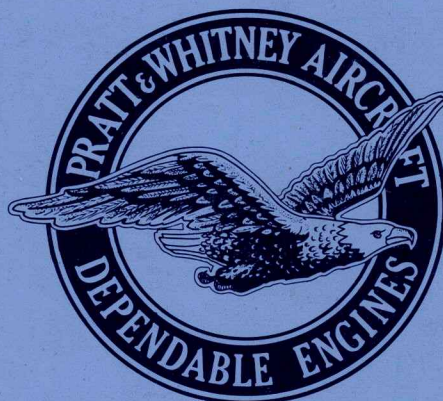


APOLLO FUEL CELL POWERPLANT  
NASA-NR PRESENTATION  
AT P&WA SWEF  
AUGUST 7-8, 1968



**Pratt & Whitney Aircraft** DIVISION OF UNITED AIRCRAFT CORPORATION

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EAST HARTFORD, CONNECTICUT

APOLLO FUEL CELL POWERPLANT  
NASA-NR PRESENTATION  
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Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION





*Papineau*

~~233-8553~~

NR SD DNY

PW PWRCEL EH

NR/SD WCO 6/28/68 4:30PM LR

NORTH AMERICAN ROCKWELL CORPORATION

SPACE DIVISION

12214 LAKEWOOD BOULEVARD

DOWNEY, CALIFORNIA

ATTENTION: MR. D. OVIST, ADMINISTRATIVE BUYER

APOLLO MATERIAL - DEPT 41-653

BLDG NO. 1 AA90

SUBJECT: APOLLO FUEL CELL EXTENDED MISSION LIFE REQUIREMENTS

REFERENCES: (A) NR LETTER M8MA4-3-2131, DATED 22 APRIL 1968

(B) P&WA LETTER OD-2962, DATED 6 JUNE 1968

OD-3006

-----  
AS A RESULT OF RECENT CORRESPONDENCE (REFERENCES A & B) AND DISCUSSIONS WITH NR PERSONNEL ABOUT POSSIBLE REQUIREMENTS FOR EXTENDED FUEL CELL POWERPLANT OPERATING TIMES, IT SEEMS APPROPRIATE TO SUMMARIZE PRESENT QUALIFICATION STATUS AND POTENTIAL CAPABILITY FOR NR'S INFORMATION AND CONSIDERATION.

IN AUGUST, 1965, THE BLOCK I APOLLO FUEL CELL POWERPLANT QUALIFICATION TEST WAS COMPLETED. THE POWERPLANT WAS QUALIFIED FOR 12 STRTS AND 400 HOURS OF TOTAL LOAD TIME INCLUDING 366 HOURS (NOMINAL (14 DAYS) OF SIMULATED MISSION ENDURANCE. THE VIBRATION TEST SIMULATING LAUNCH CONDITIONS WAS CONDUCTED AFTER 18 HOURS OF LOAD TIME.

IN DECEMBER, 1966, THE BLOCK II APOLLO FUEL CELL COMPONENT QUALIFICATION TEST UNDER THE NR BASIC BLOCK II PURCHASE ORDER WAS COMPLETED. THE BLOCK II POWERPLANT WAS QUALIFIED FOR 8 STARTS (6 RESTARTS) AND 501 HOURS OF TOTAL LOAD TIME INCLUDING 459 HOURS (19 DAYS) OF SIMULATED MISSION ENDURANCE. THE VIBRATION TEST SIMULATING LAUNCH CONDITIONS WAS CONDUCTED AFTER 26 1/2 HOURS OF LOAD TIME. THE TEST WAS CONTINUED WITH A DIFFERENT LOAD PROFILE AND COOLANT RETURN REQUIREMENTS UNDER NASA CONTRACT NAS 9-4476. THE PRIMARY GOAL WAS A TOTAL COMBINED LOAD TIME OF 720 HOURS AND THE SECONDARY GOAL WAS A TOTAL COMBINED LOAD TIME OF 1000 HOURS. THE TEST WAS TERMINATED AFTER A TOTAL COMBINED LOAD TIME OF 941 HOURS AND THE PRIMARY GOAL WAS ACHIEVED.

IN SUMMARY THE BLOCK II APOLLO FUEL CELL POWERPLANT IS QUALIFIED FOR EITHER 12 STARTS AND 400 HOURS TOTAL LOAD TIME OR 8 STARTS AND 501 HOURS TOTAL LOAD TIME. THIS MAY BE EXTENDED TO 720 HOURS TOTAL LOAD TIME, IF THE NASA SUPPORTED EXTENSION IS ACCEPTED. THIS QUALIFICATION STATUS INCLUDES SUCCESSFUL COMPLETION OF A SIMULATED MISSION AFTER THE LAUNCH SIMULATING VIBRATION TEST WITH UP TO 26 1/2 HOURS OF LOAD TIME ACCUMULATED PRIOR TO THE VIBRATION TEST.

APOLLO FUEL CELL LIFE IS A FUNCTION OF TIME AND TEMPERATURE. IN ORDER TO ESTABLISH A CONSISTENT BASIS FOR COMPARISON WE CONSIDER HOT TIME AS THE TIME ABOVE 300F. THE BLOCK II QUALIFICATION TEST AND 488 HOURS OF HOT TIME AFTER THE VIBRATION TEST NOT INCLUDING THE NASA TEST EXTENSION. INCLUDING THE NASA EXTENSION 952 HOURS OF HOT TIME WERE ACCUMULATED AFTER THE VIBRATION TEST.

WE HAVE REVIEWED THE GROUND TEST TIME EXPERIENCED ON S/C 017 AND S/C 020 PRIOR TO LAUNCH AND THE ANTICIPATED GROUND TEST TIME FOR S/C 101 AND FUTURE MISSIONS IN COMPARISON WITH THE QUALIFICATION STATUS OF THE POWERPLANTS. PAST EXPERIENCE (S/C 020) SHOWS ABOUT 76 HOURS HOT TIME REQUIRED FOR CDDT AND 36 HOURS HOT TIME REQUIRED



FOR LAUNCH. FOR MANNED MISSIONS, S/C 101 AND ON, WE UNDERSTAND APPROXIMATELY 72 HOURS OF VACUUM CHAMBER HOT TIME SHOULD BE ADDED. THUS, ASSUMING NO SIGNIFICANT CDDT HOLDS, LAUNCH COUNT-DOWN HOLDS, OR RECYCLES, IT APPEARS THAT BLOCK II POWERPLANTS WILL ACCUMULATE A MINIMUM OF 234 HOURS HOT TIME PRIOR TO LAUNCH (AND VIBRATION). THUS THE INTENDED 10 DAY MISSION TOTAL MINIMUM HOT TIME WILL BE ON THE ORDER OF 480 HOURS; WELL WITHIN THE BLOCK II QUALIFICATION TEST TOTAL. HOWEVER, LAUNCH VIBRATION WILL OCCUR AFTER CONSIDERABLY MORE HOT TIME THAN IT DID ON THE BLOCK II QUALIFICATION TEST. ANALYSIS OF THE LIMITED DATA AVAILABLE INDICATES THAT 240 HOURS OF HOT TIME CAN BE ACCUMULATED PRIOR TO LAUNCH VIBRATION WITHOUT JEOPARDIZING THE SUCCESS OF A 10 DAY MISSION. IN ADDITION, AN EARTH ORBIT MISSION MAY BE SAFETY ADJUSTED IF GRADUAL SHORTING APPEARS DUE TO THE EFFECTS OF VIBRATION AFTER PROLONGED OPERATION.

THE SIGNIFICANT DATA AVAILABLE IS TABULATED BELOW:

TEST	HOT TIME	SHORTING AFTER	HOT TIME	SHORTING
	BEFORE VIBRATION,	VIBRATION	AFTER VIBRATION	
-----	-----	-----	-----	-----
BLK I				
QUAL TEST				
P650717	81.9(VIB#1)	NO	473.5	NO
P650717	555.4(VIB#2)	YES	100	YES*
P650718	86.4(VIB#1)	NO	408	NO
P650718	494.4(VIB#2)	YES	0	--

BLK II

QUAL TEST

P650718	120	NO	488	NO
---------	-----	----	-----	----

P650718

(EXTENDED)	120	NO	952	NO
------------	-----	----	-----	----

DEVELOPMENT

TESTING

X-404-16	442	YES	200	YES
----------	-----	-----	-----	-----

X-405-11	470	YES	0	--
----------	-----	-----	---	----

NASA

POWERPLANT

P650725	575	YES	TEST NOT YET RUN
---------	-----	-----	------------------

S/C-101

ESTIMATE

240 MIN.	NO	240	NO
----------	----	-----	----

\* 70 HOURS AFTER VIBRATION TEST NO. 2 STACK SHORTING WAS EQUIVALENT TO 2 AMPS AND 30 HOURS LATER THE POWERPLANT WAS SHUTDOWN DUE TO STACK SHORTING EQUIVALENT TO 5 AMPS

FROM THE ABOVE, IT APPEARS THAT SUCCESSFUL COMPLETION OF A 400 HOUR MISSION AFTER VIBRATION HAS BEEN DEMONSTRATED WITH NOT MORE THAN 120 HOT HOURS BEFORE SIMULATED LAUNCH. CERIA/COBALT TREATED ELECTRODES, HOWEVER, HAVE SHOWN SUBSTANTIALLY INCREASED RESISTANCE TO SHORTING RESULTING IN GREATLY EXTENDED POWERPLANT LIFE POTENTIAL. THIS ADVANTAGE IS ALSO EXPECTED TO POSTPONE ANY PREMATURE SHORTING THAT MIGHT OCCUR WHEN LAUNCH VIBRATION IS EXPERIENCED AFTER EXTENDED



OPERATIONS OF THE POWERPLANTS ON THE GROUND. IT IS ESTIMATED, BASED ON THE PLANNED GROUND TEST PROGRAM OF REFERENCE (A), THAT ABOUT 400 HOURS OF HOT TIME CAN BE ACCUMULATED PRIOR TO LAUNCH ON A CERIA/ COBALT TREATED POWERPLANT WITHOUT JEOPARDIZING THE SUCCESS OF AN APOLLO MISSION.

WE THEREFORE SUGGEST NR GIVE CONSIDERATION TO THE FOLLOWING ALTERNATIVES:

1. PROVIDE FOR A TEST PROGRAM TO DETERMINE THE MAXIMUM HOT TIME WHICH CAN BE ACCUMULATED ON THE BLOCK II B/M POWERPLANT PRIOR TO LAUNCH VIBRATION WITH ASSURANCE OF SUCCESSFULLY COMPLETING 336 HOURS (14 DAYS) OF MISSION TIME AFTER VIBRATION. INCLUDED IN THIS PROGRAM SHOULD BE A CONSIDERATION OF VIBRATION EFFECTS DUE TO IN-FLIGHT SPS ENGINE FIRING.
2. MINIMIZE POWERPLANT PRELAUNCH HOT TIME ASSURING THAT IT DOES NOT EXCEED THE DEMONSTRATED 120 HOURS FOR LUNAR MISSIONS OR THE ESTIMATED 240 HOURS FOR EARTH ORBIT MISSIONS.
3. QUALIFY THE BLOCK II POWERPLANT WITH CE/CO INCLUDING VIBRATION TESTING AFTER ACCUMULATION OF REALISTICALLY EXPECTED GROUND TEST HOT TIME.

P&WA, AS STATED IN REFERENCE (B), RECOMMENDS CE/CO QUALIFICATION AS REQUIRING THE LEAST EFFORT AND TIME, RESULTING IN MINIMUM CONSTRAINTS ON PRELAUNCH TEST TIME, AND SUBSTANTIALLY REDUCING THE RISK OF EXPENSIVE POWERPLANT REPLACEMENT OR OVERHAUL PRIOR TO LAUNCH DUE TO ACCUMULATED GROUND TEST TIME. OUR UNDERSTANDING OF APOLLO PROGRAM SCHEDULES LEADS US TO BELIEVE THIS CAN BE ACCOMPLISHED PRIOR TO THE S/C 106 MISSION. SHOULD NR DESIRE TO DISCUSS THIS MATTER FURTHER OR REVIEW EXISTING DEVELOPMENT AND QUALIFICATION TEST DATA IN MORE DETAIL, P&WA WILL ASSIST IN ANYWAY POSSIBLE.

UNITED AIRCRAFT CORPORATION

PRATT & WHITNEY AIRCRAFT DIVISO;

J. M. LEE

PROGRAM MANAGER

APOLLO FUEL CELL SYSTEM

ENDCORRECTIONS:

IN SECOND PARA , 3RD LINE ( ) SHOULD INCLUDE THE WORD NOMINAL

IN FIFTH PARA, 3RD LINE AFTER WORD TEST PLEASE ADD "RESULTED IN  
120 HOURS OF HOT TIME BEFORE THE LAUNCH SIMULATING VIBRATION TEST"  
AND 488 HOURS. . .

IN PARA AFTER TABLE STARTING "FROM THE ABOVE,. . .",  
2ND LINE , PLEASE UNDERLINE THE WORDS HAS BEEN DEMONSTRATED

END PLSACK

NR SD DNY



EEP

Collo Area

3700 hrs

20 cell  
amp short

743

accept 5 hrs

Equiv. time

100

2TV-1 C/S M 101

420

2TV-1 C/S M 103 unmanned

0

2TV-1 C/S M 103 manned

190

Total

710

743 equiv. hrs.

to get to 850 equiv. hrs.

50 hrs. @ 50 amps

- PRODUCTION PROGRAM
- FAILURE REPORTS
- WATER/GLYCOL SYSTEM
- PC3A-2 1000 HOUR CAPABILITY
- POST - BLOCK II PROGRAM SUPPORT



PRODUCTION PROGRAM

PRODUCTION EFFORT

POWERPLANTS DELIVERED

- BLOCK I . . . . . 37
- BLOCK II . . . . . 20
- OVERHAUL ACTIVITY . . . 63 - INCLUDING N<sub>2</sub> TANK, GLYCOL REPLACEMENTS 731-2-3 AND 723

POWERPLANTS TO BE DELIVERED

- BLOCK I . . . . . 0
- BLOCK II . . . . . 31 PLUS 6 UPDATES

HARDWARE

- VENDOR PARTS ON ORDER . . . . . 95%
- VENDOR PARTS RECEIVED . . . . . 71%
- P&WA FABRICATED PARTS MEETING POWERPLANT NEED DATES
- ELECTRODES IN HOUSE THROUGH 780 AND FIRST SET OF UPDATE POWERPLANTS

SHIPPING CONTAINERS

- TOTAL AVAILABLE . . . . . 6 SETS
- AT P&WA 8/7 . . . . . 1 1/3 SETS
- ONE SET REQUIRED AT P&WA 1 MONTH PRIOR TO POWERPLANT DELIVERY
- STAGNATION TURNAROUND TIME PER SET AT NR . . . . . 3 1/2 MONTHS



# Powerplant Delivery Schedule

## LEGEND

△ NEW POWERPLANTS

○ UPGRADED POWERPLANTS

● 8-23-67 P650749-740-743

▲ 9-25-67 P650745-746-747

▲ 11-12-67 P650748-749-750

▲ 1-15-68 P650751-752-753

▲ 3-7-68 P650754-755-756

● 4-22-68 P650739-742-743

▲ 7-1-68 P650757-758-759

▲ 7-22-68 P650760-761-762

▲ 8-19-68 P650763-764-765

▲ 9-9-68 P650766-767-768

▲ 10-14-68 P650769-770-771

▲ 11-21-68 P650772-773-774

▲ 11-25-68 P650775-776-777

▲ 12-16-68 P650778-779-780

○ 1-6-68 P650781-782-783

○ 1-31-68 P650784-785-786

▲ 3-7-69 P650787-788-789

▲ 4-4-69 P650791-792-793

▲ 4-28-69 P650794-795-796

▲ 5-26-69 P650798-799-800

▲ 6-10-69 P650802-803-804

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

1967

1968

1969

CALENDAR - 1968

NOTE: BLOCKED IN SYMBOL - DELIVERED



OUTSTANDING FAILURE REPORTS



# OUTSTANDING FAILURE REPORTS

<u>REPORT NO.</u>	<u>PART NAME</u>	<u>P/P NO.</u>	<u>FAILURE DATE</u>	<u>WHEN NOTICED</u>	<u>SYMPTOMS</u>	<u>STATUS OF ANALYSIS</u>
R.O.	N <sub>2</sub> PRESSURE TRANSDUCER	743 (O&R)	4/17/68 GO AHEAD DATE	BEGINNING OF GLYCOL SYSTEM FILL DURING ACCEPTANCE TEST AT P&WA.	LOW READING	1) FAILURE OCCURRED AT P&WA 2) FAILURE NOT TIME DEPENDENT
5064	INLINE HEATER CONTROL	764	7/16/68	DURING COOLDOWN PORTION OF SHUT- DOWN PROCEDURE OF ACCEPTANCE TEST AT P&WA.	ENERGIZED AT 345°F NOT 380°F	1) BENCH CHECKS CON- FIRMED FAILURE 2) RETURNED TO VENDOR ON 7/24/68
5067	N <sub>2</sub> FILL VALVE	764	7/30/68	POST TEST ELEC- TRICAL INSULATION CHECK OF ACCEP- TANCE TEST AT P&WA	LOW IN- SULATION RESIS- TANCE	PRELIMINARY VENDOR IN- VESTIGATION SHOWS COR- ROSION ON BACK OF CONNECTOR
5069	SECONDARY BYPASS VALVE	765	8/6/68	PRE-PERFORMANCE LOAD OPERATION	HIGH TCE	
<hr/>						
R.O.	H <sub>2</sub> PRESSURE TRANSDUCER	753	7/23/68	DURING OCP-1201 CHECKOUT IN S/C 104	LOW READING	WAITING RETURN OF PART

WATER/GLYCOL SYSTEM CONTAMINATION REVIEW

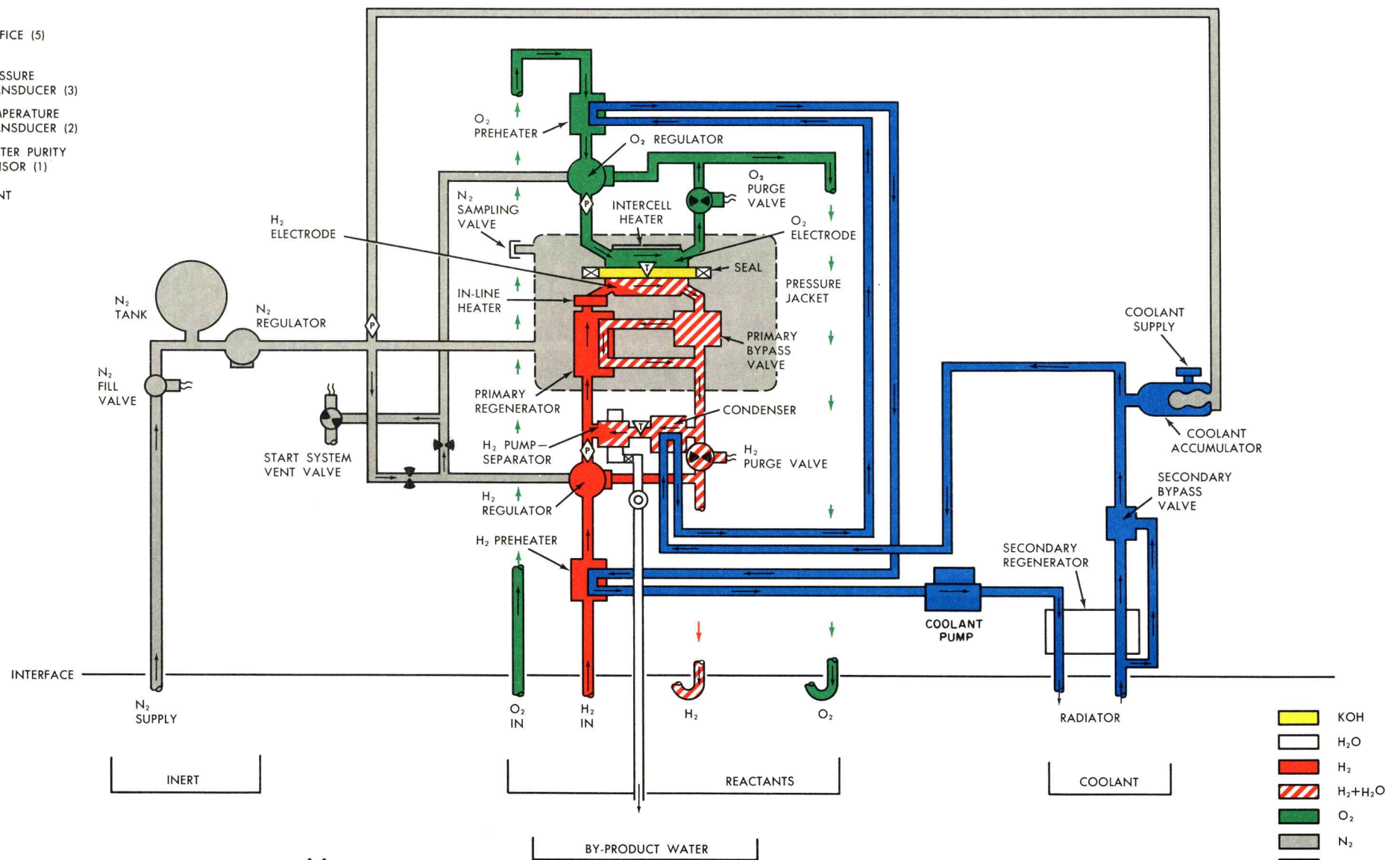


P&WA COOLANT LOOP DESIGN

- GLYCOL PUMP AND SECONDARY BYPASS VALVE ARE AFFECTED BY CONTAMINATION.
- GLYCOL PUMP FILTER
  - 75 NOMINAL - 100 ABSOLUTE MICRON FILTER (1 MICRON/.0004")
  - 6.6 IN<sup>2</sup> EFFECTIVE AREA
- FILTER LOCATED UPSTREAM OF PUMP INLET AND DOWNSTREAM OF SECONDARY BYPASS VALVE.
- LOOP LIMITING CLEARANCE IS IN SECONDARY VALVE.
  - PUMP MIN CLEARANCE - .0003"
  - SECONDARY VALVE MIN CLEARANCE - .0002"
- GLYCOL LOOP - 2240 CC. PER POWERPLANT

# APOLLO FUEL CELL POWERPLANT MODEL PC3A-2 FLOW SCHEMATIC BLOCK II

- ORIFICE (5)
- PRESSURE TRANSDUCER (3)
- TEMPERATURE TRANSDUCER (2)
- WATER PURITY SENSOR (1)
- VENT

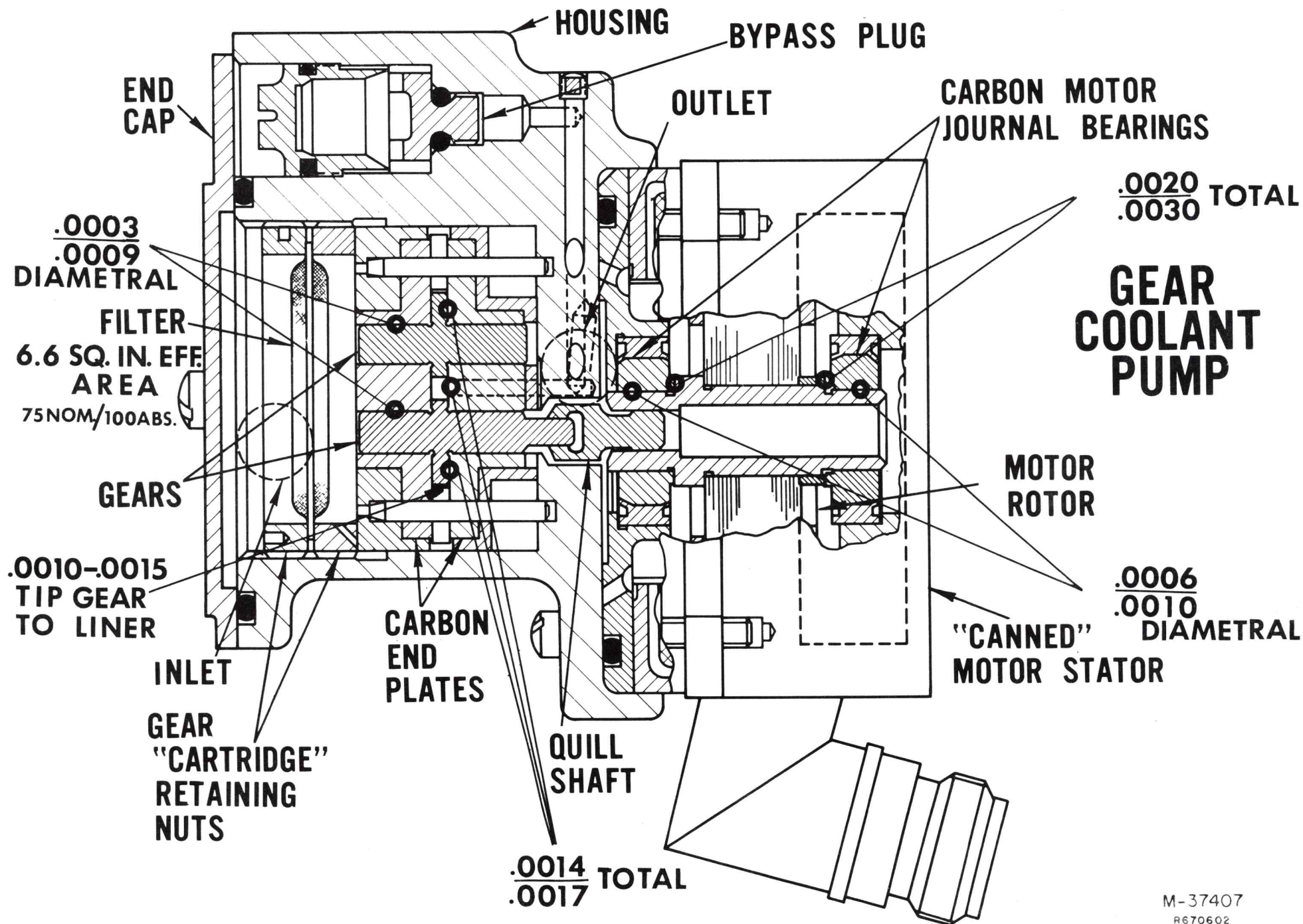


Pratt & Whitney Aircraft

DIVISION OF UNITED AIRCRAFT CORPORATION

M-39970  
R661209





M-37407  
 R670602

# COOLANT LOOP CONTAMINATION EXPERIENCE

## PARTICLE SIZE AND DISTRIBUTION/100 ml.

	MICRONS 50-100	MICRONS 100-175	MICRONS > 175	REMARKS
NR SPEC - ORIGINAL	100	10	0	----
NR SPEC - PROPOSED	200	75	25	----
SAE HYDRAULIC CLASS II	56	(>100) 5		COMPARISON ONLY
SAE HYDRAULIC CLASS III	110	(>100) 11		COMPARISON ONLY
SAE HYDRAULIC CLASS IV	225	(>100) 21		COMPARISON ONLY
SAE HYDRAULIC CLASS VI	1000	(>100) 92		COMPARISON ONLY
S/C 012 (MAX.)				
LOOP #1	TNTC	87	30	> ORIG. NR SPEC
LOOP #2	85	59	2	> ORIG. NR SPEC
LOOP #3	76	17	2	> ORIG. NR SPEC
S/C 017				
#1	34	24	6	BASICALLY > ORIG. NR SPEC
#2	141	23	10	> ORIG. NR. SPEC
#3	90	12	4	> ORIG. NR SPEC
S/C 101				
#1	6	2	5	> ORIG. NR SPEC MAX RANGE ONLY
#2	4	4	0	< ORIG. NR SPEC
#3	69	14	6	> ORIG. NR SPEC MAX RANGE ONLY
S/C 103				
#1	42	4	4	> ORIG. NR SPEC MAX RANGE ONLY
#2	43	12	8	> ORIG. NR SPEC MAX RANGE ONLY
#3	22	0	1	> ORIG. NR SPEC MAX RANGE ONLY

## P&WA 2500 HOUR CORROSION LOOP TEST

BEFORE TEST	480	(>100)	190
AFTER TEST	4,212	(>100)	1,475



P&WA COOLANT PUMP AND LOOP CONTAMINATION EXPERIENCE

- SIX TESTS WITH FILTERS UPSTREAM AND DOWNSTREAM OF PUMP INDICATE BLOCK II CONFIGURATION IN NORMAL OPERATION GENERATES SAE HYDRAULIC CLASS II TYPE PARTICLES - APPROXIMATES NR ORIGINAL SPEC.
- IN BLOCK I PUMP TESTS, 10 NOMINAL -25 ABS MICRON FILTERS RESULT IN COMPLETE PLUGGING WITHIN 50 HOURS. NORMAL OPERATION CREATES PARTICLES WHICH WILL PASS PRESENT B/M FILTER SIZE.
- PUMP, FLUSH AND DRY TESTING REVEALS FORCE FLUSH THROUGH A PUMP-NOT-OPERATING SYSTEM WILL JAM PARTICLES INTO PUMP CRITICAL CLEARANCES, PROHIBITING START.
- ONE BLOCK II TEST INDICATED A PUMP COULD RUN SUCCESSFULLY, STOP AND START, FOR 24 HOURS PUMPING A SEVERELY CONTAMINATED SOLUTION (9,696 PARTICLES >100 MICRONS, 1.6 MILLION PARTICLES <100 MICRONS).
- THE 2500 HOUR CORROSION LOOP TEST INDICATED PARTICLES IN ONE-G SITUATION TEND TO REMAIN IN TRAPPED AREAS.
- ONE BLOCK I GEAR PUMP RUNNING WITHOUT FILTERS RAN, STOP AND START, 382 HOURS PUMPING SAE CLASS 7+ COOLANT. FLUID ANALYSIS INDICATED THE FOLLOWING PARTICLE SIZE AND DISTRIBUTION:

26-50 MICRONS

1325

50-100 MICRONS

750

>100 MICRONS

325

- SECONDARY BY-PASS VALVE CONTAMINATION EXPERIENCE IS LIMITED TO THE 2500 HOUR CORROSION LOOP TEST.

## CONCLUSIONS

- EFFECT OF LONGTIME ZERO-G OPERATION IS UNKNOWN.
  - . A GREATER NUMBER OF PARTICLES MAY REMAIN IN FLUID STREAM
  - . MAY CLOG FILTER QUICKER
  - . COMPONENTS WILL EXPERIENCE GREATER AMOUNTS OF CONTAMINATION.
- IN ONE-G OPERATION PUMP CONTAMINATION WILL BE A PROBLEM IF FORCE FLUSHED.
- SAMPLES OF A GIVEN LOOP YIELD PARTICLE SIZE AND DISTRIBUTION RESULTS WHICH VARY WIDELY MAKING DATA ANALYSIS VERY DIFFICULT - P&WA ANALYSIS ASSUMES RESULTS OF ENCLOSED TABLE ARE TYPICAL.
- GLYCOL PUMP EXPERIENCE INDICATES NO PROBLEM IN ONE-G ENVIRONMENT WITH CONTAMINATION AT NR PROPOSED SPECIFICATION LEVELS UNDER NORMAL OPERATING CONDITIONS.
- LIMITED SECONDARY BY-PASS VALVE EXPERIENCE (2500 HOUR CORROSION LOOP TEST ONLY) INDICATES NO PROBLEM IN ONE-G ENVIRONMENT WITH CONTAMINATION AT NR PROPOSED SPECIFICATION LEVELS UNDER NORMAL OPERATING CONDITIONS.



PC3A-2 1000 HOUR CAPABILITY TEST

## SUMMARY

### PROBLEM

400 HOUR QUALIFIED LIFE OF BLOCK II PC3A-2 MUST BE EXTENDED TO:

- ALLOW INCREASED PAD OPERATING TIME BECAUSE :
  - (400 HOURS) MINUS (14 DAYS X 24 HOURS) = 64 HOURS MAXIMUM QUALIFIED PAD TIME
- AVOID RUNNING MISSION ON LAST FEW HOURS OF POWERPLANT OPERATING LIFE.
- PREVENT COSTLY ON-SITE REPLACEMENT OF POWERPLANTS THAT HAVE EXCEEDED THEIR QUALIFIED LIFE.

### P&WA SOLUTION

- QUALIFY BLOCK II PC3A-2 FOR 1000 HOUR OPERATING LIFE BY INCORPORATING:
  - CELLS WITH EXTENDED OPERATING LIFE - CERIA/COBALT
  - COMPONENTS CAPABLE OF 1000 HOURS OF OPERATION - CANNED STATOR H<sub>2</sub> PUMP.



# QUALIFICATION VS MISSION REQUIREMENTS

## P&WA ASSUMED APOLLO MISSION REQUIREMENTS

<u>ACTIVITY</u>	<u>CUM. * HOT HOURS</u>
. ALTITUDE CHAMBER TEST	60
. LAUNCH PAD SIMULATION AND ABORT	233
. LAUNCH PAD SIMULATION AND ABORT	406
. LAUNCH PAD SIMULATION	579
. VIBRATION TEST	600
. MISSION SIMULATION	988

## PC3A-2 BLOCK II COMPONENT QUALIFICATION TEST

<u>ACTIVITY</u>	<u>CUM. * HOT HOURS</u>
. LAUNCH VIBRATION SIMULATION (RESTART TEST (6) AND VIBRATION TEST)	120
. MISSION SIMULATION	608
. NASA EXTENSION	1072

## PC3A-2 BLOCK I QUALIFICATION TEST SEQUENCE

<u>ACTIVITY</u>	<u>CUM. * HOT HOURS</u>
. RESTART TEST (4)	82.0
. VIBRATION TEST	100
. ACCELERATION TEST	100 (N <sub>2</sub> )
. RESTART TEST (4)	160
. MISSION SIMULATOR	555
. VIBRATION TEST	570

## NR PROPOSED P650743 DEMONSTRATION TEST

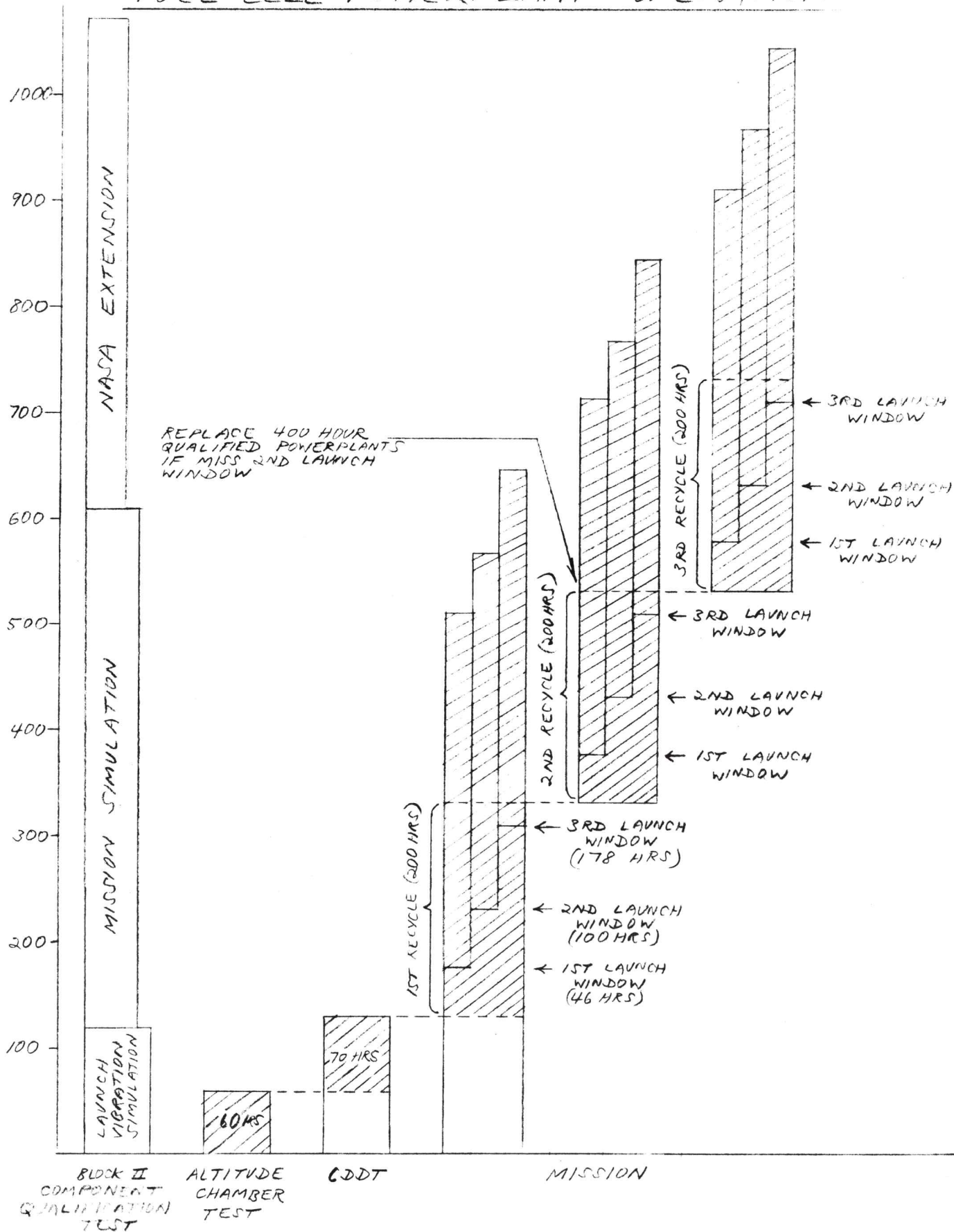
<u>ACTIVITY</u>	<u>CUM. * HOT HOURS</u>
. S/C 2TV-1 TEST	240
. STARTUP AND SHUTDOWN	251
. STARTUP AND SHUTDOWN	262
. STARTUP AND SHUTDOWN	273
. STARTUP AND SHUTDOWN	284
. LAUNCH PAD SIMULATION	450
. VIBRATION	456
. MISSION SIMULATION	710
. MISSION SIMULATION	964

. MISSION MAY REQUIRE 1000 HOUR OPERATING LIFE WITH VIBRATION TEST AT APPROXIMATELY 600 HOURS

\* HOT HOURS - TIME ABOVE 300°F

# FUEL CELL POWERPLANT OPERATION

4-4

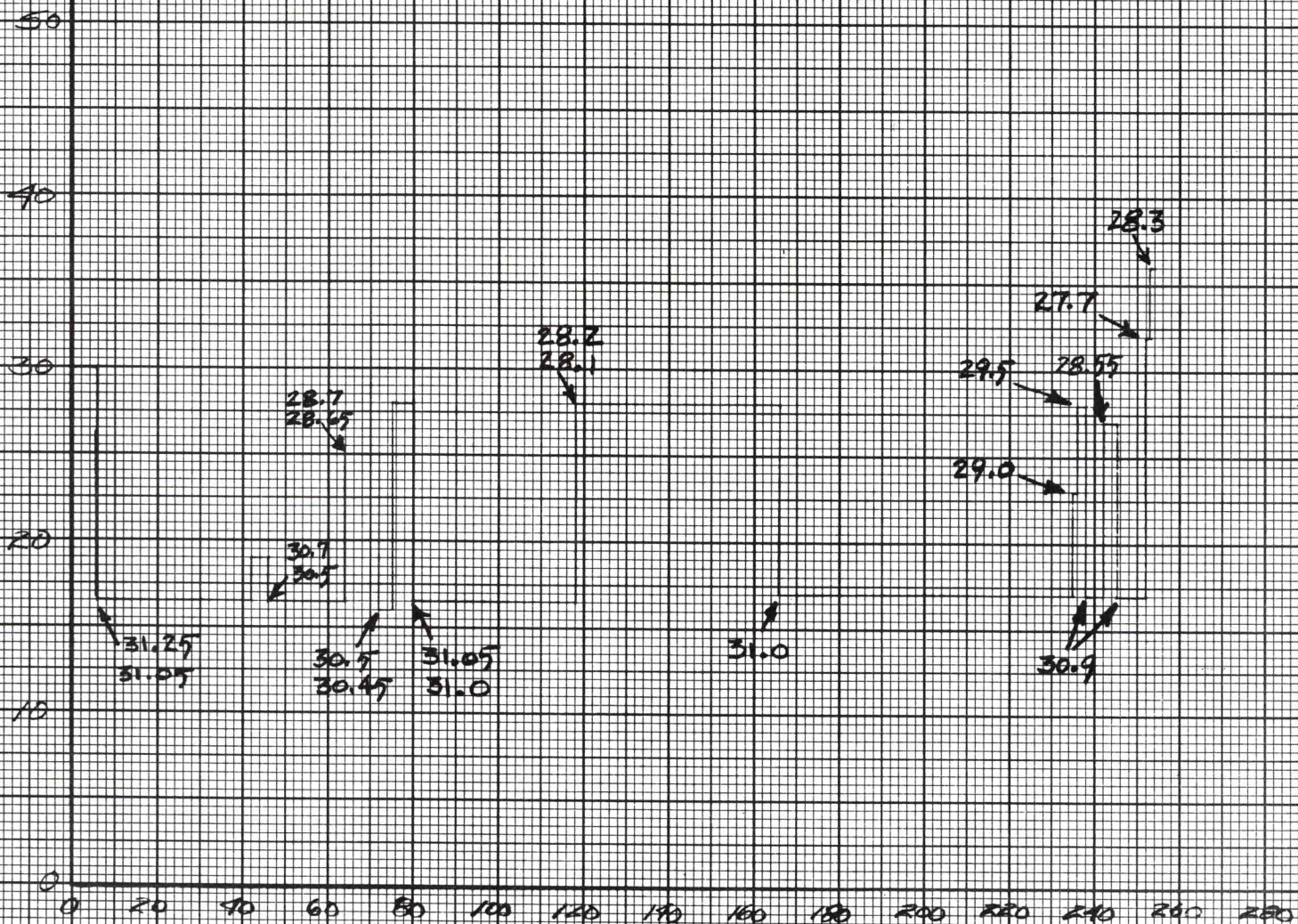


ACTIVITY



# NR PROPOSED DEMONSTRATION PROFILE VACUUM ENDURANCE PROFILE

PERCENTAGE GROSS LOAD ~ AMPS



ELAPSED TIME ~ HOURS



SUMMARY OF NR PROPOSED DEMONSTRATION TEST

● PERFORMANCE EXPECTED OF A BLOCK II POWERPLANT DURING THE MISSION PHASE  
(ASSUMING NO PREMATURE SHORTING)

- MIN VOLTAGE OF 27 VOLTS WILL BE EXCEEDED FOR ALL SCHEDULED LOADS  
IN THE NR MISSION PROFILE.
- MAX VOLTAGE OF 31 VOLTS WILL BE MARGINAL ON SOME EARLY POWER DOWN  
TRANSIENTS DURING EITHER PROFILE.
- FUEL CONSUMPTION WILL BE WITHIN SPECIFICATION LIMITS
- P&WA RECOMMENDS THE BLOCK II QUALIFICATION TEST LOAD PROFILE AS A  
BETTER TEST TO EVALUATE END-OF-LIFE PERFORMANCE.

- . DURING THE BLOCK II LOAD PROFILE MIN VOLTAGE WOULD BE APPROXIMATELY 26.5V
- . FUEL CONSUMPTION WILL BE UP TO 1% HIGH AT THE END OF THE BLOCK II  
LOAD PROFILE.

● ENDURANCE - BLOCK II QUAL TEST AND NASA TEST COMBINED DEMONSTRATED AN  
ENDURANCE CAPABILITY OF 1072 HOURS

- A SIMILAR CAPABILITY WOULD BE EXPECTED IF VIBRATION TESTING WAS EARLY  
IN THE TEST SEQUENCE AS IT WAS FOR BLOCK II QUALIFICATION
- DELAYED VIBRATION IS EXPECTED TO JEOPARDIZE ENDURANCE



# VIBRATION SHORTING EXPERIENCE

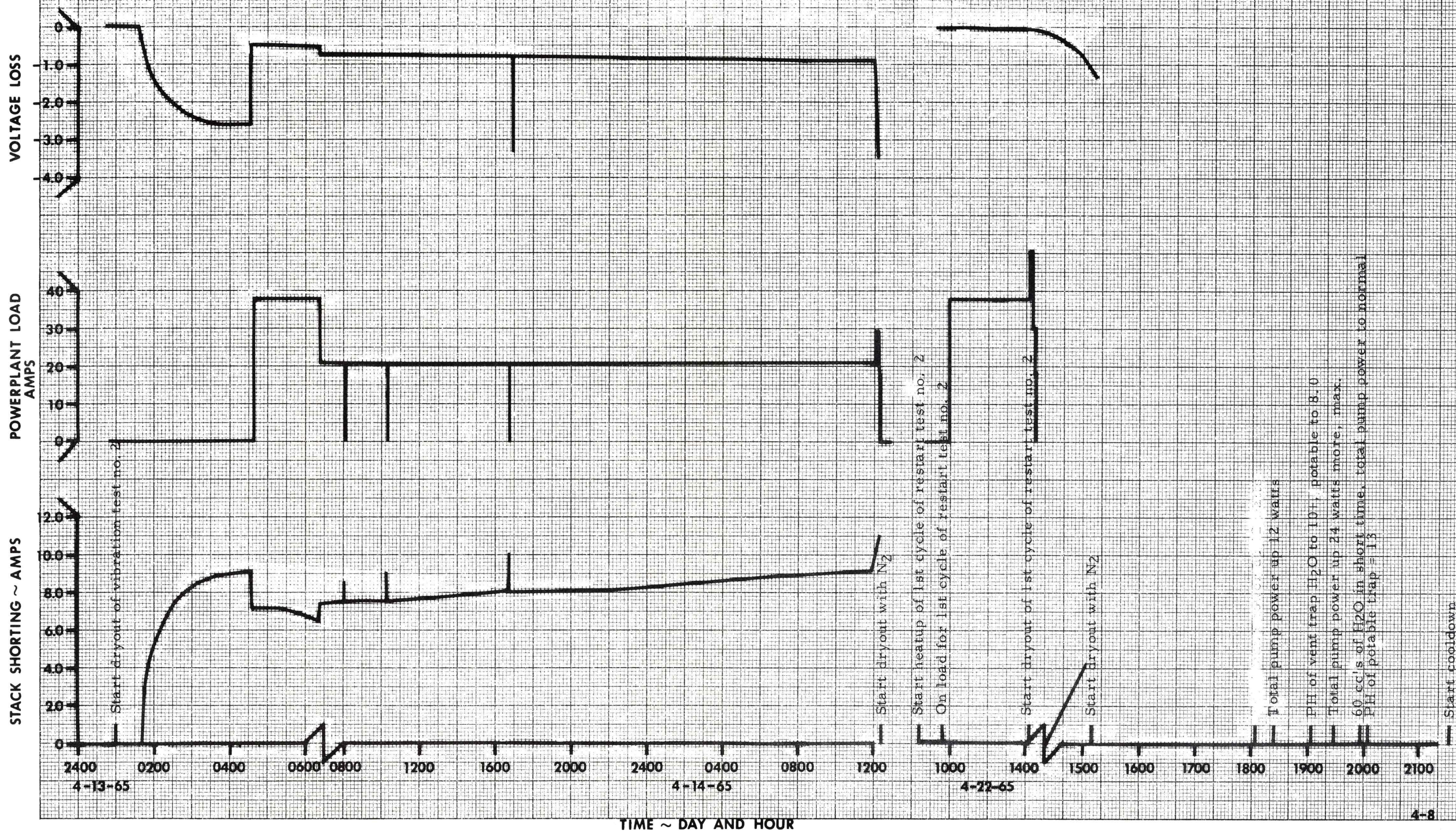
<u>TEST</u>	<u>HOT TIME BEFORE VIBRATION</u>	<u>SHORTING AFTER VIBRATION</u>	<u>HOT TIME AFTER VIBRATION</u>	<u>SHORTING</u>
BLK I				
QUAL TEST				
P650717	81.9 (VIB #1)	NO	473.5	NO
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BLK II				
QUAL TEST				
P650718	120	NO	488	NO
P650718 (EXTENDED)	120	NO	952	MINOR
DEVELOPMENT				
TESTING				
X-404-16	442	YES	200	YES
X-405-11	470	YES	0	-
NASA POWERPLANT				
P650725	575	YES	TEST IN PROCESS	
S/C-101 ESTIMATE	240 MIN.	NO	240	NO

\* 70 HRS AFTER VIBRATION TEST NO. 2, STACK SHORTING WAS EQUIVALENT TO 2 AMPS  
 30 HRS LATER POWERPLANT SHUTDOWN DUE TO STACK SHORTING EQUIVALENT TO 5 AMPS



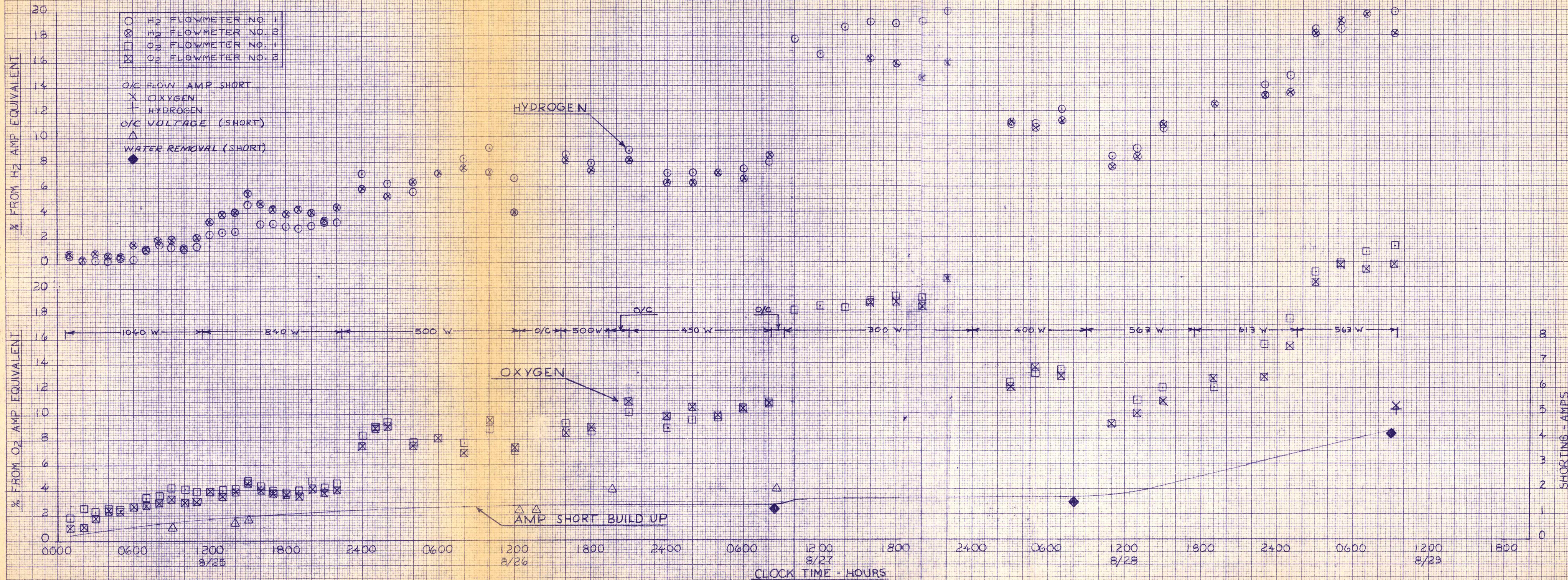
## SHORTING HISTORY OF POWERPLANT P650718

BASED ON REACTANT FLOWS, O/C VOLTAGES AND  
WATER REMOVAL RATE





P-650717-3 MEASURED FLOW RELATIVE TO AMP EQUIVALENT FLOW  
FOR CONTINUED VACUUM TESTING



WT/MD 7/1/65



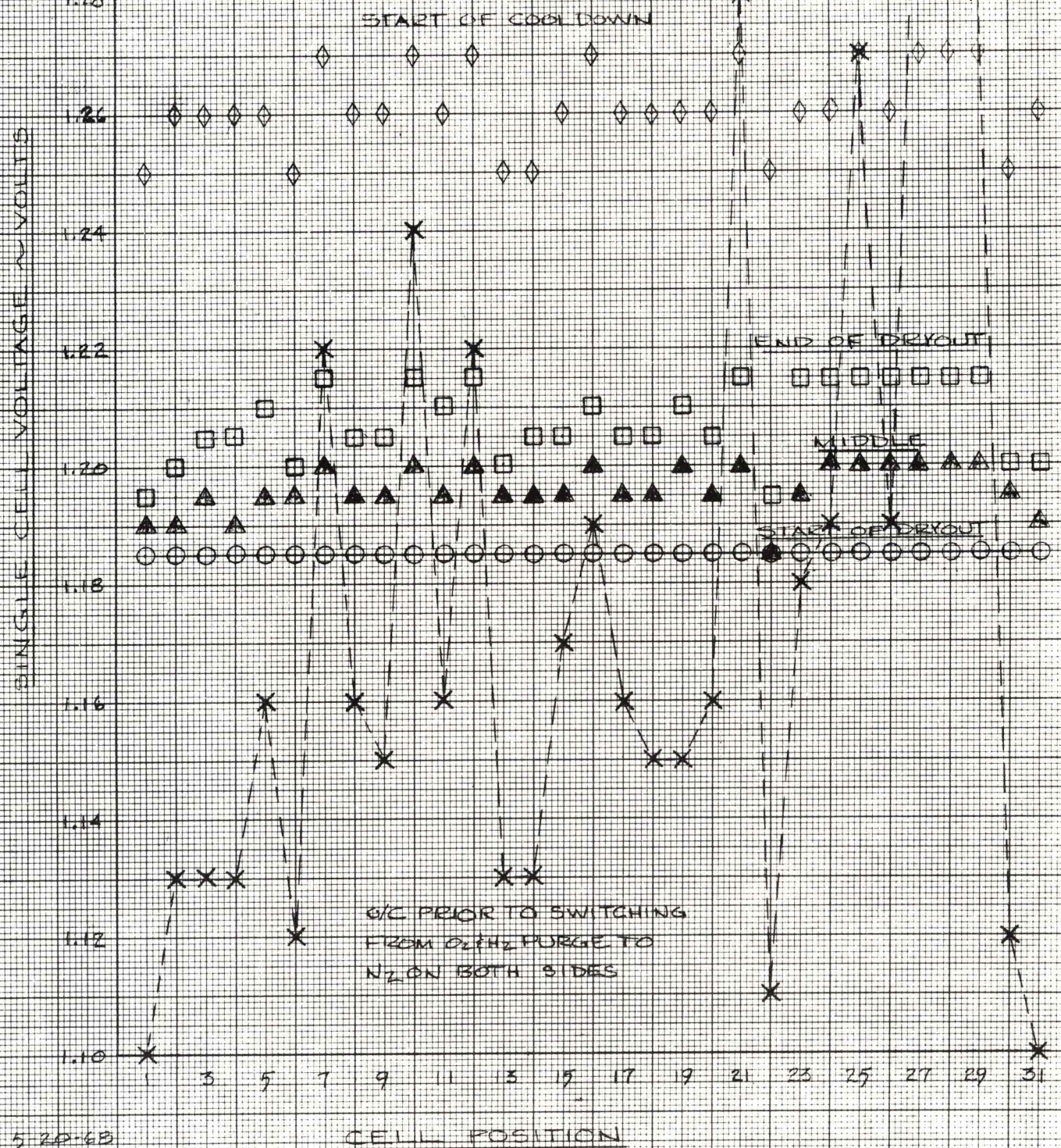
P-650725

VIBRATION TEST AT PEWA

# SINGLE CELL VOLTAGE PROFILE SUMMARY DURING DRYOUT AND COOL DOWN

- STAND NO. : X-572

- DATES : 5-7-68 TO 5-8-68

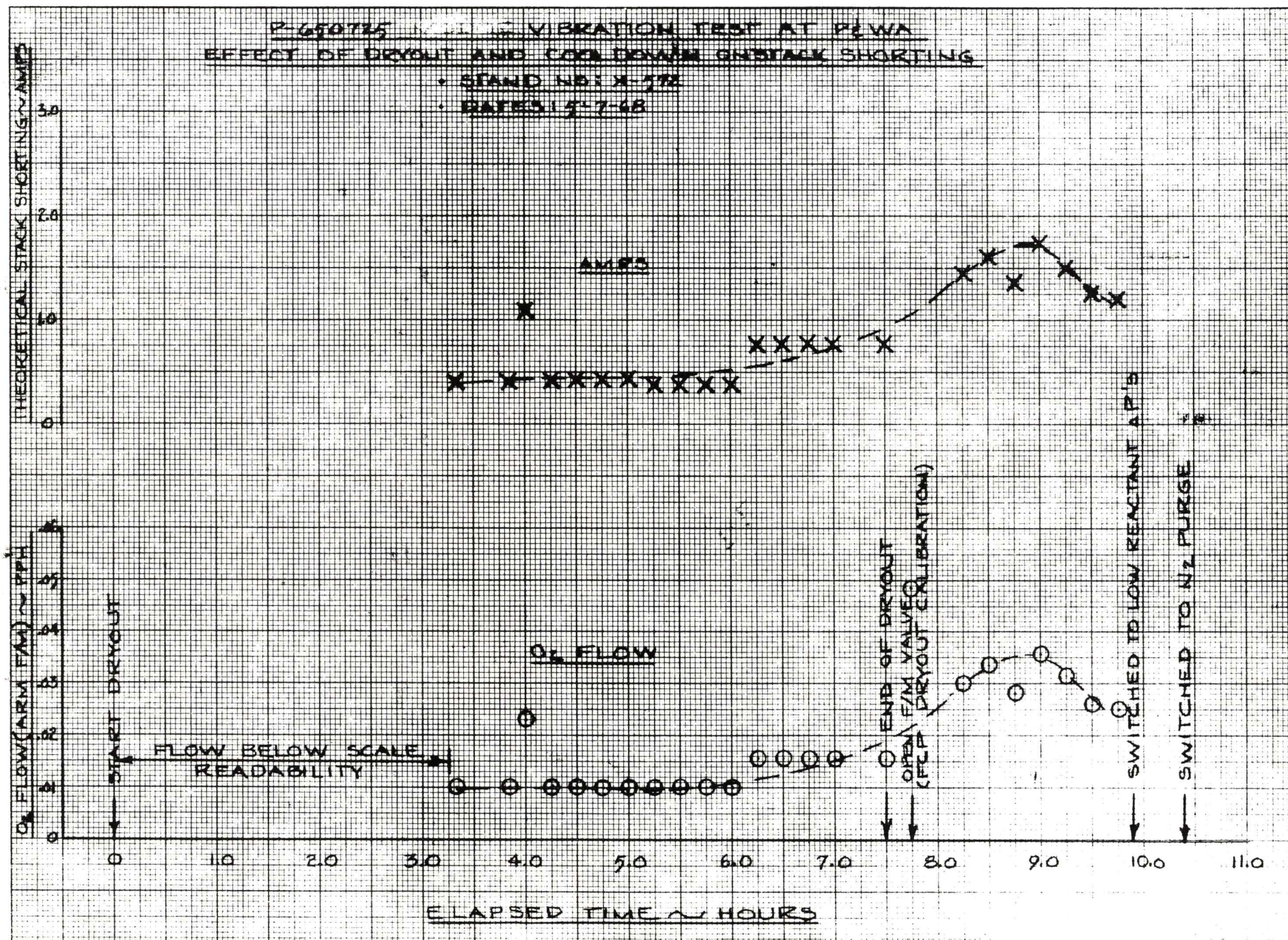


5-20-68

ABO/DD

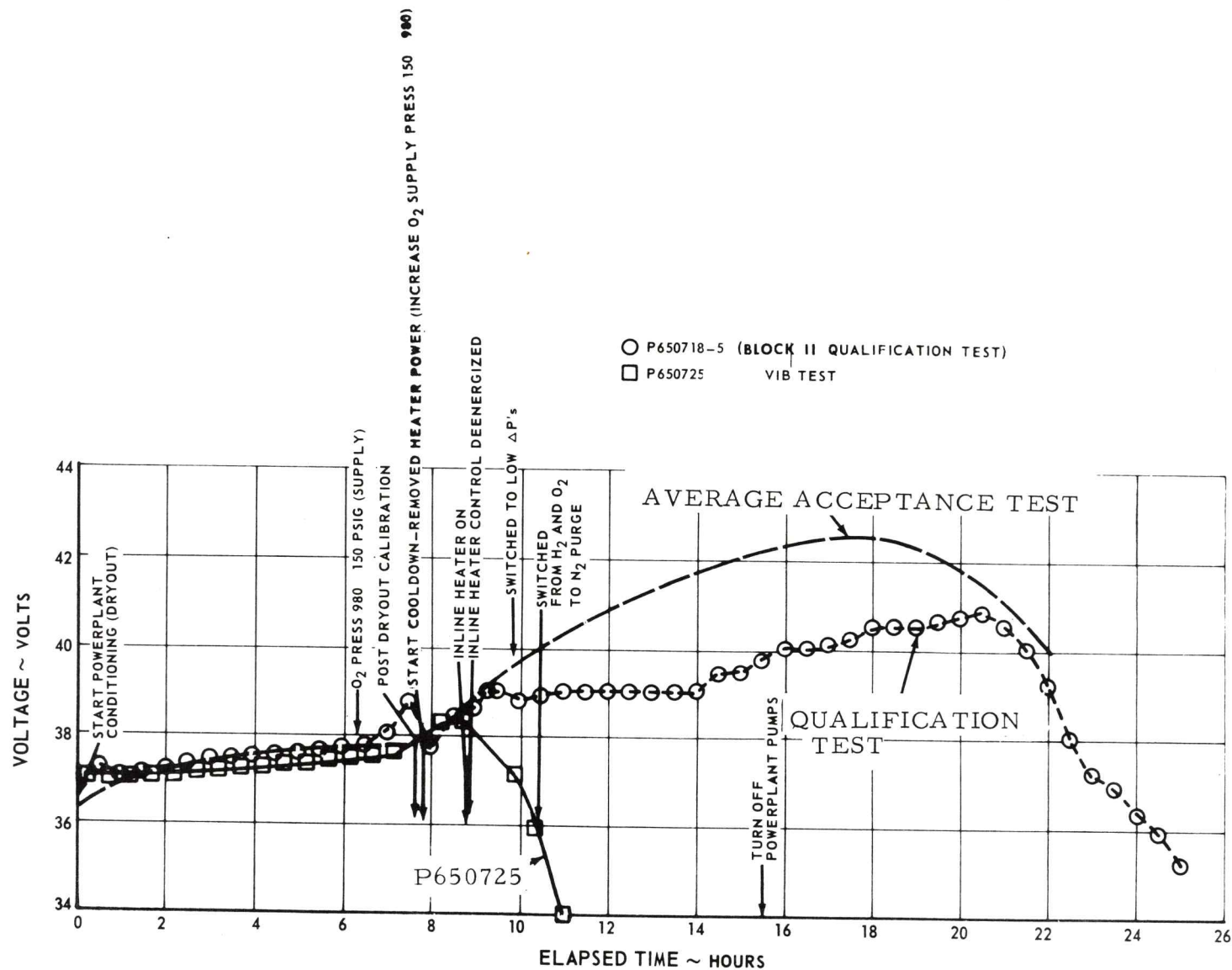
FCD-5080-25







# P650725 VOLTAGE AS A FUNCTION OF TIME COMPARED TO BLOCK II QUALIFICATION TEST

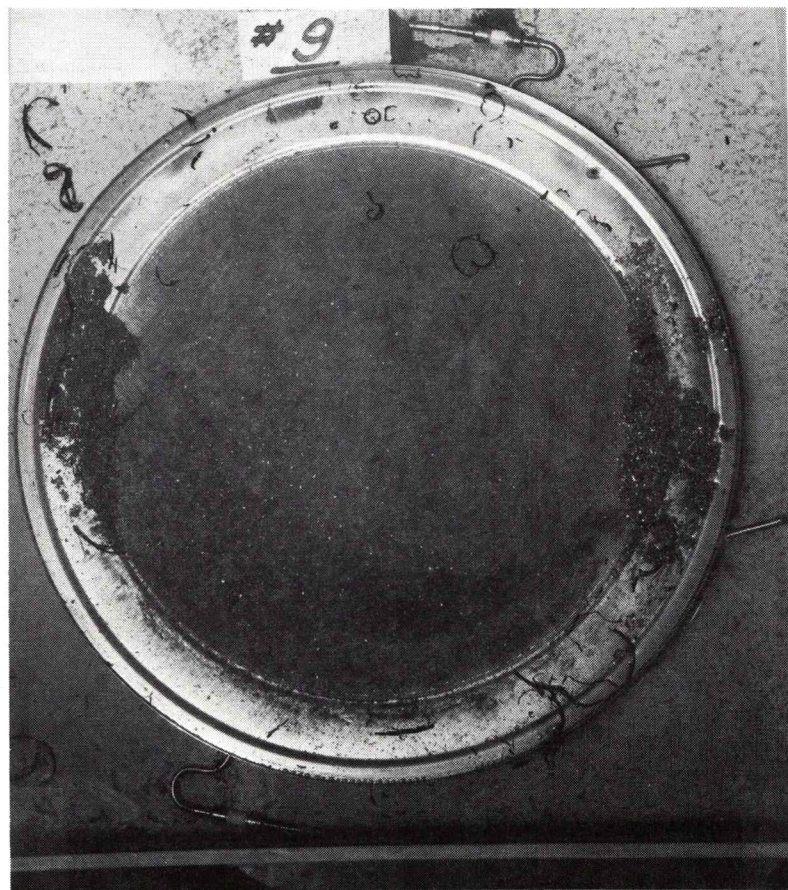




### VIBRATION SHORTING

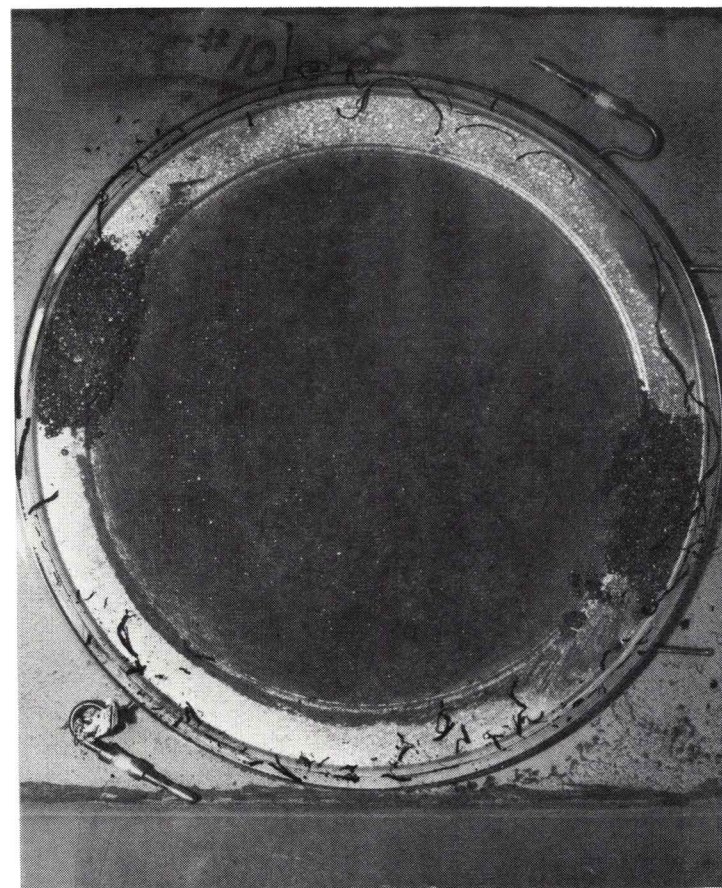
- PREMATURE SHORTING AFTER VIBRATION ATTRIBUTED TO DENDRITE PILING IN ELECTRODE DIAPHRAGM AREA (NEXT PAGE)
  - SUSCEPTIBILITY TO SUCH SHORTING IS DUE TO:
    - EASE IN BRIDGING ELECTRODES WITH PILED DENDRITES
    - QUANTITY OF DENDRITES
- EXPOSURE OF ELECTRODE SURFACE WHERE DENDRITIC PILE OFFERS LARGE AREA FOR SHORTING CURRENT PATHS
- QUANTITY OF DENDRITES IS FUNCTION OF OPERATING TIME AND TEMP.
  - QUALIFICATION TEST VIBRATION AND DENDRITE EXPERIENCE (PAGE 4-15)
  - DELAYING LAUNCH AS IN THE P&WA ASSUMED MISSION REQUIREMENTS ADDS SUFFICIENT HOT TIME TO EXCEED VIBRATION SHORTING EXPERIENCE
  - P&WA ASSUMED MISSION REQUIREMENTS ADD HOT TIME PRIOR TO LAUNCH VIBRATION EQUAL TO THE COMPLETE BLOCK I QUAL. TEST

DENDRITE PILING POWERPLANT P650718



CELL #9

LM-1394



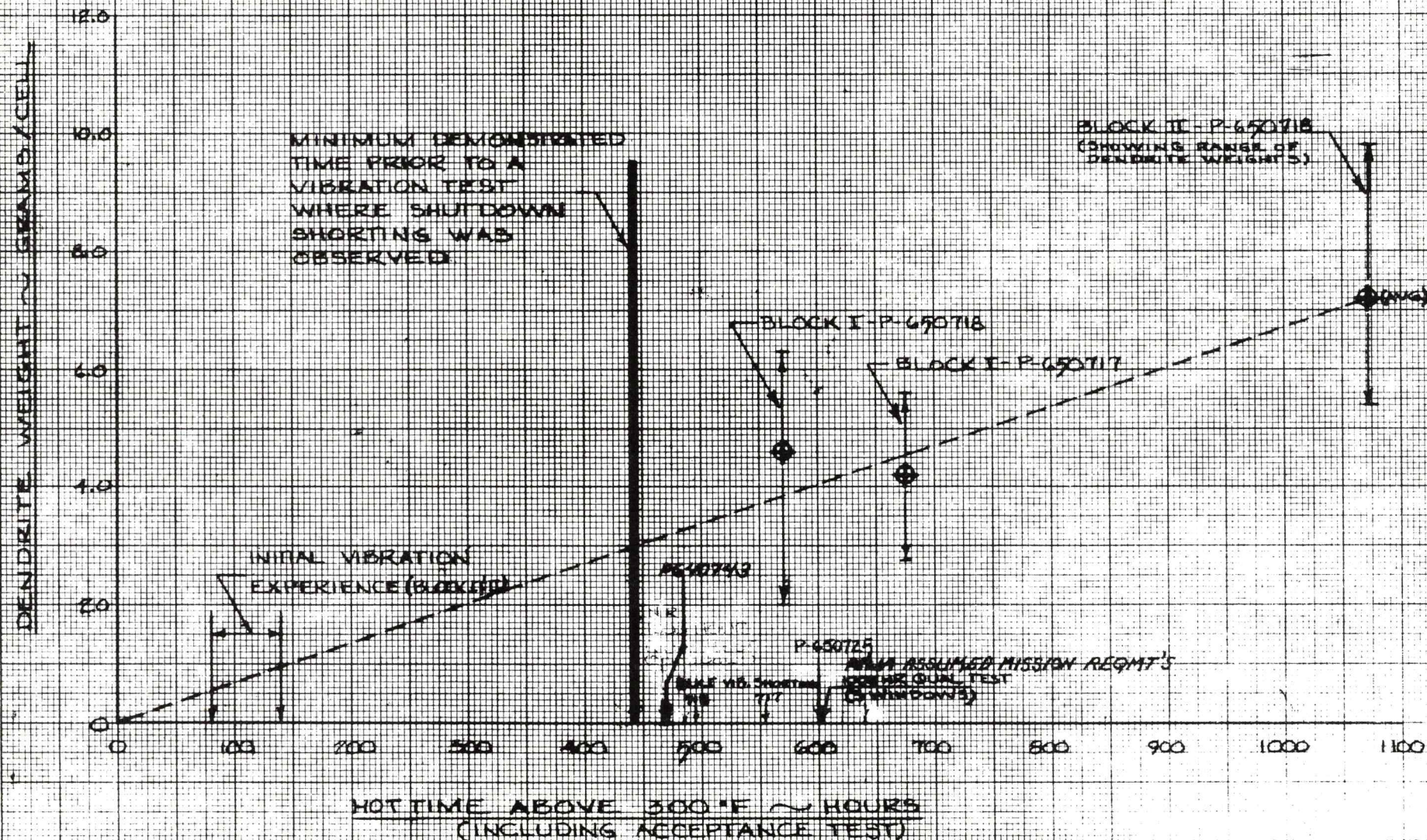
CELL #10

LM-1454



PC 3A-E

DENDRITE AND POST VIBRATION SHUTDOWN SHORTING EXPERIENCE





## INFLUENCE OF OPERATING TEMPERATURE ON PERFORMANCE AND ENDURANCE

### PERFORMANCE

- . VARIATION OF VOLTAGE-POWER WITH TEMP. ALLOWS DEFINITION OF CONTROL SCHEDULES TO MEET SYSTEM REQUIREMENTS

### ENDURANCE

- . LIFE IS INVERSELY PROPORTIONAL TO TEMPERATURE.
- . OPERATING TEMPERATURE LEVELS SELECTED MUST BE COMPATIBLE WITH BOTH PERFORMANCE AND ENDURANCE REQUIREMENTS



TEMPERATURE INFLUENCE ON CELL PERFORMANCE

- HIGHER TEMPERATURE IMPROVES CELL EFFICIENCY ALLOWING FIXED POWER OPERATION AT HIGHER VOLTAGE AND LOWER REACTANT CONSUMPTION
- STEADY-STATE AND TRANSIENT PERFORMANCE CHARACTERISTICS FOR THE BLOCK II POWERPLANT (NEXT PAGE) ILLUSTRATE TEMP. VARIABLE
- TEMP. SCHEDULING OF THE REGENERATOR BYPASS CONTROL PROVIDES STEADY STATE PERFORMANCE OVER REQUIRED POWER RANGE
- CONSTANT TEMPERATURE TRANSIENT CAPABILITY MEETS LOAD PROFILE POWER-UP/POWER-DOWN REQUIREMENTS

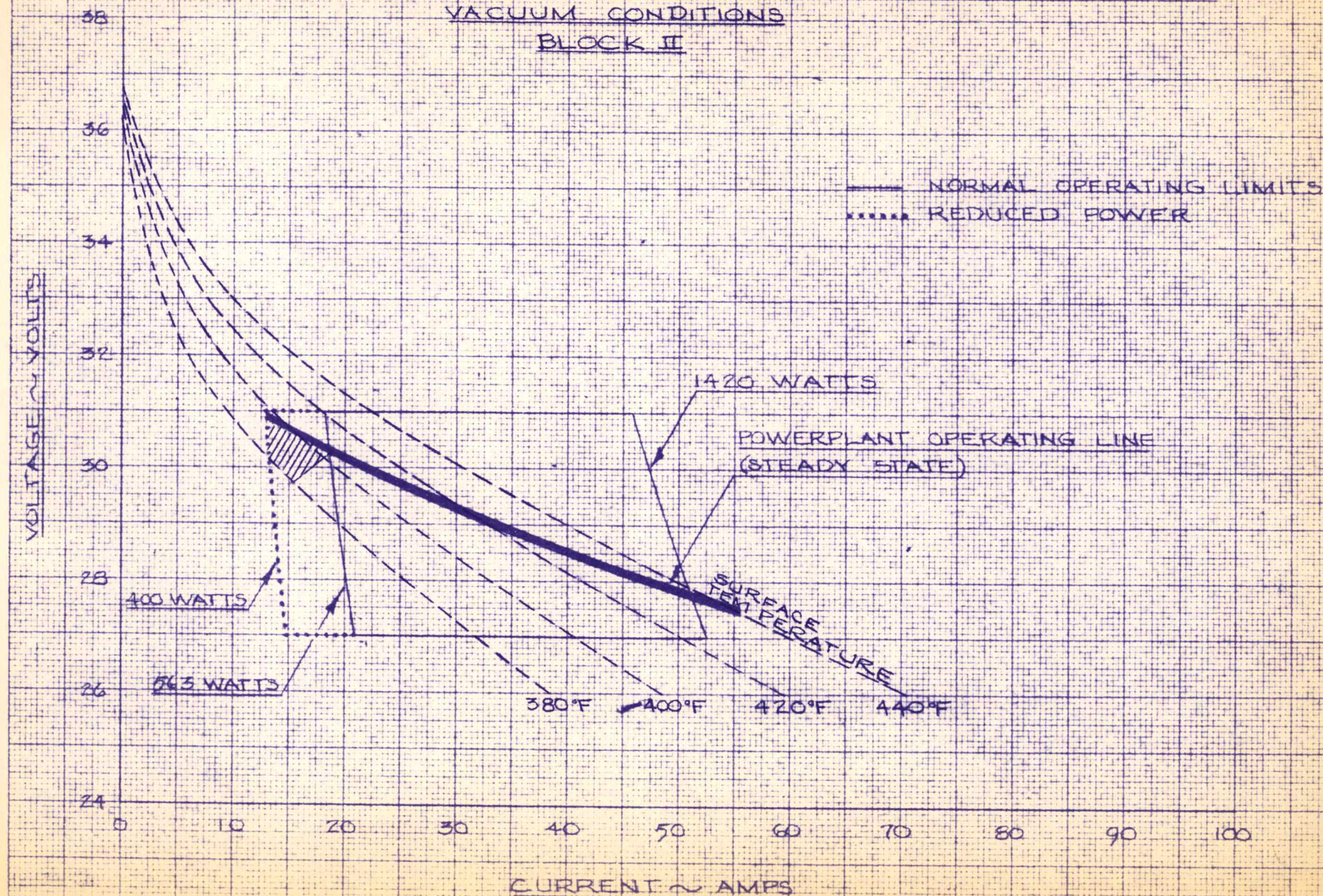


# FUEL CELL POWERPLANT PC3A-2E

NOMINAL PERFORMANCE CHARACTERISTICS DURING NORMAL OPERATION

VACUUM CONDITIONS

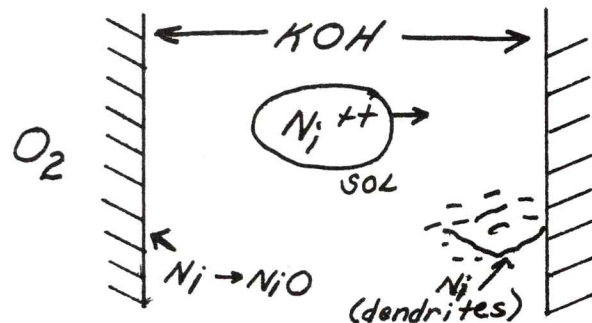
BLOCK II





## TEMPERATURE INFLUENCE ON CELL ENDURANCE

- CELL INTERNAL CORROSION PROCESSES ESTABLISH POWERPLANT ENDURANCE



- $Ni \rightarrow NiO$  - ELECTRODE CORROSION AT OXYGEN ELECTRODE
- $(Ni^{++})_{soln}$  - NICKEL IONS DISSOLVE FROM OXYGEN ELECTRODES IN  $KOH$
- DISSOLVED IONS REDUCE TO NICKEL DENDRITES AT HYDROGEN ELECTRODE

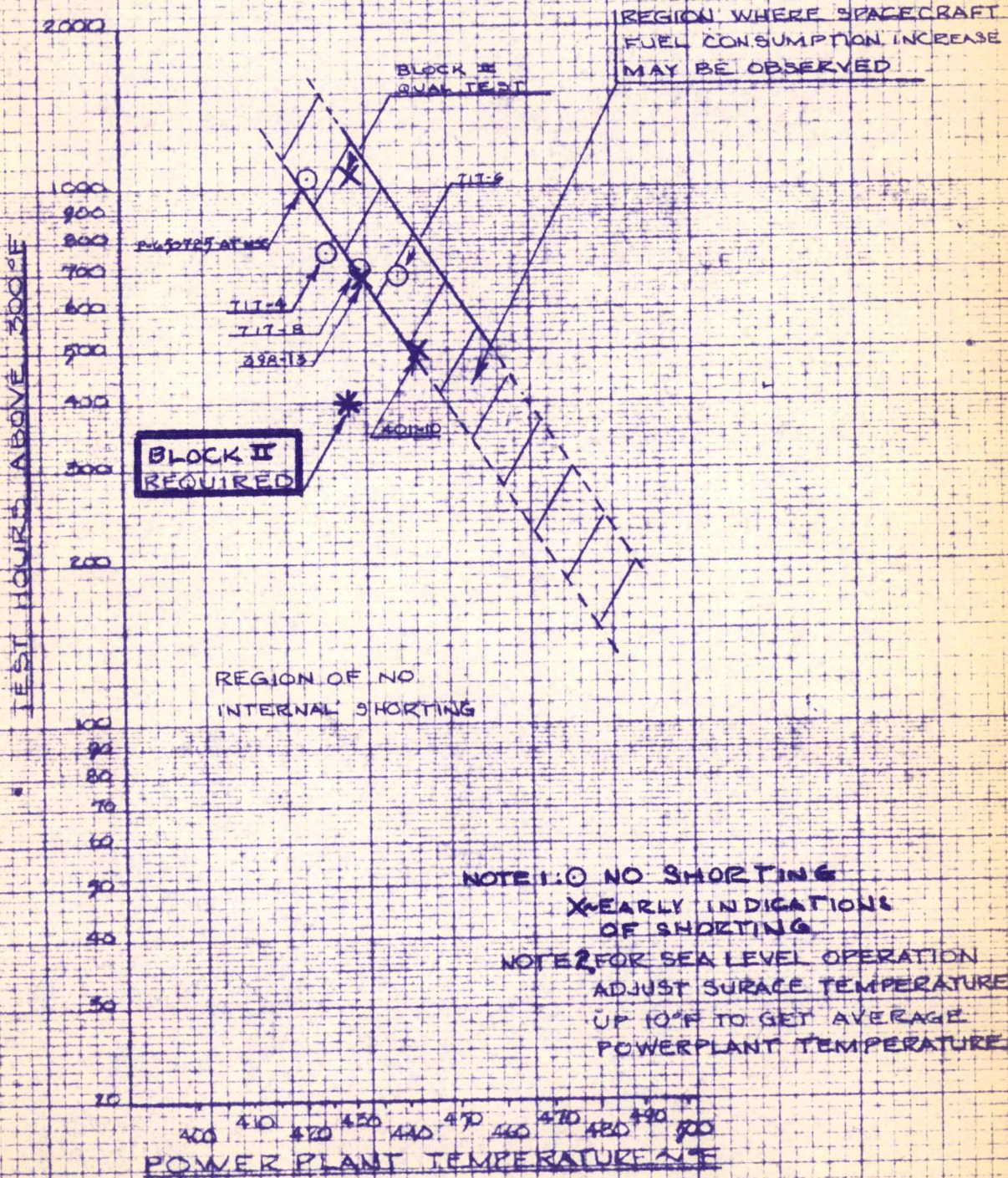
- CORROSION PROCESS VARIES DIRECTLY WITH TEMPERATURE.
- OXYGEN ELECTRODE CORROSION CHANGES PORE STRUCTURE AND CAUSES PERFORMANCE DECAY
  - CLOSING DOWN OF FINE PORE INCREASES IR LOSS
  - REDUCED SURFACE AREA IN COARSE PORE REDUCES REACTION SITES
- NICKEL ION REDUCTION AT HYDROGEN ELECTRODE CREATES DENDRITES
  - WITH TIME DENDRITES WILL BRIDGE THE ELECTRODE SPACING AND CAUSE INTERNAL SHORTING
  - VIBRATION WITH DENDRITES PRESENT IN THE CELL CREATES "PILING" IN THE DIAPHRAGM REGION
- CHARACTERISTIC OF TEMP. INFLUENCE ON CORROSION PROCESS
  - CHEMICAL THEORY INDICATES VALID RELATIONSHIP BETWEEN REACTION RATE AND TEMPERATURE IS
 
$$\text{REACTION RATE} = K_e^{-E/T}$$

$$\text{OR } \ln(RR) = f(-1/T)$$
  - IMPLICATION IS STRAIGHT LINE RELATION BETWEEN LN OF CORROSION RESULTS AND  $1/T$
  - DETERMINATION OF RELATIONSHIP WAS A SIGNIFICANT OBJECTIVE OF DEVELOPMENT TEST.



# PC3A-2 ESTIMATED INTERNAL SHORTING CHARACTERISTICS

NOTES  
1) NO DELAYED VIBRATION  
2) NO CERIA COATING



NOTE 1: ○ NO SHORTING  
X HEAVILY INDICATIONS  
OF SHORTING  
NOTE 2: FOR SEA LEVEL OPERATION  
ADJUST SURFACE TEMPERATURE  
UP 10°F TO GET AVERAGE  
POWERPLANT TEMPERATURE

6-24-68

JPF/MD

RECIPROCAL OF POWER PLANT TEMPERATURE ~ 1/T  
1.16 x 10<sup>-3</sup> 1.12 x 10<sup>-3</sup> 1.08 x 10<sup>-3</sup> 1.04 x 10<sup>-3</sup> FLD-1541-25



## ESTIMATED INTERNAL SHORTING CURVE

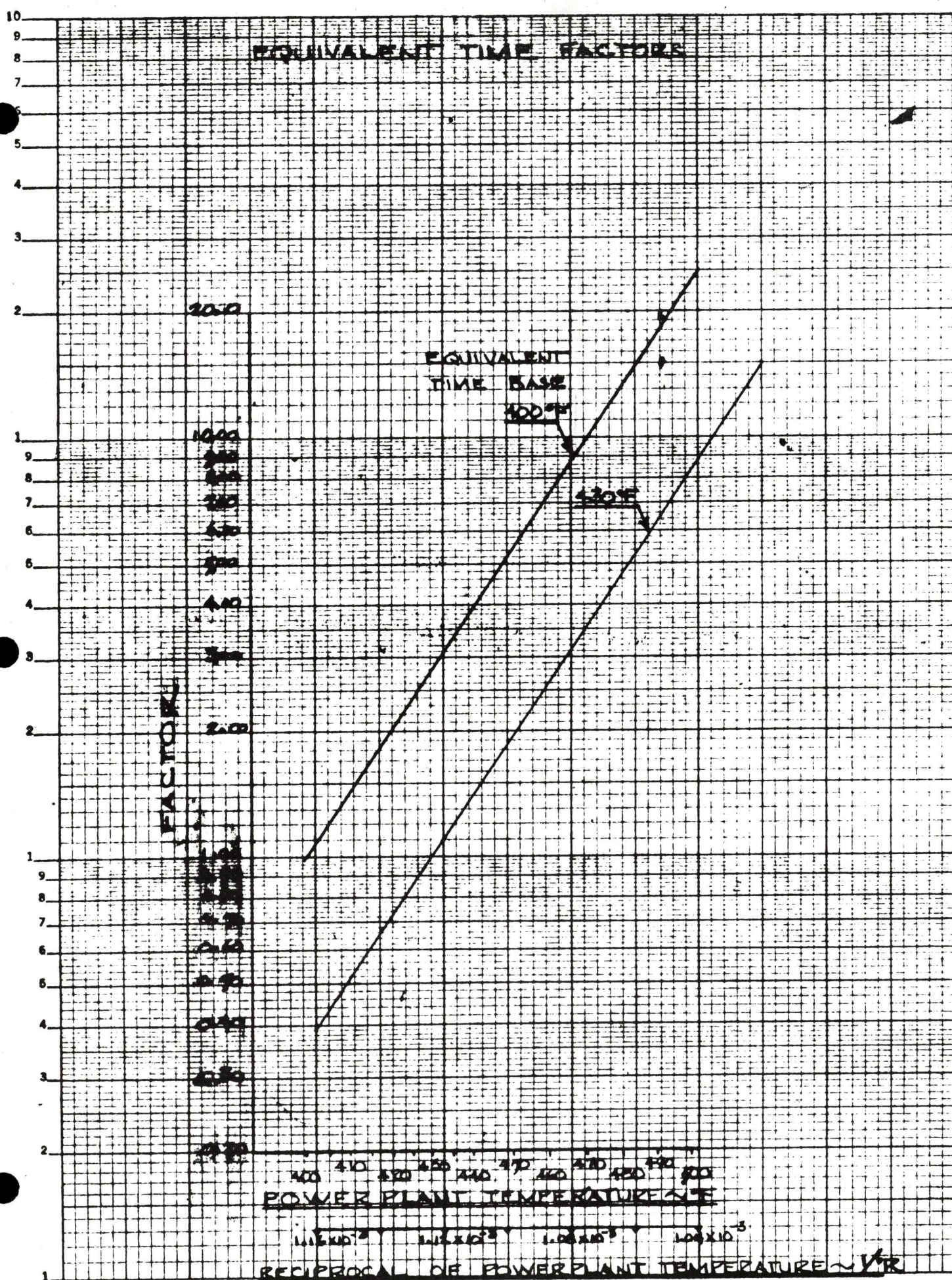
- SHOWS ENDURANCE CAPABILITY BEFORE APPEARANCE OF INTERNAL SHORTING
  - INCREASING FUEL CONSUMPTION OVER NEXT 100 + HRS
  - SPACECRAFT FLOW METER ACCURACY OF  $\pm 6\%$  PERMITS 3 AMP SHORTS BEFORE FUEL CONSUMPTION VARIATIONS NOTED
    - P&WA TEST EXPERIENCE SHOWS APPROXIMATELY 15% ADDITIONAL OPERATING TIME IS NECESSARY AFTER EARLY INDICATIONS OF SHORTING TO ATTAIN THE 3 AMP SHORT
- TIME TO REACH THIS REGION AT BLOCK II AVERAGE TEMPERATURES VARIES FROM 1.9 TO 2.0 TIMES THE 400 HOUR QUALIFIED BLOCK II LIFE WITHOUT DELAYED VIBRATION.
- TEST DATA COMPARED ON BASIS OF ACTUAL HOT TIME AND WEIGHTED AVERAGE TEMP
  - WEIGHTED TEMP DERIVED BY USING SLOPE OF TEMP-TIME PLOT TO WEIGH TEST HOURS AND OBTAIN AN EQUIVALENT TIME
  - NEXT PG DEFINES THE FACTOR USED FOR CALCULATING EQUIVALENT TIME

$$\begin{aligned} \text{EQUIVALENT TIME} &= \sum_{T_i = \text{MIN}}^{T_i = \text{MAX}} t_{T_i} F_{T_i} \\ F_{T_{\text{avg}}} &= \text{EQUIVALENT TIME/HOT TIME} \end{aligned}$$

WHERE:

$t_{T_i}$	=	TEST HOURS AT INDICATED TEMPERATURE
$F$	=	EQUIVALENT TIME FACTOR
$T_{\text{avg}}$	=	WEIGHTED AVERAGE TEMPERATURE







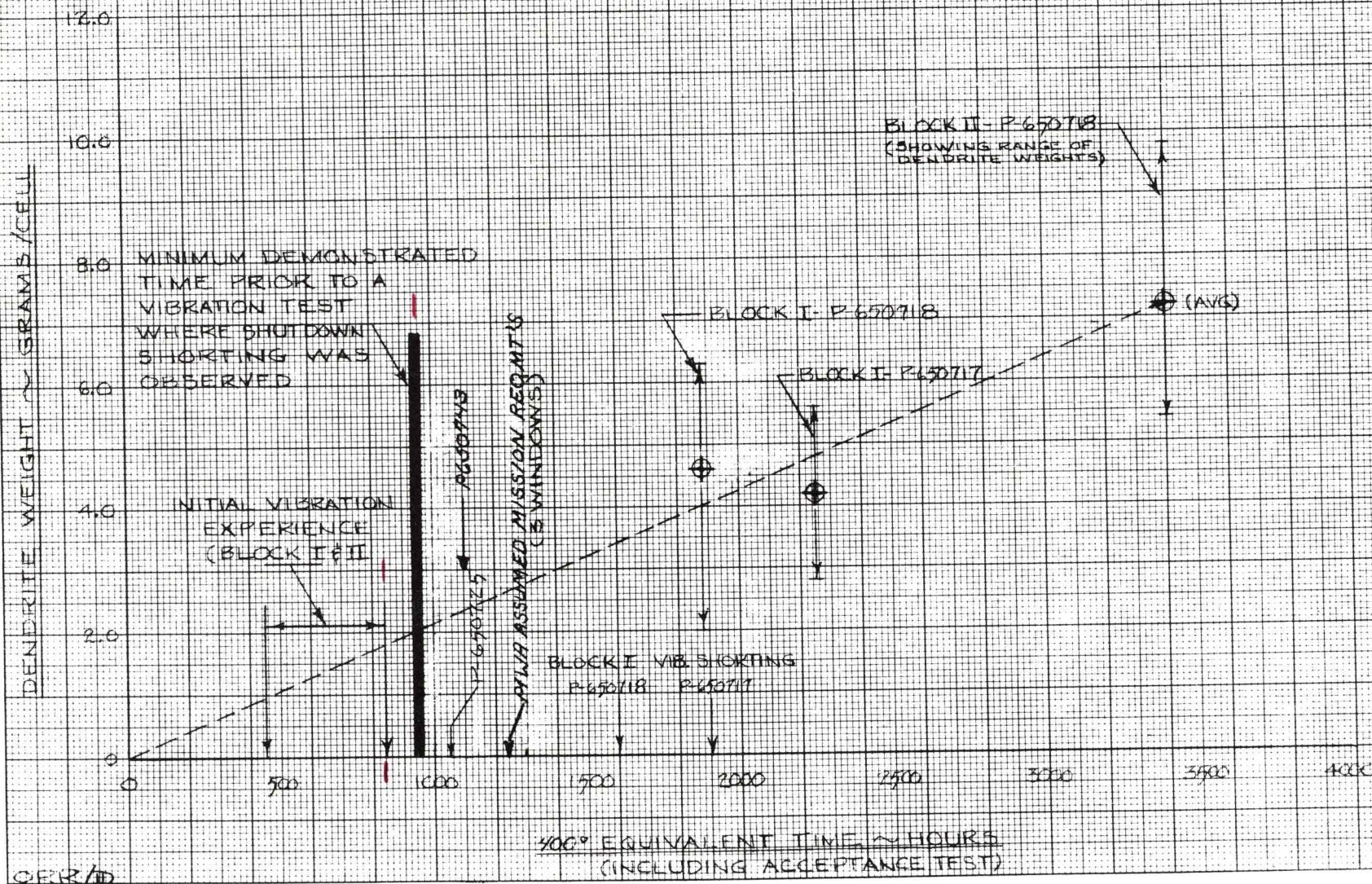
VIBRATION SHORTING EXPERIENCE ON EQUIVALENT TIME BASIS

- VIBRATION SHORTING EXPERIENCE COMPARED ON EQUIVALENT TIME BASE - 400° (NEXT PAGE)
- EXTENDED GROUND HOLD TESTS, AS IN THE P&WA ASSUMED SIMULATION AND THE NR PROPOSED P650743 TEST SHOW RELATIVELY LOWER EQUIVALENT TIME THAN HOT TIME.
  - DUE TO EXTENDED IN-LINE HEATER OPERATION
  - EQUIVALENT TIME WOULD INCREASE IF ADDITIONAL LOAD RUNNING WAS INCLUDED.
- BOTH TESTS ACCUMULATE SUFFICIENT TIME TO PRESENT A VIBRATION SHORTING PROBLEM.



PC3A-2

## DENDRITE AND POST VIBRATION SHUTDOWN SHORTING EXPERIENCE





CONCLUSIONS - P&WA ASSUMED 1000 - HOUR REQUIREMENTS

- DELAYING LAUNCH VIBRATION IS EXPECTED TO CAUSE DENDRITE PILING AND PREMATURE SHORTING
- IMMEDIATE SHORT IF SHUTDOWN IS MADE
- WITHOUT A SHUTDOWN SOME ADDITIONAL OPERATION NECESSARY TO INDUCE SHORTING
- FUEL CELL VIBRATION CHARACTERISTICS PREVENT DENDRITE PILES FROM COMPLETELY BRIDGING ELECTRODES DURING VIBRATION.
- DENDRITE PILES DO FORM, LEAVING ONLY A SMALL GAP BETWEEN ELECTRODES TO BE BRIDGED BEFORE A CONCENTRATED AREA OF SHORTING FORMS.
- TIME REQUIRED TO START SHORTING AND RATE OF INCREASE AFTER IT APPEARS IS UNKNOWN.
- EFFECT OF ZERO GRAVITY UNKNOWN.
- PROGRAM CONSIDERED FOR 743 EXPECTED TO SHOW SIMILAR TEST RESULTS.
- TWO TIMES LIFE FACTOR EXPECTED OF CERIA COATED CELLS AVOIDS THIS PROBLEM.



CHANGING FUEL CELLS AT PAD

<u>ACTIVITY</u>	<u>ESTIMATED TIME (HOURS)</u>
. CONDITION AND SHUTDOWN POWERPLANT	35
. REPLACE MSS AND RECONNECT GASES (OXYGEN, HYDROGEN, NITROGEN)	27
. DRAIN WATER/GLYCOL LOOP	4
. REMOVE FUEL CELL POWERPLANT	24
. PURGE, DRY RADIATORS	72
. INSTALL FUEL CELL POWERPLANT	24
. PRESSURE CHECK INTERFACE	16
. ELECTRICAL CHECK PUMPS & CONTROLS	2
. FILL EPS WATER/GLYCOL SYSTEM	24
. COUNTDOWN RECYCLE	?
	<hr/>
TOTAL	248 + HOURS



P&WA 1000 HOUR POWERPLANT RECOMMENDATIONS

CERIA/COBALT CELLS

- CERIA INSULATING LAYER SPRAYED ON ANODE RETARDS DENDRITE SHORTING AND IMPROVES TOLERANCE TO DELAYED VIBRATION.
- COBALT ACTIVATION IMPROVES CELL PERFORMANCE - COMPENSATES FOR CERIA.

PUMP SEPARATOR

- CANNED STATOR PROVIDES POSITIVE MOISTURE BARRIER.
- OVERBOARD RELIEF VALVE PREVENTS WATER BLOCKAGE.



PUMP SEPARATOR

PRESENT BILL OF MATERIAL PUMP

- ENCAPSULATED STATOR LOSES RESISTANCE FROM LONG EXPOSURE TO HOT, MOIST HYDROGEN ENVIRONMENT.

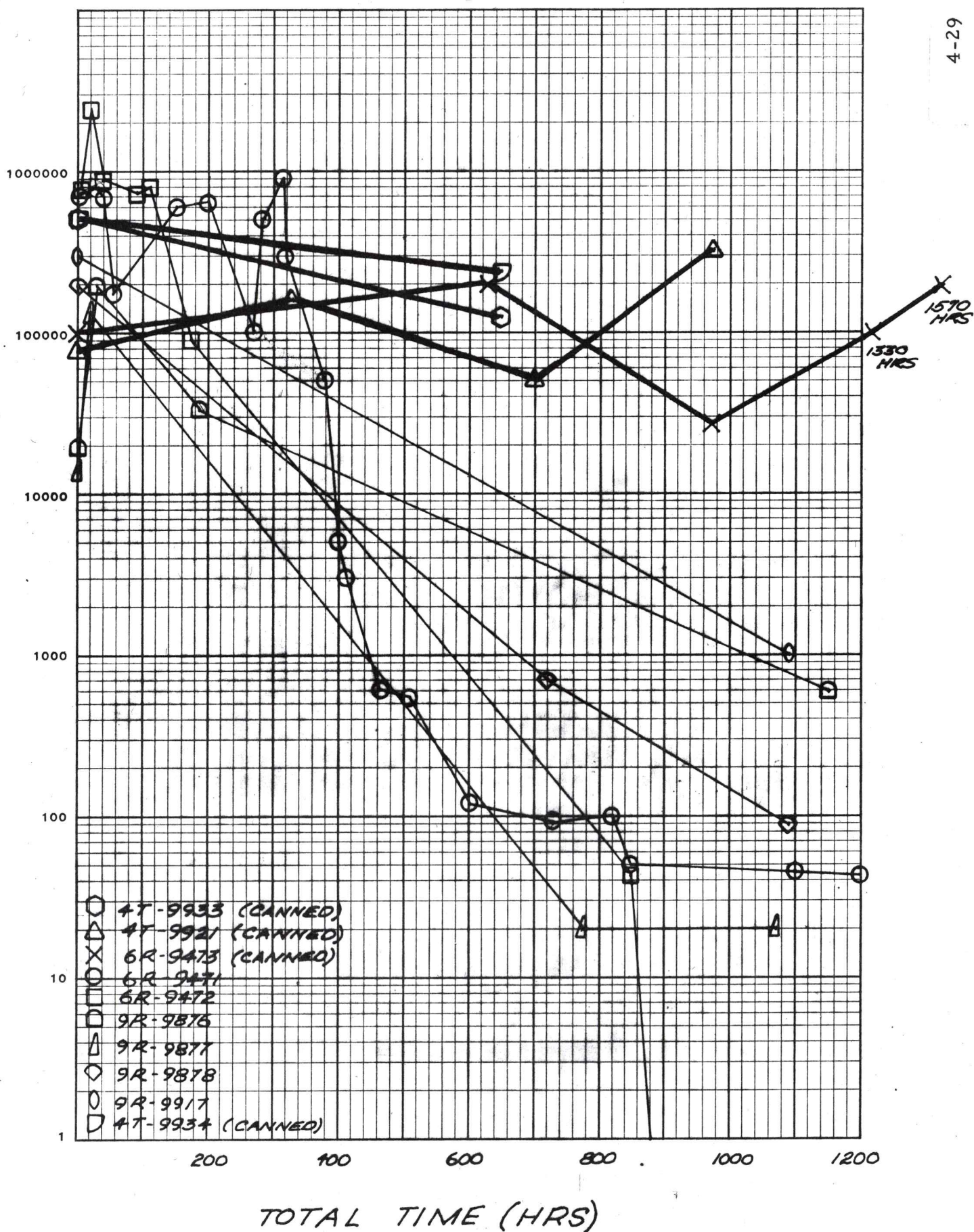
PROPOSED PUMP SEPARATOR

- CANNED STATOR PROVIDES POSITIVE MOISTURE BARRIER AND INCREASED RELIABILITY.
- OVERBOARD WATER RELIEF VALVE - PROTECTS POWERPLANTS FROM S/C SYSTEM FAILURES.



# RESISTANCE DECAY BLK II H<sub>2</sub> PUMP SEPARATOR

4-29





## CONCLUSIONS AND RECOMMENDATIONS

### CONCLUSIONS

- BLOCK II POWERPLANT DEMONSTRATED CAPABILITY FOR ONE LAUNCH WINDOW.
- BLOCK II POWERPLANT ESTIMATED CAPABILITY FOR TWO LAUNCH WINDOWS.
- 725 AT MSC PROVIDING FIRST FIRM DATA.
- CERIA/COBALT EXPERIENCE INDICATES THREE LAUNCH WINDOW CAPABILITY.
- ECONOMICS OF CHANGE TO CERIA/COBALT POWERPLANT.
  - . DEVELOPMENT HAS BEEN COMPLETED.
  - . BETTER THAN 50% CELL RECLAMATION EXPECTED .
  - . REPLACING THREE POWERPLANTS ON THE PAD IS COSTLY IN TIME AND DOLLARS.
- CERIA/COBALT CHANGE CAN BE MADE WITHOUT DISRUPTING NASA SCHEDULE
- THE CHANGE WILL NOT IMPACT THE NASA MISSION SCHEDULE, POWERPLANT/ SPACECRAFT INTERFACE, GSE OR OPERATIONAL CHECK-OUT PROCEDURES.

### RECOMMENDATIONS

- QUALIFY THE PC3A-2 POWERPLANT FOR 1000 HOUR OPERATING LIFE BY INCORPORATING CERIA/COBALT CELLS.
- DETERMINE EXPERIMENTALLY, MAXIMUM BLOCK II HOT TIME PRIOR TO LAUNCH VIBRATION WHICH WILL STILL PERMIT SUCCESSFUL 14 DAY MISSION WITH ADEQUATE MARGIN.
- CONSIDER EFFECTS ON LIFE, IF ANY, OF SPS ENGINE INDUCED VIBRATION DURING MISSION.



POST - BLOCK II  
APOLLO PROGRAM SUPPORT



- CURRENT APOLLO PROGRAM REQUIREMENTS
- ALTERNATE PROGRAMS PREVIOUSLY DISCUSSED WITH NR
  - WEIGHT REDUCTION (AP-341 DATED 21 MAY 1968)
  - 1000 HOUR, THREE LAUNCH WINDOW CAPABILITY-NR INITIATED (AP-351 DATED 6 JUNE 1968)
  - OVERBOARD WATER RELIEF VALVE
  - STAINLESS STEEL H<sub>2</sub> PUMP SEPARATOR (AP-353 DATED 3 JULY 1968)
  - DEFERRAL OF EXPENDITURES TO FISCAL YEAR 1970 NR INITIATED (AP-363 DATED 10 JULY 1968)
  - SUSTAINING ENGINEERING PRESENTATION TO NR
- SUMMARY OF PROPOSED PROGRAM CHART
- MANPOWER PROJECTION CURVES
  - WEIGHT REDUCTION PROGRAM AP-341
  - DEFERRAL OF EXPENDITURES PROGRAM
  - SUSTAINING ENGINEERING PROGRAM



CURRENT APOLLO PROGRAM REQUIREMENTS

BLOCK II BASIC PROGRAM - ENDS 30 JUNE 1969

- DELIVERY
  - FABRICATE, TEST AND DELIVER
    - . 51 NEW BLOCK II QUALIFIED POWERPLANTS - 20 DELIVERED
    - . 9 POWERPLANTS UPDATED FROM BLOCK I TO BLOCK II - 3 DELIVERED
    - . PROVIDE ENGINEERING SUPPORT FOR DELIVERY PROGRAM

SUPPORT

- PROVIDE PROGRAM MANAGEMENT SUPPORT
- PROVIDE PROJECT TECHNICAL SUPPORT OF FIELD OPERATIONS



CURRENT APOLLO PROGRAM REQUIREMENTS

SPARES PROGRAM - ENDS WITH LAST BLOCK II DELIVERY

- MANAGE SPARE PARTS PROGRAM PER NR SUPPLIED PROGRAMMING DATA

OVERHAUL AND REPAIR PROGRAM - ENDS 28 AUGUST 1968

- TT&E POWERPLANTS AND COMPONENTS RETURNED FROM FIELD
- CONDUCT OVERHAUL AND REPAIR ACTIVITY
- REFURBISH SHIPPING CONTAINERS

FIELD OPERATIONS PROGRAM

- PROVIDE FIELD PERSONNEL AT MSC AND DOWNEY PLUS IN-HOUSE SUPPORT  
THRU 31 DECEMBER 1968



ALTERNATE PROGRAMS PREVIOUSLY DISCUSSED WITH NR

● WEIGHT REDUCTION - (AP-341 - 21 MAY 1968)

- 6 MONTH DEVELOPMENT AND FIELD SUPPORT PROGRAM ADDED TO CURRENT APOLLO PROGRAM - NOW 8 MONTHS
  - . REDUCTION IN SPACECRAFT SYSTEM WEIGHT UP TO 138.3 POUNDS PLUS POTENTIAL FOR ADDITIONAL 93.0 POUNDS
  - . INCREASE OPERATIONAL FLEXIBILITY (INCREASED POWERPLANT LIFE)
  - . EXTENDS BASIS FOR O&R CAPABILITY
  - . EXTENDS ENGINEERING SUPPORT OF APOLLO MISSIONS.



ALTERNATE PROGRAMS PREVIOUSLY DISCUSSED WITH NR (CONTINUED)

- 1000 HOUR, 3 LAUNCH WINDOW CAPABILITY-NR INITIATED (AP-351 - 6 JUNE 1968 PLUS DISCUSSION WITH NR/NASA)

- PROPOSED WITHIN THE CURRENT BLOCK II PROGRAM - COULD PROVIDE BASIS FOR PROGRAM EXTENSION

- . NEEDED TO MEET CURRENT EXTENDED GROUND TEST PLUS MISSION REQUIREMENTS
- . INCREASE OPERATIONAL FLEXIBILITY (INCREASED POWERPLANT LIFE)
- . REDUCTION IN POWERPLANT WEIGHT
- . INCREASES GROWTH CAPABILITY FOR FUTURE MISSIONS



ALTERNATE PROGRAMS DISCUSSED WITH NR (CONTINUED)

- OVERBOARD WATER RELIEF VALVE
  - DISCUSSED WITH NR APRIL 1967
  - INCLUDED WITH H<sub>2</sub> PUMP PROGRAM - CANCELLED
  - INCLUDED IN WEIGHT REDUCTION PROPOSAL - COULD PROVIDE BASIS FOR PROGRAM EXTENSION
    - . PROVIDES POSITIVE POWERPLANT WATER REJECTION
    - . INCREASES SYSTEM RELIABILITY



ALTERNATE PROGRAMS DISCUSSED WITH NR (CONTINUED)

- STAINLESS STEEL H<sub>2</sub> PUMP SEPARATOR (NR/NASA INITIATED AP-353 - 3 JULY 1968)
  - PROPOSED WITHIN CURRENT BLOCK II PROGRAM - COULD PROVIDE BASIS FOR PROGRAM EXTENSION.
  - PROVIDES POSITIVE CONTAINMENT OF ELECTROLYTE
  - INCREASES SYSTEM RELIABILITY



ALTERNATE PROGRAMS DISCUSSED WITH NR (CONTINUED)

- DEFERRAL OF EXPENDITURES TO FISCAL YEAR 1970 - (AP-363 NR INITIATED - 10 JULY 1968)
  - 5 MONTH SLIPPAGE OF CURRENT APOLLO PROGRAM DELIVERY SCHEDULE
    - . REDUCES FISCAL 1969 EXPENDITURES
    - . EXTENDS BASIS FOR O & R CAPABILITY FOR FIVE MONTHS
    - . EXTENDS ENGINEERING SUPPORT FOR APOLLO MISSIONS FOR FIVE MONTHS
    - . INCREASES TOTAL PROGRAM COSTS WITHOUT IMPROVING POWERPLANT CAPABILITY



ALTERNATE PROGRAMS DISCUSSED WITH NR (CONTINUED)

- SUSTAINING ENGINEERING PRESENTATION TO NR (NR INITIATED 29 OCTOBER, 1966)
  - PROVIDE TECHNICAL ABILITY TO RESOLVE PROBLEMS RESULTING FROM:
    - . INTERFACE MISMATCHES
    - . NEW PHYSICAL ENVIRONMENTS
    - . NEW AND MORE ACCURATELY DEFINED MISSION PROFILES
    - . PERFORMANCE OF OTHER EQUIPMENT AND THE OVERALL SPACECRAFT SYSTEM
    - . POSSIBLE EXTENDED MISSION GOALS
    - . UNANTICIPATED FAILURES OR FAILURE MODES
  - PROVIDE ABILITY TO SOLVE IN-FLIGHT PROBLEMS AND INVESTIGATE PRE-FLIGHT, FLIGHT, AND POST-FLIGHT ANOMALIES
  - PROVIDE PROGRAM TO CONSTRUCTIVELY UTILIZE AVAILABLE TECHNICAL RESOURCES DURING PERIODS OF REDUCED FIELD ACTIVITY
  - PROVIDE OVERHAUL AND REPAIR PROGRAM TO SUPPORT ONE OVERHAUL PER MONTH
  - MAINTAIN SPARE PARTS INVENTORY PER NR SUPPLIED PROGRAMMING DATA



ALTERNATE PROGRAMS DISCUSSED WITH NR (CONTINUED)

- REVISIONS TO SUSTAINING ENGINEERING PRESENTATION REQUIRED TO BE CONSISTENT WITH CURRENT REQUIREMENTS.
- PROVIDE O & R PROGRAM TO SUPPORT ONE OVERHAUL EVERY THREE MONTHS
- PROVIDE ON-SITE FIELD REPRESENTATIVES AT MSC AND DOWNEY
- UPDATE ENGINEERING SUPPORT BASED ON S/C 101, 008, 017 LAUNCH EXPERIENCE
- UPDATE OVERALL MANPOWER SUPPORT BASED ON CURRENT INFORMATION.



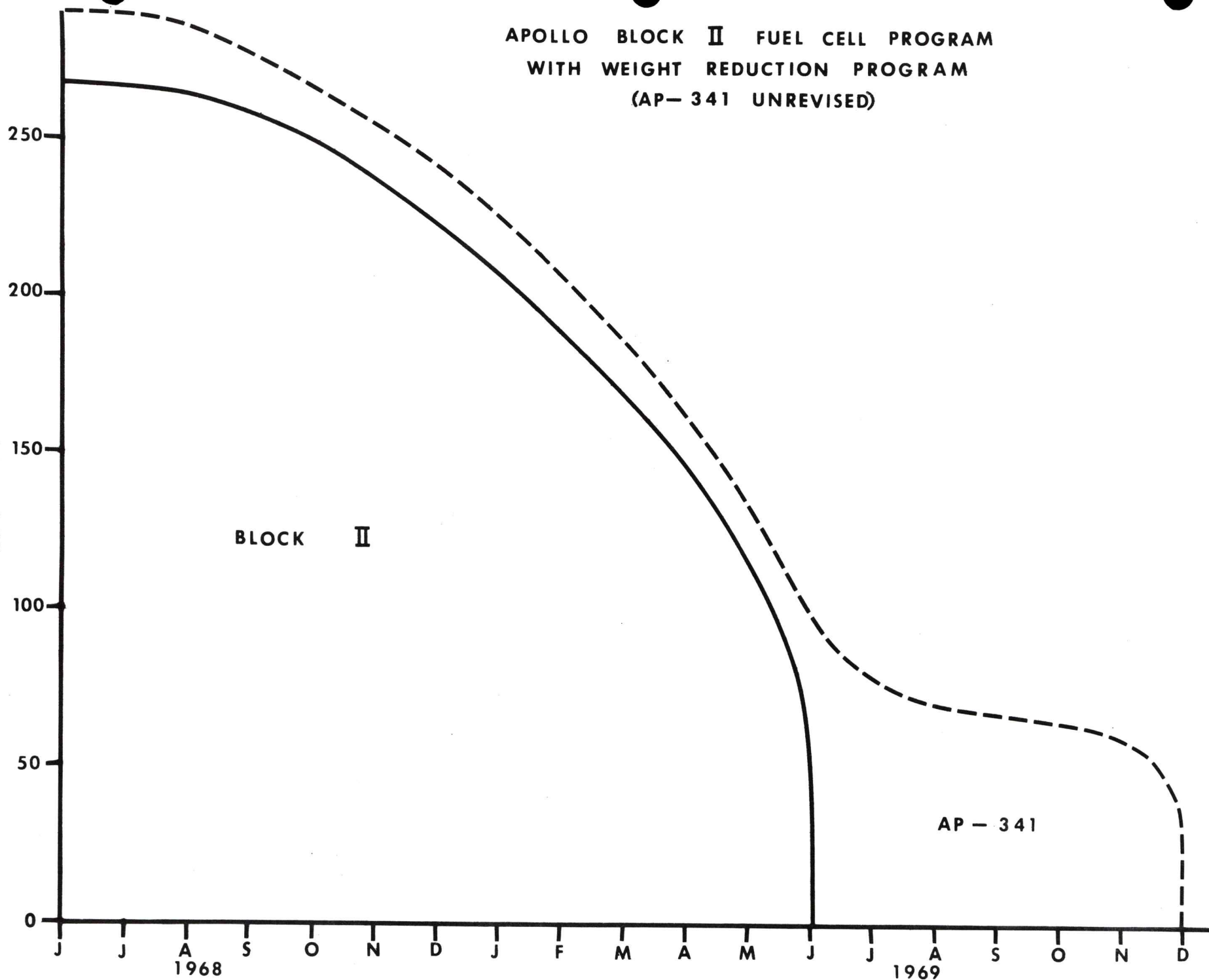
SUMMARY OF PROPOSED PROGRAMS

COVERAGE PROVIDED	AP-341 OPERATIONAL READINESS AND POST FLIGHT ANALYSIS	FISCAL 1969 EXPENDITURE DEFERAL	SUSTAINING ENGINEERING PROGRAM
DELIVERY		X	
DEVELOPMENT	X		X
PRODUCTION SUPPORT		X	
FIELD OPERATIONS		X	X
SPARES			X
O & R			X
PROGRAM MANAGEMENT	X	X	X
PROJECT SUPPORT OF FIELD	X	X	X
PROGRAM EXTENSION (MONTHS)	6 (8)	5	

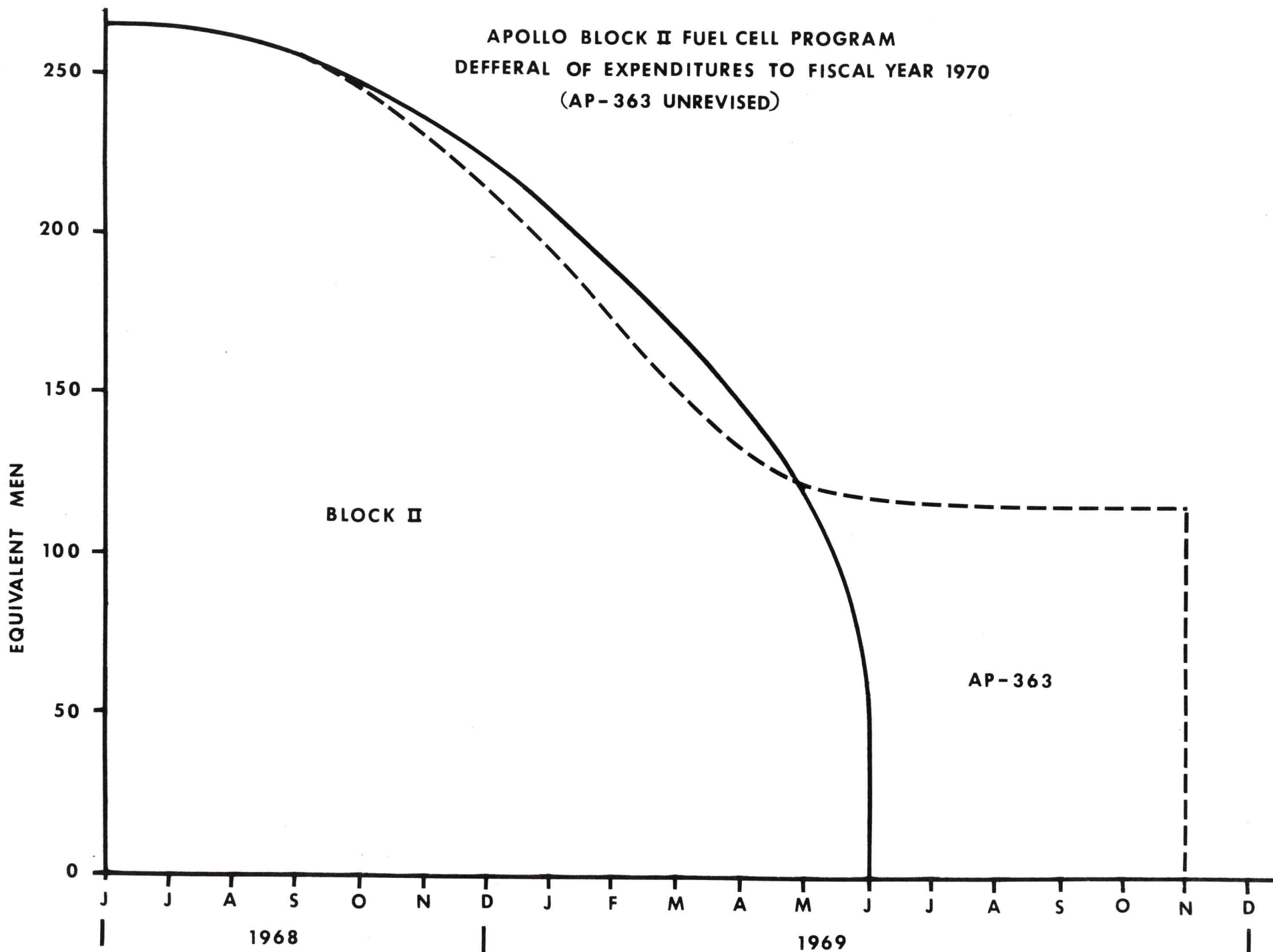


APOLLO BLOCK II FUEL CELL PROGRAM  
WITH WEIGHT REDUCTION PROGRAM  
(AP-341 UNREVISED)

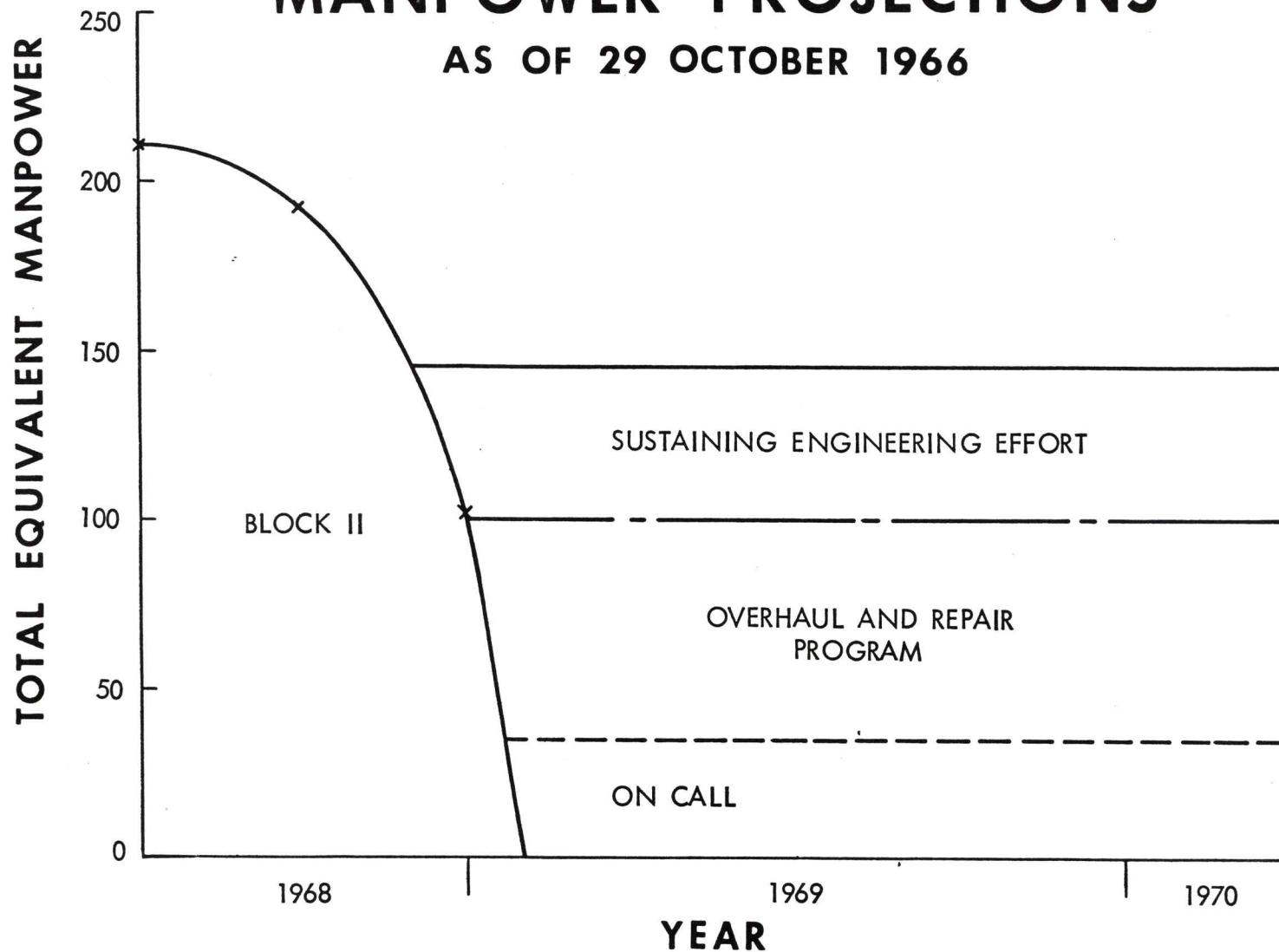
EQUIVALENT MEN







APOLLO FUEL CELL PROGRAM  
**MANPOWER PROJECTIONS**  
AS OF 29 OCTOBER 1966



Pratt &  
Whitney  
Aircraft

**U  
A**

DIVISION OF UNITED AIRCRAFT CORPORATION

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