



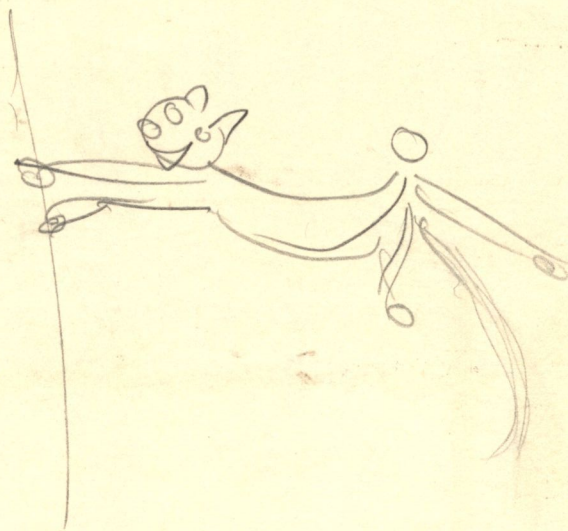
APOLLO TRAINING

ELECTRICAL POWER SUBSYSTEM

FEB 22, 1967

FOR TRAINING PURPOSES ONLY







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ELECTRICAL POWER SUBSYSTEM

A. POWER GENERATION

1. DC SYSTEM

(a) FUEL CELL POWER PLANTS (3)

*1420 watts
440 watts & maintain volt limits
27V → 31V.*

(b) CRYOGENIC STORAGE SYSTEM

(c) ENTRY & POST LANDING
BATTERIES (A, B, & C)

2. AC SYSTEM

(a) SOLID STATE INVERTERS (3)

1250 VA @ .9 pf. ≈ 1100 watts



ELECTRICAL POWER SUBSYSTEM

B. POWER DISTRIBUTION & CONTROLS

1. DC DISTRIBUTION

- (a) BUS SYSTEM
- (b) UNDERVOLTAGE SENSING
- (c) FUEL CELL CONTROLS
 - (1) DC BUS CONNECTION
 - (2) OVERLOAD/REVERSE CURRENT SENSING

2. AC DISTRIBUTION

- (a) BUS SYSTEM
- (b) INVERTER CONTROL CIRCUITS
 - (1) AC BUS CONNECTION
 - (2) OVERLOAD SENSING — *automatic Disconnect*
 - (3) OVER/UNDER VOLTAGE SENSING — *warning light*



ELECTRICAL POWER SUBSYSTEM

ELECTRICAL POWER SYSTEM

5764-760713

C. SPECIAL CIRCUITS

1. BATTERY CHARGER (1)
2. PYROTECHNIC BATTERIES (2)

FUEL CELL
MODULES (3)

OXYGEN
TANKS (2)

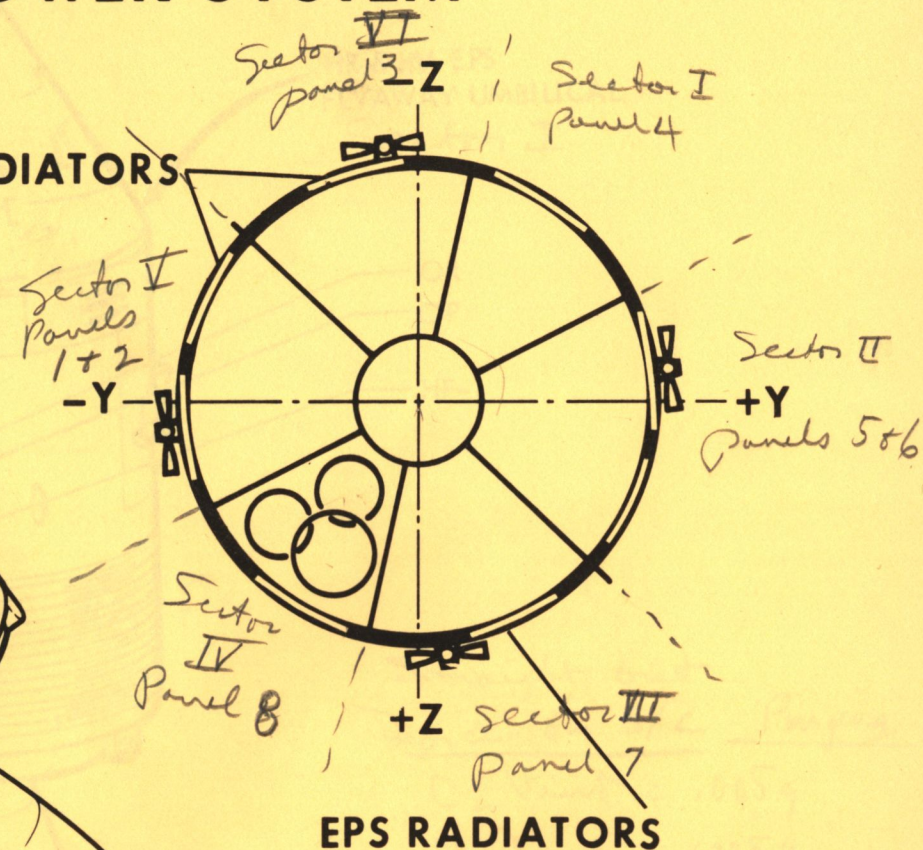
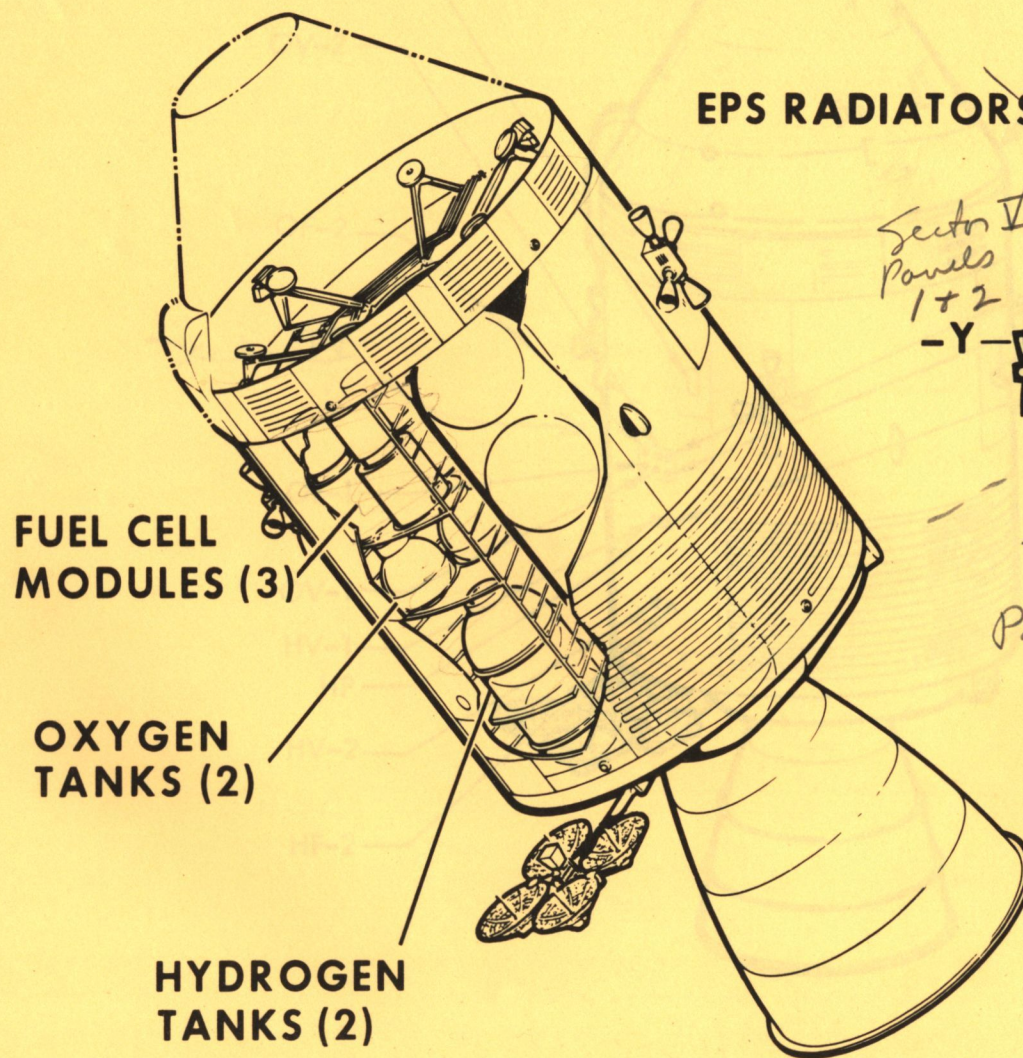
HYDROGEN
TANKS (2)

EPS RADIATORS

EPS RADIATORS

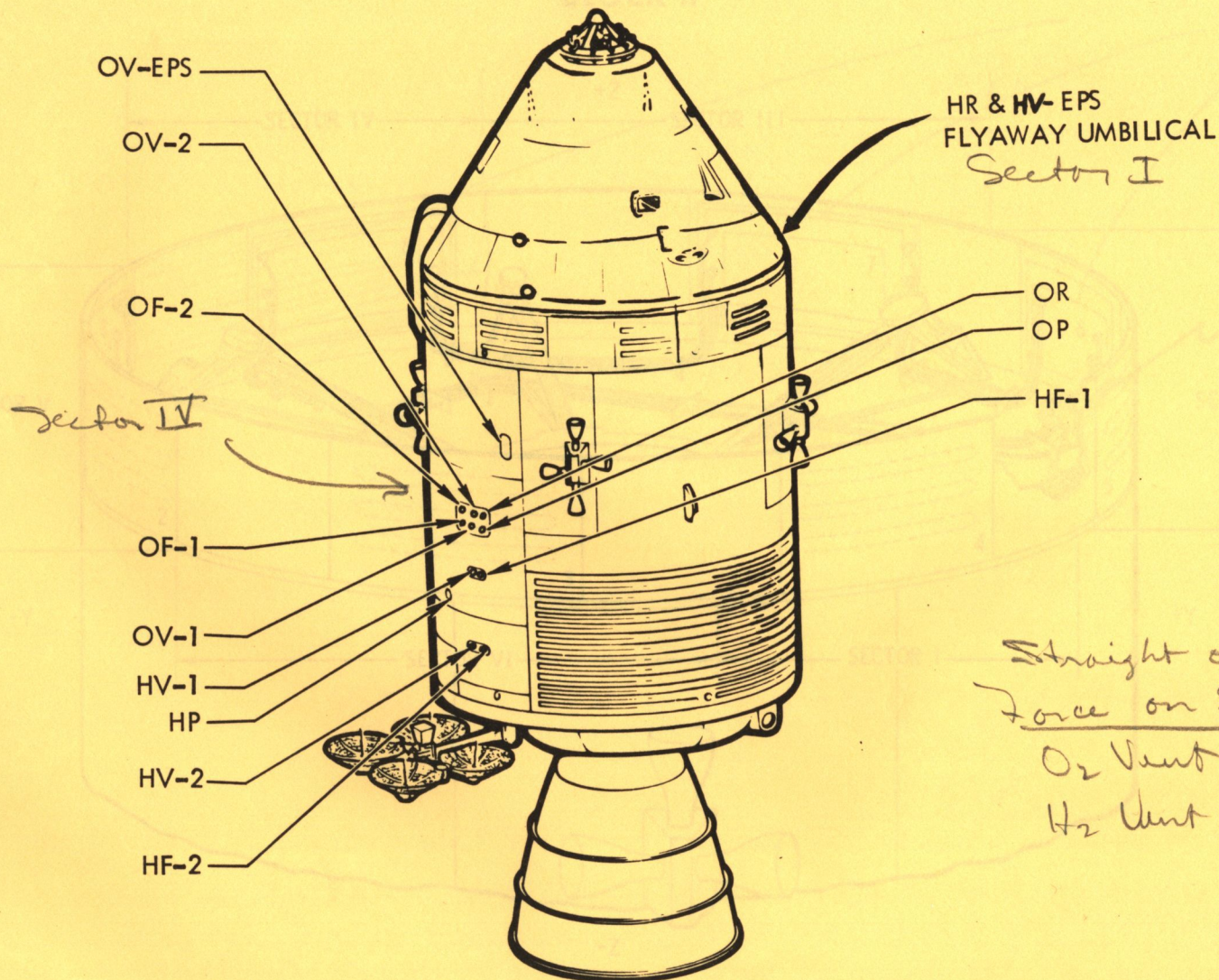
ELECTRICAL POWER SYSTEM

S76AP83071B



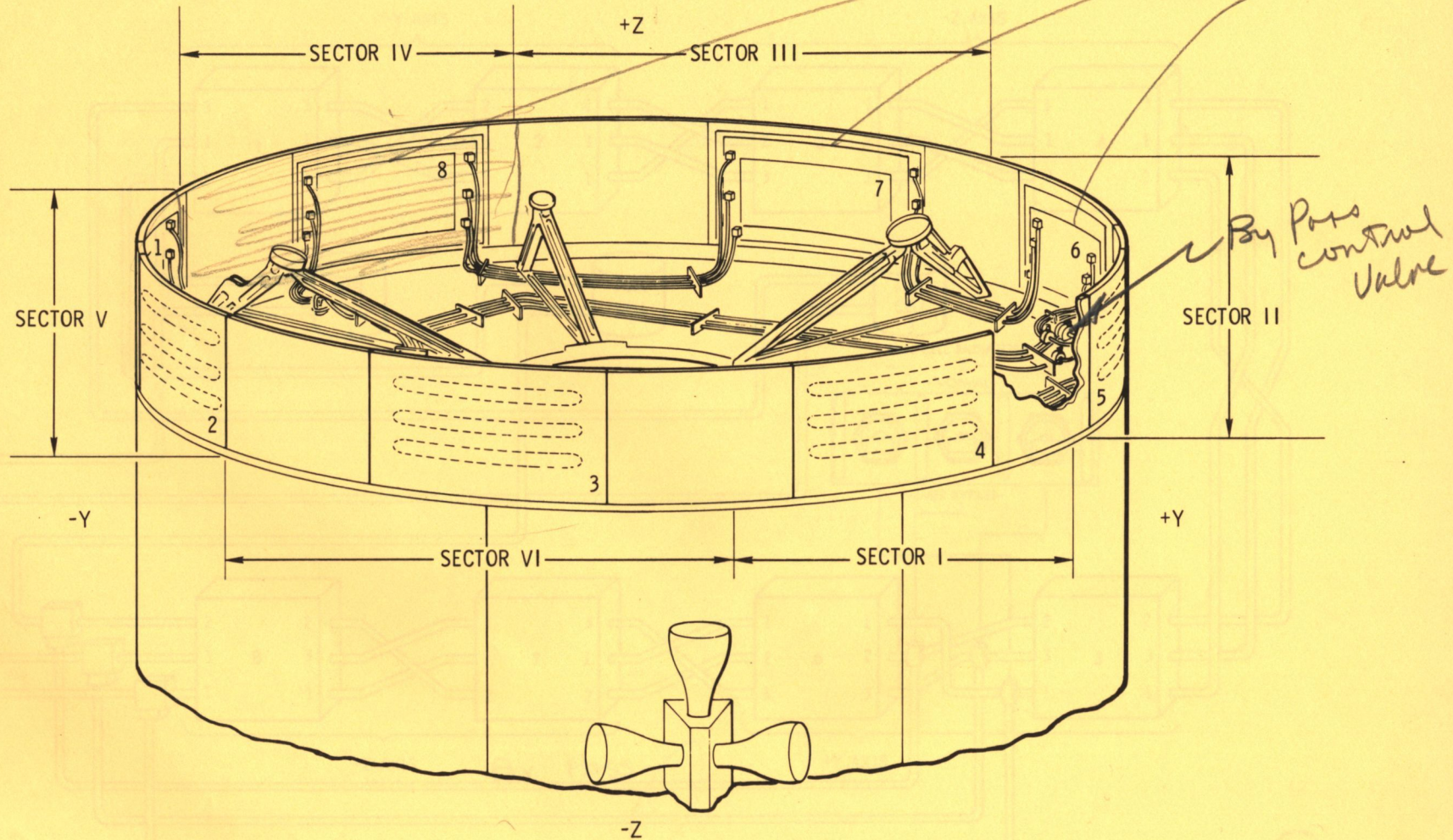
*panels 6, 7 & 8
can be bypassed*

SM CRYOGENIC SYSTEM INTERFACE (EXTERNAL)



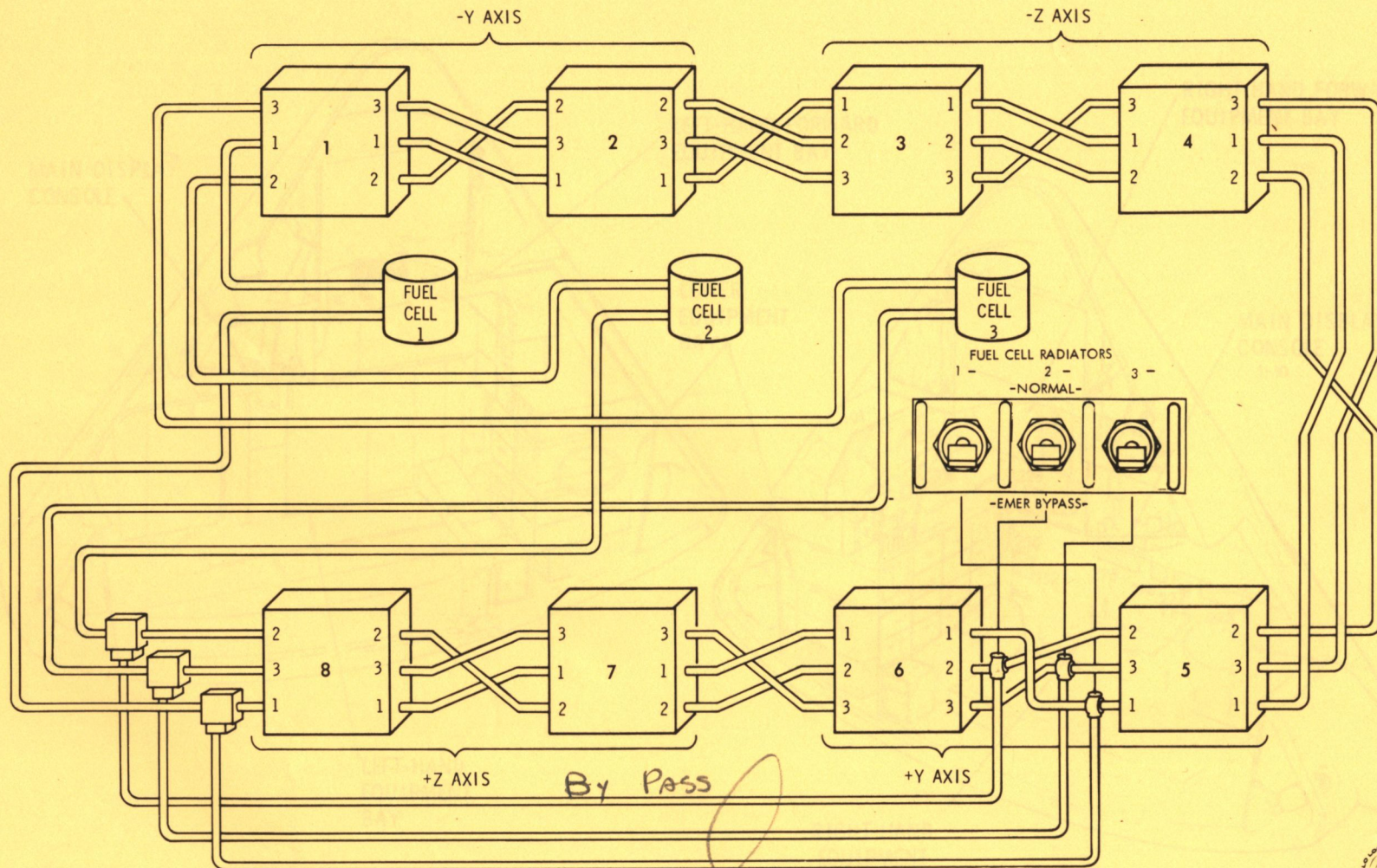
EPS RADIATOR LOCATION BLOCK II

*Panels 6, 7 & 8
can be bypassed.*

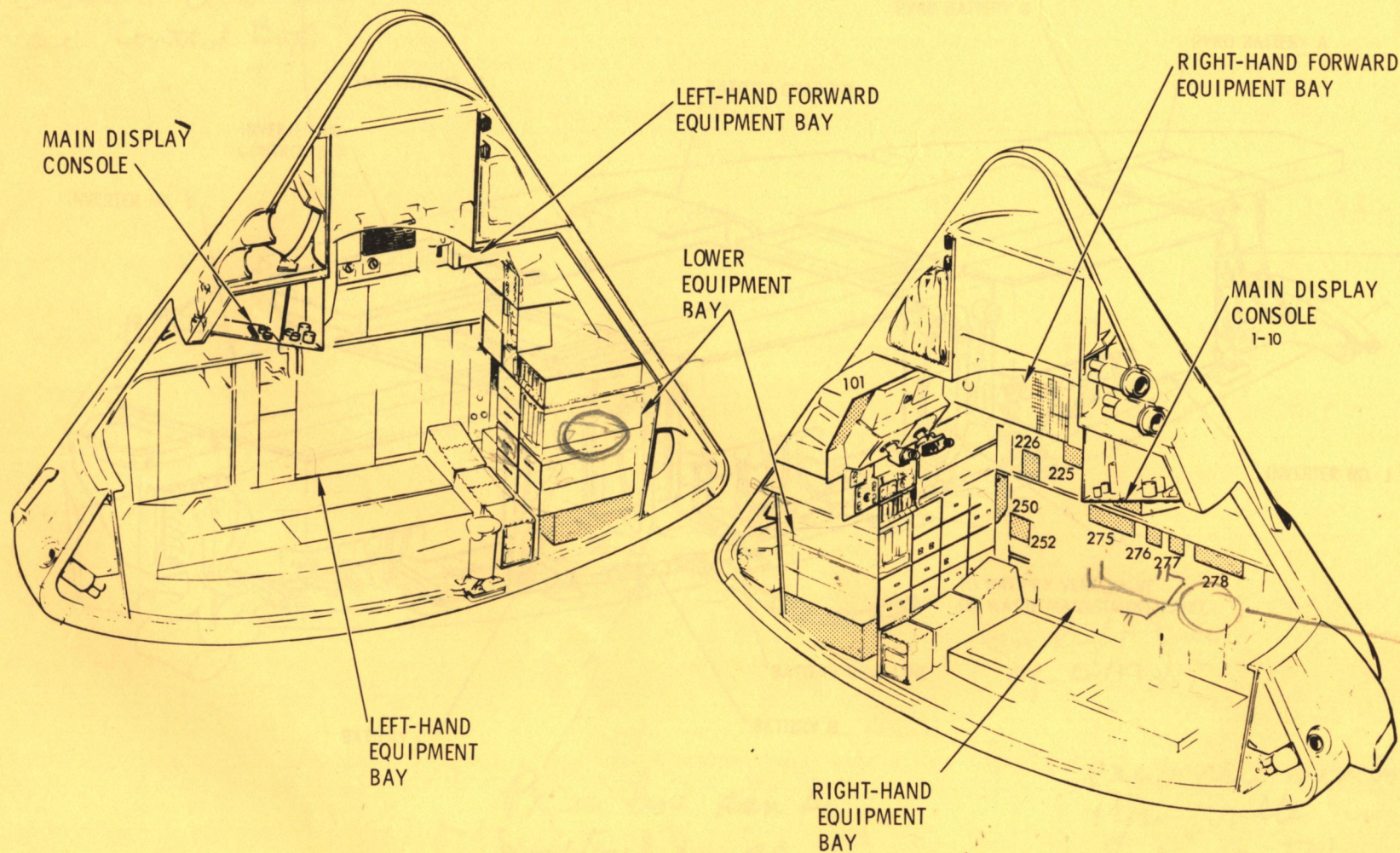


EPS RADIATOR CONTROL

BLOCK II

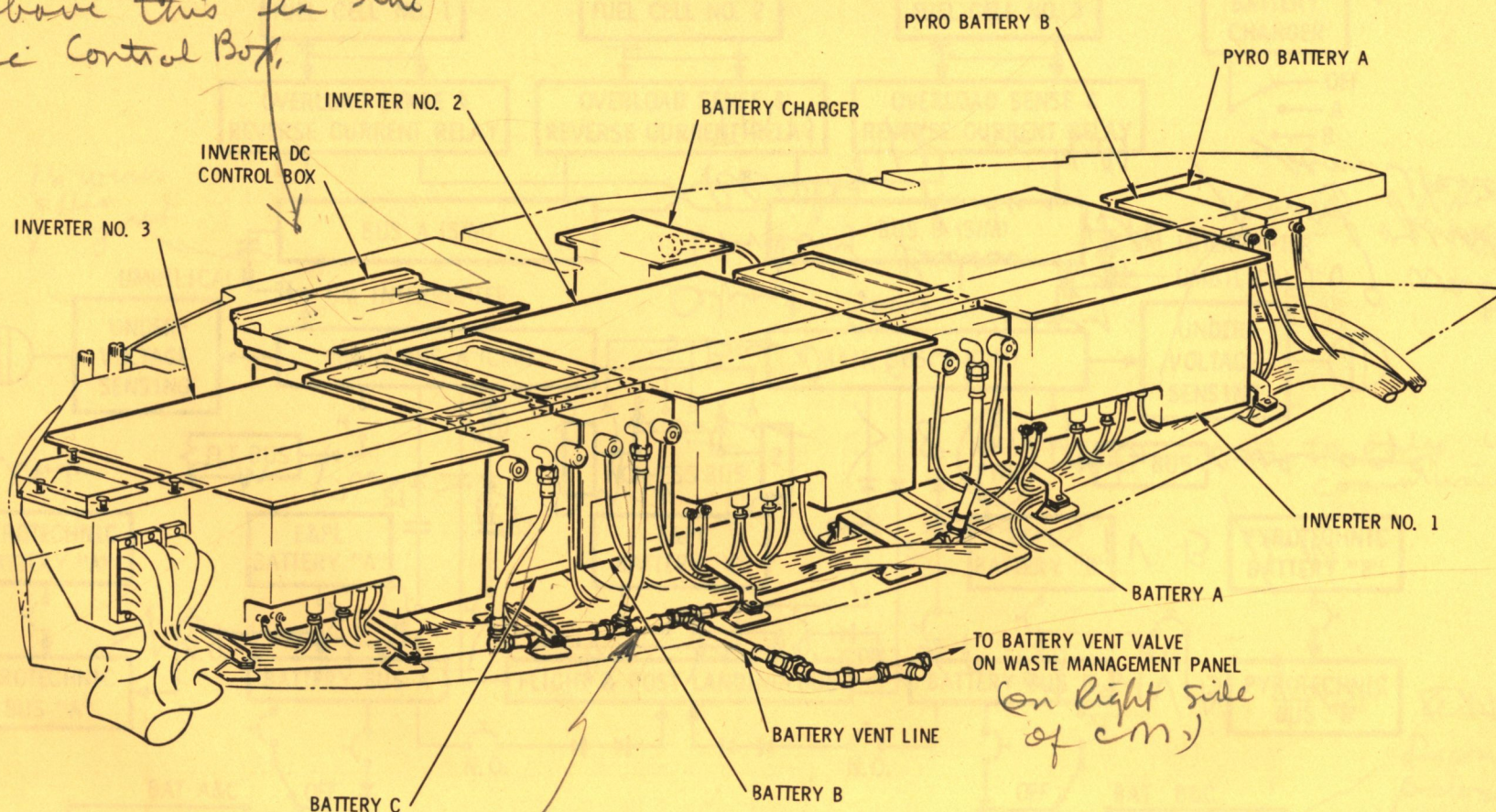


C/M EQUIPMENT BAYS



EPS COMPONENTS LOWER EQUIPMENT BAY (BLOCK II)

*On shelf directly
above this is the
ac Control Box.*



*Px in line can be
monitored on sc
meter.*

*Crew can monitor
Pyro volts on sc
but no TM*

Manually Tried: prior to Sep of SIV B from LM

Unb. LM Pwr = ① P yw ties to sep SIV B / LM
② 5 Heaters > 81 watts average

S. Band Ant.
Abort Sens. Assy
Landing Radar Htr
Radar Htr
IMU Htr in LM

209 watts
if operated
simultaneously

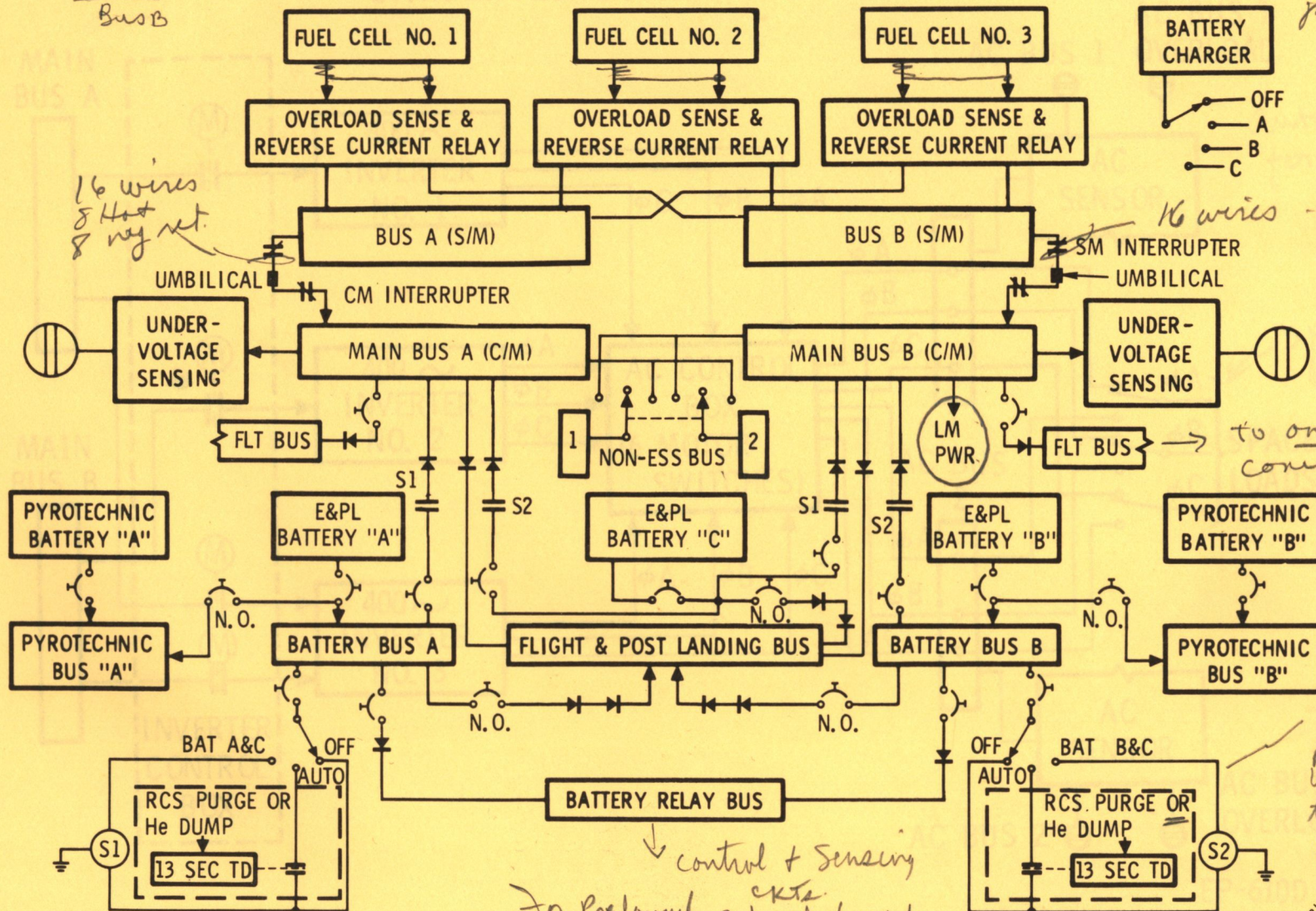
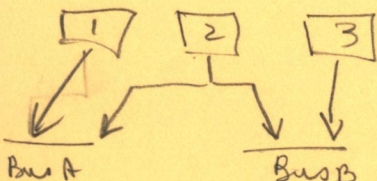
(BLOCK II)

EB2 COMPONENTS COMEB EQUIPMENT VAL

DC POWER DISTRIBUTION

SIMPLIFIED SCHEMATIC DIAGRAM

2 FC can handle mission
1 FC can return safely from any point in mission but powered down



16 wires - 8 Hot & 8 neg. ret.

to only inflight communications

auto Disconnect prior water land. to isolate all Main Bus (and SM) & FCS

control & sensing cks
In Prelaunch pad about 10 min. will be changed back to BIK I configuration

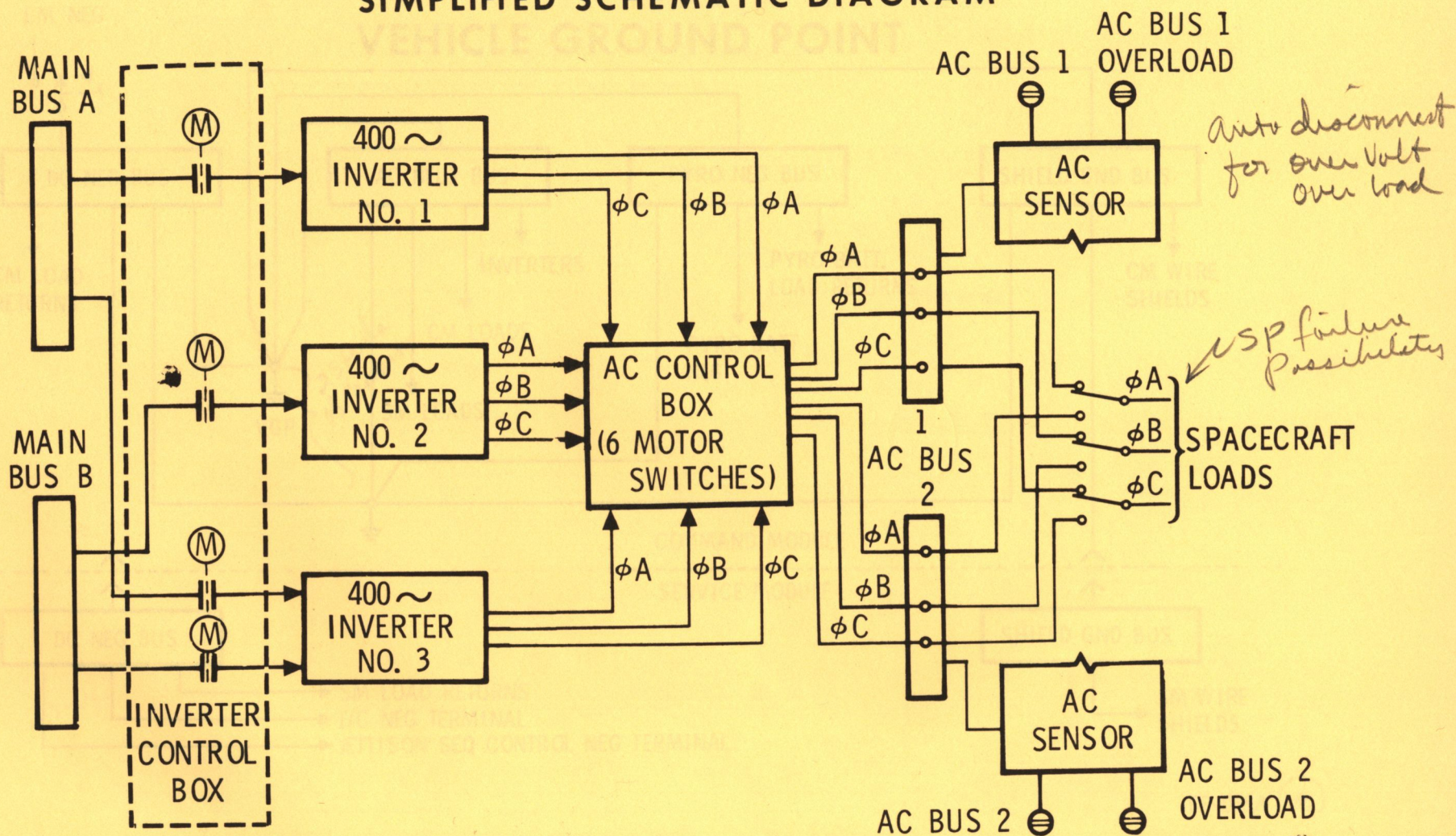
For 1 astronaut return from moon.

EP-606G



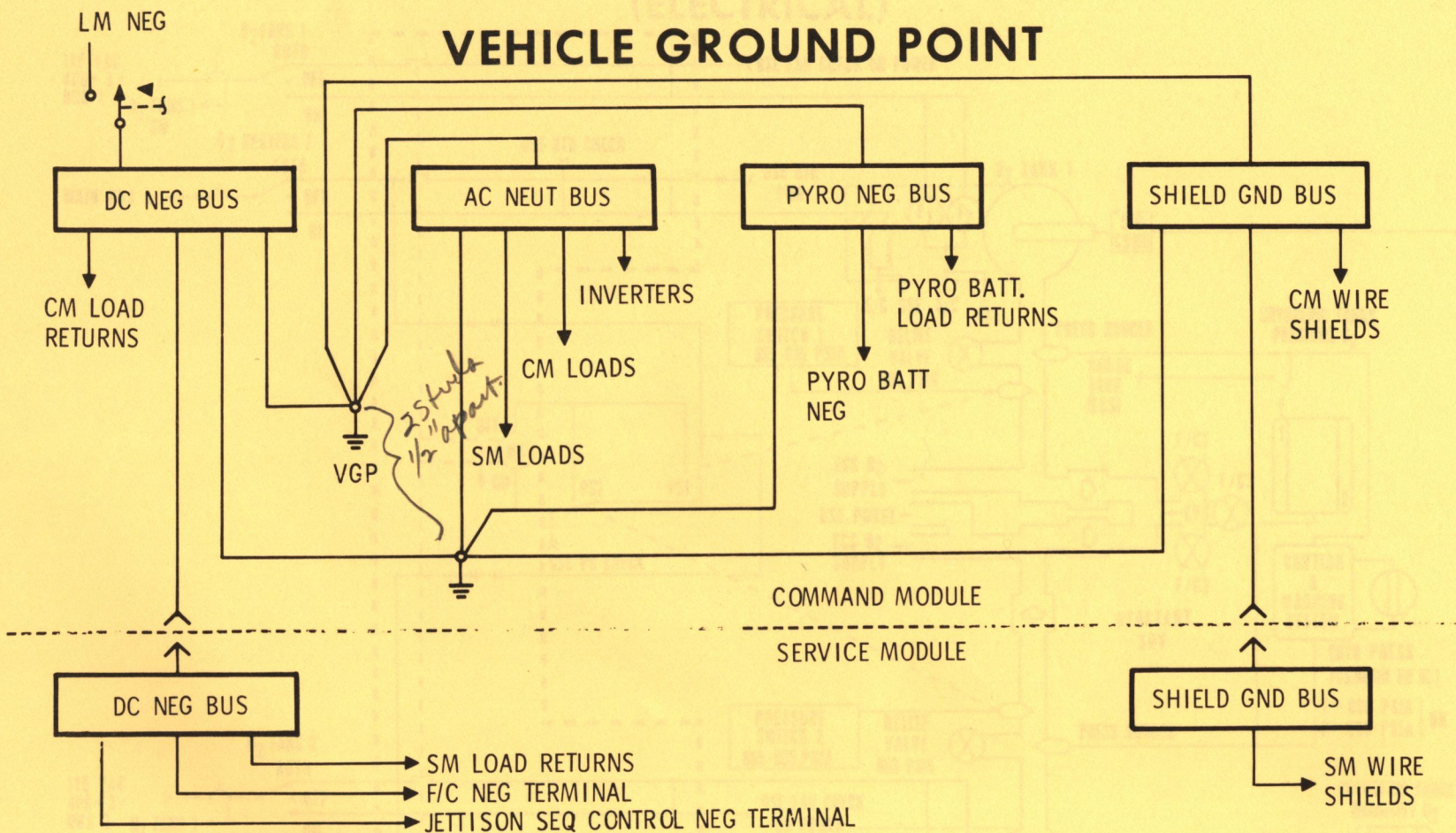
AC POWER DISTRIBUTION

SIMPLIFIED SCHEMATIC DIAGRAM



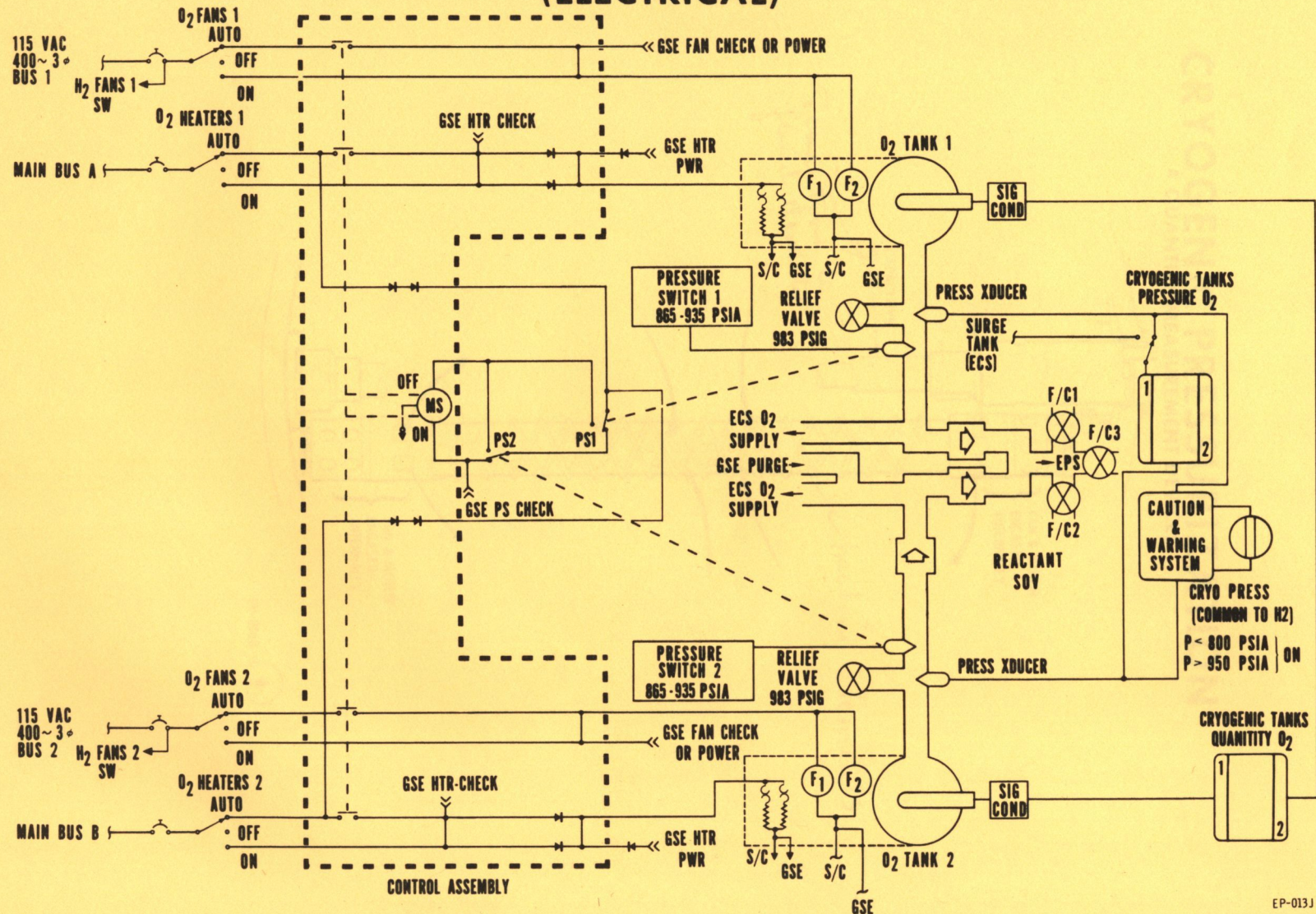
OXYGEN STORAGE SYSTEM (ELECTRICAL)

VEHICLE GROUND POINT

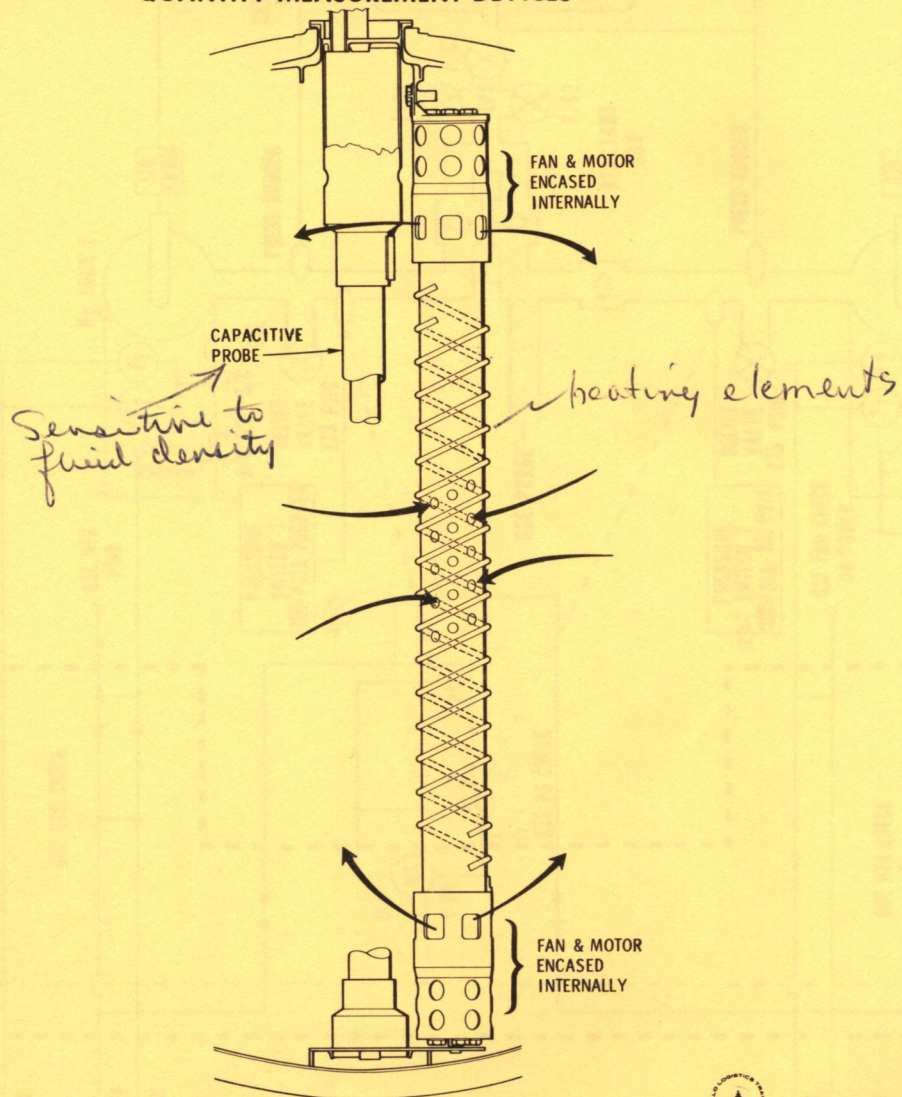


EP-038A

OXYGEN STORAGE SYSTEM (ELECTRICAL)



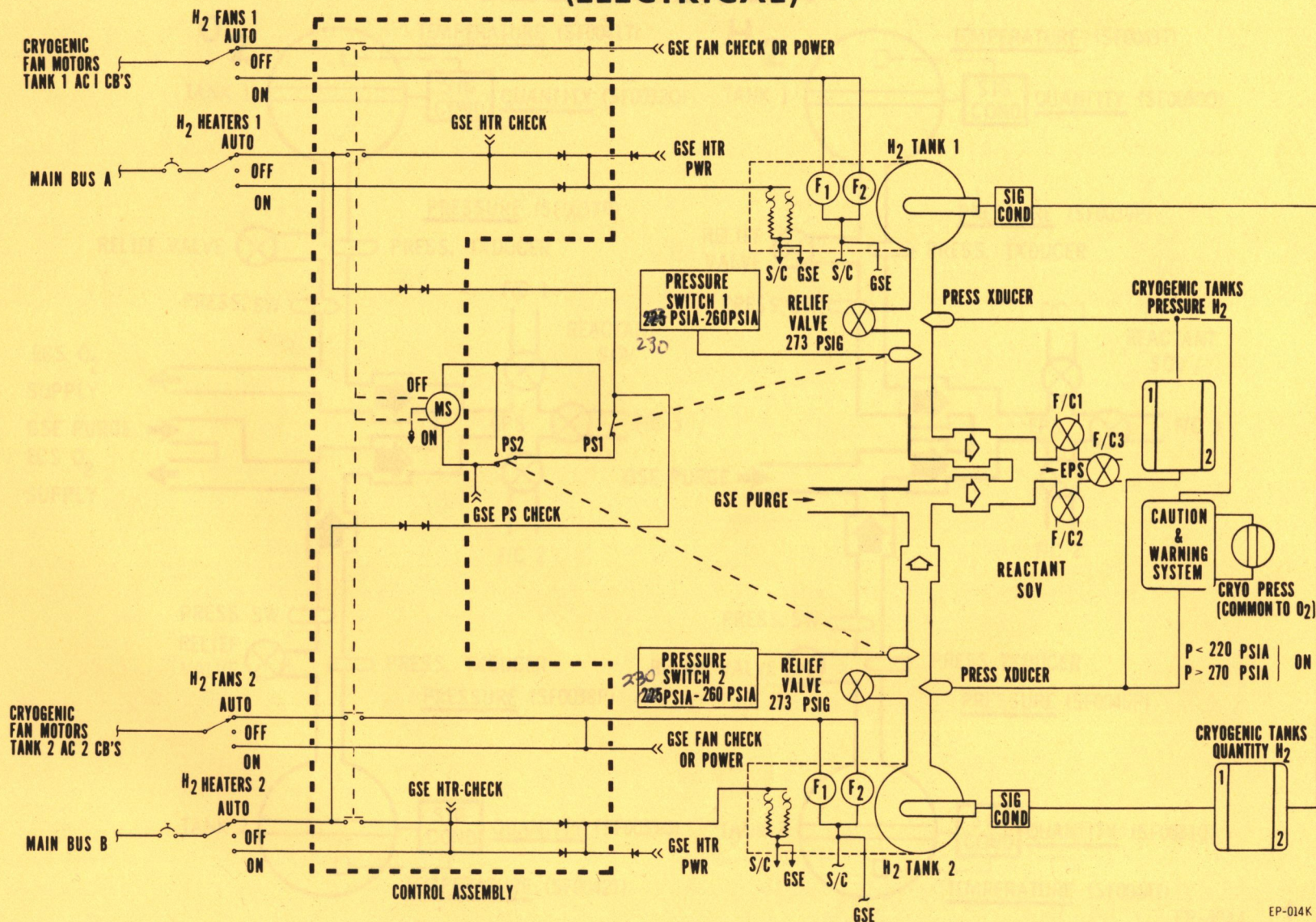
CRYOGENIC PRESSURIZATION & QUANTITY MEASUREMENT DEVICES



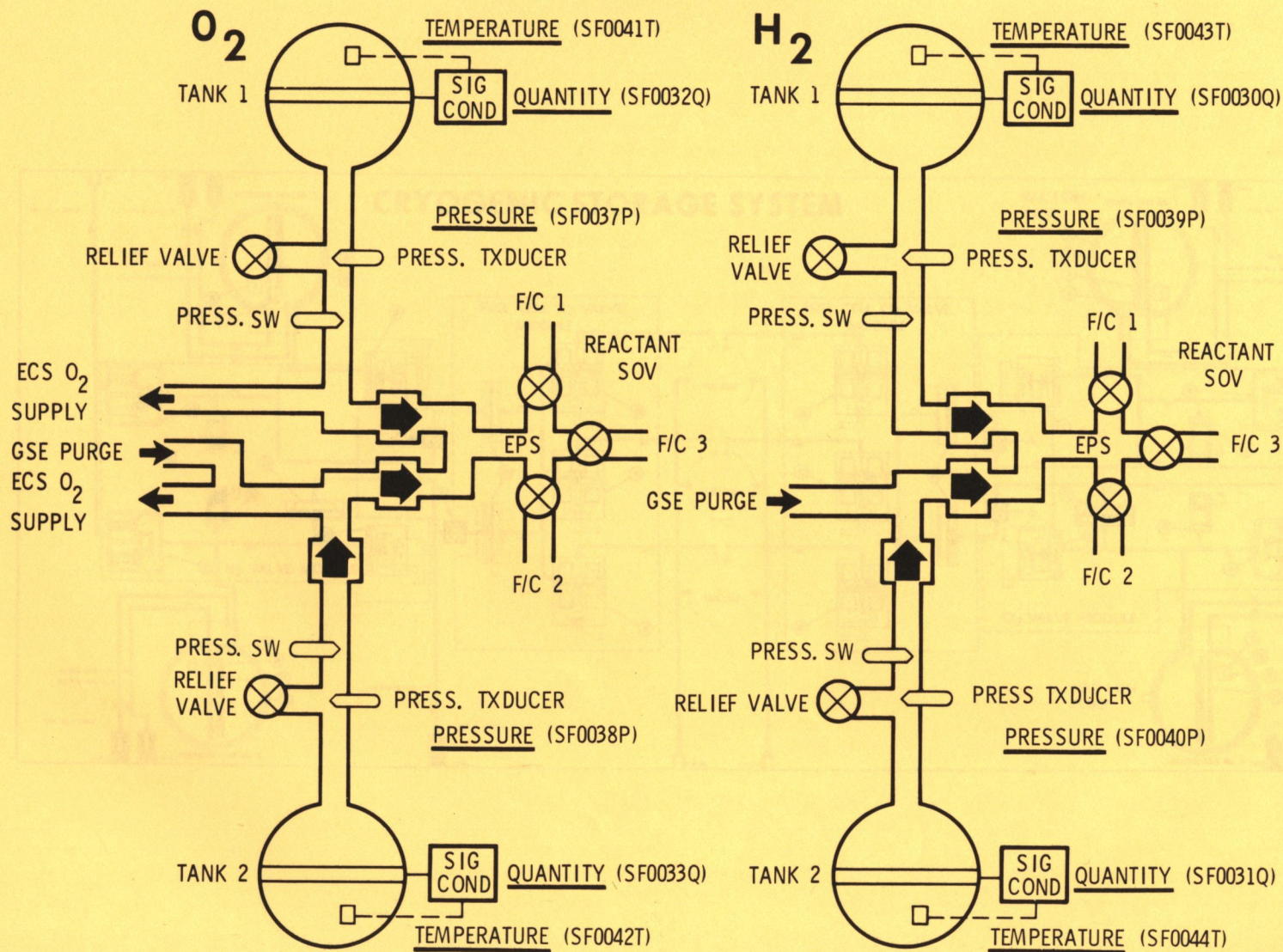
EP-096B



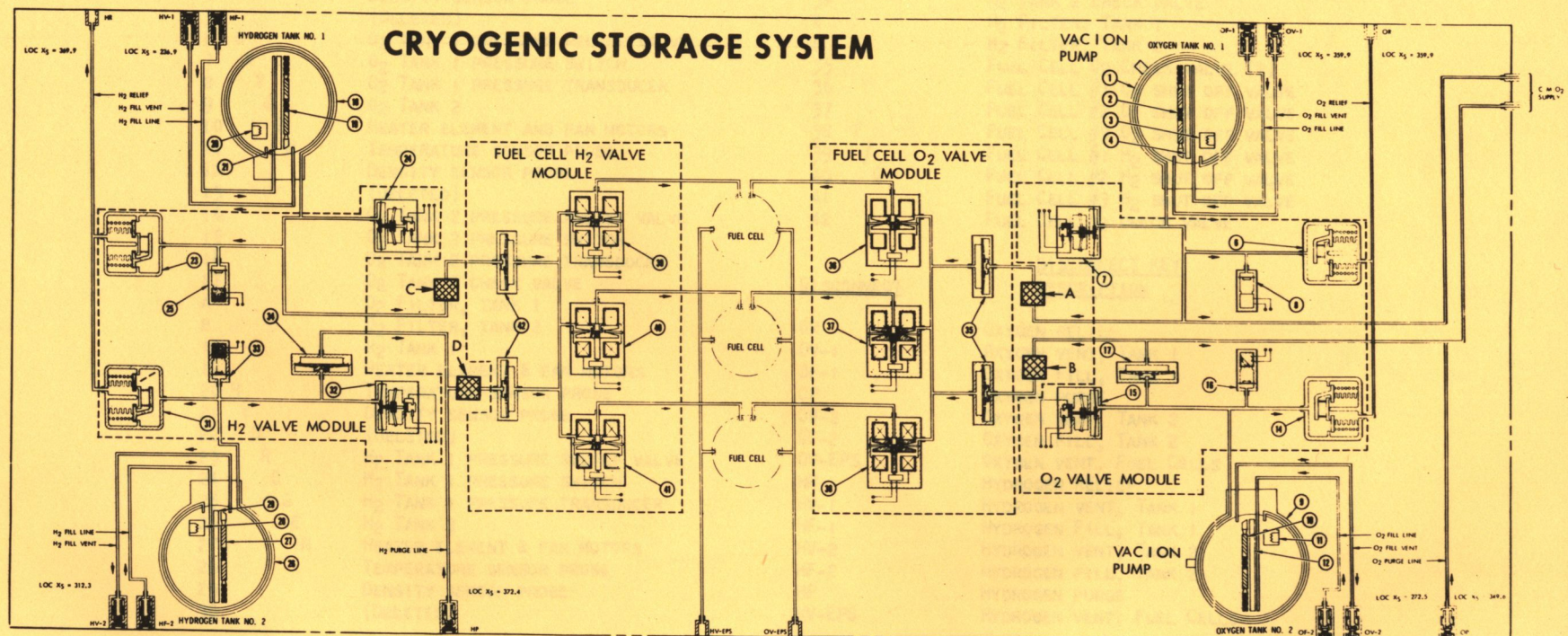
HYDROGEN STORAGE SYSTEM (ELECTRICAL)



CRYOGENIC STORAGE SYSTEM TELEMETRY



CRYOGENIC STORAGE SYSTEM



EP-030B

CRYOGENIC STORAGE SYSTEM

TEMPERATURE/NORMAL MISSION PROFILE

ITEM NO.	DESCRIPTION
1	O ₂ TANK 1
2	HEATER ELEMENT & FAN MOTORS
3	TEMPERATURE SENSOR PROBE
4	DENSITY SENSOR PROBE
5	(DELETED)
6	O ₂ TANK 1 PRESSURE RELIEF VALVE
7	O ₂ TANK 1 PRESSURE SWITCH
8	O ₂ TANK 1 PRESSURE TRANSDUCER
9	O ₂ TANK 2
10	HEATER ELEMENT AND FAN MOTORS
11	TEMPERATURE SENSOR PROBE
12	DENSITY SENSOR PROBE
13	(DELETED)
14	O ₂ TANK 2 PRESSURE RELIEF VALVE
15	O ₂ TANK 2 PRESSURE SWITCH
16	O ₂ TANK 2 PRESSURE TRANSDUCER
17	O ₂ TANK 2 CHECK VALVE
A	O ₂ FILTER, TANK 1
B	O ₂ FILTER, TANK 2
18	H ₂ TANK 1
19	HEATER ELEMENT & FAN MOTORS
20	TEMPERATURE SENSOR PROBE
21	DENSITY SENSOR PROBE
22	(DELETED)
23	H ₂ TANK 1 PRESSURE RELIEF VALVE
24	H ₂ TANK 1 PRESSURE SWITCH
25	H ₂ TANK 1 PRESSURE TRANSDUCER
26	H ₂ TANK 2
27	HEATER ELEMENT & FAN MOTORS
28	TEMPERATURE SENSOR PROBE
29	DENSITY SENSOR PROBE
30	(DELETED)

TABLE 2-2

ITEM NO.	DESCRIPTION
31	H ₂ TANK 2 PRESSURE RELIEF VALVE
32	H ₂ TANK 2 PRESSURE SWITCH
33	H ₂ TANK 2 PRESSURE TRANSDUCER
34	H ₂ TANK 2 CHECK VALVE
C	H ₂ FILTER, TANK 1
D	H ₂ FILTER, TANK 2
35	FUEL CELL O ₂ CHECK VALVE (2)
36	FUEL CELL #1 O ₂ SHUT OFF VALVE
37	FUEL CELL #2 O ₂ SHUT OFF VALVE
38	FUEL CELL #3 O ₂ SHUT OFF VALVE
39	FUEL CELL #1 H ₂ SHUT OFF VALVE
40	FUEL CELL #2 H ₂ SHUT OFF VALVE
41	FUEL CELL #3 H ₂ SHUT OFF VALVE
42	FUEL CELL H ₂ CHECK VALVE

DISCONNECT

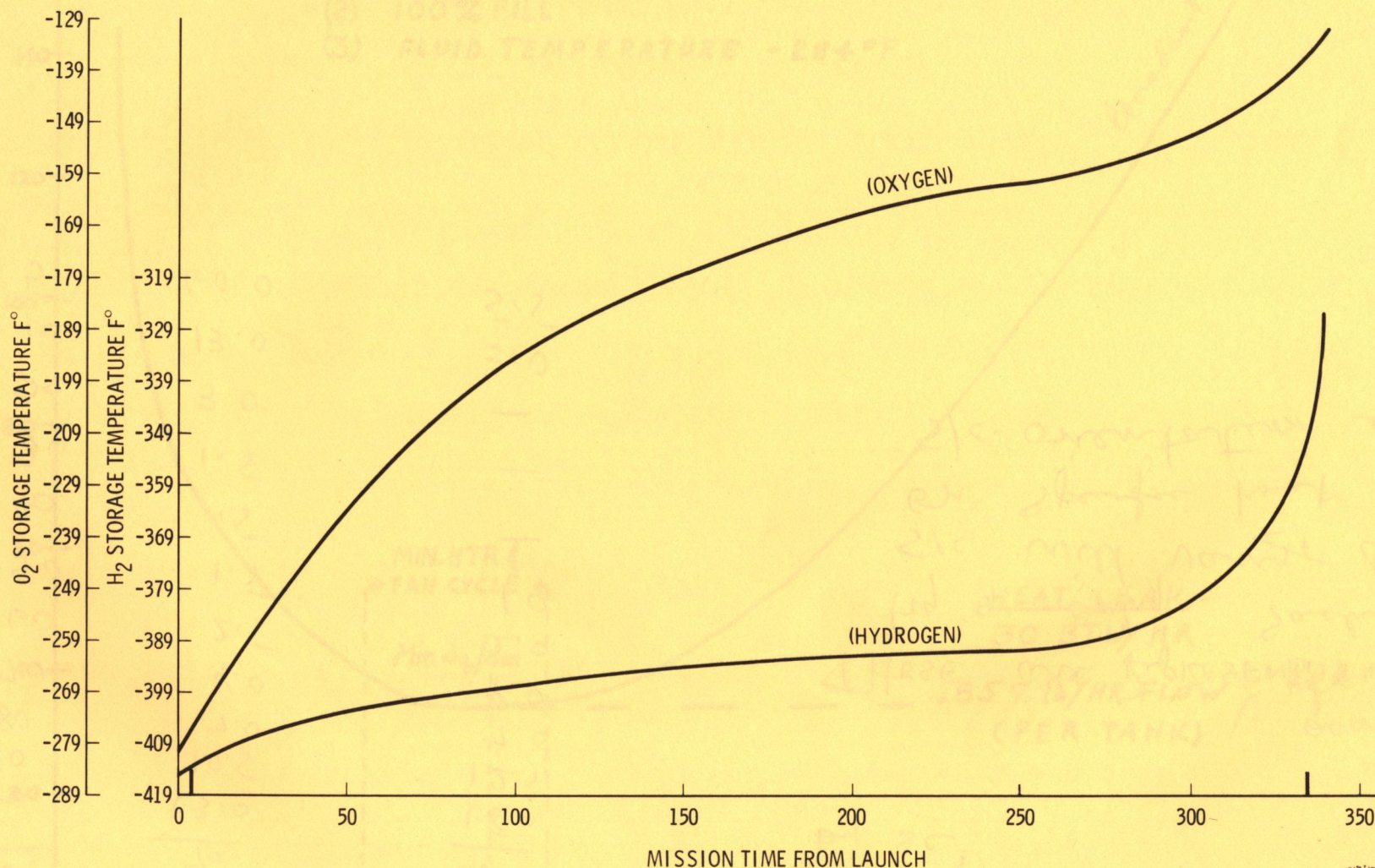
OR
OV-1
OF-1
OP
OV-2
OF-2
OV-EPS
HR
HV-1
HF-1
HV-2
HF-2
HP
HV-EPS

DISCONNECT KEY DESCRIPTION

OXYGEN RELIEF
OXYGEN VENT, TANK 1
OXYGEN FILL, TANK 1
OXYGEN PURGE
OXYGEN VENT, TANK 2
OXYGEN FILL, TANK 2
OXYGEN VENT, FUEL CELLS
HYDROGEN RELIEF
HYDROGEN VENT, TANK 1
HYDROGEN FILL, TANK 1
HYDROGEN VENT, TANK 2
HYDROGEN FILL, TANK 2
HYDROGEN PURGE
HYDROGEN VENT, FUEL CELLS

CRYOGENIC STORAGE SYSTEM

TEMPERATURE/NORMAL MISSION PROFILE



% Tank fill	151 #/hr H ₂ Duty %	1.655 #/hr O ₂ Duty %
100	13.0	18.0
90	10.5	12.5
80	7.0	7.0
70	4.0	4.0
60	2.5	2.0
50	1.5	1.0
40	.5	—
30	1.5	—
20	3.0	—
10	13.0	3.0
5	60.0	5.5

H₂ + O₂ use at
@ 1700 watt
or ~~100~~ pwr
consumption
by SC.

1.655 #/hr
= 1.23 - FCA's
+ 425 - ECS

THESE are REPRESENTATIVE
fig's only - Each
S/C will vary depending
on specific heat load,
S/C orientation etc.

TEMPERATURE/NORMAL MISSION PROFILE
CRYOGENIC STORAGE SYSTEM

OXYGEN SPECIFIC HEAT INPUT BASED UPON:

- (1) TANK PRESSURE OF 900 PSIA
- (2) 100% FILL
- (3) FLUID TEMPERATURE -284°F

SPECIFIC HEAT INPUT BTU/LB WITHDRAWN

constant PX line

MIN. HTR &
FAN CYCLE

Min dq/dm

HEAT LEAK
30 BTU/HR

.857 lb/HR FLOW
(PER TANK)

*Rqd to avoid
over PX*

25 36 40

PERCENT OF INITIAL WEIGHT

Y 61

SPECIFIC HEAT INPUT BTU/LB WITHDRAW

HYDROGEN SPECIFIC HEAT INPUT BASED UPON:

- (1) TANK PRESSURE OF 250 PSIA
- (2) 100 % FILL
- (3) FLUID TEMPERATURE - 416 °F
- (4) 100% PARAHYDROGEN

to stay in this PX ~~range~~
range ~~reps~~ FEA loads:
2 FEA w/ 27 amps/FEA
3 FEA w/ 19 amps/FEA

constant PX line

MIN. HTR/FAN CYCLE

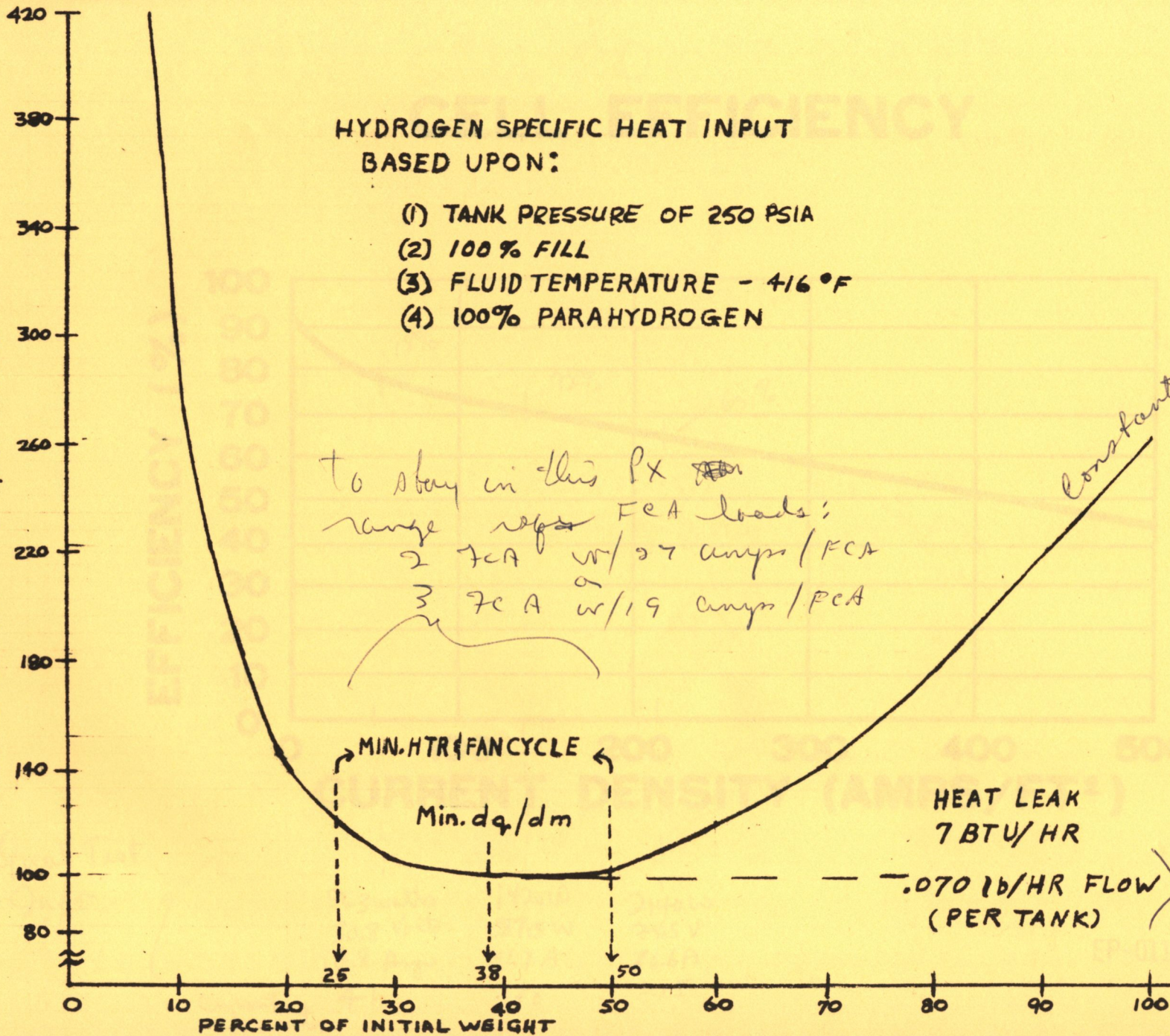
Min. dq/dm

HEAT LEAK
7 BTU/HR

.070 lb/HR FLOW
(PER TANK)

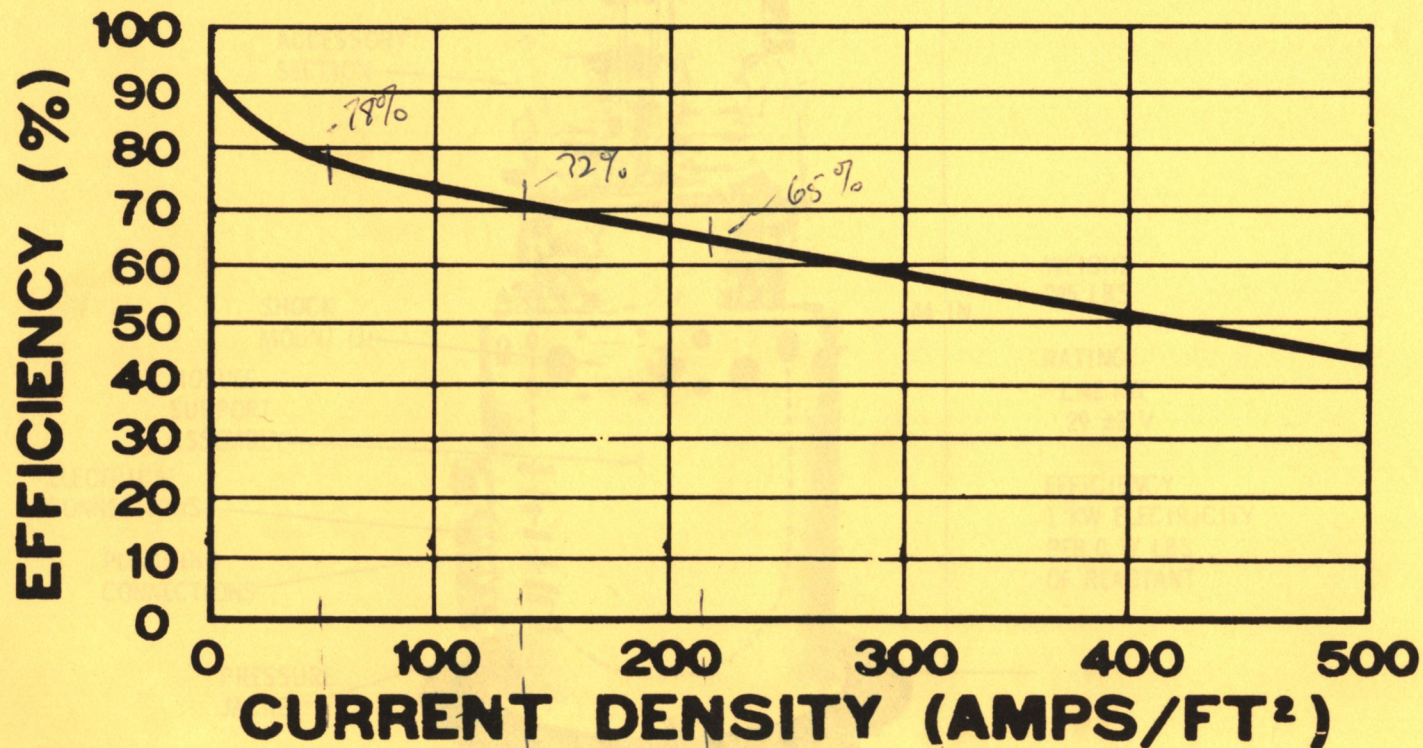
Ref'd to
avoid
over PX

PERCENT OF INITIAL WEIGHT



FUEL CELL POWER PLANT

CELL EFFICIENCY



Qual Test
Info

Current
density

563 watts
30.8 Volts
18.8 Amps

47

1420 W
27.5 V
51.7 A

128

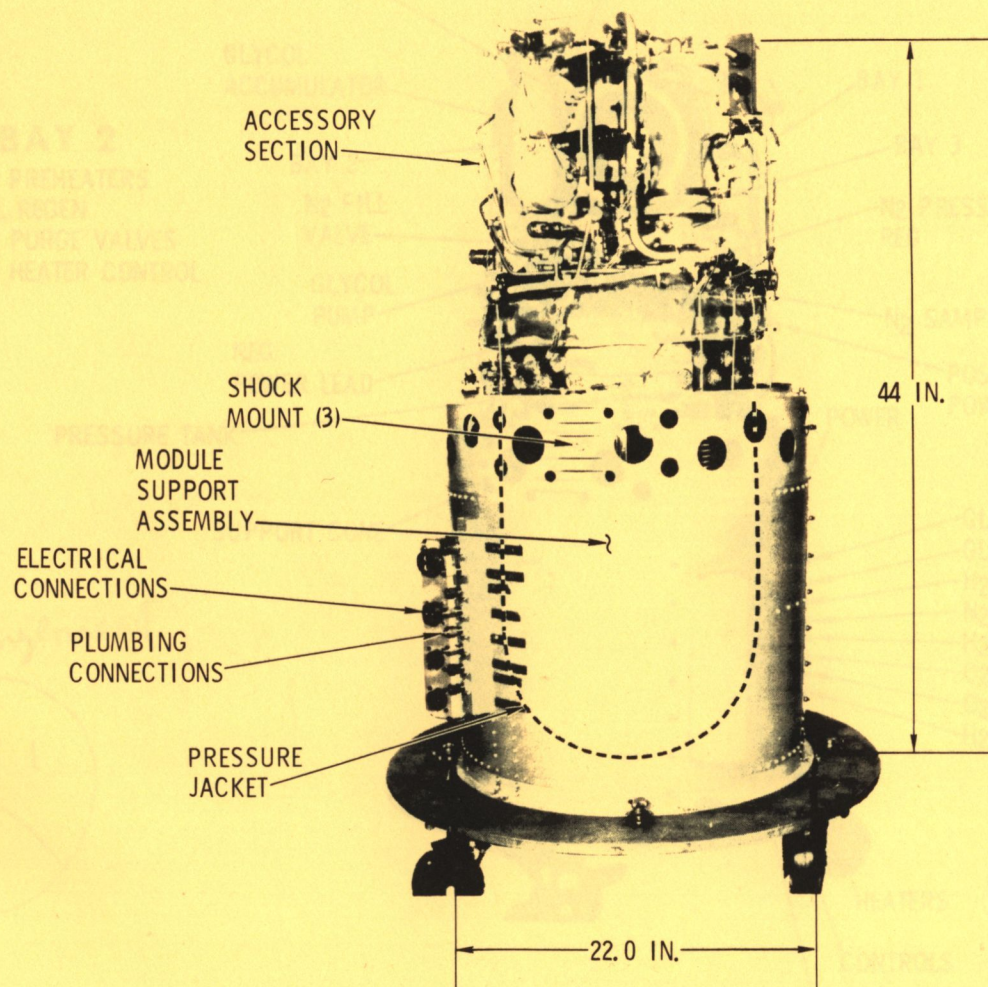
2140 W
24.5 V
86.6 A

215

EP-011B



FUEL CELL POWER PLANT



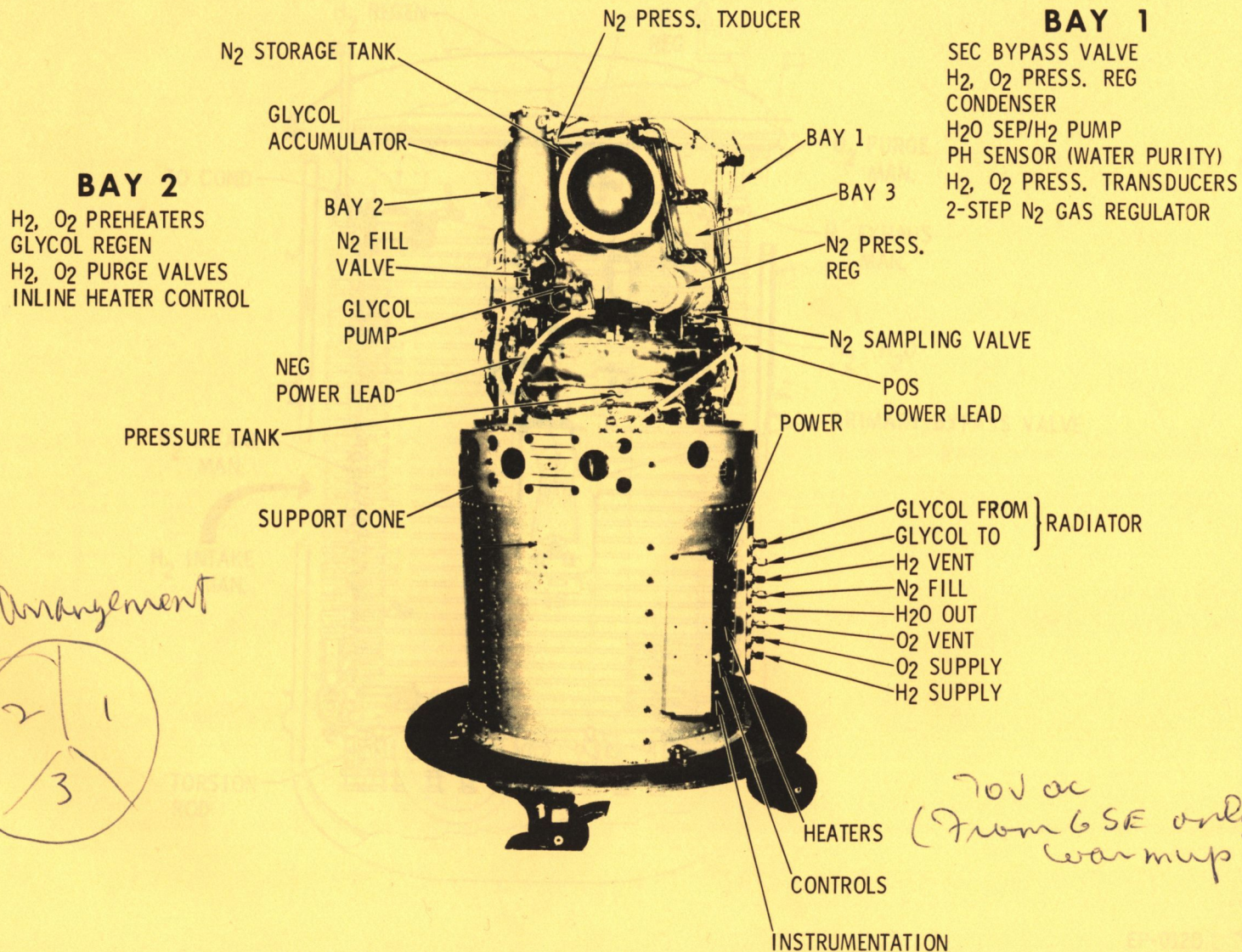
WEIGHT
245 LBS

RATING
1.42 KW
29 $\pm$ 2 V

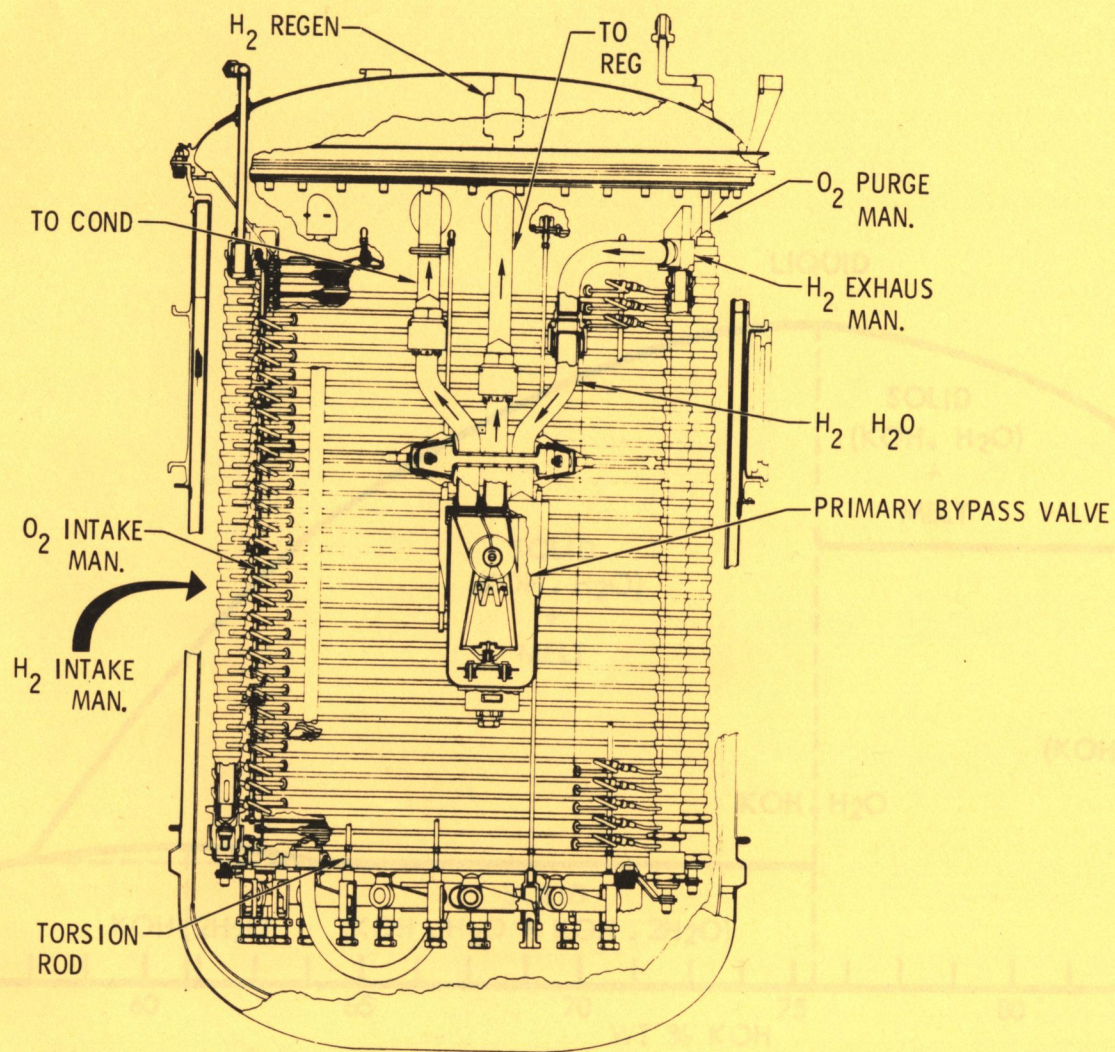
EFFICIENCY
1 KW ELECTRICITY
PER 0.77 LBS
OF REACTANT



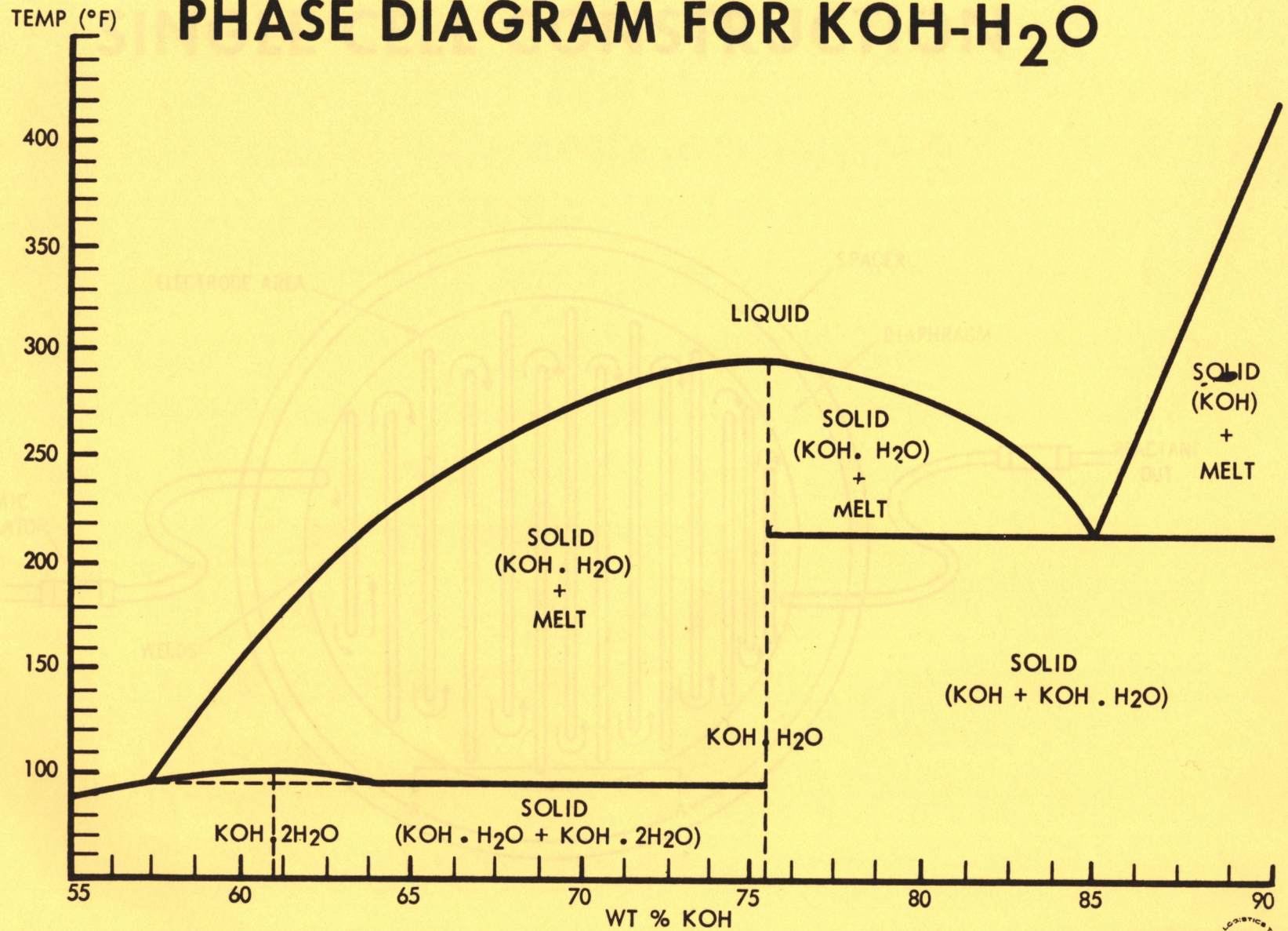
FUEL CELL MODULE ACCESSORIES



FUEL CELL MODULE



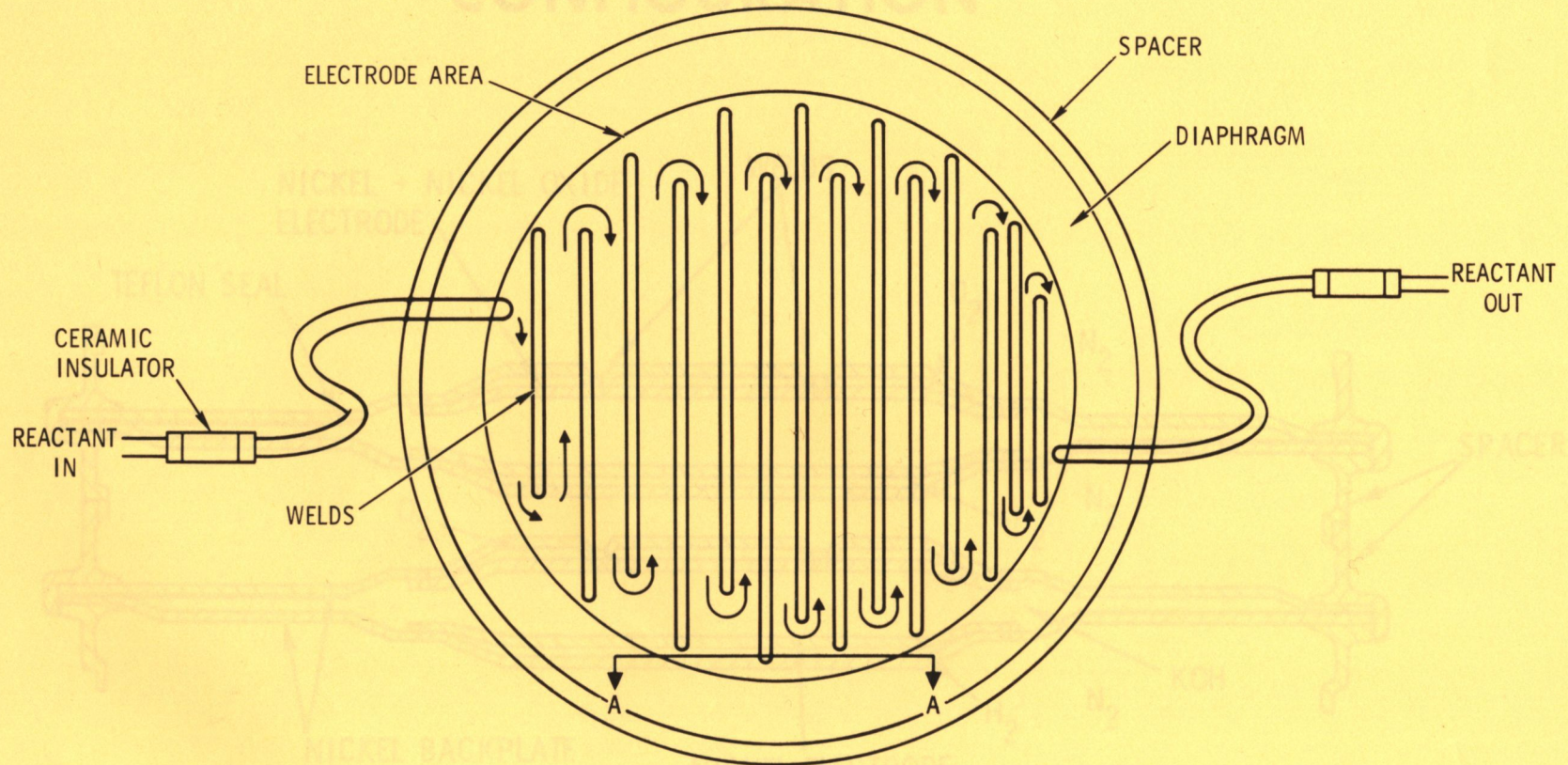
PHASE DIAGRAM FOR KOH-H₂O



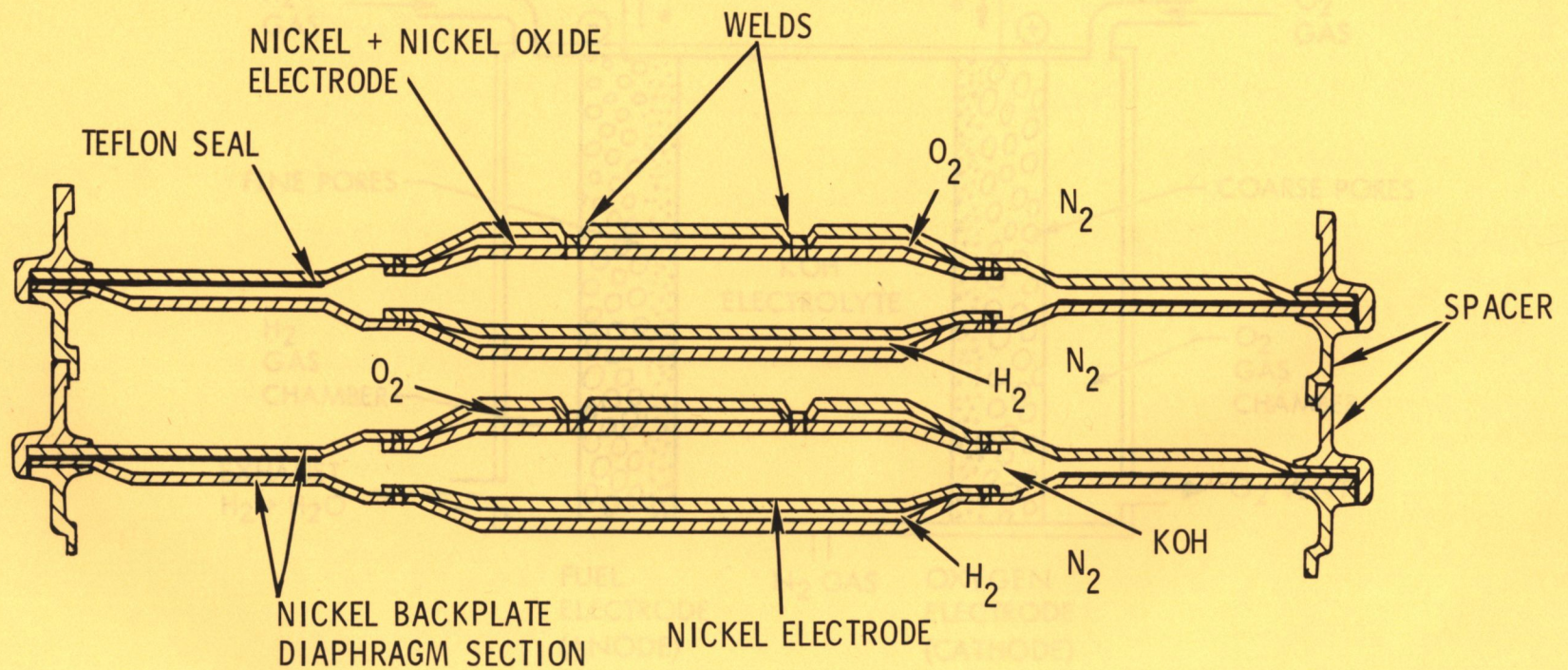
EP-007



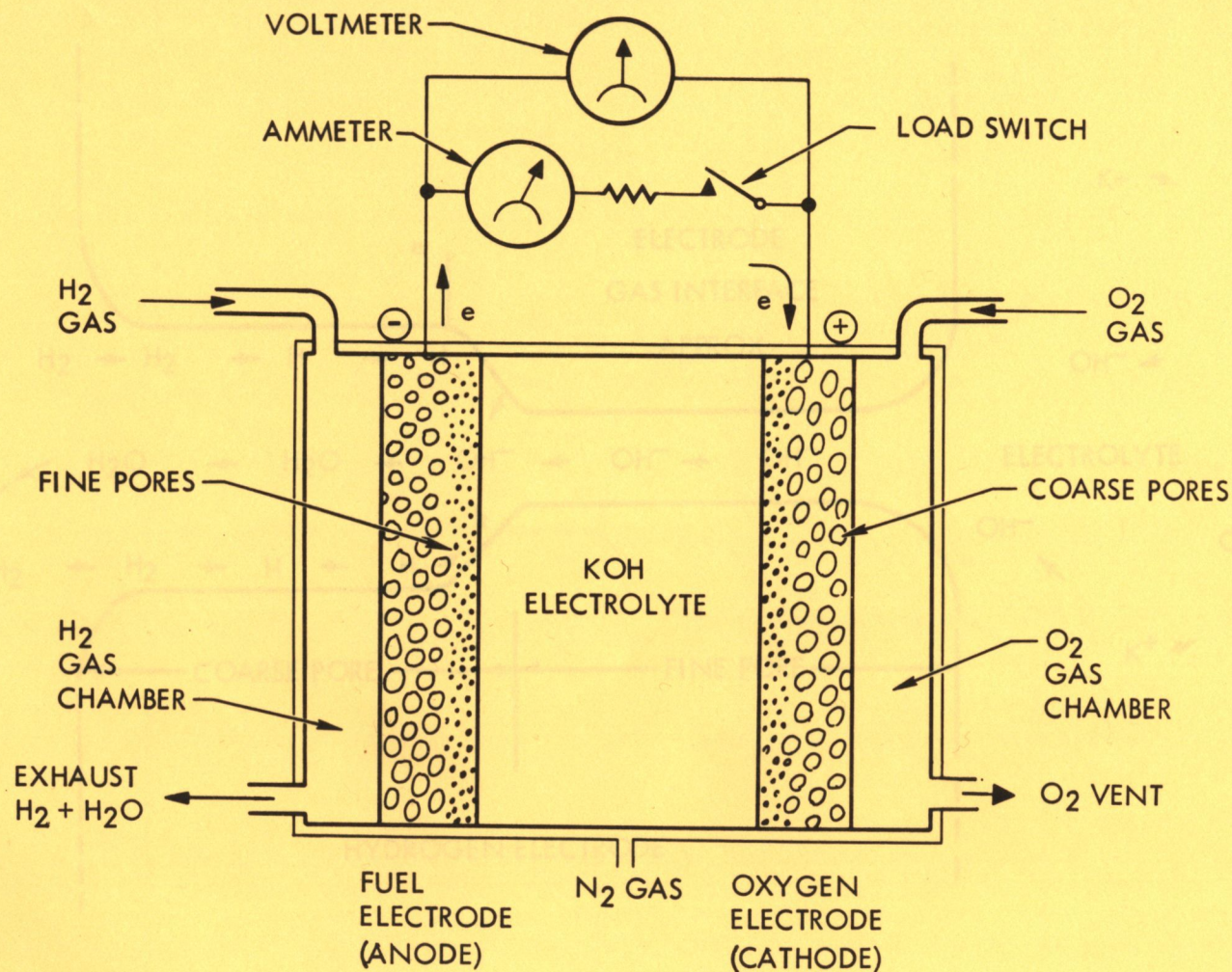
SINGLE CELL CONSTRUCTION



CELL CUTAWAY AND MOUNTING CONFIGURATION



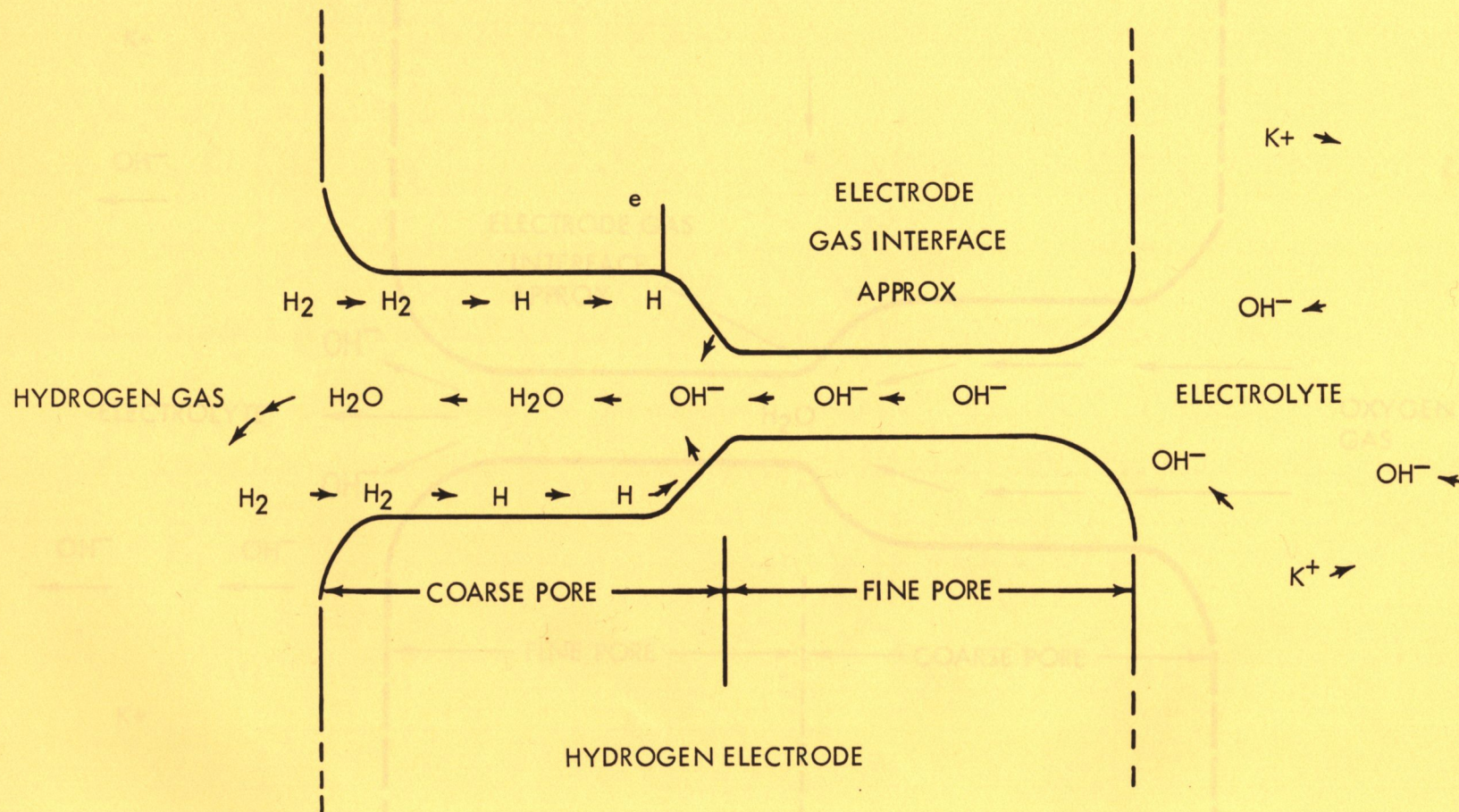
FUEL CELL ELECTROCHEMICAL FLOW SCHEMATIC



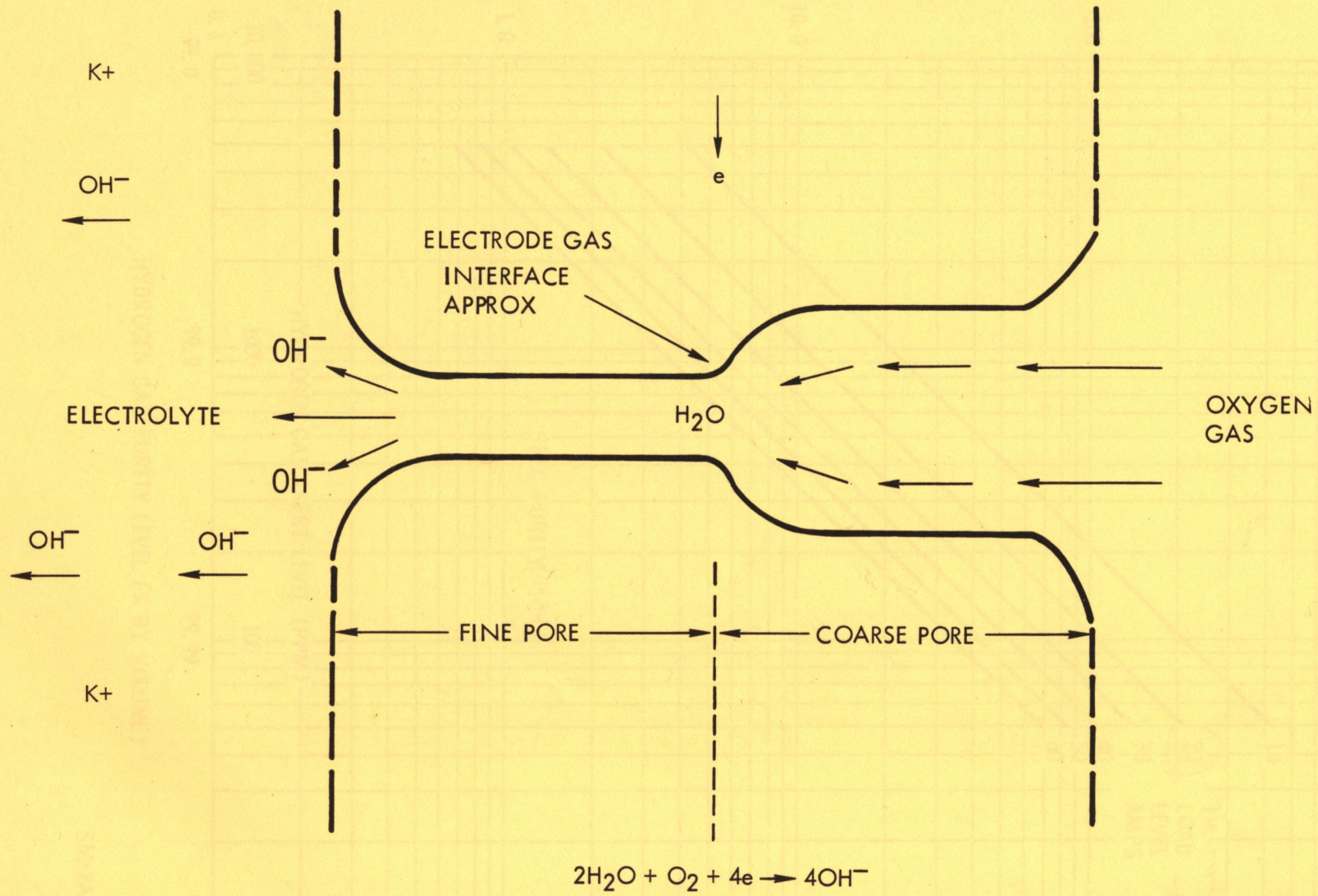
EP-003A

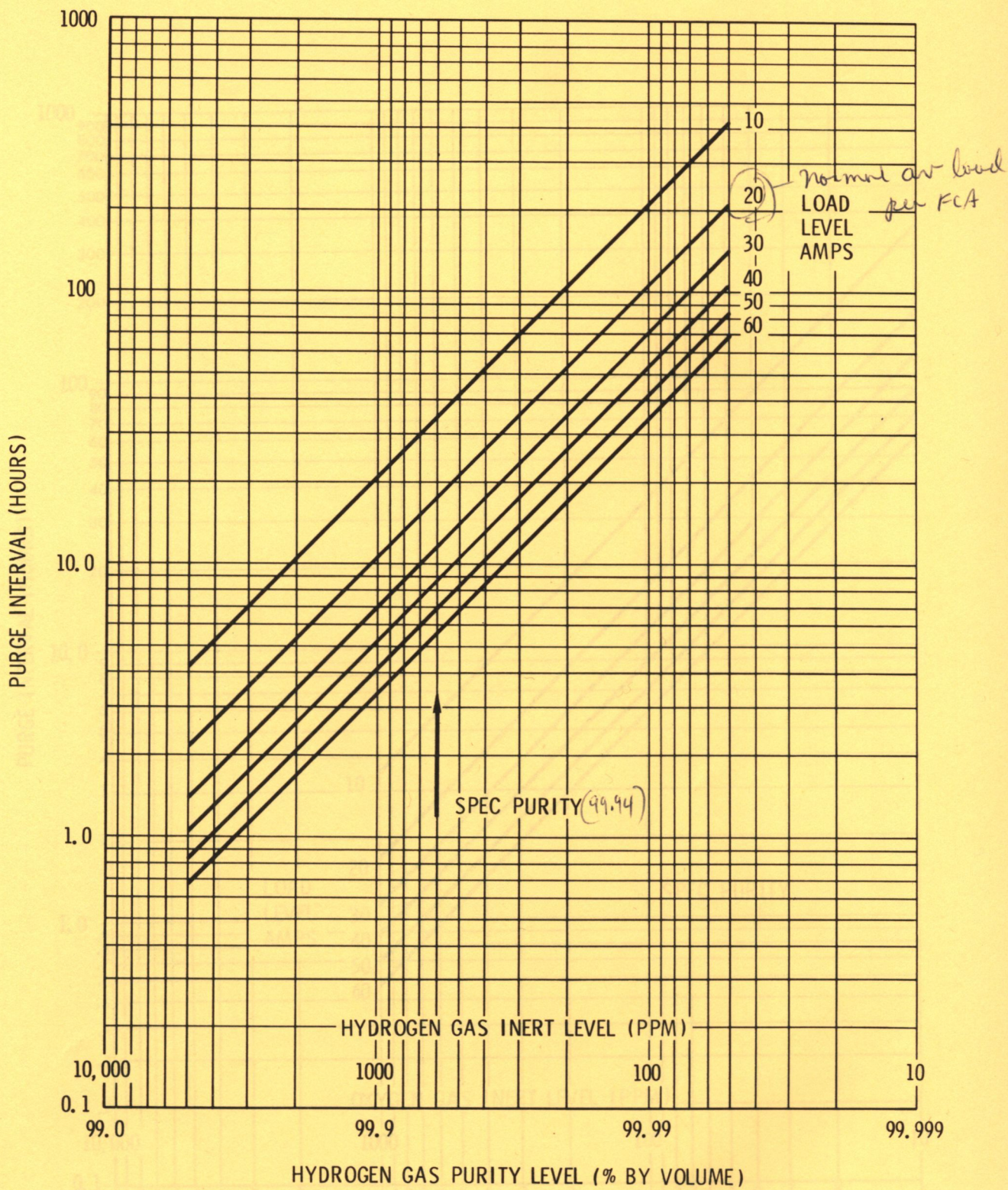


HYDROGEN ELECTRODE REACTION

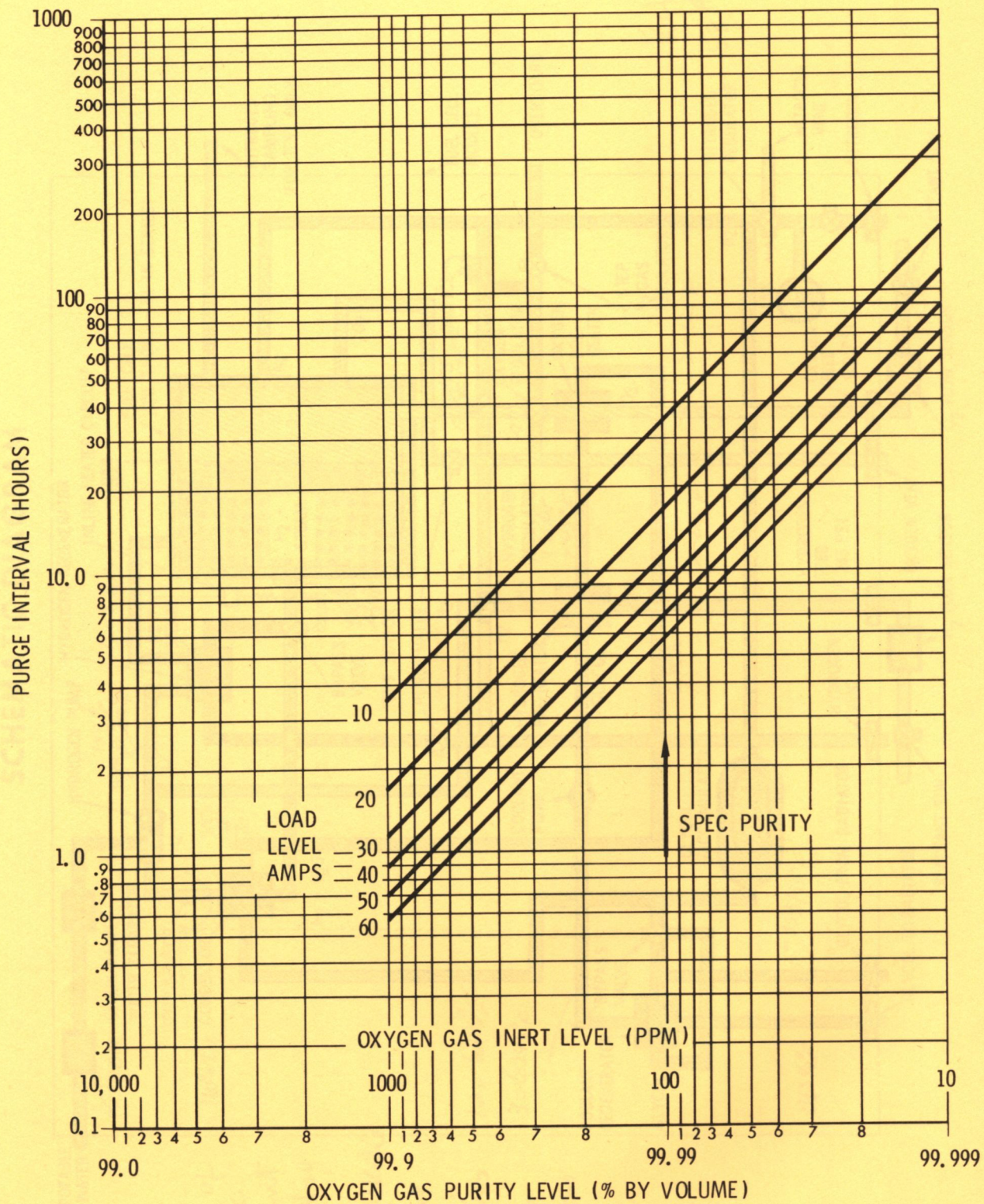


OXYGEN ELECTRODE REACTION



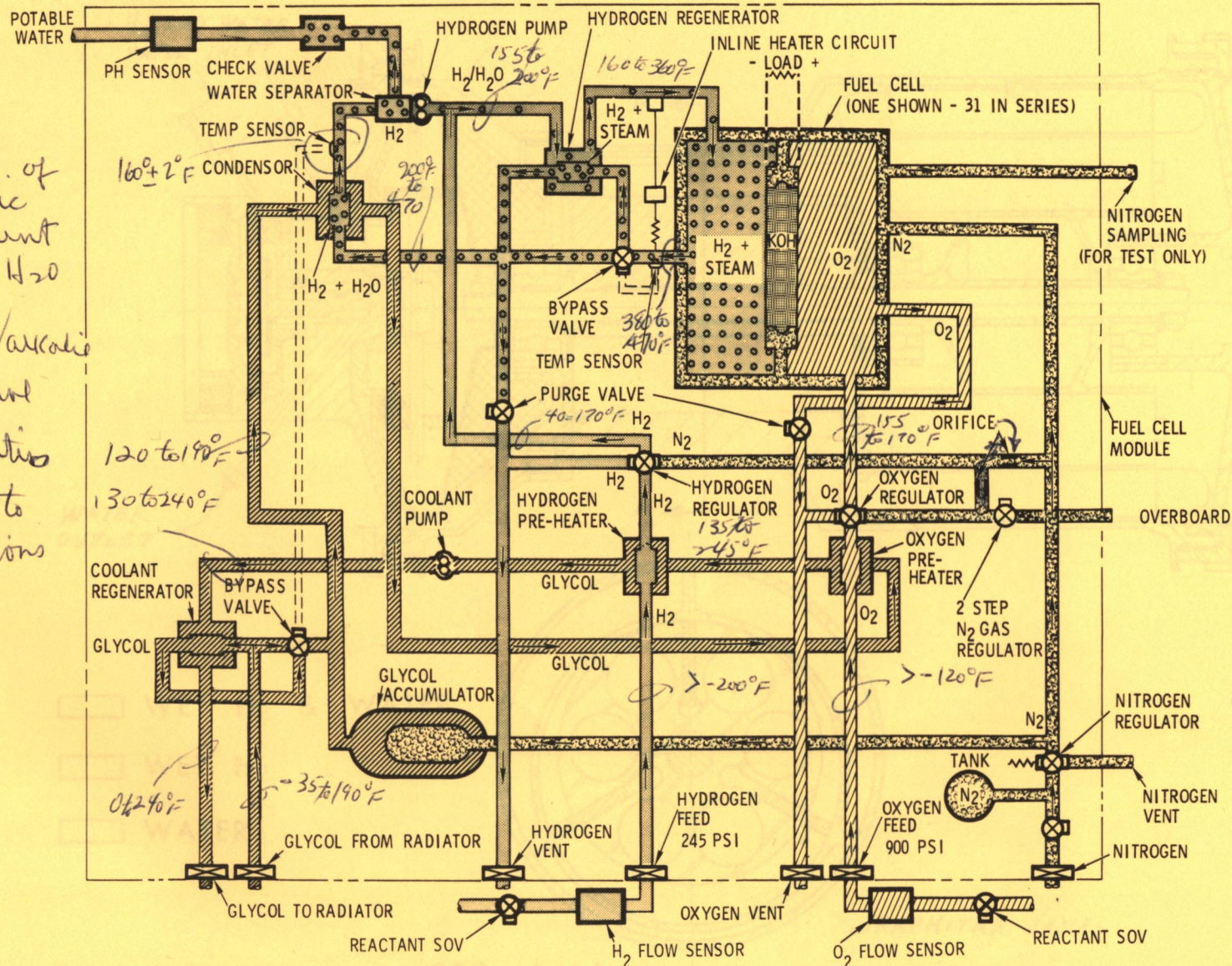


SM-2A-1215



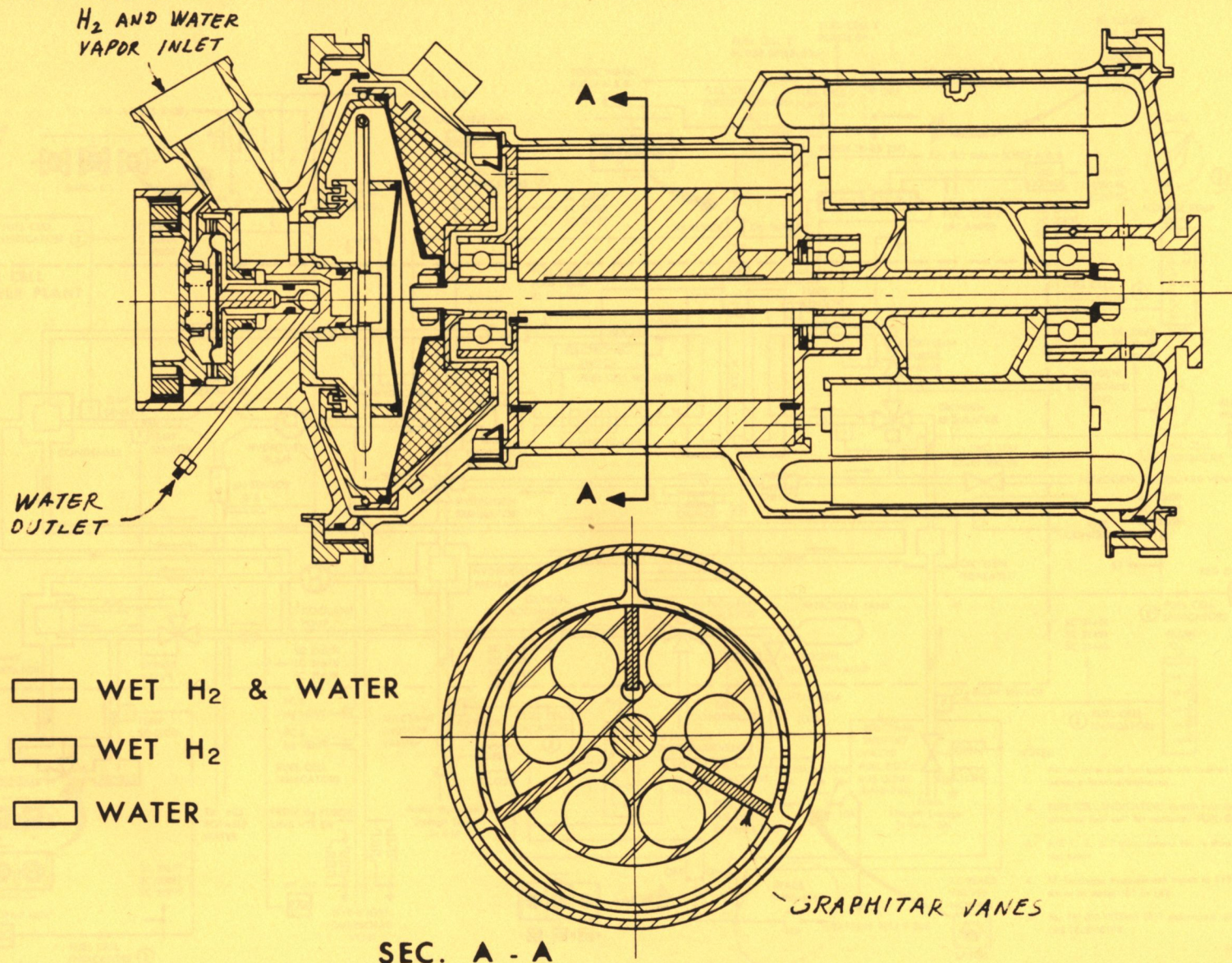
SM-2A-1214

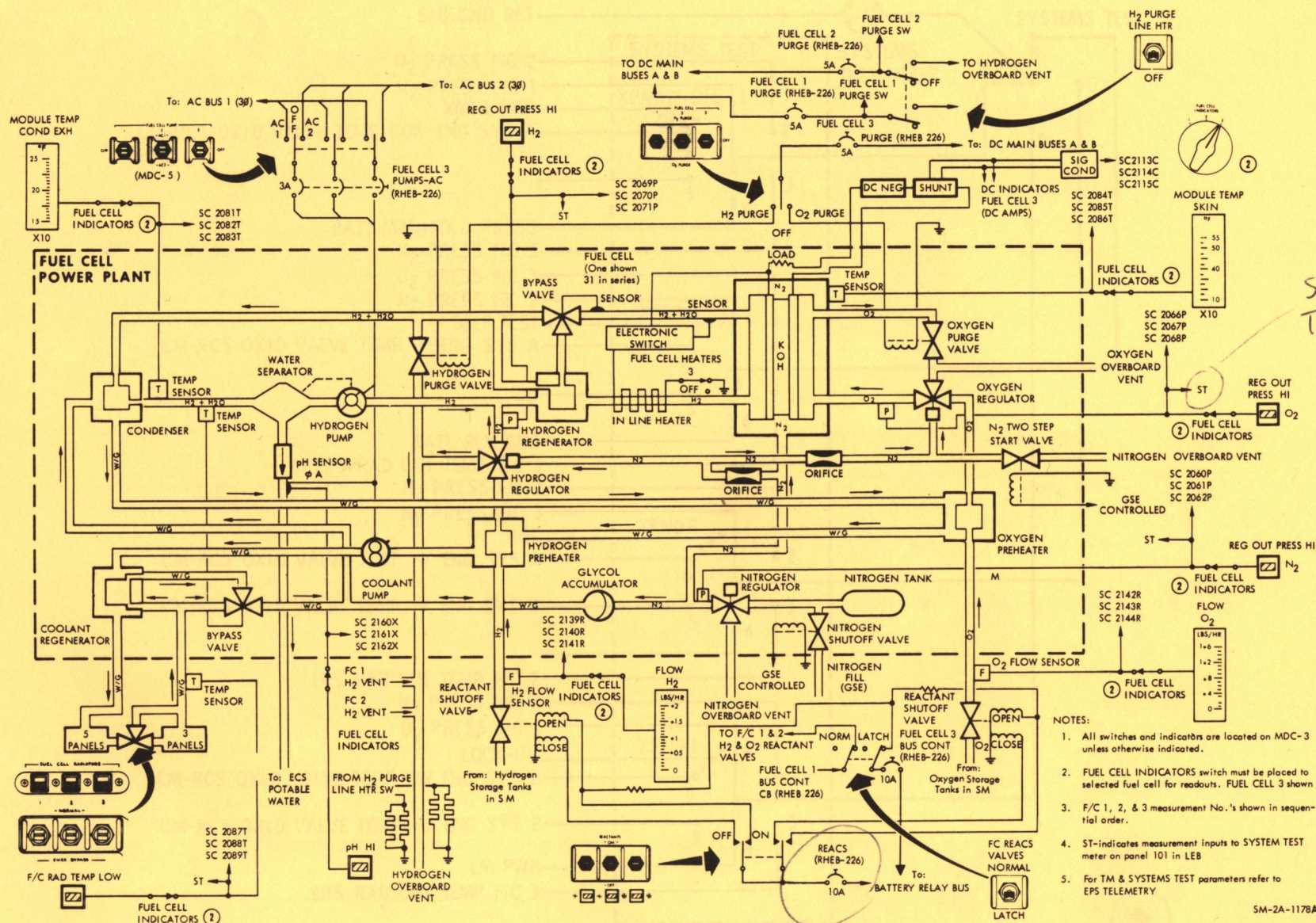
FUEL CELL MODULE SCHEMATIC DIAGRAM



Reference =
53# Nitrogen PX

HYDROGEN CIRCULATING PUMP & WATER SEPARATOR





Systems Test mater

I.D. NO.	PROJECT REPORT	SCT. FIG.	TITLE
(...)	(...)	...	C.I.E.I. 11-11 ANEMATIC DIAGRAM

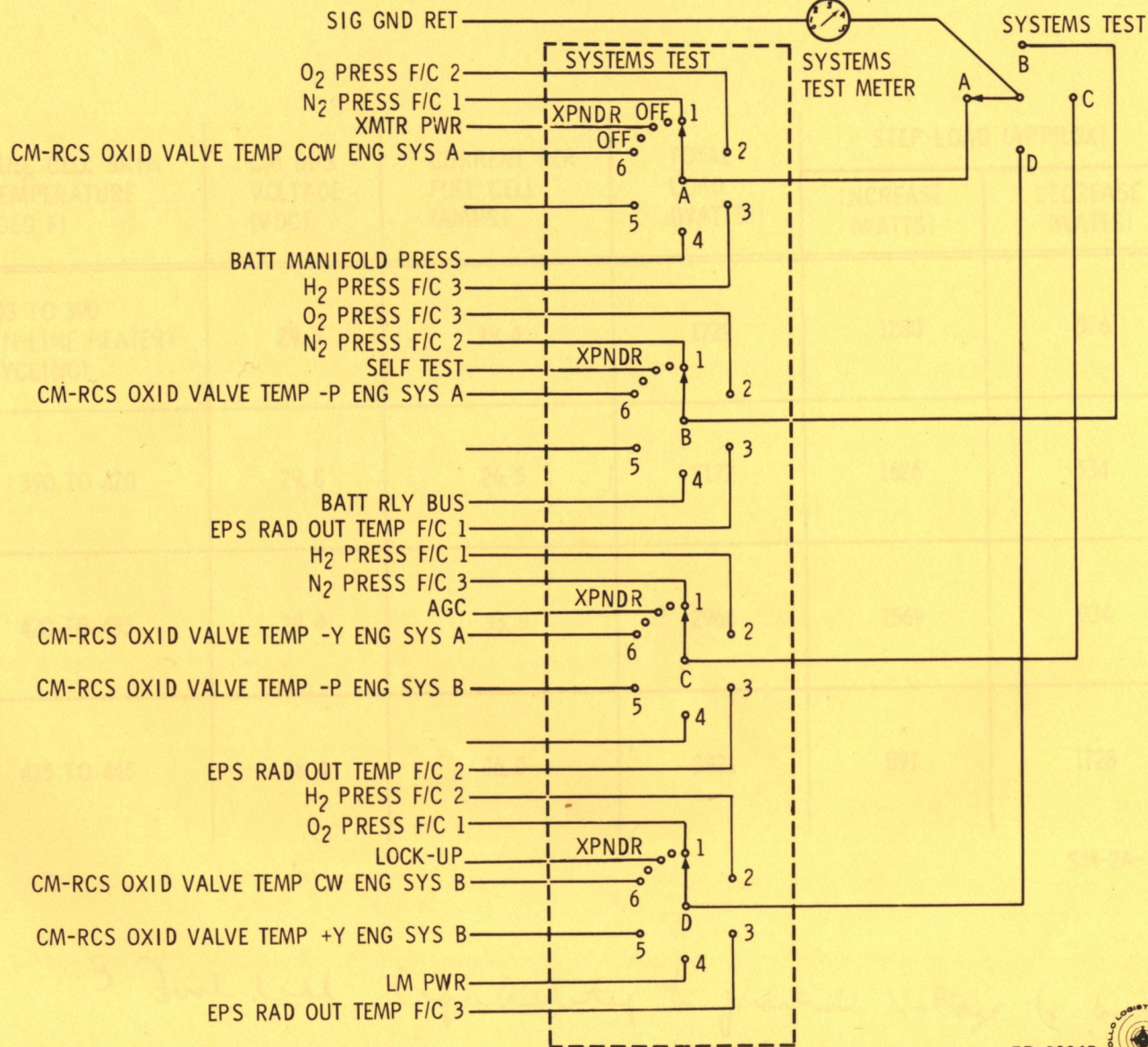
NOTES:

1. All switches and indicators are located on MDC-3 unless otherwise indicated.
2. FUEL CELL INDICATORS switch must be placed to selected fuel cell for readouts. FUEL CELL 3 shown.
3. F/C 1, 2, & 3 measurement No.'s shown in sequential order.
4. ST-indicates measurement inputs to SYSTEM TEST meter on panel 101 in LEB
5. For TM & SYSTEMS TEST parameters refer to EPS TELEMETRY

SM-2A-1178A

open -
in flight

SYSTEMS TEST



ENTRY & POST LANDING BATTERY

INTERIOR

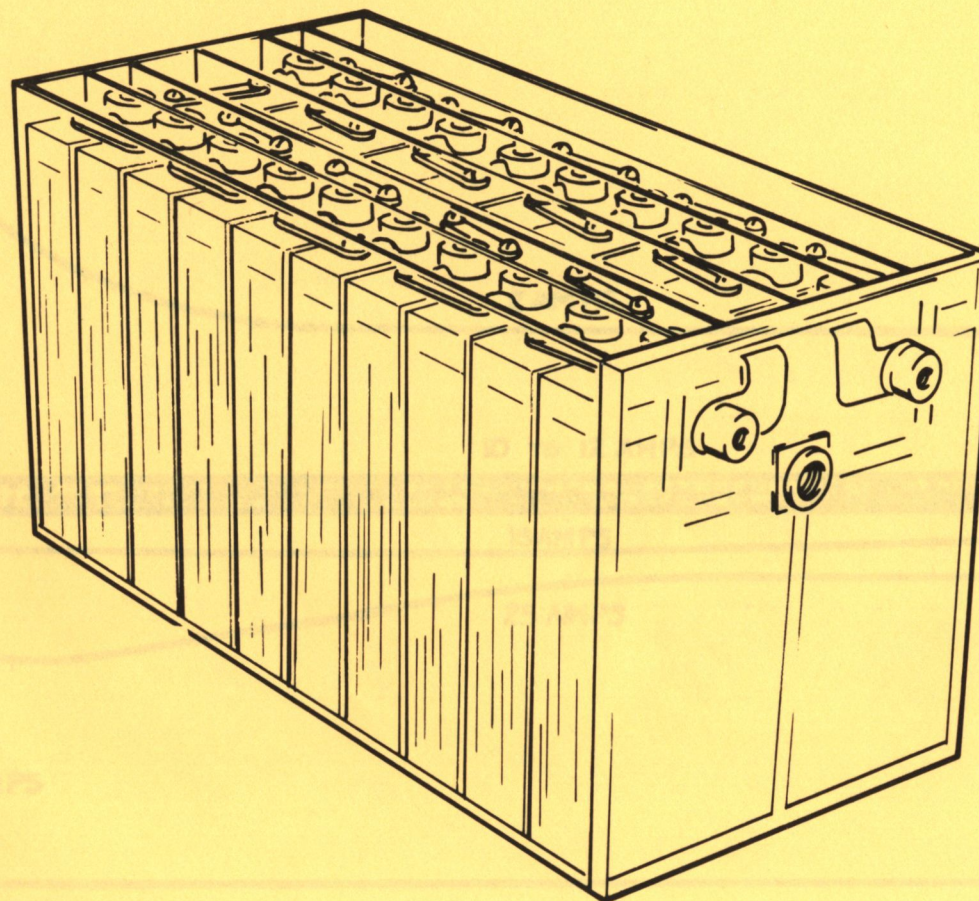
FUEL CELL SKIN TEMPERATURE (DEG F)	CM BUS VOLTAGE (VDC)	CURRENT PER FUEL CELL (AMPS)	TOTAL LOAD (WATTS)	STEP LOAD (APPROX)	
				INCREASE (WATTS)	DECREASE (WATTS)
383 TO 390 (IN-LINE HEATER) CYCLING)	29.5	19.4	1722	1280	576
390 TO 420	29.8	26.5	2172	1626	534
420 TO 435	29.4	33.5	2964	1569	924
435 TO 445	28.4	46.0	3921	891	1728

SM-2A-1217

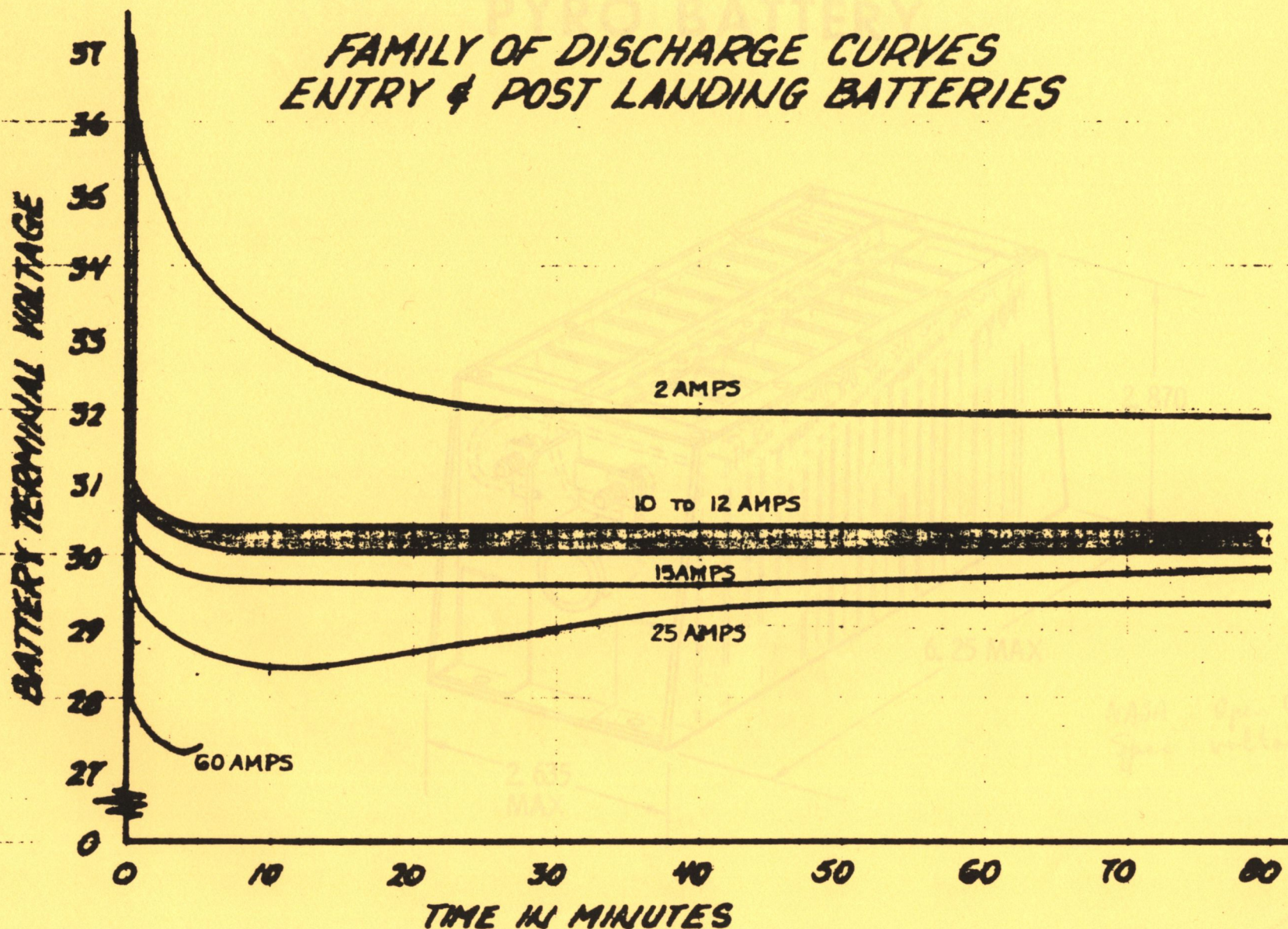
3 Fuel cell Capability to provide Voltage to busses

ENTRY & POST LANDING BATTERY

INTERIOR

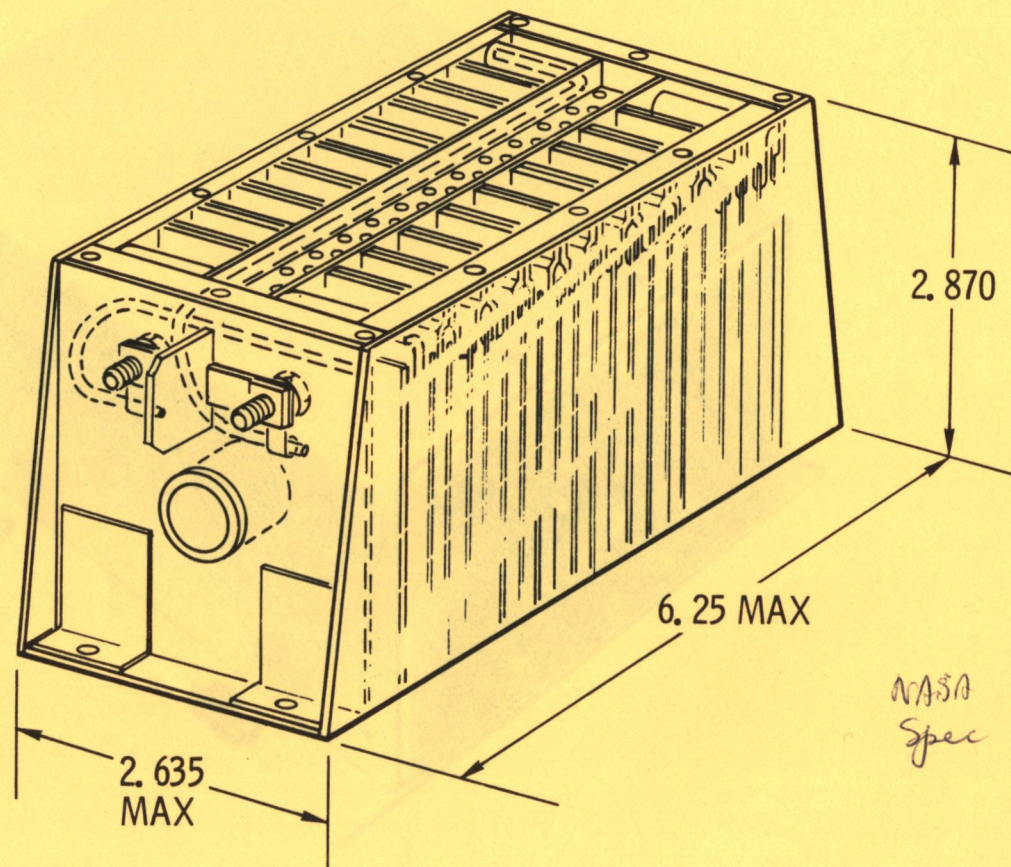


FAMILY OF DISCHARGE CURVES ENTRY & POST LANDING BATTERIES



APOLLO PYRO BATTERY

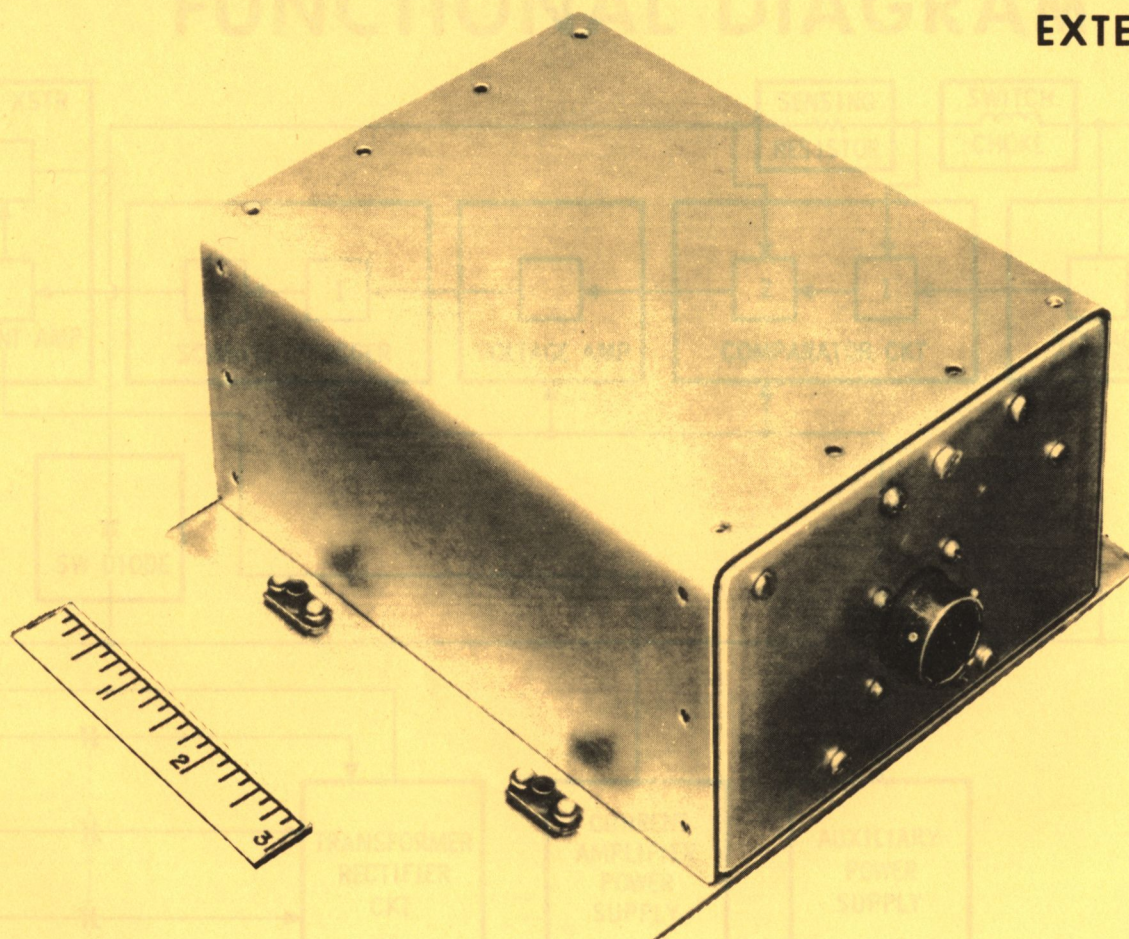
EXTERIOR



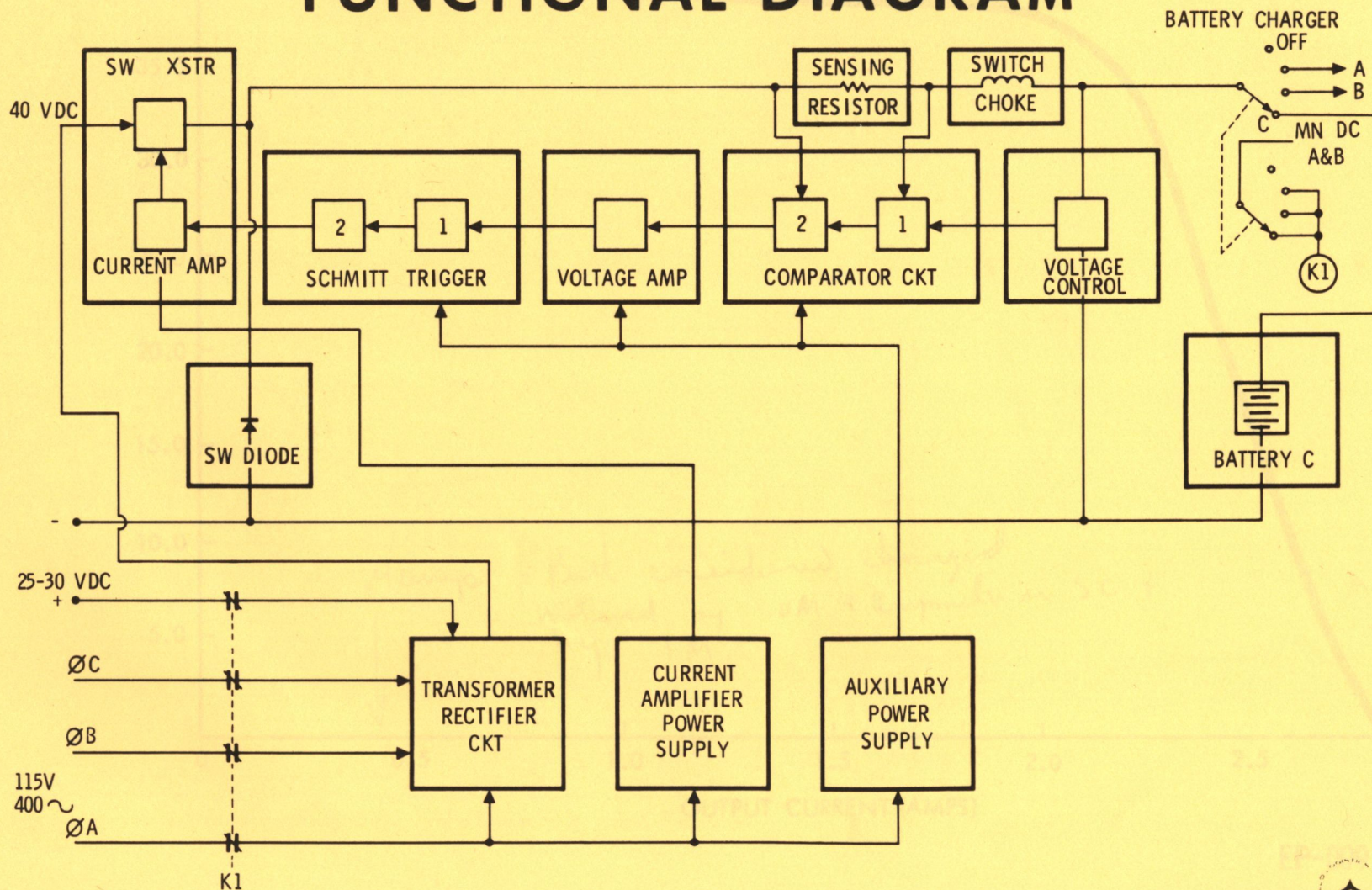
NASA Open CKT ?
Spec voltage = 34 wts

APOLLO BATTERY CHARGER

EXTERIOR

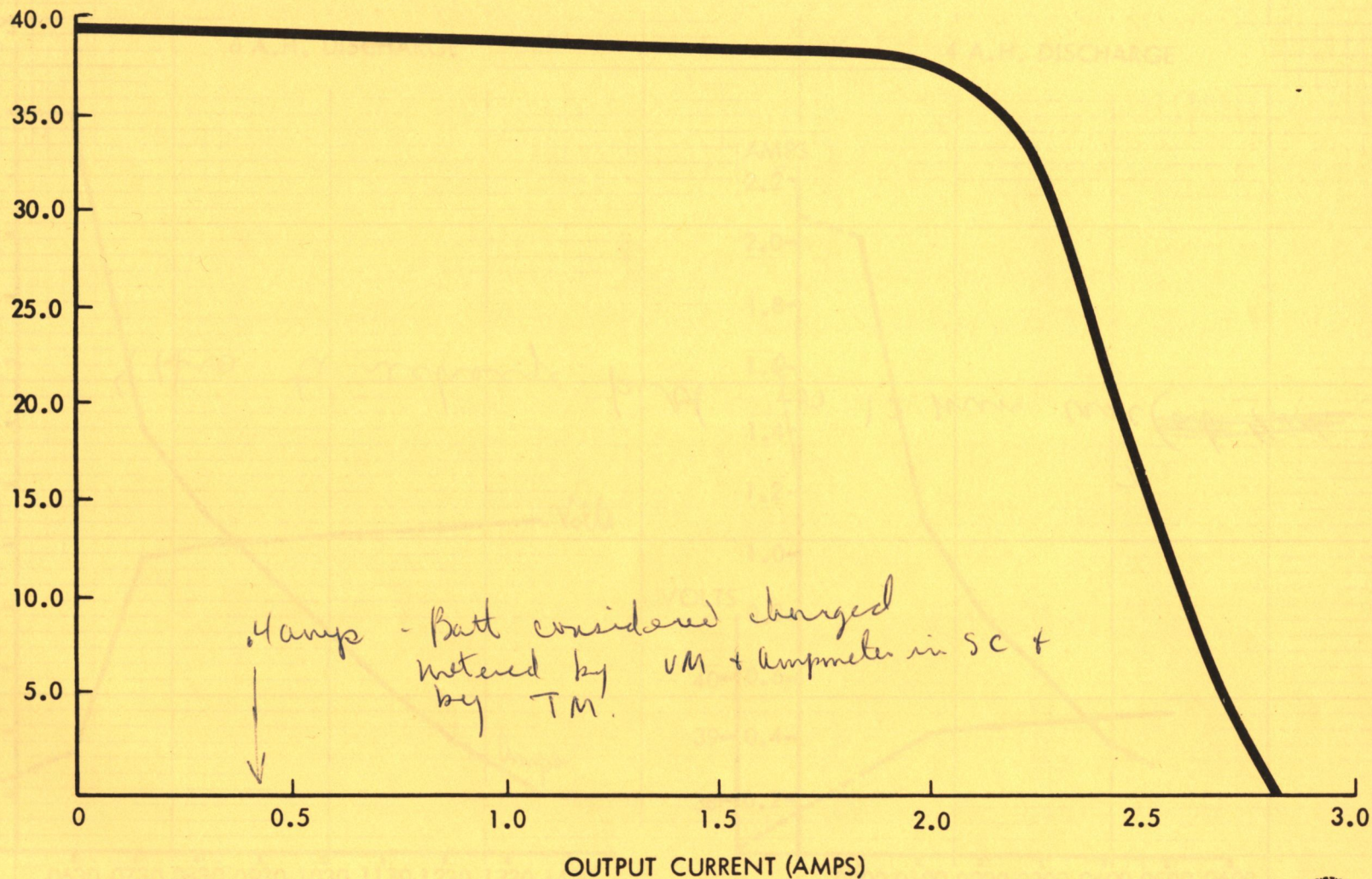


BATTERY CHARGER FUNCTIONAL DIAGRAM



CURRENT VS VOLTAGE REGULATION CURVE

OUTPUT VOLTAGE
(VOLTS)



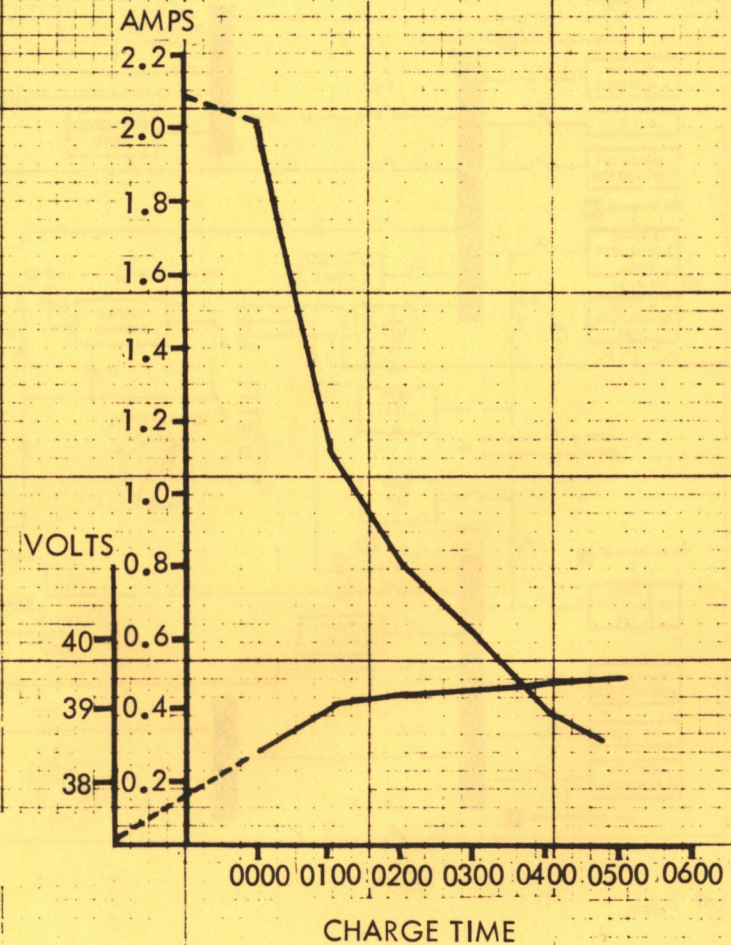
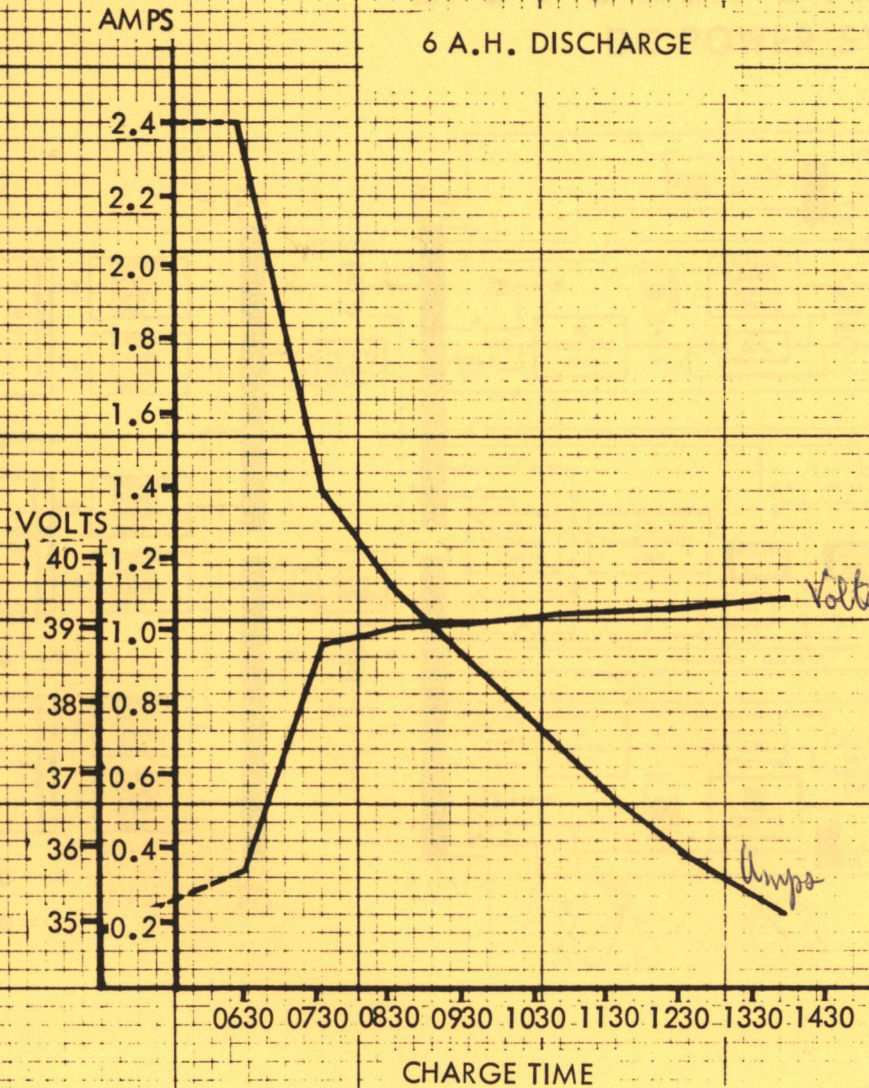
EP-009 A



BATTERY RECHARGE CHARACTERISTICS

6 A.H. DISCHARGE

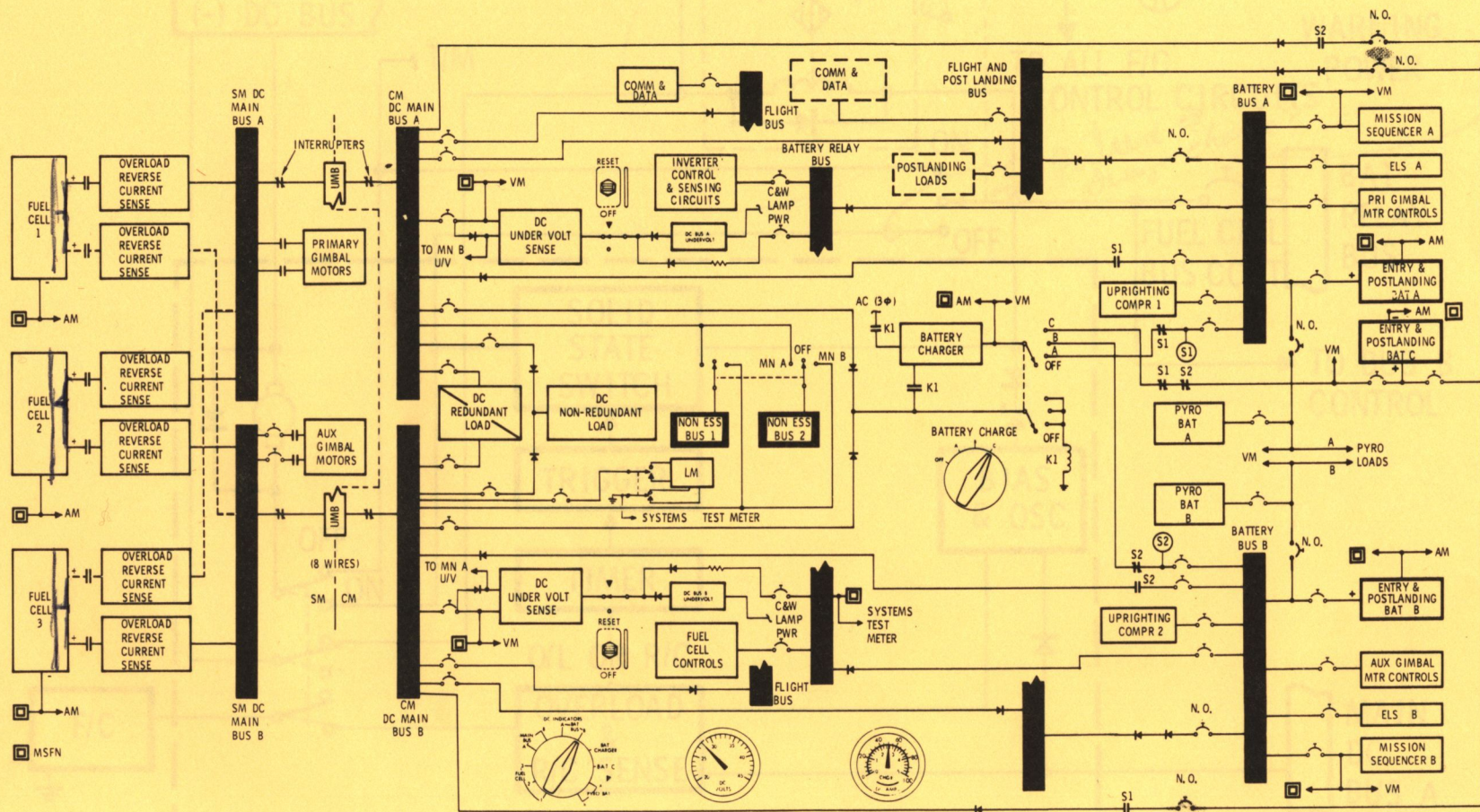
4 A.H. DISCHARGE



EP-2014

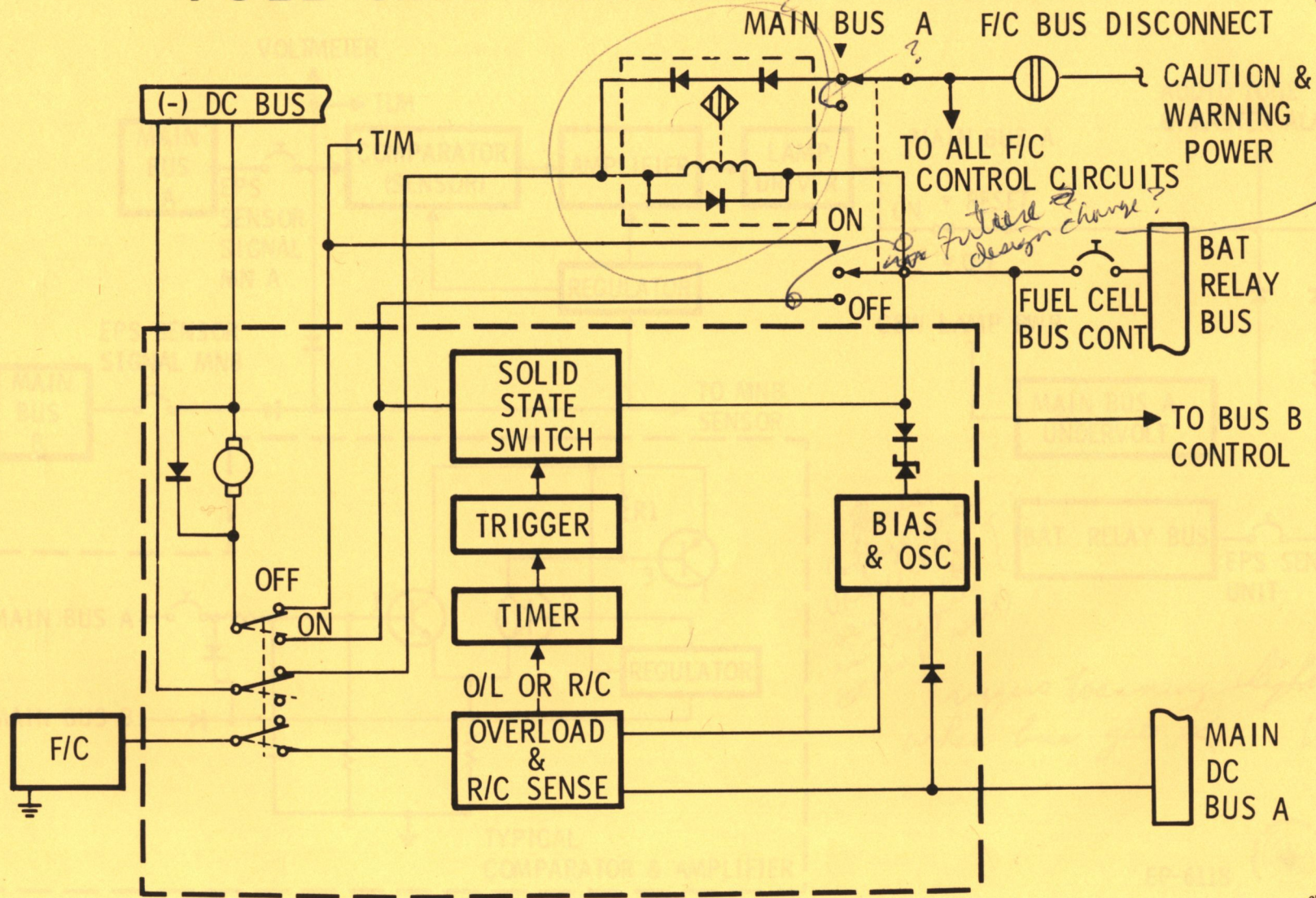
EPS POWER DISTRIBUTION

DC POWER SYSTEM

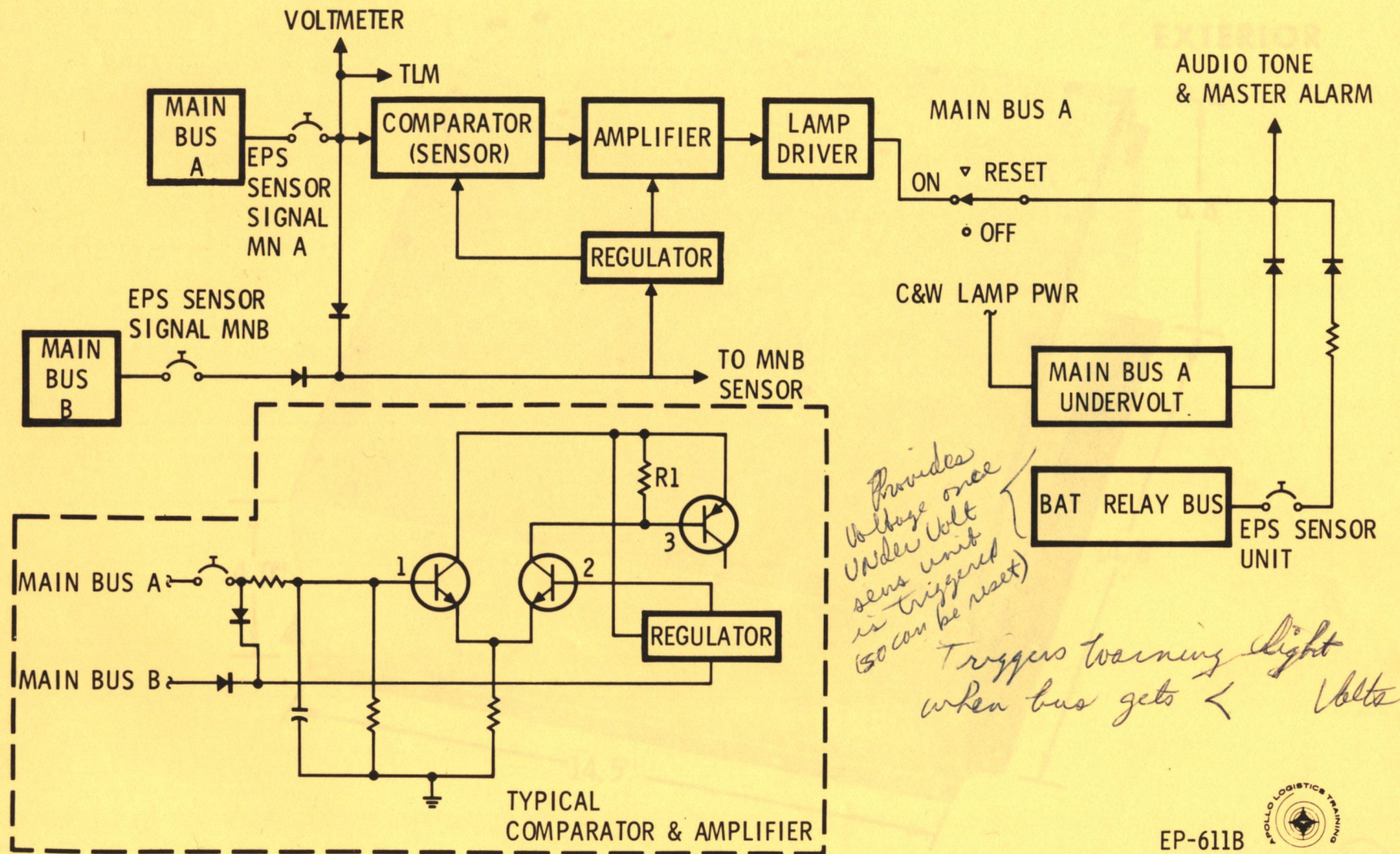


FUEL CELL CONTROL CIRCUIT

can't take 40 volts of charge



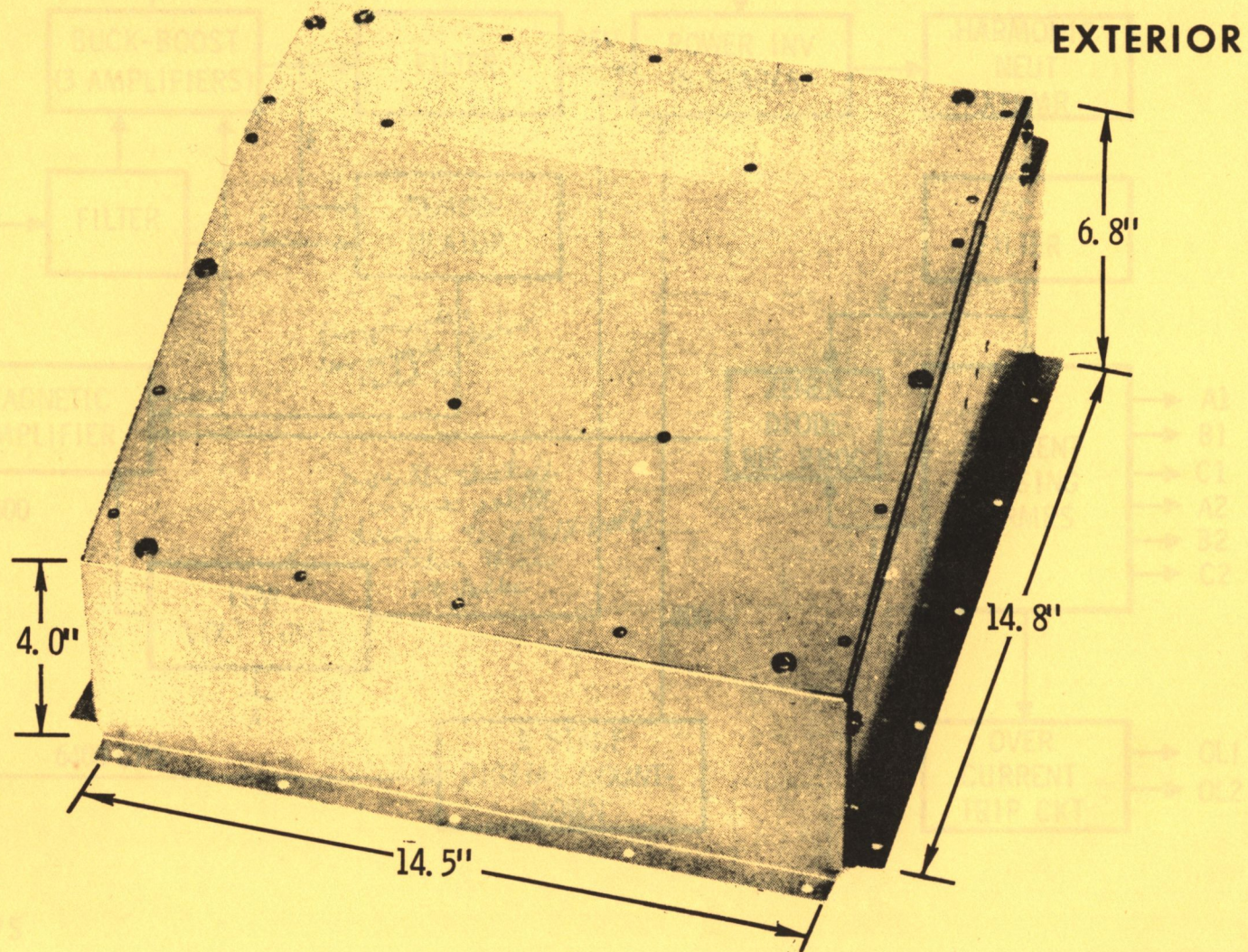
DC UNDER VOLTAGE SENSING



EP-611B



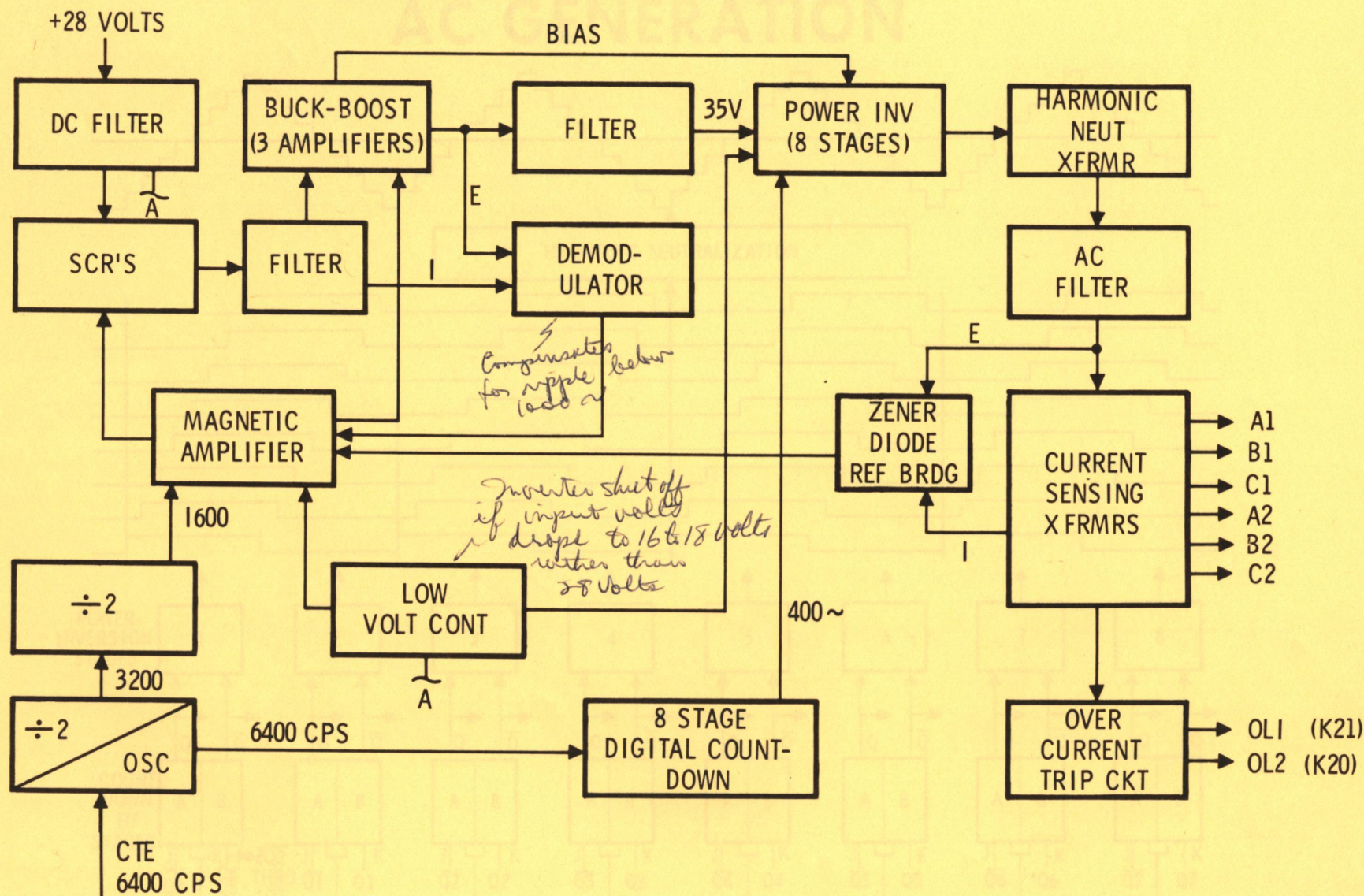
APOLLO STATIC INVERTER



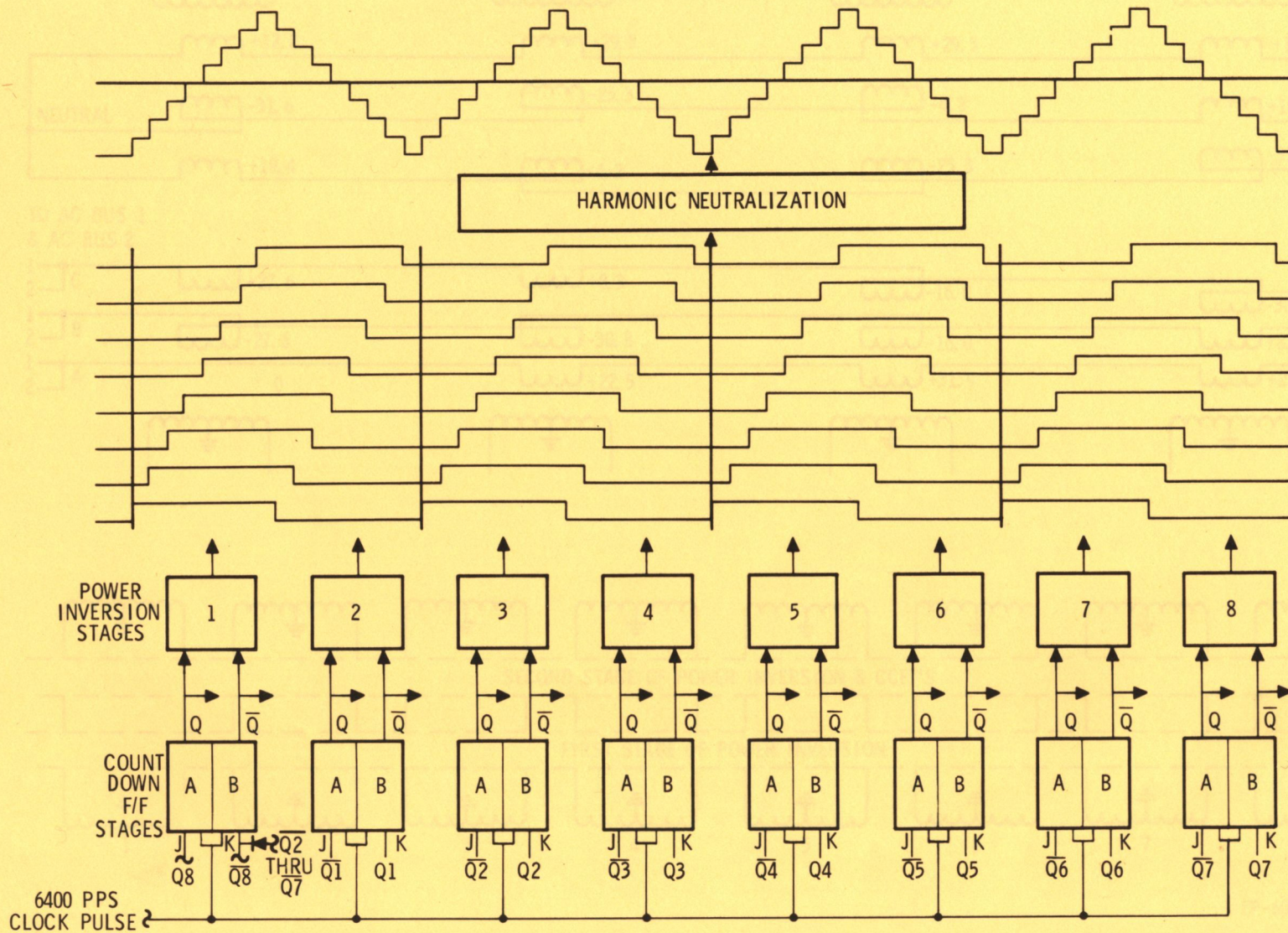
EP-025-1



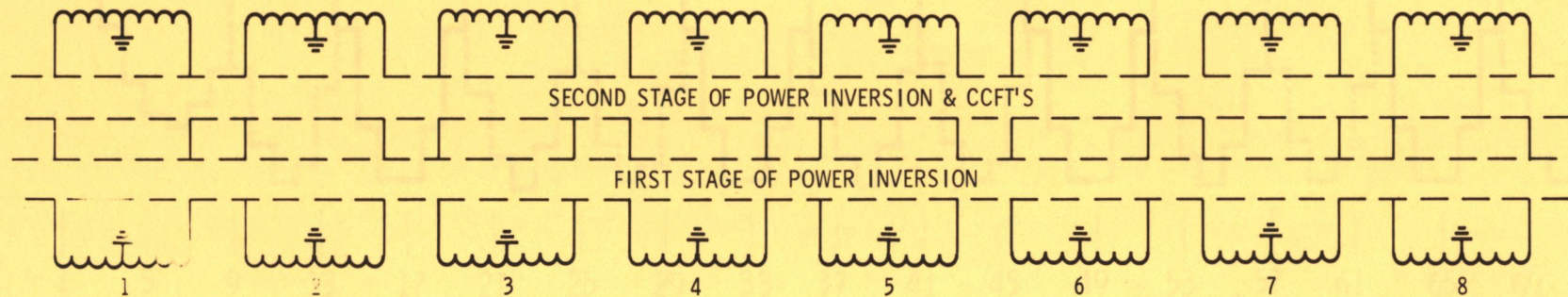
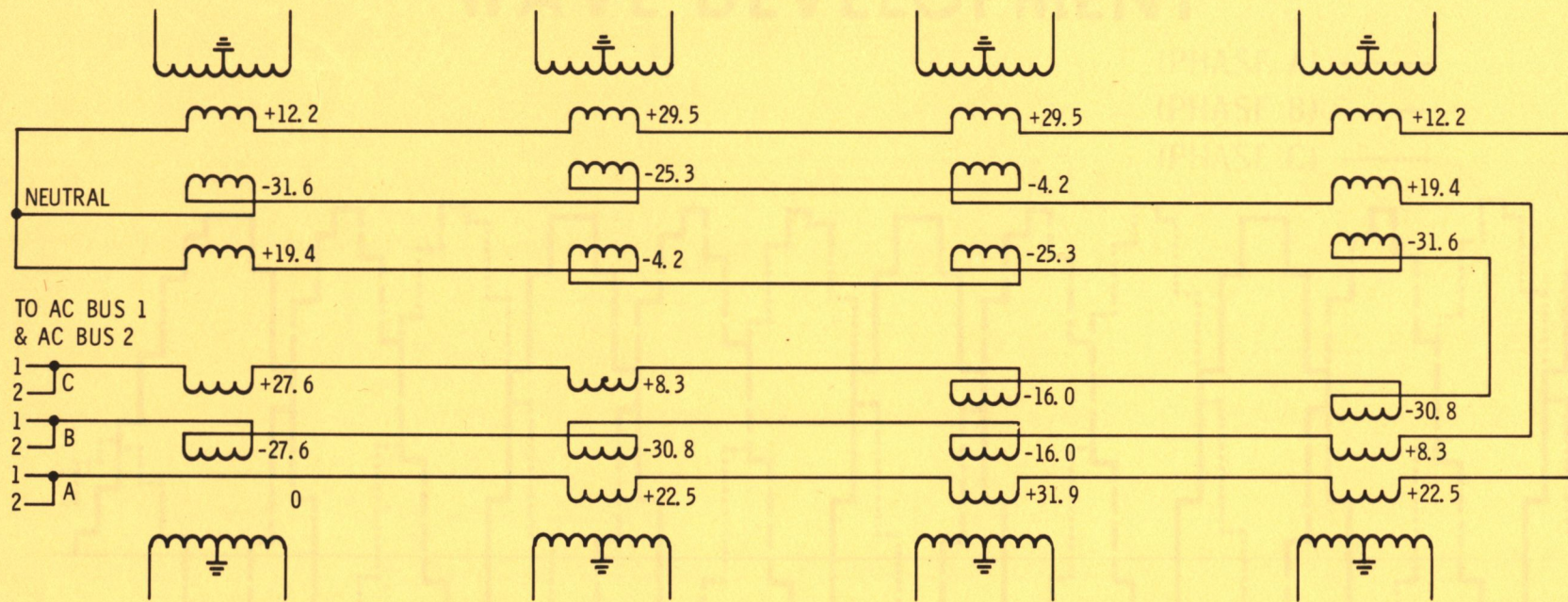
INVERTER BLOCK DIAGRAM



AC GENERATION

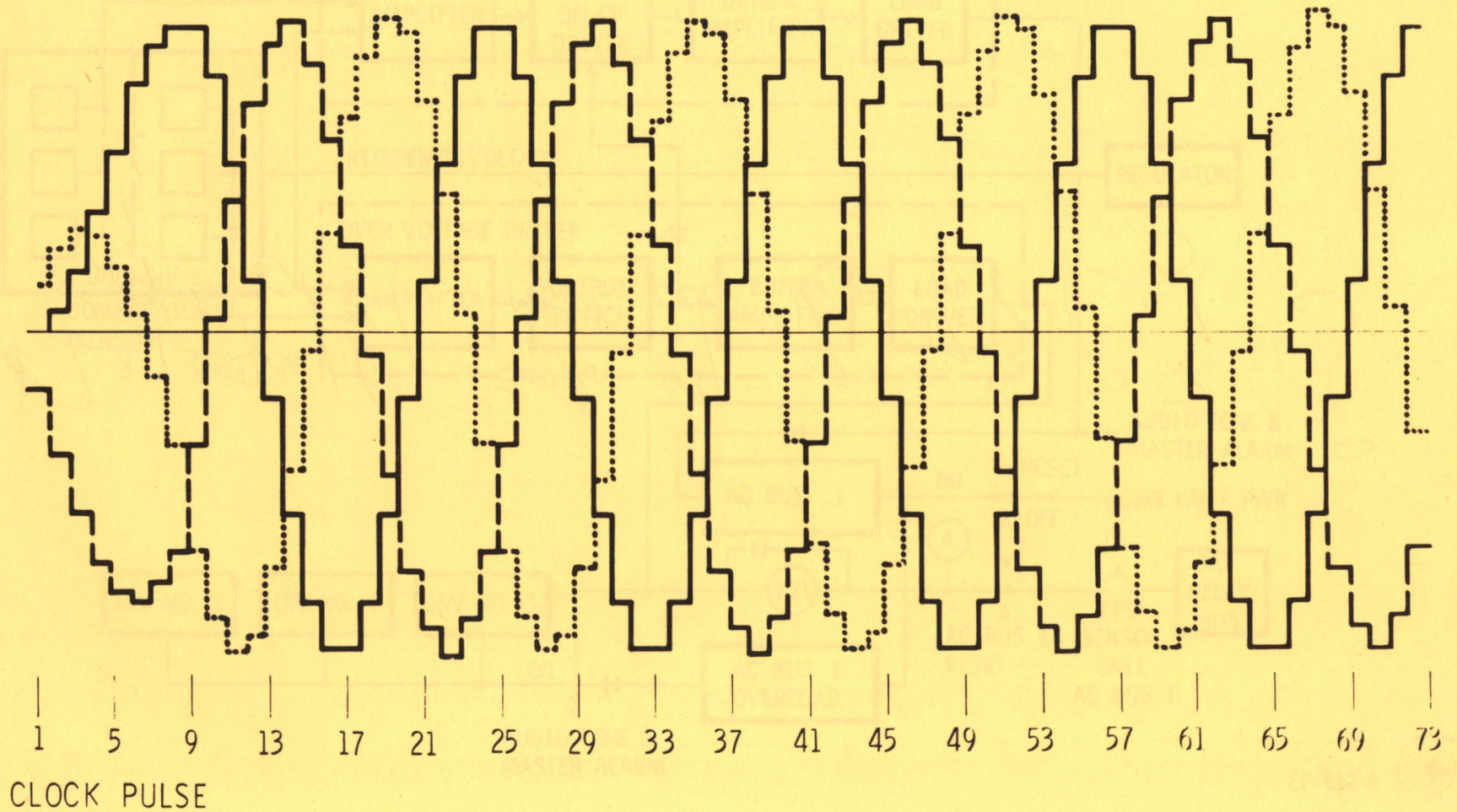


PHASING & HARMONIC NEUTRALIZATION



WAVE DEVELOPMENT

(PHASE A) ———
(PHASE B) - - - -
(PHASE C) ·····



STOCK 5012E

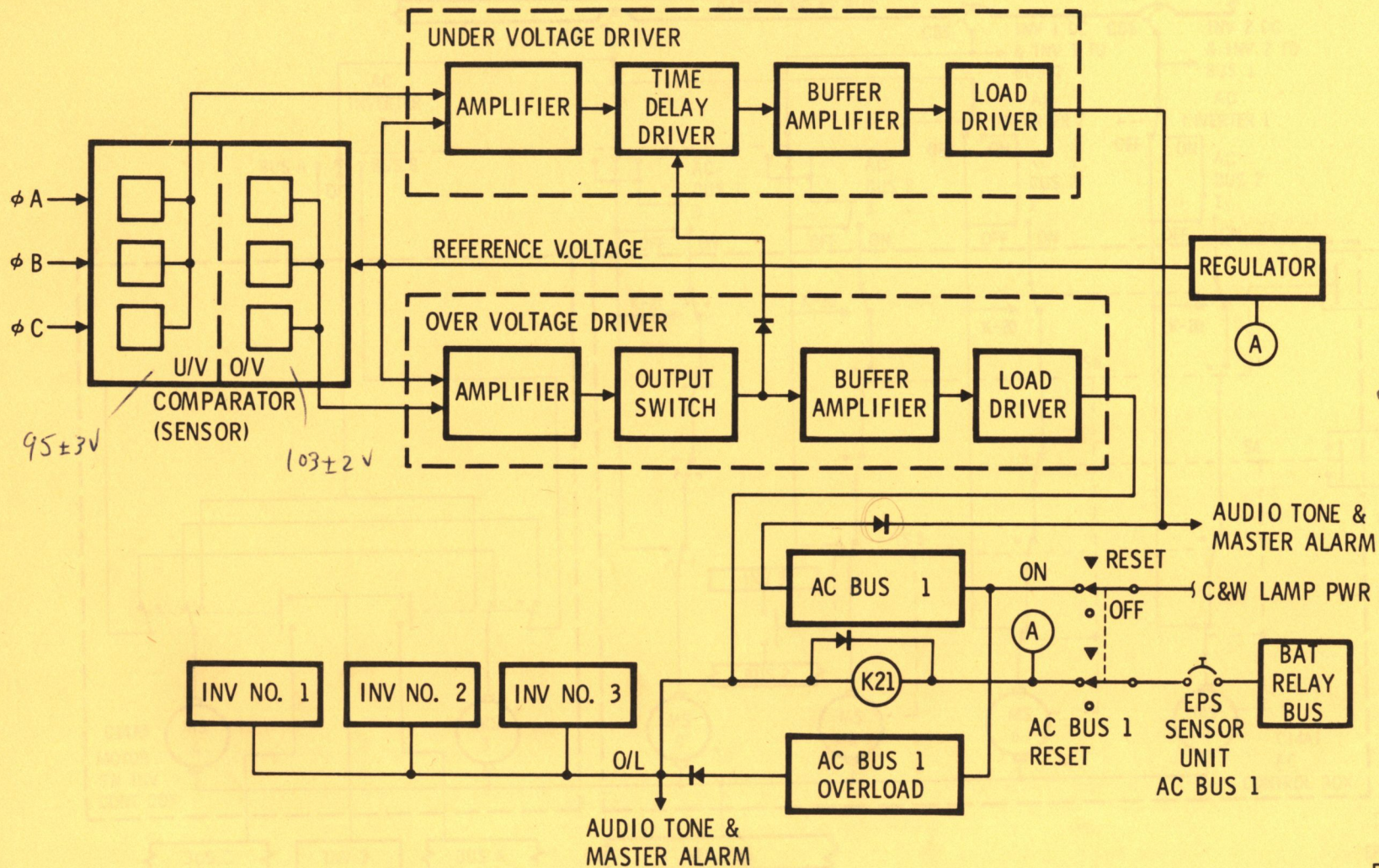
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

Single ϕ 3.7 amps / ϕ 300% 0.2
3 ϕ ~~3.7~~ 1.5 amps / ϕ 150% 0.1
1/2
5

CA 12A119
BA 12A119
CA 12A119

MALE DELEGORMENT

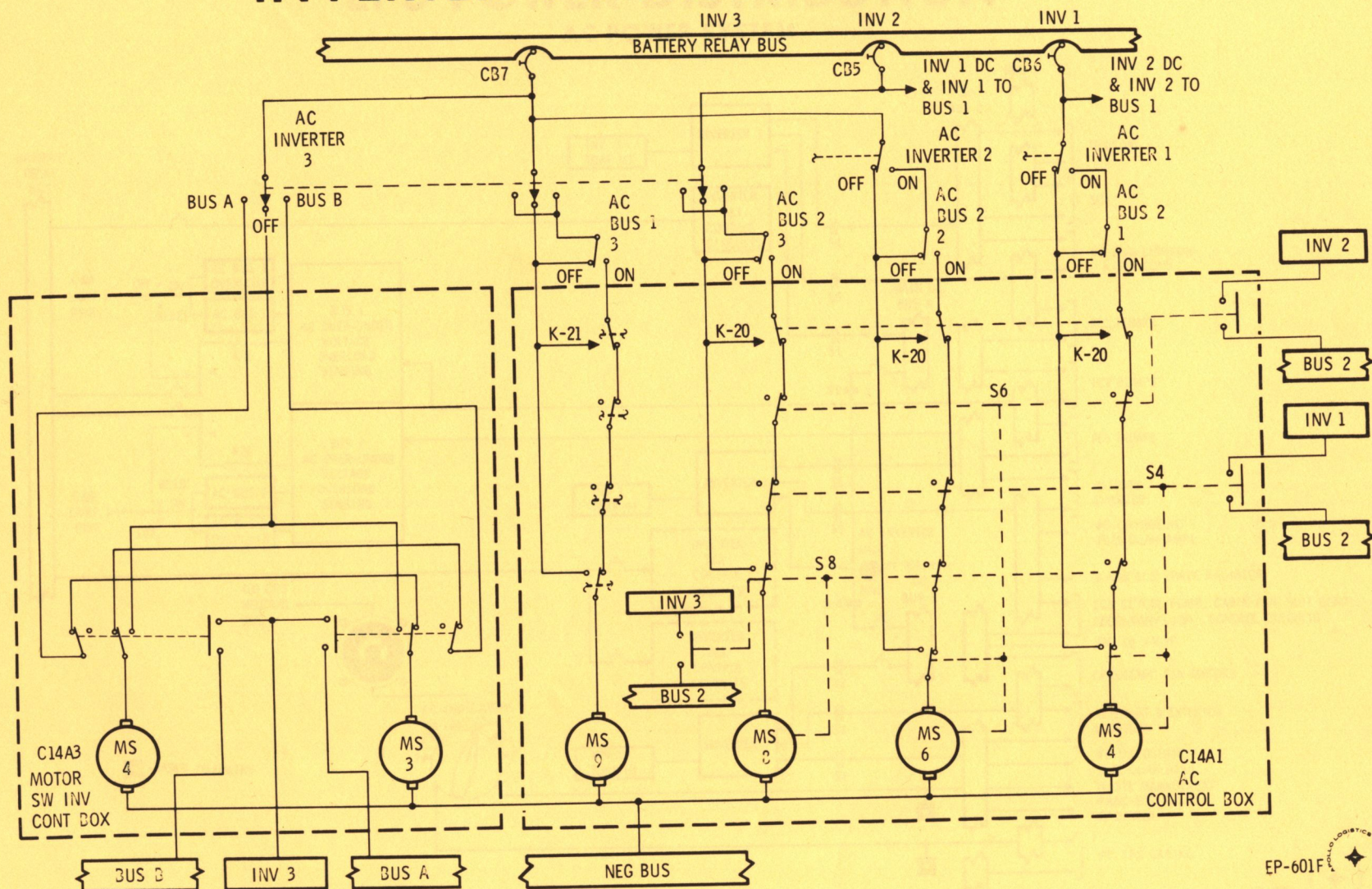
AC SENSING



EP-612 A

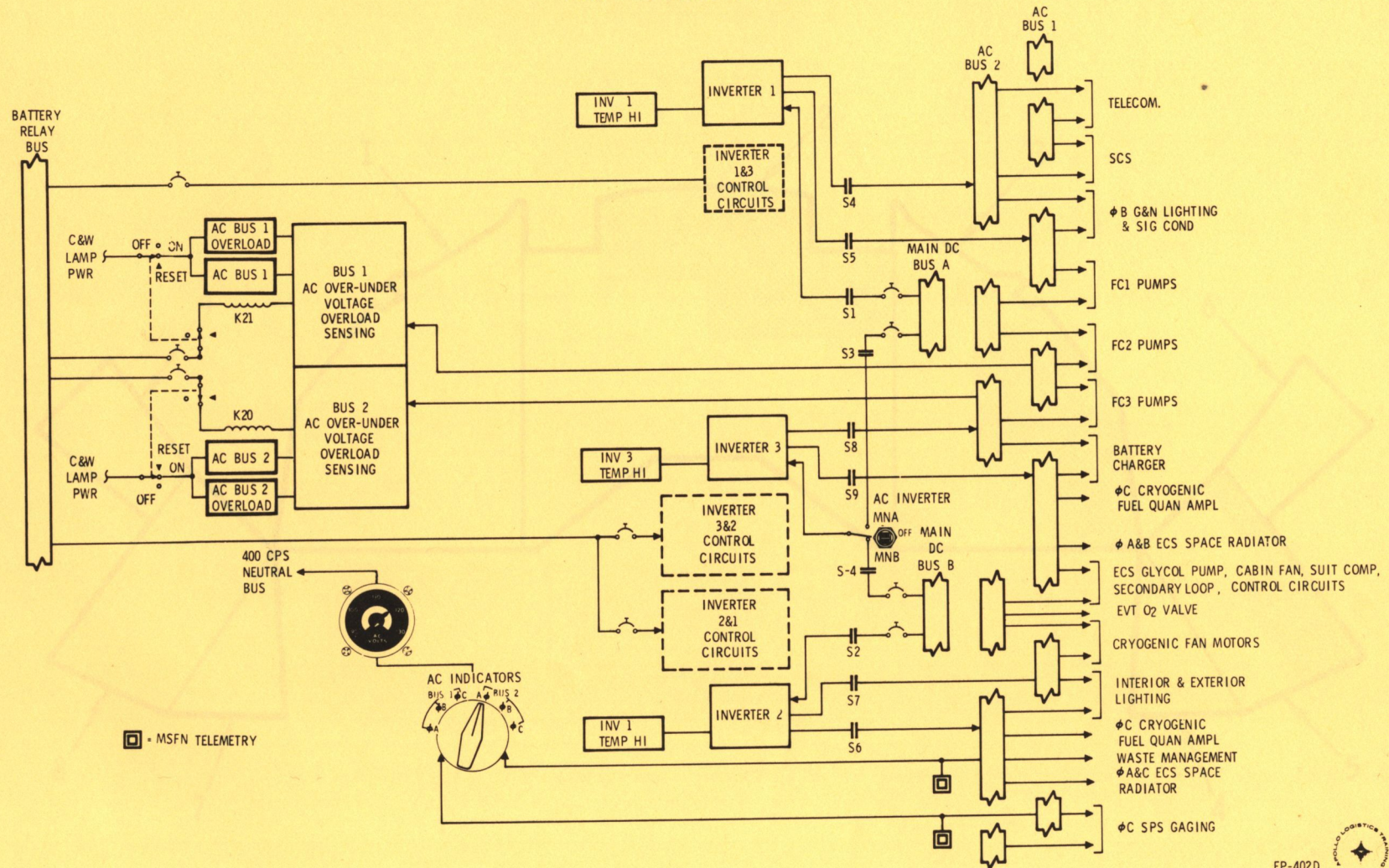


INVERTER CONTROL CIRCUIT



EPS POWER DISTRIBUTION

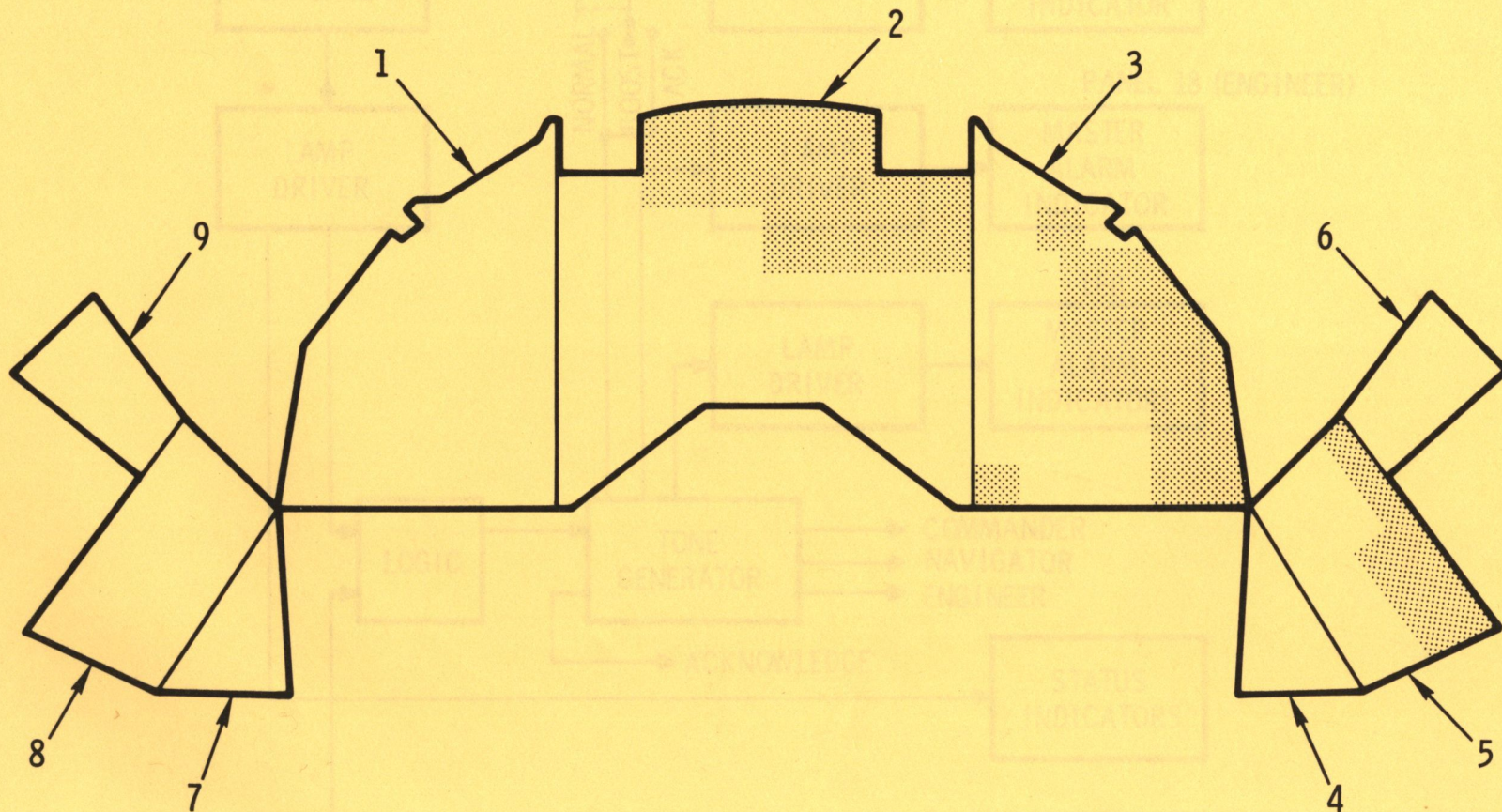
AC POWER SYSTEM



EP-402D



MAIN DISPLAY CONSOLE LOCATOR



CAUTION & WARNING BLOCK DIAGRAM

