

APOLLO TRAINING

ELECTRICAL POWER SUBSYSTEM
BLOCK II CSM

1 AUGUST 1967

FOR TRAINING PURPOSES ONLY



NORTH AMERICAN AVIATION, INC.
SPACE DIVISION

QUESTIONS RELATIVE TO THE CONTENTS OF THIS



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QUESTIONS RELATIVE TO THE CONTENTS OF THIS
DOCUMENT SHOULD BE DIRECTED TO:

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ELECTRICAL POWER SUBSYSTEM

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ELECTRICAL POWER SUBSYSTEM

A. POWER GENERATION

1. DC SYSTEM

(a) FUEL CELL POWER PLANTS (3)

(b) CRYOGENIC STORAGE SYSTEM

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

2. AC SYSTEM

(a) SOLID STATE INVERTERS (3)

(b) INVERTER CONTROL CIRCUITS

(1) AC BUS CONNECTION

(2) OVERLOAD SENSING

(3) OVER/UNDER VOLTAGE SENSING

EP-045



EP-044

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

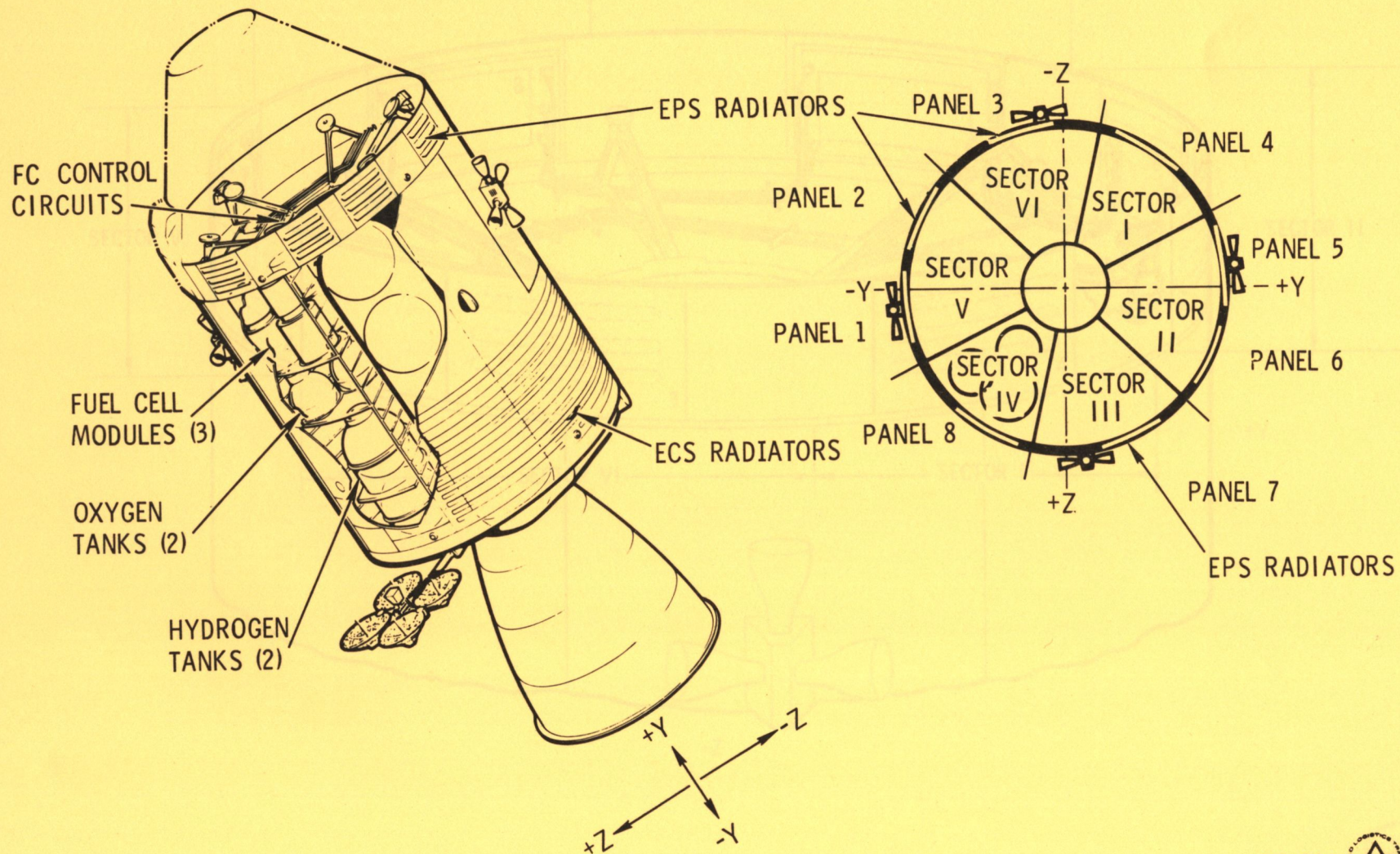
- (a) BUS SYSTEM
- (b) INVERTER CONTROL CIRCUITS
 - (1) AC BUS CONNECTION
 - (2) OVERLOAD SENSING
 - (3) OVER/UNDER VOLTAGE SENSING

ELECTRICAL POWER SUBSYSTEM

C. SPECIAL CIRCUITS

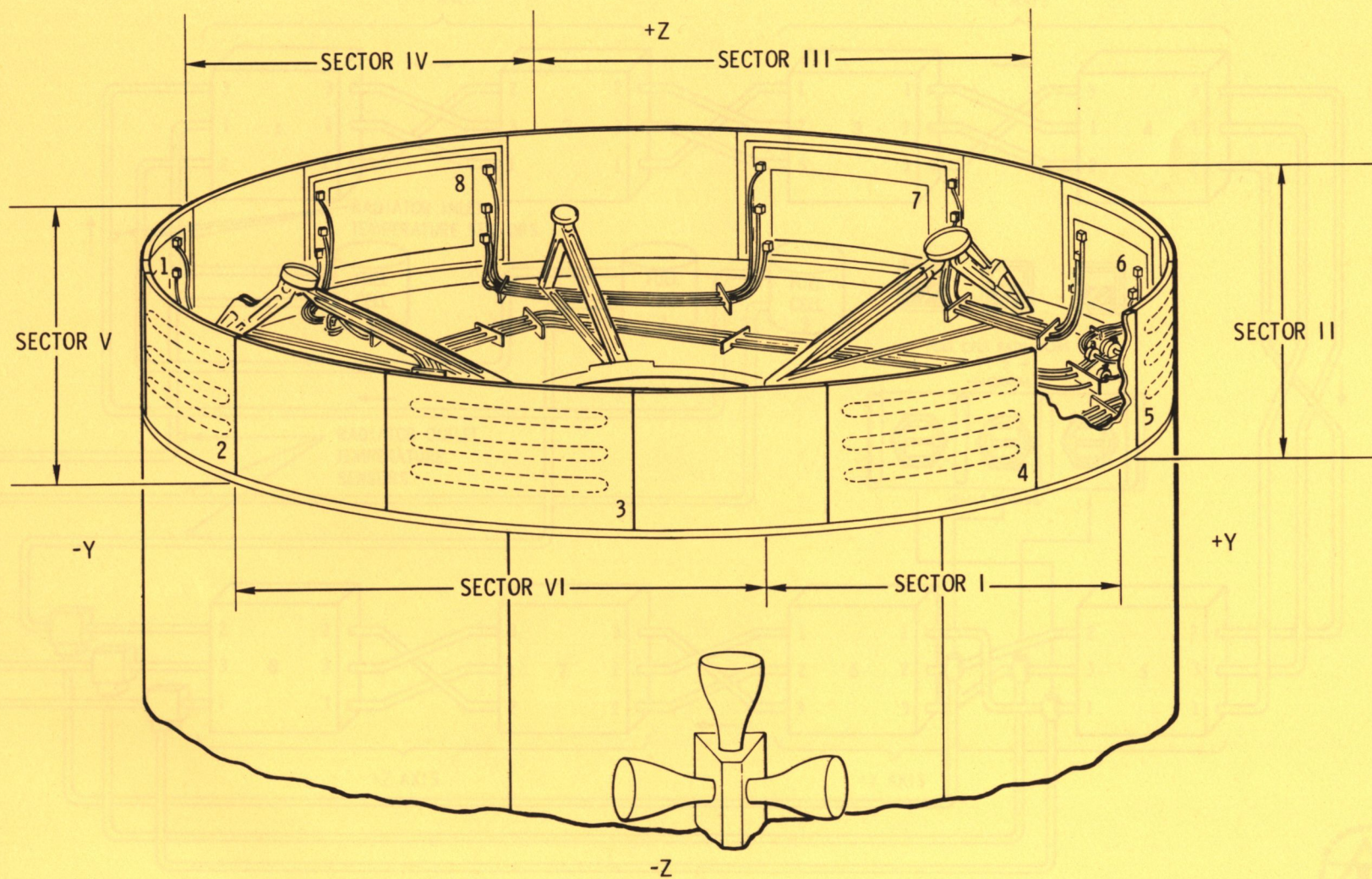
1. BATTERY CHARGER (1)
2. PYROTECHNIC BATTERIES (2)

ELECTRICAL POWER SYSTEM



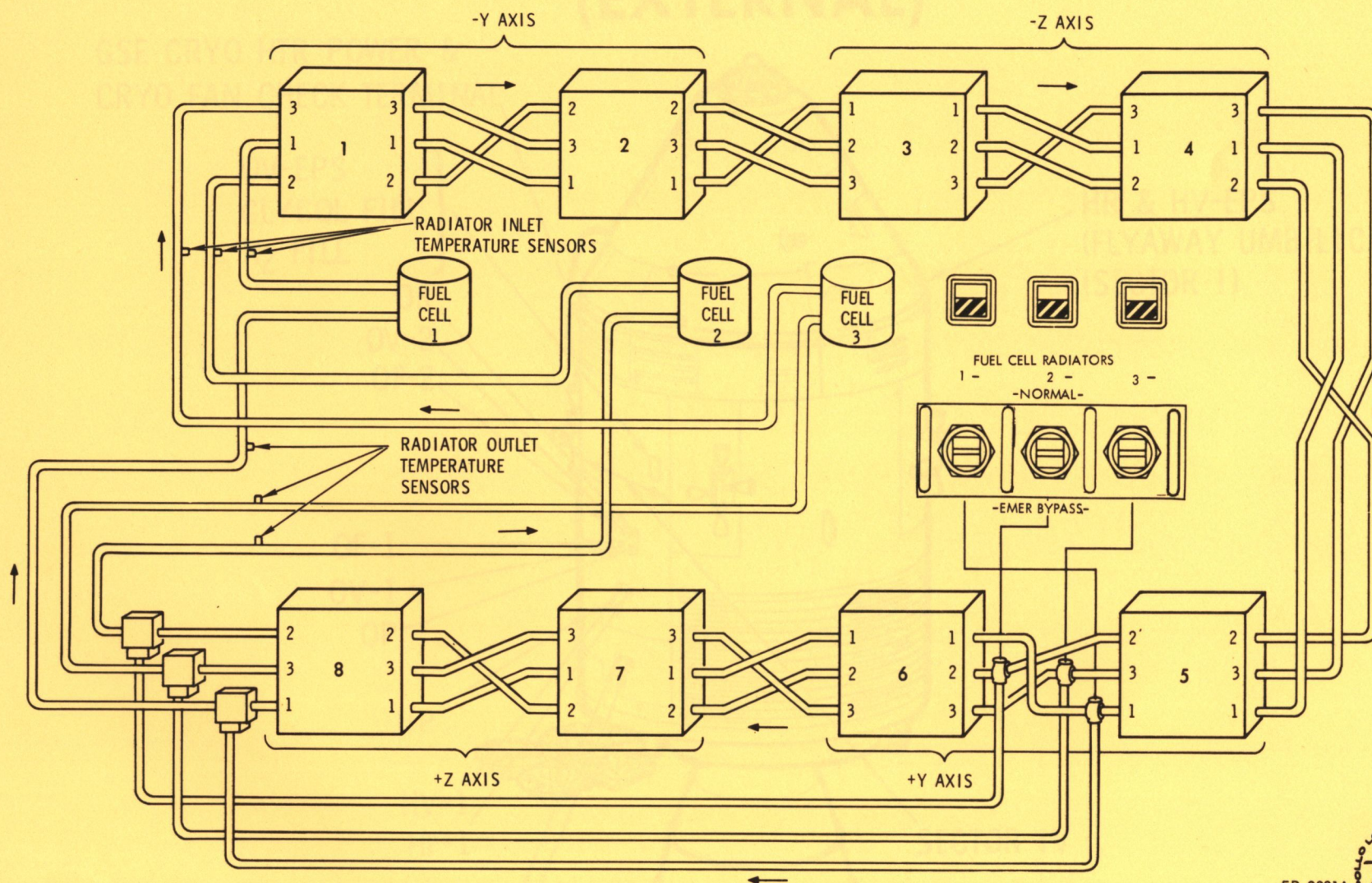
EP-046

EPS RADIATOR LOCATION BLOCK II



EPS RADIATOR CONTROL

BLOCK II



SM CRYOGENIC SYSTEM INTERFACE (EXTERNAL)

GSE CRYO HTR POWER &
CRYO FAN CHECK TERMINAL

OV-EPS
GLYCOL FILL
N₂ FILL

OR

OV-2
OF-2

OF-1

OV-1

OP

HP

HV-1

HF-1

HV-2

HF-2

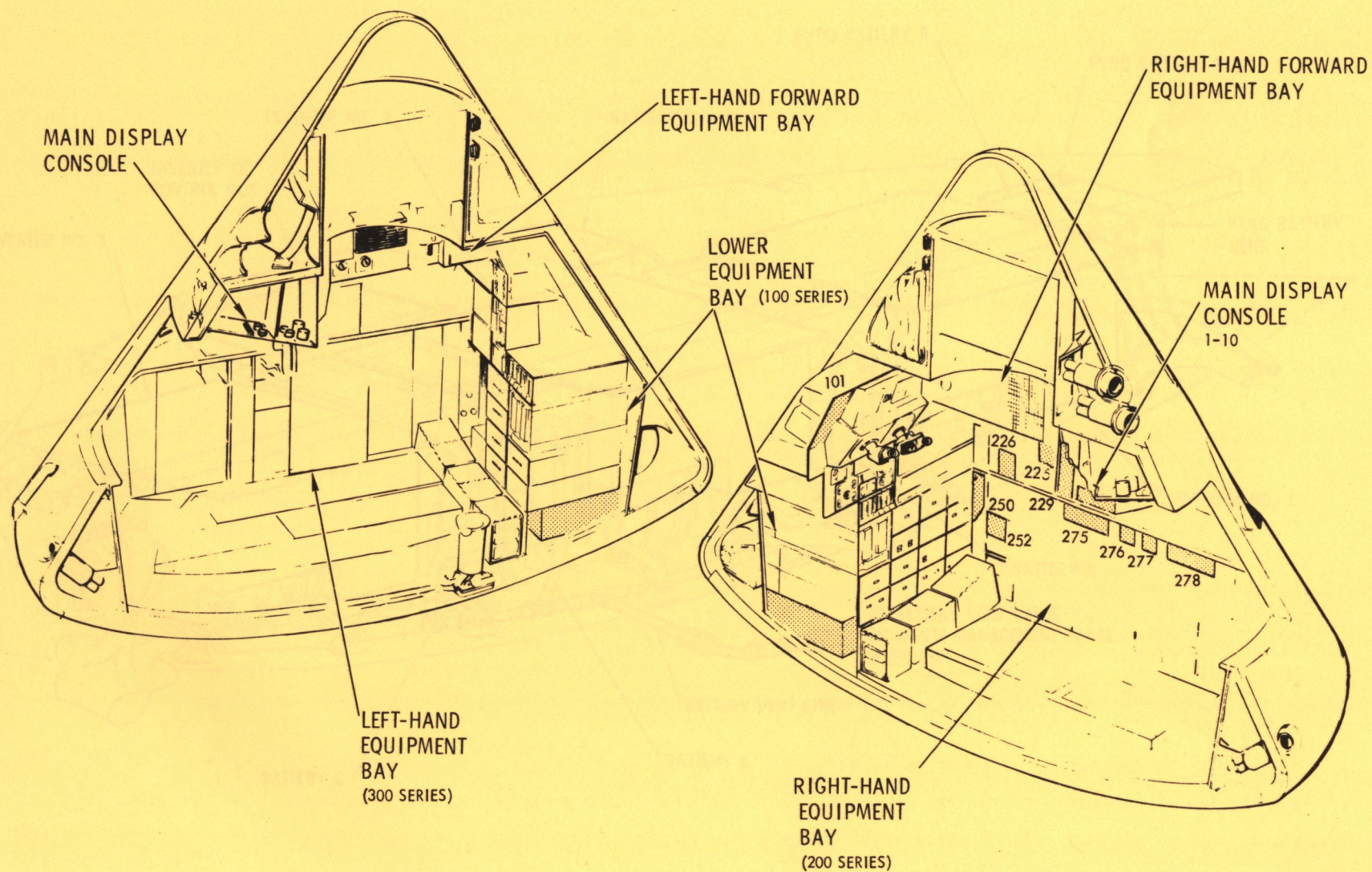
HR & HV-EPS
(FLYAWAY UMBILICAL)
(SECTOR I)

SECTOR IV

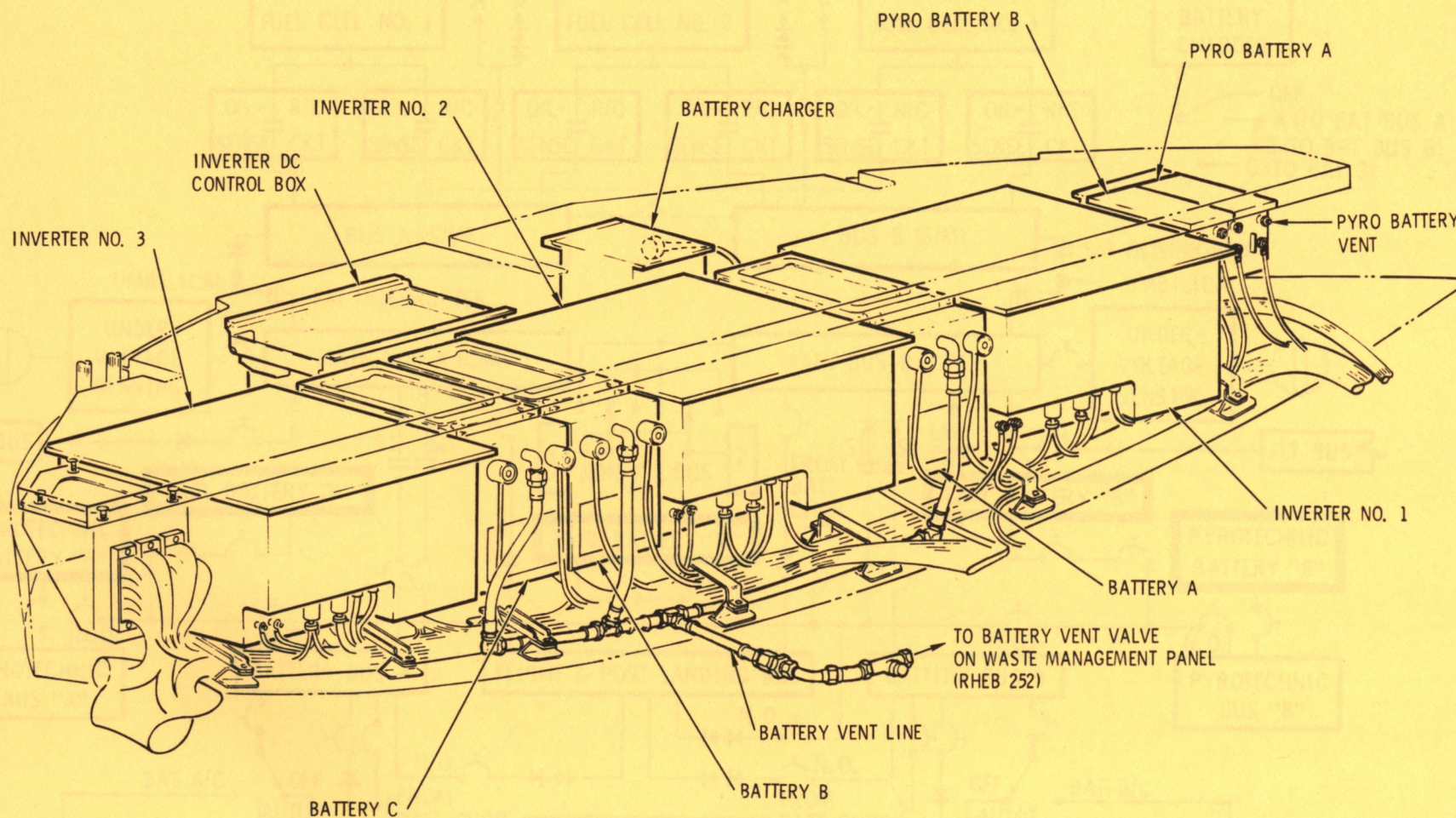
EP-2007A



CM EQUIPMENT BAYS & CONTROL PANEL IDENTIFICATION

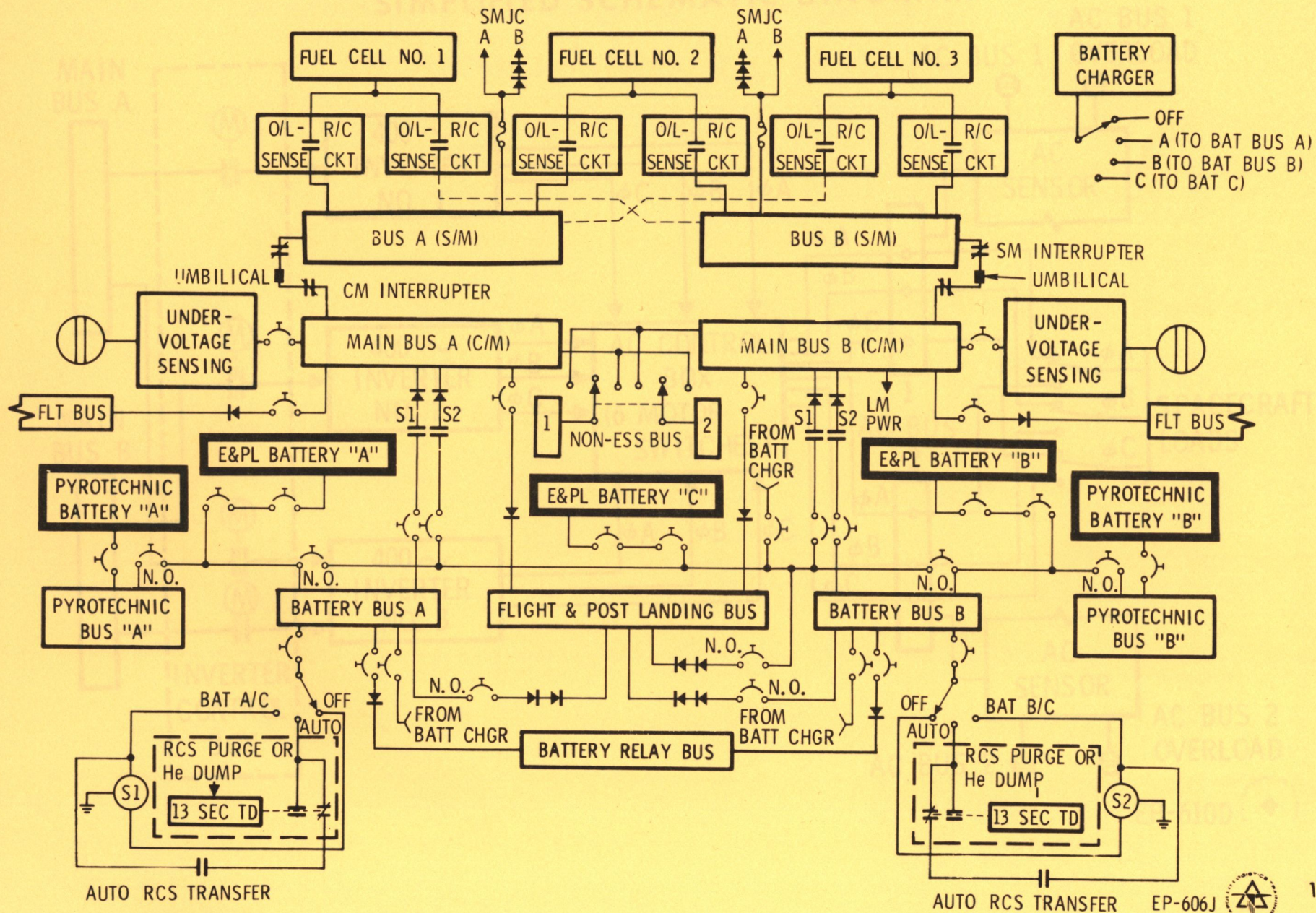


EPS COMPONENTS LOWER EQUIPMENT BAY (BLOCK II)



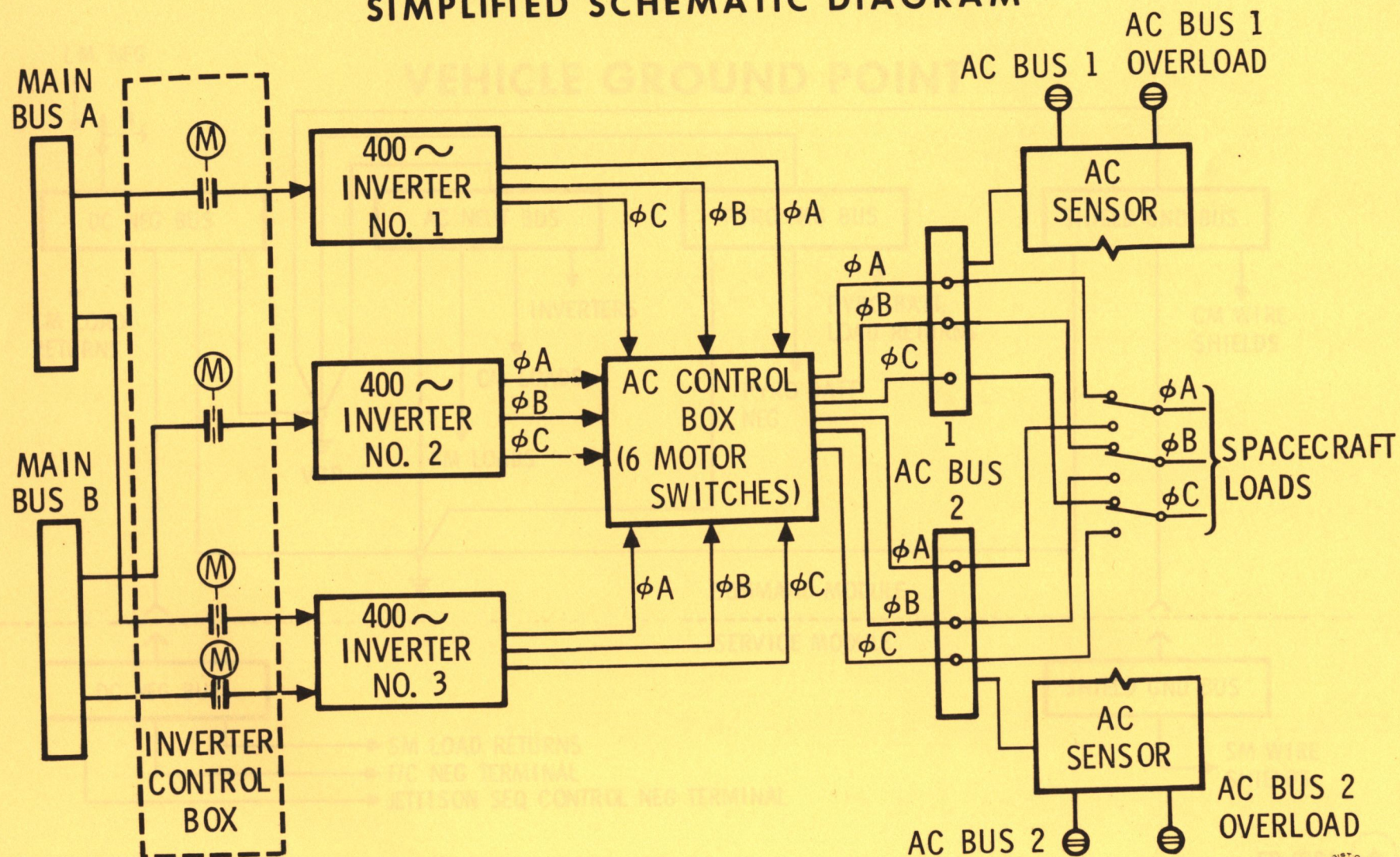
DC POWER DISTRIBUTION

SIMPLIFIED SCHEMATIC DIAGRAM



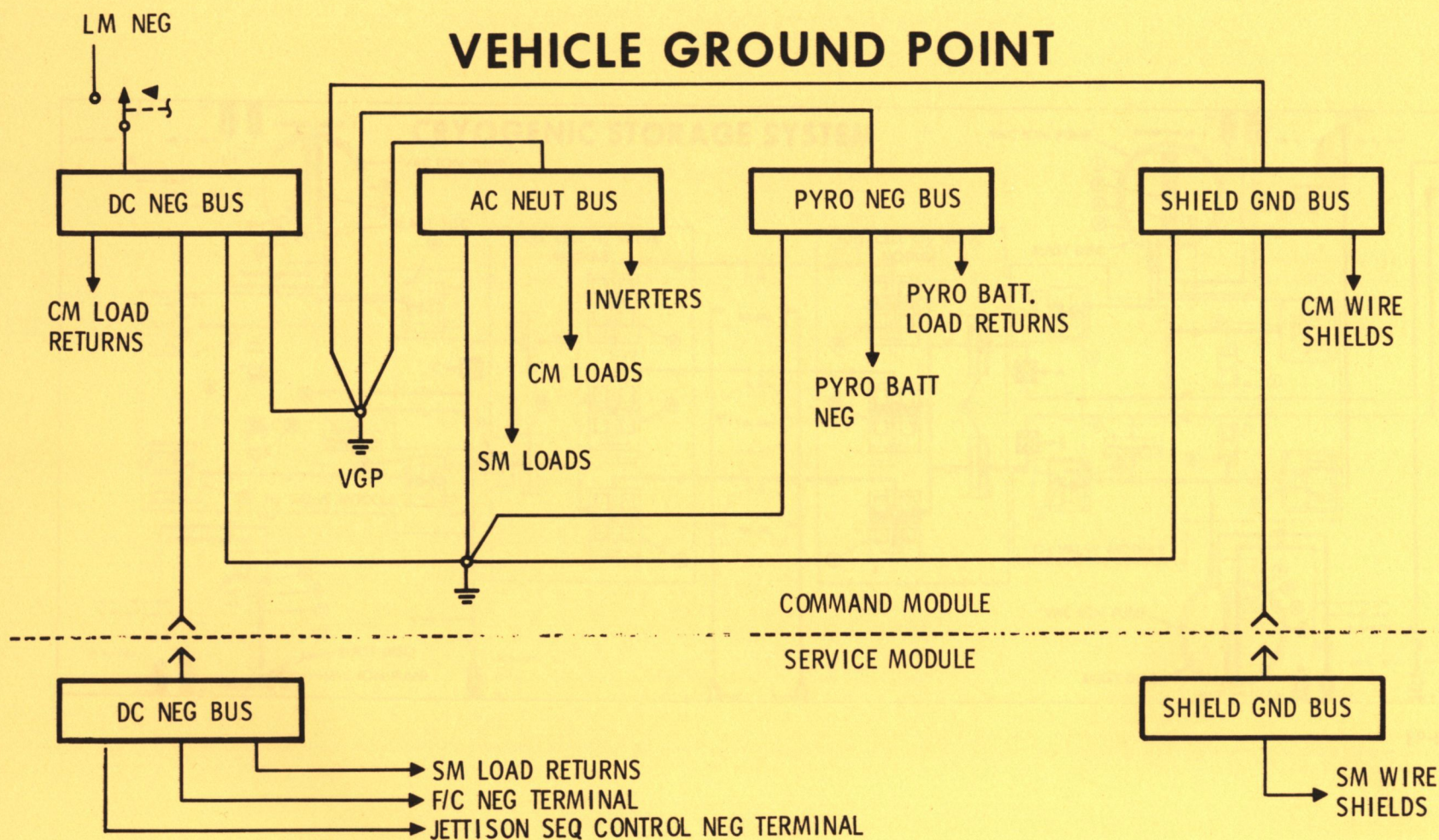
AC POWER DISTRIBUTION

SIMPLIFIED SCHEMATIC DIAGRAM

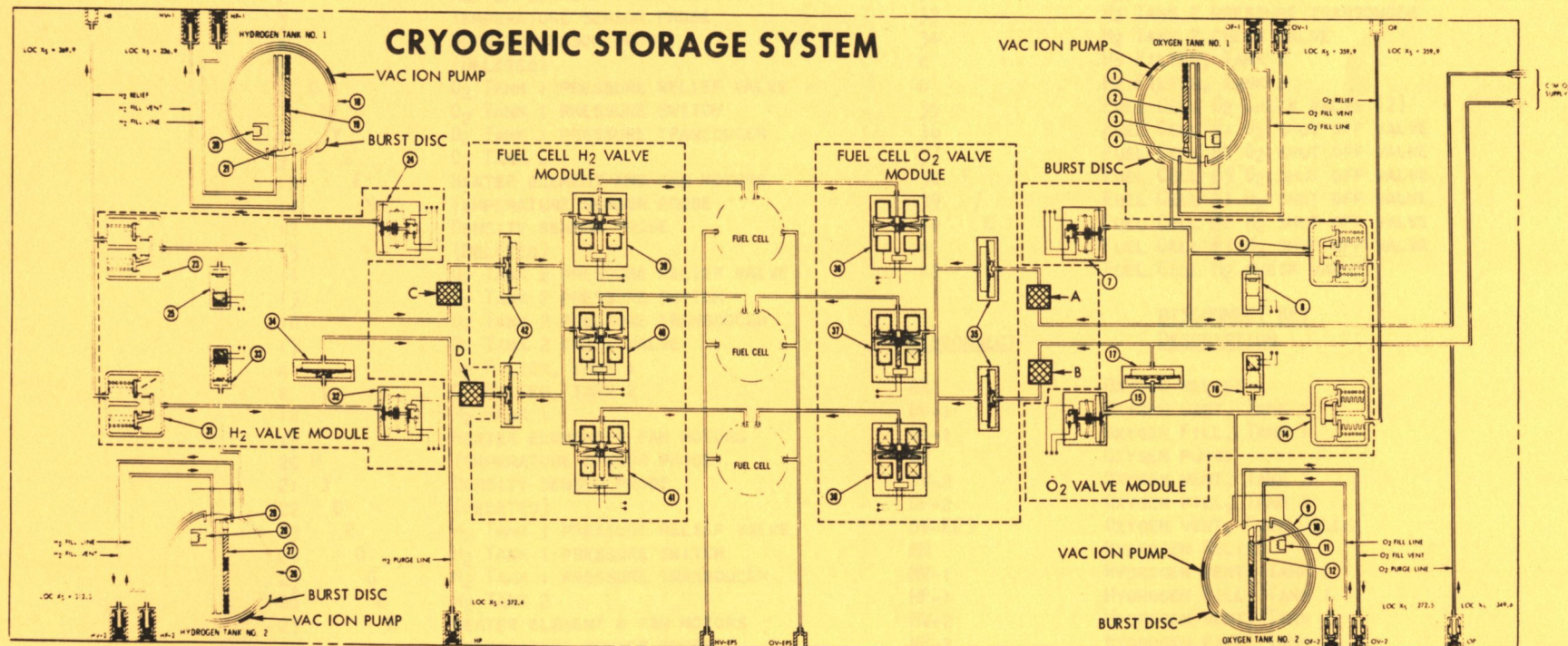


EP-610D





EP-038A (◆)



2-10
EP-030C

<u>ITEM NO.</u>	<u>DESCRIPTION</u>
1	O ₂ TANK 1
2	HEATER ELEMENT & FAN MOTORS
3	TEMPERATURE SENSOR PROBE
4	DENSITY SENSOR PROBE
5	(DELETED)
6 O	O ₂ TANK 1 PRESSURE RELIEF VALVE
7 X	O ₂ TANK 1 PRESSURE SWITCH
8 Y	O ₂ TANK 1 PRESSURE TRANSDUCER
9 G	O ₂ TANK 2
10 E	HEATER ELEMENT AND FAN MOTORS
11 N	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 H	TEMPERATURE SENSOR PROBE
21 Y	DENSITY SENSOR PROBE
22 D	(DELETED)
23 R	H ₂ TANK 1 PRESSURE RELIEF VALVE
24 O	H ₂ TANK 1 PRESSURE SWITCH
25 G	H ₂ TANK 1 PRESSURE TRANSDUCER
26 E	H ₂ TANK 2
27 N	HEATER ELEMENT & FAN MOTORS
28	TEMPERATURE SENSOR PROBE
29	DENSITY SENSOR PROBE
30	(DELETED)

TABLE 2-2

<u>ITEM NO.</u>	<u>DESCRIPTION</u>
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 F	FUEL CELL #3 O ₂ SHUT OFF VALVE
39 /	FUEL CELL #1 H ₂ SHUT OFF VALVE
40 C	FUEL CELL #2 H ₂ SHUT OFF VALVE
41	FUEL CELL #3 H ₂ SHUT OFF VALVE
42	FUEL CELL H ₂ CHECK VALVE

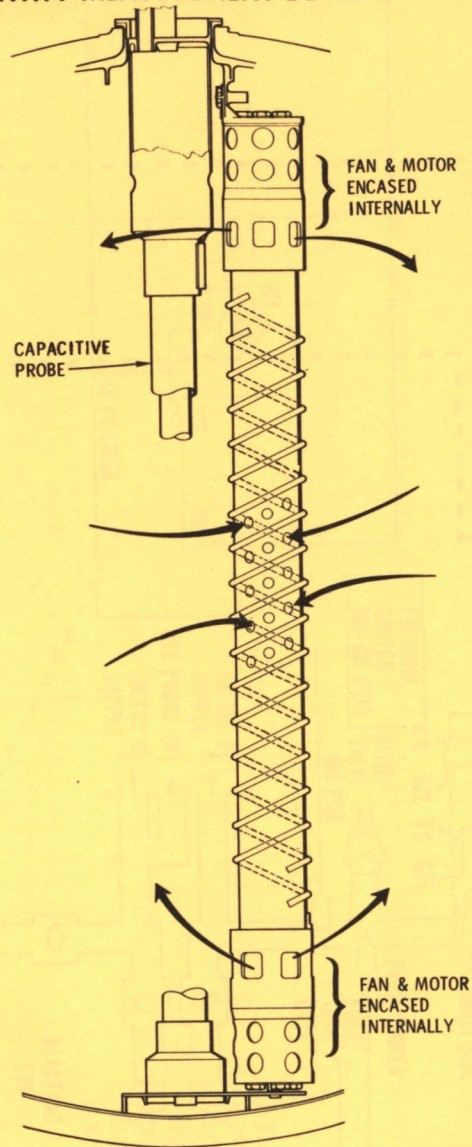
DISCONNECT

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 PRESSURIZATION & QUANTITY MEASUREMENT DEVICES

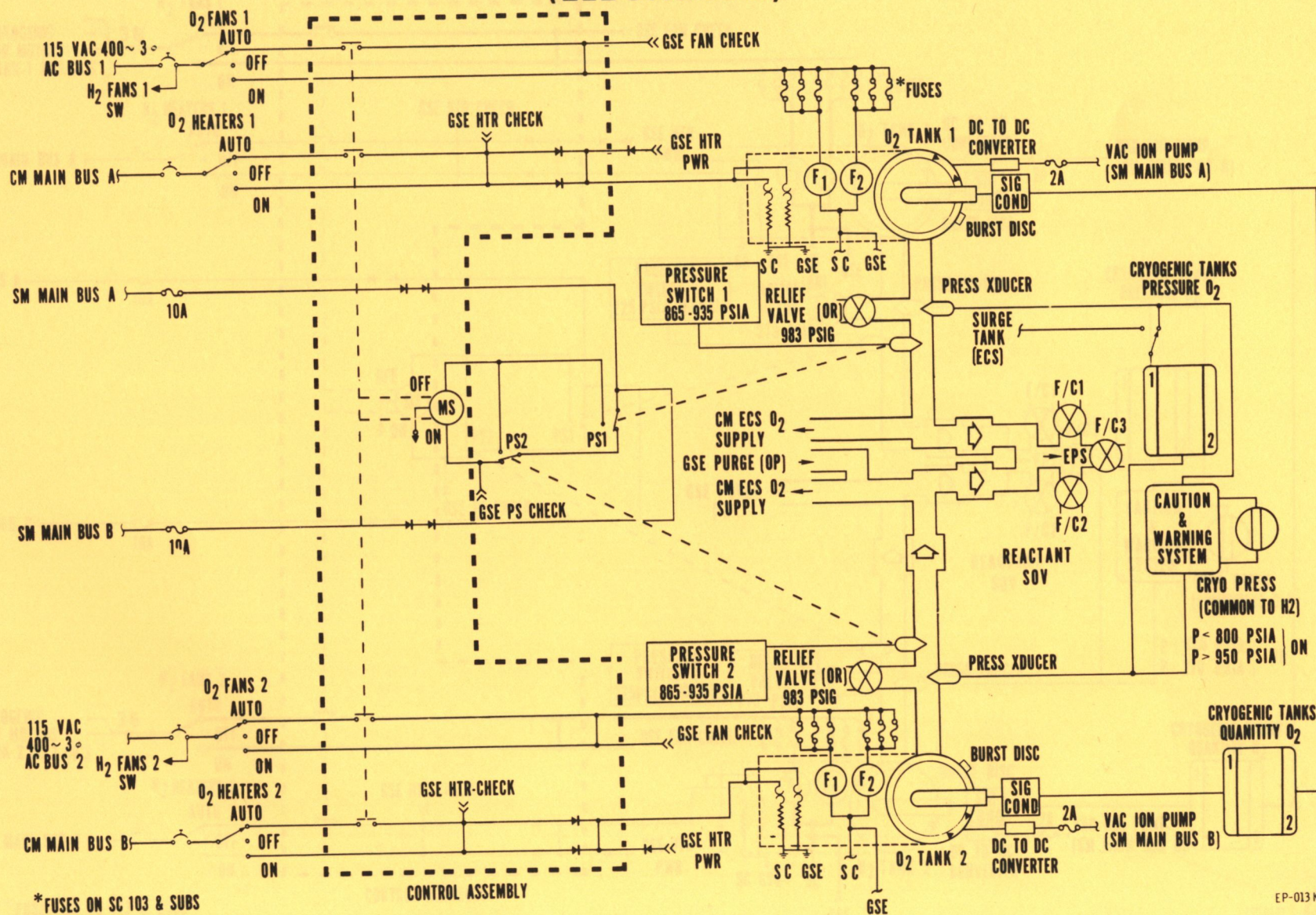


EP-036B

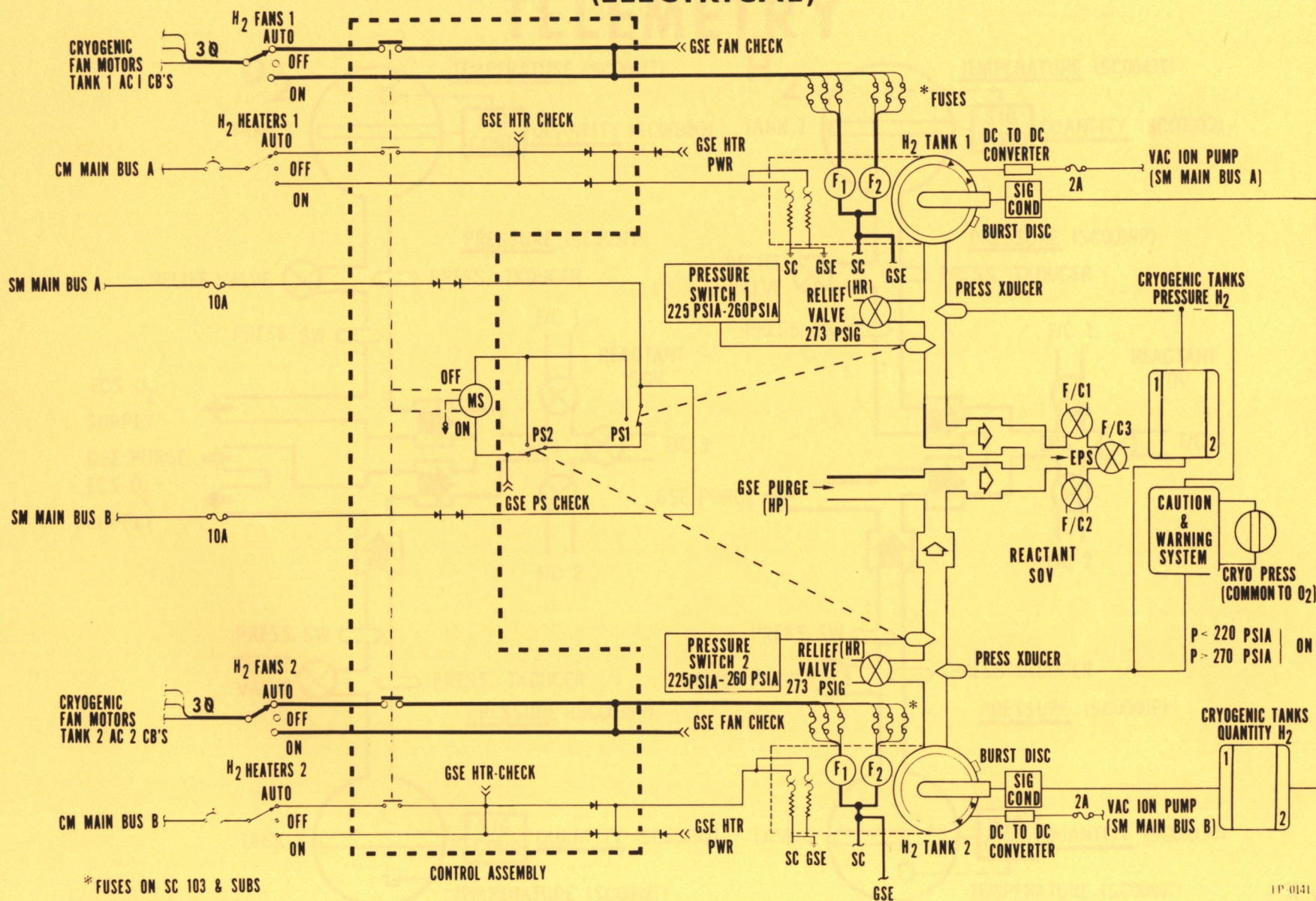


OXYGEN STORAGE SYSTEM
(TECHNICAL)

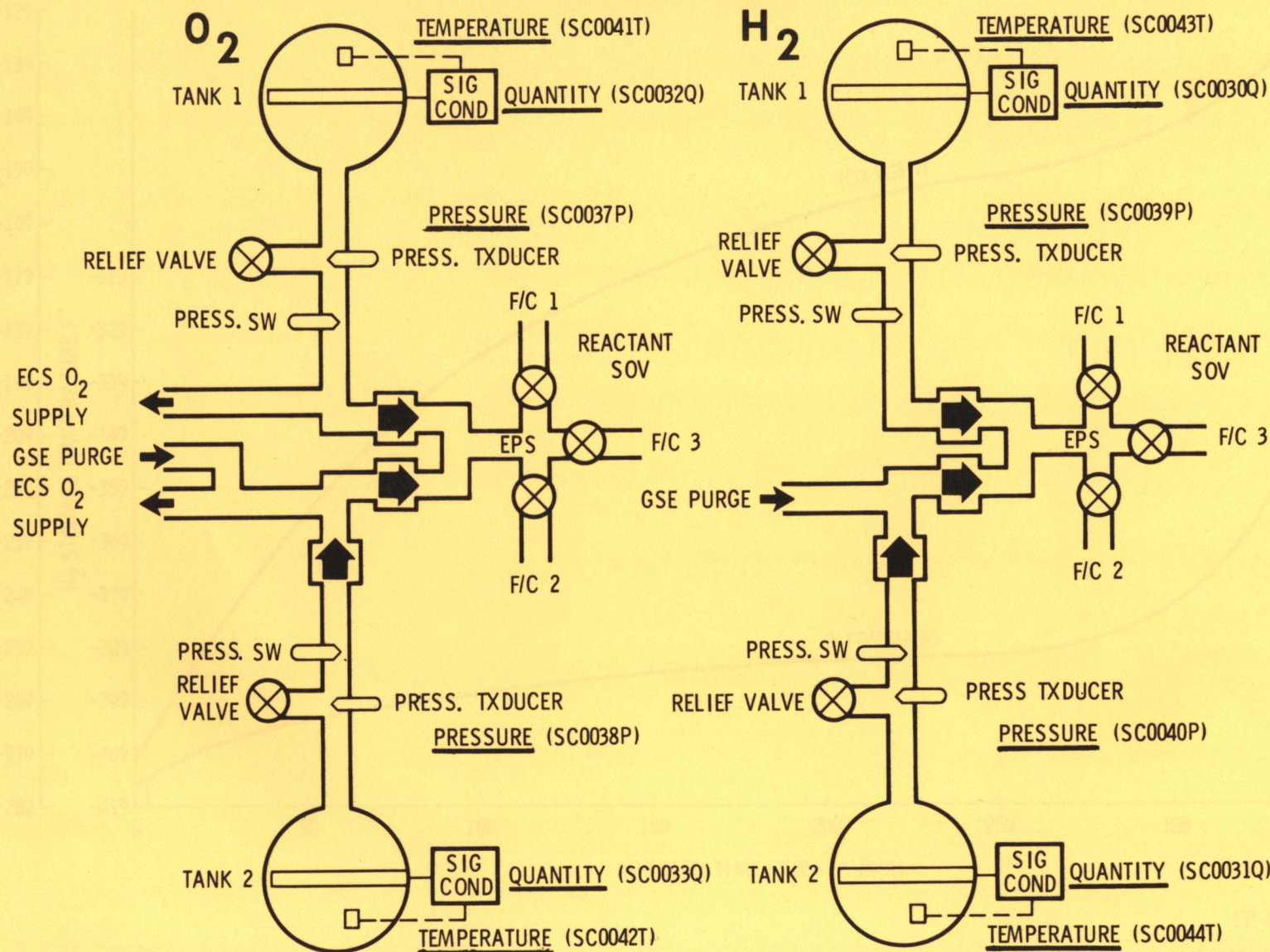
OXYGEN STORAGE SYSTEM (ELECTRICAL)



HYDROGEN STORAGE SYSTEM (ELECTRICAL)

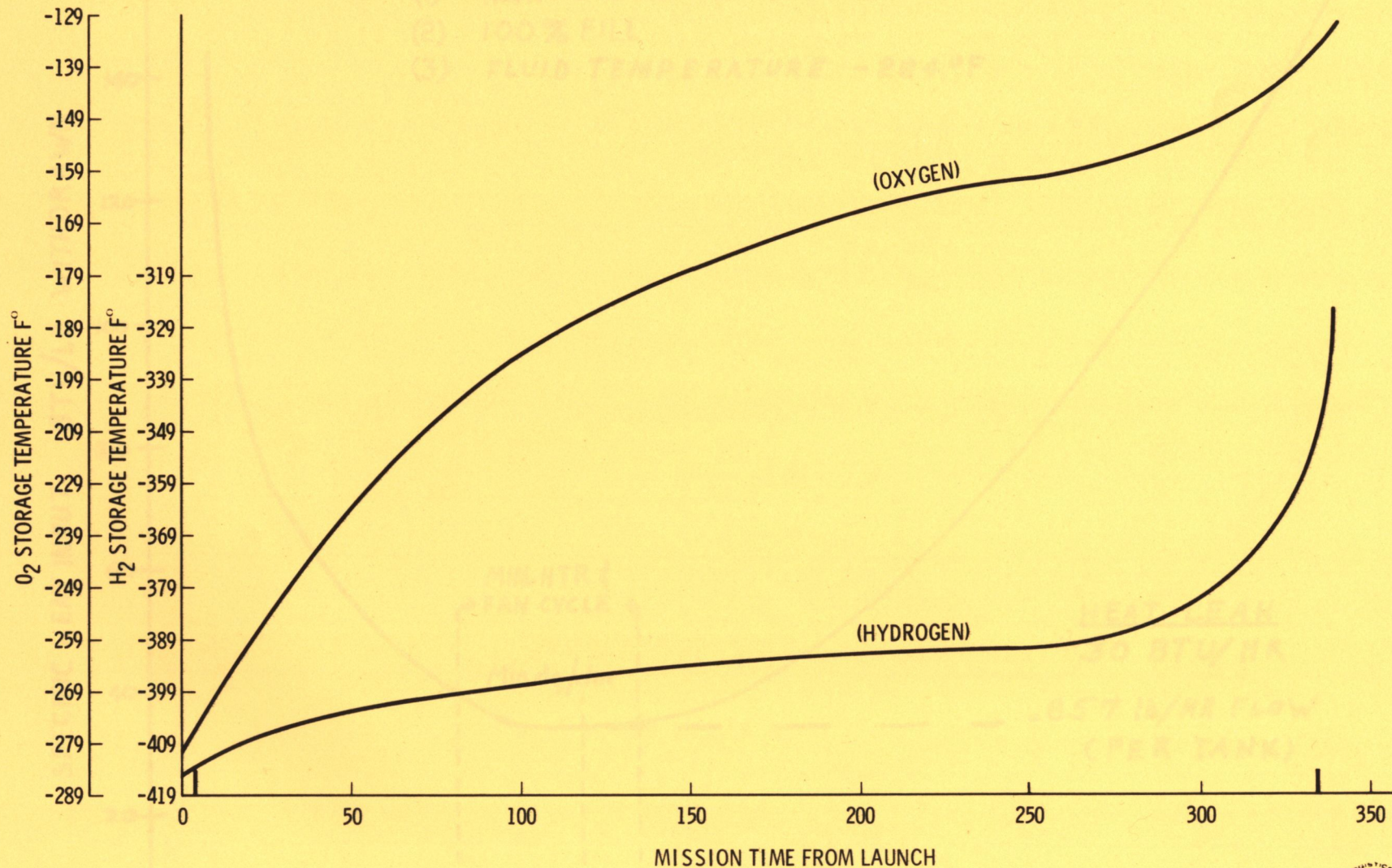


CRYOGENIC STORAGE SYSTEM TELEMETRY



CRYOGENIC STORAGE SYSTEM

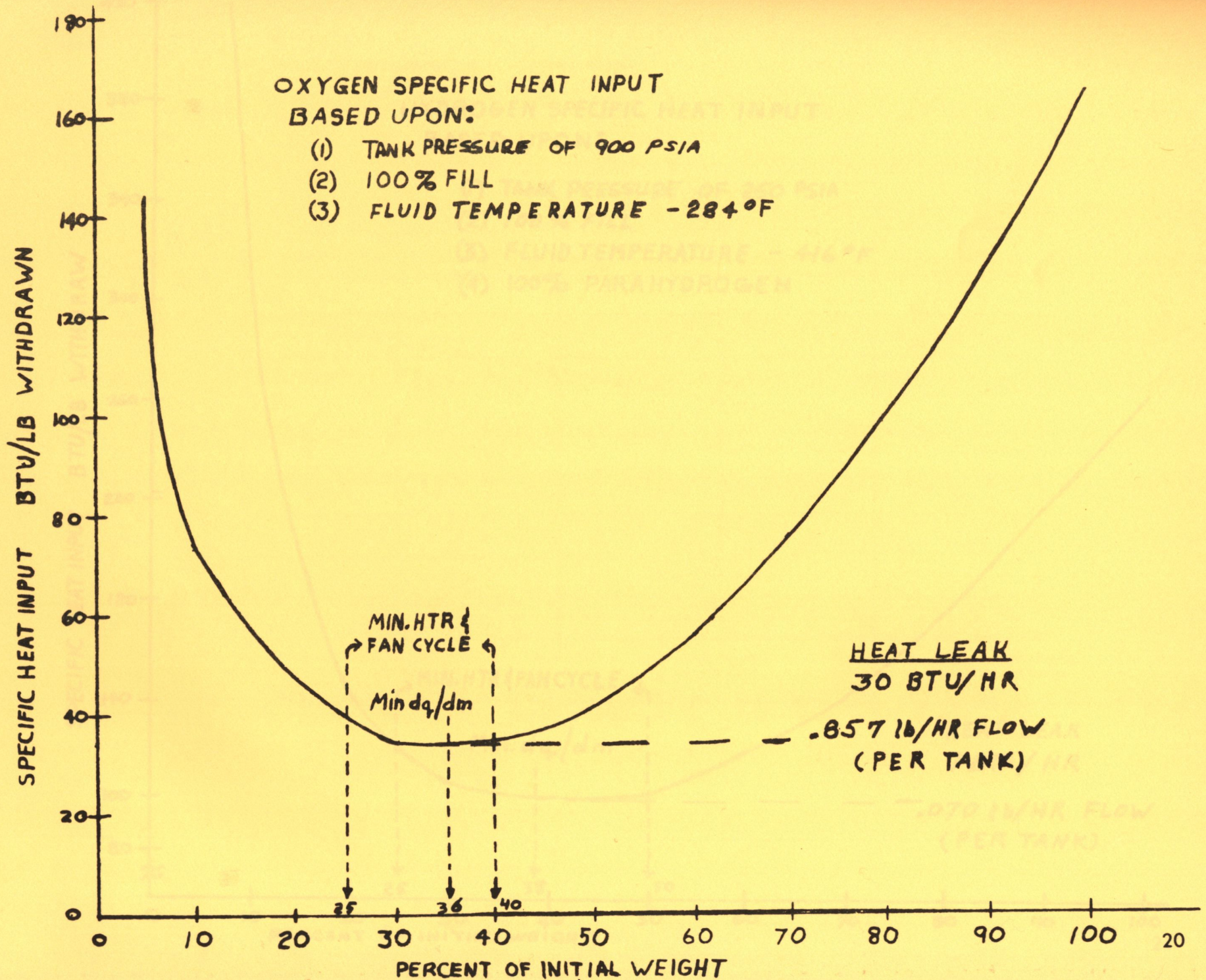
TEMPERATURE/NORMAL MISSION PROFILE

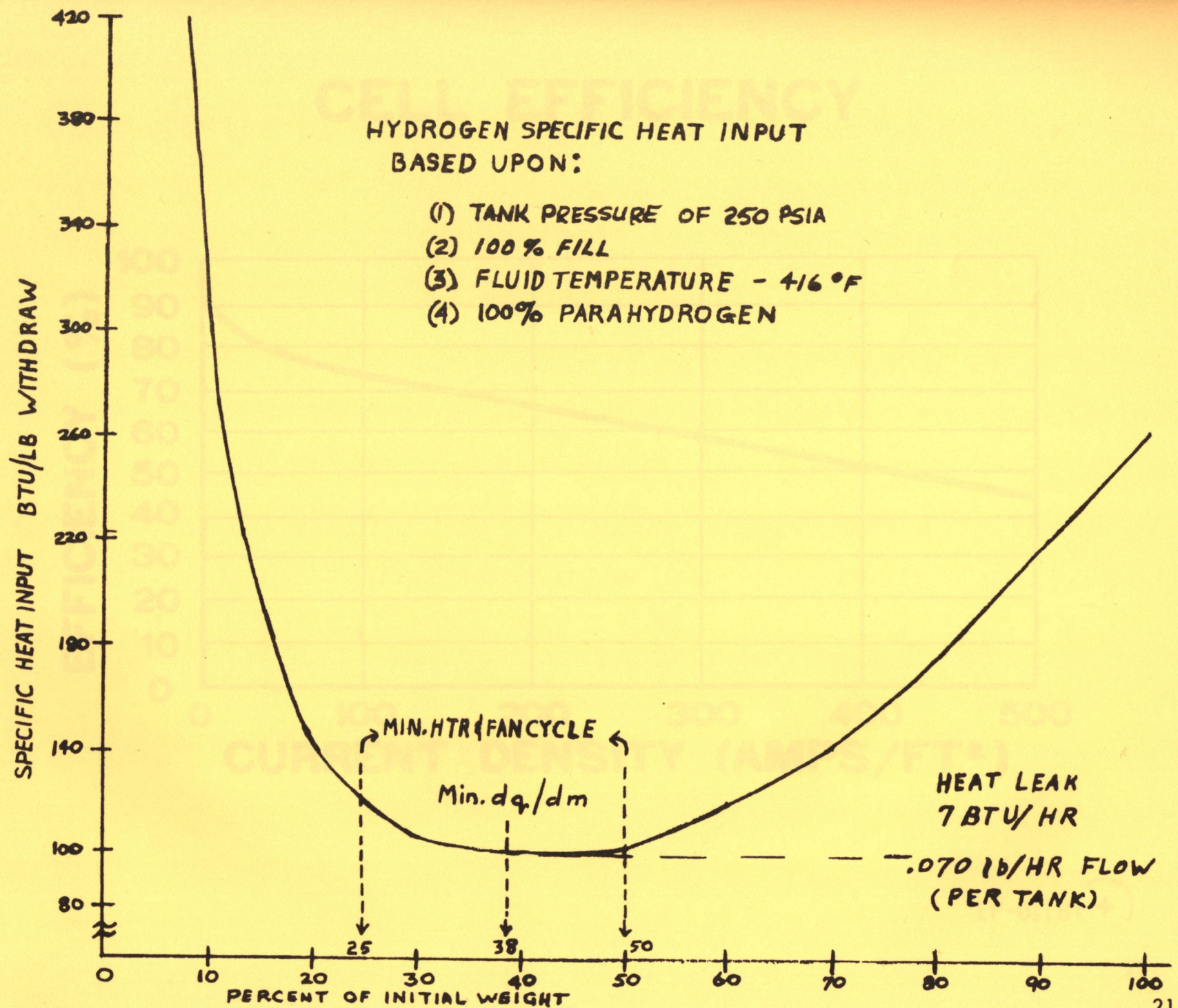


EP-019 B

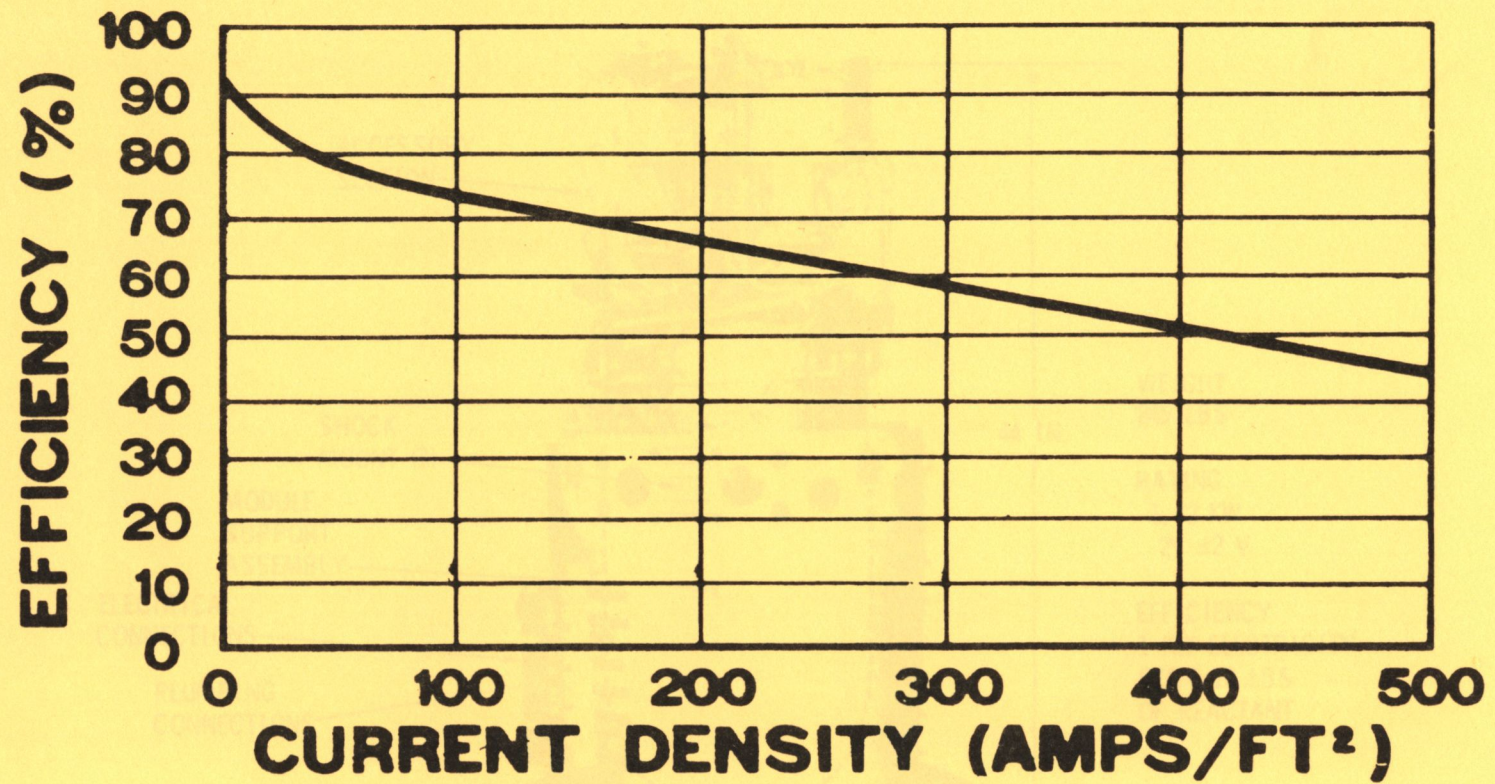
OXYGEN SPECIFIC HEAT INPUT
BASED UPON:

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

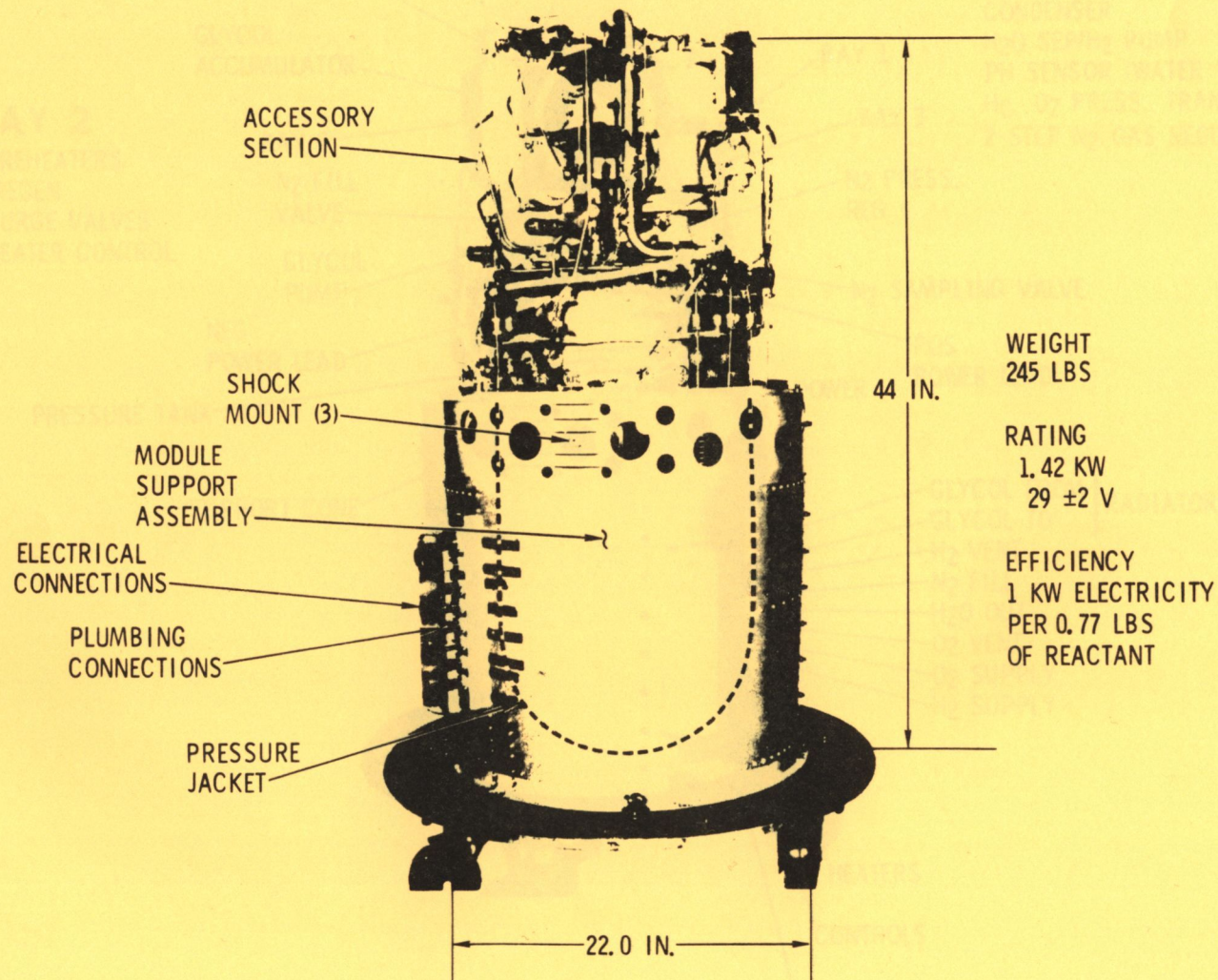




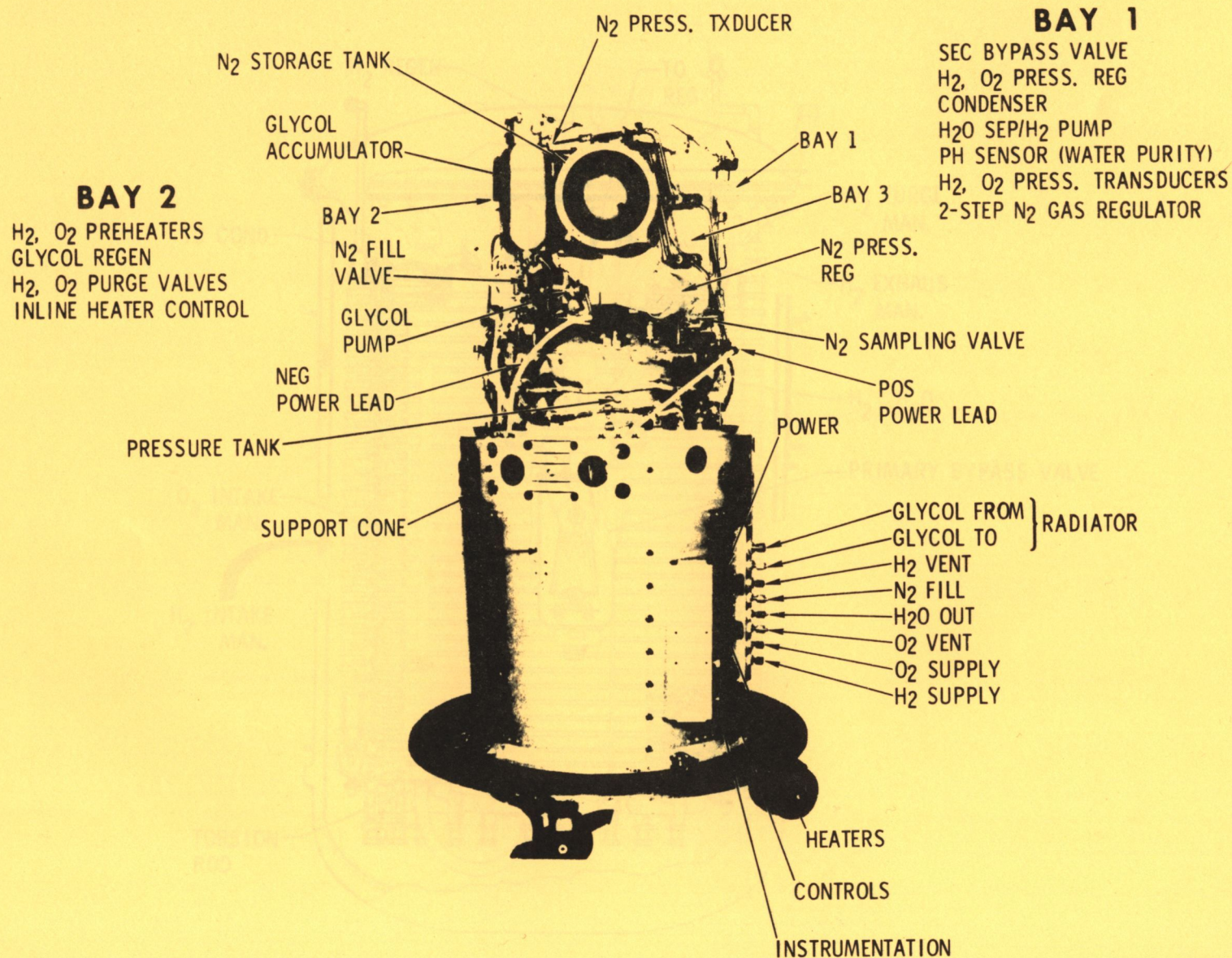
CELL EFFICIENCY



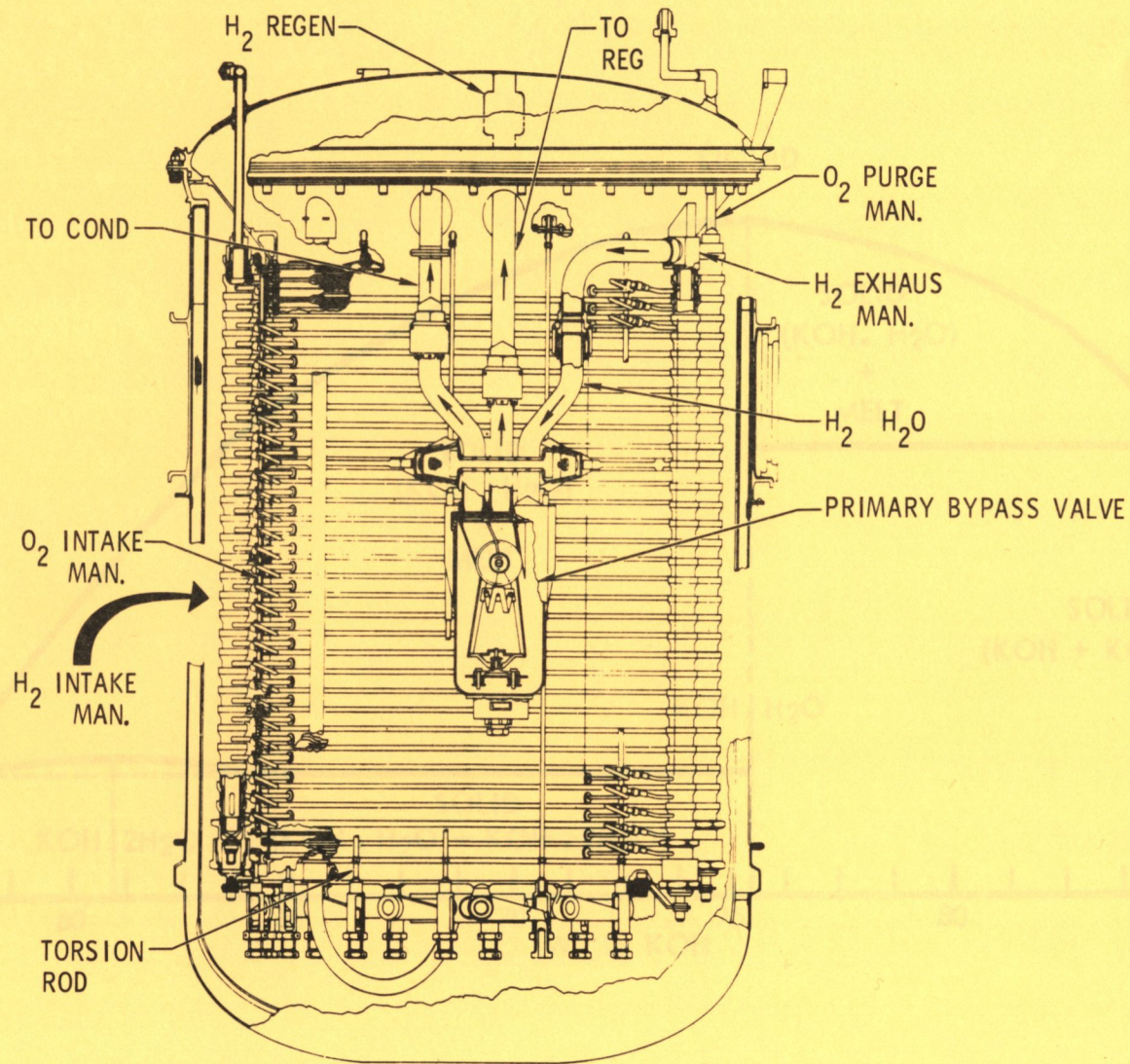
FUEL CELL POWER PLANT



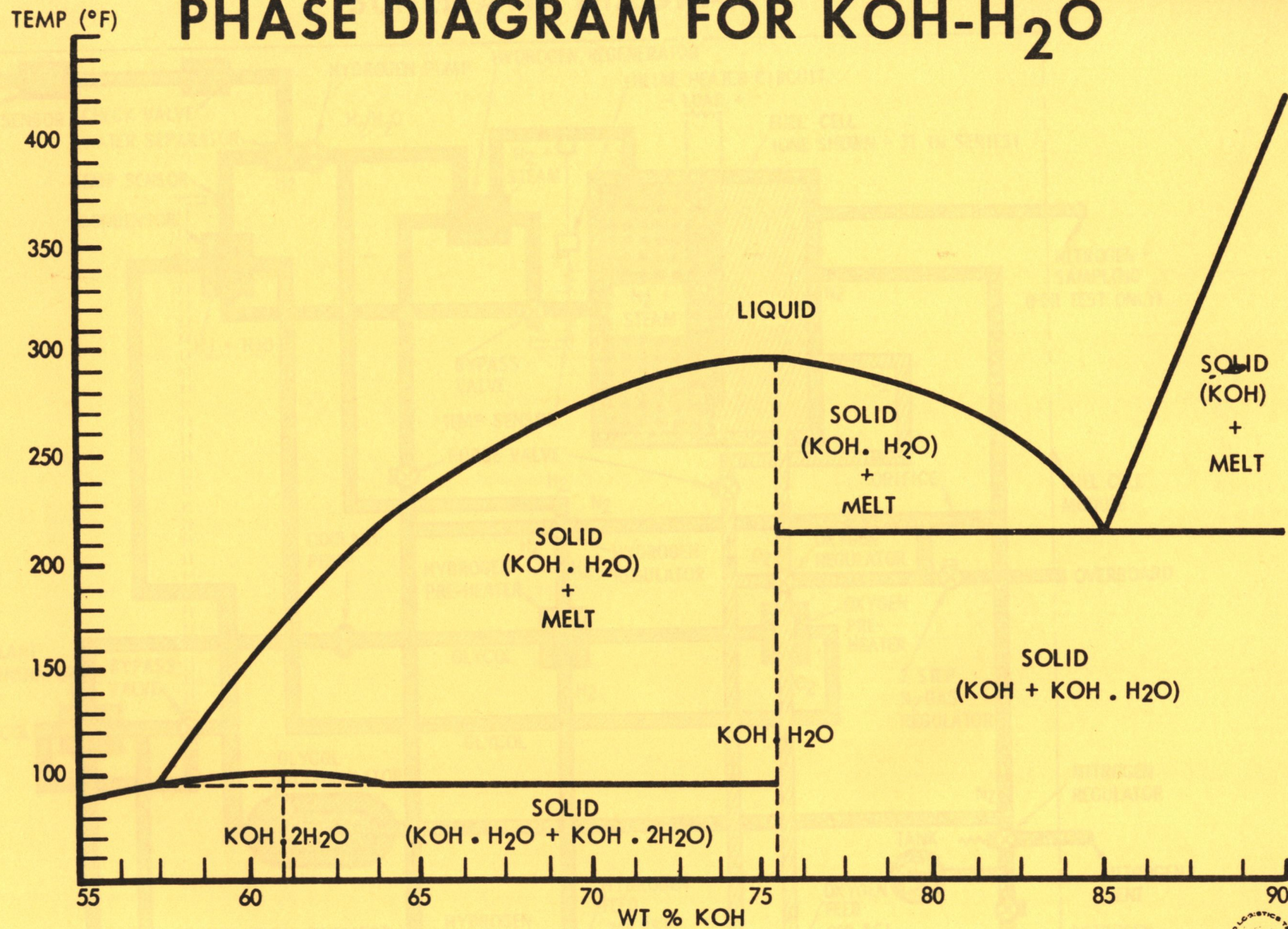
FUEL CELL MODULE ACCESSORIES



FUEL CELL MODULE



PHASE DIAGRAM FOR KOH-H₂O

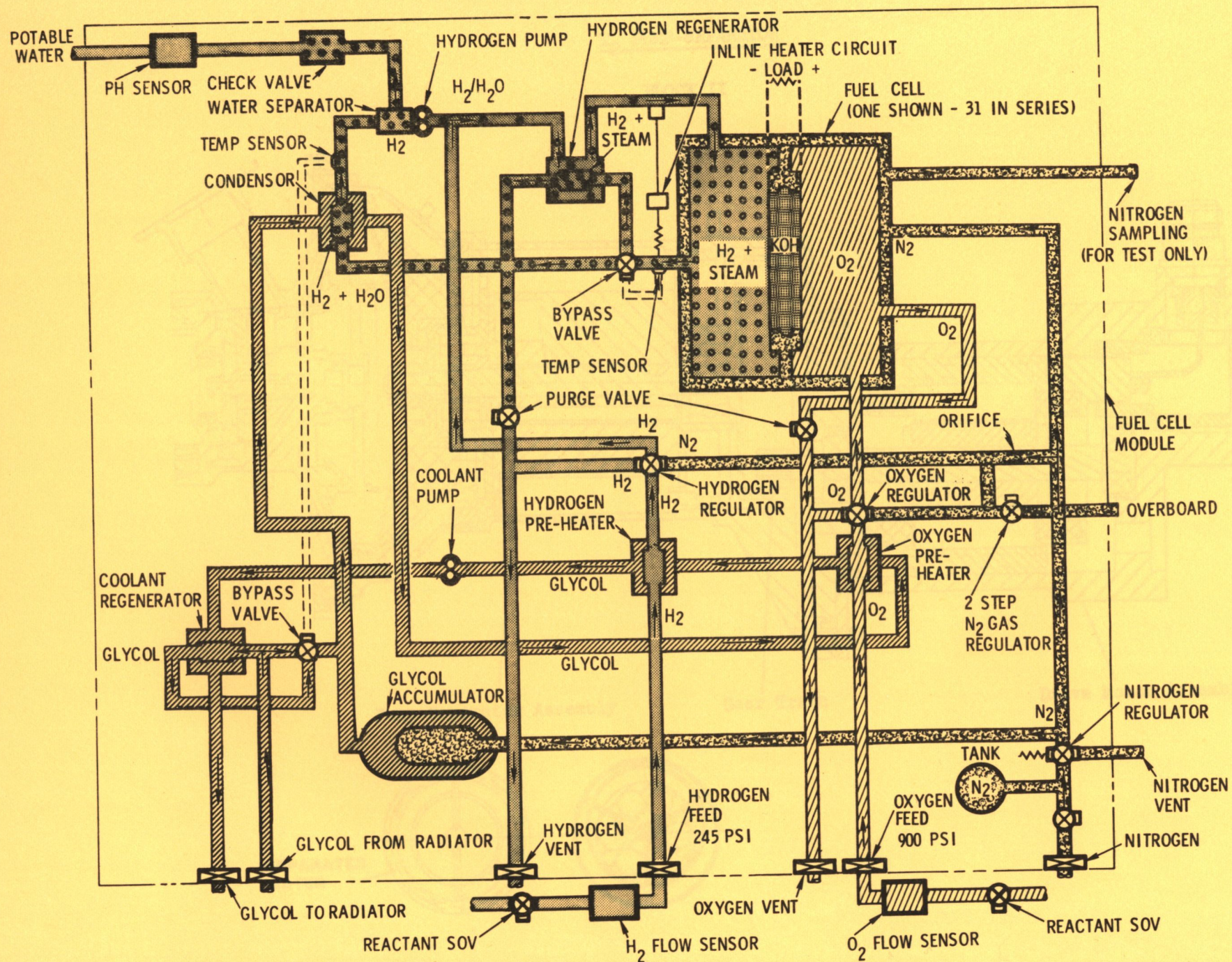


EP-007



FUEL CELL MODULE

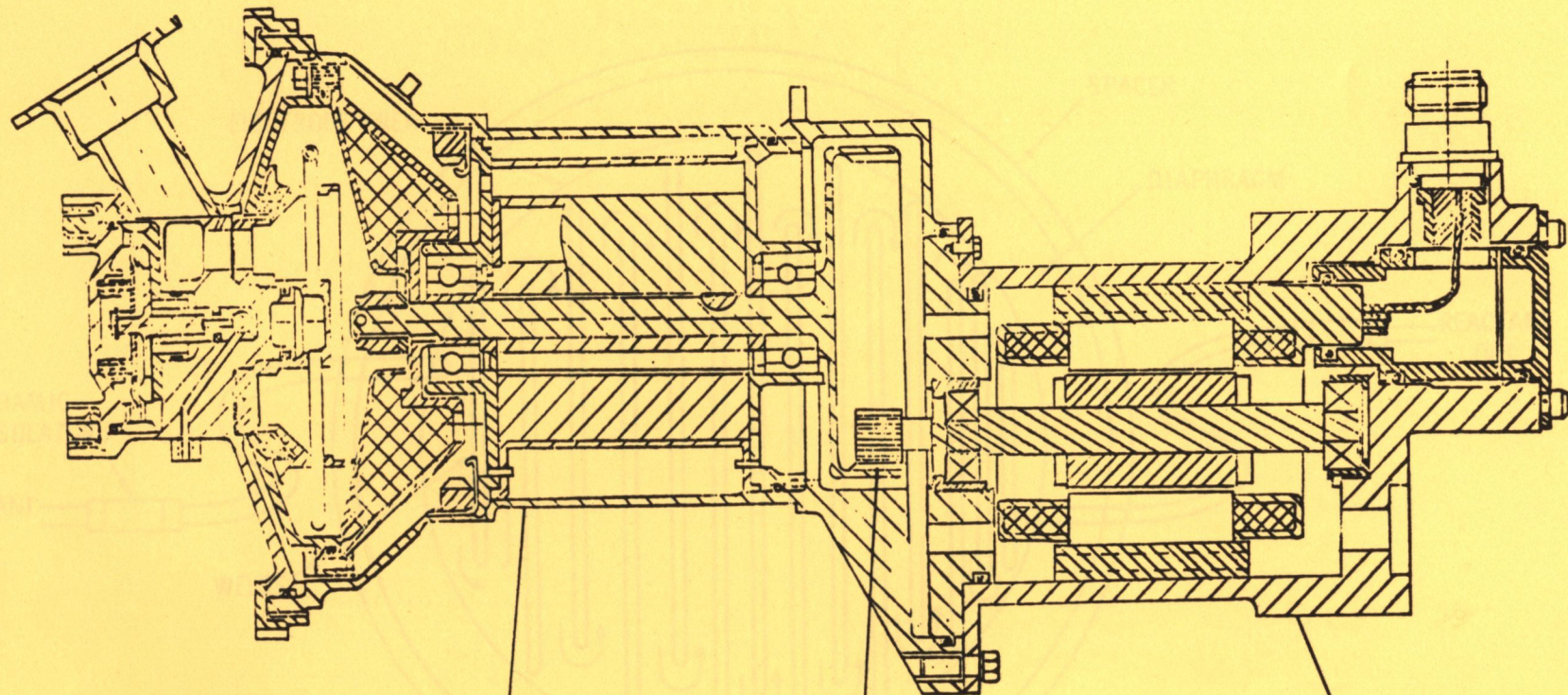
SCHEMATIC DIAGRAM



SINGLE CELL CONSTRUCTION

H₂ PUMP-SEPARATOR

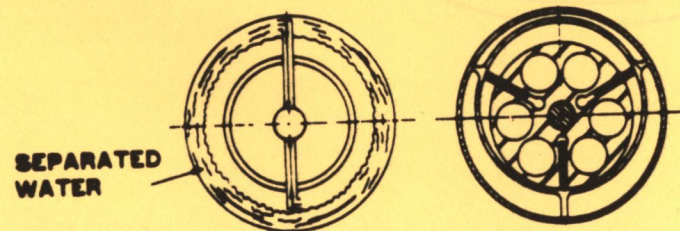
BLOCK II



Pump-Separator Assembly

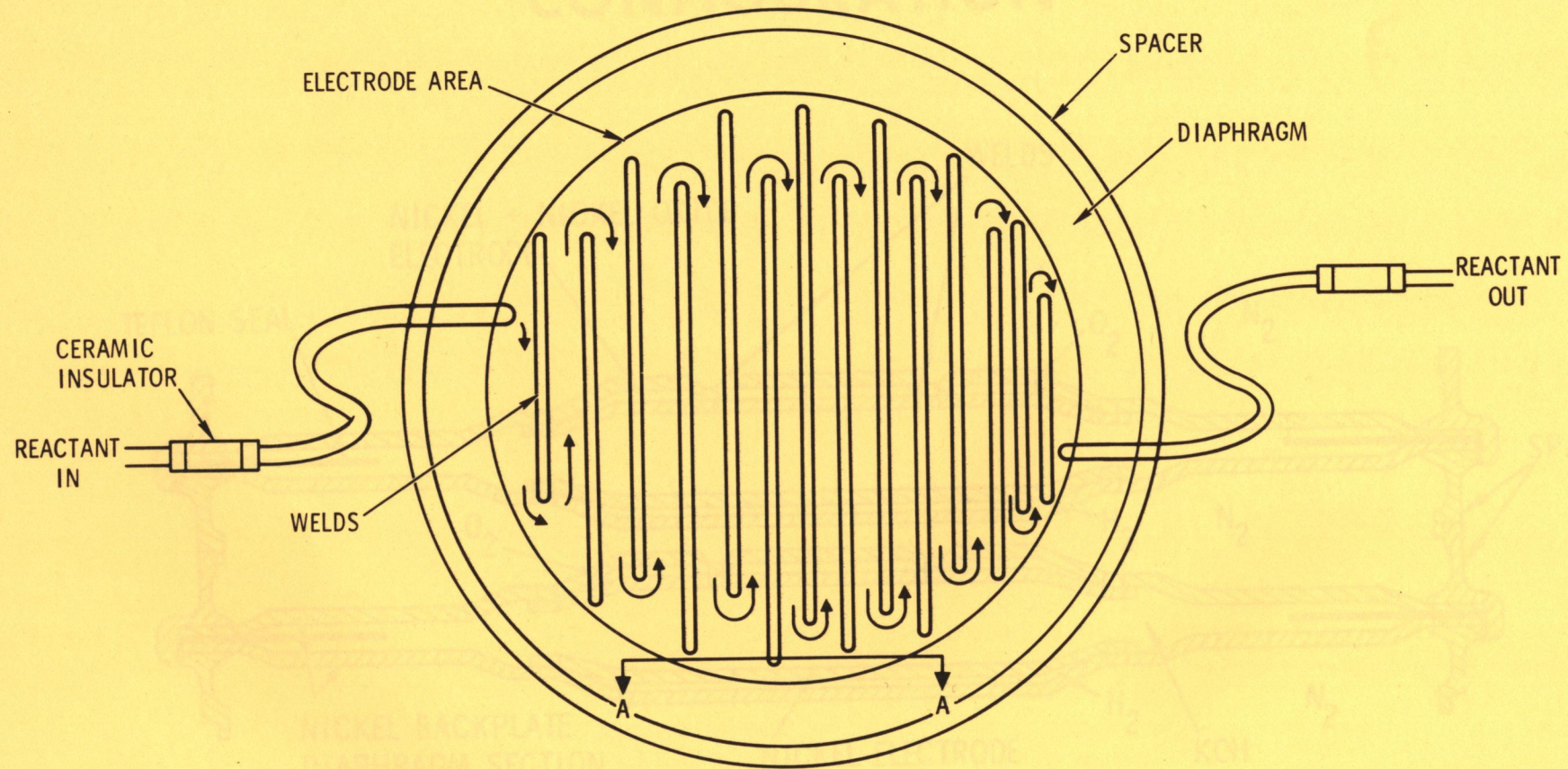
Gear Train

Drive Motor Assembly



SEPARATED
WATER

SINGLE CELL CONSTRUCTION

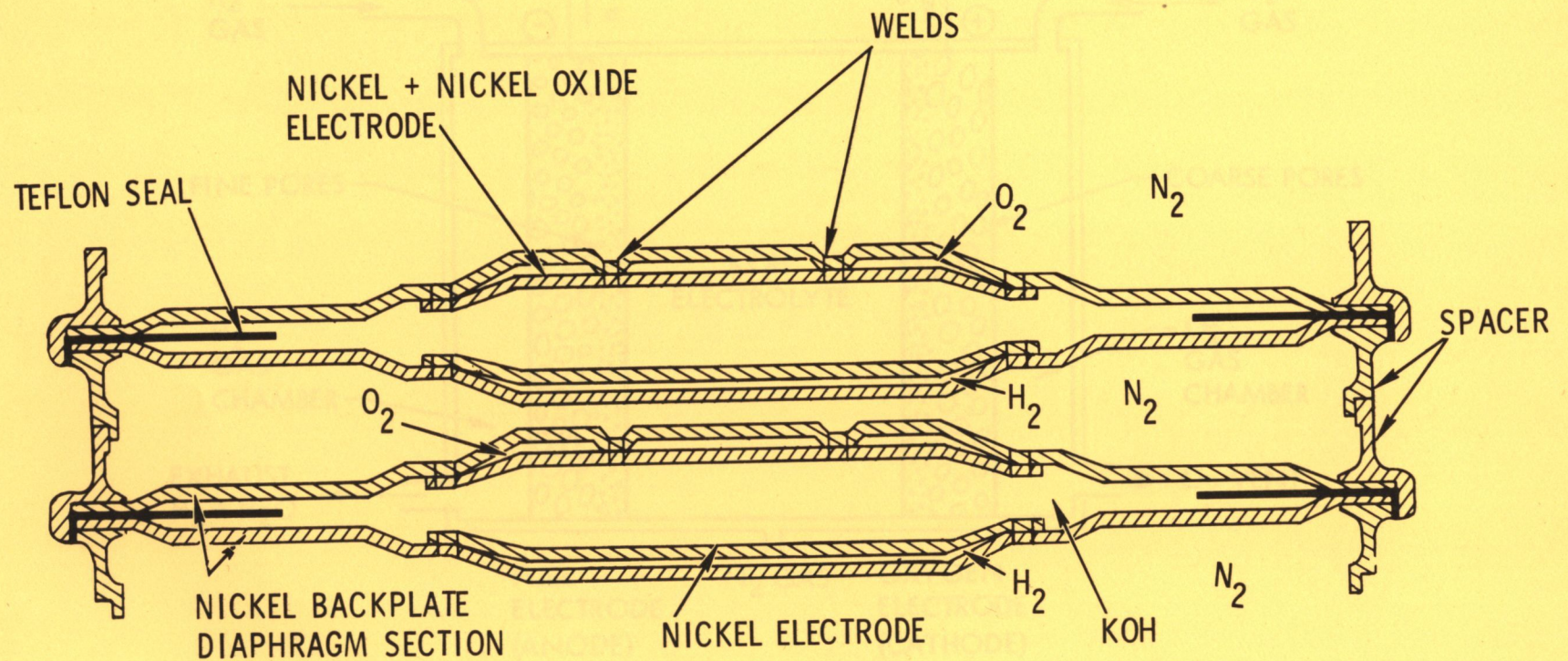


EP-004C



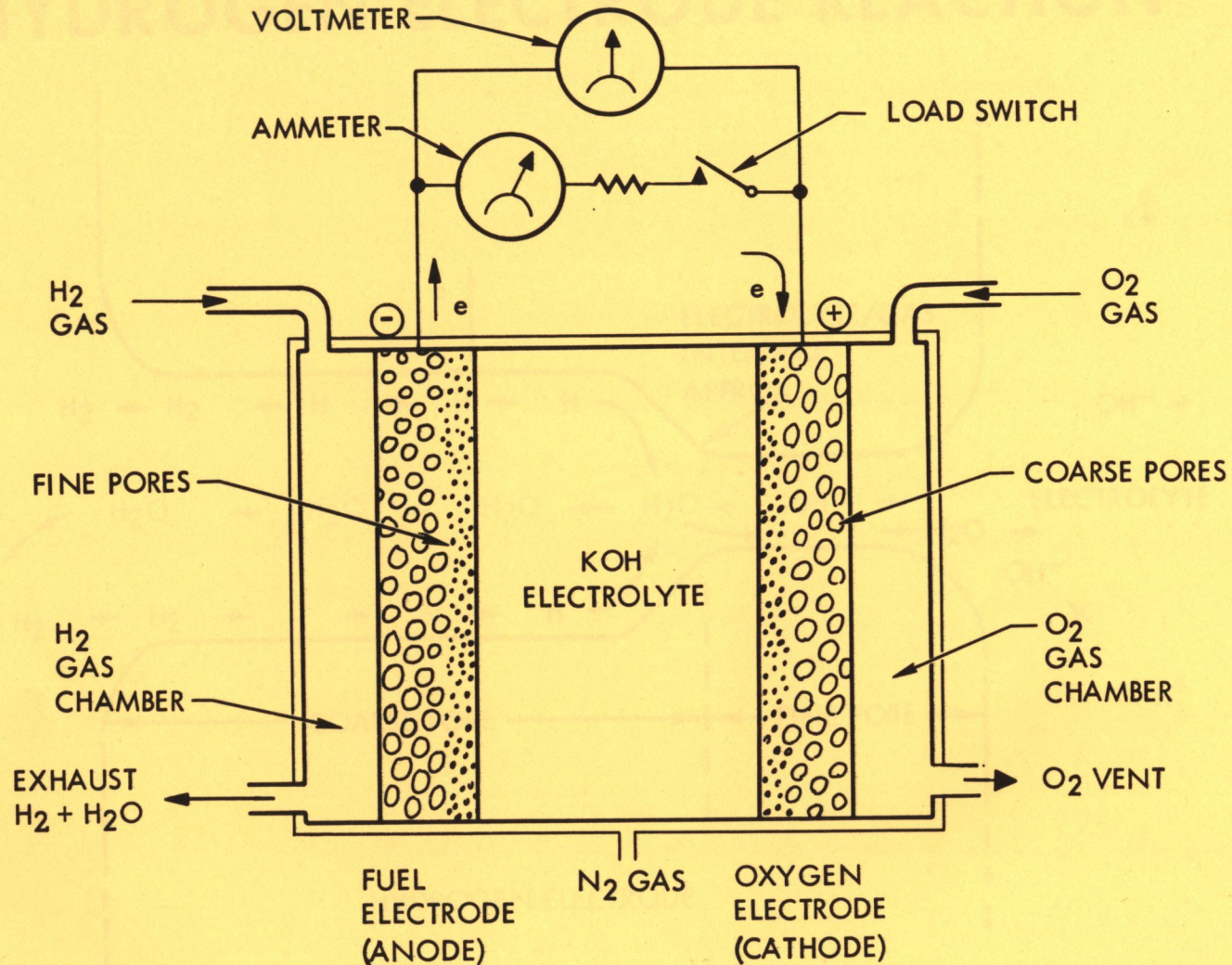
FUEL CELL ELECTROCHEMICAL FLOW SCHEMATIC

CELL CUTAWAY AND MOUNTING CONFIGURATION

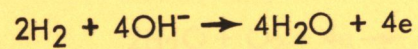
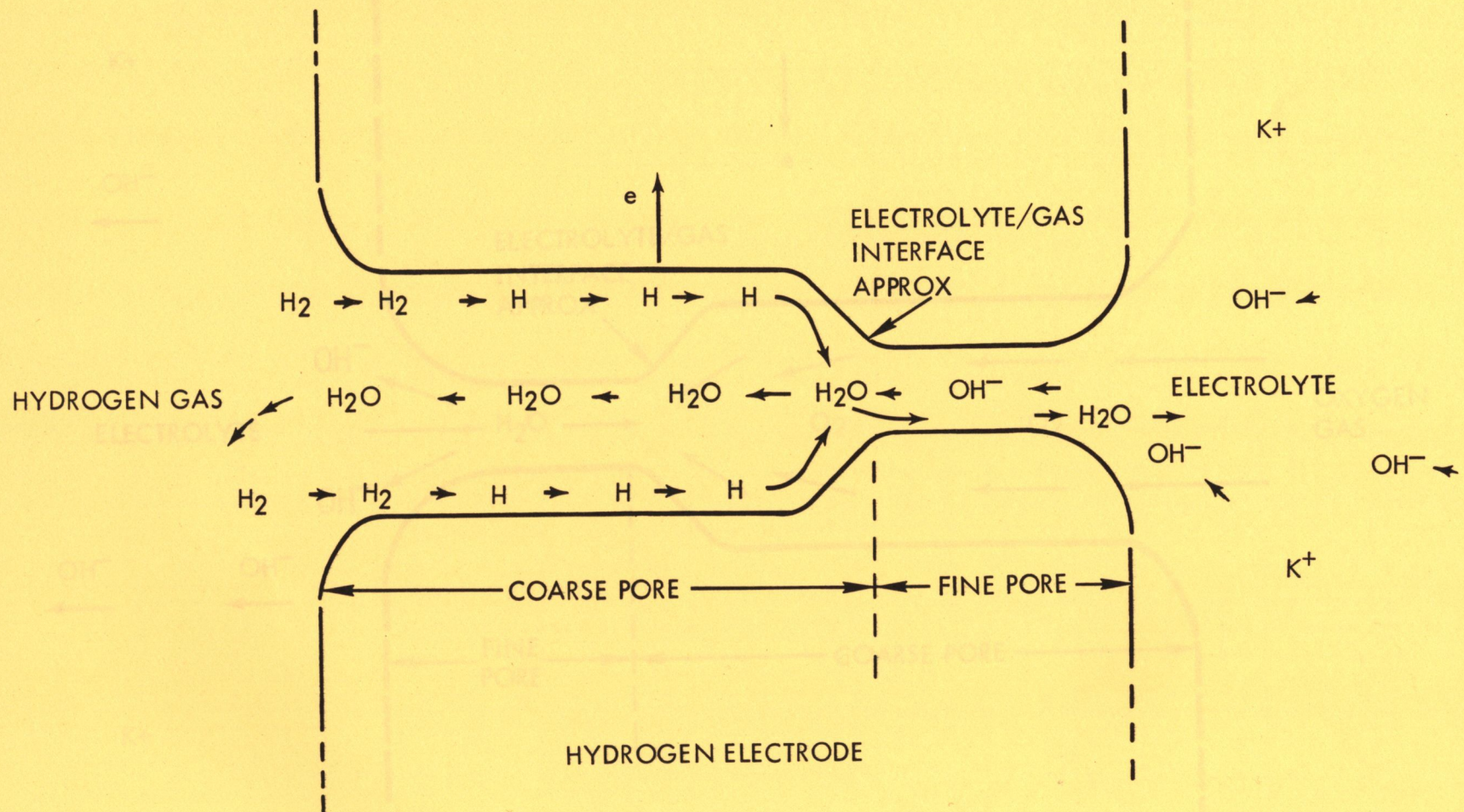


EP-039A 

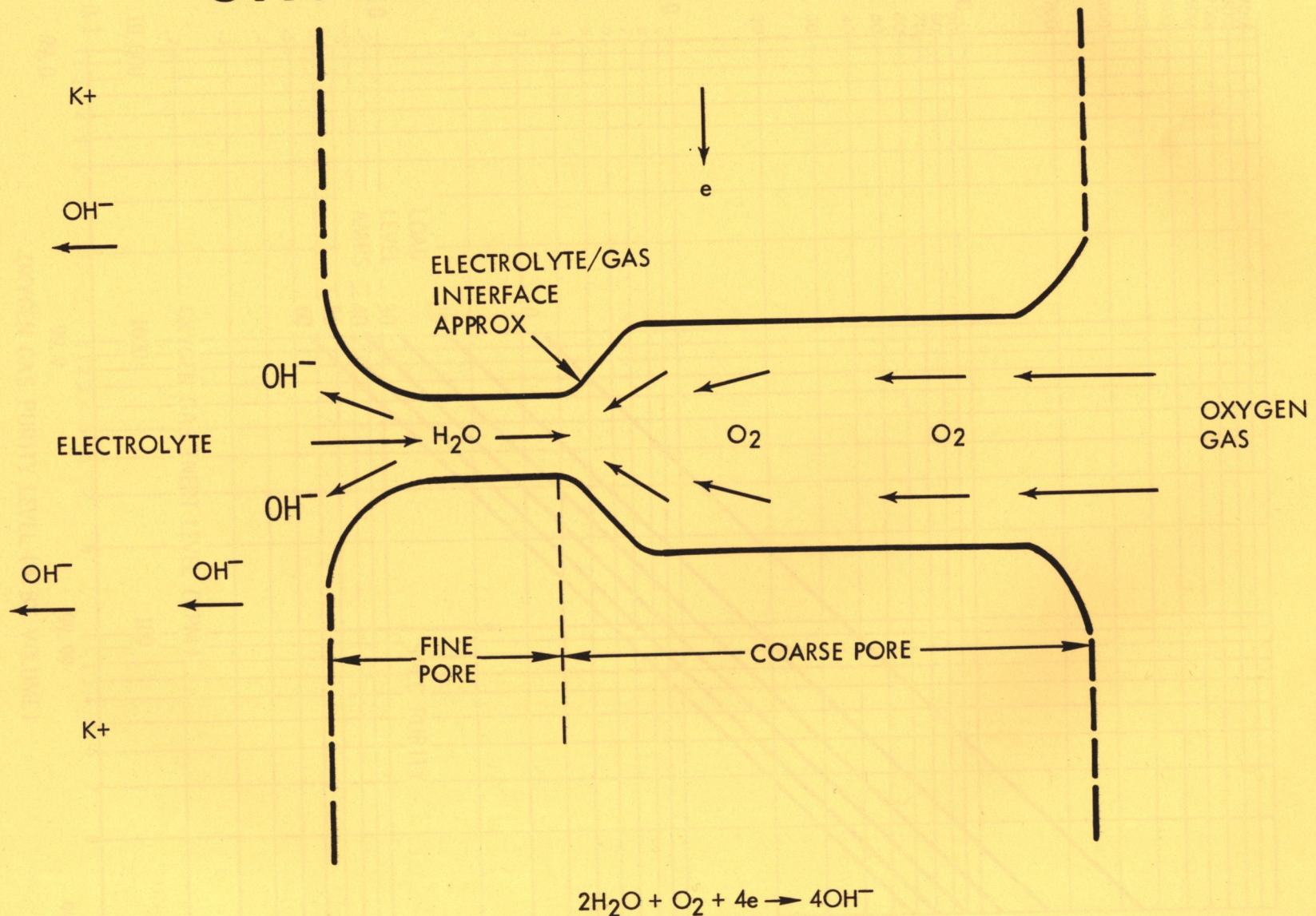
FUEL CELL ELECTROCHEMICAL FLOW SCHEMATIC

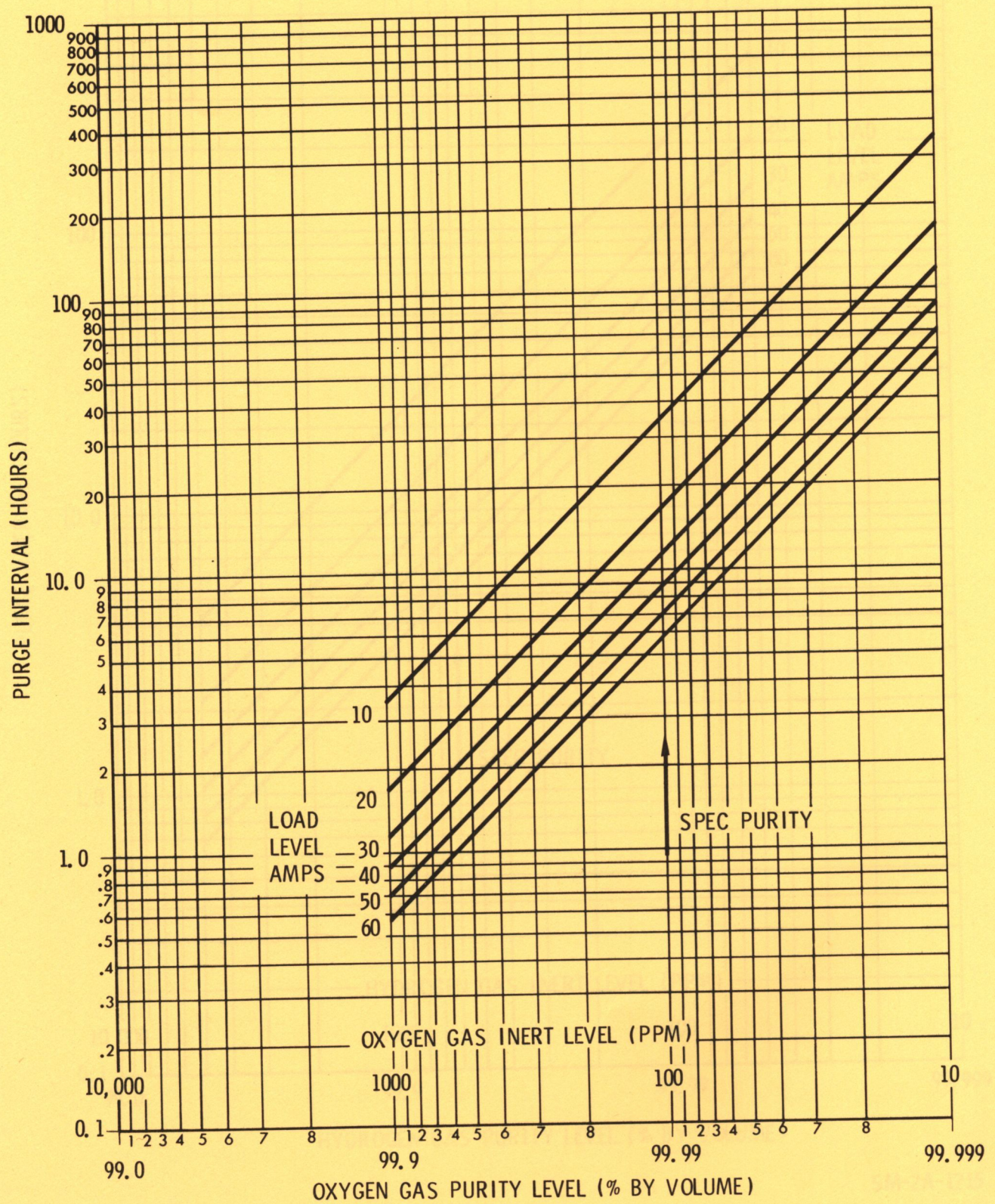


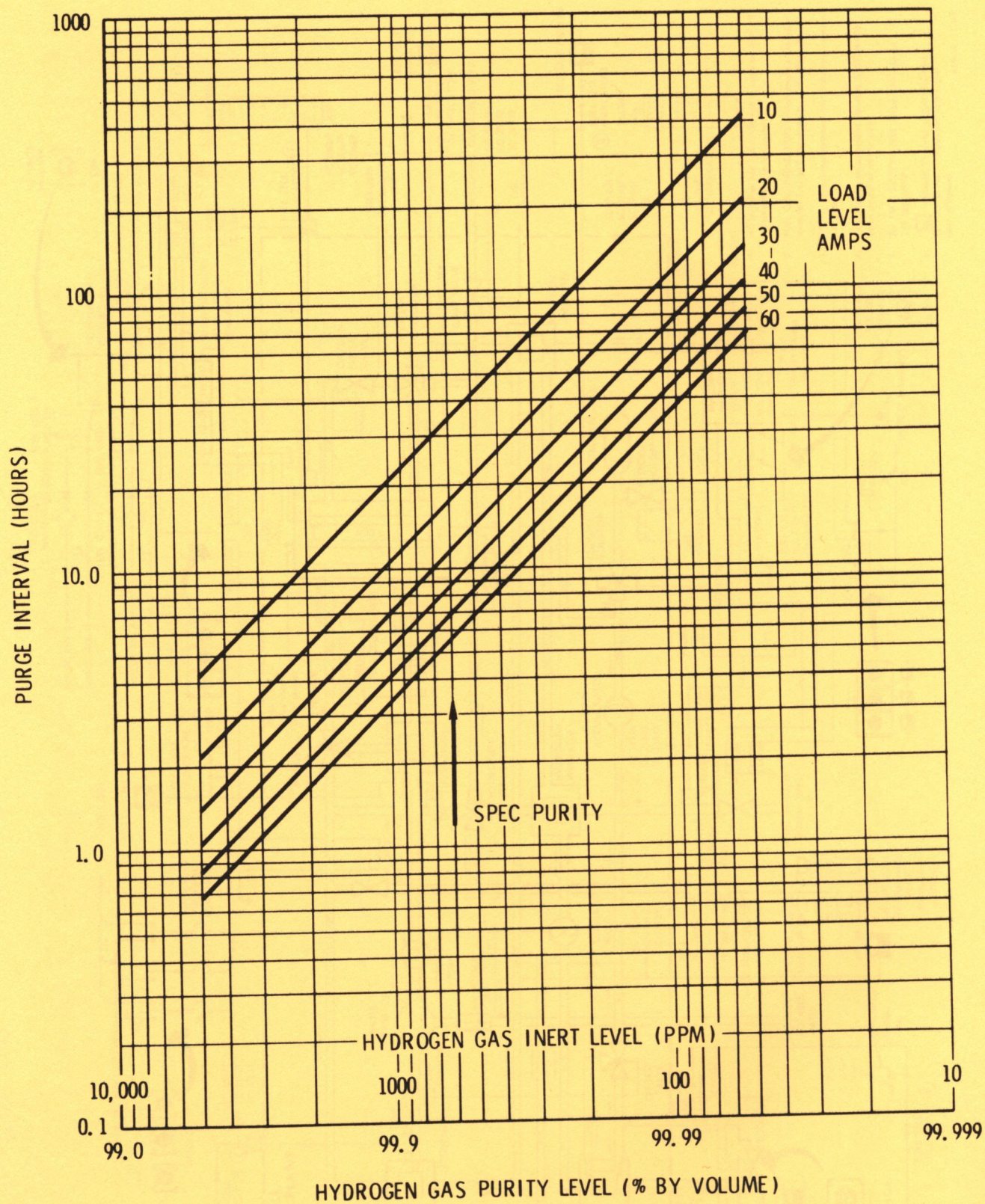
HYDROGEN ELECTRODE REACTION

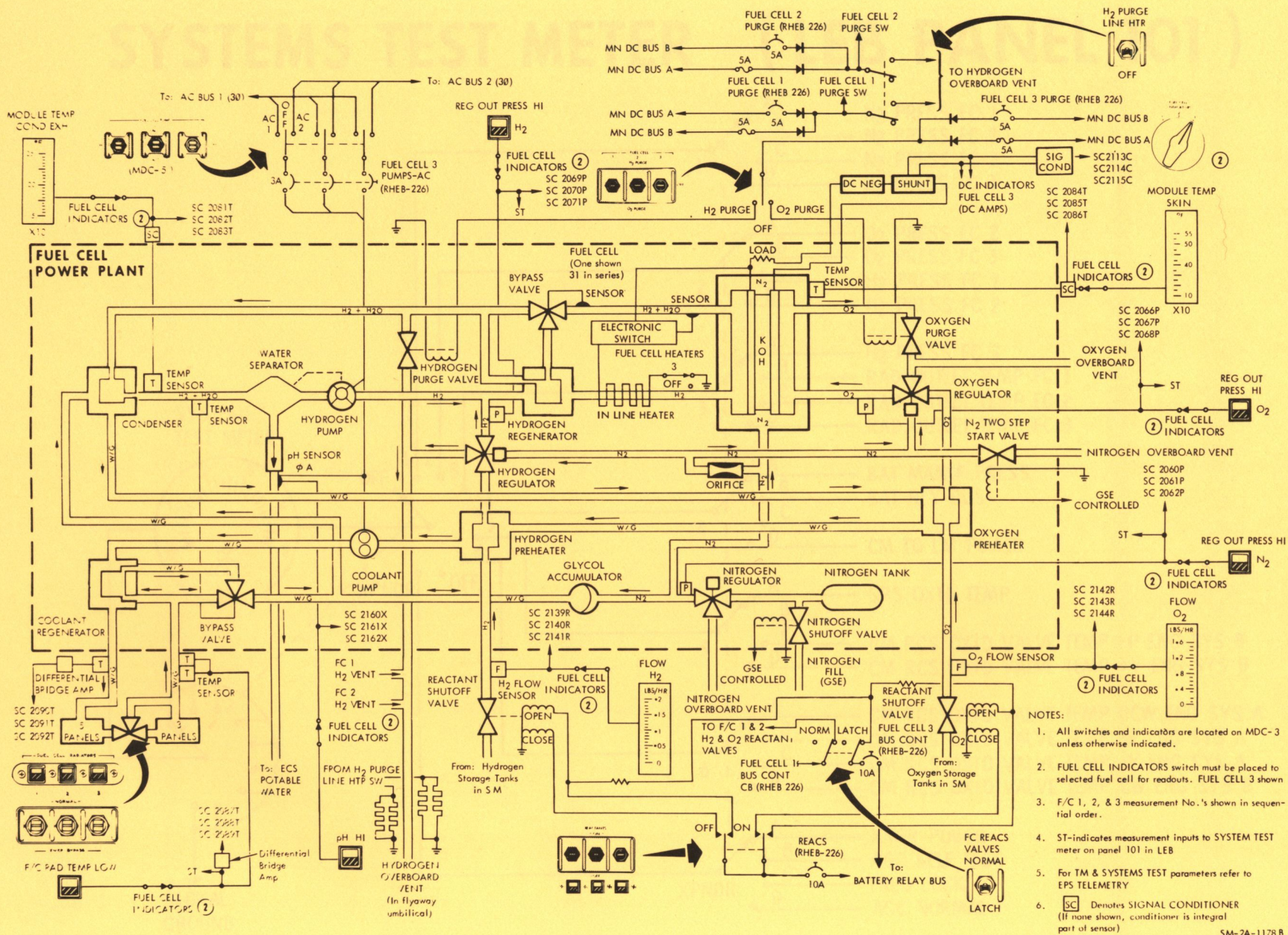


OXYGEN ELECTRODE REACTION



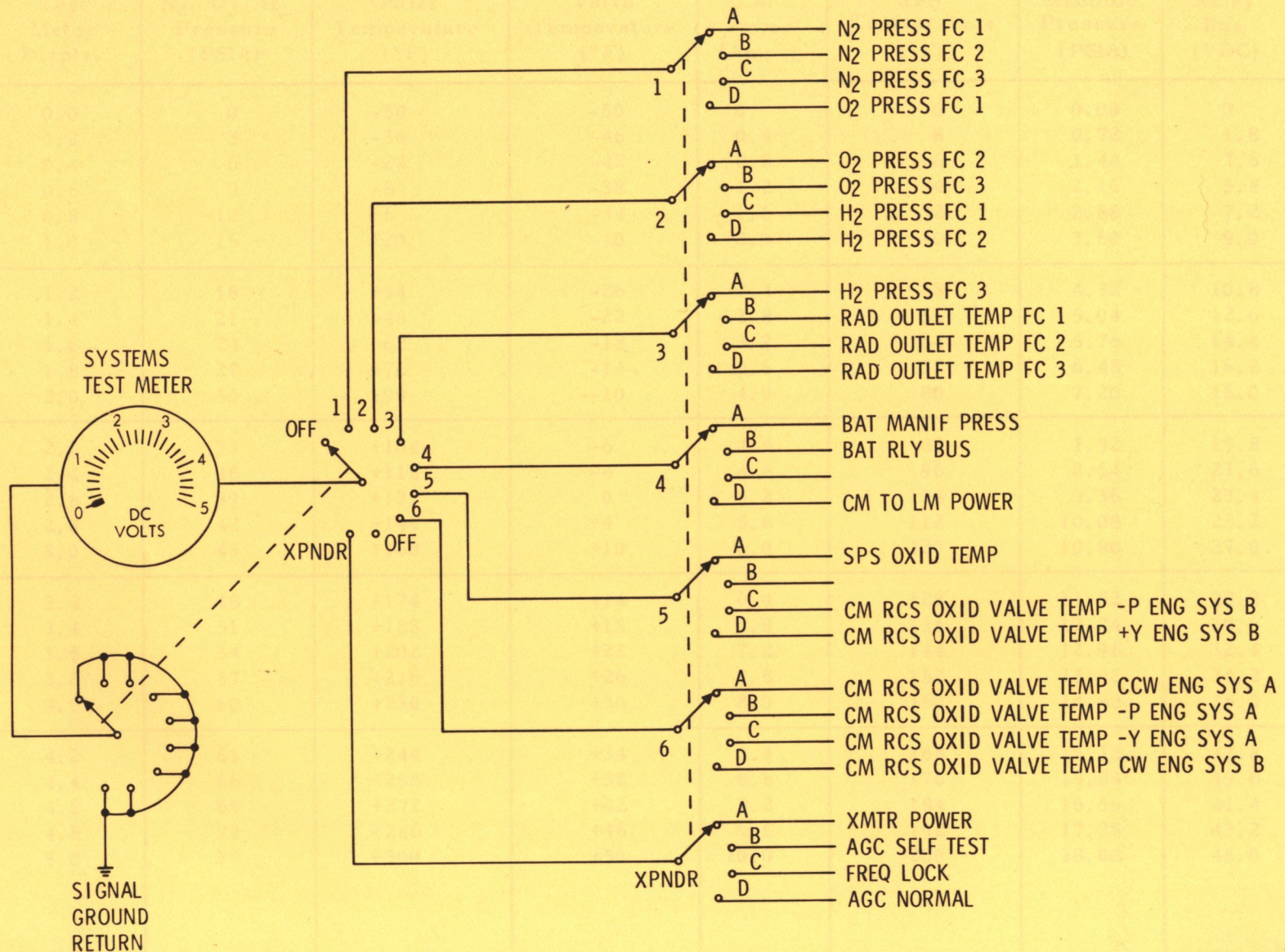






THIS IS THE FUEL CELL SCHEMATIC DIAGRAM

SYSTEMS TEST METER (LEB PANEL 101)



Systems Test Meter Display	N ₂ . O ₂ . H ₂ Pressure (PSIA)	EPS Radiator Outlet Temperature (°F)	CM-RCS Oxidizer Valve Temperature (°F)	LM Power (Amps)	SPS Temperature (°F)	Battery Manifold Pressure (PSIA)	Battery Relay Bus (VDC)
0.0	0	-50	-50	0	0	0.00	0
0.2	3	-36	-46	0.4	8	0.72	1.8
0.4	6	-22	-42	0.8	16	1.44	3.6
0.6	9	-8	-38	1.2	24	2.16	5.4
0.8	12	+6	-34	1.6	32	2.88	7.2
1.0	15	+20	-30	2.0	40	3.60	9.0
1.2	18	+34	-26	2.4	48	4.32	10.8
1.4	21	+48	-22	2.8	56	5.04	12.6
1.6	24	+62	-18	3.2	64	5.76	14.4
1.8	27	+76	-14	3.6	72	6.48	16.2
2.0	30	+90	-10	4.0	80	7.20	18.0
2.2	33	+104	-6	4.4	88	7.92	19.8
2.4	36	+118	-4	4.8	96	8.64	21.6
2.6	39	+132	0	5.2	104	9.36	23.4
2.8	42	+146	+4	5.6	112	10.08	25.2
3.0	45	+160	+10	6.0	120	10.80	27.0
3.2	48	+174	+14	6.4	128	11.52	28.8
3.4	51	+188	+18	6.8	136	12.24	30.6
3.6	54	+202	+22	7.2	144	12.96	32.4
3.8	57	+216	+26	7.6	152	13.68	34.2
4.0	60	+230	+30	8.0	160	14.40	36.0
4.2	63	+244	+34	8.4	168	15.12	37.8
4.4	66	+258	+38	8.8	176	15.84	39.6
4.6	69	+272	+42	9.2	184	16.56	41.4
4.8	72	+286	+46	9.6	192	17.28	43.2
5.0	75	+300	+50	10.0	200	18.00	45.0

SYSTEMS DATA

ENTRY & POST LANDING BATTERY

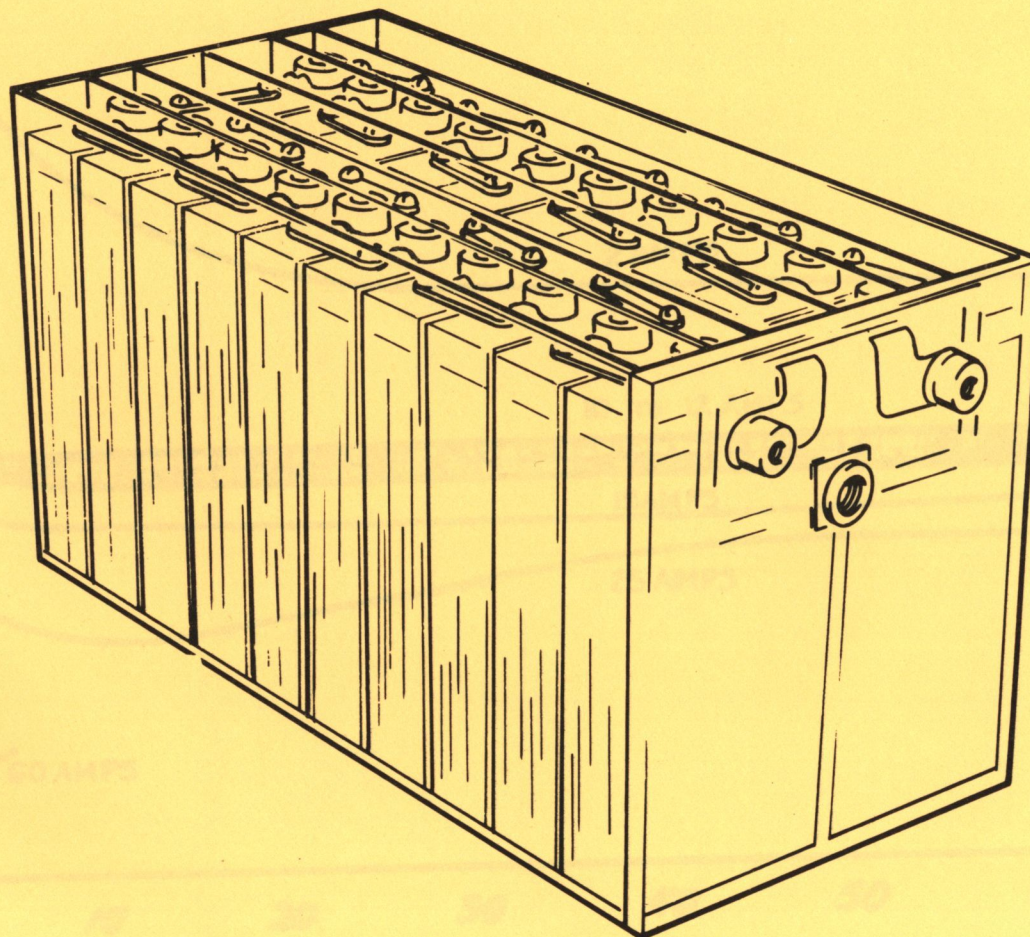
INTERIOR

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

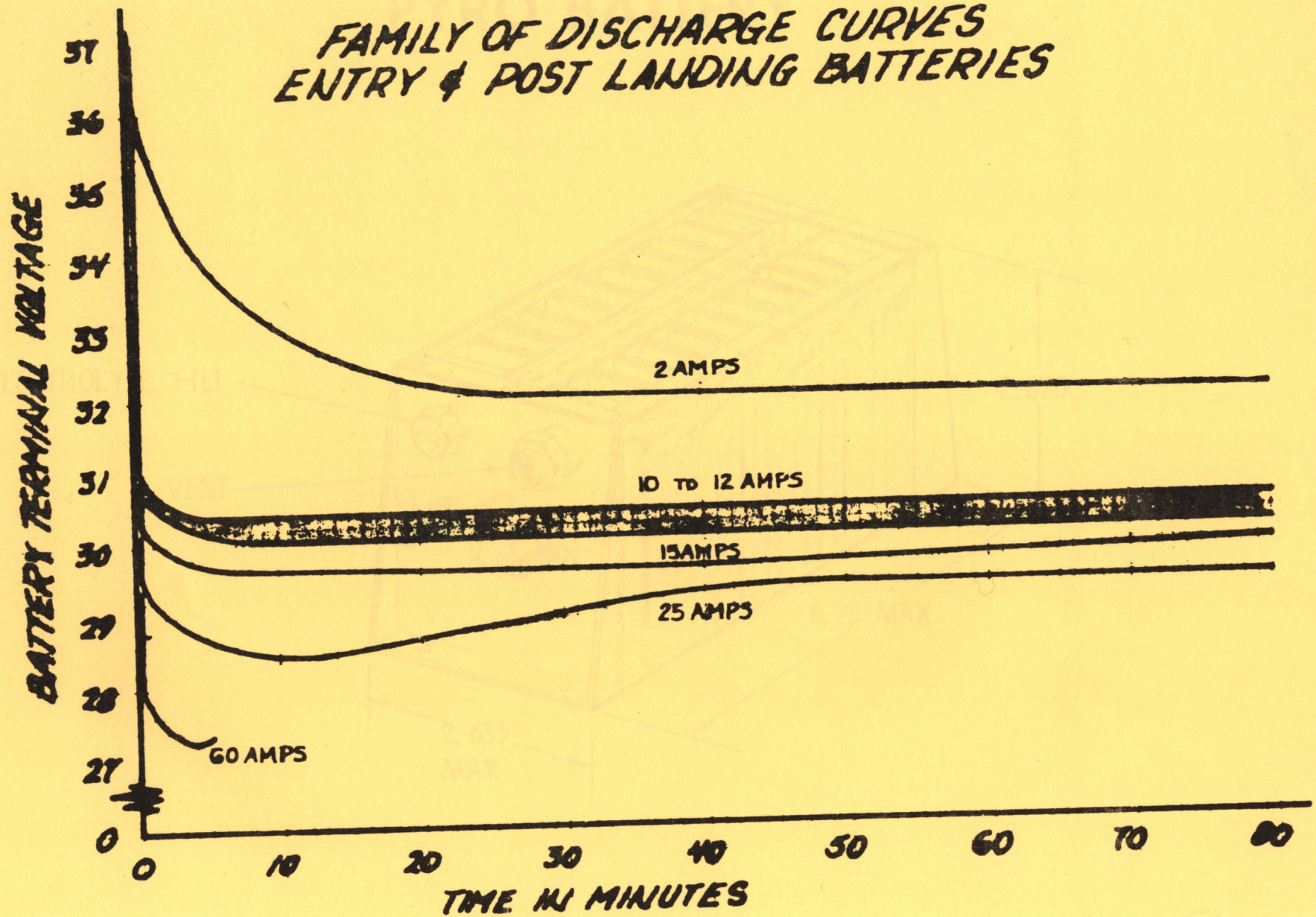
SM-2A-1217

ENTRY & POST LANDING BATTERY

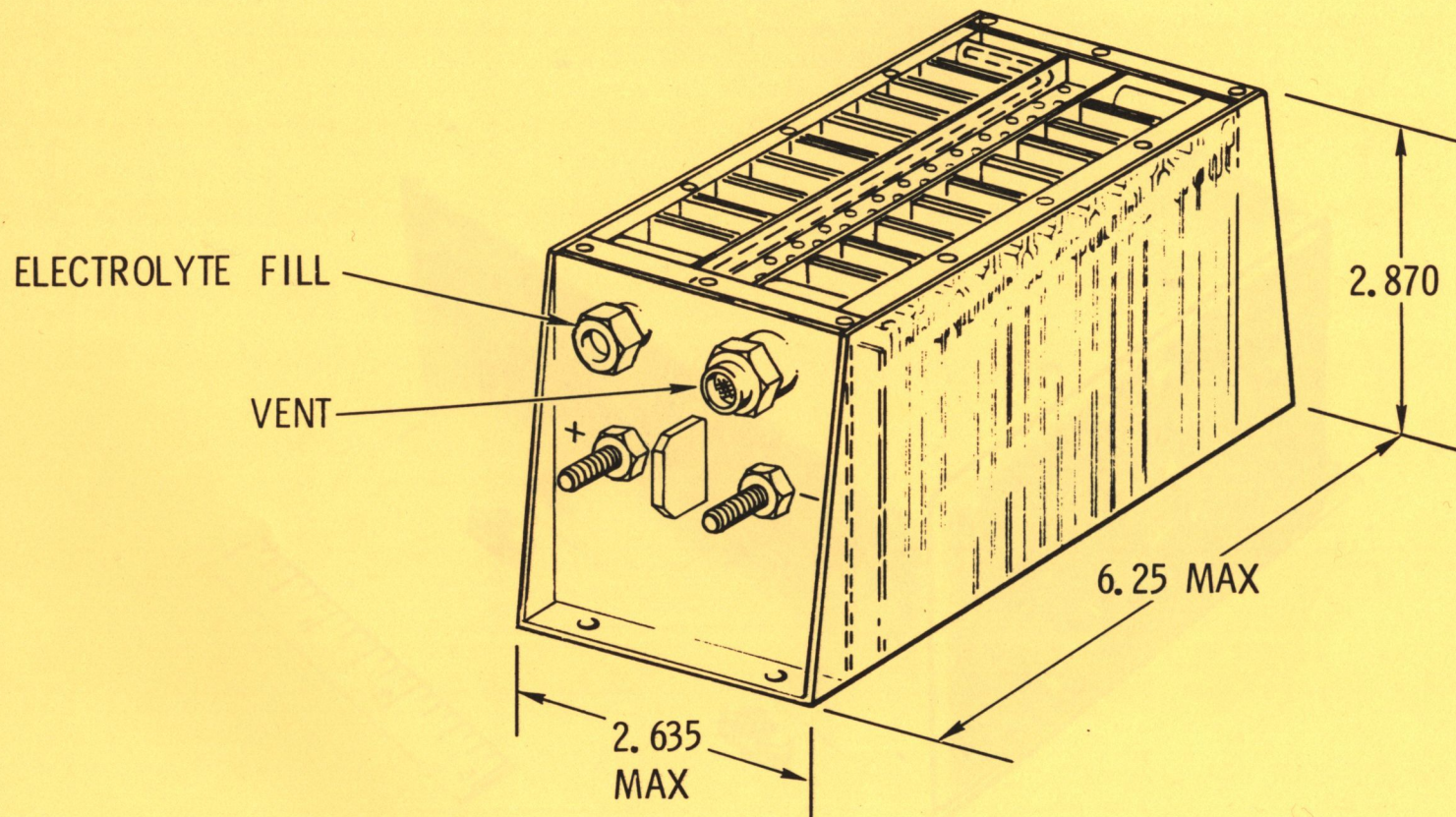
INTERIOR



FAMILY OF DISCHARGE CURVES ENTRY & POST LANDING BATTERIES

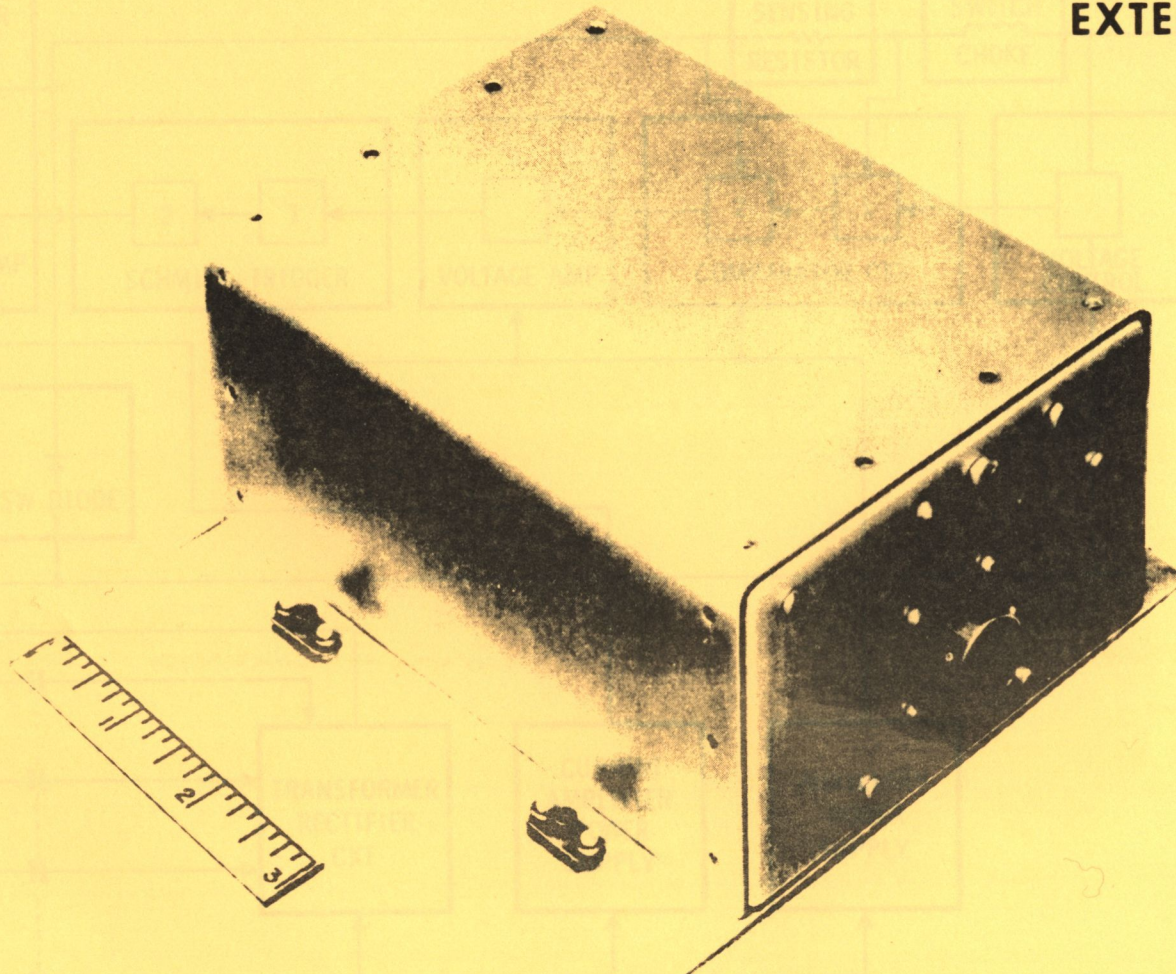


PYRO BATTERY

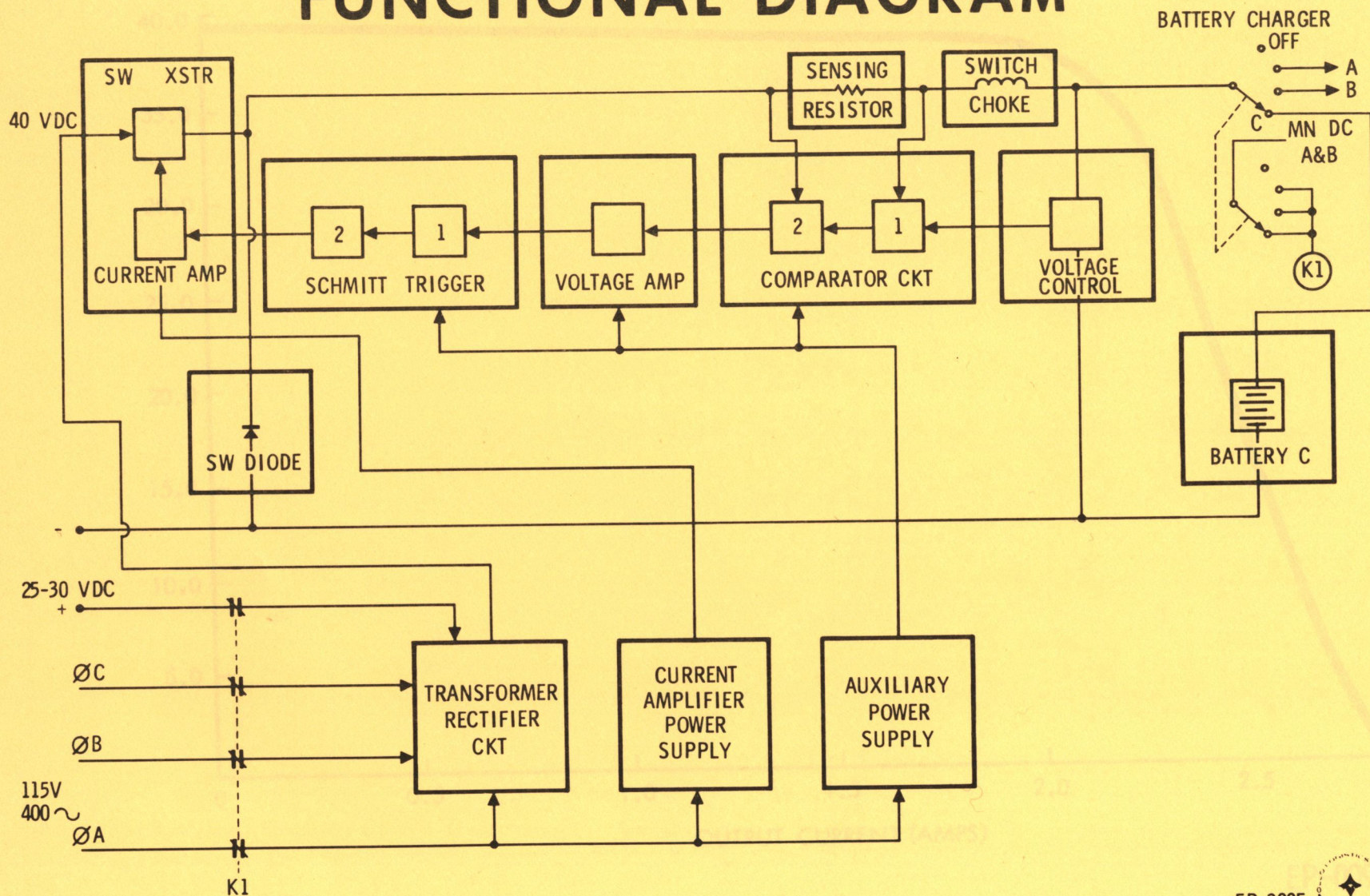


APOLLO BATTERY CHARGER

EXTERIOR



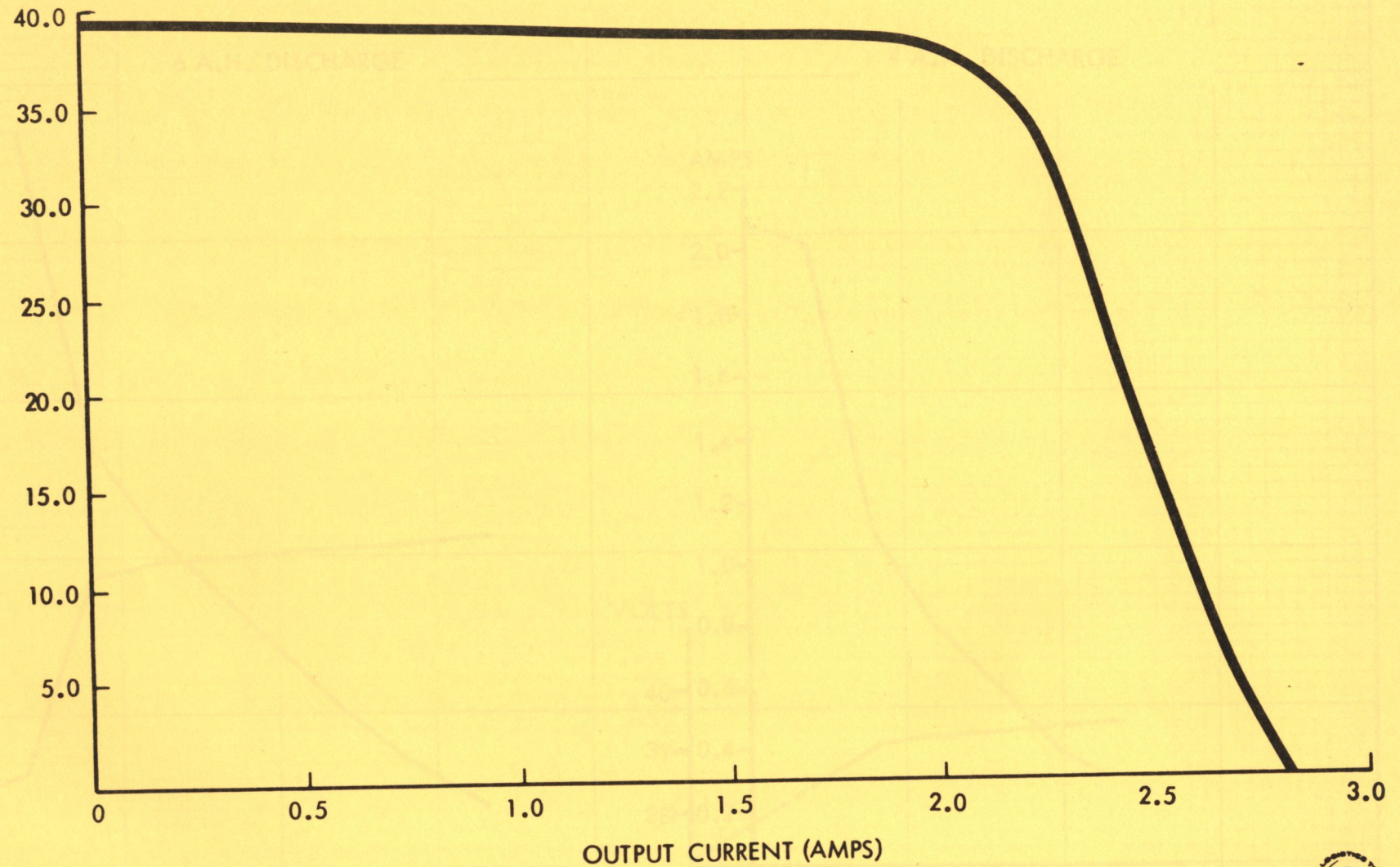
BATTERY CHARGER FUNCTIONAL DIAGRAM



EP-300E

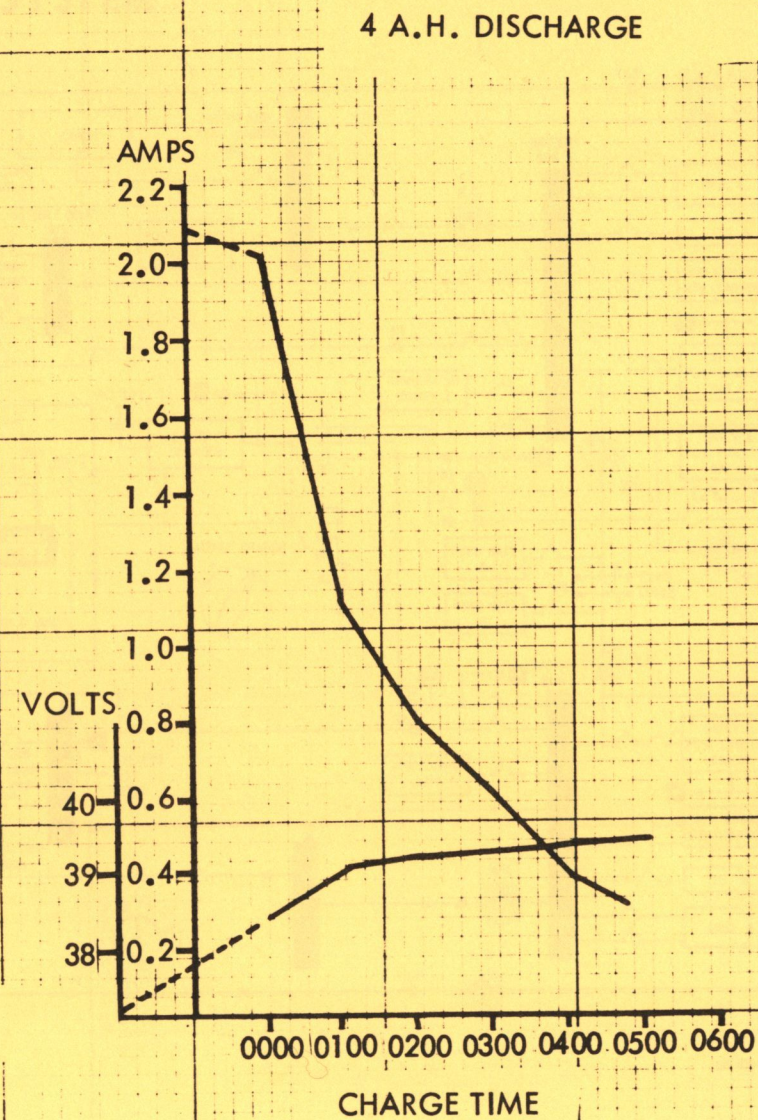
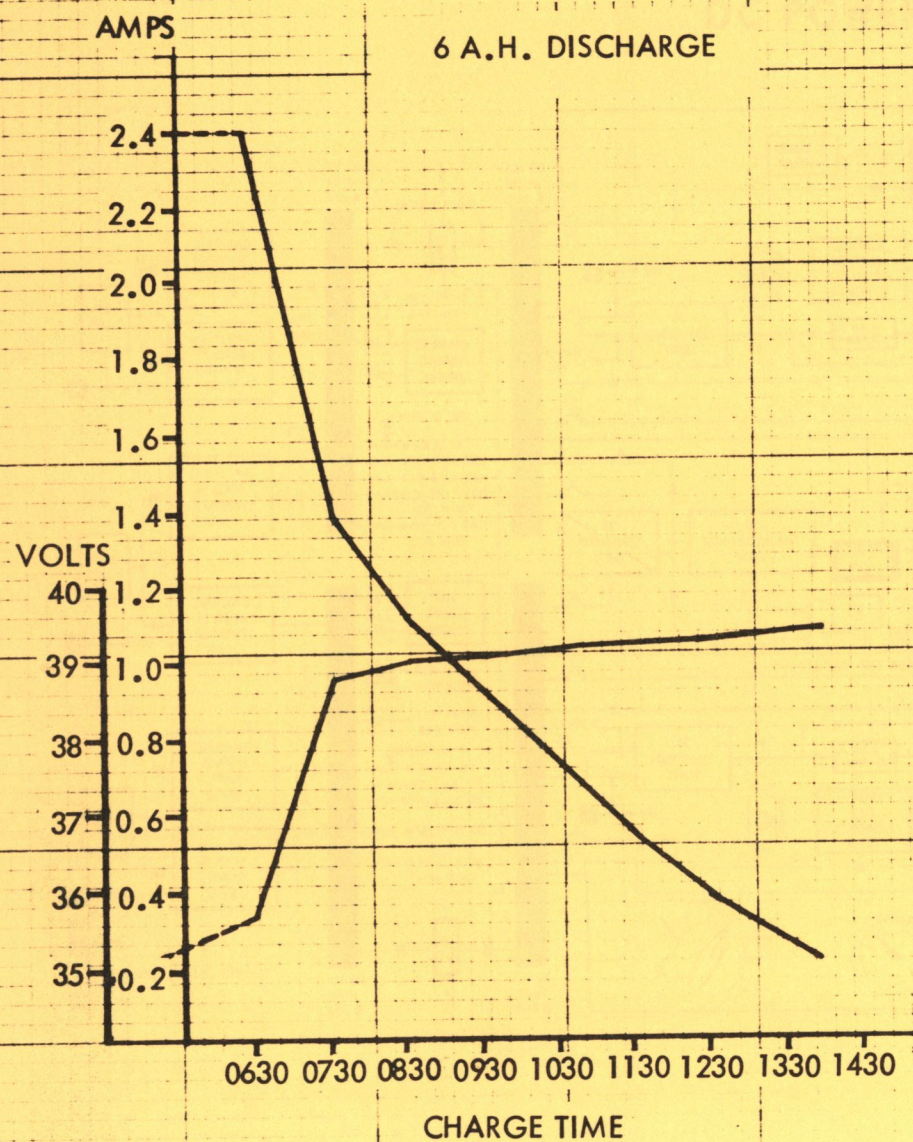
CURRENT VS VOLTAGE REGULATION CURVE

OUTPUT VOLTAGE
(VOLTS)



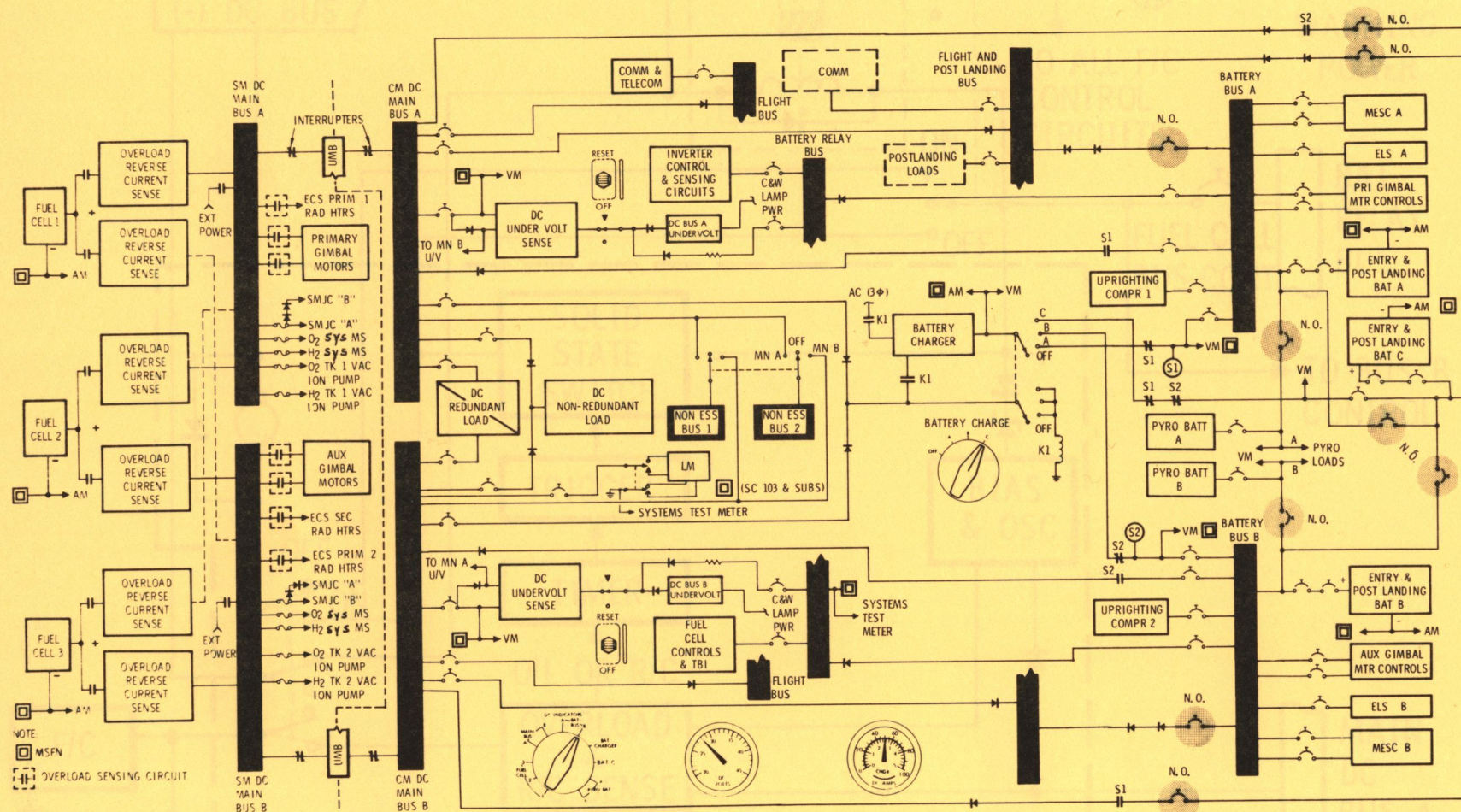
EP-009 A

BATTERY RECHARGE CHARACTERISTICS

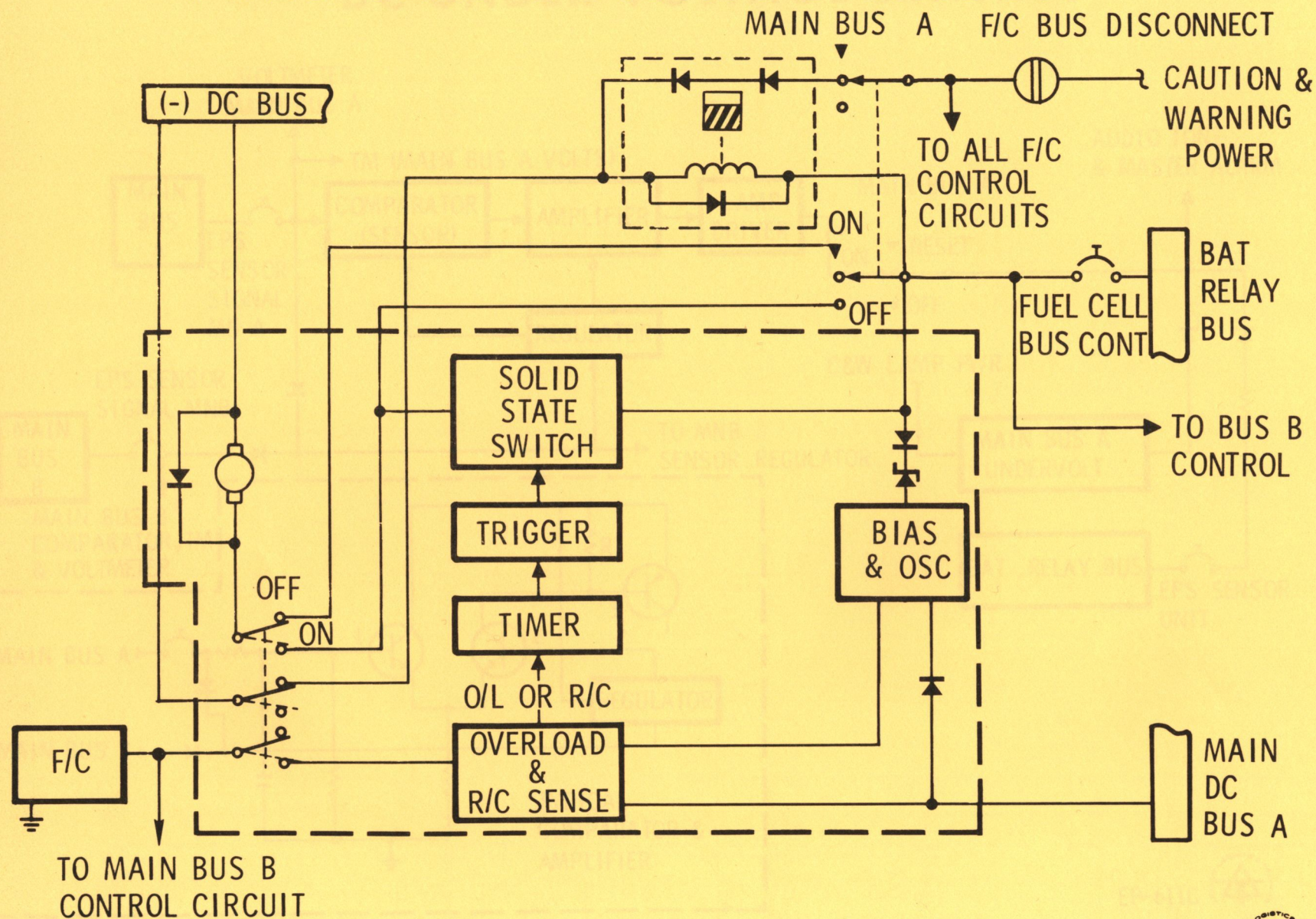


EPS POWER DISTRIBUTION

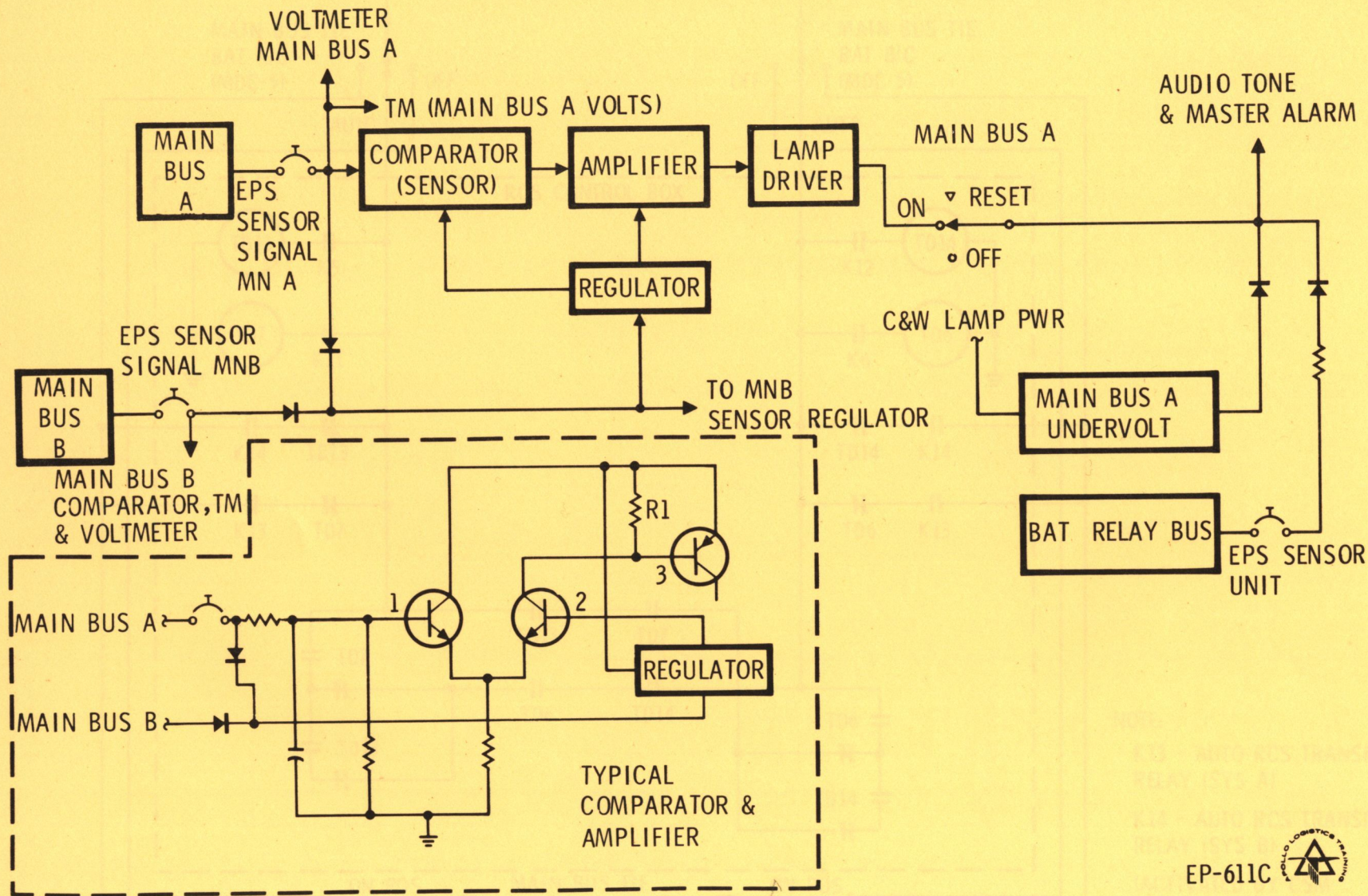
DC POWER SYSTEM



FUEL CELL CONTROL CIRCUIT



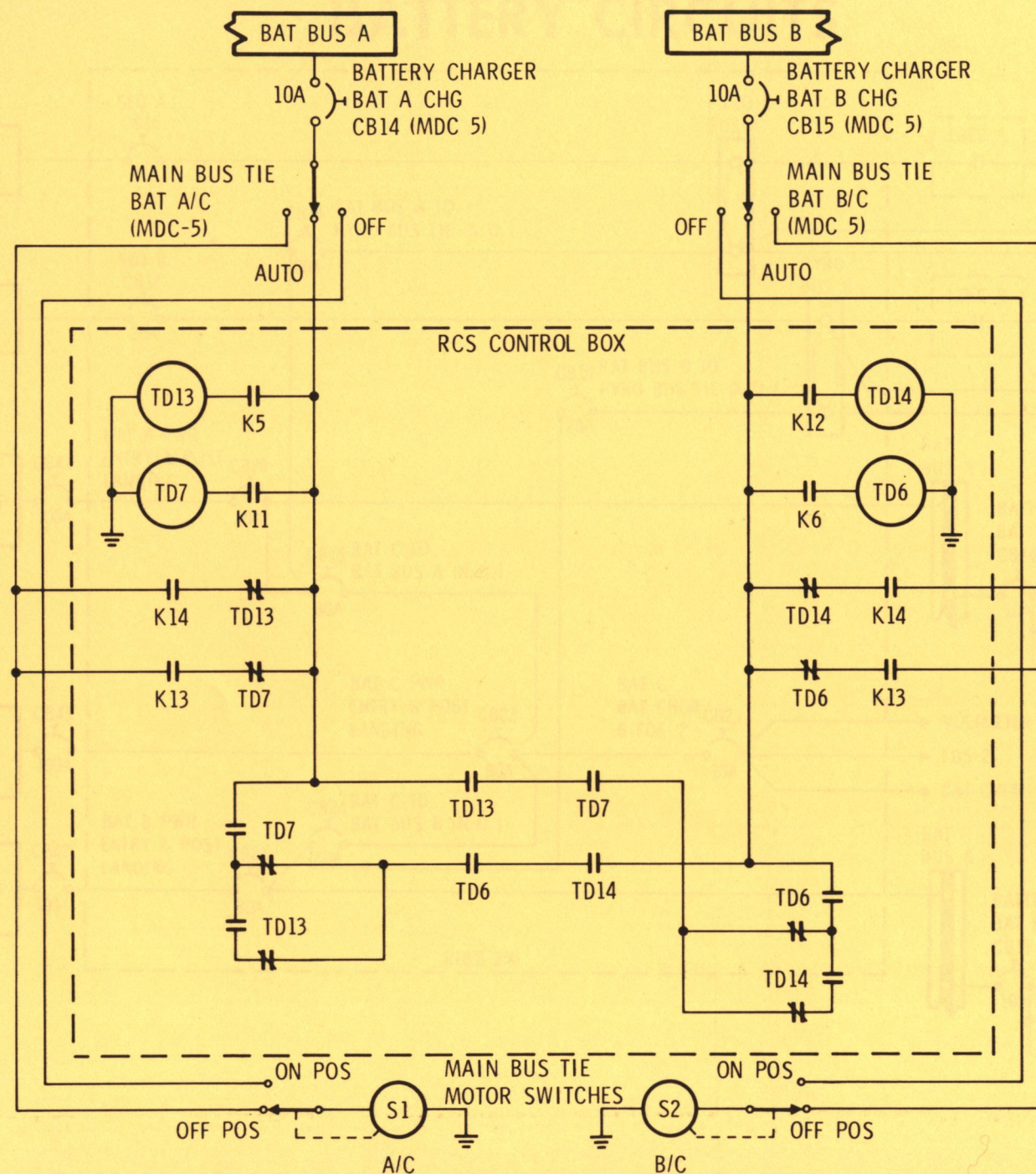
DC UNDER VOLTAGE SENSING



EP-611C



ENTRY BATTERY/MAIN BUS TIE CONTROL



NOTE:

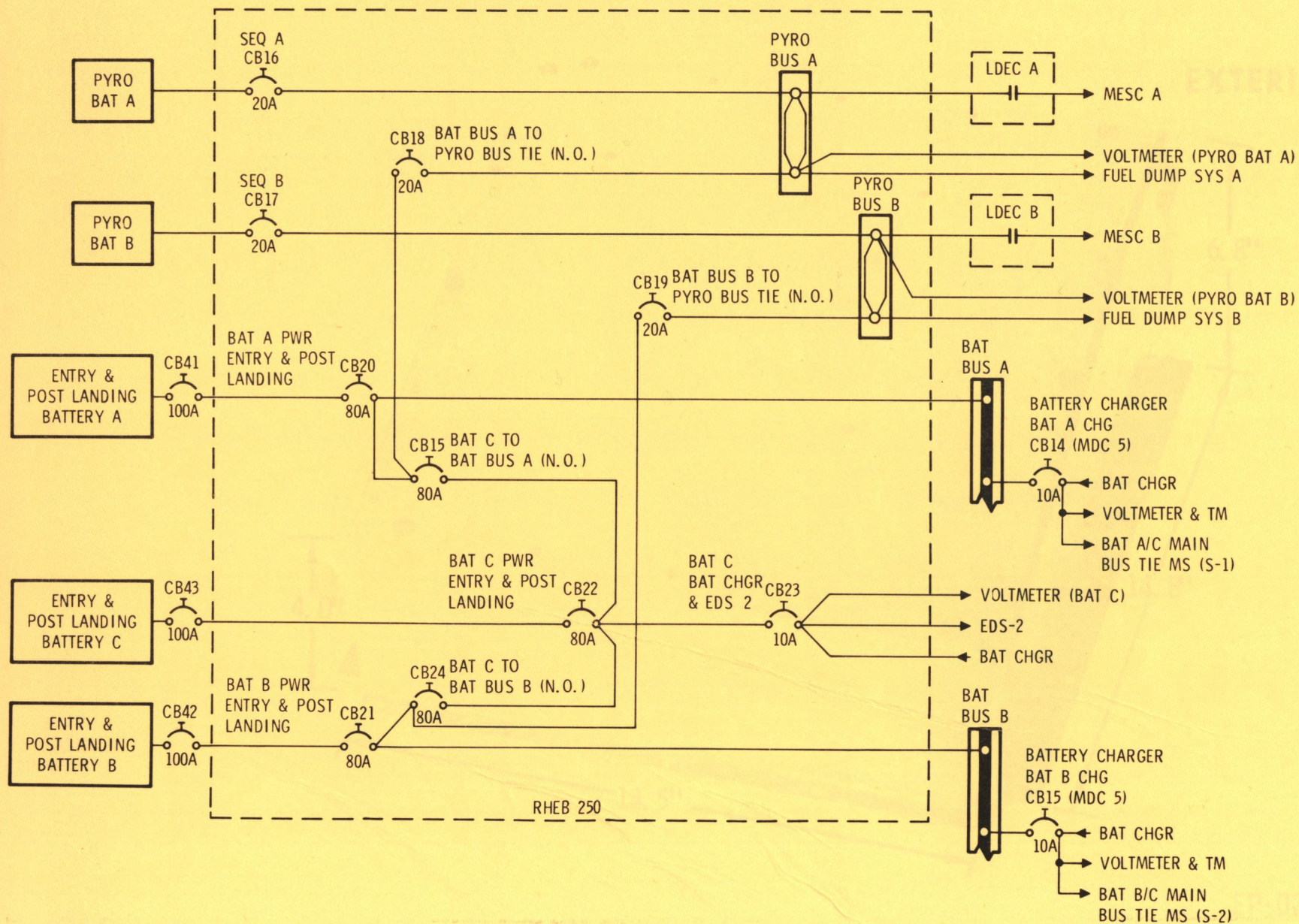
K13 - AUTO RCS TRANSFER RELAY (SYS A)

K14 - AUTO RCS TRANSFER RELAY (SYS B)

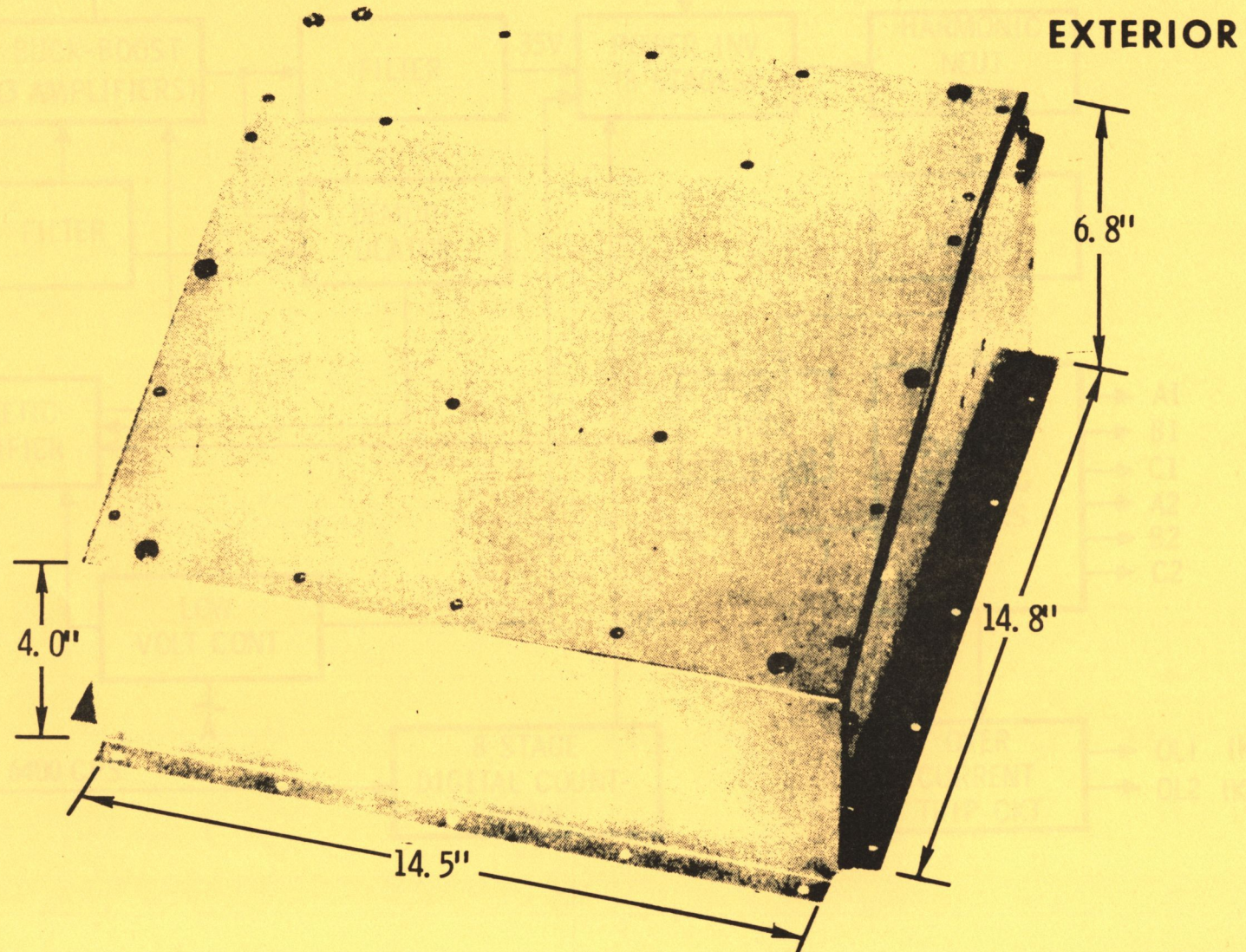
(ACTIVATED BY CSM SEPARATION)



BATTERY CIRCUITS



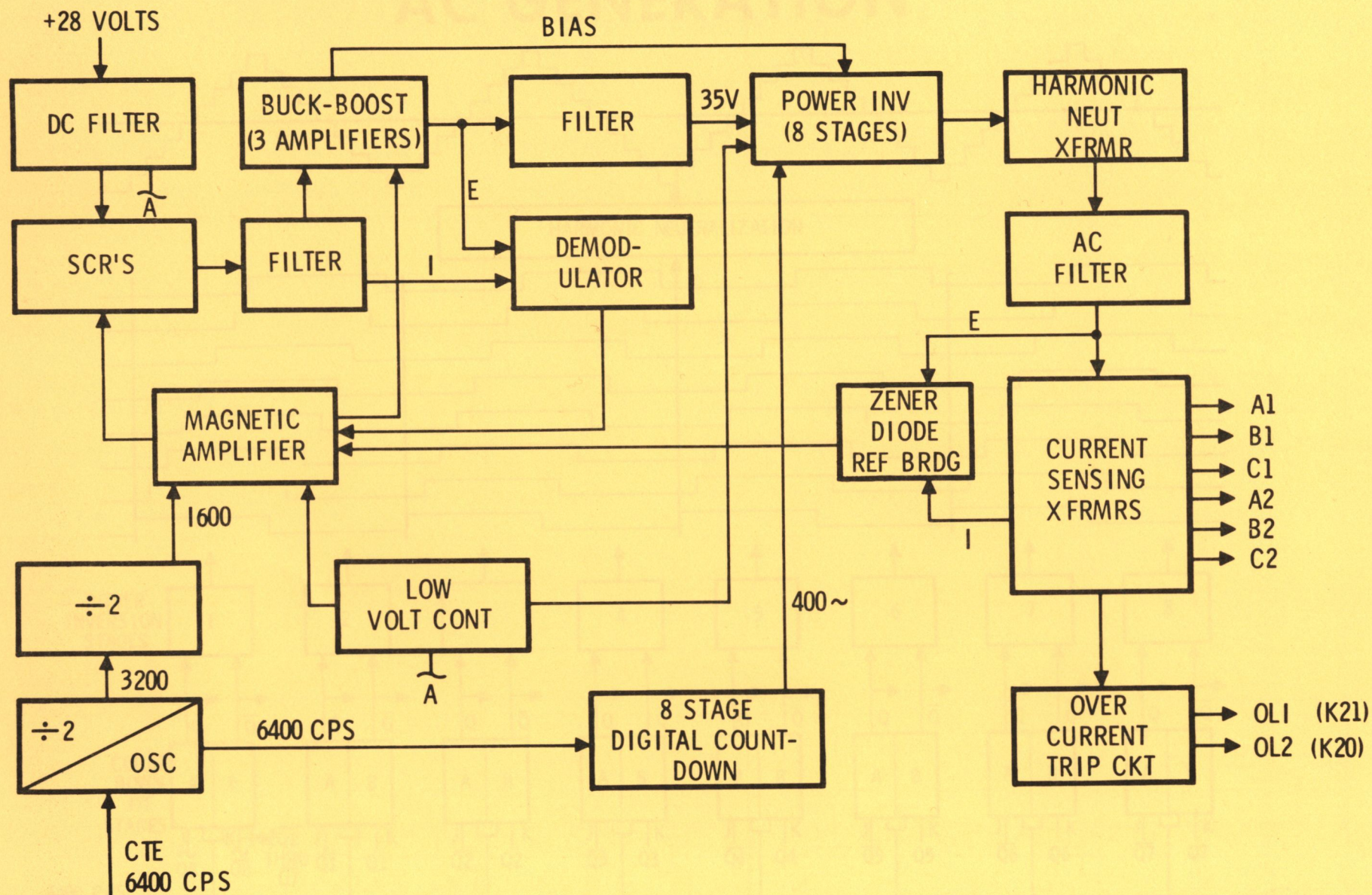
APOLLO STATIC INVERTER



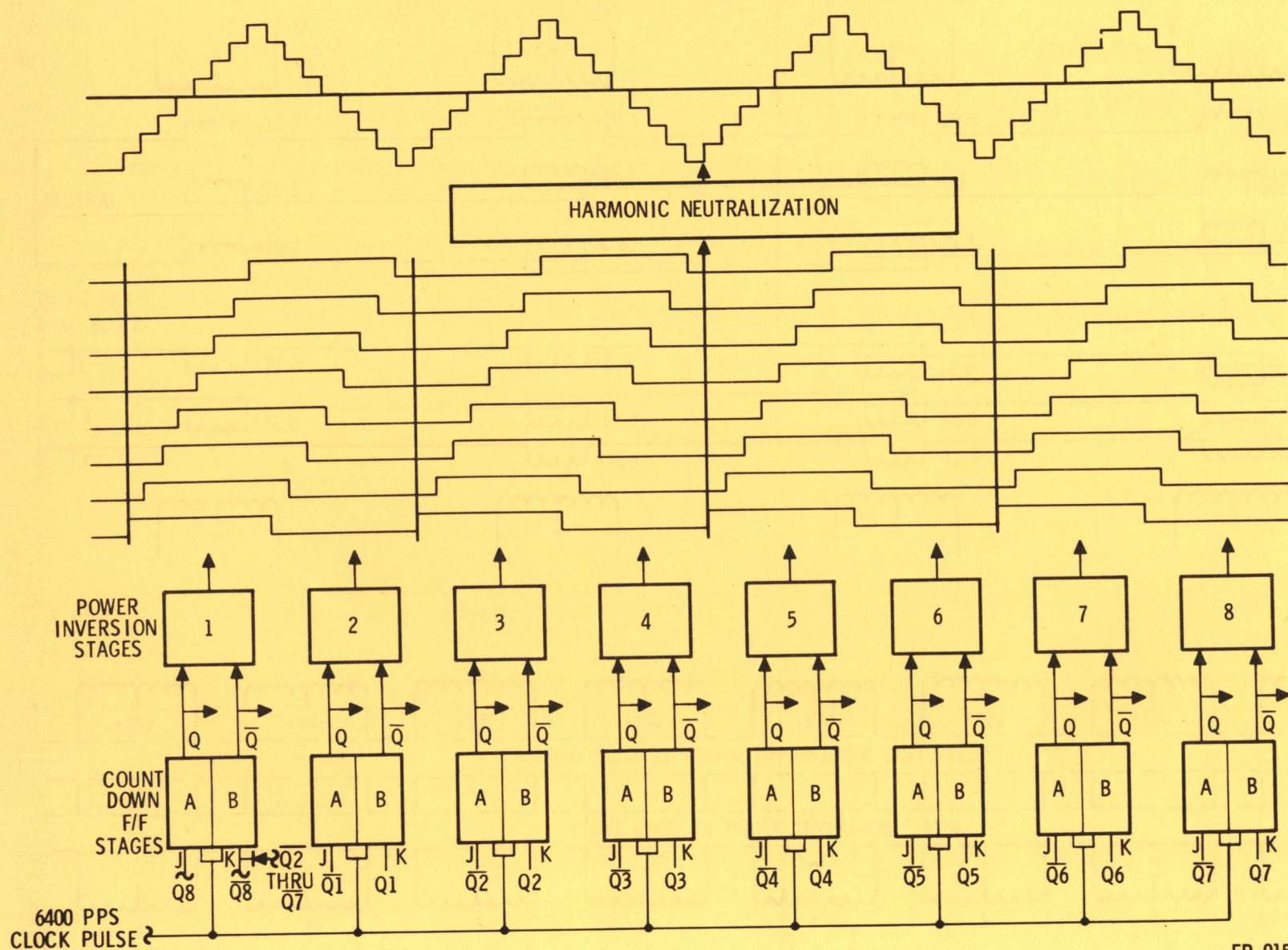
EP-025-1



INVERTER BLOCK DIAGRAM

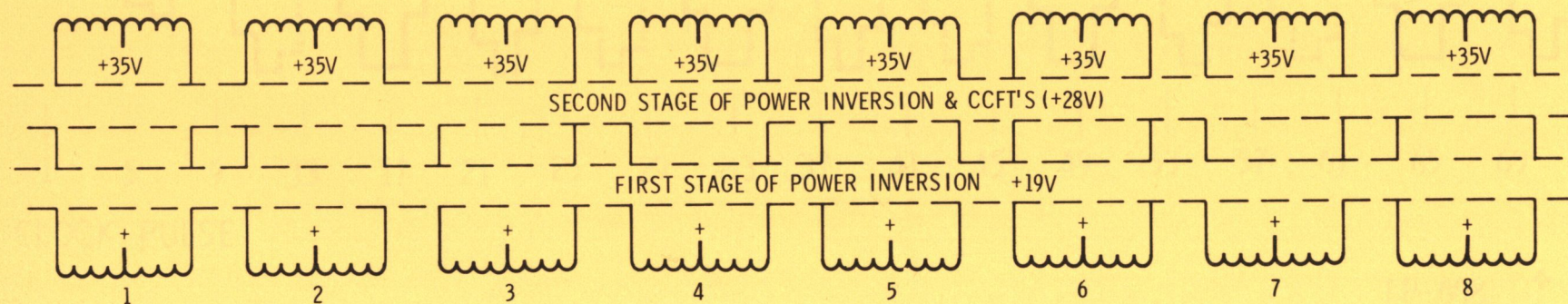
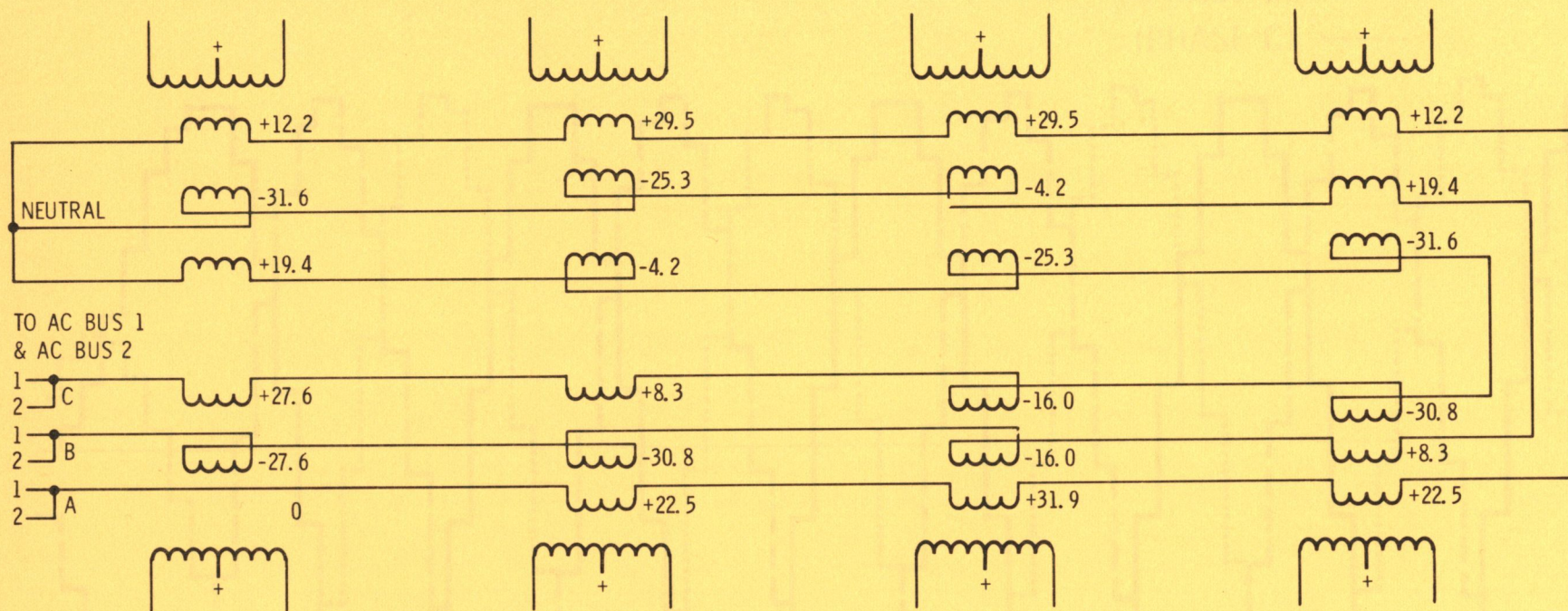


AC GENERATION



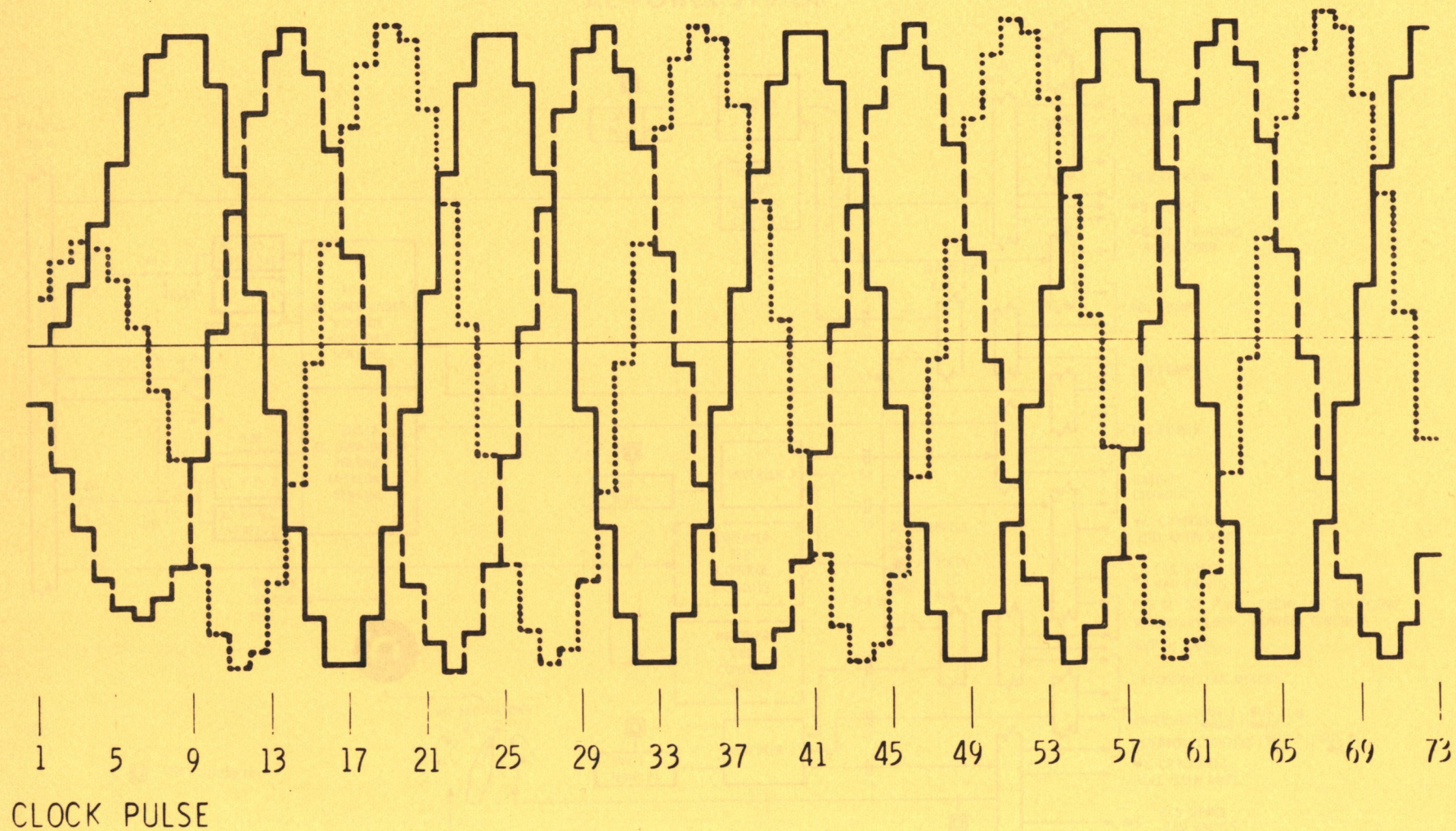
EP-015B

PHASING & HARMONIC NEUTRALIZATION



WAVE DEVELOPMENT

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

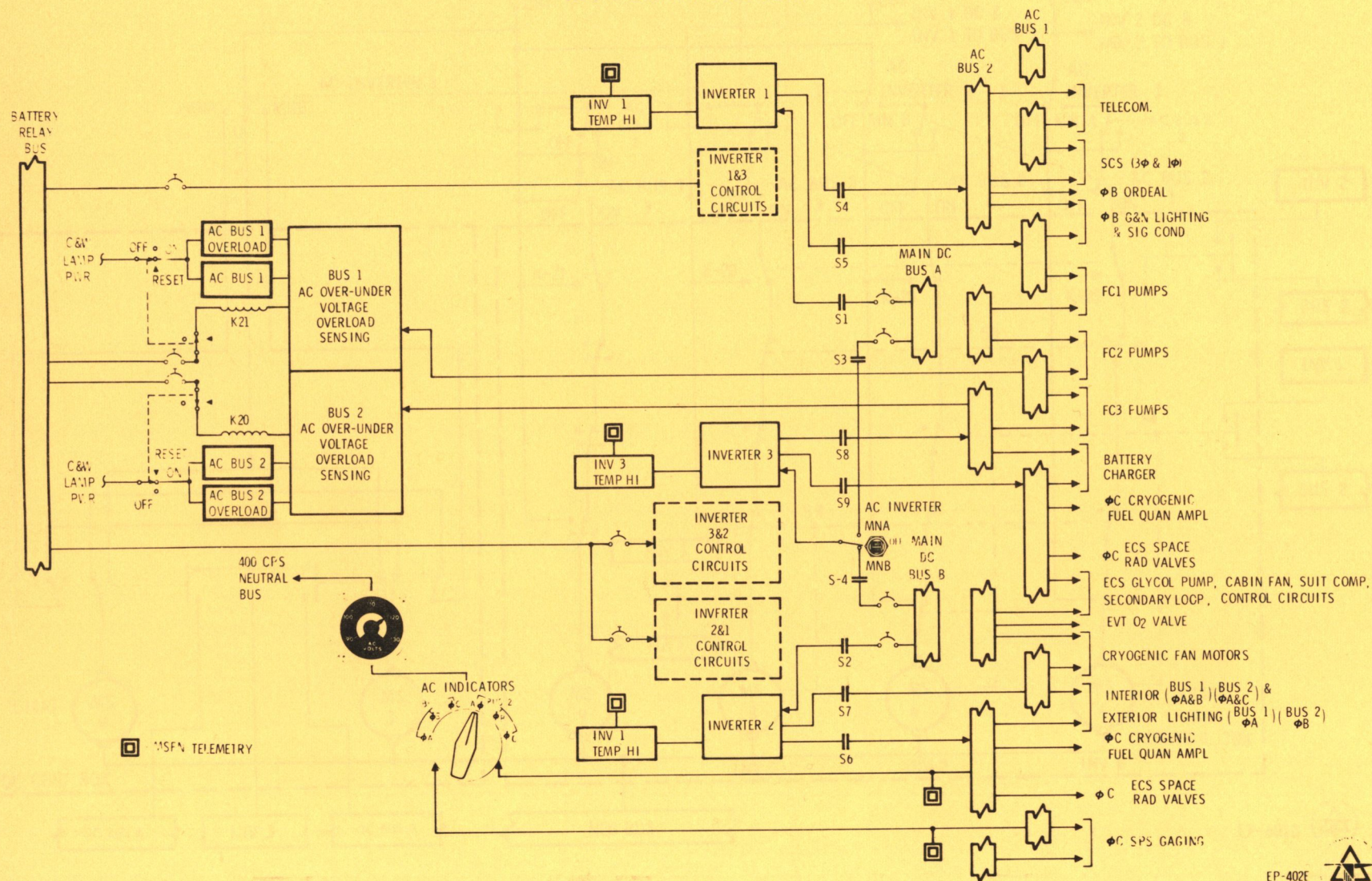


FP-608

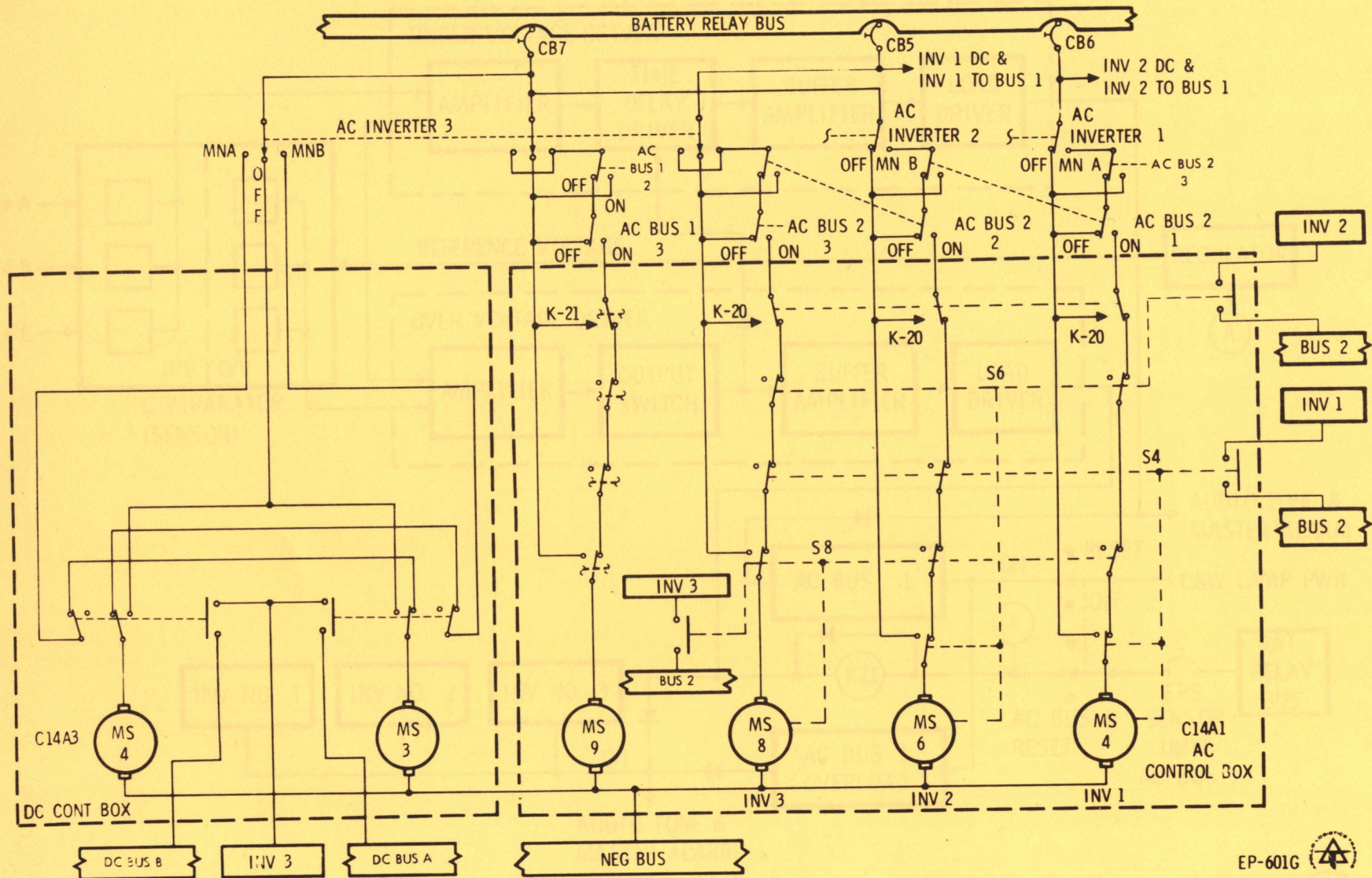


EPS POWER DISTRIBUTION

AC POWER SYSTEM

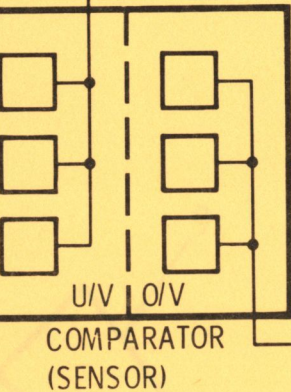


INVERTER CONTROL CIRCUIT

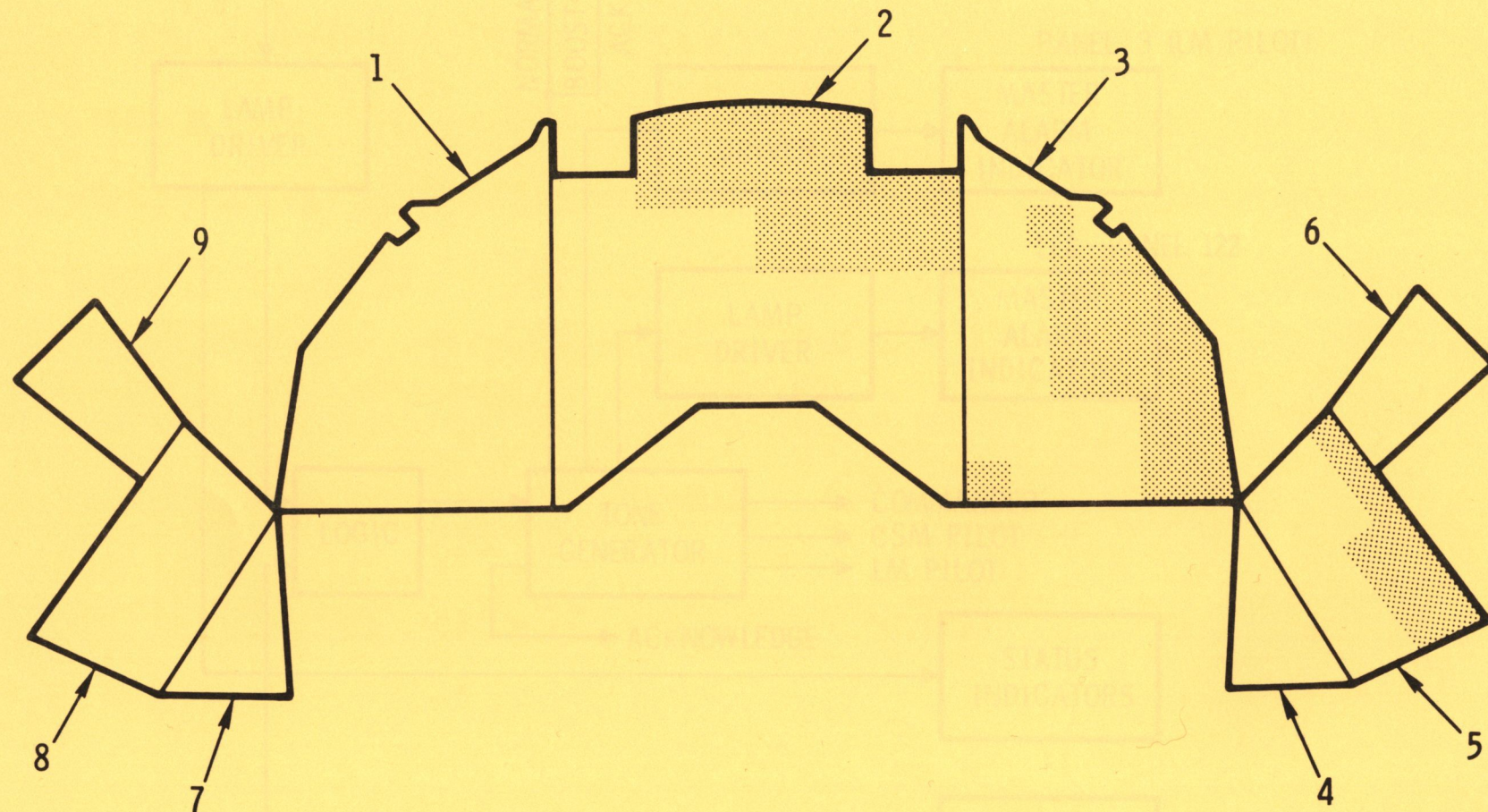


EP-601G 

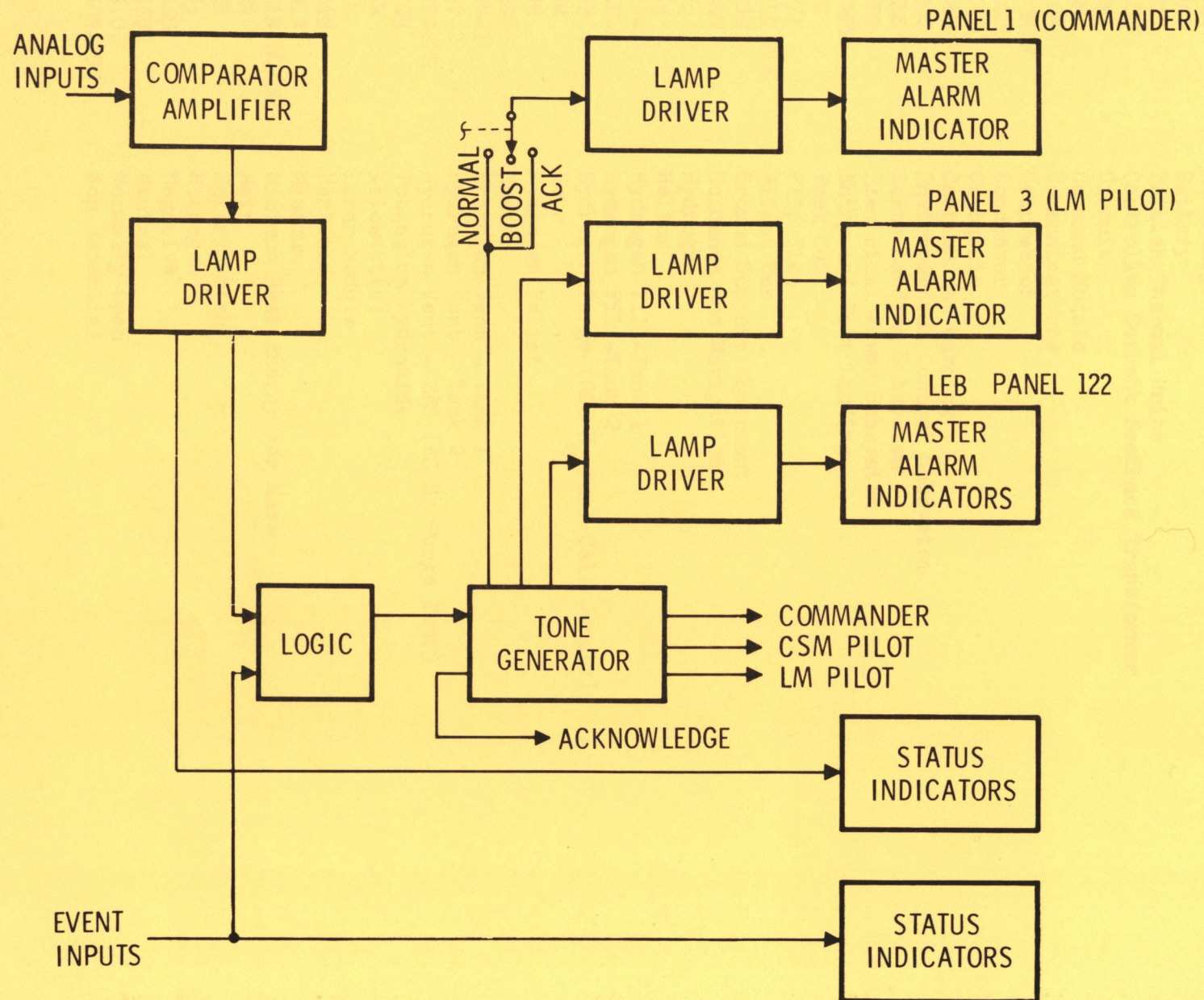
AC SENSING



MAIN DISPLAY CONSOLE LOCATOR



CAUTION & WARNING BLOCK DIAGRAM



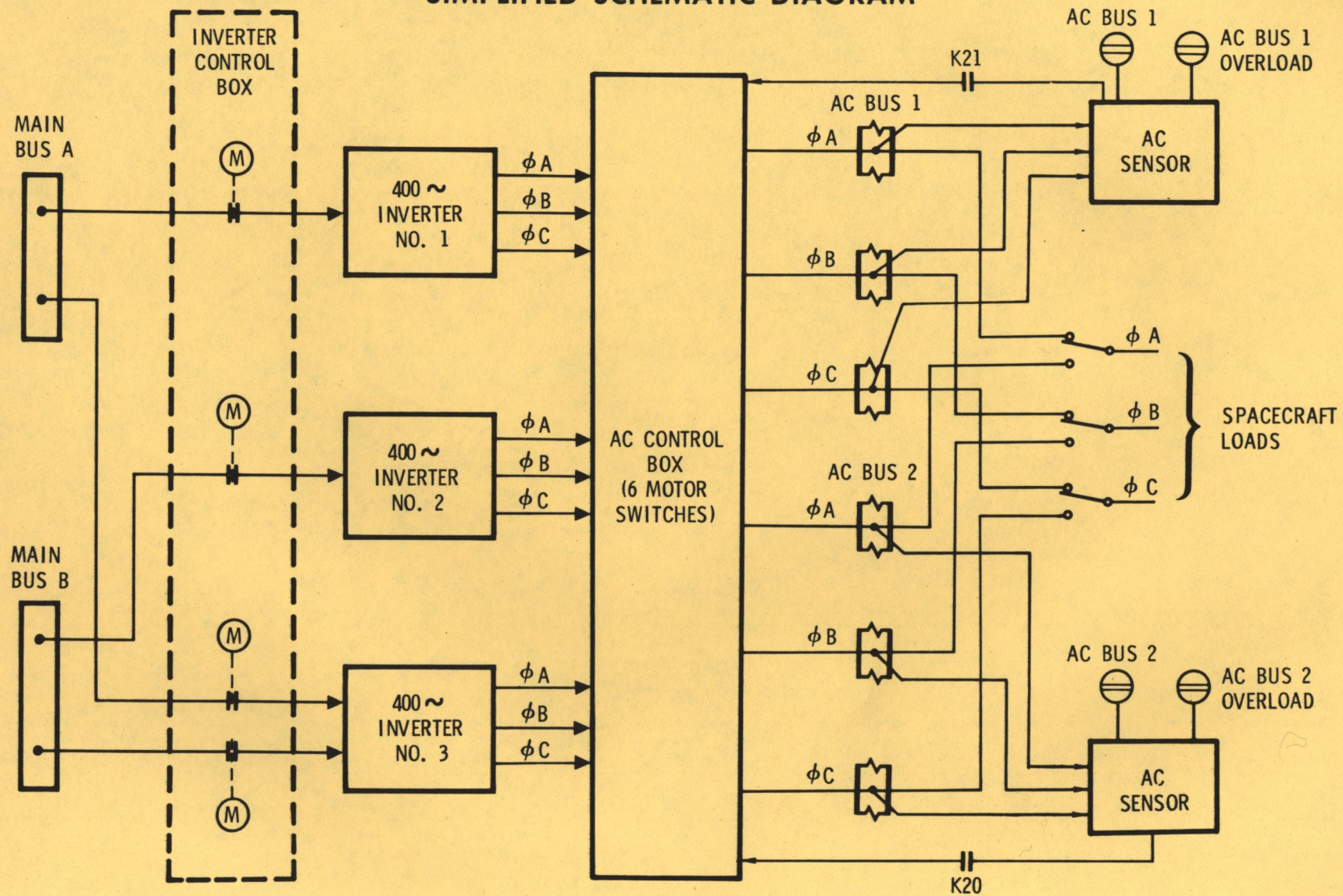
ACRONYMS

AH	Ampere Hour(s)
AM	Ammeter
AMPS	Amperes
AUX	Auxiliary
BAT	Battery
BTU	British Thermal Units
CCFT	Controlled Current Feedback Transformer
CKT	Circuit
CM	Command Module
COMM	Communications
COMPR	Compressor
COND	Condensor
CRYO	Cryogenic
C&W	Caution and Warning
ECS	Environmental Control Subsystem
ELS	Earth Landing Subsystem
EPS	Electrical Power Subsystem
E&PL	Entry and Post Landing
FC	Fuel Cell
F/F	Flip Flop
BLT BUS	Flight Bus
GSE	Ground Support Equipment
G&N	Guidance and Navigation
H ₂	Hydrogen
He	Helium
HF-1	Hydrogen Fill-Tank 1
HF-2	Hydrogen Fill-Tank 2
HP	Hydrogen Purge (GSE H ₂ Fuel Cell Supply)
HR	Hour
HR	Hydrogen Relief
HTR	Heater
HV-1	Hydrogen Vent - Tank 1
HV-2	Hydrogen Vent - Tank 2
HV-EPS	Hydrogen Vent - EPS (FC H ₂ Purge Vent)
KOH	Potassium Hydroxide
KW	Kilowatt(s)
LM	Lunar Module
MAN	Manifold
MIN	Minimum
MIN DQ/DM	Minimum Heat Energy Per Mass
MN	Main
MS	Motor Switch
N ₂	Nitrogen
NEG	Negative
NEUT	Neutral
N.O.	Normally Open
NON-ESS	Non Essential

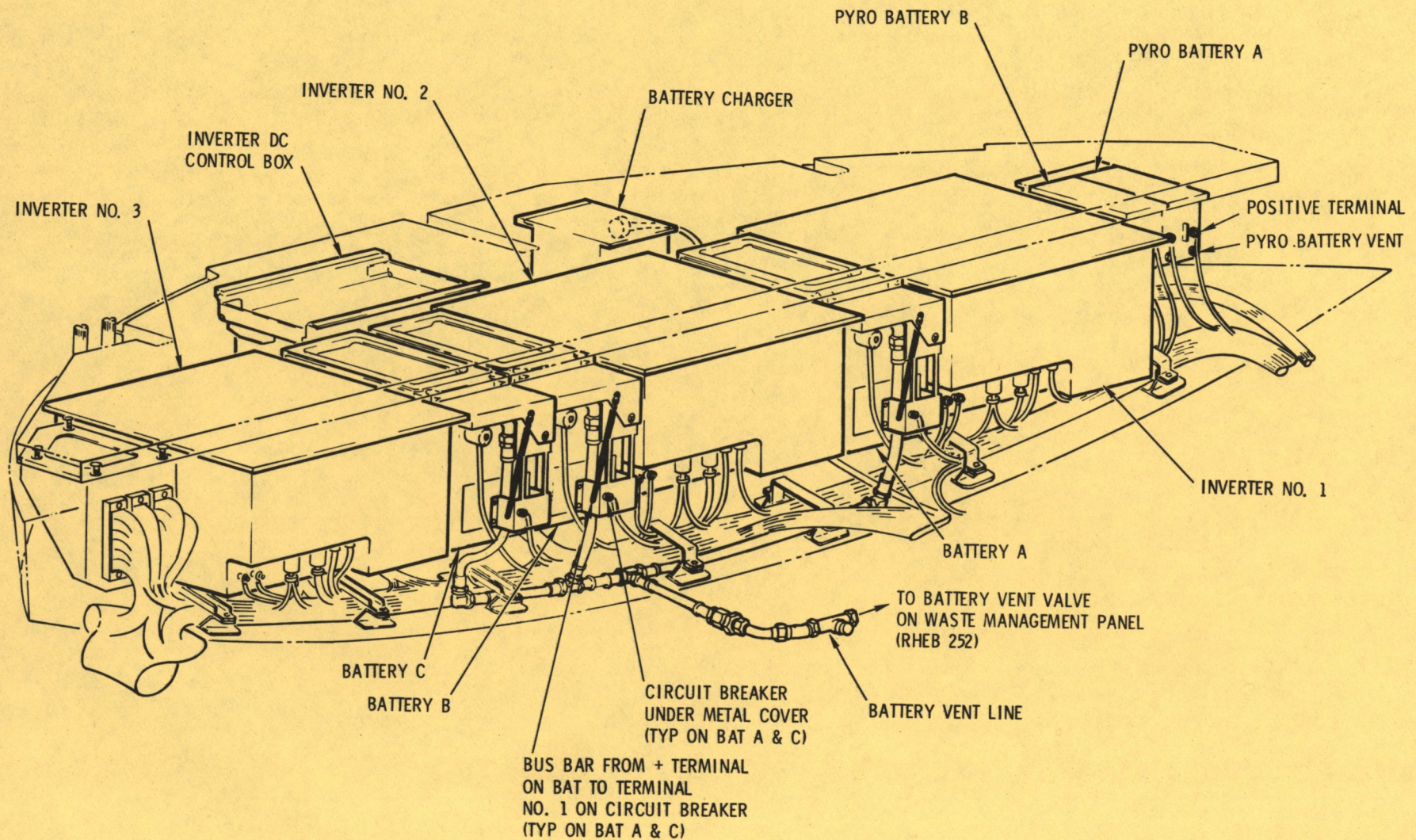
O ₂	Oxygen
OF-1	Oxygen Fill - Tank 1
OF-2	Oxygen Fill - Tank 2
OH	Hydroxyl Ion
O/L - R/C	Overload - Reverse Current
OP	Oxygen Purge (GSE O ₂ Fuel Cell Supply)
OR	Oxygen Relief
O/V	Overvoltage
OV-1	Oxygen Vent - Tank 1
OV-2	Oxygen Vent - Tank 2
OV-EPS	Oxygen Vent - EPS (FC O ₂ Purge Vent)
p ^H	Hydrogen Ion Concentration
POS	Positive
PPM	Parts Per Million
PPS	Pulses Per Second
PRI	Primary
PS	Pressure Switch
PSIA	Pounds Per Square Inch Absolute
PSIG	Pounds Per Square Inch Gauge
PWR	Power
REGEN	Regenerator
RCS	Reaction Control Subsystem
SC	Spacecraft
SEC	Secondary
SECS	Sequential Events Control Subsystem
SIG COND	Signal Conditioner
SM	Service Module
SMJC A	Service Module Jettison Controller A
SMJC B	Service Module Jettison Controller B
SOV	Shut Off Valve
SPEC	Specification
SPS	Service Propulsion Subsystem
SW	Switch
T/D	Time Delay
U/V	Undervoltage
VGP	Vehicle Ground Point
VM	Voltmeter
XDUCER	Transducer
XSTR	Transister Cycle

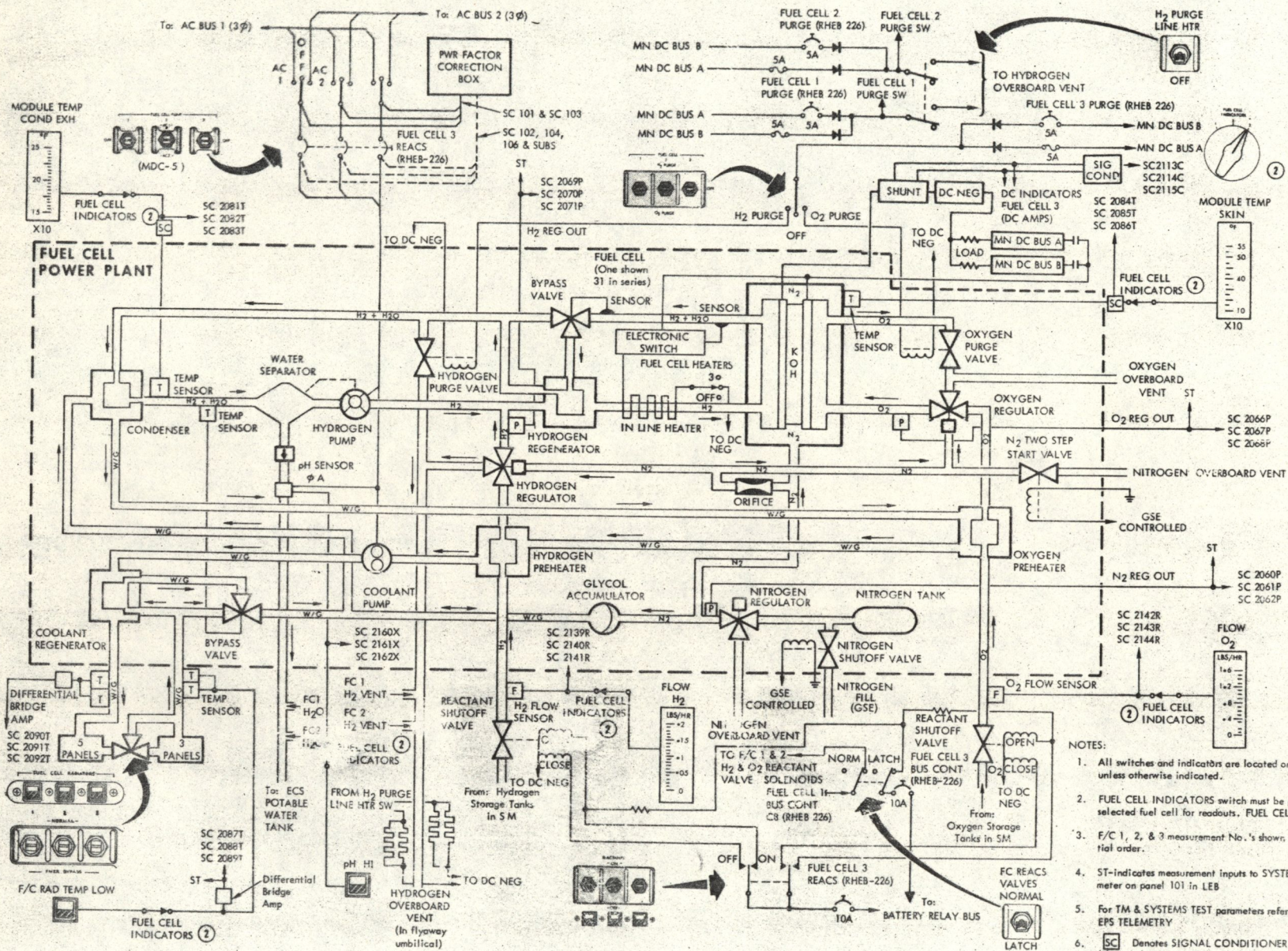
AC POWER DISTRIBUTION

SIMPLIFIED SCHEMATIC DIAGRAM



EPS COMPONENTS LOWER EQUIPMENT BAY (BLOCK II)





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
6. SC Denotes SIGNAL CONDITIONER (if none shown, conditioner is integral part of sensor)

SM-2A-1178C