTING OPERATIONS, PRESENTING A COMPREHENSIVE DESCRIPTION OF THE PROGRESS OF THE ANALYSIS, AND THUS ASSIST THEM IN DETERMINING THE RESULTING IMPACT ON TEST OPERATIONS.

TO SIMPLIFY THE INITIATED STUDY, ONLY CRITICAL MEASUREMENTS WERE USED IN EACH SYSTEM. THE MOST CRITICAL MEASUREMENTS, THE LAUNCH MISSION RULES REDLINES, ALONG WITH OTHER MEASUREMENTS SUCH AS REDLINE BACK-UPS AND BLUELINES WERE USED TO SUPPORT TROUBLESHOOTING.

AN ADDITIONAL REQUIREMENT OF THIS DOCUMENT WAS TO COMPILE ELECTRO-MECHANICAL SYSTEM SCHEMATICS WITH SUFFICIENT CONTINUITY TO DESCRIBE THE CONTROL NETWORKS, INSTRUMENTATION, AND MECHANICAL DESIGN ELEMENTS ON ONE DRAWING. THIS WAS ACCOMPLISHED BY THE OMISSION OF SOME DETAILED INFORMATION SUCH AS CONNECTOR PIN NUMBERS. BUT IN EACH CASE THE DOCUMENTS FROM WHICH THESE SCHEMATICS WERE DERIVED ARE REFERENCED DOWN TO THE PAGE NUMBER, SO THAT WHEN THE FAULT HAS BEEN SUFFICIENTLY ISOLATED, THE RELEASED SUBSYSTEM DRAWING CAN BE UTILIZED FOR EXTENSIVE TROUBLESHOOTING AS REQUIRED.

THE LATEST VEHICLE AND ESE SCHEMATIC CONFIGURATION AVAILABLE ON AS-510 AND LAUNCH COMPLEX 39 1-1 AS OF APRIL, 1971, WAS USED FOR THIS REVISION. DISCUSSION CONCERNED WITH THE UPDATING OF THE INFORMATION CONTAINED HEREIN IS NOT WITHIN THE SCOPE OF THIS DOCUMENT.

1.3 GUIDELINES

1.3.1 SYSTEM SCHEMATICS:

THE SYSTEM SCHEMATICS ARE PRESENTED TO SHOW A TOTAL ELECTRO-MECHANICAL CONCEPT. THE FOLLOWING RULES WERE USED IN PREPARATION OF THE SYSTEM SCHEMATICS.

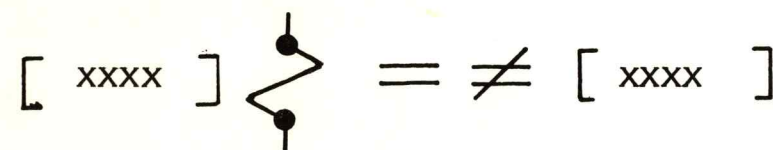
- 1) ESE AND STAGE CIRCUITS ARE BOTH SHOWN
- 2) ESE PANELS ARE IDENTIFIED
- 3) STAGE REFERENCE DESIGNATIONS ARE SHOWN
- 4) ALL RELAYS ARE IDENTIFIED ALONG WITH A PAGE REFERENCE TO THE ESE OR STAGE SCHEMATICS
- 5) DDAS MEASUREMENTS AND CHANNEL ASSIGNMENTS ARE SHOWN.
- 6) ESE DISCRETE NUMBERS ARE SHOWN
- 7) MECHANICAL AND ELECTRICAL INFORMATION IS SHOWN

1.4 REVISION "A"

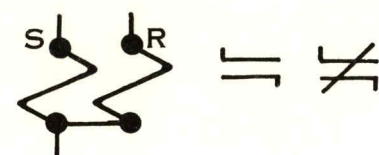
NARRATIVE INFORMATION, SYSTEM SCHEMATICS, AND LOGIC DIAGRAMS WERE THE ONLY ITEMS UPDATED. FLOW CHARTS AND MALFUNCTION MATRICES WERE NOT ATTEMPTED TO BE UPDATED. THE TABLE OF CONTENTS HAS BEEN MODIFIED TO ILLUSTRATE SPECIFICALLY WHAT PAGES WERE UPDATED AND WHAT EXACTLY THE NEW REV. "A" OF THE F.I.G. DOCUMENT CONTAINS. THE REVISED PAGE NUMBERS ARE COMPATIBLE WITH INSERTING INTO THE ORIGINAL DOCUMENT, OR THE REVISED F.I.G. DOCUMENT MAY BE USED AS IS. IN ORDER TO USE THE REVISED DOCUMENT AS DISTRIBUTED, IT WAS NECESSARY TO REPRODUCE SOME ORIGINAL VELLUMS WHICH DID NOT REQUIRE UPDATE. THE TABLE OF CONTENTS CLEARLY DEFINES EACH SHEET'S UPDATE CONFIGURATION.

2.0 LEGENDS

2.1 SCHEMATIC SYMBOLS



RELAY COIL AND CONTACTS
REFERENCE INFORMATION IN
BRACKET REGARDING LOCATION
OF OTHER CONTACTS OR COILS
ON RELEASED SCHEMATICS



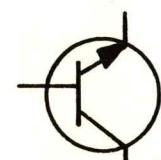
[ESE-XXX] IS ESE PAGE XXX
[P-XXX] IS PWR PAGE XXX
[C-C1/3] IS ∇ CONT. SEQ. 1 SHT. 3
[I-C3/4] IS ∇ INST. SEQ. 3 SHT. 4



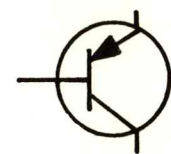
DIODE



ZENER DIODE



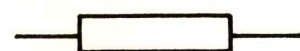
NPN TRANSISTOR



PNP TRANSISTOR



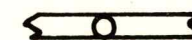
CAPACITOR



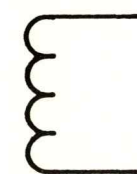
RESISTOR



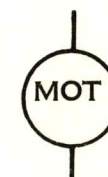
CIRCUIT BREAKER



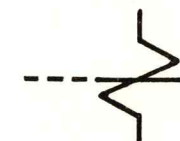
ELECTRICAL BUS



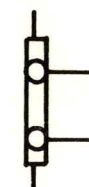
INDUCTOR



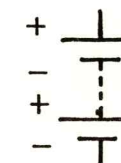
MOTOR



SOLENOID VALVE
(DOTTED LINE GO TO VALVE OPERATED
BY SOLENOID)



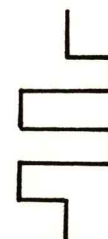
SHUNT



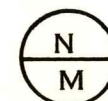
BATTERY



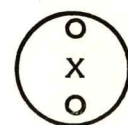
FUSE



HEATER



CONTINUATION SYMBOL
N IS THE FIND NUMBER
M IS THE PAGE NUMBER



PANEL LIGHT
X MAY INDICATE COLOR
I.E. R=RED G=GREEN



PRESSURE SWITCH. SHOWN IN
DEPRESSURIZED STATE UNLESS
OTHERWISE SPECIFIED



PANEL METER - (ASSOCIATED
METER CIRCUIT)



3 POSITION



PUSH BUTTON SWITCH



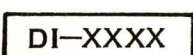
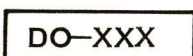
INDICATES THAT SIGNAL IS
DISPLAYED ON THE EVENTS PANEL



STRIP CHART



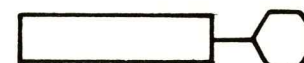
COMPUTER DISCRETE
DI INDICATES AN INPUT
DO INDICATES AN OUTPUT



MOBILE LAUNCHER COMPUTER
DISCRETE INPUT WITH PARALLEL
INPUT TO DIGITAL EVENTS EVALUATOR



PRESSURE TRANSDUCER



MOBILE LAUNCHER DISCRETE WITH
INPUT TO DEE ONLY



INDICATES MEASUREMENT ON DDAS
MEASUREMENT NO. , XDUCER RANGE
AND CHANNEL ASSIGNMENT ARE SPECIFIED
IN BLOCK. XXX INDICATES GND OR
VEHICLE, * INDICATES MEAS. IS REDUN-
DANTLY XMITTED ON THE DI1 LINK.



INDICATES SIGNAL TO INTEGRATION
DISTRIBUTOR.



CONTROL PNEUMATICS



FUEL FLOW (LH2 OR GH2)
(MMH)



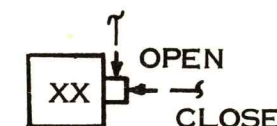
OXIDIZER FLOW (LOX OR GOX)
(N₂O₄)



PRESSURIZATION HELIUM



HELIUM BOTTLE


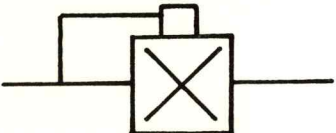



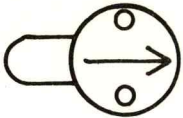
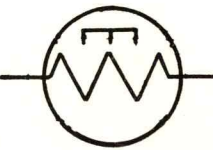

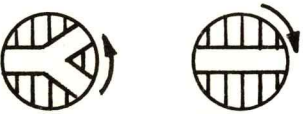



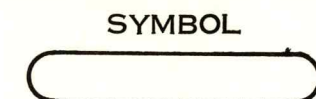
PNEUMATICALLY OPERATED VALVE SHOWING
OPENING AND CLOSING PNEUMATICS WHAT-
EVER IS APPLICABLE. XX MAY INDICATE:
M/L = MECH LATCH
N.C. = NORMALLY CLOSED
N.O. = NORMALLY OPEN



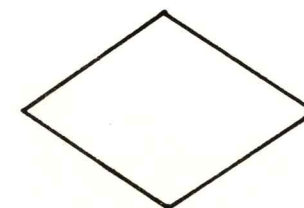
TEMPERATURE TRANSDUCER

2.2 FLOW CHART SYMBOLS:

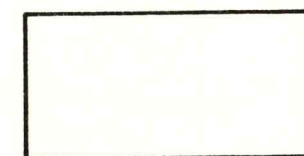
	FLOWMETER
	PRESSURE REGULATOR
	PLENUM CHAMBER
	CHECK VALVE
	ORIFICE
	PUMP
	TEMP SENSOR
	FILTER
	VALVES — AREAS NOT CROSS HATCHED INDICATE FLOW PATH. ARROWS INDICATE DIRECTION OF ROTATION UPON ACTUATION
	VALVES XX INDICATES N.C. OR N.O. N.C. NORMALLY CLOSED N.O. NORMALLY OPEN



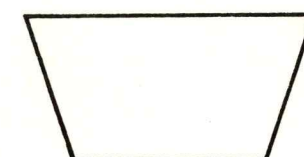
START OF ROUTINE



INTERROGATION



NARRATIVE (INFORMATION)



TUTORIAL (INSTRUCTION)



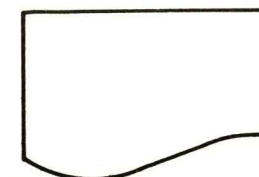
PRE-DEFINED PROCESS



OFF PAGE CONNECTOR



ON PAGE CONNECTOR

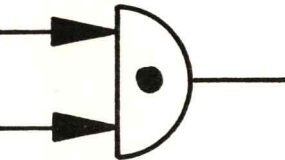


INFORMATION

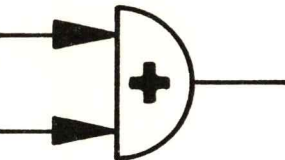
2.3 LOGIC SYMBOLS

SYMBOL

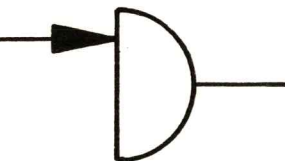
DEFINITION



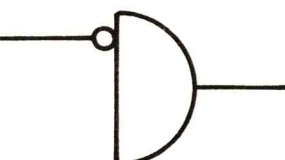
AND GATE



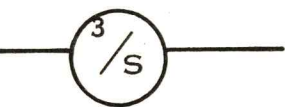
OR GATE



ARROW INDICATES THAT THIS SIGNAL MUST BE ON TO ENABLE THE GATE OUTPUT TO BE ON



CIRCLE INDICATES THAT SIGNAL MUST BE OFF TO ENABLE THE GATE OUTPUT TO BE ON



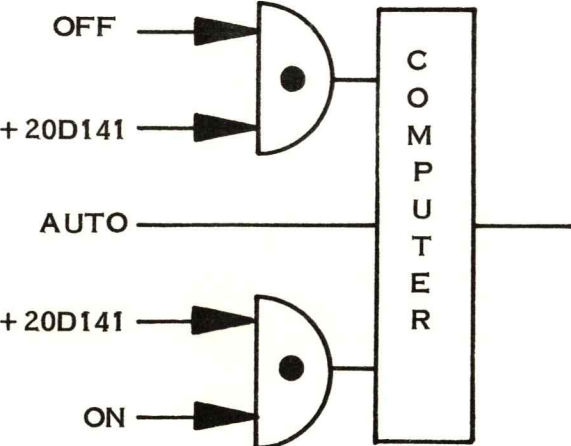
TIMING SYMBOL
NUMBER INDICATES TIME INTERVAL AND THE LETTER INDICATES TIME
S = SECONDS, U = MICRO-SECONDS,
M = MILLISECONDS



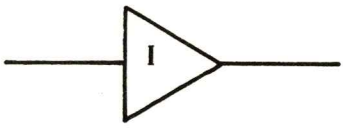
ON PAGE CONNECTION



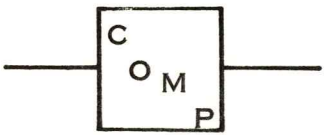
DIAMOND FLAG
USED TO SHOW SIGNALS THAT ARE INDICATIONS AND HAVE NO CONTROL FUNCTION



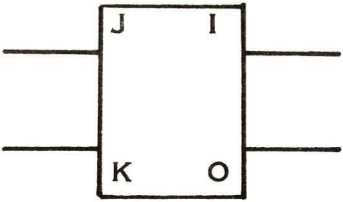
COMPUTER SWITCH INTERFACE
ON ISSUE MDO ON/OFF AND INHIBIT
AUTO ISSUE MDO OFF IF ON AND
RELEASE INHIBIT
OFF ISSUE MDO OFF/ON AND INHIBIT



INVERTER



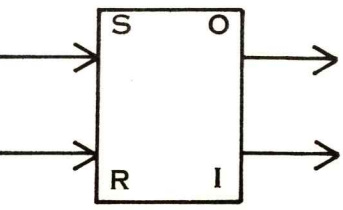
COMPUTER DISCRETE INTERFACE



J-K FLIP FLOP

A	0	1	0	1
B	0	0	1	1
C^n	0	1	0	1
	0	1	0	0
C^{n+1}				

 C^n = PRESENT STATE
 C^{n+1} = NEXT STATE



MAG. LATCH RELAY (FLIP FLOP)
SHOWN IN RESET STATE:
"0" OUTPUT GOES TO "1" AT SET
"1" OUTPUT GOES TO "0" AT SET

(RELAY NO)

3.0

POWER DISTRIUBTION

3.1

SYSTEM DESCRIPTION

I.

GENERAL DESCRIPTION

A. INTRODUCTION

FOR THE PURPOSE OF THIS DOCUMENT, POWER DISTRIBUTION SYSTEM WILL MEAN THE FOLLOWING:

1. THAT PORTION OF SATURN V ELECTRONIC SUPPORT EQUIPMENT (ESE) THAT SUPPLIES POWER TO SIVB ORIENTED GROUND SUPPORT EQUIPMENT (GSE).
2. THE SIVB POWER ORIENTED FLIGHT HARDWARE.
3. THE FLIGHT AND ESE CIRCUITS USED TO CONTROL AND MONITOR 1 AND 2 ABOVE.

NOTE: IN CASES INVOLVING OVERLAP OF RESPONSIBILITY (POWER SOURCES NOT EXCLUSIVELY FOR SIVB USE)

ONLY THE SIVB APPLICATION WILL BE CONSIDERED.

EXAMPLE: REF. FIG. 7 (REDUNDANT POWER)

THE GSE POWER IS SUPPLIED BY MOBILE LAUNCHER (ML) POWER SUPPLIES AND IS DISTRIBUTED TO THE SIVB STAGE AND THROUGHOUT THE SIVB MOBILE LAUNCHER EQUIPMENT. THREE 28VDC AND ONE 56VDC POWER SUPPLIES ARE USED. ALTHOUGH THESE HAVE LOCAL MOBILE LAUNCHER CONTROL, ONLY REMOTE CONTROL FROM LAUNCH CONTROL CENTER (LCC) WILL BE CONSIDERED.

EACH POWER SUPPLY HAS BUILT-IN PROTECTION FOR OVER-VOLTAGE, UNDER-VOLTAGE, OVER-CURRENT AND OVER-TEMPERATURE. BUILT-IN PROTECTION IS SUPPLEMENTED BY EXTERNAL PROTECTION FOR VOLTAGE (OVER AND UNDER VOLTAGE MONITORS) AND CURRENT (FUSES). SINCE EXTERNAL PROTECTION FOR THESE FUNCTIONS FURNISH PROTECTIVE ACTION AT PARAMETER LEVELS WELL WITHIN THE SAFE LIMITS OF BUILT-IN PROTECTION, NO FURTHER MENTION OF BUILT-IN PROTECTION WILL BE MADE.

NOTE: AC POWER TO ML POWER SUPPLIES IS PROTECTED BY CIRCUIT BREAKERS.

THE ML POWER SUPPLY REGULATORS SENSE LOCALLY OR, IF SIVB STAGE POWER IS APPLIED (EXTERNALLY), FROM SIVB STAGE BUSES. THIS ASSURES UNIFORM VOLTAGE AT THE APPROPRIATE BUS-IN ADDITION, SHOULD A ML POWER SUPPLY OUTPUT VOLTAGE REACH A PRE-DETERMINED MAXIMUM OR MINIMUM, ITS ASSOCIATED OVER AND UNDER VOLTAGE MONITOR WILL TRANSFER THE LOAD TO A BACKUP BATTERY.

NOTE: FIGURES 3A THROUGH 3D ARE SIMPLIFIED SCHEMATICS FOR THE DERIVATION OF THE PRINCIPAL ESE BUSES.

NOTICE +23D210 CAN BE USED AS A REDUNDANT POWER SUPPLY FOR 4D100, 4D200 AND 4D300. THIS CAPABILITY IS NOT USED IN COUNTDOWN CONFIGURATION. SHOULD A BACKUP BATTERY NOT BE AVAILABLE DURING CHECK-OUT, THIS SOURCE SERVES AS A BACKUP. ALSO NOTICE THE BACKUP BATTERIES SUPPLY TWO VOLTAGE LEVELS. THE LOWER LEVEL VOLTAGE IS DIRECTLY (EXCEPT FOR BLOCKING DIODES) IN PARALLEL WITH ITS ASSOCIATED POWER SUPPLY. IF, FOR ANY REASON, THE ML POWER SUPPLY IS SWITCHED OFF, THE LOWER BACKUP BATTERY VOLTAGE ASSUMES THE LOAD AND IS USED AS A POWER SOURCE FOR SWITCHING THE HIGHER BACKUP BATTERY VOLTAGE ON LINE. THIS ASSURES THE PRINCIPAL BUS A TRANSIENT LEVEL NOT LOWER THAN THE ASSOCIATED BACKUP BATTERY LOWER LEVEL VOLTAGE.

FIGURES 3A THROUGH 3D ALSO SHOW FUSING AND CIRCUIT BREAKER PROTECTION LEVELS FOR PRINCIPAL BUSES.

B. SIVB/V ESE AND STAGE BUSES

1. LCC BUSSES

10 VOLT BUSSES

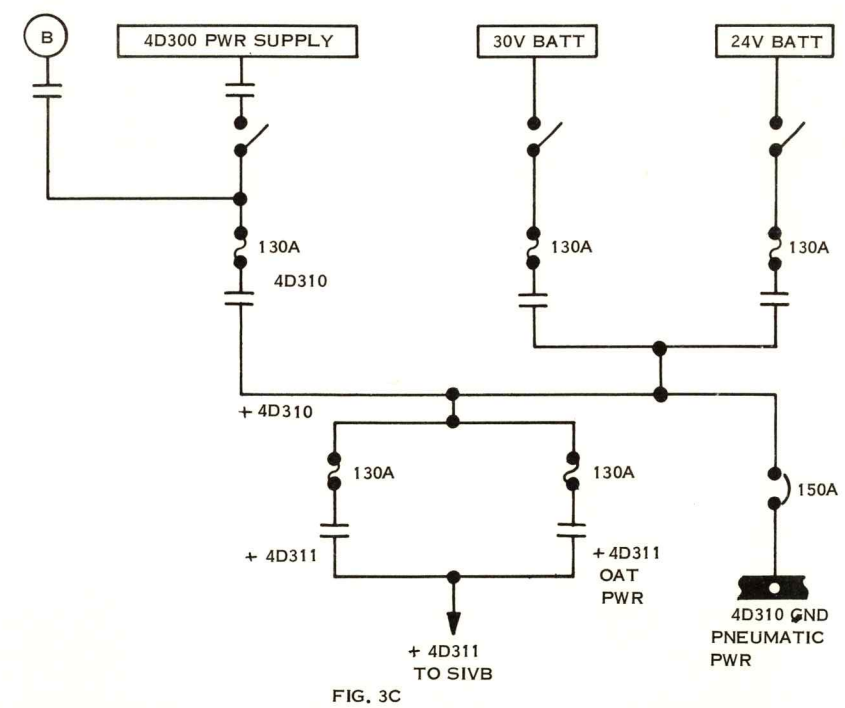
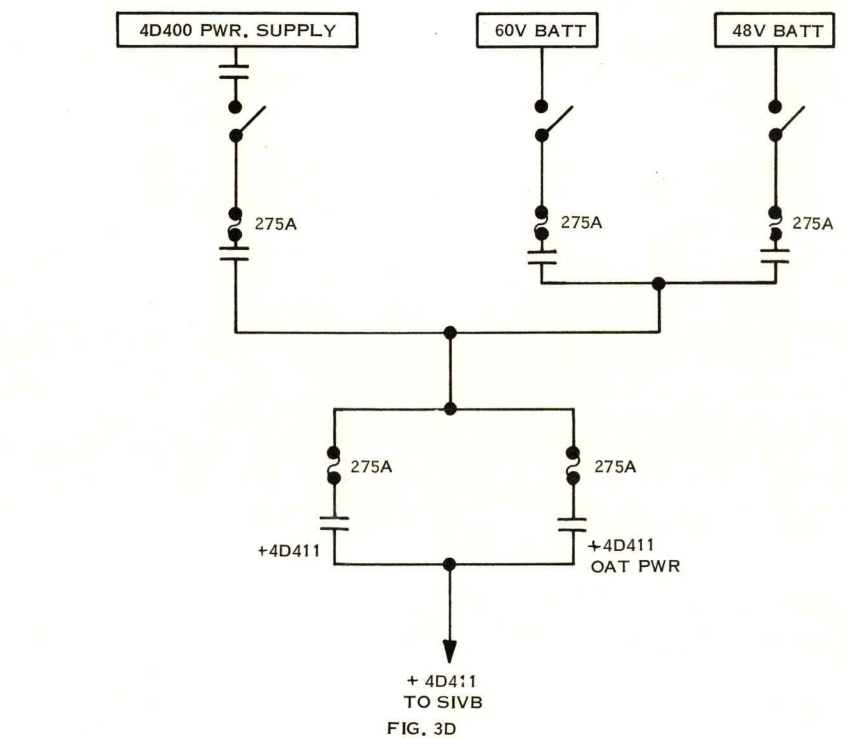
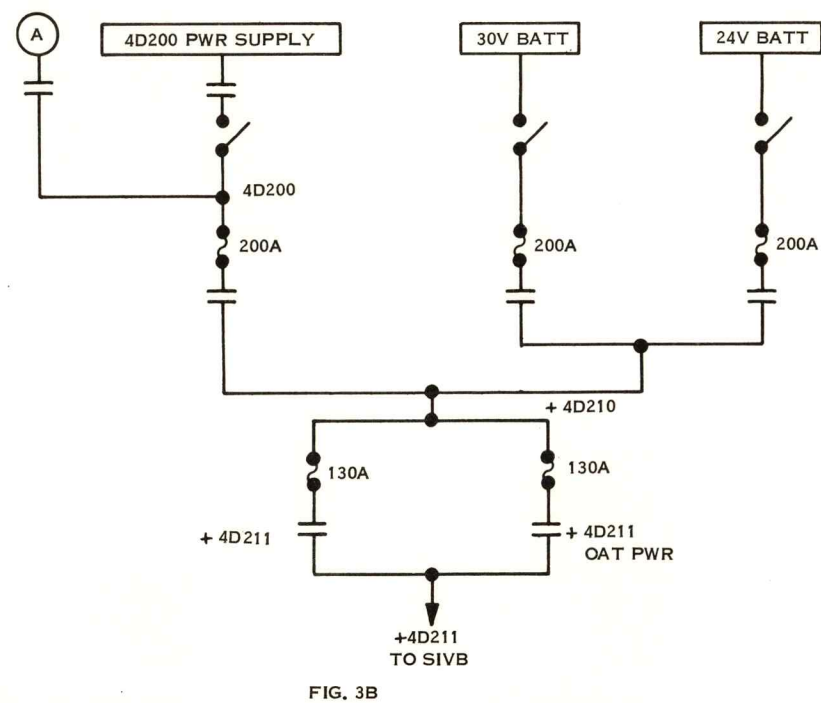
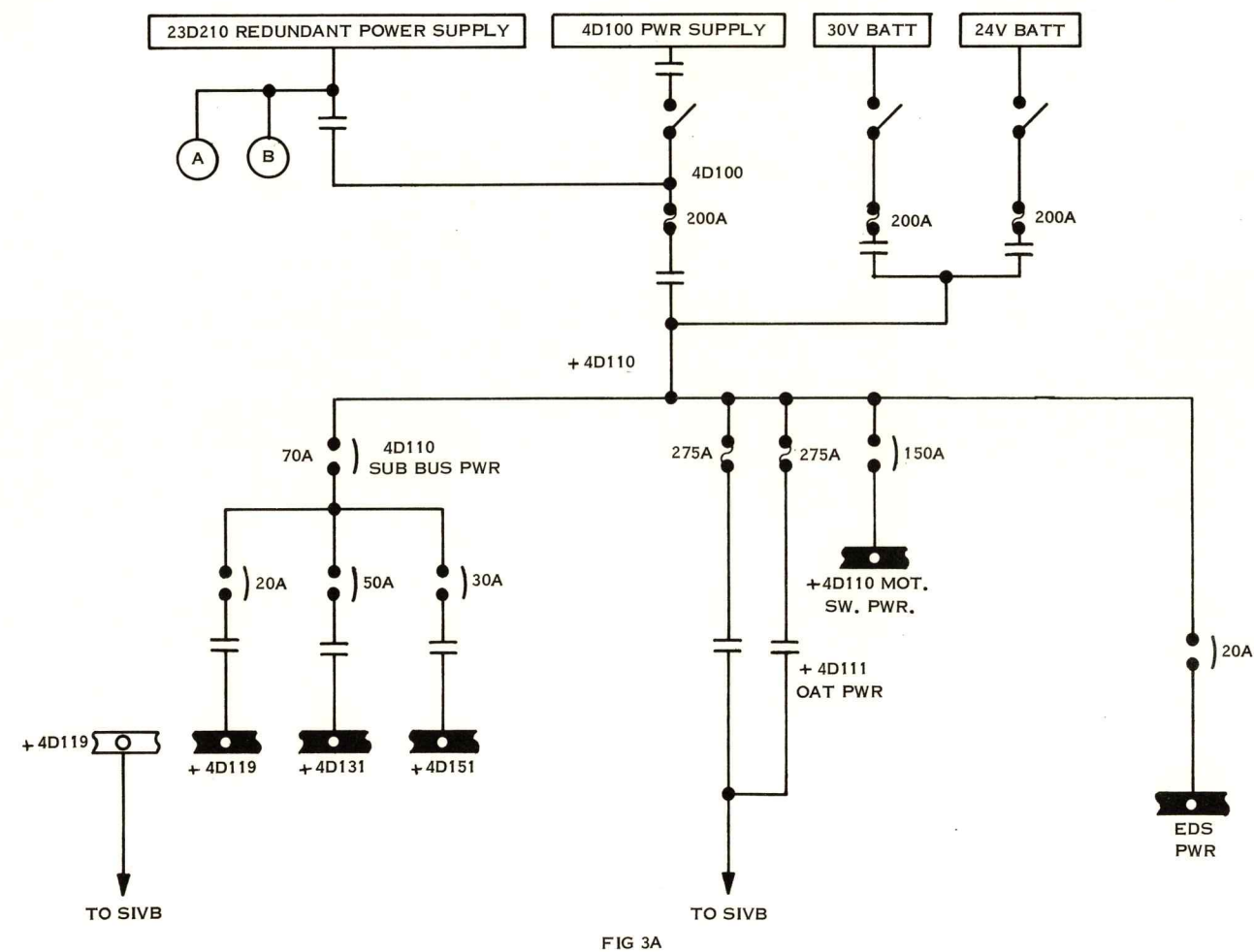
+24D810 BUS SUPPLIES FROM S-IVB DIGITAL RECEIVING STATION AND USED FOR REFERENCING STAGE DDAS ANALOG SIGNALS.

+24D910 BUS SUPPLIED FROM I.U. DIGITAL RECEIVING STATION AND USED FOR REFERENCING STAGE DDAS ANALOG SIGNALS.

+34D810 BUS SUPPLIED FROM SYSTEMS INTEGRATION AND USED FOR REFERENCING GROUND DDAS ANALOG SIGNALS.

+34D910 BUS SUPPLIED FROM SYSTEMS INTEGRATION AND USED FOR REFERENCING GROUND DDAS ANALOG SIGNALS.

DERIVATION OF PRINCIPAL BUSES



- +20D233 BUS SUPPLIED FROM 20D200 POWER SUPPLY THAT CONTROLS RELAY LOGIC TO ENABLE 4DX00 POWER SUPPLIES.
- +20D133 BUS SUPPLIED FROM 20D100 POWER SUPPLY THAT ENABLE SWITCHES IN THE DC POWER SUP CONTROL PANEL.
- +28-VOLT BUSSES
- +20D141 BUS SUPPLIED FROM 20D100 POWER SUPPLY MANUALLY SWITCHES ON AND OFF. SUPPLIES HARDWIRE LIGHT FUNCTIONS AND COMPUTER INTEGRATED SWITCH FUNCTIONS.
- +KDP-4 BUS IS USED TO POWER PROPELLANT LOADING MASS DECODERS AND INDICATORS ON PROPELLANT MONITOR PANEL.
- +20D241 BUS IS SUPPLIED FROM 20D200 POWER SUPPLY AND IS MANUALLY SWITCHED ON AND OFF. HARDWIRE SWITCH FUNCTIONS USE THIS POWER.

2. MOBILE LAUNCHER AND STAGE BUSES

5-VOLT BUSES

- +4D81 STAGE MEASURING BUS FWD. NO. 1 SUPPLIED FROM 4D31.
- +4D82 STAGE MEASURING BUS AFT SUPPLIED FROM 4D31.
- +4D83 STAGE MEASURING BUS FWD. NO. 2 SUPPLIED FROM 4D21.
- +4D810 ESE GROUND MEASURING BUS ENERGIZED WHEN GROUND MEASURING SWITCH IS POSITIONED ON.

20-VOLT BUSES

- +4D51 STAGE INSTRUMENTATION BUS
- 4D71.1 STAGE INSTRUMENTATION BUS -20VDC GENERATED BY THE FWD. 5VDC EXCITATION MODULE.
- 4D71.2 STAGE INSTRUMENTATION BUS -20VDC GENERATED BY THE AFT 5VDC EXCITATION MODULE.

28-VOLT BUSES

- +4D10 SUPPLIED DIRECTLY FROM AFT BATTERY NO. 1
- +4D11 STAGE BUS SUPPLIED FROM 4D111 BEFORE POWER TRANSFER AND 4D10 AFTER TRANSFER TO INTERNAL.
- +4D12 APS MODULE I POWER SUPPLIED FROM 4D11 STAGE BUS.
- +4D13 APS MODULE II POWER SUPPLIED FROM 4D11 STAGE BUS.
- +4D15 SEQUENCER BUS SUPPLIED FROM 4D11 STAGE BUS.
- +4D20 SUPPLIED DIRECTLY FROM FORWARD BATTERY NO. 2.
- +4D21 STAGE BUS SUPPLIED FROM 4D211 BEFORE POWER TRANSFER AND 4D20 AFTER POWER TRANSFER TO INTERNAL.
- +4D30 SUPPLIED DIRECTLY FROM FORWARD BATTERY NO. 1
- +4D31 STAGE BUS SUPPLIED FROM 4D311 BEFORE POWER TRANSFER AND 4D30 AFTER POWER TRANSFER TO INTERNAL.
- +4D110 ESE BUS NO. 1 SUPPLIED FROM 4D100 POWER SUPPLY. MANUALLY SWITCHES ON AND OFF.
- +4D111 STAGE BUS SUPPLIED FROM 4D110 BUS THROUGH POWER CONTACTOR. DE-ENERGIZED WHEN POWER TRANSFER TO INTERNAL IS COMPLETE.
- +4D119 ESE AND STAGE INDICATION BUS ENERGIZED WHEN THE COMMIT SIGNAL IS NOT PRESENT, ALL PLUGS ARE CONNECTED, AND THE INDICATION BUS SWITCH IS ON. THIS BUS MAY ALSO BE ENERGIZED BY THE SIMULATED FLIGHT SWITCH AND DE-ENERGIZED BY THE PLUG DROP TEST. THE COMMIT SIGNAL DE-ENERGIZES THE BUS DURING NORMAL SEQUENCE.
- +4D121 STAGE BUS SUPPLIED FROM 4D211. CONTROLLED BY CHECKOUT MEASUREMENT GROUP SWITCH.
- +4D131 ESE COMMIT BUS SUPPLIED FROM 4D110. IT IS ENERGIZED WHEN STAGE POWER ON COMMAND IS GIVEN AND COMMIT SIGNAL IS NOT PRESENT. BUS IS DE-ENERGIZED WHEN COMMIT SIGNAL IS GIVEN.
- +4D151 ESE PRELAUNCH BUS SUPPLIED FROM 4D110. ENERGIZED WHEN SIVB POWER ON IS GIVEN AND COMMIT SIGNAL IS NOT PRESENT AND S-IC FUNCTION SELECTOR IS IN THE PRELAUNCH POSITION. DE-ENERGIZED WHEN S-IC FUNCTION SELECTOR IS MOVED TO THE LAUNCH POSITION.
- +4D152 ESE PRE LAUNCH O₂-H₂ BURNER BUS.
- +4D210 ESE BUS NUMBER 2 SUPPLIED FROM 4D200 POWER SUPPLY. MANUALLY SWITCHED ON AND OFF.

- +4D211 STAGE BUS SUPPLIED FROM 4D210 BUS THROUGH POWER CONTRACTOR. DE-ENERGIZED WHEN POWER TRANSFER IS COMPLETE.
- +4D310 ESE BUS NO. 3 SUPPLIED FROM 4D300 POWER SUPPLY. MANUALLY SWITCHED ON AND OFF.
- +4D311 STAGE BUS SUPPLIED FROM 4D310 BUS THROUGH POWER CONTRACTOR. DE-ENERGIZED WHEN POWER TRANSFER IS COMPLETE.
- +40D185 BUS IS USED TO POWER INDICATORS FOR PROPELLANT LOADING.

56-VOLT BUSES

- +4D40 SUPPLIED DIRECTLY FROM STAGE AFT BATTERY NO. 2.
- +4D41 STAGE BUS SUPPLIED FROM 4D411 BEFORE POWER TRANSFER AND 4D40 AFTER POWER TRANSFER TO INTERNAL.
- +4D410 ESE BUS NO. 4 SUPPLIED FROM 4D400 POWER SUPPLY. MANUALLY SWITCHED ON AND OFF.
- +4D411 STAGE BUS SUPPLIED FROM 4D410 THROUGH POWER CONTACTOR ENERGIZED WHEN 4D411 ON COMMAND IS GIVEN. DE-ENERGIZED WHEN SIVB POWER TRANSFER IS COMPLETE.

3. SPECIAL 28-VOLT BUSES PLUG SUPERVISION BUS

THIS BUS IS FED BY A SEPARATE POWER SUPPLY. IT IS USED TO VERIFY SIVB STAGE UMBILICALS ARE PROPERLY MATED BEFORE ANY OTHER POWER IS APPLIED TO THE SIVB. THE POWER SUPPLY IS UNGROUNDED TO AVOID POSSIBLE DAMAGE TO EQUIPMENT IN THE EVENT OF CABLING ERROR.

SAFETY BUS

BUS IS ENERGIZED WHEN VEHICLE NETWORKS (CVNP) GIVES DESTRUCT ENABLE ON COMMAND. BUS IS USED TO PROVIDE POWER TO THE PROPELLANT DISPERSION SYSTEM.

II. DETAILED DESCRIPTION

A. INTRODUCTION

NO ATTEMPT WILL BE MADE TO GIVE DETAILED DESCRIPTIONS OF ALL CIRCUITS INVOLVED. IN MOST CASES, THE SYSTEM SCHEMATICS CONTAINED HEREIN ARE SELF-EXPLANATORY. WHEN THIS IS JUDGED NOT TO BE THE CASE, A CIRCUIT ANALYSIS WILL BE SUPPLIED.

B. WIDE RANGE VOLTAGE MONITOR (M 5821) 40M12149

1. INTRODUCTION

THE 40M12149 VOLTAGE MONITOR CARD IS USED IN TWO APPLICATIONS. FOR THE 4D100, 4D200, 4D300 AND 4D400 VOLTS OK LIGHTS (REF. FIG. 10), THE MODULE SUPPLIES THE STIMULUS IF THE RESPECTIVE BUS IS WITHIN ACCEPTABLE LIMITS. FOR TRANSFER TO BACKUP BATTERY (REF. FIGURES 2, 4, 6 AND 9), THE MODULE INHIBITS TRANSFER IF THE POWER SUPPLY IS FURNISHING ACCEPTABLE VOLTAGE. IF THE SENSED VOLTAGE DEVIATES FROM THE ALLOWED RANGE, THE INHIBIT IS REMOVED AND A TRANSFER IS EFFECTED.

2. CIRCUIT DESCRIPTION

WHEN 28 VDC POWER AND THE VOLTAGE BEING SENSED ARE APPLIED, THE SENSED VOLTAGE (IF IN ACCEPTABLE RANGE, EXCEEDS THE REFERENCE ZENER VOLTAGE) BIASES Q9 TRANSISTOR ON. NOTICE Q8 TURN ON IS NOW INHIBITED. THE 28V INPUT POWER BIASES Q3 ON WHICH FORWARD BIASES Q6 AND Q7 INTO CONDUCTION RANGE (Q7 IS THE OUTPUT TRANSISTOR). THE P.C. CARD CALIBRATION PROCEDURE (V-21343) ESTABLISHES TRIMPOT SETTINGS SUCH THAT Q4 IS ON AND THE BASE VOLTAGE OF Q8 DOES NOT REMOVE THE INHIBIT PLACED ON IT BY Q9. WITH Q4 ON, Q5 TURN ON IS INHIBITED.

ASSUME THE SENSED VOLTAGE INCREASES. NOTICE THIS WOULD CAUSE AN INCREASE OF BASE VOLTAGE ON Q5. IF THE VOLTAGE INCREASE IS OF SUFFICIENT MAGNITUDE, THE INHIBIT IMPOSED ON Q5 BY Q4 WILL BE REMOVED. WITH Q5 ON, Q1 AND Q2 ARE BIASED ON. COUPLING CAPACITOR C1 SPIKES Q3 OFF AND SINCE $R3 \gg R8 + R7$, Q3 STAYS OFF. WITH Q3 OFF, Q6 AND Q7 ARE NO LONGER BIASED ON. CONSEQUENTLY, THE OUTPUT VOLTAGE NO LONGER EXISTS.

ASSUME THE SENSED VOLTAGE DECREASES. AS THE SENSED VOLTAGE DECREASES, THE CURRENT THROUGH THE REFERENCE ZENERS DECREASES. THE RESULTING DECREASE OF Q9 BASE VOLTAGE TENDS TO TAKE THAT TRANSISTOR OUT OF CONDUCTION. IF THE DECREASE IS SUFFICIENT THE EMITTER VOLTAGE OF Q8 WILL DECREASE UNTIL THE BASE-EMITTER JUNCTION IS FORWARD BIASED. AT THIS INSTANT Q8 CONDUCTS. NOTICE THE COLLECTORS OF Q5 AND Q8 ARE TIED TO THE SAME BIASING NETWORK OF Q1 AND Q2. SINCE THESE TWO ARE NOW CONDUCTING, THE REMAINDER OF THE ARGUMENT IS IDENTICAL TO THE LATTER PART OF THE PRECEEDING PARAGRAPH.

TABLE I BELOW GIVES THE SETTINGS USED FOR THE VARIOUS 40M12149 MONITOR CARDS.

NOMENCLATURE	MONITOR CARD SETTING	
	LOW (VDC)	HIGH (VDC)
BAT XFER 4D100	$26.0 \pm .2$	$32.0 \pm .2$
BAT XFER 4D200	$25.0 \pm .2$	$32.0 \pm .2$
BAT XFER 4D300	$26.0 \pm .2$	$32.4 \pm .2$
BAT XFER 4D400	$53.0 \pm .4$	$63.0 \pm .4$
4D100 VOLTS OK	$27.0 \pm .2$	$30.8 \pm .2$
4D200 VOLTS OK	$26.5 \pm .2$	$30.1 \pm .2$
4D300 VOLTS OK	$27.6 \pm .2$	$30.8 \pm .2$
4D400 VOLTS OK	$54.0 \pm .4$	$61.0 \pm .4$

TABLE I

C. VOLTAGE MONITOR CARD (M 5821) 40M17541

1. INTRODUCTION

THE 40M17541 CARD IS SIMILAR TO THE 40M12149 DESCRIBED IN B ABOVE. THE PRINCIPAL DIFFERENCE IS THE 40M17541 DOES NOT HAVE A HIGH VOLTAGE SETTING. ITS ONLY APPLICATION IS IN THE "VOLTAGE MALFUNCTION" AND "POWER TRANSFER COMPLETE" CIRCUITS (REF. FIG. 16).

2. CIRCUIT DESCRIPTION

THE SENSED INPUT EXCEEDS THE REFERENCE ZENER VOLTAGE AND BIASES Q7 ON. THE TRIMPOT SETTING (R16) IS SUCH THAT Q6 IS NOT ON IF Q7 IS ON. THE POWER ISOLATION MODULE INPUT TO THE VOLTAGE MONITOR CARD BIASES Q2, Q5 AND Q8 ON.

ASSUME THE SENSED VOLTAGE DECREASES. THIS RESULTS IN A LOWER VOLTAGE ON THE BASE OF Q7. IF THE VOLTAGE DECREASE IS SUFFICIENT TO TAKE Q7 OUT OF SATURATION, Q6 CONDUCTS. THE BIASING NETWORK TURN Q3 AND Q1 ON. COUPLING CAPACITOR C1 SPIKES Q2 OFF. THE BIASING NETWORK FOR Q5 AND Q8 NO LONGER MAINTAINS THEM IN CONDUCTION. CONSEQUENTLY, THE OUTPUT (TRANSISTOR Q8) IS NO LONGER ACTIVE.

TABLE 2 BELOW GIVES THE SETTINGS USED FOR THE VARIOUS 40M17541 MONITOR CARDS.

NOMENCLATURE	MONITOR CARD SETTINGS LOW ONLY (VDC)
4D11 VOLTS OK	$24.0 \pm .2$
4D21 VOLTS OK	$24.0 \pm .2$
4D31 VOLTS OK	$24.0 \pm .2$
4D41 VOLTS OK	$50.0 \pm .4$

TABLE 2

D. POWER ISOLATION CARD (M-6797) 40M55778

1. INTRODUCTION

THE 40M55778 POWER ISOLATION CARDS SUPPLY 28VDC TO THE VARIOUS VOLTAGE MONITOR CARDS DISCUSSED IN B AND C ABOVE. THE POWER ISOLATORS ASSURE THE SENSED VOLTAGE SUPPLY AND POWER SOURCE FOR MONITOR CARDS ARE ISOLATED.

NOTE: IN FIG. 16, M6051 POWER ISOLATORS ARE SHOWN FEEDING VOLTAGE MONITOR CARDS. THESE WERE PLACED IN ESE ON AN INTERIM BASIS AND WERE SUBSEQUENTLY REPLACED BY M6797 ISOLATORS. CONSEQUENTLY, THE M6051 ISOLATOR WILL NOT BE DESCRIBED. THE NEXT RELEASE OF THIS DOCUMENT WILL REFLECT THE 6797 CARD IN THIS APPLICATION.

2. CIRCUIT DESCRIPTION

NOTICE THIS CIRCUIT DOES NOT USE THE SATURABLE CORE CHARACTERISTIC FOR FREQUENCY CONTROL. TRANSISTOR Q2 (UNIUNCTION 2N491) OSCILLATES AT 2 KHz AND IS CAPACITIVELY COUPLED TO THE BASES OF Q1 AND Q3. WHEN THE UNIUNCTION TRIGGERS, THE BISTABLE CONSISTING OF Q1 AND Q3 CHANGES STATE. SINCE THE COLLECTORS OF Q1 AND Q3 CONTROL BASE VOLTAGES OF Q4 AND Q5, THE LATTER CONDUCT WHEN THEIR RESPECTIVE BASE CONTROL TRANSISTORS CONDUCT. THE COLLECTORS OF Q4 AND Q5 ARE TRANSFORMER COUPLED TO THE BASES OF Q6 AND Q7. NOTICE THE TRANSFORMER ACTION CLAMPS ONE TRANSISTOR (Q6 OR Q7) OFF AND ESTABLISHES THE REQUIREMENTS FOR CONDUCTION FOR THE OTHER IN EACH HALF CYCLE. IN THE SUBSEQUENT HALF CYCLE THESE CONDITIONS ARE REVERSED. THE COLLECTORS OF Q6 AND Q7 ARE TRANSFORMER COUPLED TO THE RECTIFIED OUTPUT CIRCUIT.

E. POWER SUPPLY REGULATION SENSING

FIG. 17 SHOWS THE TWO MODES OF VOLTAGE SENSING USED FOR GROUND POWER SUPPLY VOLTAGE REGULATION. CONSIDER THE CASE FOR THE +4D100 POWER SUPPLY. BEFORE STAGE POWER IS APPLIED, THE SUPPLY IS SENSING +4D110. WHEN STAGE POWER IS APPLIED, RELAY K14 REMOVES +4D110 SENSE AND APPLIES +4D111. RELAY K63 IS NOT USED IN THE COUNTDOWN CONFIGURATION. IT IS ACTUATED BY THE SIMULATED FLIGHT SWITCH AND IS ASSOCIATED WITH OVERALL TEST (OAT) POWER CONFIGURATION.

WHEN POWER TRANSFER OCCURS (REF. FIG. 14) THE STAGE BUSES OK LOGIC EXCITES A ONE SECOND TIMER. AT THE END OF THE ONE SECOND INTERVAL, THE K14 RELAY OF FIGURE 17 IS DEACTIVATED AND THE SENSE INPUT IS SWITCHED TO +4D110. IN ADDITION THE UMBILICAL POWER INPUTS ARE DEADFACED.

3.2 CRITICAL MEASUREMENTS

I. REDLINES

A. VOLTAGE-AFT BUS NO. 1 (4D11)

MEASUREMENT: M-151

RANGE : 20-40 VDC

REDLINE LIMITS: MAXIMUM: 31.0 VDC
MINIMUM: 26.0 VDC

BACKUPS BEFORE TRANSFER: C4NP HARDLINE ON + 4D11V
AFTER TRANSFER: 4D10 STRIP CHART

CHANNEL ASSIGNMENTS: EP1A0-09-05

B. VOLTAGE-FWD BUS NO. 2 (4D21)

MEASUREMENT: M-152

RANGE : 20-40 VDC

REDLINE LIMITS: MAXIMUM: 32.0 VDC
MINIMUM: 24.5 VDC

BACKUPS BEFORE TRANSFER: C4NP HARDLINE ON + 4D21V
AFTER TRANSFER: 4D20 STRIP CHART

CHANNEL ASSIGNMENTS: CP1A0-08-04

C. VOLTAGE-FWD BUS NO. 1 (4D31)

MEASUREMENT: M-154

RANGE : 20-40 VDC

REDLINE LIMITS: MAXIMUM: 32.0 VDC
MINIMUM: 26.0 VDC

BACKUPS BEFORE TRANSFER: C4NP HARDLINE ON + 4D31V
AFTER TRANSFER: 4D30 STRIP CHART

CHANNEL ASSIGNMENTS: EP1A0-02-06

D. VOLTAGE-AFT BUS NO. 2 (4D41)

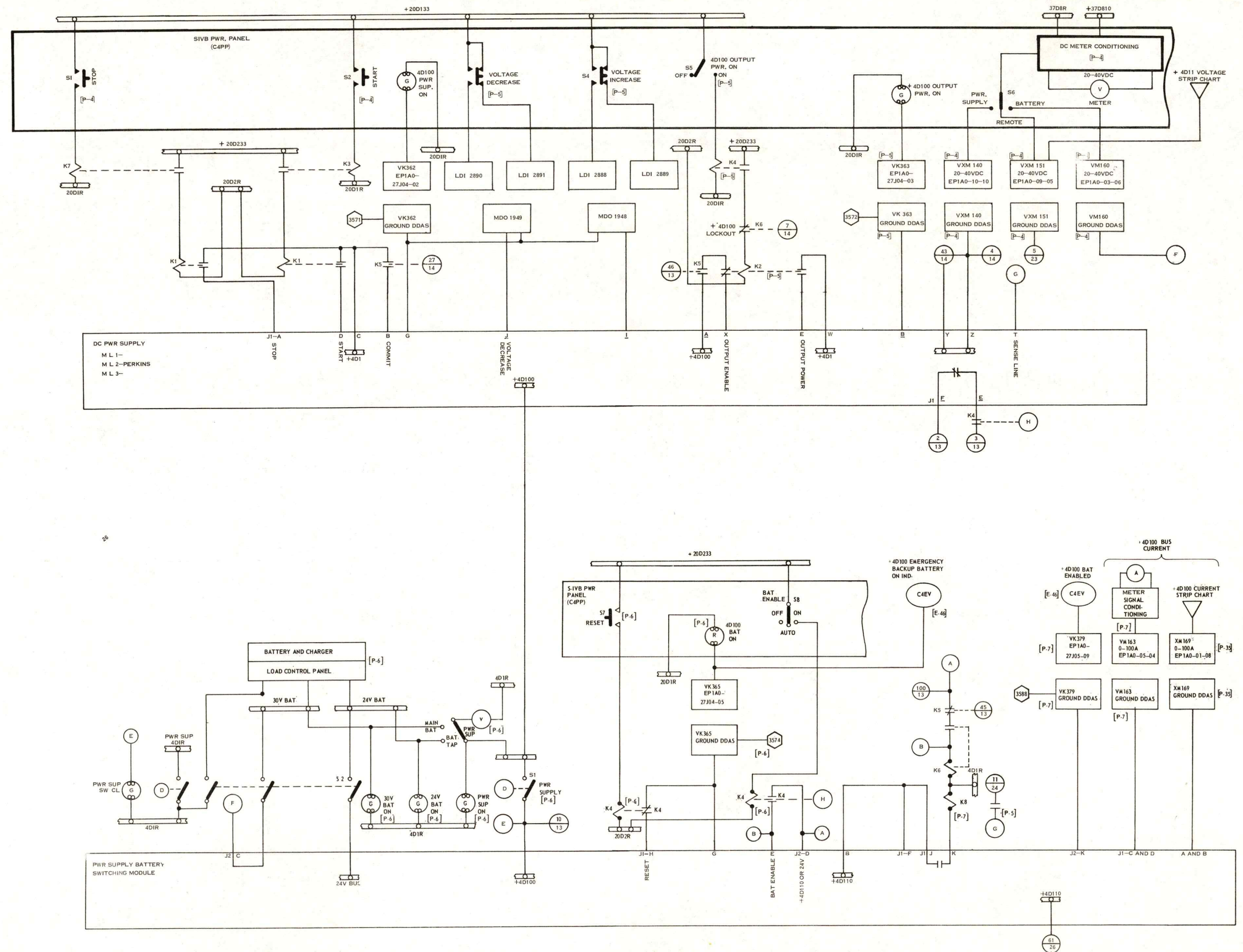
MEASUREMENT: M-153

RANGE : 35-70 VDC

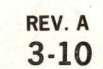
REDLINE LIMITS: MAXIMUM: 61.0 VDC
MINIMUM: 51.0 VDC

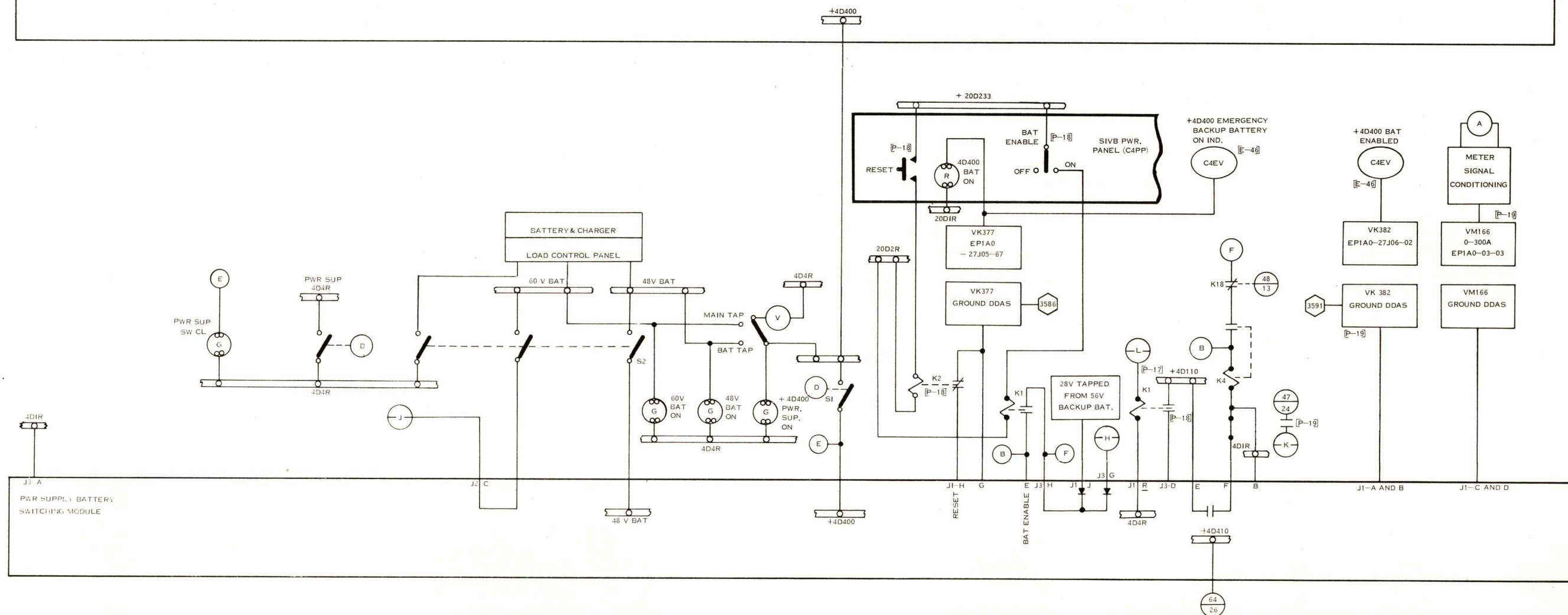
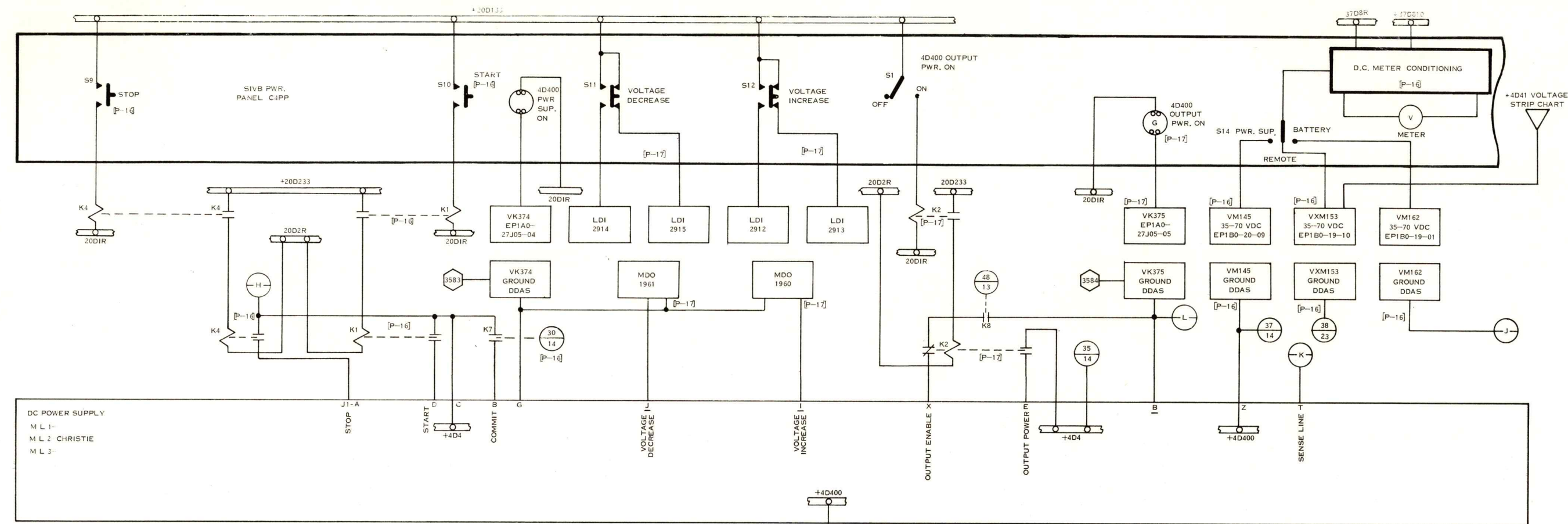
BACKUPS BEFORE TRANSFER: C4NP HARDLINE ON + 4D41V
AFTER TRANSFER: 4D40 STRIP CHART

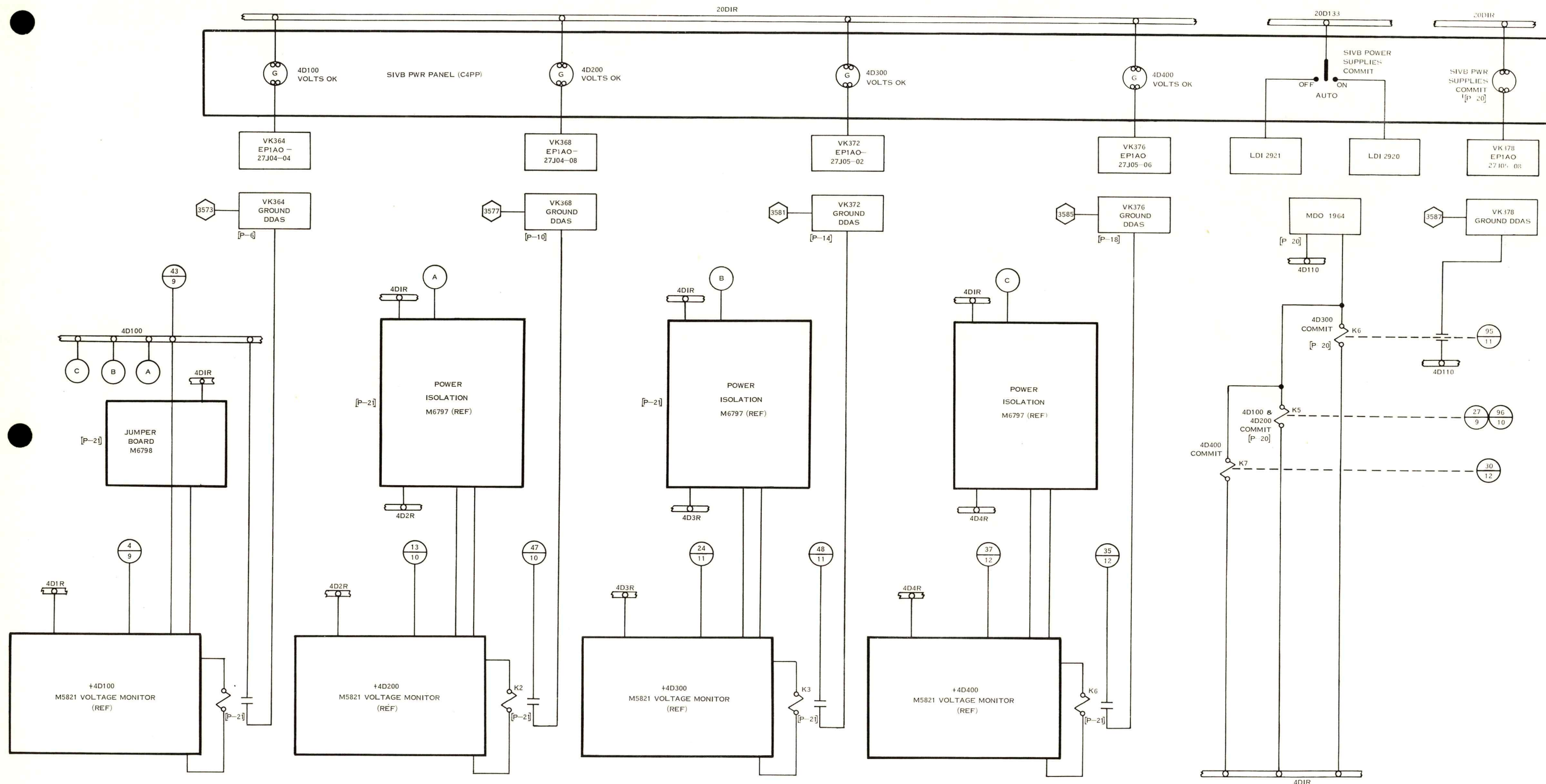
CHANNEL ASSIGNMENTS: EP1B0-19-10



DERIVATION OF 4D110 POWER

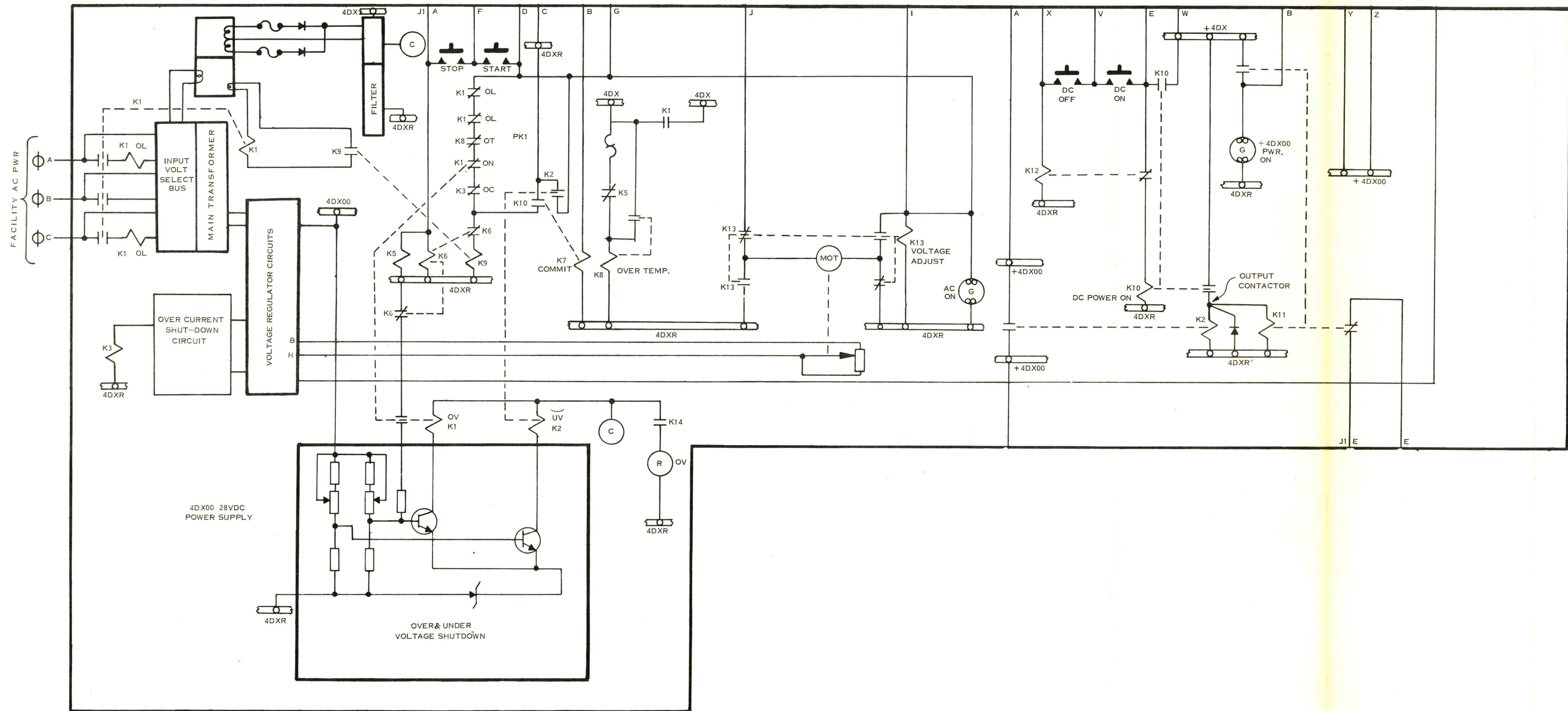


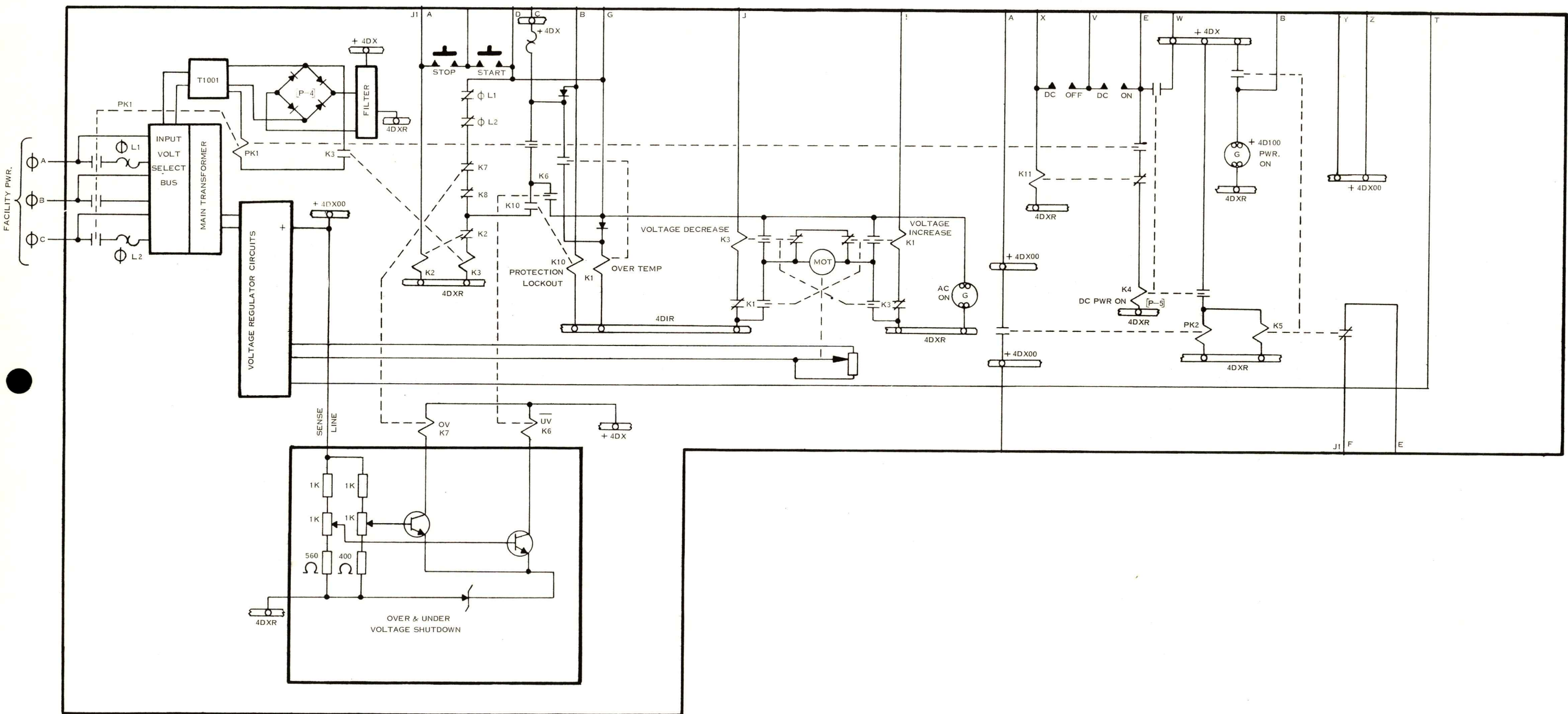




PWR. SUPPLY VOLTAGE OK & PWR. SUPPLIES COMMIT
FIG. 10

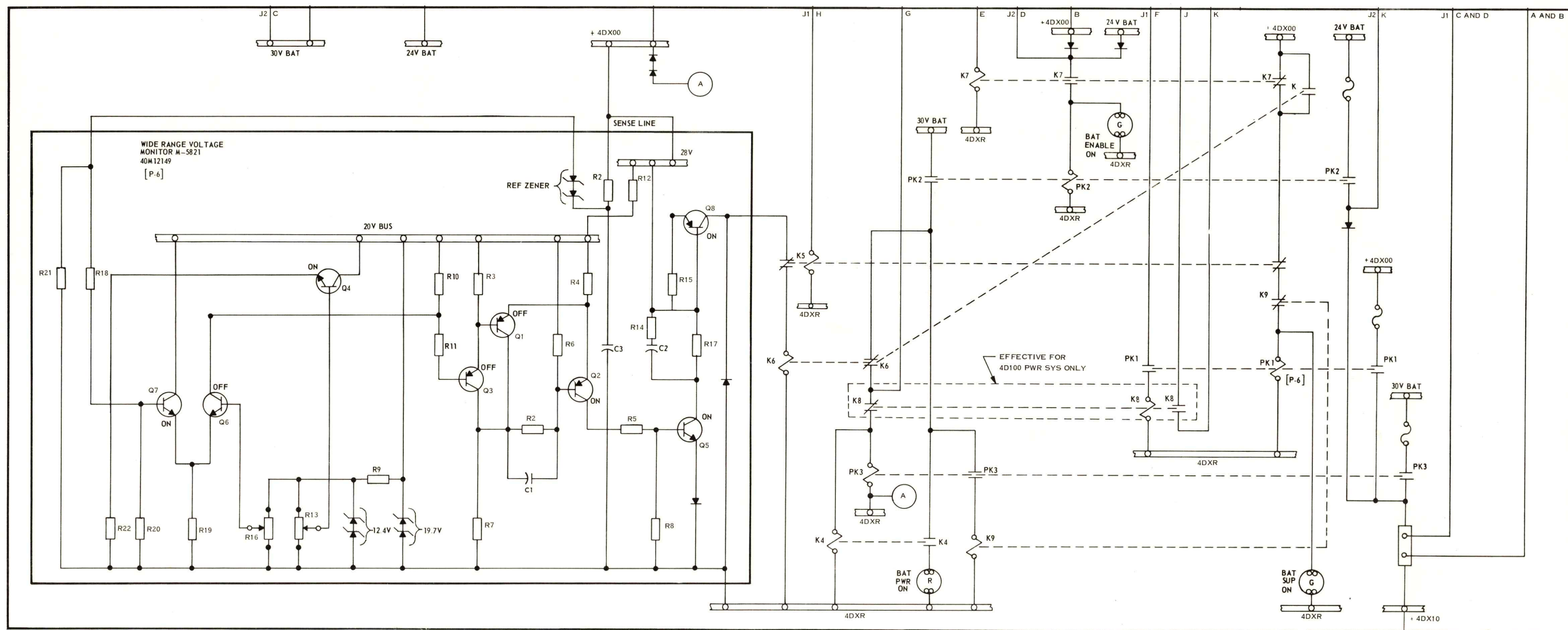
REV. A
3-13.1



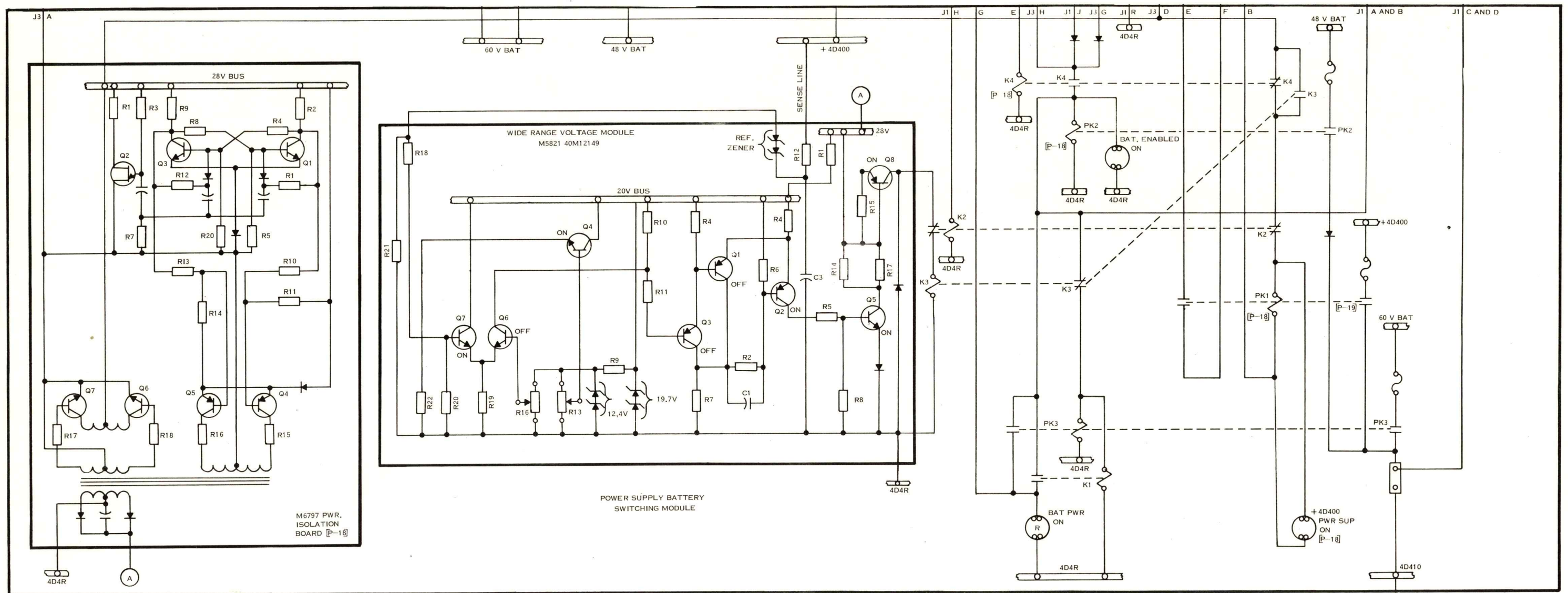


CRISTIE POWER SUPPLY

REV. A
3-15

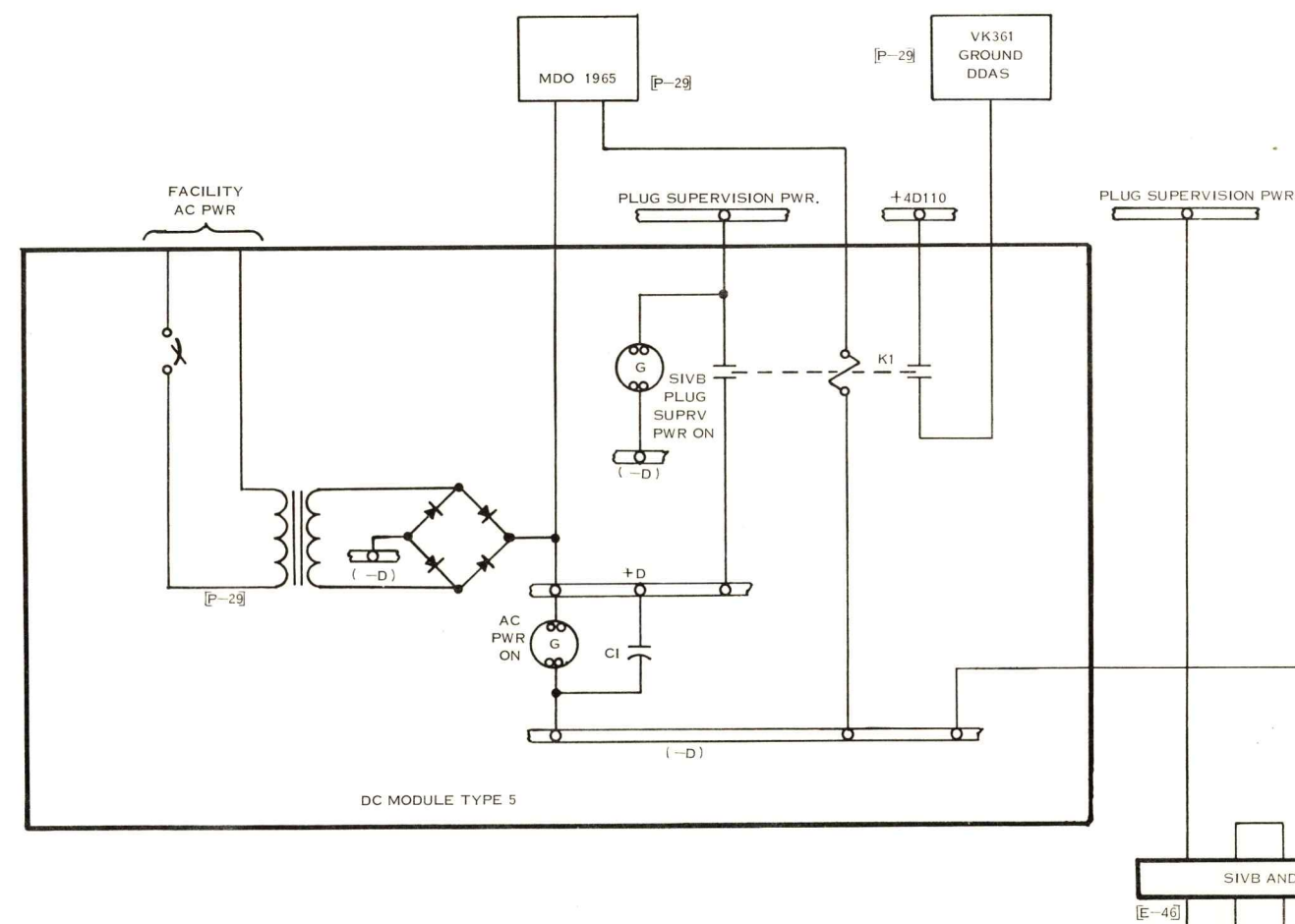
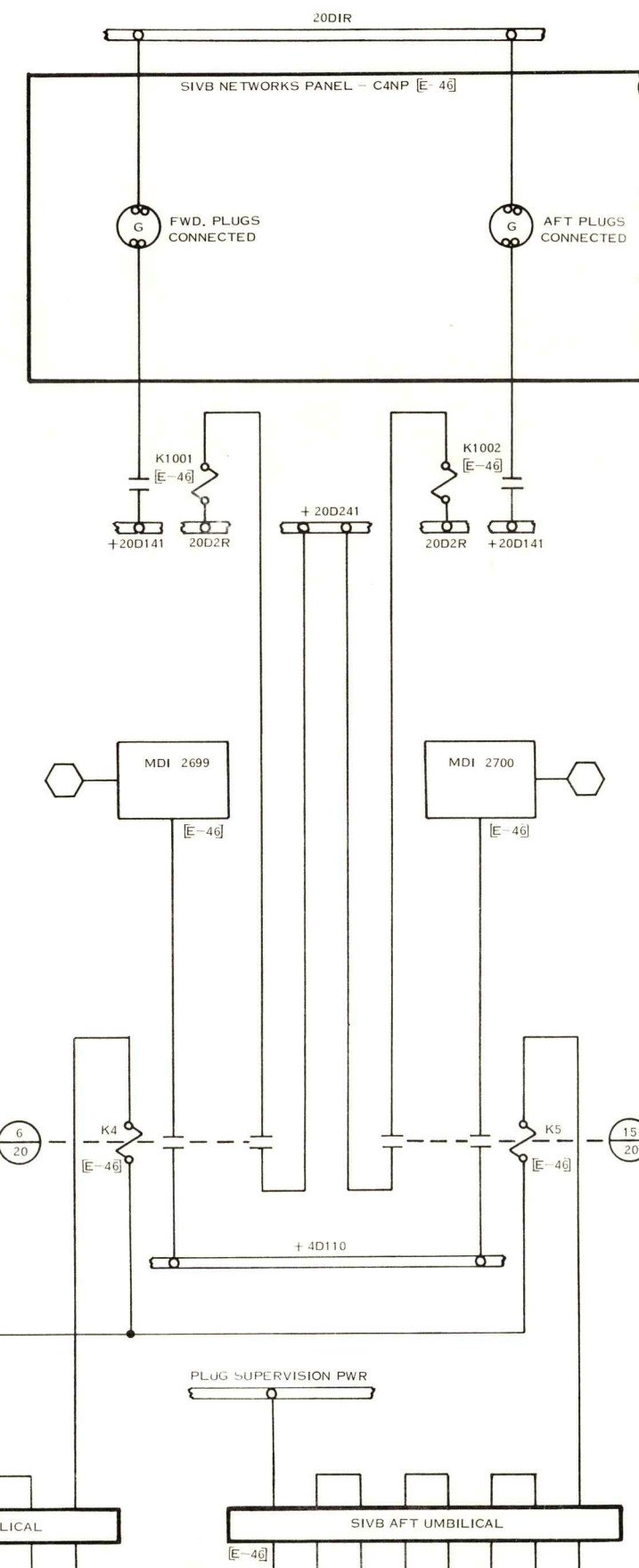
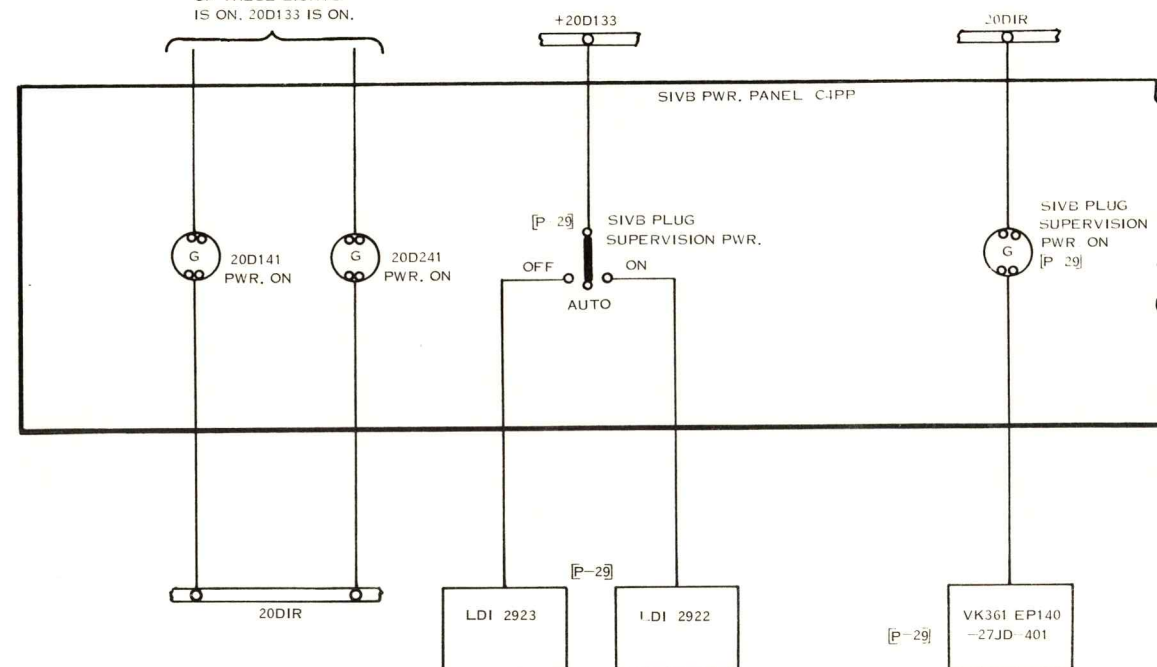


POWER SUPPLY BATTERY SWITCHING MODULE FOR THE 4D100, 200 & 300 SYSTEM

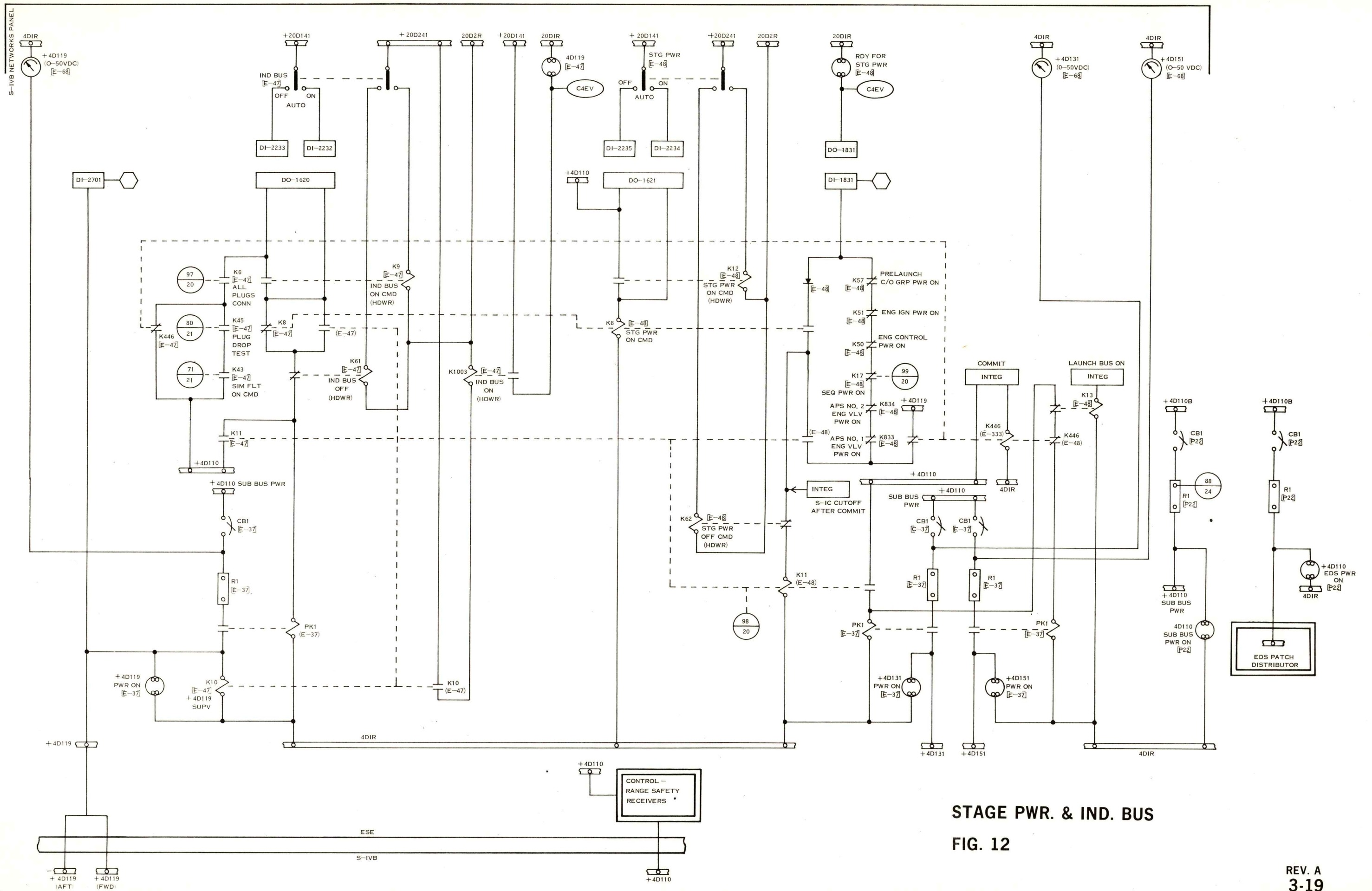


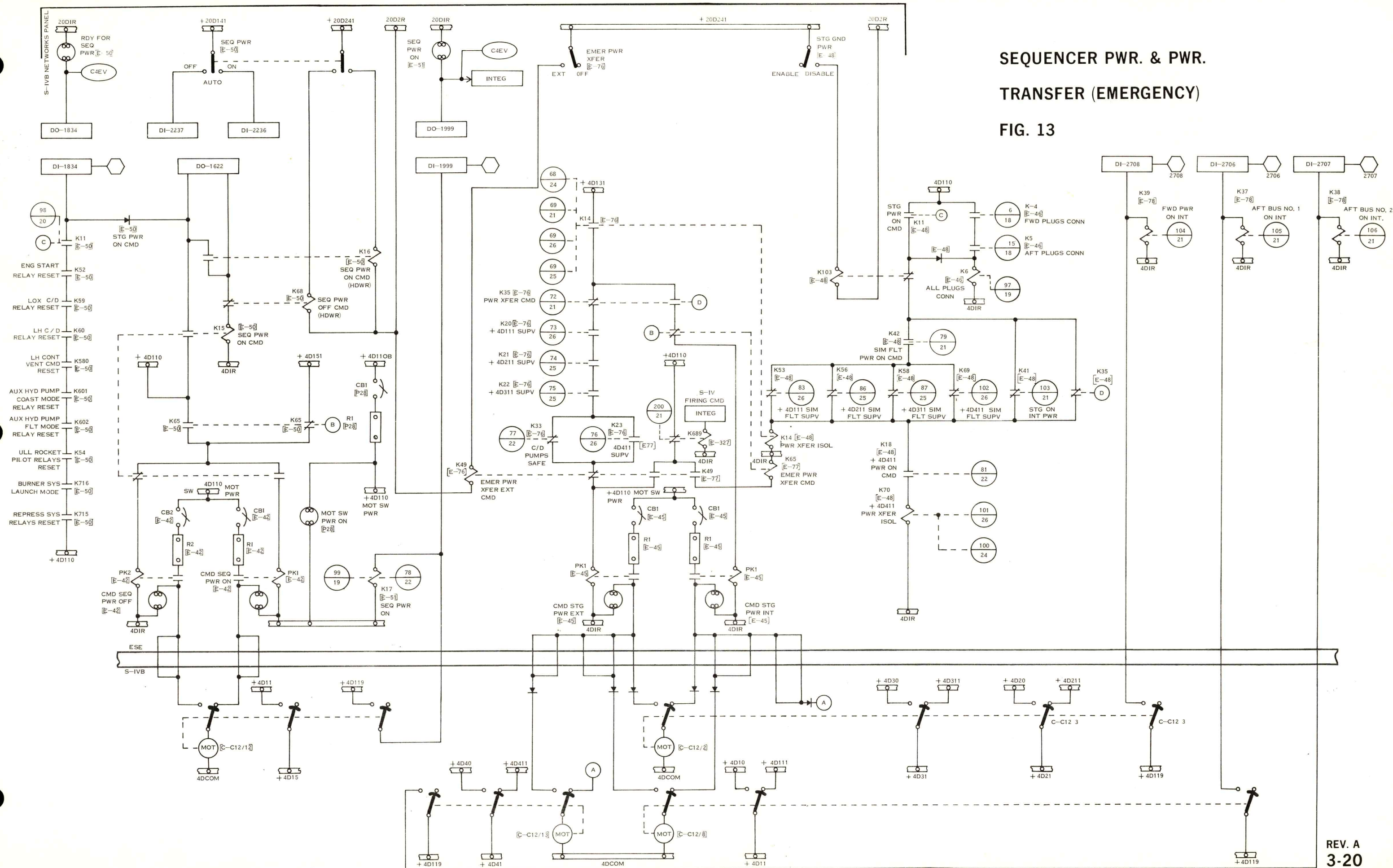
POWER SUPPLY BATTERY SWITCHING MODULE FOR THE 4D400 SYSTEM

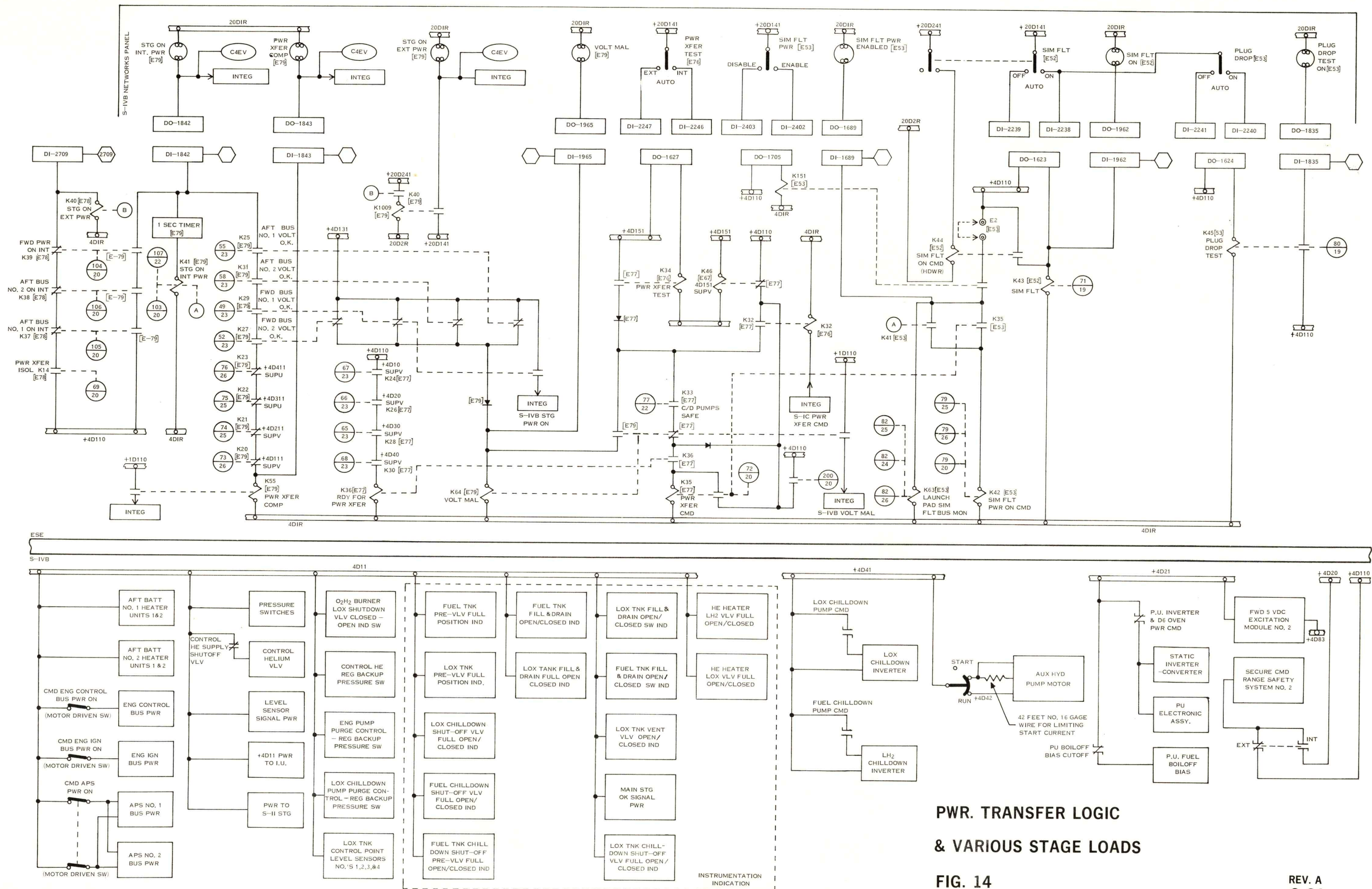
NOTE: 20D133 POWERS
THESE TWO
LIGHTS, THEREFORE,
WHEN EITHER
OF THESE LIGHTS
IS ON, 20D133 IS ON.



DERIVATION & DISTRIBUTION OF PLUG SUPERVISION PWR FIGURE 11

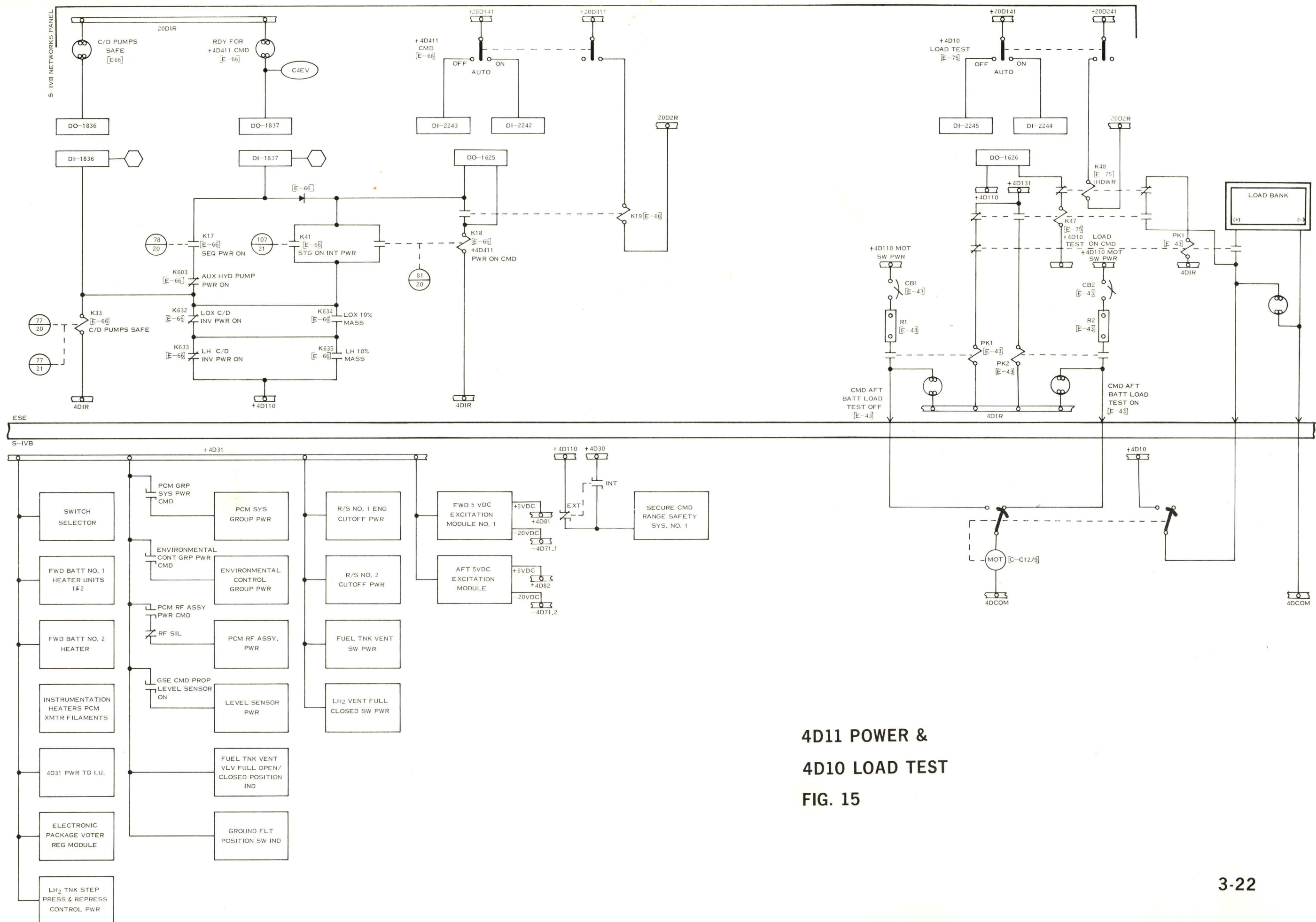


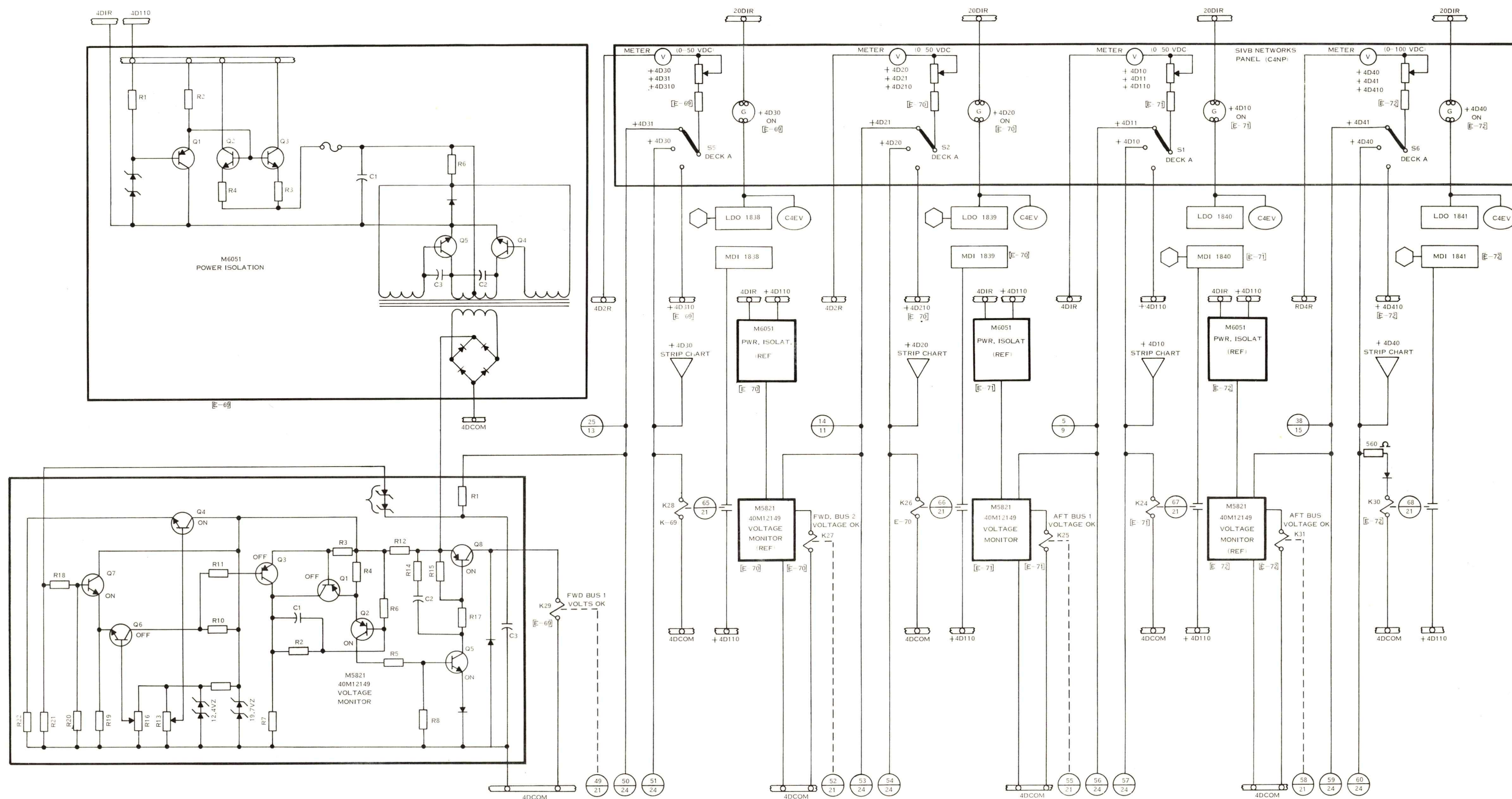




**PWR. TRANSFER LOGIC
& VARIOUS STAGE LOADS**

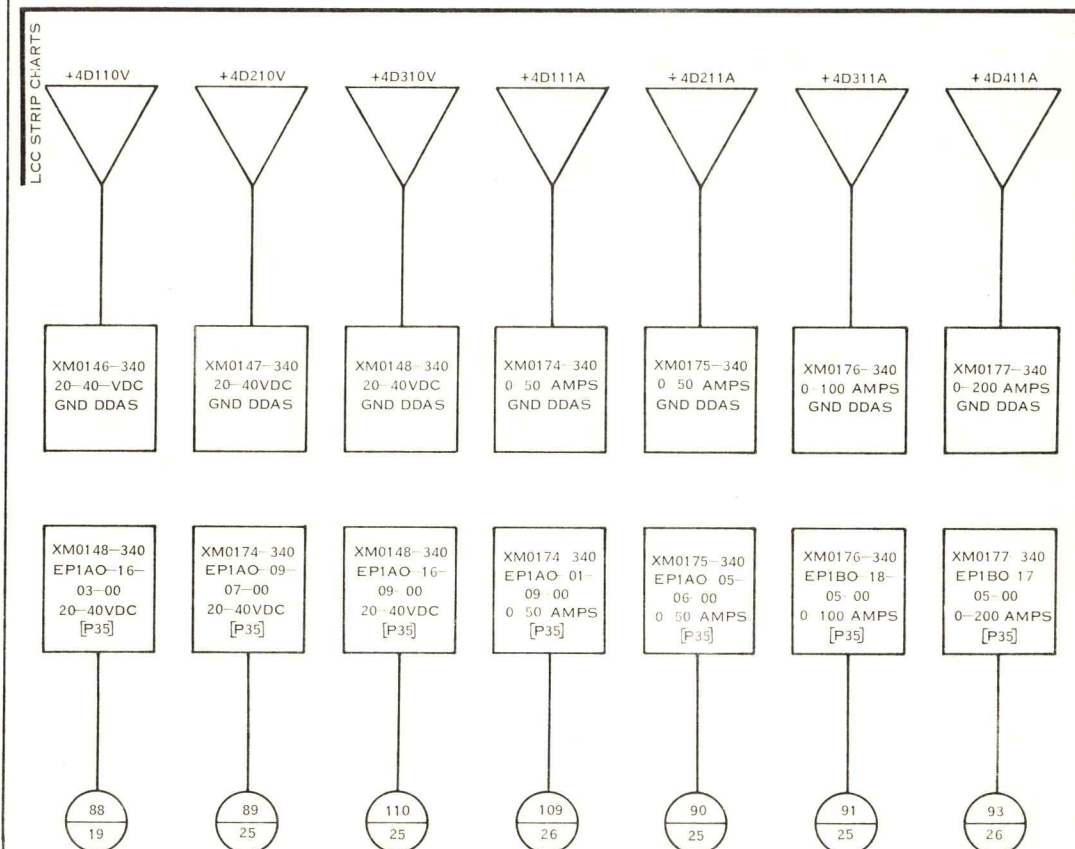
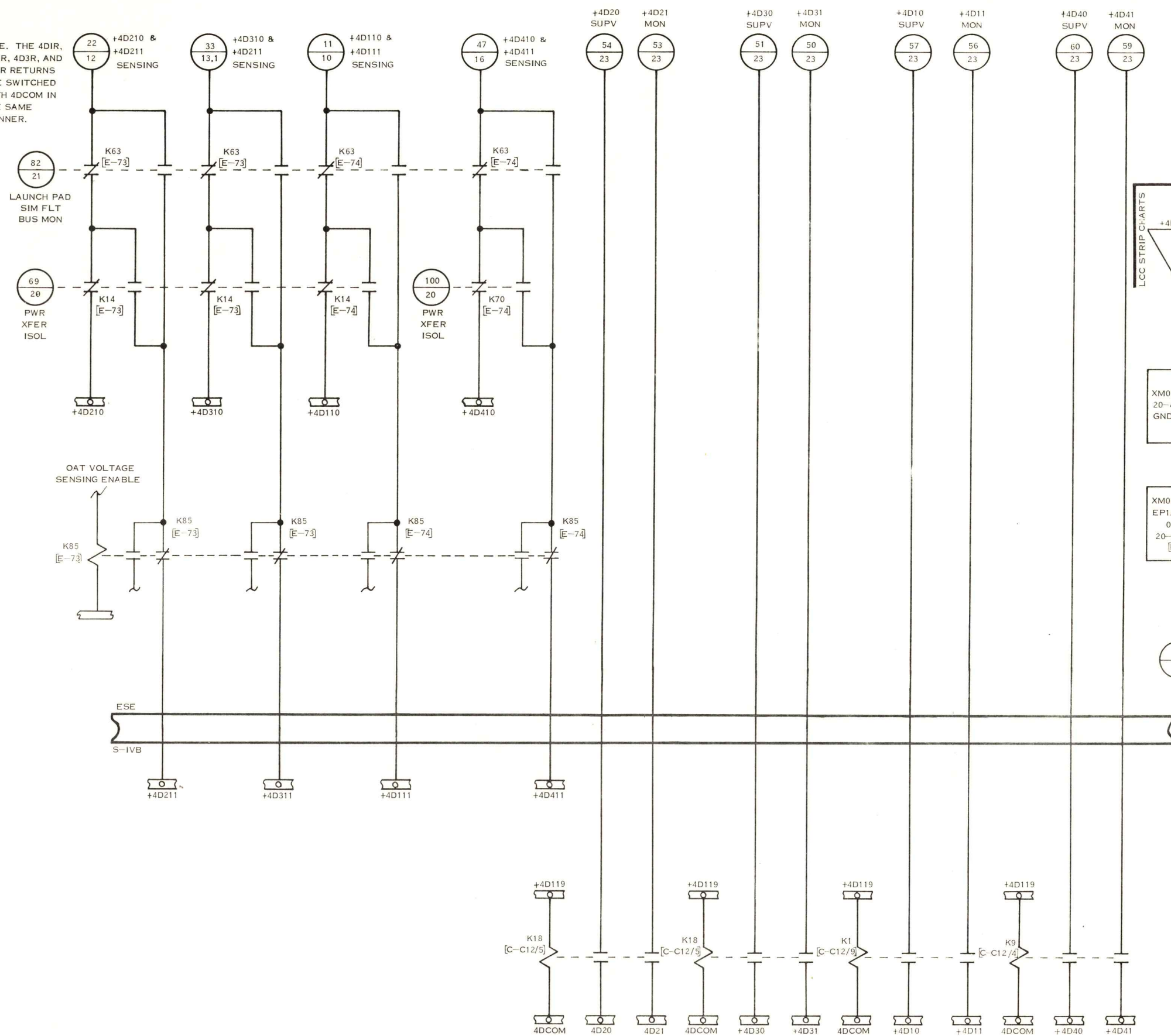
FIG. 14





STAGE BUSES OK ESE FIGURE 16

NOTE. THE 4DIR,
4D2R, 4D3R, AND
4D4R RETURNS
ARE SWITCHED
WITH 4DCOM IN
THE SAME
MANNER.



STAGE BUSSES OK
& POWER MEAS.
FIG. 17

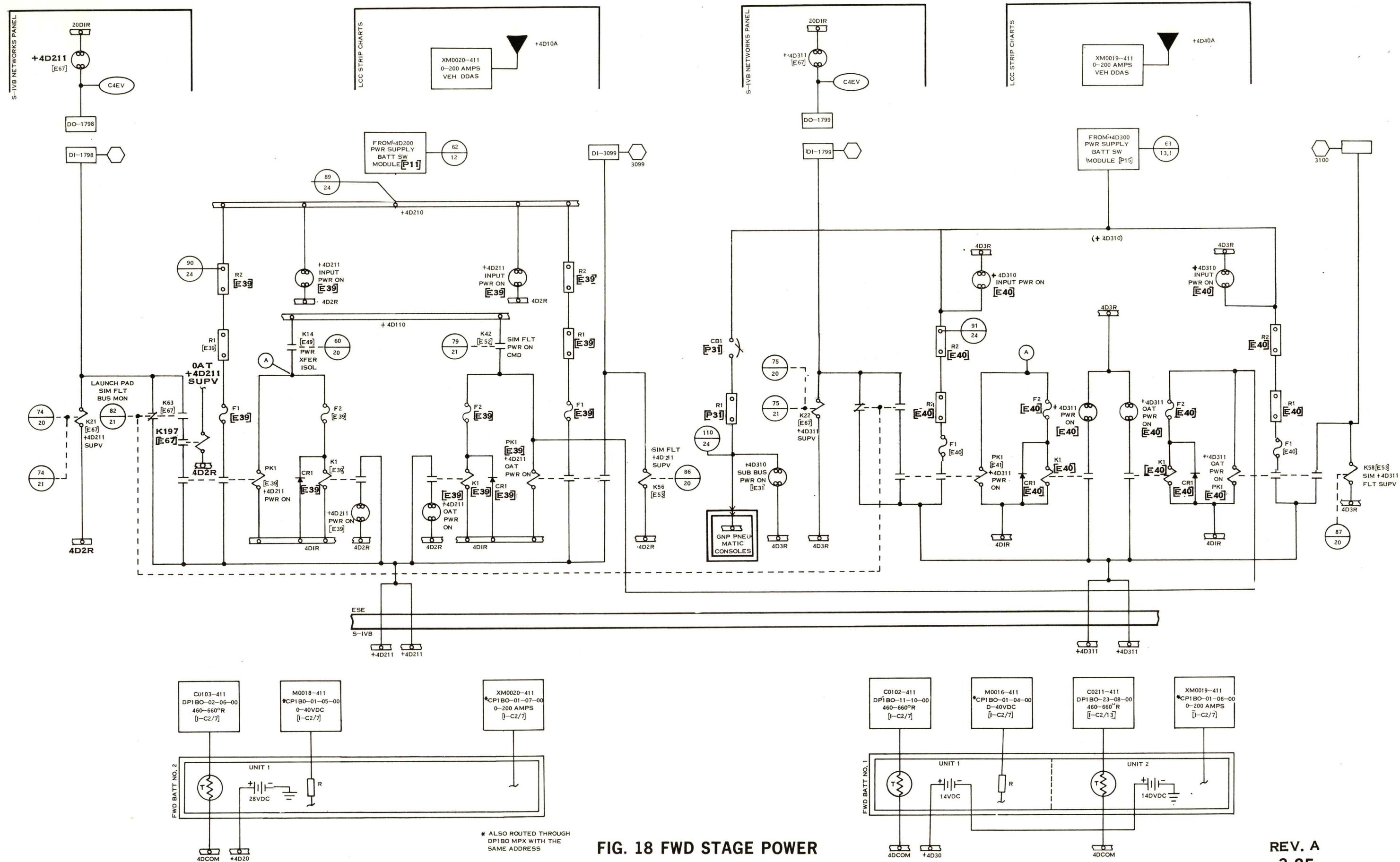
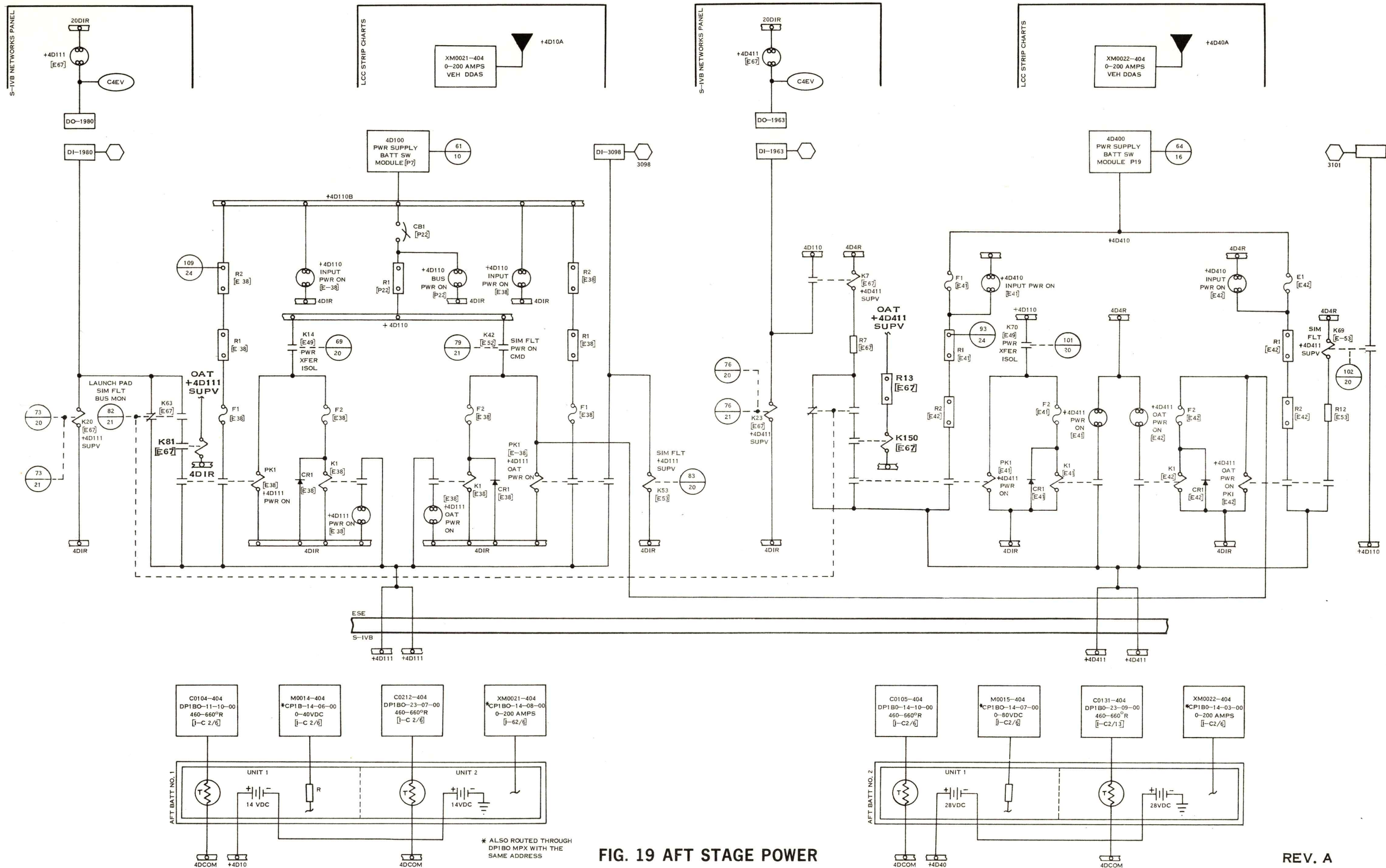
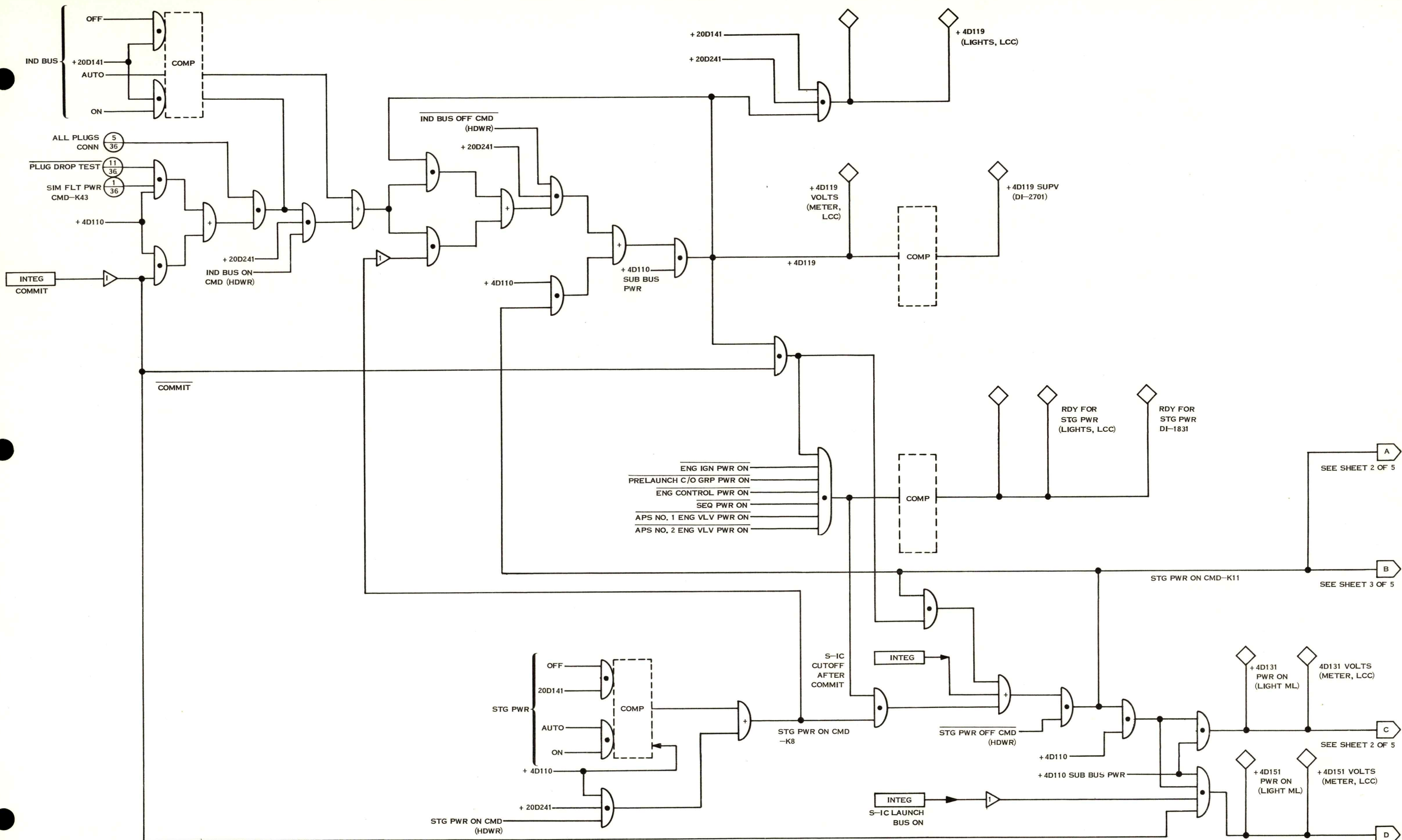
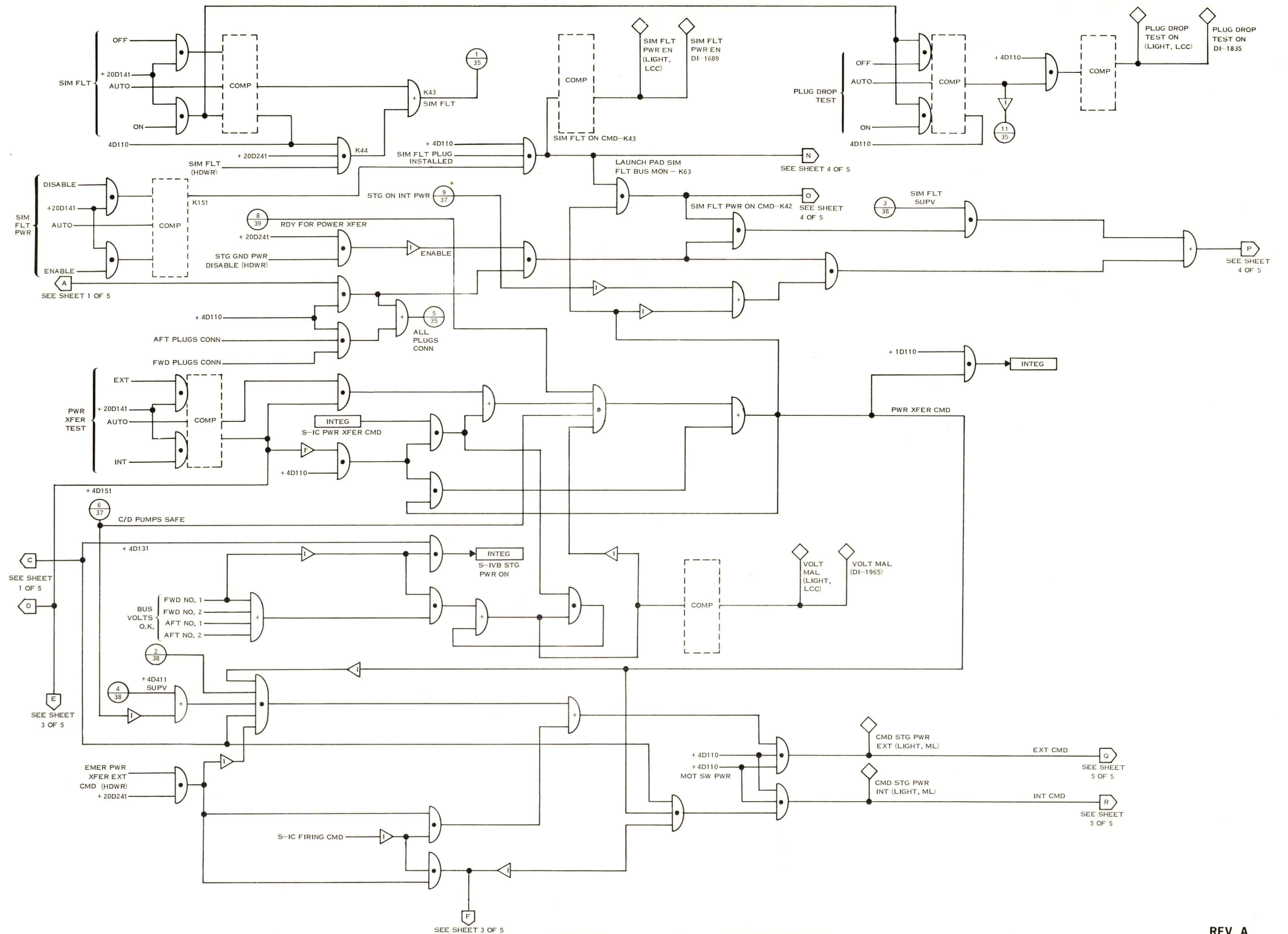


FIG. 18 FWD STAGE POWER

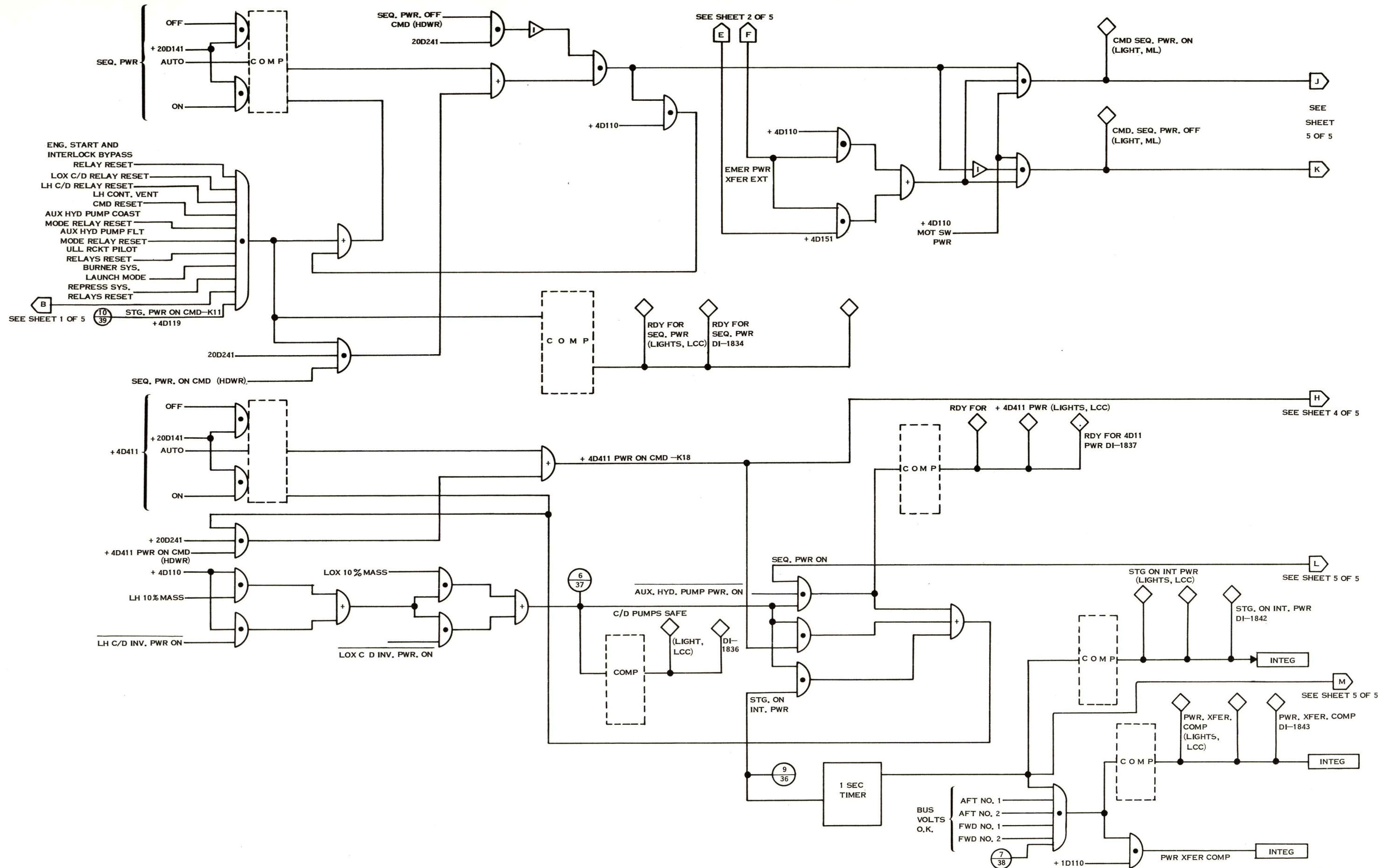




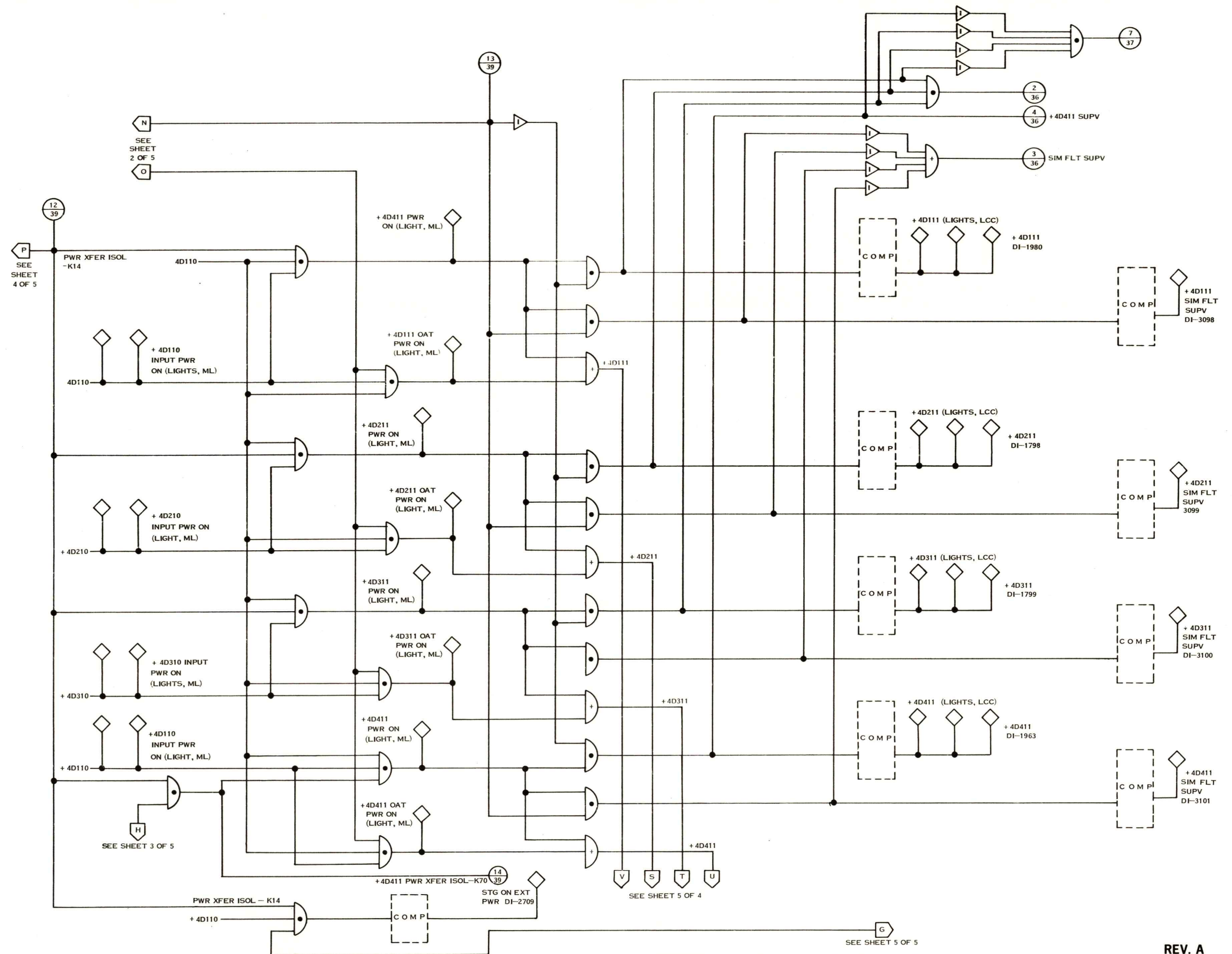
S-IVB STAGE POWER LOGIC DIAGRAM 1 of 5



S-IVB STAGE POWER LOGIC DIAGRAM 2 of 5

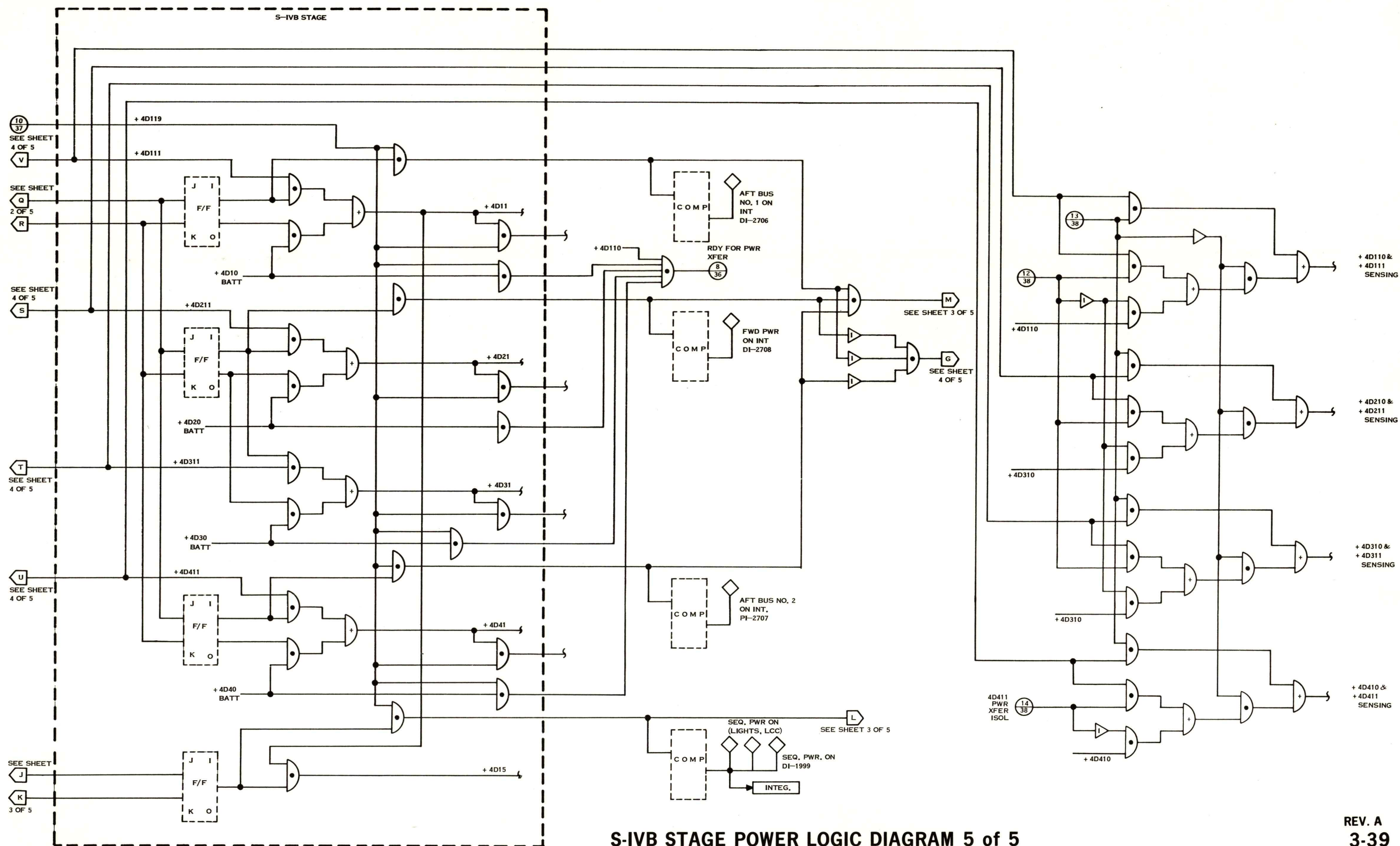


S-IVB STAGE POWER LOGIC DIAGRAM 3 of 5



S-IVB STAGE POWER LOGIC DIAGRAM 4 of 5

REV. A
3-38



S-IVB STAGE POWER LOGIC DIAGRAM 5 of 5

4.0
4.1

PCM/DDAS SYSTEM
SYSTEM DESCRIPTION

THE DIGITAL DATA ACQUISITION INSTRUMENTATION SYSTEM ON THE SIVB STAGE MEASURES PHYSICAL QUANTITIES AND ELECTRICAL SIGNALS ONBOARD THE STAGE AND TRANSMITS THE DATA TO THE GROUND AS SHOWN IN FIGURE 4.1.1. THE TRANSMITTED DATA SUPPLIES INFORMATION FOR:

- A. MONITORING OF STAGE SYSTEMS DURING CHECKOUT.
- B. MONITORING OF STAGE SYSTEMS DURING POWERED FLIGHT AND ORBITAL OPERATIONS.
- C. POSTFLIGHT EVALUATION OF STAGE PERFORMANCE.

THE DIGITAL DATA ACQUISITION SYSTEM CONSISTS OF TWO BASIC SUBSYSTEMS, THE MEASUREMENT SUBSYSTEM AND THE TELEMETRY SUBSYSTEM. THE MEASUREMENT SUBSYSTEM CONSISTS OF TRANSDUCERS AND SIGNAL CONDITIONERS NECESSARY TO CONVERT VEHICLE FUNCTIONS INTO COMPATIBLE SIGNAL LEVELS FOR APPLICATION TO THE TELEMETRY SUBSYSTEM. THE TELEMETRY SUBSYSTEM CONSISTS OF BI-LEVEL SUMMING MODULES, MODEL 270 PULSE AMPLITUDE MODULATION (PAM) MULTIPLEXERS, MODEL 102 REMOTE ANALOG SUBMULTIPLEXER (RASM), MODEL 1D REMOTE DIGITAL SUBMULTIPLEXER (RDSM), AND A MODEL 301 PULSE CODE MODULATION/DIGITAL DATA ACQUISITION SYSTEM (PCM/DDAS) ASSEMBLY. THE PCM/DDAS ASSEMBLY IS CAPABLE OF SCANNING THE WAVEFORMS FROM THE MODEL 270 PAM MULTIPLEXERS AND ENCODING THE WAVEFORMS INTO A 10-BIT DIGITAL PCM FORMAT. THE PCM/DDAS ASSEMBLY ALSO ACCEPTS DIGITAL DATA FROM THE DISCRETE TYPE MEASUREMENTS AND FROM THE REMOTE DIGITAL SUBMULTIPLEXER. THE DIGITAL DATA IS INSERTED INTO PROGRAMMED SECTIONS ON THE SERIAL OUTPUT FORMAT. THE RASM ACCEPTS THE LOW VOLTAGE (0 TO 30 MV) MEASUREMENTS, MULTIPLEXES AND AMPLIFIES THESE SIGNALS, AND INPUTS THEM INTO THE MODEL 270 MULTIPLEXER.

THE SIVB STAGE IS INTERCONNECTED WITH THE IU TELEMETRY SYSTEM FOR THE PURPOSE OF REDUNDANT TRANSMISSION MODE. AN ILLUSTRATION OF THE PCM/DDAS TELEMETRY SYSTEM IS PRESENTED IN FIGURE 4.1.2.

THE PCM/DDAS SYSTEM IS POWERED BY THE 4D31.1 BUS WHICH IS ENERGIZED WHEN PCM GROUP POWER IS POSITIONED ON. THIS IS ILLUSTRATED IN FIGURE 4.1.3.

ANALOG PARAMETERS DESIGNATED AS FLIGHT CONTROL DATA (FCD) ARE FED IN PARALLEL TO BOTH OF THE SIVB 270 MULTIPLEXERS (CP1BO AND DP1BO). FCD BI-LEVEL OR DISCRETE FUNCTIONS ARE PLACED ON THAT MULTIPLEXER RECEIVING SYNCHRONIZATION FROM THE IU (DP1BO) AND ALSO ROUTED TO THE REMOTE DIGITAL SUBMULTIPLEXER OR PCM/DDAS DIRECTLY. ENGINEERING ANALOG DATA IS INPUT TO THE 270 MULTIPLEXERS. LOW-LEVEL ENGINEERING MEASUREMENTS LOCATED AFT ARE INPUT TO THE RASM WHILE THOSE LOCATED FORWARD REQUIRE INDIVIDUAL AMPLIFIERS. ENGINEERING BI-LEVELS WILL ORDINARILY BE INPUT TO EITHER THE RDSM AFT OR THE PCM/DDAS FORWARD.

4.2
4.2.1

TELEMETRY SUBSYSTEM
TELEMETRY SUBSYSTEM COMPONENT DESCRIPTION

THE FOLLOWING TELEMETRY COMPONENT DESCRIPTIONS AND ILLUSTRATIONS ARE PRESENTED TO AID THE TROUBLE SHOOTING EFFORT.

4.2.1.1

MODEL 270 MULTIPLEXER

THE MODEL 270 PAM MULTIPLEXER HAS 27 PRIME DATA CHANNELS PLUS 3 CHANNELS FOR REFERENCE AND SYNCHRONIZATION WITH EACH CHANNEL SAMPLED 120 TIMES PER SECOND. PRIME CHANNELS 1 TO 23 MAY BE SUBMULTIPLEXED INTERNALLY INTO TEN SUBCHANNELS WITH EACH SUBCHANNEL SAMPLED 12 TIMES PER SECOND. ALL DATA CHANNELS OF THE MULTIPLEXER MAY BE MULTIPLEXED EXTERNALLY BY THE REMOTE ANALOG SUBMULTIPLEXER.

A BLOCK DIAGRAM IS GIVEN IN FIGURE 4.2.3 TO SHOW THE INTERCONNECTION OF THE FUNCTIONAL UNITS. THE SUBMULTIPLEXERS CONSIST OF TEN INPUT FILTERS AND DATA SWITCHES WHICH ARE CONNECTED IN PARALLEL TO PRODUCE AN ELECTRONIC SINGLE POLE — TEN POSITION SWITCH AS SHOWN IN FIGURES 4.2.1 THRU 4.2.4. DUMMY SUBMULTIPLEXER CARDS ARE USED TO PROVIDE PRIME CHANNELS FOR CHANNELS 1 THRU 23 AS REQUIRED. THE MAIN MULTIPLEXER CONSISTS OF 30 DATA SWITCHES WHICH ARE ALSO CONNECTED IN PARALLEL TO PRODUCE AN ELECTRONIC SINGLE POLE — 30 POSITION SWITCH AS SHOWN IN FIGURE 4.2.4.

INFLIGHT CALIBRATION OF THE MODEL 270 MULTIPLEXERS IS INITIATED BY A TM CAL. COMMAND FROM THE SEQUENCER AS ILLUSTRATED IN FIGURE 4-2-5. THE CALIBRATION SEQUENCE CONSISTS OF FIVE PRECISE INTERNALLY GENERATED VOLTAGE STEPS FROM 0 TO 5 VOLTS DC. EACH STEP IS APPLIED FOR THE DURATION OF ONE MASTER FRAME (10 FRAMES), THUS REQUIRING 5 MASTER FRAMES OR APPROXIMATELY 400 MILLISECONDS FOR A COMPLETE CALIBRATION SEQUENCE. THE CALIBRATION VOLTAGE PROFILE AND THE LOGIC DIAGRAM OF THE CALIBRATION AND ISOLATION AMPLIFIER ARE GIVEN IN FIGURES 4.2.6 AND 4.2.7.

SYNCHRONIZATION IS NORMALLY ACCEPTED FROM THE PCM/DDAS ASSEMBLY ALTHOUGH UNITS WILL OPERATE ON AN INTERNAL CLOCK IF THE SYNCHRONIZATION SIGNAL IS LOST. OUTPUTS ARE PROVIDED TO SYNCHRONIZE THE RASM UNITS.

4.2.1.2 MODEL 102 REMOTE ANALOG SUBMULTIPLEXER

THE REMOTE ANALOG SUBMULTIPLEXER (RASM) TIME SHARES SIX GROUPS OF 10 LOW LEVEL (0 TO 30 MV DIFFERENTIAL) INPUTS AND PRODUCES SIX SEPERATE 0 TO 5 VOLT SINGLE ENDED PAM OUTPUTS. THESE OUTPUTS ARE ROUTED TO SIX PRIME CHANNELS OF THE DP1BO (270) MULTIPLEXER. EACH OUTPUT CHANNEL OF THE RASM CONSIST BASICALLY OF AN ELECTRONIC TWO POLE — 10 POSITION SWITCH, AND A DIFFERENTIAL INPUT AMPLIFIER. A EQUIVALENT ELECTRICAL SCHEMATIC IS GIVEN IN FIGURE 4.2.8. THE DATA SWITCH CIRCUIT AND EQUIVALENT CIRCUITS ARE GIVEN IN FIGURE 4.2.9.

4.2.1.3 MODEL 1D REMOTE DIGITAL SUBMULTIPLEXER

THE REMOTE DIGITAL SUBMULTIPLEXER (RDSM) ACCEPTS UP TO 100 BI-LEVEL INPUTS. THESE INPUTS ARE SAMPLED SEQUENTIALLY IN GROUPS OF TEN. THE DATA LEVELS OF THESE TEN LINES IS CODED INTO ONE DIGITAL WORD, WHICH IS OUTPUT TO THE PCM/DDAS ASSEMBLY. THE RDSM OUTPUTS 10 WORDS (100 BITS TOTAL) TO THE PCM/DDAS ASSEMBLY. EACH GROUP OF 10 BITS IS SAMPLED AT A RATE OF 12 SAMPLES PER SECOND.

A BLOCK DIAGRAM OF THE RDSM IS PROVIDED IN FIGURE 4.2.10.. THE DIGITAL GATE CARD IS COMPOSED OF 10 DIGITAL GATE CIRCUITS WHICH ARE EACH SWITCHED ON BY THE OUTPUT COUNT FROM THE DECODER CARD. THE EQUIVALENT CIRCUIT OF THE DIGITAL GATE CARDS AND THE ACTUAL CIRCUIT OF A DIGITAL GATE ARE SHOWN IN FIGURES 4.2.11 AND 4.2.12. THE DECODER CARD GENERATES 10 OUTPUT COUNTS FROM THE PCM/DDAS SYNC OUTPUTS (FIGURE 4.2.13). THE LOGIC LEVEL OF THE 10 INPUTS OF A CHANNEL ARE SAMPLED SEQUENTIALLY AND USED TO SET THE FLIP FLOP TO THE APPROPRIATE STATE. THE FLIP FLOP RETAINS THE LOGIC LEVEL UNTIL AFTER THE PCM/DDAS ASSEMBLY HAS ENCODED THE DIGITAL WORD. A RESET COMMAND RESETS THE FLIP FLOP PRIOR TO SAMPLING THE NEXT INPUT.

4.2.1.4 BI-LEVEL SUMMING MODULE

THE PURPOSE OF THE BI-LEVEL SUMMING MODULE IS TO MULTIPLEX THREE 28 VOLT ON-OFF FUNCTIONS ON ONE PAM CHANNEL. THE SCHEMATIC OF THE BI-LEVEL SUMMING MODULE IS GIVEN IN FIGURE 4.2.14. A 28V SIGNAL APPLIED TO A INPUT CHANNEL CAUSES THE APPROPRIATE TRANSISTOR TO CONDUCT. THIS APPLIES 20 VOLTS INTO THE SUMMING RESISTOR. THE OUTPUT VOLTAGE FOR EACH INPUT MUST CODE THE FIRST THREE BITS OF THE TEN BIT BINARY PCM WORD (REF. TABLE 4.2.1).

4.2.1.5

MODEL 301 PULSE CODE MODULATION/DIGITAL DATA ACQUISITION SYSTEM (PCM/DDAS)

THE PCM/DDAS ASSEMBLY OPERATES AT A BIT RATE OF 72,000 BITS PER SECOND RATE AND USES NONRETURN TO ZERO (NRZ) CODING. THE 3,600 SAMPLE PER SECOND PAM WAVETRAINS FROM THE TWO MULTIPLEXERS (SIVB CP1BO AND IU CP1AO) ARE FED INTO A PAM SCANNER IN THE PCM DDAS ASSEMBLY. THE PAM SCANNER TIME SHARES THIS DATA INTO A SINGLE CHANNEL OF DATA AT 7,200 SAMPLES PER SECOND AND FEEDS IT INTO AN ANALOG-TO-DIGITAL (A/D) CONVERTER. THE CONVERTER ENCODES THE DATA INTO A SERIES OF 10-BIT DIGITAL WORDS TO GIVE THE 72,000 BIT RATE OF THE SYSTEM. BI-LEVEL PARAMETERS, MEASUREMENTS WHICH INDICATE THE EXISTENCE OF ONE OF TWO POSSIBLE STATES, ARE INSERTED IN GROUPS OF 10 INTO PRE-PROGRAMMED TIME SLOTS. ALONG WITH THE OUTPUT GROUPS OF BITS FROM THE REMOTE DIGITAL SUBMULTIPLEXER. A SYSTEM BLOCK DIAGRAM IS GIVEN IN FIGURE 4.2.15.

THE PCM/DDAS ASSEMBLY HAS TWO OUTPUT MODES, PULSE CODE MODULATION, AND A 600 KHZ VOLTAGE CONTROLLED OSCILLATOR. THE OSCILLATOR FREQUENCY IS MODULATED BY THE PULSE CODE MODULATED SIGNAL. THE PULSE CODE MODULATION SIGNAL IS ROUTED DIRECTLY TO A RF TRANSMITTER (CPI LINK) WHICH TRANSMITS THE INFORMATION TO THE GROUND STATION. THE 600 KHZ SIGNAL IS ROUTED TO THE GROUND STATION THROUGH THE UMBILICAL CABLE AND IS USED FOR CHECKOUT OPERATIONS.

4.2.2

PCM/DDAS TELEMETRY FAULT ISOLATION

THE FAULT ISOLATION ROUTINES FOR THE PCM/DDAS TELEMETRY SUBSYSTEM ARE PRESENTED IN THIS SECTION. THEY CAN BE USED AS AIDS IN ANY TROUBLE SHOOTING EFFORT THAT MAY BE ENCOUNTERED AS A RESULT OF AN INDICATED TELEMETRY SYSTEM FAILURE. THE STAGE IS CONSIDERED TO BE IN NORMAL CONFIGURATION, AND STAGE POWER IS APPLIED ON THE SIVB AND IU STAGES.

IT IS REALIZED THAT THE FAULT ISOLATION ROUTINES OFFER ONLY ONE APPROACH TO ISOLATING THE PROBLEM, HOWEVER, THE ROUTINES HAVE BEEN PREPARED IN THE ABSENCE OF COUNTDOWN ANXIETIES AND IT IS FELT THAT THE PRE-PLANNED EFFORT INHERENT IN THE ROUTINES DOES PRESENT A DIRECT AND SYSTEMATIC APPROACH TO ISOLATING THE FAILURE QUICKLY AND EFFICIENTLY. THE FAULT ISOLATION ROUTINES ARE LISTED BELOW ACCORDING TO THE NORMAL CONDITIONS THAT WOULD INDICATE A SYSTEM FAILURE.

4.2.2.1

PCM GROUP POWER ON INDICATION OFF

4.2.2.2

PCM/DDAS 600 KHZ SIGNAL FAILURE

4.2.2.3

LOSS OF SIVB DATA VALID

4.2.2.4

LOSS OF IU DATA VALID

4.2.2.5

PCM/DDAS CHANNEL FAILURE

4.3

MEASUREMENT SUBSYSTEM COMPONENT DESCRIPTION

4.3.1

TRANSDUCERS

A TRANSDUCER IS A DEVICE FOR CHANGING ENERGY FROM ONE FORM TO ANOTHER. IN MEASURING TECHNIQUES, THEY ARE USED AS ELECTROMECHANICAL MEASURING INSTRUMENTS WHICH CONTAIN SENSING DEVICES FOR CONVERTING MECHANICAL AND ENVIRONMENTAL QUANTITIES INTO ELECTRICAL SIGNALS. THE FOLLOWING PARAGRAPHS CONTAIN A BRIEF DESCRIPTION OF SOME TYPICAL S-IVB-503N TRANSDUCERS.

4.3.1.1

TEMPERATURE MEASUREMENTS

THE MAJORITY OF TEMPERATURE MEASUREMENTS ON THE S-IVB STAGE UTILIZE RESISTANCE THERMOMETERS WHICH ARE EXTREMELY ACCURATE, POSITIVE TEMPERATURE COEFFICIENT RESISTORS. A TYPICAL RESISTANCE THERMOMETER TYPE OF TRANSDUCER IS C0132-414 (TEMPERATURE OXIDIZER TANK OUTLET MODE 1 (APS)), TELEMETRY CHANNELS CP1BO-11-04 AND DP1BO-11-04 WITH A RANGE FROM 460 DEG TO 590 DEG R. DATA REDUCTION IS ACCOMPLISHED BY MEANS OF A STRAIGHT-FORWARD TEMPERATURE-VERSUS RESISTANCE METHOD. THE SIGNAL FROM THE TRANSDUCER IS SENT TO A BRIDGE ASSEMBLY AND THEN TO A DC AMPLIFIER WHICH INCREASES THE VOLTAGE LEVEL TO THE REQUIRED 0-5V TELEMETRY INPUT. THIS SIGNAL THEN GOES TO THE MULTIPLEXER. TWO BASIC TYPES OF TEMPERATURE MEASUREMENT DEVICES ARE ILLUSTRATED IN FIGURE 4.3-1.

4.3.1.2

PRESSURE MEASUREMENTS

THE TYPES OF TRANSDUCERS MOST COMMONLY USED FOR PRESSURE MEASUREMENT ARE THE POTENTIOMETER AND THE STRAIN GAGE. THE POTENTIOMETER TRANSDUCER IS, BASICALLY, A WIRE WOUND POTENTIOMETER WITH THE WIPER MECHANICALLY CONNECTED TO A PRESSURE CONTROLLED BELLOWS OR BOURDON TUBE (SEE FIGURE 4.3-2). THE OUTPUT VOLTAGE IS OBTAINED BY APPLYING 5 VDC TO THE POTENTIOMETER, WITH THE OUTPUT VARYING BETWEEN 0 V - 5 V DEPENDING ON THE POSITION OF THE WIPER. SINCE THE OUTPUT IS WITHIN THE LIMIT REQUIRED BY THE TELEMETRY SYSTEM NO SIGNAL CONDITIONING IS NECESSARY. AN EXAMPLE OF A TYPICAL POTENTIOMETER TYPE TRANSDUCER IS D0041-403 (PRESSURE - HYDRAULIC SYSTEM), 1,500 - 4,500 PSIA RANGE, TELEMETRY CHANNELS CP1BO-13-05 AND DP1BO-13-05. AN EXAMPLE OF THIS TYPE TRANSDUCER IS ILLUSTRATED IN FIGURE 4.3-3 .

EACH STRAIN GAGE TRANSDUCER CONSISTS OF FOUR INDIVIDUAL STRAIN GAGES MECHANICALLY CONNECTED TO A PRESSURE SENSITIVE DIAPHRAGM AND ARRANGED IN SUCH A MANNER THAT COMPRESSION ON TWO OF THE GAGES RESULTS IN TENSION ON THE OTHER TWO. THIS ACTION RESULTS IN AN OUTPUT WHEN THE STRAIN GAGE TRANSDUCER IS EXCITED BY AN EXTERNAL VOLTAGE. THE OUTPUT VOLTAGE OF THE STRAIN GAGE IS APPROXIMATELY 40 MV. THEREFORE, THE SIGNAL MUST BE FED INTO A DC AMPLIFIER, EITHER AN INTEGRAL PART OF THE TRANSDUCER OR A SEPERATE UNIT ON A SIGNAL CONDITIONING PANEL, BEFORE IT CAN BE APPLIED TO THE MULTIPLEXERS. A TYPICAL STRAIN GAGE TRANSDUCER IS D0019-401 (PRESSURE - ENGINE CONTROL HELIUM SPHERE), TELEMETRY CHANNELS CP1BO-13-04 AND DPIBO-13-04, AND A RANGE OF 0 TO 3,500 PSIA.

4.3.1.3

FLOWRATE MEASUREMENTS

THE FLOWRATE MEASUREMENTS ARE MADE BY FLOWMETERS WHICH CONVERT THE RATE OF FLOW OF A FLUID WITHIN A PIPE INTO AN ELECTRICAL SIGNAL (SEE FIGURE 4.3-4). THE FLOWMETER CASING CONSISTS OF A SHORT PIECE OF PIPE FORMING PART OF A FLUID-FLOW LINE AND CONTAINING A FREE-RUNNING TURBINE. EXTERNAL TO THE CASING IS A COIL SURROUNDED BY A PERMANENT MAGNETIC FIELD. FLUID PUMPED THROUGH THE FLOWMETER CAUSES THE TURBINE TO TURN AT A RATE DIRECTLY PROPORTIONAL TO THE VELOCITY OF THE FLUID. THE METAL TURBINE BLADES DISTURB THE MAGNETIC FIELD, INDUCING A CURRENT IN THE COIL. EACH TIME A BLADE DISTURBS THE FIELD THE CURRENT FLOWS. THE FREQUENCY OF THESE CURRENT CHANGES IS DIRECTLY PROPORTIONAL TO THE TURBINE SPEED AND THEREFORE FLUID FLOWRATE. THE AC OUTPUT SIGNAL IS SENT TO A FREQUENCY-TO-DC CONVERTER AND THEN TO THE 270 MULTIPLEXER. A TYPICAL FLOWMETER IS F0004-424 (FLOWMETER-OXIDIZER CIRCULATION PUMP), TELEMETRY CHANNEL DP1BO-21-03, WITH A RANGE OF 0 TO 50 GPM. AN ILLUSTRATION OF THIS MEASUREMENT IS PRESENTED IN FIGURE 4.3-4.

4.3.1.4

LIQUID LEVEL

THE LIQUID-LEVEL SENSORS ARE THE CAPACITIVE TYPE CONSISTING OF AN AIR-GAP CAPACITANCE SENSOR AND A CONTROL UNIT HAVING A RELAY AS AN OUTPUT (SEE FIGURE 4.3-5). THE DRY SENSOR INCREASES IN CAPACITANCE WHEN IMMERSSED IN LIQUID OXYGEN OR LIQUID HYDROGEN DUE TO THE HIGH DIELECTRIC CONSTANT OF THE LIQUID. THE CONTROL UNIT DETECTS THE INCREASED CAPACITANCE OF THE SENSOR AND ENERGIZES AN INTERNAL RELAY. THE RELAY CONTACTS SWITCH THE 5 V INSTRUMENTATION EXCITATION GIVING A DISCRETE OUTPUT. A TYPICAL LEVEL SENSOR IS L0014-408 (LEVEL-LIQUID HYDROGEN TANK, POSITION A), TELEMETRY CHANNEL CP1BO-09R07-04.

4.3.1.5

VIBRATION (OPTIONAL - DEPENDENT UPON MISSION REQUIREMENTS)

THE VIBRATION SENSORS ARE PIEZOELECTRIC ACCELEROMETERS WHICH CONSIST OF A SEISMIC MASS WHICH APPLIES FORCE TO A PIEZOELECTRIC CRYSTAL, CAUSING IT TO GENERATE AN ELECTRICAL SIGNAL. THE ELECTRICAL OUTPUT IS PROPORTIONAL TO THE FORCE APPLIED TO THE CRYSTAL AND THEREFORE, TO THE AMPLITUDE OF THE VIBRATION. A TYPICAL VIBRATION MEASUREMENT IS E0042-403 (VIBRATION, THRUST STRUCTURE AT HELIUM BOTTLE - PITCH), TELEMETRY CHANNEL DFI-14.

4.3.1.6

ACCELERATION (OPTIONAL - DEPENDENT UPON MISSION REQUIREMENTS)

THE ACCELERATION SENSORS ARE OF A OIL DAMPED FORCED BALANCE LINEAR SERVO-ACCELEROMETER WHICH MEASURES THE ACCELERATION DURING LAUNCH OF THE VEHICLE. THE ACCELEROMETER FUNCTIONS AS A MINIATURE SERVO SYSTEM RESPONSIVE TO INPUT ACCELERATIONS ALONG ITS SENSITIVE AXIS. INPUT ACCELERATION CAUSES A FORCE WHICH TENDS TO MOVE A SEISMIC MASS AND OFF SETS THE SERVO'S BALANCE. THIS OFF SET IS DETECTED AND A SERVO-NULLING AMPLIFIER REQUIRES A GIVEN PRE-SET INPUT. THE AMPLIFIER, THEREFORE, SENDS A FEEDBACK CURRENT THROUGH A RESTORING COIL WHICH IS LOCATED IN A PERMANENT MAGNETIC FIELD, THUS CAUSING A FORCE EXACTLY EQUAL AND OPPOSITE TO THE INPUT FORCE CAUSED BY ACCELERATION. THE RESTORING FORCE RETURNS THE SEISMIC SYSTEM TO ITS ORIGINAL POSITION. AN ANALOG VOLTAGE OUTPUT DIRECTLY PROPORTIONAL TO INPUT ACCELERATION IS OBTAINED BY MEASURING THE DROP THIS CURRENT PRODUCES ACROSS A KNOWN RESISTOR. A TYPICAL ACCELEROMETER MEASUREMENT IS A 0012-403 (ACCELERATION-GIMBAL BLOCK, LONGITUDINAL, LOW FREQUENCY), TELEMETRY CHANNEL DFI-09.

4.3.1.7

POSITION MEASUREMENT

A TYPICAL POSITION MEASUREMENT IS G0001-403 (POSITION-ACTUATOR PISTON POT-PITCH), TELEMETRY CHANNEL DP1BO-23-01. THE DATA IS OBTAINED BY MEANS OF A DIRECT, MECHANICALLY COUPLED POTENTIOMETER WHICH INDICATES THE POSITION OF THE J-2 ENGINE PITCH ACTUATOR. THE CALIBRATION OF THIS MEASUREMENT YIELDS A 0 TO 5 V SIGNAL CORRESPONDING TO -7.5 TO +7.5 DEG OF ENGINE DISPLACEMENT IN THE PITCH PLANE. AN ILLUSTRATION OF THIS TYPE OF MEASUREMENT IS PRESENTED IN FIGURE 4.3-3.

4.3.2

ELECTRICAL SIGNAL MEASUREMENT

MANY SIGNALS OF AN ELECTRICAL NATURE MAY BE MONITORED DIRECTLY, PROVIDED THE SIGNAL CHARACTERISTICS AND THE TELEMETRY SYSTEM INPUT CIRCUITRY ARE COMPATIBLE. THE TELEMETRY SYSTEM TIME-DIVISION MULTIPLEXERS AND PCM/DDAS INPUT CIRCUITS WILL ACCEPT DC OR LOW-RESPONSE ANALOG SIGNALS IN THE RANGE OF 0 TO 30 MV OR 0 TO 5 V AND BI-LEVEL SIGNALS IN THE RANGE OF 0 TO 5 V AND 0 TO 28 V. IF THE SIGNAL TO BE MONITORED IS OUTSIDE THESE RANGES IT MUST FIRST BE SIGNAL-CONDITIONED AS DESCRIBED IN PARAGRAPH 4.3.3.

ELECTRICAL SIGNALS WHICH DO NOT REQUIRE SIGNAL CONDITIONING INCLUDE:

- (1) EVENTS - THE PRESENCE OR ABSENCE OF A VOLTAGE WHICH IS CHARACTERISTIC OF THE SYSTEM BEING MONITORED OR ALTERNATIVELY, THE ACTION OF A SET OF SWITCH OR RELAY CONTACTS MONITORED BY APPLYING VOLTAGE TO AN AUXILIARY SET OF CONTACTS OR TAPPING THE SWITCHED SIGNAL WITH SUITABLE ISOLATION TO PROTECT IT FROM FAILURES IN THE TELEMETRY SYSTEM.
- (2) TRANSDUCER OUTPUTS - MANY TRANSDUCERS, SUCH AS POTENTIOMETER TYPE PRESSURE TRANSDUCERS OR POSITION INDICATORS, HAVE OUTPUTS WHICH DO NOT REQUIRE SIGNAL CONDITIONING. OTHER TRANSDUCERS MAY CONTAIN INTEGRAL SIGNAL CONDITIONING WHICH CONVERTS THE SIGNALS SO THAT THEY ARE ACCEPTABLE TO THE TELEMETRY.

4.3.3

SIGNAL CONDITIONING

MANY TYPES OF ELECTRICAL SIGNALS REQUIRE SIGNAL CONDITIONING TO CONVERT THEM FROM THEIR ORIGINAL CHARACTERISTICS TO A SIGNAL WHICH IS ACCEPTABLE TO THE TELEMETRY SYSTEM. SIGNAL CONDITIONING ON THE S-IVB IS PERFORMED BY MODULES MOUNTED ON SIGNAL CONDITIONING PANELS. SIGNAL CONDITIONING REQUIRES PRECISE VOLTAGES AND THE MODULES ARE SUPPLIED, AS REQUIRED WITH REGULATED +20 VDC FROM THE 20 V EXCITATION MODULES LOCATED ON EACH SIGNAL CONDITIONING PANEL AND -20 VDC FROM THE 5 V EXCITATION MODULES IN ADDITION TO THE UNREGULATED 28 VDC SUPPLIED FROM THE STAGE BUS.

THE FOLLOWING PARAGRAPHS PRESENT A BRIEF DESCRIPTION OF SOME COMMON SIGNAL CONDITIONING NETWORKS AND THE 5 V AND 20 V EXCITATION MODULES.

4.3.3.1

5-VOLT EXCITATION MODULE

THE 5 V EXCITATION MODULE IS A TRANSISTORIZED POWER CONVERSION DEVICE WHICH OPERATES ON UNREGULATED 28 VDC POWER AND SUPPLIES (1) 5 VDC EXCITATION TO POTENTIOMETER TYPE PRESSURE AND POSITION TRANSDUCERS, (2) -20 VDC FOR SIGNAL CONDITIONING NEGATIVE BIAS SUPPLY AND (3) 10 V PEAK-TO-PEAK, 2,000 HZ SQUARE WAVE MAGNETIC AMPLIFIER EXCITATION FOR TEMPERATURE AND CURRENT MEASUREMENTS INTERNAL TO THE STAGE BATTERIES. THE MODULE EMPLOYS A DC-TO-DC CONVERTER FOR POWER EFFICIENCY IN THE VOLTAGE TRANSFORMATION AND GENERATES THE 5 V AND -20 V SUPPLIES FROM A COMMON SATURATING FREQUENCY OSCILLATOR. THE LOWER VOLTAGE SECTIONS CONTAIN SEPARATE FULL WAVE RECTIFIERS AND ARE SERIES REGULATED USING AN ERROR AMPLIFIER TYPE SERIES REGULATOR.

4.3.3.2

20-VOLT EXCITATION MODULE

THE 20 V EXCITATION MODULE IS A TRANSISTORIZED POWER CONVERSION DEVICE USED TO SUPPLY REGULATED +20 VDC USED FOR THE SIGNAL CONDITIONING POSITIVE BIAS SUPPLY OR BRIDGE EXCITATION. THE MODULE IS BASICALLY A SERIES REGULATOR EMPLOYING AN ERROR AMPLIFIER TYPE SERIES VOLTAGE REGULATOR AND IS CAPABLE OF SUPPLYING 200 MA AT 20 VDC. ONE MODULE IS MOUNTED ON EACH SIGNAL CONDITIONING PANEL.

4.3.3.3 TEMPERATURE BRIDGE

THE TEMPERATURE SENSING ELEMENT IS USED AS ONE ARM OF A BRIDGE NETWORK. THE NETWORKS ARE DESIGNED TO OPERATE WITH A BRIDGE EXCITATION OF 20 VDC AND HAVE AN OUTPUT RANGE OF 0 TO 30 MV CORRESPONDING TO THE FULL RANGE OF TEMPERATURE BEING MEASURED. THE 0 TO 30 MV OUTPUT CAN BE INPUT DIRECTLY INTO THE REMOTE ANALOG SUB-MULTIPLEXER (RASM) OR AMPLIFIED BY A DC AMPLIFIER TO A 0 TO 5 V LEVEL.

4.3.3.4 AMPLIFIERS

MANY INFLIGHT AMPLIFICATION REQUIREMENTS CAN BE SATISFIED BY A SINGLE-ENDED DIRECT COUPLED AMPLIFIER HAVING A GAIN OF 50 OR LESS. SEVERAL CONFIGURATIONS OF SUCH A LOW-GAIN DC AMPLIFIER ARE UTILIZED FOR MEASUREMENTS SUCH AS RF POWER (N0018) AND RF REFLECTED POWER (N0055-411)

FOR TEMPERATURE BRIDGES, AND CERTAIN OTHER LOW-LEVEL SIGNAL CONDITIONING MODULES, A HIGH GAIN DC AMPLIFIER, OF SEVERAL CONFIGURATIONS, PROVIDES GAIN FROM 45 TO 975 VOLTS PER VOLT. IT IS BASICALLY AN AC OPERATION CONSISTING OF A POWER SUPPLY SECTION AND AN AMPLIFIER SECTION CONTAINING A MODULATOR, AC AMPLIFIER, DEMODULATOR AND FILTER. THE GAIN AND ZERO OFFSET OF AN AC AMPLIFIER ARE INHERENTLY STABLE SINCE THE DC BIAS LEVELS HAVE LITTLE EFFECT ON AMPLIFIER STABILITY. BOTH TYPES OF AMPLIFIER HAVE ADJUSTABLE GAIN TO ENABLE ADJUSTMENT TO A 0 TO 5 V OUTPUT SWING CORRESPONDING TO THE PARTICULAR INPUT SIGNAL RANGE.

4.3.3.5 EXPANDED SCALE MEASUREMENTS

WHEN A REQUIREMENT EXISTS TO MEASURE A SIGNAL HAVING A NORMAL OPERATIONAL VOLTAGE RANGE CONSIDERABLY LESS THAN ITS MAXIMUM AMPLITUDE IT BECOMES NECESSARY TO CONDITION THE SIGNAL SO THAT THE OPERATIONAL RANGE CORRESPONDS TO THE FULL T/M CHANNEL OUTPUT. THIS WOULD BE THE CASE FOR A SIGNAL SUCH AS THE STATIC INVERTER VOLTAGE (M0001-411) WHICH HAS A MEASUREMENT RANGE OF 90 TO 135 VAC AT 400 HZ. IF THE SIGNAL WERE ONLY RECTIFIED THE NORMAL RANGE WOULD OCCUPY ONLY $1/3$ OF THE 0 TO 5 V T/M CHANNEL RANGE AND THE ACCURACY WOULD NOT BE SUFFICIENT TO MEET THE MEASUREMENT REQUIREMENTS. THEREFORE THE SIGNAL IS RECTIFIED AND DIVIDED TO GIVE AN OUTPUT VOLTAGE SWING OF 5 V (14 TO 19 VDC) CORRESPONDING TO THE 45 VAC SWING OF THE INPUT. THE SIGNAL IS THEN BIASED BY THE NEGATIVE SUPPLY VOLTAGE TO A LEVEL SUCH THAT THE OUTPUT VARIES FROM 0 TO 5 VDC FOR A 90 TO 135 VAC INPUT.

4.4

MEASUREMENT SUBSYSTEM FAULT ANALYSIS

AS A RESULT OF THE FAULT ISOLATION GROUND RULE THAT TROUBLESHOOTING WOULD BE LIMITED TO WHAT COULD BE PERFORMED FROM THE LCC, EXACT DETERMINATION OF A MEASUREMENT FAILURE COULD PROVE TO BE DIFFICULT. SOME FAILURE MODES ARE IMMEDIATELY EVIDENT SUCH AS A SHORTED OR OPEN TEMPERATURE PATCH WHILE OTHERS MAY NOT BE SO APPARENT.

THE FAULT ISOLATION PHILOSOPHY FOR A MEASUREMENT FAILURE AS PRESENTED IN THIS SECTION IS ONE OF MANY ALTERNATIVES.

SINCE THERE ARE THREE BASIC TYPES OF MEASUREMENTS DISPLAYED ON THE FIRING ROOM STRIP CHARTS, EACH TYPE HAS BEEN CONSIDERED INDIVIDUALLY AND AN ASSOCIATED FLOW CHART PREPARED. THE THREE TYPES ARE AS FOLLOWS:

1. STAGE DDAS MEASUREMENTS
2. GROUND (ESE) DDAS MEASUREMENTS
3. HARDWIRE MEASUREMENTS

IN ORDER TO SIMPLIFY THE FLOW CHARTS SOME BASIC CONDITIONS WERE ESTABLISHED. IT WAS ASSUMED THAT THE RECORDER DISPLAYING THE MEASUREMENT IN QUESTION HAD NOT MALFUNCTIONED, AND, IF THE MEASUREMENT WAS ON DDAS THAT THE DDAS LINK WAS VALID. PRE-PLANNED TROUBLESHOOTING COULD THEN PROCEED DIRECTLY INTO ANALYSIS OF THE SUSPECTED MEASUREMENT FAILURE.

ALL THREE OF THE SUSPECTED MEASUREMENT FLOW CHARTS ARE BASICALLY THE SAME FORMAT. A DISCUSSION OF EACH CATEGORY FOLLOWS:

4.4.1

SUSPECTED STAGE DDAS MEASUREMENT FAILURE

THE FLOW CHART FOR THESE MEASUREMENTS IS PRESENTED IN FIGURE 4.4-3. AFTER OBSERVING AN ABNORMAL INDICATION ON A STRIP CHART DISPLAYING A STAGE DDAS MEASUREMENT, IT MUST BE DETERMINED AS QUICKLY AS POSSIBLE THAT THIS DATA ABNORMALITY IS DEFINITELY A MEASUREMENT PROBLEM. IN SOME CASES THIS CAN BE QUICKLY ESTABLISHED BY REFERRING TO THE BACKUP FOR THE SUSPECTED MEASUREMENT FOR CORRELATION. IF NO BACKUP IS AVAILABLE THEN RELATED MEASUREMENTS SHOULD BE EXAMINED. IF NO RELATED MEASUREMENTS EXIST, THEN THE SUSPECTED MEASUREMENTS EXCITATION VOLTAGE SHOULD BE OBSERVED EITHER DIRECTLY BY T/M READOUT, (E.G. 5-VOLT MODULES) OR INDIRECTLY BY OBSERVING OTHER MEASUREMENTS UTILIZING THE SAME SUPPLY (E.G. 20-VOLT MODULES). TABLE 4.4-1 PROVIDES A COMPLETE LISTING OF ALL MEASUREMENTS AND THEIR APPLICABLE EXCITATION SUPPLIES. FIGURES 4.4-1 AND 4.4-2 PROVIDE AN ILLUSTRATION OF MEASUREMENTS VERSUS EXCITATION VOLTAGE FOR QUICK REFERENCE. IF AN EXCITATION SUPPLY FAILURE IS EVIDENT, THE MEASUREMENT FAILURE IS OBVIOUS AND OTHER MEASUREMENTS WOULD BE EFFECTED.

4.4.2

SUSPECTED GROUND DDAS MEASUREMENT FAILURE

THE FLOW CHART FOR THESE MEASUREMENTS IS PRESENTED IN FIGURE 4.4-4. AFTER OBSERVING AN ABNORMAL INDICATION ON A STRIP CHART DISPLAYING A GROUND DDAS MEASUREMENT, IT MUST BE DETERMINED AS QUICKLY AS POSSIBLE THAT THIS DATA ABNORMALITY IS DEFINITELY A MEASUREMENT PROBLEM. IN SOME INSTANCES THIS CAN BE QUICKLY ESTABLISHED BY REFERRING TO THE ASSIGNED BACKUP FOR THE SUSPECTED MEASUREMENT FOR CORRELATION. IF NO ASSIGNED BACKUP IS AVAILABLE THEN RELATED MEASUREMENTS SHOULD BE EXAMINED IF AVAILABLE, OR OBSERVE OTHER BACKUP INDICATION SUCH AS HARDWIRE METERS IN THE CASE OF POWER MEASUREMENTS. IN SOME CASES THE BACKUP READINGS COULD CONFIRM A SIGNAL CONDITIONING FAILURE WHILE OTHERS MAY ONLY AROUSE SUSPICION. IN THE EVENT THE SUSPECTED MEASUREMENT HAS NO BACKUP INDICATION OR RELATED MEASUREMENTS, THEN EXCITATION OR REFERENCE VOLTAGES OR BOTH SHOULD BE INVESTIGATED. MEASUREMENTS HAVING BOEING SIGNAL CONDITIONING IN THE ML CAN BE CHECKED USING THE VERIFICATION CIRCUIT BUT THIS CIRCUIT ONLY CHECKS THE MAGNETIC AMPLIFIER ASSOCIATED WITH THE MEASUREMENT AND DOES NOT VERIFY THE SIGNAL CONDITIONING IF APPLICABLE. HOWEVER, A MAG AMP FAILURE WOULD BE IMMEDIATELY EVIDENT IF THE VERIFICATION CIRCUIT WAS ENERGIZED. UPON ESTABLISHMENT OF A DEFINITE MEASUREMENT FAILURE, PAD ACCESS WOULD BE REQUIRED FOR CORRECTIVE ACTION IF THE MEASUREMENT COULD NOT BE WAIVERED.

4.4.3

SUSPECTED HARDWIRE MEASUREMENT FAILURE

THE FLOW CHART FOR THESE MEASUREMENTS IS PRESENTED IN FIGURE 4.4-5. SOME PERTINENT INFORMATION FOR HARDWIRE MEASUREMENTS IS ILLUSTRATED IN THE MEASUREMENT SUBSYSTEM SCHEMATIC OF FIGURE 4.4-6 AND CAN BE USED FOR REFERENCE. MEASUREMENTS D545, D576 AND D577 HAVE EXCITATION AND REFERENCE VOLTAGE ASSOCIATED WITH THEIR CIRCUITS AS CAN BE SEEN IN FIGURE 4.4-6. ALL THREE OF THESE MEASUREMENTS HAVE STAGE DDAS BACKUP MEASUREMENTS FOR EASY CORRELATION IN THE EVENT OF A SUSPECTED MEASUREMENT FAILURE. MEASUREMENTS 554, 555, 556 AND 557 HAVE BOEING EXPANDED SCALE SIGNAL CONDITIONERS IN THE BASE OF THE ML. THE OUTPUT OF THESE SIGNAL CONDITIONERS DRIVE THE RECORDERS DIRECTLY. ALL FOUR OF THESE MEASUREMENTS HAVE BACKUP HARDWIRE METER INDICATIONS ON THE NETWORKS PANEL FOR EASY CORRELATION IN THE EVENT OF A SUSPECTED MEASUREMENT FAILURE.

4.5

5-VOLT EXCITATION MODULES

THESE MODULES PROVIDE 5VDC AND -20 VDC POWER FOR POT-TYPE TRANSDUCERS AND SIGNAL CONDITIONERS REQUIRING THESE VOLTAGES. IN ADDITION, THEY ALSO PROVIDE 10 VOLT PEAK-TO-PEAK OUTPUTS AT 2000 HZ FOR BATTERY INSTRUMENTATION AND TEMPERATURE CONTROL. THERE ARE THREE 5-VOLT MODULES ON THE STAGE. SEVERAL MEASUREMENTS ARE AVAILABLE ON T/M TO DETERMINE THE PERFORMANCE OF THESE MODULES. THESE MEASUREMENTS ARE AS FOLLOWS:

- (A) M0024 - EXPANDED SCALE MEASUREMENT OF THE FWD NO. 1 5-VOLT EXCITATION MODULE BUS OUTPUT VOLTAGE. THE RANGE OF THIS MEASUREMENT IS 4.5 TO 5.5VDC AND IS ON T/M CHANNELS CP1 AND DP1BO-05-09.
- (B) M0043 - THE FREQUENCY OF THE 10 VOLT P-P, 2000 HZ SQUAREWAVE OUTPUT FROM THE FWD, NO. 1 5-VOLT MODULE. THE RANGE OF THIS MEASUREMENT IS 0 TO 2300 HZ AND IS ON T/M CHANNEL DP1BO-04-08.
- (C) M0068 - EXPANDED SCALE MEASUREMENT OF THE FWD, NO. 2 5-VOLT EXCITATION MODULE BUS OUTPUT VOLTAGE. THE RANGE IS 4.5 TO 5.5 VDC AND IS ON T/M CHANNEL CP1BO-05-08.
- (D) M0025 - EXPANDED SCALE MEASUREMENT OF THE AFT 5-VOLT EXCITATION MODULE BUS OUTPUT VOLTAGE. THE RANGE IS 4.5 TO 5.5 VDC AND IS ON T/M CHANNELS CP1 AND DP1BO-05-10.
- (E) M0069 - DIRECT MEASUREMENT OF THE AFT 5-VOLT MODULE. RANGE IS 0-5 VDC ON CHANNELS CP1 AND DP1BO-28-10.
- (F) M0042 - THE FREQUENCY OF THE 10 VOLT P-P, 2000 HZ SQUAREWAVE OUTPUT FROM THE AFT 5-VOLT MODULE. RANGE IS 0 TO 2300 HZ AND ON CHANNEL CP1BO-14-10.

4.5.1

AFT 5 VOLT EXCITATION MODULE

- (A) LOSS OF THE 10VP-P SQUAREWAVE VOLTAGE WILL RESULT IN THE LOSS OF TEMPERATURE CONTROL FOR AFT BATTERY NO. 1 AND AFT BATTERY NO. 2 ILLUSTRATED IN FIGURE 4.5-1. IT WILL ALSO RESULT IN THE LOSS OF ALL VOLTAGE, CURRENT, AND TEMPERATURE MEASUREMENTS ASSOCIATED WITH THESE BATTERIES. WITH NO TEMPERATURE CONTROL, THE BATTERIES MAY COOL SUFFICIENTLY TO REDUCE THE BATTERY CAPACITY.
- (B) A SIGNIFICANT SHIFT IN THE VOLTAGE OR FREQUENCY MAY RESULT IN THE LOSS OF TEMPERATURE CONTROL FOR AFT BATTERY NO. 1 AND AFT BATTERY NO. 2. IT WILL ALSO RESULT IN A DECREASE IN THE ACCURACY OF THE VOLTAGE, CURRENT, AND TEMPERATURE MEASUREMENTS ASSOCIATED WITH THESE BATTERIES. IF BATTERY TEMPERATURE CONTROL IS LOST, THE BATTERIES MAY COOL SUFFICIENTLY TO REDUCE THE BATTERY CAPACITY.

4.5.2

FWD 5 VOLT EXCITATION MODULE NO. 1

- (A) LOSS OF VOLTAGE WILL RESULT IN THE LOSS OF TEMPERATURE CONTROL FOR FWD BATTERY NO. 1 AND FWD BATTERY NO. 2 ILLUSTRATED IN FIGURE 4.5-2 AND TEMPERATURE MEASUREMENTS ASSOCIATED WITH THESE BATTERIES. WITH NO TEMPERATURE CONTROL, THE BATTERIES MAY COOL SUFFICIENTLY TO REDUCE THE BATTERY CAPACITY.
- (B) A SIGNIFICANT SHIFT IN THE VOLTAGE OR FREQUENCY MAY RESULT IN THE LOSS OF TEMPERATURE CONTROL FOR FWD BATTERY NO. 1 AND FWD BATTERY NO. 2. IT WILL ALSO RESULT IN A DECREASE IN THE ACCURACY OF THE VOLTAGE, CURRENT, AND TEMPERATURE MEASUREMENTS ASSOCIATED WITH THESE BATTERIES. IF BATTERY TEMPERATURE CONTROL IS LOST, THE BATTERIES MAY COOL SUFFICIENTLY TO REDUCE THE BATTERY CAPACITY. REFER TO PARAGRAPH 2.10.5 FOR THE MISSION EFFECTS OF BATTERY COOLING.

20-VOLT EXCITATION MODULES

TEN 20-VOLT EXCITATION MODULES FORM A PART OF THE S-IVB INSTRUMENTATION SYSTEM. THE MODULES ARE POWERED FROM THE PCM SYSTEM GROUP BUS (+4D31.1). THEY PROVIDE +20VDC TO SIGNAL CONDITIONERS AND TRANSDUCERS REQUIRING THIS VOLTAGE.

NUMEROUS MEASUREMENTS DERIVE POWER FROM THE 20-VOLT EXCITATION MODULES, BUT THERE ARE NO DIRECT MEASUREMENTS OF 20-VOLT MODULE PERFORMANCE.

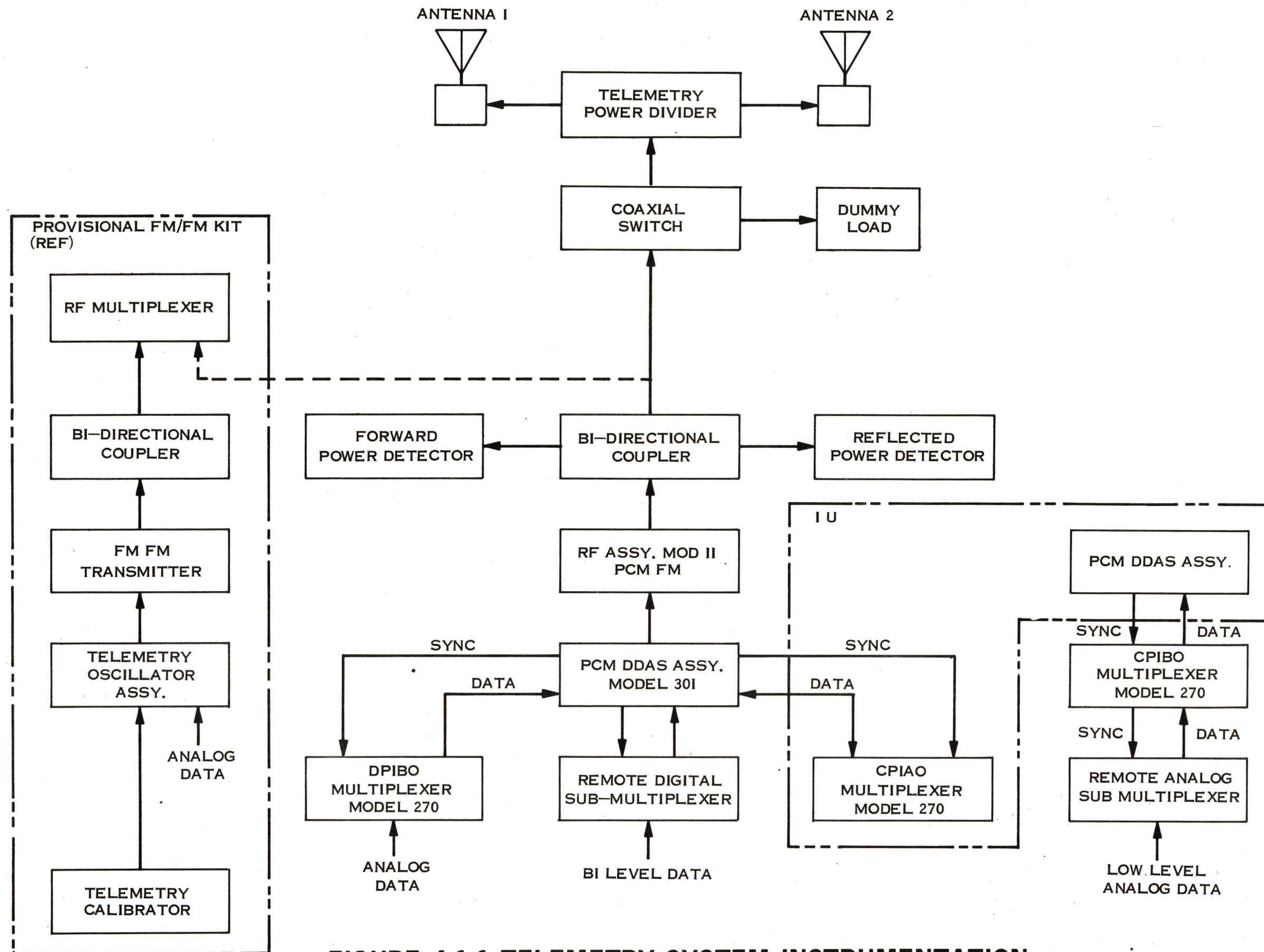


FIGURE 4.1-1 TELEMETRY SYSTEM INSTRUMENTATION

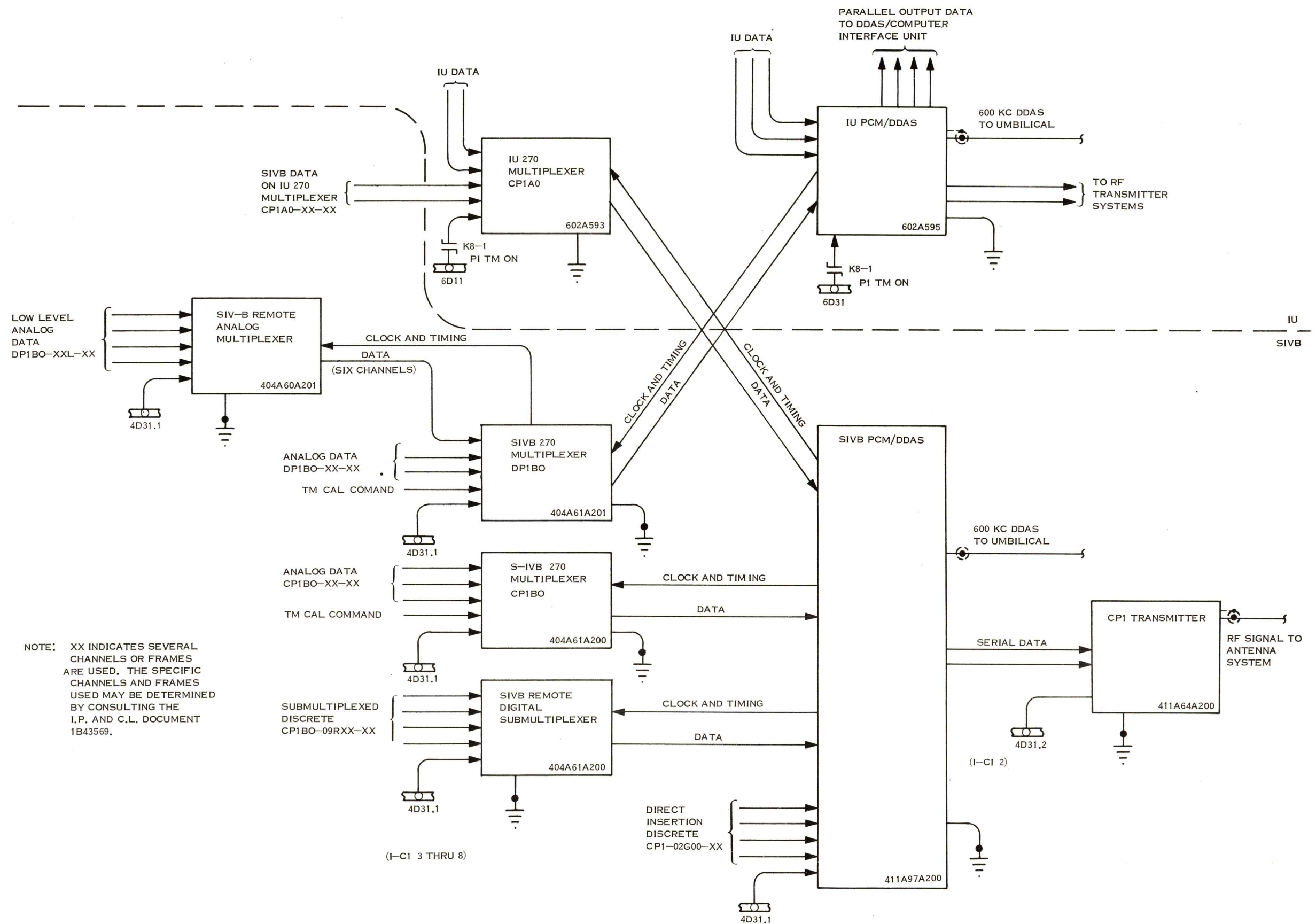


FIGURE 4.1.2 SIVB PCM/DDAS INSTRUMENTATION SYSTEM

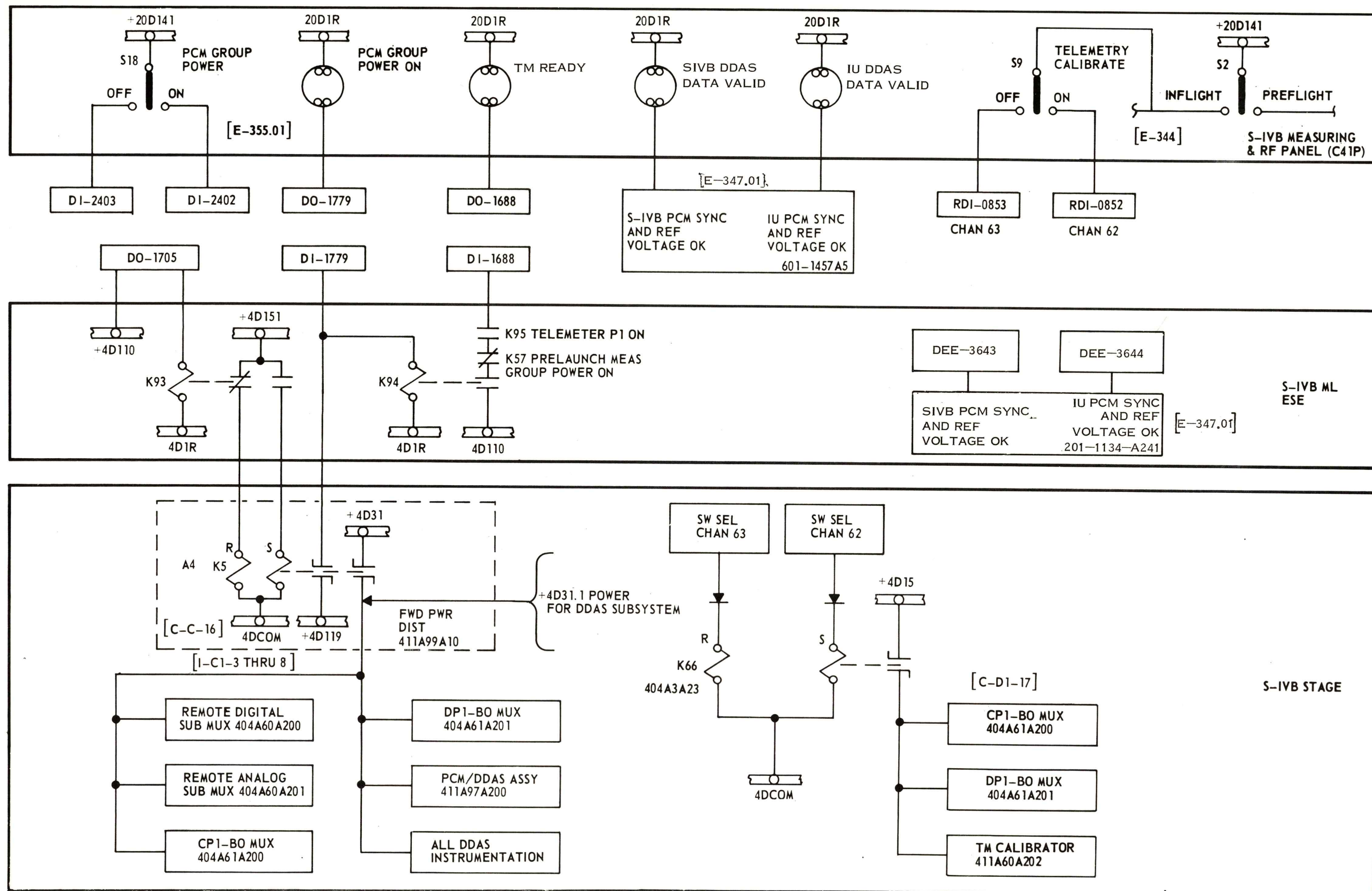


FIGURE 4.1.3 PCM/DDAS SYSTEM CONTROL

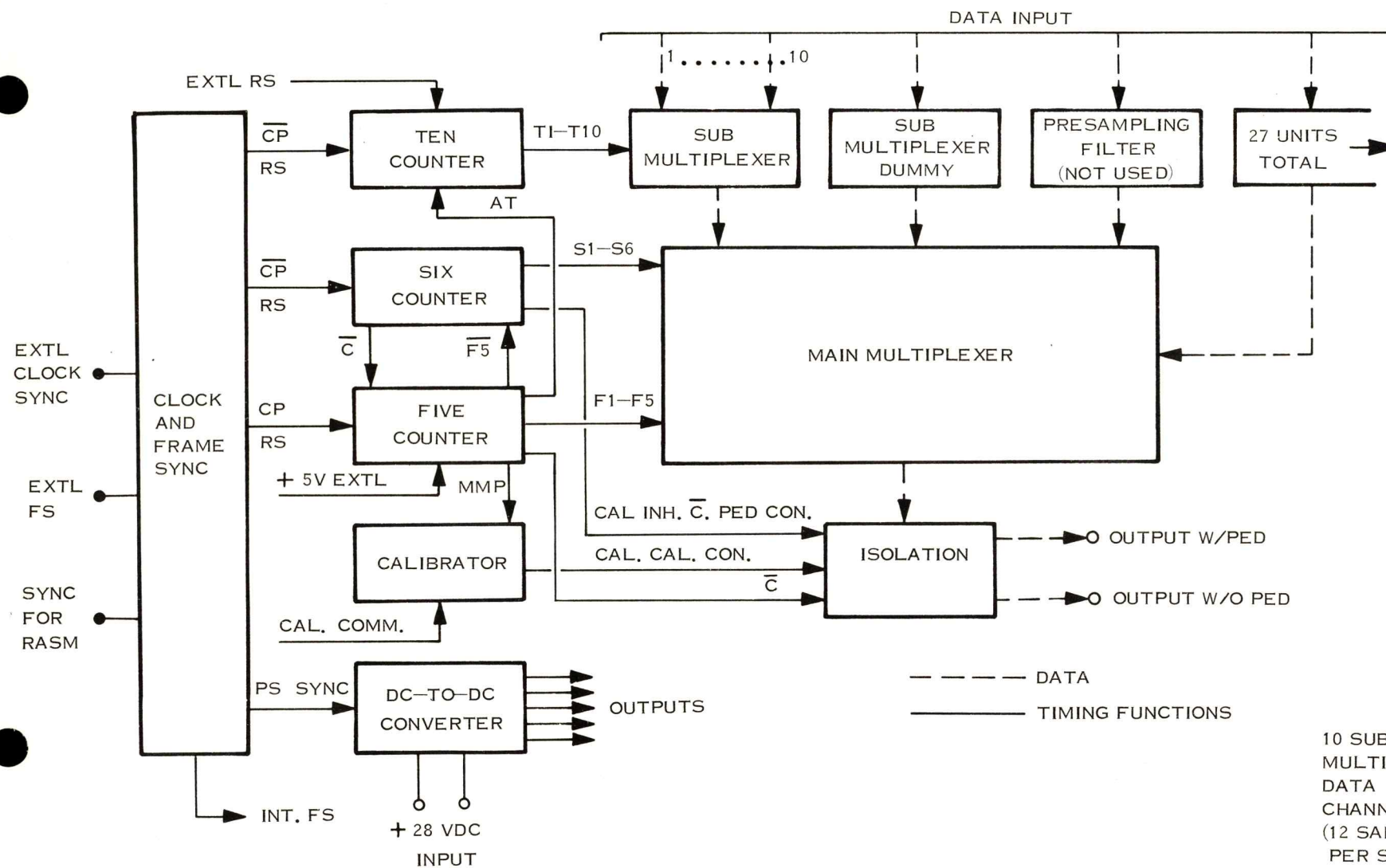


FIGURE 4.2.1 MODLE 270 MULTIPLEXER BLOCK DIAGRAM

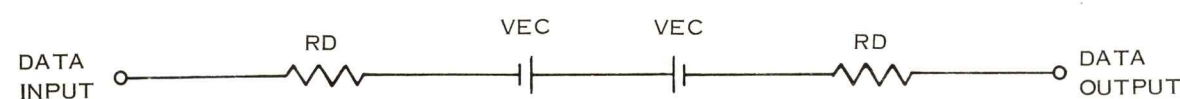


FIGURE 4.2.3 EQUIVALENT CIRCUIT WHEN CONDUCTING

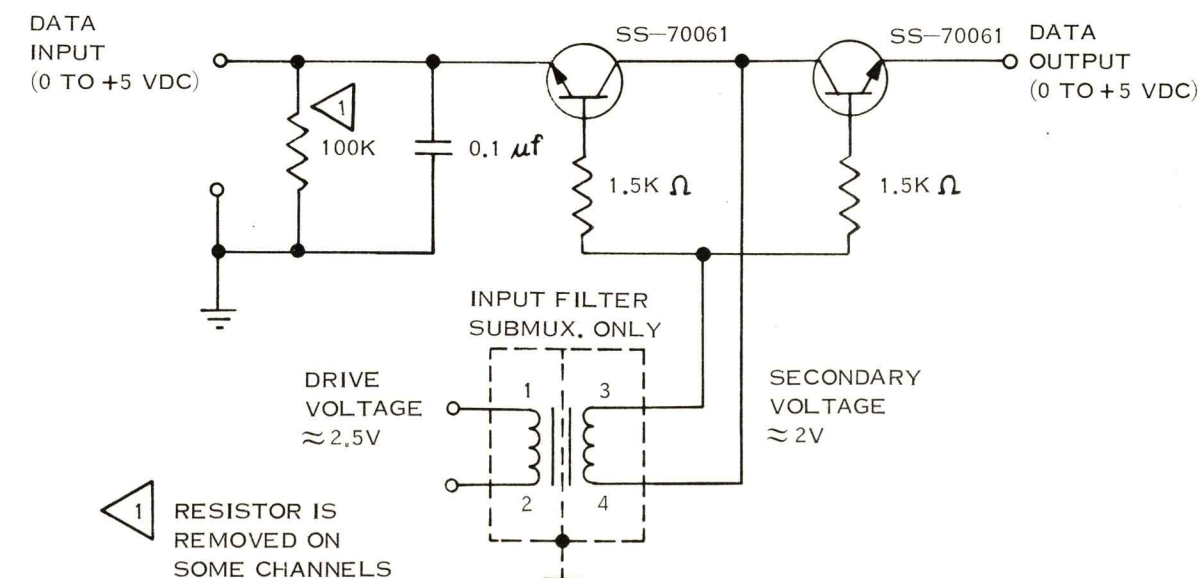


FIGURE 4.2.2 TYPICAL DATA SWITCH AND INPUT FILTER

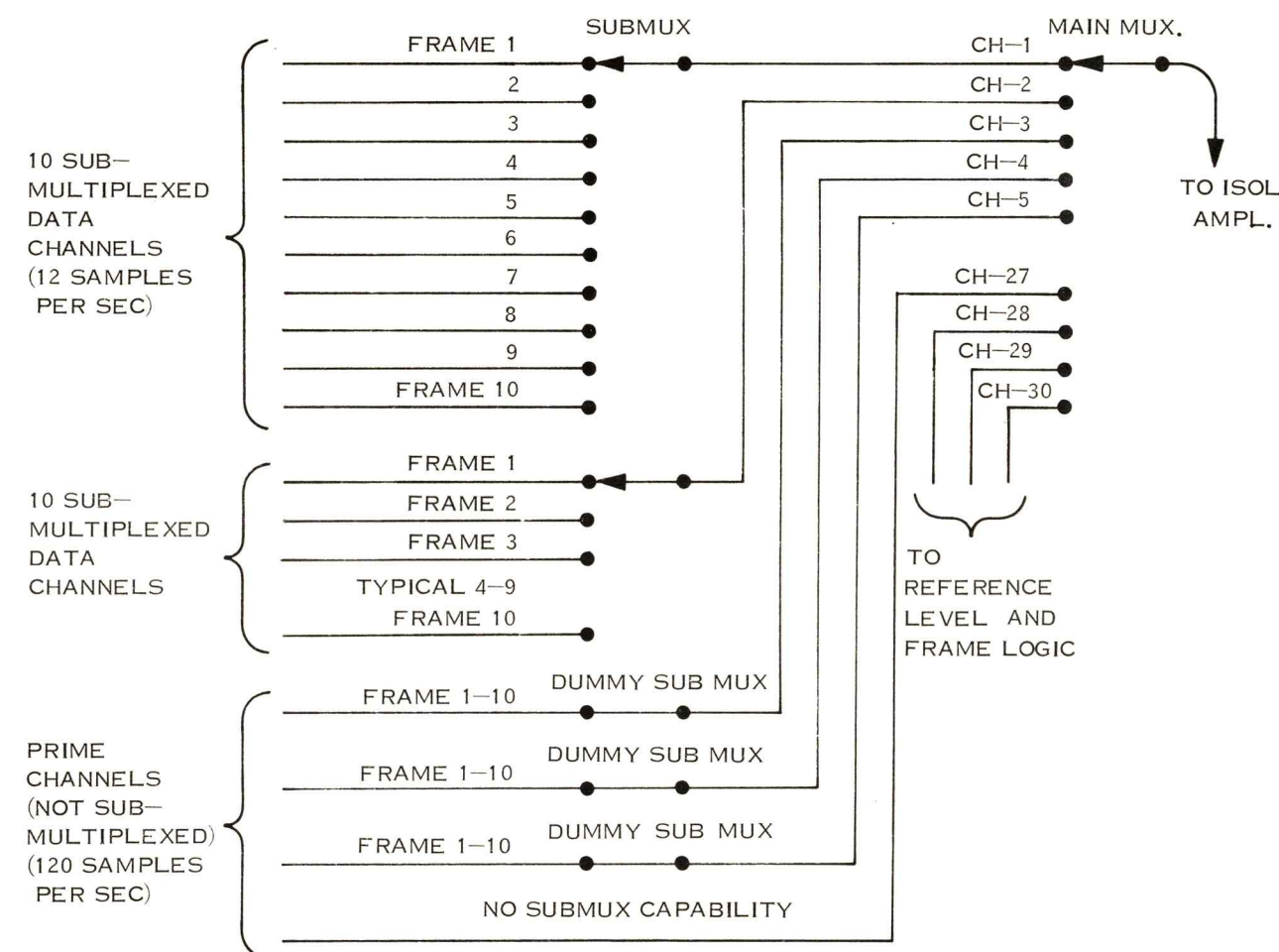


FIGURE 4.2.4 EQUIVALENT SCHEMATIC OF SUB MULTIPLEXER AND MAIN MULTIPLEXER

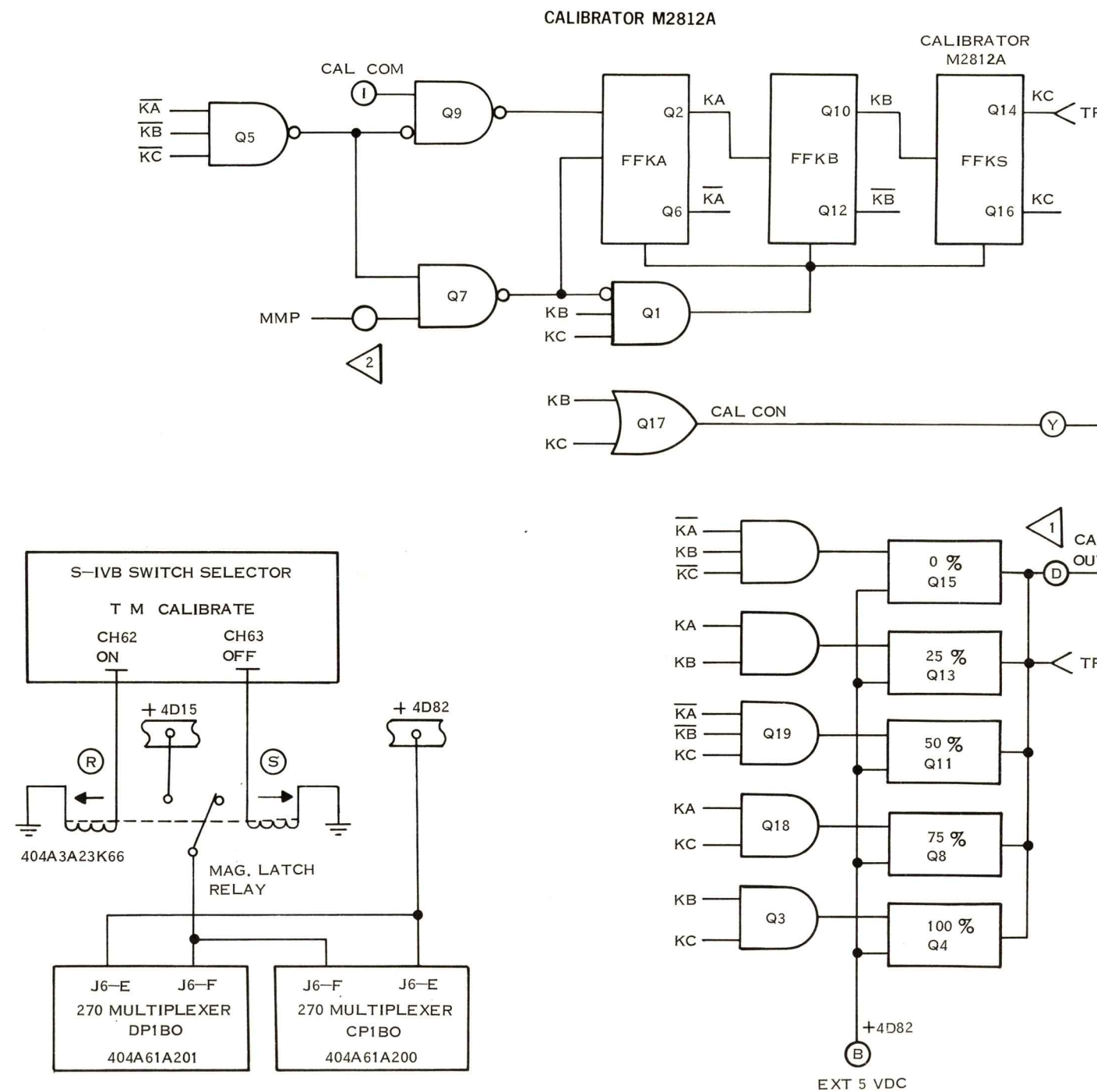


FIGURE 4.2.5 TM CALIBRATION CONTROL SCHEMATIC

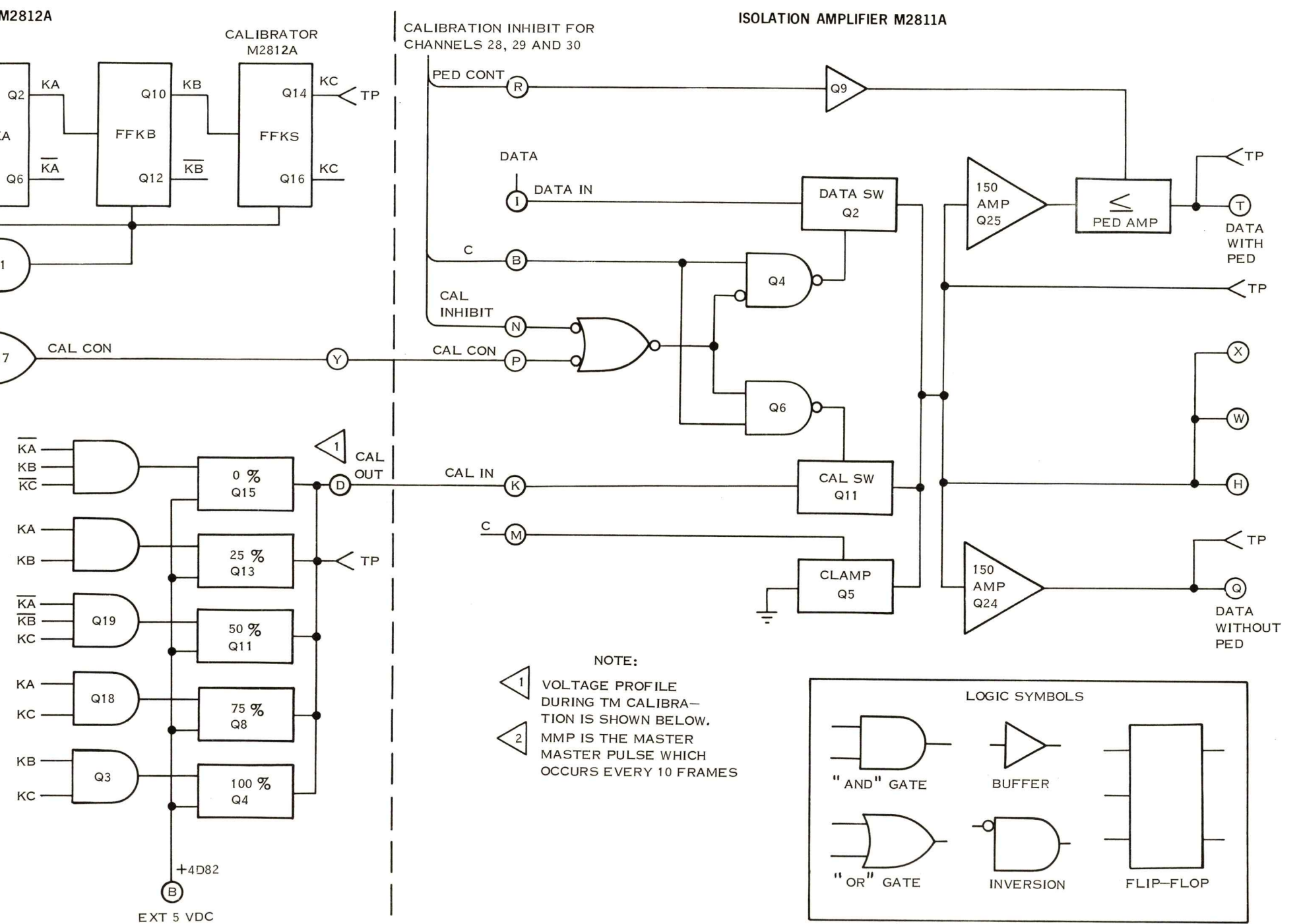


FIGURE 4.2.6 SCHEMATIC OF CALIBRATION CIRCUIT AND ISOLATION AMPLIFIER IN THE 270 MULTIPLEXER

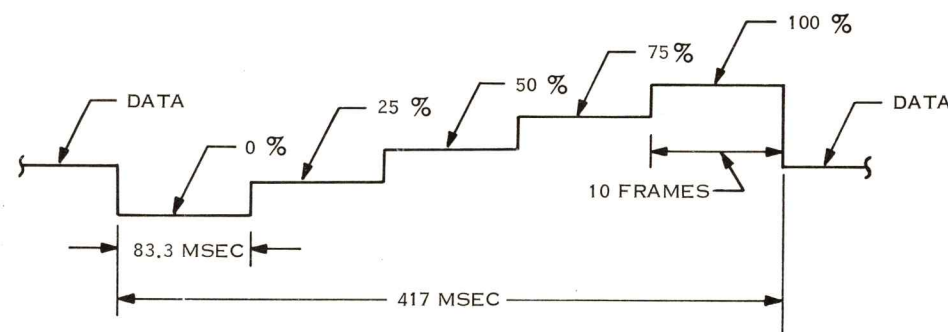


FIGURE 4.2.7 270 MULTIPLEXER CALIBRATION PROFILE

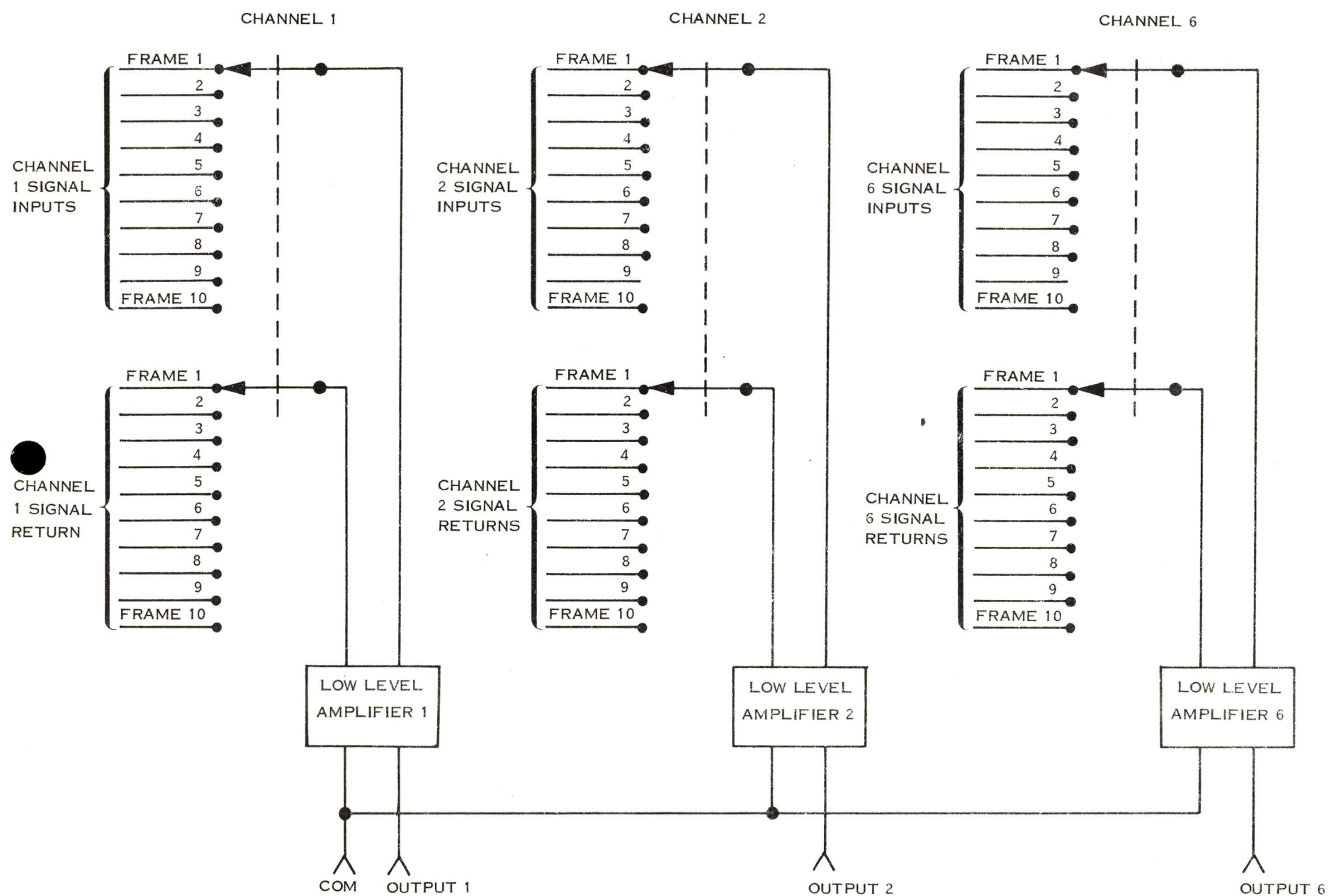


FIGURE 4.2.8 REMOTE ANALOG SUBMULTIPLEXER EQUIVALENT SCHEMATIC

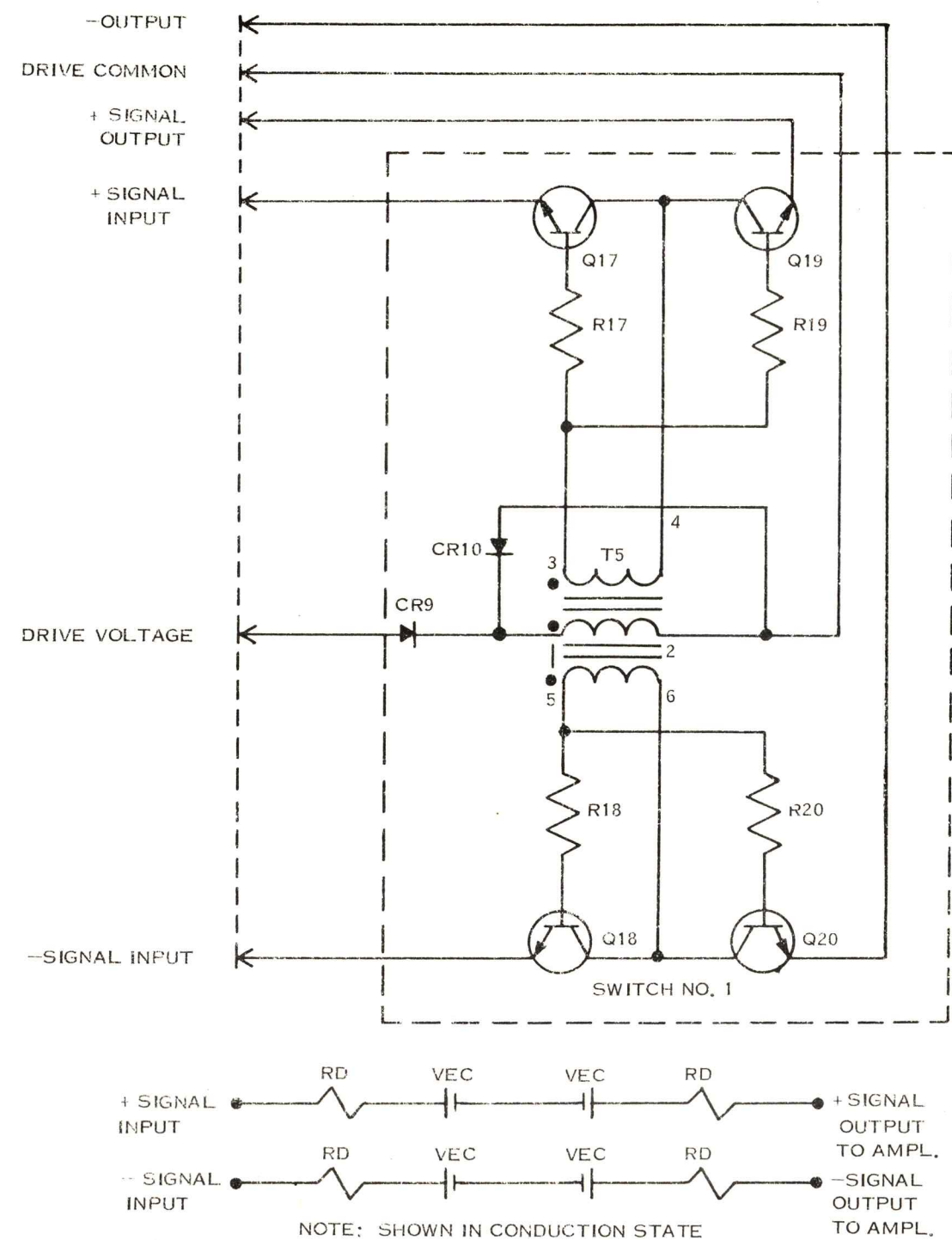


FIGURE 4.2.9 LOW LEVEL DATA SWITCH AND EQUIVALENT CIRCUIT

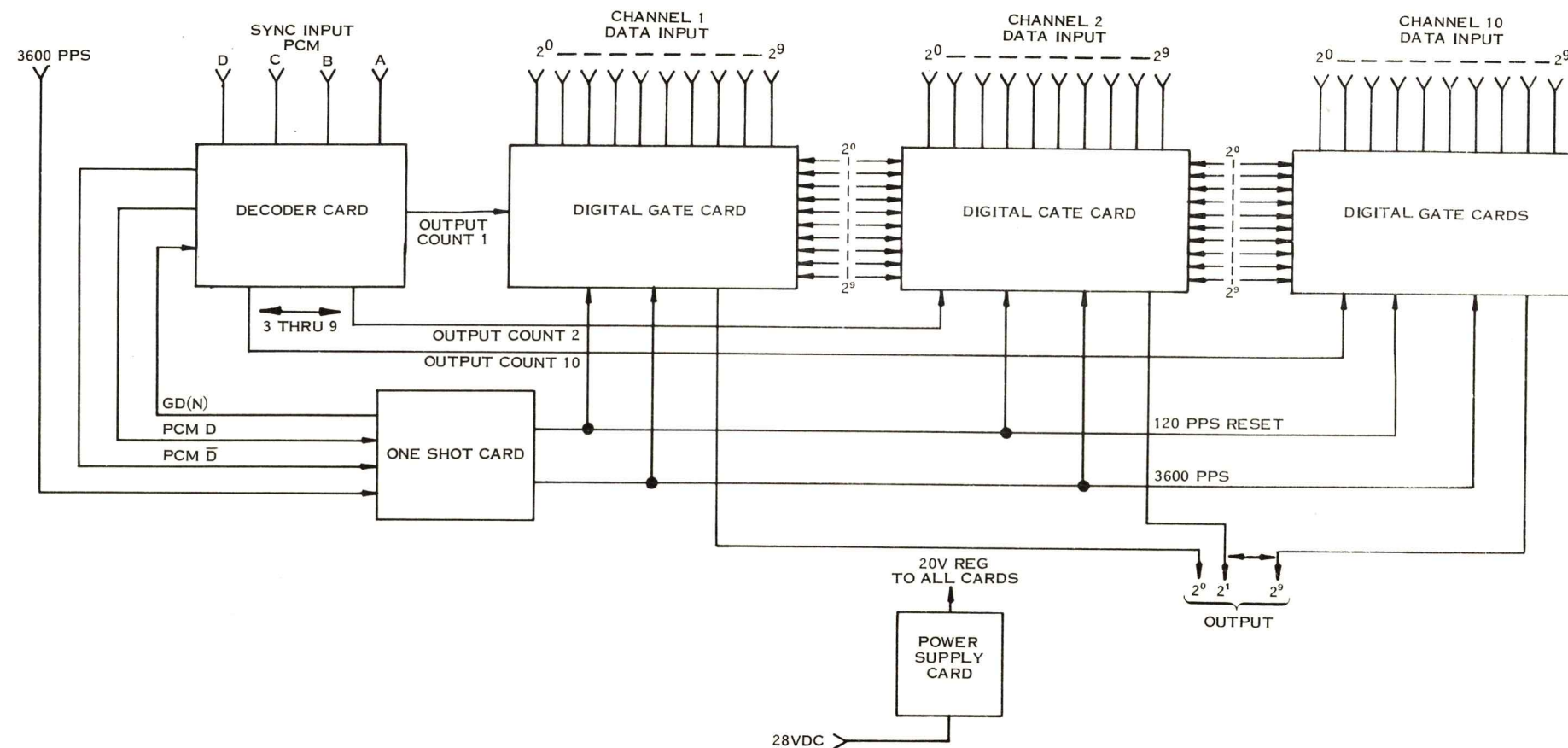


FIG. 4.2.10 RDSM BLOCK DIAGRAM

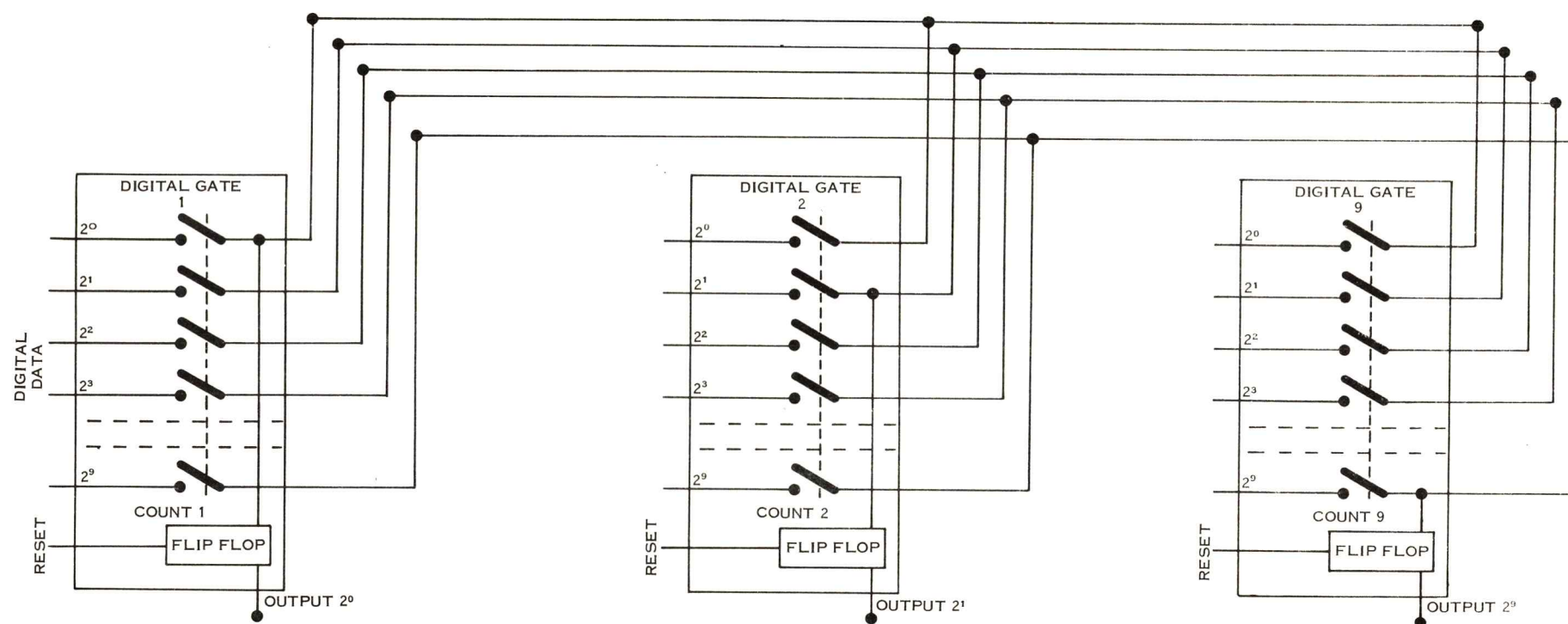


FIG. 4.2.11 EQUIVALENT CIRCUIT OF DIGITAL GATE CARDS

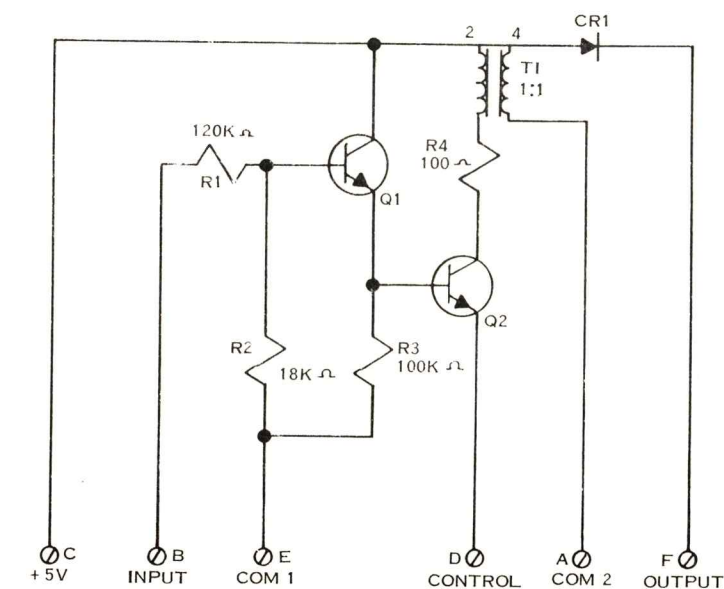


FIG 4.2.12 TYPICAL DIGITAL GATE

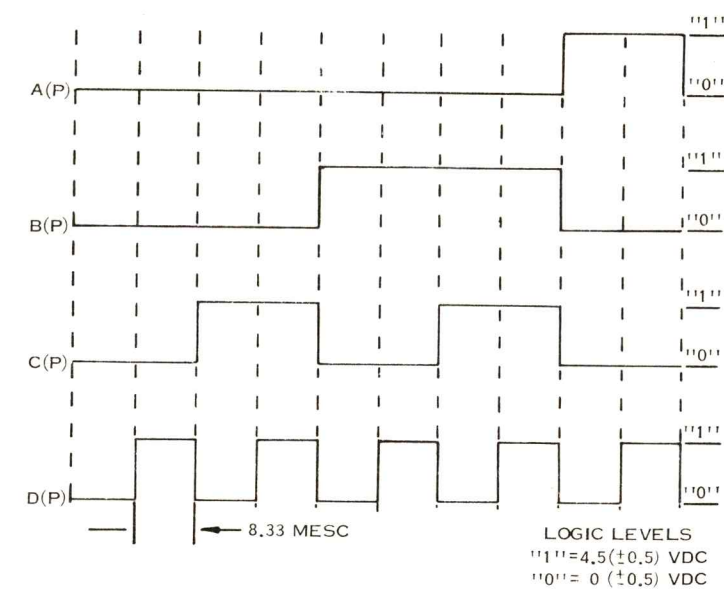
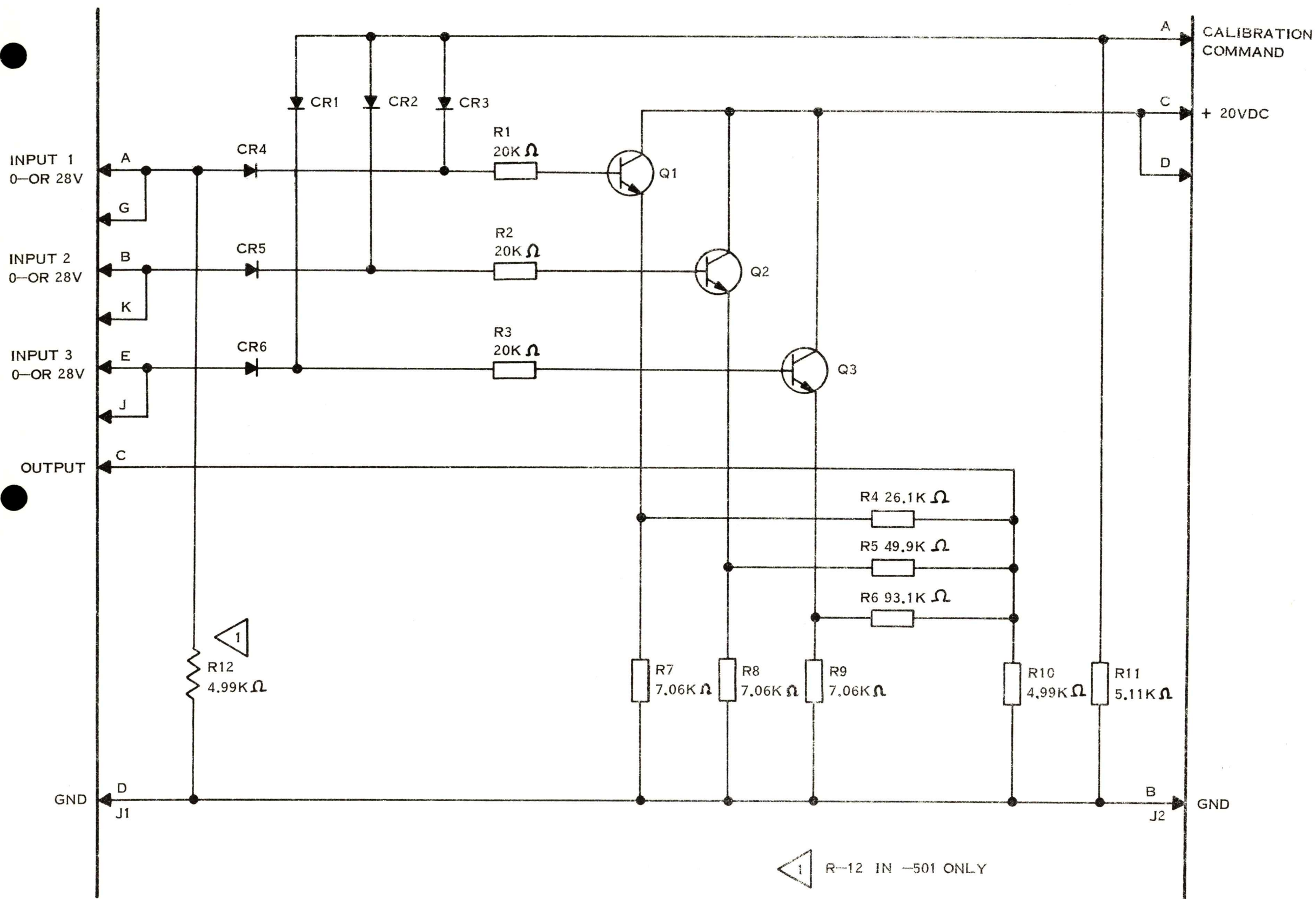


FIG 4.2.13 SYNC INPUTS FROM PCM/DDAS



**TABLE 4.2.1 LOGIC
FOR SUMMING MODULE**

INPUTS O = OFF X = ON			OUTPUT VOLTAGE ± 0.300 VDC	DIGITAL MSB		
1	2	3		1	2	3
0	0	0	0.000	0	0	0
0	0	X	0.796	0	0	1
0	X	0	1.476	0	1	0
0	X	X	2.272	0	1	1
X	0	0	2.764	1	0	0
X	0	X	3.570	1	0	1
X	X	0	4.240	1	1	0
X	X	X	5.036	1	1	1

FIGURE 4.2.14 SCHEMATIC OF BI LEVEL SUMMING MODULE

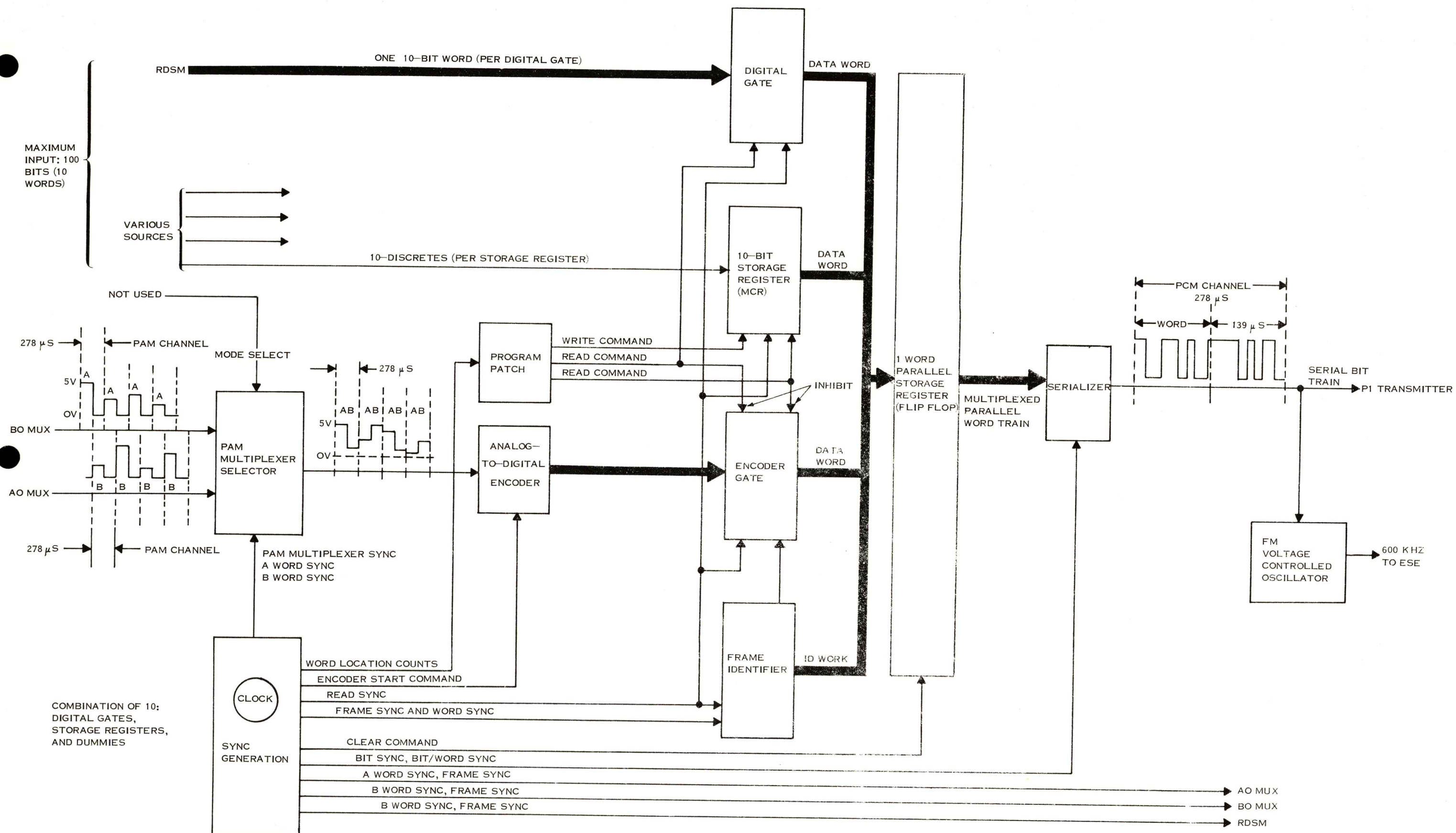
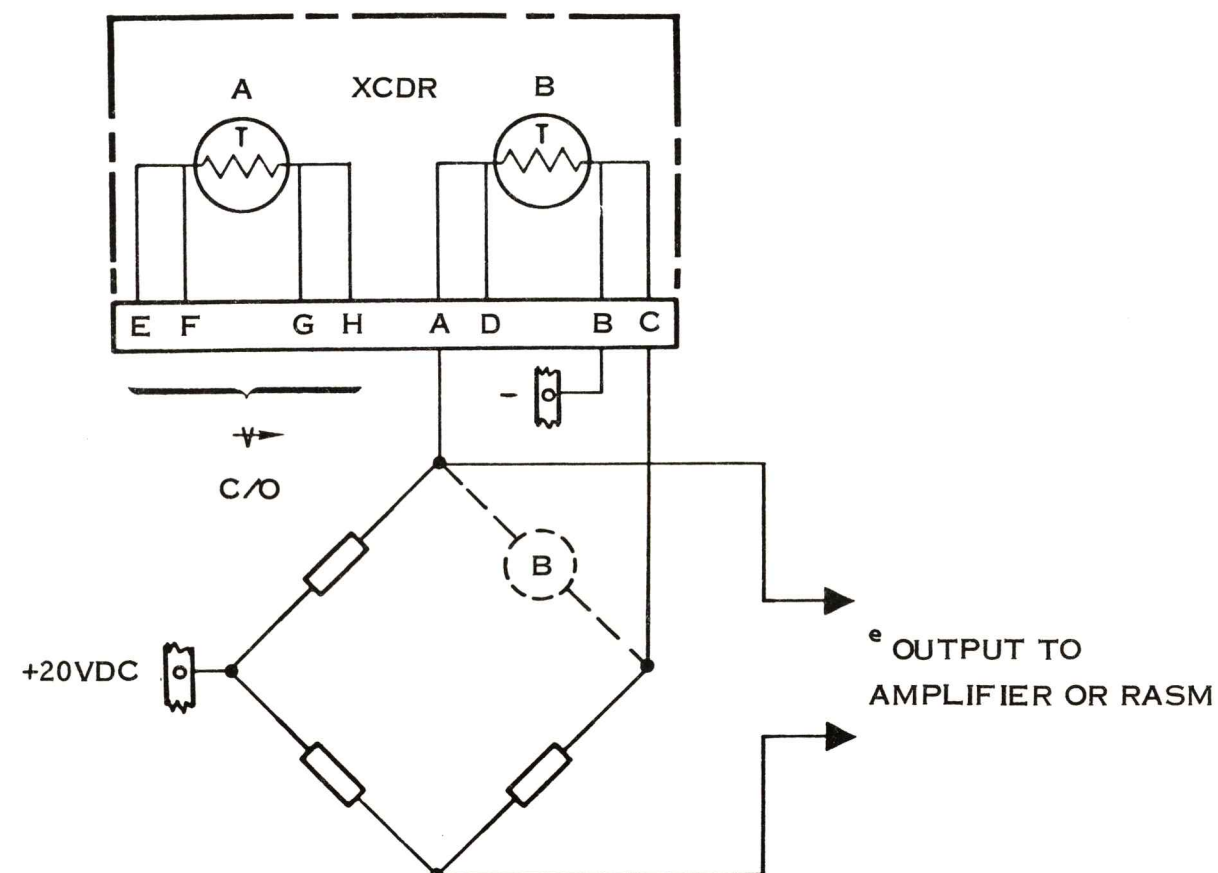


FIG. 4.2.15 PCM/DDAS TELEMETER FUNCTIONAL DIAGRAM



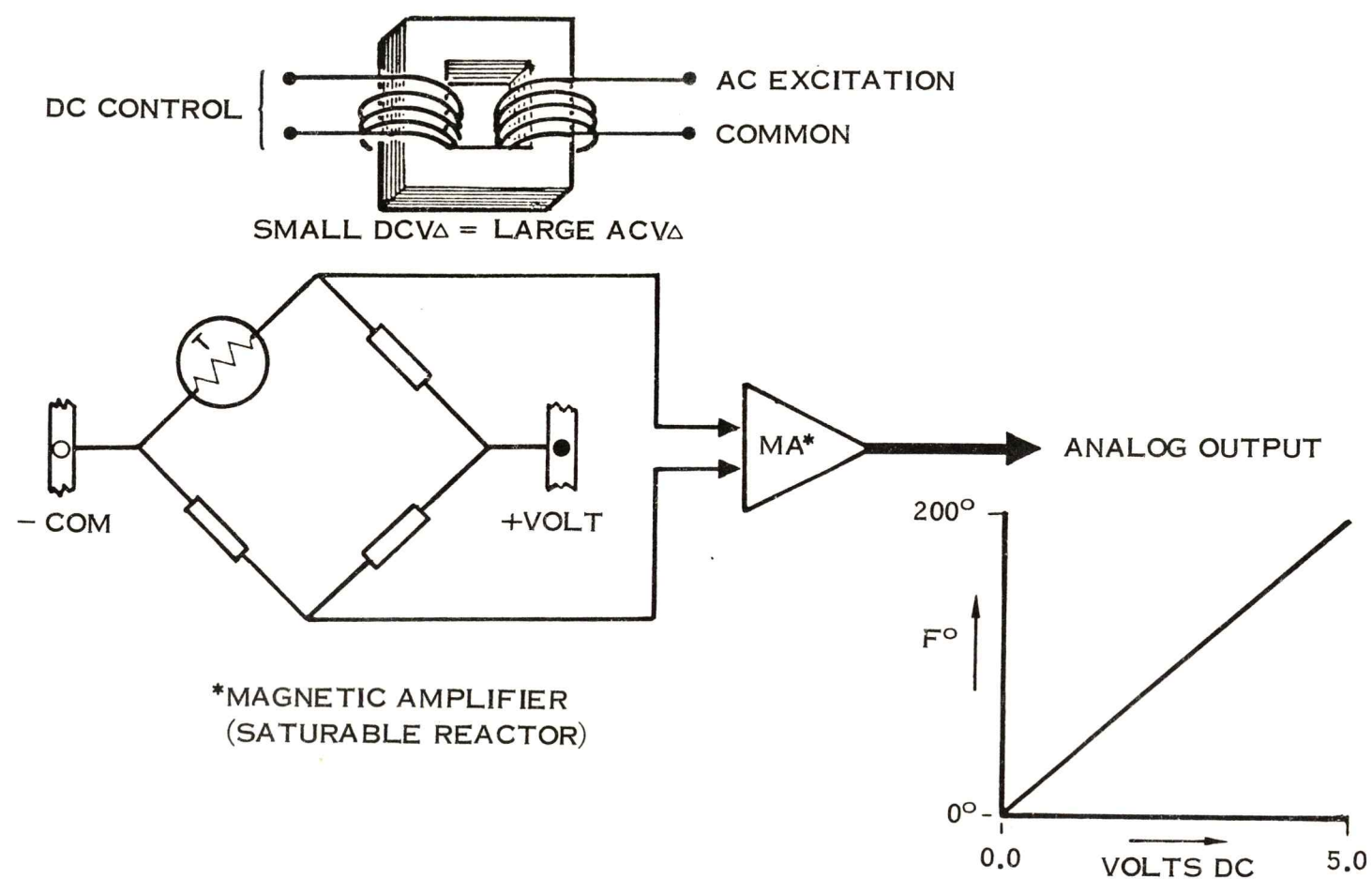
MEASUREMENT CAPABILITIES

- AIR
- GASEOUS HYDROGEN/OXYGEN AND HELIUM
- LIQUID OXYGEN
- LIQUID HYDROGEN
- LIQUID HYPERGOLIC

NOTE: INCREASE TEMPERATURE RESULTS IN INCREASE RESISTANCE

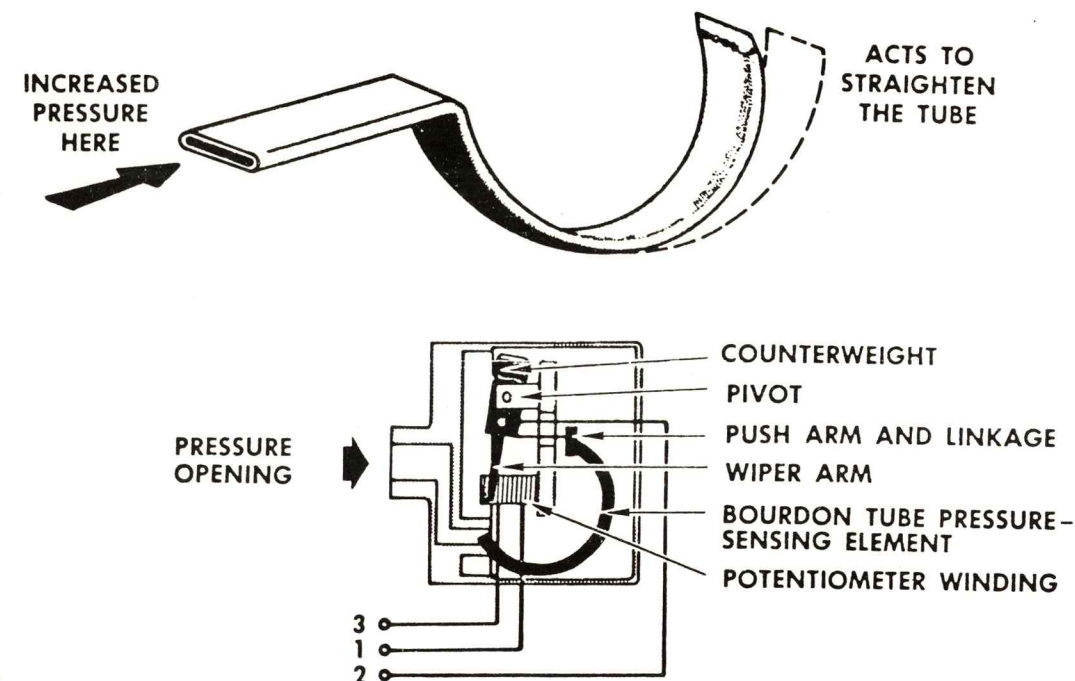
(TYPICAL)

NOTE: WHILE BRIDGE INPUT IS FOR TEMPERATURE MEASUREMENT, SIMILAR BRIDGE ARRANGEMENTS CAN BE USED TO MEASURE DC VOLTAGE (TERMINAL VOLT BECOME ONE LEG OF BRIDGE).

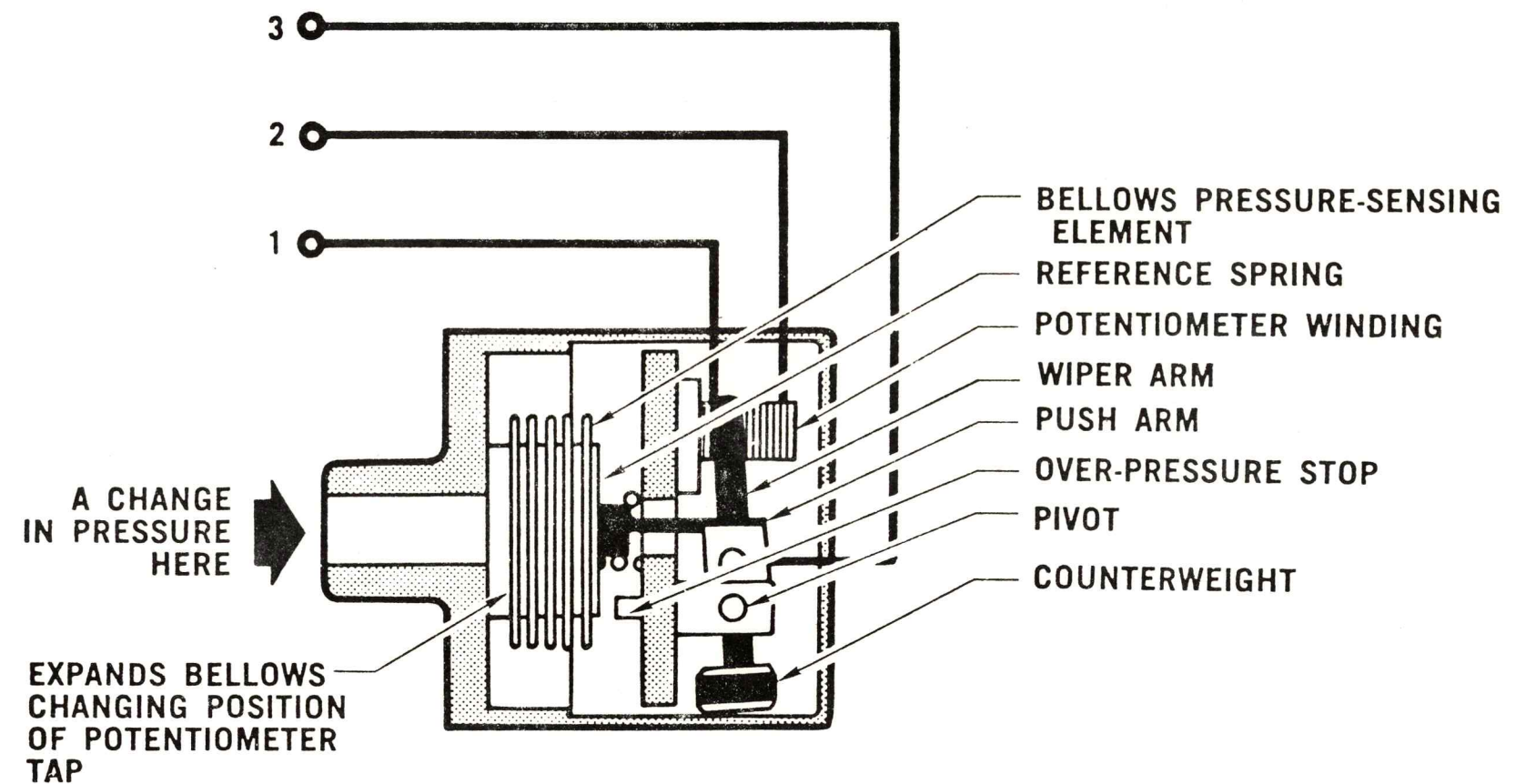


(TYPICAL BATTERY)

TEMPERATURE MEASUREMENT

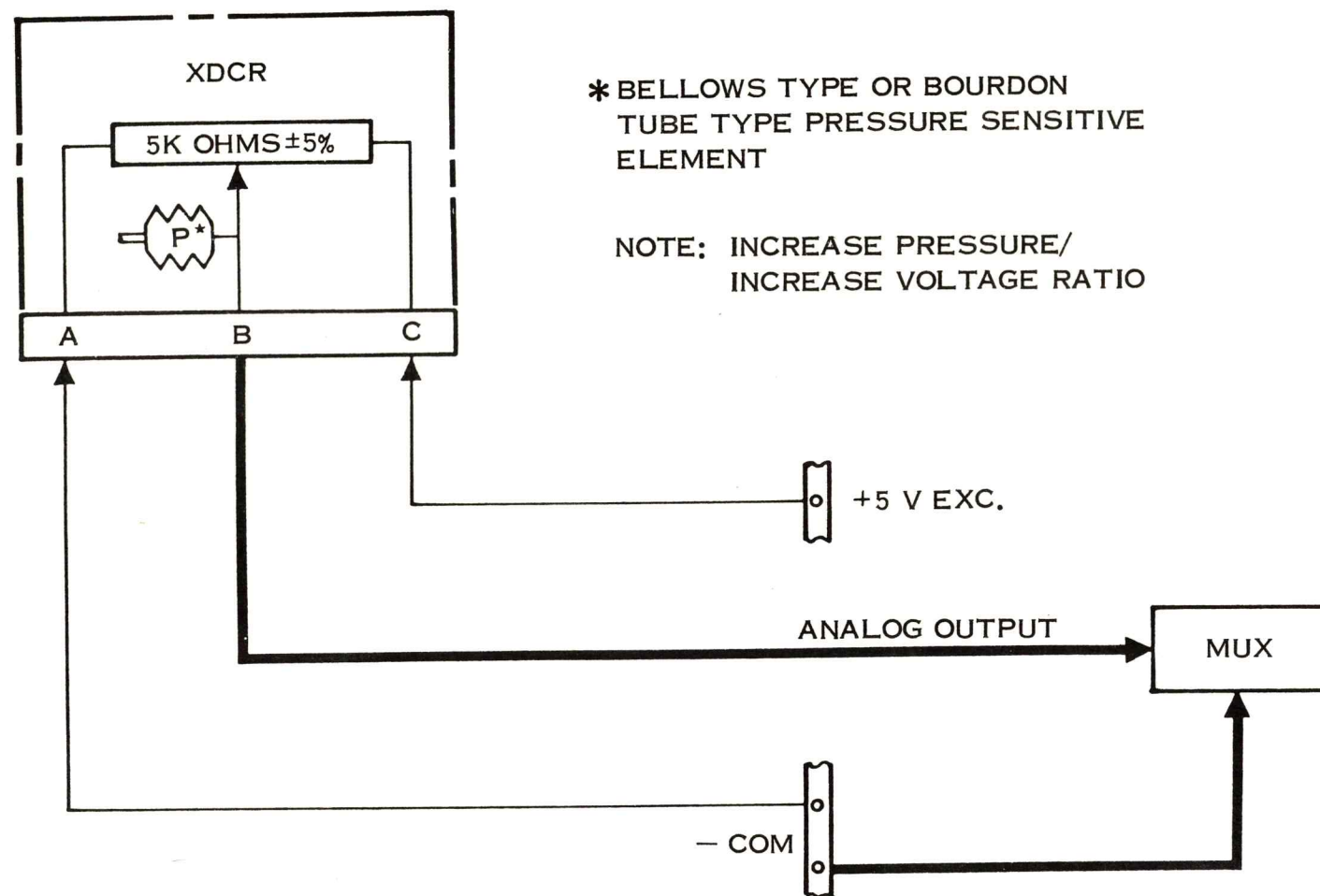


(BOURDON TUBE TYPE)

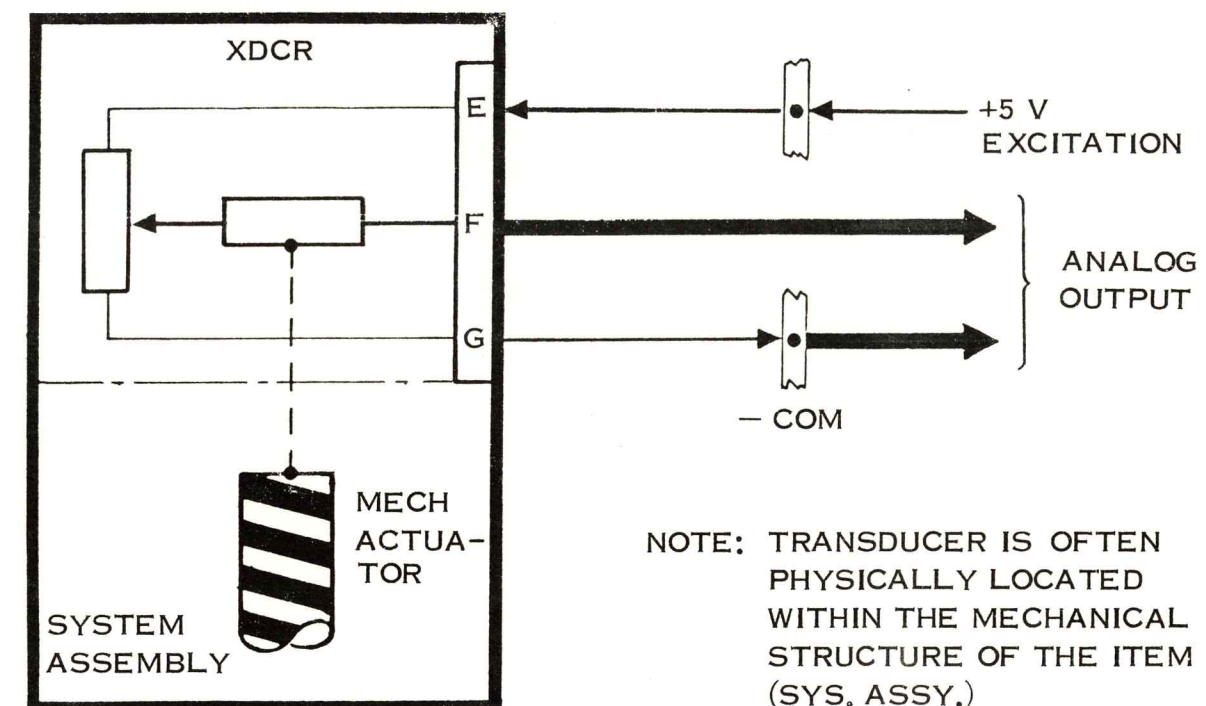


(BELLOWS TYPE)

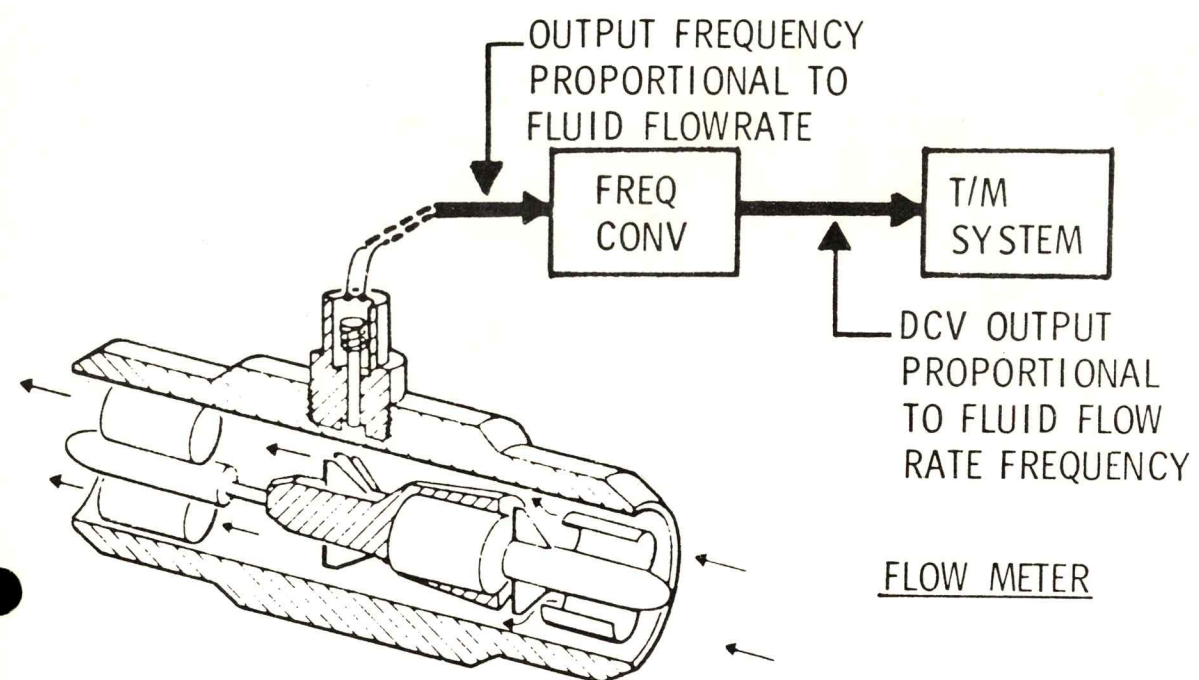
PRESSURE TRANSDUCER



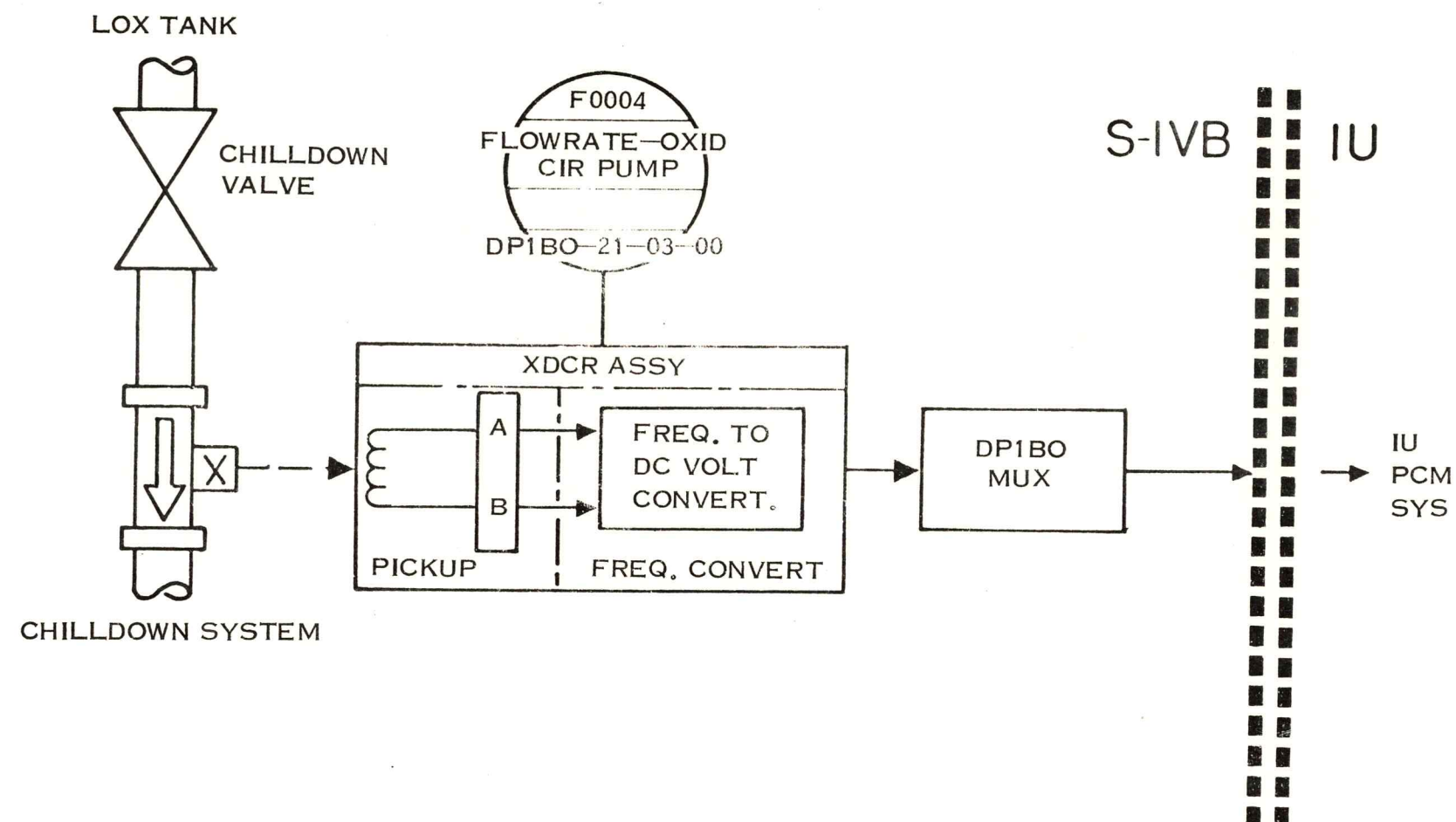
PRESSURE MEASUREMENT
(TYPICAL)



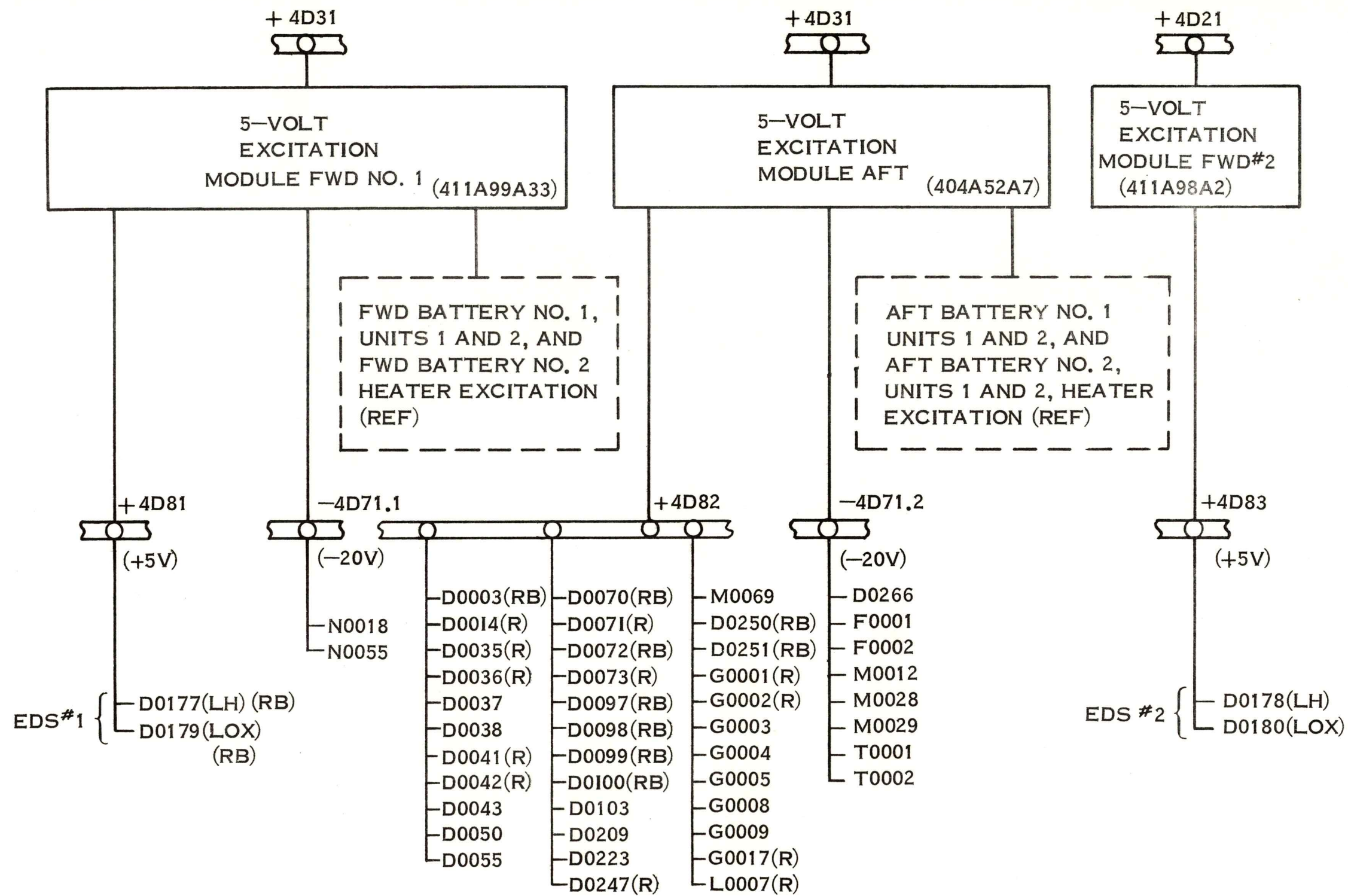
POSITION MEASUREMENT
(TYPICAL)



**TRANSDUCER TYPES
(FLOW)**



**MEASUREMENT INTERFACE
(MEASUREMENT: F4-424)**



(R) REDLINE
(RB) REDLINE BACKUP

5-VOLT EXCITATION - SCHEMATIC FIG. 4.4-1

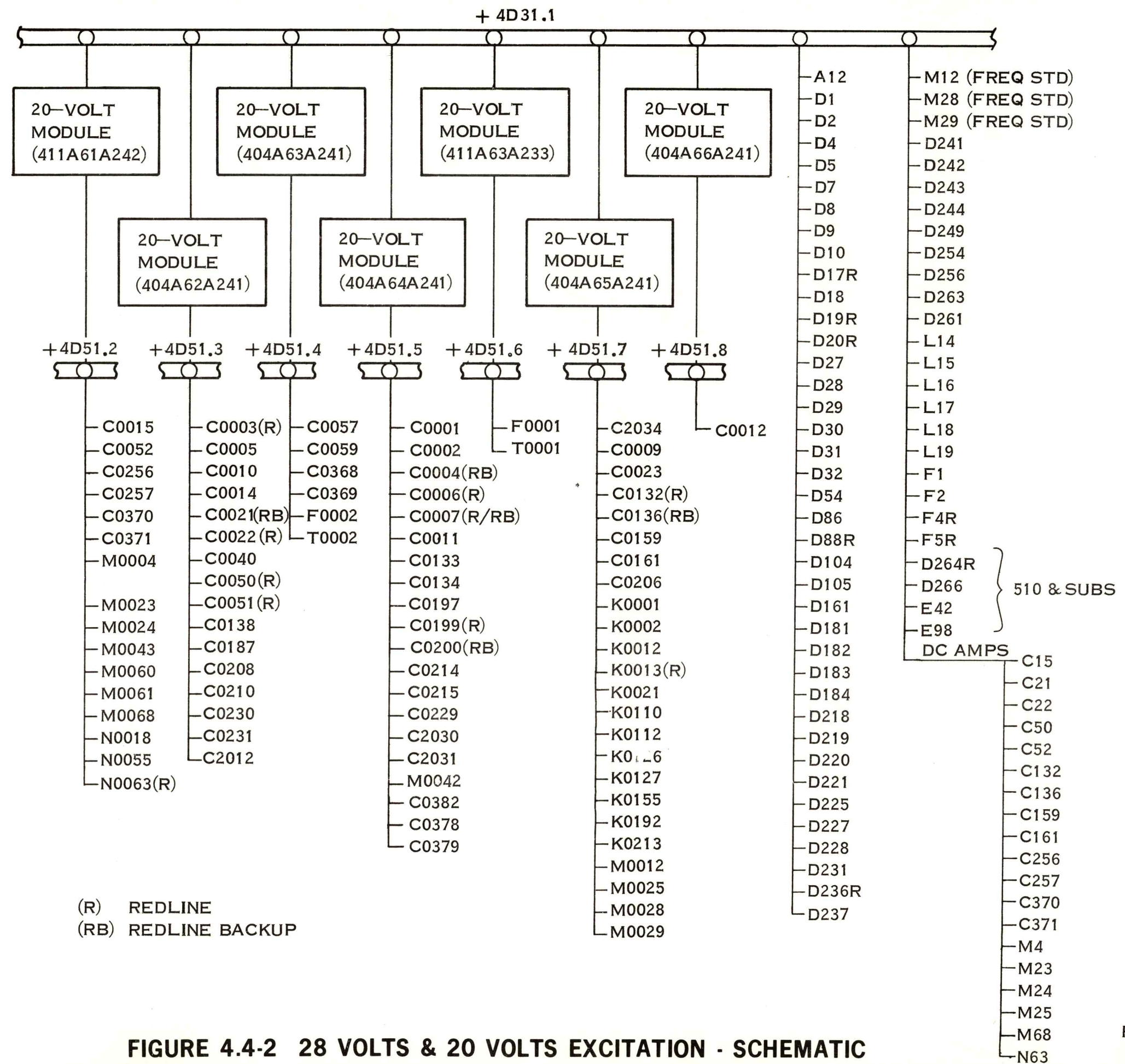


FIGURE 4.4-2 28 VOLTS & 20 VOLTS EXCITATION - SCHEMATIC

TABLE 4.4-1
5-VOLT EXCITATION-INSTRUMENTATION

FAILURE	GROUP NO.	BUS AFFECTED	SYSTEM AFFECTED		
			MEASUREMENT NO.	TELEMETRY CHANNEL	
FWD. #1 5-VOLT EXCITATION MOD (411A99A38)	A	+4D81	D0177	CP1BO-01-02-00 DP1BO-01-02-00	
			D0179	CP1BO-14-02-00 DP1BO-14-02-00	
	B	-4D71.1	N0018	CP1BO-03-06-00 DP1BO-03-06-00	
			N0055	CP1BO-05-07-00 DP1BO-05-07-00	
	AFT 5-VOLT EXCITATION MOD (404A52A7)	C	+4D82	D0003	CP1BO-13-02-00 DP1BO-13-02-00
					D0014
D0035				CP1BO-13-07-00 DP1BO-13-07-00	
				D0036	CP1BO-13-09-00 DP1BO-13-09-00
D0037					CP1BO-13-08-00 DP1BO-13-08-00
				D0038	CP1BO-13-10-00 DP1BO-13-10-00
D0041					CP1BO-13-05-00 DP1BO-13-05-00
				D0042	DP1BO-06-07-00
D0043				CP1BO-13-06-00 DP1BO-13-06-00	
				D0050	DP1BO-06-08-00
D0055				DP1BO-06-09-00	
D0070				DP1BO-07-02-00	
D0071				DP1BO-07-05-00	
D0072				DP1BO-07-04-00	
D0073				DP1BO-07-03-00	

NOTE: THIS TABLE IS INCOMPLETE. REFER TO 5-VOLT EXCITATION SCHEMATIC (FIGURE 4.4-1)

**TABLE 4.4-1
20-VOLT EXCITATION**

FAILURE	GROUP NO.	BUS AFFECTED	SYSTEM AFFECTED		FAILURE	GROUP NO.	BUS AFFECTED	SYSTEM AFFECTED		FAILURE	GROUP NO.	BUS AFFECTED	SYSTEM AFFECTED	
			MEASUREMENT NO.	TELEMETRY CHANNEL				MEASUREMENT NO.	TELEMETRY CHANNEL				MEASUREMENT NO.	TELEMETRY CHANNEL
20-VOLT MODULE (411A61A242)	A	+4D51.2	C0015	DP1BO-02-02-00	20-VOLT MODULE (404A62A41) CONTINUED	B	+4D51.3	C0021	DP1BO-11-07-00	20-VOLT MODULE (404A64A241) CONTINUED	D	+4D51.5	C0197	DP1BO-18L03-00
			C0052	DP1BO-02-04-00				C0022	CP1BO-11-05-00 DP1BO-11-05-00				C0199	DP1BO-18L05-00
			C0256	DP1BO-05-01-00				C0040	DP1BO-19L04-00				C0200	DP1BO-18L06-00
			C0257	DP1BO-05-02-00				C0050	CP1BO-11-03-00 DP1BO-11-03-00				C0214	DP1BO-20L08-00
			C0370	DP1BO-02-03-00				C0051	DP1BO-19L05-00				C0215	DP1BO-18L09-00
			C0371	DP1BO-02-10-00				C0138	DP1BO-19L06-00				C0229	DP1BO-19L07-00
			M0004	DP1BO-04-02-00				C0187	DP1BO-20L02-00				C2030	CP1BO-08-07-00
								C0208	DP1BO-18L07-00				C2031	CP1BO-08-08-00
			M0023	DP1BO-04-04-00				C0210	DP1BO-18L08-00				M0042	CP1BO-14-10-00
			M0024	CP1BO-05-09-00 DP1BO-05-09-00				C0230	DP1BO-19L08-00	20-VOLT MODULE (404A63A233)	E	+4D51.6	F0001	DP1BO-21-01-00
			M0043	DP1BO-04-08-00				C0231	DP1BO-19L09-00				T0001	DP1BO-21-05-00
					20-VOLT MODULE (404A63A241)	C	+4D51.4	C2012	DP1BO-20L06-00	20-VOLT MODULE (404A65A241)	F	+4D51.7	C0009	DP1BO-17L07-00
			M0068	CP1BO-05-08-00 DP1BO-05-08-00				C0057	DP1BO-18L04-00				C0023	DP1BO-20L01-00
			N0018	CP1BO-03-06-00 DP1BO-03-06-00				C0059	DP1BO-18L04-00				C0132	CP1BO-11-04-00 DP1BO-11-04-00
			N0055	CP1BO-05-07-00 DP1BO-05-07-00				C0368	DP1BO-20L04-00				C0136	CP1BO-11-06-00 DP1BO-11-06-00
								C0369	DP1BO-20L05-00				C0159	CP1BO-11-01-00 DP1BO-11-01-00
								F0002	DP1BO-21-02-00				C0161	CP1BO-11-02-00 DP1BO-11-02-00
								T0002	DP1BO-21-06-00				C0206	DP1BO-20L07-00
20-VOLT MODULE (404A62A241)	B	+4D51.3			20-VOLT MODULE (404A64A241)	D	+4D51.5	C0001	DP1BO-17L01-00				K0001	CP1BO-09R01-01 DP1BO-09R01-01
								C0002	DP1BO-17L02-00				K0002	CP1BO-09R02-01 DP1BO-09R02-01
			C0003	DP1BO-19201-00				C0004	DP1BO-19L02-00				K0012	CP1BO-09R03-02 DP1BO-09R03-02
			C0005	DP1BO-17L03-00				C0006	DP1BO-17L04-00					
			C0010	DP1BO-17L08-00				C0007	DP1BO-17L05-00					
			C0014	DP1BO-20L03-00				C0011	DP1BO-17L09-00					
			C0021	CP1BO-11-07-00				C0133	DP1BO-18L01-00					
								C0134	DP1BO-18L02-00					

NOTE: THIS TABLE IS INCOMPLETE. REFER TO 20-VOLT EXCITATION SCHEMATIC (FIGURE 4.4-2)

TABLE 4.4-1
20-VOLT EXCITATION

FAILURE	GROUP NO.	BUS AFFECTED	SYSTEM AFFECTED	
			MEASUREMENT NO.	TELEMETRY CHANNEL
20-VOLT MODULE (404A65A241)	F	+ 4D51.7	K0013	CP1BO-09R03-01 CP1BO-09U03-01
			K0021	CP1BO-02G00-01 DP1BO-02U01-01
			K0110	CP1BO-09R02-02 DP1BO-09U02-02
			K0112	CP1BO-09R02-03 DP1BO-09U02-03
			K0126	CP1BO-09R04-01 DP1BO-09U04-01
			K0127	CP1BO-09R04-02 DP1BO-09U04-02
			K0155	CP1BO-09R01-02 DP1BO-09U01-02
			K0192	DP1BO-09U03-03
			M0012	DP1BO-04-03-00
			M0025	CP1BO-05-10-00 DP1BO-05-10-00
			M0028	CP1BO-15-01-00
			M0029	CP1BO-15-02-00
20-VOLT MODULE (404A66A241)	G	+ 4D51.8	SEE NOTE	SEE NOTE

NOTE. THIS TABLE IS INCOMPLETE. REFER TO 20-VOLT EXCITATION SCHEMATIC (FIGURE 4.4-2)

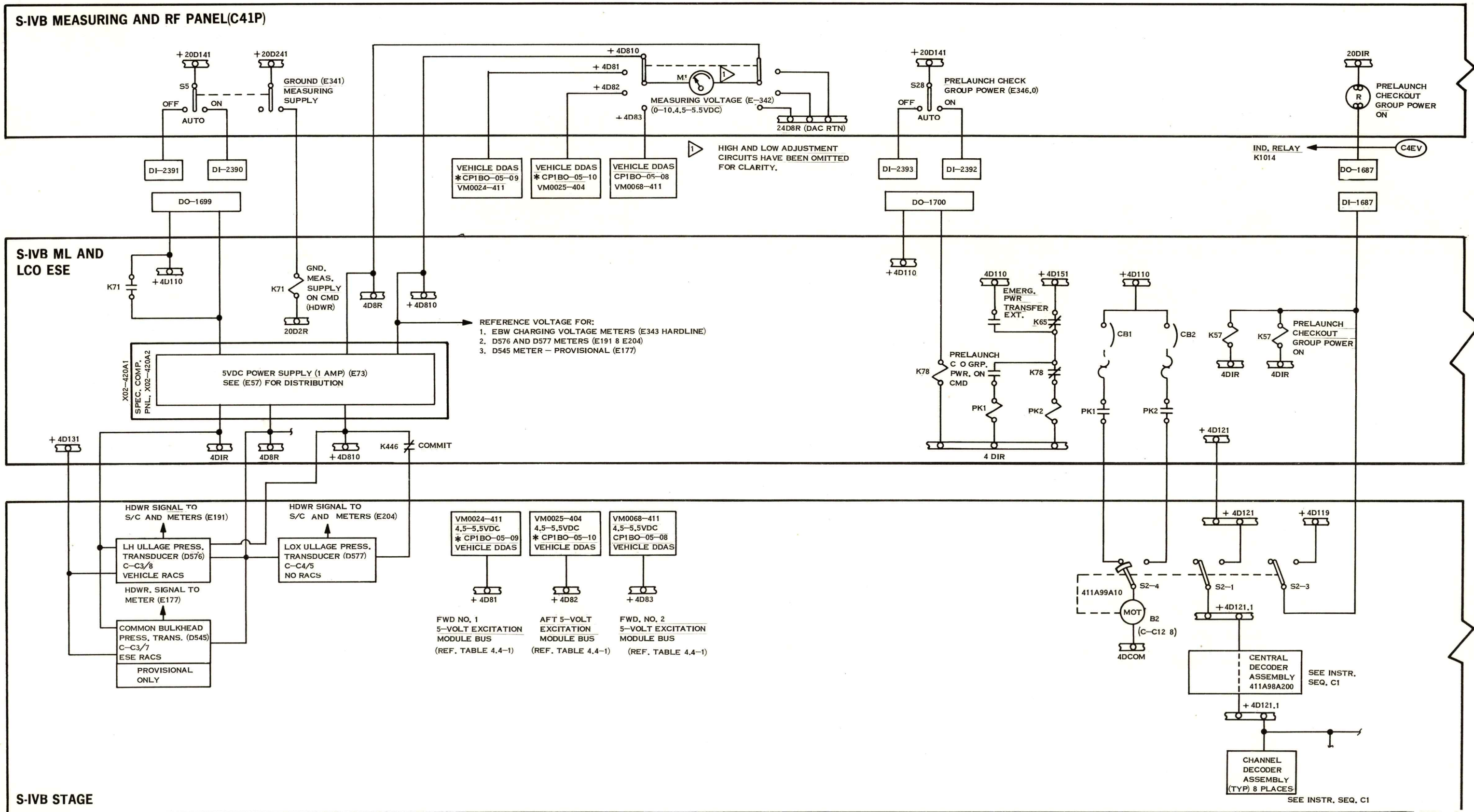


FIGURE 4.4-6 MEASUREMENT SUBSYSTEM SCHEMATIC

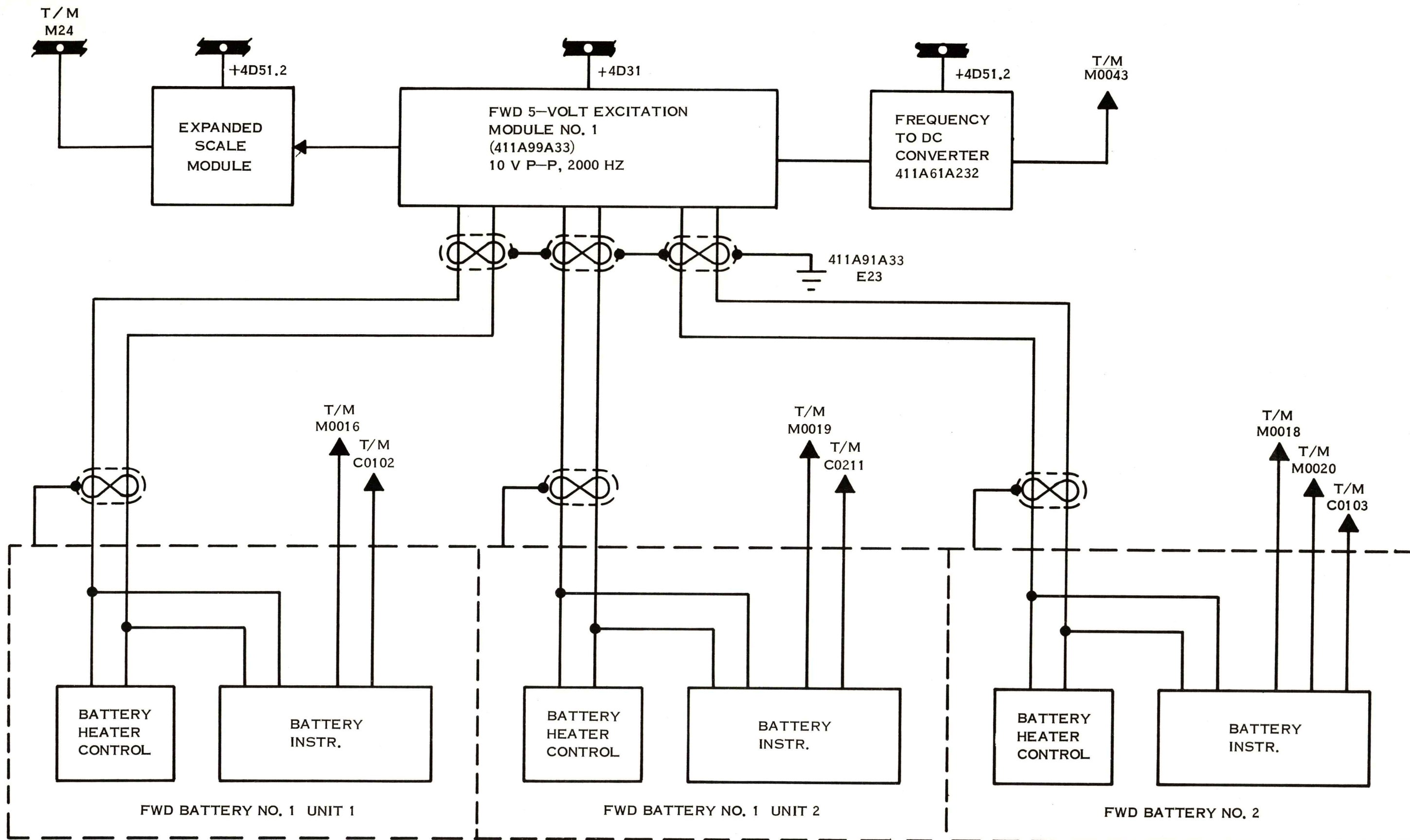


FIGURE 4.5-2 FWD 5-VOLT MODULE NO. 1 - 10 V P-P, 2000 HZ - SCHEMATIC

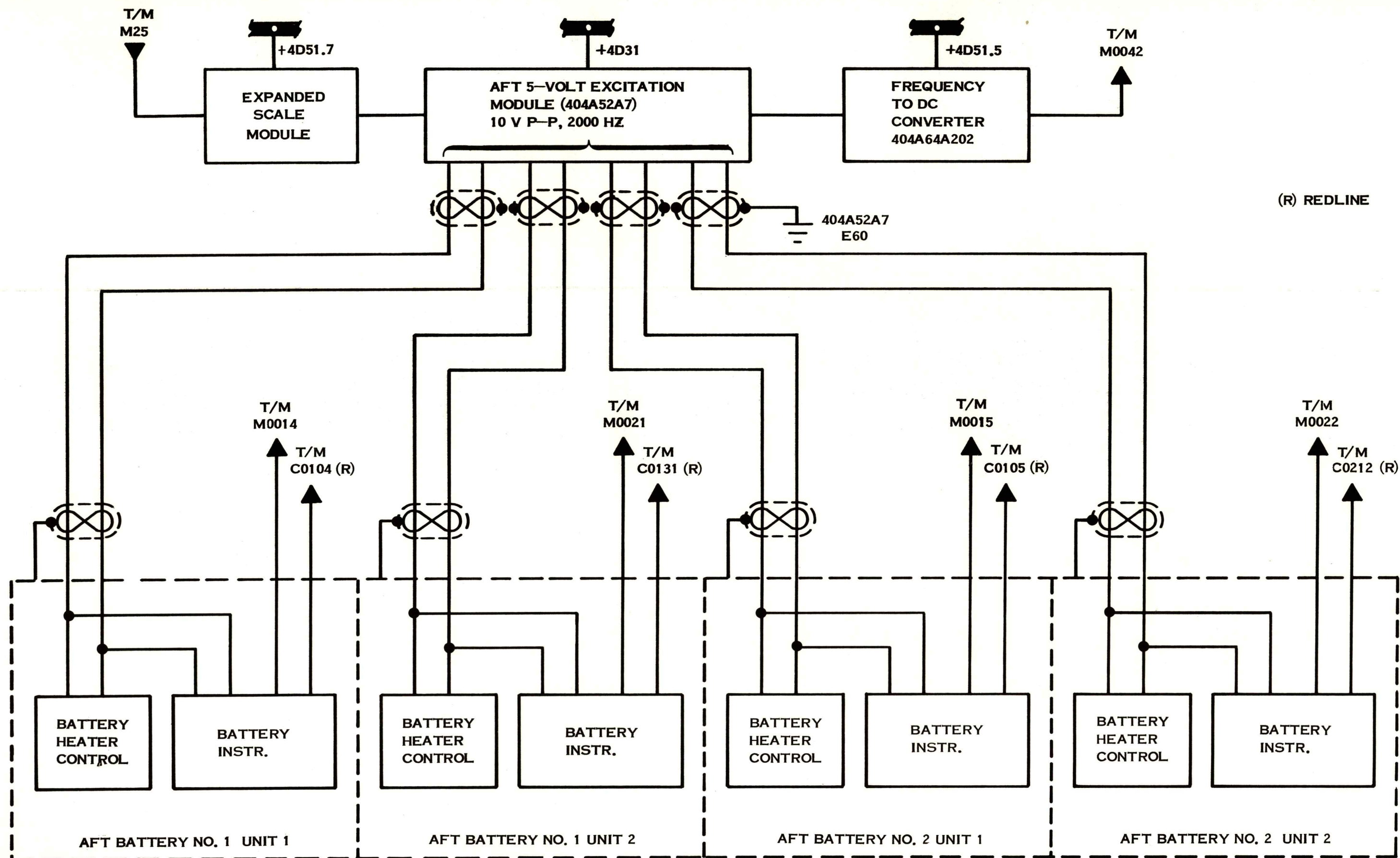


FIG. 4.5-1 AFT 5-VOLT MODULE - 10 V P-P, 2000 HZ - SCHEMATIC

5.0 EBW SYSTEM

5.1 SYSTEM DESCRIPTION

THE S-IVB EBW SYSTEM IS COMPOSED OF TWO SOLID FUELED ULLAGE ROCKETS, AN ULLAGE ROCKET IGNITION SYSTEM, AN ULLAGE ROCKET JETTISON SYSTEM AND EBW'S USED IN CONJUNCTION WITH THE RANGE SAFETY SYSTEM (TO BE COVERED IN ANOTHER SECTION). THE ULLAGE ROCKET IGNITION SYSTEM IS COMPOSED OF TWO EBW FIRING UNITS. TWO EBW DETONATORS, EXPLOSIVE MANIFOLD AND CDF TRAIN.

THE JETTISON SYSTEM CONSISTS OF TWO EBW FIRING UNITS, CDF MANIFOLD, CDF TRAIN AND EXPLOSIVE BOLTS.

BOTH IGNITION AND JETTISON SYSTEMS OPERATE IN THE SAME MANNER BY APPLYING A 28 VDC CHARGING COMMAND; WAITING A MINIMUM OF 1 1/2 SECONDS AND APPLYING A 28 VDC TRIGGER COMMAND WHICH STARTS THE ORDNANCE.

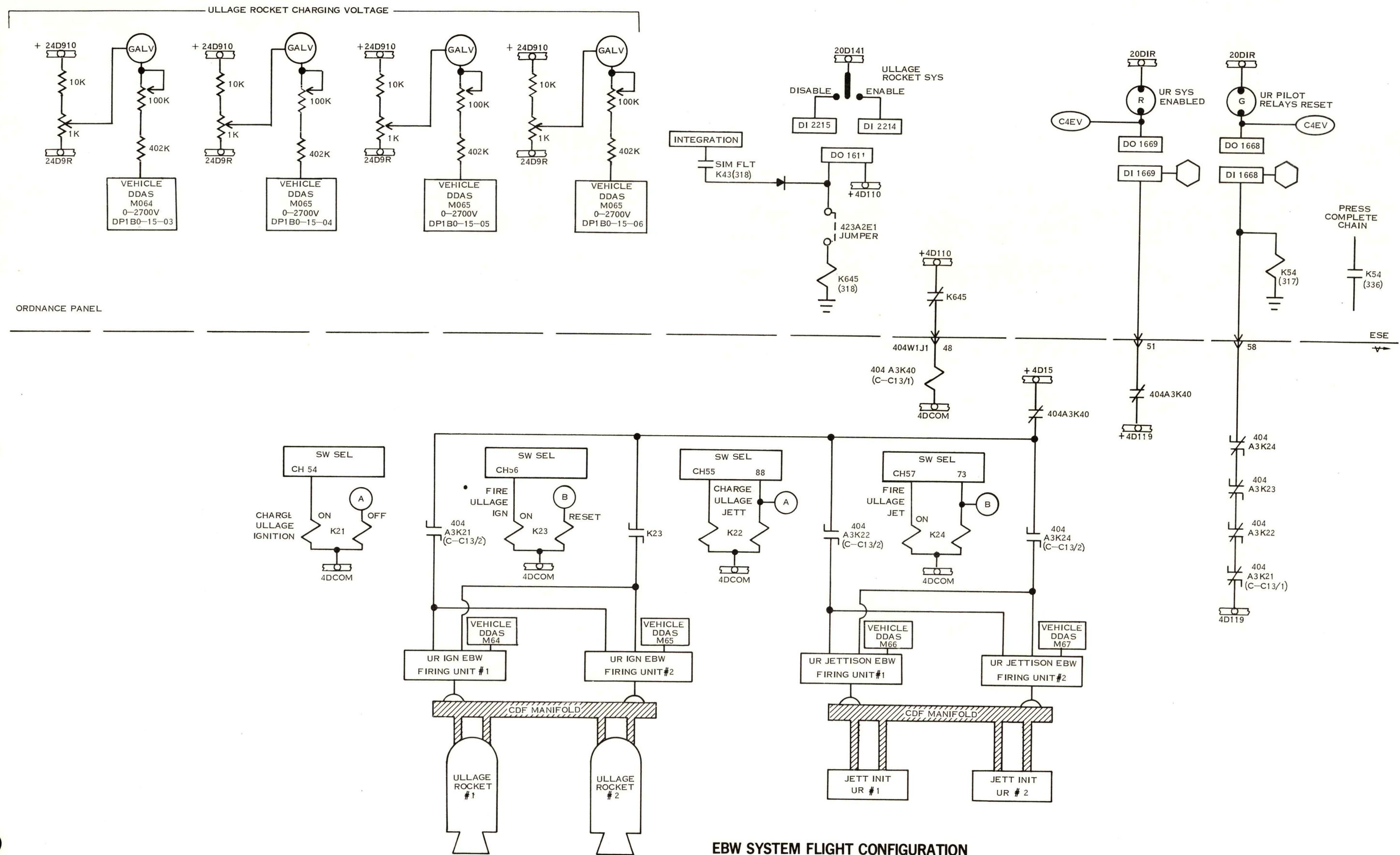
FOR CHECKOUT AND OAT'S, PULSE SENSORS ARE USED IN PLACE OF THE ORDNANCE. THE PULSE SENSOR IS AN ELECTRONIC DEVICE THAT ACCEPTS THE OUTPUT OF THE EBW FIRING UNIT AND PROVIDES A DDAS OUTPUT IF THE ENERGY OF THE PULSE WAS SUFFICIENTLY HIGH. THE PULSE SENSOR ALSO HAVE A SELF(TEST AND A RESET CAPABILITY.

THE ESE PROVIDES CONTROL FOR PULSE SENSOR POWER, SELF-TEST AND RESET COMMANDS. THERE ARE FIRED INDICATIONS FROM EACH PULSE SENSOR AND AN INDICATION FOR THE STATUS OF PULSE SENSOR POWER.

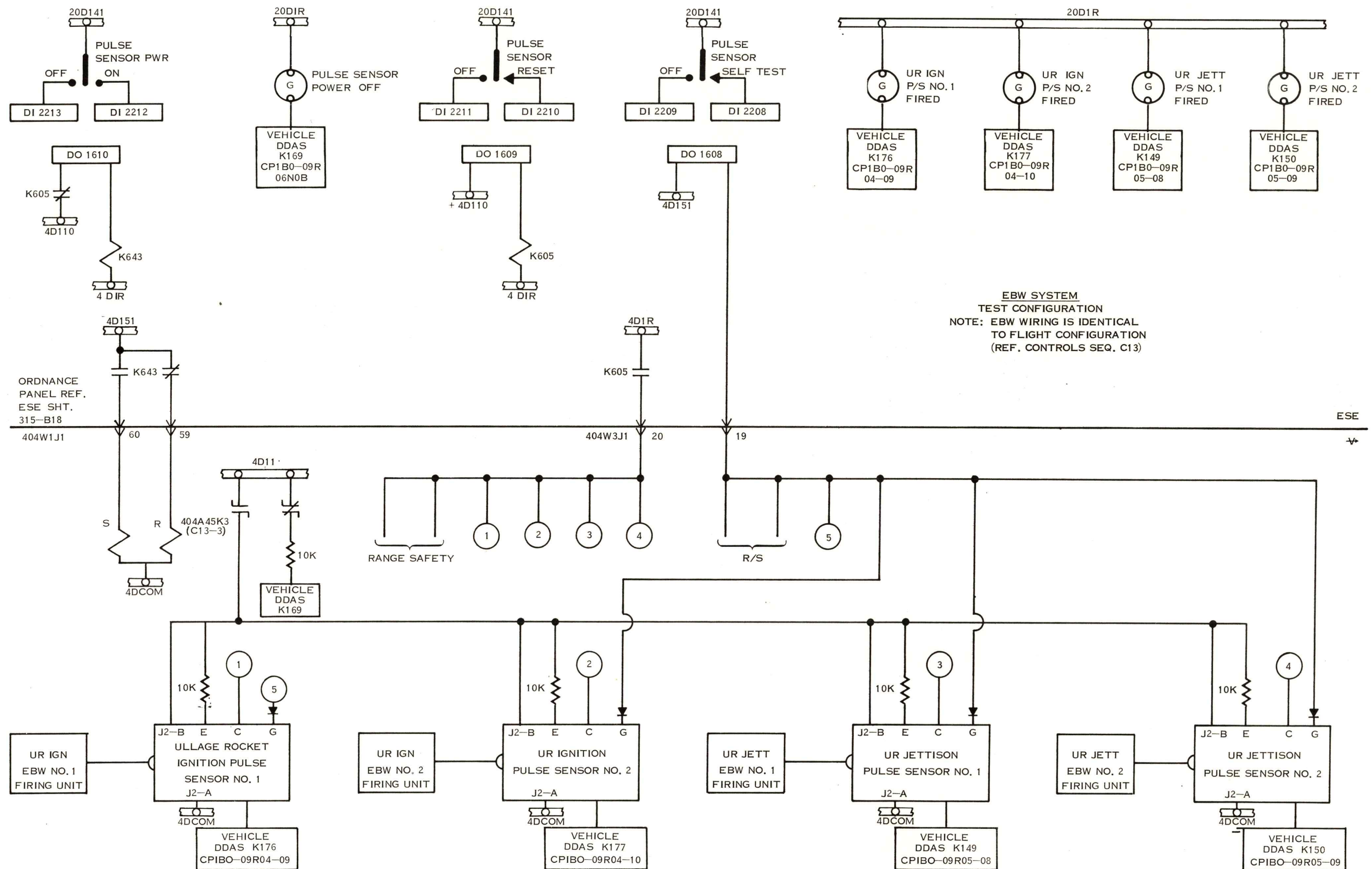
THE ESE ALSO HAVE THE EBW FIRING UNIT CHARGING VOLTAGES DISPLAYED AS WELL AS THE STATUS OF THE EBW SYSTEM RELAYS. THERE IS AN UR SYSTEM ENABLE SWITCH WHICH MUST BE ON AS WELL AS A JUMPER INSTALLED TO ENABLE THE EBW'S.

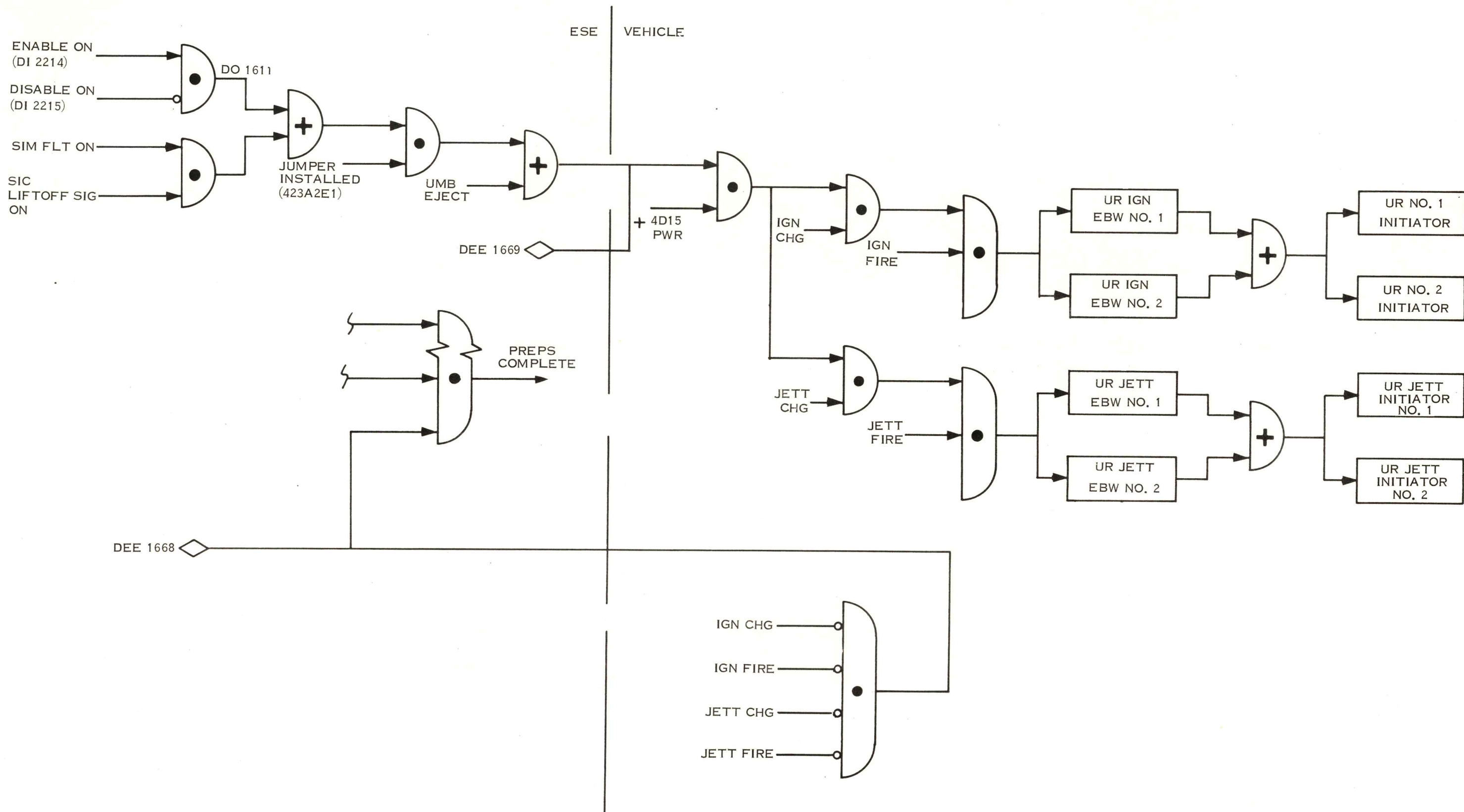
5.2 CRITICAL MEASUREMENTS

THE EBW SYSTEM HAS NO REDLINE MEASUREMENTS. THE PILOT RELAY RESET INDICATION IS THE ONLY CRITICAL INDICATION AND IS A PART OF THE PREPS COMPLETE LOGIC CHAIN.



EBW SYSTEM TEST CONFIGURATION





LOGIC DIAGRAM
EBW SYSTEM

REV. A
5-4

6.0
6.1

RANGE SAFETY SYSTEM

SYSTEM DESCRIPTION

THE RANGE SAFETY SYSTEM CONSISTS OF A RANGE SAFETY ANTENNA SUBSYSTEM, TWO SECURE COMMAND RECEIVERS, TWO RANGE SAFETY CONTROLLERS, TWO SECURE RANGE SAFETY DECODERS, TWO EXPLODING BRIDGEWIRE (EBW) FIRING UNITS, TWO EBW DETONATORS AND A COMMAND SAFE AND ARM DEVICE THAT CONNECTS THE TERMINATION SYSTEM TO THE TANK-CUTTING CHARGE. ELECTRICAL POWER FOR ALL THE ELEMENTS EXCEPT THE SAFE AND ARM DEVICE IS SUPPLIED FROM SEPARATE STAGE BATTERIES.

GROUND INITIATED COMMANDS ARE TRANSMITTED IN THE FORM OF TONE SIGNALS. THE TONE SIGNALS ARE RECEIVED BY THE RECEIVER AND DECODED BY A DECODER NETWORK WHICH IN TURN ENERGIZES RELAYS IN THE RECEIVER AND RANGE SAFETY CONTROLLER. THE RELAYS SUPPLY 28 VDC FOR THE DESTRUCT ARM CUTOFF, DESTRUCT, AND TURNOFF EVENTS.

THE DESTRUCT ARM/CUTOFF COMMAND WORD ACTIVATES A RELAY IN THE RANGE SAFETY CONTROLLER. THE CONTROLLER RELAY ACTIVATES THE ENGINE CUTOFF CIRCUITS IN THE SEQUENCER THEREBY CUTTING OFF THE ENGINE. AT THE SAME TIME, POWER IS SUPPLIED TO THE RANGE SAFETY EBW FIRING UNIT STORAGE CIRCUITS CHARGING THE UNITS. THE SYSTEM IS THEN READY FOR A DESTRUCT COMMAND.

AS A RESULT OF THE DESTRUCT COMMAND WORD, 28 VDC IS ROUTED FROM THE RANGE SAFETY RECEIVER CONTROLLER TO THE TRIGGER CIRCUIT IN THE EBW FIRING UNITS, THUS ENDING THE STAGE FLIGHT AND DUMPING THE REMAINING ONBOARD PROPELLANTS. THE PROPELLANT DISPERSION ORDNANCE COMPONENTS ARE ILLUSTRATED IN FIGURE

IF NO DESTRUCT COMMAND IS GENERATED (I.E., SUCCESSFUL LAUNCH), THE TURNOFF COMMAND WORD IS INITIATED. CONTROLLER RESPONSE TO THIS COMMAND ENERGIZES A SERIES OF RELAYS SWITCHING THE SYSTEM FROM INTERNAL TO EXTERNAL POWER, THUS CUTTING OFF POWER TO THE RANGE SAFETY FLIGHT TERMINATION SYSTEM AND RETURNING IT TO THE "SAFE" STATE. FIGURE ILLUSTRATES THE RANGE SAFETY SYSTEM DATA FLOW. THERE ALSO ARE TWO PULSE SENSORS WHICH ARE USED FOR CHECKOUT.

6.1.1

ANTENNAS

THE ANTENNA SUBSYSTEM CONSISTS OF TWO FOLDED-SLEEVE ANTENNAS MOUNTED DIAMETRICALLY ON THE STAGE. LONGITUDINALLY, BOTH ANTENNAS ARE MOUNTED AT THE MIDSECTION OF THE FORWARD SKIRT. THE TWO ANTENNAS ARE INDIVIDUALLY CONNECTED TO A HYBRID RING POWER DIVIDER BY COAXIAL CABLES OF EQUAL PHASE LENGTH. THE POWER DIVIDER IS A 3 DB HYBRID RING IN A STRIPLINE ASSEMBLY THAT SEPARATELY SUPPLIES SUM AND DIFFERENCE SIGNALS TO A DIRECTIONAL POWER DIVIDER.

THE DIRECTIONAL POWER DIVIDER IS ESSENTIALLY A 24-DB DIRECTIONAL COUPLER AND A POWER DIVIDER COMBINED INTO ONE STRIPLINE ASSEMBLY. ITS FUNCTION IS TO PROVIDE A MEANS OF APPLYING A SECURE CLOSED-LOOP CHECKOUT SIGNAL TO THE RECEIVERS FROM THE GSE. TWO OUTPUTS OF THE DIRECTIONAL POWER DIVIDER ARE SEPARATELY APPLIED TO TWO SECURE COMMAND RECEIVERS.

THE ANTENNA RADIATION PATTERN COVERAGE IS BASICALLY OMNIDIRECTIONAL, PROVIDING ADEQUATE GAIN OVER 96 PERCENT OF THE SPHERICAL SOLID ANGLE REPRESENTING GROUND STATION LOOK ANGLES DURING POWERED FLIGHT. THE RF SUBSYSTEM LOSSES ARE APPROXIMATELY 3-DB AND THE SUBSYSTEM VSWR IS 1.5:1.

6.1.2

RECEIVERS

EACH SECURE COMMAND RECEIVER IS A DOUBLE CONVERSION, CRYSTAL CONTROLLED, SOLID-STATE, SUPERHETERODYNE FM RECEIVER HAVING TWO ISOLATED AUDIO OUTPUTS OF A NOMINAL 1 VRMS LEVEL WITH A BANDPASS CHARACTERISTIC OF APPROXIMATELY 300 HZ TO 250 KHZ. THE RECEIVER HAS AN INTERNAL POWER SUPPLY TO PROVIDE POWER, ISOLATION, AND REGULATION.

COMMANDS TO THE SECURE SYSTEM CONSIST OF A MESSAGE FORMAT OF TWO WORDS: AN "ADDRESS" WORD AND A "COMMAND" WORD. THE ADDRESS WORD CONSISTS OF 9 CHARACTERS AND THE COMMAND WORD CONSISTS OF TWO CHARACTERS, THUS THE TOTAL MESSAGE COMPRISES 11 CHARACTERS. EACH CHARACTER CONSISTS OF TWO SIMULTANEOUS TONE PAIRS IN THE RANGE OF 7.35 TO 13.65 KHZ:

6.1.3

DECODERS

THE DECODER ACCEPTS THE DEMODULATED TONE PAIRS FROM ONE OF THE AUTO OUTPUTS OF THE RECEIVER. SEVEN TONE FILTERS AND SEVEN THRESHOLD DETECTORS DETECT THE PRESENCE OF A PARTICULAR TONE AND ESTABLISH A DECISION LEVEL. THE DATA IS PROCESSED THROUGH 21 AND GATES TO THE INPUT OF A CODE PLUG. THE CODE PLUG SETS UP THE CHOSEN CODE-OF- THE- DAY CONFIGURATION AND UNSCRAMBLES THE CODE FOR USE BY THE SEQUENCER REGISTER WHICH DETERMINES IF THE ADDRESS IS CORRECT AND SETS UP THE ENABLING CIRCUITS TO ACCEPT THE COMMAND. IF THE ADDRESS IS WRONG IN TIMING OR SEQUENCE, THE ENABLE CIRCUITS ARE INHIBITED AND THE UNIT RESETS TO AWAIT ANOTHER ADDRESS. IF THE ADDRESS IS CORRECT, THE COMMAND WORD IS PROCESSED THROUGH THE FILTERS AND ENABLES THE CLOSING OF THE APPROPRIATE RELAYS WHICH SUPPLY 28 VDC POWER TO THE CONTROLLER.

THE CODE PLUG SUPPLIED WITH THE DECODER IS A "TEST" PLUG AND WILL BE EXCHANGED FOR A "CODE-OF- THE- DAY" PLUG UPON ARMING OF THE VEHICLE.

THE RECEIVER AND DECODER ARE SUPPLIED BY 28 VDC POWER FROM EITHER A GROUND SOURCE (EXTERNAL) OR BY AN INTERNAL SOURCE. THE SOURCE USED IS DETERMINED BY THE SETTING OF A RELAY IN THE RANGE SAFETY CONTROLLER.

6.1.4

CONTROLLERS

THE RANGE SAFETY CONTROLLER IS A RELAY PACKAGE THAT CONTROLS THE INPUT TO THE RECEIVER POWER SUPPLY AND THE OUTPUT OF THE RECEIVER AND PROVIDES INPUTS (CHARGE AND FIRE) TO THE TWO RANGE SAFETY EBW FIRING UNITS.

6.1.5

SAFE AND ARM DEVICE

WHEN IN "SAFE" POSITION, THE DEVICE PREVENTS ACCIDENTAL ACTIVATION OF THE RANGE SAFETY ORDNANCE DEVICES DURING PRELAUNCH ACTIVITIES. THE SAFE AND ARM DEVICE ARMS THE RANGE SAFETY FLIGHT TERMINATION SYSTEM ON COMMAND BY ALIGNING TWO EXPLOSIVE LEADS WITH EXPLOSIVE TRAINS. THE TANK- CUTTING CHARGE LEADS ARE CONNECTED TO THE VARIOUS DESTRUCT ORDNANCE DEVICES LOCATED ON THE S-IVB STAGE. THE SAFE AND ARM DEVICE CONSISTS OF A 28 VDC SOLENOID-OPERATED UNIDIRECTIONAL SHAFT THAT CONTAINS TWO EXPLOSIVE CHARGES PLACED IN "SAFE" OR "ARMED" POSITION WHEN THE SOLENOID IS ACTIVATED. THE SHAFT IS MECHANICALLY ATTACHED TO THE SOLENOID BY A RATCHET AND IS POWERED THROUGH 90 DEGREES OF CLUTCH TRAVEL BY THE SOLENOID. AT THE 90 DEGREE POINT, POWER IS REMOVED FROM THE SOLENOID BY A CAM-OPERATED MICROSWITCH. THE SOLENOID THEN RETURNS TO THE STARTING POSITION. BECAUSE OF THE RATCHET ACTION OF THE CLUTCH, AND IS HELD IN THIS POSITION BY A SPRING-LOADED DETENT. EACH SUBSEQUENT APPLICATION OF POWER CAUSES THE SHAFT TO ROTATE 90 DEGREES CLOCKWISE: "SAFE" TO "ARM" TO "SAFE", ETC. PRIOR TO LAUNCH, THE SAFE AND ARM DEVICE IS SET TO "ARM" POSITION BY GROUND SUPPORT EQUIPMENT IN THE BLOCKHOUSE. AFTER UMBILICAL DISCONNECT DURING LAUNCH, THERE IS NO CONTROL OF THE SAFE AND ARM DEVICE.

6.1.6

EBW FIRING UNIT

THE EBW FIRING UNIT CONTAINS THE ELECTRONICS NECESSARY TO FIRE AN EBW DETONATOR. THE FIRING UNIT CONSISTS OF A HIGH VOLTAGE POWER SUPPLY, AN ENERGY STORAGE UNIT, A TRIGGER CIRCUIT AND A SPARE GAP. APPLICATION OF 28 VDC TO THE FIRING UNIT CAUSES THE INTERNAL CAPACITOR TO CHARGE TO 2300 VOLTS. UPON APPLICATION OF THE TRIGGER COMMAND, THE SPARK TUBE IS BROKEN DOWN CAUSING THE CAPACITOR TO DISCHARGE ACROSS THE DETONATOR, THEREBY EXPLODING IT.

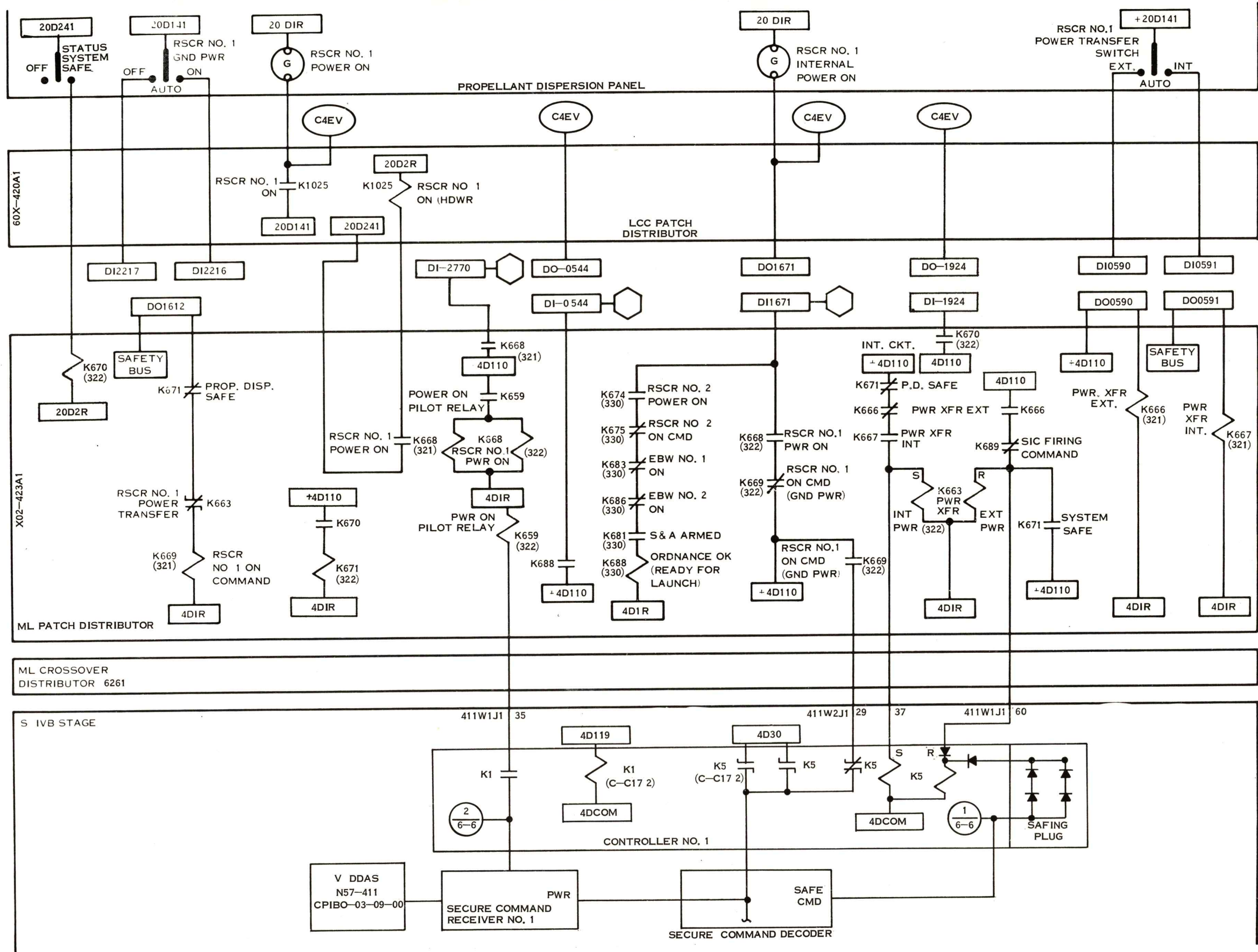
6.2

CRITICAL MEASUREMENTS

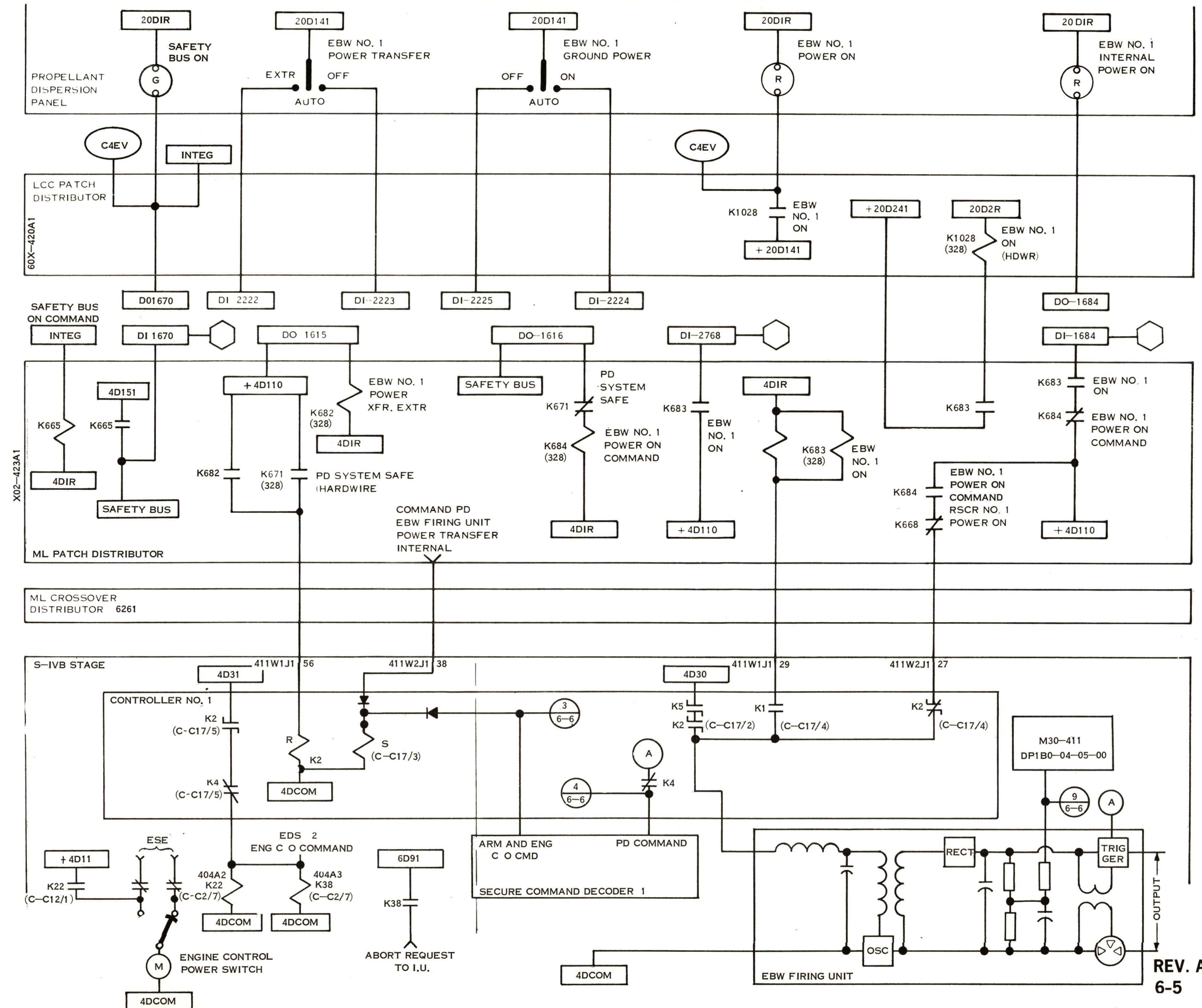
THE RANGE SAFETY SYSTEM DOES NOT CONTAIN ANY REDLINE MEASUREMENTS. HOWEVER, SIGNAL STRENGTH MEASUREMENTS N57 AND N62 ARE MONITORED DURING COUNTDOWN AND ARE CAUSE FOR A HOLD OR SCRUB.

RECEIVER# 1 SIGNAL STRENGTH (N57) AND RECEIVER# 2 SIGNAL STRENGTH (N62) PROVIDE AN INDICATION OF THE CARRIER REQUIRED FOR PROPER OPERATION OF THE SYSTEM.

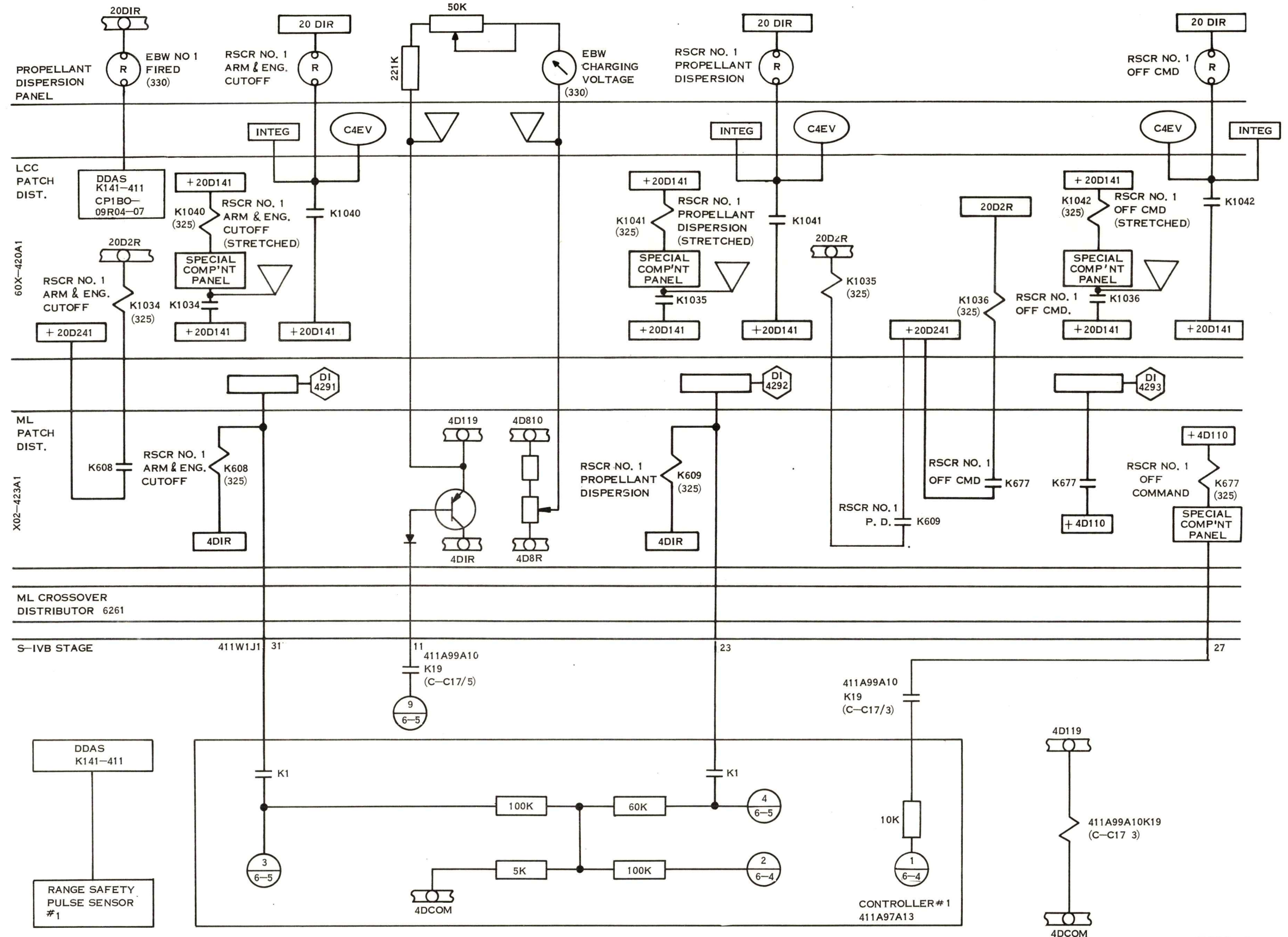
S-IVB-V RSCR NO.1 POWER CONTROL



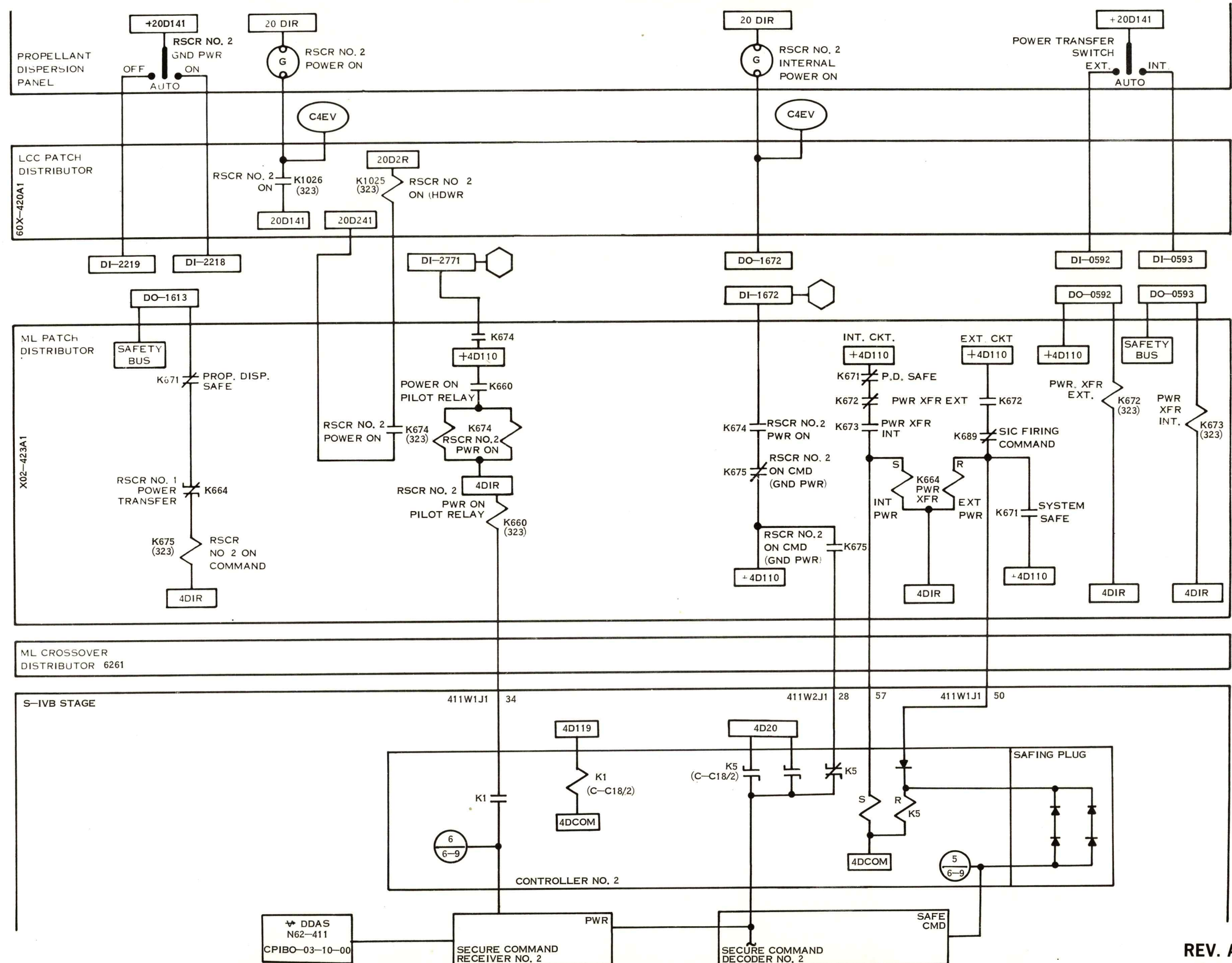
S-IVB-V EBW POWER CONTROL



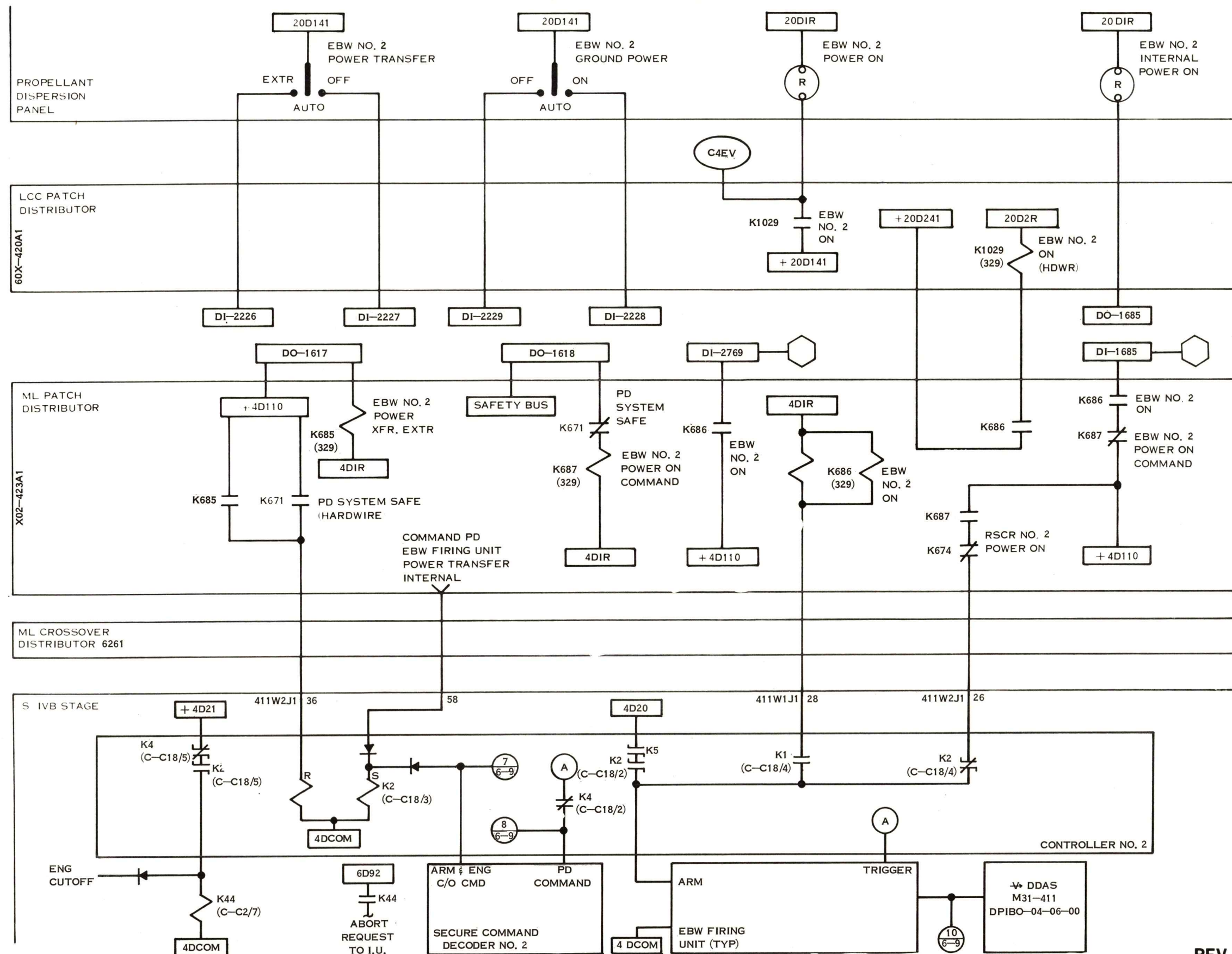
PROPELLANT DISPERSION RSCR NO.1 MONITOR



S-IVB-V RSCR NO.2 POWER CONTROL

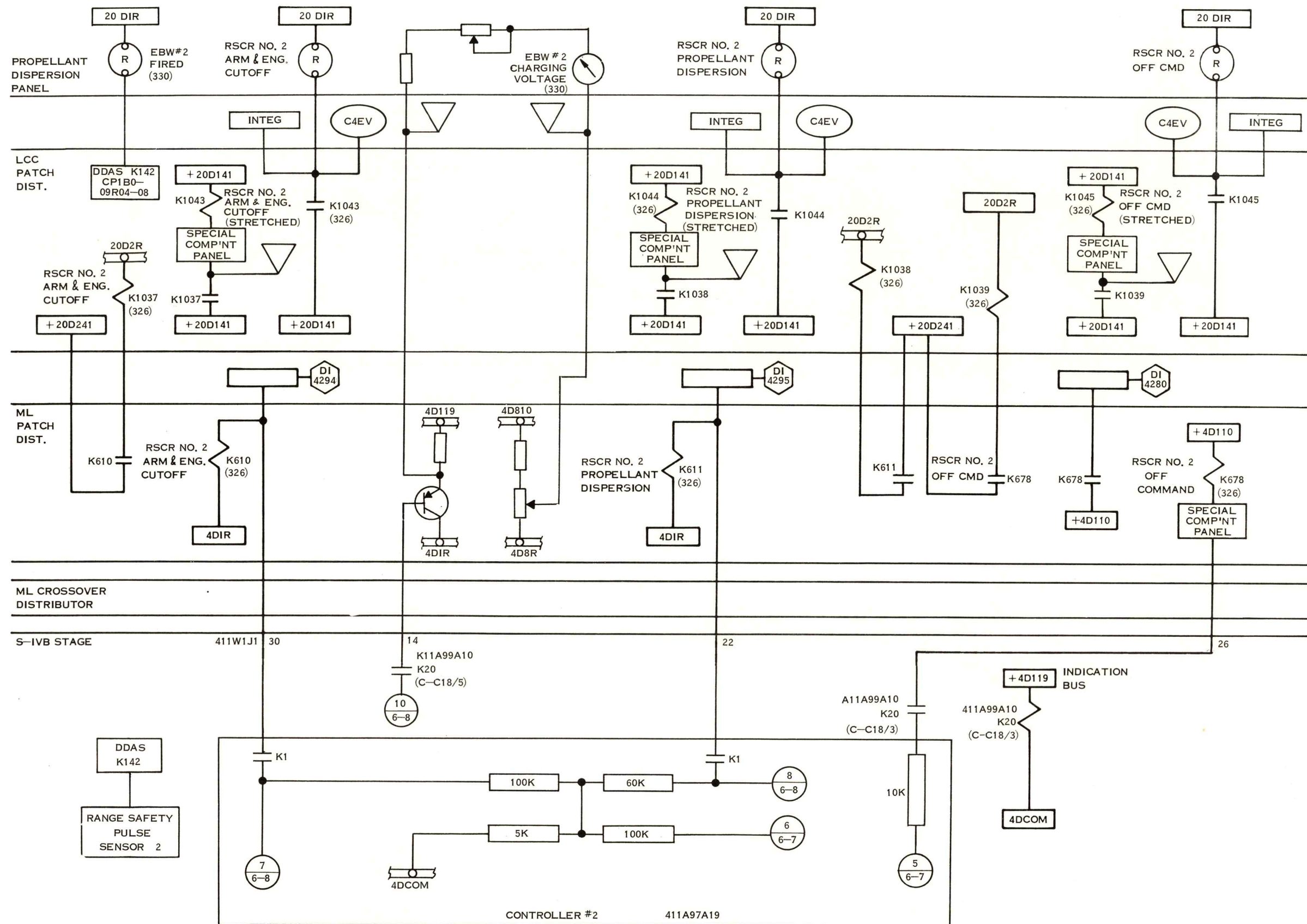


S-IVB-V EBW POWER CONTROL

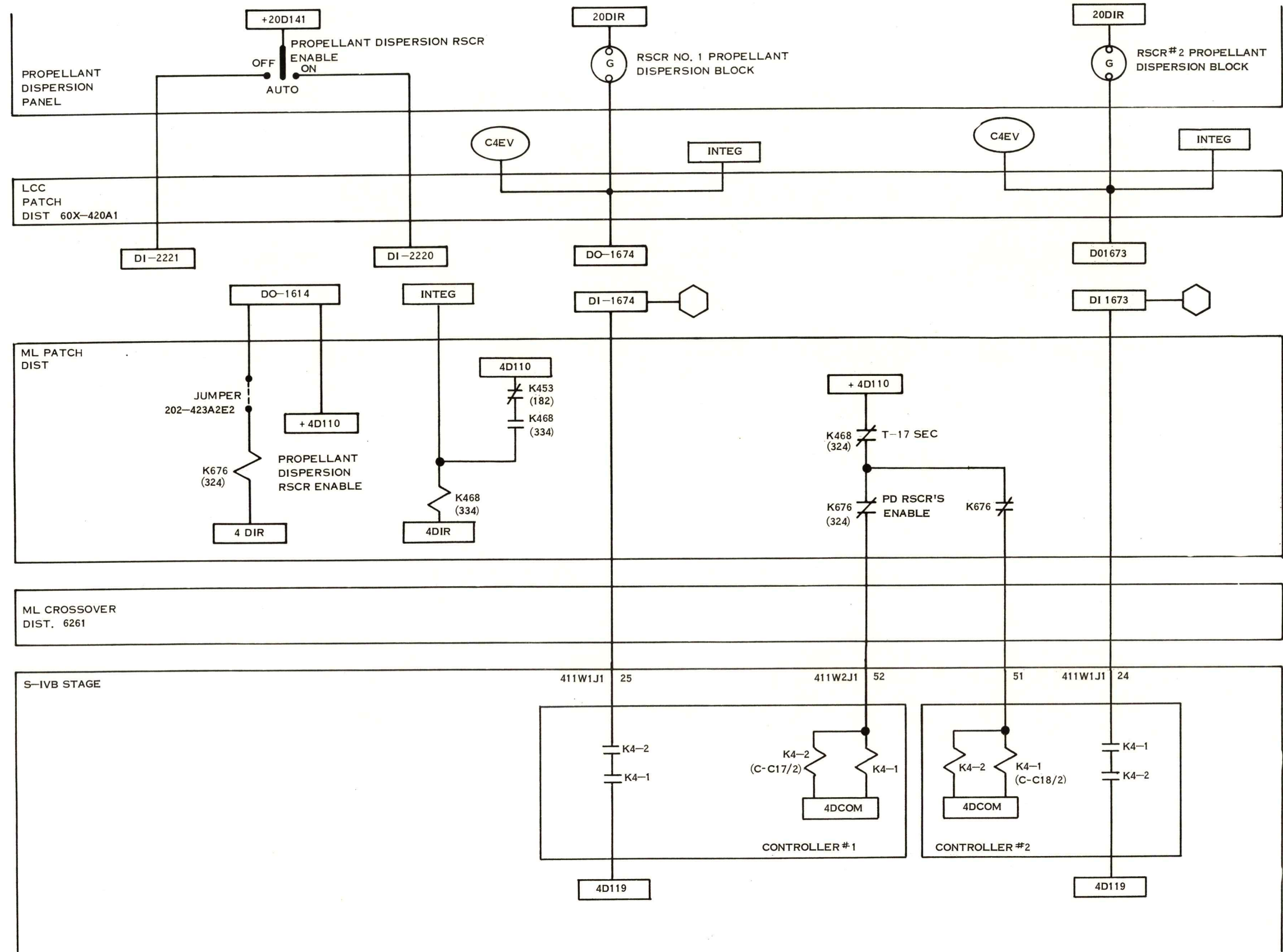


REV. A
6-8

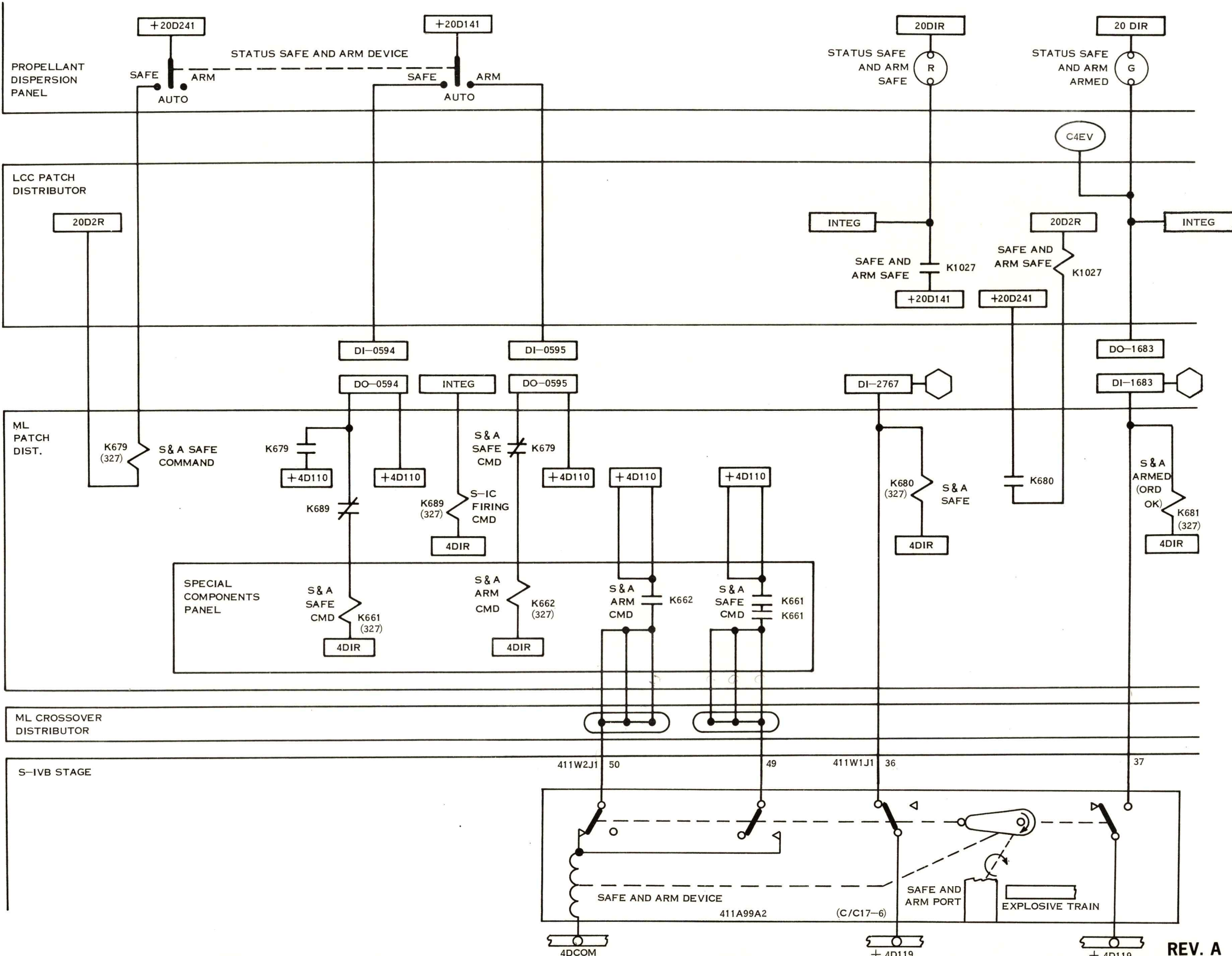
PROPELLANT DISPERSION RSCR NO.2 MONITOR



S-IVB-V PROPELLANT DISPERSION RSCR ENABLE



PROPELLANT DISPERSION SAFE & ARM CONTROL



7.0

PROPELLANT UTILIZATION SYSTEM SYSTEM DESCRIPTION

THE PROPELLANT UTILIZATION (P.U.) SYSTEM IS A PROPELLANT MASS MONITORING SYSTEM CONSISTING OF THE FOLLOWING SUBASSEMBLIES:

1. LOX AND FUEL TANK CAPACITANCE PROBES POSITIONED IN THE LOX AND FUEL TANKS.
2. A P.U. ELECTRONICS ASSEMBLY TOGETHER WITH THE STATIC-INVERTER CONVERTER WHICH PROVIDES ALL THE REGULATED DC AND AC VOLTAGES NECESSARY TO OPERATE THE P.U. ASSEMBLY.

7.1.1

DESCRIPTION OF OPERATION

EACH MASS PROBE FORMS ONE LEG OF A BRIDGE NETWORK LOCATED IN THE P.U. ELECTRONICS ASSEMBLY. A BRIDGE RATIO TRANSFORMER FORMS TWO OTHER LEGS (ONE CONTAINING THE FEEDBACK REBALANCE POTENTIOMETER), AND THE FOURTH LEG CONSISTS OF A REFERENCE CAPACITOR. THIS REFERENCE CAPACITOR IS TEMPERATURE STABILIZED BY MEANS OF A COMPONENT OVEN AND THUS MAINTAINS OVERALL BRIDGE STABILITY UNDER VARIOUS TEMPERATURE CONDITIONS. AS THE PROPELLANT MASS IN THE TANK CHANGES, THE CAPACITANCE OF THE MASS PROBE CHANGES AND CREATES AN IMBALANCE IN THE BRIDGE. THIS IMBALANCE SIGNAL IS AMPLIFIED AND THEN TRANSMITTED TO A QUADRATURE REJECTION CIRCUIT.

THE QUADRATURE REJECTION CIRCUITRY IS REQUIRED DUE TO THE OUT-OF-PHASE SIGNAL THAT IS PRODUCED IN THE BRIDGE CIRCUIT. THIS QUADRATURE SIGNAL IS PRODUCED BY HAVING A RESISTANCE-CAPACITANCE COMBINATION BALANCE A PURE CAPACITANCE (MASS PROBE). THIS SIGNAL IS A MIXTURE OF THE DESIRED CONTROL SIGNAL AND THE QUADRATURE SIGNAL.

SINCE THE QUADRATURE SIGNAL IS 90° OUT-OF-PHASE WITH THE DESIRED CONTROL SIGNAL, BY PROPER GATING, ONLY THE CONTROL SIGNAL IS ALLOWED TO PASS INTO THE POWER AMPLIFIER AND THE QUADRATURE SIGNAL IS REJECTED. FROM THE QUADRATURE REJECTION CIRCUIT, THE SIGNAL IS FURTHER AMPLIFIED TO DRIVE A TWO-PHASE SERVO-MOTOR WHICH DRIVES A FOUR-GANG, TEN-TURN POTENTIOMETER.

THE TWO FOUR-GANG POTENTIOMETERS, ONE FOR THE LOX BRIDGE AND THE OTHER FOR THE LH2 BRIDGE, ARE DRIVEN INDEPENDENTLY OF EACH OTHER. ONE GANG OF EACH POTENTIOMETER PRODUCES FEEDBACK SIGNALS TO REBALANCE THE BRIDGE AS IMBALANCES OF THE BRIDGE DUE TO PROPELLANT MASS CHANGES OCCUR. TWO GANGS, THE COARSE MASS AND FINE MASS, ARE USED TO PROVIDE TM SIGNALS INDICATING THE QUANTITY OF PROPELLANT ON BOARD. DURING TANKING AND DETANKING OPERATIONS, THE COARSE MASS SIGNALS ARE FED TO THE PROPELLANT TANKING COMPUTER SYSTEM (PTCS) THUS ENABLING THE STAGE TO BE LOADED. THE COARSE MASS SIGNAL TOGETHER WITH THE FINE MASS T/M SIGNAL PROVIDES CONTINUOUS LOADING STATUS AND PROPELLANT MASS DATA. THE FOURTH GANG OF EACH POTENTIOMETER IS NOT USED.

7.2

CRITICAL MEASUREMENTS

7.2.1

REDLINE MEASUREMENTS

7.2.1.1

N0063-411 P.U. OVEN STABILITY MONITOR

MEASUREMENT N63 GIVES A DIRECT INDICATION OF THE TEMPERATURE STABILITY OF THE REFERENCE CAPACITOR OVEN. THE TRANSDUCER FOR THE MEASUREMENT IS A PLATINUM RESISTANCE WIRE LOCATED IN THE P.U. OVEN CAVITY. THE P.U. OVEN MAINTAINS THE LOX AND LH2 REFERENCE CAPACITORS AT A STABLE TEMPERATURE IN ORDER TO PREVENT ERRONEOUS P.U. SYSTEM MASS INDICATIONS INDUCED BY CAPACITANCE CHANGES DUE TO ENVIRONMENTAL TEMPERATURE CHANGES. THE P.U. OVEN MONITOR STABILIZES WITHIN 45 MINUTES AFTER P.U. POWER TURN ON.

THE TEMPERATURE WILL BE STABLE WITHIN ± 0.3 VDC OF A REFERENCE READING DETERMINED DURING MANUAL P.U. CALIBRATION. ANY VOLTAGE VARIATIONS GREATER THAN ± 0.3 VDC OF THE STABILIZED REFERENCE VALUE OCCURRING DURING THE TIME INTERVAL STARTING WITH THE INITIATION OF S4B PROPELLANT LOADING TO T-3 MIN, 7 SEC. IS DEFINED AS A REDLINE VARIATION. OVEN FAILURE CAN BE DETECTED ON THE STRIP CHARTS AS AN APPARENT DRIFT IN BOTH THE LH2 AND LOX FINE MASS INDICATIONS.

7.2.1.2

VXN2-411 LH2 FINE MASS

MEASUREMENT N2 IS DERIVED FROM THE LH2 FINE MASS POTENTIOMETER IN THE PUEA. THE POTENTIOMETER GENERATES A 20 LEG SAWTOOTH, 10 WITH POSITIVE SLOPES, 10 WITH NEGATIVE SLOPES. THE POTENTIOMETER WIPER IS MECHANICALLY COUPLED TO THE LH2 COARSE MASS POTENTIOMETER WIPER AND THUS PROVIDES A TWENTY TO ONE SCALE EXPANSION OF THE INDICATED COARSE MASS. MEASUREMENT N2 IS A VERY SENSITIVE P.U. MEASUREMENT THAT QUICKLY REFLECTS CHANGES IN TANK CONDITIONS OR CHANGES IN CAPACITANCE SEEN BY THE LH2 P.U. BRIDGE ASSEMBLY. ANY ERRATIC CHANGES IN OUTPUT, UNEXPLAINED, DRIFT, NOISY OUTPUT, OR INDICATIONS IMPLYING SLEW OF THE BRIDGES TO THE POTENTIOMETER ENDSTOPS ARE GROUNDS FOR REPORTING P.U. MALFUNCTIONS.

MEASUREMENT N2 MUST BE WITHIN ITS REDLINE LIMITS FROM T-4 MIN 30 SEC TO T-3 MIN 7 SEC.

7.2.1.3

VXM1-411 115 VAC

M1 IS AN EXPANDED SCALE MEASUREMENT OF THE INVERTER CONVERTER 115 VAC OUTPUT. IN ADDITION TO FURNISHING EXCITATION VOLTAGES FOR THE LH2 AND LOX BRIDGE TRANSFORMERS, THE 115 VAC IS APPLIED TO THE FIXED PHASE WINDINGS OF BOTH BRIDGE SERVO MOTORS. SYSTEM REQUIREMENTS LIMIT THE 115 VAC TO A MINIMUM OF 110 VAC AND A MAXIMUM OF 121 VAC. ADDITIONALLY, A VOLTAGE CHANGE OF ± 2.5 VAC IS AN INDICATION OF COMPONENT FAILURE WITHIN THE INVERTER/CONVERTER.

MEASUREMENT M1 ASSUMES REDLINE STATUS FROM PU TURN ON UNTIL T-4 MIN 30 SEC.

7.2.1.4

VXN4-411 LOX FINE MASS (ALTERNATE)

IN THE EVENT OF PTCS READOUT FAILURE, N4 (ALT. REDLINE) WILL ASSUME PRIME REDLINE STATUS.

SEE PARAGRAPH 7.2.1.2, SAME NOTES APPLY.

7.2.2

BLUELINE MEASUREMENTS

7.2.2.1

VXN2-411 LH2 FINE MASS

VXN4-411 LOX FINE MASS

BOTH N2 LH2 FINE MASS AND N4 LOX FINE MASS ASSUME BLUELINE STATUS WHEN THE LH2 TANK AND LOX TANK ARE PRESSURIZED.

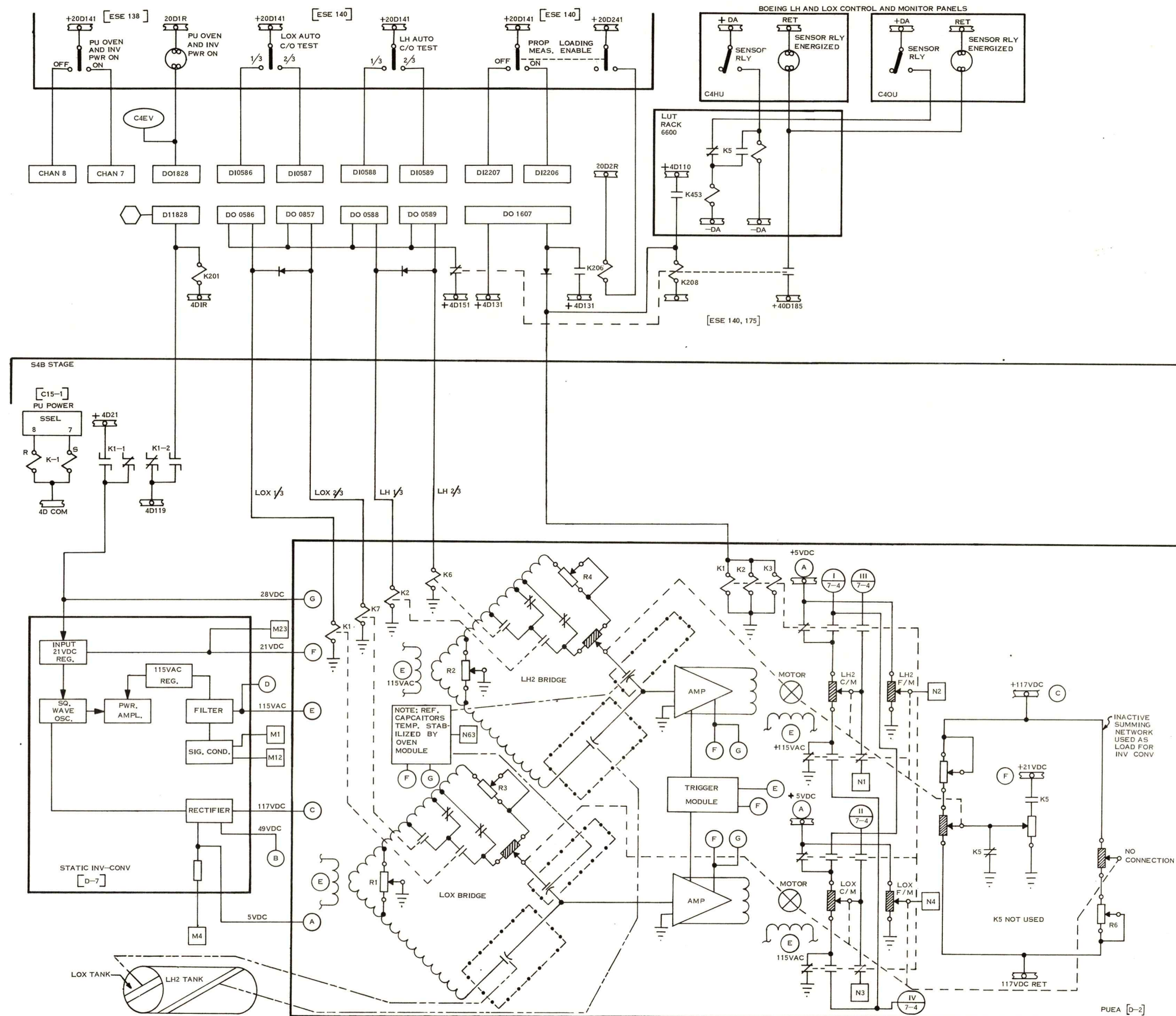
IF AN ANOMALY OCCURS AFTER A TANK IS PRESSURIZED UNTIL T-11 SECONDS, BLUELINE LIMITS FOR THE FUNCTION ARE SAID TO BE EXCEEDED. LOSS OF EITHER MEASUREMENT AFTER TANKS ARE PRESSURIZED WILL NOT IMPAIR MISSION SUCCESS. HOWEVER, AN ANOMALY MAY BE SYMPTOMATIC OF MORE SERIOUS P.U. PROBLEMS, AND THEREFORE SHOULD BE REPORTED AND INVESTIGATED.

7.2.2.2

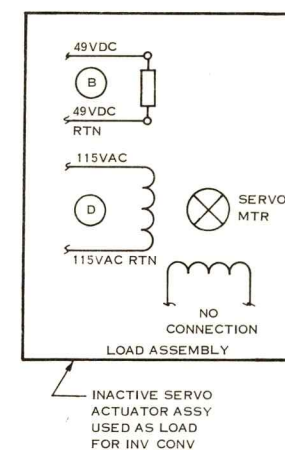
VXM12-411 FREQ-STATIC INV CONV

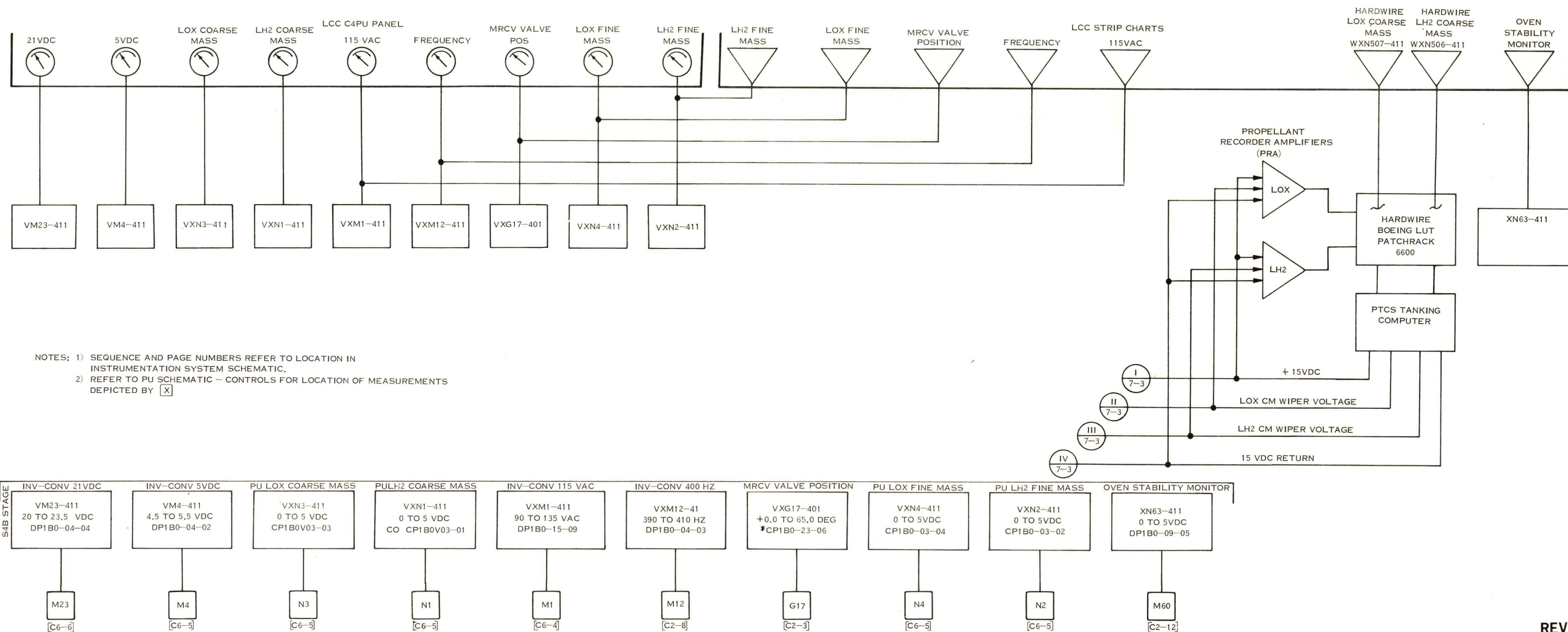
M12 IS AN EXPANDED SCALE MEASUREMENT OF THE INV/CONV 400 HZ OUTPUT FREQUENCY. VARIATIONS OUTSIDE NORMAL OPERATING LIMITS MAY INDICATE COMPONENT FAILURES WITHIN THE P.U. SYSTEM. ABNORMAL VARIATIONS SHOULD BE REPORTED AND INVESTIGATED.

MEASUREMENT M12 ASSUMES BLUELINE STATUS WHENEVER THE INVERTER/CONVERTER IS OPERATING.

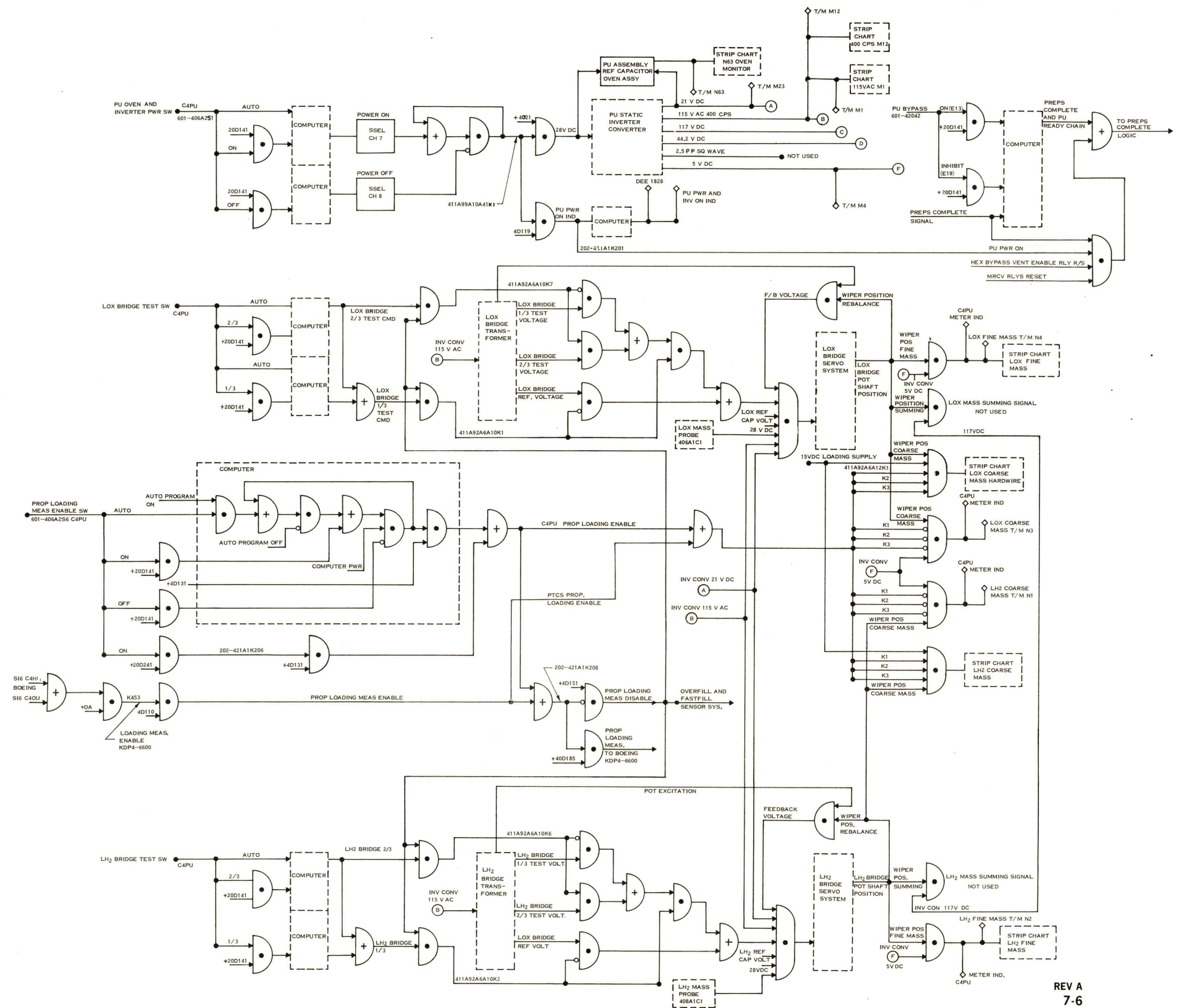


PU SYSTEM SCHEMATIC-CONTROLS





P.U. SYSTEM SCHEMATIC-INSTRUMENTATION



P. U. SYSTEM LOGIC DIAGRAM

8.0 HELIUM SYSTEM — ENGINE CONTROL AND TANK PRESSURIZATION

8.1 SYSTEM DESCRIPTION

8.1.1 GENERAL

THE UNIQUE PROPERTIES OF HELIUM, ITS INERTNESS, LOW FREEZING POINT, AND LOW DENSITY MAKES IT AN IDEAL GAS TO USE ON SPACE VEHICLES FOR A VARIETY OF PURPOSES. HELIUM ON BOARD THE SIVB STAGE IS USED TO PRESSURIZE THE LH₂ AND LOX TANK THEREBY EXERTING A NET POSITIVE SUCTION PRESSURE (NPSP) ON THE PROPELLANTS AND THUS PREVENTS PUMP CAVITATION DURING J2 ENGINE OPERATING. HELIUM IS ALSO USED TO CONTROL PNEUMATICALLY OPERATED VALVES, AND TO PURGE CRITICAL AREAS OF THE SIVB.

THE COLD HELIUM BOTTLES, THE LOX AND LH₂ AMBIENT BOTTLES AND ASSOCIATED HARDWARE USED TO CONTROL OR CONDITION THE STORED HELIUM, TOGETHER WITH THE ASSOCIATED GSE, FORM THE BASIS OF THREE INDEPENDENT TANK PRESSURIZATION SYSTEMS. THEY ARE:

1. GROUND PRESSURIZATION SYSTEM
2. FLIGHT CRYOGENIC REPRESSURIZATION SYSTEM
3. FLIGHT AMBIENT REPRESSURIZATION SYSTEM

A FOURTH INDEPENDENT PRESSURIZATION SYSTEM EXISTS FOR THE LH₂ TANK ONLY. THE LH₂ TANK IS PRESSURIZED WITH GASEOUS HYDROGEN DURING ENGINE BURN. HIGH PRESSURE GH₂ IS TAPPED OFF THE ENGINE INJECTOR AND RECYCLED BACK TO THE TANK TO MAINTAIN THE NPSP REQUIRED AT THE PUMP TURBOPUMP INLET. ADDITIONALLY, HELIUM GAS IS UTILIZED FOR PRESSURIZATION OF THE ENGINE CONTROL SPHERE. A STANDBY START TANK RECHARGE SYSTEM IS ALSO PROVIDED. BOTH SYSTEMS RECEIVE GASEOUS HELIUM FROM THE LOX REPRESS BOTTLES NO. 1 AND NO. 2. (SEE ALSO LH SYSTEM).

THE FIRST THREE PRESSURIZATION SYSTEMS NOTED ABOVE, AND THE ENGINE CONTROL HELIUM SYSTEM WILL BE THE SUBJECTS DISCUSSED IN THIS SECTION. IN ESSENCE, THE SCOPE OF THE SYSTEM DESCRIPTION SHALL BE LIMITED TO THE SYSTEMS ASSOCIATED WITH THE COLD HELIUM BOTTLE REDLINE D-261, THE LOX AND LH₂ AMBIENT BOTTLE REDLINES D88 AND D20, AND THE ENGINE CONTROL HELIUM SPHERE REDLINE D19.

8.1.2 GSE HELIUM PRESSURIZATION AND CONTROL

THE ORIGINAL GROUND SOURCE OF THE HELIUM USED ON THE SIVB STAGE IS THE 6000 PSI HELIUM SUPPLY. HELIUM FROM THE 6000 PSIA SUPPLY IS FIRST REGULATED DOWN TO 3100 PSIA. THE REGULATOR (SEE 1733 REGULATOR SHOWN IN SYSTEM SCHEMATIC) USED TO CONTROL PRESSURE, WORKS IN SUCH A MANNER THAT THE PRESSURE APPLIED TO THE DOME OF THE REGULATOR DETERMINES THE REGULATED PRESSURE. DURING COUNTDOWN, 3100 PSIA IS KEPT ON THE DOME WHENEVER THE BOTTLES ARE PRESSURIZED TO 3100 PSIA. IT SHOULD BE NOTED THAT BY CYCLING THE DOME VENT VALVE TO A DESIRED DOME PRESSURE, THE REGULATED PRESSURE CAN BE VARIED ACCORDINGLY. THIS REGULATED PRESSURE IS BRANCHED OFF THROUGH THREE SEPARATE LINES TO THE STAGE. TWO OF THE THREE LINES ARE ROUTED THROUGH THE HEAT EXCHANGER (438A CONSOLE). ONLY DURING THE FINAL PHASES OF COUNTDOWN, AFTER LH₂ STARTS COVERING THE COLD HELIUM BOTTLES DOES THE HEAT EXCHANGER BECOME OPERATIONAL AND SUPPLY COLD HELIUM TO THE COLD HELIUM BOTTLES AND THE ENGINE CONTROL HELIUM BOTTLE. THE THIRD HELIUM LINE TO THE STAGE BRANCHING OFF THE 3100 PSIA REGULATED SUPPLY SUPPLIES AMBIENT HELIUM TO THE LOX AND LH₂ AMBIENT BOTTLES.

PRIOR TO LIFTOFF, THE LOX AND LH₂ TANKS ARE BROUGHT UP TO FLIGHT PRESSURE (PRE-PRESSURIZATION) FROM THE GROUND PRESSURIZATION SUPPLY. THE PRESSURE IS CONTROLLED BY THE LOX AND LH₂ TANK PREPRESSURE SWITCH SETTINGS AND THE GROUND CONTROL EQUIPMENT.

8.1.3

FLIGHT PRESSURIZATION SYSTEMS

AFTER LIFTOFF, ALL HELIUM USED BY THE STAGE IS SUPPLIED BY THE COLD AND AMBIENT BOTTLES.

ALTHOUGH THE SIVB SYSTEMS UTILIZING HELIUM WERE DESIGNED TO USE AMBIENT HELIUM, HELIUM IS STORED IN THE COLD HELIUM BOTTLES LOCATED IN THE LH2 TANK. THE REASON FOR STORING COLD HELIUM IS THAT, BY UTILIZING THE LOW ENVIRONMENTAL TEMPERATURE OF LH2, A HIGH MASS LOAD OF HELIUM CAN BE STORED.

BEFORE THE COLD HELIUM STORED IN THE BOTTLES CAN BE USED THOUGH, IT MUST BE WARMED. DURING ENGINE BURN, THE COLD HELIUM IS WARMED BY THE J2 HEAT EXCHANGER LOCATED IN HOT GAS SYSTEM AND MIXED WITH COLD HELIUM FROM THE BOTTLES AND USED TO PRESSURIZE THE LOX TANK. THE LH2 TANK HOWEVER, IS PRESSURIZED DURING ENGINE BURN BY GASEOUS HYDROGEN.

PRIOR TO RESTART, COLD HELIUM IS WARMED BY THE O2-H2 BURNER AND USED TO PRESSURIZE THE LOX AND LH2 TANKS. THIS MODE OF OPERATION IS REFERRED TO AS THE CRYOGENIC MODE. THE OTHER MODE OF OPERATION USED IS CALLED THE AMBIENT MODE. IN THIS MODE, AMBIENT HELIUM FROM THE LOX AND LH2 AMBIENT REPRESS BOTTLES IS USED AS A BACKUP FOR THE CRYOGENIC SYSTEM OR PROVIDES MAKEUP REPRESSURIZATION CAPABILITY IN THE EVENT OF ULLAGE PRESSURE DECAY AFTER THE TERMINATION OF THE CRYOGENIC MODE OF PRESSURIZATION.

8.1.3

LH2 TANK REPRESSURIZATION AND REPRESSURIZATION DURING FLIGHT

DURING ENGINE OPERATION, THE LH2 TANK PRESSURE SWITCH SENSES TANK PRESSURE. WHEN TANK PRESSURE FALLS BELOW THE MINIMUM SWITCH SETTING, THE SOLENOID VALVES IN THE LH2 PRESSURE CONTROL MODULE ARE OPENED, ALLOWING AN INCREASED FLOW OF GAS INTO THE LH2 TANK. WHEN PRESSURE RISES ABOVE THE MAXIMUM SWITCH SETTINGS, THE VALVES CONTROLLING GH2 ARE CLOSED. GH2 USED FOR PRESSURIZATION DURING ENGINE OPERATION IS TAPPED OFF THE ENGINE LH2 MANIFOLD. DURING NONFIRING PERIODS, NO SUPPLY IS REQUIRED SINCE SUFFICIENT HEAT INPUT RESULTING IN GH2 BOILOFF ASSURES THAT TANK PRESSURE WILL NOT DROP EXCESSIVELY.

DURING THE COAST PHASE PRIOR TO SECOND BURN, THE CONTINUOUS VENT SUBSYSTEM OPERATES AS REQUIRED AT A TANK VENTING PRESSURE OF 20 PSIA NOMINAL. BEFORE ENGINE RESTART, VENTING IS TERMINATED AND THE LH2 TANK IS PRESSURIZED TO A PRESSURE RANGE OF 28 TO 31 PSIA FOR ENGINE SECOND BURN. GAS FOR REPRESSURIZATION IS SUPPLIED FROM THE AMBIENT HELIUM BOTTLES PROVIDED SPECIFICALLY FOR THIS FUNCTION OR BY HELIUM FROM THE COLD HELIUM SUPPLY CONDITIONED BY THE OXYGEN HYDROGEN BURNER. CONTROL FOR EACH PHASE OF FLIGHT IS ACCOMPLISHED BY ENABLING THE APPROPRIATE TANK PRESSURE SWITCH.

8.1.4

LOX TANK PRESSURIZATION AND REPRESSURIZATION DURING FLIGHT

THE LOX TANK PRESSURIZATION AND REPRESSURIZATION SUBSYSTEM PROVIDE CONTROLLED HELIUM SUPPLIES TO SATISFY LOX TANK PRESSURIZATION REQUIREMENTS DURING STAGE OPERATION. HELIUM FOR PRESSURIZATION DURING J-2 ENGINE FIRST AND SECOND BURN, IS STORED IN THE COLD HELIUM BOTTLES LOCATED IN THE LH2 TANK. HELIUM EMPLOYED FOR REPRESSURIZATION WHEN THE AMBIENT HELIUM SUBSYSTEM IS UTILIZED, IS STORED IN THE AMBIENT HELIUM BOTTLES.

DURING BOOST, THE PRESSURIZATION SUBSYSTEM IS ACTIVE AND WHEN PRESSURIZATION IS REQUIRED, COLD HELIUM IS PROVIDED UNDER CONTROL OF THE LOX TANK PRESSURE CONTROL MODULE.

DURING ENGINE OPERATION, TANK PRESSURE SENSED BY THE LOX TANK PRESSURE SWITCH ACTUATES THE OPENING AND CLOSING OF SOLENOID VALVES IN THE LOX TANK PRESSURE CONTROL MODULE AS WELL AS THE HEAT EXCHANGER BYPASS VALVE. THE FLOW OF THE HELIUM FROM THE BOTTLES DIRECTLY TO THE LOX TANK, COMBINED WITH HELIUM DIVERTED THROUGH THE HEAT EXCHANGER RAISES TANK PRESSURE AS REQUIRED.

8.1.5

START TANK AND HELIUM CONTROL SYSTEM

THE INTEGRAL HYDROGEN HELIUM START TANK CONSISTS OF A 4.2 CUBIC FOOT SPHERE FOR GH_2 AND A 1000 CUBIC INCH SPHERE FOR HELIUM LOCATED WITHIN IT. HELIUM STORED UNDER PRESSURE IN THE HELIUM TANK IS USED TO SUPPLY PNEUMATIC PRESSURE TO THE ENGINE CONTROL SYSTEM. THE START TANK IS INITIALLY FILLED FROM A GROUND SOURCE. THIS SOURCE PROVIDES ENERGY TO INITIALLY SPIN THE TURBINE WHICH DRIVES THE TURBO-DUMP TO PROVIDE PROPELLANT FOR ENGINE START. AFTER MAINSTAGE ENERGY IS PROVIDED BY THE GAS GENERATOR TO MAINTAIN TURBOPUMP RPM. DURING FIRST BURN THE START TANK IS REFILLED BY A TAPOFF LINE PROVIDED ON THE J-2 ENGINE. THIS PROVIDES GH_2 FOR 2ND. BURN OPERATION. DURING COAST PERIOD SHOULD LOSS START TANK PRESSURE OCCUR, HELIUM GAS CAN BE PROVIDED FROM THE LOX REPRESS BOTTLE NO. 2 FOR RECHARGE PRIOR TO 2ND BURN ENGINE START.

THE HELIUM BOTTLE IS INITIALLY FILLED FROM A GROUND SOURCE. DURING, DUAL RESTART MISSIONS, THE HELIUM TANK IS CONTINUOUSLY REFILLED BY THE STAGE AMBIENT PRESSURIZATION SYSTEM. THE PNEUMATIC CONTROL PACKAGE CONTROLS FLOW OF HELIUM GAS TO THE ENGINE CENTRAL SYSTEM AND SUPPLIES OPENING AND CLOSING CONTROL PRESSURE FOR ALL ENGINE PNEUMATICALLY OPERATED VALVES AND CONTROLS ALL ENGINE SUPPLIED PURGES. (SEE ALSO LH SYSTEM).

8.2

CRITICAL MEASUREMENTS

8.2.1

GENERAL

DURING LAUNCH COUNTDOWN, FOUR MEASUREMENTS ASSOCIATED WITH THE LOX AND LH TANK PRESSURIZATION AND ENGINE HELIUM CONTROL SYSTEM ARE CLASSIFIED AS REDLINE MEASUREMENTS. THEY ARE D261, D20, D88, D19. IN THE ENGINE CONTROL SYSTEM VXC7-401, TEMP-ENGINE CONTROL HELIUM, IS A BACKUP REDLINE. THIS MEASUREMENT IS NOT DISCUSSED IN THIS SECTION. THE TROUBLESHOOTING FLOW-CHART FOR THIS MEASUREMENT CAN BE FOUND IN THE FUEL SYSTEM UNDER THE C6 TROUBLESHOOTING FLOWCHART. TROUBLESHOOTING FLOWCHARTS FOR MEASUREMENTS D261, D20, D88 AND D19 ONLY HAVE BEEN PREPARED. IN USING THESE FLOWCHARTS, THE USER SHOULD BE COGNIZANT OF THE FOLLOWING FACTS. THE MOST COMMON FAILURE MODE IS EXCESSIVE HELIUM LEAKAGE RESULTING IN LOW PRESSURE READINGS. FOR THIS REASON, DURING LAUNCH AND CDDT, THE HELIUM BOTTLES ARE PRESSURIZED (SEE FIGURE 8-1 FOR PRESSURIZING SEQUENCE) AND LEAK CHECKS PERFORMED. MALFUNCTIONS OCCURRING AFTER THE SUCCESSFUL COMPLETION OF THESE LEAK CHECKS (APPROXIMATELY T-1 HR) PROBABLY MEANS A SCRUB. REDLINE VIOLATION INDICATING EXCESSIVE BOTTLE PRESSURES ARE PROBABLY CAUSED BY MALFUNCTION OF THE 3200 PSIA GSE REGULATOR.

8.2.2

REDLINE MEASUREMENTS

8.2.2.1

VXD 261-403 PRESSURE - COLD HELIUM SPHERE

AFTER FINAL SPHERE PRESSURIZATION TO 3100 PSIA (APPROXIMATELY T-3 HR. 45 MIN.) D261 ASSUMES REDLINE STATUS. THE PRESSURE TRANSDUCER FOR THIS MEASUREMENT IS LOCATED AT COLD HELIUM BOTTLE EIGHT LOCATED IN THE LH₂ TANK. THE BACKUP MEASUREMENT FOR D261 IS D263-403, PRESSURE MANIFOLD COLD HELIUM SPHERE BACKUP. THIS MEASUREMENT IS LOCATED IN THE THRUST STRUCTURE BETWEEN STRINGERS 12 AND 13. THE SENSE POINT OF THIS MEASUREMENT IS THE EXISTING PORT ON THE HELIUM INLET LINE TO THE LOX TANK PRESSURE CONTROL MODULE. D261 IS AN IMPORTANT PARAMETER BECAUSE TOGETHER WITH TEMPERATURE MEASUREMENTS C5, C208, THE MASS OF HELIUM STORED IN THE COLD HELIUM BOTTLES CAN BE DETERMINED, THEREBY ASSURING THAT HELIUM WILL BE AVAILABLE FOR PRESSURIZATION OF THE LOX AND LH₂ TANKS DURING FLIGHT.

NOTE: REDLINE STATUS MAY BE CHANGED TO T-1 HOUR.

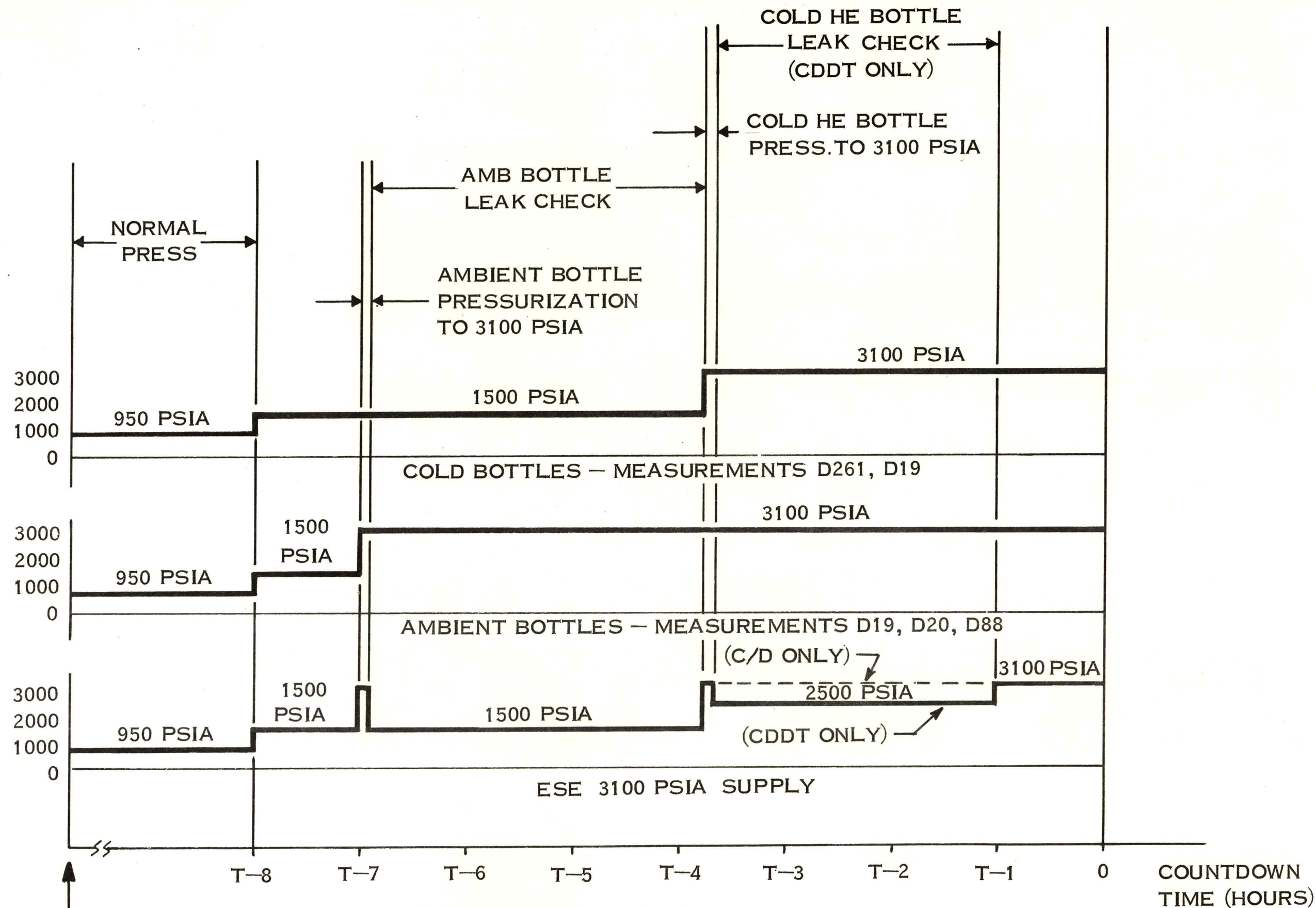
- 8.2.2.2 VXD20-403 PRESSURE FUEL TANK HE BOTTLE REPRESS (AMBIENT)
MEASUREMENT D20 ASSUMES REDLINE STATUS AFTER FINAL PRESSURIZATION TO 3100 PSIA (APPROXIMATELY T-7 HRS. 30 MINUTES). PRESSURE LIMITS ARE 3200 PSIA MAX. AND 2800 PSIA IS MINIMUM. D249-403 PRESSURE FUEL TANK HELIUM BOTTLE REPRESS IS A BACKUP MEASUREMENT FOR D20. THE SENSE POINT FOR D20 IS AN INSTRUMENTATION PORT LOCATED NEAR AMBIENT BOTTLE 10. TRANSDUCER RANGE IS 0 TO 3500 PSIA.
- 8.2.2.3 VXD88-403 PRESSURE LOX TANK REPRESS SPHERE (AMBIENT)
MEASUREMENT D88 ASSUMES REDLINE STATUS AFTER FINAL PRESSURIZATION TO 3100 PSIA (APPROXIMATELY T-7 HRS. 30 MINUTES). PRESSURE LIMITS ARE 3200 PSIA MAX. AND 2800 PSIA MINIMUM. D254-403 PRESSURE LOX TANK REPRESS SPHERES IS A BACKUP FOR THIS MEASUREMENT. TRANSDUCER RANGE IS 0 TO 3500 PSIA.
- 8.2.2.4 VXD19-401 PRESSURE - ENGINE CONTROL HELIUM SPHERE
MEASUREMENT D19 ASSUMES REDLINE STATUS AFTER FINAL PRESSURIZATION TO 3100 PSIA (APPROXIMATELY T-7 HRS. 30 MINUTES). PRESSURE LIMITS ARE 3200 PSIA MAX. AND 2800 PSIA MINIMUM. D242-401 PRESSURE ENGINE CONTROL HELIUM SPHERE BACKUP IS A BACKUP MEASUREMENT FOR THIS PARAMETER. THE SENSE POINT OF MEASUREMENT D19 IS THE HIGH PRESSURE OUTLET LOCATED ON THE PNEUMATIC LINE BETWEEN THE ENGINE HELIUM CONTROL BOTTLE AND THE ENGINE HELIUM REGULATOR. TRANSDUCER RANGE IS 0 TO 3500 PSIA.
- 8.2.3 TABLE OF MEASUREMENTS
NOTE: 1. MEASUREMENT NUMBERS PRECEDED BY X INDICATES A STRIP CHART DISPLAY.
2. MEASUREMENT NUMBERS PRECEDED BY V INDICATES A PANEL METER DISPLAY.

TABLE I

<u>DDAS NUMBER AND MEASUREMENT NUMBER</u>	<u>PAGE LOCATION</u>	<u>FUNCTION</u>	<u>RANGE</u>	<u>CHANNEL</u>
VXD 017-401	7	PRESS - GH2 START BOTTLE	0-1500 PSIA	CPIBO-13-03
VXD 019-401	7	PRESS - ENG CONTROL HE SPHERE	0-3500 PSIA	DPIBO-13-03
VXD 020-403	6,7	PRESS - FUEL TK HE BOTTLE REPRESS	0-3500 PSIA	CP1BO-13-04
D-054-410	6	PRESS - FUEL TANK INLET	0-100 PSIA	DPIBO-13-04
D-055-424	4	PRESS - OXIDIZER TANK INLET	0-300 PSIA	CPIBO-14-01
VXD 088-403	5,7	PRESS - LOX TANK REPRESS SPHERES	0-3500 PSIA	DPIBO-14-01
D 104-403	6	PRESS - LH2 PRESS MODULE INLET	0-1000 PSIA	DPIBO-01-08
XD 105-403	4	PRESS - LOX TANK PRESS MOD HE GAS	0-500 PSIA	DPIBO-06-09
VD 129-331	1	6000 PSI SUP PRESSURE	0-7000 PSIA	CPIBO-14-05
				DPIBO-14-05
				DPIBO-08-04
				DPIBO-08-06
				EPIBO-09-02

<u>DDAS NUMBER AND MEASUREMENT NUMBER</u>	<u>PAGE LOCATION</u>	<u>FUNCTION</u>	<u>RANGE</u>	<u>CHANNEL</u>
VD 137-331	1	OUTPUT DOME REG PRESS SUP PRESS	0-7000 PSIA	EPIBO-09-04
D 140-331	1	FUEL PRE-PRESS SUP PRESS	0-3500 PSIA	EPIBO-23-06
D 141-331	2	LH2 TK PRE-PRESS SUP PRESS	0-3500 PSIA	EPIBO-23-07
D 144-331	3	ENG CONT BOTTLE SUP PRESS	0-3500 PSIA	EPIBO-23-10
D 145-331	3	COLD HE BOTTLE SUP PRESS	0-3500 PSIA	EPIBO-23-09
VD 146-331	1	FIRST STAGE REG PRESS	0-7000 PSIA	EPIBO-09-05
D 161-403	4	PRESS - HEX OUTLET	0-650 PSIA	DPIBO-06-10
VXD 177-408	6	PRESS - FUEL TANK ULLAGE EDS 1	0-50 PSIA	CPIBO-01-02 DPIBO-01-02
VD 178-408	6	PRESS - FUEL TANK ULLAGE EDS 2	0-50 PSIA	CPIBO-01-03 DPIBO-01-03
VXD 179-406	5	PRESS - OXID TANK ULLAGE EDS 1	0-50 PSIA	CPIBO-14-02 DPIBO-14-02
VD 180-406	5	PRESS - OXID TANK ULLAGE EDS 2	0-50 PSIA	CPIBO-14-03 DPIBO-14-03
D 228-403	5	PRESS - GOX GN2 BNR PRESS COIL	0-500 PSIA	CPIBO-02-07
D 231-403	6	PRESS - GOX GN2 BNR PRESS COIL	0-500 PSIA	DPIBO-03-07
VXD 236-403	7	PRESS - AMBIENT HE PNEU SPH	0-3500 PSIA	CPIBO-14-04 DPIBO-14-04
D241-401	7	PRESS - GH2 START BTL BKUP MEAS	0-3500 PSIA	DPIBO-11-09
D249-403	6,7	PRESS - FUEL TK HE BTL REPRESS	0-3500 PSIA	DPIBO-09-06
D254-403	5,7	PRESS - LOX TANK REPRESS SPHERES	0-3500 PSIA	DPIBO-09-09
D256-403	7	PRESS - AMBIENT HE PNEU SPHERE	0-3500 PSIA	DPIBO-09-10
VXD 261-403	4	PRESS - MANIFOLD COLD HE SPHERES	0-3500 PSIA	CPIBO-01-01 DPIBO-01-01
D263-403	4	PRESS - MANF COLD HE SPHERES BKUP	0-3500 PSIA	DPIBO-09-05
D576	6	FUEL TANK ULLAGE PRESS	HARDWIRE	—
D577	5	LOX TANK ULLAGE PRESS	HARDWIRE	—

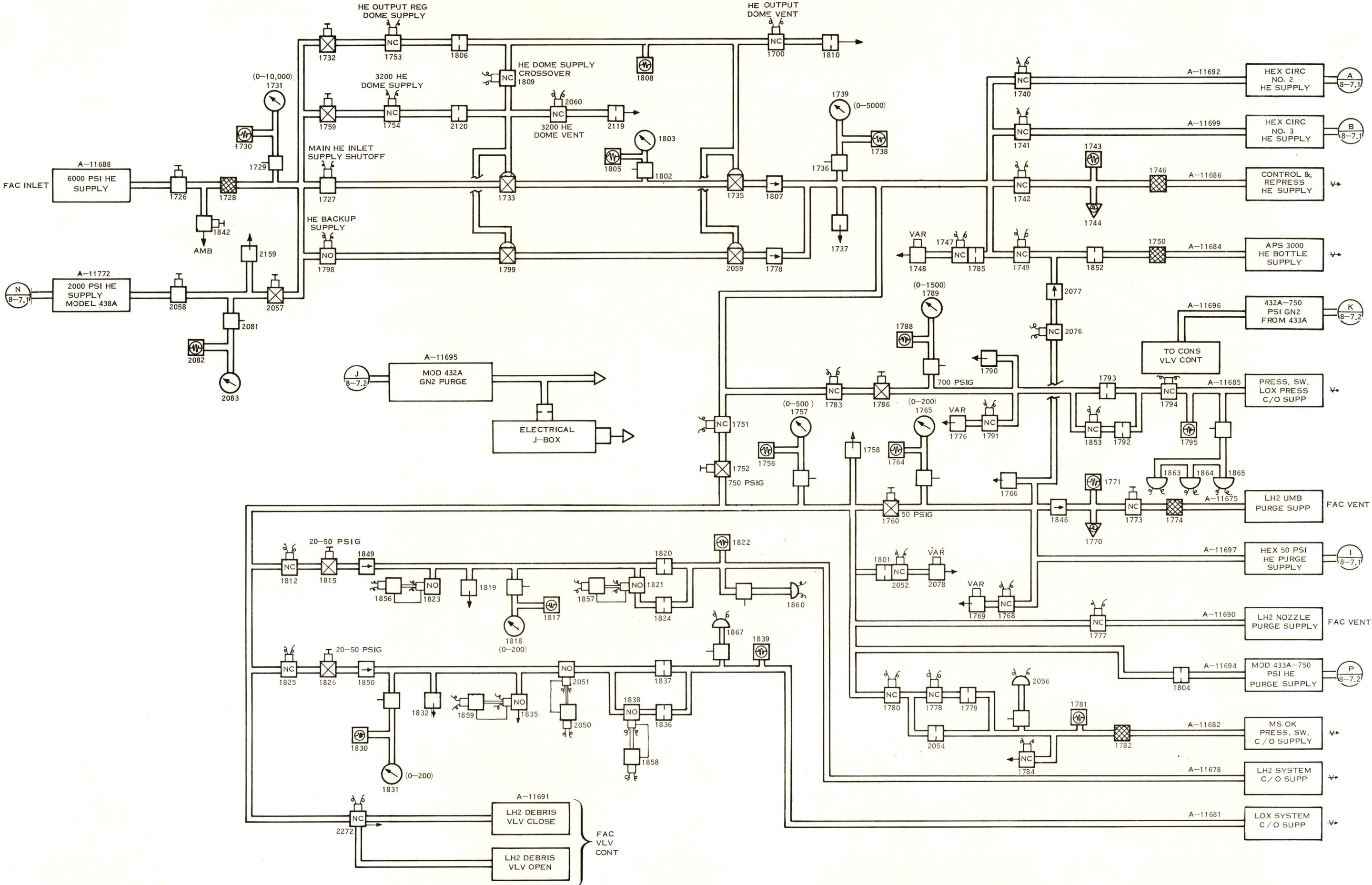
<u>DDAS NUMBER AND MEASUREMENT NUMBER</u>	<u>PAGE LOCATION</u>	<u>FUNCTION</u>	<u>RANGE</u>	<u>CHANNEL</u>
VC005-405	5	TEMP - COLD HE SPHERE NO. 3 GAS	25 TO 80 DEG R	DPIBO-17L03
VXC006-401	7	TEMP - GH2 START BOTTLE	110 TO 560 DEG R	DPIBO-17L04
VXC007-401	7	TEMP - ENG CONTROL HELIUM	110 TO 560 DEG R	DPIBO-17L05
C009-403	4	TEMP - HEAT EXCH HE OUTLET	660 TO 1360 DEGR	DPIBO-17L07
C014-403	6,7	TEMP - HE REPRESS SPHERE 5 GAS	110 TO 660 DEG R	DPIBO-20L03
C015-410	6	TEMP - FUEL TANK GH2 INLET	50 TO 520 DEG R	DPIBO-02-02
VC071-331	2	CKT NO. 2 HEX OUTLET TEMP.	-435 TO -185 F	EPIBO-09-09
VC072-331	2	CKT NO. 3 HEX OUTLET TEMP.	25 260 DEG R	EPIBO-08-02
C073-331	1	FUEL PRE-PRESS SUP TEMP.	410 610 DEG R	EPIBO-23-05
C074-331	2	LH2 TK PRE-PRESS SUP TEMP	25 260 DEG R	EPIBO-23-08
C077-331	3	COLD HE BOTTLE SUP TEMP	25 260 DEG R	EPIBO-11-01
C206-403	6,7	TEMP - HE SPHERE 10 GAS	110 TO 660 DEG R	DPIBO-20L07
C208-405	5	TEMP - COLD HE SPHERE NO. 1 GAS	25 TO 80 DEG R	DPIBO-18L07
C210-405	5	TEMP - COLD HE SPHERE NO. 4 GAS	25 TO 560 DEG R	DPIBO-18L08
C214-403	6,7	TEMP - HE REPRESS SPHERE 7 GAS	110 TO 660 DEG R	DPIBO-20L08
C230-403	4	TEMP - LOX TK PRESS MOD HE GAS	25 TO 80 DEG R	DPIBO-19L08
C231-403	6	TEMP - FUEL TK PRESS CONT MOD GH2	100 TO 300 DEG R	DPIBO-19L09
C378-403	5	LOX LH2 BNR LOX PRESS COIL	60 TO 660 DEG R	DPIBO-10L02
C379-403	6	TEMP - GOX GH2 BNR LH2 PRESS COIL	60 TO 660 DEG R	DPIBO-10L03
XC-2012-403	7	TEMP - AMBIENT HELIUM PNEU SPHERE	110 TO 660 DEG R	DPIBO-20L06



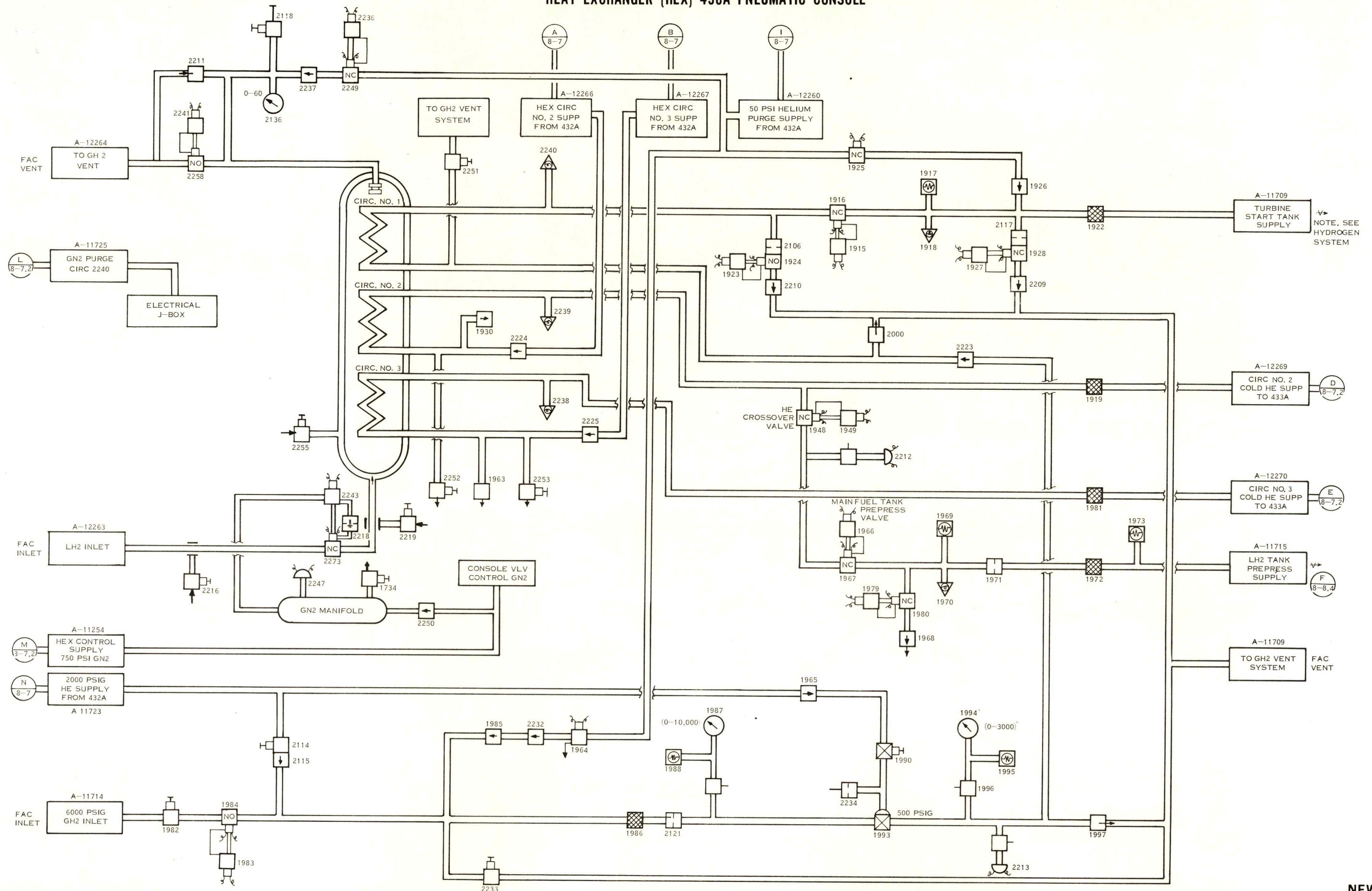
LAUNCH
VEH PWR UP

HELIUM PRESSURIZATION SEQUENCE FIGURE 8-1

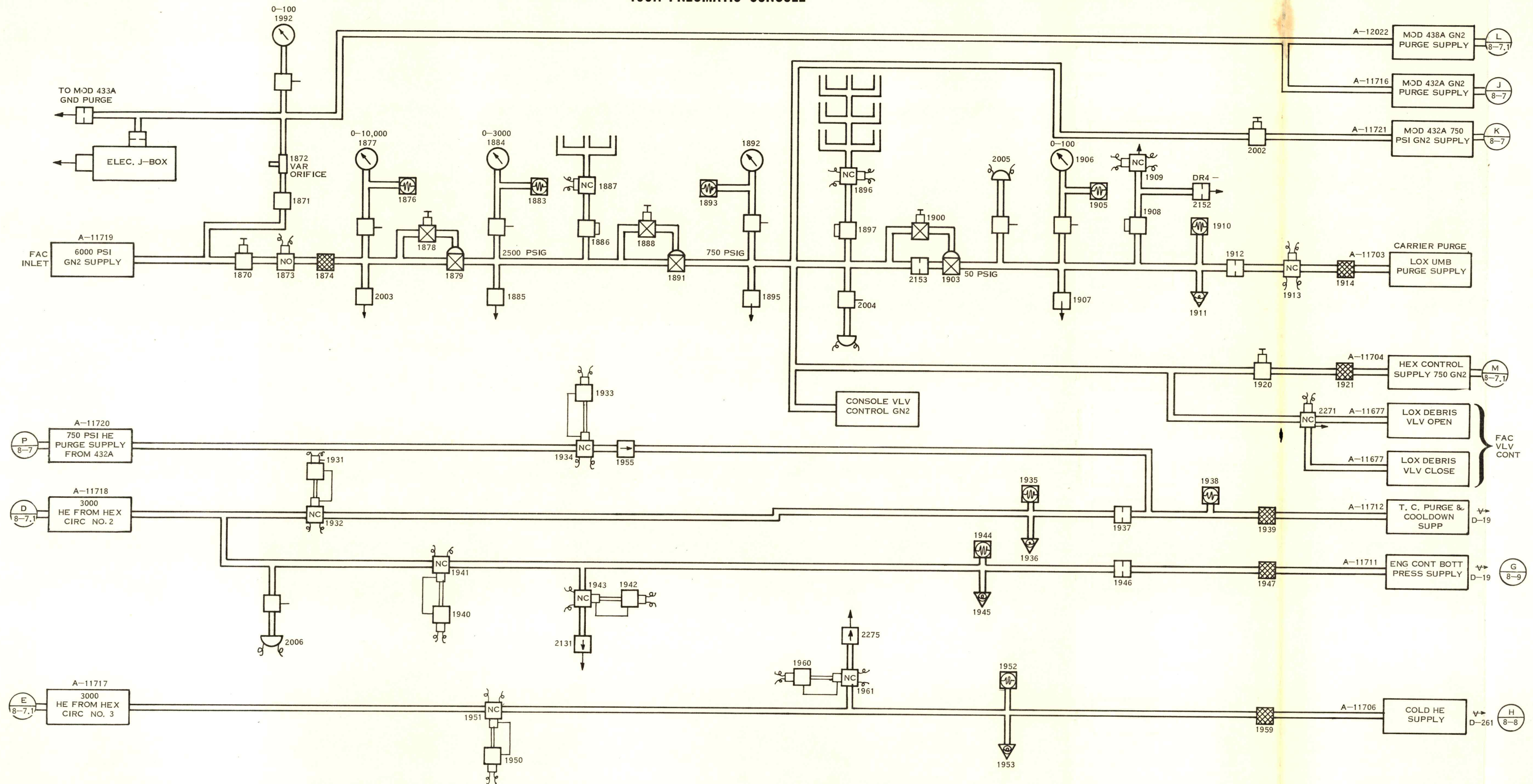
432A PNEUMATIC CONSOLE



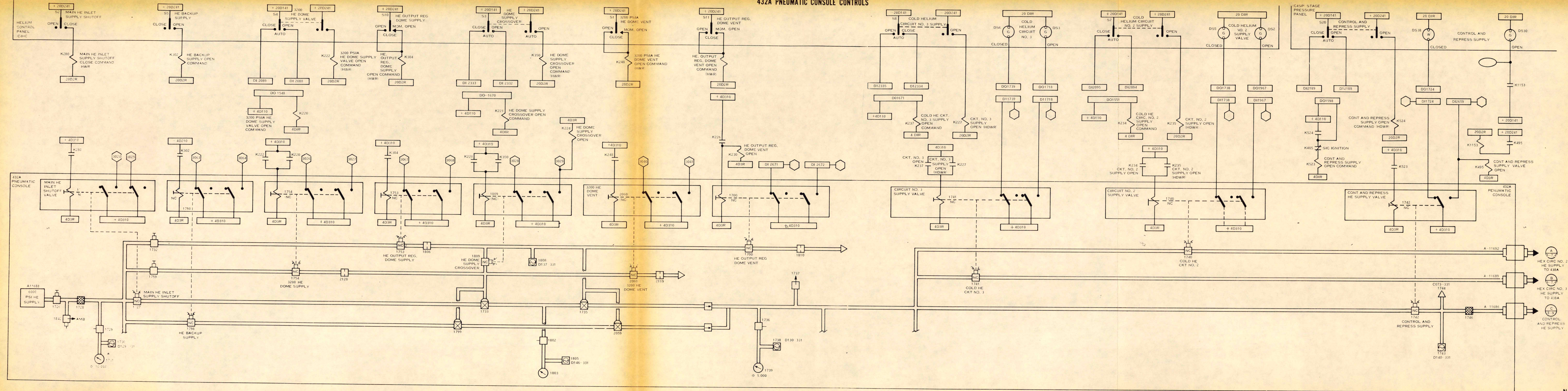
HEAT EXCHANGER (HEX) 438A PNEUMATIC CONSOLE



433A PNEUMATIC CONSOLE

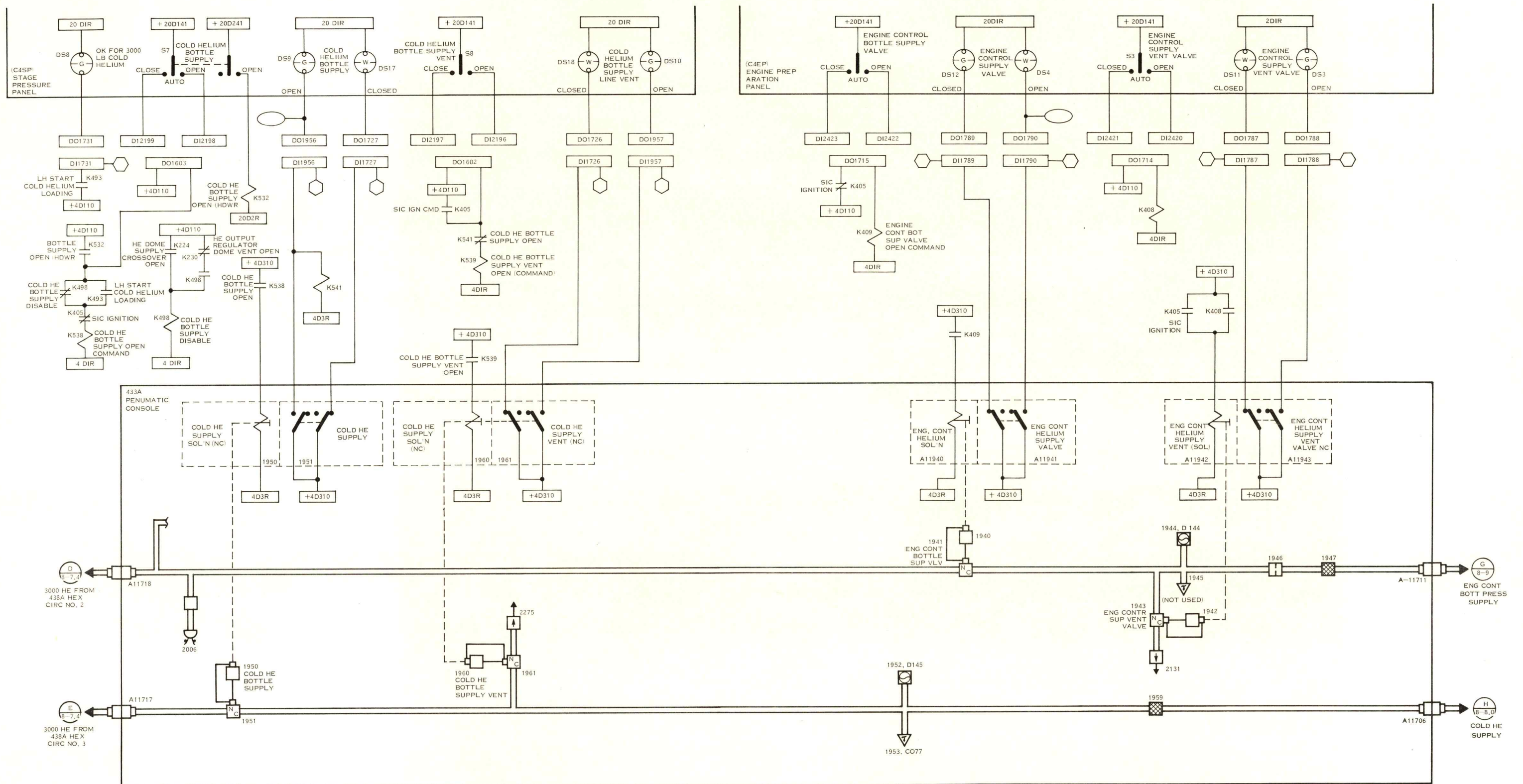


432A PNEUMATIC CONSOLE CONTROLS

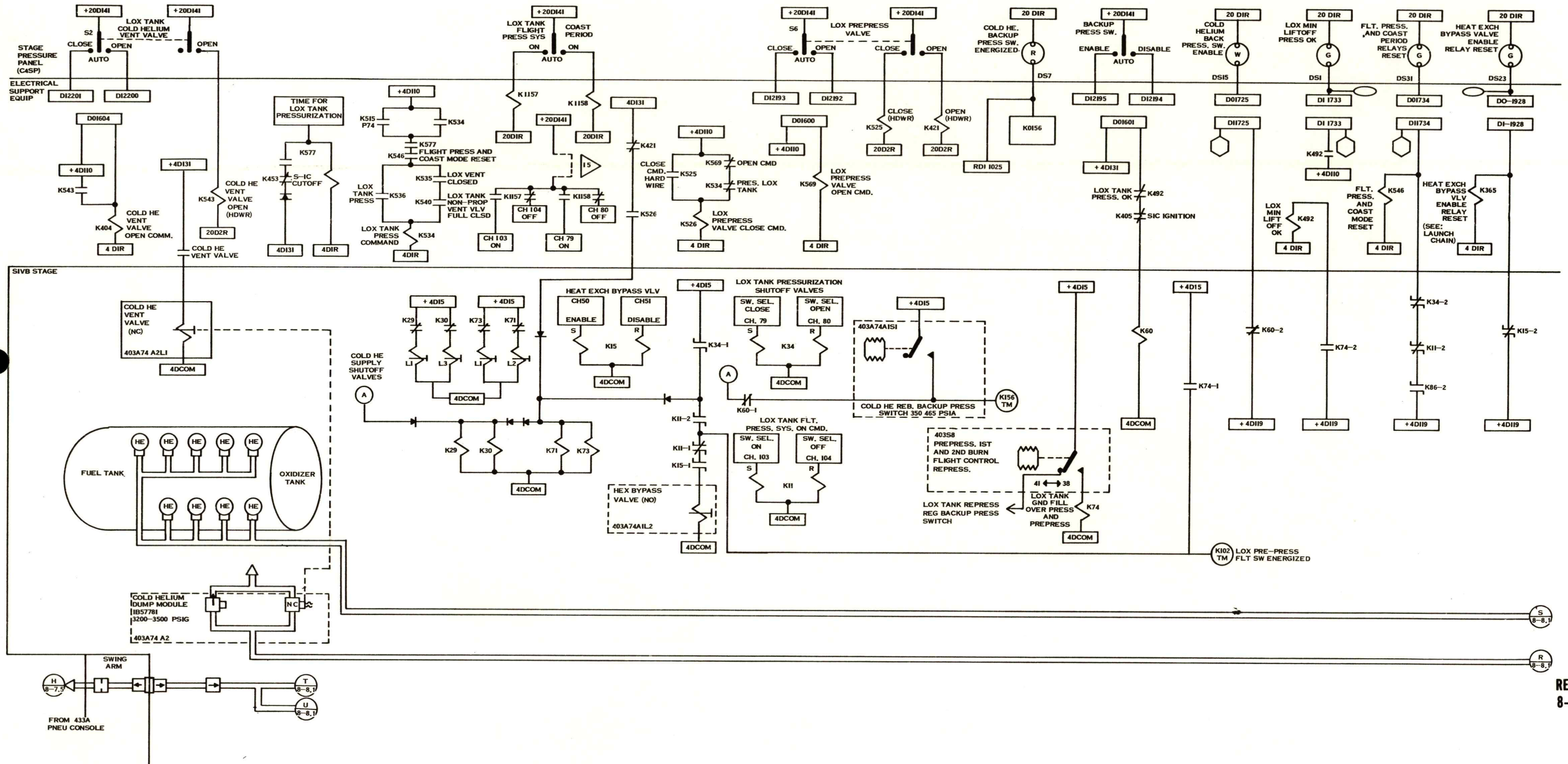




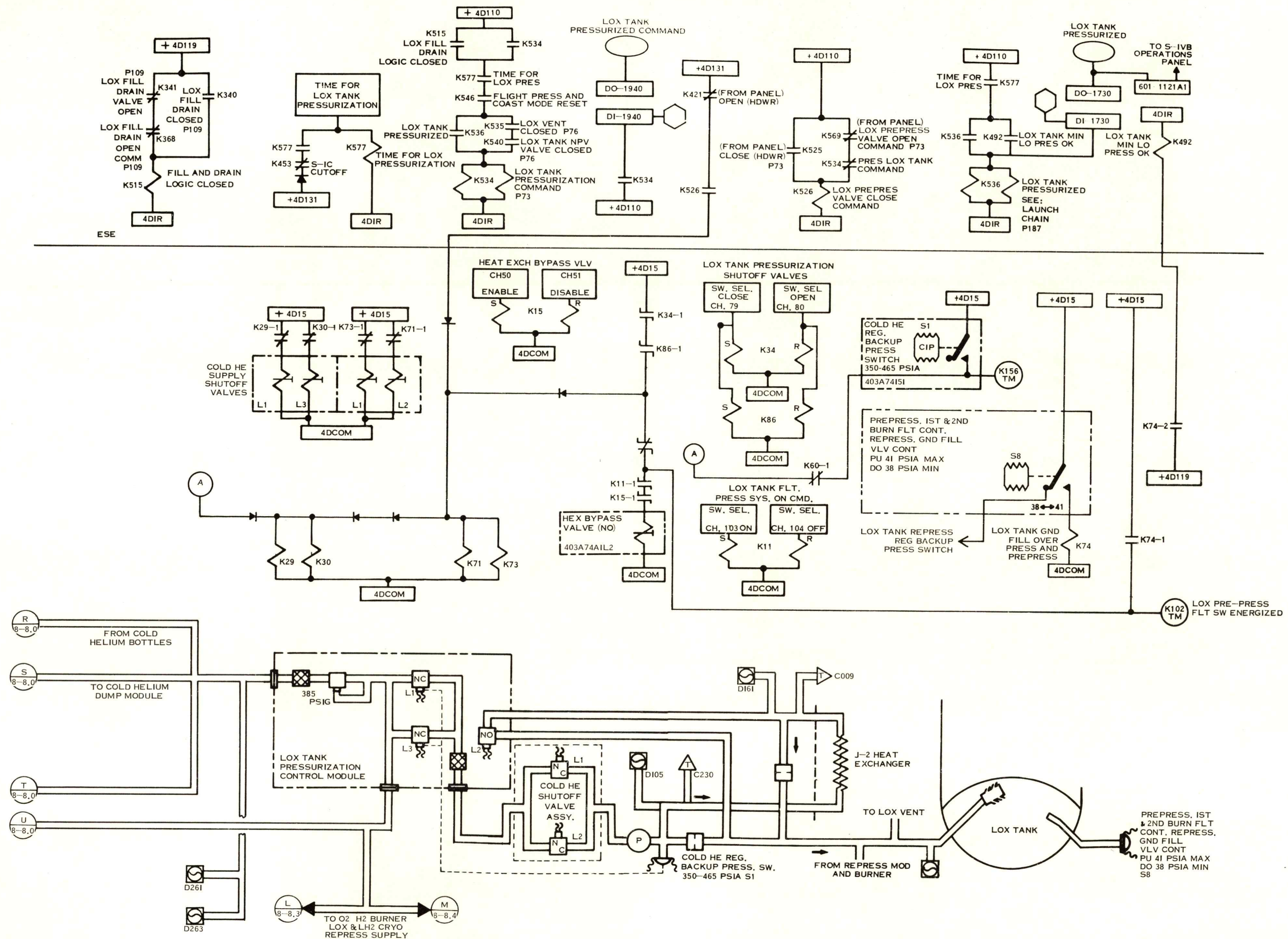
433A PNEUMATIC CONSOLE



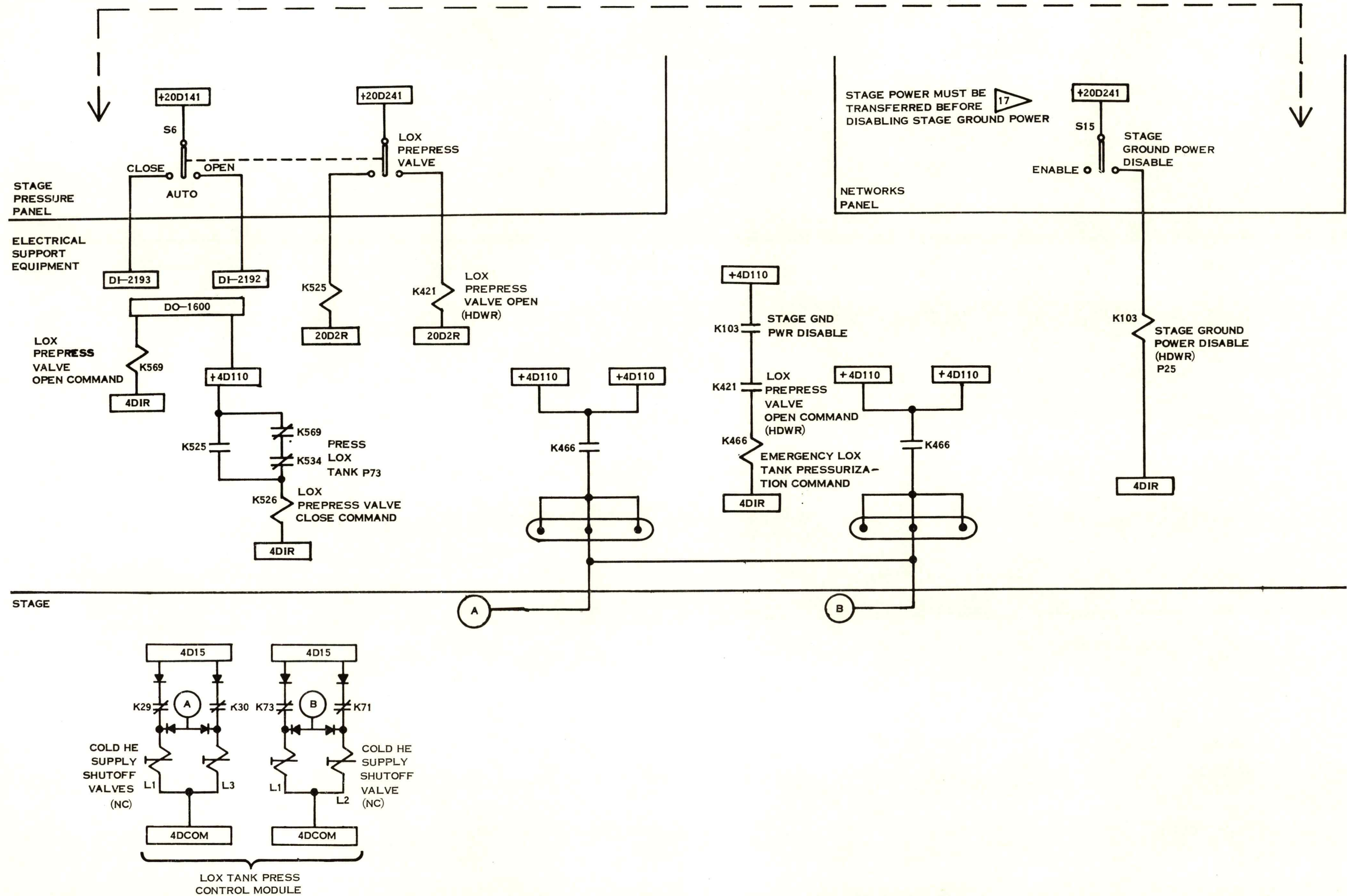
LOX TANK PRESSURIZATION



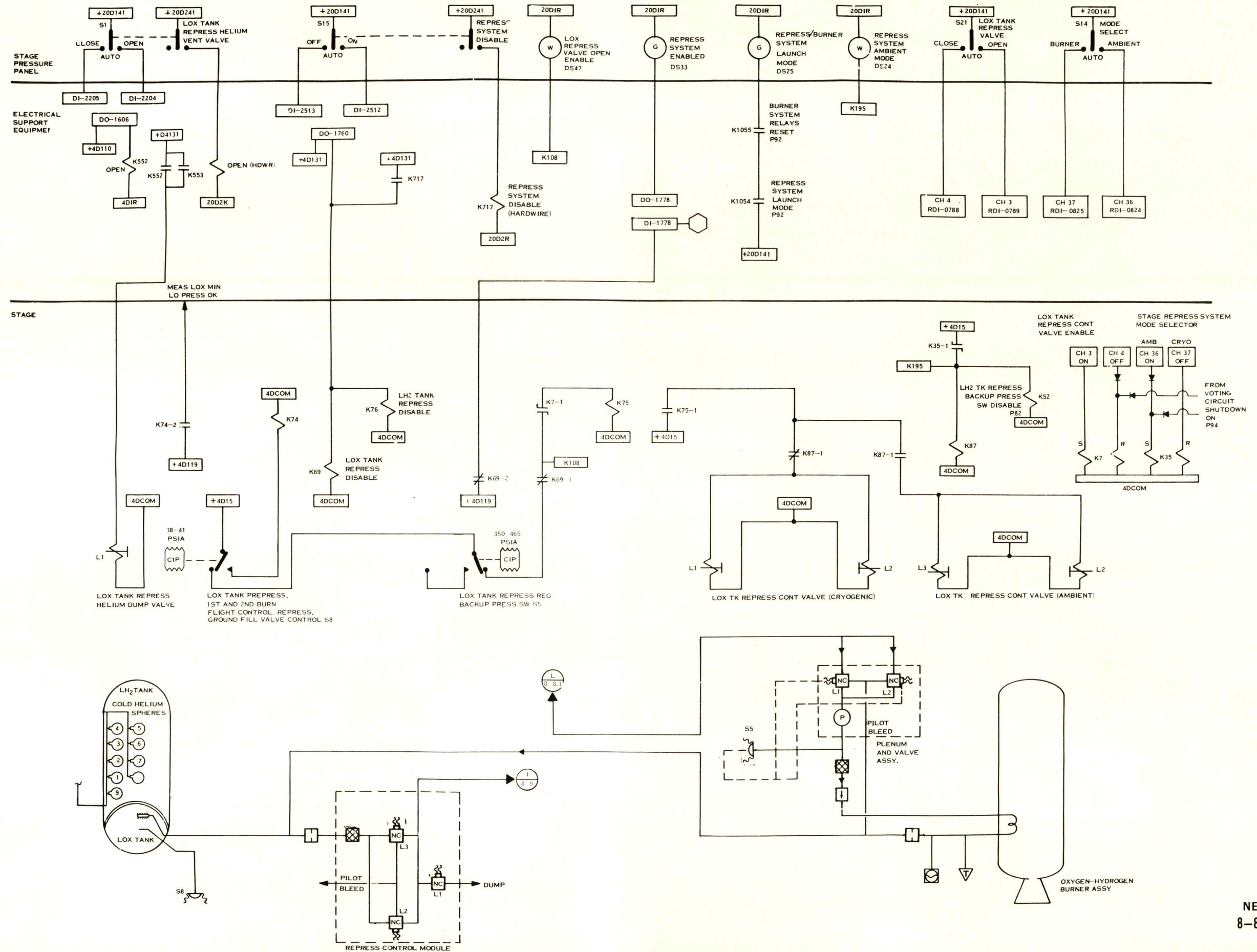
LOX TANK PRESSURIZATION



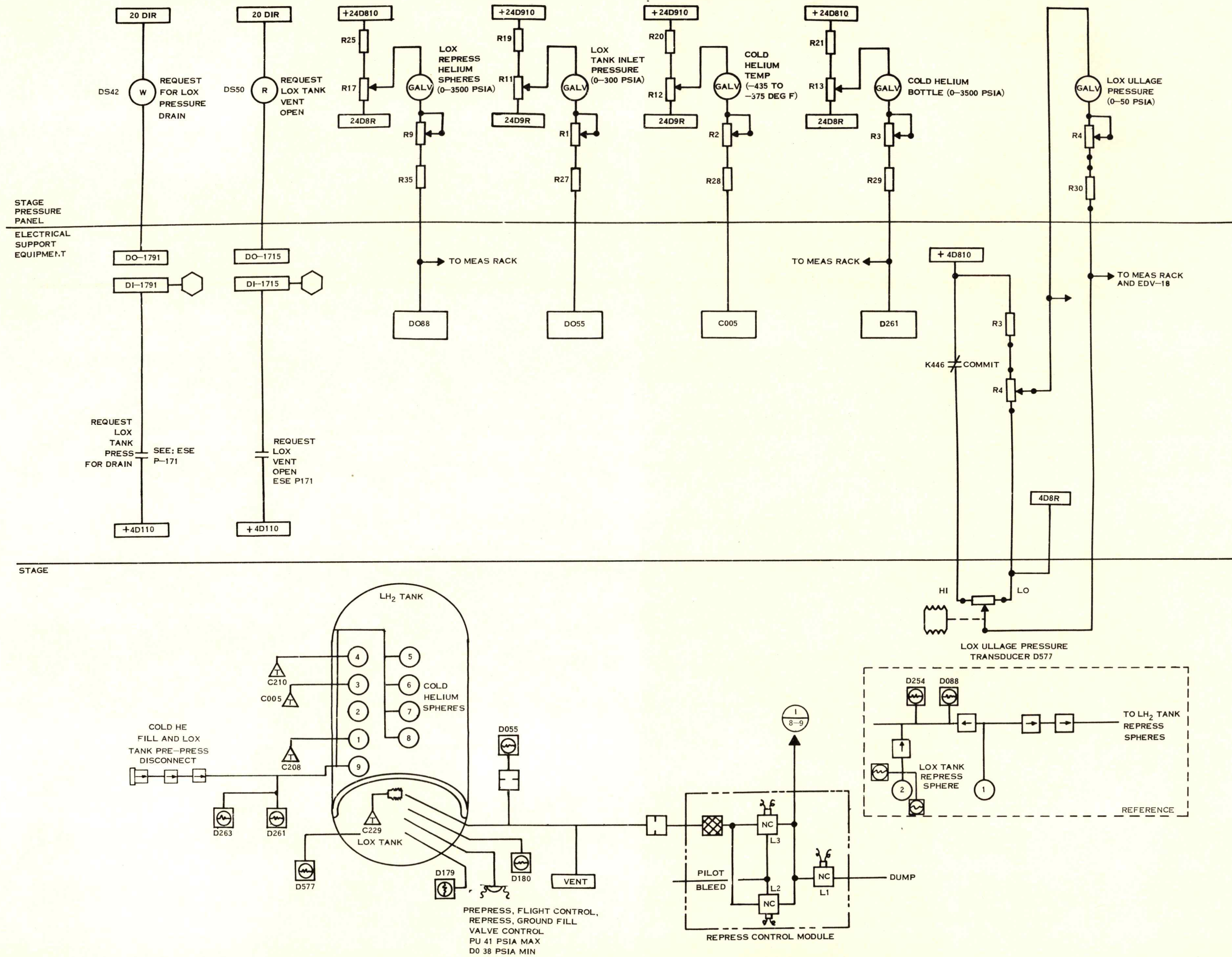
EMERGENCY LOX TANK PRESSURIZATION



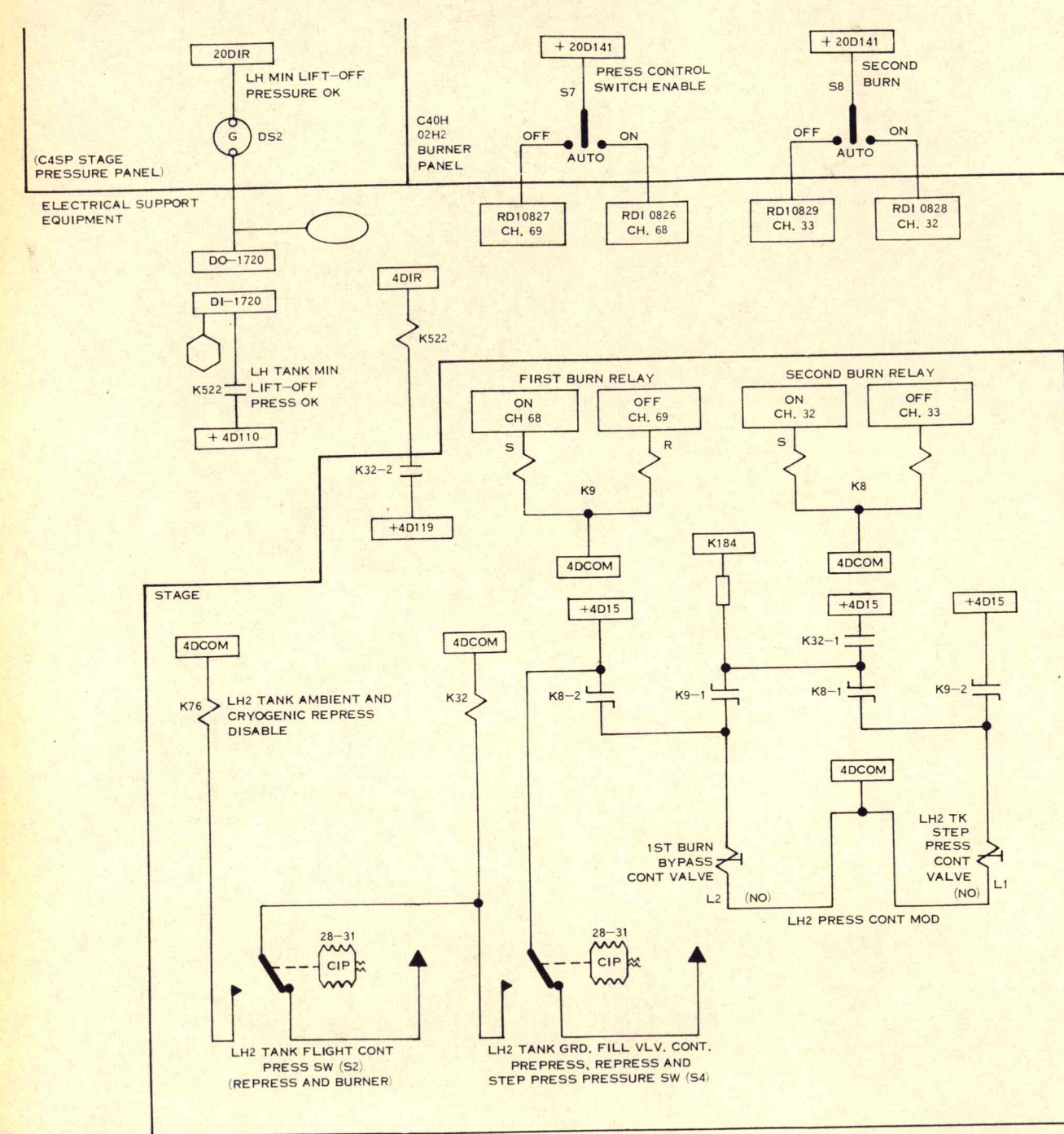
SAT V LOX TANK REPRESSURIZATION



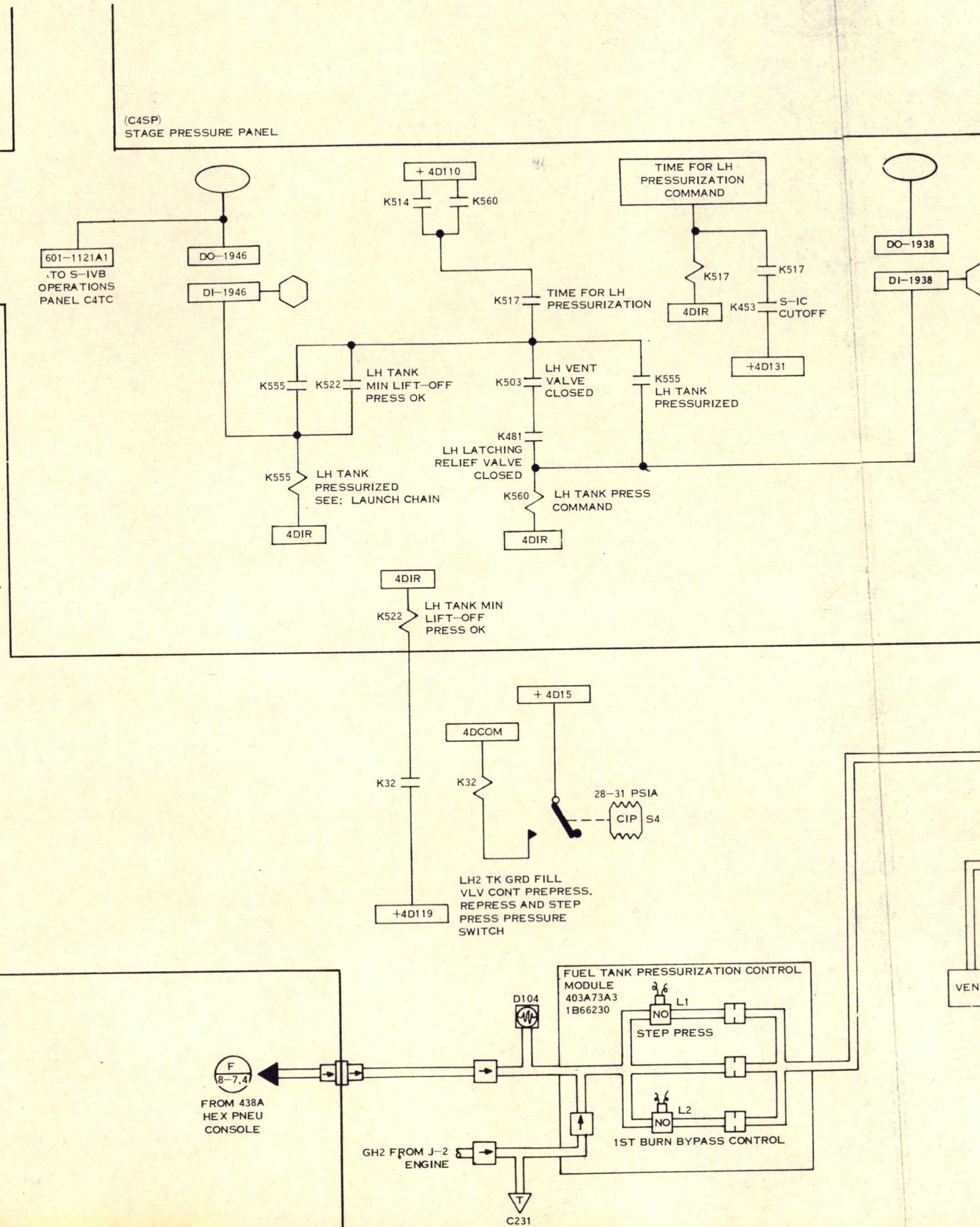
SAT V LOX TANK, REPRESS AND COLD HELIUM INDICATIONS



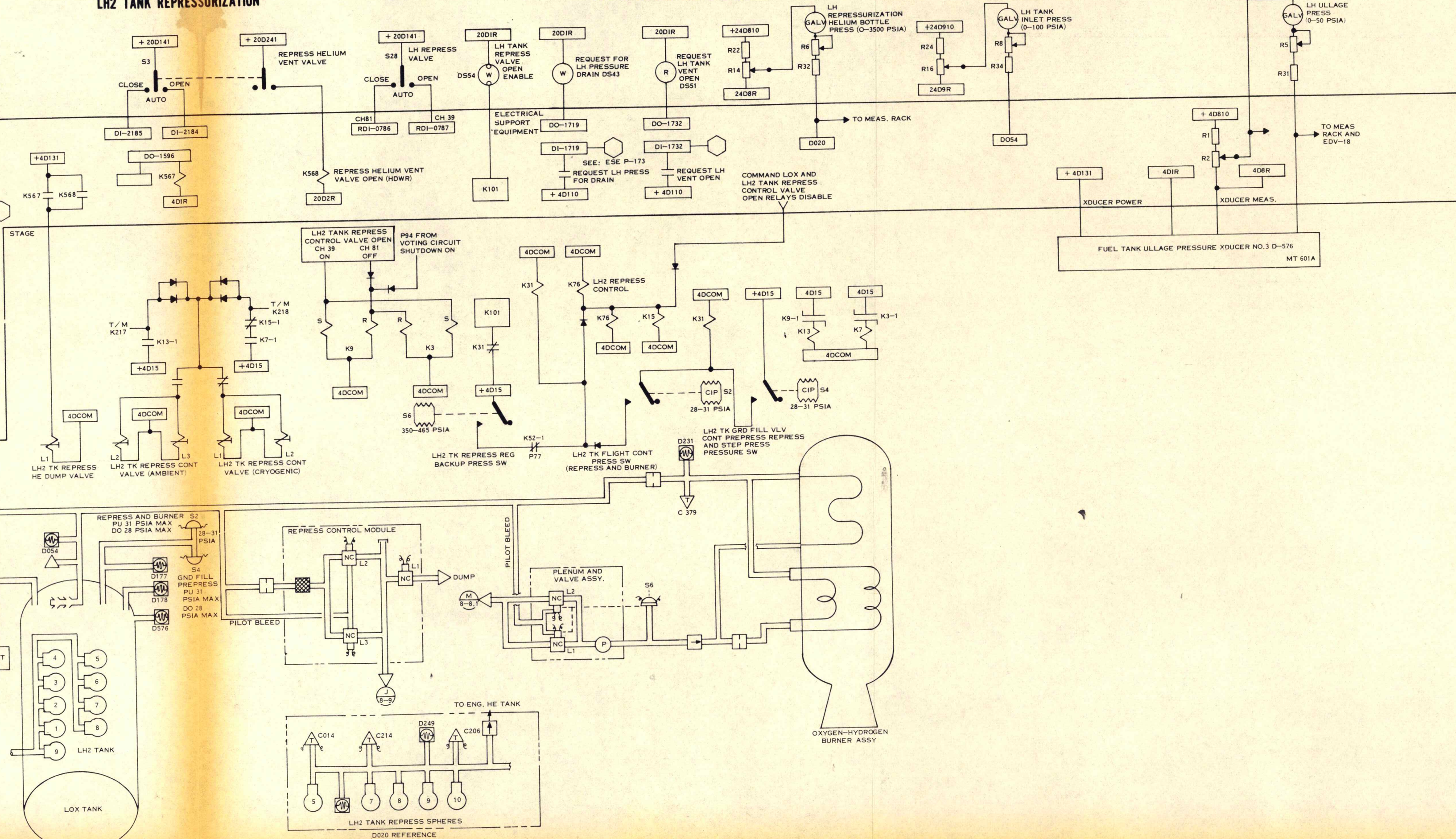
FUEL TANK PRESSURIZATION



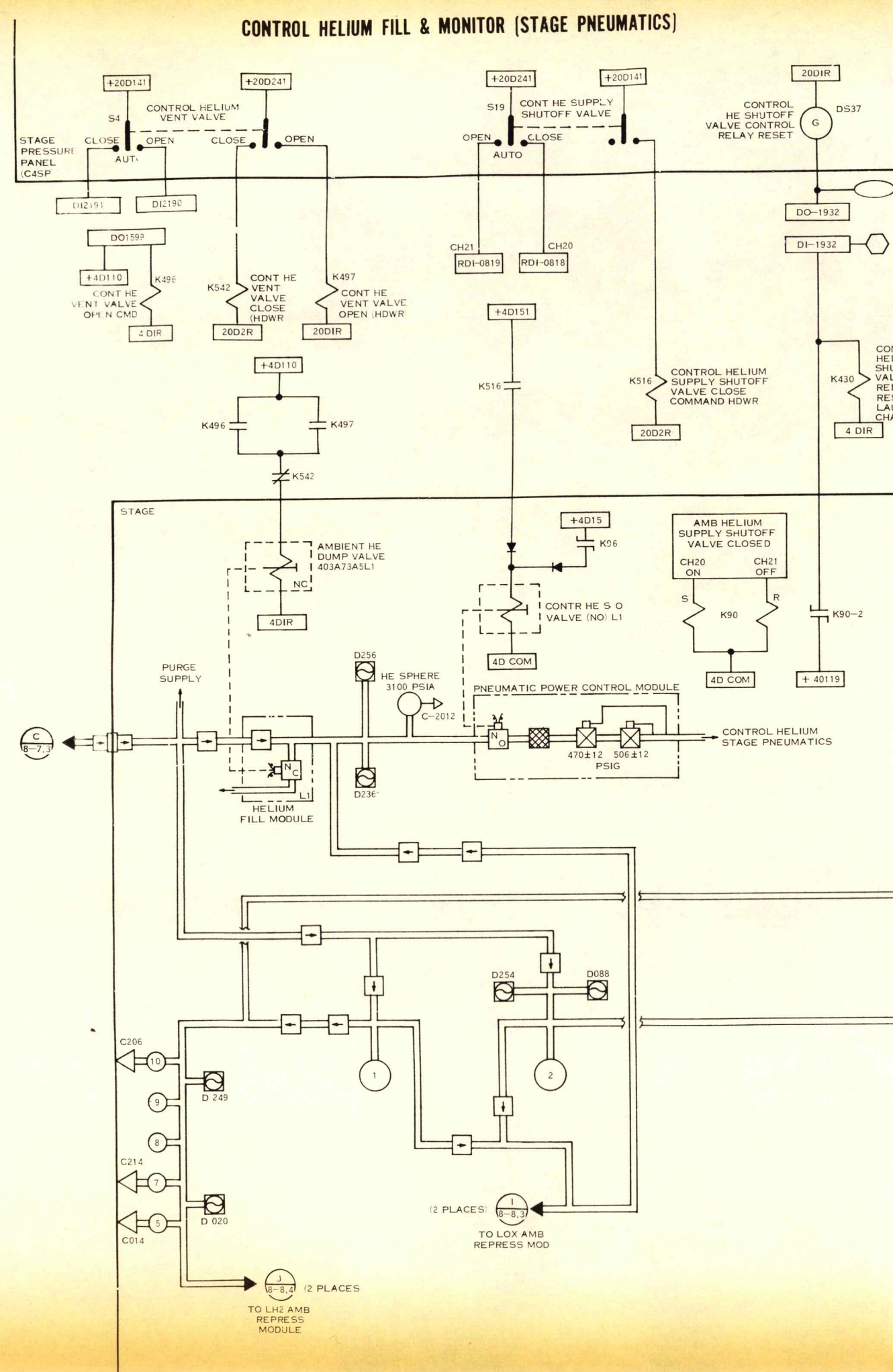
LH2 TANK REPRESSURIZATION



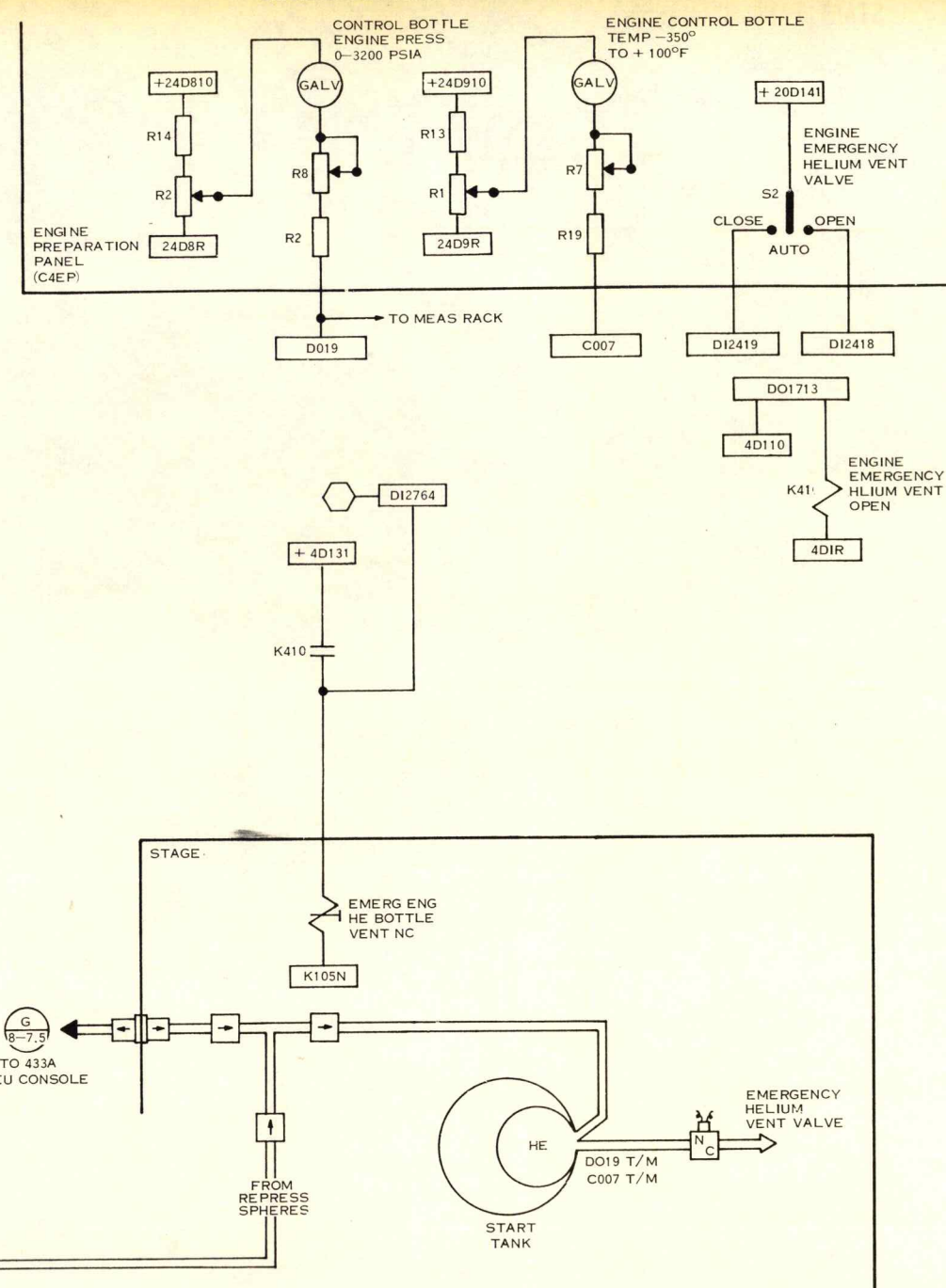
LH2 TANK AND REPRESS INDICATIONS



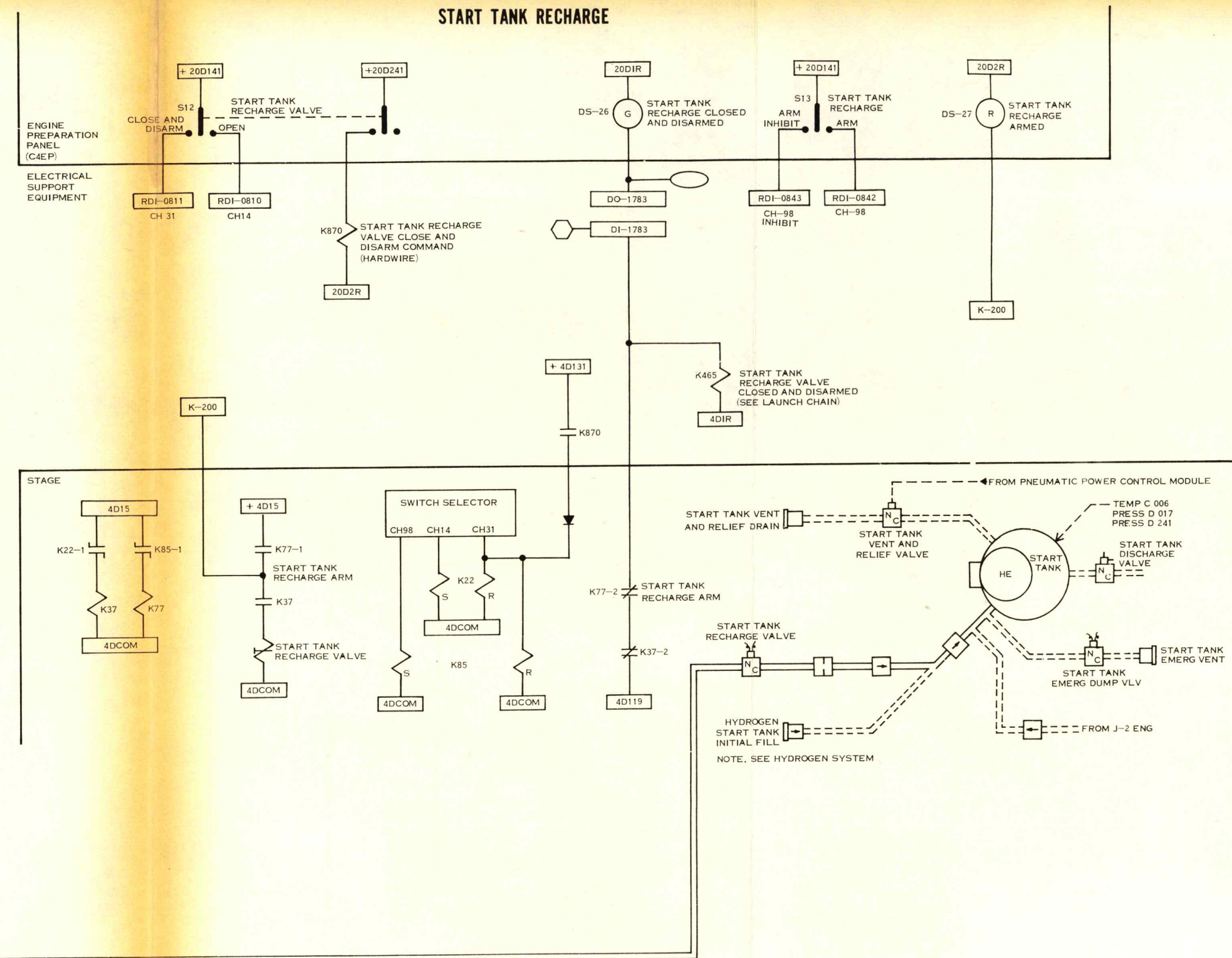
CONTROL HELIUM FILL & MONITOR (STAGE PNEUMATICS)

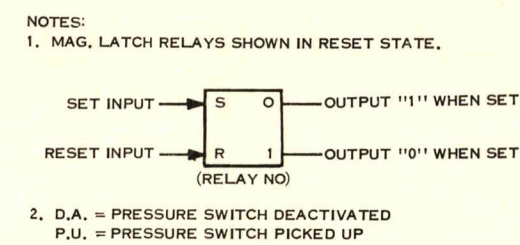


ENGINE CONTROL BOTTLE FILL

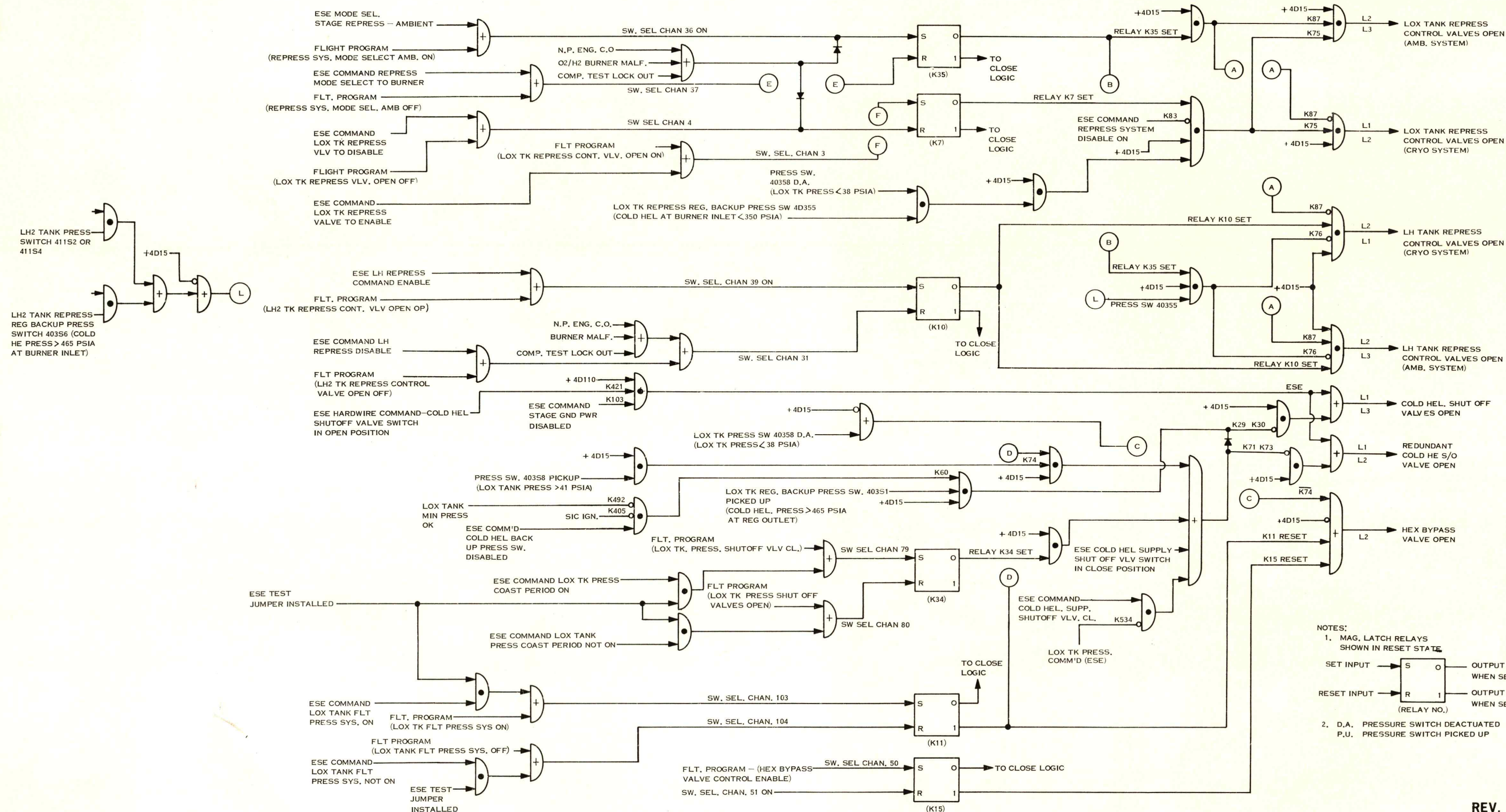


START TANK RECHARGE





REV. A
8-11



HELUM SYSTEM CONTROL VALVES OPEN LOGIC

9.0 O2/H2 BURNER

9.1 SYSTEM DESCRIPTION

9.1.1 GENERAL DESCRIPTION

THE O2/H2 BURNER IS PART OF THE SIVB/SATURN V REPRESSURIZATION SYSTEM. THE BURNER OR HELIUM HEATER AS IT IS ALSO CALLED PROVIDES THE SIVB STAGE WITH A DUAL SYSTEM FOR TANK PRESSURIZATION. COLD HELIUM STORED IN BOTTLES IN THE LH TANK IS ROUTED THROUGH A HEAT EXCHANGER IN THE BURNER AND USED TO PRESSURIZE PROPELLANT TANKS FOR J2 ENGINE RESTART. THE TANKS MAY ALSO BE REPRESSURIZED USING HELIUM STORED IN THE AMBIENT HELIUM BOTTLES LOCATED ON THE THRUST STRUCTURE. THE BURNER IS RESTARTABLE AND IN THE EVENT A CONDITION SHOULD DEVELOP IN THE VEHICLE WHICH EXTENDS BEYOND THE ORBITAL LAUNCH WINDOW AFTER INITIAL RESTART REPRESSURIZATION; THE BURNER SYSTEM CAN AGAIN BE EMPLOYED TO PRESSURIZE THE TANKS FOR ENGINE RESTART.

THE BURNER SYSTEM IS COMPRISED OF THE FOLLOWING MAJOR COMPONENTS AND ASSEMBLIES:

1. SPARK EXCITER UNITS
2. BI-LEVEL BRIDGES
3. VOTER REGULATOR MODULE
4. PROPELLANT VALVES
5. BURNER ASSEMBLY
6. TEMPERATURE TRANSDUCERS
7. ACTUATION CONTROL MODULES

A FUNCTIONAL SCHEMATIC SHOWING THE BASIC CONFIGURATION OF THE O2/H2 BURNER SYSTEM IS SHOWN IN FIGURE 9-1.

9.1.2 OPERATION

STARTING AND CUTOFF SEQUENCING OF THE BURNER IS ACCOMPLISHED BY THE INSTRUMENT UNIT THROUGH THE SIVB STAGE SWITCH SELECTOR. BURNER IGNITION IS INITIATED BY THE FOLLOWING SEQUENCED COMMANDS, LH2 VALVE OPEN, SPARK EXCITERS ON, AND LOX VALVE OPEN. PROPELLANTS ARE FED TO THE BURNER THROUGH VACUUM JACKETED DUCTS AT THE EXISTING TANK PRESSURES AND THEN VAPORIZED AS THEY PASS THROUGH REGENERATION COILS IN THE HEAT EXCHANGER PORTION OF THE BURNER.

THE PROPELLANTS ARE THEN INJECTED INTO THE COMBUSTION CHAMBER WHERE THEY ARE IGNITED BY AN ELECTRICAL SPARK. THE SUPER HEATED GASES ARE BURNED AND ROTATE WITHIN THE COMBUSTION ZONE BEFORE EXITING INTO THE HEAT EXCHANGER SECTION. THE HEAT EXCHANGER CONSIST OF THE HYDROGEN REGENERATIVE COIL, THE OXYGEN REGENERATIVE COIL AND FOUR HELIUM REPRESSURIZATION COILS FOR PROPELLANT TANK PRESSURIZATION.

9.1.3 PROPELLANT CONTROL

THE PROPELLANT FLOW TO THE BURNER IS CONTROLLED BY TWO PNEUMATICALLY ACTUATED PROPELLANT VALVES, A LH2 PROPELLANT VALVE AND A LOX SHUTDOWN VALVE. THE OPENING AND CLOSING OF THESE VALVES IS CONTROLLED BY APPLYING STAGE PNEUMATIC PRESSURE TO THE OPENING OR CLOSING PORTS ON THE VALVE. ACTIVATING PRESSURE ON THESE VALVES IS 475 PSIG AND EACH VALVE CONTAINS POSITION INDICATOR SWITCHES. THE OPENING AND CLOSING PRESSURES ARE CONTROLLED BY ELECTRICALLY OPERATED SOLENOID VALVES WHICH ARE NORMALLY CLOSED AND REQUIRE AN ELECTRICAL SIGNAL TO THE SOLENOID TO OPEN THE VALVE. THESE SOLENOID VALVES ARE CONTAINED IN TWO ACTUATION CONTROL MODULES, ONE FOR EACH PROPELLANT VALVE.

A REFERENCE SCHEMATIC OF THE VALVE CONTROL SYSTEM IS INCLUDED IN FIGURE 9-2 OF THIS DOCUMENT. IT SHOULD BE NOTED THAT OPEN COMMANDS TO THE VALVES ARE INHIBITED WHEN THE TEST JUMPER IS REMOVED. IT IS FURTHER NOTED THAT THE VALVES WILL REMAIN IN THE LAST COMMANDED STATE WHEN PNEUMATIC PRESSURE IS REMOVED. THE VARIOUS MEANS FOR COMMANDING THE PROPELLANT VALVES CLOSED ARE SHOWN IN THE SCHEMATIC.

9.1.4 IGNITION

THE PROPELLANTS ARE IGNITED BY A SPARK PLUG TYPE OF IGNITION SYSTEM. A SPARK IGNITER IS INSTALLED IN EACH INJECTOR ASSEMBLY AND CONSISTS OF A SINGLE ELECTRODE AND SELF CONTAINED CIRCULAR GAP. AS CAN BE SEEN FROM THE FUNCTIONAL SCHEMATIC A DUAL IGNITION SYSTEM IS EMPLOYED. THE IGNITION SYSTEM TOGETHER WITH ASSOCIATED ESE IS SHOWN IN FIGURE 9-3. THE MAJOR COMPONENT OF THE IGNITION SYSTEM IS THE IGNITION EXCITER UNIT. THE SPARK GAP, OUTPUT CABLE AND ELECTRONICS ARE ALL PART OF THE SPARK EXCITER UNIT. THE EXCITER BOX AND OUTPUT CABLE IS PRESSURIZED WITH DRY NITROGEN AND HELIUM. PRESSURIZATION OF THE UNIT IS MONITORED BY A PRESSURE SWITCH WHICH DEACTIVATES AT 20.5 PSIA. THE SPARK UNITS ARE TURNED ON BY A SWITCH SELECTOR COMMAND WHICH APPLIES +4D15 POWER TO SPARK EXCITER INPUT. THIS 28 VOLT INPUT IS CONVERTED INTO A HIGH VOLTAGE WHICH JUMPS THIS GAP AT THE END OF THE OUTPUT CABLE. THE AVERAGE INPUT CURRENT TO THE UNIT IS 2.5 AMPS MAXIMUM AND THE MAXIMUM PEAK INPUT CURRENT IS 10 AMPS. THE OUTPUT VOLTAGE GENERATED BY THE UNIT IS 15 KILOVOLTS MINIMUM.

FIGURE 9-4 OF THIS SECTION IS A SCHEMATIC OF THE SPARK EXCITER UNIT. THE OPERATION OF THE UNIT MAY BE EXPLAINED AS FOLLOWS. WHEN THE SPARK EXCITERS ARE TURNED ON; 28 VOLTS IS APPLIED TO COLLECTOR AND BASE CIRCUITS OF TRANSISTOR Q1. THE COLLECTOR TO BASE JUNCTION IS BACK BIASED BY THIS VOLTAGE AND THE BASE TO EMITTER IS FORWARD BIASED SLIGHTLY DUE TO THE CLAMPING ACTION OF CR2 AND CR3. THE COLLECTOR AND EMITTER CURRENTS HAVING INCREASED FROM ZERO INDUCE VOLTAGES AT THE SECONDARY OF TRANSFORMERS T1 AND T2. THESE INDUCED VOLTAGES ARE OF SUCH A POLARITY AS TO INCREASE THE BASE DRIVE (POSITIVE FEEDBACK) AND CAUSE THE TRANSISTOR TO GO INTO SATURATION. AT SATURATION THE TIME RATE OF CHANGE OF THE COLLECTOR CURRENT GOES TO ZERO. THE FEEDBACK VOLTAGES NOW DROP TO ZERO AND THE CURRENTS START TO DECAY, REVERSING THE POLARITY OF THE FEEDBACK WINDINGS AND TURNING TRANSISTOR Q1 OFF. WHEN TRANSISTOR Q1 TURNS OFF A HIGH VOLTAGE IS INDUCED IN THE OUTPUT WINDING OF T2 WHICH CHARGES CAPACITOR C3 THROUGH CR 7.

ZENER DIODES Z1 AND Z2 LIMIT THE VOLTAGE ACROSS THE TRANSISTOR AND RESISTOR R2 LIMITS THE REVERSE BIAS CURRENT. THE INDUCED VOLTAGES THEN DROP OFF AND THE PROCESS IS REPEATED. THIS SWITCHING PROCESS CONTINUES TO BUILD UP THE CHARGE ON C3 UNTIL DISCHARGE TUBE V1 FIRES. AT THIS TIME C3 DISCHARGES THROUGH THE LC CIRCUIT OF T3 AND C4. TRANSFORMER T3 ACTS AS AN AUTOTRANSFORMER AND A HIGH VOLTAGE IS INDUCED ON THE SECONDARY DUE THE SHARP CURRENT RISE IN THE PRIMARY CIRCUIT. A HIGH VOLTAGE ARC IS THUS PRODUCED AT THE IGNITER SPARK GAP.

T/M AND TEST MONITOR VOLTAGES ARE PICKED OFF BY A TEST MONITOR WINDING ON T2 AND PULSE MONITOR TRANSFORMER T4. THE SWITCHING ACTION OF Q1 INDUCES A VOLTAGE ON THE MONITOR WINDING OF T2. THIS VOLTAGE IS RECTIFIED AND FILTERED TO GIVE A 3.2 ± 0.5 VOLT DC LEVEL OUTPUT WHEN OPERATED INTO A 100K OHM LOAD. SPARK GAP DISCHARGE CURRENT GENERATES VOLTAGE PULSES IN T4 WHICH ARE SHAPED AND SUPERIMPOSED ON THE 3.2 VOLT OUTPUT TO INDICATE THE SPARK RATE WHICH IS 20 TO 100 PULSES PER SECOND. THESE PULSES ARE BETWEEN 0.3 AND 0.7 VOLTS IN MAGNITUDE.

THE SPARK UNIT IS CAPABLE OF 4000 CYCLES WHILE OPERATING AT A DUTY CYCLE OF ON FOR 5 SECONDS AND OFF FOR 5 MINUTES. THE ESE TEST CIRCUITS LIMIT OPERATION TO THIS DUTY CYCLE WHEN THE SPARK TEST COMMAND IS GIVEN FROM THE ESE. THE ESE DUTY CYCLE CIRCUIT IS NOT ACTIVATED WHEN THE SPARK COMMAND IS GIVEN FROM THE SWITCH SELECTOR AND THEREFORE CAUTION SHOULD BE OBSERVED TO AVOID EXCEEDING DUTY CYCLE WHEN OPERATING SPARK UNITS VIA THE SWITCH SELECTOR.

9.1.5 CUTOFF

BURNER CUTOFF IS SEQUENCED BY FIRST CLOSING THE LH VALVE AND THEN THE LOX VALVE WITH THE APPROPRIATE SWITCH SELECTOR COMMANDS. AN AUTOMATIC CUTOFF MAY ALSO TURN THE BURNER OFF IN THE EVENT OF AN IGNITION FAILURE OR BURNER FLAME OUT. THE FAILURE MODE IS DETECTED BY A THERMAL VOTING CIRCUIT WHICH SENSES THE TEMPERATURE OF THE GH2 PRIOR TO ENTERING INJECTOR NO. 2. THE AUTO CUTOFF CIRCUIT IS ENABLED BY THE SWITCH SELECTOR APPROXIMATELY SIX (6) SECONDS AFTER BURNER IGNITION COMMAND. CUTOFF IS INITIATED IF TWO OUT OF THREE TEMPERATURE SENSORS DETECT THAT THE HYDROGEN HAS NOT BEEN HEATED IN THE BURNER HEAT EXCHANGER.

9.1.5 CUTOFF (CONT)

THE OPERATION OF THE AUTO CUTOFF SYSTEM IS BEST EXPLAINED BY THE LOGIC DIAGRAM IN FIGURE 9-5. FOLLOWING THE SIGNAL FLOW, IT CAN BE SEEN THAT A LAMFUNCTION IS DETECTED WHEN TWO OUT OF THREE OF THE BRIDGE MODULE SENSE A TEMPERATURE OF LESS THAN 51°R. THE BRIDGE MODULES EMPLOYED ARE THE SAME TYPE OF UNITS THAT WERE USED FOR SIGNAL CONDITIONING OF THE P.U. OVEN ON MONITOR. EACH TEMPERATURE SENSOR IS IN ONE LEG OF A BRIDGE CIRCUIT AND THE BRIDGE UNBALANCE SIGNAL IS AMPLIFIED BY A DIFFERENTIAL AMPLIFIER WHICH IN TURN DRIVES A TRANSISTOR SWITCH CIRCUIT TO SUPPLY THE LOGIC LEVELS. THE BRIDGE MODULE IS ADJUSTED TO SWITCH ON (19 VOLTS) AT TEMPERATURE SENSOR RESISTANCE OF 71.5 OHMS (APPROXIMATELY 51.1°R) AND OFF (0.1 VOLTS) AT 70 OHMS (APPROXIMATELY 50.8°R). A LOW GH2 TEMPERATURE (50.8°R) IN THE INJECTOR NO. 2 FUEL LINE WILL RESULT IN LOW LEVEL VOLTAGES APPLIED TO THE INPUTS OF THE VOTER REGULATOR MODULE (SEE FIGURE 9-3). WITH THESE INPUTS LOW THE SIX INPUT DIODES ARE FORWARD BIASED CAUSING THE RELAY DRIVER TO ENERGIZE RELAY K1. PICKING UP RELAY K1 INITIATES A BURNER CUTOFF, SWITCHES REPRESS MODE TO THE AMBIENT SYSTEM AND SIGNALS THE I.U. THAT A BURNER MALFUNCTION HAS OCCURRED. A COMPONENT TEST LOCK OUT COMMAND FROM THE ENGINE TEST PANEL WILL ALSO RESULT IN A BURNER CUTOFF. EACH BRIDGE MODULE CONTAINS A HIGH AND LOW TEMPERATURE SIMULATE CIRCUIT. DURING TEST HIGH AND LOW TEMPERATURES ARE SIMULATED BY SWITCHING IN AN APPROPRIATE RESISTOR IN PLACE OF THE TEMPERATURE SENSOR. THESE TEST RESISTORS CORRESPOND TO HIGH AND LOW TEMP. OF APPROXIMATELY 52° AND 50°R RESPECTIVELY.

9.2 CRITICAL MEASUREMENTS

THERE ARE NO REDLINE MEASUREMENT ON THE BURNER ITSELF. HOWEVER, TWO BURNER FUNCTIONS ARE INCLUDED IN THE PREPS COMPLETE AND READY TO LAUNCH CHAINS. THESE ARE LISTED BELOW.

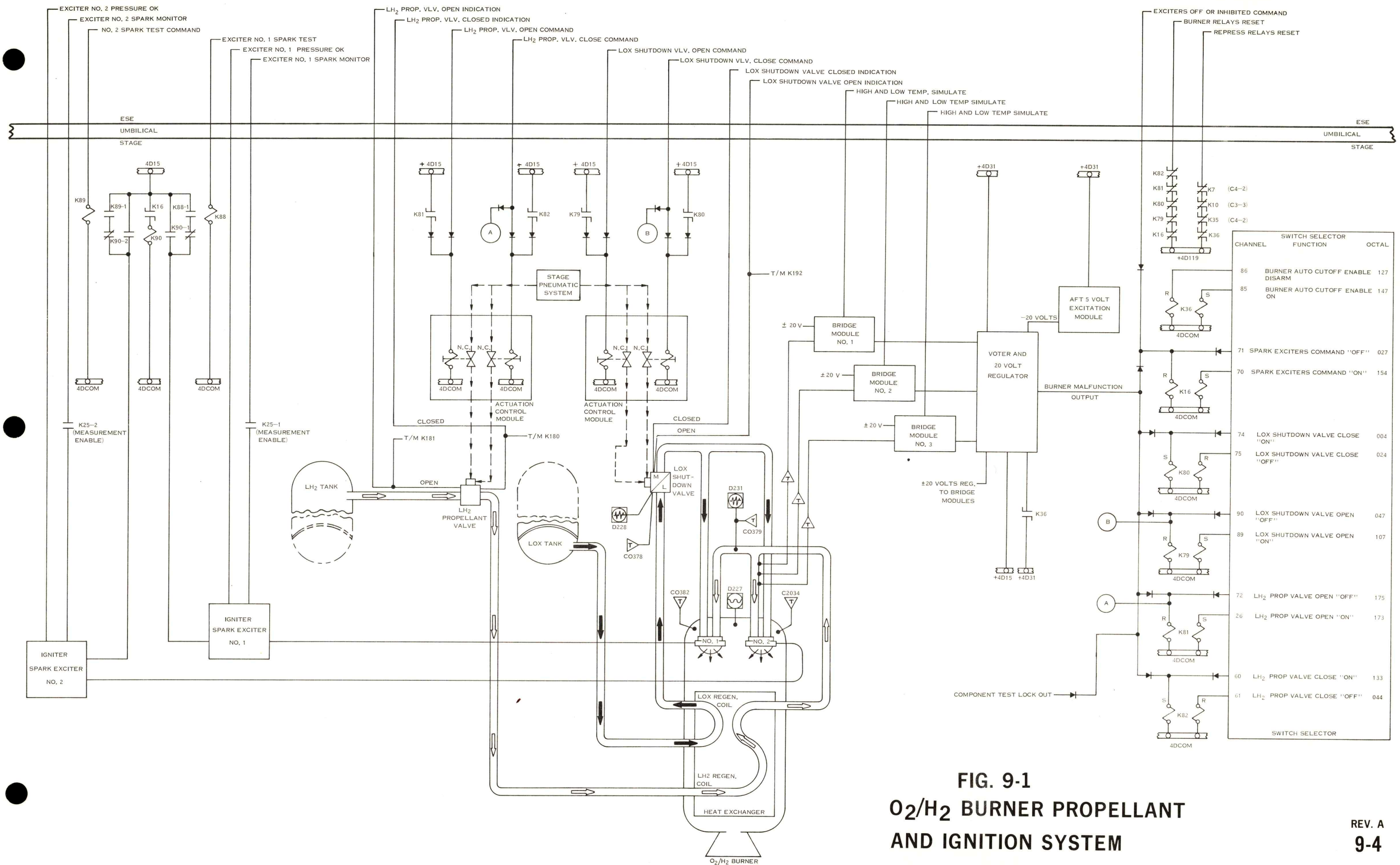
FUNCTION	MD 1
BURNER SYSTEM RELAYS RESET	1978
REPRESS SYSTEM RELAYS RESET	1977

THE RELAYS MONITORED ARE AS FOLLOWS:

<u>RELAY NO.</u>	<u>FUNCTION</u>
K16	SPARK EXCITERS ON COMMAND
K79	BURNER LOX VALVE OPEN COMMAND
K80	BURNER LOX VALVE CLOSE COMMAND
K81	BURNER LH VALVE OPEN COMMAND
K82	BURNER LH VALVE CLOSE COMMAND
K7	LOX TK REPRESS CONTROL VLV OPEN OFF
K10	LH2 REPRESS CONTROL VLV OPEN OFF
K35	AMB REPRESS SYS MODE SELECT ON
K36	BURNER AUTO CUTOFF ENABLE

THESE RELAYS MUST BE IN THE RESET STATE TO ENABLE COMPLETION OF THE S-IVB PREPS COMPLETE AND READY TO LAUNCH CHAINS.

A MALFUNCTION MATRIX AND FLOW DIAGRAM FOR FAULT ISOLATION OF THE BURNER RELAYS IS INCLUDED IN THIS SECTION OF THE F.I.G. THE LOSS OF BURNER RELAY RESET IS THE MALFUNCTION ANALYZED. THIS MALFUNCTION WAS SELECTED AS THE MOST CRITICAL BECAUSE THE PROPELLANT VALVE COMMAND CIRCUITS ARE INVOLVED WHICH COULD INADVERTENTLY DUMP PROPELLANT UPON REMOVAL OF THE HARDWIRE CLOSE COMMANDS AT COMMIT SHOULD A RELAY BE IN THE WRONG STATE.



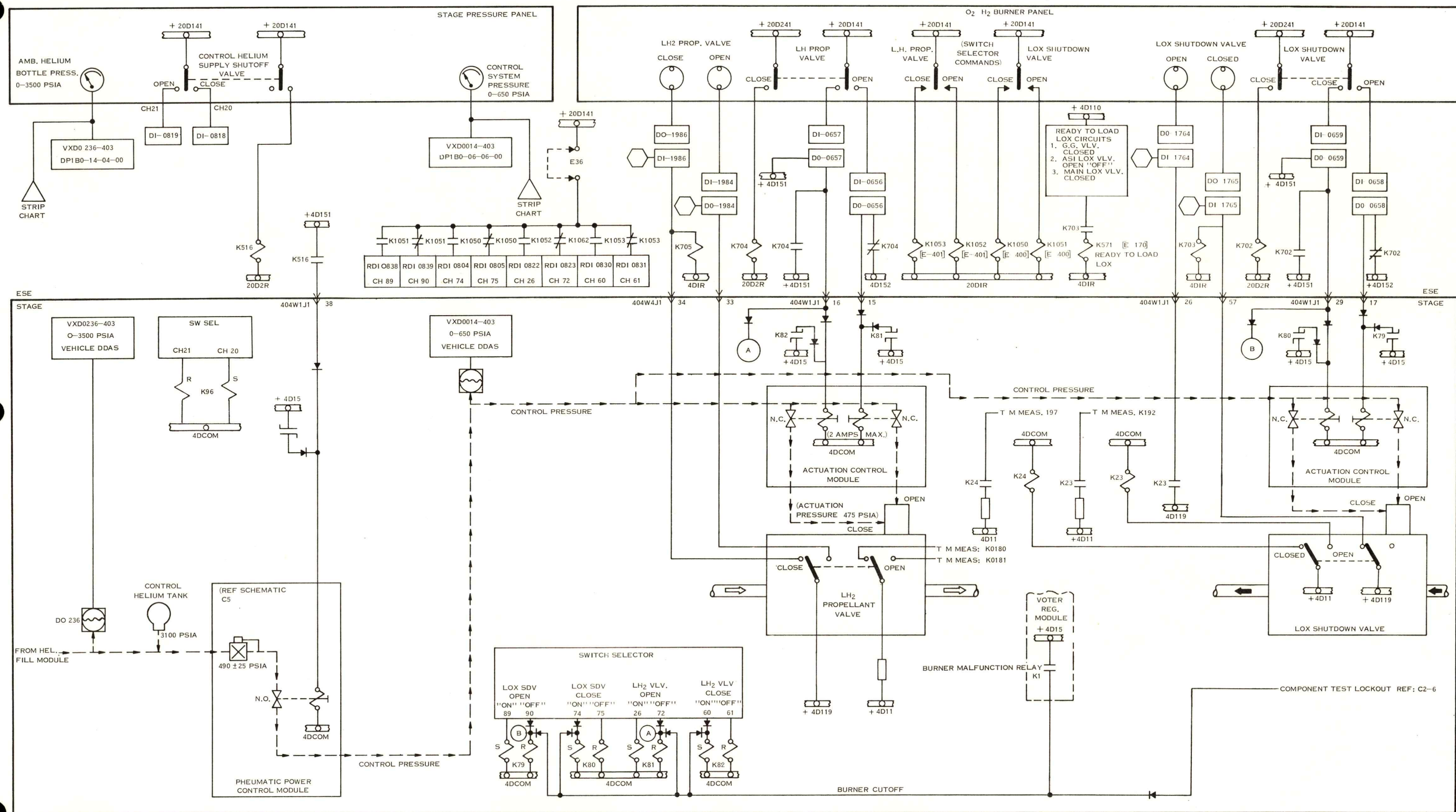
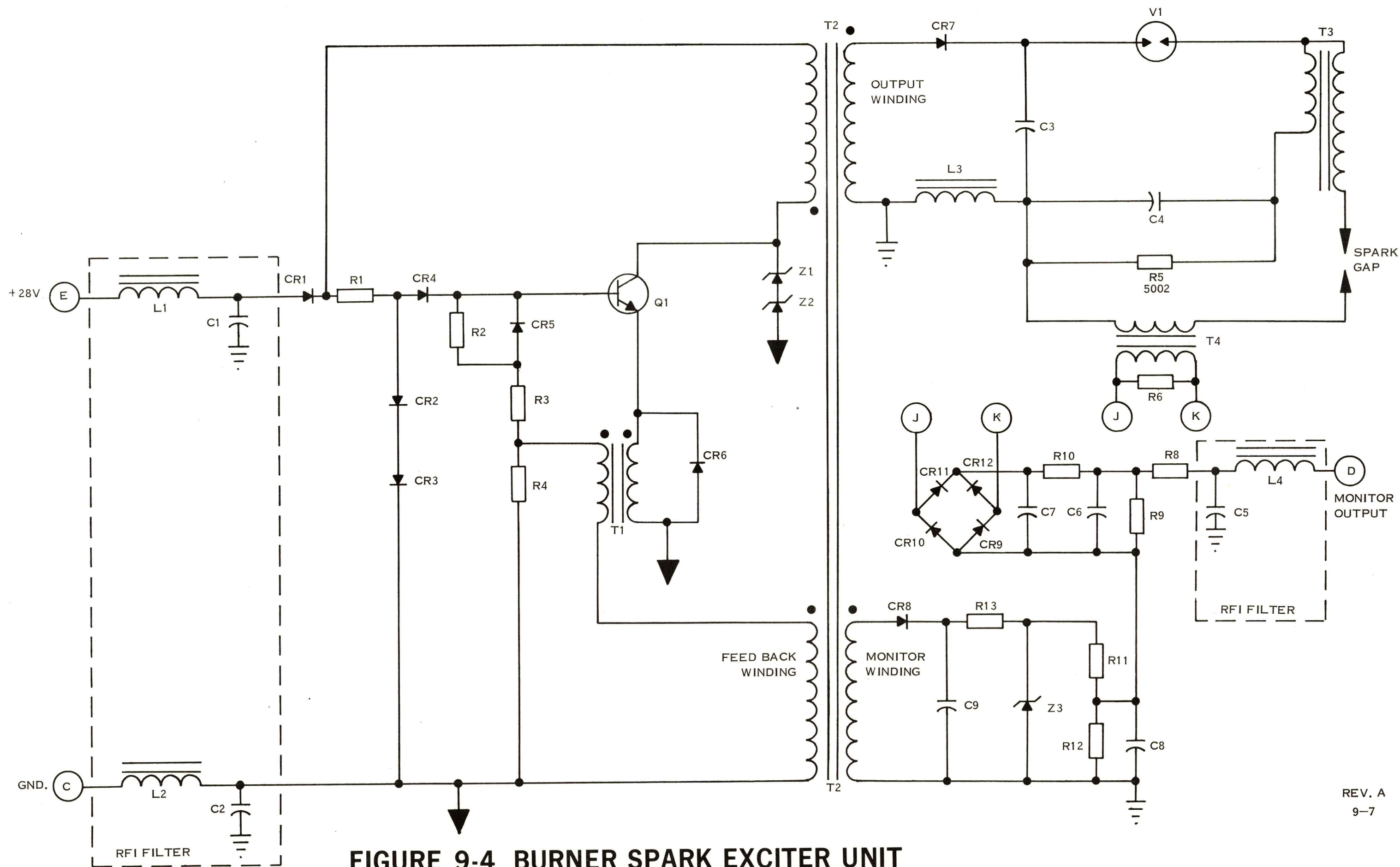
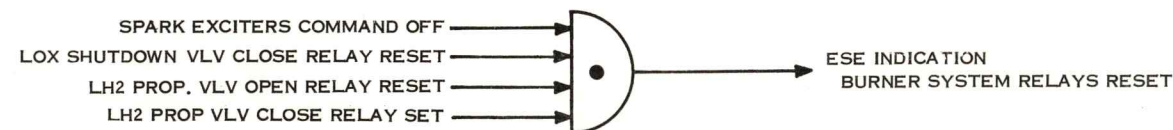
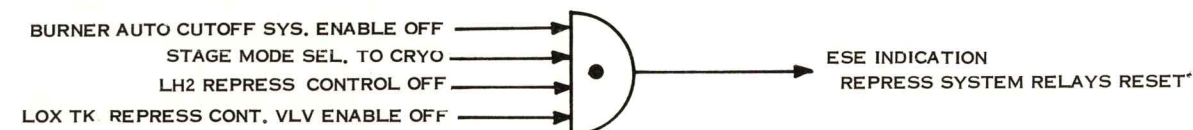


FIG. 9-2 O₂-H₂ BURNER LOX AND FUEL VALVE SYSTEM





BRIDGE MODULE LOGIC LEVELS

"1"	≅	0.15V±0.15 VDC
"0"	≅	20.0±2.5 VDC

BRIDGE OUTPUT "1" FOR TEMPERATURE
LESS THEN - 410 F (50°R)

FROM BURNER
HEX HYDROGEN
REGENERATIVE COIL



TO BURNER
INJECTOR
NUMBER 2

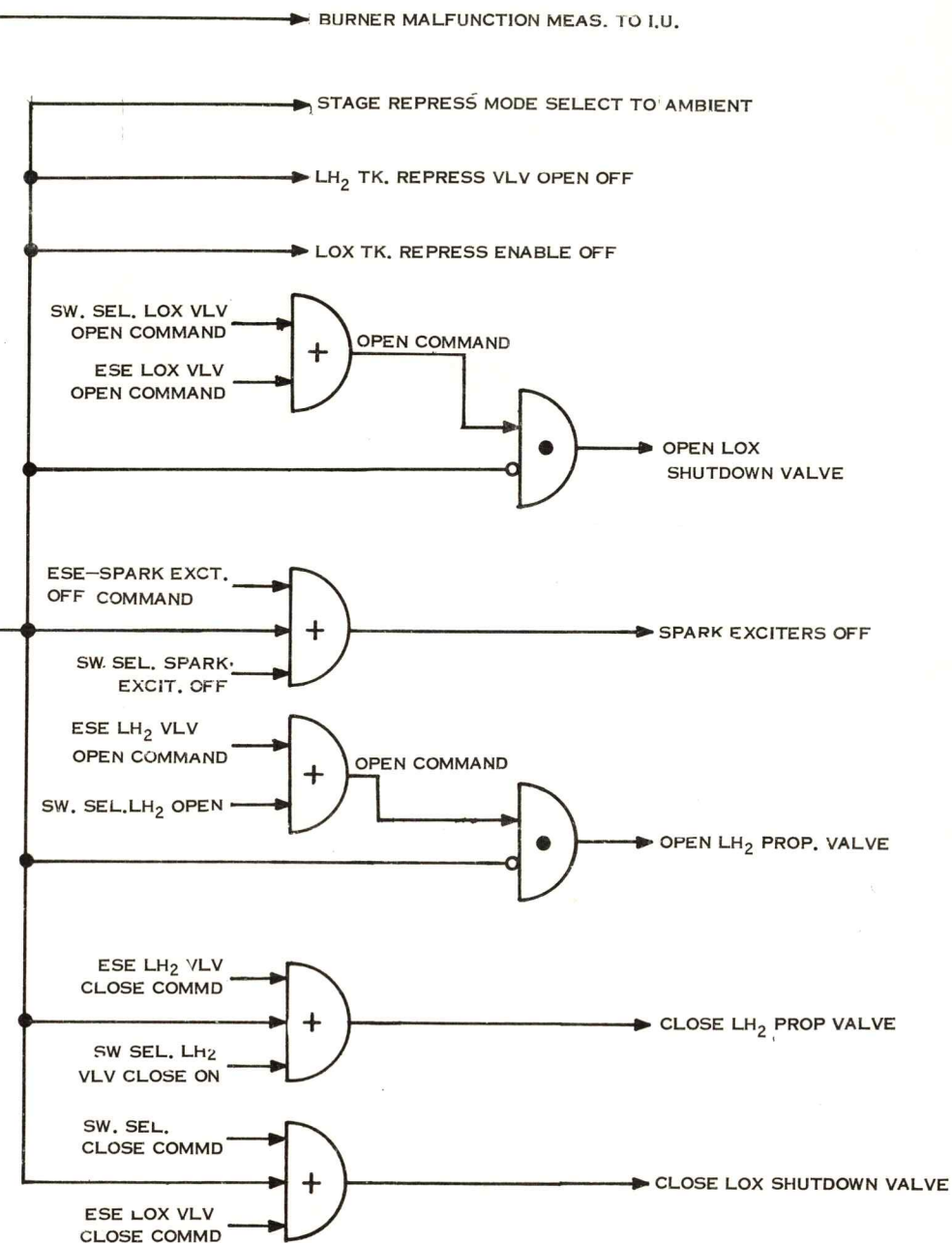
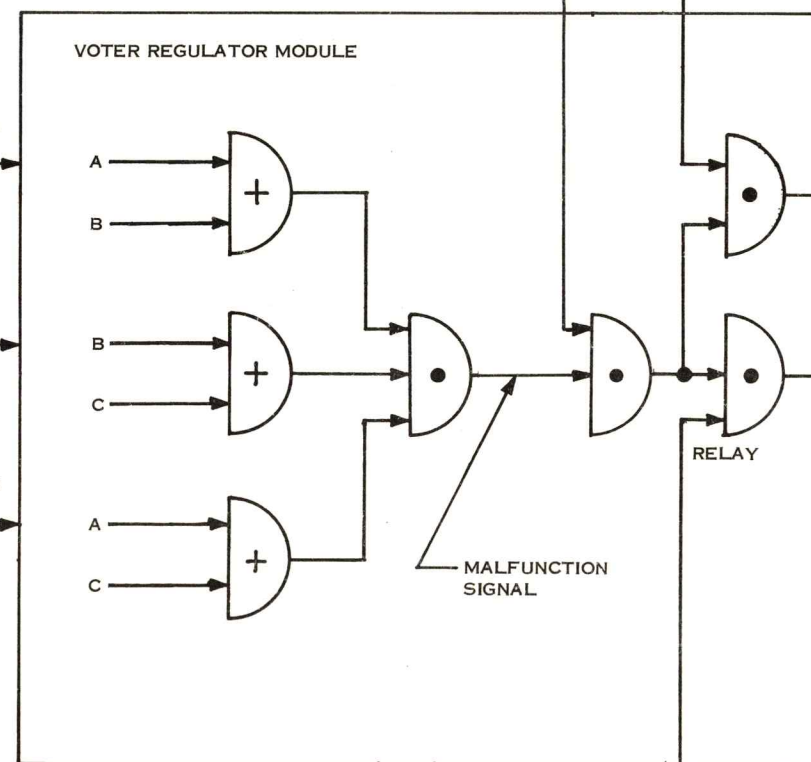
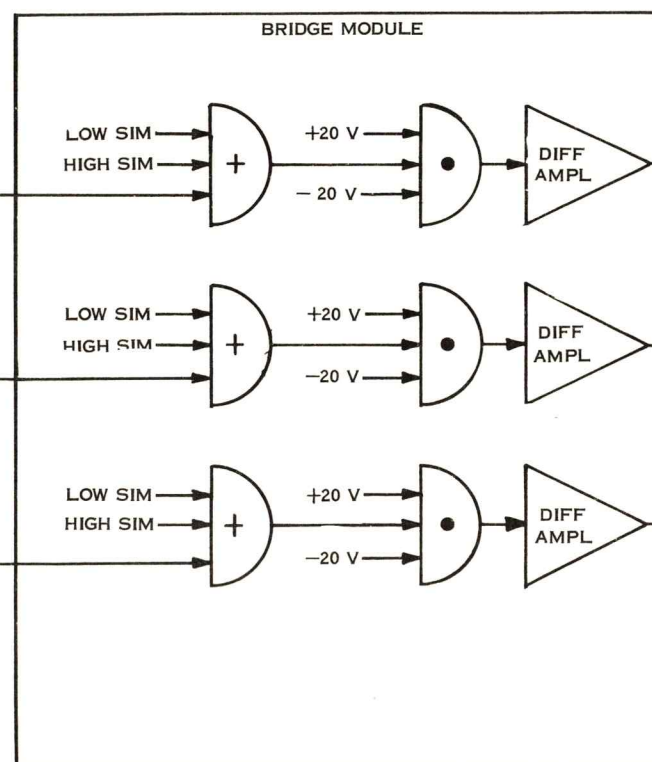


FIGURE 9-5 LOGIC DIAGRAM - O₂/H₂ BURNER AUTOMATIC CUTOFF SYSTEM

10.0
10.1

LOX SYSTEM

LOX TANK PRESSURIZATION AND REPRESSURIZATION SUBSYSTEMS

THE LOX TANK PRESSURIZATION AND REPRESSURIZATION SUBSYSTEMS PROVIDE CONTROLLED HELIUM SUPPLIED TO SATISFY LOX TANK PRESSURIZATION REQUIREMENTS DURING STAGE OPERATION. HELIUM FOR PRESSURIZATION DURING J-2 ENGINE 1ST AND 2ND BURN, AND FOR REPRESSURIZATION WHEN UTILIZING THE OXYGEN/HYDROGEN BURNER, IS STORED IN THE COLD HELIUM BOTTLES LOCATED IN THE LH2 TANK. HELIUM EMPLOYED FOR REPRESSURIZATION WHEN THE AMBIENT HELIUM SUBSYSTEM IS UTILIZED, IS STORED IN THE AMBIENT HELIUM BOTTLES.

DURING BOOST THE PRESSURIZATION SUBSYSTEM IS DEENERGIZED.

DURING ENGINE OPERATION, THE LOX PRESSURIZATION SHUTOFF VALVES AND THE LOX TANK PRESSURE CONTROL MODULE SOLENOID VALVES ARE COMMANDED OPEN. TANK PRESSURE IS SENSED BY LOX TANK PRESSURE SWITCH WHICH CONTROLS THE CYCLING OF THE VALVES FOR .3 SECONDS. THE VALVES ARE THEN MAINTAINED IN THE OPEN POSITION FOR THE DURATION OF BURN. FROM $T_4 - .6$ TO $T_4 + 24$ SECONDS, PRESSURIZATION IS MAINTAINED THROUGH THE NORMALLY OPEN HEAT-EXCHANGER BYPASS VALVE. AT $T_4 + 24$ SECONDS, WHEN THE HEAT-EXCHANGER BYPASS VALVE CONTROL IS ENABLED, THE LOX TANK PRESSURE SWITCH ASSUMES CONTROL IN CYCLING THE HEAT EXCHANGER BYPASS VALVE.

10.1.1

LOX TANK PREPRESSURIZATION, PRESSURIZATION AND REPRESSURIZATION OPERATIONS

THE SUBSYSTEM FUNCTIONS TO MONITOR TANK PRESSURE AND CONTROL HELIUM PRESSURIZATION FLOW FIRST TO SATISFY ENGINE REQUIREMENTS AND SECONDLY TO ASSURE THAT THE TANK IS NOT OVERPRESSURIZED. SPECIFIC AREAS OF OPERATION ARE AS DESCRIBED IN THE FOLLOWING PARAGRAPHS.

10.1.1.1

COLD HELIUM SPHERE FILL PRESSURIZATION

THE COLD HELIUM BOTTLES LOCATED IN THE LH2 TANK ARE INITIALLY FILLED TO 950 PSIA WITH AMBIENT HELIUM GAS. PRIOR TO FILLING TO 3100 PSIA, THE BOTTLES MUST BE SUBMERGED IN LH2. WHEN 75 PERCENT LH2 LOAD LEVEL HAS BEEN REACHED, GROUND HELIUM FILL SUPPLY IS SWITCHED TO 3100 PSIA AND ALL BOTTLES ARE THEN FILLED.

IN FILLING, GASEOUS HELIUM IS FED FROM THE GSE CONSOLE, THROUGH A DISCONNECT AND STAGE CHECK VALVES INTO THE COLD HELIUM SPHERE. COLD HELIUM IS PASSED THROUGH THE FILL CHECK VALVES AND THE GAS IS ALLOWED TO FLOW ONLY TO THE SPHERES. FLOW IS CONTINUED UNTIL THE SPHERE PRESSURE REACHES 3100 ± 100 PSIA. OVERPRESSURE IS PREVENTED BY THE RELIEF VALVE IN THE HELIUM DUMP MODULE. PRIOR TO LIFTOFF, THE INSTRUMENTATION IS MONITORED FOR PROPER HELIUM BOTTLE PRESSURE AND TEMPERATURE TO DETERMINE THE ACTUAL HELIUM LOADED.

10.1.1.2

LOX TANK AMBIENT HELIUM REPRESSURIZATION BOTTLE FILL

TWO AMBIENT HELIUM BOTTLES ARE INITIALLY PROVIDED FOR REPRESSURIZING THE LOX TANK FOR SECOND BURN. THE BOTTLES ARE FILLED THROUGH THE LOX/LH2 REPRESSURIZATION AND PNEUMATIC CONTROL FILL LINE. IN FILLING, AMBIENT GASEOUS HELIUM FLOWS THROUGH CHECK VALVES LOCATED IN THE FILL LINE AND THE REPRESSURIZATION CONTROL MODULE THEN INTO THE TWO HELIUM SPHERES. FILLING CONTINUES UNTIL THE SPHERES REACH 3100 ± 100 PSIA. BOTTLE PRESSURE IS MONITORED PRIOR TO LIFTOFF FOR PROPER HELIUM PRESSURE.

10.1.1.3

LOX TANK PREPRESSURIZATION

APPROXIMATELY THREE MINUTES PRIOR TO LIFTOFF, THE LOX TANK ULLAGE IS PREPRESSURIZED FROM A GSE CONSOLE, WHICH SUPPLIES COLD HELIUM TO THE PRESSURIZATION CONTROL MODULE. THE FOUR SHUTOFF VALVES ARE ENERGIZED OPEN, COLD HELIUM IS SUPPLIED THROUGH THE CONTROL MODULE (BY-PASSING THE LOCKED-UP REGULATOR) INTO THE PLENUM, THROUGH AN ORIFICE AND INTO THE LOX TANK ULLAGE. DURING PREPRESSURIZATION OPERATIONS, THE LOX TANK FLIGHT CONTROL PRESSURE SWITCH CONTROLS THE (NORMALLY CLOSED) SHUTOFF VALVES. THE CONTROL PRESSURE SWITCH DE-ACTUATES AT 38 PSIA MINIMUM AND ACTUATES AT 41 PSIA MAXIMUM WITH A 0.5 PSI MINIMUM DEADBAND. WHEN THE ULLAGE PRESSURE INCREASES TO A LEVEL SUFFICIENT TO ACTUATE THE CONTROL PRESSURE SWITCH, AN ELECTRICAL SIGNAL IS SENT TO CLOSE THE REDUNDANT SHUTOFF VALVES, THEREBY COMPLETING THE PREPRESSURIZATION OPERATION.

10.1.1.4

LOX TANK PRESSURIZATION DURING ENGINE OPERATION

DURING ENGINE OPERATION, THE LOX PRESSURIZATION SHUTOFF VALVES AND THE LOX TANK PRESSURE CONTROL MODULE SOLENOID VALVES ARE COMMANDED OPEN. TANK PRESSURE IS SENSED BY LOX TANK PRESSURE SWITCH WHICH CONTROLS THE CYCLING OF THE VALVES FOR .3 SECONDS. THE VALVES ARE THEN MAINTAINED IN THE OPEN POSITION FOR THE DURATION OF BURN. FROM $T_4 - .6$ TO $T_4 + 24$ SECONDS, PRESSURIZATION IS MAINTAINED THROUGH THE NORMALLY OPEN HEAT-EXCHANGER BYPASS VALVE. AT $T_4 + 24$ SECONDS, WHEN THE HEAT-EXCHANGER BYPASS VALVE CONTROL IS ENABLED THE LOX TANK PRESSURE SWITCH ASSUMES CONTROL IN CYCLING THE HEAT EXCHANGER BYPASS VALVE.

HELIUM FROM THE COLD HELIUM SPHERES LOCATED IN THE LH2 TANK FLOWS THROUGH THE PRESSURIZATION CONTROL MODULE FILTER. THE PRESSURE-CONTROLLED REGULATOR VALVE, SENSING THE DOWNSTREAM PRESSURE, ALLOWS PASSAGE OF THE GAS TO THE PLENUM. GAS PRESSURE FROM THE PLENUM IS SENSED BY THE REGULATOR BACKUP PRESSURE SWITCH. IF THE PRESSURE IS TOO HIGH, THE BACKUP SWITCH CLOSES THE REDUNDANT SHUTOFF VALVES AND GAS SUPPLY IN THE PLENUM TEMPORARILY SUPPLIES THE SYSTEM. WHEN THE PRESSURE AT THE BACKUP SWITCH DROPS, THE SWITCH COMMANDS THE SHUTOFF VALVES TO OPEN, CONTINUING THE NORMAL OPERATION. IMMEDIATELY DOWNSTREAM FROM THE BACKUP SWITCH, THE GAS FLOW IS DIVERTED INTO TWO FLOW PATHS. ONE PATH LEADS THROUGH AN ORIFICE AND THEN TO THE LOX TANK ULLAGE AREA. THE OTHER PATH FEEDS THROUGH THE J-2 ENGINE HEAT EXCHANGER. HEATED GAS FROM THE EXCHANGER IS MIXED WITH THE COLD HELIUM AND IS THEN FED TO THE LOX TANK. IF THE ULLAGE PRESSURE FALLS BELOW 38 PSIA, THE FLIGHT CONTROL SWITCH COMMANDS THE HEAT EXCHANGER BYPASS VALVE TO OPEN TO SEND A LARGE VOLUME OF HEATED HELIUM TO THE LOX TANK. WHEN THE PRESSURE RISES TO 41 PSIA, A COMMAND FROM THE FLIGHT CONTROL PRESSURE SWITCH CLOSES THE BYPASS VALVE ALLOWING NORMAL ORIFICE FLOW.

10.1.1.5

LOX TANK REPRESSURIZATION (AMBIENT) (USED ONLY IN CASE OF BURNER FAILURE)

LOX TANK PRESSURIZATION, DURING COAST AFTER FIRST BURN, IS DEACTIVATED AND TANK PRESSURE IS ALLOWED TO VENT AND/OR DECAY (NORMAL GRADUAL RISE OR DECAY). PRIOR TO SECOND BURN THE LOX REPRESSURIZATION SUBSYSTEM IS ACTIVATED TO BRING THE LOX TANK UP TO THE REQUIRED PRESSURE LEVEL PRIOR TO ENGINE START. REPRESSURIZATION IS CONTROLLED BY THE FLIGHT CONTROL PRESSURE SWITCH. AT THIS TIME, HELIUM IS SUPPLIED BY THE TWO AMBIENT HELIUM SUPPLY BOTTLES TO MEET INLET PRESSURE REQUIREMENTS FOR A SECOND ENGINE START. SUPPLY GAS IS CONTROLLED BY MEANS OF TWO SOLENOID VALVES ON THE LOX REPRESSURIZATION CONTROL MODULE. SOLENOID ON-OFF COMMANDS ARE INITIATED BY THE FLIGHT CONTROL PRESSURE SWITCH. DURING SECOND BURN, THE PRESSURIZATION SYSTEM, USING A COMBINATION OF COLD AND HEATED HELIUM GAS, AGAIN PRESSURIZES THE LOX TANK.

10.1.1.6

LOX TANK REPRESSURIZATION (CRYOGENIC)

EVENTS PRIOR TO REPRESSURIZATION ARE IDENTICAL REGARDLESS OF THE METHOD OF REPRESSURIZATION EMPLOYED, I.E.; AMBIENT HELIUM OR OXYGEN/HYDROGEN BURNER. WHEN THE OXYGEN/HYDROGEN BURNER SUBSYSTEM IS EMPLOYED, THE LOX TANK PRESSURE SENSING SWITCH, ENABLED BY COMMAND FROM THE IU, CONTROLS OPERATION OF THE LOX COLD HELIUM REPRESSURIZATION DUAL SOLENOID VALVES (LOX REPRESS VALVES) IN THE LOX TANK REPRESSURIZATION PLENUM AND VALVE ASSEMBLY TO REGULATE PASSAGE OF HELIUM FROM THE COLD HELIUM BOTTLES TO THE HEATER COIL AND THEN TO THE LOX TANK.

- 10.1.1.6 LOX TANK REPRESSURIZATION (CRYOGENIC) (CONT)
THE TWO VALVES WHICH CONTROL INLET OF OXYDIZER AND FUEL (LOX AND LH2) TO THE BURNER PROPELLANT INJECTORS ARE INDIRECTLY ACTIVATED BY COMMAND FROM THE IU. DIRECT CONTROL OF THESE TWO VALVES IS BY MEANS OF SEPARATE ACTUATION CONTROL MODULES.
- 10.1.2 LOX TANK PRESSURIZATION COMPONENTS
LOX PRESSURIZATION AND REPRESSURIZATION COMPONENTS CONSIST OF A PRESSURIZATION CONTROL MODULE, TWO PRESSURIZATION SHUTOFF VALVES, TWO AMBIENT HELIUM SPHERES AND A REPRESSURIZATION CONTROL MODULE, A PLENUM CHAMBER, A COMBINATION GROUND FILL VALVE CONTROL PREPRESSURIZATION PRESSURIZATION REPRESSURIZATION AND FLIGHT CONTROL PRESSURE SWITCH, AND THE OXYGEN HYDROGEN BURNER ASSEMBLY TOGETHER WITH ITS CONTROLS AND SUB-COMPONENTS. DISCUSSION IS CONFINED TO THESE COMPONENTS. ADDITIONAL COMPONENTS, ASSOCIATED WITH OTHER SUBSYSTEMS, AFFECTING THE LOX SUPPLY PRESSURIZATION FUNCTION AS DESCRIBED WITH THEIR RESPECTIVE SYSTEMS.
- 10.1.2.1 LOX PRESSURIZATION CONTROL MODULE
THE PRESSURIZATION CONTROL MODULE CONTAINS TWO FILTERS, A PRESSURE REGULATOR, TWO SOLENOID SHUTOFF VALVES (REDUNDANT), A HEAT EXCHANGER BYPASS VALVES AND THE NECESSARY BOSSES FOR COMPONENT AND FLANGE LEAK CHECK. THE CONTROL MODULE IS CAPABLE OF OPERATING AT ANY TEMPERATURE BETWEEN -423°F AND $+160^{\circ}\text{F}$. WITH INLET PRESSURES RANGING BETWEEN 500 PSIA AND 3100 PSIA, THE PRESSURE REGULATOR IS CAPABLE OF DECREASING HELIUM GAS FLOW TO 385 ± 25 PSIA AT THE OUTLET PORT. THE SOLENOID VALVES ARE CAPABLE OF OPENING OR CLOSING IN LESS THAN 75 MSEC AFTER THE SOLENOID IS ENERGIZED OR DE-ENERGIZED. CURRENT DRAW OF THE SOLENOIDS DOES NOT EXCEED 1.5 AMP AT 28 VDC AT 70°F . THE PRESSURE SWITCH, UNDER OPERATIONAL ENVIRONMENT CONDITIONS, IS ACTUATED AT 467.5 ± 17.5 PSIA, AND DEACTUATED AT 352.5 ± 17.5 PSIA. THE FILTERS ARE CAPABLE OF REMOVING 98 PERCENT OF ALL PARTICLES IN EXCESS OF 10 MICRONS IN DIAMETER AND OPERATES WITH A PRESSURE DROP OF LESS THAN 50 PSI AT RATED FLOW WITH TEMPERATURE AT -410°F AND INLET PRESSURE AT 500 PSIA.
- 10.1.2.2 LOX TANK REPRESSURIZATION CONTROL MODULE
THE LOX TANK REPRESSURIZATION CONTROL MODULE (USED ONLY IN THE AMBIENT HELIUM METHOD) CONSISTS OF A CHECK VALVE, SOLENOID DUMP VALVE, TWO SOLENOID CONTROL VALVES, FILTER AND ASSOCIATED ASSEMBLY LINES AND FITTINGS. THE MODULE ENABLES CONTROLLED USE OF AMBIENT HELIUM FOR REPRESSURIZATION. ON-OFF CONTROL IS INITIATED BY THE LOX TANK FLIGHT CONTROL PRESSURE SWITCH CONTROLLING PRESSURE WITHIN THE LIMITS OF 41 PSIA AND 38 PSIA.
- 10.1.2.3 REPRESSURIZATION AMBIENT HELIUM STORAGE SPHERES (LOX TANK)
THE TWO AMBIENT HELIUM LOX TANK REPRESSURIZATION STORAGE SPHERES ARE WELDED TITANIUM ALLOY CONTAINERS WITH AN INTERNAL VOLUME OF 4.5 CUBIC FEET EACH. THE SPHERES ARE CAPABLE OF STORING HELIUM AT 3100 PSIA (NOMINAL) PRESSURE AT AMBIENT CONDITIONS.
- 10.1.2.4 PLENUM CHAMBER (LOX PRESSURIZATION SUBSYSTEM)
THE PLENUM CHAMBER IS A WELDED SPHERE WITH TWO FLANGED OPENINGS HAVING A MINIMUM VOLUME OF 250 CUBIC INCHES WITH A WORKING TEMPERATURE RANGE OF -423°F TO $+160^{\circ}\text{F}$ AT A MAXIMUM SYSTEM PRESSURE OF 2000 PSIG. THE PLENUM CHAMBER IS LOCATED IN THE HELIUM PRESSURE SUPPLY LINE TO THE LOX TANK BETWEEN THE PRESSURE-SENSING SWITCH AND THE PRESSURE REGULATOR.
- 10.1.2.5 LOX TANK GROUND FILL VALVE CONTROL PREPRESSURIZATION REPRESSURIZATION AND FLIGHT CONTROL PRESSURE SWITCH
DURING PREPRESSURIZATION AND REPRESSURIZATION OPERATIONS, THIS MULTIPLE DUTY CONTROL PRESSURE SWITCH IS USED TO SENSE LOX TANK ULLAGE PRESSURE. WHEN TANK FLIGHT PRESSURE IS ATTAINED, THE SWITCH IS ACTUATED AND SENDS A SIGNAL TO CLOSE THE NORMALLY CLOSED ONBOARD SHUTOFF SOLENOID VALVES IN THE PRESSURIZATION CONTROL MODULE. AT ENGINE START, FOR BOTH 1ST AND 2ND BURN, THE SHUTOFF VALVES ARE OPENED AND FLIGHT PRESSURE SWITCH CONTROL IS TRANSFERRED TO THE HEAT EXCHANGER, CONTROL VALVE IN THE PRESSURIZATION CONTROL MODULE. THE PRESSURE-SENSING SWITCH SIGNAL THEN DIRECTS AND CONTROLS THE FLOW OF HEATED HELIUM TO THE LOX TANK. THE SWITCH ACTUATES AT 41 PSIA MAXIMUM AND DROPS OUT AT 38 PSIA MINIMUM WITH A 0.5 PSI MINIMUM DEADBAND.

10.1.3

CHILLDOWN RECIRCULATION SUBSYSTEM

CHILLDOWN CONDITIONING OF THE ENGINE PUMPS, INLET DUCTING AND THE ENGINE HARDWARE FOR ENGINE START IS ACCOMPLISHED BY SEPARATE LOX AND LH2 CHILLDOWN SUBSYSTEMS. THE PRIMARY PURPOSE OF THE RECIRCULATION SUBSYSTEM IS TEMPERATURE STABILIZATION OF PROPELLANTS AT THE INTERFACE INLET IN ORDER TO MEET MINIMUM NPSH REQUIREMENTS OF THE ENGINE PUMPS. PROPELLANTS FROM EACH TANK ARE RECIRCULATED THROUGH THE FEED SYSTEMS AND RETURN BLEED LINES BY CHILLDOWN PUMPS. CHECK VALVES, PREVALVES, SHUTOFF VALVES AND DUCTING CONTROL AND ROUTE THE FLUIDS TO PERFORM THE CHILLDOWN. PNEUMATIC PRESSURE FOR OPERATING THE SHUTOFF AND PREVALVES IS SUPPLIED BY THE STAGE PNEUMATIC HELIUM CONTROL SUBSYSTEM.

DURING FILLING OPERATIONS, THE PREVALVES ARE ALLOWED TO STAY IN THE OPEN POSITION TO PROVIDE A THERMAL-TYPE CHILLDOWN OF THE FEED SUBSYSTEM HARDWARE (LOW PRESSURE FEED DUCT AND ENGINE PUMP) ALLOWING TEMPERATURE STABILIZATION OF THIS HARDWARE PRIOR TO ACTIVATION OF THE RECIRCULATION CHILLDOWN SUBSYSTEM. AT APPROXIMATELY FIVE MINUTES BEFORE LIFTOFF, THE PREVALVES ARE CLOSED AND RECIRCULATING CHILLDOWN FLOW IS INITIATED AND CONTINUES FOR APPROXIMATELY 14 MINUTES UNTIL J-2 ENGINE PRESTART. RECIRCULATION IS INITIATED APPROXIMATELY 2 MINUTES BEFORE PREPRESSURIZATION OF THE PROPELLANT ULLAGE VOLUMES. SINCE LOX IS ALREADY A SUB-COOLED LIQUID (NO TWO PHASE FLOW IN THE RETURN LINE), PREPRESSURIZATION HAS NEGLIGIBLE EFFECT ON THE FLOWRATE. THE LH2, HOWEVER, BECOMES A SUBCOOLED LIQUID AT PREPRESSURIZATION (ELIMINATING TWO PHASE FLOW IN THE RETURN LINE) RESULTING IN AN INCREASED LH2 CHILLDOWN FLOW.

10.1.3.1

LOX CHILLDOWN SUBSYSTEM

CHILLDOWN OF THE LOX SUBSYSTEM IS ACCOMPLISHED BY A CLOSED LOOP FORWARD FLOW RECIRCULATION SUBSYSTEM. LOX IS CIRCULATED FROM THE LOX TANK THROUGH THE LOW PRESSURE FEED DUCT TO THE J-2 ENGINE LOX PUMP AND BLEED VALVE, THEN BACK TO THE LOX TANK THROUGH THE RETURN LINES. THE FORWARD FLOW CHILLDOWN SUBSYSTEM PROVIDES A PROPERLY CONDITIONED J-2 LOX TURBOPUMP ASSEMBLY TO ENSURE PROPELLANT TEMPERATURE STABILIZATION AT THE LOX PUMP INLET.

10.1.3.2

LOX CHILLDOWN SUBSYSTEM OPERATION

THE PUMP MOTOR CAVITY IS PURGED WITH HELIUM GAS AT ALL TIMES FROM STAGE PNEUMATIC SYSTEM. FOR FLIGHT, THE LOX CHILLDOWN PROCEDURE IS ESSENTIALLY AS FOLLOWS: SHORTLY BEFORE LIFTOFF, THE CHILLDOWN RECIRCULATION SHUTOFF VALVE IS OPENED, THE LOX PRE-VALVE IS CLOSED AND RECIRCULATION IS INITIATED.

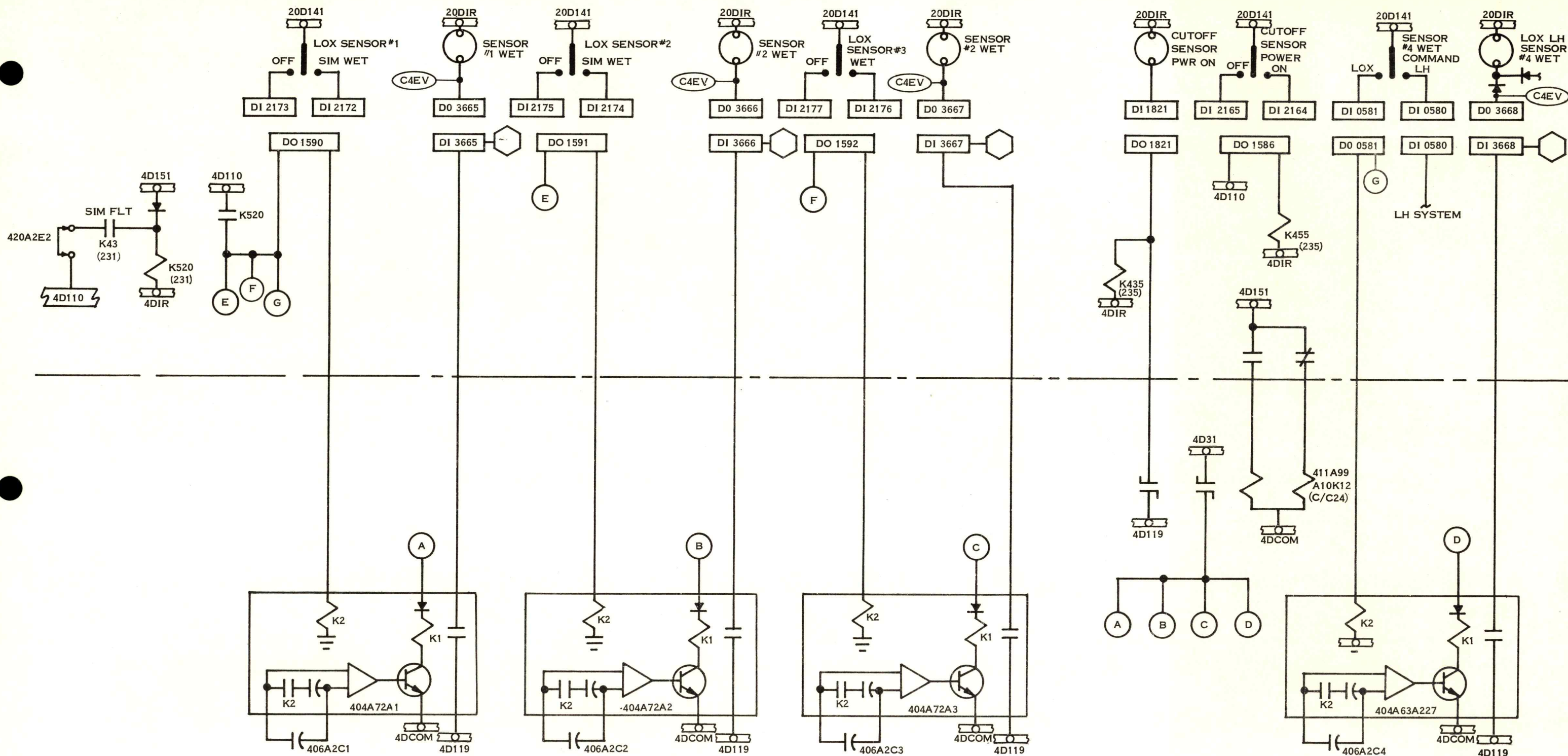
RECIRCULATION IS MAINTAINED THROUGHOUT BOOST UNTIL ENGINE PRESTART. AT PRESTART, WITH THE CHILLDOWN PUMP STILL ACTIVE, THE PRE-VALVES ARE OPENED TO ALLOW REVERSE FLOW THROUGH THE LOW PRESSURE DUCT. TRAPPED GAS BUBBLES ARE THEREBY REMOVED THROUGH THE DUCT AND THE TANK ANTIVORTEX SCREENS.

ON/OFF COMMANDS FOR THE PRE-VALVE, SHUTOFF VALVE, AND RECIRCULATION PUMP ARE INITIATED IN THE IU. IN THE EVENT AN EMERGENCY SHUTDOWN IS REQUIRED, THE CHILLDOWN SUBSYSTEM SHUTOFF VALVE CLOSSES.

DURING THE SECOND BURN START, THE INLET LINER AND ENGINE PUMP WILL BE IN A WARM CONDITION. AS CHILLDOWN BEGINS, THE LIQUID WILL INITIALLY GASIFY QUICKLY AND CREATE A POSSIBILITY FOR REVERSE FLOW THROUGH THE CHILL DUCTING. THE FLAPPER CHECK VALVE PREVENTS THE FLOW REVERSAL FROM BACK SPINNING THE PUMP AND DAMAGING THE CHILLDOWN MOTOR.

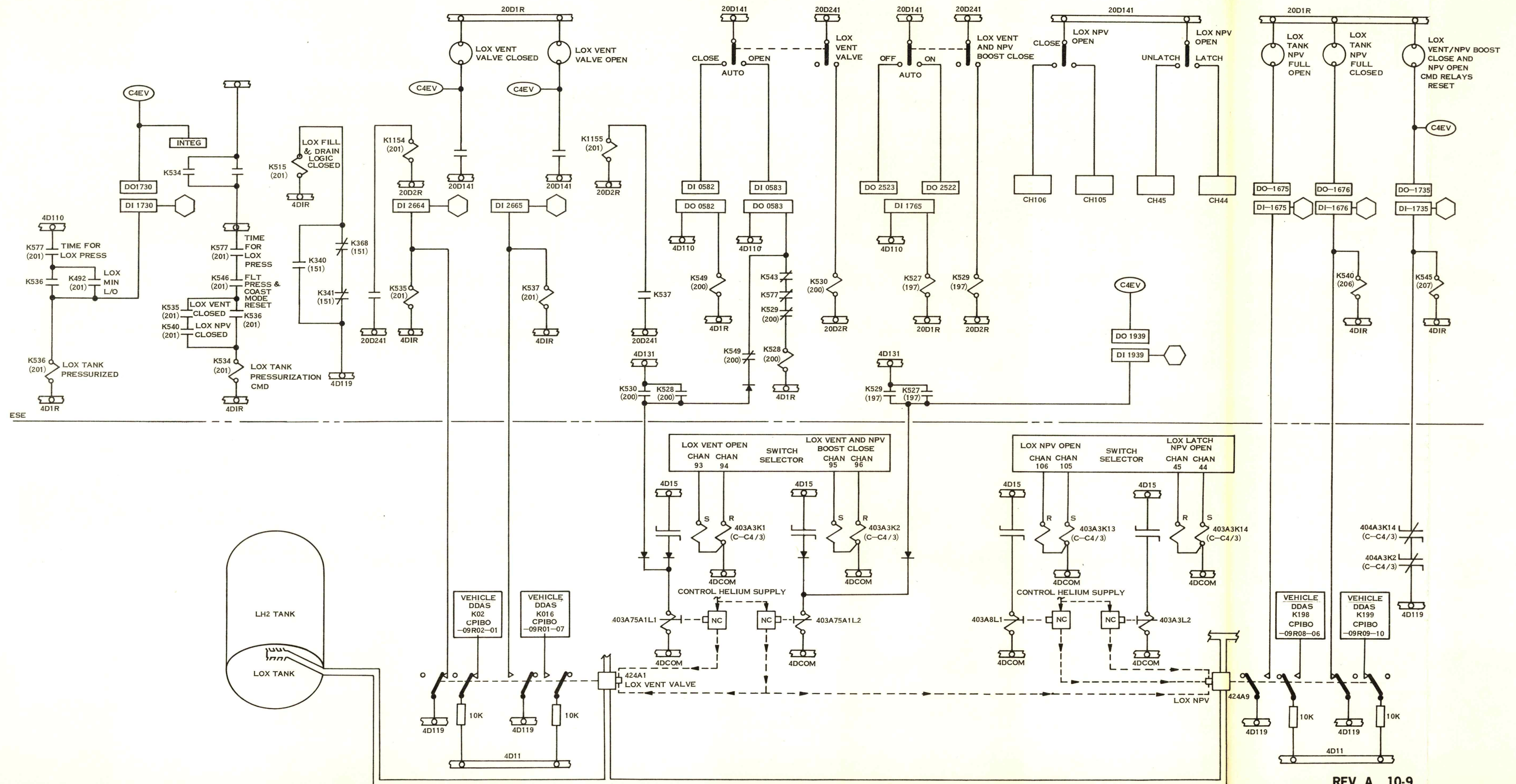
- 10.1.4 LOX CHILLDOWN SUBSYSTEM COMPONENTS
LOX CHILLDOWN SUBSYSTEM COMPONENTS CONSIST OF A PUMP AND ELECTRIC DRIVE MOTOR, RECIRCULATION SHUTOFF VALVE, FLOWMETER, FILTER, PRE-VALVE, FLAPPER CHECK VALVE, AND SUPPLY DUCT. A RETURN DUCT AND SWING CHECK VALVE ARE ALSO PROVIDED TO ROUTE THE FLUID OR GAS BACK TO THE LOX TANK.
- 10.1.4.1 LOX MOTOR-DRIVEN CENTRIFUGAL CHILLDOWN PUMP
THE MOTOR-DRIVEN CENTRIFUGAL CHILLDOWN PUMP FOR THE RECIRCULATION OF LOX IN THE CHILLDOWN SYSTEM IS MOUNTED IN THE LOX TANK. THE PUMP IS CAPABLE OF A MINIMUM LOX FLOWRATE OF 31 GPM AT 25 PSIA (00.0703 FT³/SECOND). THE ELECTRICAL MOTOR OPERATES ON 55 ± 5 VAC PEAK, LINE TO LINE, 3-PHASE, 400-CPS POWER, WHILE IMMersed IN LOX. ITS POWER SOURCE IS A QUASI-SQUARE WAVE INVERTER. THE PUMP IS CONTROLLED THROUGH CIRCUITS IN THE STAGE FLIGHT SEQUENCER AND POWER DISTRIBUTION SYSTEM. THE CHILLDOWN COMMAND IS RECEIVED FROM THE IU VIA THE SWITCH SELECTOR.
- 10.1.4.2 LOX RECIRCULATION SHUTOFF VALVE
THE RECIRCULATION SHUTOFF VALVE IS MOUNTED ON THE MOTOR-DRIVEN CENTRIFUGAL PUMP IN THE LOX CHILLDOWN SUBSYSTEM. ACTUATION WITH HELIUM CLOSES THE VALVE. THE VALVE IS PROVIDED WITH OPENED AND CLOSED POSITION INDICATOR SWITCHES. PRESSURE DROP ACROSS THE VALVE DOES NOT EXCEED 0.25 PSI AT 31 GPM LOX FLOW.
- 10.1.4.3 LOX FLOWMETER
THE LOX FLOWMETER IS MOUNTED ON THE OUTLET FLANGE OF THE SOLENOID VALVE TO MONITOR LOX FLOW IN THE LOX CHILLDOWN SYSTEM.
- 10.1.4.4 LOX FILTER
A CONICAL LOX FILTER (100-MESH SCREEN) IS INSTALLED IN THE FLANGED END-FITTING OF THE LOX RECIRCULATION DUCT ASSEMBLY IN THE LOX CHILLDOWN SUBSYSTEM.
- 10.1.4.5 LOX PREVALVE
THE LOX PREVALVE IS A 10-INCH DIAMETER SPRING-LOADED, NORMALLY OPEN BUTTERFLY VALVE. THE VALVE IS PNEUMATICALLY ACTUATED CLOSED BY A HELIUM SUPPLY PRESSURE OF 475 PSIG. THE VALVE HAS AN ALUMINUM BODY AND GATE AND IS CONNECTED TO THE LOW PRESSURE SUPPLY DUCT WITH TWO MARMAN CONOSEAL FLANGES.
- THE LOX PREVALVE BODY CONTAINS TWO POPPET-TYPE RELIEF VALVES. THE RELIEF VALVES RELIEVE PRESSURE ACROSS THE BUTTERFLY GATE TO PREVENT OVERPRESSURIZATION OF THE SYSTEM IN THE EVENT ALL SUPPLY SYSTEM VALVES ARE CLOSED AND THE LOW PRESSURE DUCT IS FILLED WITH LOX. THE RELIEF VALVES CRACK TO FULL OPEN AT A DIFFERENTIAL PRESSURE ACROSS THE PREVALVE OR 45 PSI.
- 10.1.4.6 LOX RECIRCULATION SUPPLY DUCT ASSEMBLY
THE LOX RECIRCULATION DUCT ASSEMBLY IS A 2-INCH DUCT WITH MARMAN FLANGED ENDS THAT MATE TO THE OUTLET FLANGE OF THE LOX FLOW-METER AND TO A FLANGED BOSS OF A PREVALVE LOCATED IN THE MAIN FEED DUCT. THE MARMAN FLANGE AT THE LOX FLOWMETER OUTLET IS MODIFIED TO ACCOMODATE A FLAPPER CHECK VALVE, AND THE CONICAL LOX FILTER. THE DUCT ASSEMBLY CONTAINS SUFFICIENT FLEXIBLE SECTIONS TO ALLOW FOR 0.40-INCH MOVEMENT OF EITHER END FLANGE IN ANY DIRECTION EXCEPT TORSIONAL.

- 10.1.4.7 LOX RECIRCULATION RETURN DUCT ASSEMBLY
THE LOX CHILLDOWN SYSTEM RETURN DUCT ASSEMBLY IS A 2-INCH DUCT WITH MARMAN FLANGED ENDS THAT MATE WITH AN OUTLET BOSS AT THE J-2 ENGINE INTERFACE AT THE UPSTREAM END, AND WITH THE INLET FLANGE OF A CHECK VALVE AT THE LOX TANK. THE DUCT ASSEMBLY CONTAINS FLEXIBLE SECTIONS TO ALLOW MOVEMENT OF EITHER END FLANGE IN ANY DIRECTION EXCEPT TORSIONAL.
- 10.1.4.8 LOX SWING CHECK VALVE
THE SWING CHECK VALVE IS LOCATED IN THE LOX CHILLDOWN SUBSYSTEM RETURN LINE AND HAS MARMAN FLANGES AT EACH END. THE UPSTREAM END MATES WITH THE DUCT ASSEMBLY FLANGE AND THE DOWNSTREAM END MATES WITH THE FLANGED INLET PORT IN THE LOX TANK. THE CHECK VALVE FLOWS LOX AT 31 GPM WITH A PRESSURE DIFFERENTIAL OF 0.2 PSI. THE VALVE CRACKS AND RESEATS WITH LOX AT OPERATING TEMPERATURES AND AT A PRESSURE DIFFERENTIAL BETWEEN ZERO AND 0.2 PSI.
- 10.2 CRITICAL MEASUREMENTS
- 10.2.1 GENERAL
ON VEHICLE 509 THERE ARE THREE REDLINE MEASUREMENTS IN THE LOX SYSTEM. THEY ARE THE LOX ULLAGE PRESSURE, LOX FLOW RATE AND OXIDIZER PUMP INLET TEMPERATURE. THERE ARE OTHER MEASUREMENTS USED IN THE FLOW CHARTS BUT THEY WILL NOT BE DISCUSSED IN THIS SECTION.
- 10.2.2 REDLINE MEASUREMENTS
- 10.2.2.1 LOX FLOW RATE
THE LOX FLOW RATE, F004-424, GIVES AN INDICATION OF THE FLOW IN GALLONS PER MINUTE THROUGH THE CHILLDOWN LINE. OUT OF TOLERANCE CONDITIONS INDICATE LINE RESTRICTIONS, HEAT LEAKS OR FAILURE OF THE PUMP OR CHILLDOWN INVERTER.
- 10.2.2.2 LOX ULLAGE PRESSURE
THE LOX ULLAGE PRESSURE, D577, IS A HARDWIRE MEASUREMENT WHICH INDICATES THE PRESSURE IN THE ULLAGE SPACE OF THE LOX TANK. IT IS APPLICABLE FROM LAUNCH VEHICLE POWER UP UNTIL T-11 SECONDS. AT LIFTOFF THE PRESSURE MUST BE SUFFICIENT TO MEET NPSH REQUIREMENTS OF THE J2-ENGINE AT ENGINE START.



SCHEMATIC, LOX DEPLETION SYSTEM
REV. A 10-7

LOX VENT SYSTEM



11.0 LH₂ SYSTEM

11.1 GENERAL DESCRIPTION

THE FUEL SYSTEM IS DESIGNED TO SUPPLY LH₂ TO THE J-2 ENGINE UNDER PRESCRIBED CONDITIONS TO MEET ENGINE PUMP INLET REQUIREMENTS. BASICALLY, THE FUEL SYSTEM CONSISTS OF AN LH₂ TANK, RECIRCULATION CHILLDOWN SYSTEM, NONPROPULSIVE VENT SYSTEM, PROPULSIVE VENT SYSTEM, FILL AND DRAIN SYSTEM, AND ASSOCIATED HARDWARE TO MEET PROPULSION SYSTEM REQUIREMENTS. THE PNEUMATIC CONTROL SYSTEM WHICH IS NOT ACTUALLY PART OF THE FUEL SYSTEM BUT IS ESSENTIAL FOR PROPER OPERATION OF THE ABOVE SUBSYSTEM IS INCLUDED IN SECTION 8.1.3 OF THE F.I.G. DOCUMENT. THE PRESSURIZATION SYSTEM IS DESCRIBED ALONG WITH THE ASSOCIATED PNEUMATIC CONTROL SYSTEM IN SECTION 8.1.5. FAULT ISOLATION IN THE GH₂ START BOTTLE SYSTEM IS ALSO INCLUDED IN THIS SECTION. OPERATIONAL DESCRIPTIONS OF ALL THESE SYSTEMS MAY BE FOUND IN THE FOLLOWING PARAGRAPHS.

11.1.1 FUEL SUPPLY TANK AND FEED LINE

THE LH₂ IS STORED IN AN INSULATED TANK AT APPROXIMATELY -423°F. TOTAL VOLUME OF THE TANK IS APPROXIMATELY 10,400 CUBIC FEET WITH A USABLE CAPACITY OF APPROXIMATELY 44,000 POUNDS AND AN ULLAGE VOLUME OF APPROXIMATELY 400 CUBIC FEET, WITH A USABLE PROPELLANT RESIDUAL OF 575 POUNDS. THE LH₂ HAS A FREEZING POINT OF -435°F AND A BOILING POINT OF -422.9°F AT ONE ATMOSPHERE PRESSURE.

LH₂ FROM THE TANK IS SUPPLIED TO THE J-2 ENGINE TURBOPUMP THROUGH A VACUUM-JACKETED LOW-PRESSURE DUCT CAPABLE OF FLOWING 80 POUNDS-PER-SECOND AT -423°F, AND AT A TRANSFER PRESSURE OF 28 PSIA. THE DUCT IS LOCATED IN THE FUEL TANK SIDE WALL ABOVE THE AFT HYDROGEN COMMON BULKHEAD JOINT, AND IS EQUIPPED WITH BELLOWS TO COMPENSATE FOR MANUFACTURING TOLERANCE AND THERMAL MOTION.

11.1.2 FUEL RECIRCULATION CHILLDOWN SYSTEM

CHILLDOWN CONDITIONING OF THE FUEL ENGINE PUMPS, INLET DUCTING AND THE ENGINE HARDWARE FOR ENGINE START IS ACCOMPLISHED BY THE LH₂ CHILLDOWN SUBSYSTEMS. THE PRIMARY PURPOSE OF THE RECIRCULATION SUBSYSTEM IS TO TEMPERATURE STABILIZE THE PROPELLANT AT THE INTERFACE INLET IN ORDER TO MEET MINIMUM NPSH REQUIREMENTS OF THE ENGINE PUMP. PROPELLANT FROM THE LH TANK IS, RECIRCULATED THROUGH THE FEED SYSTEM AND RETURN BLEED LINE BY THE CHILLDOWN PUMP. CHECK VALVES, PREVALVE, SHUTOFF VALVE, AND DUCTING CONTROL AND ROUTE THE FLUID TO PERFORM THE CHILLDOWN. PNEUMATIC PRESSURE FOR OPERATING THE SHUTOFF AND PREVALVE IS SUPPLIED BY THE STAGE PNEUMATIC HELIUM CONTROL SUBSYSTEM.

DURING FILLING OPERATIONS, THE PREVALVE IS ALLOWED TO STAY IN THE OPEN POSITION TO PROVIDE A DEADHEAD-TYPE CHILLDOWN OF THE FEED SUBSYSTEM HARDWARE (LOW PRESSURE FEED DUCT AND ENGINE PUMP) ALLOWING TEMPERATURE STABILIZATION OF THIS HARDWARE PRIOR TO ACTIVATION OF THE RECIRCULATION CHILLDOWN SUBSYSTEM. AT APPROXIMATELY FIVE MINUTES BEFORE LIFTOFF, THE PREVALVES ARE CLOSED AND RECIRCULATING CHILLDOWN FLOW IS INITIATED AND CONTINUES FOR APPROXIMATELY 7-1/2 MINUTES UNTIL J-2 ENGINE PRESTART. RECIRCULATION IS INITIATED APPROXIMATELY 2 MINUTES BEFORE PREPRESSURIZATION OF THE PROPELLANT ULLAGE VOLUMES.

A REFERENCE SCHEMATIC OF THE LH₂ RECIRCULATION SYSTEM AND ASSOCIATED ESE IS INCLUDED IN THIS DOCUMENT AS FIGURE 11-1.

THE MAJOR COMPONENTS AND MEASUREMENTS ARE SHOWN ON THIS SCHEMATIC. THE FEEDLINES AND COMPONENT ARRANGEMENT ON THIS SCHEMATIC IS FOR REFERENCE-ONLY AND DOES NOT DEPICT EXACT STAGE LOCATIONS. LOCATION AND OPERATIONAL DESCRIPTIONS OF THE RECIRCULATION COMPONENTS IS CONTAINED IN THE FOLLOWING PARAGRAPHS.

- 11.1.2.1 LH2 MOTOR-DRIVEN CENTRIFUGAL CHILLDOWN PUMP AND LH2 CHILLDOWN INVERTER
THE MOTOR AND PUMP ARE MOUNTED IN THE LH2 TANK ADJACENT TO THE ENGINE LOW PRESSURE FEED DUCT OUTLET PORT. THE PUMP IS CAPABLE OF A MINIMUM FLOWRATE OF 135 GPM AT 6.1 PSI DIFFERENTIAL PRESSURE. THE ELECTRIC MOTOR OPERATES ON 55 ± 5 VAC PEAK, LINE-TO-LINE, 3 PHASE, 400-CPS POWER. THE POWER SOURCE IS A QUASI-SQUARE WAVE IDENTICAL TO THAT USED FOR THE LOX CHILL-DOWN PUMP MOTOR. IT IS CONTROLLED THROUGH CIRCUITS IN THE STAGE FLIGHT SEQUENCER AND POWER DISTRIBUTION SUBSYSTEM. THE CHILLDOWN COMMAND IS RECEIVED FROM THE IU VIA THE SWITCH SELECTOR. THE PUMP MOTOR WINDINGS ARE WYE (Y) CONNECTED WITH THEIR COMMON (CENTER OF Y) TIED TOGETHER. THE LINE TO LINE RESISTANCE OF THE WINDINGS IS 0.45 OHMS MAXIMUM. THE PUMP AND MOTOR ASSEMBLY IS SUBMERGED IN LH2 AND OPERATES AT APPROXIMATELY 11,500 RPM. THE 4D41 BUS SUPPLIER DRIVE POWER TO THE CHILLDOWN INVERTER DIRECTLY AND THE INVERTER IS TURNED ON BY A MAGNETICALLY LATCHING RELAY WHICH APPLIES +4D41 POWER TO THE INVERTER CONTROL CIRCUIT. THE INVERTER DRIVE CIRCUIT, AND THE INPUT FILTER, WHICH CONTAINS A POLARIZED CAPACITOR, IS ALWAYS CONNECTED TO THE AFT # 2 BUS WHEN THE INVERTER INPUT PLUG IS CONNECTED. ANY OMMETER CHECKS ON THE AFT # 2 BUS WITH THE INVERTER CONNECTED MUST OBSERVE CORRECT POLARITIES OR AN IMPROPER VOLTAGE POLARITY WILL BE APPLIED TO THE FILTER CAPACITOR. NO TRANSFORMER ISOLATION EXISTS IN THE OUTPUTS OF THE INVERTER. ANY TEST INSTRUMENT OPERATING FROM THE POWER LINE MUST BE ISOLATED WITH AN ISOLATION TRANSFORMER IF IT IS CONNECTED TO THE INVERTER 3 PHASE OUTPUTS. IF THIS PRECAUTION IS NOT ADHERED TO SERIOUS DAMAGE WILL RESULT TO THE INVERTER.
- 11.1.2.2 LH2 RECIRCULATION SHUTOFF VALVE
THE RECIRCULATION SHUTOFF VALVE IS MOUNTED ON THE OUTLET FLANGE OF THE MOTOR-DRIVEN PUMP. THE VALVE FLOWS LH2 AT 138 GPM WITH 48 PSIA OR LESS APPLIED AT THE INLET. PRESSURE DROP ACROSS THE VALVE DOES NOT EXCEED 0.25 PSI AT 135 GPM LH2 FLOW. THE VALVE IS A NORMALLY OPEN, PNEUMATICALLY OPERATED POPPET TYPE VALVE THAT INCORPORATES TWO SETS OF MICROSWITCHES FOR POSITION INDICATION. THE FUNCTION OF THE VALVE IS TO SHUTOFF THE CHILLDOWN SYSTEM PROPELLANT FLOW AT THE LH2 TANK. CLOSING PRESSURE TO THE VALVE IS CONTROLLED BY A NORMALLY CLOSED SOLENOID VALVE LOCATED IN AN ACTUATION CONTROL MODULE. STAGE PNEUMATIC PRESSURE IS REQUIRED TO CLOSE THE SHUTOFF VALVE.
- 11.1.2.3 LH2 FLOWMETER
A FLOWMETER IS MOUNTED ON THE OUTLET FLANGE OF THE SOLENOID SHUTOFF VALVE TO MONITOR FLOW IN THE LH2 CHILLDOWN SUBSYSTEM. THIS FLOWMETER IS THE TRANSDUCER USED FOR REDLINE MEASUREMENT VXF0005-404.
- 11.1.2.4 LH2 FLAPPER CHECK VALVE
A FLAPPER CHECK VALVE IS LOCATED ON THE OUTLET SIDE OF THE FLOWMETER. THE CHECK VALVE PREVENTS REVERSE FLOW THROUGH THE CHILLDOWN LINE WHEN THE SUBSYSTEM IS NOT IN USE AND THE SHUTOFF VALVE IS IN THE OPEN POSITION. A FLOW REVERSAL WOULD BACK SPIN THE PUMP AND DAMAGE THE CHILLDOWN PUMP MOTOR.
- 11.1.2.5 LH2 RECIRCULATION SUPPLY DUCT ASSEMBLY
THE LH2 RECIRCULATION SUPPLY DUCT ASSEMBLY IS A 2-INCH, VACUUM-JACKETED DUCT WITH MARMAN FLANGED ENDS THAT MATE TO THE DOWNSTREAM FLANGE OF THE FLOWMETER AND TO A FLANGED BOSS OF THE PREVALVE, LOCATED IN THE MAIN LH2 FEED DUCT. THE MARMAN FLANGE AT THE UPSTREAM END OF THE RECIRCULATION DUCT ASSEMBLY IS MODIFIED TO ACCOMODATE A CONICAL FILTER. THE DUCT ASSEMBLY CONTAINS FLEXIBLE SECTIONS TO ALLOW MOVEMENT OF EITHER END FLANGE IN ANY DIRECTION EXCEPT TORSIONAL.

- 11.1.2.6 LH2 RETURN DUCT ASSEMBLIES
THE LH2 RETURN DUCT ASSEMBLIES ARE JOINED TOGETHER TO RETURN LH2 FROM THE J-2 ENGINE INTERFACE TO THE RETURN INLET PORT IN THE LH2 TANK. THE UPSTREAM (LOWER DUCT ASSEMBLY) CONNECTS TO A CHECK VALVE THAT IS ATTACHED TO THE RETURN INLET PORT FLANGE IN THE LH2 TANK.
- 11.1.2.7 LH2 LOWER DUCT ASSEMBLY
THE LH2 LOWER DUCT ASSEMBLY IS A 10-INCH DUCT WITH A VACUUM JACKETED INSULATION. THE UPSTREAM END IS PROVIDED WITH A MARMAN FLANGE THAT MATES WITH THE LH2 UPPER DUCT ASSEMBLY. THE DOWNSTREAM END COUPLES TO THE J2 ENGINE INTERFACE. THE DUCT ASSEMBLY HAS FLEXIBLE SECTIONS TO ALLOW MOVEMENT OF EITHER END OF THE ASSEMBLY IN ANY DIRECTION EXCEPT TORSIONAL.
- 11.1.2.8 LH2 UPPER DUCT ASSEMBLY
THE LH2 UPPER DUCT ASSEMBLY IS A 10-INCH DUCT WITH VACUUM JACKETED INSULATION. THE UPSTREAM END IS PROVIDED WITH A MARMAN FLANGE TO MATE WITH THE LH2 PRE-VALVE. THE DOWNSTREAM END IS PROVIDED WITH A MARMAN FLANGE THAT MATES WITH THE LOWER DUCT ASSEMBLY. THE DUCT ASSEMBLY HAS A FLEXIBLE SECTION TO ALLOW ANGULAR MOVEMENT OF THE DOWNSTREAM END.
- 11.1.2.9 LH2 PREVALVE
THE LH2 PREVALVE IS A 10-INCH DIAMETER, SPRING-LOADED, NORMALLY OPEN, BUTTERFLY VALVE. THE VALVE IS PNEUMATICALLY ACTUATED CLOSED BY A HELIUM SUPPLY PRESSURE OF 470 PSIG. THE VALVE HAS AN ALUMINUM BODY AND GATE AND IS CONNECTED TO THE LOW PRESSURE SUPPLY DUCT WITH TWO MARMAN CONOSEAL FLANGES. THE PREVALVE BODY CONTAINS ONE POPPET-TYPE RELIEF VALVE. THE RELIEF VALVE RELIEVES PRESSURE ACROSS THE BUTTERFLY GATE TO PREVENT OVERPRESSURIZATION OF THE SUBSYSTEM IN THE EVENT ALL SUPPLY SYSTEM VALVES ARE CLOSED AND THE LOW PRESSURE DUCT IS FILLED WITH LH2. THE RELIEF VALVES CRACK TO FULL OPEN AT A DIFFERENTIAL PRESSURE ACROSS THE PREVALVE OF 45 PSI. CLOSING PRESSURE TO THE PREVALVE IS CONTROLLED BY A NORMALLY CLOSED SOLENOID VALVE WHICH IS LOCATED IN THE SAME ACTUATION MODULE WHICH CONTAINS THE PILOT VALVE FOR THE SHUTOFF VALVE.
- 11.1.2.10 LH2 SWING CHECK VALVE
THE SWING CHECK VALVE FOR THE LH2 CHILLDOWN SUBSYSTEM HAS MARMAN FLANGES AT EACH END. THE UPSTREAM END MATES WITH THE UPPER DUCT ASSEMBLY FLANGE AND THE DOWNSTREAM END MATES WITH A FLANGED INLET PORT OF THE LH2 TANK. THE CHECK VALVE FLOWS LH2 AT 135 GPM WITH A PRESSURE DIFFERENTIAL OF 0.2 PSI. THE VALVE CRACKS AND RESEATS AT A PRESSURE DIFFERENTIAL BETWEEN ZERO AND 0.2 PSI.
- 11.1.3 FUEL VENT SYSTEMS (NON-PROPULSIVE AND PROPULSIVE)
A VENT-RELIEF SYSTEM ON THE STAGE IS PROVIDED TO PROTECT THE LH TANK AGAINST OVERPRESSURIZATION AND TO ENABLE COMMAND VENTING AT ANY TIME NORMAL STAGE OPERATIONS REQUIRE A CONTROLLED LOWERING OF TANK PRESSURE. THE TANK IS EQUIPPED WITH A SEPARATE RELIEF VALVE AND A (COMMAND CONTROL) VENT-RELIEF VALVE. THE RELIEF VALVE SENSES TANK PRESSURE AND PERFORMS A SAFETY FUNCTION BY AUTOMATICALLY OPENING AT ANY TIME TANK PRESSURE IS GREATER THAN THE RELIEF SETTING OF THE VALVE. THE VENT-RELIEF SYSTEMS ALSO PROVIDES AN AXIAL FORCE FOR POSITIONING THE PROPELLANT AT THE AFT END OF EACH TANK DURING COAST. HYDROGEN BOIL OFF GAS IS CONTINUOUSLY VENTED AFT TO PROVIDE THE REQUIRED THRUST AND THUS THIS PORTION OF THE VENT SYSTEM IS CALLED THE CONTINUOUS OR PROPULSIVE VENT SYSTEM.

FIGURE 11-2 IS A REFERENCE SCHEMATIC OF THE FUEL TANK VENT SYSTEM SHOWING PERTINENT MEASUREMENTS AND THE ASSOCIATED ELECTRICAL SUPPORT EQUIPMENT. OPERATION OF THE SYSTEM IS EXPLAINED BY THE SCHEMATIC AND THE OPERATIONAL DESCRIPTION WHICH FOLLOW.

11.1.3.1 LH2 TANK VENT RELIEF VALVE

THE VENT AND RELIEF VALVE PROVIDES BOTH COMMAND VENTING AND AUTOMATIC RELIEF VENTING CAPABILITY. IN THE COMMAND VENT MODE THE VALVE IS PNEUMATICALLY OPENED USING AN ACTUATION PRESSURE OF 470 ± 12 PSIG. WHEN THE PNEUMATIC PRESSURE IS RELEASED THE VALVE CLOSES. A BOOST CLOSE FEATURE IS PROVIDED TO ENSURE THAT THE VALVE WILL CLOSE IF IT IS FROZEN IN THE OPEN POSITION DURING VENTING. THE ACTUATION PRESSURE IS CONTROLLED BY NORMALLY CLOSED SOLENOID VALVES WHICH DIRECT THE OPENING AND BOOST CLOSING PNEUMATICS TO THE VALVE. THE RELIEF FUNCTION OF THE VALVE HAS A MAXIMUM CRACKING PRESSURE OF 34 PSIA AND A MINIMUM RESEAT PRESSURE OF 31 PSIA. THIS VALVE IS PART OF THE NON-PROPULSIVE VENT SYSTEM.

11.1.3.2 LH2 LATCHING RELIEF VALVE

THE NON-PROPULSIVE VENT SYSTEM ALSO EMPLOYS A LATCHING TYPE RELIEF VALVE. THE LH2 LATCHING RELIEF VALVE IS FUNCTIONALLY IDENTICAL TO THE LH2 TANK VENT AND RELIEF VALVE EXCEPT FOR THE INCORPORATION OF A PNEUMATICALLY OPERATED LATCH FOR THE OPEN POSITION. THIS FEATURE ENABLES ORBITAL TANK PASSIVATION AFTER LOSS OF STAGE POWER. THE VALVE IS SET AT A CRACK RESEAT RELIEF PRESSURE BAND OF 34 TO 31 PSIA. THE RELIEF MODE OF THIS VALVE PROVIDES REDUNDANCY TO THE VENT AND RELIEF VALVE.

THE LATCHING MECHANISM EMPLOYS A PNEUMATICALLY OPERATED TONGUE LATCH. THE TONGUE ENGAGES A GROOVE IN THE NOSE EXTENSION OF THE ACTUATOR PISTON AS THE PISTON IS OPENED AND THE LATCH MECHANISM PRESSURIZED. IT REMAINS IN THE LATCHED POSITION WHEN THE OPEN ACTUATOR SIGNAL AND THE LATCH OPEN SIGNALS ARE REMOVED IN THAT ORDER. THIS SEQUENCE RESULTS IN A CLOSING OF THE ACTUATOR PISTON APPROXIMATELY $1/4$ IN. UNTIL IT RESTS ON THE TONGUE OF THE LATCHING MECHANISM LOCKING THE LATCH IN THE LATCHED POSITION. UPON APPLICATION OF THE OPEN COMMAND TO THE VALVE, THE PISTON MOVES OPEN $1/4$ IN., AND THE TONGUE LATCH IS DISENGAGED BY SPRING FORCE FROM THE GROOVE IN THE PISTON NOSE EXTENSION. WHEN THE OPEN ACTUATOR PRESSURE IS REMOVED WITHOUT THE LATCH OPERATING PRESSURE ACTUATED, THE VALVE CLOSES NORMALLY.

CONTROL OF THIS VALVE IS ACCOMPLISHED BY AN ACTUATION CONTROL MODULE WHICH APPLIES OPENING AND/OR LATCHING PRESSURE TO THE LATCHING RELIEF VALVE THROUGH TWO NORMALLY CLOSED ELECTRICAL SOLENOID VALVES.

11.1.3.3 LH2 TANK DIRECTIONAL CONTROL VALVE

THE HYDROGEN GAS VENTED BY THE TANK VENT RELIEF AND/OR THE LATCHING RELIEF VALVE IS ALSO CONTROLLED BY THE DIRECTIONAL CONTROL VALVE. AS THE NAME IMPLIES, THIS VALVE IS USED TO DIRECT THE FLOW OF GAS THROUGH EITHER OF TWO VENTING SYSTEMS. DURING LH FILL OPERATIONS THE VALVE IS ACTUATED TO THE GROUND VENT POSITION, WHICH DIRECTS THE VENTED GH₂ TO THE GSE VENTING MANIFOLD THROUGH A DISCONNECT ASSEMBLY. JUST PRIOR TO LIFTOFF, THE DIRECTIONAL CONTROL VALVE IS ACTUATED TO THE FLIGHT POSITION, THEREBY VENTING THROUGH THE NONPROPULSIVE SUBSYSTEM AFTER LIFTOFF.

THIS VALVE IS ALSO PNEUMATICALLY ACTUATED BY AN ACTUATION CONTROL MODULE WITH HELIUM FROM THE STAGE PNEUMATIC PRESSURE SYSTEM. ELECTRICAL COMMAND SIGNALS FOR CONTROLLING THIS VALVE CAN COME ONLY FROM THE ESE THROUGH THE VEHICLE UMBILICAL CONNECTOR. THIS VALVE IS THE THIRD OF THE THREE VALVES WHICH ARE USED IN THE NON-PROPULSIVE VENT SYSTEM.

11.1.3.4

LH2 TANK CONTINUOUS VENT MODULE

THE CONTINUOUS (PROPULSIVE) VENT SYSTEM IS CONTROLLED BY THE LH2 CONTINUOUS VENT MODULE.

THE PURPOSE OF THE CONTINUOUS VENT MODULE IS TO CONTROL THE FLOW OF GASEOUS HYDROGEN FROM THE LH2 TANK THROUGH THE PROPULSIVE VENT SYSTEM. THE MODULE WILL AUTOMATICALLY MAINTAIN THE ULLAGE PRESSURE BETWEEN 19.5 AND 21.0 PSIA WHILE UTILIZING THE VENTED GAS TO PROVIDE A RELATIVELY LOW THRUST TO SETTLE THE PROPELLANTS THROUGHOUT THE COAST PERIOD.

THE VENT MODULE MAY BE REPRESENTED FOR DESCRIPTIVE PURPOSE AS MADE UP OF A SOLENOID OPERATED VALVE, REGULATOR, A FIXED ORIFICE AND A PNEUMATICALLY OPERATIVE VALVE.

EACH VALVE CONTROLS A SEPERATE PARALLEL FLOW PATH TO THE PROPULSIVE VENTS.

THE ELECTRICALLY OPERATED VALVE IS THE RELIEF OVERRIDE VALVE AND IS CAPABLE OF BEING LATCHED IN THE OPEN POSITION. THE FLOW THROUGH THIS VALVE IS ROUTED TO THE REGULATOR WHICH CONTROLS THE PRESSURE BETWEEN 19.5 AND 21.0 PSIA.

THE PNEUMATICALLY OPERATED VALVE IS THE ORIFICE BYPASS VALVE WHICH CONSISTS OF A NORMALLY CLOSED POPPET WHICH IS PNEUMATICALLY ACTUATED AND LATCHED IN THE OPEN POSITION. WHEN THE POPPET IS OPENED, A FIXED ORIFICE PROVIDES A CONTINUOUS FLOW.

BOTH THE ORIFICE BYPASS VALVE AND THE RELIEF OVERRIDE VALVE ARE NORMALLY ACTUATED OPEN IN UNISON SO THAT THE REGULATOR ASSEMBLY AND BYPASS ORIFICE CONTROL THE FLOW OF THE VENTED GASES.

11.1.4

LH2 TANK PRESSURIZATION SYSTEM

THE LH2 TANK PRESSURIZATION SYSTEMS PROVIDE THE NECESSARY TANK PRESSURE TO SATISFY ENGINE FUEL NET POSITIVE SUCTION PRESSURE (NPSP) REQUIREMENTS FOR ENGINE START AND BURN.

THE NPSP MUST BE SUFFICIENT TO PREVENT CAVITATION AT THE INLET TO THE FUEL PUMP WHICH WOULD RESULT IN A TURBINE OVERSPEED CONDITION. THE LH2 TANK IS PRESSURIZED BY MEANS OF FOUR SOURCES OF PRESSURANT GAS.

THESE ARE:

1. GROUND HELIUM SUPPLIED BY THE GSE HEAT EXCHANGE CIRCUIT NUMBER 3.
2. HELIUM FROM THE O₂/H₂ BURNER HEAT EXCHANGER WHICH IS SUPPLIED BY THE 9 COLD HELIUM BOTTLES STORED IN THE LH2 TANK.
3. GH₂ WHICH IS SUPPLIED BY THE J2 ENGINE SYSTEM DURING ENGINE BURN.
4. AMBIENT HELIUM STORED IN THE 5 AMBIENT HELIUM BOTTLES.

THE GROUND PRESSURIZATION SYSTEM PROVIDES THE INITIAL PRESSURANT GAS TO THE PROPELLANT TANKS AND ENSURES THAT ADEQUATE NPSP WILL BE AVAILABLE AT ENGINE START. THIS HELIUM IS SUPPLIED TO THE STAGE AT APPROXIMATELY 515 PSIA AND AT -360°F. WHEN SUFFICIENT TANK PRESSURE IS ATTAINED, THE HELIUM FLOW IS SHUT OFF BY THE CLOSING OF THE PRE-PRESS SUPPLY VALVE.

THIS VALVE CLOSES WHEN THE GROUND FILL/PREPRESS PRESSURE SWITCH PICKS UP AT A TANK PRESSURE OF 31 PSIA.

THE CRYOGENIC REPRESSURIZATION SYSTEM PRESSURIZES THE TANK, JUST PRIOR TO RESTART, WITH HELIUM GAS WHICH IS STORED INITIALLY IN SUBMERGED SPHERES INSIDE THE LH2 TANK. THE O₂/H₂ BURNER EXPANDS THE COLD HELIUM AND THE HELIUM IS THEN DIRECTED THROUGH AN ORIFICE TO THE LH TANK. THE O₂/H₂ BURNER IS PART OF BOTH THE LOX AND THE LH2 REPRESSURIZATION SUBSYSTEMS. A SEPARATE SET OF REPRESSURIZATION VALVES AND SEPARATE HELIUM HEATER COILS ARE EMPLOYED FOR THE REPRESSURIZATION OF EACH TANK.

THE PRESSURIZATION SYSTEM, DURING ENGINE BURN UTILIZES HIGH PRESSURE GH₂ TAPPED OFF THE ENGINE INJECTOR AND RECYCLED BACK TO THE LH2 TANK TO MAINTAIN REQUIRED NPSP AT THE FUEL TURBOPUMP INLET DURING BURN.

THE AMBIENT REPRESSURIZATION SYSTEM UTILIZES AMBIENT HELIUM GAS STORED IN SPHERES ON THE THRUST STRUCTURE TO PRESSURIZE THE LH2 TANK.

THE AMBIENT SYSTEM IS USED AS A BACKUP TO THE CRYOGENIC SYSTEM FOR THE RESTART.

THE MAJOR COMPONENTS MAKING UP THE LH TANK PRESSURIZATION SYSTEM ARE SHOWN IN SCHEMATIC FORM AT THE END OF THIS SECTION IN FIGURE 11-3. THE PERTINENT ESE AND MEASUREMENTS ARE SHOWN ON THIS SCHEMATIC AND THE OPERATION OF THE VEHICLE COMPONENTS TOGETHER WITH THEIR FUNCTION IN THE SYSTEM IS DESCRIBED IN THE FOLLOWING PARAGRAPHS.

11.1.4.1

LH2 TANK REPRESSURIZATION PRESSURE SWITCH

THE LH2 TANK REPRESSURIZATION PRESSURE SWITCH IS A DUAL LIMIT SWITCH WHICH SENSES ULLAGE PRESSURE IN ORDER TO MAINTAIN THAT PRESSURE BETWEEN 28 AND 31 PSIA DURING CRYOGENIC OR AMBIENT REPRESSURIZATION. THIS SWITCH IS CONNECTED IN SERIES TO AN IDENTICAL SWITCH WHICH IS USED TO CONTROL THE PREPRESSURIZATION AND PRESSURIZATION SYSTEMS. BOTH SWITCHES MUST ENERGIZE AT 31 PSIA BEFORE A SIGNAL CAN BE SENT TO EITHER OF THE LH2 TANK REPRESSURIZATION CONTROL MODULES (CRYOGENIC OR AMBIENT) TO CUTOFF THE HELIUM REPRESSURIZATION FLOW TO THE LH2 TANK. TWO SWITCHES, REQUIRED FOR CUTOFF, OFFER A SAFEGUARD AGAINST A PREMATURE LH2 REPRESSURIZATION CUTOFF DUE TO A SINGLE SWITCH MALFUNCTION. THIS SWITCH IS IDENTIFIED ON THE REFERENCE SCHEMATIC AS THE "REPRESS/BURNER SWITCH" (S2).

11.1.4.2

LH2 TANK PREPRESSURIZATION AND FLIGHT CONTROL SWITCH.

THE SERIES REDUNDANT SWITCH MENTIONED IN PARAGRAPH 11.1.4.1 IS THE PREPRESS FLIGHT CONTROL SWITCH AND IS IDENTIFIED ON THE SCHEMATIC AS THE "GROUND FILL/PREPRESS SWITCH" (S4). THIS SWITCH SENSES THE TANK ULLAGE PRESSURE TO MAINTAIN THE ULLAGE BETWEEN 28 AND 31 PSIA DURING PREPRESSURIZATION AND BURN. THE FLIGHT PRESSURE SWITCH SENDS SIGNALS TO CONTROL THE HELIUM SUPPLY VALVE IN THE GROUND PRESSURIZATION SYSTEM. DURING BURN, THIS SWITCH SENDS SIGNALS TO THE LH2 TANK PRESSURIZATION CONTROL MODULE TO INCREASE OR DECREASE THE HYDROGEN FLOW AS REQUIRED.

11.1.4.3

LH2 PRESSURIZATION CONTROL MODULE

THE PRESSURIZATION CONTROL MODULE CONTAINS A CHECK VALVE, TWO NORMALLY OPEN SOLENOID CONTROL VALVES, AND THREE ORIFICES. JUST AFTER FIRST ENGINE START, THE FIRST BURN RELAY ON COMMAND GIVES CONTROL OF THE CONTROL ORIFICE TO THE FLIGHT PRESSURE SWITCH, AND ENERGIZES THE STEP PRESSURIZATION ORIFICE SOLENOID CAUSING IT TO CLOSE THE STEP PRESSURIZATION VALVE DURING FIRST BURN. IF THE ULLAGE PRESSURE FALLS TO 28 PSIA THE PRESSURE SWITCH BREAKS CONTACT AND DE-ENERGIZES THE CONTROL ORIFICE SOLENOID VALVE WHICH CAUSES IT TO OPEN. THIS ALLOWS SUFFICIENT GAS FLOW TO INCREASE THE PRESSURE TO 31 PSIA WHERE THE CONTROL SOLENOID VALVE IS CLOSED AND THE CYCLE IS REPEATED.

DURING THE SECOND BURN THE LH2 TANK PRESSURIZATION OPERATES SIMILAR TO FIRST PRESSURIZATION EXCEPT THAT THE SECOND BURN RELAY ON COMMAND GIVES CONTROL TO THE STEP PRESSURIZATION SOLENOID VALVE INSTEAD OF THE CONTROL SOLENOID VALVE. THE CONTROL SOLENOID VALVE REMAINS CLOSED DURING THE SECOND BURN.

11.1.4.4 LH2 TANK AMBIENT REPRESSURIZATION CONTROL MODULE

THE LH2 AMBIENT REPRESSURIZATION CONTROL MODULE CONSISTS OF A CHECK VALVE, A FILTER, AND THREE NORMALLY CLOSED SOLENOID VALVES. THE CHECK VALVE PREVENTS REVERSE FLOW IN THE REPRESSURIZATION SUPPLY LINE DURING AND AFTER FILLING THE REPRESSURIZATION SUPPLY SYSTEM. THE FILTER PREVENTS CONTAMINATION FROM ENTERING THE PROPELLANT TANKS. THE FILTER IS NOT SHOWN ON THE REFERENCE SCHEMATIC BUT IS LOCATED IN THE MODULE OUTLET LINE. TWO SOLENOID VALVES ARE INSTALLED IN A PARALLEL REDUNDANT CONFIGURATION AND ARE USED TO CONTROL THE SUPPLY OF HELIUM REPRESSURIZATION GAS TO THE PROPELLANT TANKS. THE THIRD SOLENOID VALVE IS USED AS A DUMP VALVE TO DEPRESSURIZE THE HELIUM REPRESSURIZATION SPHERES ON THE GROUND. A CONTROL ORIFICE IS INSTALLED DOWNSTREAM OF THE REPRESSURIZATION MODULE TO CONTROL THE FLOWRATE DURING REPRESSURIZATION.

11.1.4.5 LH2 TANK AMBIENT REPRESSURIZATION SPHERES

FIVE 4.5 FT³ AMBIENT HELIUM SPHERES ARE MANIFOLDED DIRECTLY TO THE LH2 AMBIENT REPRESSURIZATION MODULE. ONE OF THE TWO ADDITIONAL SPHERES WHICH ARE USED FOR LOX AMBIENT REPRESSURIZATION ARE TIED TO THE FIVE LH2 AMBIENT REPRESSURIZATION BOTTLES WITH TWO CHECK VALVES IN SERIES TO PROVIDE ADDITIONAL REPRESSURIZATION GAS FOR THE LH2 TANK IF LOX REPRESSURIZATION REQUIREMENTS ARE MINIMUM. FOR CLARITY ONLY ONE OF THE CHECK VALVES IS SHOWN ON THE REFERENCE SCHEMATIC. THE SIX SPHERES ARE CONNECTED TO THE J-2 ENGINE CONTROL BOTTLE. A CHECK VALVE ALLOWS REPLENISH GAS TO FLOW TO THE CONTROL SPHERE TO MEET ENGINE REQUIREMENTS. MASS LOST FROM THE REPRESS SYSTEM FOR THIS PURPOSE IS NEGLIGIBLE.

11.1.4.6 LH2 CRYOGENIC REPRESSURIZATION CONTROL MODULE

PRESSURANT IS SUPPLIED FROM NINE HELIUM SPHERES SUBMERGED IN THE LH2 TANK. THE SUPPLY PRESSURE TO THE BURNER COILS IS REDUCED TO 385 ± 28 PSIG BY THE LOX TANK PRESSURIZATION CONTROL MODULE. THE CRYOGENIC REPRESS CONTROL MODULE UPSTREAM OF THE O₂-H₂ BURNER CONTAINS PARALLEL NORMALLY CLOSED SOLENOID VALVES WHICH ARE CONTROLLED BY COMMAND FROM THE SWITCH SELECTOR. THE LH2 TANK PRESSURE SWITCHES TERMINATE REPRESSURIZATION AT THE UPPER LIMIT OF 31 PSIA. A PLENUM CHAMBER IS INCLUDED IN THE MODULE OUTLET LINE TO CONTROL SURGE PRESSURE IN THE LINE BETWEEN THE SUPPLY SPHERES AND THE BURNER INLET. THE HELIUM IS ROUTED TO THE HELIUM COILS IN THE BURNER HEAT EXCHANGER THEN THROUGH AN ORIFICE TO THE LH2 TANK.

11.1.4.7 LH2 TANK REPRESSURIZATION REGULATOR BACKUP PRESSURE SWITCH

THIS PRESSURE SWITCH SENSES PRESSURE DOWNSTREAM OF THE LH2 CRYOGENIC REPRESS MODULE. IF THE LOX TANK PRESSURE REGULATOR FAILS OPEN, THE PRESSURE SWITCH WILL ACTUATE AT $465 \pm 20, -15$ PSIA TO DE-ENERGIZE THE CIRCUIT ALLOWING THE VALVES TO CLOSE. WHEN PRESSURE DROPS TO $350 \pm 20, -15$ PSIA THE PRESSURE SWITCH WILL DEACTUATE TO ENERGIZE THE CIRCUIT THUS OPENING THE VALVE. THIS OPERATION IS REPEATED AS THE PRESSURE CYCLES.

11.1.4.8 THE O₂/H₂ BURNER FUEL PRESSURIZATION COILS

THREE HELIUM REPRESSURIZATION COILS ARE MANIFOLDED TOGETHER IN THE BURNER HEAT EXCHANGER. ONE HELIUM COIL (175 INCHES LONG) EXTENDS HELICALLY AROUND THE LENGTH OF THE HEAT EXCHANGER SECTION. THE TWO OTHER COILS (45 AND 50 INCHES LONG) ARE LOCATED TOGETHER IN A LOWER MANIFOLD AND MOUNTED IN A PARALLEL, HELICAL CONFIGURATION AROUND THE LOWER SECTION OF THE HEAT EXCHANGER. THE HELIUM IS HEATED AND EXPANDED IN THESE COILS AND THEN ROUTED TO THE LH TANK THROUGH AN ORIFICE WHICH CONTROLS THE FLOWRATE TO THE FUEL TANK. INFORMATION REGARDING THE OPERATION OF THE BURNER MAY BE FOUND IN SECTION 9.0 OF THE DOCUMENT.

11.1.5

THE PNEUMATIC CONTROL SYSTEM

THE PNEUMATIC CONTROL SYSTEM PROVIDES A REGULATED HELIUM SUPPLY FOR ALL STAGE PNEUMATICALLY-OPERATED VALVES AND THE ENGINE START TANK VENT VALVE CONTROL. ALL OTHER ENGINE PNEUMATIC POWER IS SUPPLIED BY THE ENGINE HELIUM SPHERE. THE CONTROL SYSTEM ALSO PROVIDES AMBIENT HELIUM TO PURGE THE ENGINE TURBINE PUMP SEALS, THE GAS GENERATOR, AND THE LOX CHILL-DOWN PUMP MOTOR CONTAINER. PRIOR TO LIFTOFF, PURGING OF THE LOX AND LH2 VENT DUCTS, LH2 CHILLDOWN VALVE, AND THE LOX AND LH2 FILL AND DRAIN VALVES IS ACCOMPLISHED THROUGH SEPARATE LINES WITH GSE HELIUM SUPPLIED THROUGH THE FILL PORT DISCONNECT. THE PNEUMATIC CONTROL SYSTEM OPERATES AS REQUIRED THROUGHOUT THE MISSION PHASES OF PRELAUNCH, BOOST, BURN, COAST AND SAFING.

THE SYSTEM PROVIDES THE ACTUATION PRESSURE FOR THE FOLLOWING VALVES:

- A. LH2 DIRECTIONAL CONTROL VALVE
- B. LH2 VENT AND RELIEF VALVE
- C. LOX AND LH2 FILL AND DRAIN VALVES
- D. LOX AND LH2 PREVALVES
- E. LOX AND LH2 CHILLDOWN SHUTOFF VALVES
- F. LOX TANK VENT AND RELIEF VALVE
- G. LH2 CONTINUOUS VENT MODULE ORIFICE BYPASS VALVE
- H. LOX NON-PROPULSIVE VENT VALVE
- I. BURNER LH2 PROPELLANT VALVE
- J. BURNER LOX SHUTDOWN VALVE
- K. LH2 LATCHING VENT AND RELIEF VALVE.

A PRESSURE SPHERE PROVIDES AMBIENT HELIUM TO THE PNEUMATIC CONTROL SYSTEM AND TO THE J2 ENGINE PUMP PURGE SYSTEM. GROUND DUMPING OF THE PNEUMATIC SUPPLY IS ACCOMPLISHED BY THE AMBIENT HELIUM FILL MODULE. SAFING OF THE PNEUMATIC SUPPLY IS ACCOMPLISHED BY ACTUATION OF THE ENGINE PURGE CONTROL MODULE. A PNEUMATIC REGULATOR REDUCES THE HELIUM PRESSURE FROM THE SUPPLY SPHERE TO A NOMINAL VALUE OF $490 \pm_{35}^{25}$ PSIA. UNDER A LOW DEMAND CONDITION, MAXIMUM REGULATOR LOCK-UP (REGULATOR FULLY CLOSED) PRESSURE IS 550 PSIA. IF THE PNEUMATIC REGULATOR FAILS IN THE FULLY OPENED POSITION, A BACKUP PRESSURE SWITCH COMMANDS A NORMALLY OPEN SOLENOID VALVE CLOSED AS REQUIRED TO MAINTAIN THE HELIUM REGULATOR PRESSURE WITHIN PRESSURE SWITCH LIMITS. AT PRESSURES GREATER THAN 600 ± 15 PSIA, THE PRESSURE SWITCH ACTUATES AND CLOSES THE VALVE. AT PRESSURES BELOW 490 ± 25 PSIA, THE PRESSURE SWITCH DROPS OUT AND THE SOLENOID OPENS, THUS ACTING AS A BACKUP TO THE REGULATOR.

A SIMPLIFIED SCHEMATIC SHOWING THE REGULATOR, PRESSURE SWITCH AND SUPPLY BOTTLE IS INCLUDED IN FIGURE 9-2 OF THE BURNER SYSTEM SECTION. A DESCRIPTION OF THE PNEUMATIC POWER CONTROL MODULE IS CONTAINED IN THE NEXT PARAGRAPH.

11.1.5.1

PNEUMATIC POWER CONTROL MODULE

THE PNEUMATIC POWER CONTROL MODULE CONTAINS TWO SEPARATE FLOW PATHS. THE MAIN PATH INCORPORATES AN INLET FILTER, A PRESSURE REGULATOR, A NORMALLY OPEN SOLENOID VALVE, AND AN OUTLET FILTER. THIS PATH REGULATES THE ONBOARD AMBIENT HELIUM SUPPLY PRESSURE TO $490 \pm_{35}^{25}$ PSIG FOR OPERATING PNEUMATICALLY ACTUATED COMPONENTS. THE NORMALLY OPEN SOLENOID VALVE IS CONTROLLED BY A PRESSURE SWITCH THAT SENSES ACTUATION SYSTEM PRESSURE SUCH THAT A REGULATOR FAILURE RESULTS

IN PRESSURE SWITCH CONTROL OF THE SOLENOID VALVE (OPEN AND CLOSE) THEREBY PROVIDING A REDUNDANT MEANS OF REGULATION. THE OTHER FLOW PATH CONTAINS A NORMALLY CLOSED, THREE-WAY, TWO-POSITION SOLENOID VALVE AND A PORT FOR MOUNTING THE PRESSURE SWITCH USED TO CONTROL THE SOLENOID VALVE IN THE MAIN FLOW PATH. THE FUNCTION OF THE THREE-WAY VALVE IS TO CONTROL THE J-2 ENGINE START SPHERE VENT VALVE ACTUATION. IN THE CLOSED POSITION, THE THREE-WAY VALVE ENSURES VENTING OF THE ACTUATOR AND LINE TO PREVENT BLOWDOWN OF THE START SPHERE IN THE EVENT OF VALVE LEAKAGE.

11.1.6 LH TANK FILL AND DRAIN SYSTEM

PRIOR TO LOADING, THE LH2 TANK IS PURGED WITH HELIUM GAS. AT THE INITIATION OF LOADING, THE GROUND CONTROLLED COMBINATION VENT AND RELIEF VALVE IS PNEUMATICALLY OPENED. THE DIRECTIONAL CONTROL VALVE IS ALSO POSITIONED AT THE TIME TO ROUTE GH2 THROUGH THE OVERBOARD BURN STACKLINE.

LOADING BEGINS WITH PRECOOL AT A FLOW OF 500 GPM. WHEN THE 5 PERCENT LOAD LEVEL IS REACHED FAST FILL IS INITIATED AT A FLOW OF APPROX. 3000 GPM. AT THE 98 PERCENT LOAD LEVEL, FAST FILL STOPS AND A SLOW FILL AT 500 GPM BEGINS. A FAST FILL EMERGENCY CUTOFF SENSOR HAS BEEN PROVIDED TO COMPENSATE FOR A PRIMARY CONTROL CUTOFF FAILURE. SLOW FILL IS TERMINATED AT THE 100 PERCENT LOAD LEVEL AND THIS LEVEL IS THEN MAINTAINED BY REPLENISH FLOWRATE OF 0 TO 300 GPM, AS REQUIRED. THE REPLENISH FLOW IS MAINTAINED THROUGH THE COMPLETE LH2 TANK PREPRESSURIZATION OPERATION.

LIQUID LEVEL DURING FILL IS MONITORED BY MEANS OF THE PU MASS PROBES. A BACKUP OVERFILL SENSOR IS PROVIDED TO TERMINATE FLOW IN THE EVENT OF A 100 PERCENT LOAD CUTOFF FAILURE. TERMINATION OF FLOW (REVERT) IS ACCOMPLISHED BY CLOSING THE FILL AND DRAIN VALVE, OPENING THE UMBILICAL LINE DRAIN VALVE AND CLOSING THE FILL VALVE. A REFERENCE SCHEMATIC SHOWING THE OPERATION AND CONTROL OF THE FILL AND DRAIN VALVE IS INCLUDED IN THIS SECTION IN FIGURE 11-4. THE MAIN STAGE COMPONENTS IN THIS SYSTEM ARE THE LH2 FILL AND DRAIN VALVE AND THE LH2 FILL AND DRAIN VALVE DISCONNECT ASSEMBLY. DISCUSSION OF THESE COMPONENTS FOLLOWS IN THE SUCCEEDING PARAGRAPHS. OTHER COMPONENTS WHICH ARE ASSOCIATED WITH THE FILL SYSTEM ARE, THE COMPONENTS OF THE VENT SYSTEMS, PROPELLANT UTILIZATION AND LH TANK PRESSURIZATION. DISCUSSIONS OF THESE SYSTEMS MAY BE FOUND IN APPLICABLE SECTIONS OF THIS DOCUMENT.

11.1.6.1 LH2 FILL AND DRAIN VALVE

THE FILL AND DRAIN VALVE IS AN ASSEMBLY CONSISTING OF A VALVE BODY, A VALVE BLADE, A PNEUMATICALLY OPERATED HELIUM PRESSURE ACTUATOR AND TWO POSITION INDICATOR SWITCHES. PNEUMATIC PRESSURE FOR OPERATING THE VALVE IS SUPPLIED BY THE STAGE PNEUMATIC SYSTEM AND IS CONTROLLED BY ELECTRICALLY CONTROLLED SOLENOID VALVES IN AN ACTUATION MODULE. THE FILL AND DRAIN VALVE IS THEREFORE PNEUMATICALLY ACTUATED BUT ELECTRICALLY CONTROLLED.

THE VALVE IS CAPABLE OF ALLOWING FLOW IN EITHER DIRECTION FOR FILL AS WELL AS DRAIN OPERATIONS. DURING LH FILL THE VALVE WILL ALLOW A FLOW RATE OF 3000 GPM AT -423°F AN INLET PRESSURE OF 27 PSIA, REVERSE FLOW CAPABILITY IS 1850 GPM AT A PRESSURE OF 26 PSIA.

11.1.6.2 LH2 FILL AND DRAIN VALVE DISCONNECT ASSEMBLY

THE FILL AND DRAIN VALVE DISCONNECT ASSEMBLY CONSISTS OF TWO MATING UNITS. ONE UNIT IS ATTACHED TO THE STAGE, AND THE OTHER IS ATTACHED TO THE GROUND SUPPORT EQUIPMENT. THE MATING UNIT ATTACHED TO THE GSE IS CAPABLE OF AXIAL MOTION TO PERMIT EASY COUPLING. THE MATING SEAL IS LOCATED ON THE AIRBORNE HALF OF THE DISCONNECT ASSEMBLY. MATING IS ACCOMPLISHED BY MANUAL MECHANICAL FORCE. ASSURANCE OF A FULLY CONNECTED AND SEALED CONDITION IS PROVIDED BY A VISUAL INDICATION. THE DISCONNECT ASSEMBLY IS AUTOMATICALLY DISCONNECTED AT TIME OF LIFTOFF. ON THE GSE SIDE OF THE ASSEMBLY IS THE LH2 DEBRIS VALVE WHICH IS CONTROLLED BY THE ESE AS SHOWN IN FIGURE 11-4.

11.1.7

GH₂ START BOTTLE

THE INTEGRAL HYDROGEN-HELIUM START BOTTLE CONSISTS OF A 4.2 CUBIC FOOT SPHERE FOR HYDROGEN WITH A 1,000 CUBIC INCH SPHERE FOR HELIUM LOCATED WITHIN IT. GASEOUS HYDROGEN STORED UNDER PRESSURE IN THE HYDROGEN START TANK PROVIDES THE ENERGY SOURCE FOR STARTING THE ENGINE. HELIUM STORED UNDER PRESSURE IN THE HELIUM TANK IS USED TO SUPPLY PNEUMATIC PRESSURE TO THE ENGINE CONTROL SYSTEM. BOTH THE HYDROGEN START TANK AND THE HELIUM TANK ARE FILLED FROM A GROUND SOURCE. THE START TANK IS INSULATED TO PREVENT EXCESSIVE INTERNAL PRESSURE BUILDUP CAUSED BY EXTERNAL TEMPERATURES. DURING ENGINE OPERATION, GASEOUS HYDROGEN IS BLED FROM THE THRUST CHAMBER FUEL INJECTION MANIFOLD AND LIQUID HYDROGEN IS BLED FROM THE AUGMENTED SPARK IGNITER FUEL LINE TO REFILL THE START TANK FOR ENGINE RESTART. A CHECK VALVE AND AN ORIFICE ARE INSTALLED IN THE LIQUID REFILL LINE TO PREVENT REVERSE FLOW AND TO CONTROL TEMPERATURE CONDITIONS IN THE START TANK.

THE START BOTTLE IS FILLED WITH COLD GH₂ FROM THE HEAT EXCHANGER CONSOLE CIRCUIT NO. 1. A SCHEMATIC SHOWING THE REDLINE MEASUREMENTS AND BASIC FILL CIRCUIT IS FIGURE 11-5.

11.2

CRITICAL MEASUREMENTS

THE REDLINE MEASUREMENTS ANALYZED IN THIS SECTION OF THE F.I.G. ARE:

(A)	XC0003-403	TEMP. LH ₂ PUMP INLET
(B)	VXC0006-401	TEMP - GH ₂ START BOTTLE
(C)	VXD0014-403	PRESS. CONTROL HELIUM REG. DISCHARGE
(D)	VXD0017-401	PRESS. - GH ₂ START BOTTLE
(E)	XD0576-408	PRESS. - LH ₂ TANK ULLAGE
(F)	VXF0005-404	FLOW RATE - FUEL CIRCULATION PUMP

ALL THESE MEASUREMENTS AND BACK-UPS (IF EXISTING) ARE SHOWN ON A REFERENCE SCHEMATICS FOR EACH SYSTEM WITH EXCEPTION TO VXD0014 WHICH IS SHOWN ON THE O₂/H₂ BURNER VALVE CONTROL DRAWING. EACH MEASUREMENT AND ITS CRITICALITY IS DISCUSSED IN THE SUBSEQUENT PARAGRAPHS. FAULT ISOLATION FLOW GRAPHS USING THESE MEASUREMENTS AS STARTING POINTS ARE INCLUDED AT THE END OF SECTION 11.0.

11.2.1

MEASUREMENT XC003-403

THIS MEASUREMENT MEASURES THE LH₂ TEMPERATURE FLOWING THROUGH THE BLEED VALVE DURING CHILLDOWN AND THE MEASUREMENT POINT IS DOWNSTREAM OF THE LH₂ PUMP. THIS MEASUREMENT IS USED IN CONJUNCTION WITH XD0576-408 (FUEL TANK ULLAGE PRESSURE) TO DETERMINE THAT PROPER PROPELLANT CONDITIONS EXIST AT THE FUEL PUMP INLET. THESE CONDITIONS ARE SPECIFIED TO ASSURE A QUALITY OF PROPELLANT THAT WILL RESULT IN SATISFACTORY NET POSITIVE SUCTION HEAD AT ENGINE START. OUT OF SPECIFICATION CONDITION COULD CAUSE LH CHILLDOWN PUMP CAVITATION AND ASSOCIATED OFF-DESIGN PERFORMANCE OF THE J2 ENGINE.

11.2.2

MEASUREMENT VXC0006-401

THIS MEASUREMENT (GH₂ START BOTTLE TEMPERATURE) IS USED IN CONJUNCTION WITH THE START BOTTLE PRESSURE MEASUREMENT VXD0017-401. THESE TWO PARAMETERS INDICATE THAT THE ENERGY LEVEL OF TURBINE START SYSTEM IS AS SPECIFIED BY THE ENGINE MANUFACTURER. A LOW TEMPERATURE IN CONJUNCTION WITH HIGH PRESSURE COULD GIVE HIGH MASS AND ENERGY AND CONSEQUENTLY HIGH LOX PUMP DISCHARGE PRESSURE (AS COMPARED TO THE FUEL PUMP DISCHARGE PRESSURE) AND RESULT IN LOX RICH GAS GENERATOR PRESSURE WHICH COULD RESULT IN HIGH GAS GENERATOR TEMPERATURE. THE HIGHER TEMPERATURE IN CONJUNCTION WITH LOW PRESSURE WILL GIVE LOW MASS AND LOW ENERGY TO START TURBINES.

11.2.3 MEASUREMENT VXD0014-403

THIS MEASUREMENT MONITORS THE ACTUATION PRESSURE SUPPLIED TO ALL PNEUMATICALLY OPERATED STAGE VALVES AND THE J2 ENGINE START TANK VENT VALVE AS WELL AS PURGE HELIUM TO THE J2 TURBO PUMPS AND LOX CHILLDOWN PUMP. THE PNEUMATIC SYSTEM COMPONENTS COULD BE DAMAGED IF THE PNEUMATIC PRESSURE BECOMES EXCESSIVE AND CAUSE EVENTUAL LOSS OF CONTROL HELIUM. PROPER OPERATION OF THE PNEUMATIC POWER CONTROL MODULE IS DETERMINED BY OBSERVING THIS MEASUREMENT WHICH IS LOCATED AT THE OUTLET OF THE PLENUM DOWNSTREAM OF THE PNEUMATIC POWER CONTROL MODULE.

11.2.4 MEASUREMENT VXD0017-401

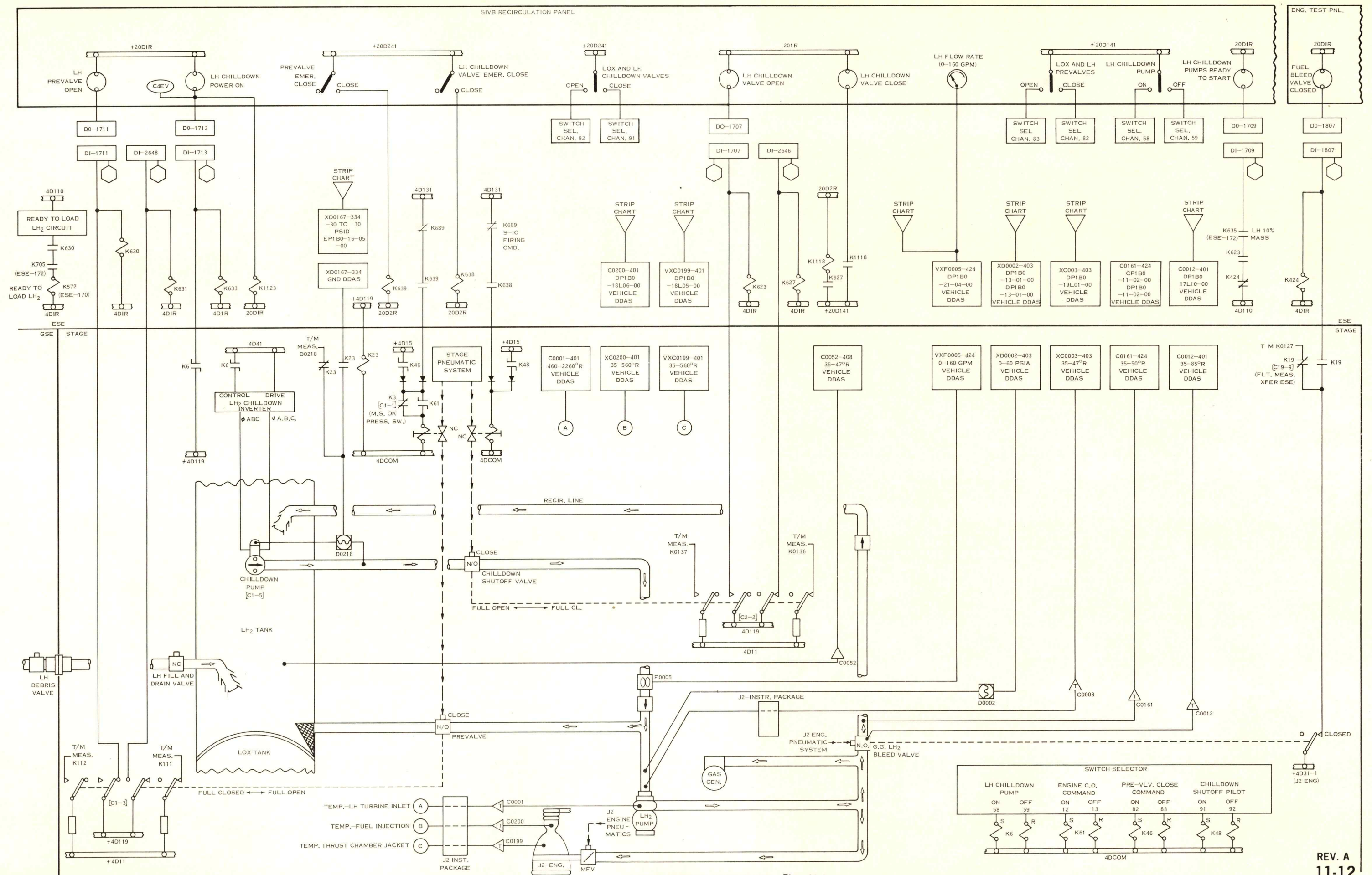
THIS MEASUREMENT INDICATES THE PRESSURE OF THE GH_2 IN THE J2 ENGINE START BOTTLE. ITS CRITICALITY HAS BEEN DISCUSSED IN PARAGRAPH 11.2.2.

11.2.5 MEASUREMENT XD0576-408

THE LH_2 TANK ULLAGE PRESSURE IS MONITORED BY MEASUREMENT XD0576-408. THIS PARAMETER IS ESSENTIAL BECAUSE USED IN CONJUNCTION WITH XD0003-403 (LH_2 PUMP INLET TEMP.) TO ASSURE SATISFACTORY ENGINE START AND REQUIRED NPSH DURING BURN. POSSIBLE ENGINE PUMP CAVITATION AND ASSOCIATED OFF-DESIGN PERFORMANCE COULD RESULT IF THE FUEL ULLAGE PRESSURE IS NOT WITHIN THE REQUIRED LIMITS. ULLAGE PRESSURE RATHER THAN PUMP INLET PRESSURE WAS CHOSEN AS A REDLINE BECAUSE THE ULLAGE PRESSURE CONDITIONS AT PRE-LIFTOFF ARE SIMILAR TO PUMP INLET PRESSURE AT ENGINE START AND VARIATIONS DUE TO LH_2 CHILLDOWN PUMP ΔP ARE DIFFICULT TO TRANSLATE INTO PUMP INLET CONDITIONS PRIOR TO LIFTOFF.

11.2.6 MEASUREMENT VXF0005-404

THIS MEASUREMENT INDICATES THE FLOWRATE OF THE LH DOWNSTREAM OF THE CHILLDOWN SHUTOFF VALVE. PROPER RECIRCULATION OF THE LH DURING CHILLDOWN IS REQUIRED TO MEET THE ENGINE REQUIREMENTS DISCUSSED IN THE PROCEEDING PARAGRAPHS. A FAILURE IN THE RECIRCULATION SYSTEM WILL BE DETECTABLE IN THIS MEASUREMENT.



FUEL SYSTEM CHILLDOWN Fig. 11-1

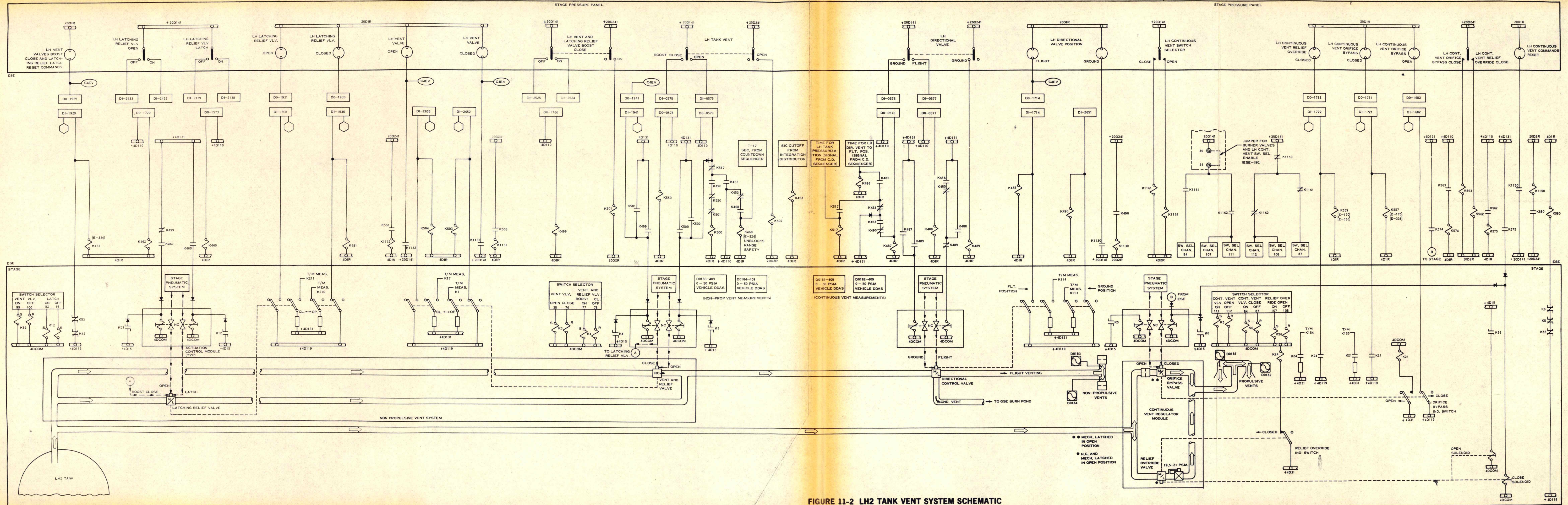
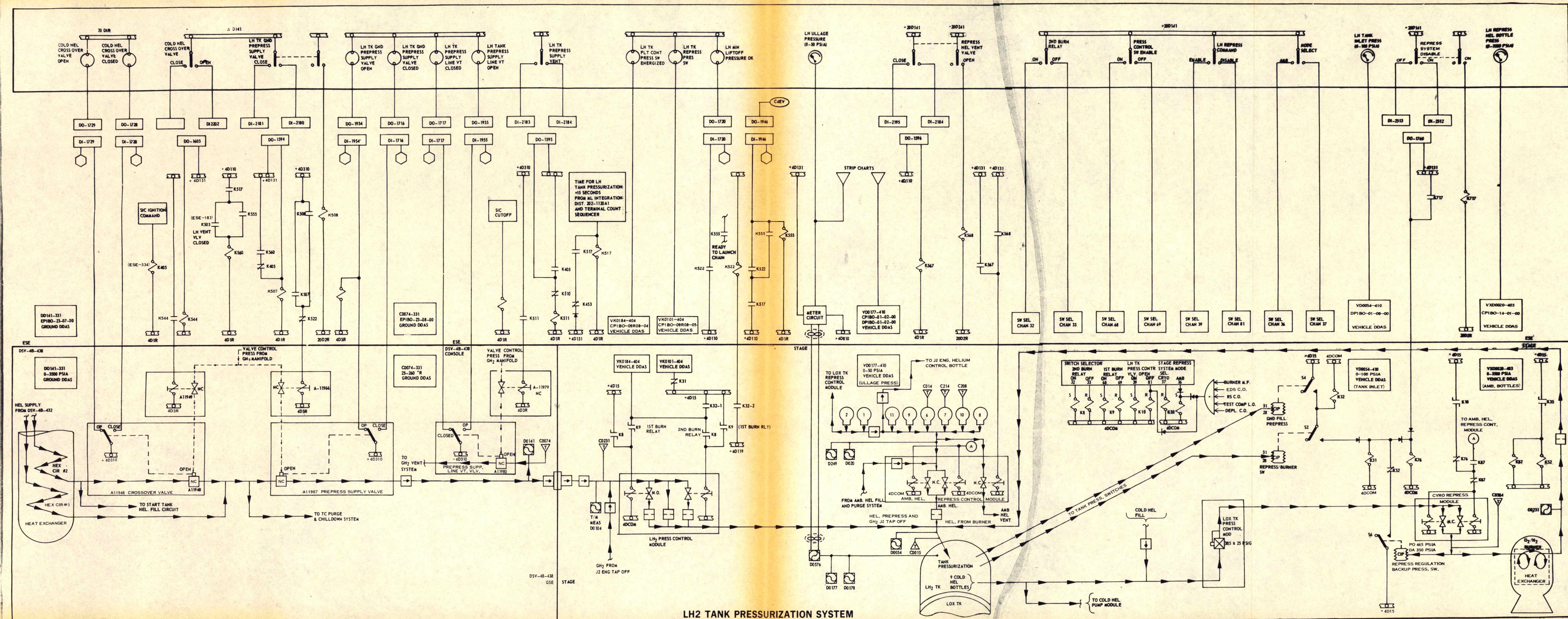


FIGURE 11-2 LH2 TANK VENT SYSTEM SCHEMATIC



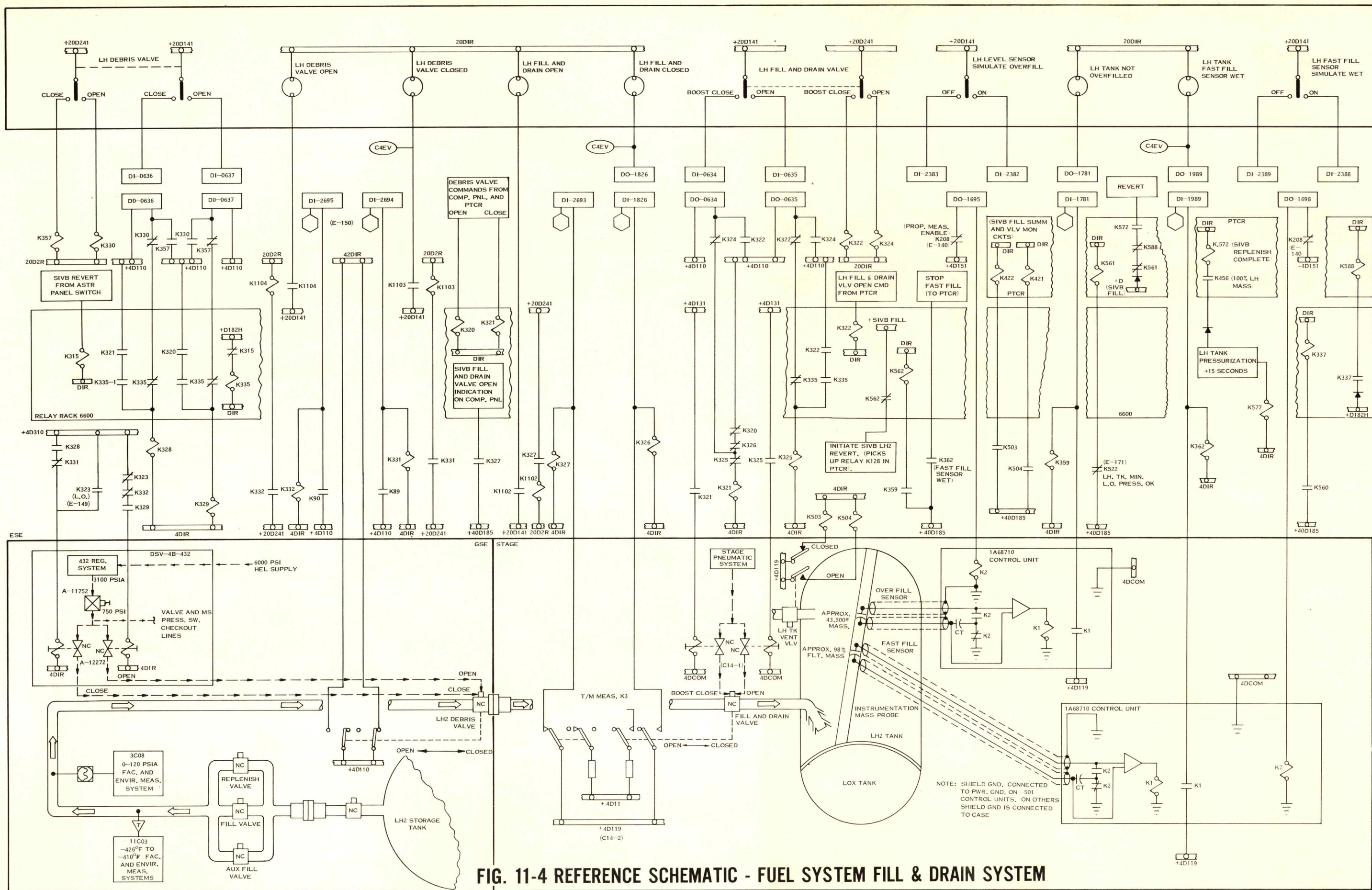
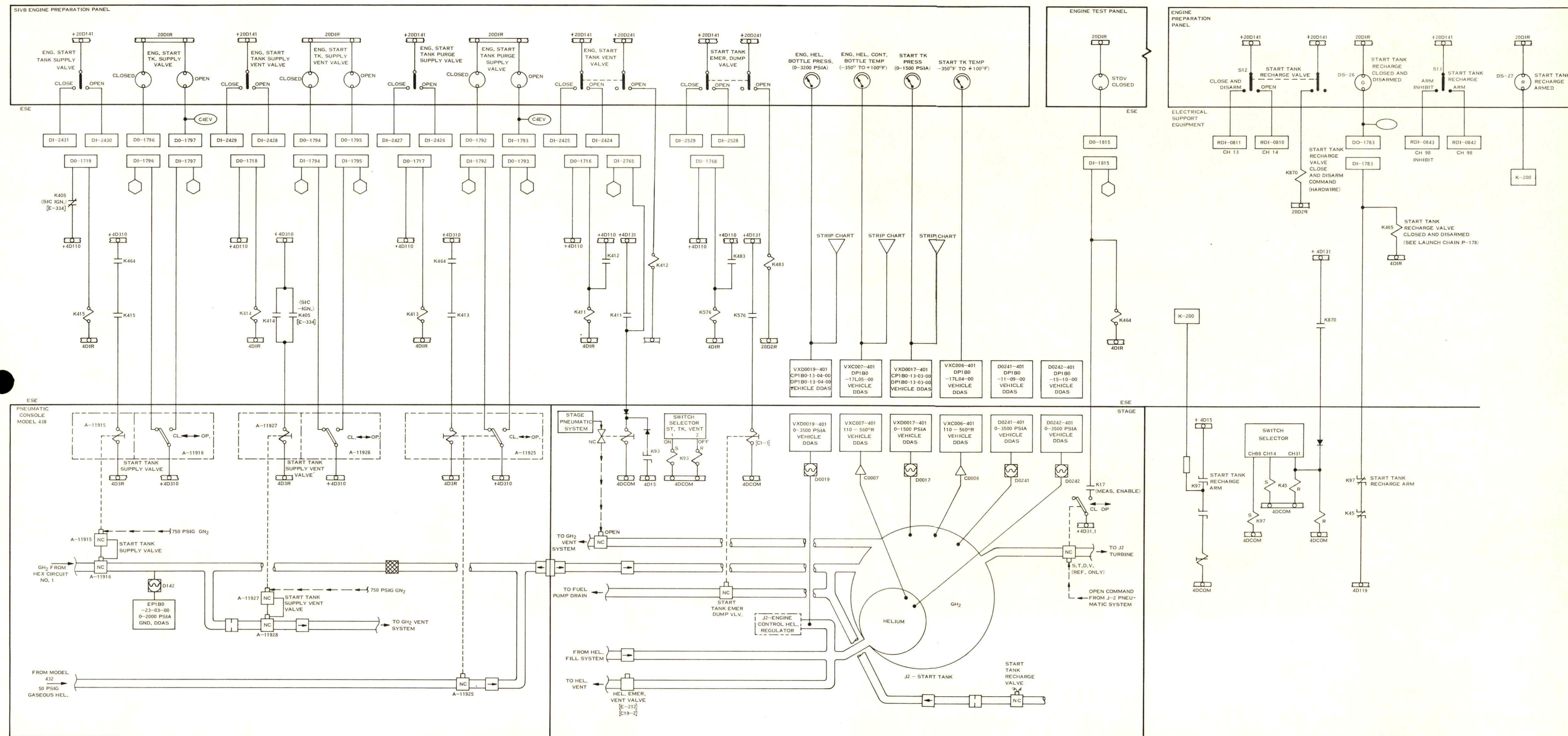


FIG. 11-4 REFERENCE SCHEMATIC - FUEL SYSTEM FILL & DRAIN SYSTEM



FUEL SYSTEM GH2 START BOTTLE Fig. 11-5

12.0
12.1
12.1.1

J-2 ENGINE
SYSTEM DESCRIPTION
GENERAL

THE S-IVB STAGE DERIVES ITS MAIN PROPULSIVE FORCE FROM A SINGLE ROCKETDYNE J-2 ENGINE. THE J-2 ENGINE (FIGURE 12-1) IS A HIGH PERFORMANCE MULTIPLE RESTART ENGINE UTILIZING LIQUID OXYGEN (LOX) AND LIQUID HYDROGEN (LH₂) AS PROPELLANTS. THE ONLY SUBSTANCES USED IN THE ENGINE ARE PROPELLANTS AND HELIUM GAS. THE EXTREMELY LOW OPERATING TEMPERATURE OF THE ENGINE PROHIBITS THE USE OF LUBRICANTS OR OTHER FLUIDS. THE ENGINE FEATURES A SINGLE TUBULAR WALLED, BELL-SHAPED THRUST CHAMBER, AND TWO INDEPENDENTLY DRIVEN, DIRECT DRIVE TURBOPUMPS FOR THE LOX AND LH₂. A HIGH SPEED, DIRECT DRIVE POWER TAKEOFF IS PROVIDED AT THE LOX TURBOPUMP TURBINE WHICH SERVES AS THE MAIN SOURCE OF POWER TO THE S-IVB HYDRAULIC SYSTEM.

BOTH THE LOX AND LH₂ TURBOPUMPS ARE POWERED IN SERIES BY A SINGLE GAS GENERATOR WHICH UTILIZES THE SAME PROPELLANTS AS THE THRUST CHAMBER.

PROPELLANT UTILIZATION (PU) IS OBTAINED FROM BYPASSING LOX FROM THE DISCHARGE SIDE OF THE TURBOPUMP TO THE INLET SIDE THROUGH A VALVE MRCV DRIVEN BY A PNEUMATIC ACTUATOR. THE MRCV VALVE HAS THE CAPABILITY OF VARYING THE ENGINE MIXTURE RATIO (EMR) FROM A NOMINAL VALVE OF 5.0:1 RATIO, LOX-TO-LH₂, TO A MINIMUM OF 4.5:1. THE MRCV 5.0/1 AND 4.5/1 EMR CAN VARY THE NOMINAL THRUST OF 200,000 POUNDS BY APPROXIMATELY 10 PER CENT.

A PNEUMATIC CONTROL SYSTEM CONSISTING OF A 1000 CUBIC INCH ENGINE MOUNTED TANK FILLED WITH GROUND SUPPLIED HELIUM AND A REGULATOR ASSEMBLY ARE USED FOR ENGINE VALVE OPERATION AND CERTAIN PURGES DURING FLIGHT. ANY ENGINE VALVE SEQUENCING PERFORMED PRIOR TO FLIGHT IS ACCOMPLISHED WITH A MINIMUM TANK SUPPLY PRESSURE OF APPROXIMATELY 1450 PSIA.

A RECHARGEABLE, ENGINE-MOUNTED, GASEOUS HYDROGEN (GH₂) START TANK FILLED WITH APPROXIMATELY 1250 PSIA GROUND SUPPLIED GH₂ PROVIDES THE ENERGY SOURCE FOR INITIAL TURBOPUMP SPIN DURING ENGINE START.

AN ELECTRICAL CONTROL ASSEMBLY (ECA) CONTAINING SOLID STATE LOGIC ELEMENTS IS USED TO SEQUENCE THE START AND SHUTDOWN OPERATIONS OF THE ENGINE. ELECTRICAL POWER FOR THIS ASSEMBLY IS DERIVED FROM AFT BUS NO. 1 (+4D11) IN THE STAGE AND IS SUPPLIED TO THE ENGINE THROUGH A MOTOR-DRIVEN SWITCH.

A HEAT EXCHANGER LOCATED IN THE LOX TURBINE EXHAUST DUCT PROVIDES FOR HELIUM PRESSURANT GAS HEATING TO THE VEHICLE LOX TANK. GASEOUS HYDROGEN TAPPED FROM THE THRUST CHAMBER FUEL INJECTION MANIFOLD IS UTILIZED FOR LH₂ TANK PRESSURIZATION.

12.1.2
12.1.2.1

FUNCTIONAL DESCRIPTION OF MAJOR J-2 ENGINE HARDWARE COMPONENTS
THRUST CHAMBER

THE THRUST CHAMBER INCLUDES THE TUBULAR BELL AND INJECTOR ASSEMBLY WHERE THE MAIN LH₂ AND LOX PROPELLANTS ARE ATOMIZED, MIXED AND BURNED TO PRODUCE THRUST FOR VEHICLE PROPULSION. MOUNTED ON THE INJECTOR IS THE AUGMENTED SPARK IGNITER WHICH PROVIDES THE INITIAL COMBUSTION FOR START.

THE BELL NOZZLE ACTS AS A HEAT EXCHANGER WHICH PROVIDES GASEOUS HYDROGEN FOR THE INJECTOR AND LH₂ PRESSURIZATION. THE HEAT ABSORBED BY THE HYDROGEN KEEPS THE NOZZLE COOL DURING ENGINE OPERATION. ENGINE CHAMBER PRESSURE RANGES FROM 590 TO 810 PSIA DURING MAINSTAGE OPERATION.

12.1.2.2

PROPELLANT FEED SYSTEM

THE MAJOR COMPONENTS IN THE PROPELLANT FEED SYSTEM ARE MADE UP OF THE LOX AND LH2 TURBO PUMPS, MAIN ENGINE VALVES, FLOWMETERS AND BLEED VALVES. THE SYSTEM TRANSFERS AND CONTROLS LOX AND LH2 FROM THE PROPELLANT TANKS TO THE THRUST CHAMBER AND THE GAS GENERATOR.

LOX

THE OXIDIZER TURBO PUMP IS A SINGLE-STAGE CENTRIFUGAL PUMP POWERED BY DIRECT TURBINE DRIVE. THE OXIDIZER PROPELLANT IS DISCHARGED AT A PRESSURE AND TEMPERATURE OF 850 TO 1,000 PSIA AND 168 TO 176 DEG R. PROPELLANT IS BYPASSED AROUND THE OXIDIZER TURBO PUMP THROUGH THE MRCV. THE FLOW THROUGH THIS VALVE VARIES FROM 85 TO 185 LB/SEC LOX WHICH CONTROLS THE ENGINE MIXTURE RATIO BETWEEN 5.0 TO 4.5 EMR UNITS. THE VALVE POSITION IS GOVERNED BY THE RATIO OF LOX AND LH2 IN THE TANK AS MEASURED BY THE PU SYSTEM.

THE LOX FLOWMETER IS LOCATED DOWNSTREAM OF THE PUMP DISCHARGE AND PRIOR TO THE GAS GENERATOR TAP-OFF AND MEASURES THE OXIDIZER FLOWRATE IN GALLONS PER MINUTE. CALCULATION OF THE PROPELLANT MASS FLOWRATE IS DETERMINED AS A FUNCTION OF PROPELLANT DENSITIES.

THE MAIN LOX VALVE IS LOCATED DOWNSTREAM OF THE GAS GENERATOR TAP-OFF. THE MOVEMENT OF THE MAIN LOX VALVE IS PRECISELY CONTROLLED BY THE MAIN OXIDIZER CONTROL ACTUATOR IN ORDER TO PROVIDE A SUCCESSFUL START OF THE J-2 ENGINE.

MAINSTAGE PRESSURE SWITCHES WHICH ARE LOCATED AT THE LOX INJECTOR PROVIDE A SIGNAL TO THE S-IVB IU (PICKUP AT 490 ± 30 PSIA, DROPOUT AT 425 ± 25 PSIA). DROPOUT OF BOTH SWITCHES DURING MAINSTAGE OPERATION WILL AUTOMATICALLY INITIATE AN ENGINE GENERATED CUTOFF.

LH2

THE LH2 TURBO PUMP IS A TURBINE-DRIVEN, AXIAL FLOW PUMP CONSISTING OF AN INDUCER AND A SEVEN-STAGE ROTOR AND STARTER ASSEMBLY. THE LH2 PROPELLANT IS DISCHARGED AT A PRESSURE AND TEMPERATURE OF 1,050 TO 1,250 PSIA AND 50 TO 55 DEG. R.

THE LH2 FLOWMETER IS LOCATED DOWNSTREAM OF THE PUMP DISCHARGE FOLLOWING THE GAS GENERATOR TAP-OFF AND MEASURES IN GALLONS PER MINUTE. LOCAL DENSITY CALCULATION IS NECESSARY IN ORDER TO CONVERT TO UNITS OF MASS FLOW.

THE MAIN LH2 VALVE IS LOCATED BETWEEN THE LH2 FLOWMETER AND THE ENGINE THRUST CHAMBER. IT IS A FAST ACTING BUTTERFLY TYPE VALVE WHICH IS ORIFICED TO OPEN FAST (100 MS) AND CLOSE SLOW (225 MS) GUARANTEEING AN LH2 RICH CUTOFF.

12.1.2.3

GAS GENERATOR

PROPELLANTS ARE FED TO THE GAS GENERATOR FROM THE LOX AND LH2 TAP-OFFS OF THE RESPECTIVE PUMP DISCHARGES THROUGH THE GAS GENERATOR CONTROL VALVE. THIS VALVE IS MECHANICALLY CONSTRUCTED TO PROVIDE LH2 PRIOR TO INTRODUCING LOX TO THE CHAMBER THUS PREVENTING A LOX RICH START UNDER NORMAL OPERATING CONDITIONS. THE GAS GENERATOR OPERATES IN AN LH2 RICH MIXTURE RATIO OF APPROXIMATELY 1.1 WITH NORMAL OPERATING PRESSURES AND TEMPERATURES OF 500 TO 750 PSIA AND 1,340 TO 1,760 DEG R. THE MAXIMUM ALLOWABLE TEMPERATURE IN THE GAS GENERATOR AREA IS APPROXIMATELY 2,650 DEG R.

THE HIGH ENERGY GASES FROM THE GAS GENERATOR ARE FED DIRECTLY TO THE LH2 PUMP TURBINE. THE LH2 TURBINE IS A TWO-STAGE DESIGN WHICH EXTRACTS ENOUGH POWER TO DRIVE THE LH2 TURBO PUMP. NORMAL TURBO PUMP SPEEDS RANGE FROM 26,500 TO 28,500 RPM. LH2 TURBINE DISCHARGE PRESSURES AND TEMPERATURES RANGE FROM 75 TO 90 PSIA AND 1,010 TO 1,310 DEG R.

12.1.2.4 LOX TURBINE

THE LOX TURBINE BYPASS VALVE IS LOCATED DOWNSTREAM OF THE LH2 TURBINE AND IS NORMALLY CLOSED DURING MAINSTAGE OPERATION. ITS MAIN FUNCTION IS TO PROVIDE EXTRA BYPASS OF THE LH2 TURBINE EXHAUST GASES AROUND THE LOX TURBINE IN ORDER TO PREVENT A LOX SYSTEM OVERSPEED DURING THE START TRANSIENT. THE VALVE CLOSURES AS THE DEMAND FOR POWER AT THE LOX PUMP INCREASES. HOWEVER, EVEN WHEN CLOSED THE VALVE ALLOWS A CERTAIN AMOUNT OF GASES TO BE BYPASSED THROUGH A NOZZLE WHOSE SIZE IS DETERMINED DURING THE ENGINE CALIBRATION AND ESTABLISHES THE CORRECT POWER MATCH BETWEEN THE LH2 AND LOX TURBOPUMP SYSTEMS.

THE TWO-STAGE LOX TURBO PUMP TURBINE EXTRACTS THE REQUIRED POWER TO OPERATE THE LOX TURBO PUMP AND THE AUXILIARY HYDRAULIC PUMP WHICH IS ATTACHED TO THE NECESSARY DRIVE PAD. THE LOX TURBO PUMP SPEED RANGES FROM 8,000 TO 9,500 RPM DURING NORMAL OPERATION. THE TURBINE DISCHARGES GAS AT PRESSURES AND TEMPERATURES OF 27 TO 40 PSIA AND 1,000 TO 1,200 DEG R TO THE ENGINE HEAT EXCHANGER WHICH HEATS THE LOX TANK HELIUM PRESSURANT GAS. THE TURBINE EXHAUST GASES DISCHARGE DIRECTLY INTO THE THRUST CHAMBER BELL DOWNSTREAM OF THE THROAT.

12.2 CRITICAL MEASUREMENTS

12.2.1 GENERAL

THERE ARE A TOTAL OF SIX REDLINE MEASUREMENTS ASSOCIATED WITH THE J-2 ENGINE. ONLY TWO OF THESE MEASUREMENTS, A TEMPERATURE AND AN EVENT, ARE CONSIDERED IN THIS SECTION. THE REMAINING MEASUREMENTS ARE DISCUSSED IN OTHER APPLICABLE SECTIONS OF THIS DOCUMENT.

FAULT ISOLATION FLOW CHARTS AND ASSOCIATED SYSTEM SCHEMATICS FOR BOTH MEASUREMENTS HAVE BEEN GENERATED AND ARE PRESENTED IN THIS SECTION. THEY CAN BE USED AS AIDS IN ANY TROUBLESHOOTING EFFORT THAT MAY BE ENCOUNTERED AS A RESULT OF A REDLINE VIOLATION INDICATED BY THE MEASUREMENTS.

IT IS REALIZED THAT THE FLOW CHARTS OFFER ONLY ONE APPROACH TO ISOLATING THE PROBLEM, BUT THEY HAVE BEEN PREPARED IN THE ABSENCE OF COUNTDOWN ANXIETIES AND IT IS FELT THAT THE PRE-PLANNED EFFORT INHERENT IN THE FLOW CHARTS DOES PRESENT A DIRECT AND SYSTEMATIC APPROACH TO ISOLATING THE PROBLEM QUICKLY AND EFFICIENTLY.

12.2.2 REDLINE MEASUREMENTS

XVC0199-401 THRUST CHAMBER JACKET TEMPERATURE (FIGURE 12-2 AND 12-3)

THE TRANSDUCER FOR MEASUREMENT C0199 IS LOCATED ON THE THRUST CHAMBER JACKET, HAS A RANGE OF -4250 TO +100° F, AND IS INTENDED TO PROVIDE DATA FOR PURPOSES OF DETERMINING THAT PRE-LIFTOFF THRUST CHAMBER CHILLDOWN REQUIREMENTS HAVE BEEN MET. THRUST CHAMBER PRE-CONDITIONING OR CHILLDOWN IS ACCOMPLISHED BY FLOWING COLD HELIUM FROM GSE FACILITIES INTO THE FUEL MANIFOLD DOWNSTREAM OF THE MAIN FUEL VALVE, THROUGH THE THRUST CHAMBER TUBES AND EXITING AT THE FUEL INJECTOR FACE. MEASUREMENT C0199 IS MONITORED FROM THE START OF THRUST CHAMBER CHILLDOWN AT APPROXIMATELY T-10 MINUTES UNTIL T-11 SECONDS.

REDLINE LIMITS FOR C0199 HAVE BEEN ESTABLISHED FOR TWO DISTINCT PERIODS DURING THE COUNTDOWN. AT THE BEGINNING OF IAS MEASUREMENT C0199 SHOULD INDICATE A READING OF NO GREATER THAN 355°R AND SHOULD HAVE A DECREASING TREND. AT T-19 SECONDS C0199 SHOULD READ NO GREATER THAN 300°R AND SHOULD MAINTAIN THE DECREASING TREND. C0199 IS DISPLAYED ON A FIRING ROOM STRIP CHART AND ALSO ON A PANEL METER. MEASUREMENT C0200, FUEL INJECTOR TEMPERATURE, HAS BEEN DESIGNATED THE REDLINE BACKUP FOR C0199 AND IS ALSO ON A FIRING ROOM STRIP CHART FOR EASY CORRELATION. DUE TO THE PHYSICAL LOCATION OF C0200, READINGS WILL BE APPROXIMATELY 8-10% LOWER THAN C0199. THE OVERALL SYSTEM SCHEMATIC FOR C0199 IS PRESENTED IN FIGURE 12-2. THE FAULT ISOLATION ROUTINE FLOW CHART IS ILLUSTRATED IN FIGURE 12-3.

VXK0013-401 ENGINE CUTOFF LOCKIN (FIGURE 12-4 AND 12-5)

IF THE ENGINE IS NOT IN A "READY" CONDITION AND AN ENGINE CUTOFF (C/O) SIGNAL IS RECEIVED, THE CUTOFF BUS (+K164) WILL BE ENERGIZED AND A "LOCKIN" CIRCUIT WILL BE TURNED ON. THIS ENGINE C/O LOCKIN CIRCUIT WILL MAINTAIN THE CUTOFF BUS IN AN ENERGIZED STATE AFTER THE CUTOFF SIGNAL HAS BEEN REMOVED. MEASUREMENT K0013 PROVIDES AN INDICATION THAT THE C/O LOCKIN CIRCUIT IS TURNED ON. WHEN ALL PRE-START REQUIREMENTS FOR THE ENGINE HAVE BEEN MET, AN "ENGINE READY" CONDITION IS GENERATED IN THE FORM OF AN ELECTRICAL SIGNAL. THIS SIGNAL IS USED AS AN INHIBIT INPUT TO THE CUTOFF LOCKIN CIRCUIT AND WHEN PRESENT WILL TURN OFF THE LOCKIN CIRCUIT, OR, IF THE LOCKIN CIRCUIT IS NOT ON, IT WILL PREVENT A LOCKIN CONDITION FROM OCCURRING IF A CUTOFF SIGNAL WAS INTENTIONALLY OR UNINTENTIONALLY ISSUED. SINCE THE ENGINE READY SIGNAL IS CAPABLE OF UNLOCKING THE C/O LOCKIN CIRCUIT, IT CAN BE CONSIDERED A CUTOFF-RESET FUNCTION AND CAN BE USED FOR THIS PURPOSE ON ENGINES REQUIRING RESTART.

FOR REASONS OF SAFETY, A CUTOFF COMMAND IS ISSUED TO THE S-IVB STAGE PRIOR TO LIFTOFF AND IS MAINTAINED THROUGH POWERED FLIGHT UNTIL JUST PRIOR TO S-IVB ENGINE START. ALTHOUGH THE CUTOFF COMMAND IS PRESENT AND THE CUTOFF BUS IS ENERGIZED, AN ENGINE READY CONDITION SHOULD EXIST PROHIBITING THE LOCKIN CIRCUIT FROM BECOMING ENERGIZED, I.E., K0013 SHOULD BE OFF. AT APPROXIMATELY T-35 MINUTES ENGINE CONTROL POWER IS TURN ON AND AN ENGINE CUTOFF IS ISSUED. AT THIS POINT, THE ENGINE CUTOFF LOCKIN INDICATION SHOULD BE ON AND WILL BE DISPLAYED ON A PANEL LIGHT AS WELL AS AN EVENT PEN ON A RECORDER IN ROW D. IN THE EVENT THIS INDICATION IS NOT RECEIVED, IMMEDIATE TROUBLESHOOTING WOULD BE REQUIRED. AFTER A NORMAL INDICATION HAS BEEN RECEIVED, ENGINE IGNITION POWER WILL BE TURNED ON AND AN ENGINE READY INDICATION SHOULD BE GENERATED. AS PREVIOUSLY DISCUSSED, K0013 SHOULD GO OFF AT THIS TIME AND THE REDLINE MONITORING REQUIREMENTS FOR THIS MEASUREMENT WOULD BEGIN. SHOULD THIS MEASUREMENT TURN ON AFTER THIS SEQUENCE HAS BEEN PERFORMED BUT PRIOR TO T-11 SECONDS, THE COUNT WILL BE INTERRUPTED AND TROUBLESHOOTING INITIATED. THE J-2 ENGINE SYSTEM SCHEMATICS OF FIGURE 12-4 AND THE FAULT ISOLATION DIAGRAM FOR MEASUREMENT K0013 ILLUSTRATED IN FIGURE 12-5 MAY BE USED AS AIDS IN THE TROUBLESHOOTING EFFORT. A DETAILED SCHEMATIC OF THE ENGINE CUTOFF CIRCUIT HAS BEEN PREPARED (REFERENCE FIGURE 12-6) AND ILLUSTRATES ONLY THAT PORTION OF THE CIRCUITRY NECESSARY FOR DETAILED FAULT ANALYSIS OF THIS CIRCUIT SHOULD THE NEED ARISE.

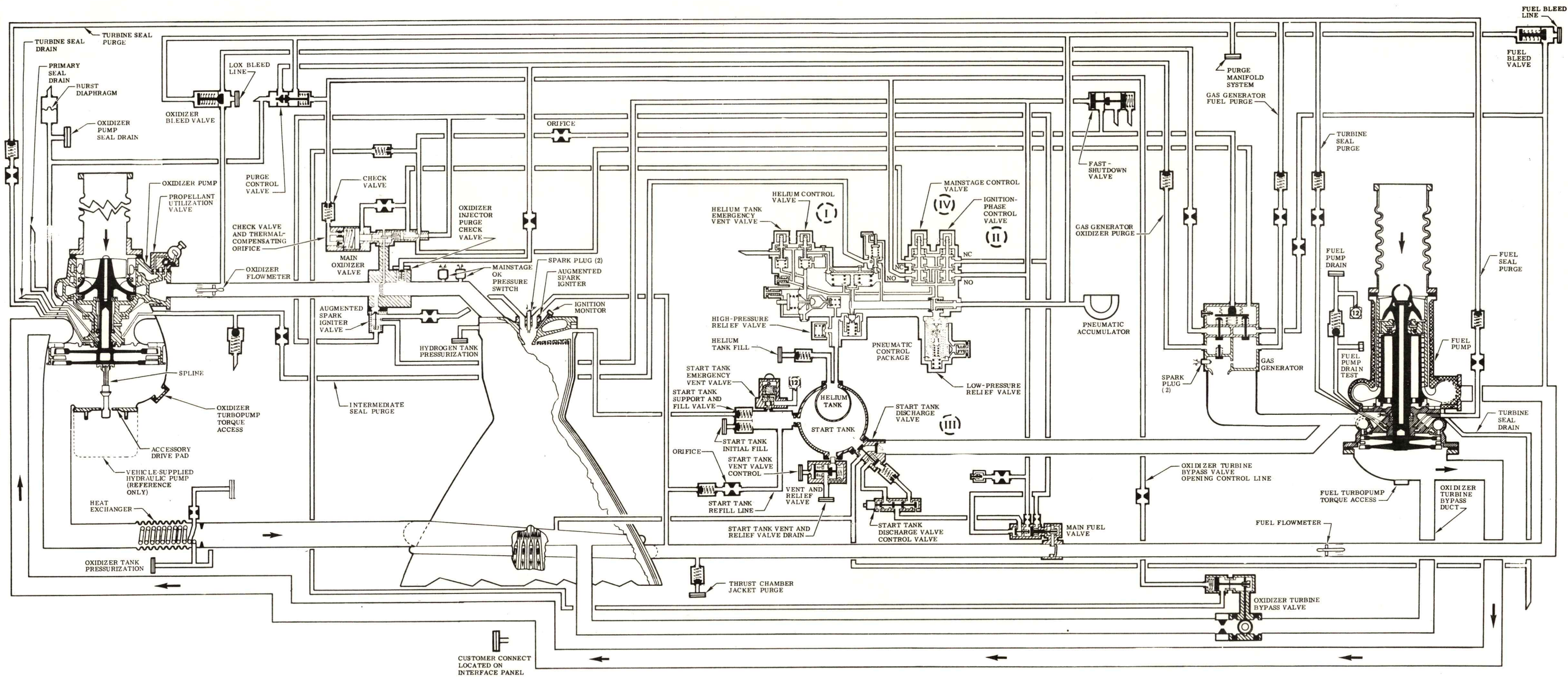


FIGURE 12-1 ENGINE SCHEMATIC

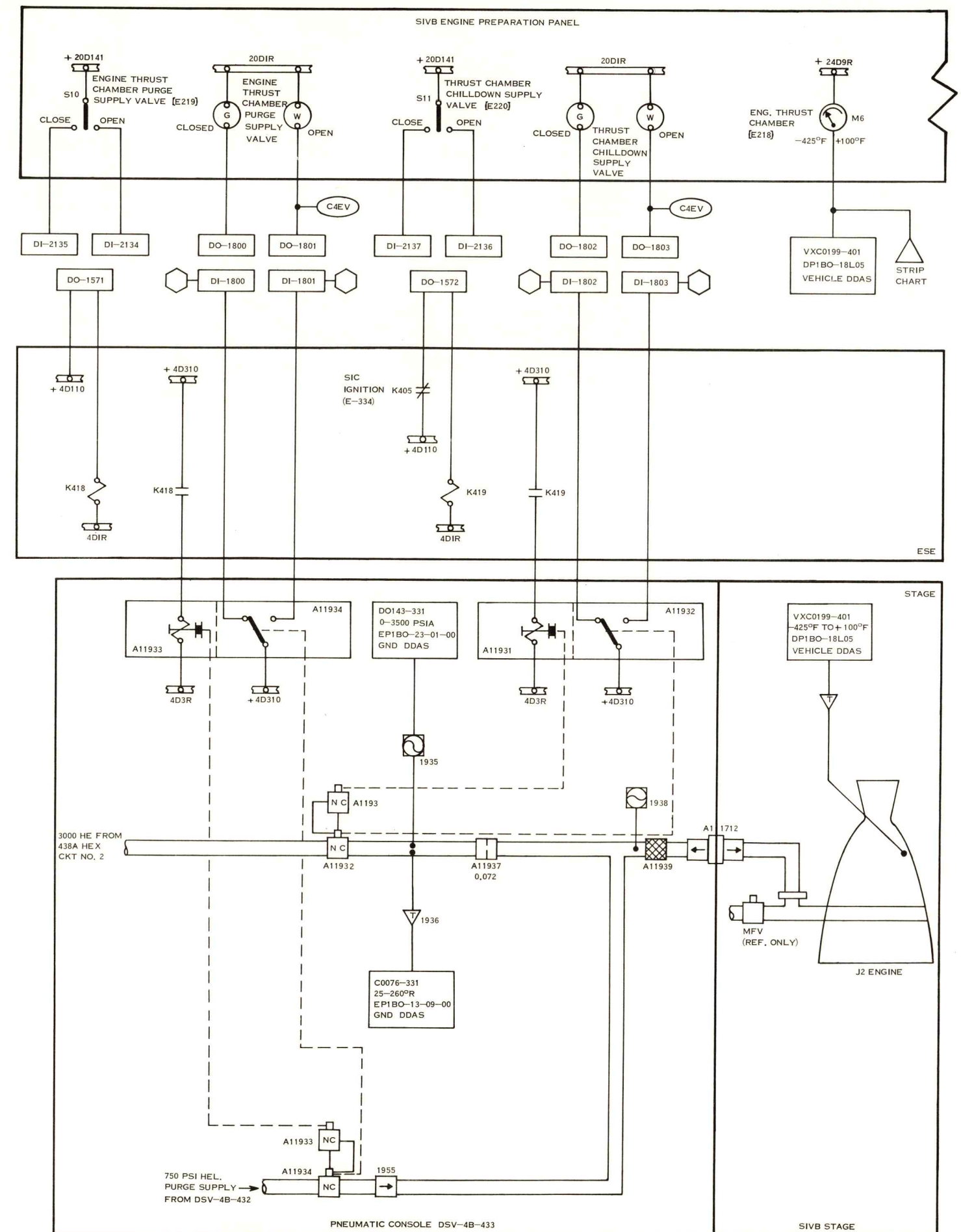


FIGURE 12-2 SCHEMATIC THRUST CHAMBER CHILLDOWN

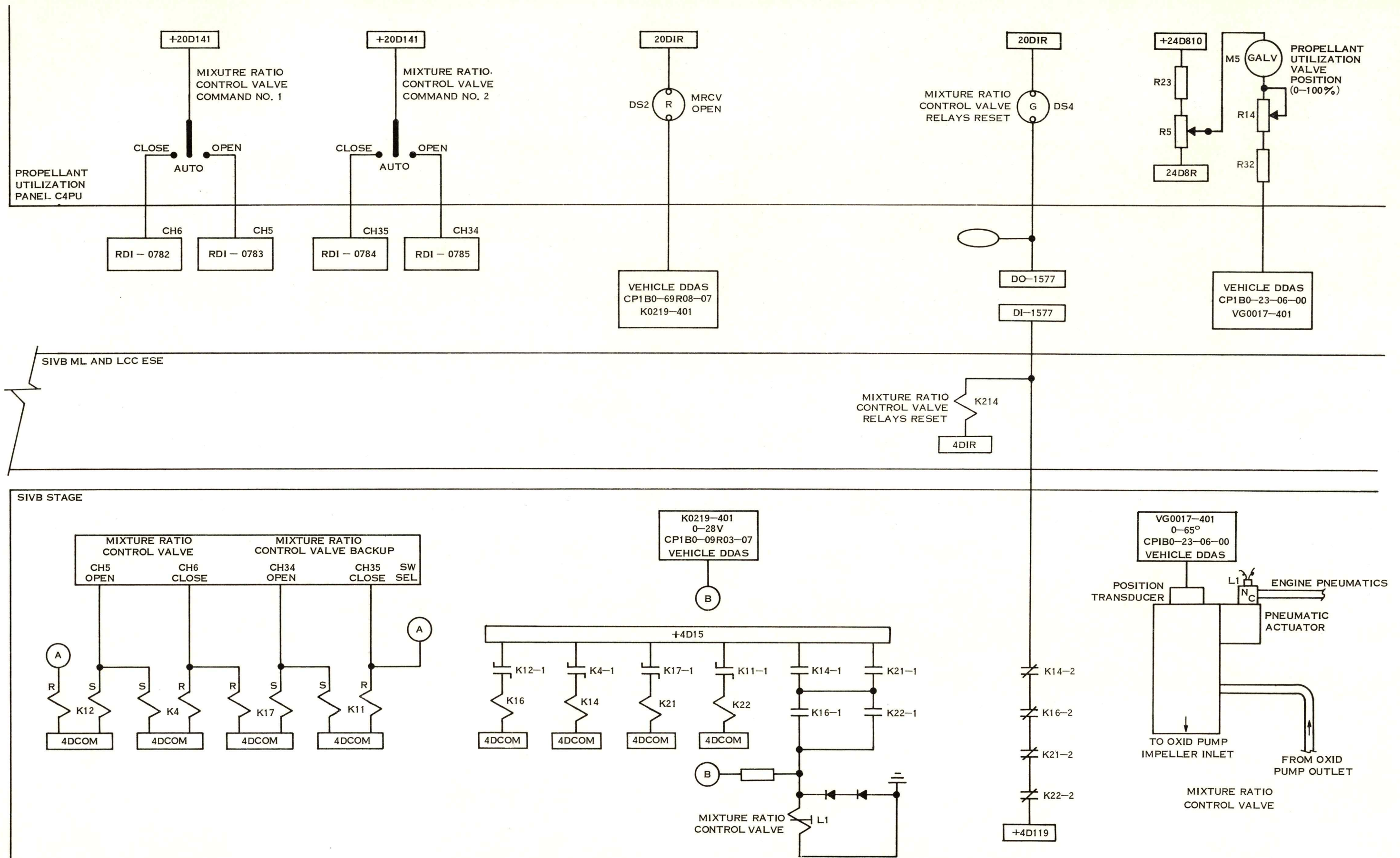


FIGURE 12-4 MIXTURE RATIO CONTROL VALVE SYSTEM SCHEMATIC (Sheet 2 of 4)

A41-911A



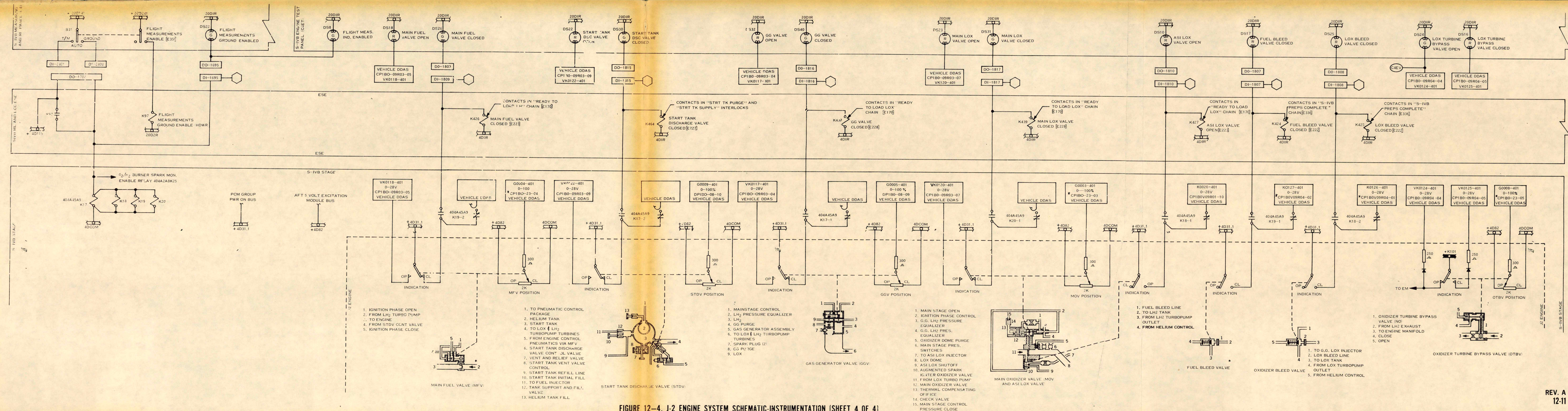
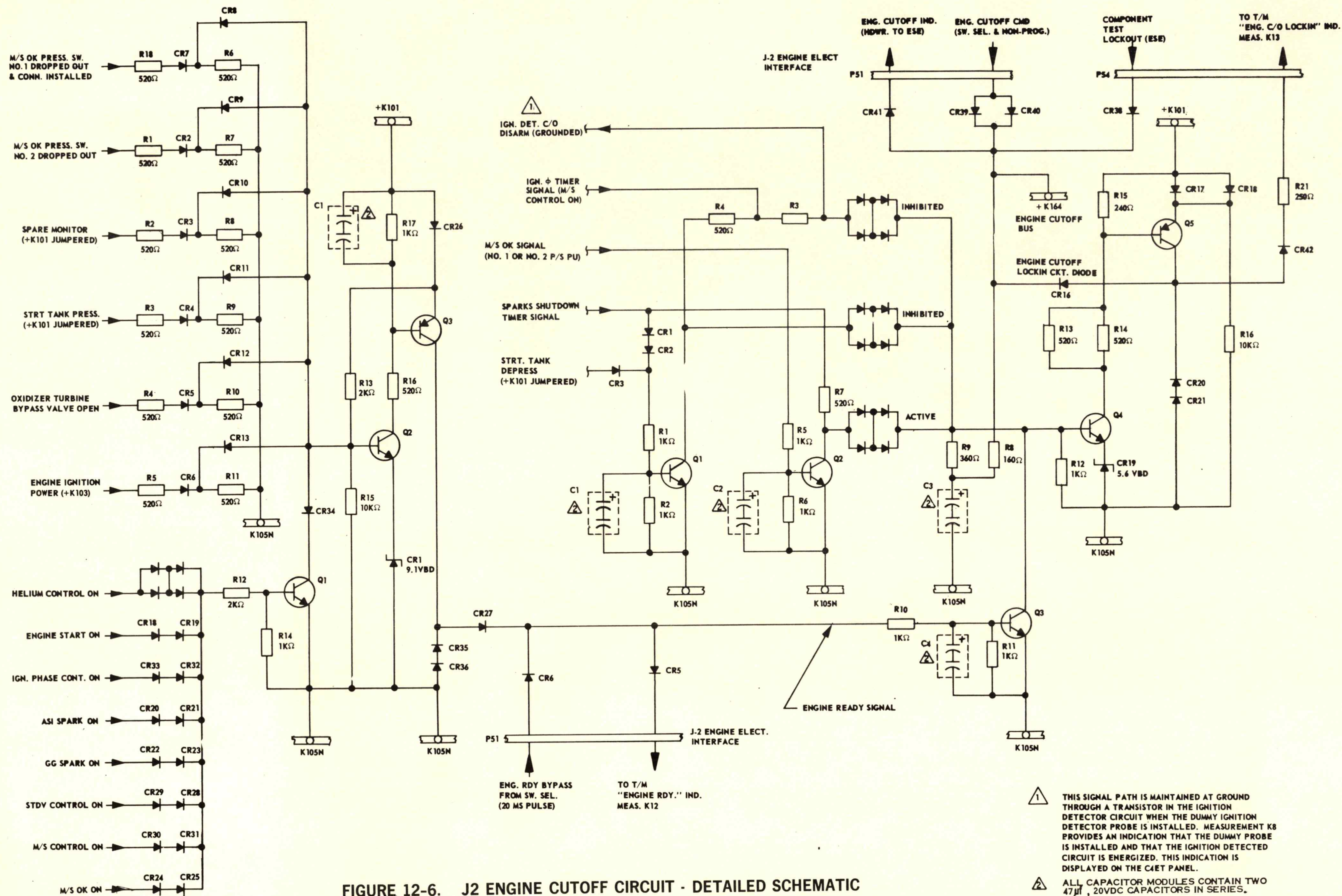


FIGURE 12-4. J-2 ENGINE SYSTEM SCHEMATIC-INSTRUMENTATION (SHEET 4 OF 4)



13.0 HYDRAULIC SYSTEM
13.1 SYSTEM DESCRIPTION
13.1.1 GENERAL

THE SIVB HYDRAULIC CONTROL SYSTEM CONSISTS OF THE HARDWARE THAT EXECUTES MANEUVERS THAT RESULTS IN CHANGING THE POSITION OF THE SATURN V VEHICLE DURING SIVB POWERED FLIGHT. COMMANDS TO THE CONTROL SYSTEM ARE GENERATED AS FOLLOWS:

DURING FLIGHT, 3 INTEGRATING ACCELEROMETERS MOUNTED ON A GYRO STABILIZED STABLE PLATFORM (LOCATED IN THE IU WITH BACKUP ON APOLLO CAPSULE) MEASURES THE 3 VELOCITY COMPONENTS RESULTING FROM VEHICLE PROPULSION. THESE SIGNALS ARE SUMMED TOGETHER WITH THE PROGRAMMED GUIDANCE SIGNALS BY THE IU LAUNCH VEHICLE DATA ADAPTER AND THEN COMBINED WITH RATE GYRO INFORMATION FURNISHED BY THIS IU CONTROL SIGNAL PROCESSOR. THE COMBINED SIGNALS ARE THE YAW AND PITCH COMMANDS GENERATED BY THE IU FLIGHT CONTROL COMPUTER. THESE COMMANDS ARE ROUTED TO THE SIVB, HYDRAULIC SYSTEM PITCH AND YAW ACTUATORS. THE ACTUATORS POSITION THE J2 ENGINE PROPORTIONALLY ACCORDING TO THE COMMANDS RECEIVED THUS PROVIDING THRUST VECTOR STEERING OF THE VEHICLE.

DURING GROUND CHECKOUT, LAUNCH OPERATIONS, AND DURING SIVB COAST PERIODS; THE HYDRAULIC CONTROL SYSTEM ENABLES THE ENGINES TO BE PROPERLY CENTERED OR ALLOWS ENGINE GIMBALLING TO PREDETERMINED POSITIONS DURING TESTS.

13.1.2 HYDRAULIC CONTROL SYSTEM COMPONENTS

THE HYDRAULIC SYSTEMS HARDWARE LOCATED ON THE SIVB STAGE CONSISTS OF 4 MAJOR COMPONENTS. THEY ARE THE ENGINE DRIVEN PUMP, AND THE AUXILIARY HYDRAULIC PUMP (AHP), THE ACCUMULATOR RESERVOIR, AND 2 ACTUATORS, WHICH CONTAIN 2 SERVO CONTROL VALVES.

13.1.2.1 ENGINE DRIVEN PUMP

THE ENGINE DRIVEN PUMP SUPPLIES HYDRAULIC PRESSURE FOR POSITIONING THE ACTUATORS DURING ENGINE BURN OPERATION ONLY. THE PUMP IS MOUNTED ON THE LOX TURBINE GAS COLLECTOR DOME AND IS MECHANICALLY POWERED BY THE TURBINE SHAFT.

IT IS A YOKE TYPE VARIABLE DELIVERY PUMP RATED AT 8 gpm AT 8000 rpm AND OFFERS HIGH EFFICIENCY EVEN UNDER VERY LOW DELIVERY OPERATING CONDITIONS.

13.1.2.2 AUXILIARY HYDRAULIC PUMP (AHP)

THE AHP IS A FIXED ANGLE, VARIABLE DELIVERY PUMP RATED AT 1.5 gpm AT A FULL LOAD SPEED OF 10,200 rpm. THE AHP IS DRIVEN BY A 56 VDC MOTOR AND PROVIDES HYDRAULIC PRESSURE THAT AUGMENTS THE ENGINE DRIVEN PUMP DURING SIVB POWERED FLIGHT AND IS THE ONLY SOURCE OF HYDRAULIC PRESSURE DURING UNPOWERED FLIGHT AND GROUND CHECKOUT. DURING THESE TIMES, THE AHP TOGETHER WITH THE POWER STORAGE CAPABILITY OF THE ACCUMULATOR ALLOWS ONLY LIMITED ACTUATOR RESPONSES TO BE MADE. FULL RANGE TESTS DURING VEHICLE TESTS REQUIRES THE USE OF A HYDRAULIC SERVICER (A3 OR A45 ONLY). THE AHP IS TURNED ON BEFORE LIFTOFF AND IS OPERATED CONTINUOUSLY DURING BOOST.

13.1.2.3 ACCUMULATOR - RESERVOIR

THE ACCUMULATOR RESERVOIR STORES THE HYDRAULIC SYSTEM FLUID AND DAMPS OUT PRESSURE SURGES IN THE SYSTEM CAUSED BY PUMP START/ STOP, OR ACTUATOR DEMANDS. DAMPING IS ACCOMPLISHED BY THE ACCUMULATOR PISTON. THIS PISTON IS BALANCED BY PRESSURIZED NITROGEN ON ONE SIDE AND HIGH PRESSURE OIL ON THE OTHER. PRESSURE INCREASES IN THE HYDRAULIC FLUID FURTHER COMPRESS THE NITROGEN THUS ABSORBING PRESSURE SURGES. THE PRESSURIZED NITROGEN ALSO EXERTS PRESSURE ON THE RESERVOIR PISTON THUS PROVIDING INITIAL PRESSURE HEAD TO THE HYDRAULIC PUMPS THEREBY PREVENTING PUMP CAVITATION AT AHP START.

13.1.2.4 ACTUATORS

TWO ACTUATORS (PITCH AND YAW) LOCATED 90 DEGREES APART WITH RESPECT TO THE LONGITUDINAL SIVB AXIS IS THE POWER CONTROL UNIT FOR CONVERTING ELECTRICAL COMMAND SIGNALS AND HYDRAULIC POWER INTO MECHANICAL OUTPUTS. BY EITHER EXTENDING OR RETRACTING INDEPENDENTLY OF EACH OTHER, THE ACTUATORS ENABLE POSITIONING OF THE J2 ENGINE THUS PROVIDING THRUST VECTOR STEERING TO THE DESIRED ATTITUDE TRAJECTORY. THE POSITIONING IS IN RESPONSE TO COMMAND SIGNALS RECEIVED FROM THE GUIDANCE SYSTEM OF THE SATURN V VEHICLE.

13.2 CRITICAL MEASUREMENTS

13.2.1 GENERAL

DURING LAUNCH COUNTDOWN, 8 OF THE 16 HYDRAULIC SYSTEM MEASUREMENTS (16 ON 503 AND 14 ON 504 AND SUBS) ARE CLASSIFIED AS REDLINE MEASUREMENTS. FOR THESE 8 PARAMETERS, TROUBLESHOOTING FLOWCHARTS HAVE BEEN PREPARED AND ARE TO BE USED AS AIDS IN SYSTEM-ATICALLY ISOLATING THE CAUSE OF REDLINE VIOLATIONS.

13.2.2. REDLINE MEASUREMENTS

13.2.2.1 D-41 PRESS-HYDRAULIC SYSTEM

MEASUREMENT D41 IS A REDLINE PARAMETER WHENEVER THE AHP IS OPERATIVE. PRESSURE READINGS IN EXCESS OF ITS ALLOWABLE REDLINE LIMITS MAY BE SYMPTOMATIC OF SERIOUS LEAKAGE PROBLEMS OR PUMP PROBLEMS THAT MAY RESULT IN MISSION FAILURE. THE PRESSURE TRANSDUCER FOR THE MEASUREMENT IS LOCATED IN THE OIL SECTION OF THE ACCUMULATOR. WHENEVER THE AHP IS ENERGIZED, D41 INCREASES TO THE ACCUMULATOR GN2 PRECHARGE OF 2350 PSIA IMMEDIATELY AND INCREASES TO ITS NORMAL OPERATING PRESSURE OF 3515 TO 3665 PSIA. REDLINE VALUES ARE 3400 (MIN) AND 3750 PSIA (MAX). WHEN THE AHP IS DE-ENERGIZED, D41 DECREASES AT A CONSTANT RATE TO THE GN2 PRE-CHARGE VALUE IN 1 MINUTE OR LESS, THEN DROPS INSTANTLY BELOW 1500 PSIA DUE TO THE PRESSURE TRANSDUCER'S RANGE LIMITATIONS. THE RESERVOIR OIL PRESSURE D42 IS A FUNCTION OF D41 (SYSTEM OIL PRESS.) AS FOLLOWS: $D41 = D42 \times 21.6$.

13.2.2.2 D-42 PRESSURE - RESERVOIR OIL

MEASUREMENT D42 GIVES AN INDICATION OF THE RETURN HYDRAULIC OIL PRESSURE. REDLINE VALUES ARE APPLICABLE WHENEVER THE AHP IS OFF. REDLINE VALUES ARE NOT APPLICABLE WHEN THE AHP IS ON BECAUSE D41 (SYSTEM PRESSURE) PROVIDES THE INDICATIONS FOR HYDRAULIC OIL PRESSURE WHEN THE AHP IS ON. SINCE D42 IS A FUNCTION D43 WHEN THE PUMPS ARE OFF, PRESSURE WILL NORMALLY REMAIN ABOVE 73 PSIA. ARE OFF, PRESSURE WILL NOT NORMALLY DECREASE BELOW 73 PSIA. HOWEVER, BECAUSE D43 (GN2 PRESSURE) IS TEMPERATURE DEPENDENT, TEMPERATURE VARIATIONS MAY CAUSE PRESSURE EXCURSIONS IN D42 TO THE MINIMUM REDLINE LIMIT OF 45 PSIA. THE MINIMUM PRESSURE LIMIT WITH AHP OFF WAS ESTABLISHED TO INSURE ADEQUATE PRESSURE TO PREVENT CAVITATION OF THE AHP AT PUMP START AND ALSO TO INSURE A USABLE GN2 ACCUMULATOR PRECHARGE.

13.2.2.3 L-7 LEVEL RESERVOIR OIL

MEASUREMENT L7 PROVIDES INDICATION OF THE RESERVOIR OIL LEVEL. A LOW INDICATION MAY INDICATE FLUID LEAKAGE AND/OR DEPLETION. THE REDLINE IS APPLICABLE WITH PUMPS ON OR OFF. REDLINE VALUES WITH PUMPS ON IS 6% MINIMUM WITH NO MAXIMUM LIMITS. WITH THE AHP OFF, THE REDLINE VALUE IS A FUNCTION OF C51 (RESERVOIR OIL TEMP). DURING PRELAUNCH CONDITIONS THE MEASUREMENT IS STEADY ABOVE 83% (REDLINE LEVEL WITH RESERVOIR OIL TEMP AT 70°F). DURING THERMAL / TEST CYCLES AND AT AHP FLIGHT MODE ON COMMAND, L7 DECREASES TO OPERATING VALUE OF 20 TO 30% . A SLIGHT INCREASE MAY BE SEEN, DUE TO A RISE IN GN2 TEMPERATURE (DECREASING ACCUMULATOR OIL VOLUME) AND ALSO DUE TO FLUID HEATING WITH ATTENDANT EXPANSION.

13.2.2.4 C-50 TEMP, ENG DRIVEN PUMP INLET

THE MINIMUM LIMIT OF -25°F WAS ESTABLISHED TO PREVENT HYDRAULIC OIL SOLIDIFICATION. DURING NORMAL CHECKOUT, A LIMIT OF 160°F IS USED TO PREVENT EXPANSION OF THE HYDRAULIC FLUID THAT WILL RESULT IN VENTING THROUGH RELIEF VALVES OF EXCESSIVE AMOUNTS OF FLUID CAUSING THE RESERVOIR OIL LEVEL TO FALL BELOW AN ACCEPTABLE VOLUME PRIOR TO AHP TURN ON.

DURING PRELAUNCH, C50 IS VARIABLE BETWEEN -20 TO 160°F DEPENDING ON THE INTERSTAGE ENVIRONMENTAL CONDITIONING AND THERMAL TEST CYCLES. THERE IS A STEADY RISE IN TEMPERATURE FROM AHP FLIGHT MODE ON COMMAND THROUGH LIFTOFF.

13.2.2.5 C-51 TEMP, RESERVOIR OIL

C51 IS A REDLINE PARAMETER WHENEVER THE AHP IS INOPERATIVE. ITS REDLINE LIMITS ARE A FUNCTION OF MEASUREMENT L7 (RESERVOIR LEVEL). THE MINIMUM LIMIT WITH THE AHP OFF WAS ESTABLISHED BY ADDING THE ACCUMULATOR OIL VOLUME TO THE MINIMUM LIMIT REQUIRED WITH THE PUMP "ON". MAINTAINING THESE LIMITS GUARDS AGAINST MISSION FAILURE DUE TO EXCESSIVE OIL LEAKAGE AND/OR DEPLETION. C51 REPRESENTS THE TEMPERATURE OF THE LARGEST BULK OF FLUID (APPROXIMATELY ONE THIRD OF THE TOTAL) IN THE SYSTEM WHEN THE PUMPS ARE OFF. IT IS USED TO BIAS THE L7 REDLINE FOR OIL THERMAL EXPANSION PRIOR TO LIFTOFF. WHEN A HYDRAULIC PUMP IS ON, FLUID TENDS TO STRATIFY IN THE RESERVOIR AND BECAUSE THE RESERVOIR STRUCTURAL MASS IS LARGE RELATIVE TO THE FLUID VOLUME, C51 IS NO LONGER AN INDICATION OF SYSTEM FLUID TEMPERATURE AND C50 (TEMP. ENG. DRIVEN PUMP INLET IS USED AS AN INDICATION OF SYSTEM TEMPERATURE.

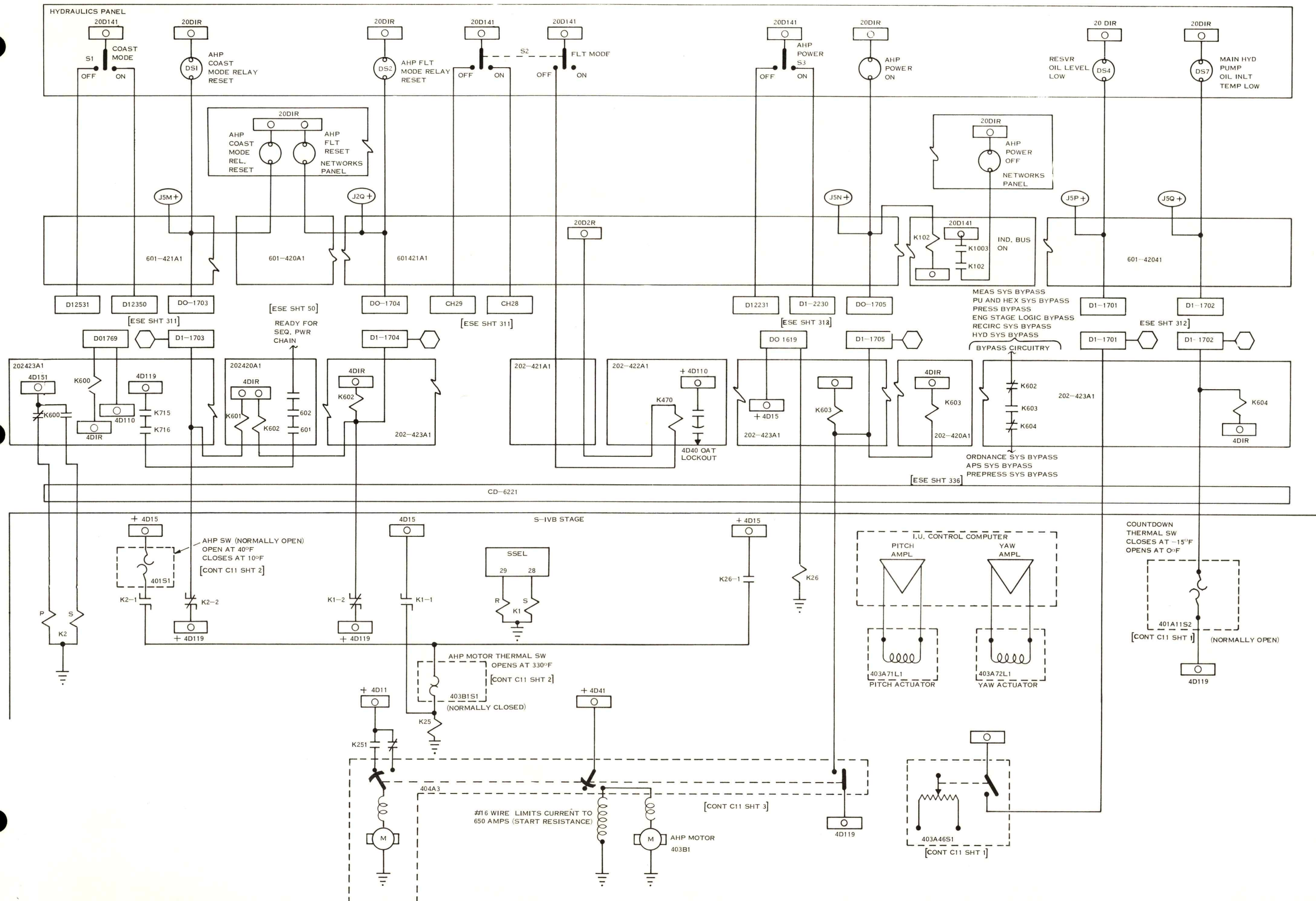
13.2.2.7 G-1 POSITION - ACTUATOR PISTON PITCH PITCH

THE TRANSDUCER FOR MEASUREMENT G1 IS A FEEDBACK POTENTIOMETER LOCATED IN THE ACTUATOR. THE POTENTIOMETER WIPER MOVES WITH THE ACTUATOR PISTON. ACTUATOR ROD LENGTHS ARE ADJUSTED TO OBTAIN READING WITHIN ± 0.5 DEGREE WITH THE J2 ENGINE CENTERED. AS THE ENGINE IS GIMBALLED BY IU COMMANDS, THE POTENTIOMETER MEASURES THE DEGREE OF MOVEMENT BY THE ACTUATOR PISTON AS IT EXTENDS OR RETRACTS. WITH HYDRAULIC SYSTEM PRESSURE (D41) GREATER THAN 1700 PSIA AND WITH A NULL COMMAND TO THE ACTUATOR SERVO VALVE, THE ACTUATOR WILL CENTER ITSELF AUTOMATICALLY. REDLINE LIMITS FOR THE MEASUREMENTS WITH NO I.U. COMMANDS GIVEN ARE 0 ± 1.5 DEGREES. EXCEEDING THIS LIMIT MAY BE AN INDICATION OF A POSSIBLE MALFUNCTION IN THE ACTUATOR SERVO SYSTEM.

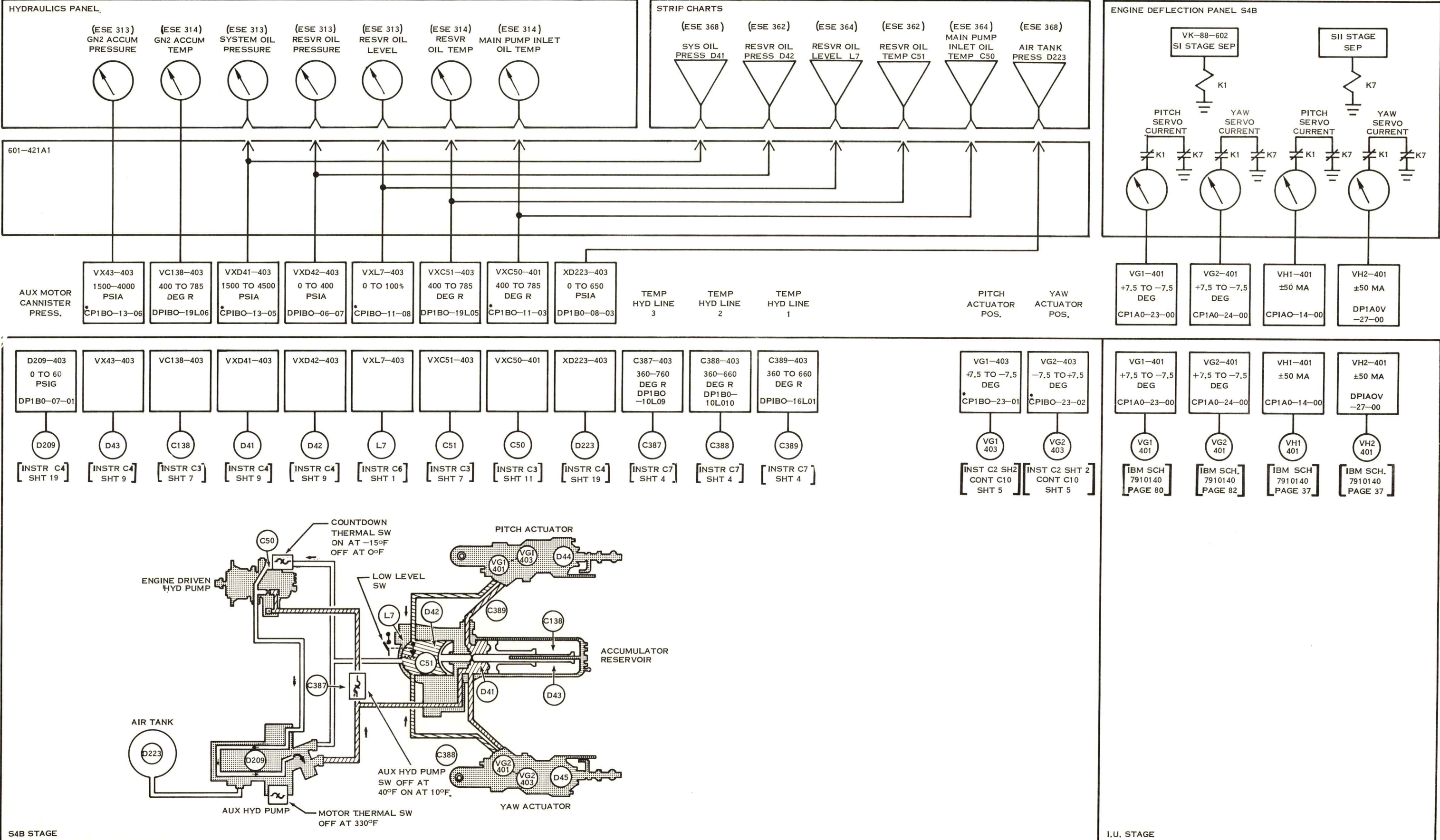
13.2.2.8 G-2 POSITION - ACTUATOR PISTON YAW

DESCRIPTION IN PARAGRAPH 13.2.2.7 APPLIES.

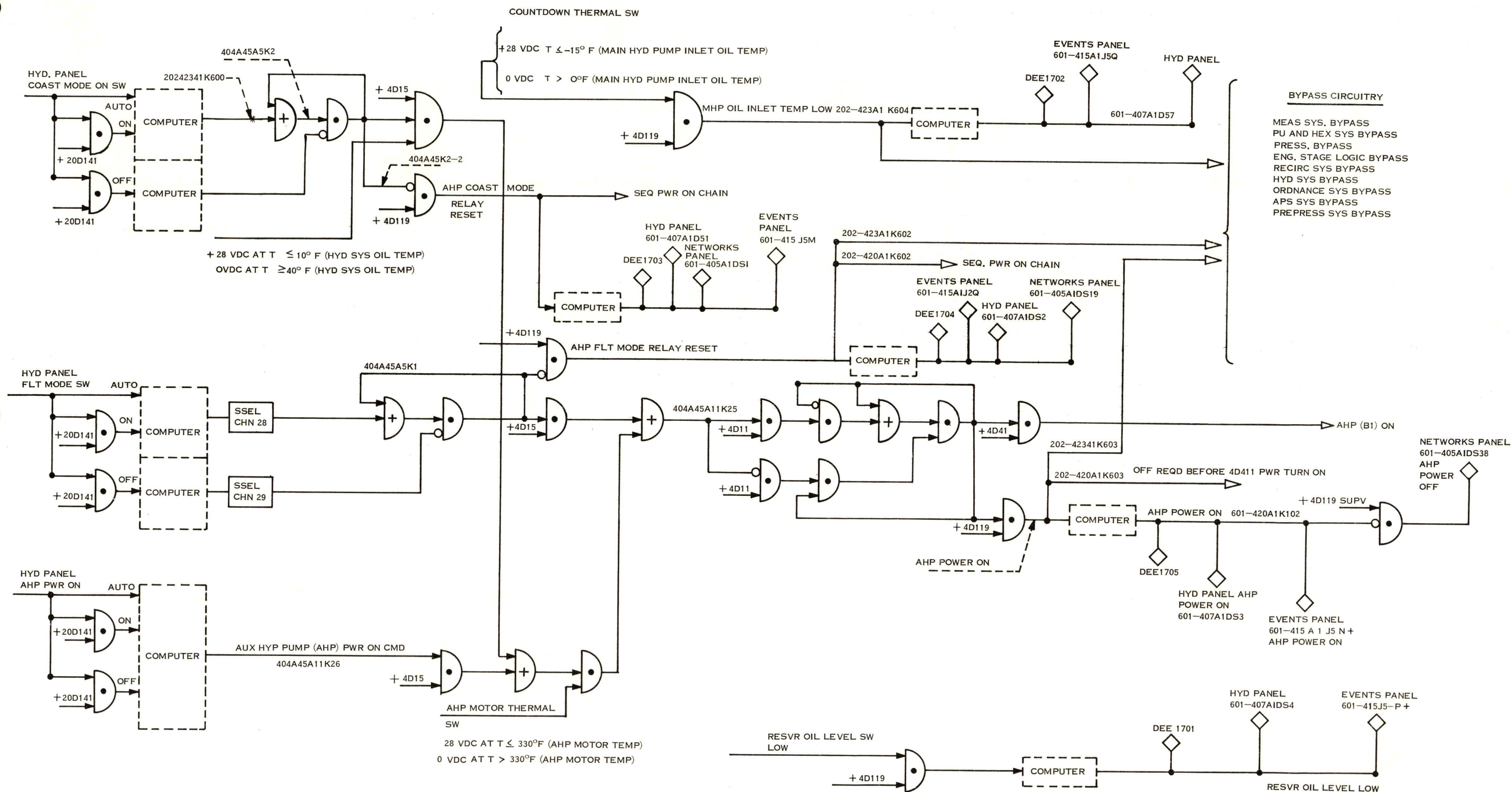
HYDRAULIC SYS CONTROL SCHEMATIC



HYDRAULICS SYSTEM INSTRUMENTATION SCHEMATIC



HYDRAULIC SYSTEM LOGIC DIAGRAM



14.0 AUXILIARY PROPULSION SYSTEM

14.1 SYSTEM DESCRIPTION

I. MECHANICAL

A. GENERAL

THE APS PROVIDES FOR ATTITUDE CONTROL OF THE STAGE DURING ALL OPERATIONAL PHASES OF S-IVB-V FLIGHT. THE SUBSYSTEM ALSO INCORPORATES A PROPELLANT SETTling CAPABILITY REQUIRED FOR ENGINE RESTART AFTER COAST AND FOR DAMPING OF STAGE PROPELLANT TRANSIENTS AT THE END OF THE FIRST J-2 ENGINE BURN AND J-2 ENGINE RESTART AFTER COAST.

SUBSYSTEM COMPONENTS ARE CONTAINED IN TWO SEPARATE MODULES PLACED 180 DEGREES APART ON THE AFT SKIRT. EACH MODULE CONTAINS HYPERGOLIC LIQUID BI-PROPELLANT ENGINES, A POSITIVE EXPULSION PROPELLANT FEED SUBSYSTEM, AND A HELIUM PRESSURIZATION SUBSYSTEM (FIGURES 7 AND 8). THE ENGINE CLUSTER IN EACH MODULE CONSISTS OF THREE 150-POUND ATTITUDE CONTROL ENGINES (ONE FOR PITCH CONTROL AND TWO FOR YAW OR ROLL CONTROL), AND ONE 70-POUND ULLAGE SETTling ENGINE.

THE APS MODULES RECEIVE COMMAND SIGNALS FROM THE IU VIA THE CONTROL RELAY PACKAGE AND PERFORM STAGE FUNCTIONS AS FOLLOWS:

- A. ROLL CONTROL DURING J-2 ENGINE BURN
- B. ATTITUDE STABILIZATION AFTER BURNOUT
- C. MANEUVERING ATTITUDE CONTROL

SIGNALS FROM THE IU VIA THE SWITCH SELECTOR AND THE FLIGHT SEQUENCER PROVIDE PROPELLANT SETTling (FIRST BURN CUTOFF AND SECOND BURN START) CAPABILITY.

THE MODULES ARE SEPARATE DETACHABLE ITEMS AND CAN BE TREATED AS REPLACEABLE UNITS. AS INDIVIDUAL UNITS, EACH MODULE PERMITS CHECKOUT TESTING TO SIMULATE OPERATING PRESSURES EXPECTED DURING FLIGHT.

EACH MODULE CONTAINS ITS OWN PROPELLANT SUPPLY AND PRESSURIZATION SUPPLY. FUEL USED BY THE APS IS MONOMETHYLHYDRAZINE, (MMH-MIL-P-27404). THE OXIDIZER IS NITROGEN TETROXIDE, (N_2O_4 - MIL-P-28539A). FUEL DENSITY IS 54.6 LB/FT³ AT 70° F OXIDIZER DENSITY IS 90.1 LB/FT³ AT 70°F. PROPELLANTS ARE STORED IN TWO SEPARATE TANKS EQUIPPED WITH POSITION EXPULSION BLADDERS FOR PROPELLANT TRANSFER IN "ZERO G" CONDITIONS. REGULATED TRANSFER PRESSURE (APPROXIMATELY 200 PSID) IS SUPPLIED BY A HELIUM SUPPLY TANK.

THE 150 POUND THRUST ENGINES IN THE APS MODULES ARE USED FOR ATTITUDE CONTROL ONLY. TWO 150 POUND THRUST ENGINES IN EACH MODULE CONTROL ROLL AND/OR YAW. ONE 150 POUND THRUST ENGINE IN EACH MODULE IS USED TO CONTROL PITCH. A 70 POUND ENGINE IN EACH MODULE PROVIDES THRUST FOR MAINSTAGE LOX AND LH2 PROPELLANT SETTling DURING COAST. THE IU PROVIDES ALL FIRING COMMANDS. THESE COMMANDS ACTUATE FUEL AND OXIDIZER SOLENOID VALVES TO RELEASE HYPERGOLIC PROPELLANTS TO THE ENGINES.

ROLL DEVIATION IS CORRECTED BY FIRING AN ENGINE IN EACH MODULE, BOTH SIMULTANEOUSLY IN OPPOSITE DIRECTIONS. YAW CORRECTION IS ACCOMPLISHED BY FIRING TWO ENGINES SIMULTANEOUSLY, ONE IN EACH OF THE MODULES, IN THE DIRECTION OPPOSITE THE ERROR. PITCH CORRECTION IS PROVIDED BY FIRING ONE OF THE TWO APS PITCH ENGINES IN THE DIRECTION OPPOSING THE ERROR. FOR PROPELLANT SETTling, THE 70 POUND ENGINE IN EACH MODULE ARE FIRED SIMULTANEOUSLY.

B. APS OPERATION

THE APS MODULES ARE ENABLED IN FLIGHT AFTER THE LOWER STAGE RETROROCKETS HAVE BEEN IGNITED. FIRST COMMAND ACTUATION OF THE APS OCCURS JUST PRIOR TO J-2 ENGINE FIRST BURN START TO PROVIDE STAGE ROLL CONTROL DURING ENGINE BURN. THE SINGLE J-2 ENGINE PERFORMS PITCH AND YAW CONTROL ONLY.

THE OXIDIZER AND FUEL TANKS UTILIZE SEPARATE TEFLON BLADDER MEMBRANES TO CONTAIN THE LIQUIDS AND ENABLES EXPULSION OF PROPELLANT UNDER "ZERO G" CONDITIONS.

HELIUM, INITIALLY FILLED TO 3100 PSIA, IS REGULATED TO 196 ± 3 PSID TO TRANSFER PROPELLANTS FROM EACH PROPELLANT TANK TO THE ENGINE. DURING PROPELLANT FLOW, THE LIQUID PASSES OUT OF EACH TANK THROUGH THE RESPECTIVE STANDPIPE AND ENGINE MANIFOLD FOR INJECTION INTO THE ENGINES ON COMMAND.

COMMANDS FOR ENGINE OPERATION ARE PROVIDED BY THE I.U. OUTPUT FROM A GUIDANCE PLATFORM INDICATING MEASURED VEHICLE ATTITUDE IS RECEIVED BY THE I.U. AND A COMPARISON IS MADE WITH THE DESIRED OR PROGRAMMED ATTITUDE.

IF A DEVIATION EXISTS, THE I.U. GIVES THE REQUIRED COMMANDS VIA THE CONTROL RELAY PACKAGE TO THE APS ENGINE INJECTOR VALVES FOR CORRECTION PROPORTIONAL TO THE MAGNITUDE OF THE DEVIATION. THE ATTITUDE ENGINES ARE NORMALLY OPERATED IN SHORT PULSE TYPE BURSTS OF NOT LESS THAN 0.65 MILLISECONDS. CONTINUOUS ENGINE OPERATION IS POSSIBLE, HOWEVER, LIMITED ONLY BY THE AMOUNT OF FUELS AVAILABLE.

AT J-2 ENGINE FIRST BURN CUTOFF, THE APS PITCH AND YAW CONTROL IS ACTIVATED AND ALL CONTROL (ROLL, PITCH, AND YAW) REMAINS ACTIVE THROUGHOUT THE COAST PHASE. AT J-2 ENGINE RESTART THE PITCH AND YAW MODE IS DE-ACTIVATED.

THE APS ULLAGE (PROPELLANT SETTling) ENGINES (ONE IN EACH MODULE) ARE FIRST ENABLED DURING THE J-2 ENGINE FIRST BURN CUTOFF TRANSIENT TO PREVENT UNDESIRABLE STAGE PROPELLANT MOVEMENT. FIRING CONTINUES FOR APPROXIMATELY 50 SECONDS, THROUGH THE ENGINE CUTOFF TRANSIENT DECAY AND THE ACTIVATION OF THE LH2 TANK PROPULSIVE VENT SYSTEM. THIS CONTINUOUS VENT ASSURES THAT THE LOX AND LH2 STAGE PROPELLANTS ARE MAINTAINED IN A SETTLED AFT POSITION FOR COAST. USE OF THE OXYGEN HYDROGEN BURNER IN THE THRUSTING MODE CAN BE UTILIZED TO AUGMENT THE PROPULSIVE VENT SUBSYSTEM IN MAINTAINING SETTLED PROPELLANTS AS REQUIRED. THE APS ULLAGE ENGINES ARE AGAIN ENERGIZED AT THE END OF COAST PRIOR TO RESTART CHILLDOWN. AT THIS TIME THE PROPULSIVE VENT SUBSYSTEM USED FOR SETTling IS DEACTIVATED AND THE STAGE FUEL TANK IS REPRESSURIZED. PROPELLANT SETTling IS THUS ASSURED THROUGHOUT COAST AND ENGINE RESTART. THE PITCH AND YAW MODE IS RE-ACTIVATED AFTER J-2 ENGINE SECOND BURN CUTOFF TO MAINTAIN ATTITUDE DURING TRANSLUNAR COAST. IT SHOULD BE NOTED THAT PROPELLANT SETTling FOR FIRST BURN START IS PROVIDED BY ULLAGE SOLID ROCKETS.

C. SERVICE OPERATIONS

PRIOR TO NORMAL LAUNCH COUNTDOWN OPERATIONS, EACH MODULE IS SERVICED AND FILLED.

PROPELLANT LOADING IS ACCOMPLISHED THROUGH CONNECTIONS IN THE AFT END OF THE APS MODULE. THE BLADDER, DURING FILLING, MUST BE IN A FULLY EXPANDED POSITION. A DIFFERENTIAL PRESSURE IS MAINTAINED THROUGHOUT THE OPERATION TO ASSURE THAT BLADDER POSITION IS MAINTAINED.

AT THE INITIATION OF FILLING, A RECIRCULATION FLOW IS ALSO ESTABLISHED INTO THE PROPELLANT LINES AND OUT THROUGH THE RECIRCULATION LINES. FILLING IS CONTINUED UNTIL ALL GAS IS EXPELLED FROM THE PROPELLANT SUBSYSTEM. A FILLED TANK AND SUBSYSTEM IS DETERMINED BY MONITORING FOR A GAS FREE FLOW FROM THE RECIRCULATION LINES. WHEN THE TANK AND SUBSYSTEMS ARE TOTALLY FILLED, THE PROPELLANT TANK IS OFF LOADED TO PROVIDE THE REQUIRED ULLAGE VOLUME.

HELIUM IS LOADED INTO THE MODULE THROUGH A PNEUMATIC SERVICE LINE THROUGH THE STAGE "FLY AWAY" UMBILICALS.

D. MAJOR SUBSYSTEMS

1. GENERAL

THE APS MODULE IS COMPRISED OF THREE MAJOR SUBSYSTEMS: HELIUM PRESSURIZATION, POSITIVE EXPULSION PROPELLANT FEED TANKS, AND ENGINES. THE HELIUM PRESSURIZATION SUBSYSTEM SUPPLIES AND REGULATES THE FLOW OF PRESSURIZED HELIUM TO THE ULLAGE SIDE OF THE POSITIVE EXPULSION BLADDER IN THE PROPELLANT TANKAGE. THE POSITIVE EXPULSION BLADDER PROVIDES PROPELLANT (FUEL AND OXIDIZER) AT THE REQUIRED PRESSURES, ON DEMAND, TO THE ENGINES UNDER ZERO OR RANDOM GRAVITY ENVIRONMENTS. THE APS ENGINES PROVIDE THE NECESSARY THRUST FOR ATTITUDE CONTROL AND MANEUVERING OF THE STAGE OR FOR PROPELLANT SETTling. A DESCRIPTION OF EACH OF THESE SUBSYSTEMS AND THEIR RELATED COMPONENTS IS PRESENTED IN THE FOLLOWING PARAGRAPHS.

2. HELIUM PRESSURIZATION

A. GENERAL

THE PRESSURIZATION SUBSYSTEM INITIALLY STORES HELIUM AT A PRESSURE OF 3100 ± 100 PSIG, AND REGULATES THIS PRESSURE THROUGH TWO REGULATORS, FOR PROPELLANT TANK ULLAGE PRESSURIZATION. THESE REGULATORS ARE CONNECTED IN SERIES AND FUNCTION BY SENSING THE REGULATOR DOWNSTREAM PRESSURE. SINCE A COMMON PRESSURIZATION SUBSYSTEM IS USED, QUAD-RUPLE CHECK VALVES ARE EMPLOYED BETWEEN THE REGULATOR AND PROPELLANT TANKAGE FOR ASSURANCE THAT HYPERGOLICS WILL NOT MIX IN THE PRESSURIZATION SUBSYSTEM.

THE HELIUM FILL CHECK VALVES PROVIDE RETENTION OF SUPPLY HELIUM. THE LOW-PRESSURE HELIUM MODULES PROVIDE GROUND VENTING CAPABILITIES OF PROPELLANT TANK ULLAGE PRESSURE AND THE HELIUM SYSTEM AS WELL AS A MEANS OF ESTABLISHING PNEUMATIC CONTROL OF THE EXPULSION BLADDER DURING LOADING AND CHECKOUT. GROUND AND FLIGHT RELIEF CAPABILITY IS ALSO PROVIDED THROUGH THE LOW-PRESSURE HELIUM MODULE. COMMAND VENTING CAPABILITIES DURING FLIGHT ARE NOT PROVIDED, ALTHOUGH THE PROPELLANT TANKS ARE PROTECTED FROM OVERPRESSURIZATION BY RELIEF VALVES IN THE LOW-PRESSURE HELIUM MODULES. ALL HELIUM ENTERING THE REGULATED PRESSURE SYSTEM IS FILTERED UPSTREAM OF THE REGULATORS.

B. PRESSURIZATION COMPONENTS

THE FOLLOWING PARAGRAPHS PROVIDE A DESCRIPTION OF COMPONENTS ASSOCIATED WITH THE APS PRESSURIZATION SUBSYSTEMS.

C. HELIUM TANK

THE HELIUM TANK STORES HIGH-PRESSURE HELIUM IN A VOLUME OF 925 CUBIC INCHES AND CONTAINS A TEMPERATURE PROBE FOR MONITORING HELIUM TEMPERATURE DURING OPERATION. HELIUM STORAGE PRESSURE IS MEASURED AT THE INLET OF THE REGULATOR.

D. HELIUM REGULATOR

HELIUM STORED AT 3100 ± 100 PSIG IN THE TANK IS FED TO THE HELIUM REGULATOR ASSEMBLY. HELIUM GAS ENTERING THE ASSEMBLY FIRST PASSES THROUGH A FILTER AND THEN THROUGH TWO REGULATORS IN SERIES, BOTH OF WHICH SENSE DOWNSTREAM PRESSURE. THE PRIMARY REGULATOR ALLOWS THE PASSAGE OF GAS UP TO 196 ± 3 PSID WHILE THE SECONDARY REGULATOR ALLOWS THE PRESSURE OF GAS AT 200 ± 3 PSID. DURING NORMAL OPERATION, REGULATED PRESSURE IS MAINTAINED BY THE PRIMARY REGULATOR. SHOULD THE PRIMARY REGULATOR FAIL TO OPEN, THE SECONDARY REGULATOR CONTROLS THE HELIUM PRESSURE. AMBIENT PRESSURE SENSING PORTS, PROVIDED ON BOTH REGULATORS, FURNISH THE NECESSARY AMBIENT PRESSURE REFERENCES. THESE PORTS ARE ALSO USED TO CHECKOUT THE SECONDARY REGULATOR BY SIMULATING A PRIMARY REGULATOR FAILURE. PRESSURE TRANSDUCERS ARE INSTALLED IMMEDIATELY BEFORE AND AFTER THE REGULATORS TO MONITOR INLET AND OUTLET PRESSURES. REGULATED HELIUM IS FED THROUGH THE QUAD CHECK VALVES TO THE ULLAGE AREA OF THE FUEL AND OXIDIZER TANKS.

E. QUADRUPLE CHECK VALVES

TWO SETS OF QUADRUPLE CHECK VALVES ARE EMPLOYED IN THE HELIUM PRESSURIZATION SUBSYSTEM: ONE SET IN THE FUEL TANK PRESSURIZATION LINE AND THE OTHER SET IN THE OXIDIZER TANK PRESSURIZATION LINE. THESE CHECK VALVES ARE PROVIDED AS A SAFETY FEATURE TO PREVENT CONTACT OF FUEL AND OXIDIZER VAPORS IN THE PRESSURIZATION SUBSYSTEM.

EACH SET OF CHECK VALVES CONSISTS OF FOUR CHECK VALVES CONTAINED IN ONE BODY CONNECTED IN A SERIES-PARALLEL ARRANGEMENT. FAILURE OF A CHECK VALVE SET REQUIRES OPEN FAILURE OF TWO CHECK VALVES IN SERIES OR CLOSED FAILURE OF TWO CHECK VALVES IN PARALLEL.

F. LOW-PRESSURE HELIUM MODULE

THE LOW-PRESSURE HELIUM MODULE CONSISTS OF A SOLENOID DUMP VALVE AND A RELIEF VALVE. TWO LOW-PRESSURE MODULES ARE EMPLOYED IN THE PRESSURIZATION SUBSYSTEM, ONE CONNECTED TO EACH PROPELLANT ULLAGE AREA. THE SOLENOID DUMP VALVE IS A NORMALLY CLOSED, DIRECT-ACTING VALVE WITH A DUAL (REDUNDANT) COIL. THIS VALVE PERFORMS NO FLIGHT FUNCTION AND IS EMPLOYED TO CONTROL THE PROPELLANT TANK ULLAGE DURING GROUND SERVICING AND CHECKOUT OPERATIONS.

3. POSITIVE EXPULSION PROPELLANT FEED SUBSYSTEM

A. GENERAL

THE POSITIVE EXPULSION PROPELLANT FEED SUBSYSTEM ASSURES THAT HYPERGOLIC PROPELLANTS ARE SUPPLIED TO THE ENGINES UNDER "ZERO G" OR RANDOM GRAVITY CONDITIONS. THIS SUBSYSTEM CONSISTS OF TWO SEPARATE FUEL AND OXIDIZER PROPELLANT TANK ASSEMBLIES EACH CONTAINING A BLADDER FOR PROPELLANT EXPULSION, INDIVIDUAL PROPELLANT CONTROL MODULES THAT FILTER THE PROPELLANTS AND PROVIDE AUXILIARY PORTS FOR SUBSYSTEM SERVICING OPERATIONS, AND A PROPELLANT MANIFOLD FOR DISTRIBUTION OF PROPELLANTS TO THE ENGINES. A MORE DETAILED DESCRIPTION OF THESE COMPONENTS IS PRESENTED IN THE FOLLOWING PARAGRAPHS.

B. PROPELLANT TANK ASSEMBLY

EACH TANK (OXIDIZER AND FUEL) CONSISTS OF AN OUTER TITANIUM PRESSURE VESSEL AND AN INTERNAL BLADDER FOR CONTAINING THE PROPELLANT. THE FLEXIBLE TEFLON BLADDER PROVIDES A SEPARATION MEMBRANE BETWEEN THE PRESSURIZATION GAS (ULLAGE) AND THE PROPELLANT AND PROVIDES A METHOD OF TRANSFERRING PROPELLANT UNDER A "ZERO G" ENVIRONMENT. THE BLADDER SERVES TO ENCAPSULATE THE LIQUID IN THE TANK. THE ULLAGE SPACE BETWEEN THE TANK AND BLADDER IS PRESSURIZED WITH HELIUM GAS TO PROVIDE THE EXPULSION PRESSURE NECESSARY FOR PROPELLANT FLOW.

A STANDPIPE IS LOCATED IN THE CENTER OF THE TANK ASSEMBLY WITHIN THE BLADDER. HOLES ARE LOCATED RADially ALONG THE LENGTH OF THE STANDPIPE THROUGH WHICH THE PROPELLANT PASSES DURING EXPULSION AS WELL AS DURING FILLING. THE DESIGN ASSURES THAT PROPELLANT CAN BE EXPELLED REGARDLESS OF THE PROPELLANT MASS LOCATION WITHIN THE TANK.

THE PROPELLANT ULLAGE VOLUME IS CONNECTED TO THE LOW PRESSURE HELIUM MODULE WHICH CONTAINS A RELIEF VALVE AND SOLENOID VENT. THE RELIEF VALVE ASSURES THAT THE TANK ASSEMBLY WILL NOT BE OVERPRESSURIZED. THE SOLENOID VENT VALVE PROVIDES GROUND SERVICING CONTROL.

TO PREVENT EXCESSIVE EXPANSION AND CONTRACTION CYCLES ON THE BLADDER, PROVISIONS ARE MADE TO MAINTAIN THE BLADDER IN A FULLY-EXPANDED POSITION DURING ALL SERVICING OPERATIONS. A GSE KIT IS PROVIDED TO MONITOR PRESSURE DIFFERENTIAL ACROSS THE BLADDER.

C. PROPELLANT CONTROL MODULES

THE TWO PROPELLANT CONTROL MODULES FILTER THE PROPELLANTS AND PROVIDE ACCESS INTO THE PROPELLANT SUBSYSTEM FOR SERVICING. EACH MODULE CONTAINS A PROPELLANT TRANSFER VALVE, A RECIRCULATION VALVE, TWO FACILITY LINE PURGE CHECK VALVES, AND A FILTER. THE FLIGHT FUNCTION PERFORMED BY THE MODULES IS FILTRATION OF PROPELLANTS GOING TO THE ENGINES. THE PROPELLANT TRANSFER VALVE IS A DIRECT OPERATING, NORMALLY CLOSED SOLENOID VALVE. THE TRANSFER VALVE CANNOT BE OPENED BY APPLICATION OF POWER IF THE SUBSYSTEM PRESSURE EXCEEDS THE GROUND SUPPLY PRESSURE BY MORE THAN 10 PSI, AND THE TRANSFER VALVE WILL NOT CLOSE OR REMAIN CLOSED IF THE GROUND SUPPLY PRESSURE EXCEEDS SUBSYSTEM PRESSURE BY MORE THAN 40 PSI. THIS VALVE IS PRIMARILY EMPLOYED TO FILL AND DRAIN THE APS MODULE.

THE PROPELLANT RECIRCULATION VALVE IS A DIRECT ACTING, NORMALLY CLOSED SOLENOID VALVE WITH TWO INDEPENDENT POPPETS AND SEATS. THE TWO-POPPET DESIGN ISOLATES THE ENGINE RECIRCULATION LINE FROM THE TANK RECIRCULATION LINE REQUIRING THAT ALL PROPELLANT FLOWING TO THE ENGINE WILL PASS THROUGH THE FILTER. THE FILTER HAS A 10-MICRON NOMINAL AND 25-MICRON ABSOLUTE RATING.

D. PROPELLANT MANIFOLD

THE PROPELLANT MANIFOLD DELIVERS PROPELLANT TO THE ENGINE FROM THE PROPELLANT CONTROL MODULE AND PROVIDES A SECONDARY PATH FOR THE CIRCULATION OF PROPELLANT THROUGH THE ENGINE VALVES AND BACK TO THE CONTROL MODULE. THE MANIFOLD EMPLOYS MARMEN CONOSEAL FLANGES TO CONNECT TO THE ATTITUDE CONTROL ENGINES, AND MC FITTINGS TO CONNECT TO THE PROPELLANT CONTROL MODULES AND 70 POUND THRUST ULLAGE ENGINE.

4. ATTITUDE CONTROL AND ULLAGE ENGINES

A. GENERAL

THREE 150 POUND THRUST ATTITUDE CONTROL ENGINES AND ONE 70 POUND ULLAGE ENGINE ARE EMPLOYED IN EACH APS MODULE. THESE ENGINES ARE ALL ABLATIVELY COOLED BY THE DECOMPOSITION OF REFRASIL FIBER. THE 150 POUND ENGINES EMPLOY QUADRUPLE PROPELLANT INJECTOR VALVES FOR REDUNDANT VALVE ACTION. THE ULLAGE ENGINE EMPLOYS ONLY SINGLE VALVES ON BOTH THE FUEL AND OXIDIZER LINES.

THE THRUST CHAMBER IS COMPOSED OF FOUR NON-SEPARABLE UNITS; THE COMBUSTION CHAMBER, THE NOZZLE THROAT SECTION, THE NOZZLE EXPANSION CONE, AND THE INJECTOR.

THE INJECTOR CONSISTS OF TWELVE PAIRS OF PROPELLANT ORIFICES ARRANGED TO MINIMIZE HOT SPOTS IN THE COMBUSTION CHAMBER. THE VALVE SIDE OF THE INJECTOR IS FILLED WITH SILVER BRAZE HEAT SINK WHICH INDUCES HEAT TRANSFER TO THE OXIDIZER AND FUEL AND REDUCES INJECTOR OPERATING TEMPERATURE. THE 70 POUND ENGINE HAS AN INJECTOR CONFIGURATION TO MINIMIZE OVERHEATING OF THE INJECTOR FACE AREA.

THE ENGINES START, OPERATE, AND STOP, IN ANY ATTITUDE OVER AN ENVIRONMENTAL PRESSURE RANGE BETWEEN SEA LEVEL AND 10^{-9} mm Hg.

B. PROPELLANT VALVE ASSEMBLY (150 POUND THRUST ENGINES)

THE PROPELLANT VALVE ASSEMBLY CONSISTS OF EIGHT NORMALLY CLOSED, QUAD REDUNDANT PROPELLANT VALVES (FOUR OXIDIZER AND FOUR FUEL), ARRANGED IN TWO SERIES PARALLEL ARRANGEMENTS. DUAL FAILURE WITHIN THE MANIFOLD FUEL OR OXIDIZER ARRANGEMENT IS REQUIRED TO CAUSE FAILURE OF THE ROCKET ENGINE ASSEMBLY. AN ASSEMBLY CLOSED FAILURE PREVENTS ANY ENGINE OPERATION WHILE AN ASSEMBLY OPEN FAILURE RESULTS IN CONTINUOUS FLOW AND LOSS OF ALL PROPELLANT. ASSEMBLY VALVE FAILURE CANNOT OCCUR UNLESS TWO VALVES FAIL OPEN IN SERIES OR TWO VALVES FAIL CLOSED

4. ATTITUDE CONTROL AND ULLAGE ENGINES (CONT)

IN PARALLEL. THE INJECTOR VALVES PROVIDE POSITIVE ON-OFF CONTROL OF PROPELLANT FLOW UPON COMMAND FROM AN EXTERNAL POWER SOURCE. FOUR VALVES, INTEGRAL IN AN ASSEMBLY, ARE CAPABLE OF SIMULTANEOUS OPERATION AND ARE SYNCHRONIZED TO ALLOW FLOW OR TERMINATE FLOW WITHIN 3 MILLISECONDS OF EACH OTHER. THE OPENING TIME FOR EACH VALVE ASSEMBLY, DEFINED AS THE TIME FROM INITIATION OF THE OPEN SIGNAL TO A FULLY OPEN VALVE PACKAGE, DOES NOT EXCEED 23 MILLISECONDS.

EACH VALVE PLUNGER AND SOLENOID CONSISTS OF A COMPLETE ASSEMBLY THAT MAY BE REMOVED FROM THE PROPELLANT VALVE ASSEMBLY TO ALLOW THOROUGH VALVE CLEANING AND SOLENOID REPLACEMENT. EACH VALVE ASSEMBLY (FOUR FUEL OR FOUR OXIDIZER VALVES) MAY BE REMOVED SEPARATELY FROM THE ROCKET ENGINE. ALL VALVE ASSEMBLIES ARE INTERCHANGABLE WITHIN THEIR OWN SUBSYSTEM; OXIDIZER WITH OXIDIZER AND FUEL WITH FUEL. ALL EXTERNAL LEAK PATHS, AT INDIVIDUAL SOLENOID COILS, ARE SEALED BY MARMAN CONOSEALS (EXCLUDING WELDED JOINTS).

C. PROPELLANT VALVE ASSEMBLY (70 POUND THRUST ENGINE)

THE TWO PROPELLANT VALVE ASSEMBLIES EMPLOYED FOR THE ULLAGE ENGINE ARE ITEMS OF GFE AND ARE SINGLE ON-OFF VALVES. ONE CONTROLS THE OXYDIZER AND THE OTHER THE FUEL. THE VALVES DO NOT EMPLOY ANY REDUNDANT VALVING FEATURES AND FAILURE WOULD OCCUR WITH THE VALVES EITHER OPENED OR CLOSED. AN OPEN FAILURE WOULD CAUSE LOSS OF PROPELLANT, WHILE A CLOSED FAILURE WOULD INHIBIT ENGINE OPERATION.

E. INCIDENTAL CONSIDERATIONS

1. SYSTEM PURGES

A. FUEL (OXIDIZER) TRANSFER AND RECIRCULATION LINES PURGE

THE FUEL (OXIDIZER) TRANSFER AND RECIRCULATION LINES ARE PURGED WITH GROUND-SUPPLIED GN_2 PRIOR TO FUEL (OXIDIZER) TANK PURGE, PRIOR TO AND IMMEDIATELY AFTER FUEL (OXIDIZER) TANK FILL, AND AFTER THE FUEL (OXIDIZER) TANK IS UNLOADED IN THE EVENT OF A LAUNCH ABORT.

FACILITY GN_2 ENTERS THE APS THROUGH THE FUEX (OXIDIZER) LINE PURGE COUPLING. FLOW OF GN_2 THROUGH THE FUEL (OXIDIZER) TRANSFER LINE PURGE CHECK VALVE AND FUEL (OXIDIZER) TRANSFER COUPLING PURGES THE FUEL (OXIDIZER) TRANSFER LINE. THE FUEL (OXIDIZER) RECIRCULATION LINE IS PURGED BY A FLOW OF GN_2 THROUGH THE FUEL (OXIDIZER) RECIRCULATION LINE PURGE CHECK VALVE AND THE FUEL (OXIDIZER) RECIRCULATION COUPLING.

B. FUEL (OXIDIZER) TANK PURGE

THE FUEL (OXIDIZER) TANK PLENUM AND BLADDER ARE PURGED WITH GROUND-SUPPLIED GN_2 PRIOR TO FUEL (OXIDIZER) TANK FILL AND IMMEDIATELY AFTER THE FUEL (OXIDIZER) IS UNLOADED IN THE EVENT OF A LAUNCH ABORT.

PRIOR TO FUEL (OXIDIZER) TANK FILL, THE PLENUM IS PURGED BY A FLOW OF GN_2 THROUGH THE FUEL (OXIDIZER) TANK BLADDER COLLAPSE AND VENT COUPLING, THE PLENUM AND TO GSE THROUGH THE FUEL (OXIDIZER) TANK FLUSH AND VENT OUTLET. TO PURGE THE BLADDER, THE NORMALLY-CLOSED FUEL (OXIDIZER) RECIRCULATION CONTROL SOLENOID VALVE IS OPENED AND A GN_2 PURGE ENTERS THROUGH THE FUEL (OXIDIZER) RECIRCULATION COUPLING, FLOWS THROUGH THE FUEL (OXIDIZER) RECIRCULATION CONTROL SOLENOID VALVE, AND ENTERS THE FUEL (OXIDIZER) TANK ASSEMBLY. THE PURGE GAS EXITS THROUGH THE NORMALLY CLOSED FUEL (OXIDIZER) TRANSFER CONTROL SOLENOID VALVE AND VENTS TO GSE THROUGH THE NORMALLY-CLOSED FUEL (OXIDIZER) TRANSFER COUPLING. A PORTION OF THE PURGE GAS ALSO FLOWS THROUGH THE FUEL (OXIDIZER) RECIRCULATION ORIFICE, FUEL (OXIDIZER) RECIRCULATION FILTER, THE ENGINE FUEL (OXIDIZER) BLEED PORTS, FUEL (OXIDIZER) FILTER AND EXITS THROUGH THE FUEL (OXIDIZER) TRANSFER CONTROL SOLENOID VALVE AND FUEL (OXIDIZER) TRANSFER COUPLING. AFTER PURGING FOR APPROXIMATELY TEN MINUTES (FIVE MINUTES WITH THE BLADDER COLLAPSED AND FIVE MINUTES WITH THE BLADDER EXPANDED, THE FUEL (OXIDIZER) TRANSFER CONTROL SOLENOID VALVE IS DE-ENERGIZED AND THE NORMALLY-CLOSED FUEL (OXIDIZER) FEED VALVES AND FUEL (OXIDIZER) SOLENOID VALVES (ULLAGE MOTOR) ARE OPENED. THE PURGE IS THEN ROUTED THROUGH THE FUEL (OXIDIZER) RECIRCULATION CONTROL SOLENOID VALVE, FUEL (OXIDIZER) TANK ASSEMBLY, FUEL (OXIDIZER) RECIRCULATION FILTER, FUEL (OXIDIZER) SOLENOID VALVES, AND INJECTORS TO THE ATMOSPHERE.

B. FUEL (OXIDIZER) TANK PURGE

IN THE EVENT OF A LAUNCH ABORT, THE FUEL (OXIDIZER) TANK ASSEMBLY IS DRAINED AND FLUSHED WITH FREON TRI-FLUORO (FREON T.F.) AND ISOPROPYL ALCOHOL. THIS FLUSH IS FOLLOWED BY A GN₂ PURGE SIMILAR TO THAT USED PRIOR TO FUEL (OXIDIZER) TANK FILL. UPON COMPLETION OF THE PURGE, THE MODULE IS REMOVED FROM THE STAGE AND REPLACED.

2. APS HELIUM REGULATOR (REF. FIG. 5)

THE PRIMARY SENSE LINE IS COUPLED FROM PORT B (OUTLET) OF THE SECONDARY REGULATOR TO THE PRIMARY REGULATOR. THE SENSED PRESSURE, IF GREATER THAN THE REFERENCE AMBIENT PRESSURE (PORT D) PLUS THE PRESSURE RESULTING FROM SPRING COMPRESSION, CAUSES DOWNWARD MOTION OF THE PRIMARY PILOT PISTON. THE PRIMARY PILOT POPPET IS DRAWN CLOSER TO ITS SEAT AND RESTRICTS HELIUM FLOW TO THE TOP FACE OF THE PRIMARY MAIN PISTON. THIS RESULTS IN DECREASED PRESSURE ON THE TOP FACE OF THE MAIN PISTON AND ALLOWS THE ASSOCIATED SPRING TO MOVE THE MAIN PISTON UPWARD. AS THE MAIN PISTON DRAWS THE MAIN POPPET TOWARD ITS SEAT, HELIUM FLOW FROM INPUT PORT A TO THE OUTPUT OF THE MAIN REGULATOR IS DIMINISHED. THE RESULTING LOWER PRIMARY REGULATOR OUTPUT PRESSURE CAUSES LOWER SECONDARY REGULATOR OUTPUT PRESSURE (THE SECONDARY REGULATOR IS ASSUMED TO BE STATIC BECAUSE THE PRIMARY REGULATOR IS OPERATING). THIS PROCESS CONTINUES UNTIL THE PRIMARY SENSED PRESSURE COMPENSATES FOR SPRING COMPRESSION PLUS AMBIENT PRESSURE AND THE MAIN REGULATOR IS CLOSED.

II ELECTRICAL

A. APS PORTION OF ENGINE DEFLECTION PANEL.

NOTE: THIS PORTION OF NARRATIVE IS INCLUDED FOR THE PURPOSE OF DISTRIBUTING GENERAL INFORMATION ONLY. IT IS NOT PERTINENT TO THE TIME FRAME DURING WHICH RED LINES ARE APPLICABLE.

THE ENGINE DEFLECTION PANEL CONTAINS LOGIC METERS AND LIGHTS NECESSARY TO DETERMINE REAL TIME ACTIVITY OF APS ATTITUDE CONTROL ENGINES (REF. FIG. 6). SEVEN MEASUREMENTS, FOUR FROM THE SIVB AND THREE FROM THE I.U. ARE USED TO DERIVE THIS INFORMATION. THE FOUR SIVB MEASUREMENTS ARE CURRENT TO THE QUAD VALVES ON APS ENGINES. THE THREE I.U. MEASUREMENTS ARE CURRENT TO THE RELAY COILS IN THE ATTITUDE CONTROL RELAY ASSEMBLIES.

TABLE I SHOWS RELATIONSHIPS BETWEEN DETECTED ATTITUDE ERROR AND APS ENGINE RESPONSE. IN TABLE 1, E DESIGNATES ERROR, Y DESIGNATES YAW, P DESIGNATES PITCH, R DESIGNATES ROLL AND F DESIGNATES WHICH ENGINES FIRE TO CORRECT A DETECTED ERROR.

FIGURE 1 DEPICTS ORIENTATION OF THE APS ENGINES AND WILL AID IN INTERPRETATION OF TABLE 1.

THE LOWER LEFTHAND CORNER OF THE ENGINE DEFLECTION PANEL HAS THREE METERS WHICH ENABLE THE OPERATOR TO DETERMINE THE OPERATION OF THE APS SYSTEM. FIGURES 2 THRU 4 SHOW THE METER RESPONSES TO THE VARIOUS ATTITUDE ERROR CONDITIONS.

EXAMPLE: (REF. FIGURE 2)

THE PLATFORM DETECTS VEHICLE ATTITUDE. IF THE I.U. INTERPRETS THE ATTITUDE TO HAVE A NEGATIVE YAW (-EY) ERROR, THE APS IS COMMANDED TO CORRECT VEHICLE YAW ATTITUDE BY ROTATING THE VEHICLE ABOUT THE YAW AXIS IN A POSITIVE DIRECTION.

NOTE: ACTUALLY, THE PROCESS IS CONSIDERABLY MORE COMPLEX THAN PRESENTED HERE BECAUSE OF RATE AND DURATION OF COMMAND CONSIDERATION. HOWEVER, IT IS SUFFICIENT TO SAY APS ENGINES WILL BE FIRED A MINIMUM OF 0.065 SEC. WHEN CORRECTING ATTITUDE ERRORS.

THE REMAINING COMPONENTS OF THE ENGINE DEFLECTION PANEL ARE SELF EXPLANATORY AND WILL NOT BE COVERED HERE.

B. SPATIAL VALVE TELEMETERING AMPLIFIER

THE TELEMETERING AMPLIFIERS (REF. FIG. 6) SUPPLY OUTPUTS DIRECTLY PROPORTIONAL TO THE AMOUNT OF CURRENT DELIVERED TO THE APS QUAD VALVES. EACH ATTITUDE CONTROL RELAY ASSEMBLY HAS AMPLIFIER "B" (ASSOCIATED WITH YAW AND ROLL) AND AMPLIFIER "A" (ASSOCIATED WITH PITCH).

TRANSISTORS Q_1 , Q_2 , THE PRIMARY OF T_1 AND ASSOCIATED COMPONENTS CONSTITUTE A 2KHZ OSCILLATOR. THE OSCILLATOR OUTPUT IS COUPLED TO RECTIFIERS CR1, CR2, CR3 AND CR4. THE RECTIFIED SIGNAL IS DELIVERED TO RESISTORS R_4 , R_5 , A1 WINDING AND THE B1 WINDING. IF THERE IS NO CONTROL WINDINGS (A4 AND B4) CURRENT BEING DELIVERED TO THE QUAD VALVES, THE REACTANCE OF A1 AND B1 IS BALANCED. SINCE R_4 AND R_5 HAVE IDENTICAL RESISTANCE THERE WOULD BE NO OUTPUT. IF THERE IS CONTROL WINDINGS CURRENT, THE FIELDS GENERATED BY COILS A1 AID IN THE SATURATION OF CORE A WHILE B1 FIELDS OPPOSE SATURATION OF CORE B. SATURATION OF CORE A ALLOWS INCREASED CURRENT THROUGH R_4 AND CONSEQUENTLY AN OUTPUT VOLTAGE TO TELEMETRY. THE OUTPUT VARIES FROM ZERO VOLTS FOR NO CONTROL WINDING CURRENT TO FIVE VOLTS FOR FULL CONTROL WINDING CURRENT. THE B_2 AND A_2 WINDINGS (CONTROLLED BY TRIMPOT) ARE USED TO ADJUST THE ZERO OUTPUT. THE A_3 AND B_3 WINDINGS COMPENSATE FOR VARIATIONS THE OSCILLATOR OUTPUT VOLTAGE.

NOTE: THE INSTRUMENTATION FOR THE I.U. COMMANDS IS SIMILAR TO THAT DESCRIBED ABOVE. HOWEVER, THE OUTPUT IS 2.5VDC FOR ZERO CONTROL WINDING CURRENT AND GOES TO ZERO OR FULL SCALE — DEPENDING UPON THE COMMAND GIVEN. TABLE 2 GIVES THE RELATIONSHIPS BETWEEN COMMANDS AND I.U. TELEMETRY OUTPUTS FOR MEASUREMENTS H_3 , H_4 AND H_5 .

C. VOLTAGE MONITOR CARD, M-5711A (REF. FIG. 6)

THE VOLTAGE MONITOR CARDS PROCESS SIX OF THE SEVEN MEASUREMENTS MENTIONED IN PARAGRAPH A. THE OUTPUTS OF THE MONITOR CARDS AND THE SEVENTH MEASUREMENT CONTROL RELAY LOGIC THAT FEEDS A GROUP OF SIX LIGHTS (SEE. RIGHT SIDE OF FIG. 6) ON THE ENGINE DEFLECTION PANEL. EACH OF THE LIGHTS IS ASSOCIATED WITH A PARTICULAR APS ATTITUDE CONTROL ENGINE AND WILL LIGHT ONLY IF ITS ASSOCIATED ENGINE WAS COMMANDED TO FIRE AND RECEIVED CURRENT TO ITS QUAD VALVES.

THE KEY TO THE OPERATION OF THE VOLTAGE MONITOR CARDS IS THE FIELD EFFECTS TRANSISTOR.

THE INITIAL APPLICATION OF POWER TURNS Q_3 AND Q_{2B} TRANSISTORS ON. THIS CLAMPS THE BASE OF Q_4 TO GROUND AND PREVENTS IT FROM CONDUCTING. THE FIELD EFFECTS TRANSISTOR, Q_1 , IS BIASED BY ITS ASSOCIATED TRIMPOT. THE BIAS IS SUCH THAT Q_1 CONDUCTS ONLY BY DETECTING OVER HALF SCALE DEFLECTION FOR ITS ASSOCIATED MEASUREMENT. IF TRANSISTOR Q_1 CONDUCTS, Q_{2A} CONDUCTS AND Q_3 IS CLAMPED OFF. THIS ALLOWS Q_4 TO SUPPLY A GROUND TO ONE OF THE LOGIC RELAYS MENTIONED ABOVE.

NOTE: SEE POWER DISTRIBUTION PORTION OF THIS DOCUMENT FOR DESCRIPTION OF M6797 PWR. ISOLATION BOARD.

D. ATTITUDE CONTROL RELAY ASSEMBLY

THE ATTITUDE CONTROL RELAY ASSEMBLIES CONTAIN (IN ADDITION TO THE TELEMETERING AMPLIFIERS DESCRIBED IN PARAGRAPH B) THE COMMAND RELAYS THROUGH WHICH CURRENT TO THE ATTITUDE CONTROL ENGINE QUAD VALVE IS DELIVERED. EACH ASSEMBLY CONTAINS TWELVE RELAYS. EACH ATTITUDE CONTROL ENGINE REQUIRES FOUR RELAYS TO CONTROL ITS QUAD VALVES.

E. APS ULLAGE ENGINES

EACH APS ASSEMBLY CONTAINS AN ULLAGE ENGINE. THEY ARE CONTROLLED BY SWITCH SELECTOR COMMANDS.

III ENVIRONMENTAL CONTROL SYSTEM — APS INTERFACE (REF. FIG. 10)

SIVB AFT COMPARTMENT TEMPERATURE CONTROL IS ACCOMPLISHED BY TWO DUAL-ELEMENT THERMISTOR ASSEMBLIES LOCATED IN THE GASEOUS EXHAUST STREAM OF EACH APS MODULE. TWO ELEMENTS (ONE FROM EACH ASSEMBLY) ARE WIRED IN SERIES. ONE SUCH CIRCUIT IS USED FOR TEMPERATURE CONTROL. THE OTHER IS USED FOR TEMPERATURE RECORDING.

14.2 CRITICAL MEASUREMENTS

I REDLINES

- A. TEMP-ATTITUDE CONTROL OXID. MOD. 2 (1) MEASUREMENT XC022-415 (XC132-414)
APS MODULE 2 (1) OXIDIZER TEMPERATURE REDLINE LIMITS APPLY FROM LAUNCH VEHICLE POWER UP TO T-15 MIN. THE REDLINE LIMITS ARE:

MAXIMUM: 100°F
MINIMUM: 75°F

OTHER PERTINENT DATA CONCERNING THE MEASUREMENTS ARE AS FOLLOWS:

RANGE: 0 TO 130°F
BACKUPS:

1. MEASUREMENT XC021-415 (TEMP-ATT CONTROL FUEL MOD. 2) IS BACKUP FOR XC022-415
2. MEASUREMENT XC136-414 (TEMP-ATT CONTROL FUEL MOD. 1) IS BACKUP FOR XC132-414

CHANNEL ASSIGNMENTS (REDLINES AND BACKUPS):

MEASUREMENT	CHANNEL
XC022-415	C(D)P1BO-11-05
XC021-415	C(D)P1BO-11-07
XC132-414	C(D)P1BO-11-04
XC136-414	C(D)P1BO-11-06

- B. PRESS — OXID. SUPPLY MANIFOLD MOD. 1 (2) MEASUREMENT VXD071-414 (VXD073-415)
APS MODULE 1 (2) OXIDIZER MANIFOLD PRESSURE REDLINE LIMITS APPLY FROM SYSTEM PRESSURIZATION COMPLETE TO T-11 SECONDS. THE REDLINE LIMITS ARE:

MAXIMUM: 219 PSIA
MINIMUM: 203 PSIA

OTHER PERTINENT DATA CONCERNING THE MEASUREMENTS ARE AS FOLLOWS:

RANGE: 0 TO 400 PSIA
BACKUPS:

1. MEASUREMENT VXD070-414 (PRESS — APS MOD 1 FUEL SUPPLY MANIFOLD) IS BACKUP FOR VXD071-414
2. MEASUREMENT VXD072-415 (PRESS — FUEL SUPPLY MANIFOLD MOD. 2) IS BACKUP FOR VXD073-415.

CHANNEL ASSIGNMENTS (REDLINES AND BACKUPS)

MEASUREMENT	CHANNEL
VXD071-414	DP1BO-07-05
VXD070-414	DP1BO-07-02
VXD073-415	DP1BO-07-03
VXD072-415	DP1BO-07-04

C. PRESS — ATT. CONT. HE PRES TANK MOD 1 (2) MEASUREMENT VXD035—414 (VXD036—415)
APS 1 (2) HE TANK PRESSURE REDLINE LIMITS APPLY FROM SPHERE PRESSURIZATION COMPLETE TO T-11 SECONDS. THE REDLINE LIMITS ARE:

MAXIMUM: 3200 PSIA
MINIMUM: 2800 PSIA

OTHER PERTINENT DATA CONCERNING THE MEASUREMENTS ARE AS FOLLOWS:

RANGE: 0 TO 3500 PSIA

BACKUPS:

1. MEASUREMENT D250—414 (PRESS — ATT. CONT. HE. PRES TANK 1) IS BACKUP FOR: VXD035—414
2. MEASUREMENT D251—415 (PRESS — ATT. CONT. HE. PRES TANK 2) IS BACKUP FOR: VXD036—414

CHANNEL ASSIGNMENTS (REDLINES AND BACKUPS)

MEASUREMENT	CHANNEL
VXD035—414	DP1BO—13—07
D250—414	DP1BO—09—07
VXD036—415	DP1BO—13—09
D251—415	DP1BO—09—08

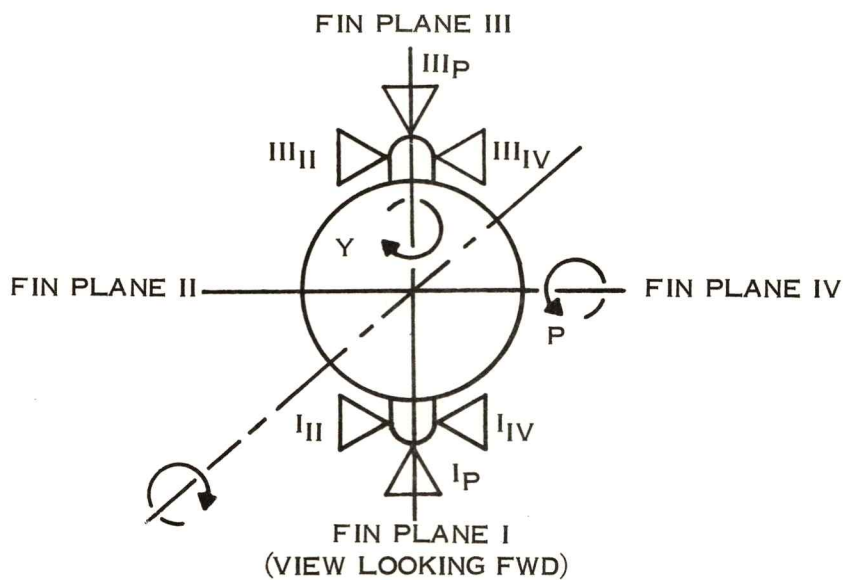


FIG. 1

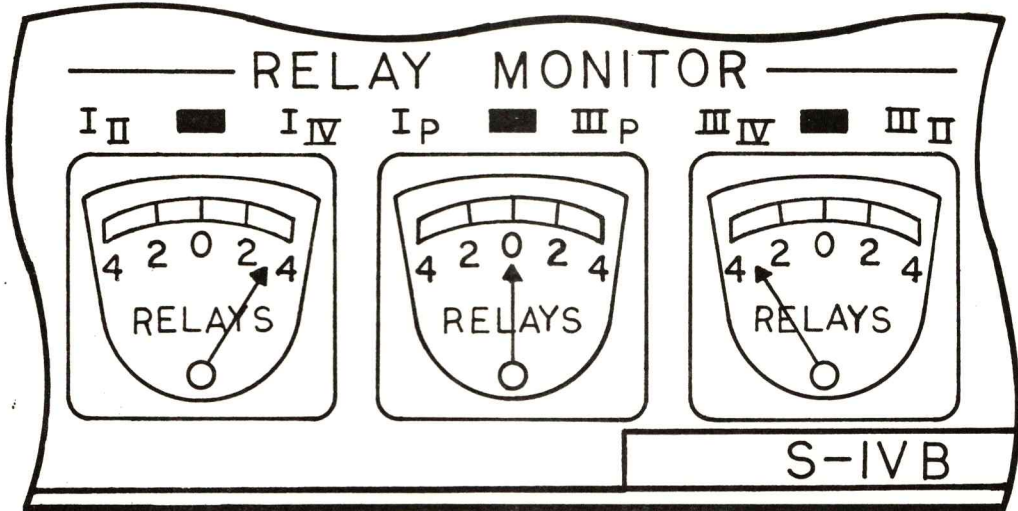


FIG 2

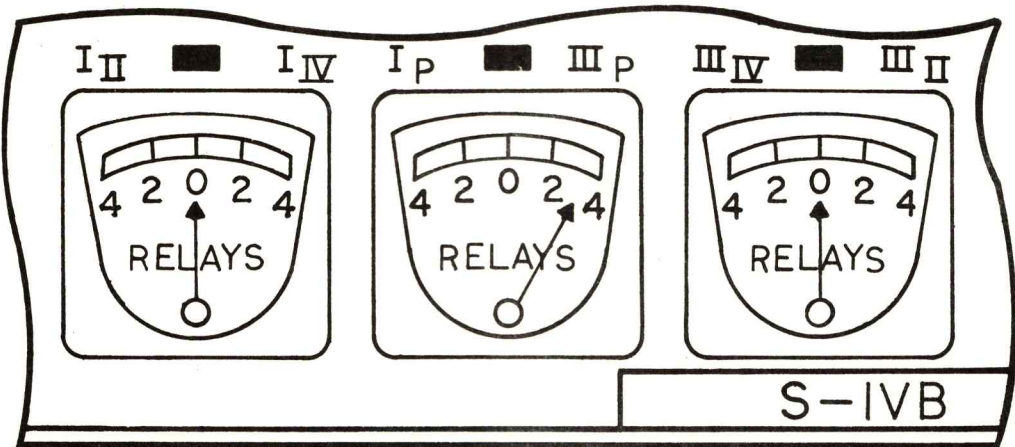


FIG. 3

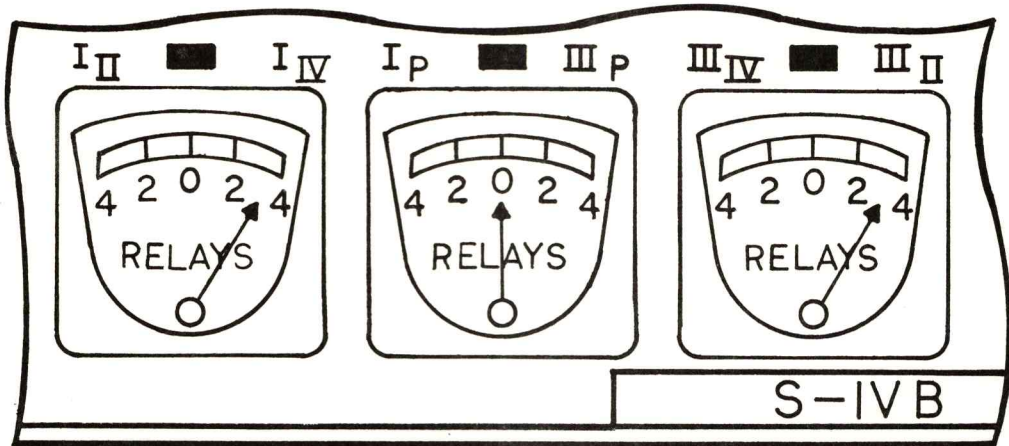


FIG. 4

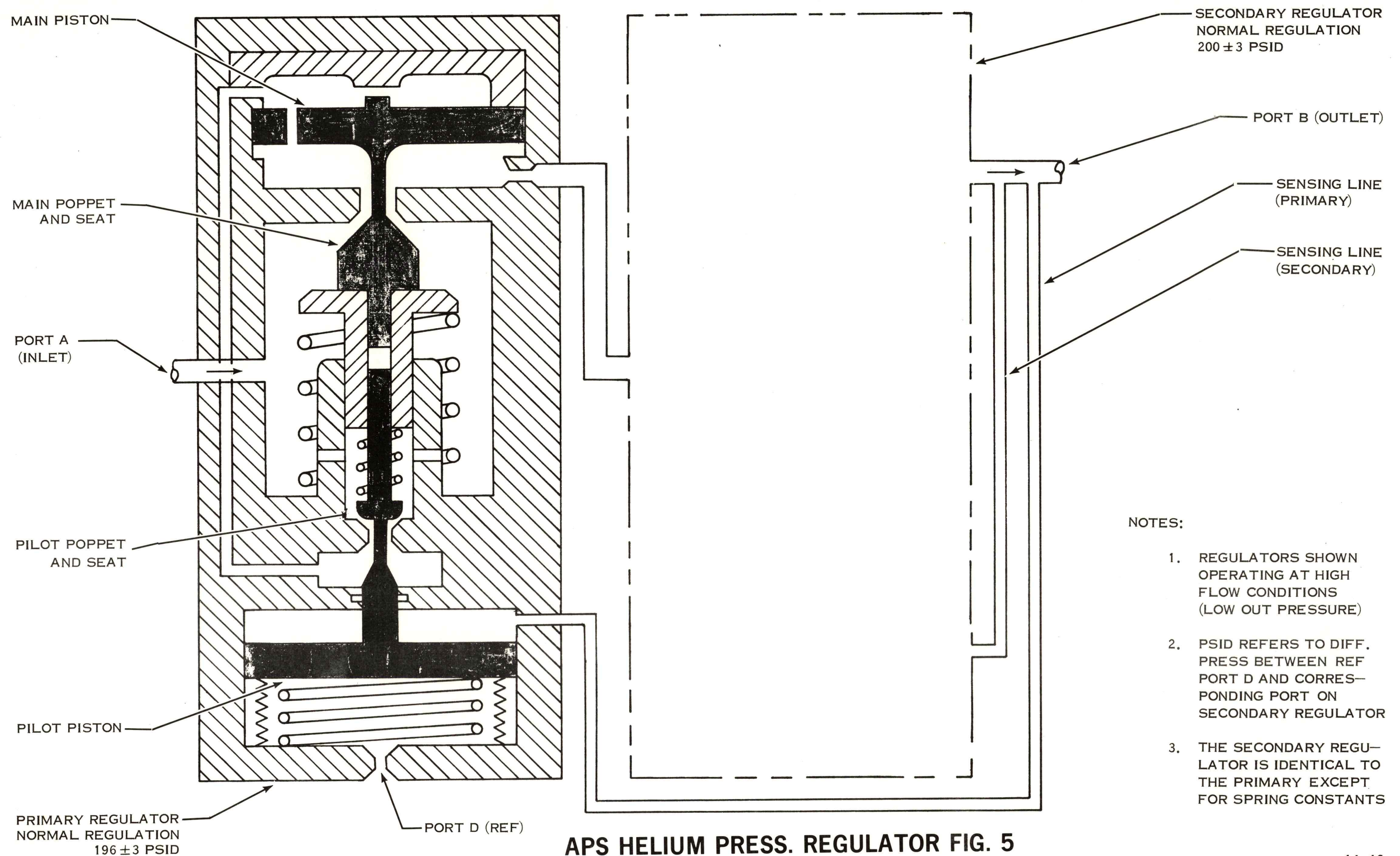
ENGINE COMMANDED	OUTPUT		
	H ₃	H ₄	H ₅
I _P	ZERO SCALE	2.5V	2.5V
III _P	FULL SCALE	2.5V	2.5V
III _{IV}	2.5V	2.5V	FULL SCALE
III _{II}	2.5V	2.5V	ZERO SCALE
I _{II}	2.5V	FULL SCALE	2.5V
I _{IV}	2.5V	ZERO SCALE	2.5V

TABLE 2

DETECTED ERROR	ENGINE RESPONSES					
	I _P	III _P	III _{IV}	III _{II}	I _{II}	I _{IV}
- EY			F			F
+ EY				F	F	
- ER				F		F
+ ER			F		F	
- EP		F				
+ EP	F					

TABLE 1

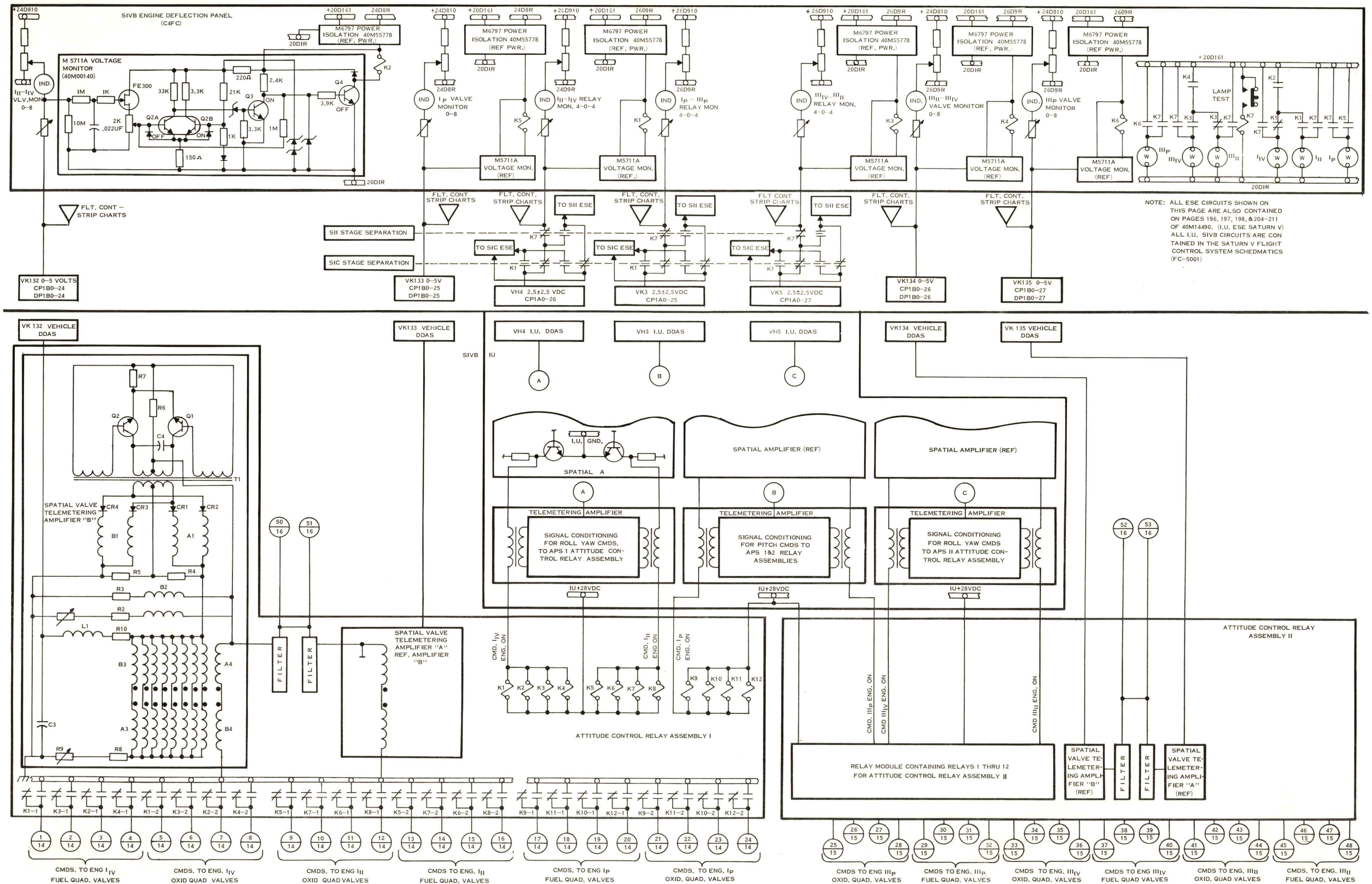
NOTE: FIGURES 2, 3 & 4 SHOW METER RESPONSES FOR POSITIVE COMMANDS (CORRECTING DETECTED NEGATIVE ERRORS) FOR YAW, PITCH & ROLL RESPECTIVELY. THOSE METERS DEFLECTED OFF ZERO WOULD REVERSE DEFLECTION FOR NEGATIVE COMMANDS.



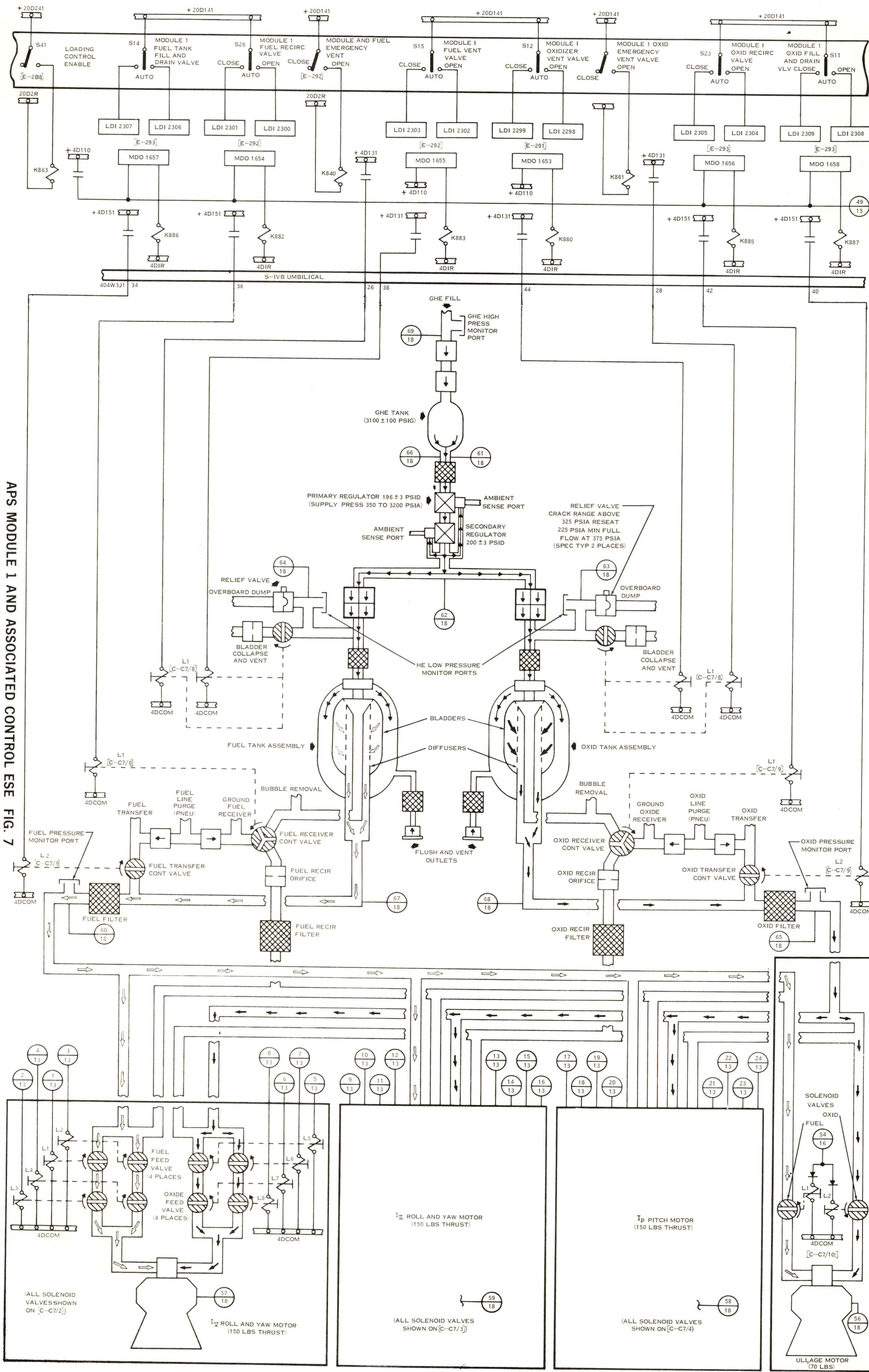
NOTES:

1. REGULATORS SHOWN OPERATING AT HIGH FLOW CONDITIONS (LOW OUT PRESSURE)
2. PSID REFERS TO DIFF. PRESS BETWEEN REF PORT D AND CORRESPONDING PORT ON SECONDARY REGULATOR
3. THE SECONDARY REGULATOR IS IDENTICAL TO THE PRIMARY EXCEPT FOR SPRING CONSTANTS

APS HELIUM PRESS. REGULATOR FIG. 5

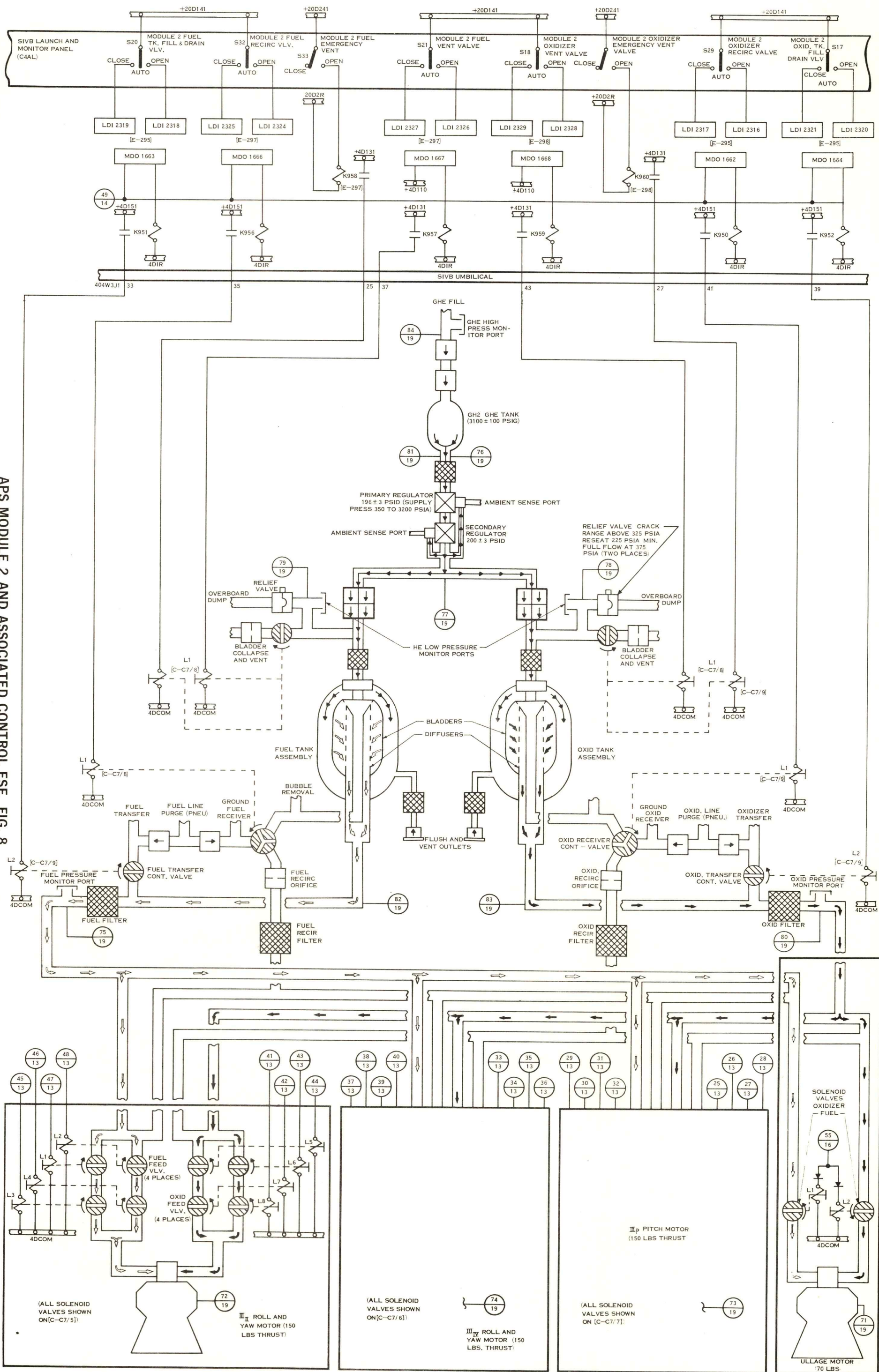


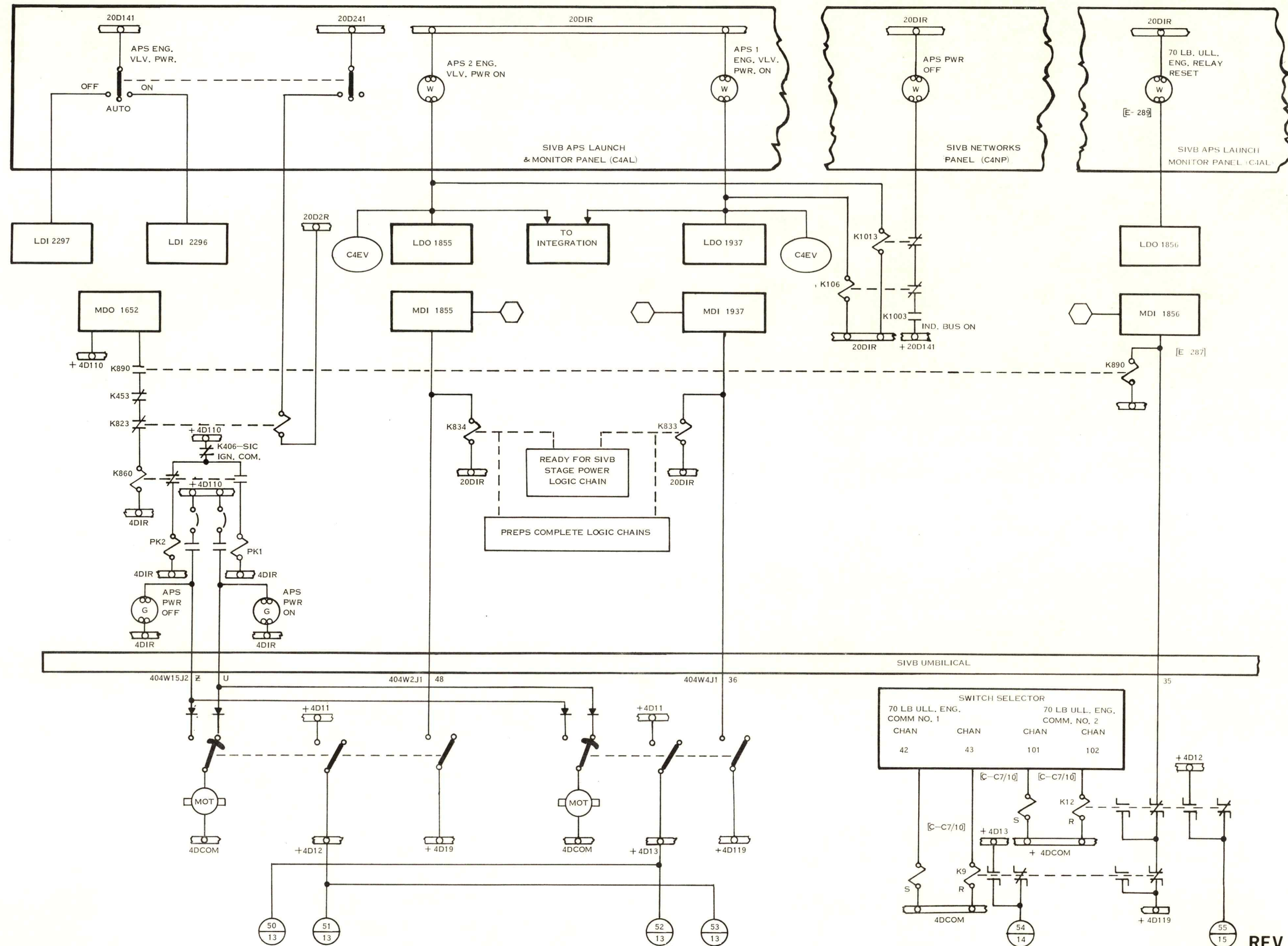
APS ATTITUDE CONTROL COMMAND & COMMAND MONITOR SYSTEM FIG. 6



APS MODULE 1 AND ASSOCIATED CONTROL ESE FIG. 7

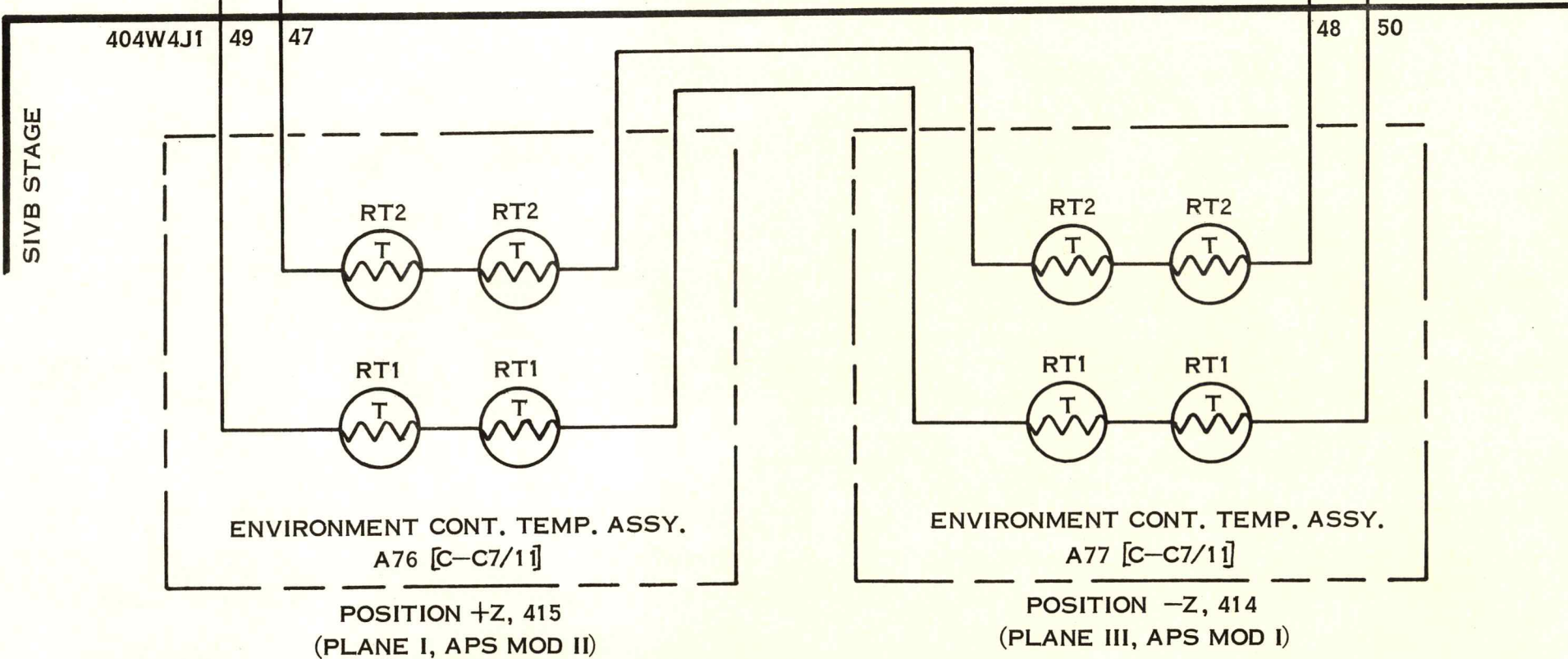
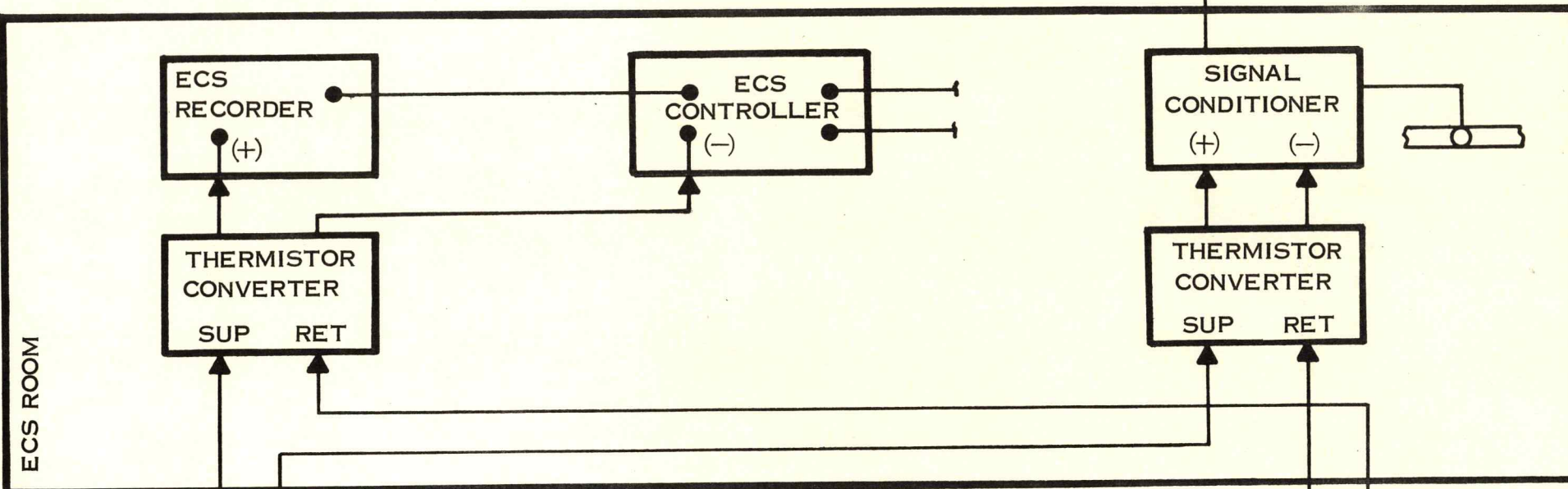
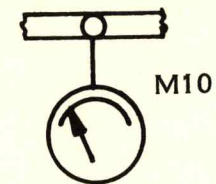
APS MODULE 2 AND ASSOCIATED CONTROL ESE FIG. 8





DERIVATION OF APS POWER FIG.9

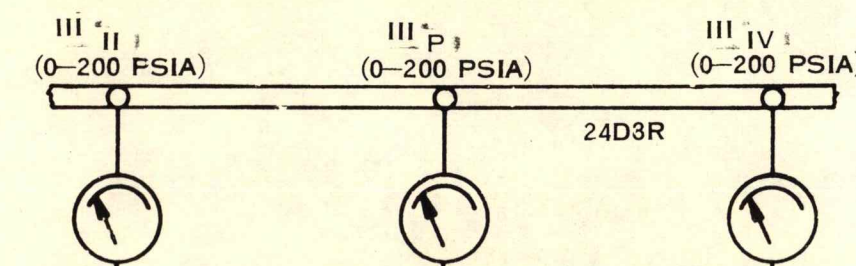
ECS Ψ CONT. & MONITOR
PANEL, LCC



ENVIRONMENTAL CONT. SYSTEM

14-17
REV. A

SIVB APS CHAMBER PRESS MONITOR PANEL (IU-ESE 267)

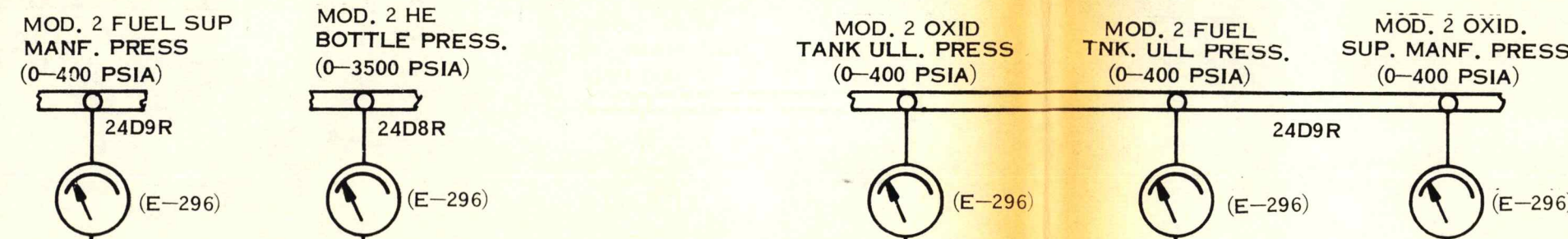


VEHICLE DDAS
VD0030-415
0-200 PSIA
(E-360)

VEHICLE DDAS
VD0031-415
0-200 PSIA
(E-360)

VEHICLE DDAS
VD0032-415
0-200 PSIA
(E-360)

SIVB APS LAUNCH AND MONITOR PANEL



VEHICLE DDAS
VXD072-415
0-400 PSIA
(E-365)

VEHICLE DDAS
VXD036-415
0-3500 PSIA
(E-365)

VEHICLE DDAS
D038-415
0-400 PSIA
(E-365)

VEHICLE DDAS
VXD099-415
0-400 PSIA
(E-365)

VEHICLE DDAS
VXD100-415
0-400 PSIA
(E-365)

VEHICLE DDAS
VXD073-415
0-400 PSIA
(E-365)

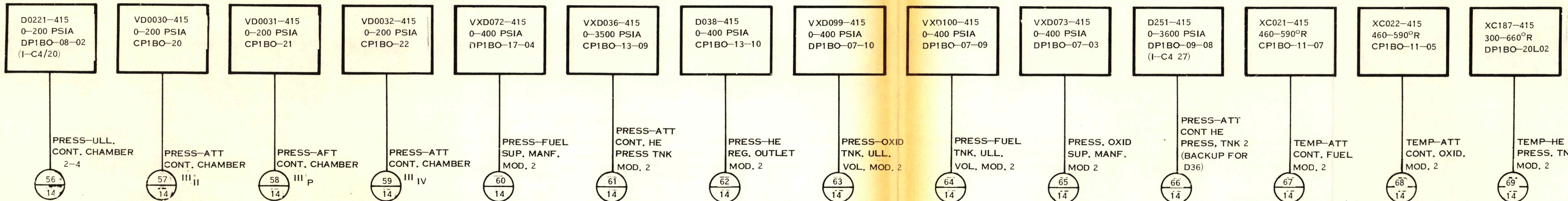
VEHICLE DDAS
VC021-415
460-590°R
(E-365)

VEHICLE DDAS
XC022-415
460-590°R
(E-365)

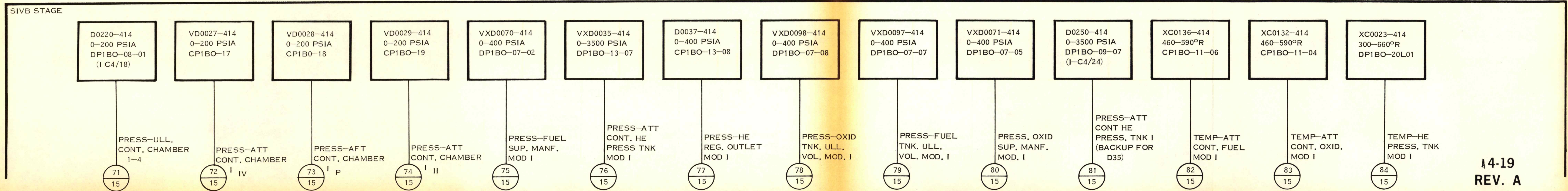
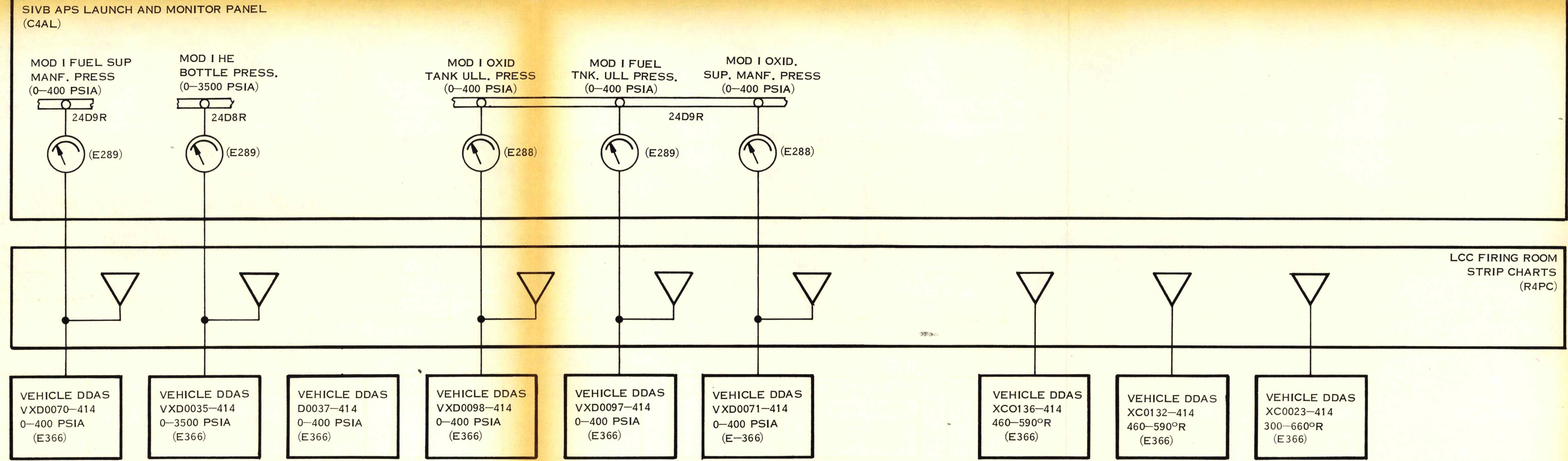
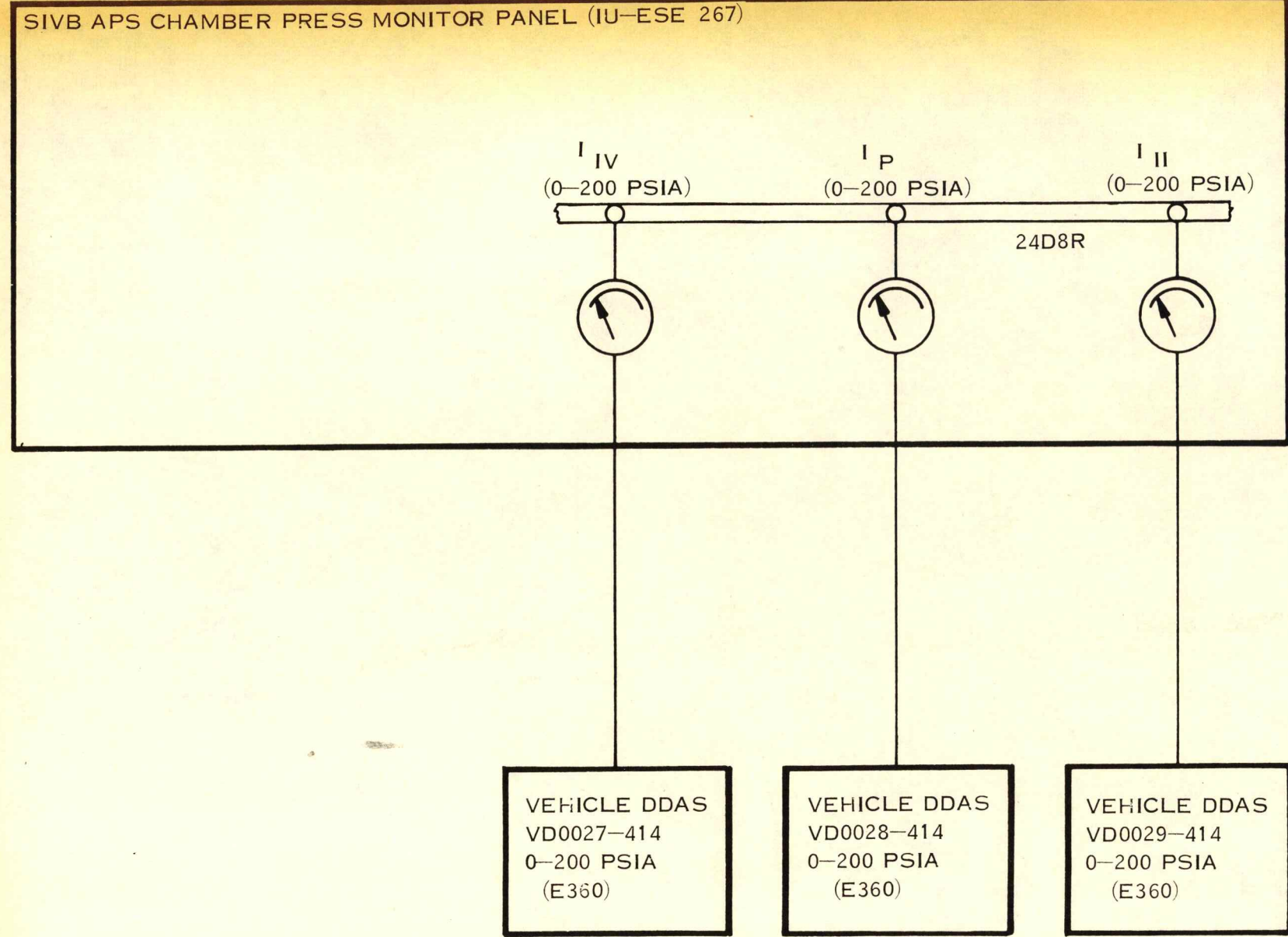
VEHICLE DDAS
XC187-415
300-660°R
(E-363)

LCC FIRING ROOM
STRIP CHARTS

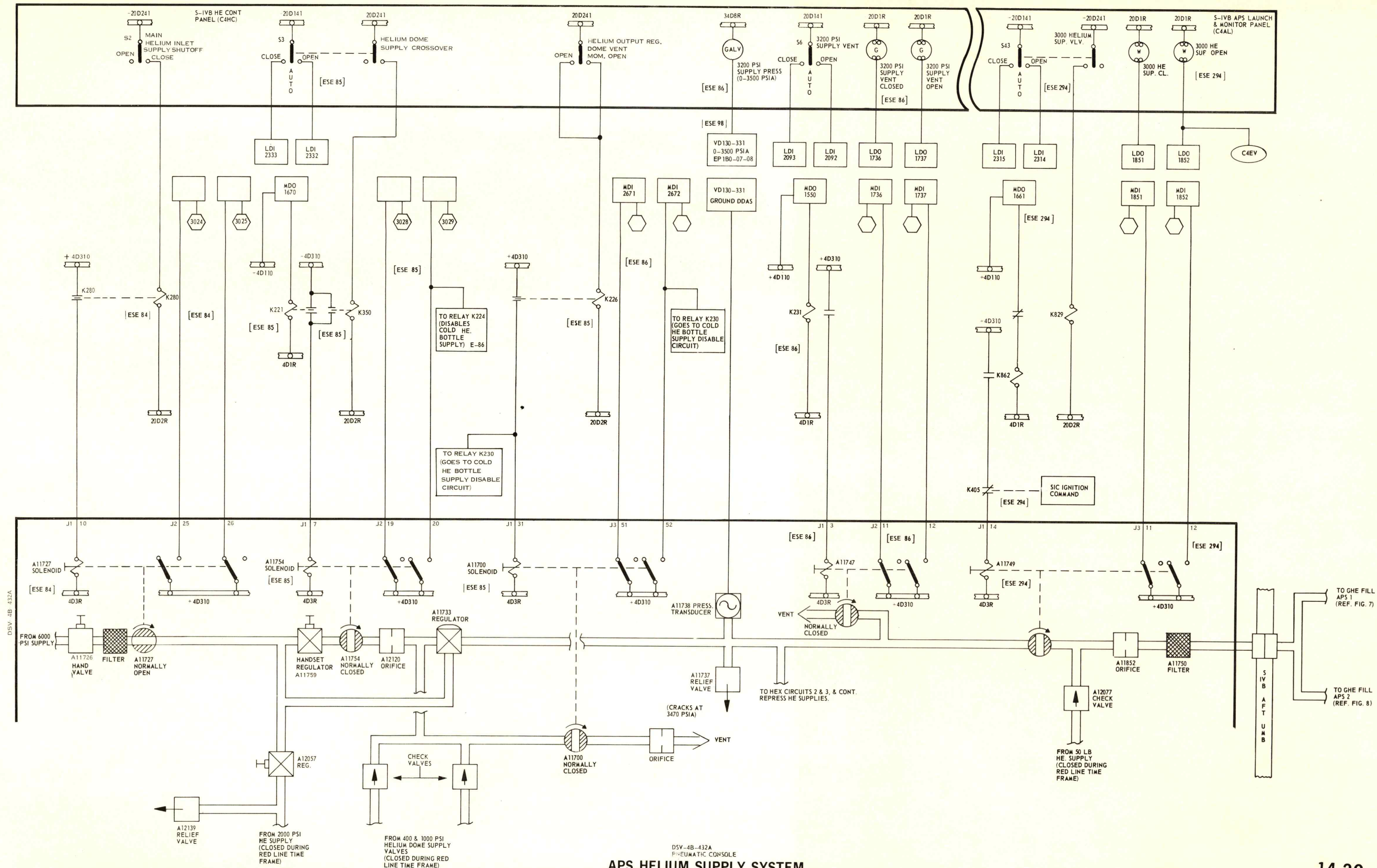
SIVB STAGE



APS 2 MEASUREMENTS
FIG. 12



APS 1 MEASUREMENTS FIG. 11



APS HELIUM SUPPLY SYSTEM

15.0 PROPELLANT TANKING SYSTEM

15.1 INTRODUCTION

THE PROPELLANT LOADING SYSTEM PROVIDES THE CAPABILITY OF LOADING THE S-IVB STAGE WITH LH2 AND LOX EITHER AUTOMATICALLY OR MANUALLY. EMPHASIS HAS BEEN PLACED ON THE INTERFACE BETWEEN THE S-IVB AND THE PROPELLANT TANKING SYSTEM. ONLY THE LH2 PORTION OF THE SYSTEM HAS BEEN SCHEMATICALLY REPRESENTED SINCE THE LOX PORTION IS VERY SIMILAR TO THE LH2 PORTION. THE MAJOR DIFFERENCE ARISES FROM THE FACT THAT THE LOX IS PUMPED INTO THE S-IVB TANK FROM THE STORAGE TANK, WHEREAS THE LH2 IS LOADED INTO THE S-IVB TANK BY PRESSURIZING THE LH2 STORAGE TANK.

A DETAILED LOGIC DIAGRAM HAS BEEN PREPARED TO FACILITATE THE ELECTRICAL SCHEMATIC. A NORMAL LH2 FILL SEQUENCE LOGIC DIAGRAM HAS ALSO BEEN PREPARED TO EMPHASIZE THE AUTOMATIC VALVE COMMANDS AND THE AUTOMATIC REVERT LOGIC. THE AUTOMATIC REVERT CIRCUITRY DOES NOT APPEAR IN THE ELECTRICAL SCHEMATIC.

15.2 SYSTEM DESCRIPTION

A. PROPELLANT TANKING COMPUTER (REFERENCE PART III)

1. REPLENISH VALVE CONTROL

REPLENISH VALVE CONTROL IS PROVIDED BY THE REPLENISH VALVE DRIVE SIGNAL OUTPUTED FROM THE COMPUTER. THE DRIVE SIGNAL IS DERIVED FROM THE S-IVB PU COARSE MASS POTENTIOMETER INPUT ANALOG SIGNAL WHEN THE COMPUTER IS IN THE AUTOMATIC MODE.

IN THE COMPUTER MANUAL MODE, MANUAL CONTROL OF THE REPLENISH VALVE IS PROVIDED BY A SET OF THUMBWHEEL SWITCHES LOCATED ON THE LCC CONTROL AND MONITOR (C/M) PANEL.

2. GENERATION OF DISCRETES

WHEN THE COMPUTER IS OPERATING IN THE AUTOMATIC MODE, IT IS CAPABLE OF ISSUING DISCRETES BASED UPON THE PERCENT OF FLIGHT MASS IN THE S-IVB TANK. THE PERCENT OF FLIGHT MASS IS CALCULATED FROM THE PU COARSE MASS POTENTIOMETER INPUT ANALOG SIGNAL, DIGITIZED AND COMPARED WITH A DIGITAL THUMBWHEEL SETTING ON THE DISCRETE GENERATOR PANEL. IF THE DIGITIZED PERCENT OF MASS IS EQUAL TO OR GREATER THAN THE THUMBWHEEL SETTING, A DISCRETE (+28 VDC) IS ISSUED TO THE LOADING NETWORKS. THE ONLY EXCEPTION TO THIS IS THE 100 % FLIGHT MASS DISCRETE WHICH HAS AN UPPER AND LOWER LIMIT. ALL DISCRETES CAN BE ISSUED MANUALLY FROM THE C/M PANEL.

3. PERCENT OF MASS DISPLAYS

IN CONJUNCTION WITH THE ABOVE FUNCTION OF THE TANKING COMPUTER, THE COMPUTER PROVIDES DIGITAL PERCENT OF FLIGHT MASS OUTPUTS TO VARIOUS LCC PANELS FOR A CONTINUOUS MONITORING CAPABILITY OF THE PERCENT OF FLIGHT MASS IN THE S-IVB LH2 TANK.

B. PROPELLANT LOADING NETWORKS

1. AUTOMATIC VALVE SEQUENCING

AUTOMATIC SEQUENCING OF THE LH2 VALVES DURING THE FILL, DRAIN AND REVERT ASPECTS OF PROPELLANT LOADING IS THE PRIMARY FUNCTION OF THE LOADING NETWORKS. AUTOMATIC VALVE CONTROL DURING FILL IS ACCOMPLISHED BY UTILIZING THE DISCRETE INPUTS FROM THE TANKING COMPUTER TO SPECIFY WHAT VALVE SEQUENCE IS TO BE PERFORMED. (REFERENCE FIGURE 15-1)

FIGURE 15-1. NORMAL LH2 LOADING SEQUENCE

SIVB LH2 LOADING SEQUENCE (NORMAL FILL)	APPROXIMATE TIME OF EVENT OCCURENCE IN REFERENCE TO COUNTDOWN	SYSTEM RESPONSE (NORMAL)
1. FILL SEQUENCE INITIATED (MAN)	T-5 HRS 4'0"	S-II LOADING INITIATED
2. S-II SLOW FILL TO 100% COMP (AUTO)		S-II LH2 DISCRETE GEN ISSUES S-II LH2 STOP SLOW FILL
3. START S-IVB LH2 CHILLDOWN (AUTO)	T-4 HRS 21'0"	REQUEST SIVB LH2 TNK VENT VLV TO BE OPENED OPENS S-IVB LH2 F&D VLV AND DEBRIS VLV OPEN S-IVB FILL VLV TO REDUCED POSITION SLOW FILL @ 500 GPM BEGINS
4. 4% FLT MASS C4SP ENABLES FILL VLV (MAN)		ENABLES FILL VLV TO BE AUTOMATICALLY OPENED TO FULL OPEN POSITION
5. 5% FLT MASS (AUTO)	T-4 HRS. 7'0"	S-IVB LH2 DISCRETE GEN ISSUES S-IVB LH2 C/D COMP: A. OPENS S-IVB FILL VLV TO FULL B. FAST FILL @ 3000 GPM BEGINS
6. 10% FLT MASS (AUTO)		S-IVB LH2 DISCRETE GEN ISSUES S-IVB RECIRC PUMP ENABLE: A. RDY FOR + 4D411 PWR LOGIC CHAIN B. RDY TO LOAD LH2 LOGIC CHAIN C. LH2 C/D PUMP RDY TO START LOGIC CHAIN
7. 90% FLT MASS (AUTO)		S-IVB LH2 DISCRETE GEN ISSUES S-IVB START COLD HE LOADING: ILLUMINATES "RDY FOR 3000 PSI COLD HE" ON S-IVB STG PRESS PANEL (SUBSEQUENT MAN LOADING OF COLD HE)
8. 98% FLT MASS (AUTO)		S-IVB LH2 DISCRETE GEN ISSUES S-IVB STOP FAST FILL: A. REDUCES FILL VLV POS B. SLOW FILL @ 500 GPM BEGINS
9. 100% FLT MASS (MAN)	T-3 HRS 38'0"	S-IVB LH2 DISCRETE GEN ISSUES S-IVB STOP SLOW FILL: A. CLOSES FILL VLV B. ENABLES REPLENISH AUTO VLV DRIVE SIGNAL C. REPLENISH CYCLE TO 100% FLT MASS BEGINS.

FIGURE 15-1.

NORMAL LH2 LOADING SEQUENCE (CONTINUED)

SIVB LH2 LOADING
SEQUENCE (NORMAL
FILL)

APPROXIMATE TIME OF
EVENT OCCURRENCE IN
REFERENCE TO COUNTDOWN

SYSTEM RESPONSE
(NORMAL)

10. TERMINATE LH2
REPLENISH

T-0 HRS 3'6"
(START OF TERM. SEQ)

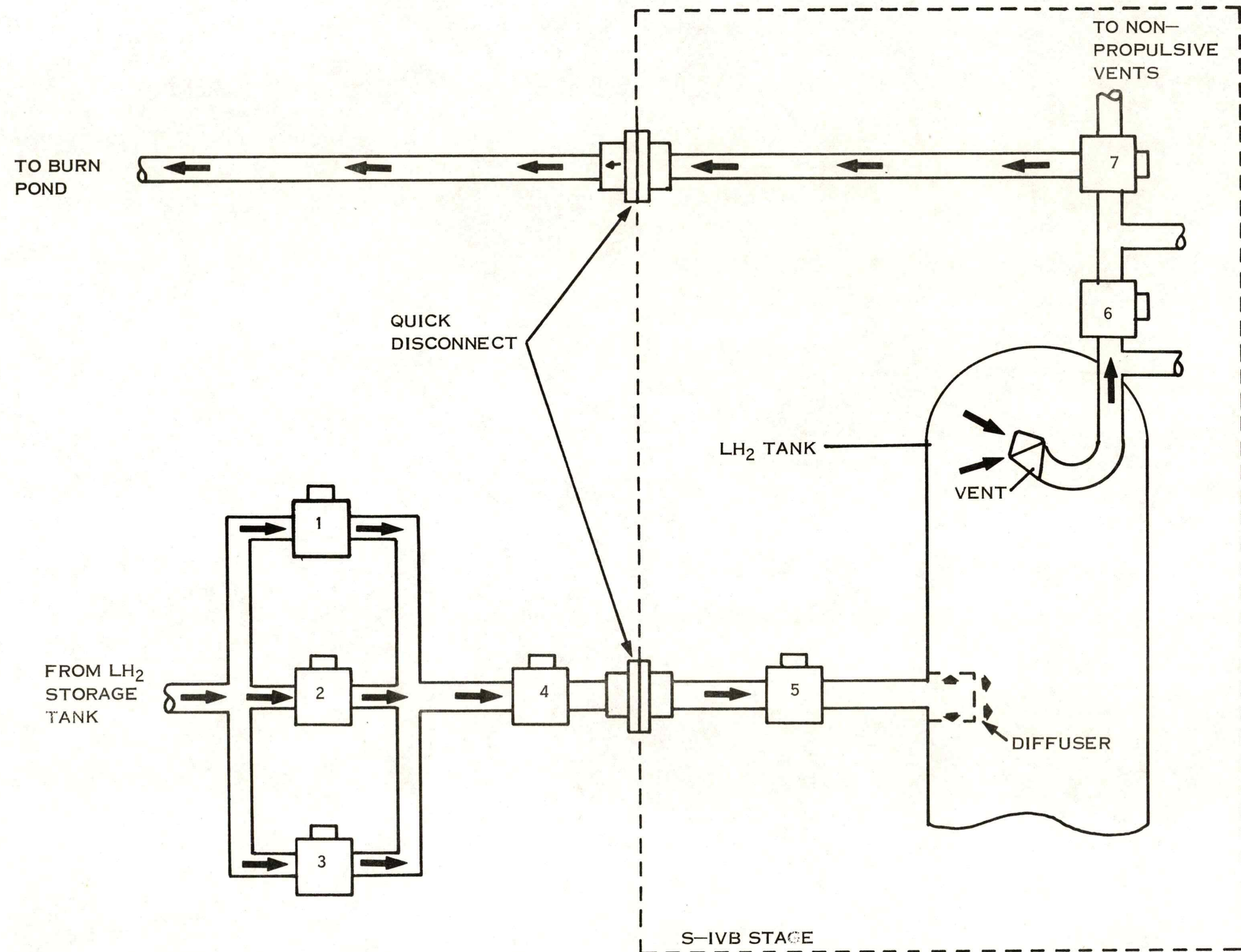
S-IVB LH2 DISCRETE GEN ISSUES S-IVB FLT MASS (IF FLT MASS IS
WITHIN TOLERANCE, CAN BE ISSUED PRIOR TO THIS TIME)
TERMINAL SEQUENCER ISSUES "TERMINATE LOX AND LH2 REPLENISH
(T-186 SEC)":
A. RESULTS IN A FORCED S-IVB REPLENISH COMP CMD
B. CLOSES S-IVB REPLENISH VLV
C. CLOSES S-IVB F&D VLV

2. **AUTOMATIC VALVE MONITORING**
THE VALVE POSITIONS ARE CONTINUOUSLY MONITORED BY THE VALVE CONTROL LOGIC VIA VALVE TALKBACKS DURING LOADING. INADVERTENT VALVE OPERATIONS OR MALFUNCTIONS DURING A FILL SEQUENCE WILL CAUSE AN AUTOMATIC REVERT VALVE SEQUENCE.
3. **MANUAL VALVE CONTROL**
THE PROPELLANT LOADING NETWORKS PROVIDES THE CAPABILITY TO MANUALLY OVERRIDE ANY AUTOMATIC VALVE COMMAND. IN ADDITION, THE NETWORKS PROVIDE TALKBACKS OF VALVE POSITIONS TO PANELS LOCATED IN THE LCC.
4. **VALVES**
ONLY THE S-IVB LH2 VALVES (FILL AND DRAIN VALVE, DEBRIS VALVE, TANK VENT VALVE) AND THE REPLENISH AND FILL VALVE HAVE BEEN SHOWN IN THE ELECTRICAL AND LOGIC SCHEMATICS FOR CLARITY. THE FOLLOWING SKETCH REPRESENTS THEIR LOCATION (FIGURE 15-2).

FIGURE 15-2 LH₂ NORMAL FLOW DURING FILL

VALVE DESCRIPTION:

- NO. 1 - AUX FILL VLV, PNEUMATIC NC, 3 POSITION
- NO. 2 - MAIN FILL VLV, PNEUMATIC NC, 3 POSITION
- NO. 3 - REPLENISH VLV, PNEUMATIC NC, FLOW CONTROL
- NO. 4 - S-IVB DEBRIS VLV, PNEUMATIC NC, 2 POSITION
- NO. 5 - S-IVB FILL AND DRAIN VLV, PNEUMATIC NC, 2 POSITION
- NO. 6 - S-IVB TANK VENT VLV, PNEUMATIC NC, 2 POSITION
- NO. 7 - S-IVB DIRECTION VENT VLV, PNEUMATIC NC, BUTTERFLY, 2 POSITION



SYSTEM BLOCK DIAGRAM

THE FOLLOWING BLOCK DIAGRAM REPRESENTS THE S-IVB LH2 PROPELLANT LOADING SYSTEM (FIGURE 15-3). BELOW IS A LISTING OF THE VARIOUS BLOCK FUNCTIONAL DESCRIPTIONS.

A. LEVEL SENSOR

THE LEVEL SENSOR CONSISTS OF THE S-IVB LH2 PU COARSE MASS POTENTIOMETER. THE SUPPLY VOLTAGE (+15 VDC) IS FED TO THE POTENTIOMETER FROM THE COMPUTER WHEN THE SENSOR IS ENERGIZED. THIS SUPPLY VOLTAGE IS USED AS A REFERENCE SIGNAL AND THE WIPER OF THE POTENTIOMETER IS USED AS THE SENSOR SIGNAL TO THE MANUAL AND AUTOMATIC COMPUTERS.

B. FULL LOAD RATIO NETWORKS

THIS NETWORK IS A FILTER AND A DC AMPLIFIER WHOSE GAIN IS VARIABLE BY USE OF A FOUR-DECADE THUMBWHEEL SWITCH ON THE COMPUTER PANEL. THE INPUT SIGNAL (LEVEL SENSOR REFERENCE VOLTAGE) REPRESENTS A FULL TANK; ITS OUTPUT REPRESENTS 100 % FLIGHT MASS, WHICH IS ADJUSTED ACCORDING TO THE FLIGHT MISSION REQUIREMENTS VIA THE THUMBWHEEL SWITCHES.

THE DC AMPLIFIER GAIN IS CHANGED ON RECEIPT OF THE TANK PRESSURIZING COMMAND. THIS COMMAND SWITCHES THE REFERENCE FROM THE FOUR-DECADE UNPRESSURIZED REFERENCE SETTING TO THE FOUR-DECADE PRESSURIZED REFERENCE SETTING.

C. FILTERS

THE FILTER MINIMIZES DISTURBANCES CAUSED BY FUEL SLOSHING AND FILTERS THE INPUT SIGNAL (WIPER OF THE LEVEL SENSOR) FOR LINE NOISE PICKUP.

D. AUTO RATIOMETER

THE AUTO RATIOMETER COMPUTES THE SIGNAL-TO-REFERENCE RATIO. THIS COMPUTED RATIO REPRESENTS PERCENT OF FLIGHT MASS. THE RATIO IS PRODUCED IN A 17 BIT BCD SIGNAL. THIS SIGNAL IS USED IN THREE WAYS:

- (1) IT IS DECODED IN THE RATIOMETER FOR DRIVING AUTO MASS READOUTS FROM 000.0 TO 199.9 PERCENT.
- (2) THE FOUR MOST SIGNIFICANT DIGITS (MSD) OF THIS PERCENTAGE ARE SENT TO THE DISCRETE GENERATOR FOR PRODUCING DISCRETES.
- (3) THE ORIGINAL 17 BIT BCD SIGNAL IS ROUTED TO THE S-IVB PANELS AND TO THE C /M PANEL FOR PROPELLANT MASS DISPLAY.

E. MANUAL RATIOMETER

THE FUNCTION OF THE MANUAL RATIOMETER IS IDENTICAL TO THE AUTO RATIOMETER EXCEPT FOR ONE ASPECT. THE DECIMAL OUTPUT OF THE MANUAL RATIOMETER IS FED TO THE DISCRETE GENERATOR WHICH IS USED TO GENERATE A REDUNDANT EMERGENCY STOP FAST FILL DISCRETE.

F. INVERTER

THE INVERTER IS USED TO INVERT THE OUTPUT SIGNAL OF THE FILTER.

G. ERROR AMPLIFIER, INTEGRATOR AND SUMMER
THE FUNCTION OF THESE ARE AS FOLLOWS:

1. WHEN THE COMPUTER STABILIZES THE REPLENISH RATE, PROPELLANT MASS IS EQUAL TO FLIGHT MASS AND NO ERROR IS GENERATED. THE INPUT TO THE INTEGRATOR IS LIKEWISE ZERO (NO ERROR), BUT ITS OUTPUT IS A TIME INTEGRATION OF ALL PREVIOUS ERRORS, POSITIVE AND NEGATIVE AND MAY BE A VALUE OTHER THAN ZERO. IT IS A VALUE WHICH IS ENOUGH TO CAUSE THE PROPELLANT REPLENISH RATE TO EQUAL BOILOFF RATE AND CREATE A FINAL COMPUTER ERROR SIGNAL OF ZERO.
2. IF FOR SOME REASON THE PROPELLANT BOILOFF RATE INCREASES SLIGHTLY, THE ERROR AMPLIFIER GENERATES A NEGATIVE SIGNAL WHICH CAUSES THE REPLENISH VALVE TO OPEN WIDER (THE SUMMER IS A VOLTAGE-TO-CURRENT AMPLIFIER WHICH GENERATES A 0-50 MA DRIVE SIGNAL TO THE CURRENT-TO-AIR TRANSDUCER IN THE VALVE CONTROL ASSEMBLY FOR REPLENISH VALVE CONTROL). TO COMPENSATE FOR THE INCREASED BOILOFF RATE. AT THE SAME TIME, THE OUTPUT OF THE INTEGRATOR CHANGES SLIGHTLY NEGATIVE CREATING A REVISED MEMORY OF THE "CORRECT" REPLENISH RATE. WHEN THE ERROR SIGNAL AGAIN BECOMES ZERO THE SYSTEM IS RESTABLIZED WITH A NEW INTEGRATOR OUTPUT.

H. DISCRETE GENERATOR

THE DISCRETE GENERATOR RECEIVES FROM THE AUTO RATIOMETER AN INPUT SIGNAL CONSISTING OF A 28 LINE DECIMAL SIGNAL REPRESENTING A PROPELLANT LEVEL (PERCENT OF FLIGHT MASS) OF 000.0 TO 199.9 PERCENT. A NINE-LINE DECIMAL SIGNAL IS ALSO RECEIVED FROM THE MANUAL RATIOMETER FOR GENERATING THE BACK-UP EMERGENCY STOP FAST FILL DISCRETE.

EACH OF THE SEVEN 3-DECADE THUMBWHEEL SWITCHES ON THE DISCRETE GENERATOR PANEL ARE SET AS A REFERENCE FOR A PARTICULAR DISCRETE, AND A DISCRETE WILL BE GENERATED WHEN THE RATIO FROM THE AUTO RATIOMETER IS EQUAL TO OR GREATER THAN THE SETTING OF THE CORRESPONDING THUMBWHEEL. TWO 4-DECADE THUMBWHEEL SWITCHES ON THE PANEL ARE SET FOR UPPER AND LOWER LIMIT REFERENCES FOR THE FLIGHT MASS DISCRETE. THIS DISCRETE IS GENERATED WHEN THE RATIO FROM THE AUTO RATIOMETER IS EQUAL TO OR GREATER THAN THE LOWER LIMIT AND LESS THAN THE UPPER LIMIT.

ONE FURTHER DISCRETE IS ESTABLISHED BY A SINGLE-DECADE THUMBWHEEL SWITCH INSIDE THE DISCRETE GENERATOR. THIS DISCRETE, EMERGENCY STOP FAST FILL, CAN BE SET TO OCCUR BETWEEN 90 AND 99 PERCENT FLIGHT MASS. THIS SIGNAL IS BASED UPON THE DECIMAL SIGNAL FROM THE MANUAL RATIOMETER AND CONSTITUTES A REDUNDANT STOP FAST FILL SIGNAL.

I. DRIVER

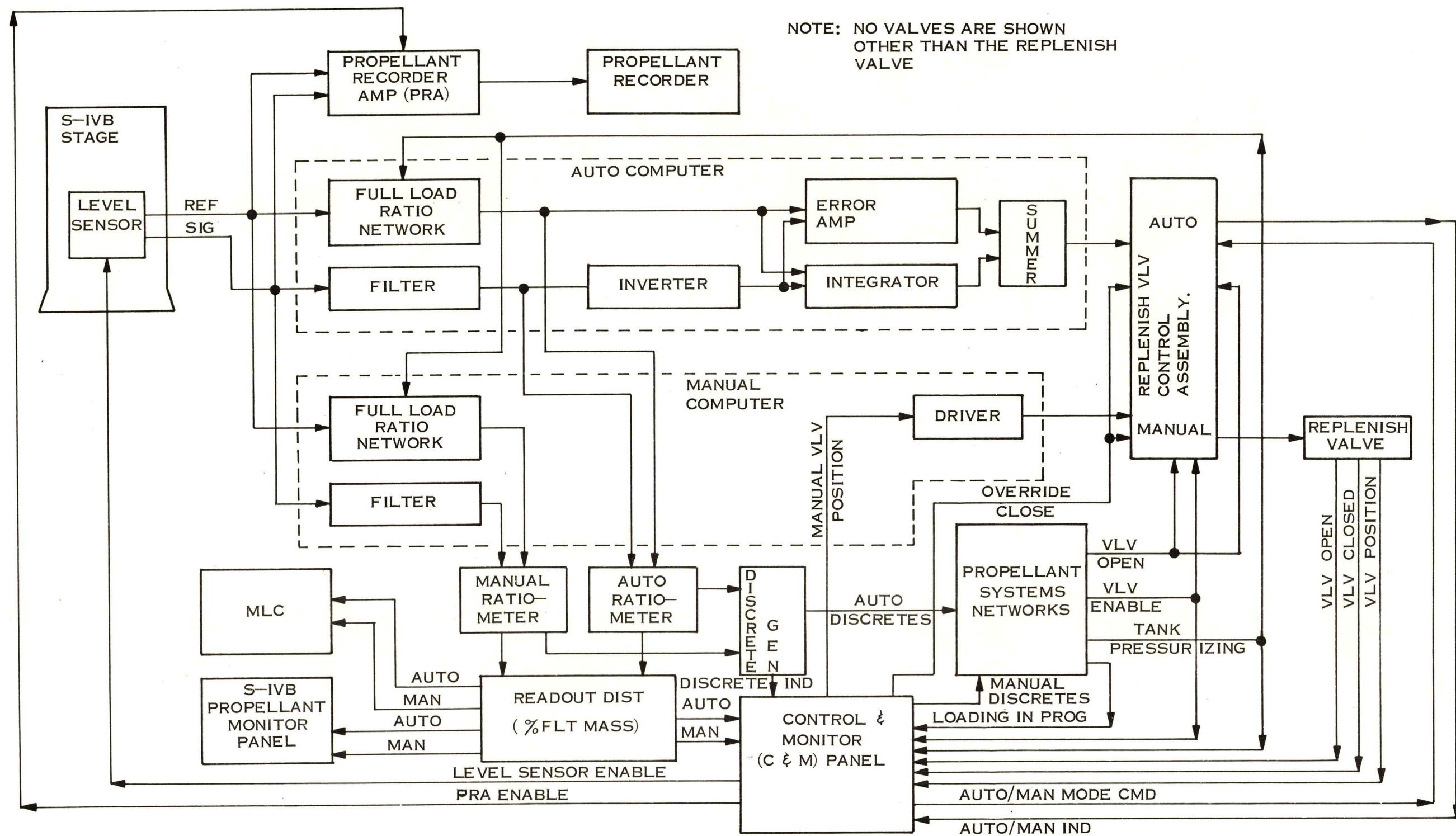
THE REPLENISH VALVE POSITION CAN BE OPERATED MANUALLY BY USE OF A TWO-DECADE THUMBWHEEL SWITCH LOCATED ON THE C /M PANEL. THE THUMBWHEEL SWITCH CONTROLS THE AMOUNT OF FEEDBACK OF THE DRIVE AMPLIFIER (DRIVER) AND HENCE, THE OUTPUT SIGNAL WHICH DRIVES THE CURRENT-TO-AIR TRANSDUCER IN THE REPLENISH VALVE CONTROL ASSEMBLY CAN BE VARIED. THE TRANSDUCER CONVERTS THE 0-50 MA DRIVE SIGNAL TO A 3-15 PSI PNEUMATIC SIGNAL FOR MODULATING THE VALVE ACTUATOR.

J. REPLENISH VALVE CONTROL ASSEMBLY

THIS ASSEMBLY CONTAINS THE PNEUMATIC PILOT VALVES AND CURRENT-TO-AIR TRANSDUCERS FOR CONTROL OF THE REPLENISH VALVE.

- K. REPLENISH VALVE
THE REPLENISH VALVE IS PNEUMATICALLY OPERATED VALVE USED TO CONTROL THE LH2 REPLENISH FLOW RATE. THE VALVE ALSO PROVIDES OPEN, CLOSED AND POSITION (POTENTIOMETER) TALKBACKS.
- L. READOUT DISTRIBUTORS
THE READOUT DISTRIBUTOR ROUTES THE MANUAL AND AUTO RATIO METER OUTPUT SIGNALS TO THE VARIOUS READOUT DISPLAYS.
- M. PROPELLANT SYSTEM NETWORKS
THE PROPELLANT SYSTEM NETWORK CONTAINS THE RELAY LOGIC TO ACTUATE AND MONITOR THE PROPELLANT LOADING VALVES.
- N. CONTROL AND MONITOR PANEL
THE C / M PANEL PROVIDES CENTRAL CONTROL AND MONITORING OF THE PROPELLANT LOADING SYSTEM.

FIGURE 15-3. LH2 PTCS BLOCK DIAGRAM



15-4. SYSTEM SAFING (REVERT)

REVERT REFERS TO THE OVERALL LH2 (OR LOX) SAFING OF THE PROPELLANT TANKING SYSTEM. THE REVERT SEQUENCE RESULTS IN VALVE COMMANDS TO SAFE THE VEHICLE. A REVERT SEQUENCE CAN BE INITIATED AS FOLLOWS:

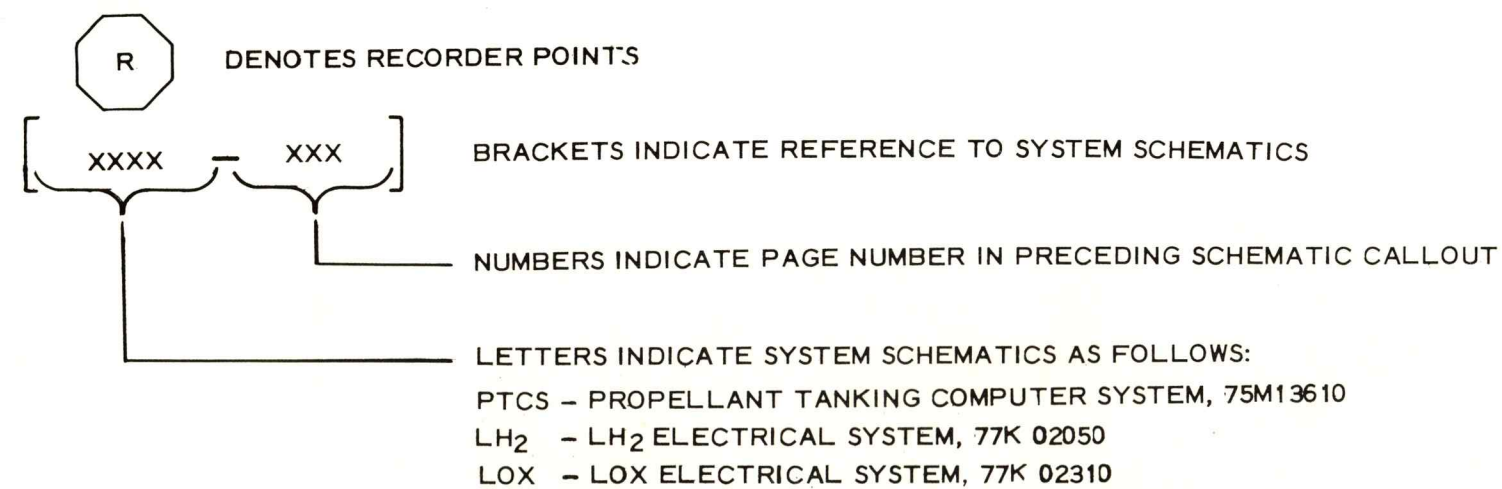
A. AUTOMATIC REVERT

1. VALVE MONITORING — THE LH2 VALVE SEQUENCING IS MONITORED DURING A FILL SEQUENCE AND IF A PROPER VALVE CONFIGURATION DOES NOT OCCUR UPON RECEIVAL OF A DISCRETE WITHIN A SPECIFIED TIME (30 SECONDS) AN AUTOMATIC REVERT COMMAND WILL BE GENERATED.
2. S-IVB LH2 RUPTURE DISK — IF THE S-IVB LH2 FILTER RUPTURE DISK PRESSURE SWITCH CLOSSES, A REVERT COMMAND WILL BE GENERATED. THE FILTER IS LOCATED BETWEEN THE S-IVB LH2 FILL VALVES AND THE LH2 DEBRIS VALVE. (S-IVB FILL BUS MUST BE ENERGIZED).
3. S-IVB LH2 TANK PRESSURE — THE S-IVB LH2 TANK PRESSURE IS MONITORED VIA A PRESSURE SWITCH WHILE THE TANK IS NOT PRESSURIZED WITH HELIUM. IF THE PRESSURE SWITCH CLOSSES, A REVERT COMMAND WILL BE GENERATED. (S-IVB FILL BUS MUST BE ENERGIZED).
4. S-IVB LH2 OVERFILL SENSOR — THE S-IVB LH2 OVERFILL SENSOR WILL CAUSE A REVERT COMMAND TO BE GENERATED WHEN IT BECOMES WET. (S-IVB FILL BUS MUST BE ENERGIZED).

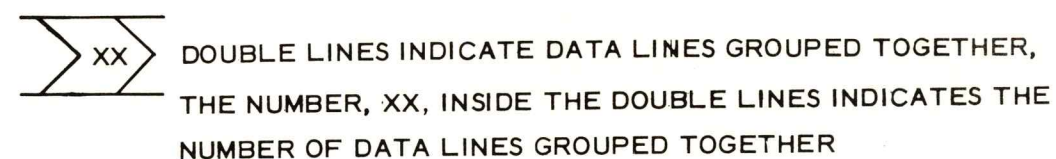
B. MANUAL REVERT

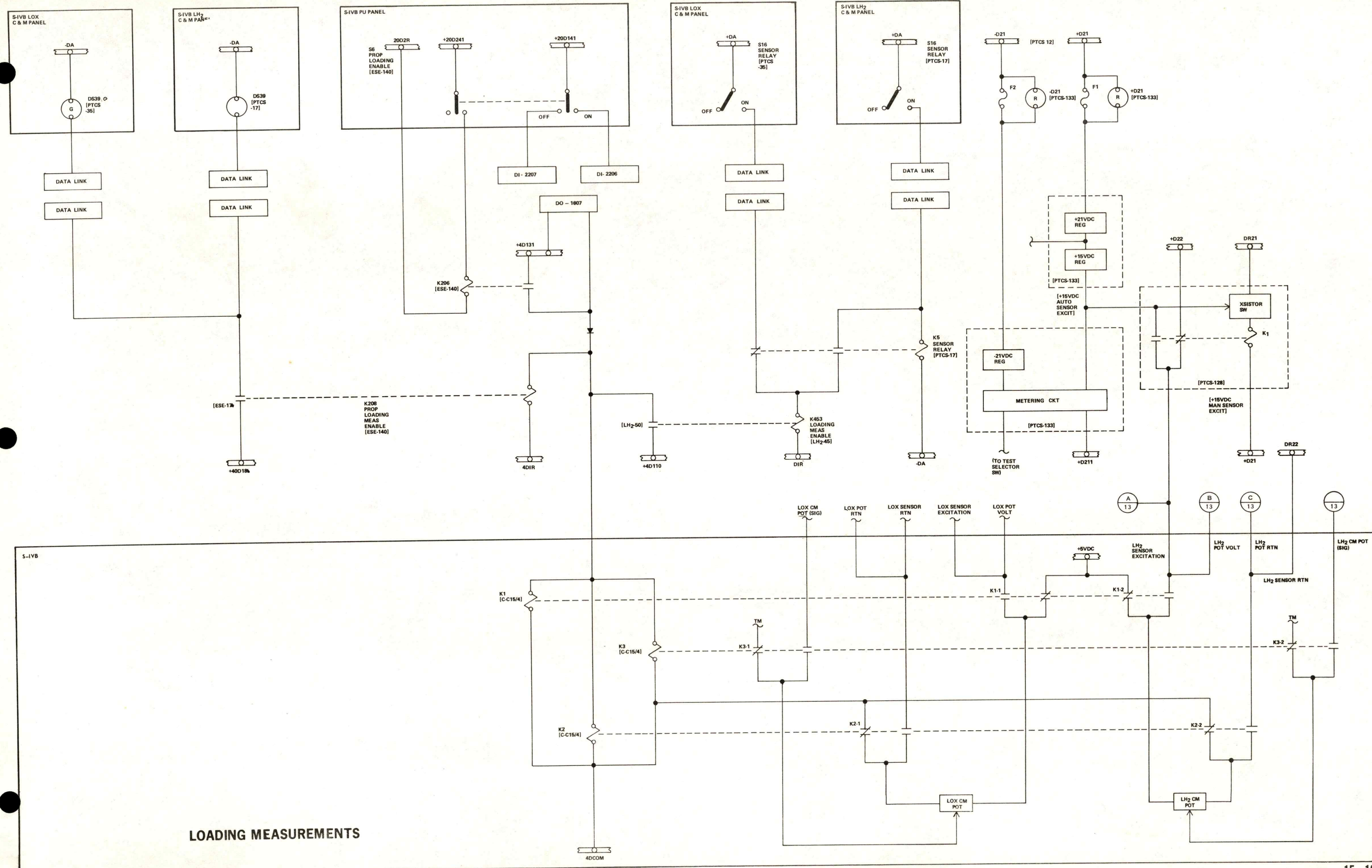
1. S-IVB LH2 REVERT — A MANUAL REVERT CAN BE INITIATED BY THE S-IVB PROPELLANT MONITOR PANEL OPERATOR VIA THE S-IVB LH2 REVERT SWITCH (MDAC FUNCTION).
2. LH2 REVERT (SYSTEM) — A MANUAL REVERT CAN ALSO BE ISSUED FROM THE PROPELLANT TANKING SYSTEM CONTROL PANEL (TBC FUNCTION).

SYMBOLS: (NOT USED PREVIOUSLY)



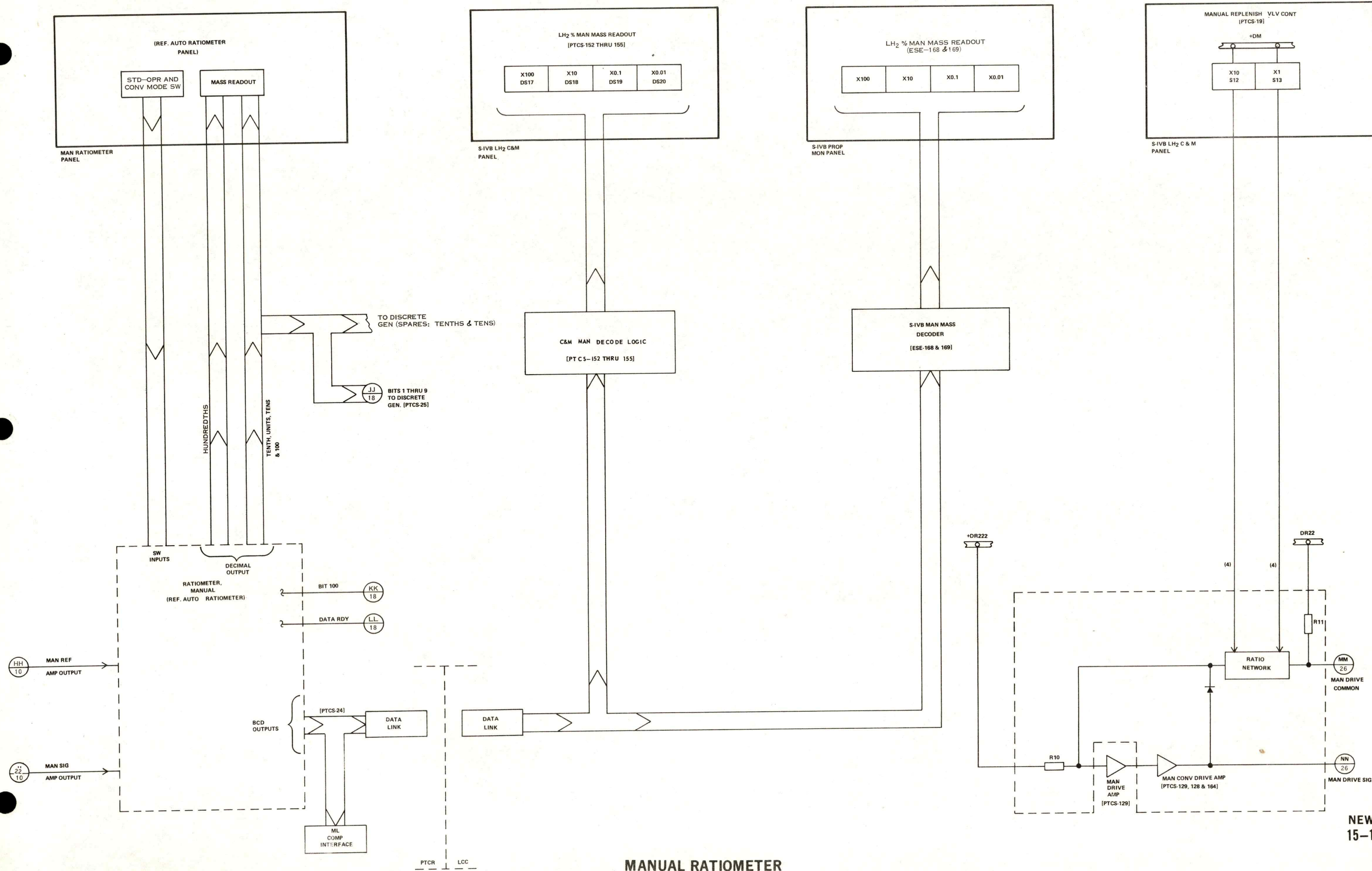
(XX) NUMBERS IN PARENTHESES, XX, INDICATE NUMBER OF SIGNALS REPRESENTED BY ONE SIGNAL LINE



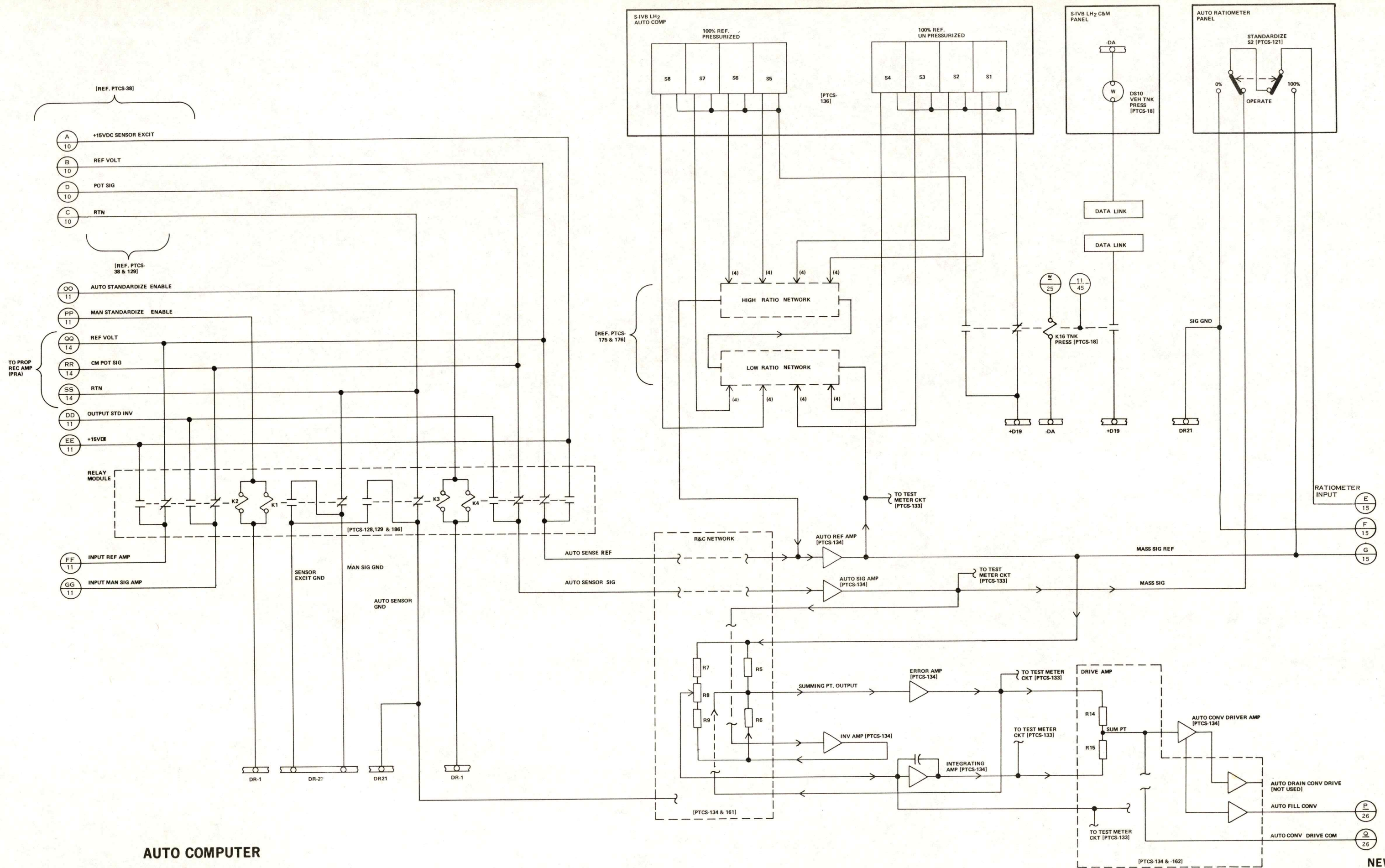


LOADING MEASUREMENTS

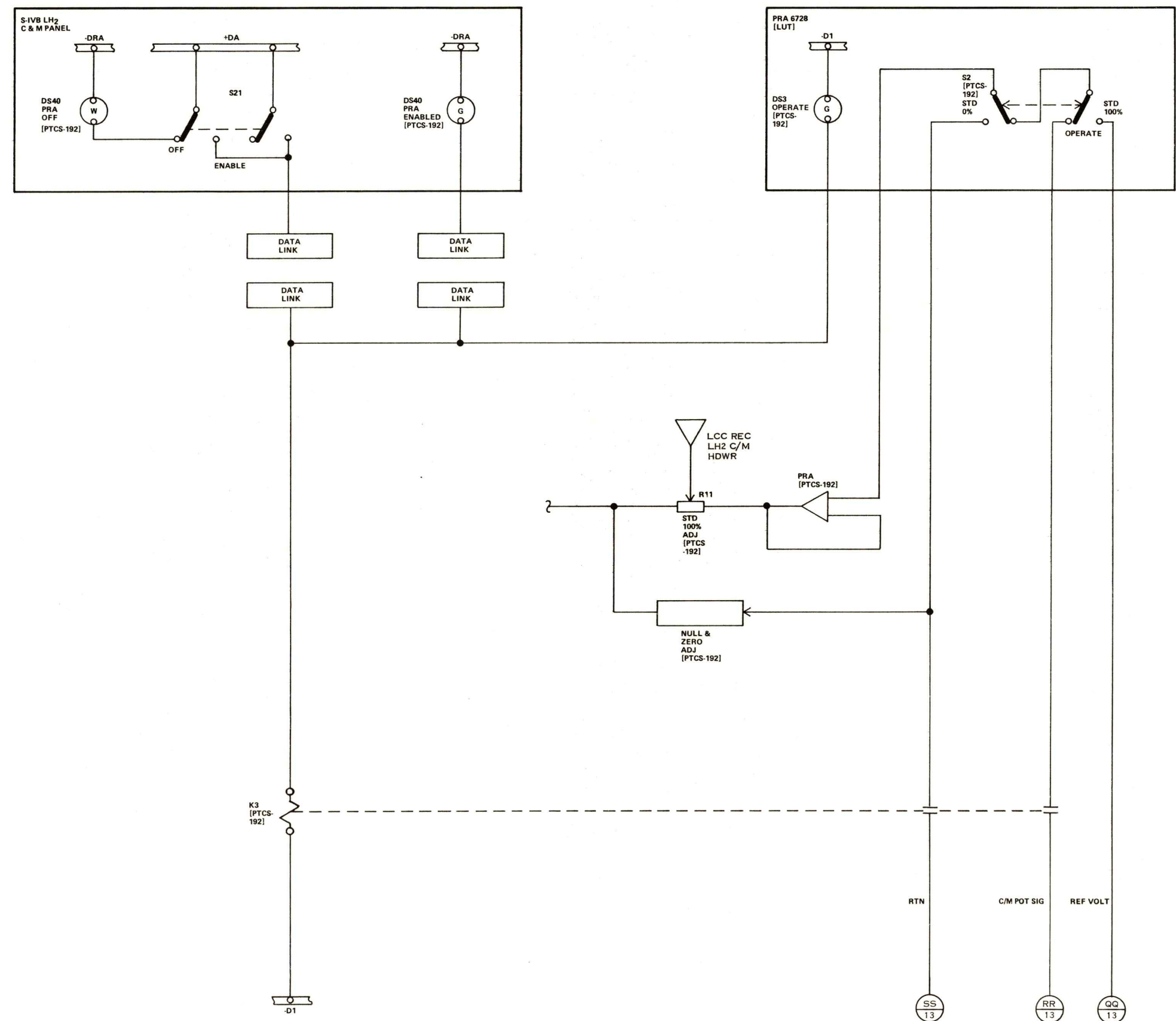




MANUAL RATIOMETER

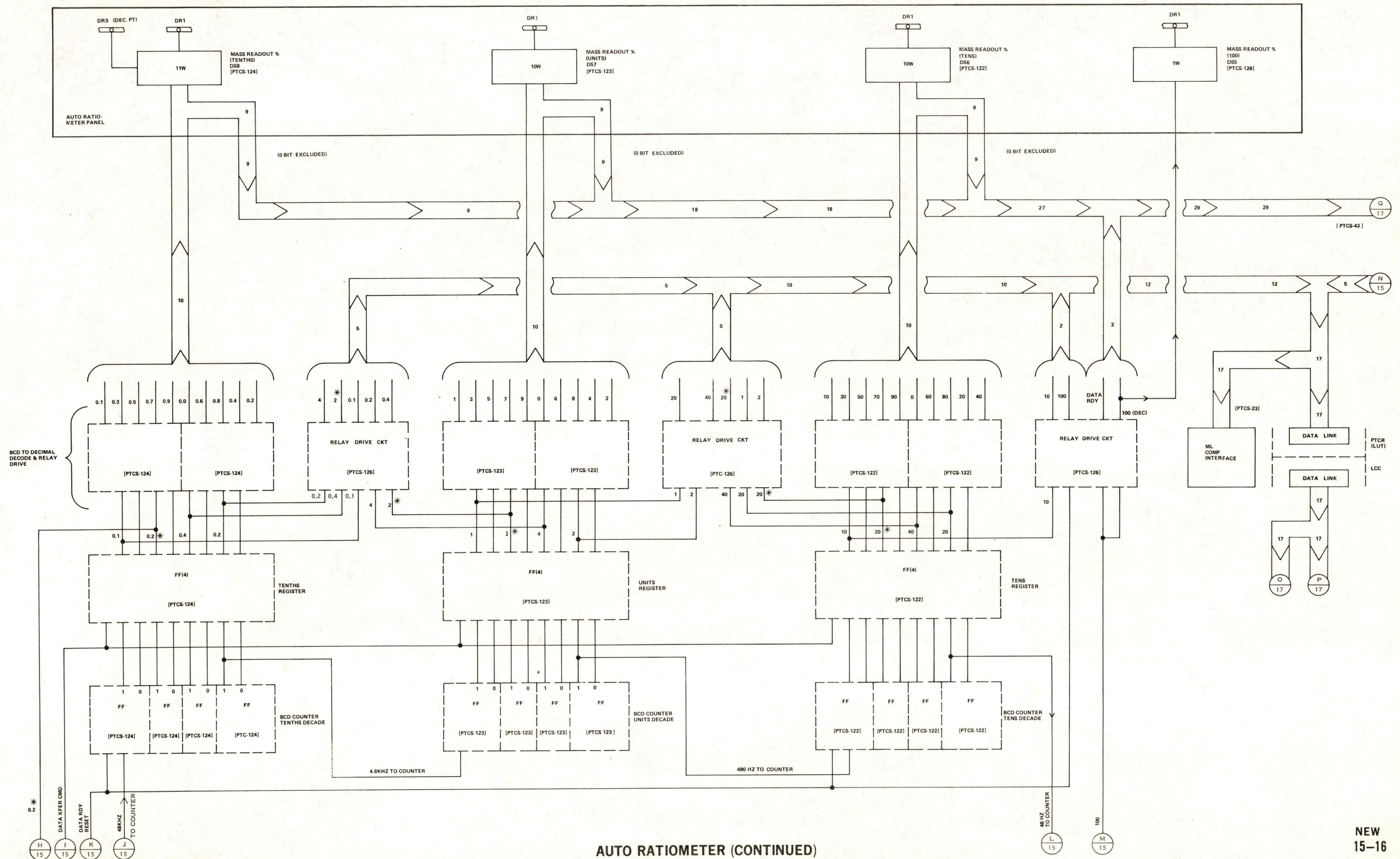


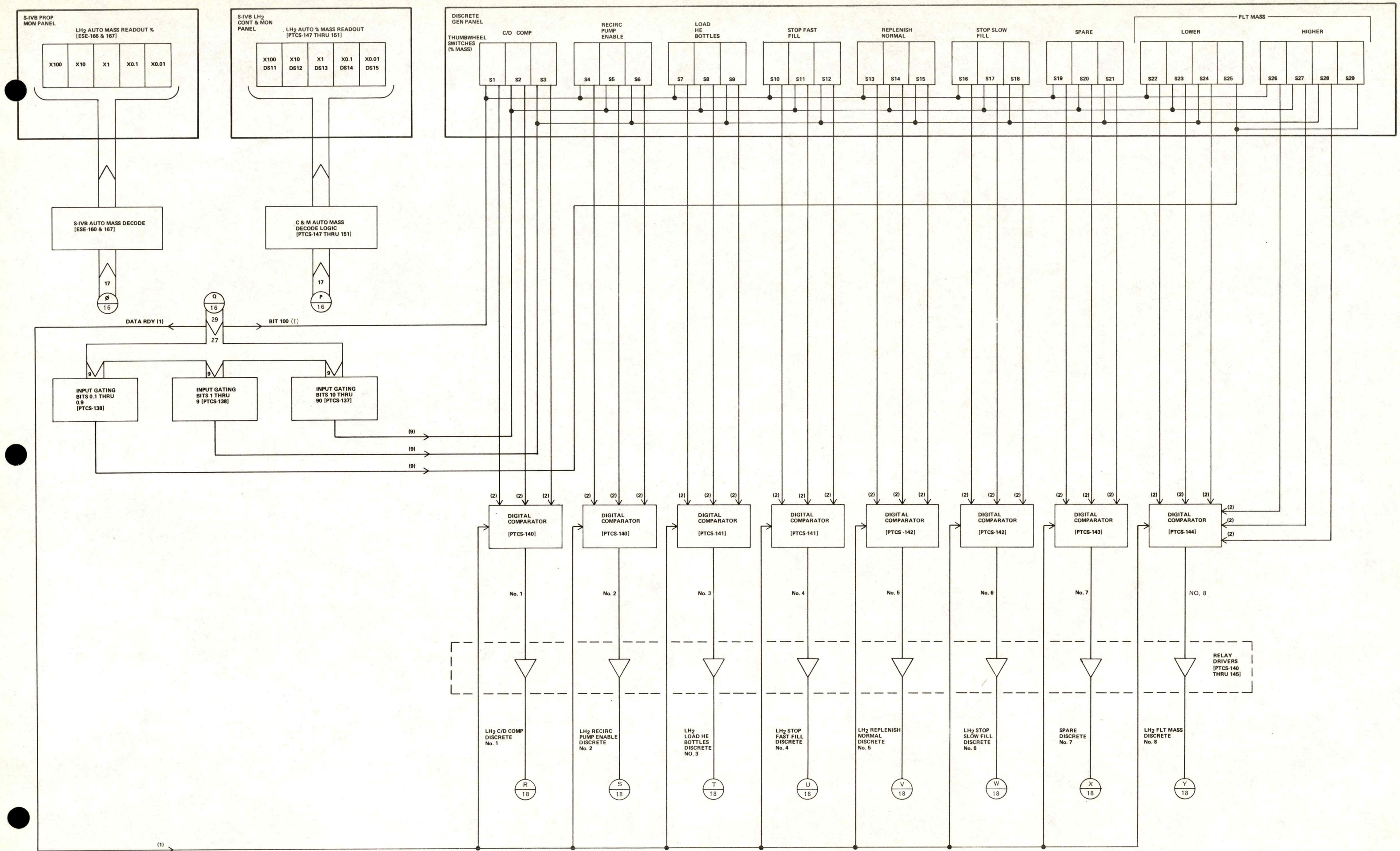
AUTO COMPUTER



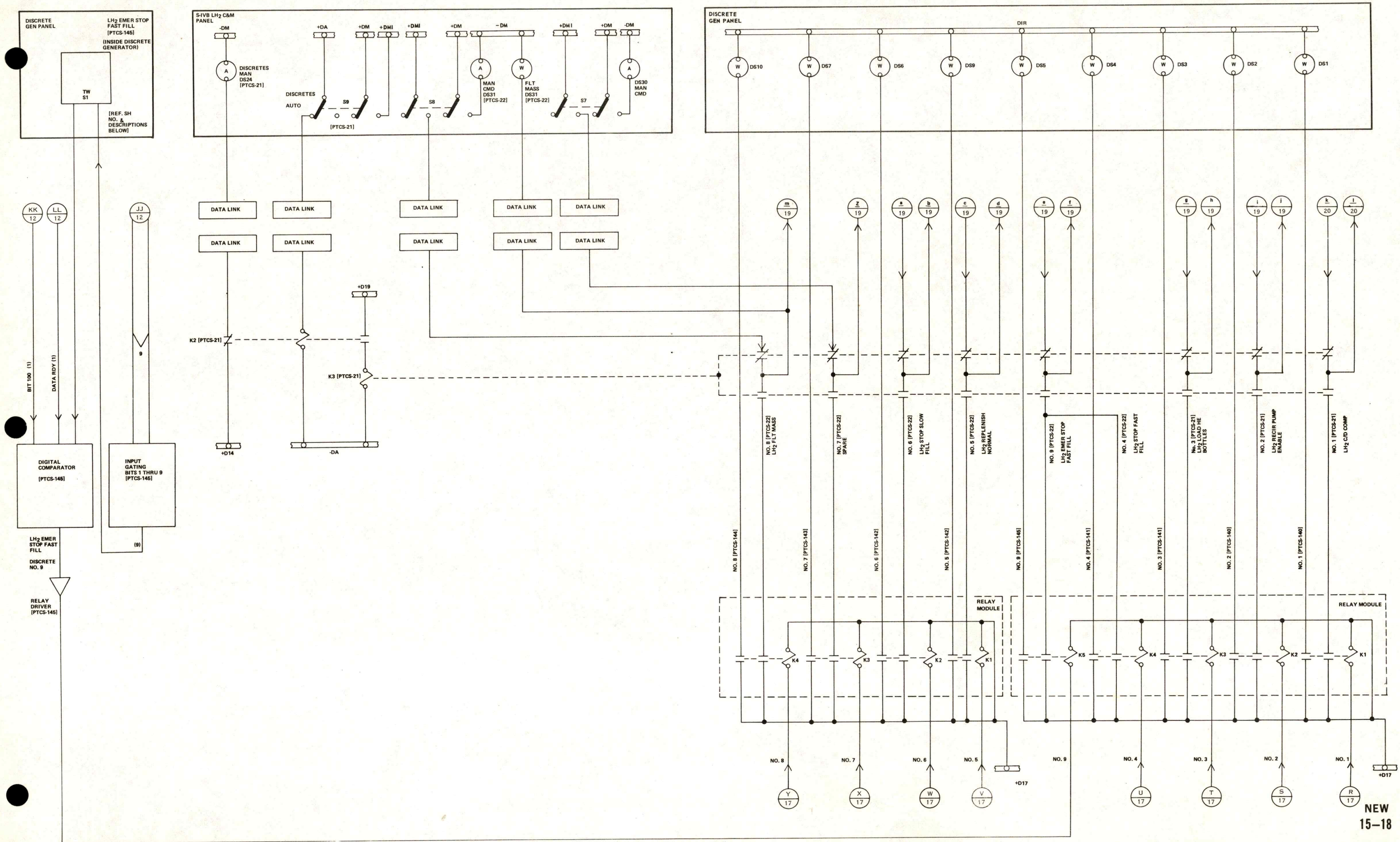
PROPELLANT RECORDER

NEW
15-14

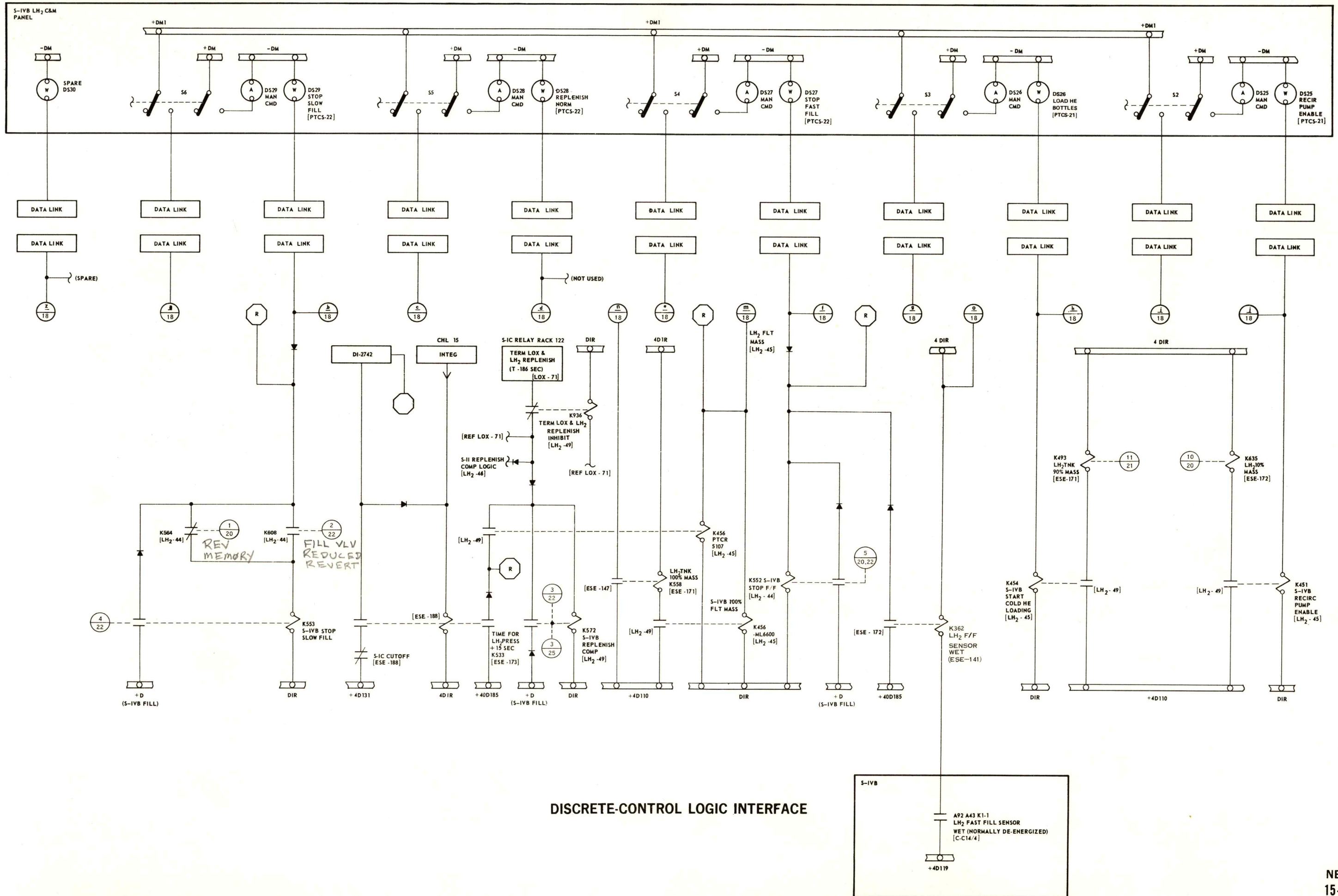


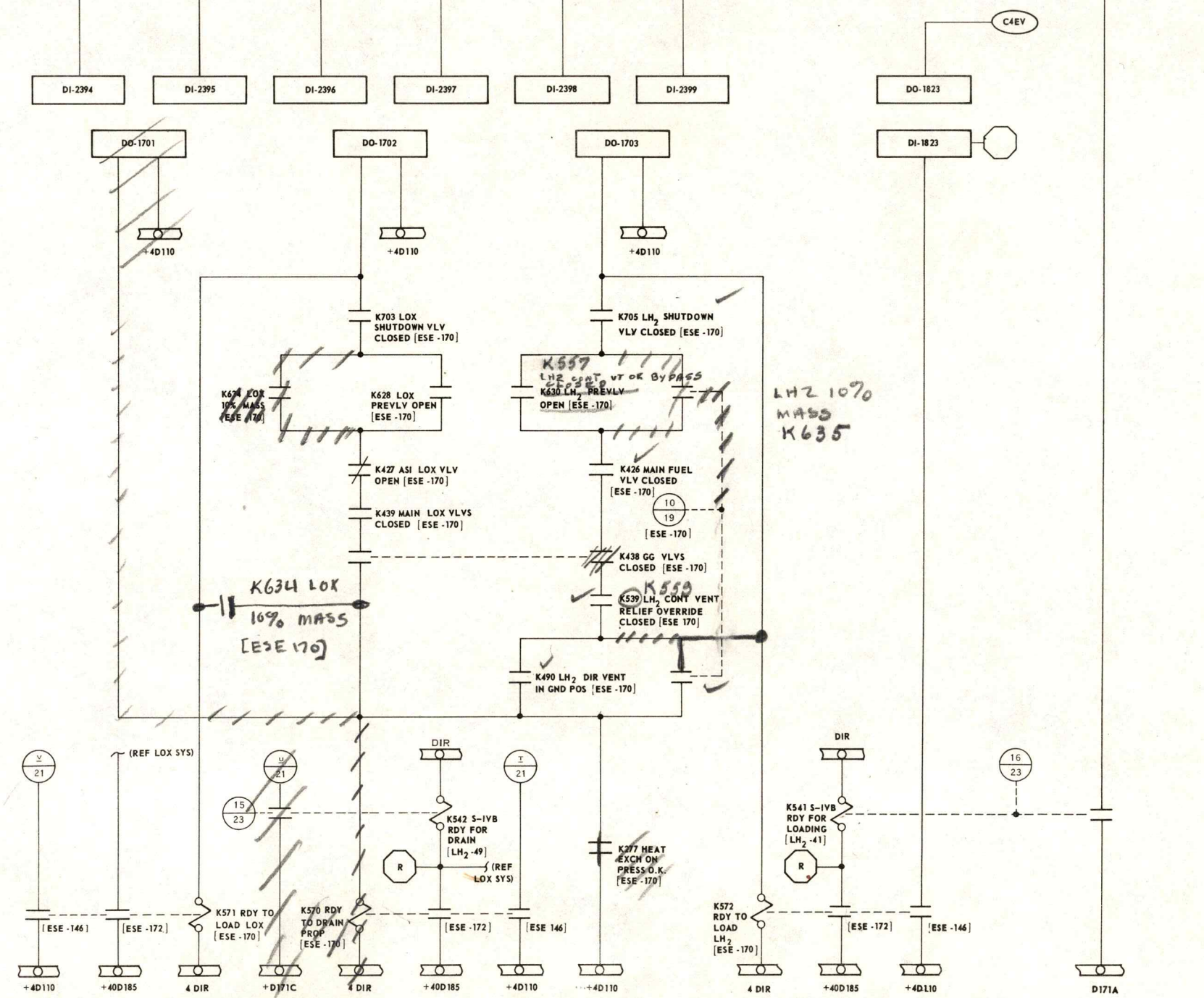
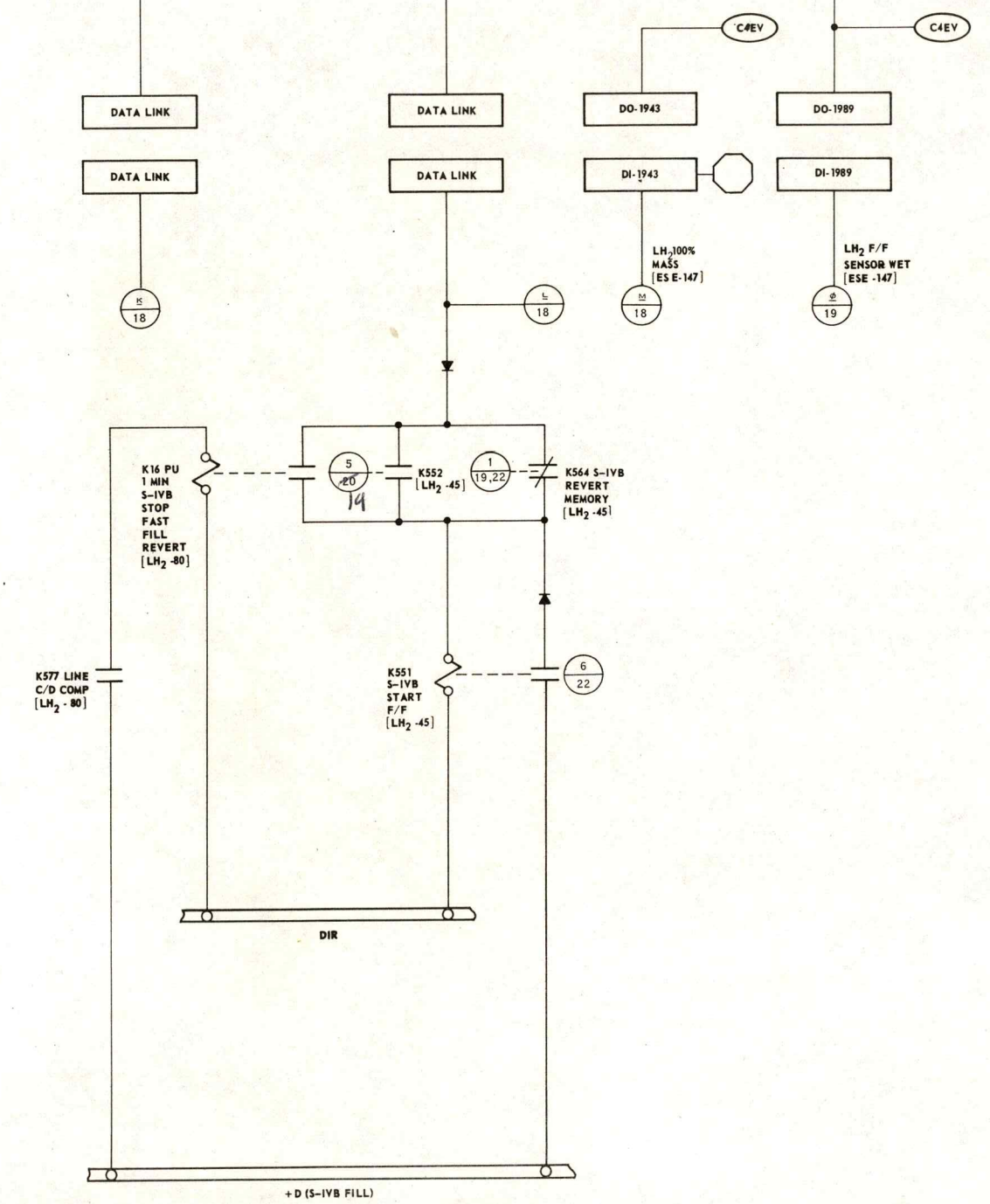
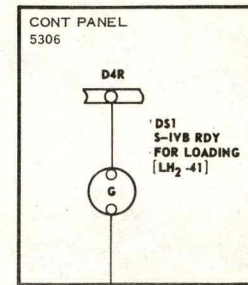
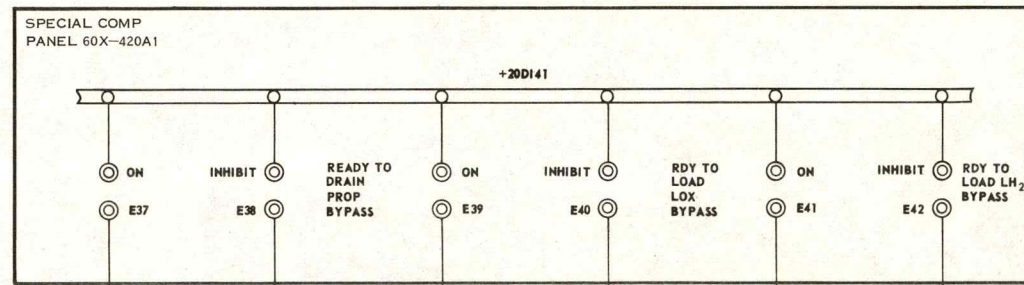
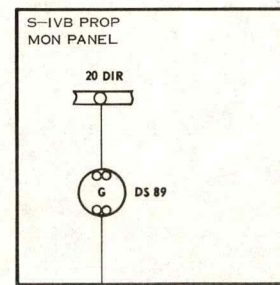
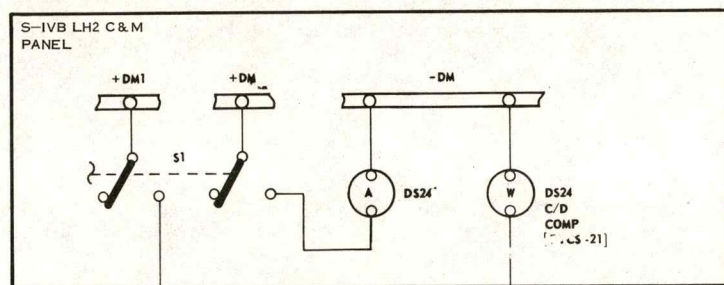


DISCRETE GENERATOR

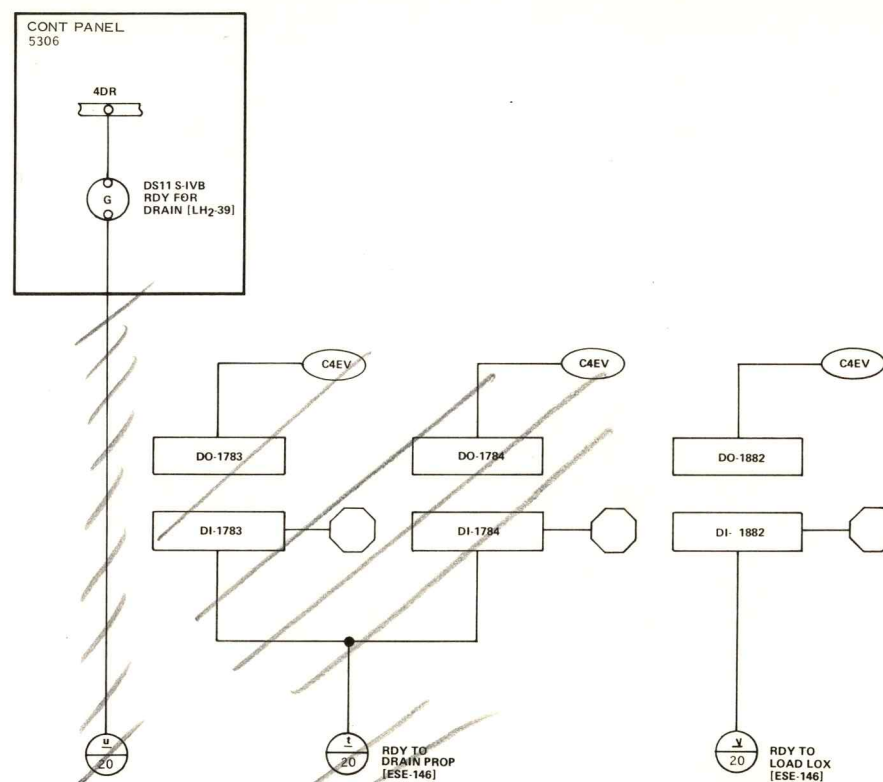
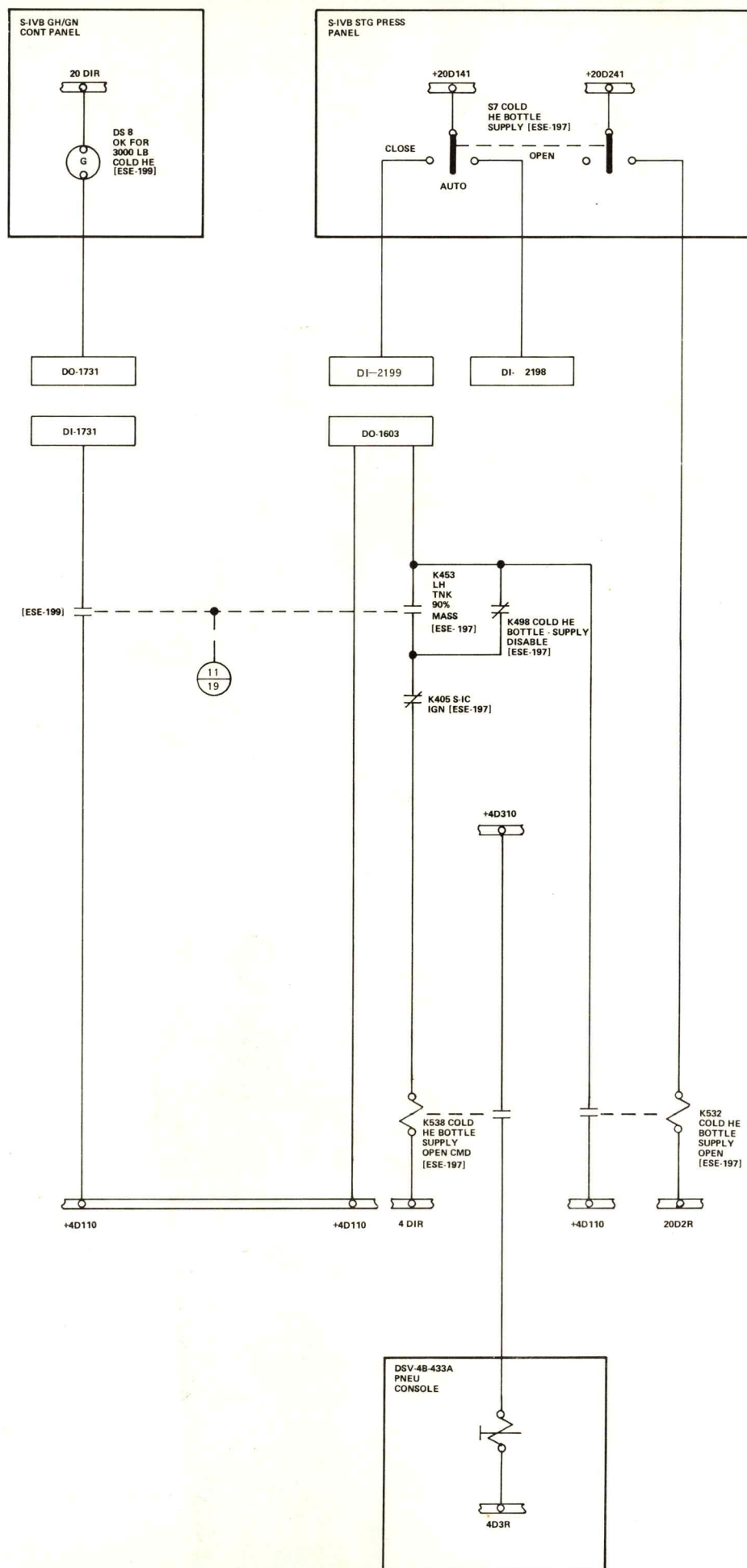


MANUAL DISCRETES

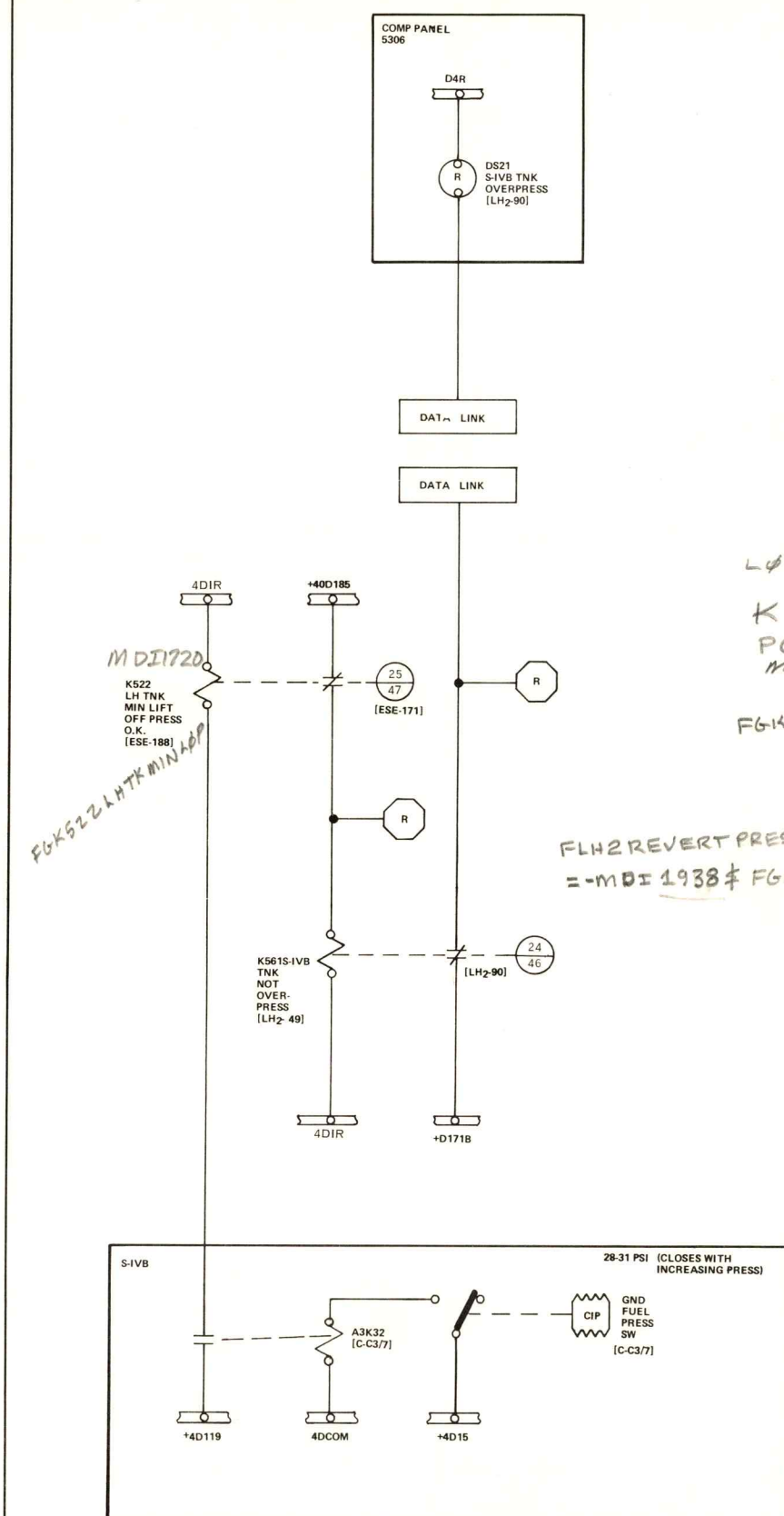




READY-TO-LOAD LOGIC



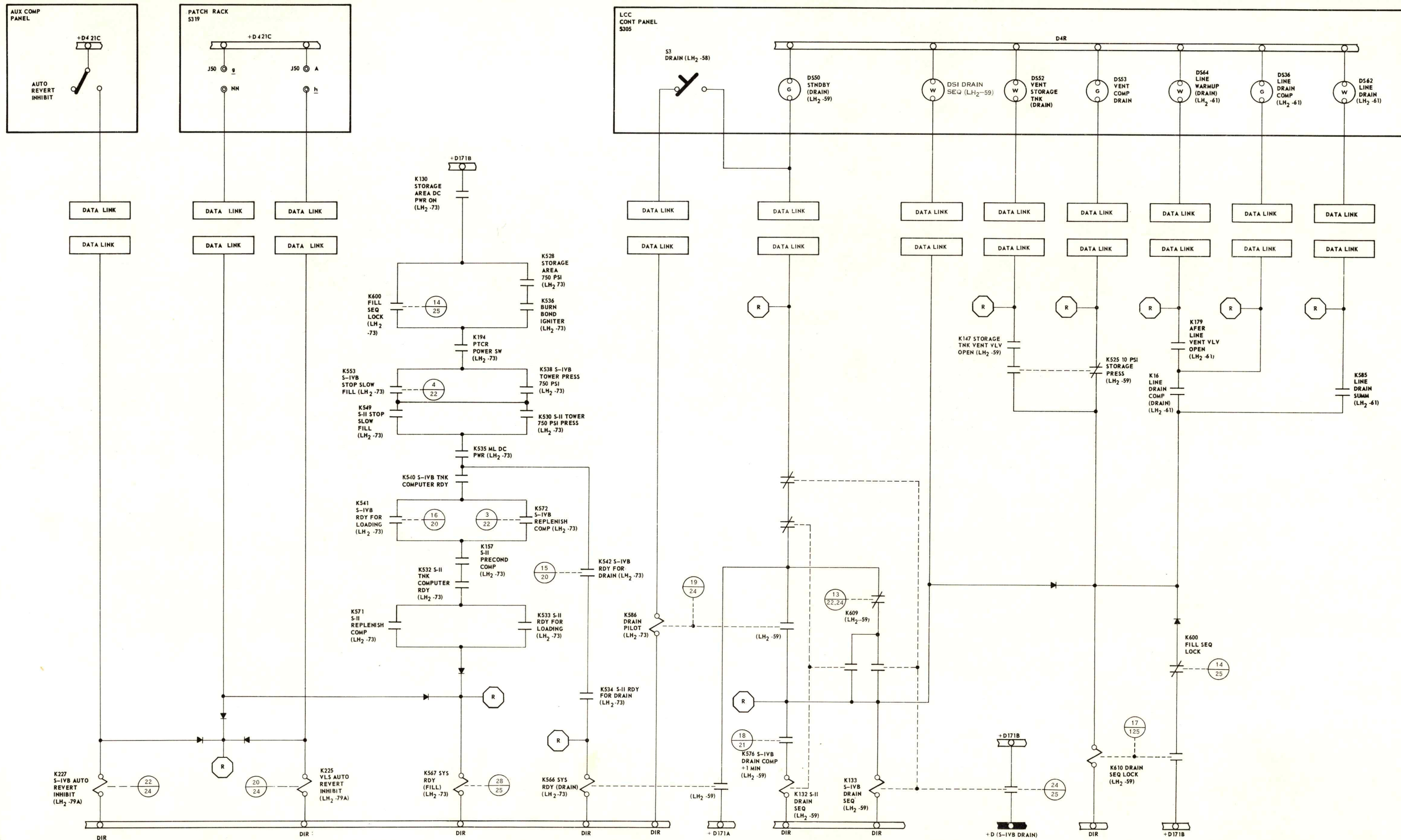
COLD HELIUM LOADING



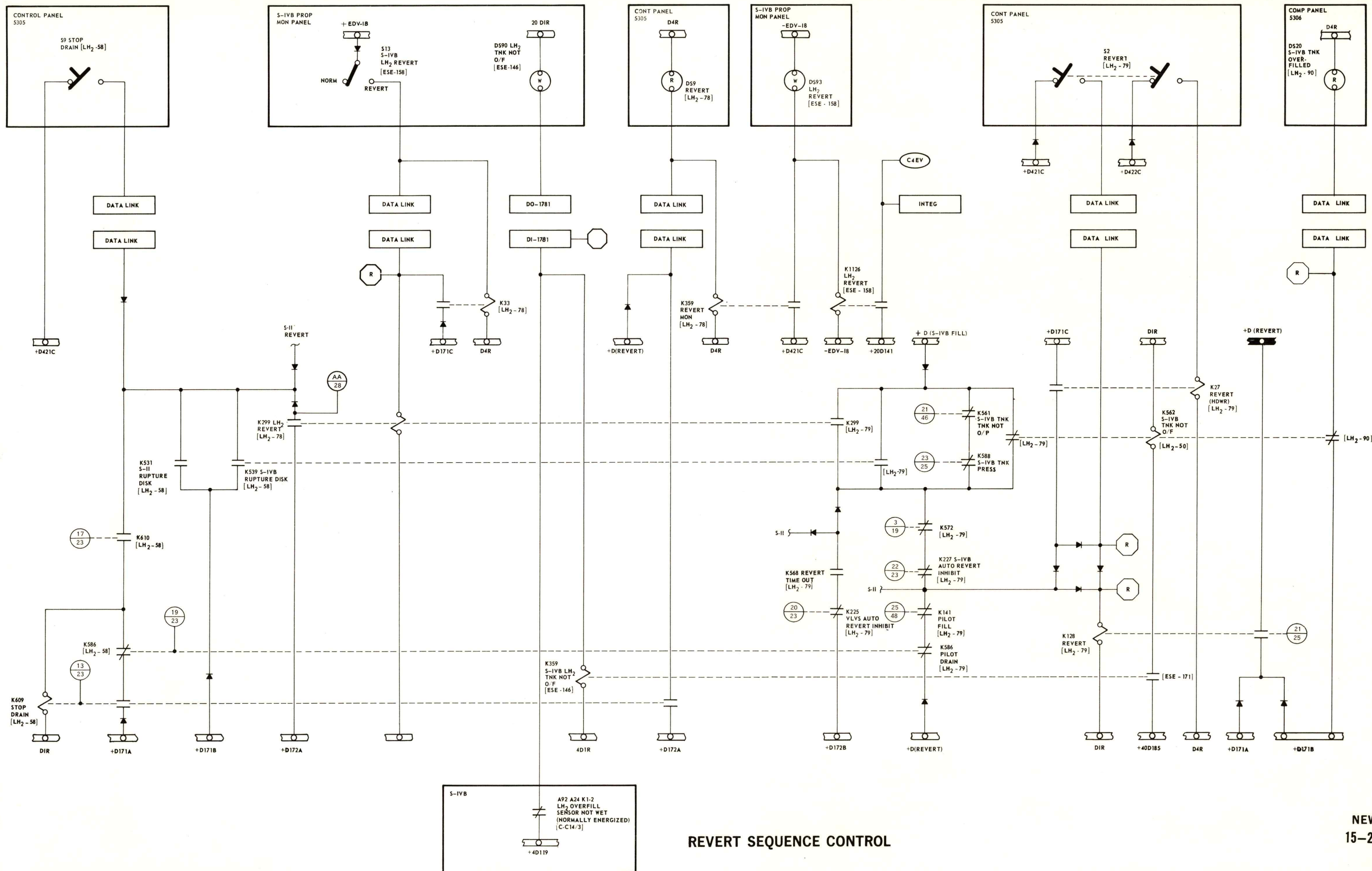
S-IVB LH₂ TANK OVERPRESSURE INDICATION

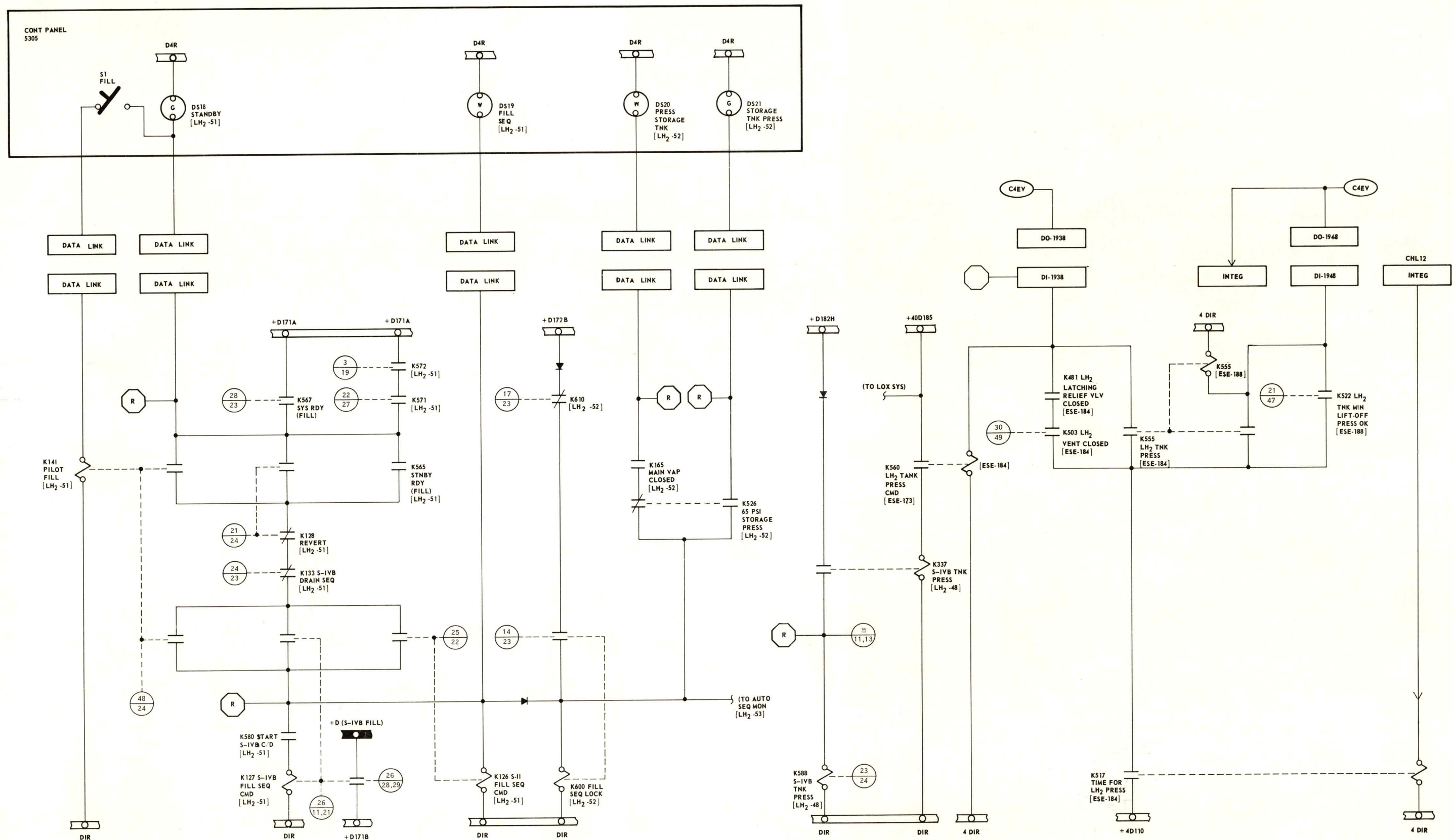
LHX MIN 4/8
K492
PG. 202
MDI 1733
FGK492 LHX MIN LIFT

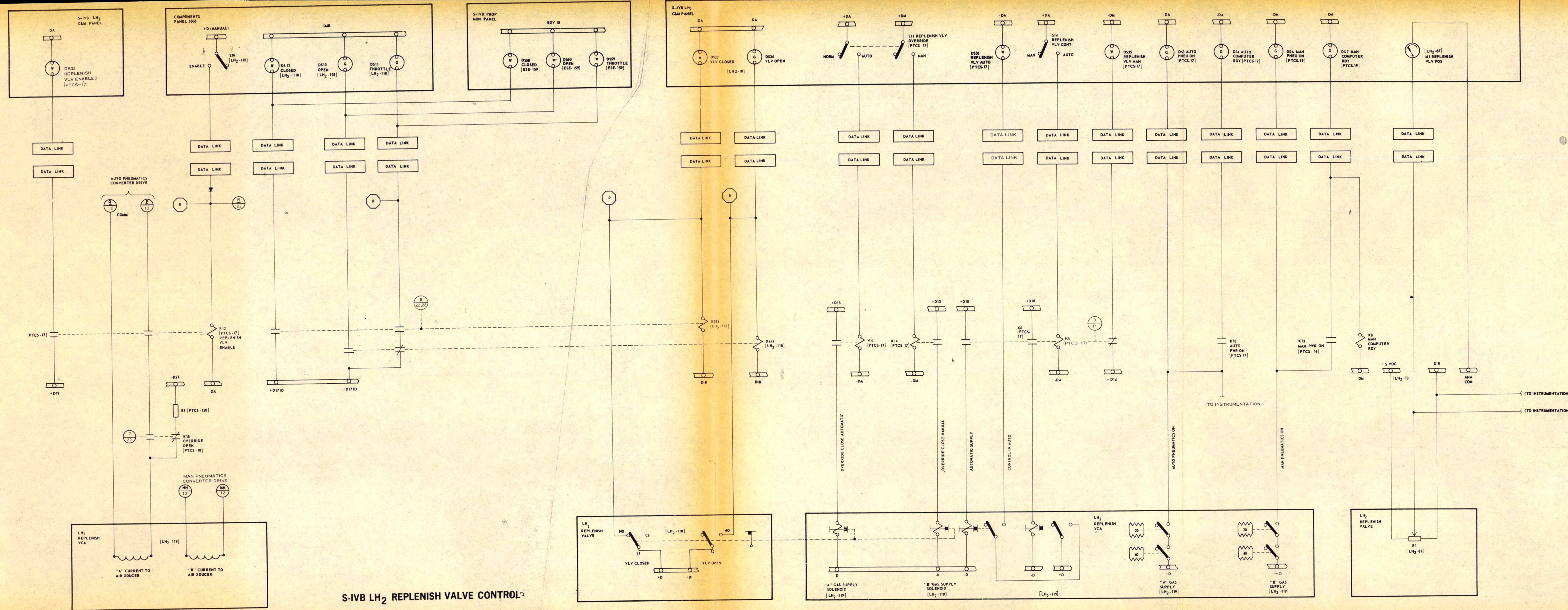
FLH2 REVERT PRESS
= MDI 1938 & FGK522

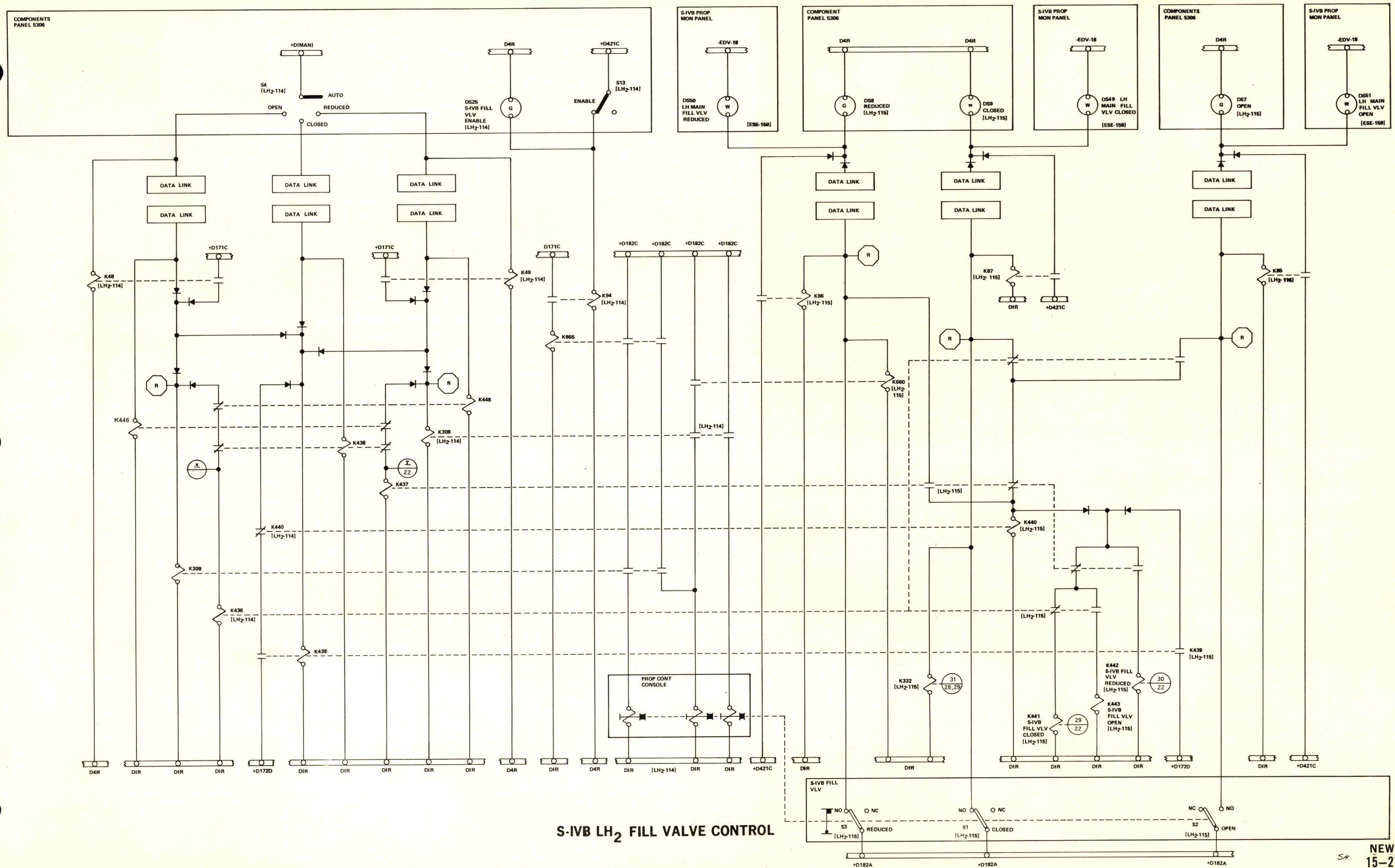


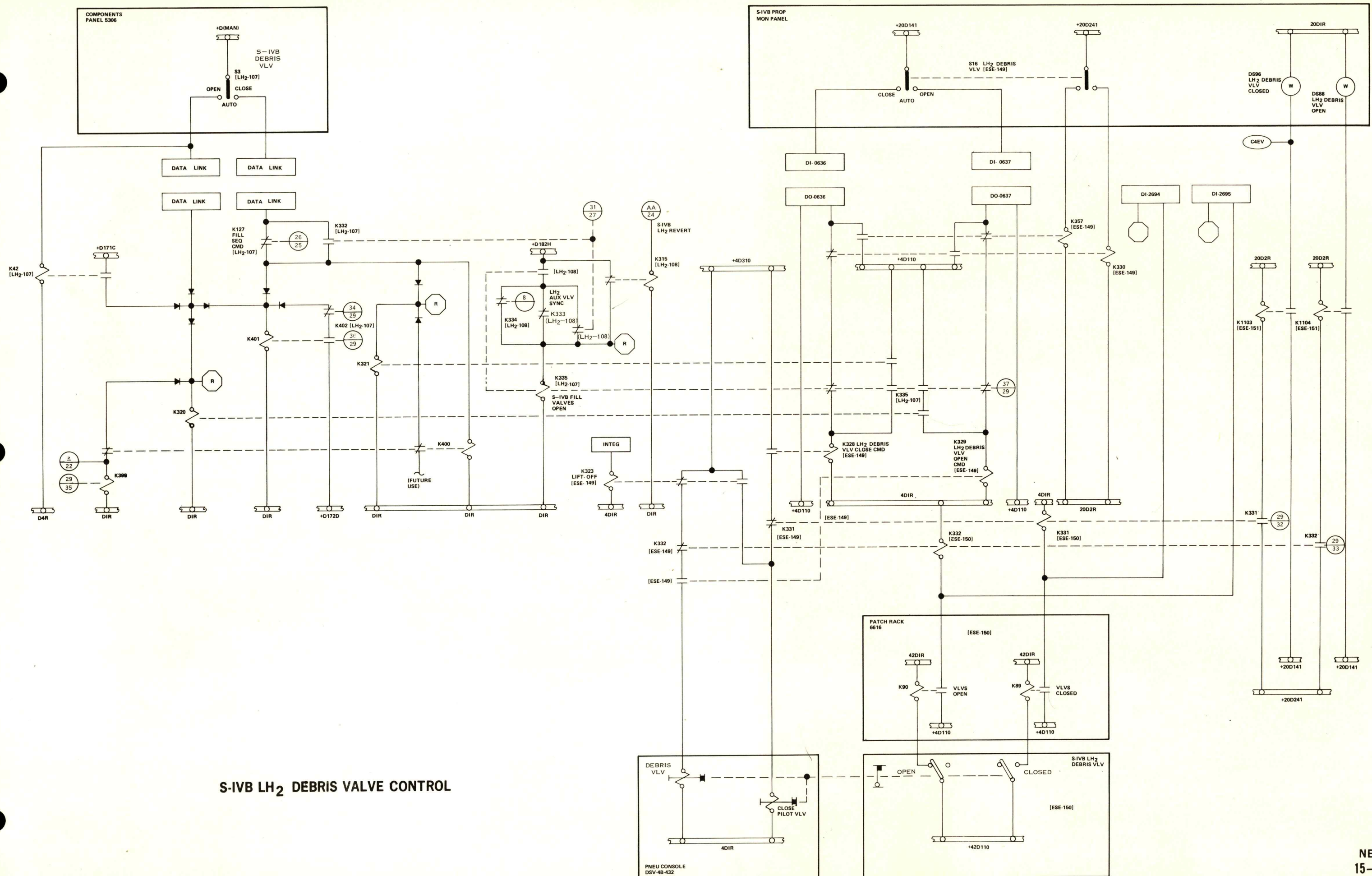
READY-TO-LOAD AND -DRAIN LOGIC,
DRAIN SEQUENCE CONTROL

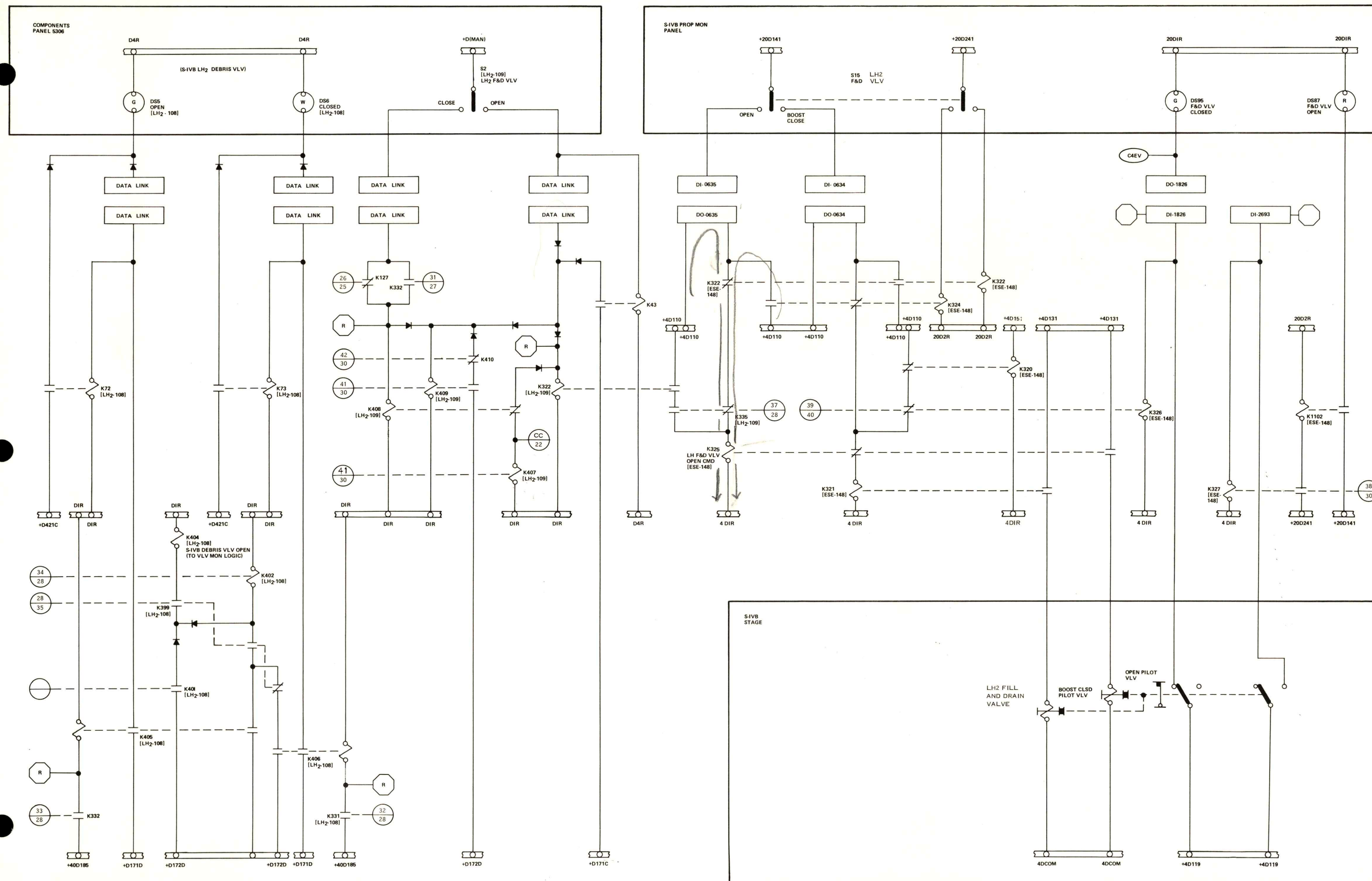




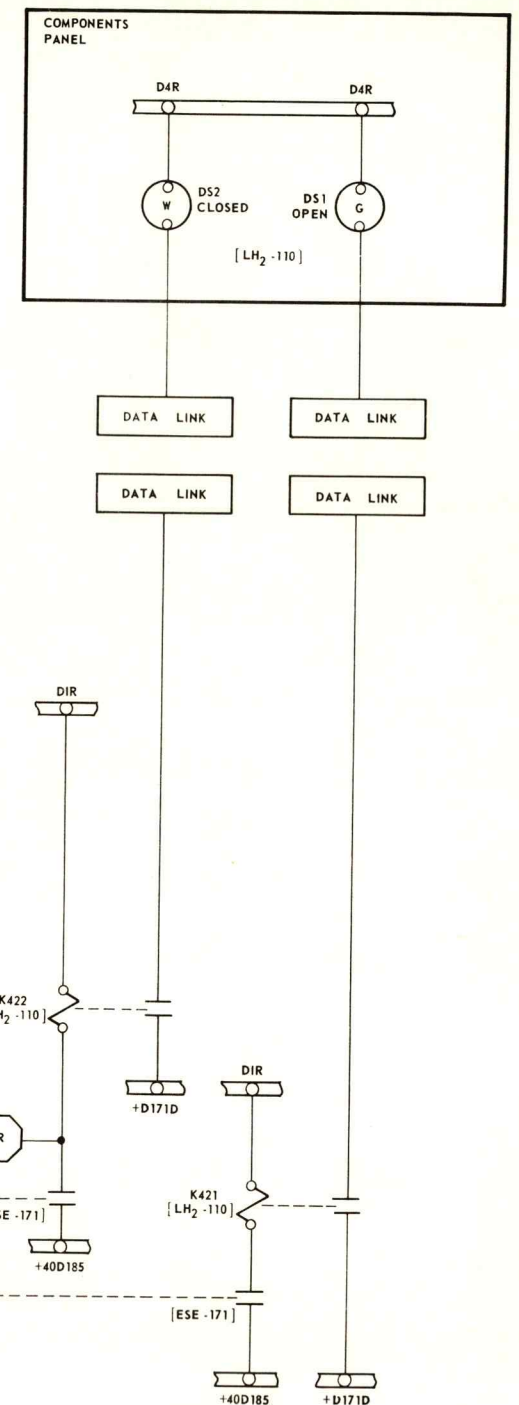
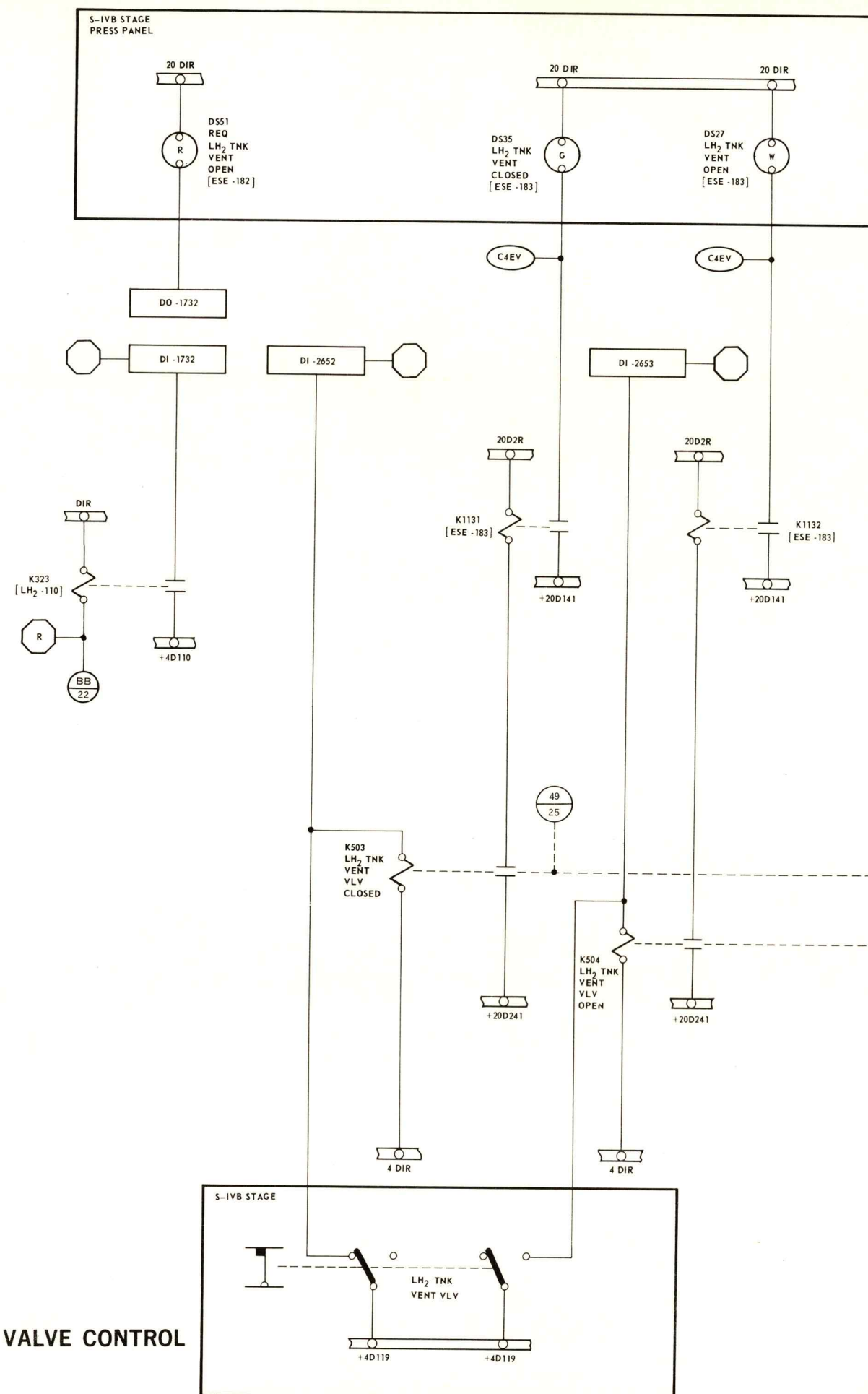
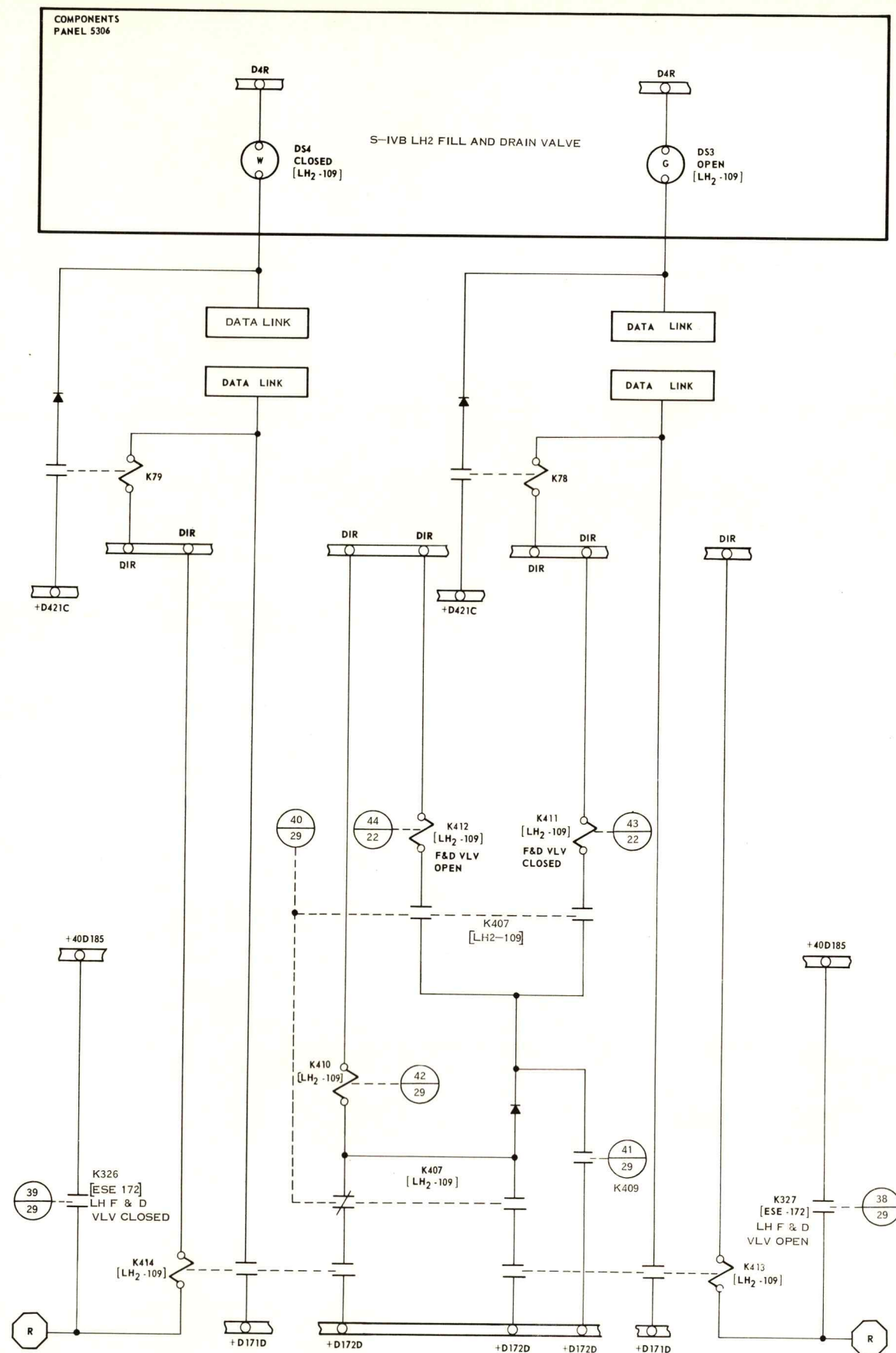




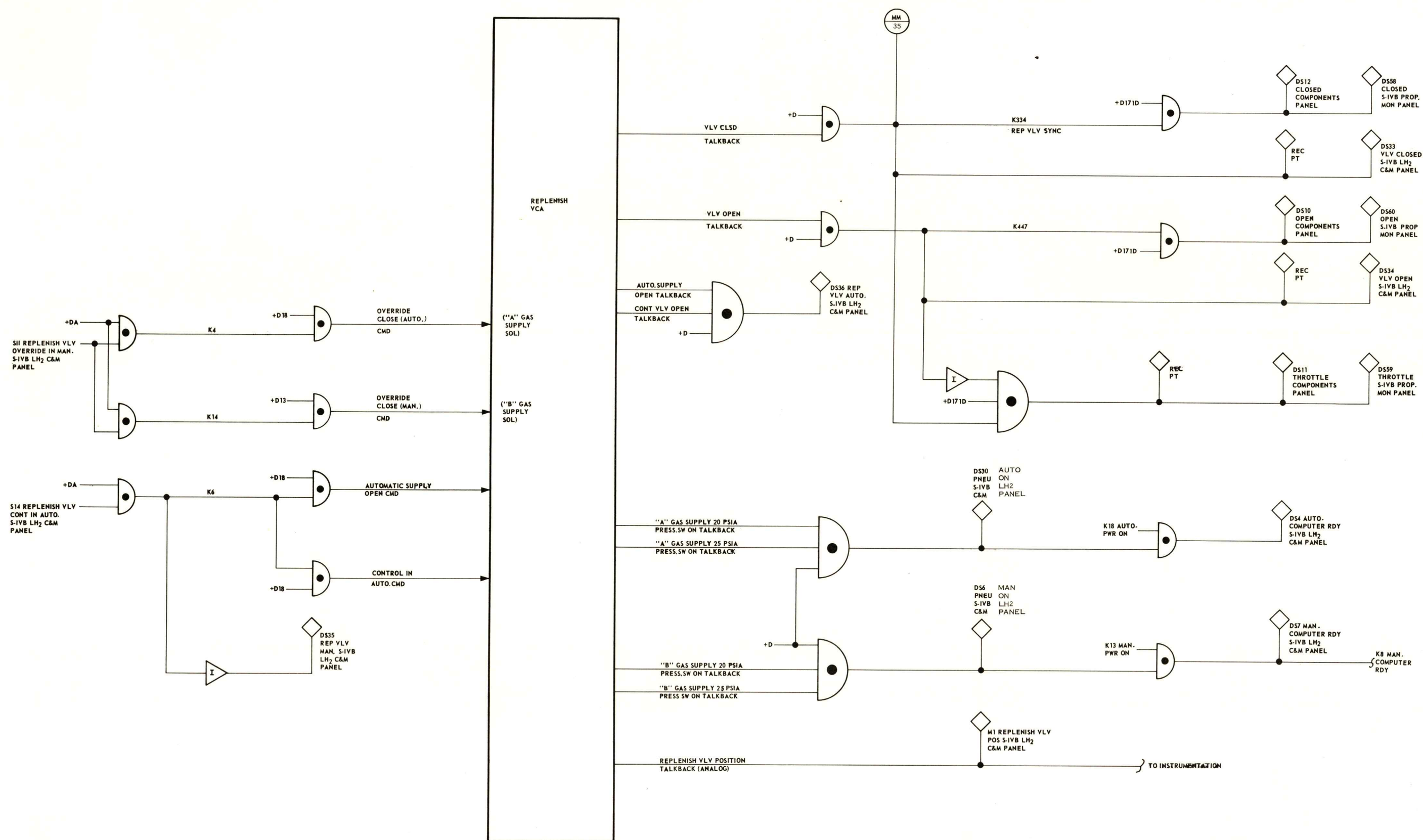




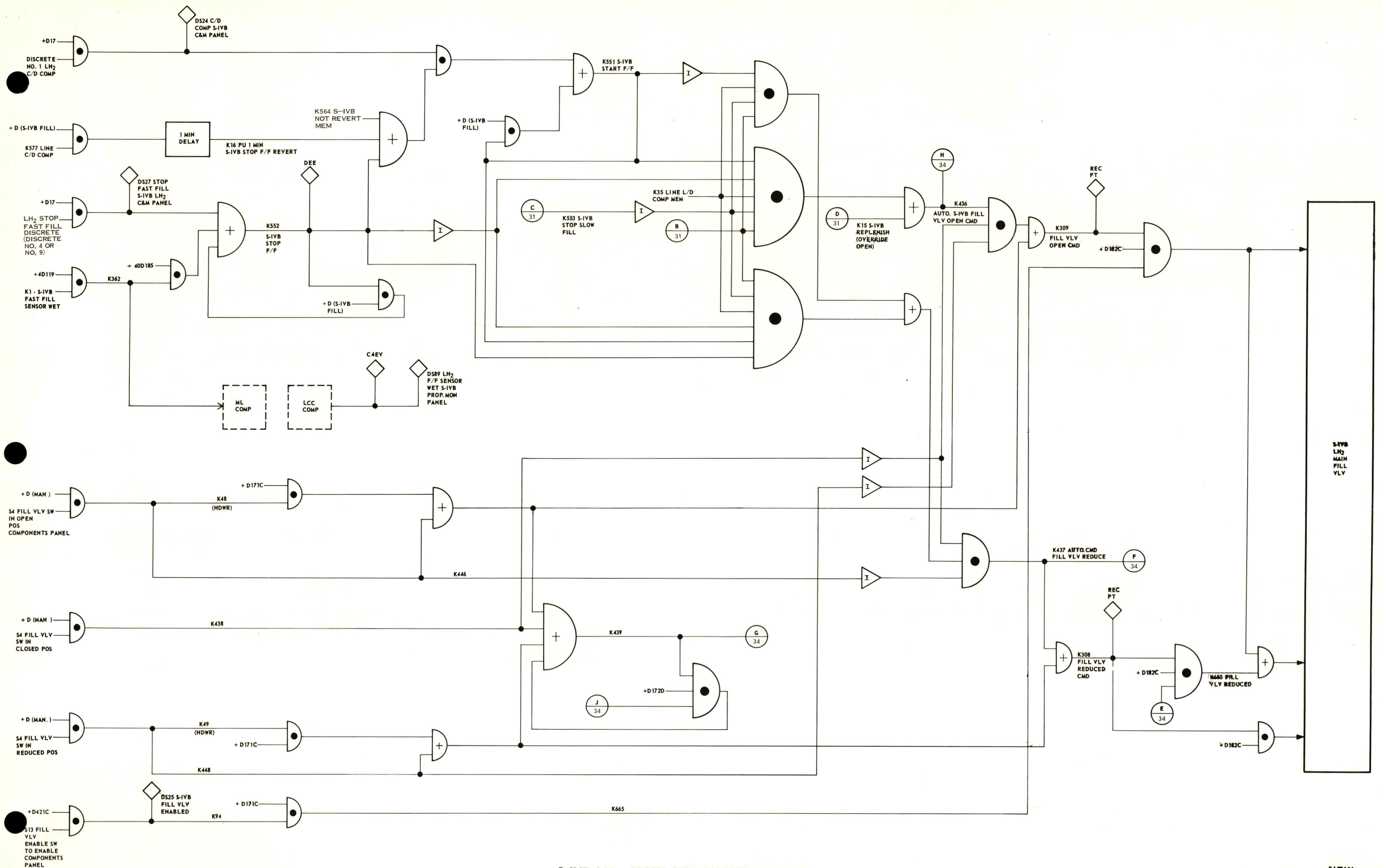
S-IVB LH2 FILL AND DRAIN VALVE CONTROL



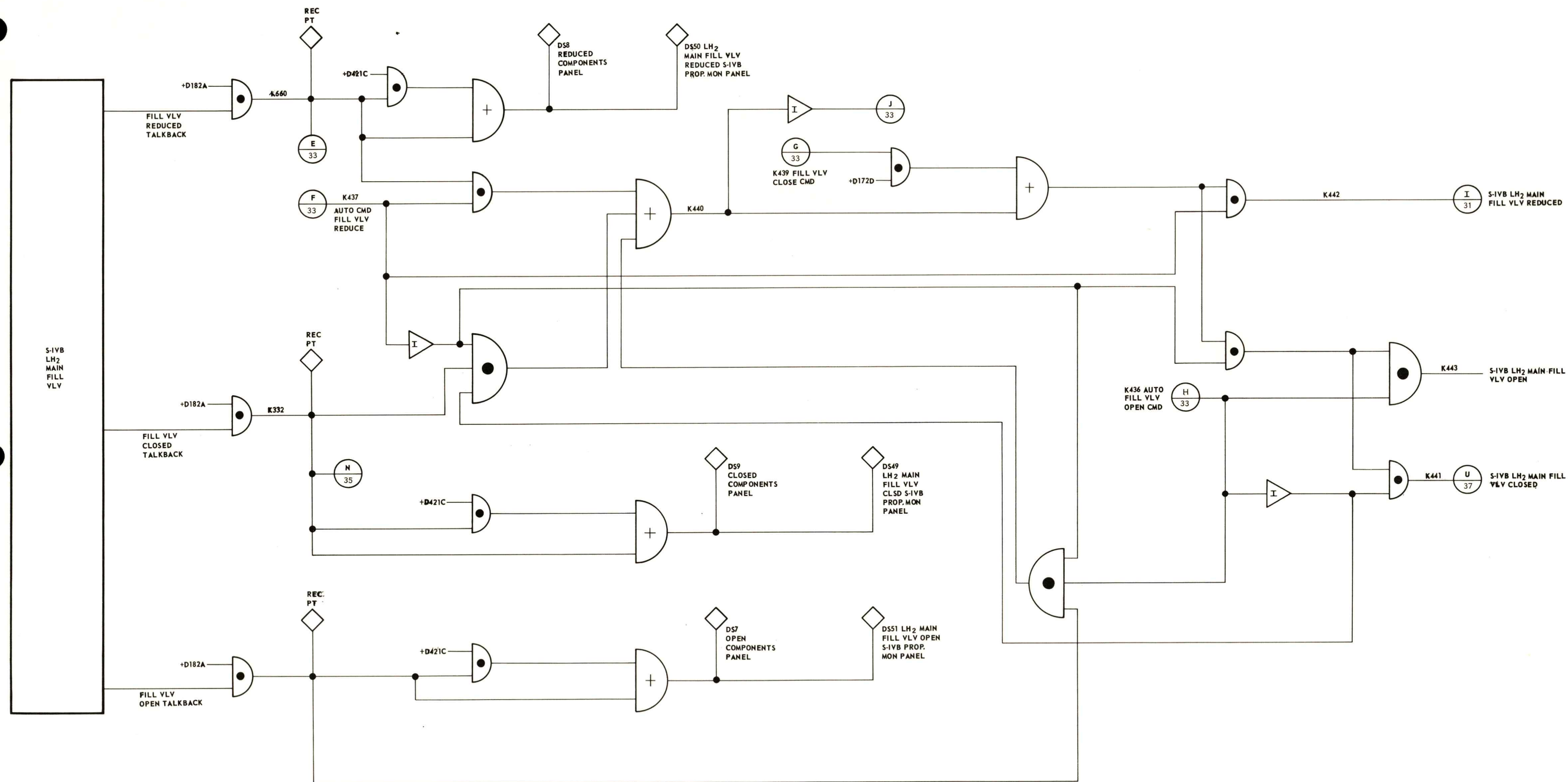




S-IVB LH₂ REPLENISH VALVE CONTROL



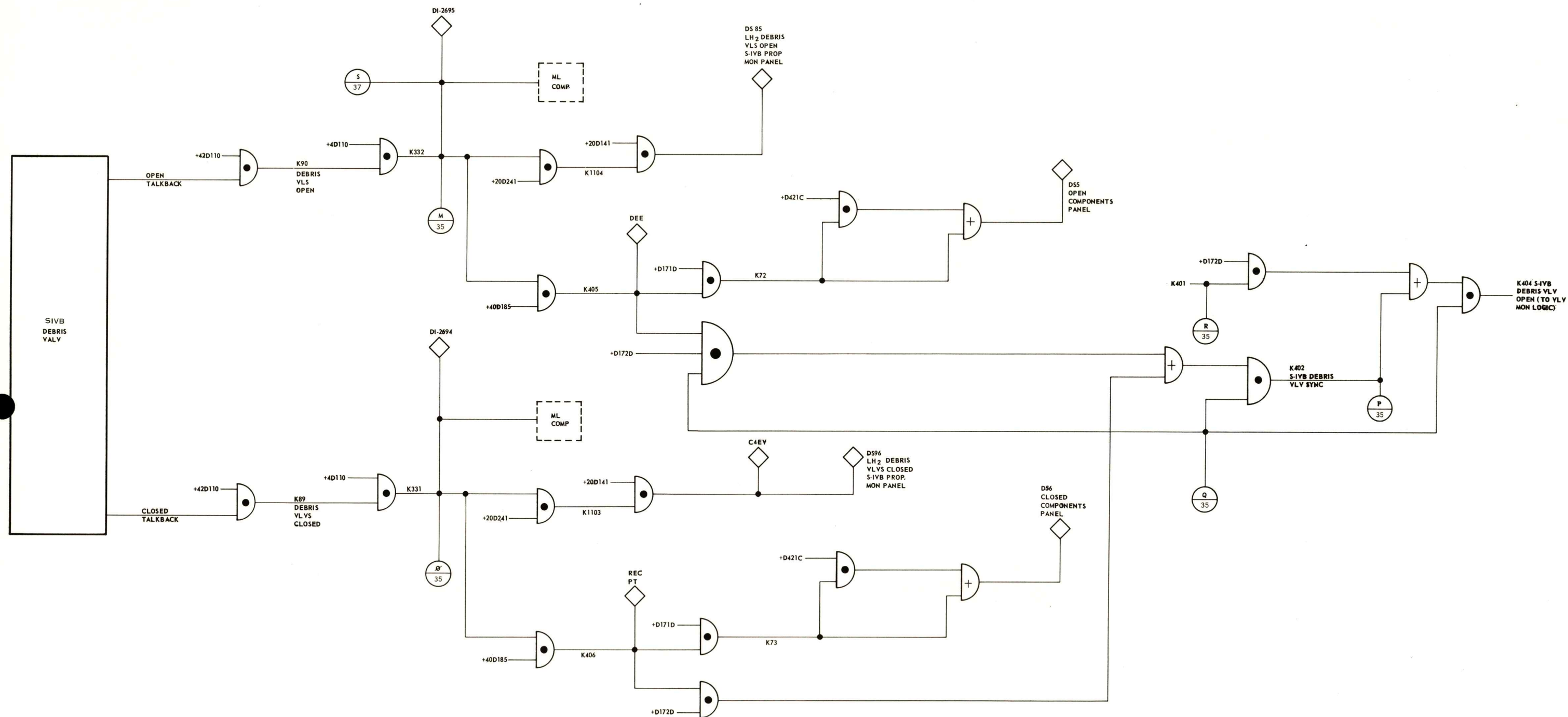
S-IVB LH2 MAIN FILL VALVE CONTROL



S-IVB LH₂ MAIN FILL VALVE TALKBACKS

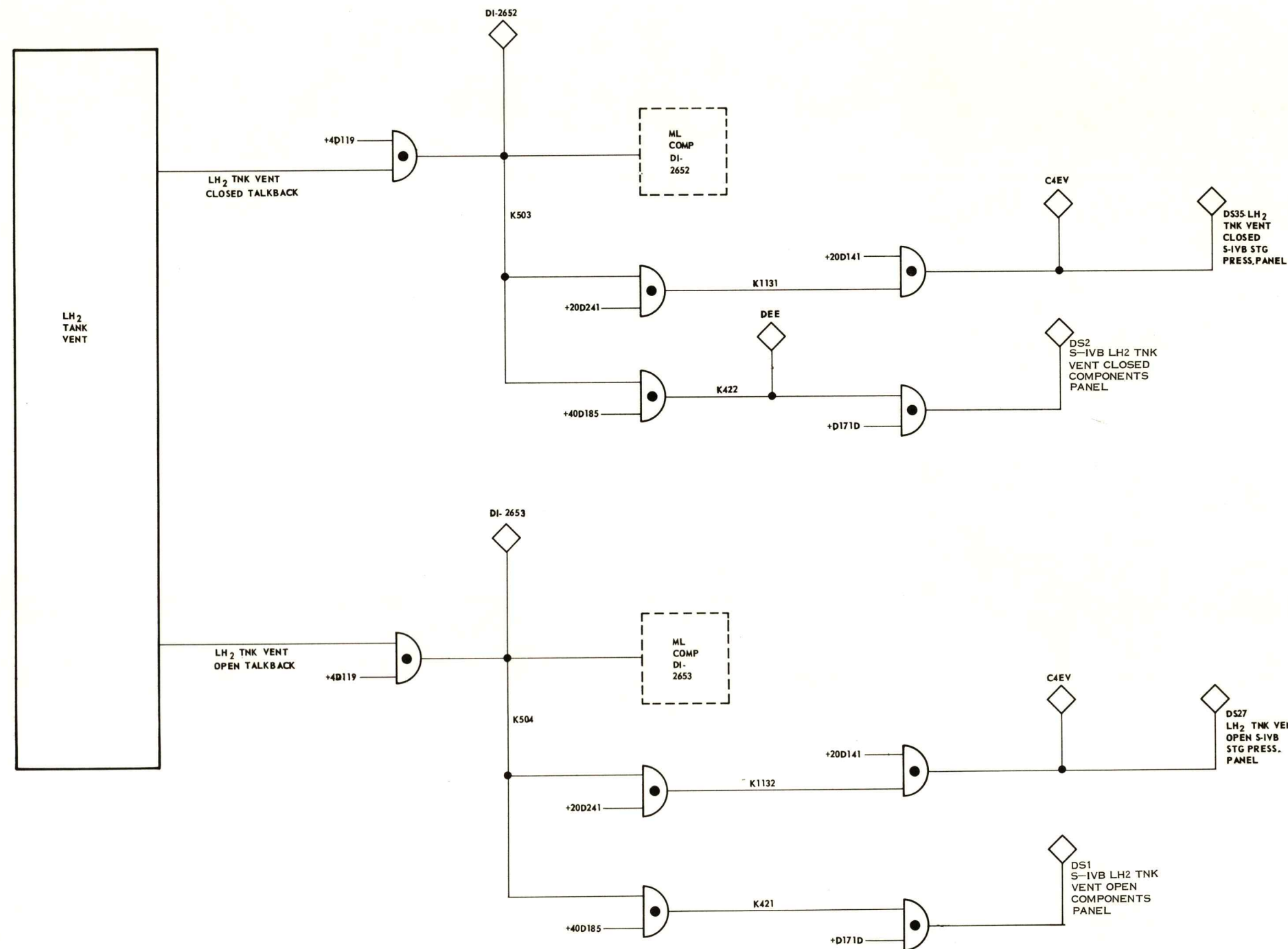
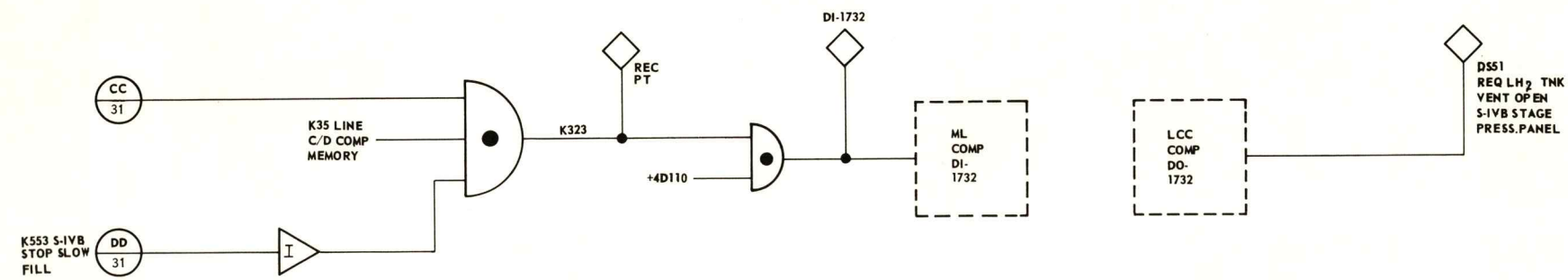
S-IVB LH₂ DEBRIS VALVE CONTROL

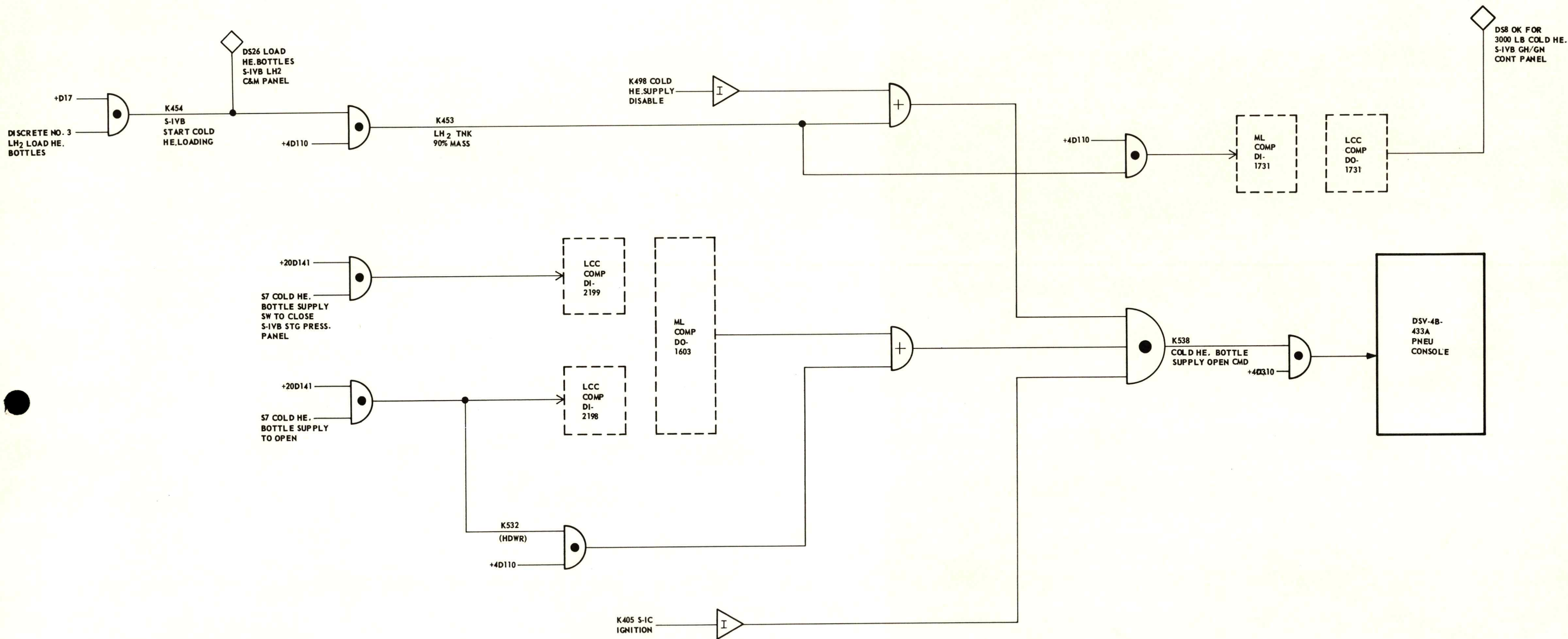




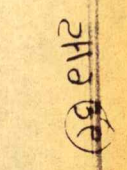
S-IVB LH₂ DEBRIS VALVE TALKBACKS

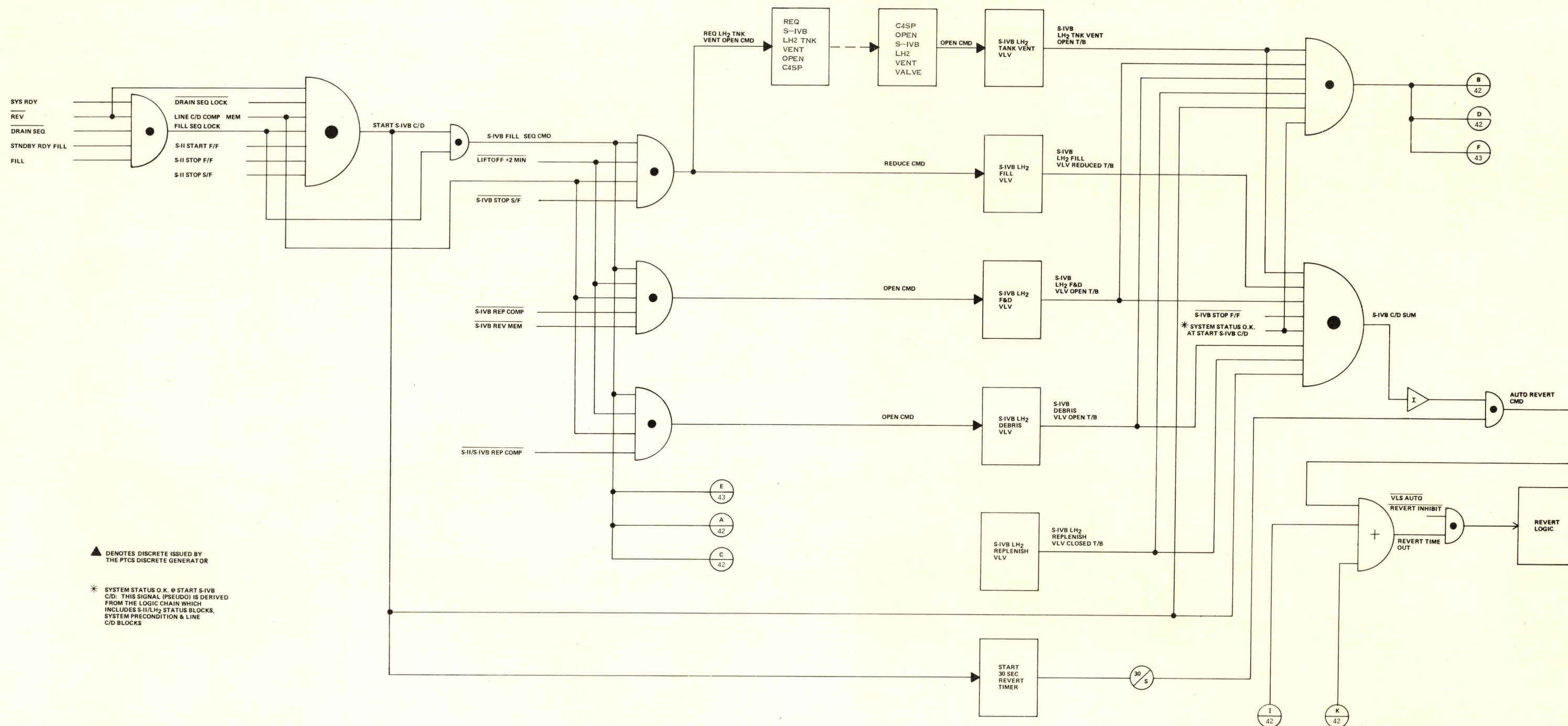




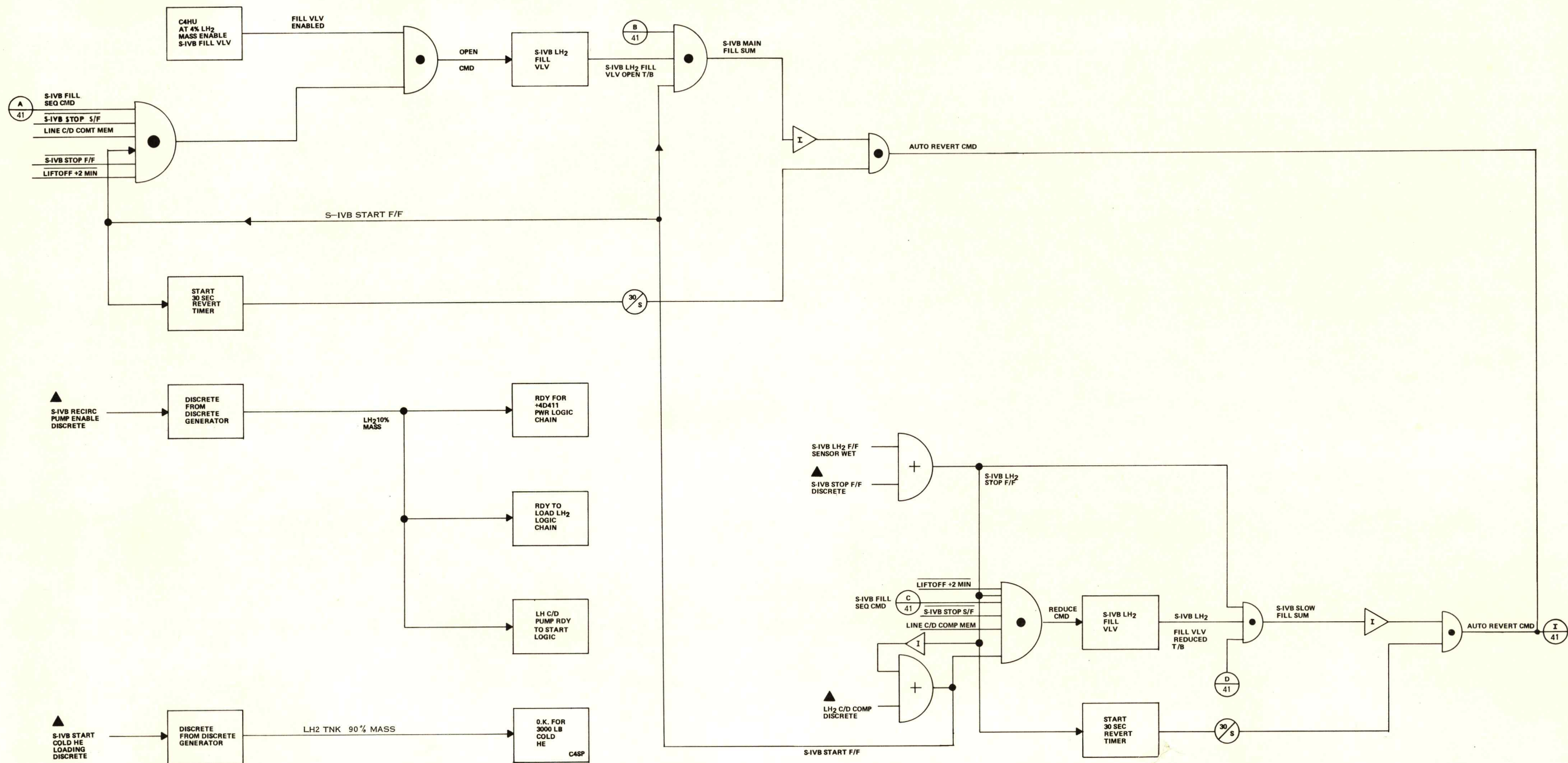


S-IVB COLD HE LOADING CONTROL





S-IVB LH₂ CHILLDOWN (FROM 0% TO 5%, SLOW FILL)



S-IVB LH₂ FAST FILL (FROM 5% TO 98%)

S-IVB LH₂ SLOW FILL (FROM 98% TO 100%)