NTO-R-0164

Records

Spear Report

XE-Prime

EP-1 Initial Criticality & EP-SL2 Steam Line.

18 DECEMBER 1968

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SPEAR TEAM REPORT

TO: TEST REVIEW BOARD
W. E. Stephens, D. Reilly, P. W. Davison

DATE: 18 December 1968
NTO-M-25855
FBD:cjd

FROM: SPEAR Team

SUBJECT: SPEAR Team Initial Criticality and Steam Line Tests EP-I and EP-SL2

ENCLOSURES: (1) through (28) SPEAR Memoranda (See Table of Contents)

Enclosed are the SPEAR Team memos for XE Prime Initial Criticality, and Steam Line test, EP-I and EP-SL2 conducted on December 4 and December 6, 1968.

The memos cover detailed analysis of the engine, facility and data processing systems by the Facility, Instrumentation, Controls and Non-Nuclear Component groups of the SPEAR Team. Individual members participating in this activity are identified in the Table of Contents.

F. B. Damerval

F. B. Damerval, Chairman
SPEAR Team

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SPEAR Memo No. 1
F. B. Damerval:cjd

XE-PRIME

EP-I and EP-SL2

Subject: SUMMARY OF SPEAR ANALYSES

Experimental Plan I of the XE-Prime Test Series was performed on December 4 and December 6, 1968, at ETS-1 of the Nuclear Rocket Development Station, Jackass Flats, Nevada.

Initial criticality at an average drum bank position of 99.8° was attained at approximately 20:08 PST on December 4, 1968. A hold to investigate a drum torque motor anomaly (see Memo 12) delayed completion of the test for several hours.

The Nuclear Autostart, integral worth of drums 1 and 7, the intermediate power dosimetry irradiation ahd thermal calibration operations were not performed therefore these objectives were not met. All other objectives for EP-I and all objectives of the Steam Line test were successfully met.

The power integral for EP-I was 10.8 kw-Hr and for EP-SL2 was 6.5 kw-Hr (refer to Memo 2).

Data processing problems were encountered because no formal procedure exists for selecting valid calibrations to be used in reducing digital data to engineering units. The data acquisition system performed quite well, however, problems exist in the wide band system and must be corrected before meaningful data can be obtained. (see Memo 9).

Significant operations included: (1) Initial Criticality, (2) Controls System Checks, (3) S-1 Shield Water Worth Measurements, (4) Low Power Dosimetry Irradiation and (5) Drum Worth Checks. Water flow and steam line checkout operations were included in the test performed on December 6, 1968, which is designated as EP-SL2 in this report.

Control System checks included transfer function measurements; and scram and step function demands in various control modes. S-1 Shield Worth Measurements included Steady State 1 kw runs with the S-1 shield in place dry and in place filled with water. The worth of the water was not large enough to give a statistically significant difference in critical drum position from the dry S-1 Shield Critical Drum Position.

Concurrent with the low power dosimetry irradiation, sulfur pellets at the nozzle throat and a fission chamber were exposed inside the engine shield. The actual power during this operation was 171 kw (100 kw planned) and is discussed in Memo 2.

The drum worth span determined by the drum bump method is approximately 6 - 8% lower than predicted. Integral drum worth of two individual drums measurements are required to check this result.

The SGS water injection modification resulted in stable steam temperatures up to and including 1600°R with duct water flow of 39,000 gpm and a water tank level of 15 feet. Water injection was easily controlled by the console operator.

The steam line and separator performed satisfactorily, however, a sudden increase in temperature downstream of the separator occurred around 1350 - 1400°R accompanied by steam pressure oscillations. The steam temperature is not affected by these pressure oscillations.

Following are the SPEAR recommendations from XE-Prime EP-I and EP-SL2:

	RECOMMENDATIONS	REFERENCE MEMO
1.	Readjust linear gains and log offset voltages as listed in the section on Reactor Power Calibration in Memo 2.	2
2.	Reset Linear No. 2 Range trip point so that it won't chatter. Avoid selecting No. 2 for display until this is accomplished.	2
3.	Perform a one point (LRE) neutronics and a source calibration after the data system last pre run calibration and prior to the post calibration. This will insure that the neutronics calibrations are recorded on data.	2
4.	The LRE should keep a standard pre-printed log sheet during each test showing the range time for the following: when each log channel is rejected or reset in the averagers, which log and linears are selected for control and display. This data is not otherwise available except by memory.	2
5.	The fitting of the calibration steps (0, 25, 50, 75 and 100%) in determining the corrected digital output of drum position should be based on the expected drum positions to be encountered in a given test. For example, EP-I fitting should be based on the 50% calibration point (90°) since all of the data was collected between drum bank angles near 100°. For subsequent full power tests, the data will fall in the 100 to 130° range and the 75% (135°) calibration or a calibration between 50 and 75% will be satisfactory.	3
6.	To complete the determination of the cold critical drum bank angle, the drums should be actuated out to their lock position individually.	3

RECOMMENDATIONS	REFERENCE MEMO
7. To facilitate the data reduction and SPEAR effort for subsequent tests, a running average of 5 to 10 seconds duration on the individual drum positions should be calculated. Also, a numerical average of the 12 individual drum positions to obtain the average drum bank position along with a running average should be calculated and made available with the thinned digital listings.	3
8. The standard procedure of measuring the integral worth of two drums is recommended for obtaining the best estimate of the XE-Prime drum span, since the differential worth measurements indicate the worth is approximately 8% lower than predicted.	5
9. The installation of TE662 through TE605 should be checked to verify proper contact and spring loading.	8
10. The steam line displacement potentiometer data, which is recorded on FM tape, should be processed to Engineering unit plots and digital listings within three days of the test.	8
11. The effect of steam pressure oscillations on system performance at separator exit temperatures above 1400°R will be further evaluated. Pending this evaluation, operation at steam temperatures above 1400°R should be minimized.	8
12. A more formalized procedure should be established for selecting valid calibrations to be used in reducing digital information to engineering units.	9
13. A complete evaluation of the wide band measurement system (transducer output to engineering unit data output) should be performed to assure adequate performance.	9
14. The oscillogram headers should reflect the ranges and engineering units as noted by the applicable data log.	9
15. All FExxx flow channels, which require a frequency calibration, should include the setup information needed at ETS-1 (see format of FE429..F of XE-P Datalog Issue 4, as an example) and should include the equivalent frequency of the applicable calibration step to be used in data reduction.	9
16. The nominal range values listed in the coding and signal conditioner setup range column of the Datalog should reflect the actual measurement range that the signal conditioner mode card will produce. This will indicate to the data user the exact range over which the data should be considered valid. This in no way changes setup requirements or data reduction techniques.	9

RECOMMENDATIONS		REFERENCE MEMO
17.	The "101 Point Listing" should contain listings of all mode card/engineering unit conversion combinations as specified under the signal conditioner setup range column of the Datalog.	9
18.	The output of the function generator used for transfer function measurements (measurement VC900..E) should be calibrated and ranged so that the predicted maximum value will be 75% of the measurement full scale.	9
19.	Record VC900..E on FM tape No. 2 (as well as No. 4) in place of MC043.F which is the only non-zero suppressed channel on tape No. 2. MG043.F should be moved to tape No. 4 where it can replace deleted measurement NX901..N. This will reduce possible time base errors in performing transfer function analyses.	9
20.	The grounding modifications made during SL2 test should be made permanent. Further investigations should be conducted to determine if any other wiring exists which connects the 24 VDC common to the 10 VDC common in Rack 50.	12
21.	Proper adjustment of the scram indicator lamp detectors should be verified prior to further testing.	13
22.	Investigate why Drum Position Average reading changes when the drum lock/unlock relay in chassis 40R048A2 operates and correct the problem.	14
23.	Correct noise in Engine Log Channel No. 1 (NC801..N).	14
24.	If engine operation requires power level changes in excess of two decades on a two second period, further checkout of the power controller is required to insure that a period scram will not be generated. This further checkout requires a three decade power level change on a two second period.	15
25.	Perform the transfer function measurements planned for EP-I during EP-IA using step, sine, and pseudo random inputs. To achieve a better signal to noise ratio on data channels, power should be above 1 kilowatt, preferably 10 kilowatts or 100 kilowatts.	15
26.	Increase the range on the function generator channel, VC900, to avoid the saturation experienced in EP-I.	15
27.	Record the function generator output, VC900, on a 100 sps digital channel. This will permit transfer function computation from digital data.	15
28.	Correct the power demand generator output channel, CC605, so that valid data is obtained.	15
29.	Range the zero suppressed log power channels to obtain a larger signal amplitude during transfer function measurements.	15

RECOMMENDATIONS	REFERENCE MEMO
30. The indicated discrepancy between the drum demand and the computed average drum position should be corrected before the next test.	16
31. Transfer function measurements should not be aborted on the basis of control room strip charts which may not have enough resolution.	16
32. The wide band drum override channel should be recorded at the tracker output rather than at the manual position demand output in order to show tracker functioning in the position control mode.	16
33. Incorporate as part of the operating procedure the closing of the separator water drain valve (RSV-439) when operating two generators at full steam temperatures over 760°R.	17
34. Post-test torque checks and bolt tightening as necessary should be made a standard procedure for the steam line flanges, since significant decreases in bolt tightness occurred as a result of the test.	17
35. The steam line position lowered as a result of the test, and if left as is, thermal expansion on a succeeding test will cause snubbers and load hangers to approach or exceed limits of travel. The "constant-load" hangers supporting the steam line in the pipe chase should be re-adjusted to support a greater load, such that the steam line at the lower elbow will be raised approximately one inch, establishing a new support condition for reference on a succeeding test.	17
36. The water from the shield discharge which sprayed on the steam line in the duct vault during testing should be diverted such that the steam line gimbal and severange plane connector are not deluged during the test.	17
37. Rework RSV-69 so that it will not freeze up.	18
38. Rework RSV-329 so that it will not leak.	18
39. Insulate and, if necessary, re-route the water sensing lines away from the liquid oxygen lines in the SGS.	18
40. New type pressure switches should be procured and installed. If this is not done, a new differential pressure switch, PDS-480, should replace the existing switches on Units 1 and 3. The low side port of each switch should be manifolded to a common 1/4 inch sensing line and the line connected to a port on the plenum exist flange. The sensing location should not use the same port as PT-425 and PT-426.	18

RECOMMENDATIONS	REFERENCE MEMO
41. The pressure transducers used for PT047X..FSG and PT408X..FSG (first and second stage propane pressure on Module 2) should be temporarily installed to the top of the combustion chamber of Modules 1 and 3 to evaluate the differential pressure during the next test.	18
42. During engine tests, all three modules should be started to idle steam and the spare module shut down after the other two are at full steam.	18
43. The second stage LOX valve on Module 3 should be removed, evaluated at cryogenic temperatures and disassembled to determine why the valve hung up.	18
44. It is recommended that those leaking duct coolant water inlet valves be repaired as soon as spare parts are available.	19
45. The duct flare systems should be re-evaluated prior to the next test to determine if modifications or adjustments can be incorporated to increase their operational reliability.	19
46. Criteria for evaluation of duct strain data should be provided by source engineering prior to the next test.	19
47. Re-direct the nozzles on the duct vault door vertical coolant line to spray on the side wing of the west duct door.	20
48. The one line from the discharge manifold of the bottom eight tubes of Section 3 of the duct should be used to cool the lower part of the side wing of the west duct door. At present, this line just discharges onto the floor of the drainage ditch.	20
49. The seemingly excessive pressure drop in the shield water flow supply header should be further evaluated. If no explanation is possible, then water flow rate requirements should be re-evaluated to determine whether the present requirements are too conservative.	21
50. The PT-290 and 291 transducer lines should be checked for either open lines or hand valves that may have been left open.	21
51. In order to conserve helium, flow to the control drum actuators should be terminated during hold periods of any significant length.	22
52. The requirement that the chiller level indication (PD852) be maintained at .5 psid should be deleted and the operational requirement should be changed to maintain the exit gas temperature below 165°R during cryotrap operations.	23

RECOMMENDATIONS	REFERENCE MEMO
53. The duct water supply valves should be repaired as soon as possible.	25
54. The SGS operating procedures and the cooldown temperature requirement should be reviewed for possible means of reducing LOX useage during bleed-in.	25

The recommendations are usually associated with an anomaly, therefore, the anomalies are not listed separately. However, as one last recommendation (for this report), the anomalies from Table 1 of Memo 9 should be resolved.

SPEAR Memo No. 2
W. F. Booty:cjd
B/BSH

XE-PRIME

EP-I and EP-SL2

Subject: NEUTRONICS SYSTEM PERFORMANCE

INTRODUCTION

The ETS-1 neutronics systems were exercised for the first time with a nuclear reactor during EP-I. For the purpose of this memo, the neutronics system includes the following subsystems:

Permanent

Primary - Control and Diagnostic

1. BF_3 Startup Channels.
2. Linear Power channels.
3. Engine Mounted Log Power and Period Channels.
4. Test Stand Log Power and Period Channels.

Secondary - Diagnostic Only

1. UTS Gamma Detectors.
2. ETC Gamma Detectors.
3. Fast Fission Detectors.

Temporary - Initial Calibration Only

1. WANEF PAX Fast Fission Chamber.
2. Sulfer Pellets.

SUMMARY

The neutronics system in general performed satisfactorily for EP-I and SL2. Calibrated fission chamber and sulfer pellets were used to establish absolute power level vs. indicated powers data. The indicated levels were within the expected accuracy. Some minor adjustments still need to be made prior to the next test. The integral actual power as determined from the low power sulfer pellet dosimetry was 38833 kw sec (10.79 kw hr) for EP-I (100 kw x 1/20 hr = 5 kw hr expected). The integral power for SL2 was 23,253 kw sec (6.459 kw hr).

TECHNICAL DISCUSSION

A. System Performance

Primary Systems

1. BF_3 LCR Startup Channels

The three log count rate startup channels all performed well throughout both EP-I and SL2. They were used to obtain inverse multiplication data for critical drum bank predictions. Prior to SL2, the discriminator voltage was raised in order to reduce the noise count rate component. This also reduced the countrate above background to about 45 cpm which was below the 60 cpm required before startup is permitted. The required countrate was obtained when the drums were at about 68 deg.

2. Linear Power Channels

The performance of the three linear power channels was generally satisfactory during both tests. Linear No. 2 range setpoint was too close which caused it to chatter when changing ranges. This can be seen on Figure 1 which is a plot of calculated Linear No. 1, Linear No. 2, and Linear No. 3 Powers during the third differential drum worth measurement. Linear No. exhibited about ± 5% oscillations throughout most of the tests and drifted slightly down.

3. Engine Log Power Channels

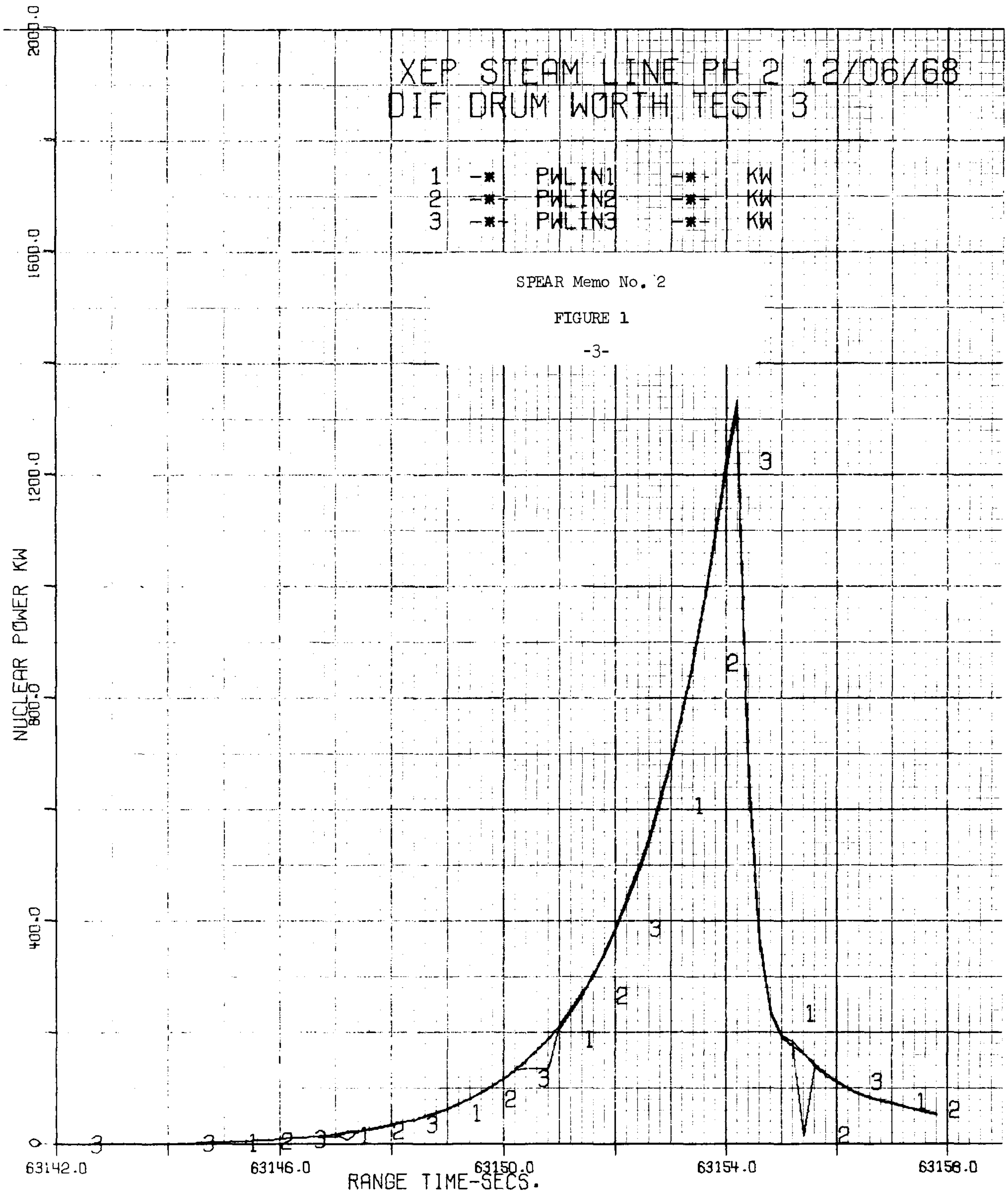
All three engine log channels functioned properly during both tests except for a difference in console DVM and data system readings.

4. Test Stand Log Power Channels

T. S. Log No. 2. did not function during either test because the stationary side S-2 connector was pulled out inside the box. Test Stand Logs 1 and 3 functioned properly other than a difference in the LRE console meter and data.

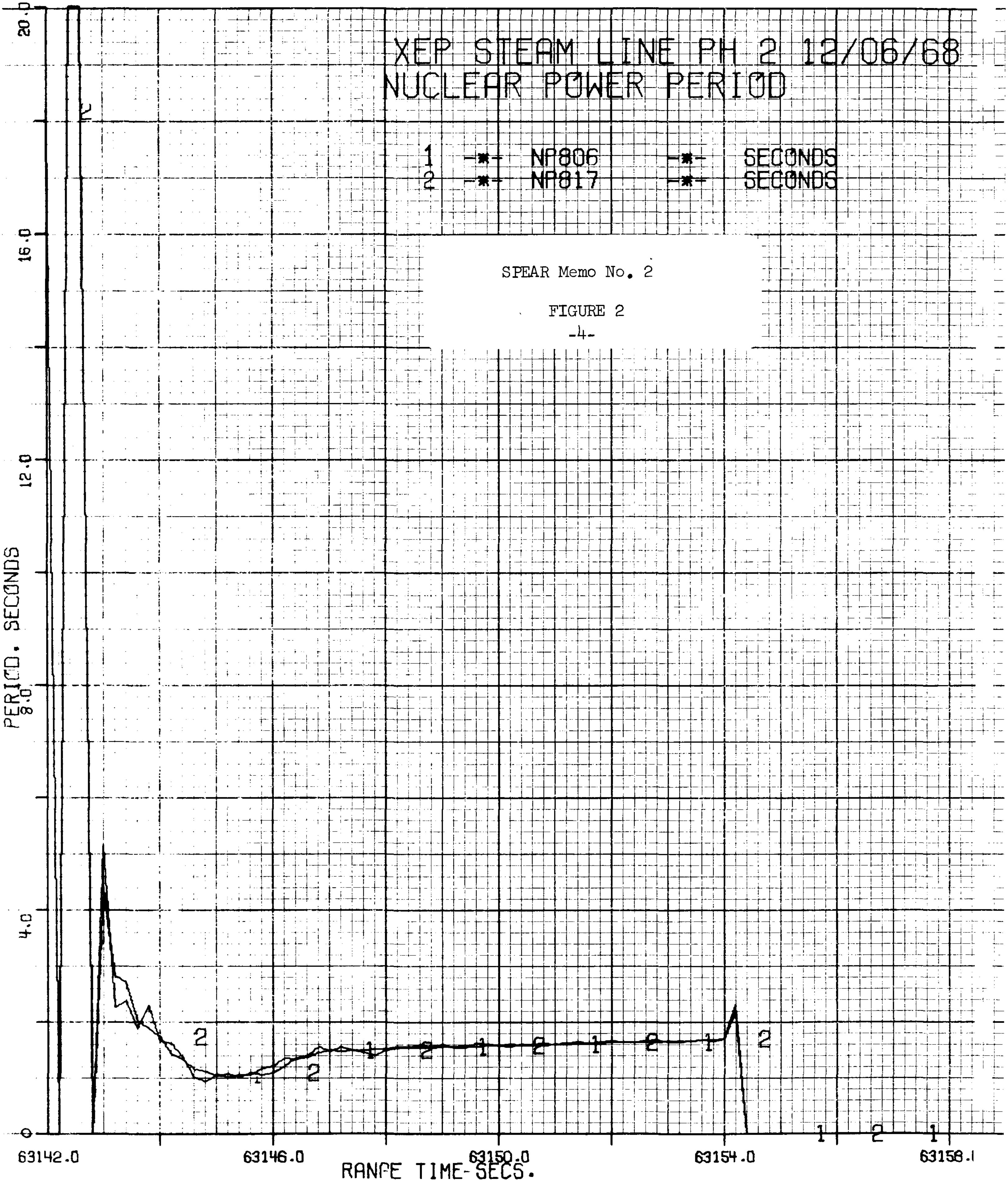
5. Engine and Test Stand Period Channels

Both Period Channels worked satisfactorily. Figure 2 shows the two calculated periods for the third differential drums worth measurement. There is a slight drift in the indicated stable period which must be attributable to amplifier drift because the actual period is stable.



SPEAR Memo No. 2

FIGURE 1



SPEAR Memo No. 2

FIGURE 2

Secondary Systems

1. UTS Gamma Detectors

All three of these channels failed. The output to data of the detectors is taken from the plate circuit of the electrometer tube used to measure the chamber current. The signal conditioning equipment used with these channels initially was not designed to accept the 150 v common mode voltage applied to the gamma circuit. As a result, excessive current was drawn from the circuit which probably caused the electrometer tube to fail.

Spare components will be installed in the engine at E-MAD prior to the next test and the circuit incompatabilities corrected.

2. ETC Gamma

The level channel was very sluggish to changing power levels. Also, it was not set up to 100 mv full scale due to lack of time problems. The range channel worked correctly on EP-I. On SL2 it was set to 12 decades full scale instead of the correct 10.

3. Fast Fission Channels

N.845 output was lower than expected probably due to a conservative discriminator setting. The chamber is very sensitive to vibration caused by the steam generator system. The high range channel N.846 was not set up for these low power tests.

Miscellaneous Systems

1. Averagers

Both log averagers appeared to work properly. Automatic rejection occurs if any input is ± .25 v (10 v full scale) from the average. At 1.25 v/decade this is .2 decades or a factor of 1.584. On the first startup of EP-I, T. S. Log No. 1 was rejected. Since No. 2 didn't work, this caused the average to be low and the actual full power scram check was at about 20 kw. Test Stand Log No. 2 was always rejected after this so it was not possible to check the reject feature of the T. S. Log Averager. Engine Log No. 1 was rejected most of SL2. An effort was made to reset it several times but it was too noisy and would not stay in very long. Later it drifted too far out. See Memo 14 for a detailed evaluation of the averages.

2. Power Loop Closure

The power loop closure pot was set at zero divisions for both tests. Power loop closure as indicated by the digital data event occurred consistently in the 250 watt range which is correct for 0 pot divisions.

B. Reactor Power Calibration

The calibration of indicated to actual nuclear power was performed by two different methods during EP-I. The two standards used for comparison were a calibrated fast fission chamber and sulfur pellets.

a. Fast Fission Chamber Calibration Results

The purpose of the pre-calibrated fast flux fission chamber was to obtain an initial calibration of the permanent test stand detectors to insure a sufficiently accurate power exposure of the low power dosimetry. For this purpose, two identical Westinghouse WX-30748 U^{238} (2 ppm U^{235}) fast fission chambers and their pre-amplifiers were calibrated at the WANEF PAX reactor. The calibration factor for both chambers was determined to be 33.8 counts/sec/watt. A detailed report of this calibration is in WANEF-487-67. Due to a detector failure, it was necessary to replace the original fission chamber S/N 672601 and its pre-amp with S/N 672602 shortly before EP-I. It appeared that a mounting bracket set screw had pierced the detector case. The fission chamber is located with its axis centerline on and parallel to the nozzle throat station in a special holding bracket which was also used on the PAX reactor.

After achieving initial criticality, indicated linear No. 1 power was brought to nominal power levels of 10, 50, and 100 watts and held long enough to take a count rate on the fission chamber. The data associated with this initial XE-P power calibration which was taken during the test is shown in Table 1 below:

TABLE 1

FISSION CHAMBER CALIBRATION

Nominal Indicated Power, w	10	50	100
Fission Chamber 100 sec count	14,496	73,832	140,681
Fission Chamber 100 sec count	14,168		144,000
Fission Chamber cps, avg.	143.3	738.3	1,423
Fission Chamber Power @ 36 cps/w	3.98	20.5	39.6
Linear No. 1 Indicated Power, w	10	52	100
Linear No. 2 Indicated Power, w	9.5	48	90
Linear No. 3 Indicated Power, w	10	50	95
Correction Factor Linear No. 1	.398	.396	.396
Correction Factor Linear No. 2	.419	.427	.440
Correction Factor Linear No. 3	.398	.410	.417

On the basis of the above preliminary data, a factor of 2.4 indicated Linear No. 1 power to fission chamber power was selected to perform the low power dosimetry irradiation.

Due to the lack of time between installing the spare fission chamber on R morning and the start of EP-I, it was not possible to set it up the same as the original chamber. It was decided to use the original discriminator voltage settings and adjust the WANEF calibration K factor of 33.8 counts/sec/watt by using the known effect of discriminator voltage. For this reason, a K of 36 cps/w was used. Actually the factor should have been corrected the other direction; i.e. $33.8 \times \frac{33.8}{36} = 31.73$. Had this K been used, the ratio of indicated to fission chamber power would have been closer to unity by a factor of 1.135 as follows:

	AVERAGE CORRECTION FACTORS at 10, 50 and 100 WATTS K = 36		K = 31.73
Linear No. 1	.397		.451
Linear No. 2	.429		.487
Linear No. 3	.408		.463
		Avg	.467

b. Low Power Dosimetry

The EP-I low power dosimetry consisted of three 1.5 in. diameter pure sulfur pellets. Similar ones were calibrated at the WANEF PAX reactor as reported in WANL-TME-1758. The calibration factor was established as 9060 nv/watt. It was planned to irradiate the sulfur pellets at 100 kw for 180 seconds. Scram was at 78171 sec - 2142:51 hours. The counts were initiated 28 minutes after shutdown. Two 30 minute counts were taken on each sample. The counter was calibrated and corrected for background. The results of the computer data reduction DOSCO program, which indicates normalized flux, is shown in Table 2 below:

TABLE 2

SULFUR PELLET LOW POWER DOSIMETRY DATA

Sample Identification	Experiment Number	Item No.	Normalized Flux
200	8403	1	1.9128×10^9 nv
200	8403	2	1.9744×10^9 nv
300	8403	3	1.8967×10^9 nv
300	8403	4	1.9734×10^9 nv
80	8408	1	1.9605×10^9 nv
80	8408	2	2.0054×10^9 nv

AVERAGE = 1.9538×10^9 nv

Using the WANEF sulfur pellet calibration factor of 9060 nv/watt this gave a reactor power of 215.4 kw. On the basis of data taken during EP-I, the following adjustments shown in Table 3 below were made to the linear and logs prior to and used on SL2.

TABLE 3

LINEAR CORRECTION FACTORS AND LOG OFFSETS USED FOR SL2

	Power Indicated On Meter		Correction Factor $\frac{\text{Actual Power}}{\text{Indicated Power}}$
	Volts	Kw	
Linear No. 1	$.32 \times 10^6$	320	.67
Linear No. 2	$.30 \times 10^6$	300	.72
Linear No. 3	$.30 \times 10^6$	300	.72
			OFFSETS
Engine Log 1	5.02	550	-.52
Engine Log 2	4.86	420	-.36
Engine Log 3	4.90	450	-.40
Test Stand Log 1	4.85	410	-.35
Test Stand Log 2	-	-	-.17
Test Stand Log 3	4.68	300	-.18

Log 215 kw = 4.50 v

$$\text{Offset} = \log \frac{\text{actual}}{\text{indicated}} = \log \text{actual} - \log \text{indicated}$$

The normalized flux at the indicated 320 kw (on Linear No. 1) hold as determined by the original sulfur pellet dosimetry data reduction program was high for two (2) reasons as follows:

1. The total dosage was assumed to have been accumulated in 3 minutes (180 sec) whereas the actual time at the hold was 208 sec (from 77960 to 78168 sec). The actual flux, due to this, was thus $\frac{180}{208}$ lower = .8654
2. Significant integral power was accumulated at other than the high power plateau. The computer calculated integral powers for the engine logs, Test Stand logs, and linears are shown in Table 4 below.

TABLE 4

SUMMARY OF LOG AND LINEAR POWERS FOR EP-I

	INTEGRAL POWERS, KW SEC.		
	Engine Log	Test Stand Log	Linear
Prior to Flux Run	1896	1908	1523
Ramp to Plateau	4352	3712	3104
On Plateau	88,322	75,712	63,520
Shutdown & Decay	1536	1408	1008
	96,106	82,740	69,155
Ratio Plateau/Total	.9199	.9150	.9185
Average =.9178			

While there is a difference in the total integral power as measured by the three different systems, the fraction of each integral at each phase is consistent.

Thus the corrected flux level at the plateau is the product of the originally reported 1.954 x 10^9 nv x .8654 correction factor for being at the plateau for 208 sec instead of 180 sec x .9178 for the total dose not all being accumulated at the plateau = 1.552 x 10^9 nv. The corrected plateau average power level is then 1.552 x 10^9 nv/9060 nv/watt = 171.3 kw.

The average plateau power levels for average engine log, average test stand log, and average linear powers were found by dividing their individual integral powers by 208 seconds. These values are 424.6, 364.0 and 305.4 kw. The corrected integral power can then be calculated as shown in Table 5 below.

TABLE 5

EP-I CORRECTED INTEGRAL POWER SUMMARY

		Corrected Integral Power		
(173.1/424.6) 96106	=	38773	kw sec	Eng. Log
(171.3/364.0) 82740	=	38938	kw sec	T. S. Log
(171.3/305.4) 69155	=	38789	kw sec	Linear
AVERAGE	=	38833	kw sec	
	=	10.79	kw hr	

On the basis of the above calculations, the linear gains and log offset adjustments which were made for SL2 should be re-adjusted prior to the next test as shown in Table 6 and Table 6A below.

TABLE 6

CORRECTED LINEAR GAIN ADJUSTMENTS

	Average Calculated Power at 171.3 kw Power Plateau	Corrected Gains Which Should have Been Used on SL2	Actual Correction Factor Used On SL2
Linear No. 1	322.5 kw	.531	.67
Linear No. 2	297.0 kw	.577	.72
Linear No. 3	296.5 kw	.578	.72
AVERAGE		.562	.703

TABLE 6A

CORRECTED LOG OFFSETS

	Average Plateau Power				
	Kw	Log w	Volts	- Volts @ 171.3 kw	= Offset
Eng. Log 1	520	5.716	4.970	-4.367	= -.603 v
Eng. Log 2	408	5.611	4.838	-4.367	= -.471 v
Eng. Log 3	423	5.626	4.857	-4.367	= -.490 v
T. S. Log 1	430	5.633	4.866	-4.367	= -.499 v
T. S. Log 2					=
T. S. Log 3	330	5.519	4.723	-4.367	= -.356 v

C. Integral Power for EP-I and SL2

The EP-I integral power was 38833 kwsec (10.79 kw hr) as discussed in the section on Reactor Power Calibration.

During SL2 the integral of the average of linear 1, 2, and 3 calculated powers was 29,087 kw sec. However, the average gain adjustment was .703 instead of the recommended .562 (also as discussed in the Reactor Power Calibration Section). The actual integral power is therefore:

$$(.562/.703)\ 29{,}087 = 23253 \text{ kw sec}$$
$$= 6.459 \text{ kw hr}$$

D. Source, One Point (LRE) and Data System Calibrations

1. Source Calibration

The Pu Be source in each of the three S2 shield locations was exposed during both tests long enough to insure that the startup channels and the Test Stand Log systems were functional. The average count rates on LCR 1, 2, and 3 during the pre-test check of EP-I were 4200, 3150, and 3300 cps. After adjusting the discriminator voltage prior to SL2 the count rate was about 3000 cps. This is compares to an expected 450 cps.

The Test Stand logs showed the following increase above background for No. 1 and 3 (2 didn't work) .50 and .42 logwatts (decades) or .625 and .525 volts. This compares to an expected value of .42 logwatts or .55 volts so No. 3 was right on. The linears increased to 3.4, 1.0, and 1.1 watts indication.

2. One Point (LRE) Calibration

This substitutes a 2×10^{-3} amp current for all the logs and linears and locks the linear ranges on the 8th decade. The LCR's are shown a 10^5 cps signal. This provides an approximate full power signal to all primary neutronics channels and is used as a final functional check.

All channels responded approximately correctly to this signal.

3. Data System Calibrations

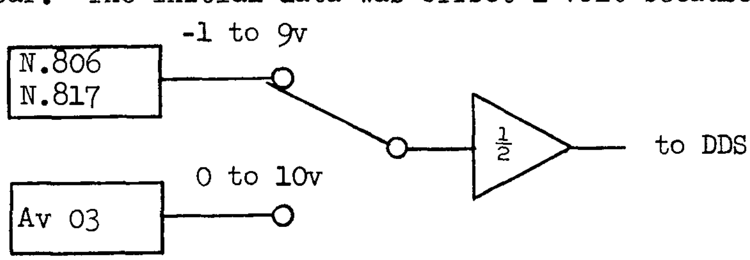
a) Startup Channels - Good.

b) Linear Channels - The neutronics data signals are different in that they are calibrated through the amplifiers. Due to this, feedback in the linear channels causes the data calibration to be attenuated by a factor of .9279, .9256 and .9243 respectively for Linears No. 1, 2 and 3. The data system calibration voltage vs. the actual measured channel voltage is plotted for the three linears on Figure 3. All are virtually identical at a factor of about .926. For purposes of digital data reduction, the linear channel slopes should thus be multiplied by .926. This caused the initial EP-I and SL2 linear data to be high.

The linear range channels will not calibrate on 0% step. Slopes thus have to be hand calculated.

c) Log Channels - The 100% calibration steps are very non-linear due to the log amplifier characteristics, however, the other steps are good.

d) Periods - The data signal is -1 to 9v; however, the DDS calibration is 0 to 10 v. as shown in the sketch below. This caused some initial confusion because the data log doesn't make this clear. The initial data was offset 1 volt because of this.



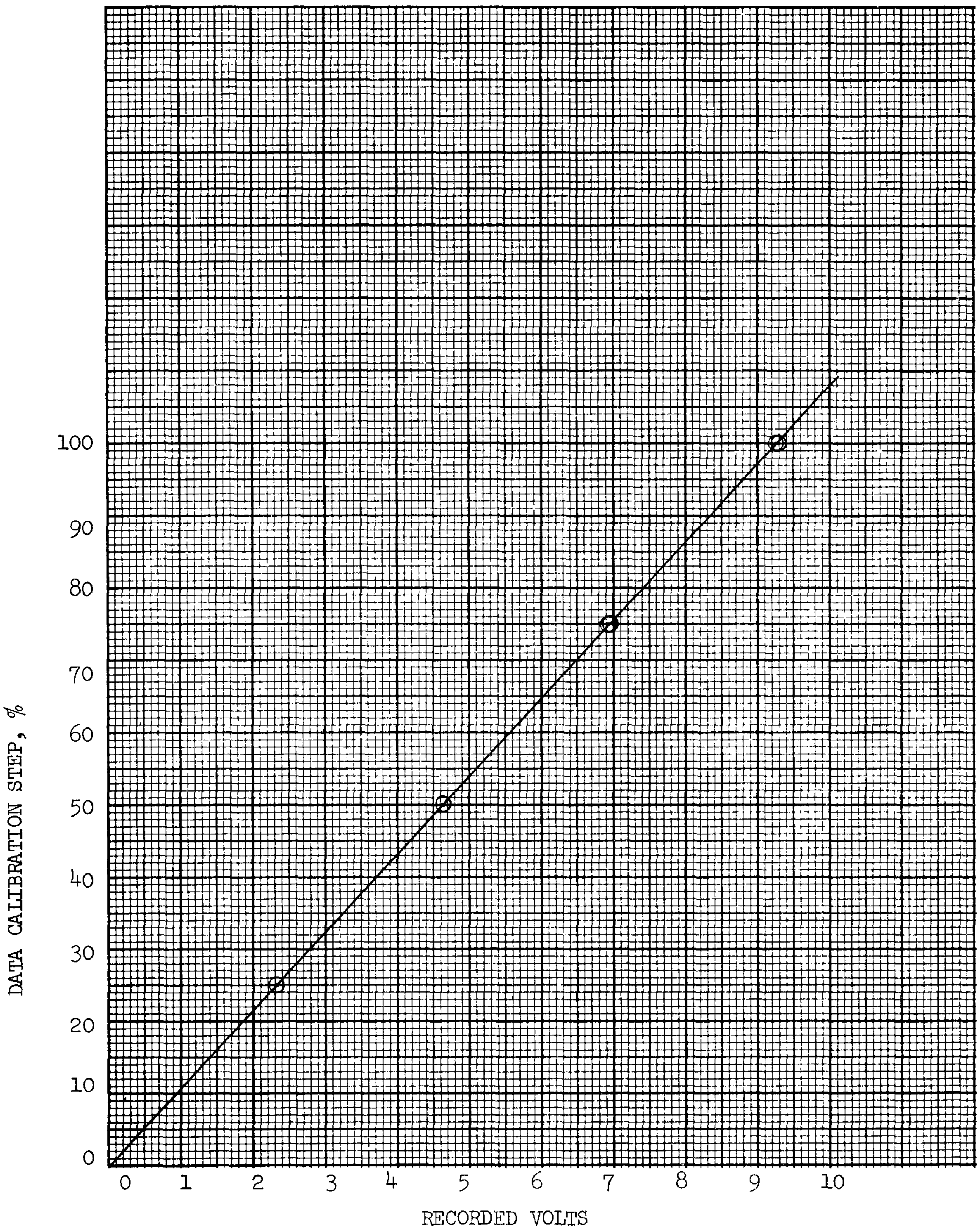


FIGURE 3

DATA CALIBRATION STEPS vs. RECORDED VOLTS

SHOWING ATTENUATION ON LINEARS 1, 2, & 3.

4. Miscellaneous Calibrations

The following Figures are presented here for reference purposes:

Figure 4 - Log Power vs. Voltage & Logwatts

Figure 5 - Fixed Power Scram Setting vs. Pot Divisions

Figure 6 - Power Loop Closure vs. Pot Settings

Figure 7 - Nuclear Autostart Exponential and Ramp Demands vs. Pot Settings

E. Digital Data Reduction

Data reduction of the neutronics channels is not as straight forward as most other channels, for instance, pressure and temperature. In addition, this was the first test to use these channels. As a result, there was some initial confusion as to ranging and calibration. A few errors were made on the first listings; these were all corrected on subsequent listings. However, the DN-3 tapes which the NRO and WANL plots were made from contain some of these original errors. Table 7 lists the neutronics channels recorded on the digital data system, the channel title, the full scale range as listed in the As Run Data Log, the DDS Setup and Calibration range, the reduced data range, and remarks.

Special Calculations

The following computed parameters were made using the CEC 3200 and measured parameters:

$LCR1 = 10^{NC808}$ Converts NC808 from log counts/sec to counts/sec

$LCR2 = 10^{NC809}$ Converts NC809 from log counts/sec to counts/sec

$LCR3 = 10^{NC810}$ Converts NC810 from log counts/sec to counts/sec

$$\left.\begin{aligned} PWLIN1 &= .001\ (NC819)(10^{NR822}) \\ PWLIN2 &= .001\ (NC820)(10^{NR823}) \\ PWLIN3 &= .001\ (NC821)(10^{NR824}) \end{aligned}\right\}$$ converts the raw linear power and range channels to single channels indicating power in kw.

where: NR822, NR823, and NR824 = (NC822, 3, 4) + .5 with the decimal truncated. This converts to integers, in case the calibration is as much as ± .499 volt off.

$PW801 = 10^{NC801}/10^3$	Converts	NC801,	from logwatts	to kw.
$PW802 = 10^{NC802}/10^3$	"	2	"	"
$PW803 = 10^{NC803}/10^3$	"	3	"	"
$PW804 = 10^{NC804}/10^3$	"	4	"	"
$PW812 = 10^{NC812}/10^3$	"	12	"	"
$PW813 = 10^{NC813}/10^3$	"	13	"	"
$PW814 = 10^{NC814}/10^3$	"	14	"	"

CHANNEL NUMBER	CHANNEL TITLE	RANGE LISTED IN DATA LOG	DDS SETUP & CALIBRATION RANGE	DATA REDUCTION RANGE	REMARKS
NC808	LCR Startup No. 1	$.1 - 10^{(5)}$	0-10 volts	$10^{-1} - 10^{5}$ log counts/sec	The data channels are set up 0-10 v. To reduce this to log counts/sec the data is multiplied by $\frac{1}{10/6}$ v/decade and 1 decade offset subtracted to get 10^{-1} to 10^{5}.
NC809	LCR Startup No. 2	$.1 - 10^{(5)}$	0-10 volts	$10^{-1} - 10^{5}$ log counts/sec	
NC810	LCR Startup No. 3	$.1 - 10^{(5)}$	0-10 volts	$10^{-1} - 10^{5}$ log counts/sec	
NC819	Linear Power No. 1	0-10 volt	0-10 volts	0-2 x 10 exponent watts	The data is divided by 5 in order to get numbers which (when multiplied by the corresponding 10 to the exponent range channel) represent nuclear power in watts. The calibration slope must be multiplied by .926 to compensate for amplifier feed-back. This was not initially known.
NC820	Linear Power No. 2	0-10 volt	0-10 volts	0-2 x 10 exponent watts	
NC821	Linear Power No. 3	0-10 volt	0-10 volts	0-2 x 10 exponent watts	
NC822	Linear No. 1 Range	0-10 volt	0-10 volts	0-10 decades	
NC823	Linear No. 2 Range	0-10 volt	0-10 volts	0-10 decades	
NC824	Linear No. 3 Range	0-10 volt	0-10 volts	0-10 decades	
NC801	Engine Log Power 1	0-10 volt	0-10 volts	1.74 - 9.74 logwatts	To reduce the raw data from 0-10 volts which corresponds to an 8 decade power range of 55 w to 5500 mw; it is multi-plied by $\frac{1}{10/8\text{ v/decade}}$ and an offset of 1.7404 (which is the log of 55) added. Nuclear power from the log channels can then be read directly in watts from a log table or slide rule. It can also be used directly in com-puter calculations. Since the DDS can go ± 9999 counts, log power less than 55 w is recorded as - voltage.
NC802	Engine Log Power 2	0-10 volt	0-10 volts	1.74 - 9.74 logwatts	
NC803	Engine Log Power 3	0-10 volt	0-10 volts	1.74 - 9.74 logwatts	
NC804	Avg. Eng. Log Power	0-10 volt	0-10 volts	1.74 - 9.74 logwatts	
NC812	T. S. Log Power 1	0-10 volt	0-10 volts	1.74 - 9.74 logwatts	
NC813	T. S. Log Power 2	0-10 volt	0-10 volts	1.74 - 9.74 logwatts	
NC814	T. S. Log Power 3	0-10 volt	0-10 volts	1.74 - 9.74 logwatts	
NC815	Avg. T.S. Log Power	0-10 volt	0-10 volts	1.74 - 9.74 logwatts	
NC806	Engine Power Period	-1 to 9v	0-10 volts	0 - 10 volts	The two period channels are scaled -1 to 9v on the console meters correspon-ding to -7 to .1 seconds. On data they are 0-10 v. This was a point of initial confusion. The ± 9999 counts DDS capability permits negative voltage to be recorded.
NC817	T. S. Power Period	-1 to 9v	0-10 volts	0 - 10 volts	

TABLE 7 (Contd)

CHANNEL NUMBER	CHANNEL TITLE	RANGE LISTED IN DATA LOG	DDS SETUP & CALIBRATION RANGE	DATA REDUCTION RANGE	REMARKS
N.840	UTS Gamma No. 1	0 - 10 mv	0 - 10 mv	0 - 6 log R/hr	The 0-10 mv raw data is converted to 10^0 to 10^6 r/hr by multiplying by $\frac{1}{10/6 \text{ mv/decade}}$
N.841	UTS Gamma No. 2	0 - 10 mv	0 - 10 mv	0 - 6 log R/hr	
N.842	UTS Gamma No. 3	0 - 10 mv	0 - 10 mv	0 - 6 log R/hr	
N.844	ETC Gamma	2 x 10(4) - 2.5 x 10(8)	0 - 10 volts	0 - 100 mv	0 - 100 mv corresponds to 10^{-13} to 10^{-12} amps on the lowest range, through 11 decades, to 10^{-3} to 10^{-2} decades on the highest range.
N.847	ETC Gamma Range	10 v	0 - 10 volts	0 - 10 decades	
N.845	ETC Fast Fission, Low	3 x 10(8) - 3 x 10 (11)	0 - 5 v	0 - 5 v	0 - 1 v = 0 to 10^2 counts (10 mv/count) 1.25 - 2.25 v = 0 to 10^3 counts 2.5 - 3.5v = 0 to 10^4 counts
N.846	ETC Fast Fission, High	3 x 10 (10) - 3 x 10 (13)	0 - 5 v	0 - 5 v	

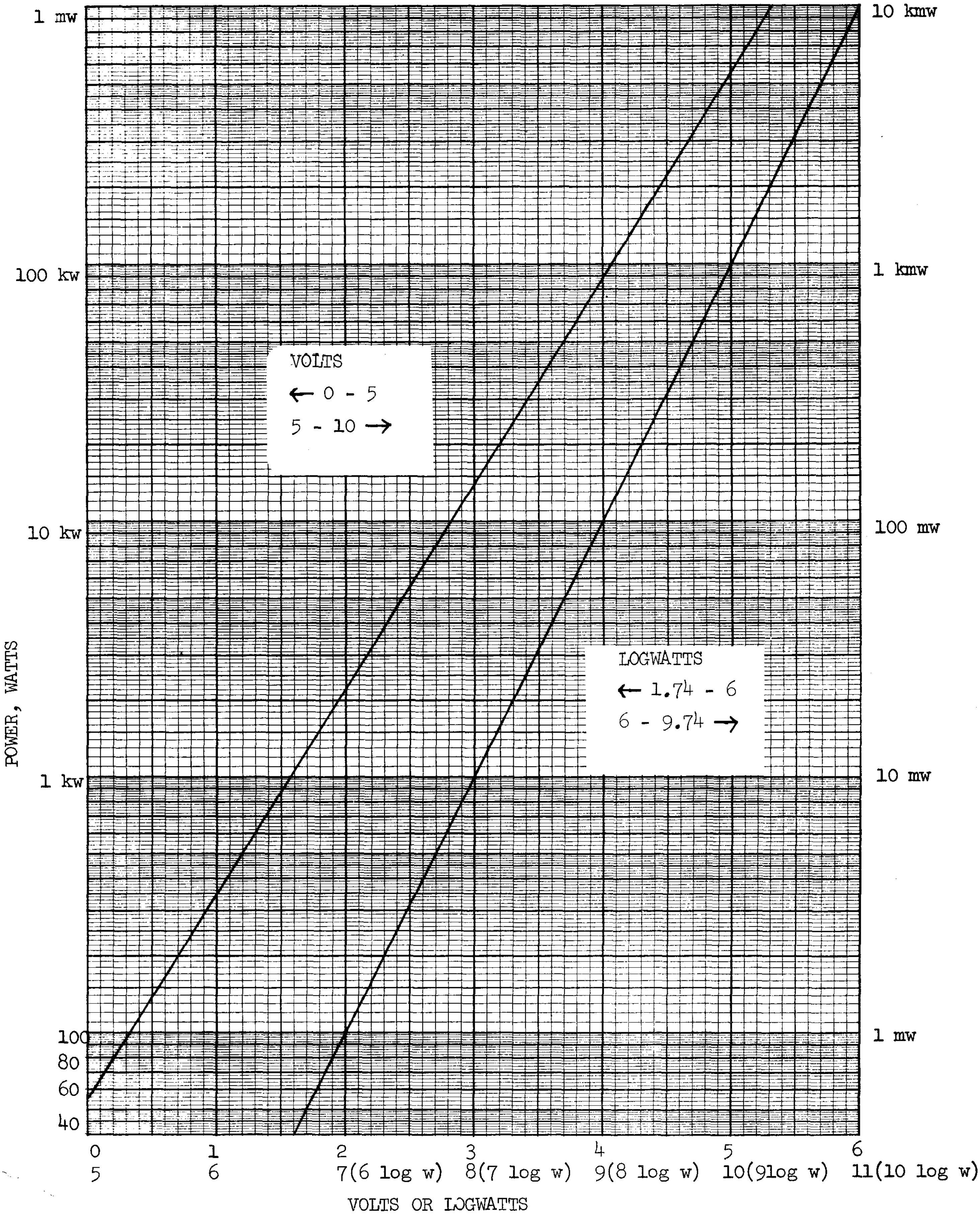


FIGURE 4

LOG POWER vs. VOLTAGE & LOGWATTS

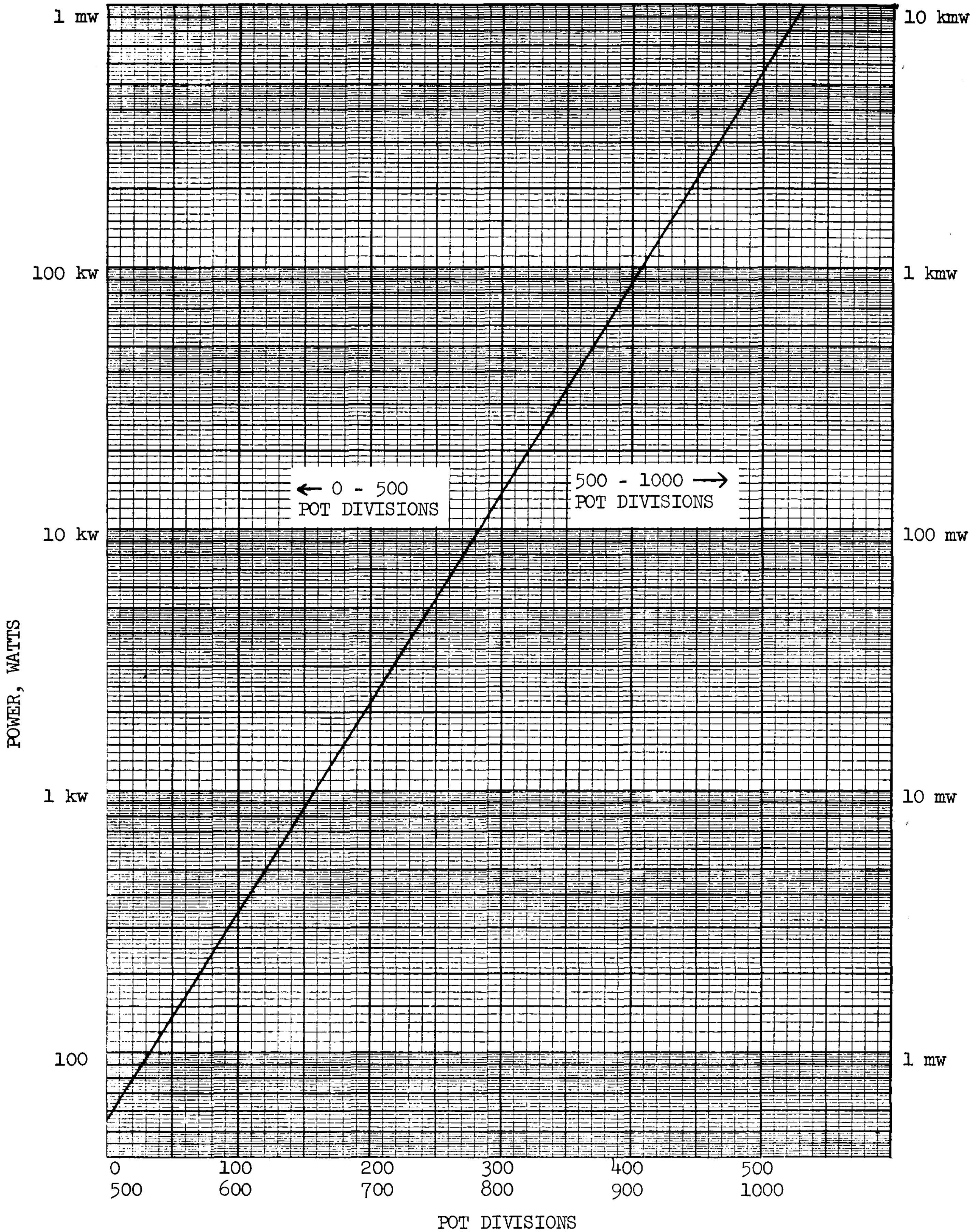


FIGURE 5
FIXED POWER SCRAM SETTING vs. POT DIVISIONS

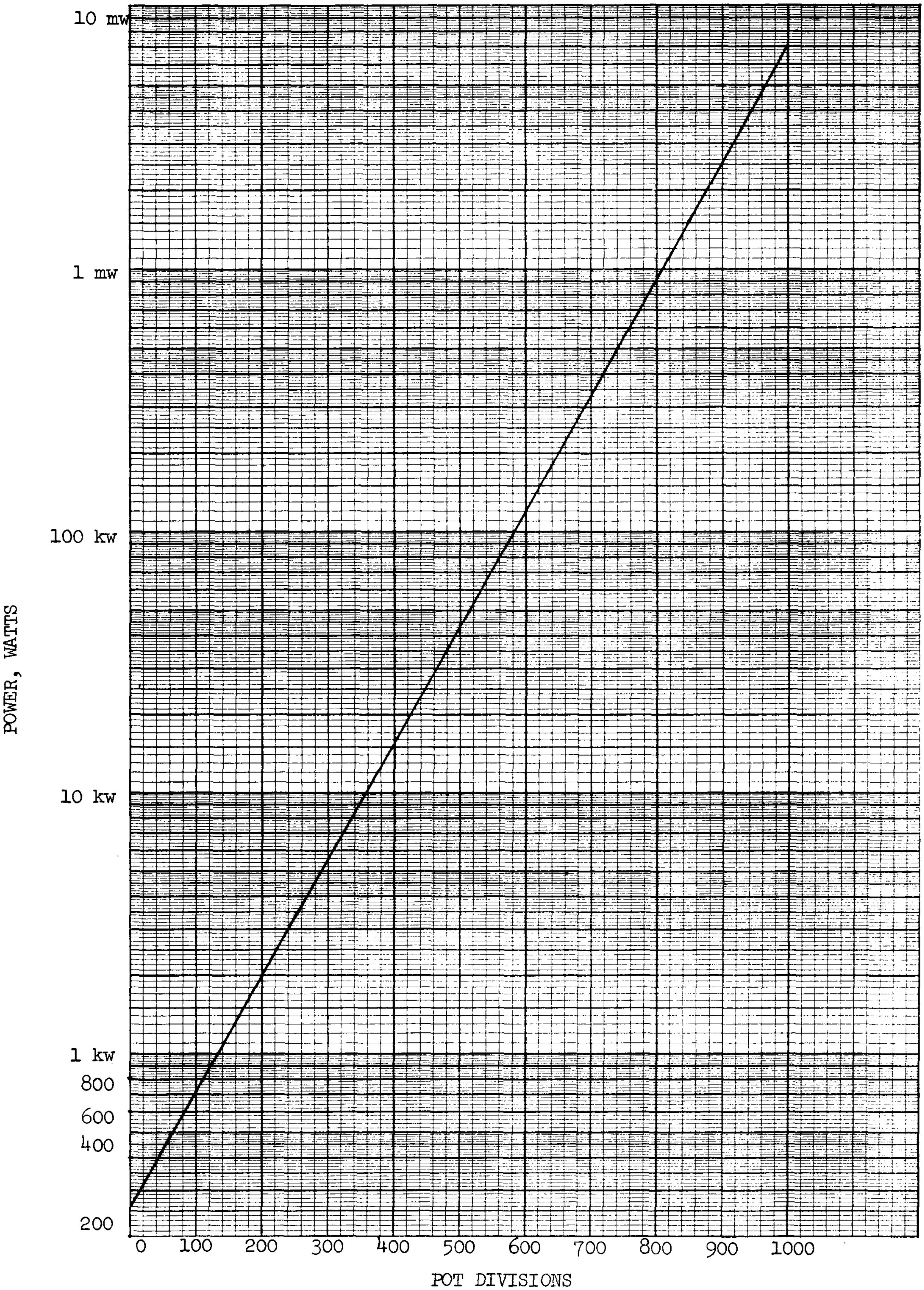


FIGURE 6
POWER LOOP CLOSURE vs. POT DIVISIONS

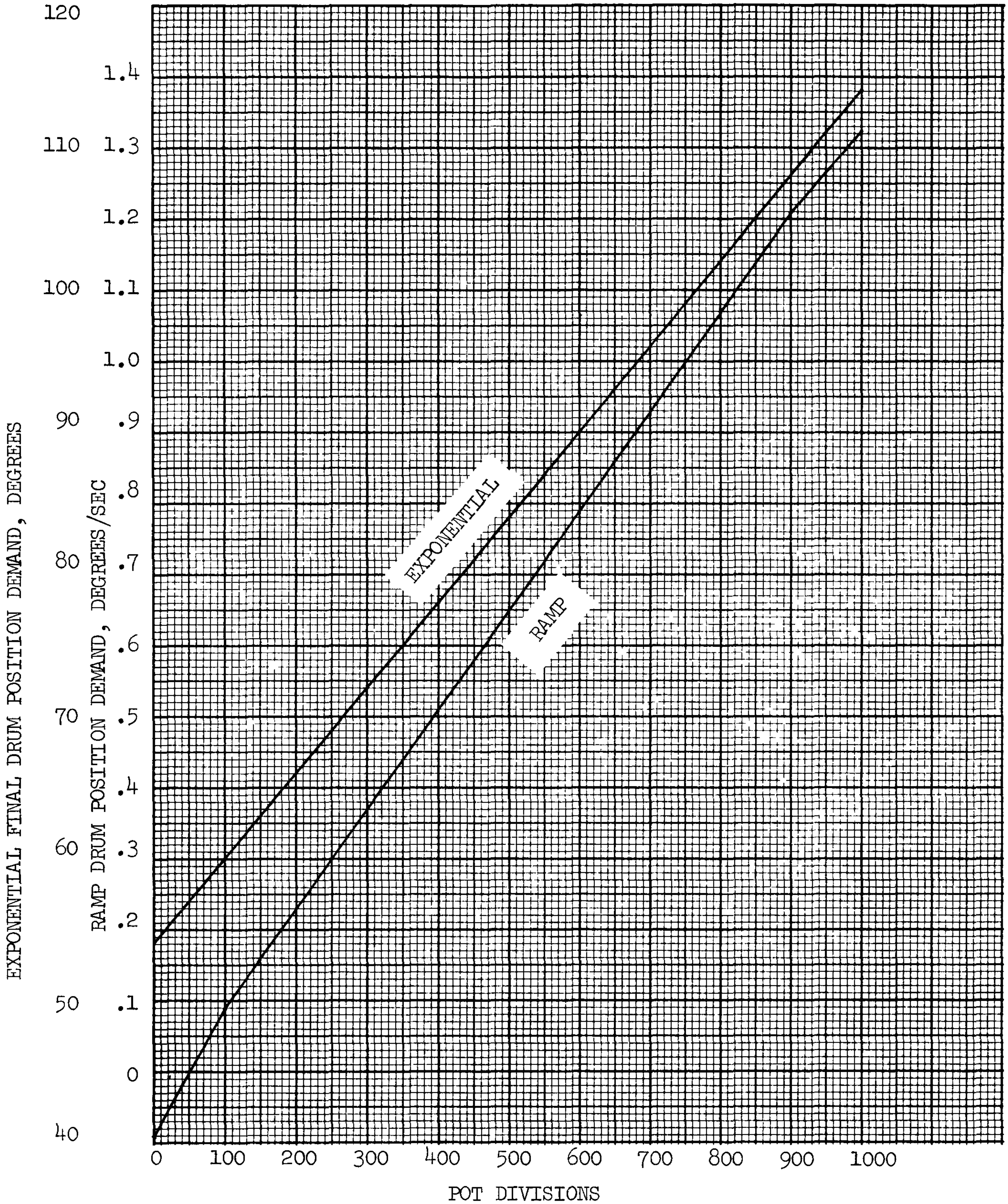


FIGURE 7

NUCLEAR AUTOSTART

EXPONENTIAL AND RAMP DEMANDS vs. POT SETTINGS

$PW815 = 10^{NC815}/10^{3}$ Converts NC815 from logwatts to kw.

$$NP806 = \quad NP817 = \begin{cases} 7/NC806,\ NC817 & \text{if } NC806,\ 817 > -1\text{ v} < 7\text{ v} \\ .222/(NC806,\ NC817-6.778) & \text{if } NC806,\ 817 > 7\text{v} < 9\text{ v} \end{cases}$$

Converts NC806 and NC817 from volts to seconds

IPWALIN = Integral of average linear power

IPW804 = Integral of average engine log power

IPW815 = Integral of average test stand log power

GUTS840 = $10^{N.840}$ (converts N.840, 1 & 2 from log R/hr to R/hr.

GUTS841 = $10^{N.841}$ " " " " " "

GUTS842 = $10^{N.842}$ " " " " " "

GETC844 = $2.463\ (N.847)\ (10^{-26\ +\ NR\ 847})$

where: NR841 = (N.847) + .5 with the decimal truneated.

converts ETC gamma from mv to R/hr.

RECOMMENDATIONS

1. Readjust linear gains and log offset voltages as listed in the section on Reactor Power Calibration.

2. Reset Linear No. 2 Range trip point so that it won't chatter. Avoid selecting No. 2 for display until this is accomplished.

3. Correct the other neutronics instrumentation discrepancies noted in Anomalies.

4. Perform a one point (LRE) neutronics and a source calibration after the data system last pre run calibration and prior to the post calibration. This will insure that the neutronics calibrations are recorded on data.

5. The LRE should keep a standard pre-printed log sheet during each test showing the range time for the following: when each log channel is rejected or reset in the averagers, which log and linears are selected for control and display. This data is not otherwise available except by memory.

ANOMALIES

Data - After the resolution of those problems discussed in the sections on Digital Data Reduction and Electrical Calibration, there were no uncorrected data anomalies. All of the calculated parameters worked correctly.

Instrumentation

Primary Neutronics

Startup Channels - None.

Linear Channels - No. 3 noisy (± 5%). No. 2 range change setpoint appears to be set slightly too close causing it to chatter on ramps.

Period Channels - Drift slightly at stable periods.

Engine Logs - A significant difference appears between console meter powers and digital data powers. 0%, 25%, 50%, and 75% calibrations points are good.

Secondary Neutronics

UTS Gamma Channels - An electrometer tube/data voltage mismatch caused failure of these channels.

ETC Gamma - Range channel appears to function correctly. There was a high level/low level patching mis-understanding on the level channel. It also exhibited a large lag during gamma flux changes.

ETS Fast Flux - Appeared sensitive to noise when the steam generators went to full steam.

Hardware - None.

XE-PRIME

EP-I and EP-SL2

Subject: CRITICALITY

INTRODUCTION

The approach to critical procedure employed for XE-Prime was similar to that of NRX-A5 and A6. For these reactors, poison wire removal had been completed prior to installation of the reactor in the Test Stand.

A best estimate of cold critical drum bank position was calculated by averaging the critical drum bank angles taken during EP-I. An error in the calibration of the drums was determined and was applied to all the drum readings. The error was one percent and is constant over the drum range.

SUMMARY

Based on the inverse count rate data shown in Table 1, the initial critical was estimated at 99.6° (including + 1% bias correction in drum angle data). This is in reasonable agreement with the best estimate of $99.80 \pm 0.35^\circ$. Both values are within the original prediction estimate of $94.4^\circ \pm 10^\circ$.

The critical drum bank angle decreased one percent after the steam line test. This decrease was probably caused by cooling the reactor with GN_2 during the test. The core and reflector temperature coefficients are not known accurately enough in this temperature region to form a positive conclusion.

TECHNICAL DISCUSSION

Theoretically, the inverse count rate variation should be proportional to reactivity near critical. With the source/detector geometry used in the XE-Prime approach to critical, it has been shown that an unmultiplied background exists that is higher than the measured background. This unaccounted background is probably due to neutrons diffusing around the reflector and will manifest itself as a negative curvature in the inverse count rate data.

The best approach to critical inverse count rate estimates were obtained by determination of the constant "background" that will yield a straight line on an inverse count rate versus shutdown reactivity plot. The "background" count rates estimated by this method are listed in Table 2. Figure 1 shows the inverse count rate vs. shutdown for the background correction in comparison to typical (Detector # 2) uncorrected data.

A tabulation of steady state calculated average drum angles is given in Table 3 for four time slices. The data were taken from the digital listings Pass Q0005, 12/4/68. Care was taken to ensure that the drum bank position reached its steady state value. The best estimate of cold critical drum bank position as calculated from Table 3 is 99.8°.

During the steam line tests the critical drum bank angle shifted inward almost 1° (6¢). The core and reflector average temperatures dropped some 50°R. A correlation of several critical drum bank angles with the corresponding average core temperature is shown in Figure 2. The line drawn through the data shows the predicted change in critical drum bank position based on the NRX-A2 measured coefficient in the low temperature range of 0.11 ¢/°R. This should be considered the maximum possible variation in reactivity with temperature since the reflector temperature coefficient should tend to cancel the core effect and the average core temperature coefficient to operating temperature is measured at 0.06 ¢/°R.

RECOMMENDATIONS

1. The fitting of the calibration steps (0, 25, 50, 75 and 100%) in determining the corrected digital output of drum position should be based on the expected drum positions to be encountered in a given test. For example, EP-I fitting should be based on the 50% calibration point (90°) since all of the data was collected between drum bank angles near 100°. For subsequent full power tests, the data will fall in the 100 to 130° range and the 75% (135°) calibration or a calibration between 50 and 75% will be satisfactory.

2. To complete the determination of the cold critical drum bank angle the drums should be actuated out to their lock position individually. This will give a base point with respect to the 15° lock position to correct any offset in buffer amplifier and electrical circuitry not considered in the calibration. The electrical circuitry requires that the measured value be increased 1% over its range to obtain a true measured value.

3. To facilitate the data reduction and SPEAR effort for subsequent tests, a running average of 5 to 10 seconds duration on the individual drum positions should be calculated. Also, a numerical average of the 12 individual drum positions to obtain the average drum bank position along with a running average should be calculated and made available with the thinned digital listings.

ANOMALIES

1. Some spurious counts were observed by the LRE during EP-I. Anomalous count rates were not found in the thinned listings during the critical experiment.

2. A decrease in cold critical drum bank position of 1 degree was measured after the steam line test. It is believed that this decrease may be attributed to cooling the reactor with GN_2.

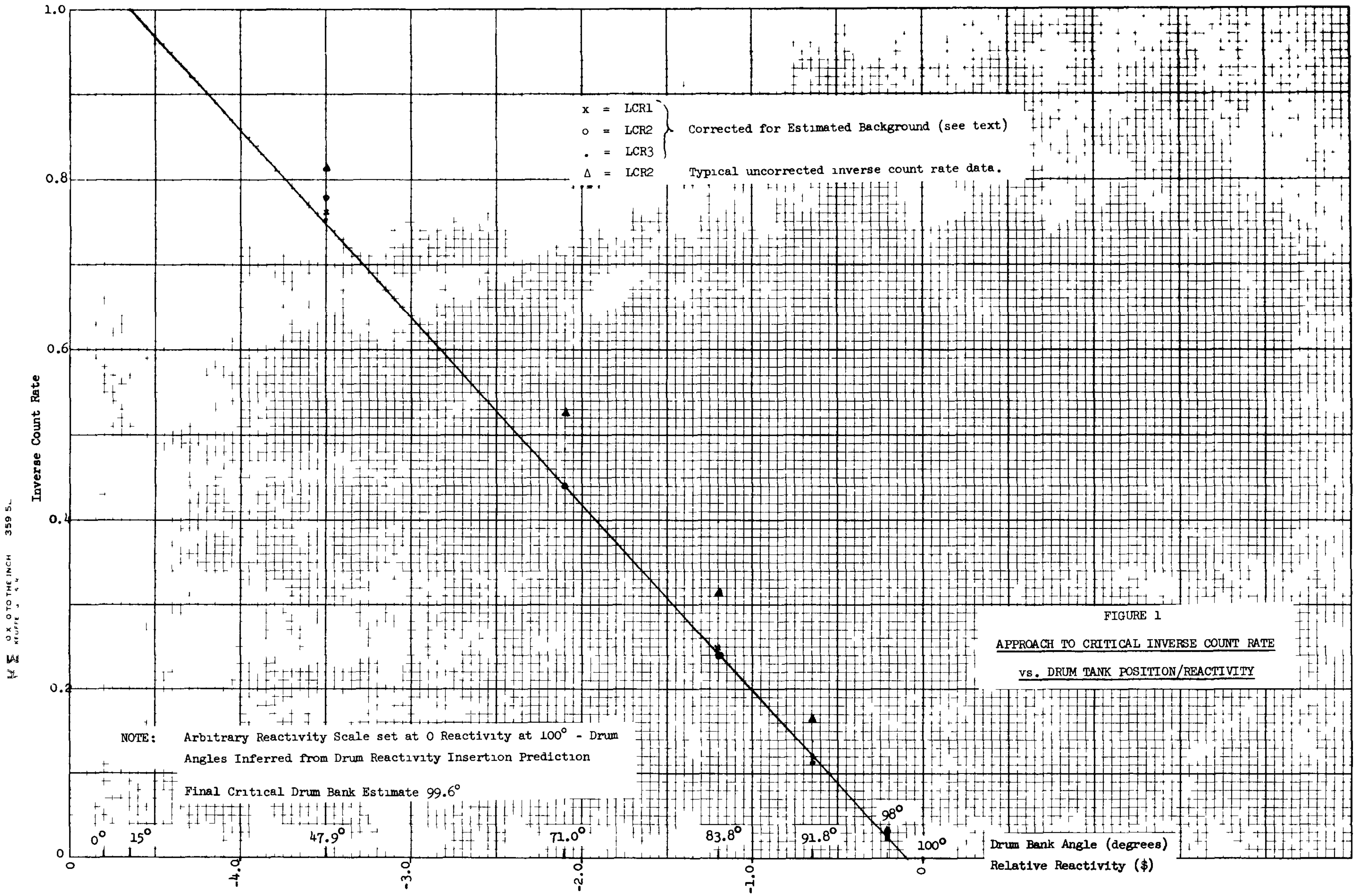


FIGURE 1

APPROACH TO CRITICAL INVERSE COUNT RATE

vs. DRUM TANK POSITION/REACTIVITY

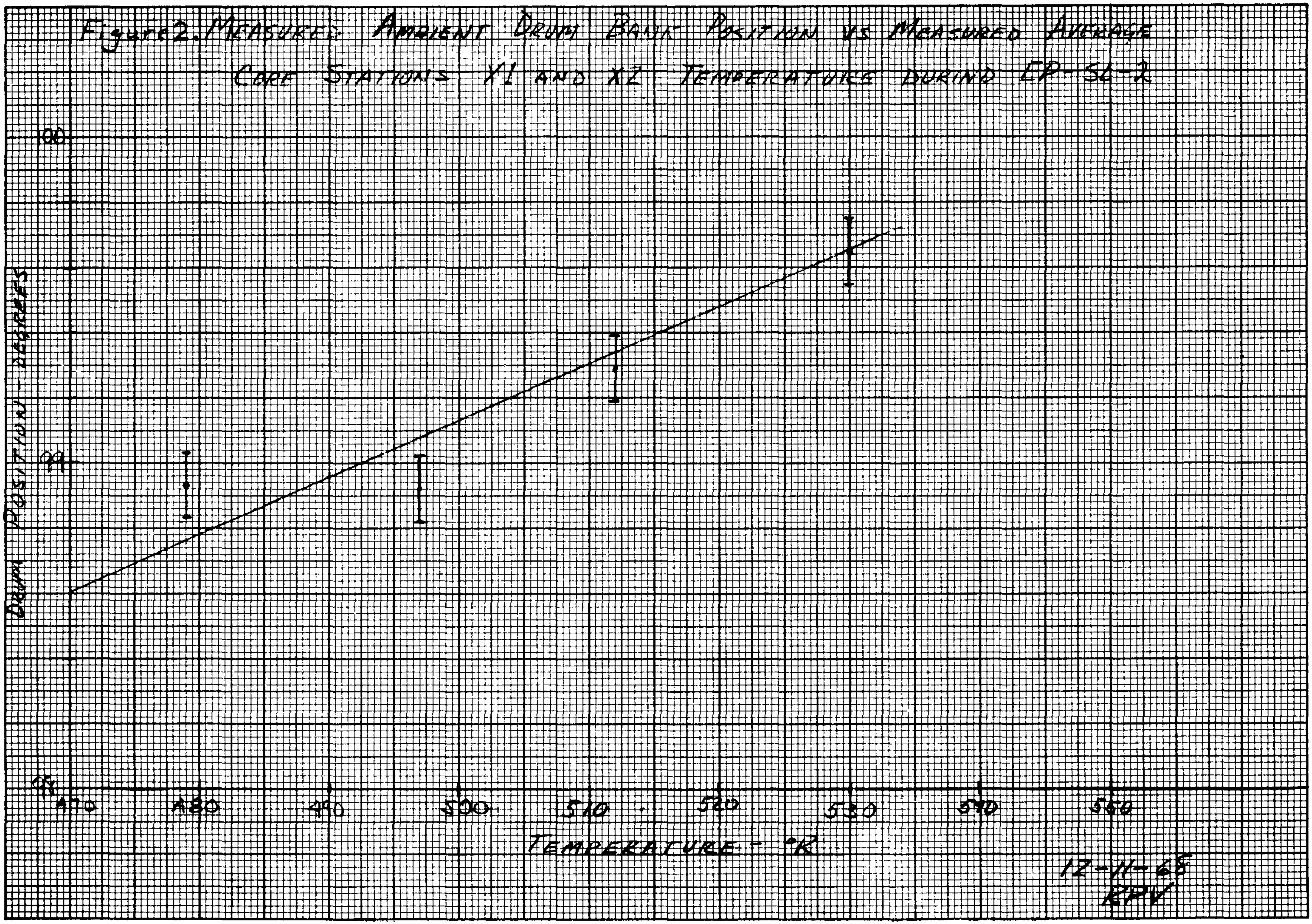


Figure 2. MEASURED AMBIENT DRUM BANK POSITION VS MEASURED AVERAGE CORE STATIONS X1 AND X2 TEMPERATURE DURING EP-SL-2

TABLE 1

DATA IN SUPPORT OF

APPROACH TO CRITICAL PREDICTION

ESTIMATED EFFECTIVE BACKGROUND	AVERAGE DRUM BANK ANGLE (degrees)	LCR 1* AVERAGE COUNTS/SEC	LCR 2* AVERAGE COUNTS/SEC	LCR 3* AVERAGE COUNTS/SEC	RANGE TIME
		6.1	39.4	20.2	
Co	15	36.7	52.7	40.6	65937 - 67337
C_1	47.9	46.4	59.1	49.9	68290 - 68590
C_2	71.0	76.0	84.6	76.8	69405 - 69715
C_3	83.8	129.6	132.2	129.3	70545 - 70845
C_4	91.8	264.2	249.8	246.5	71238 - 71358
C_5	98.0	1255.0	1154.2	1154.5	71938 - 72238

* Uncorrected for background - Source EP-I, Thinned Data Pass Q001, 12/04/68

TABLE 2

ESTIMATED BACKGROUND COUNT RATES

	SHUTDOWN COUNT RATE (cps), C_o	ESTIMATED BACKGROUND COUNT RATE (cps)	ESTIMATED C_o (Less background) (cps)
DETECTOR 1	38.4	6.2	32.2
DETECTOR 2	75.0	39.4	35.6
DETECTOR 3	67.2	20.2	47.0

TABLE 3 - TABULATION OF COLD CRITICAL DRUM BANK POSITION

RANGE TIME	LIN 1	LIN 2	LIN 3	AVG LIN	D.800	θ AVG	DEV +	DEV -	
72776.5	57	53	58	56	104.9	103.1	104.9	102.3	(2)
72903.5	58.1	50.3	59.4	55.9	100.2	98.7	100.0	97.9	(3)
72904.5	60.5	52.5	52.8	55.3	100.7	98.7	100.2	97.7	$\bar{\theta}$ = 98.8
72905.5	60.9	51.1	54.8	55.6	100.1	98.7	100.1	97.9	
72906.5	55.1	57.2	59.4	57.2	100.5	98.8	100.5	97.7	$\bar{Q}$ = 56.8 w
72907.5	59.0	55.2	63.5	59.2	100.4	98.8	100.3	97.8	
72908.5	57.3	53.9	52.5	54.6	100.3	98.8	100.3	97.9	
72909.5	65.0	55.0	56.9	59.0	100.3	98.7	100.2	97.8	
72910.5	59.2	52.6	56.7	56.2	100.6	98.8	100.2	97.8	
72911.5	60.3	53.8	51.4	55.2	100.1	98.8	100.3	97.8	
72912.5	58.5	54.1	51.4	54.7	99.9	98.8	100.5	97.7	
74295.9	116.7	102.0	107.4	108.7	105.4	103.7	105.5	102.8	(2)
74410.8	112.8	101.7	99.3	104.6	100.0	98.8	100.3	97.8	(2)
74411.8	111.7	100.6	86.1	99.5	99.9	98.7	100.3	97.7 *	$\bar{\theta}$ = 98.7
74412.8	110.4	104.8	105.5	106.9	100.2	98.7	100.2	98.0	
74413.8	112.0	100.9	101.7	104.9	99.6	98.7	100.0	97.9	
74414.8	113.4	101.1	99.6	104.7	100.0	98.8	100.4	97.8	$\bar{Q}$ = 104.0 w
74415.8	110.2	98.9	88.8	99.3	99.9	98.7	100.4	97.7	
74416.8	112.3	100.0	109.3	107.2	99.9	98.7	100.3	97.9	
74417.8	108.6	104.7	104.5	105.9	100.1	98.7	100.5	97.6	
74418.8	114.0	104.3	97.2	105.2	100.1	98.8	100.3	97.7	
74419.8	107.5	102.1	96.8	102.1	99.8	98.6	100.1	97.6	

RANGE TIME	LIN 1	LIN 2	LIN 3	AVG LIN	D.800	θ AVG	DEV +	DEV -	
75470.0	1074	987	954	1005	104.9	103.9	106.2	102.8	(2)
75615.0	1126	1016	933	1025	99.8	98.8	100.3	97.7	(3)
75616	1103	1031	1018	1051	99.9	98.8	100.4	97.7	θ = 98.8
75617	1103	1010	1027	1047	100.1	98.7	100.2	97.7	
75618	1138	1021	1051	1070	99.8	98.8	100.5	97.6	
75619	1108	1022	1034	1055	100.1	98.7	100.5	97.6	
75620	1164	1024	1104	1097	99.9	98.7	100.5	97.6	$\bar{Q}$ = 1063 w
75621	1105	1009	1079	1064	100.1	98.8	100.5	97.5	
75622	1099	1002	1103	1068	99.9	98.8	100.2	97.7	
75623	1095	1051	1107	1084	100.0	98.7	100.2	97.3	
75624	1099	1024	1077	1067	99.9	98.8	100.6	97.6 *	
76246.7	1491	1372	1391	1418	102.6	101.4	103.0	100.3	(2)
76510.7	1522	1390	1441	1451	100.0	98.6	100.0	97.6	(3)
76511.7	1549	1393	1485	1476	99.9	98.7	100.5	97.4	$\bar{\theta}$ = 98.7
75612.7	1532	1384	1412	1443	99.7	98.6	100.3	97.4	
76513.7	1464	1383	1467	1438	99.8	98.6	100.3	97.7	$\bar{Q}$ = 1450 w
75614.7	1516	1393	1433	1447	99.9	98.6	100.7	97.5	
76515.7	1519	1400	1392	1437	99.8	98.7	100.2	97.6	
76516.7	1527	1390	1422	1446	99.7	98.7	100.4	97.6	
76517.7	1514	1392	1438	1448	99.9	98.6	100.0	97.6	
76518.7	1534	1386	1427	1449	100.3	98.6	100.5	97.2	
76519.7	1531	1421	1441	1464	100.0	98.9	100.5	97.6	

(*) Drum measurements not corrected for 1% error in calibration.
(2) Time at which power reaches steady state.
(3) Time at which drums reaches steady state.

cjd

SPEAR Memo No. 4
R. P. Vijuk:cjd

XE-PRIME

EP-I and EP-SL2

Subject: SHUTDOWN REACTIVITY MEASUREMENTS

INTRODUCTION

This memo summarized data analysis of shutdown reactivity measurements during EP-SL2. The data used for this analysis was obtained from thinned digital listings.

SUMMARY

The measured shutdown reactivity is \$4.73. The difference between predicted and measured shutdown reactivity is only 9.0 cents based on an estimate of \$4.82 using the predicted drum bank worth and the actual critical drum bank angle.

TECHNICAL DISCUSSION

The shutdown reactivity value for the XE-Prime reactor was determined from the ratio of measured power 15 seconds after scram to that immediately prior to scram. The shutdown reactivity is determined from a tabulation of the above power ratio versus shutdown reactivity which is derived from solutions to the nuclear kinetics equations for various shutdown reactivity values. Table 1 summarizes the shutdown reactivity measurements taken during EP-SL2. The numerical average of the measured values is \$4.73 with a precision of ± \$0.12 ($2\sigma_M$ calculated from data). This value agrees well with the predicted value of \$4.82 ± 0.20 (corrected to measured critical drums position of 99.8° and a minimum drum position of 7°). The drum scram measurements used for calculation of the shutdown reactivity were those from a stable operating condition of at least 60 seconds duration prior to scram.

TABLE 1

SUMMARY OF SHUTDOWN REACTIVITY MEASUREMENTS

EP	RANGE TIME AT SCRAM	P_o POWER INDICATIONS** - WATTS				P_{15} POWER INDICATIONS** - WATTS				P_{15}/P_o	DRUM POSITION PRIOR TO SCRAM	SHUTDOWN REACTIVITY
	SECONDS	NC 819	NC 820	NC 804	NC 815	NC 819	NC 820	NC 804	NC 815		DEGREES	DOLLARS
SL-2	46686.1	1054.				46.				.0436	99.7	4.72
			1056.				47.			.0445		4.64
				2165.				102.		.0471		4.39
					1250.				60.	.0480		4.30
SL-2	47638.8	1046.				42.				.0402	100.0	5.12
			1061.				42.			.0396		5.20
				2259.				98.		.0434		4.75
					1222.				55.	.0450		4.59
SL-2	57053.2	1117.				48.				.0429	99.8	4.80
			1106.				48.			.0438		4.70
				2406.				107.		.0445		4.63
					1349.				62.	.0460		4.50
SL-2	82855.5	1133.				47.				.0412	98.9	5.07*
			1133.				48.			.0422		4.95*
				2392.				105.		.0439		4.76*
					1339.				62.	.0463		4.54*
												AVERAGE = $4.73
												σ_M = ± $0.06

* Corrected for shift in critical drum position during the Steam Generator Test.

** These values have not been corrected for the constant calibration effect since only a ratio of values was needed.

NOTE: Data was taken from EP-SL-2 thinned digital listings, passes Q001, Q002, Q004 and Q005, dated 12/6/68.

SPEAR Memo No. 5
A. Mowery:cjd

XE-PRIME

EP-I and EP-SL2

Subject: DIFFERENTIAL DRUM BANK WORTH

INTRODUCTION

The drum bank differential worth measurements were made in SL2. These measurements calibrate the drum bank differential worth in the range between cold and hot critical drum bank angles.

SUMMARY

The best estimate of the differential drum bank worth over a nominal 10 degree range from cold critical is 6.50 ± 0.05 ¢ per degree. The cold critical drum bank angle was 98.9. Assuming the characteristic S-curve for drum span is valid, using the measured 6.5 ¢ per degree yields an estimate of the total drum bank worth of \$7.4 compared to the predicted \$7.9 (15° to 165°).

TECHNICAL DISCUSSION

Estimates of the reactivity change for the three differential drum bank measurements are listed in Table 1. These reactivity values were derived from period measurements (typical data shown in Figure 1) and converted to reactivity using figure 2*. The data was very consistent, excluding occasional bad points, indicating high accuracy on the period estimates.

The predicted values of reactivity change were taken from the characteristic S-curve of the drum bank.

$$\text{Drum Bank Reactivity Insertion (\$)} = \frac{\text{Drum Span}}{2}(1-\cos\theta) = 4.1\,(1-\cos\theta)$$

The values quoted for the drum angles include the 1% bias in the measurement.

RECOMMENDATIONS

Accurate estimates of the drum span have not been obtained from differential drum bank worth measurements in previous NRX tests. The quoted estimate of \$7.4 for the XE-Prime 15° to 165° drum span is probably not sufficiently accurate to conclude that the predicted value of \$7.9 is incorrect. Therefore,

* XE-Prime EP-1 Prediction Report

the standard procedure of measuring the integral drum worth of two drums is recommended for obtaining the best, consistent estimate of the XE-Prime drum span. Based on the drum uniformity test results, it is further recommended that drums 11 and 12 be excluded since data was lost on these drums.

ANOMALIES

Data: Occasional data points appeared to be incorrect. Examples:

Channel	Range Time
PWLIN 1	62499.8
PWLIN 2	62827.9
PWLIN 2	63150.7

The average log power channels NC804.. and 815.. showed no anomalies.

TABLE I

SUMMARY OF DIFFERENTIAL DRUM BANK WORTH MEASUREMENTS*
AND
COMPARISON WITH PREDICTIONS

DATA CHANNEL	EXPERIMENT 1		EXPERIMENT 2		EXPERIMENT 3	
	RANGE TIME 62488.8 - 62503.8		62820.9 - 62830.9		63143.7 - 63152.7	
	Period (SEC)	Reactivity**(¢)	Period (SEC)	Reactivity(¢)	Period (SEC)	Reactivity (¢)
NC 804..	2.76	61.8	1.85	69.1	1.68	71.3
NC 815..	2.75	61.8	1.87	69.3	1.74	70.6
PWLIN 1	2.82 to	61.2	1.794	69.9		
PWLIN 2	2.64	62.5			1.65	71.0
PWLIN 3			1.788	69.9		
AVERAGE REACTIVITY		61.8		69.6		71.0
FINAL AVERAGE DRUM BANK ANGLE		108.50		109.72		110.02
INITIAL CRITICAL DRUM BANK ANGLE		98.90		98.90		98.90
CHANGE IN DRUM BANK ANGLE		9.60°		10.82		11.12
PREDICTED REACTIVITY		67.0		75.3		77.2
PERCENTAGE ERROR PREDICTED - MEASURED		+ 8		+ 8		+ 9

* SOURCE SL PHASE II, THINNED LISTING PASS Q004, 12/10/68.

** SEE FIGURE 1

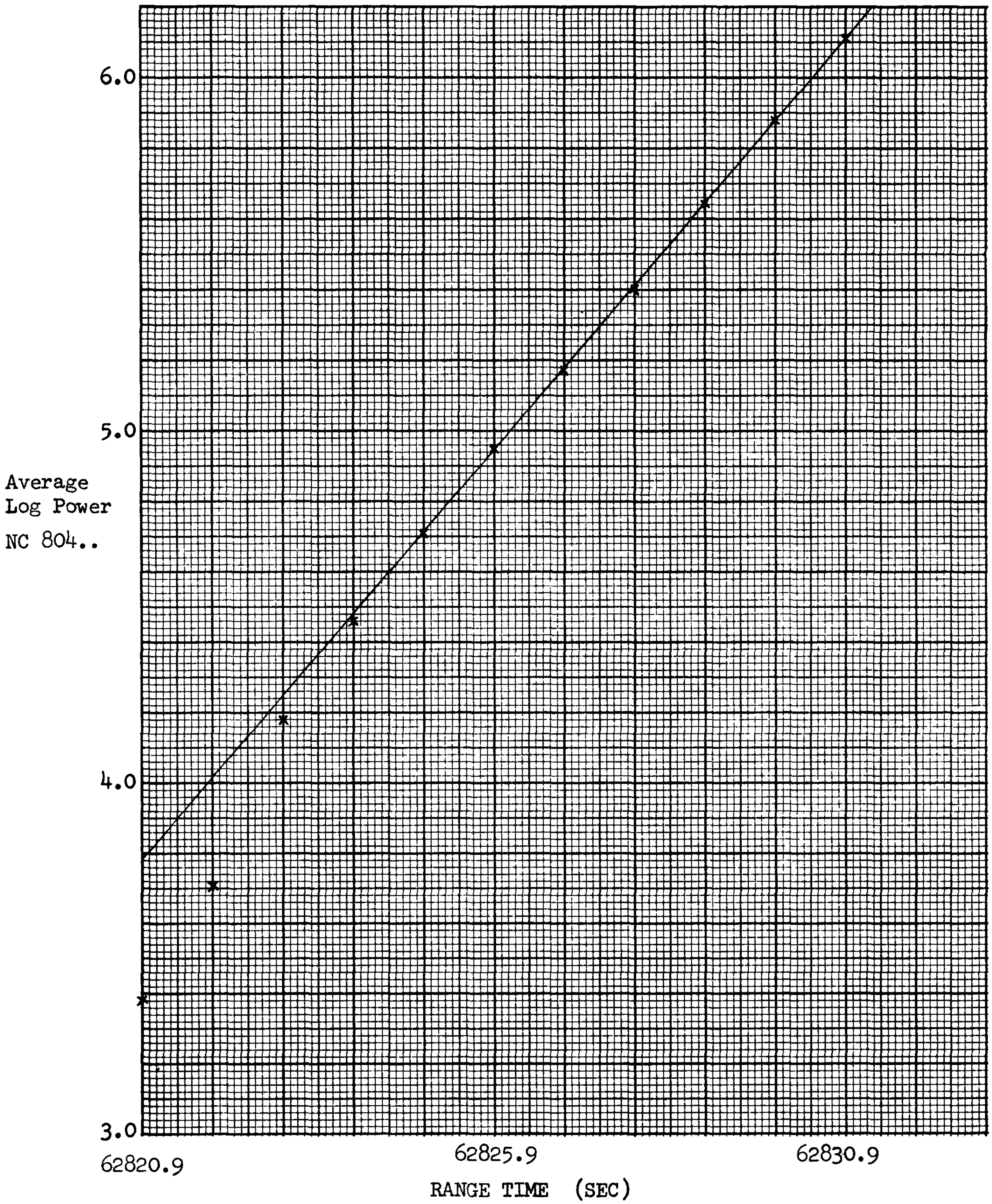


FIGURE 1 - Typical Log Power Variation During Experiment No. 2 of the Differential Drum Bank Worth Measurement

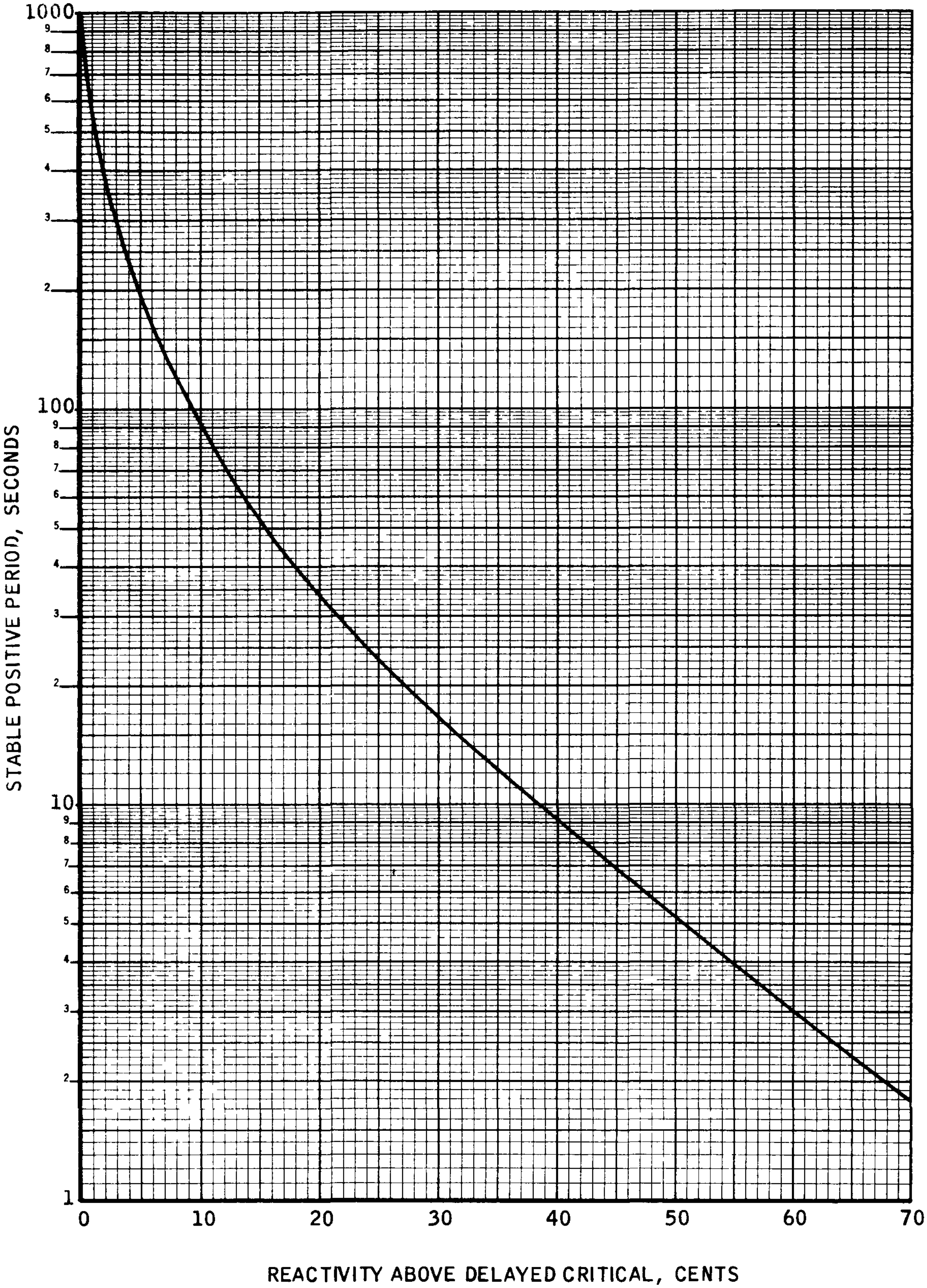


Figure 2 - Variation of Stable Positive Period with Reactivity above Delayed Critical

XE-PRIME

EP-I and EP-SL2

Subject: RELATIVE DRUM WORTH COMPARISON

INTRODUCTION

Relative worth of the control drums was determined by rotating each drum between 15° and 165° while operating in Power Control at 1 KW.

SUMMARY

Drum worths for drums 1 through 10 averaged 63.83¢ with a range from 62.13¢ to 64.49¢. Predicted worth was 66.0 ± 1.7¢. No data was obtained for the Relative Drum Worth Comparisons for Drums No. 11 and 12. Table I contains the drum angle and worth data used in this analysis. The total drum span from 15° to 165° based on these 10 drums was $7.66. The predicted total drum span was $7.90.

TECHNICAL DISCUSSION

Thinned Digital Data Listings from XE-Prime SL2, 12/6/68, Pass Q0005 for drum angle D.801.A through D.812.A were used to calculate eleven drum averages during the relative worth calibrations for drums 1-10.

A set of 5 time increment printouts was selected near the end of each hold point. The average drum bank position for 11 drums was calculated for steady state conditions with the 12th drum at 15° and 165° drum angle. Each run was made at 1 KW in the power control mode. The averages of the 5 time points at each hold point were used to determine the 11 drum differential angle corresponding to rotation of each drum from 15° to 165°. The difference in reactivity worth of the 11 drum average is the 15° to 165° worth of the drum being rotated. Using the experimentally determined value of 6.53 ¢/°[1] reactivity worth in the angular positions being considered, each drum span was calculated from the differential angle.

Between the times when Drum No. 5 and Drum No. 6 were compared, a steam generator run was initiated. The critical drum bank position immediately before and after the steam generator run was calculated to determine possible effect on the relative worth calibration.

[1] See EP-1 SPEAR Memo No. 5.

TIME	AVERAGE DRUM POSITION PASS Q0005 [2] D.801.A -- D.812.A
58879.8	
58880.8	
58881.8	98.65°
58882.8	
58883.8	
59941.4	
59951.4	
59961.4	98.29°
59971.4	
59981.4	

In order to determine the cause of this apparent shift in Critical Position, the T.600 Core Temperature was reviewed and found to have shifted -20° during the Steam Generator Run.[3] The shift in critical drum position was, therefore, considered valid and all subsequent average drum positions were adjusted up by .36°.

Total span for 12 drums from 15° to 165° can be estimated:

$$63.83\ (12) = \$7.66$$

The average drum worth obtained is 63.83. This average is 2.17¢ below the predicted 66.0 but is close to the ± 1.7¢ predicted accuracy. The range of the individual drum worths around this average is 63.83 + .66¢ -1.70¢ and is close to the ± 1¢ predicted range around the mean. Therefore, even though the No. 11 and No. 12 drum relative worths were not determined, the objectives of this test were achieved.

ANOMALIES

In the Digital Data Listings for SL2 Pass Q 0005 and Q 0004, no data was printed from time 60844.6 through time 61364.9 during the Relative Drum Worth Comparisons for Drums Nos. 11 and 12.

[2] The 1.01 Correction for Drum Position was not used.

[3] Refer to SPEAR Memo No. 3.

RELATIVE DRUM WORTH

EP-I, SL2 - 12/6/68

TIME	DRUM	DRUM ANGLE	11 DRUM AVERAGE D.801.A/ D.812.A	DIFF.	WORTH[1]
57955.3 57960.3	D.801.A	15.4°	104.50		
58047.3 58071.7		167.4°	94.23	10.27°	62.13
58360.2 58364.2	D.802.A	14.9°	104.49		
58450.3 58454.4		167.0	94.13	10.36°	63.68
58627.3 58631.3	D.803.A	15.7	104.57		
58687.3 58692.3		167.0	94.05	10.52	63.64
58785.8 58789.8	D.804.A	15.4	104.60		
58847.8 58851.8		166.8	93.98	10.62	64.25
58927.8 58931.8	D.805.A	15.2	104.69		
58972.8 58976.8		167.0	94.06	10.63	64.31
60047.7 60051.7	D.806.A	14.8	*104.66		
60089.7 60093.7		166.7	* 94.01	10.65	64.43
60172.7 60176.7	D.807.A	15.2	*104.70		
60205.7 60209.7		167.0	* 94.04	10.66	64.49
60316.7 60321.7	D.808.A	15.1	*104.71		
60362.7 60366.7		167.1	* 94.07	10.64	64.37

[1] 6.53 ¢/° (Diff. Angle) (1.01) Refer to EP-I SPEAR Memo 3. For the correction factor (1.01) for drum position, refer to EP-I SPEAR Memo 3.

RELATIVE DRUM WORTH (Contd)

EP-I, SL2 - 12/6/68

TIME	DRUM	DRUM ANGLE	11 DRUM AVERAGE D.801.A/ D.812.A	DIFF.	WORTH
60444.7 60448.7	D.809.A	15.5	*104.58		
60489.7 60493.7		166.9	* 94.11	10.47	63.35
60553.7 60557.7	D.810.A	14.7	*104.59		
60602.0 60606.0		166.3	* 94.07	10.52	63.64
			TOTAL		638.29
			MEAN		63.83

* Adjusted for critical drum position shift. See paragraph 1 page 2 .

SPEAR Memo No. 7

G.O. Patmor/H. Henze

G.OP/HH/BSH

XE-PRIME

EP-I AND EP-SI2

Subject: SGS WATER INJECTION MODIFICATION PERFORMANCE DURING PHASE II NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

During the Phase I NES Steam Line Demonstration Tests (9 October 1968) steam temperature surges of approximately 200°R were observed when the steam temperature was above 1325°R. SGS pressure oscillations were also noted. The data was analyzed and a modification was recommended. This modification consisted of installing a parallel water line from the 24-inch water line to the 6-inch SGS injection water manifold and installing a cavitating venturi and a $1\frac{1}{2}$-inch trim valve in each module's water injection system. The modification, Program Directive 1730 and 1731, was completed and checked out during the Phase II Tests.

SUMMARY

The SGS water supply and injection system modifications were evaluated at the most severe condition of water supply pressure and steam operating temperature.

The steam temperature was stable up to and including 1600°R with maximum duct water flow of 39,000 gpm and a water tank level of 15 feet. The water injection control proved to be easily controllable by the console operator.

Evaluation of the data indicated that the modification exceeded the design predictions in that the water system venturis will cavitate for all water tank levels at the maximum duct flow rate and at steam temperatures up to 1600°R. It had been predicted that the system would decavitate at a water tank level of 13 feet.

TECHNICAL DISCUSSION

Objectives

The objectives of the Phase II NES Steam Line Design Demonstration Test pertaining to the SGS water supply and injection modifications were: 1) demonstrate the ability of the modification to maintain stable SGS plenum temperature of 1460°R at low water tank level; and 2) demonstrate ease of water injection control by the console operator. The steam line checkout requirement of reaching 1560 +0, -50°R permitted the water injection modification to be evaluated at an even higher temperature.

Discussion

General Discussion of Test

The test was conducted by starting with the water bypass valves, FCV-423-2 and -3, 100% open. The steam temperature was increased gradually from 775°R to 1600°R by slowly closing the bypass valves. The temperature was being monitored by T-534 to determine level and stability. The SGS plenum pressure was being monitored by P-425. The steam temperature was then decreased to 1257°R and the duct coolant water was decreased from 39,000 gpm to 12,500 gpm. The steam temperature decreased to 1151°R as a result of the increased injection water flow rate caused by the increase in water supply pressure. The steam temperature was then being increased to 1460°R by closing FCV-423-2 and -3 when Steam Generator No. 3 received a shutdown signal and the test was terminated. The reason for this shutdown is discussed in Memo No. 18.

The test results are tabulated below:

1. The water injection control proved to be non-sensitive and easy for the operator to control.

2. The steam temperature is fully controllable and stable from 775°R to 1600°R with maximum duct water flow of 39,000 gpm and a water tank level of 15 feet.

3. The comparison of the pre-test predictions and the measured values of pressures and temperatures is shown in Table 1.

4. The steam line and separator pressure loss was less than predicted by 7.1 psi which is 30%. The reason in part for this is due to a 2.8 psi lower separator pressure drop than expected. This results in a lower SGS plenum pressure than expected which yields a "harder" water injection control system.

5. A curve of steam temperature versus total water injected is shown in Figure 1.

6. A curve of FCV-423 position (average of each FCV-423) vs steam temperature is shown in Figure 2. This curve is defined for a supply water header pressure (P427) of 200 psia. Increasing this pressure shifts the curve to the left, conversely, decreasing the supply pressure shifts the curve to the right.

Steam Plenum Pressure Variations

During the Phase I steam separator evaluation the data indicated that the plenum pressure for a steam temperature of 1325°R had pressure variations of +4 psi with random pressure spikes of +25 psi and temperature surges of 200°R.

Evaluation of the test data after completion of the injection system modification and the installation of the steam line indicated that the plenum pressure for a steam temperature of 1325°R had pressure variations of ±2.5 psi. No significant pressure or temperature spikes were noted at this temperature.

Several minor pressure surges were noted during the operation. Table 2 presents the pertinent data relating to two of the surges. The data tabulated for range time 80457, during which module No. 2 shut down, indicates that although a 10.7% variation occurred in the steam plenum pressure (P425) only a 1% variation occurred in the water flow rate.

For range time 80061, a 11.4% variation occurred in P-425 while the water flow rate changed only 1.4%.

During both periods evaluated the flow control valves (FCV-423) did not vary. For more information on system pressures, see Memo 8.

Performance of the Water System Modification

The existing water header between the end of the 24-inch line in the duct vault and the steam generator enclosure was paralleled with a similar line to decrease the supply system pressure drop. The pressure drop at flow conditions was 18.3 psi before modification.

The system resistance (kw) was predicted to be 104.5 based on the equation $Kw = \frac{W}{\sqrt{\Delta P}}$ where W is the total water flow in lbs/sec and delta P the pressure drop in psi. The actual average resistance during a 40-second interval was 96.6 and the pressure drop obtained of 4.8 psi was found to be in good agreement with the predicted value of 4.1 psi.

It was predicted that the water injection system would cavitate at all tank levels down to 13 feet for the extreme conditions of 44,000 gpm water flow and 1510°R steam temperature.

Analysis of the data indicates that at these conditions with the 90% venturi recovery, (verified during the venturi calibration) the system will cavitate at all levels of the process water tank.

Cavitation will occur for P-427 pressures as low as 183.5 psia. This is due to the fact that the steam and the water injection system pressure drops were less than predicted as shown in Table 3.

The system as installed exceeds the predicted values and is a much "harder" system.

External Water System Interaction on SGS Stability

During the test with the SGS operating at 1250°R steam conditions, the duct flow rate was decreased from 39,000 gpm to 12,600 gpm by closing FCV-32 completely in 54 seconds. No temperature oscillations were noted during the period of closing with the temperature gradually decreasing to

$1106^{\circ}R$ as noted in Table 4 at the instant FCV-32 closed. The water supply pressure P-427 then stabilized 11 psi lower and caused the steam temperature to stabilize at $1151^{\circ}R$. This phenomenon can be explained by the loss of inertial pressure drop as a result of the long water supply. A value of 12 psi is obtained when using the equation

$\Delta P_{Inertial} = \frac{L}{12gA} \frac{dw}{dt}$ as described in Appendix B of RN-S-0433. This value is in good agreement with the actual value. No other external water system interactions were noted during the test.

The PCV-449 circuit tripped only when a module was shut down; no other trips were experienced during the test.

RECOMMENDATIONS

None.

ANOMALIES

None.

TABLE 1

SGS WATER INJECTION MODIFICATION DATA

FUNCTION	PREDICTED		ACTUAL 80046.7	ACTUAL 80070.7
P168, psia	213	213	212.7	212.8
P427, psia	204	204	202.0	201.3
P406Y, psid			200.0	199.8
P438Y, psia	144.8	142.2	136.5	133.8
P425, psia	134	132	126.6	126.0
P239, psia	121.0	118.4	119.2	117.1
P865, psia	128.0	125.4	123.1	120.5
P864, psid	139.0	136.4	132.3	128.7
P866, psia	11.0	11.0	9.2	8.2
T534, °R	1600	1460	1600.7	1460.5
T159, °R	1600	1460	1600.8	1459.9
P870Y, psid			31.61	31.73
Wventuri 2,pps			32.38	32.44
Wventuri 3,pps			32.53	32.51
WBP 2, pps			4.74	4.99
WBP 3, pps			4.80	4.87
L-15, feet	15	15	15.08	15.01

Predicted values revised based on tank height of 15 feet and temperatures of 1600 and 1460°R.

TABLE 2

Range Time	Separator Outlet Press. P865 psia	Steam Plenum Press. P425 psia	Water Injec. Press. P914-X psia	Water Injec. Flow Rate lb/sec	Water Manifold Pressure psia	Separator Outlet Temperature °R	Water Injec. Kw
80457.7	116.0	123.8	165.4	37.47	209.1	1429.6	6.8
80457.8	115.7	124.2	163.5	37.54	210.7	1433.6	7.0
80457.9	117.2	125.9	164.3	37.45	209.1	1429.6	6.9
80458.0	119.2	131.5	169.8	37.22	207.9	1414.3	6.8
80458.1	122.5	133.4	168.8	37.17	210.7	1428.5	7.0
80458.2	126.1	127.9	168.2	37.17	209.4	1442.0	6.8
80458.3	126.0	125.8	165.7	37.31	209.3	1446.1	6.9
80458.4	123.5	124.8	166.3	37.36	210.2	1445.9	6.8
80458.5	121.0	127.7	165.2	37.48	207.8	1454.7	6.9
80458.6	118.4	123.5	163.2	37.49	209.7	1449.6	6.9
80458.7	117.2	119.1	163.2	37.54	211.4	1472.3	6.8
80458.8	116.6	122.7	163.9	37.56	209.8	1467.3	6.9
Variation	8.3%	10.7%	3.9%	1%	1.7%	3.9%	2.9%
80061.7	122.1	125.9	165.1	37.5	201.7	1389.4	6.7
80062.1	120.4	131.5	166.8	37.47	200.4	1394.7	6.8
80063.7	126.1	125.6	166.7	37.25	200.2	1405.4	6.8
80064.7	127.6	136.0	173.7	37.09	200.0	1417.7	6.7
80065.7	125.0	125.7	165.8	37.21	201.6	1472.3	6.7
80066.7	121.2	123.8	166.0	37.62	201.1	1449.0	6.8
80067.7	121.2	125.9	164.9	37.40	199.9	1418.7	6.8
80068.7	121.0	123.1	164.1	37.56	199.2	1422.8	6.8
80069.7	121.0	120.5	163.8	37.42	200.4	1407.6	6.9
80070.7	120.5	126.0	166.1	37.43	201.3	1394.3	6.8
Variation	5.7%	11.4%	5.5%	1.4%	1.2%	5.4%	2.9%

TABLE 3

	Steam Temp. °R	Module Ch.Pr. P-438 psia	Delta P Venturi Outlet to Ch.Pr. psia	Venturi Outlet Press. psia	Venturi Inlet Press. (P427) Necessary for Cavitation psia
Predicted	1510	143.6	34	177.6	197
Actual	1513	132.3	31.9	164.2	183.5

TABLE 4

Range Time	Total Duct Flow gpm	P427 psia	Module Pressure P438-X psia	Plenum Pressure P-425 psia	Module Water Flow lb/sec	Separator Inlet Temperature TE582 °R	TE534 Steam Line Temperature °R	FCV-32 Position %
80259.3	38737	201.4	128.9	117.8	42.18	1225.6	1257.4	37.0
80270.3	36049	207.1	129.1	117.5	42.91	1173.0	1223.0	24.7
80280.3	32350	210.3	130.2	119.0	43.53	1139.6	1195.0	20.1
80290.3	26860	213.6	128.3	115.6	44.41	1098.7	1164.8	12.0
80300	21421	218.7	128.7	120.2	44.98	1049.3	1133.5	6.7
80313.3	12650	221.9	126.6	122.9	45.57	982.6	1106.0	.2
80350.3	11752	211.0	128.1	124.1	43.50	1113.7	1151.5	0

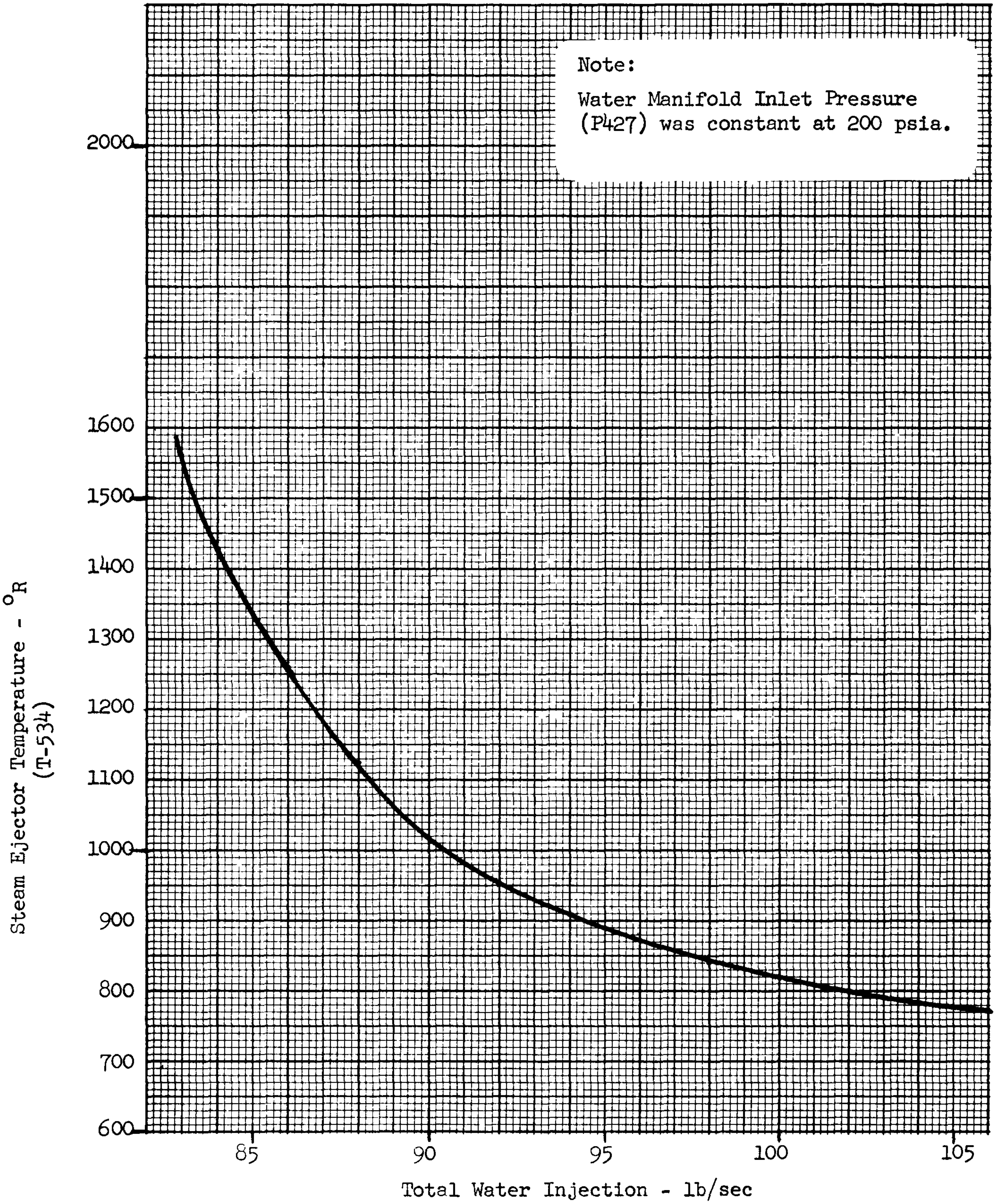

Note:
Water Manifold Inlet Pressure (P427) was constant at 200 psia.
2000
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
Steam Ejector Temperature - °R
(T-534)
85
90
95
100
105
Total Water Injection - lb/sec

FIGURE 1

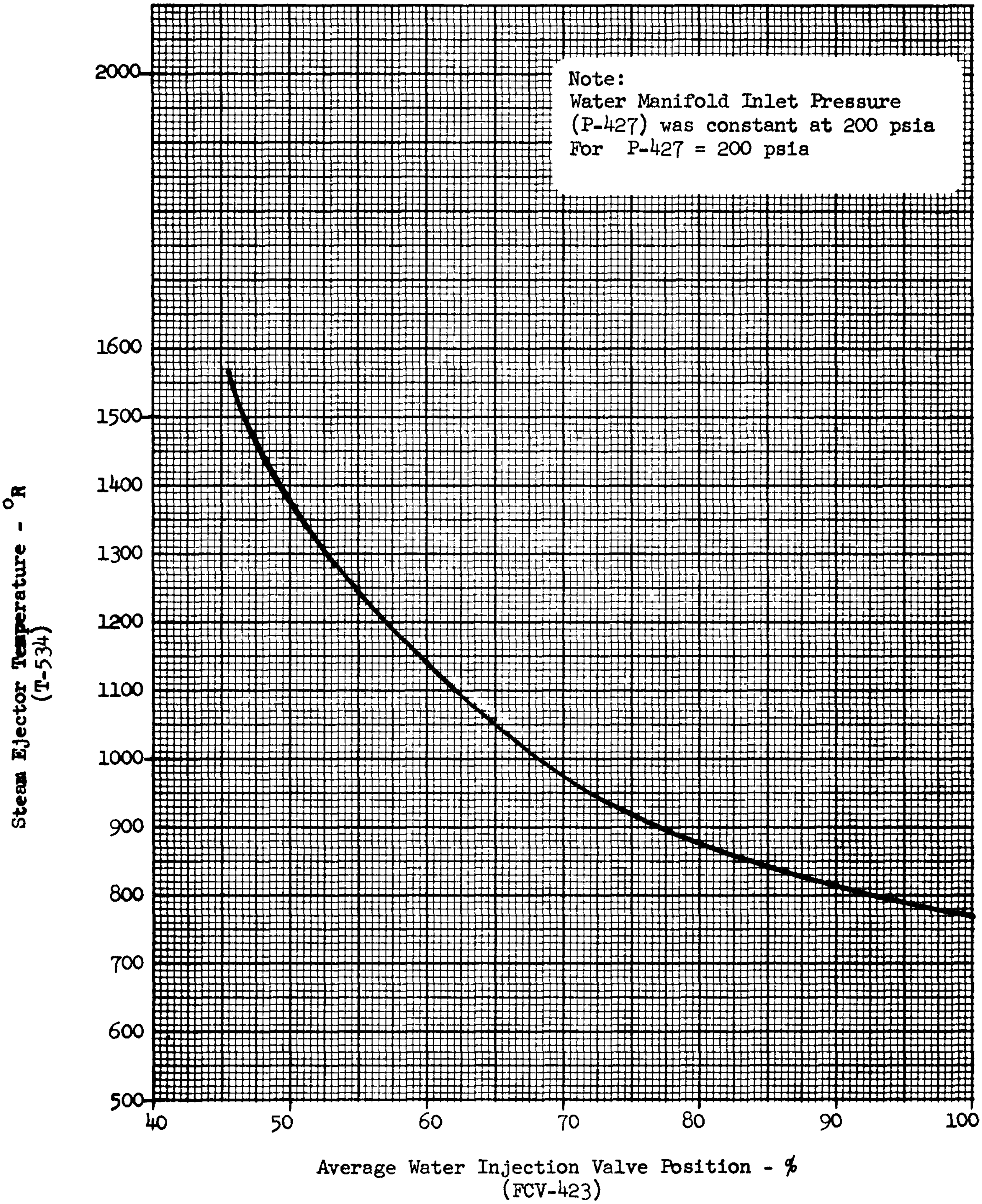

Note:
Water Manifold Inlet Pressure
(P-427) was constant at 200 psia
For P-427 = 200 psia
Steam Ejector Temperature - °R
(T-534)
2000
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
40
50
60
70
80
90
100
Average Water Injection Valve Position - %
(FCV-423)

FIGURE 2

SPEAR Memo No. 8
Goodman/Henze/Soo
McCarty/Keasling:cjd

XE-PRIME

EP-I and EP-SL2

Subject: STEAM LINE EVALUATION

INTRODUCTION

After the completion of the Phase I steam separator test program on 9 October 1968, the new steam line was installed between the separator outlet and the duct steam ejector. The line was subsequently insulated, instrumented and balanced per NRO requirements.

The Phase II steam line evaluation was designed to verify its operational capability at steam temperatures up to 1560°R.

SUMMARY

The steam line was subjected to 740 seconds of two module full steam operation during which time the steam temperature was varied between 775°R and 1617°R.

The steam line operated normally throughout the test with all observed hanger movements occurring in the proper direction. There was no evidence of free water in the steam line downstream of the separator, at any time, although the steam at certain operating conditions was saturated.

Although the steam line "cold position" after the test was, in general, lower than the pre-test position, there was no indication of any steam line deformation. **Hanger No. H3R and H3L were bottomed at the cold position during the post-test inspection, but no damage was observed.**

TECHNICAL DISCUSSION

Data Acquisition

The following data were collected during the tests:

1. Steam temperature and pressure upstream of the separator inlet.

2. Sump temperature of the separator.

3. Steam temperature and pressure at the separator outlet.

4. Steam temperature and pressure near the steam ejector.

5. Pipe temperature of the separator inlet spool.

6. Pipe temperature of the steam line near hanger 4.

7. Pipe temperature of the steam line near hanger 1.

The location and number of the thermocouples and pressure probes are shown in Figures 1 and 2.

The displacement transducer information was unavailable at the time of this evaluation. No strain gage measurements were made.

Photographic and TV Data

Several movie cameras were set up in the Pipe Chase and Duct Vault to record the steam line hangers movements during the Phase II test. In addition, one TV camera was set up in the Pipe Chase and another TV camera was installed in the Duct Vault to provide direct, "time-of-test" observations of the steam line.

The duct vault door was positioned such that the front of the Pipe Chase was partially uncovered, and during daylight hours a significant amount of outdoor light was present in the vault. Auxiliary lighting was used to supplement the natural light in the Pipe Chase, but since the test was planned to be conducted in the daylight hours, provision was not made for complete artificial lighting. With the test actually performed after dark, the available light in the Pipe Chase and near the steam line water separator was inadequate for the movie photography. All of the movie film was underexposed, and two of the cameras malfunctioned, resulting in film of little or no value for test observations.

The TV coverage in the Duct Vault and Pipe Chase was quite good under the test conditions. The duct vault camera gave good over-all views, and with the zoom lens, the Hanger No. 1 position was observed satisfactorily.

In the Pipe Chase, the TV camera could observe the steam line lower elbow, the lower horizontal pipe section, Hangers No. 1A and 2, and provided an overall view of the vertical and upper horizontal piping.

During the course of the steam line test, the TV observations were recorded on video tape.

General Discussion of Test

Steam generator modules No. 2 and 3 were brought full steam using a standard startup sequence. The two units were run at full steam conditions for 740 seconds, during which time the steam temperature, as measured by T534, was controlled between 775°R, the lowest two module steam temperature, and 1617°R.

No excessive temperature or pressure excursions occurred during the test. The separator drain valve RSV439 was closed when the separator sump temperature (T591) was above 760°R. No increase in steam ejector pressure (PT239) was noted when RSV-439 closed.

Observation of the lower pipe chase steam line elbow, with the TV monitor, indicated no sudden movement during either startup or shutdown of a unit to or from full steam condition.

In the original steam line installation, this elbow was subject to sudden movement during startup of a module to full steam. This improvement indicates that the separator performs part of its design function, i.e., dampening the pressure surges and preventing water slugs from entering the steam line during a startup of a module to full steam. Another contribution to the improvement is due to the increased rigidity and dampening resulting from the heavier pipe and more supports in the new steam line. Observation of Hangers 1, 1a and 2 with the TV monitor indicated that all hangers operated normally, moving in the expected direction approximately as anticipated.

The movement of the bottom elbow was noted to be approximately three inches downward and four inches horizontally away from the NES duct.

As a result of a visual post-test inspection, it is concluded that the steam line installation is basically unchanged. The following movements were noted, however:

> The water separator position appears to have changed slightly, being a little closer to the shadow wall by about 1/8 inch.
>
> Hanger No. H3R and H3L were bottomed at the cold position during the post-test inspection, but no damage was observed.
>
> The steam line "cold" position after the Phase II test was, in general, lower than the pre-test position, and at the Pipe Chase lower elbow the decrease in elevation was 11/16 inch; the vertical steam line section in the Pipe Chase was also displaced toward the shadow wall approximately 1/4 inch when compared to the pre-test location.

Separator Inlet Temperature Distribution

The steam temperatures at the separator inlet were measured by TE582 through TE585, with the noted depths of penetration and location as shown in Figure 2.

As shown in Figure 3, there is a large difference between TE585 and the other three thermocouples. For this test, TE585 was reading in the same manner as it did during Phase I test when it was reported to be bad. This thermocouple should be checked to verify its immersion depth and a new probe installed prior to the next test. Approximately an 80°R difference exists in the other three thermocouples (TE582, TE583, and TE584) indicating incomplete mixing in this section of pipe.

Also shown in Figure 2 is the location of the six thermocouples on the pipe surface at the separator inlet (TE592 through TE597). The temperature spread was 60°R when the steam temperature was at a maximum.

Separator Outlet Temperature Distribution

The separator outlet steam temperature was measured by TE586, through TE590 with depths of penetration and location shown in Figure 2. All five thermocouples were very close to one another (within 20°R) during the full steam operation, indicating very good mixing in the separator.

Steam Line Surface Temperature Distribution

There are two surface temperature profiles downstream of the separator located as shown in Figure 2. The profile on the steam line in the top of the Pipe Chase (TE598 through TE601) were very close together. The profile downstream (TE602 through TE605) was further apart. The top of the pipe (TE602) was consistently lower than the bottom (TE605) by an average of 120°R, which does not seem consistent with the upstream temperatures. Each installation utilizes spring loaded probes and it is recommended that the installation of TE602, TE603, TE603 and TE605 be inspected.

The maximum temperature that the pipe surface near hanger 1A reached was approximately 1280°R. This temperature was reached 255 seconds after the steam temperature (TE534) was reduced from 1600°R to 1440°R.

Temperature Comparison

Pipe Wall Temperature

Figure 4 is a plot of external pipe wall temperatures at three locations:

TE594	Separator Inlet Spool
TE599	Separator Outlet - Hanger 4
TE603	Separator Outlet - Hanger 1A

Evaluation of this figure indicates a steam line temperature decrease between the SGS and Duct during periods that the steam temperature is being increased, with the reverse occurring during periods that the steam temperature is being decreased.

Steam Temperatures

As stated earlier, the gas temperature entering the separator was non-uniform, indicating "coring" whereas the separator outlet was uniform indicating mixing in the separator. There was, however, a lag between the temperature entering the steam ejector (TE534) and the separator outlet temperature (TE588). TE534 lagged behind TE588 on an up-ramp and TE588 lagged behind TE534 on a down-ramp, as shown in Figure 5. This indicates that the pipe and separator are absorbing heat on the up-ramp and causing the temperature drop and then giving off heat as the steam temperature is decreased.

This phenomenon is also exhibited between the separator inlet and outlet. It is recommended that TE588 be displayed on the FEL console to assure that the SGS operator does not exceed the 1560°R limit when raising the steam temperature to the operating value at TE534.

Pipe Wall and Steam Temperature Comparison

A comparison of Figure 4 (Pipe Wall) with Figure 5 (Steam) shows that the pipe wall temperature lags the steam temperature an average of 300°R during the steam temperature increase from 775°R to 1600°R. It is estimated that the steam temperature would be required to be held at 1500°R for an additional 120 seconds in order for the pipe wall temperatures to reach 1460°R.

System Operation

Superimposed on Figure 5 is the water bypass valve position FCV 423-Y. It can be seen, for the water supply pressure available during the test, that steam temperature modulation was not initiated until the valve was closed to approximately 85%. The effect of reducing the duct flow from 39000 to 12000 GPM, as discussed in Memo 7, is quite apparent on this plot, starting at range time 80260.

A plot of system pressures is shown in Figure 6 with PT864 and PT865 being the separator inlet and outlet pressure respectively, and PT239 being the duct ejector inlet pressure.

Evaluation of Figures 5 and 6 indicate that a sudden increase in temperature downstream of the separator (TE588 and TE534)occurs around 1350-1400°R accompanied by steam pressure oscillations (PT864, PT865 and PT239). The steam temperature appears to be reasonably insensitive to these pressure fluctuations.

The pressure drop across the separator is reduced from 11 psi during the separator demonstration test to 8.5 psi in this test at the same temperature conditions.

Shutdown Transients

Figure 7 is the temperature transient of a module shutting down from a two unit operation at approximately 1500°R. Although TE591, the sump temperature, dips to 800°R in 1-1/2 seconds, indicating the presence of wet steam or water, no carryover was experienced at the separator outlet.

Figure 8 is the temperature transient during the shutdown of a single generator from full steam conditions. The separator steam outlet temperature generally drops from 750°R to 670°R and there is no indication of any water carryover during this transient period.

It can be concluded that separator performs the remainder of its function in preventing water carryover into the new steam line.

Recommendations

1. The installation of TE662 through TE605 should be checked to verify proper contact and spring loading.

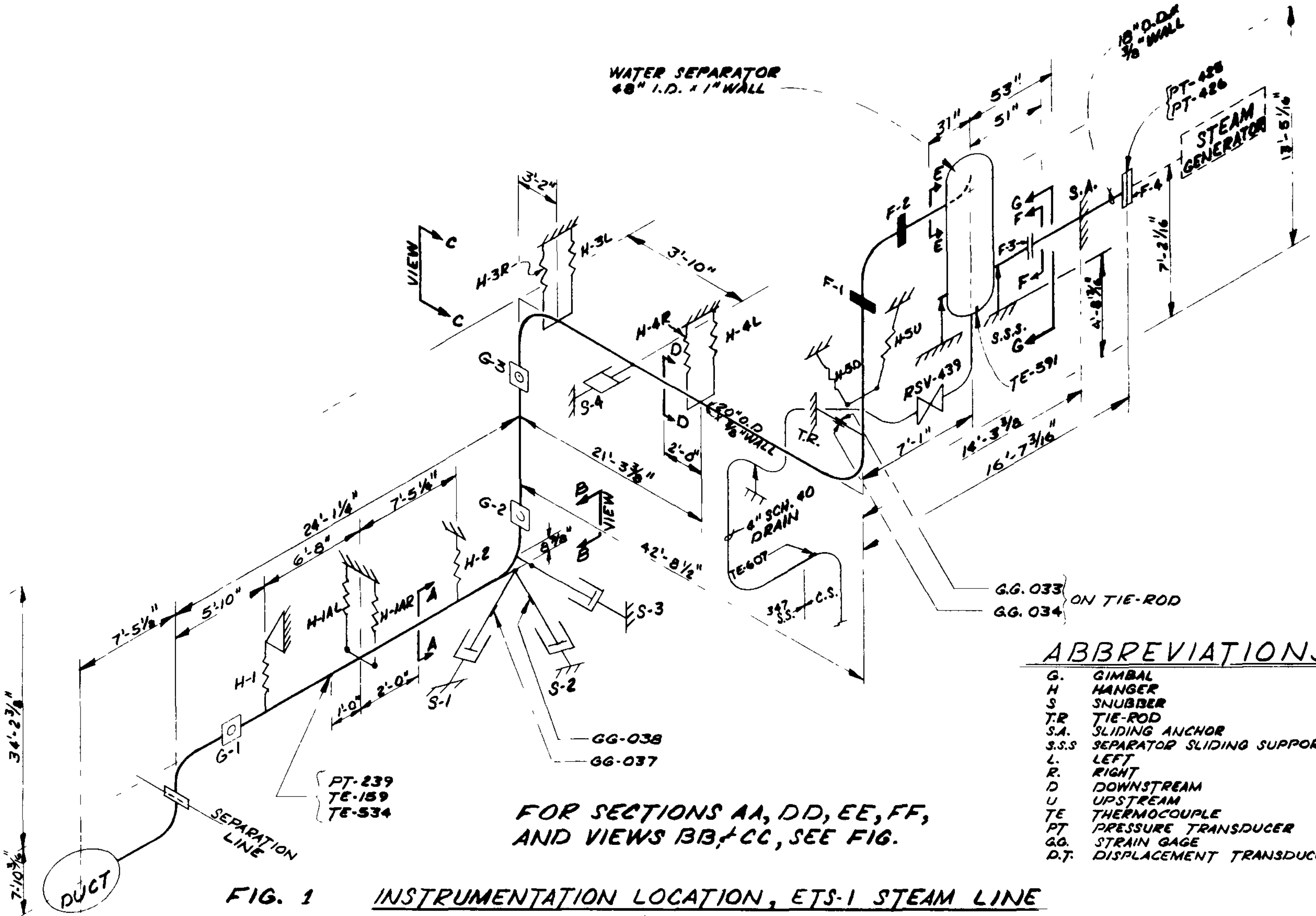
2. The steam line displacement potentiometer data, which is recorded on FM tape) should be processed to Engineering unit plots and digital listings within three days of the test.

3. The effect of steam pressure oscillations on system performance at separator exit temperatures above 1400°R will be further evaluated. Pending this evaluation, operation at steam temperatures above 1400°R should be minimized.

ANOMALIES

1. TE 585 appears to be reading low.

2. The temperature spread of 120°R between TE 602 and TE 605 is abnormal.



FOR SECTIONS AA, DD, EE, FF,
AND VIEWS BB & CC, SEE FIG.

ABBREVIATIONS

G.	GIMBAL
H	HANGER
S	SNUBBER
T.R	TIE-ROD
S.A.	SLIDING ANCHOR
S.S.S	SEPARATOR SLIDING SUPPORT
L.	LEFT
R.	RIGHT
D	DOWNSTREAM
U	UPSTREAM
TE	THERMOCOUPLE
PT	PRESSURE TRANSDUCER
G.G.	STRAIN GAGE
D.T.	DISPLACEMENT TRANSDUCER

FIG. 1 INSTRUMENTATION LOCATION, ETS-1 STEAM LINE

JOB # 424

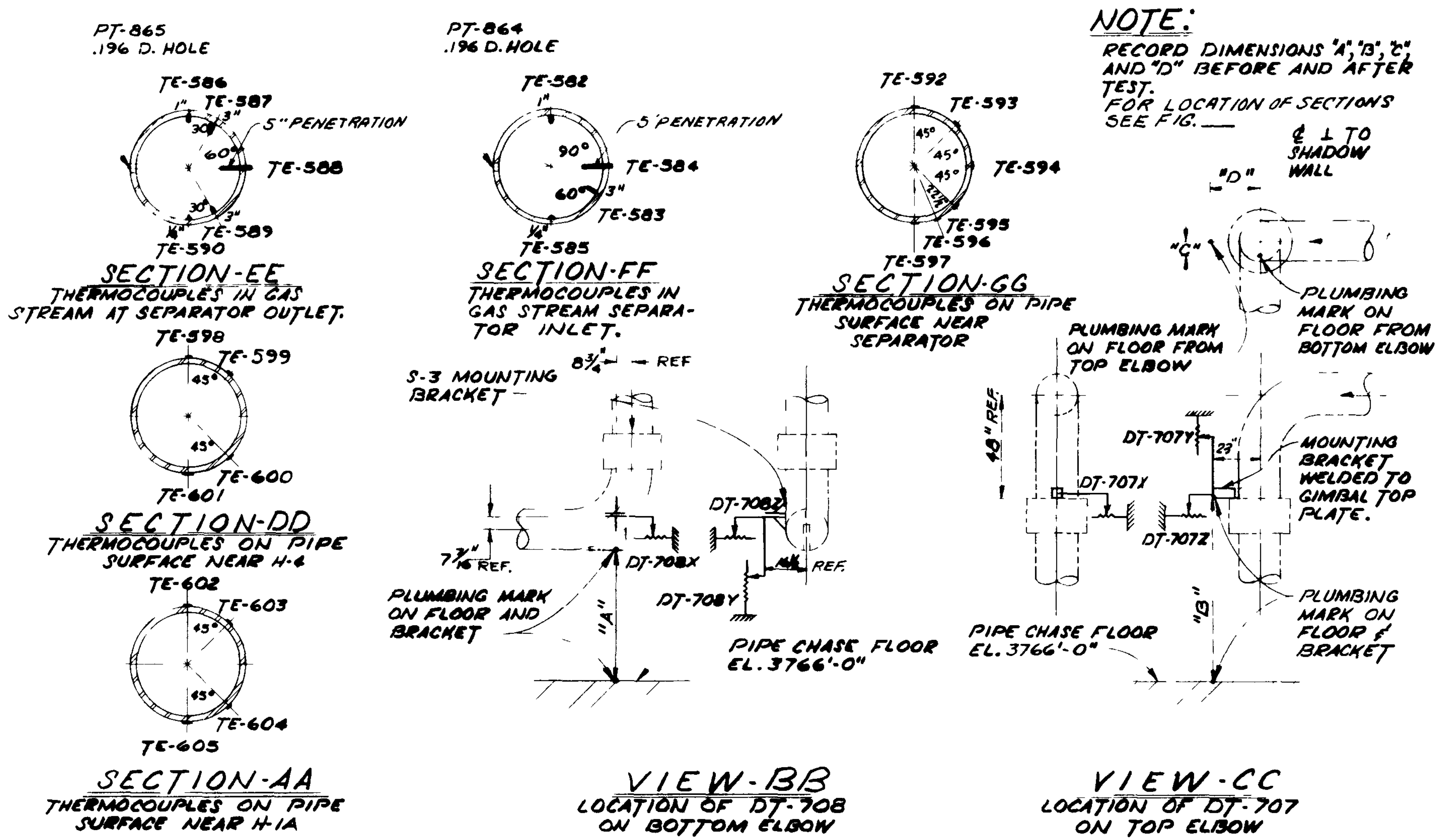
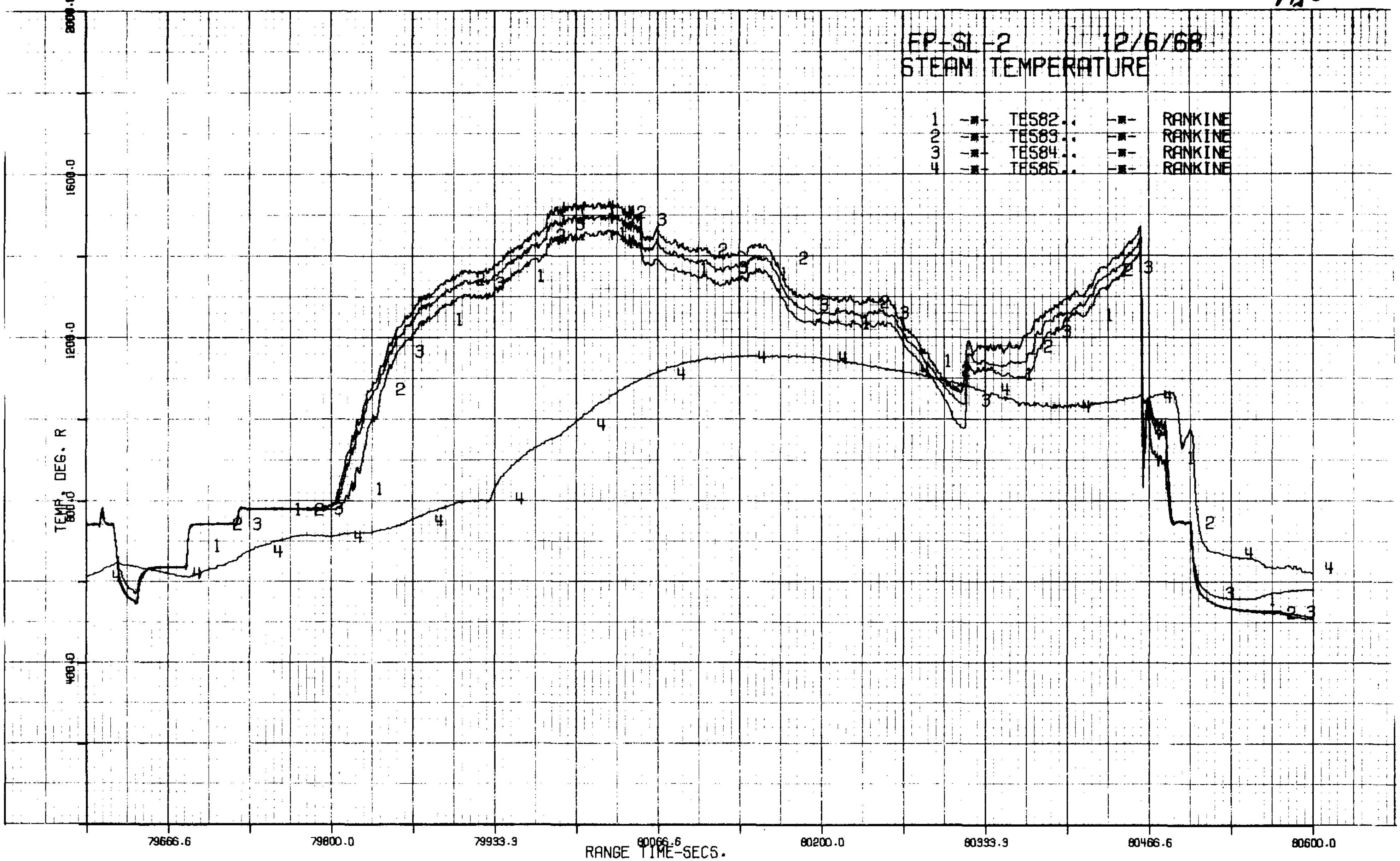


FIG. 2 INSTRUMENTATION LOCATION, ETS-1 STEAM LINE

JOB # 424

Fig 3



FP-SL-2 12/6/68
STEAM TEMPERATURE
1 TE582. RANKINE
2 TE583. RANKINE
3 TE584. RANKINE
4 TE585. RANKINE
TEMP. DEG. R
2000.0
1600.0
1200.0
800.0
400.0
79666.6
79800.0
79933.3
80066.6
80200.0
80333.3
80466.6
80600.0
RANGE TIME-SECS.

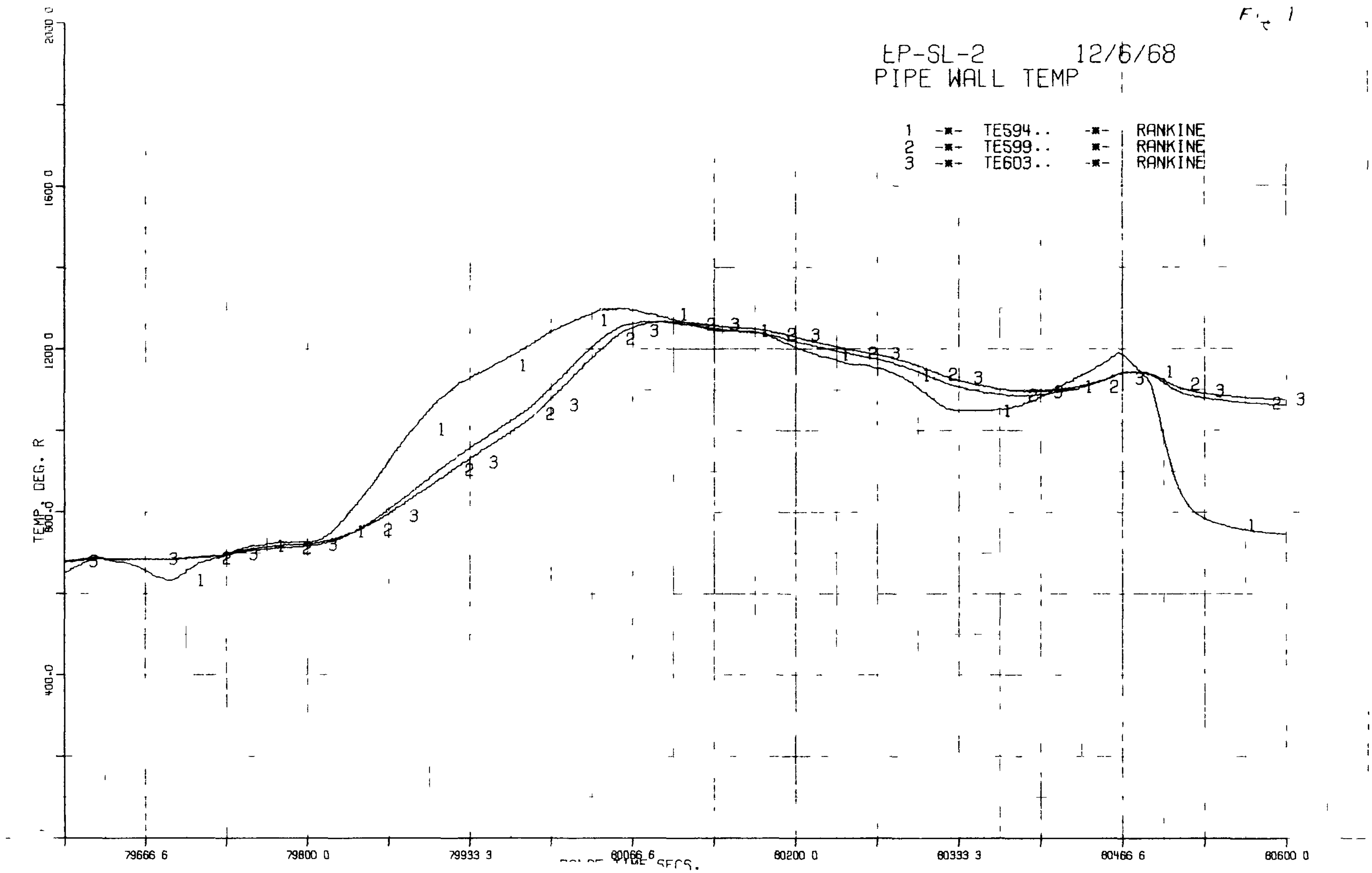


Fig 1
EP-SL-2 12/6/68
PIPE WALL TEMP
1 -*- TE594.. -*- RANKINE
2 -*- TE599.. -*- RANKINE
3 -*- TE603.. -*- RANKINE
TEMP. DEG. R
2000.0
1600.0
1200.0
800.0
400.0
79666.6
79800.0
79933.3
80066.6
80200.0
80333.3
80466.6
80600.0
TIME SECS.

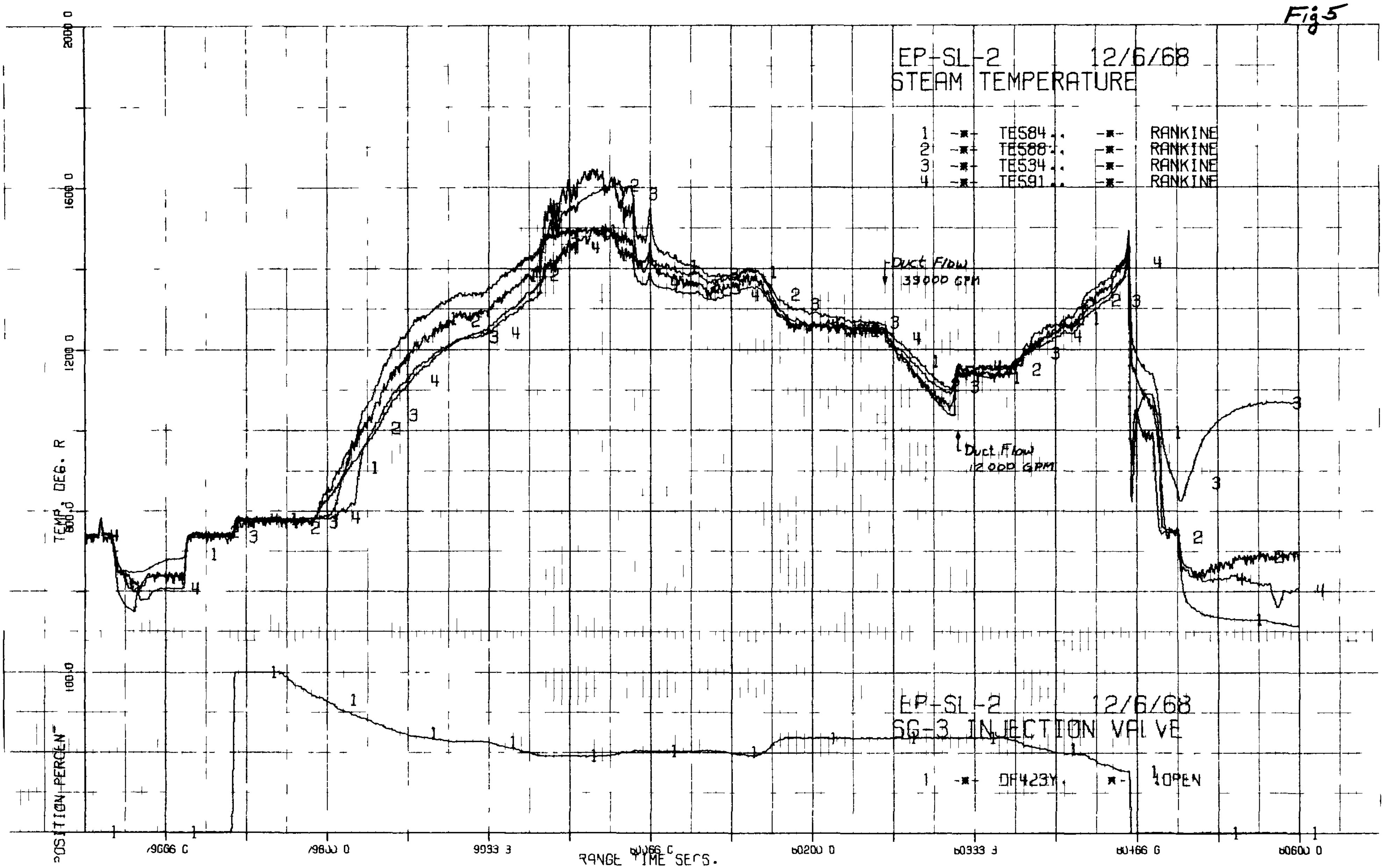
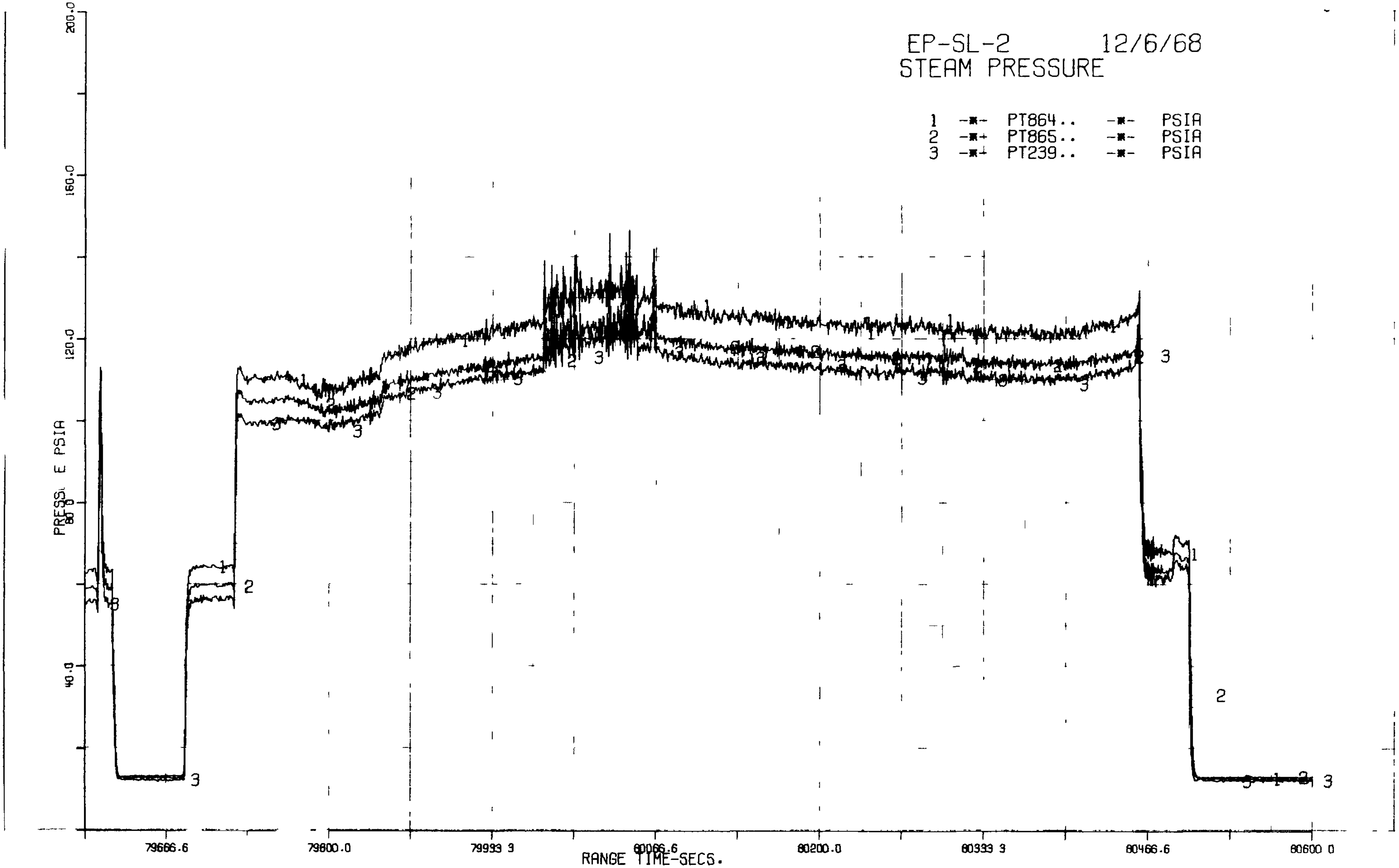


Fig 5
EP-SL-2 12/6/68
STEAM TEMPERATURE
1 TE584 RANKINE
2 TE588 RANKINE
3 TE534 RANKINE
4 TE591 RANKINE
Duct Flow 39000 GPM
Duct Flow 12000 GPM
EP-SL-2 12/6/68
SG-3 INJECTION VALVE
1 DF423Y OPEN
TEMP. DEG. R
POSITION PERCENT
RANGE TIME SECS.



EP-SL-2 12/6/68
STEAM PRESSURE
1 PT864.. PSIA
2 PT865.. PSIA
3 PT239.. PSIA
PRESSURE PSIA
200.0
160.0
120.0
80.0
40.0
79666.6
79800.0
79933.3
80066.6
80200.0
80333.3
80466.6
80600.0
RANGE TIME-SECS.

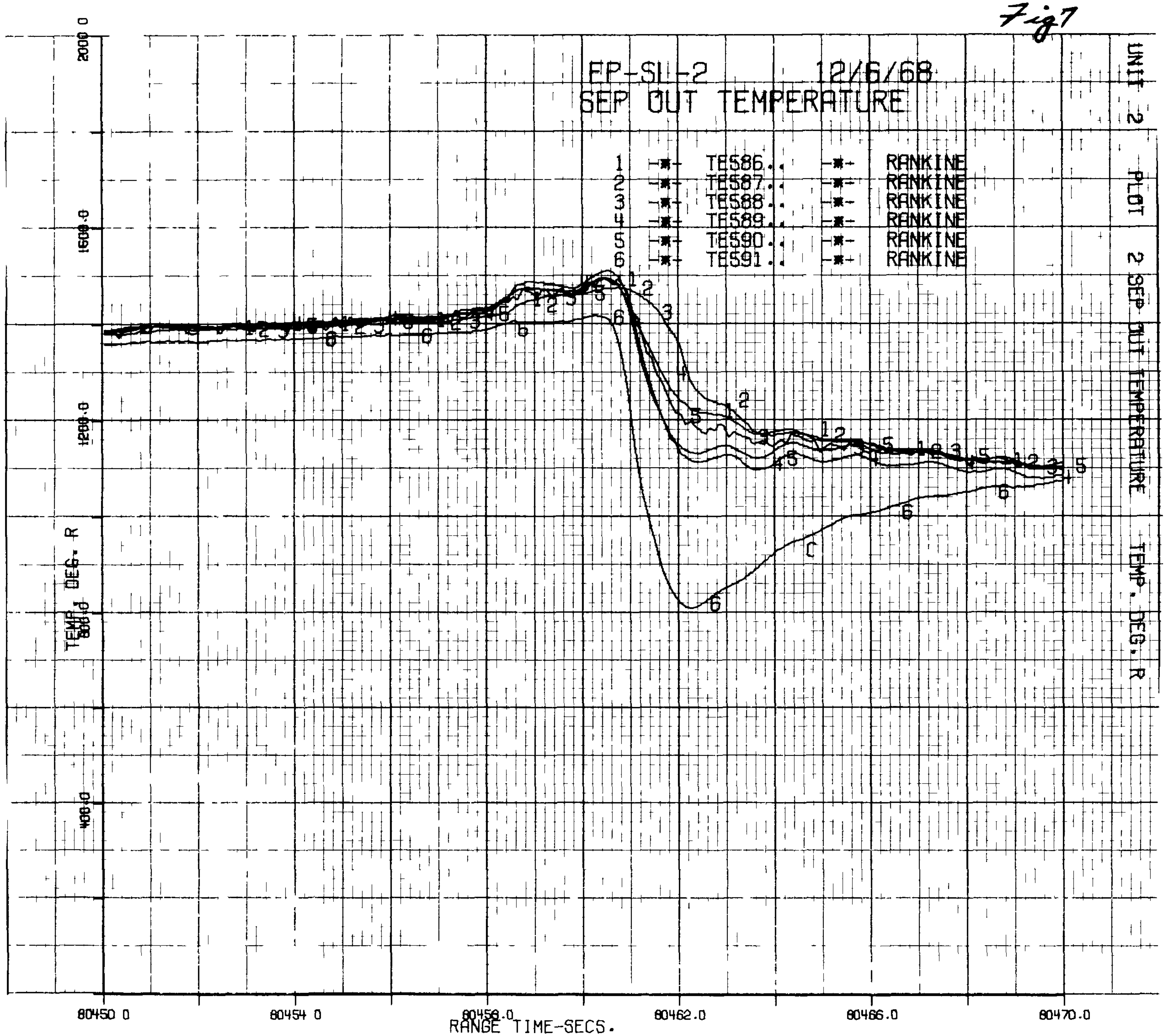
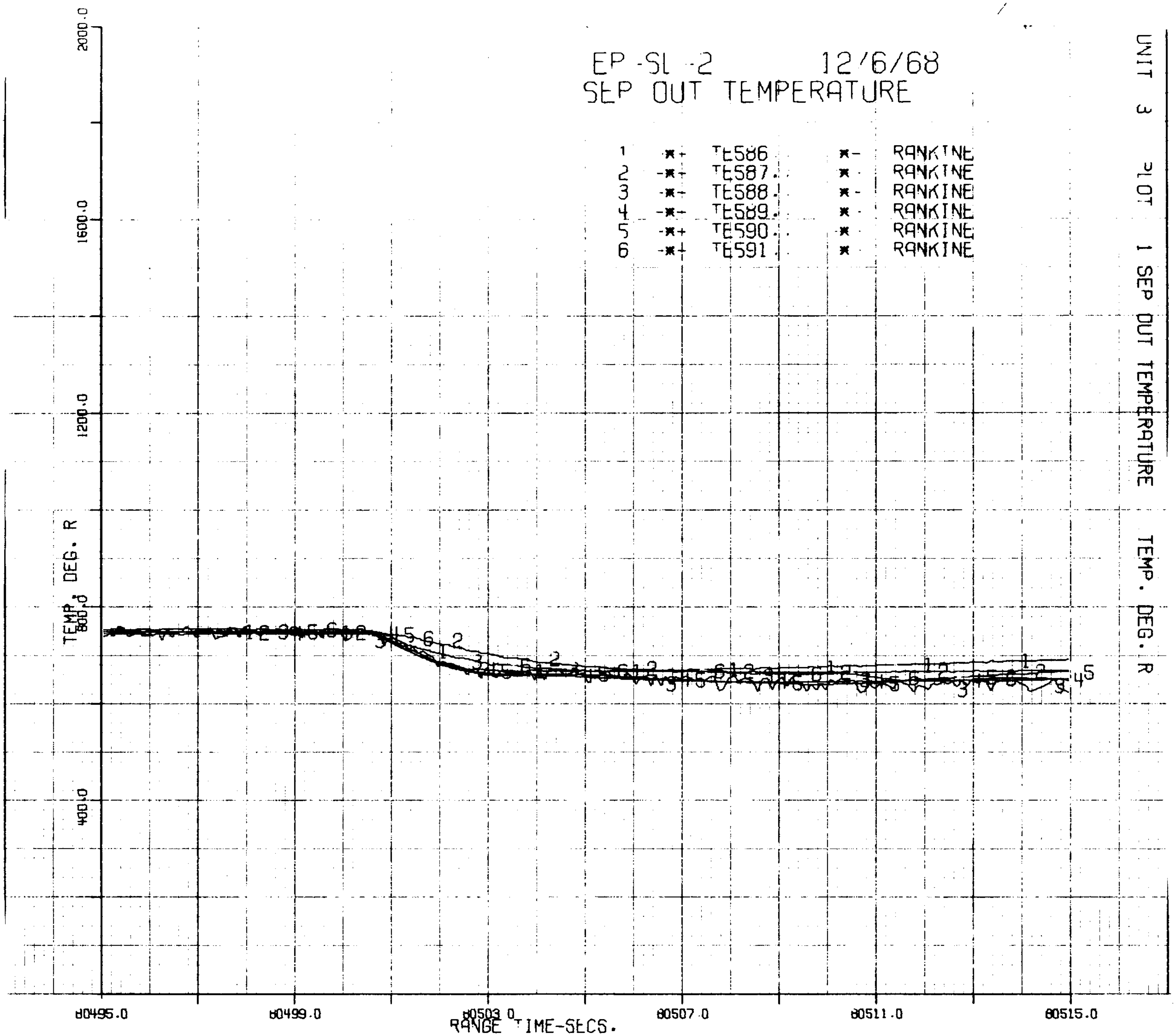


Fig 7
FP-SL-2 12/6/68
SEP OUT TEMPERATURE
1 TE586. RANKINE
2 TE587. RANKINE
3 TE588. RANKINE
4 TE589. RANKINE
5 TE590. RANKINE
6 TE591. RANKINE
UNIT 2 PLOT 2 SEP OUT TEMPERATURE TEMP. DEG. R
TEMP. DEG. R
2000.0
1600.0
1200.0
800.0
400.0
80450.0
80454.0
80458.0
80462.0
80466.0
80470.0
RANGE TIME-SECS.



EP-SL-2 12/6/68
SEP OUT TEMPERATURE
1 -*- TE586 * RANKINE
2 -*- TE587 * RANKINE
3 -*- TE588 * RANKINE
4 -*- TE589 * RANKINE
5 -*- TE590 * RANKINE
6 -*- TE591 * RANKINE
UNIT 3 PLOT 1 SEP OUT TEMPERATURE TEMP. DEG. R
TEMP. DEG. R
2000.0
1600.0
1200.0
800.0
400.0
80495.0
80499.0
80503.0
80507.0
80511.0
80515.0
RANGE TIME-SECS.

SPEAR Memo No. 9
D. Swartz et. al:cjd

XE-PRIME

EP-I and EP-SL2

Subject: MEASUREMENT SYSTEM REVIEW

INTRODUCTION

A review was made of available data processed before and after XE-P EP-I and SL2 in order to ascertain the quality of the data and to detect areas of possible malfunction within the measurement system. By measurement system, it is meant the complete area of activity and hardware that extends from the sensor to the data presented to data users. Areas of concern were then reported to NTO, NRO, or WANL as applicable. Correctable data were reprocessed for the data users.

Although every attempt was made to ready the measurement system as would be required for EP-III, the available time and manpower made it necessary for operating personnel to establish a priority list of channels. The results of the review are therefore broken down by EP and by channels designated as priority channels for EP-I. Although there were other channels designated as priority ones for SL2, the available review time permitted no further breakdown in reporting. Under each of the major headings, the measurement anomalies are listed by reported anomaly with a channel usually being reported only once under the anomaly considered most serious. Where some information has been received as to the cause of the anomaly it is so stated. If no such comment is made it is because the resolution to the problem has not been made as of the writing of this memorandum. The review of and reporting on non-priority channels was felt desirable so that problems could be corrected prior to the channel being considered "priority". A complete review of oscillograms, events, strip chart recorders, and CRT multiple plots was not completed within the time limitation of the SPEAR effort.

SUMMARY

Approximately 1100 measurement channels were reviewed on each of tests EP-I and SL2. Of these, over half were considered priority channels for EP-I. Of the priority channels about 8% displayed anomalies which resulted in data loss which ranged from complete to none. In general, problems in the digital data acquisition system have been greatly reduced with respect to previous ETS-1 test programs. The number of anomalies reported reflects the greater number of channels involved, the added manpower utilized in the SPEAR effort, and the deeper investigation into problem areas. Some serious problems do remain with special effort required in the wide band measurement system area. A list of anomalies (suspected discrepancies) reported by various data users is presented by experimental plan and priority designation in Table I.

TECHNICAL DISCUSSION

The function of the Measurement Group of the SPEAR team is to evaluate the measurement system performance from the installation of the sensor to the production of information for the data user. Where a measurement problem is believed to exist such a problem is pointed out and recommendations made as to a solution. During this SPEAR effort additional support was made available at the start of the formal test series in an effort to add manpower to NTO measurement system activity with the hope of being able to point out problem areas with enough advance notice to permit rectification. Included in the review of the measurement system was a review of some of the practices employed to collect and produce data.

Data review prior to EP-I included the digital diagnostics routine containing calibration No. 06 data dating from 27 November 1968. This is calibration data as recorded in counts on digital tape at ETS-1 and does not include the data processing needed to convert the information to usable engineering units. This document gives indications of the functioning of the calibration system, noise on the system during ambient and calibration functions, and the non-linearity of the electronics in the system. Another early review was made of the wide band calibrations recorded on tape and sent to NRO for processing through a diagnostics routine and an analog recording of the tape information on oscillograms. A review of this data permitted a similar rapid review of the data with the inherent problems of noise, non-linearity, and drift being brought to light rapidly. The results of the wide band review were phoned to NTO personnel and proved to be their main source of information as to problems existing in the wide band tape recording system prior to EP-I.

Preparations for the reduction of raw digital data into engineering units were assisted by SPEAR measurement personnel immediately following the test and the finished digital data was reviewed in engineering units to verify the data reduction portion of the measurement system. The latter effort was greatly aided by the inputs of the data user who, many times, detected system problems in the actual data through its review with respect to expected or known engine/facility systems performance.

A daily review of reported anomalies was held with measurement system personnel, reported anomalies were discussed and action items were assigned as appropriate. A member of Quality Assurance attended these meetings to assure that proper follow-up action was taken. Priority channels received priority attention.

The most far-reaching problem noted during the review was the lack of formal and complete interfacing between the data processing group and those groups responsible for setting-up measurement channels, for providing conditioned signals to be recorded, and for providing detailed calibration/data reduction information. This lack of information was especially evident in the many manual and special calibrations performed over a period of time preceding an EP, and in the special calibration requirements of nuclear measurement channels. A variety of anomalies existed on many of the neutronic channels. These consisted mainly of applying incorrect calibrations to questionable and/or incorrect output data during the run.

As a result of the questionable or uncertain validity of some calibrations, a "best estimate" approach has been employed for some time to provide the best data routinely available. Since it is felt that no data is less dangerous than possibly misleading data, recommendation 1.e is made at the end of this document. The proposed method of presenting questionable data will not destroy the availability of data to the data user but will make him immediately aware that the calibration information is not clear and that special care and techniques may be required to produce acceptable data. This, too, may help point out areas of communication problems that should be resolved prior to future testing.

Wide band FM data taken during the pre and post test calibrations and at randomly selected time intervals during the tests were examined separately. Table I contains the anomalies detected in the finished data produced by processing a duplicate of the original magnetic tape. Many of the channels discussed were not considered priority channels for EP-I. Because of schedular requirements, the data was affected in three ways: first, known anomalous conditions in low priority channels were not always corrected prior to a test; second, processing and review of data provided by low priority channels were delayed; third, the definition of whether anomalous behavior constituted a discrepancy was not completed. The data provided by over one-third of these channels could not be reviewed prior to adjournment of the SPEAR Team and diagnostic analyses of some data were not completed.

One hundred thirty two (132) wide band data channels were scheduled to be recorded during EP-I. One channel had been deleted and eleven recent facility channels did not as yet have their sensors installed. Of the remaining 120 channels, 71 were reviewed during SPEAR effort. No anomaly was noted in 30 of these channels except for some isolated spikes. The other channels reviewed contained one or more of the following anomalies:

	ANOMALY	FREQUENCY OF OCCURRENCE
a.	Part or all of pre or post calibration missing.	18
b.	Calibration did not verify charge amplifier setup (generally true of all charge amplifier channels).	
c.	Calibration polarity was negative.	2
d.	Noise (random, 60 Hz, or pulses)	15
e.	Ringing at or rounding of leading edge of calibration steps.	5
f.	DC drift or shifts.	7
g.	Isolated spikes	General
h.	The time code as recorded by tape recorded F4 was not useable at times because of noise.	

The presence of the isolated spikes in the system is general and may or may not be cause for concern depending on whether or not it fortells coming problems.

It should be noted that part of item (2) is attributable to the fact that some low priority channels not required for EP-I were disconnected prior to the test to reduce noise in the remaining portion of the system. Item (d) includes full scale saturation which resulted when the FM band edge was exceeded.

The DATALOG produced by Channel Engineering from the inputs of the various measurement system groups is the prime document used by ETS-1 personnel to set-up measurement channels and, because of the great amount of information in it, has become the main information document in the measurement system. The content of the document and its value have increased greatly over recent months and it is now the main formal document used to inform data reduction personnel of system requirements. However, historically, this document has been directed to ETS-1 set-up personnel. Now, it must also be directed towards data reduction needs and all information needed by data reduction personnel should be contained in it. If such input information were thus documented it would reduce the misunderstandings between groups and would permit better data the first time around.

The foldover problem with channels continues and is one reason why a channel by channel review of calibrations must be performed after every test and before data conversions to engineering units can be attempted. By foldover, it is meant the false voltage values (or counts) recorded by the digital data system when a full scale value of voltage is reached and then exceeded. Depending upon the channel and the voltage level attained the recorded overscale voltage may appear at a lower level with no other indication that the data is invalid. During calibrations such a problem is readily noted because the level of the calibration steps is known and any deviation from that level is easily recognized. However, when such a condition appears in data it may or may not be readily detected and mis-information may result. Of the 31 channels that were detected to have foldover, 29 were on subsystem 2, and of these 29, 16 were on multiplexer B2. No easy and inexpensive solution to this problem is proposed. The subject is repeated here in an attempt to keep the potential problem before the eyes of the data user so that he may be constantly mindful of it.

RECOMMENDATIONS

1. A more formalized procedure should be established for selecting valid calibrations to be used in reducing digital information to engineering units. This should include:

    a. A listing of all measurement channels requiring special calibrations normally accomplished prior to run day.

    b. A log of valid calibrations for the special channels mentioned in 1.a. The input to the log would be provided by personnel responsible for setting up and performing the special calibrations.

    c. Modification to the existing digital diagnostic calibrations listing to include special calibration information and flagged for proper use.

d. A re-emphasis by all personnel responsible for providing calibration information to input to the datalog the complete information necessary to accurately reduce recorded information to engineering units.

e. The establishing of the practice by data reduction to "dump" in counts all pass listing information which has a questionable or unknown calibration.

f. The listing on tape chronology sheets the inhibit mode conditions which existed during system calibration runs.

g. The establishing of a focal point for collecting calibration inputs from the various groups providing calibration information. This point would communicate the information to the data reduction group.

2. A complete evaluation of the wide band measurement system (transducer output to engineering unit data output) should be performed to assure adequate performance.

3. The oscillogram headers should reflect the ranges and engineering units as noted by the applicable data log.

4. All FExxx flow channels, which require a frequency calibration, should include the setup information needed at ETS-1 (see format of FE429..F of XE-P Datalog Issue 4, as an example) and should include the equivalent frequency of the applicable calibration step to be used in data reduction.

5. The nominal range values listed in the coding and signal conditioner setup range column of the Datalog should reflect the actual measurement range that the signal conditioner mode card will produce. This will indicate to the data user the exact range over which the data should be considered valid. This in no way changes setup requirements or data reduction techniques.

6. The "101 Point Listing" should contain listings of all mode card/engineering unit conversion combinations as specified under the signal conditioner setup range column of the Datalog.

7. The output of the function generator used for transfer function measurements (measurement VC900..E) should be calibrated and ranged so that the predicted maximum value will be 75% of the measurement full scale.

8. Record VC900..E on FM tape No. 2 (as well as No. 4) in place of MC043.F which is the only non-zero suppressed channel on tape No. 2. MG043.F should be moved to tape No. 4 where it can replace deleted measurement NX901..N. This will reduce possible time base errors in performing transfer function analyses.

TABLE 1

MEASUREMENT ANOMALIES

SPEAR Memo No. 9

XE-P EP- I

PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			NO DATA	
1	TE951..A	Drum Act. Lock Sol. 2	No data	No card to convert to EU
2	TT055..R	LN to Atomizer System	No data. No engineering unit calibration.	" " " " " "
3	FE052..R	LN Flow	No engineering unit data or calibration.	
4	PT001..F	GF V-3201 Tnk Pr	" " " " " "	
5	TT217..A	Reflect. Inlet Plenum	" " " " " "	No card to convert to EU
6	TT371.AE	Reflector Inlet Plenum	" " " " " "	
7	T.306..E	Reflector Inlet Plenum	" " " " " "	
8	TT372.AE	Reflector Inlet Plenum	" " " " " "	Conversion to EU used wrong polynomial. Has been corrected.
9	TT373.AE	Reflector Inlet Plenum	" " " " " "	
10	TT374.AE	Reflector Inlet Plenum	No engineering unit data or calibration.	
11	TE712.AE	Tie Rod Material	No engineering unit data.	
12	CC800..E	Control Drum Demand	No data on CRT plots.	
13	CC605..E	PWR dmnd. sig. gen. Outp.	Power demand generator output remains at 0-volts on CRT plots during power control ramp 1-KW to 100-KW.	
			NO CALIBRATION OR QUESTIONABLE CALIBRATION	
14	FE433..F	Eng. Purge Flow		
15	TE661.AE	Core Element	No calibration.	Relay hangup.
16	T.622..E	Avg. Core Station Temp		Averager not reset
17	LT026..F	LN V-3601 Tnk Lvl	Questionable "0" level calibration.	
18	PX907..E	Zero Supp. P.158..E	Drifts during pre and post cals, does not return to zero after calibration.	
19	PT710..A	Core Exit Internal XDCR	No calibration on wide band tape.	

TABLE 1

MEASUREMENT ANOMALIES

SPEAR Memo No 9

XE-P EP- I

PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			NO CALIBRATION OR QUESTIONABLE CALIBRATION	
20	VC900..E	Function Generator	No pre or post calibration. Exceeds full scale and is noisy during run on the wide band tape.	No provisions for cal.
21	CC802..E	Drum Velocity Dmnd	No pre or post cal on wide band data	
22	NX902..N	Zero Supp. NC815..E	Wide band data ringing at leading edge for 25% and 50% calibration steps. Does not return to zero.	
23	NX903..N	Zero Supp. NC804..E	" " " " " " " " "	
24	NC805..E	Log Power Error	No wide band calibrations.	
25	NX904..N	Zero Supp. NC819..N	No wide band data pre or post calibration. Drifts during pre. cal. time period.	Patch loose in 10R037
26	PT891..R	Cooldown Line Above CSV	Wide band data 100% cal step exceed full scale	
27	PT708..A	Core Exit Internal XDCR	No wide band data calibration	Needs manual calibration
28	PT149.AE	Nozzle Chamber	" " " " "	
29	HT816T.A	Act Turb LN Accel	" " " " "	
30	HT701L.A	Core Support Plate	No wide band data calibration. Noisy.	
31	HT702R.A	Core Support Plate	" " " " " "	
32	HT810L.A	Drum Actr 1 Pedestal	Incorrect cal. ratio, noise during run.	
33	HT811R.A	Drum Actr 1 Pedestal	" " " " " "	
34	HT812T.A	Drum Actr 1 Pedestal	" " " " " "	
35	HT813L.A	Drum Actr 1 Housing	" " " " " "	
36	HT814R.A	Drum Actr 1 Housing	" " " " " "	
37	HT821X.A	TPCV Actuator	Incorrect cal ratio, noisy post calibration.	

TABLE 1

MEASUREMENT ANOMALIES

XE-P EP-I

PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			DATA REDUCTION	
38	MG401..A	Inner Reflector Spring	Improper data reduction information	
39	MG402..A	Inner Reflector Spring	" " " "	
40	MG403..A	Inner Reflector Spring	" " " "	
41	MG701..A	Tie Rod Strain DC + AC	" " " "	
42	MG702..A	Tie Rod Strain DC + AC	" " " "	
43	MG703..A	Tie Rod Strain DC + AC	" " " "	
44	MG704..A	Tie Rod Strain DC + AC	" " " "	
45	MG705..A	Tie Rod Strain DC + AC	" " " "	
46	MG706..A	Tie Rod Strain DC + AC	" " " "	
47	MG707..A	Tie Rod Strain DC + AC	" " " "	
48	MG708..A	Tie Rod Strain DC + AC	" " " "	
49	MG709..A	Tie Rod Strain DC + AC	" " " "	
50	MG710..A	Tie Rod Strain DC + AC	" " " "	
51	PT810..A	Turb Inlet Line Entr	" " " "	
			NOISE	
52	HT123R.A	Nozzle Manifold	Noisy wide band data.	
53	HT815T.A	Drum Actr 1 Housing	Noisy, step changes in precal level.	
54	HT820Z.A	TPCV Actuator	" " " " " "	
55	CX902..E	Zero Supp CC800..E	60 Hz noise during run on wide band data.	
56	YT806..A	Control Drum Torque 6	Noisy wide band data calibration.	

TABLE 1
MEASUREMENT ANOMALIES

XE-P EP- I

PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			DATA LOG	
57	DX902..E	Zero Supp. D.800..E	Set up range units should be degrees, not %.	
58	DX903..E	Zero Supp. D.801..E	" " " " " " " " %.	
59	N.844..A	ETC Gamma Detector	Datalog calls out AV03 card and 2AI mux.	FC1712-48 drops voltage to 100 MV for 2AI mux.
			WIDE BAND SPIKES	
60	DX902..E	Zero Supp. D.800..E	Isolated wide band data, spikes. 60 Hz noise.	
61	DX903..E	Zero Supp. D.801..E	" " " " " " " "	
			MISCELLANEOUS	
62	FE436..R	Flow integral of FEC52	Engineering unit data being reset each file. Not listed in parameter cards.	
63	CP517.MR	LN CD Sys PCV-MAN Ctl Pot	Zero and 100% calibration should agree but do not.	
64	DP517..R	LN CD Sys PCV-VLV pos	" " " " " " " " "	

TABLE 1

MEASUREMENT ANOMALIES

XE-P EP- I

NON-PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			NO DATA	
65	PT004..F	GFV3202 Tnk Pr	No data, no calibration.	
66	Recorder "G"	Strip Chart	Data exists from approximately CRT 7000 only.	
67	DF032..F	DCT H20 Flw CTL Pos	Indicated 17% during EP-I	
68	CC631..E	Drum Override	Channel shows no def. during test.	
			NO SYSTEM CALIBRATION OR QUESTIONABLE SYSTEM CALIBRATION	
69	TT479..F	LO_2 Mnflo Temp	Wrong slope used. 1.027 used, should be .5038	
70	PT896..R	Eng Val Act He Pneu Sup	Bad Calibration.	
71	PX903..E	Zero Supp for PT124..E	Calibration steps go negative.	
72	PX910..E	Zero Supp PT866..E	No zero return after calibration.	
73	PX913..A	Zero Supp PD209..A	No zero return after calibration.	
74	MG019..A	DCT Sec 3 Fwd Hor Truss Str	Erroneous calibration.	
75	TX901..E	Zero Supp. TE835..E	No zero return after calibration.	
76	TX902..E	Zero Supp. T.158..F	Drift during pre-cal., no post cal.	
77	TX903..E	Zero Supp T.600..E	Leading edge of cal steps rounded.	
78	TX904..E	Zero Supp. T.622.E	No pre or post calib.	
79	TX905..E	Zero Supp. T.623..E	No post calib., precal. <20% F.S., noise during 75630-75918.	
80	TX906..E	Zero Supp. T.710..E	Cal. steps have rounded leading edges. 60Hz noise at run.	
81	TX911..E	Zero Supp. T.680..E	Cal. steps have rounded leading edges.	
82	HT805R.A	Turbine Inlet Line	No calibration.	

TABLE 1

SPEAR Memo No. 9

MEASUREMENT ANOMALIES

XE-P EP- I

NON-PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			NO SYSTEM CALIBRATION OR QUESTIONABLE SYSTEM CALIBRATION	
83	T.604..E	Control Temp. Error	No calibration.	
84	EX901..E	Zero Supp. EN800..E	" "	Will be setup for EP-II
85	FX901..R	Zero Supp. FE014..R	" "	" " " " "
86	HT809L.A	External Shield	No known charge calibration	
			SATURATION	
87	TE068..F	DCT Sec 3 Lft H_2O Otlt	Pegged out at 693.3°R during run. "NOT TRUE".	Thermocouple opened.
			NOISE	
88	F-4 Dup TiCode	AGC Dupe F4	Noisy 75631-75697 & during post calib.	
89	TX909..A	Zero Supp. TE501..A	Noisy during run.	

TABLE 1

MEASUREMENT ANOMALIES

SPEAR Memo No. 9

XE-P SL2

PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			NO SYSTEM CALIBRATION OR QUESTIONABLE SYSTEM CALIBRATION	
90	NC819..N	Linear Power 1	No calibration indicated in thinned data listings.	Neat System cal has non valid zero
91	NC820..N	Linear Power 2	" " " " "	
92	NC821..N	Linear Power 3	" " " " "	
93	NC822..N	Linear Power Range	" " " " "	
94	N.840..A	UTS Gamma Detector 1	" " " " "	
95	N.841..A	UTS Gamma Detector 2	" " " " "	
96	N.842..A	UTS Gamma Detector 3	" " " " "	
97	TE661.AE	Core Element	The 50%, 75% & 100% calibration step values equal the 25% calibration step values.	
98	TE663.AE	Core Element	" " " " "	
99	TE664..E	Core Element	" " " " "	
100	TE665..E	Core Element	" " " " "	
101	TE668.AE	Core Element	" " " " "	
102	P.158..E	Avg. Noz. Cont. Chamber	Erratic cals.	
103	PT708..A	Core Exit Internal Xducer	No cals.	
104	T.158..E	Nozzle Chamber Temp - Avg.	Erratic cals.	Averager not reset. Averager normalizes output to linear degrees.
105	T.602..E	Control Temperature	Erratic cals.	Averager not reset.
106	T.621..E	Avg. Core Station Temp.	Erratic cals.	" " "
107	T.622..E	Avg. Core Station Temp.	Erratic Cals.	" " "
108	PT712..A	Core Exit Internal Xducer	No cals.	

TABLE 1

MEASUREMENT ANOMALIES

PEAR Memo No.

XE-P SL2

PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			NO SYSTEM CALIBRATION OR QUESTIONABLE SYSTEM CALIBRATION	
109	T.623..E	Avg. Core Station Temp.	No cals.	Averager not reset..
110	TE274..F	Bot Shld H_2O in Temp	NO POST CALS.	
111	TE224..F	S2 INTRMD Shld H_2O Temp	NO 100% CAL	Intermittent relay
			DATA REDUCTION ANOMALIES	
112	NC801.AE	Engine Log Power 1	Engineering unit calibration steps do not agree with the data log set-up range. The set-up range (0-10 volts) does not agree with the range (0-5 volts) of the selected mode card (AV01).	
113	NC802.AE	Engine Log Power 2		
114	NC803.AE	Engine Log Power 3		
115	NC804..E	Avg. Engine Log Power		
116	NC812.AN	Test Stand Log Power 1		
117	NC813.AN	Test Stand Log Power		
118	NC814.AN	Test Stand Log Power		
119	NC815..N	Avg. Test Stand Log Power		
120	NC806..E	Engine Power Period	Zero thinned data calibration step misranged. Datalog calls for -1 to 9 volts, calibration indicates 0 to 0 volts.	
121	NC817..E	Test Stand Power Period		
122	TT479..F	LO_2 Mnfl Temp	Wrong slope used.	
123	PT168..A	Hot Gas Port Diluent On	Should be PT168..F word 340.	
			NOISE	
124	NC801.AE	Engine Log Power 1	Gross Raise on 0% step.	NEAT SYSTEM CAL HAS INVALID ZERO STEP.
125	NC802.AE	Engine Log Power 2	" " " " "	" " " " "
126	NC803.AE	Engine Log Power 3	" " " " "	" " " " "

TABLE 1

MEASUREMENT ANOMALIES

SPEAR Memo No. 9

XE-P SL2

PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			NOISE	
127	NC804..E	Ave. Engine Log Power	Gross Noise on 0% step.	NEAT SYSTEM CAL HAS INVALID ZERO STEP.
128	NC812.AN	Test Stand Log Power 1	" " " " "	" " " " "
129	NC813.AN	Test Stand Log Power	" " " " "	" " " " "
130	NC814.AN	Test Stand Log Power	" " " " "	" " " " "
131	NC815..N	Avg. Test Stand Log Power	" " " " "	" " " " "
132	NC819..N	Linear Power 1	" " " " "	" " " " "
133	NC820..N	Linear Power 2	" " " " "	" " " " "
134	NC821..N	Linear Power 3	" " " " "	" " " " "
			MISCELLANEOUS ANOMALY SOURCE	
135	CP251.MR	GH CD PCV-MAN CTL VLV	Thinned data 0-100% calibration span exceeds datalog measurement span.	
136	CP517.MR	LN CD Sys PCV-Man Ctl Pot	Increasing calibration steps yield decreasing engineering unit values.	
137	T.300..E	Avg. Out Reflector Sector	Engineering Unit Calibration Steps do not represent the average step values of the channels used to obtain an average.	Averager not reset.
138	BC662..E	Drum Override	No override indication although many overrides reported.	

EAR Memo No.

TABLE 1

MEASUREMENT ANOMALIES

XE-P SL2

NON-PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			NO DATA	
139	IWPSGT	Computed Parameter	Data always zero.	
140	IWOSGT	Computed Parameter	" " "	
141	WPSGI	Computed Parameter	" " "	
142	WSSGI	Computed Parameter	" " "	
143	WOSG2	Computed Parameter	" " "	
144	WPSG3	Computed Parameter	" " "	
145	IWPSGT	Computed Parameter	" " "	
146	IWOSGT	Computed Parameter	" " "	
			NO SYSTEM CALIBRATION OR QUESTIONABLE SYSTEM CALIBRATION	
147	CC804..E	State Prog. Temp. Ctl State	No 75% cal.	
148	T.604..E	Control Temp. Error	No cals.	
149	FT406W.F	SGl H_2O Vntr. Dp (flow)	Offset questionable - negative slope - went to 193 psia.	
150	DF031..F	Dct H_2O Flw Ctl Pos	100% step 1.3% Non-linear.	
151	DF032..F	Dct H_2O Flw Ctl Pos	100% step 1.2% Non-linear.	
			DATA REDUCTION	
152	WOSG3	Computed Parameter	Calculation wrong.	
153	WWSGLBP	Computed Parameter	Wrong equation used.	
154	WWSG2BI	Computed Parameter	" " "	
155	WWSG3BP	Computed Parameter	" " "	
156	KSGWS	Computed Parameter	Calculation in doubt.	
			NOISE	
157	DF423W.F	SGl H_2O Throttle Vlv-Pos	Noise: 2.1% on Zero, 1.8% on ambient.	

TABLE 1

MEASUREMENT ANOMALIES

SPEAR Memo No. 9

XE-P SL2

NON-PRIORITY CHANNELS

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
			MISCELLANEOUS	
158	WOSG1	Calculated Parameter	Should be .00	
159	PD870W.F	SG1 H_2O Bypass Vlv Delta P	2.2 psid low.	
160	PD870X.F	SG2 H_2O Bypass Vlv Delta P	Zero is 1.1 psid low.	
161	PT913W.F	SG1 H_2O Venturi Dschg Pr	Was not listed.	Listed under PT407 W
162	PT913X.F	SG2 H_2O Venturi Dschg Pr	" " "	Listed under PT407 X
163	PT914W.F	SG1 H_2O Injctr Mnfld Inlet	" " "	Listed under PT408 W
164	PT914X.F	SG2 H_2O Injctr Mnfld Inlet	" " "	Listed under PT408 X
165	WWSG1T	Computed Parameter	" " "	Listed in Pass SG02
166	WPSG2	Computed Parameter	Data no good.	
167	PT118..F	Pro V-3401 Tnk Press.	Not listed.	
168	TE585..F	Sim-Separator Inlet-Bot	Looks low.	
169	BC701W.F	SG-1 Start Sequence	Off scale at full steam.	
170	BC701X.F	SG-2 Start Sequence	" " " " "	
171	BC701Y.F	SG-3 Start Sequence	Off scale all the time.	
172	CF423Y.F	SG-3 H_2O Throttle Vlv - Ctl	Swapped with CF423X.F	
173	CF423X.F	SG-2 H_2O Throttle Vlv - Ctl	Swapped with CF423Y.F	

SPEAR Memo No. 10
N. Norman:cjd

XE-PRIME

EP-I and EP-SL2

Subject: S-1 SHIELD WATER WORTH MEASUREMENTS

INTRODUCTION

The change in reactor reactivity with the S-1 Side Shield dry and filled with water was obtained by measuring the critical drum bank position at 1 KW in Power Control before and after filling the S-1 Shield. The reactor was not maintained critical as planned in the Test Specification during the filling. Instead the reactor was shut down after the dry critical run and taken critical again after the S-1 Shield was filled.

SUMMARY

The measured worth of the S-1 Shield water was 0 ± 2.85 cents for a 3 sigma range of data system accuracy. The predicted worth was 2.75 cents. The probability that the worth was as high as .64 cents is 50%. The water level of the Shield as indicated by P-623 was 85% corresponding to a full S-1 shield.

TECHNICAL DISCUSSION

Thinned digital data listings from EP-1 Book 1, Pass Q0004 and Q0005 were used to calculate the S-1 Shield water worth. A 45 second stable power time span starting at least 60 seconds after reaching criticality was selected by reviewing the Linear Power Printouts from NC819, 820 and 821. The power range was 1.025 to 1.087 KW dry and 1.077 to 1.168 KW filled. Core temperatures (T.600) and Outer Reflector Temperatures (TE 301, AE56, 302 and 303) were constant within ± 2°R during each run and between the two runs. Drum angle printouts from D801A through D812A were averaged for 10, 5 second intervals over a 45 second run time and the overall mean was calculated to be 98.76°, dry and filled. The D.806A was indicating over 180° during the filled run and was disregarded. The averages over the 10 points ranged 98.58° to 98.8° dry and 98.45° to 98.89° filled. The 3 sigma accuracy of an individual drum indication is ± .58%[1] of full scale. For the average of 12 drums:

$$\frac{.0058\ (180^\circ)}{\sqrt{12}} = \pm .302^\circ$$

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[1] Reference AGC NRO Report RN-S-0459 ETS-1 Data Acquisition System Accuracy Report - Final, April 1968

and for 11 drums:

$$\frac{.0058\ (180^\circ)}{\sqrt{11}} = \pm\ .315$$

and for the difference:

$$\sqrt{(.302)^2 + (315)^2} = \pm\ .436^\circ$$

The worth of $\pm\ .436^\circ$ is $.436\ (6.53\ ¢/^\circ) = \pm\ 2.85\ ¢$ [2]

For 50% probability or .67 sigma the accuracy of the worth determined from the difference is: $\pm\ \frac{2.85}{3}\ (.67) = \pm\ .64$ cents.

ANOMALIES

1. During the time interval from 77208 to the end of the run on 12/4/68, the thinned digital data listings in EP-1, Book 1, Q0005 for D.806.A are approximately twice the value of the other drum printouts and of the average.

2. During the time interval from 75580 to 75612 on 12/4/68 the thinned digital data listings in EP-1, Book 1, Q0005 for D.800.A Drum Electrical Average was reading only intermittently.

RECOMMENDATIONS

None

[2] Refer to SPEAR Memo No. 5.

S-1 SHIELD WATER WORTH

EP-1, 12-4-68, S-1 UNFILLED

TIME	POWER WD 819, 820, 821 KW	AVERAGE DRUM POSITION $\frac{(D.801.A \quad D.812.A)}{12}$
75570.0	1.062	98.88
75575.0	1.071	98.85
75580.0	1.064	98.70
75585.0	1.045	98.81
75590.0	1.055	98.71
75595.0	1.030	98.58
75600.0	1.054	98.74
75605.0	1.064	98.87
75610.0	1.087	98.73
75615.0	1.025	98.75
MEAN	1.056	98.76

S-1 SHIELD WATER WORTH

EP-1, 12-4-68, S-1 FILLED

TIME	POWER WD 819, 820, 821 KW	AVERAGE DRUM POSITION (D.801.A D.812.A)[1] 11
77880.4	1.131	98.83
77885.4	1.150	98.84
77890.4	1.144	98.89
77895.4	1.128	98.81
77900.4	1.140	98.83
77905.4	1.168	98.77
77910.4	1.155	98.79
77915.4	1.093	98.78
77920.4	1.077	98.45
77925.4	1.108	98.60
MEAN	1.129	98.76

[1] D.806.A was not included since it read 182° during the entire run.

SPEAR Memo No. 11
A. Mowrey:cjd

XE-PRIME

EP-I and EP-SL2

Subject: EVALUATION OF TDC CALCULATION OF DRUM WORTH

INTRODUCTION

An individual drum roll in/out procedure was initiated in SL2 to verify the TDC reactivity computation during reactor transients. X-Y plotters were used on-line to display the characteristic S-curve of drum insertion versus angular position.

SUMMARY

The results of the two individual drum roll in/out tests from critical to 15° are summarized in Table 1. These data were taken from the on-line TDC X-Y plotter. The calculated reactivity data agrees well with test results.

TECHNICAL DISCUSSION

The reactivity computation appears to be in excellent overall agreement with the test results. The drum worth is about 6% below the prediction and the differential worth is within 3% of the predicted value. Dividing the measured differential drum bank worth of 6.67 ¢/°. The computed value is within 3% of this result also. Thus, the reactivity computation appears to be accurate to better than 6% with a possibility of 3% if the differential drum bank measurement is indicative of an individual drum differential worth.

No anomalies were seen in Drums No. 1 and No. 6 worths from the drum uniformity test.

RECOMMENDATIONS

Careful evaluation of the TDC reactivity computer should be made in light of its potential value. The integral drum worth measurements should provide a good basis for evaluation with the TDC reactivity computer operational.

ANOMALIES

"Noise" was apparent on the X-Y plot of reactivity versus individual drum angle. Though the extent of this noise was about ± 5¢ in places, the worth at about 10° stabilized out to less than a 2¢ range. This noise may be due, in part, to the jerky motion of the drum rolls, especially on the roll-in from critical. The roll-out to critical was substantially smoother and the reactivity computation appeared smoother during this phase.

TABLE 1

REACTIVITY COMPUTER RESULTS FOR INDIVIDUAL DRUM WORTHS

	RANGE TIME INTERVAL	ANGULAR RANGE (DEGREES)	WORTH (¢)	PREDICTED WORTH (¢)	DIFFERENTIAL WORTH AT 90° (¢/°)	PREDICTED DIFFERENTIAL WORTH AT 90° (¢/°)	MEASURED DIFFERENTIAL WORTH[12] ADJUSTED TO 90° (¢/°)
DRUM NO. 1	75650 75749	99.5 8.6	37.5±1	40	0.58 ± 0.03	0.596	0.56
DRUM NO. 6	~77000 77064	~99.8 7.5	37.5±1	40	0.58 ± 0.03	0.596	0.56

SOURCE: SL PHASE II - THINNED LISTINGS OF PASS Q 005. ISSUE DATE 12/10/68.

SPEAR Memo No. 12
R.A. Peterson/V. Winter
cjd

XE-PRIME

EP-I and EP-SL2

Subject: CONTROL DRUM ACTUATION SYSTEM PERFORMANCE DURING EP-I AND SL2 TESTS

SUMMARY

During EP-I, a large oscillation in torque motor current was observed by the torque motor current (TMI) limits monitor. This oscillation appeared in all the monitor channels at an approximate average drum bank position of 40°. Subsequent investigation by the control team determined the oscillations to be approximately 200 ma peak-to-peak at 135 cps. Several attempts were made to locate the source and to eliminate the oscillation during EP-I. The only success being the reduction of the amplification of the oscillation in one amplifier - actuator loop.

The limited investigation conducted during EP-I resulted in the temporary modification of amplifier # 9:

1. The addition of an isolation capacitor (1000μf) from the ± 24 vdc test points to the amplifier SRC ground.

   Result: The drum bank went to 70° before oscillations started in # 9.

2. The addition of a 430 PF capacitor to the feedback network (rate stage).

   Result: The maximum oscillation in # 9 loop was reduced to 25 ma.

The EP-I test was resumed at this point with the remaining torque motor currents oscillating a maximum of 200 ma. The actuator position loop was stable and performed acceptably for the remainder of EP-I. (Subsequent tests at WANL confirmed that this oscillation does not significantly change any of the small signal performance characteristics of the actuator).

Analysis and testing at WANL, Pittsburgh, (Reference Memo ASE-011, Subject: ETS-1 Ground Loop Analysis, by D. Armstrong, dated 12/6/68) determined that the problem was associated with power supply grounding. Tests were performed during SL2 and the oscillations eliminated (10ma maximum) by revising the ground wiring within Rack 50 and between Rack 50 and the actuator amplifiers (Rack 48). During SL2, tests while installing 500μf isolation capacitors, a torque motor current fuse was blown. This was probably due to surge current to the isolation capacitor while being installed.

The scram and dynamic response of the actuators were as anticipated and fully acceptable during EP-I and SL2.

TECHNICAL DISCUSSION

A. Torque Motor Current Oscillations

Figure 1 is a simplified schematic diagram of the control drum amplifier illustrating the various power supplies, grounding, and feedback potentiometer of the actuator.

The system equations which describe this circuit are:

(1) $I_{TM} = -KG(s)e_f$

(2) $e_P = -R_L I_{TM}$

(3) $e_f = e_P \theta$

where

$G(s)$ = voltage gain as a function of frequency of actuator amplifier

$K = 0.2 \frac{\text{amps}}{\text{volt}}$ = current gain of torque motor driver

R_L = 24 VDC ground wire resistance between rack 50 and rack 48

θ = drum angle in radians

I_{TM} = torque motor current

e_P = voltage on top of actuator feedback pot

e_f = voltage on arm of feedback pot.

In the above equations, A-C perturbations about the null are assumed. When N control drums are considered, equation 1 becomes:

(4) $I_{TM} = 0.2 \times N\, G(s)\, e_f$

Equations 2, 3, and 4 can be put into block diagram form which is shown in Figure 2.

From the block diagram of Figure 2, it is seen that positive feedback exists through the ground wire between Rack 48 and Rack 50. For the positive feedback loop an instability will exist if the loop gain becomes unity at zero degrees phase shift. Figure 3 is a bode plot of the actuator amplifier voltage gain G(s). From this figure it is observed that the phase is zero at 130 CPS. This indicates that the frequency of oscillation will be 130 CPS which is in good agreement with the observed frequency of 135 CPS. At 130 CPS, G(s) is

$$G\ (130) = 50\angle 0^\circ \ \frac{\text{volts}}{\text{volt}}$$

From the block diagram of Figure 2, it is observed that the loop gain is proportional to the actuator position. Since it is known that oscillations occurred at approximately 40 degrees when all 12 drums were operating, the ground wire resistance at which oscillations will be sustained can be calculated. (use 45 deg for ease of calculations).

$$1 = 0.2 \times 12\ G(s)\ \theta\ R_L = 2.4 \times 50 \times \tfrac{1}{4}\ R_L = 30\ R_L$$

OR

$$R_L = \frac{1}{30} = 0.033 \text{ ohms.}$$

Using the value of 0.033 ohms for R_L and the block diagram of Figure 2, it can be shown that if 3 drums (N = 3) are withdrawn to 165° no oscillation in torque motor current will exist. This agrees with test data.

A slight modification of the schematic diagram of Figure 1 can be made to incorporate the effects of isolation capacitors on the 24VDC power supply. Including this refinement into the analysis shows that the actuator torque motor current should not oscillate until the drum bank is withdrawn to approximately 65 degrees. This also agrees quite well with the observed results.

The effects of additional filtering in the rate amplifier can also be calculated by an appropriate modification of G(s).

In order to insure no oscillation of torque motor current regardless of drum angle with the existing grounding system, it would be required that

$$1 = 120\ R_L$$

or $$R_L = 0.0083 \text{ ohms.}$$

A preferable method of eliminating the torque motor current oscillations is to break the positive feedback loop established by existing power supply grounding. This can be accomplished by disconnecting the 24 VDC ground from the SRC in Rack 50. A simplified diagram showing this is given in Figure 4. From this diagram, it is seen that the torque motor current coupling to the actuator amplifier through the 10VDC power supply is broken.

B. Actuator Scram Performance

All scrams were initiated in the closed loop mode and position-torque motor current traces conformed to previous records of static position scrams. No open loop scrams were initiated.

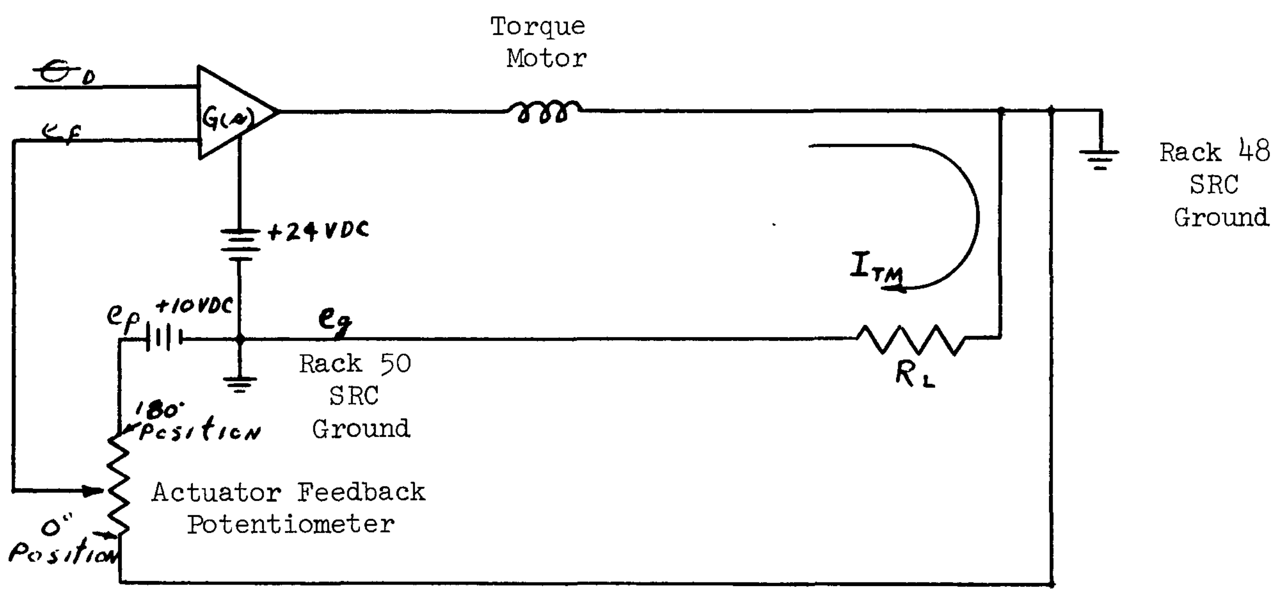
C. Frequency Response

Frequency response measurements during EP-I and SL2 of the drum bank resulted in data which agree well with the average of the individual frequency responses taken during P-9 checkout. Figure 5 shows data taken during Section 7 of P-9 tests and during EP-I and SL-2. An apparent deviation of the anticipated roll-off is apparent in the gain curve for the EP-I tests. Since this data was developed from Fourier analysis of square wave data, the accuracy in the roll-off area is questionable. Data presented in SPEAR Memo No. 16 confirms the roll of the gain curve for EP-I and SL-2 tests.

RECOMMENDATIONS

The grounding modifications made during SL2 test should be made permanent. Further investigations should be conducted to determine if any other wiring exists which connects the 24 VDC common to the 10 VDC common in Rack 50.

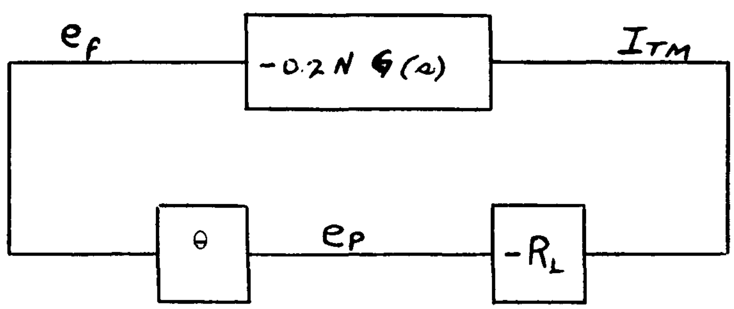
Figure 1 - Simplified Schematic of Actuator Amplifier



R_L = 24 VDC Ground Wire Resistance Between Rack 50 and Rack 48

G(s) = Voltage Gain of Actuator Amplifier

Figure 2 - Simplified Block Diagram of Actuator Amplifier



K+E SEMI-LOGARITHMIC 46 6012
4 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

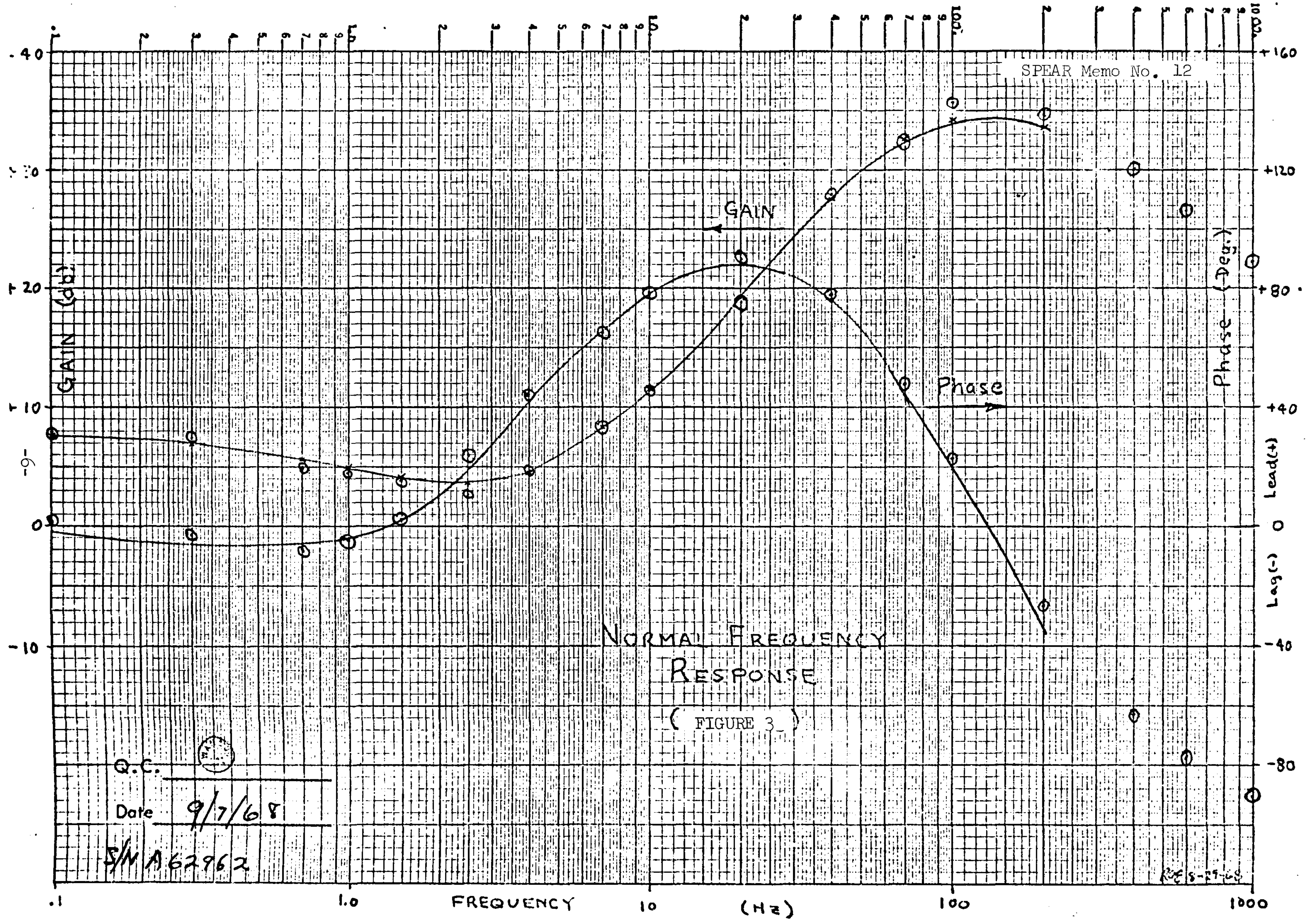
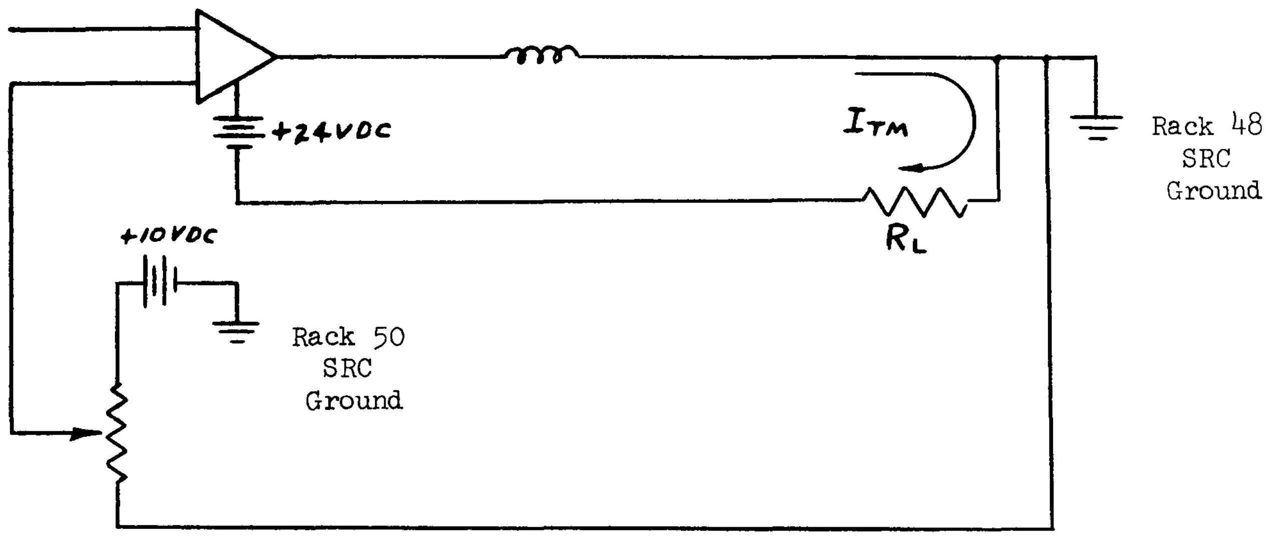


Figure 4 - Revised Actuator Amplifier Grounding



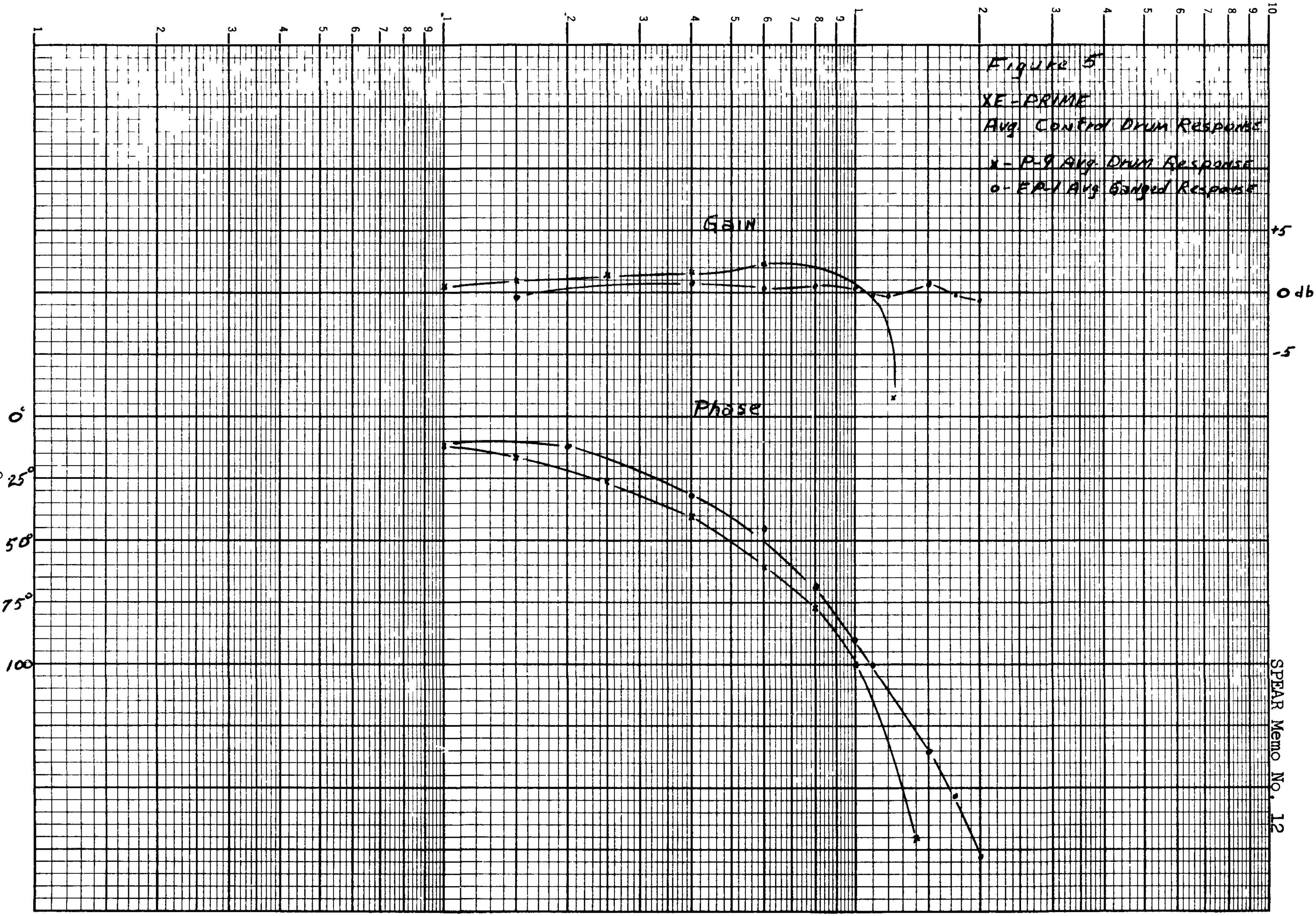


Figure 5
XE-PRIME
Avg. Control Drum Response
x - P-9 Avg. Drum Response
o - EP-1 Avg. Ganged Response
Gain
Phase
+5
0 db
-5
0°
25°
50°
75°
100
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
2
3
4
5
6
7
8
9
10

SPEAR Memo No. 13
C. W. Hennige:cjd

XE-PRIME

EP-I and EP-SL2

Subject: SCRAM CIRCUIT EVALUATION

INTRODUCTION

This memo summarizes the performance evaluation for the fixed power, period and drum roll-in scram circuits exercised during tests EP-I and SL2. EP-I provided data for the fixed power, period and drum roll-in scram circuits, and SL2 provided additional data for the fixed power and period scram circuits. Tests were not conducted using the floating power scram circuit and it will therefore not be included in this evaluation.

SUMMARY

There were no anomalies identified by this evaluation of the scram detector circuits. An anomaly was observed by the test operators with the scram indicator lamp circuitry and will be included as part of this evaluation.

The fixed power, period and drum roll-in scram circuits were exercised during the following tests and range times and performed satisfactorily:

SCRAM CIRCUIT	EP-I RANGE TIME	SL2 RANGE TIME
Fixed Power	73178	45556
Period Scram	74424	46685
Drum Roll-In Scram	78171	

It should be noted that in using the figures attached to this memo which display log power measured, the abscissa is range time and the ordinate is log watts, scaled from zero to 10. The data system has computed log watts from volts by the following method:

The log power signal is scaled from 55 watts = 0 volts to 5500×10^6 watts = 10 volts, corresponding to eight decades of 1.25 volts/decade. The equation for this is:

$$\operatorname{Log}_{10} P_1 = \frac{v}{1.25} + 1.74$$

$$\text{OR} \quad P_1 = 10^{\frac{v}{1.25} + 1.74}$$

Where: v is in volts

P_1 is in watts

1.25 is the decade conversion from 10 to 8

1.74 is the 55 watt zero offset

To convert period in volts to period in seconds, the following equations are to be used:

Use $= \frac{7}{v}$ for v = -1 volts to + 7 volts (= -7 to +1)

Use $= \frac{0.2222}{v-6.7777}$ for v = +7 volts to +9 volts (= +1 to +0.1

TECHNICAL DISCUSSION

A. Fixed Power Scram Circuit

The fixed power scram circuit operates by comparing the measured log power signal to a bias signal set by the Fixed Power Set Potentiometer located on the LRE console. A scram signal will be initiated when the absolute value of the measured log power signal is greater than the absolute value of the bias signal by a few millivolts.

A fixed power scram was initiated by adjusting the set point potentiometer on the LRE to 160 divisions, which corresponds to a power level setting of 1000 watts. The power was then increased in drum position control until a fixed power scram occurred. This scram was produced during EP-I and repeated in SL2.

It can be seen from Figure 1 (EP-I data) that a scram occurred at 3.2 log watts which corresponds to 1500 watts. This represents a variance of 0.2 out of 10 or 2%. A similar scram was produced during SL2 at 3.09 log watts which corresponds to 1200 watts.

It should be noted, however, that the actual measured power for the EP-I test was significantly higher during this period. The log power measured was an average of Log Power # 2 and Log Power # 3, and Log Power # 2 was not performing properly. This anomaly is covered by the averager evaluation and does not invalidate the results of the fixed power scram since the circuitry is dependent upon voltage rather than power.

B. Period Scram

The period scram circuit operates by initiating a scram signal when the measured reactor period becomes shorter than some limit value which is selected at the LRE console. The increment of linear power change (sample time) over which the limit comparison will be made is also selectable from the LRE console. The circuitry utilizes the average log power measured to compute period.

A one second period and 25% sample time was selected from the LRE. A period scram was initiated by increasing the power to a steady state value and demanding the drums open in drum position control. A period scram was conducted during EP-I (Figure 2) and SL2 (Figure 3).

EP-I Period Scram

From Figure 2 it can be seen that the measured log power increased to 2.45 log watts, which corresponds to 280 watts, during a time interval of 0.32 seconds. The measured period when the scram occurred was 1.03 seconds.

Initial Power = 2.2 log watts = 160 watts

Final Power = 2.45 log watts = 280 watts

Measured Period = 1.03 seconds

Δ T = 0.32 seconds

$$\text{Calculated Period} = \frac{0.32 \times 2.72 \times 160}{120} = 1.16 \text{ seconds}$$

Calculated sample time   final power - Initial Power = 0.25 log watts

DATA SOURCE	PERIOD	SAMPLE TIME (Log Watts)
Calculated	1.16	0.25
Measured	1.03	N/A
Set Point	1.0	0.1

SL2 Period Scram

From Figure 3 it can be seen that the measured log power increased to 3.25 log watts, which corresponds to 1750 watts, during a time interval of 0.1 seconds. The measured period when the scram occurred was 1.03 seconds.

Initial Power = 3.1 log watts = 1250 watts

Final Power = 3.25 log watts = 1750 watts

Measured period = 1.03 seconds

ΔT = 0.1 seconds

$$\text{Calculated Period} = \frac{0.1 \times 2.72 \times 1250}{500} = 0.68 \text{ seconds}$$

Calculated Sample Time ≅ Final Power - Initial Power = 0.15 log watts

DATA SOURCE	PERIOD	SAMPLE TIME in Log Watts
Calculated	0.68	0.15
Measured	1.03	N/A
Set point	1.0	0.1

An examination of the above data for EP-I and SL2 indicates a close correlation between the calculated, measured and demanded periods, and relatively large differences in sample times. Possible reasons for these variations are as follows:

1. Resolution of data plots and thinned data available was not sufficiently expanded to accurately calculate periods and sample rates from log power. For example, a difference in time of 50 milliseconds would result in a change of calculated period from 0.68 seconds to 1.0 seconds.

2. On EP-I, the operator achieved a one second period scram by ramping the control drums in two or more steps.

3. Calculations were based on average slopes of log power measured whereas the period scram circuit compares period incrementally.

4. An uncertainty exists as to precisely where on the box car generator the sampling begins, which would influence the actual sampling period.

C. Drum Roll-In Scram

The drum roll-in scram operates by comparing an adjustable (1 to 5 degrees per second) rate limited tracker which tracks average drum position, against the absolute value of average drum position, and initiates a scram whenever the difference between the two exceeds a fixed value. This difference value is adjustable from zero to 20 degrees. Both adjustments are within the chassis and are not accessible during test periods. The drum roll-in detector was initially adjusted to track at 1.5 degrees per second and to initiate a scram whenever the difference value was greater than 12.5 degrees. A drum roll-in scram was initiated by increasing the power to approximately 360,000 watts, and then decreasing the power on a 2 second period in power control (see Figure 5).

It can be seen from Figure 4 (EP-I data) that the average drum position decreased 17 degrees during an elapsed time of 2.4 seconds, at which time a scram was initiated. During this period the rate limited tracker decreased 1.5 x 2.4 = 3.5 degrees. The difference value is therefore 17 - 3.5 = 13.5 degrees which represents a 7.4% variance from the set point.

D. Scram Lights

It was reported during EP-I tests that on three scram tests (2 period scrams and 1 max. drum scram) the scram indicator lamps on the LRE and ATE consoles, as well as the primary scram indication on the CTE console (emergency shutdown switch/lamp) did not illuminate.

An examination of the circuitry in the reactor safety system revealed that a detector circuit is used to provide a scram signal to the individual scram lights on the ATE or LRE console, which is separate from the detector circuit used to initiate a scram signal to the scram gate in the engine safety system. An adjustment is provided to set the trip level of each lamp indication detector, and this trip level is purposely adjusted slightly below the trip level of the scram detector, to avoid the possibility of indicating a scram without actually initiating one.

As a result of the method employed in initiating scheduled scrams during EP-I, wherein the operator slowly approached the scram settings, it was possible to trip the scram circuitry, and thus instantaneously removing the scram condition, before the lamp indicator circuitry could trip. This would not occur during a "hard" scram condition, and is therefore not considered to be of significant concern, providing the detectors are properly adjusted.

It is not readily apparent why the CTE light did not illuminate. Additional analysis and/or trouble-shooting is required.

RECOMMENDATIONS

It is recommended, on the basis of this study, that:

1. Proper adjustment of the scram indicator lamp detectors should be verified prior to further testing.

2. The EP-I anomaly listed below be investigated and corrected.

ANOMALIES

Data - None

Instrumentation - None

Hardware -

1. The CTE scram indication (emergency shutdown lamp/switch) did not illuminate when a scram was initiated. This occured twice during period scrams and once during a max. drum scram.

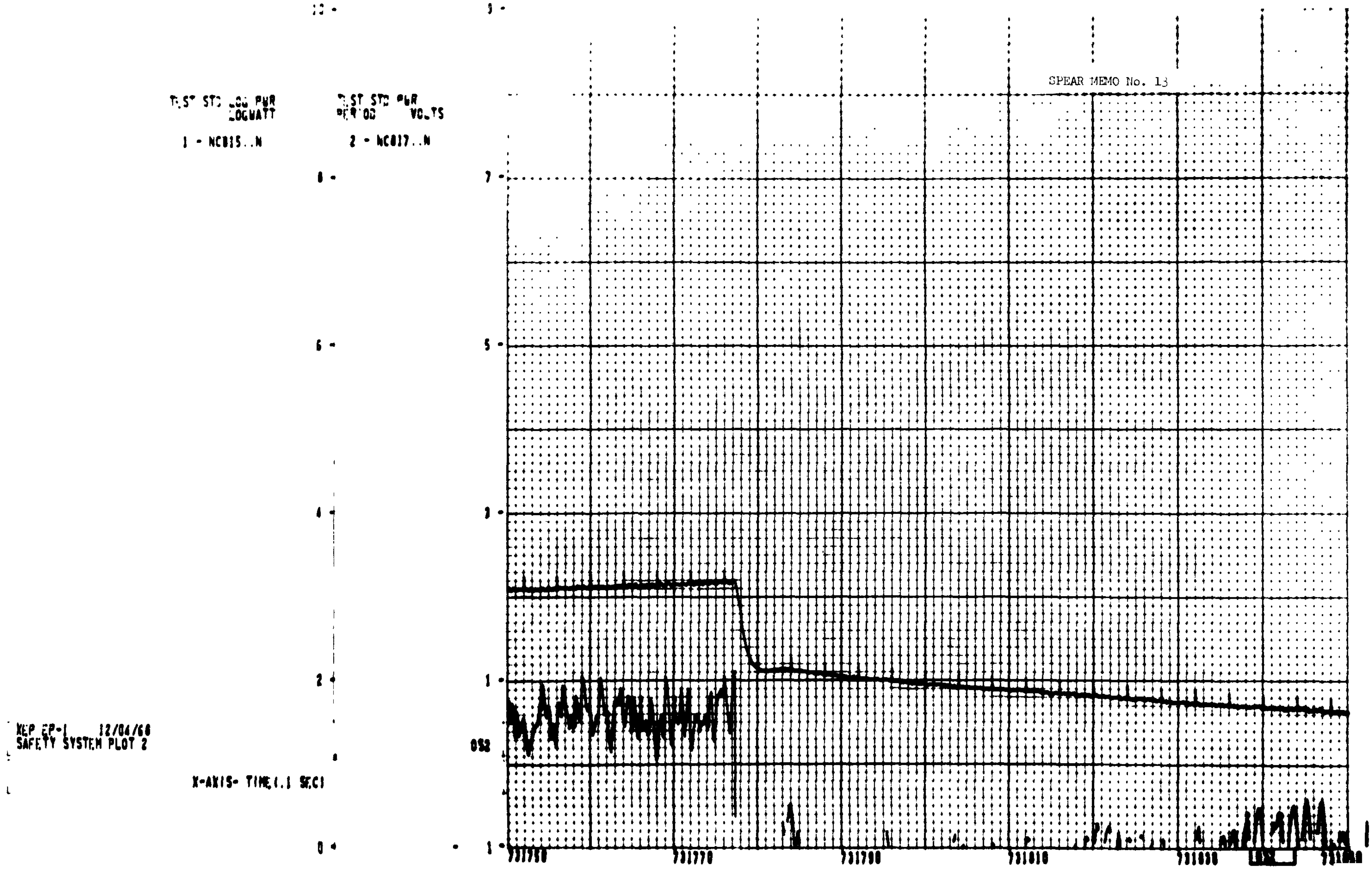

KEP EP-1 12/04/68
SAFETY SYSTEM PLOT 2
X-AXIS- TIME(.1 SEC)
1 - NC815..N
2 - NC817..N
VOLTS
LOGWATT
731750
731770
731790
731810
731830

FIGURE 1

SPEAR MEMO No. 13

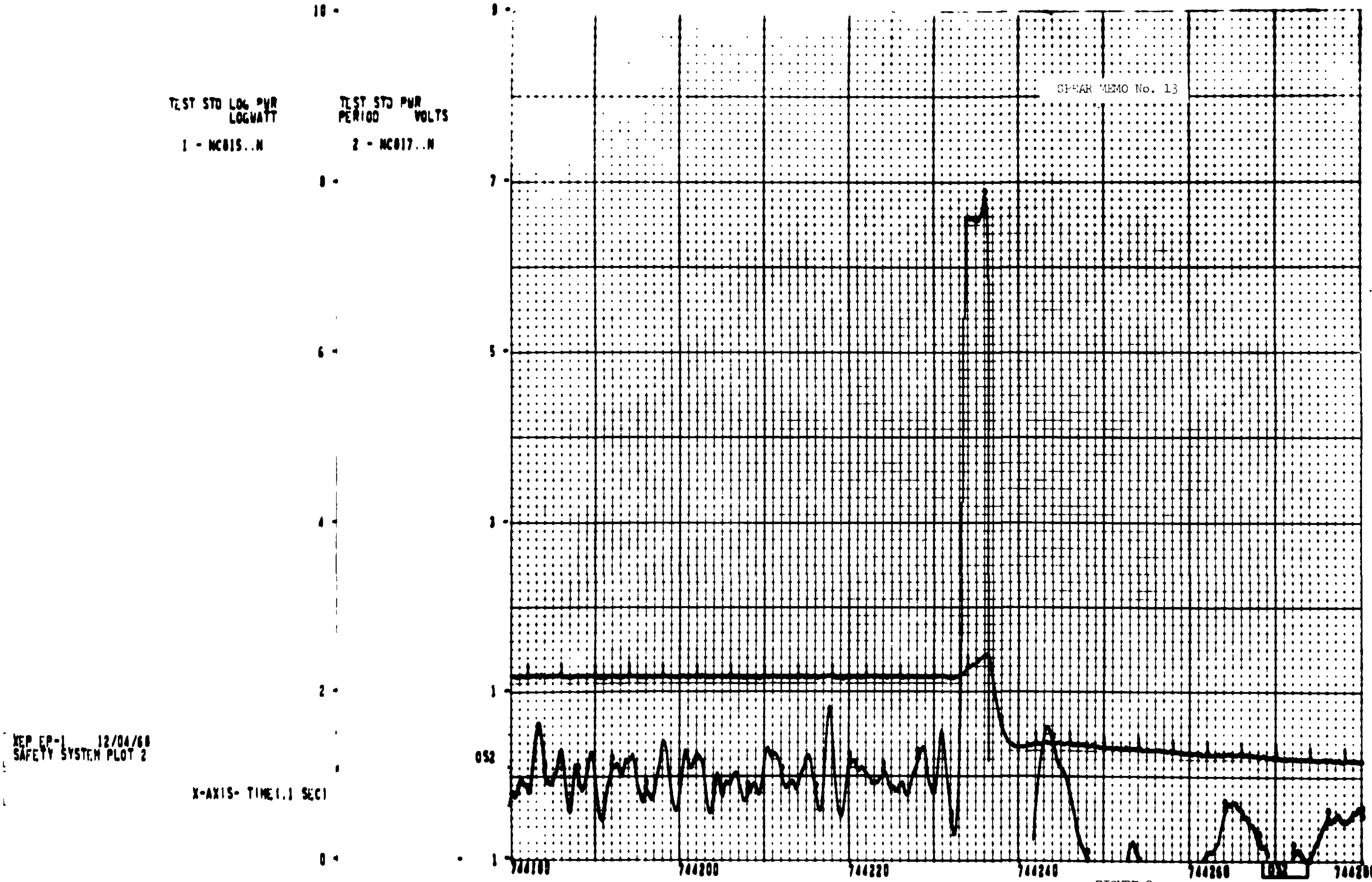


FIGURE 2

SPEAR MEMO No. 13

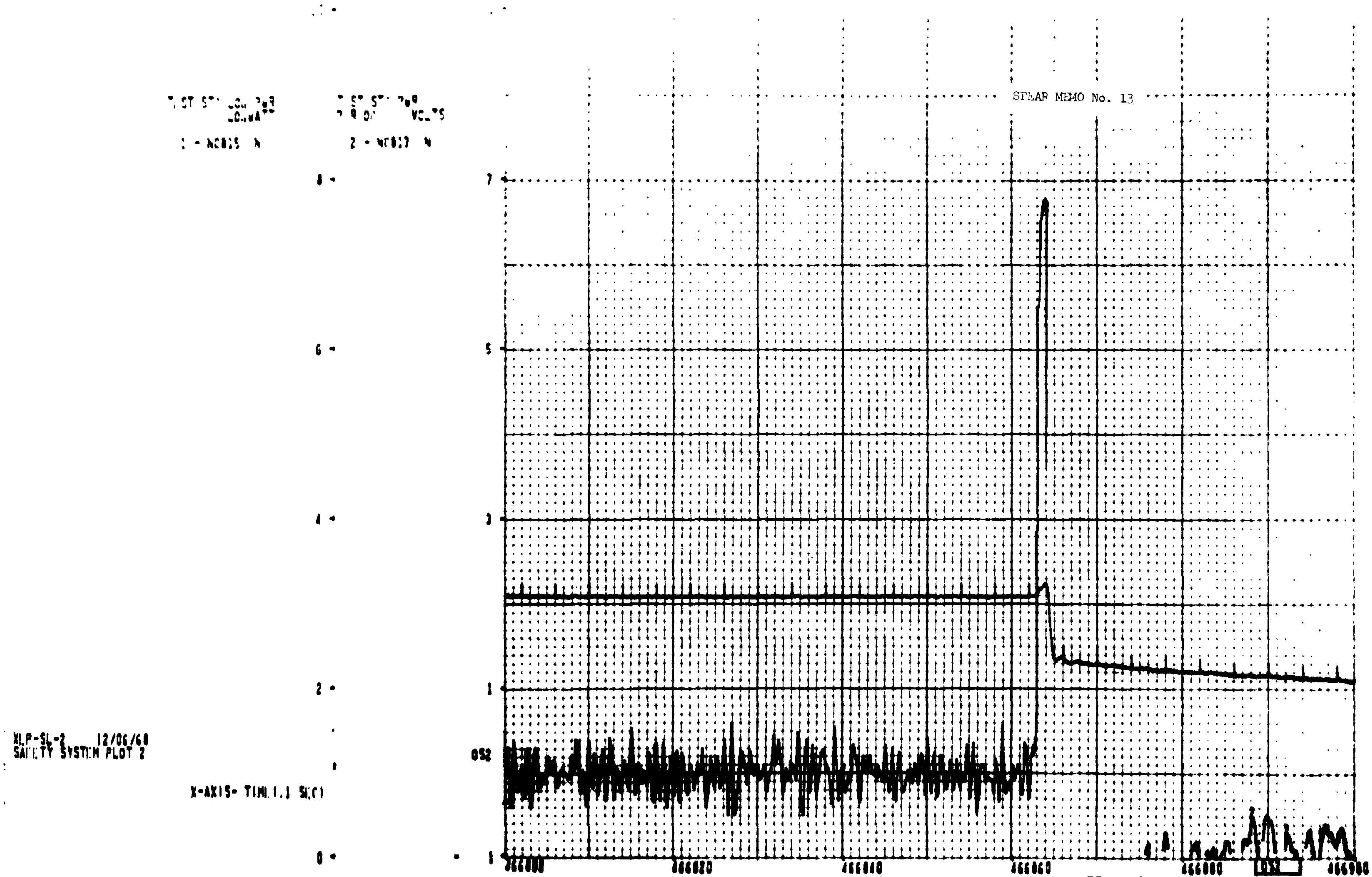


FIGURE 3

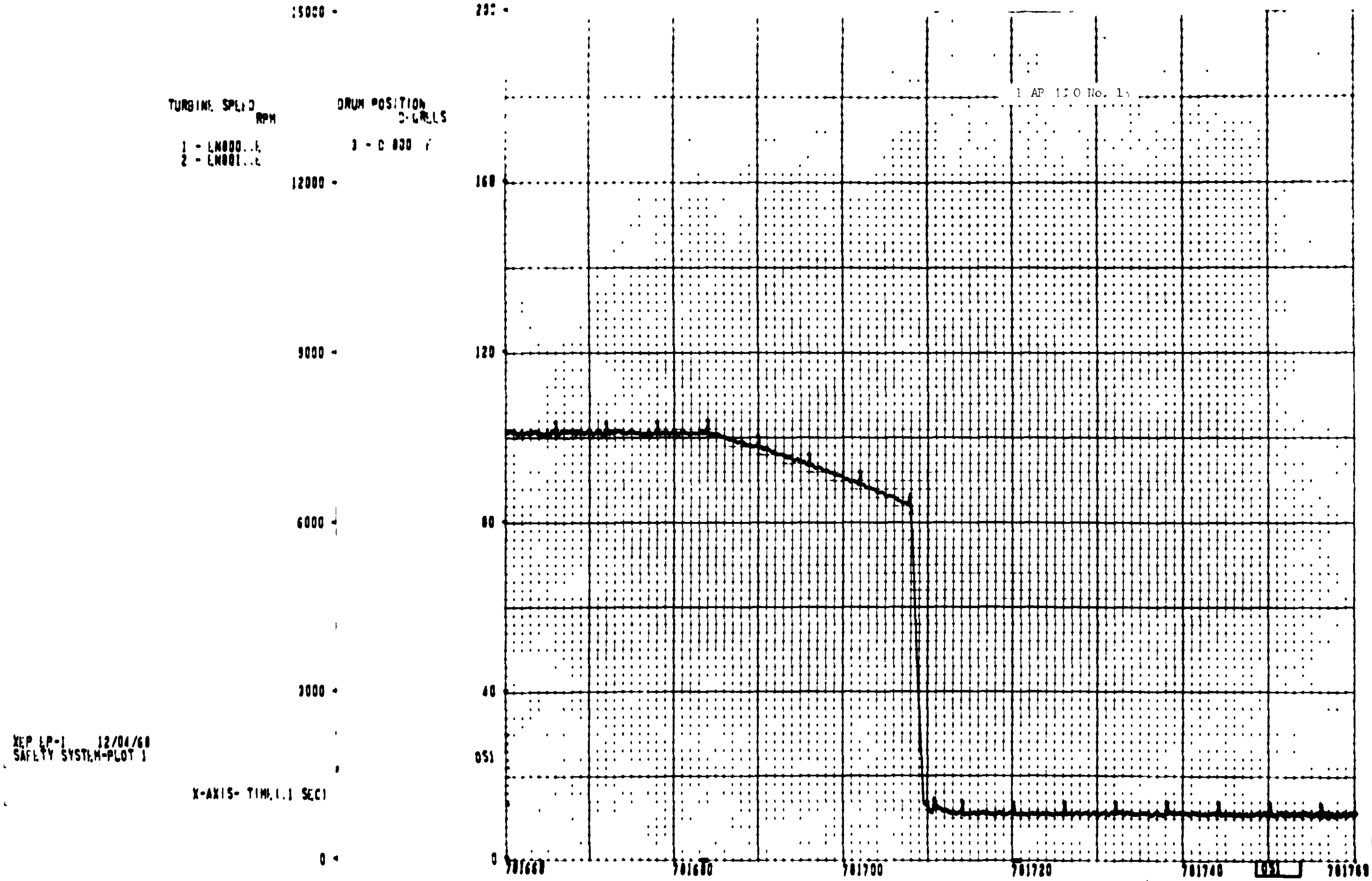

TURBINE SPEED
RPM
DRUM POSITION
15000
12000
9000
6000
3000
0
160
120
80
40
0
SAFETY SYSTEM-PLOT 1
X-AXIS- TIME(.1 SEC)
701680
701700
701720
701740

FIGURE 4

SPEAR MEMO No. 13

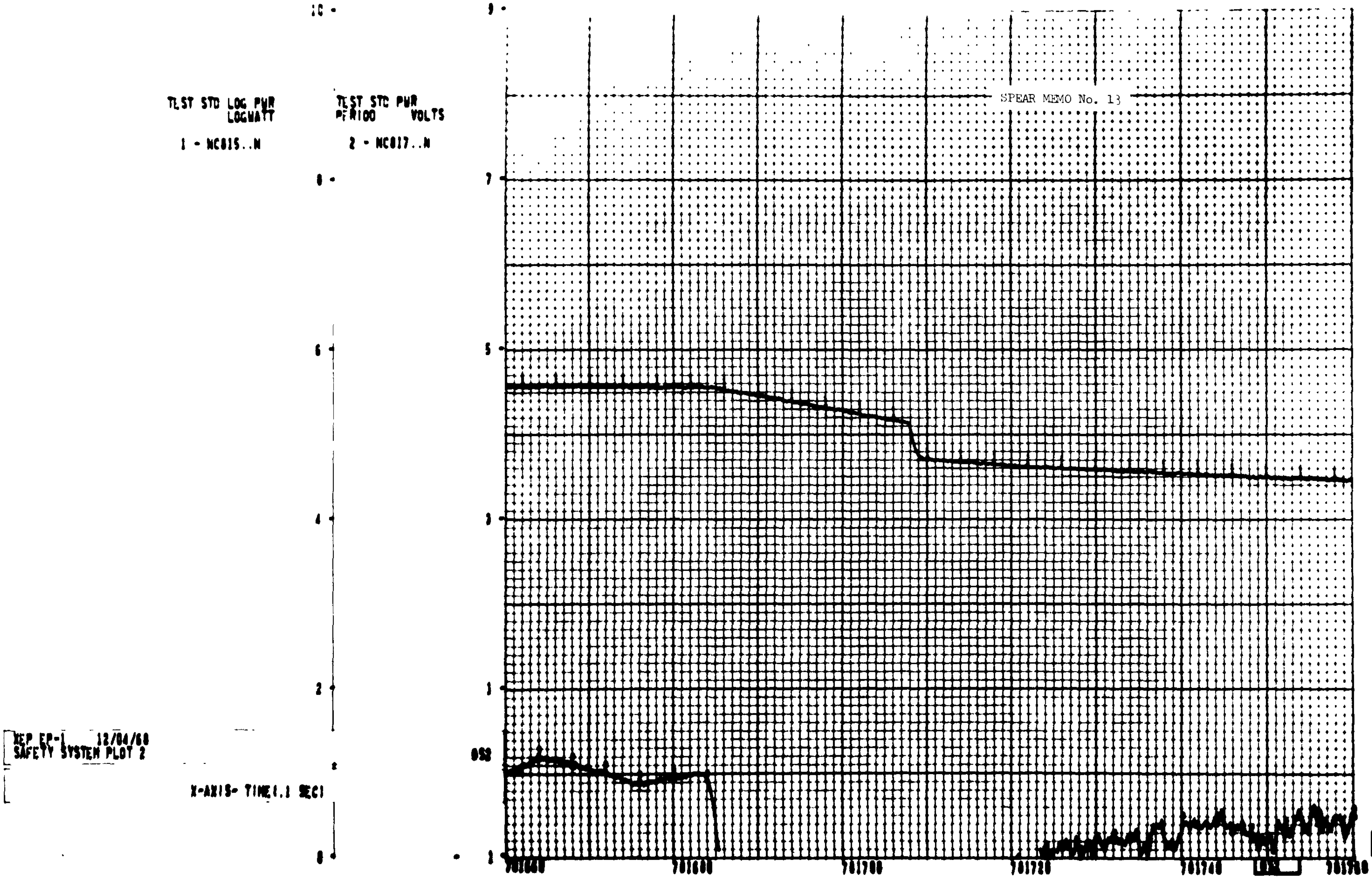


FIGURE 5

SPEAR Memo No. 14
D. Glover/jsb DG

XE-PRIME

EP-I AND EP-SL2

Subject: EVALUATION OF DRUM POSITION AVERAGER AND LOG POWER AVERAGERS

INTRODUCTION

Testing at ETS-1 on 4 December 1968 and 6 December 1968 permitted evaluation of three of the fourteen signal averagers expected to be used in the XE-P engine. These three averagers are (a) Drum Position Averager, (b) Engine Log Power Averager and (c) Test Stand Log Power Averager. The remaining averagers were operated only at ambient level signal which did not permit an adequate evaluation. Also, most of these other averagers were not pertinent to the EP-I test and were, therefore, not functionally checked out and/or calibrated for it.

SUMMARY

The three subject averagers were evaluated during EP-I and SL2 and their performance is adequate to support the next EP. However, there were certain problems and/or anomalies with the input channels which should be corrected for subsequent EP's. These are summarized in the recommendation and/or anomaly section of this memo.

TECHNICAL DISCUSSION

A. Drum Position Averager

1. Technical Description. The Drum Position Averager is shown in functional schematic form in Figure 1. It can be seen from the functional schematic that the Drum Position Averager is a very simple arithmetic averager with no automatic or manual reject features built into it. Failure of an individual drum position signal will affect the averaged position by 1/12th of the signal deviation. With a stack up of resistance tolerances it is possible for the averaged value to differ from the mathematically averaged individual signals by about 3%. The 3% figure is arrived at by assuming (a) that the input 1% resistors to the averager contribute no error because there are 12 of them and the $\pm$ tolerance should be random, and (b) that the averager feedback resistor is 1% high, the buffer input resistor is 1% low and the buffer feedback resistor is 1% high. The averaged output signal would then be approximately 3% higher than the arithmetic average of the individual signals. The 1K isolation resistor in series with the actuator potentiometer will cause the actual position of the drum to be approximately 1% greater than the position indicated, how-

ever, this is of no importance in the performance of the Drum Position Averager. A discussion of this 1% error is contained in SPEAR Memo No. 3.

2. Drum Position Averager Performance Evaluation

Table 1, presents the performance of the Drum Position Averager during EP-1 and SL2. The Table presents the averaged drum position as calculated from each of the twelve individual positions indicated and compares it with the averager signal D.800..E. The Table indicates the performance of the averager was within the possible 3% error with the following exception:

a. At range time 73185.6 during EP-I the calculated average is 8.1° whereas the averager indicates 11.6°. This is an error of approximately 43%.

b. At range time 47268.7 during SL2 the calculated average is 6.2° whereas the indicated average is 10.9°. This is an error of approximately 78%.

c. At range times 77556.4 and 78160.4 during EP-I the calculated average was significantly higher than the averager reading. The high calculated value is due to the high reading of D.806.AE.

Item c is believed to be a data system anomaly because the drums were in power control and no discrepancy in Drum Position Number 6 reading was observed by the operators or Test Limit Monitors.

With regard to exceptions (a) and (b) discussed above it has been observed by the operators that when the drum position command exceeds approximately 15°, that the averaged reading has a step reduction in value. This is believed due to an interaction between the averager circuitry and the operation of drum lock/unlock relays which also occurs at approximately 15° and are located in the same chassis as the Drum Position Averager.

B. Engine and Test Stand Log Power Averagers

1. Technical Description. The Engine Log Power Averager and the Test Stand Log Power Averagers are identical pieces of electronic equipment. The only difference is in the physical location of the Ion Chambers. Basically, the Log Power Averagers average three Ion Chamber input signals, establishes a rejection band around this average (this reject band is adjustable within the equipment) and rejects any one channel that is outside this band, it then provides an output signal equal to the average of the inputs not rejected. A second channel may be manually rejected by the operator at the LRE console. Circuitry within the equipment prevents the rejection of all three channels. A rejected channel may be reset by the LRE operator providing its reading is written the allowable error band. The allowable error band for the EP-I and SL2 tests was set at 0.250 volts which is equivalent to 0.200 log watts.

2. Performance Evaluation

The performance evaluation of the Log Power Averagers is presented in Tables 2 and 3 for EP-I and EP-SL2, respectively. Six readings at a wide range of power levels were selected for this evaluation. The EP-I data indicates an average variation of only 0.016 log watts between the engine measured and calculated values over the six readings. The corresponding variation for the EP-I test stand values is only 0.007. Corresponding data for EP-SL2 provided an average variation of 0.002 and 0.003 log watts for the engine and test stand values, respectively.

Performance evaluation of the Test Stand Log Averager was difficult because information was not readily available as to when and which channels in the averagers were rejected. It was determined from talking with operations personnel that on a startup one of the Log Channels will automatically reject due to the spread in individual readings in the subpower levels. During EP-I, Engine Log 2, and Test Stand Log 1 had automatically rejected. These channels would normally have been reset by the operator after the Log Power level reached a reasonable value for measurement. This reasonable value is estimated to be approximately 5 to 50 watts. However, the Test Stand Log 1 channel could not be reset due to the faulty reading in Test Stand Log 2 channel. If Test Stand Log 2 was manually rejected to permit the reset of Test Stand Log 1,it was possible that a period trip would occur because of the resulting power transient. Based on the information obtained from operating personnel it is believed that in Table 2 for range times of 72758.5 and 73180.6 Engine Log Channel 2 and Test Stand Log Channel 1 were rejected. At the other range times and during EP-SL2 Test Stand Log Channel 2 and Engine Log Channel Number 1 were rejected. With this knowledge, it was possible to calculate an "arithmetic average" using only the channels believed to be active in the averager. Engine Log Channel 1 had been manually rejected because it was "noisy."

The Engine Log Averager reading agrees so well with the calculated average that it is not really necessary to consider if a log channel was rejected. However, the fact that the Engine Log Channel 1 had been rejected is substantiated by Figure 2 which shows the noise on channel 1 did not affect the averager output signal NC804..E. The noise on Engine Log Channel Number 1 seems to reduce after range time 77950. This fact is also indicated in the digital printout The digital listing for SL2 also did not indicate significant noise on this channel. The magnitude of this noise was checked over a 9 second interval during EP-I and is presented in Table 4. The log watt signal noise during this time is equivalent to a change in power between 1550 watts and 2100 watts. The performance of the Test Stand Log Averager is shown in Figure 3. This figure shows the discrepancy in the reading of Test Stand Log Channel Number 2 and also shows good agreement between the averaged output signal and the Test Stand Log Channels 1 and 3.

RECOMMENDATIONS

1. Investigate why Drum Position Average reading changes when the drum lock/unlock relay in chassis 40R048A2 operates and correct the problem.

2. Correct noise in Engine Log Channel Number 1 (NC801..N).

3. Record when any Log Power Channels are automatically or manually rejected and/or reset.

ANOMALIES

Data

1. Data printout of drum position number 6 (D.806.AE) at range times near 77550 - 78000 during EP-I is not substantiated by other indications

2. The scale shown on the multiple plots of Figures 2 and 3 for the Log Power Signals are given in volts. However, if they were translated to log watts, they would not agree with the digital printout data for this time. This anomaly is in the plot routine and is being corrected for subsequent EP's.

Instrumentation

None Observed.

Hardware

1. Test Stand Log Channel Number 2 (NC813.AN) was not functional.

2. Interaction of Drum Position Averager with operation of drum lock/ unlock relay.

3. Noise in Engine Log Power Channel Number 1 (NC801..N).

TABLE 1

EP-I DRUM POSITION AVERAGER PERFORMANCE

Range Time	Calculated Avg. Pos.	D.800..E	D.801.AE	D.802.AE	D.803.AE	D.804.AE	D.805.AE	D.806.AE	D.807.AE	.808.AE	D.809..AE	D.810.AE	D.811.AE	D.812.AE		
73185.6	8.1	11.6	7.4	6.3	7.8	7.4	7.4	8.8	6.5	6.4	8.5	7.4	7.9	6.6		
75300.8	14.9	15.5	15.3	12.1	15.1	15.6	16.5	16.1	14.3	14.2	15.9	13.7	15.6	14.0		
42074.9	47.6	47.2	47.7	46.1	48.4	47.8	47.5	47.5	48.0	48.1	48.2	46.4	47.8	47.6		
75650.0	96.6	97.8	96.9	95.4	97.4	96.9	96.2	96.9	96.4	96.8	98.2	95.7	96.4	96.5		
74418.8	98.7	100.1	98.9	98.1	99.1	98.6	99.0	98.7	98.8	99.0	100.3	97.7	98.7	98.3		
77556.4	53.9	46.5	46.6	44.7	46.6	47.2	47.7	137.0	46.5	46.4	46.9	46.5	47.2	45.3		
78160.4	107.1	101.0	99.9	99.5	101.0	99.9	100.4	182.8	100.5	100.0	102.1	99.0	100.1	100.1		
SL-2 DRUM POSITION AVERAGER PERFORMANCE																
47268.7	6.2	10.9	6.1	5.5	6.8	6.1	6.5	7.4	5.7	5.1	6.9	6.0	6.9	5.4		
47396.8	20.1	19.4	20.1	18.1	20.7	21.2	21.5	21.3	19.9	19.4	20.5	19.1	20.5	19.2		
47412.8	51.9	51.5	52.7	50.7	52.4	52.6	52.4	52.0	52.0	51.7	51.8	51.0	52.1	51.1		
47511.8	104	105.4	104.5	103.5	104.5	104.2	104.2	104.3	104.2	103.9	104.3	103.6	103.7	104.2		
77510.9	105.2	107.2	105.3	104.9	105.8	105.4	105.4	105.3	105.4	105.1	105.4	104.8	104.7	105.2		
57945.3	97.2	99.2	14.7	104.3	105.0	104.9	104.8	104.8	105.1	104.7	104.9	104.4	104.3	104.4		
58692.3	100.0	101.9	94.3	93.4	167.1	94.2	94.4	94.2	94.9	94.3	94.2	93.4	94.2	93.5		

TABLE 2

EP-I LOG POWER AVERAGER EVALUATION

	ENGINE LOG CHANNELS			ENGINE AVERAGER		TEST STAND LOG CHANNELS			TEST STAND AVERAGER	
RANGE TIME	NC801..N IN LOG WATTS	NC802..N IN LOG WATTS	NC803..N IN LOG WATTS	NC804..N IN LOG WATTS	CALCULATED AVERAGE IN LOG WATTS	NC812.AN IN LOG WATTS	NC813.AN IN LOG WATTS	NC814.AN IN LOG WATTS	NC815..N IN LOG WATTS	CALCULATED AVERAGE IN LOG WATTS
72758.5	1.343	1.225	1.109	1.158	1.226 [a]	1.444	-.302	1.274	.467	.4 86 [c]
73180.6	2.976	2.967	2.970	2.985	2.973 [a]	3.107	.889	3.019	1.960	1.954 [c]
74418.8	2.202	2.101	2.026	2.037	2.063 [b]	2.222	.023	2.080	2.182	2.151 [d]
75650.0	2.790	2.870	2.817	2.828	2.843 [b]	2.998	.883	2.876	2.944	2.937 [d]
77934.4	4.237	4.155	4.140	4.131	4.146 [b]	4.191	1.988	4.052	4.104	4.121 [d]
78160.4	5.722	5.603	5.621	5.622	5.612 [b]	5.637	-5.482	5.502	5.549	5.596 [d]

NOTES: a. CHANNEL NC802..N IN AUTOMATIC REJECTION

b. CHANNEL NC802..N RESET AND NC801..N MANUALLY REJECTED

c. CHANNEL NC812.AN IN AUTOMATIC REJECTION

d. CHANNEL NC812.AN RESET AND NC813.AN MANUALLY REJECTED

TABLE 3

SL2 LOG POWER AVERAGER EVALUATION

	ENGINE LOG CHANNELS			ENGINE LOG AVERAGER		TEST STAND LOG CHANNELS			TEST STAND LOG AVERAGER	
Range Time	NC801..N in Log Watts	NC802..N in Log Watts	NC803..N in Log Watts	NC804..N in Log Watts	Calculated Avg. in Log Watts	NC812.AN in Log Watts	NC813.AN in Log Watts	NC814.AN in Log Watts	NC815..N in Log Watts	Calculated Avg. in Log Watts
46756.1	1.418	1.306	1.404	1.334	1.355[a]	1.194	-1.453	1.119	1.147	1.155[b]
47512.8	1.677	1.566	1.696	1.637	1.631[a]	1.426	-2.776	1.384	1.424	1.405[b]
47580.8	3.450	3.320	3.415	3.368	3.367[a]	3 147	1.453	3.094	3.109	3.120[b]
56925.2	2.580	2.460	2.576	2.519	2.518[a]	2.274	.306	2.250	2.278	2.262[b]
56935.2	3.001	2.880	2.992	2.940	2.936[a]	2.693	.907	2.665	2.681	2.680[b]
62501.8	6.029	5.945	5.981	5.940	5.963[a]	5.686	3.378	5.684	5.677	5.675[b]

NOTES:
a. CHANNEL NC801..N MANUALLY REJECTED
b. CHANNEL NC813.AN MANUALLY REJECTED

TABLE 4

DATA SHOWING NOISE ON ENG. LOG #1 CHANNEL DURING EP-I

SPEAR MEMO No. 14

Range Time		NC801..N in Log Watts		NC802..N in Log Watts		NC803..N in Log Watts		NC804..N in Log Watts								
77871.4		3.232		3.149		3.192		3.180								
77872.4		3.232		3.143		3.179		3.168								
77873.4		3.267		3.150		3.174		3.167								
77874.4		3.315		3.147		3.181		3.169								
77875.4		3.205		3.137		3.192		3.167								
77876.4		3.224		3.137		3.181		3.164								
77877.4		3.195		3.140		3.174		3.160								
77878.4		3.319		3.157		3.177		3.164								
77879.4		3.286		3.139		3.193		3.174								
READING	SPREAD	.124		.020		.019		.020								

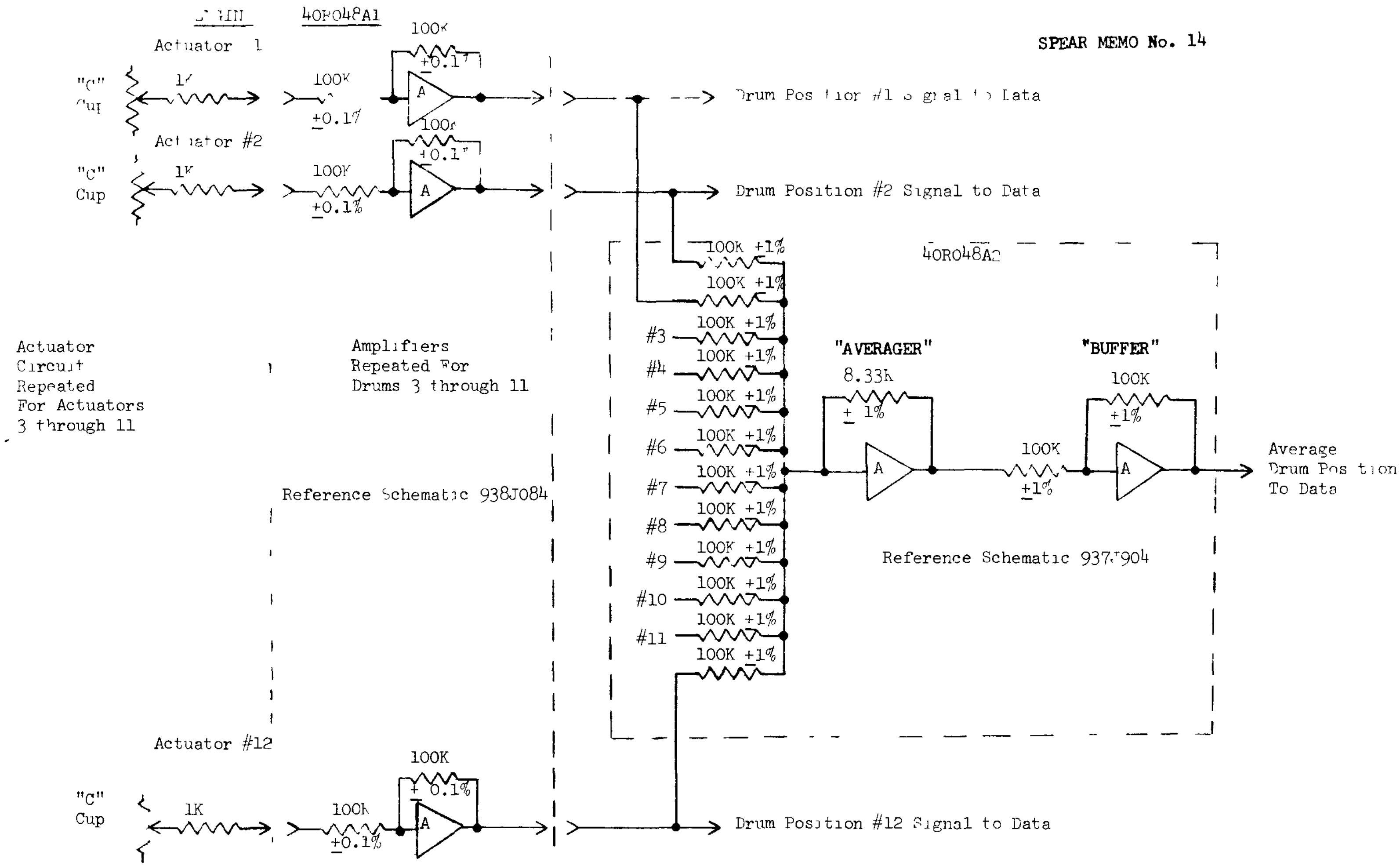
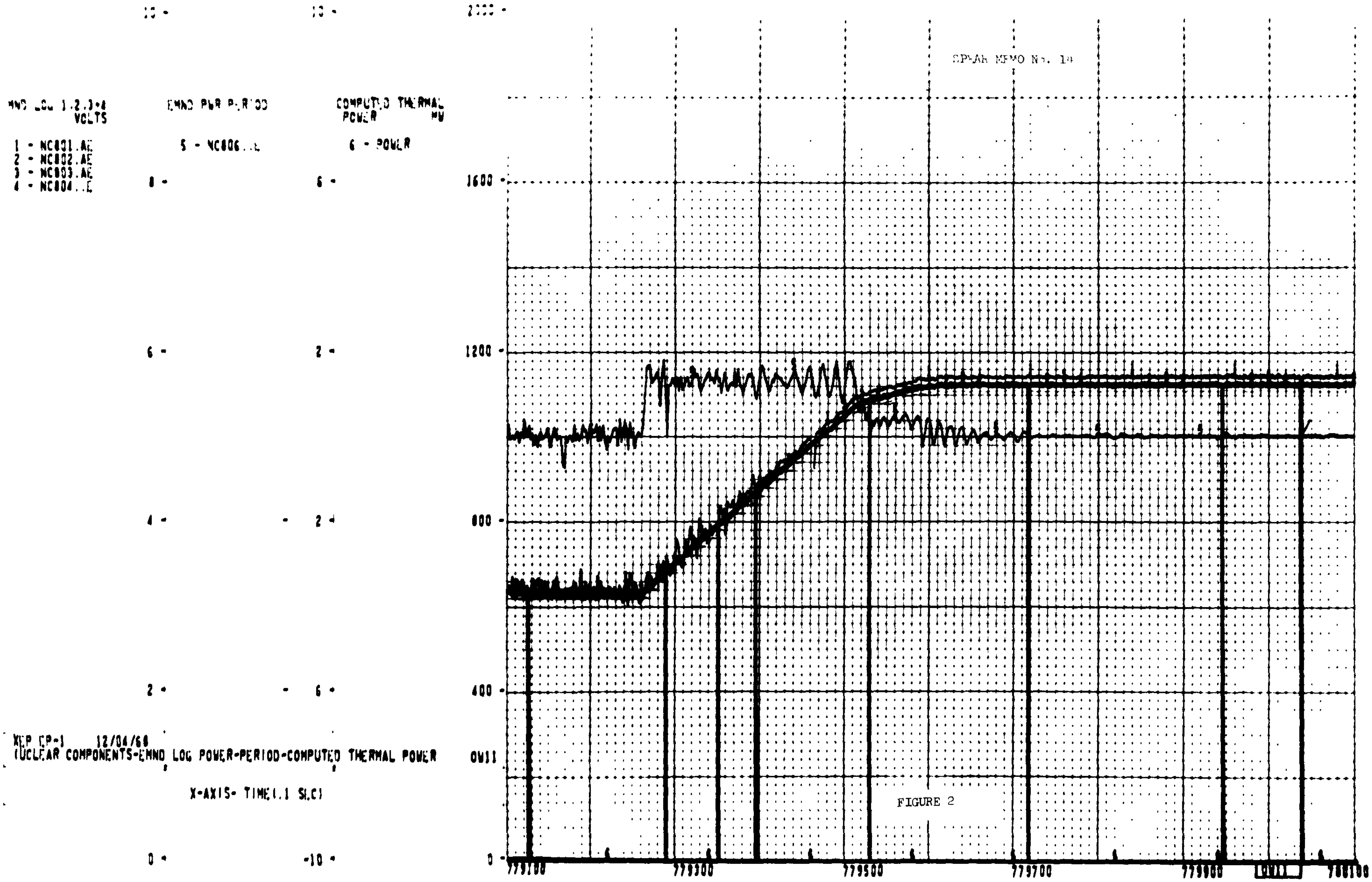


FIGURE 1

SIMPLIFIED FUNCTIONAL SCHEMATIC OF DRUM POSITION AVERAGER



VOLTS
1 - NC801.AE
2 - NC802.AE
3 - NC803.AE
COMPUTED THERMAL POWER MW
6 - POWER
NUCLEAR COMPONENTS-EMND LOG POWER-PERIOD-COMPUTED THERMAL POWER
X-AXIS- TIME(.1 SEC)

FIGURE 2

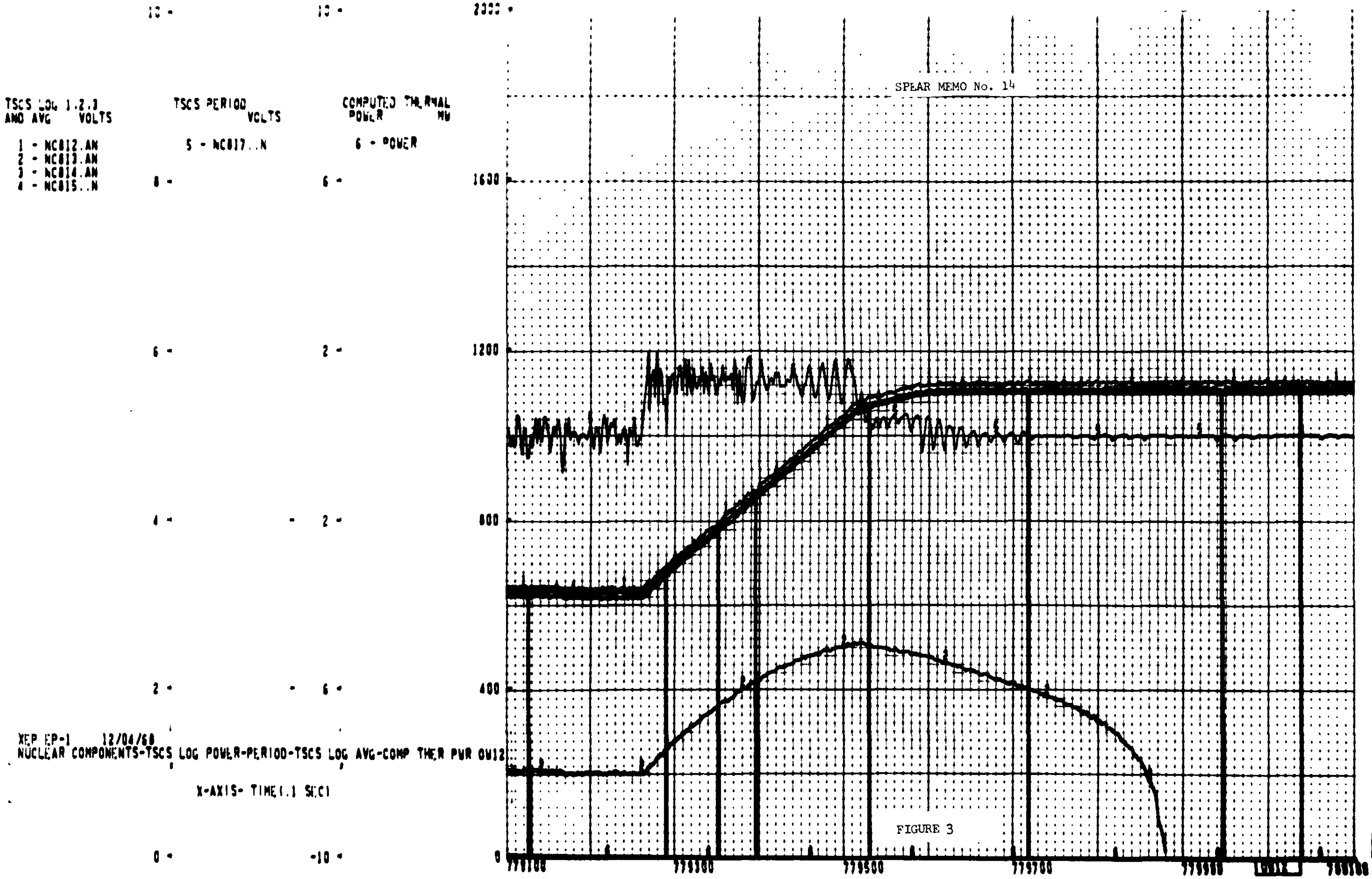

TSCS LOG 1.2.3 AND AVG VOLTS
1 - NC812.AN
2 - NC813.AN
3 - NC814.AN
4 - NC815..N
TSCS PERIOD VOLTS
5 - NC817..N
COMPUTED THERMAL POWER MW
6 - POWER
XEP EP-1 12/04/68
NUCLEAR COMPONENTS-TSCS LOG POWER-PERIOD-TSCS LOG AVG-COMP THER PWR OW12
X-AXIS- TIME(.1 SEC)
1600
1200
800
400

FIGURE 3

SPEAR Memo No. 15
E.F. Dowling/L. Mackey
cjd

XE-PRIME

EP-I and EP-SL2

Subject: POWER CONTROL EVALUATION

INTRODUCTION

Performance of the log power control loop was checked out during EP-I and EP-SL2 at low power/ no flow conditions to evaluate the suitability of the power control for further testing.

SUMMARY

During EP-I and SL2 tests a partial checkout of the power controller was made. This checkout using average test stand log power as the measured feedback signal revealed no anomalous performance and the log power control loop is ready for further testing and checkout.

The static accuracy of the power control loop was computed from demanded log power and measured test stand log power. Measured log power was found to be 2% higher than demanded log power at 1 kilowatt and 1% higher than demanded log power at 130 kilowatts. However, calibration of the measured log power channel, NC815..E, indicates the channel was reading high by an unspecified amount.

Closed loop power control frequency response was reduced from steps in power demand taken during EP-I. The frequency range of the response was restricted due to noise on the zero suppressed log power data channel. Planned transfer function measurements of the power control loop using sinusoidal and pseudo random demands were not run during EP-I or SL2. These tests should be completed to determine more completely the dynamic performance of the power controller and to provide checkout of the data acquisition system.

A power loop limit cycle did appear, with approximately the same amplitude and frequency as predicted, during EP-SL2. During EP-I the limit cycle did not appear during infinite period operation. This lack of a limit cycle is suspected to be the result of a dither effect produced by the high drum torque motor current noise level during EP-I.

Checkout of the power controller on five and 2 second periods were made during EP-I and SL2. These checkouts were made for a two decade change in power level. Satisfactory performance on these ramps was obtained. Further checkout for a three decade change in power level on a two second period is required if power

level changes in excess of two decades on a two second period are required during engine operation. This further checkout is required to insure that a period scram will not be generated by the power loop limit cycle while operating on a two second period.

TECHNICAL DISCUSSION

a. Static Accuracy

The static accuracy of the log power controller as a percent of demanded log power can be determined by comparing the demand, CC629, and the measured, NC815, during steady state operation. The ratio of measured log power to demanded log power was found to be 1.02 for operation at 1 kilowatt and 1.01 for operation at 130 kilowatts during EP-SL2 (reference Figure 1). However, calibration for channel NC 815 is suspect and the channel is expected to read high by an unspecified amount.

b. Transfer Function Measurement

During EP-I at 1 kilowatt, negative and positive 100 watt steps were made in log power demand. Noise on the zero suppressed measured log power wide band channels was approximately 100% of the step amplitude. The time response for log power demand, drum demand, and engine log power for the step down in power is given in Figure 2. The closed loop frequency response for the power loop reduced from the step data is compared with the predicted response in Figure 3. The frequency range was limited by noise on the log power channel.

c. Power Loop Limit Cycle

A predicted power loop limit cycle did appear to varying degrees in both EP-I and EP-SL2. In EP-I the limit cycle appeared only during a constant 5 second period ramp to 100 kilowatts (reference Figure 4) and did not appear during infinite period (Refer Figure 5). During EP-SL2, the limit cycle appeared during infinite period operation at 1 kilowatt prior to the 2 second and 5 second period ramps (reference Figures 6 and 7). Although not plotted, digital listings for the period channels, NC806 and NC817, confirm the existance of a limit cycle during operation at 100 kw for EP-SL2 (range time 77950 to 78047). The cause of the limit cycle is the stiction characteristic of the drum actuators. During EP-I, the high noise level that existed on the drum torque motor currents probably acted as a dither to keep the drums in motion and minimize the stiction effects. During EP-SL2, the torque motor current noise level was considerably reduced and the limit cycle was more pronounced.

d. Two Second Period Ramp Performance

During the SL2 tests from range time 77934.9 to 77945.0 a two second period was established in power control. The reactor power was increased 2 decades from an initial level of 1 kw to 100 kw.

Figure 6 is a plot showing power demand, average test stand log power, average engine log power, and period during the 2 second period ramp. Prior to initiation of the ramp the power loop limit cycle is observed in the period trace. At range time 77934.9 the ramp in log power demand is initiated. During the ramp it is observed that the limit cycle is not present. This is due to the fact that the control drums are moving to a new position to establish the constant period.

Just prior to termination of the power ramp, it is observed that period decreases to approximately 1.1 seconds then rings and damps out to an infinite period at the ramp termination. It is noted that just prior (0.2 seconds) to this 1.1 second period the power demand generator slope changes in the final approach to 100 kw.

The minimum period near the end of the ramp is probably due to the fact that the control drums are approaching a steady state position and the power loop limit cycle is starting. Test predictions made with a single control drum indicate the power loop limit cycle while increasing power on a two second period will produce minimum periods of 0.5 seconds once the limit cycle is established.

If planned engine operation includes power ramps in power control in excess of two decades on a two second period, it is recommended that the power controller be checked out on a 2 second period for a power level change of 3 decades. This checkout should be performed to insure that a period scram is not generated. If the log power ramp is made over a 3 decade range, this will be sufficient time for the limit cycle to be established.

e. Power Demand Generator

The power demand generator was used to generate log power ramps between steady state power levels. Drift of the demand at steady state was negligible. The 2 and 5 second period ramps appeared to be correct within 2 - 3%.

RECOMMENDATIONS

1. If engine operation requires power level changes in excess of two decades on a two second period, further checkout of the power controller is required to insure that a period scram will not be generated. This further checkout requires a three decade power level change on a two second period.

2. Perform the transfer function measurements planned for EP-I during EP-IA using step, sine, and pseudo random inputs. To achieve a better signal to noise ratio on data channels, power should be above 1 kilowatt, preferably 10 kilowatts or 100 kilowatts.

3. Increase the range on the function generator channel, VC900, to avoid the saturation experienced in EP-I.

4. Record the function generator output, VC900, on a 100 sps digital channel. This will permit transfer function computation from digital data.

5. Correct the power demand generator output channel, CC605, so that valid data is obtained.

6. Range the zero suppressed log power channels to obtain a larger signal amplitude during transfer function measurements.

ANOMALIES

Data

1. Function generator output, channel VC900, saturated during drum position transfer function measurements.

2. Power demand generator output, channel CC605, appeared as zero volts throughout EP-I and EP-SL2.

3. Engineering unit conversion for log power error, NC805..E, and engine log power, NX903..E, were missing from the transfer function listing derived from the EP-I log power step wide band data.

TABLE I

EP-I AND EP-SL2 POWER LOOP LIMIT CYCLE

TEST	TIME (sec)	REACTOR PERIOD (sec)	LIMIT CYCLE	
			P-P Ampl. (% power)	Freq. (cps)
EP-I	78010	∞	0	0
EP-I	77910	5	3	0.6
EP-SL2	77495	∞	6	0.5
EP-SL2	77930	∞	6	0.5
EP-SL2	77512	5	10	0.8
EP-SL2	77942	2	12	1.0

PREDICTED POWER LOOP LIMIT CYCLE

REACTOR PERIOD (sec)	LIMIT CYCLE	
	P-P Ampl. (% power)	Freq. (cps)
∞	2	0.4
4	7	0.7
2	15	1.0

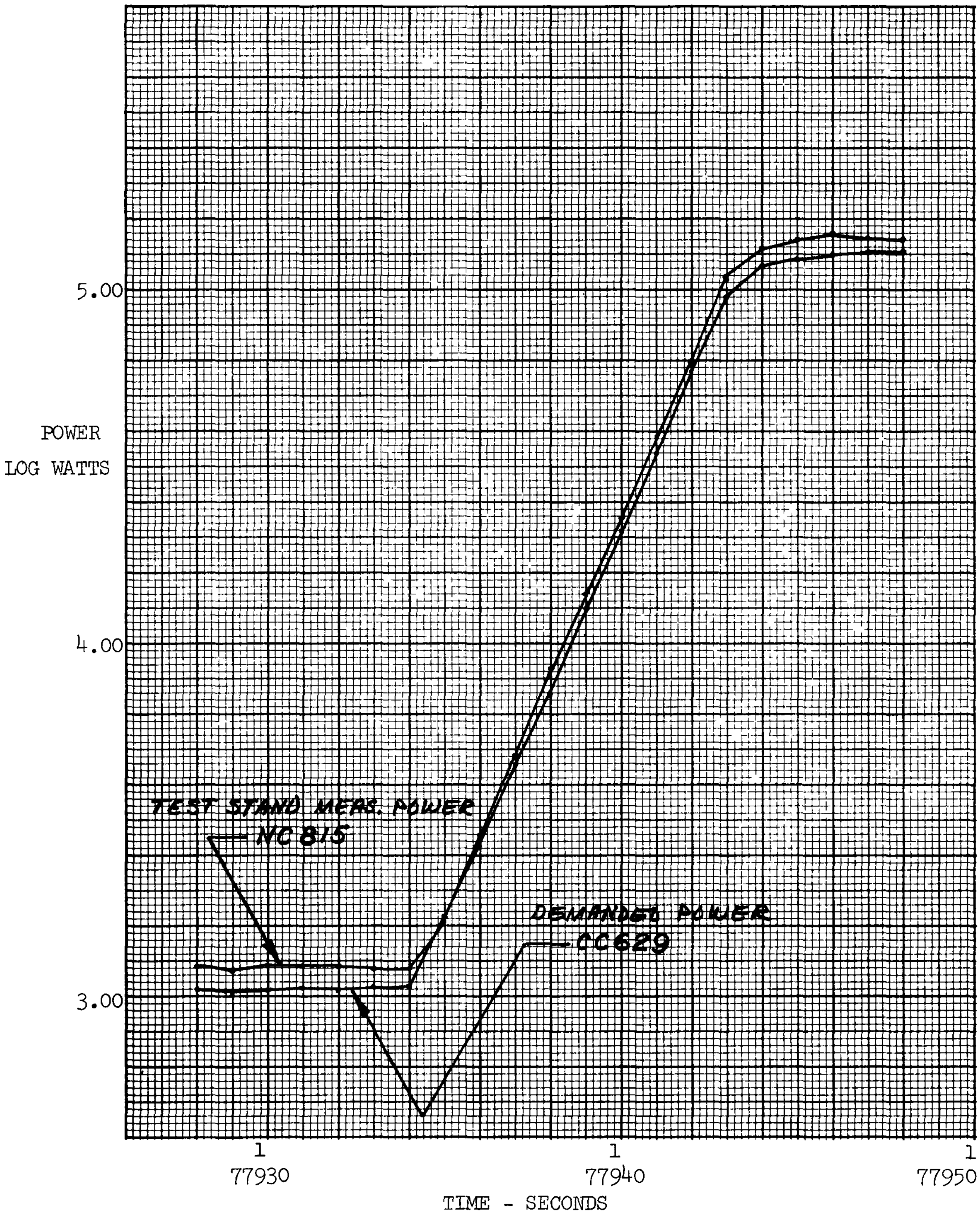
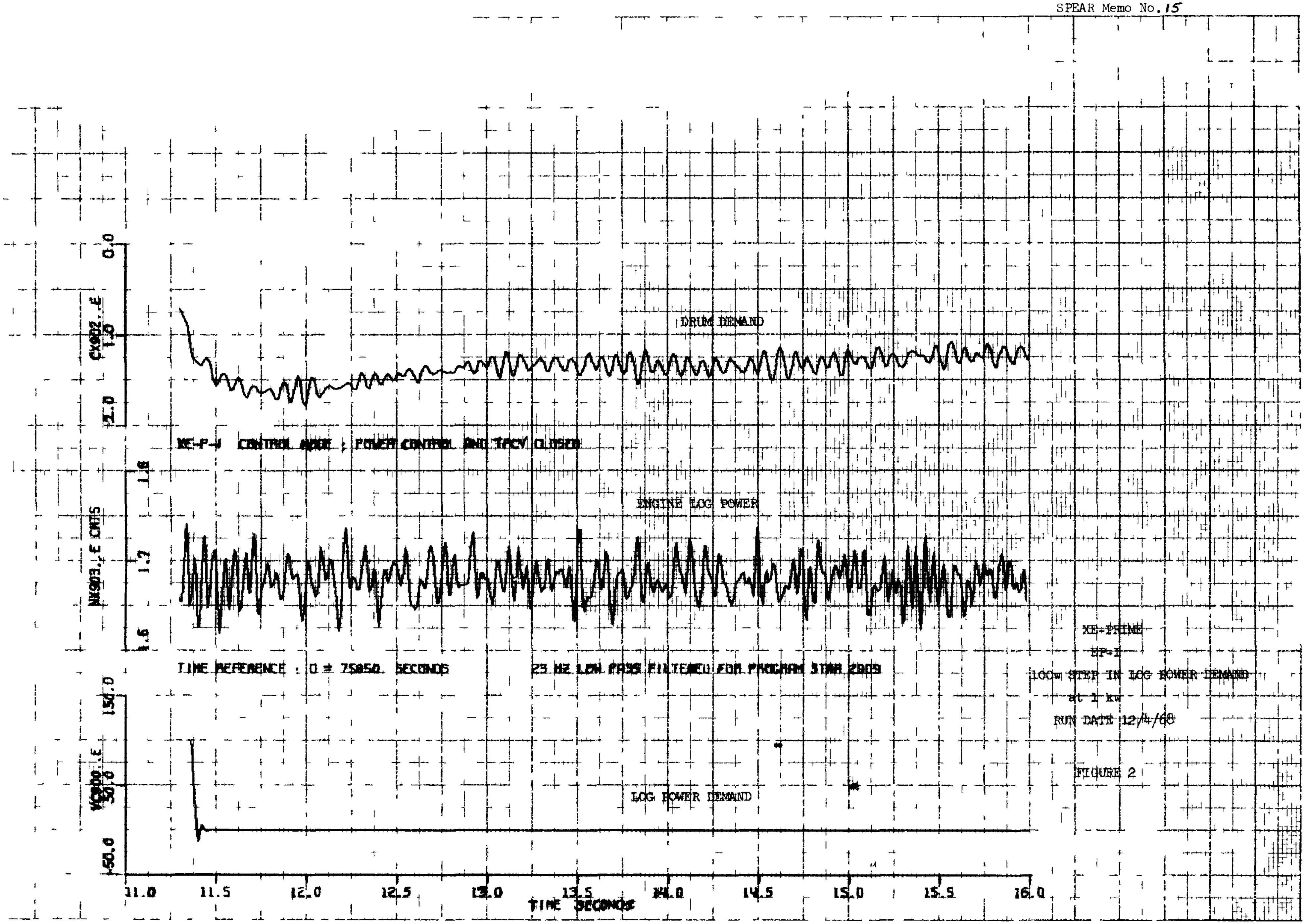


FIGURE 1

XE-PRIME

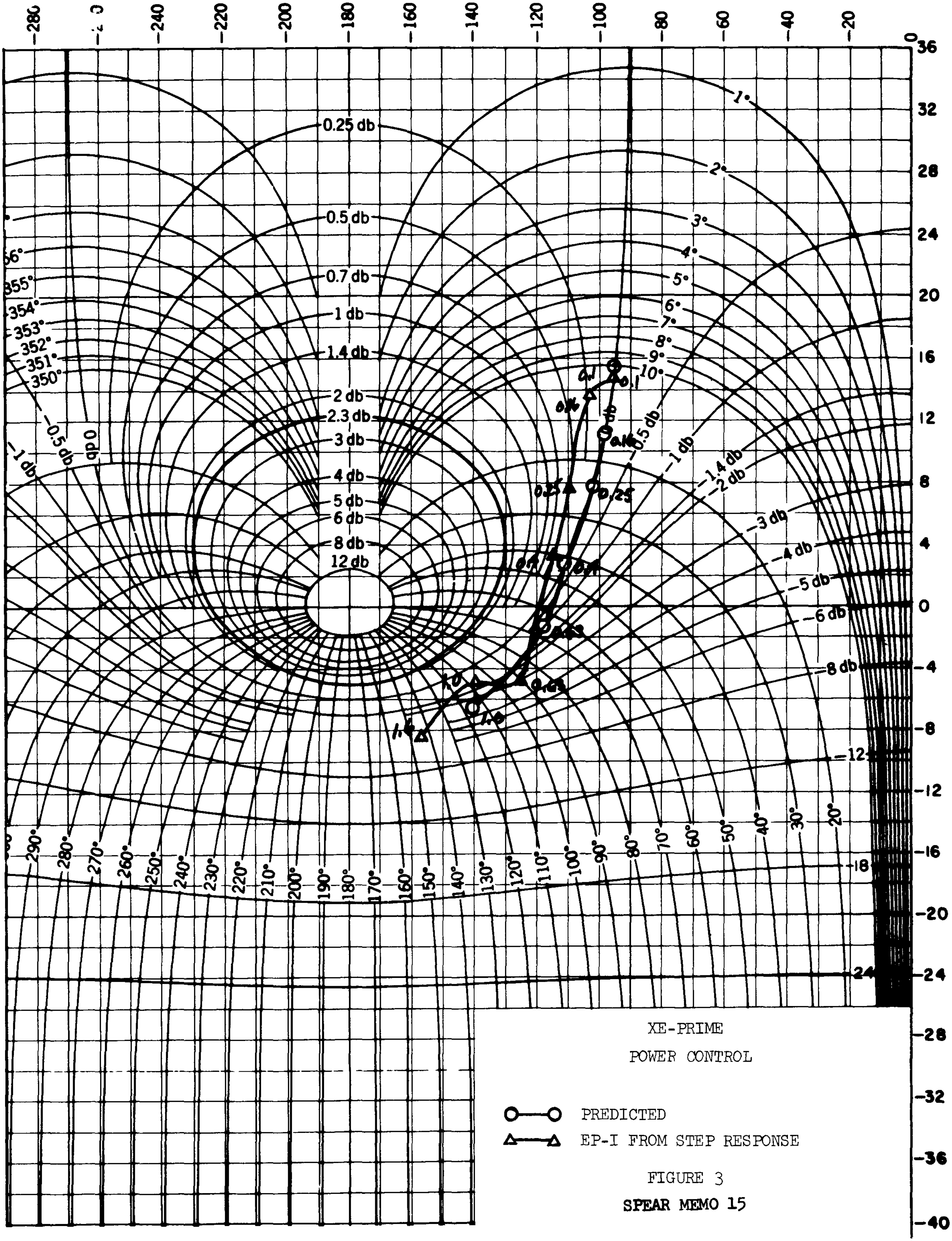
EP-SL2

DEMANDED and MEASURED POWER vs. TIME



XE-PRIME
EP-I
100w STEP IN LOG POWER DEMAND
at 1 kw
RUN DATE 12/4/68

FIGURE 2



XE-PRIME

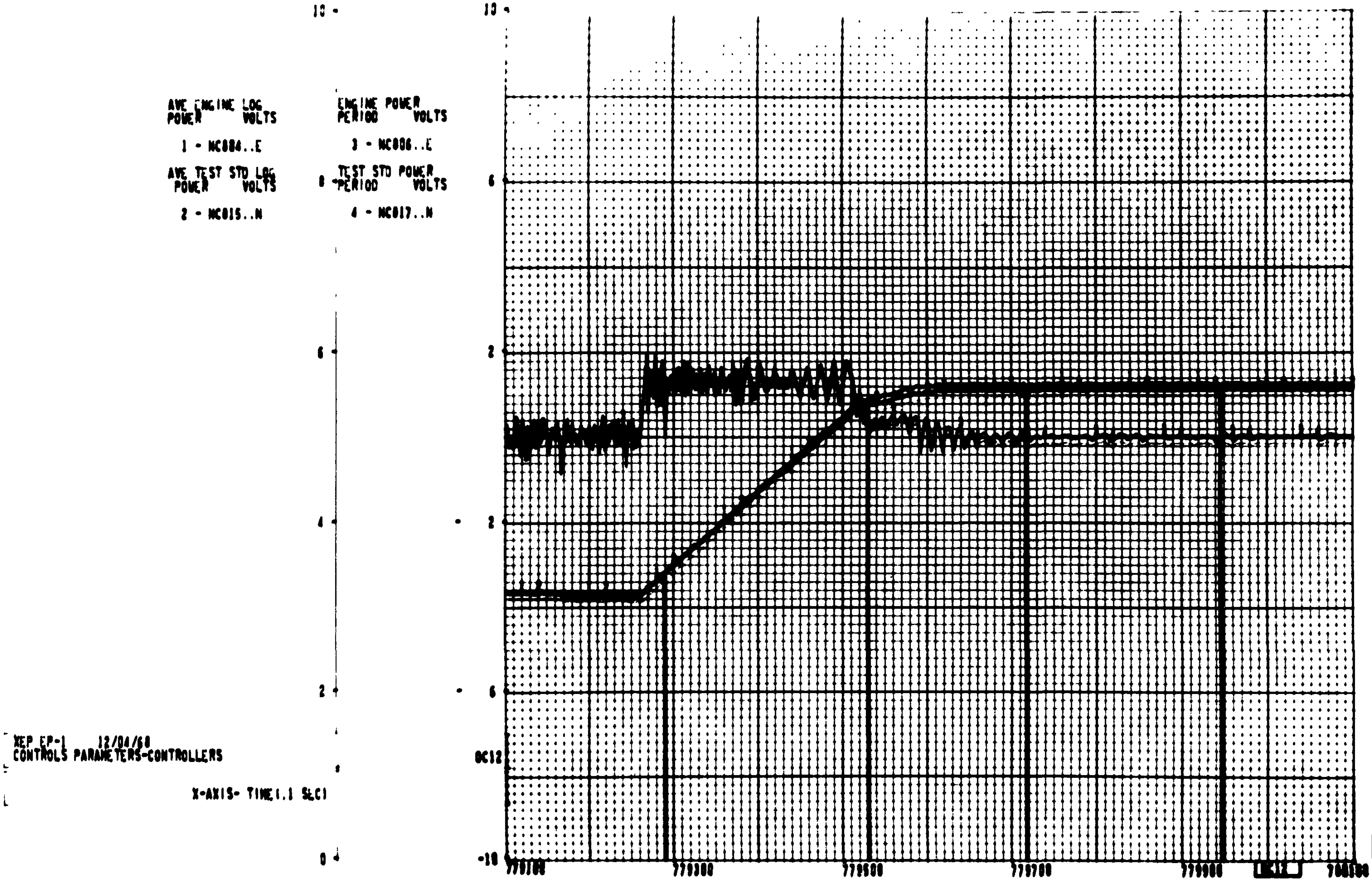
POWER CONTROL

O——O PREDICTED

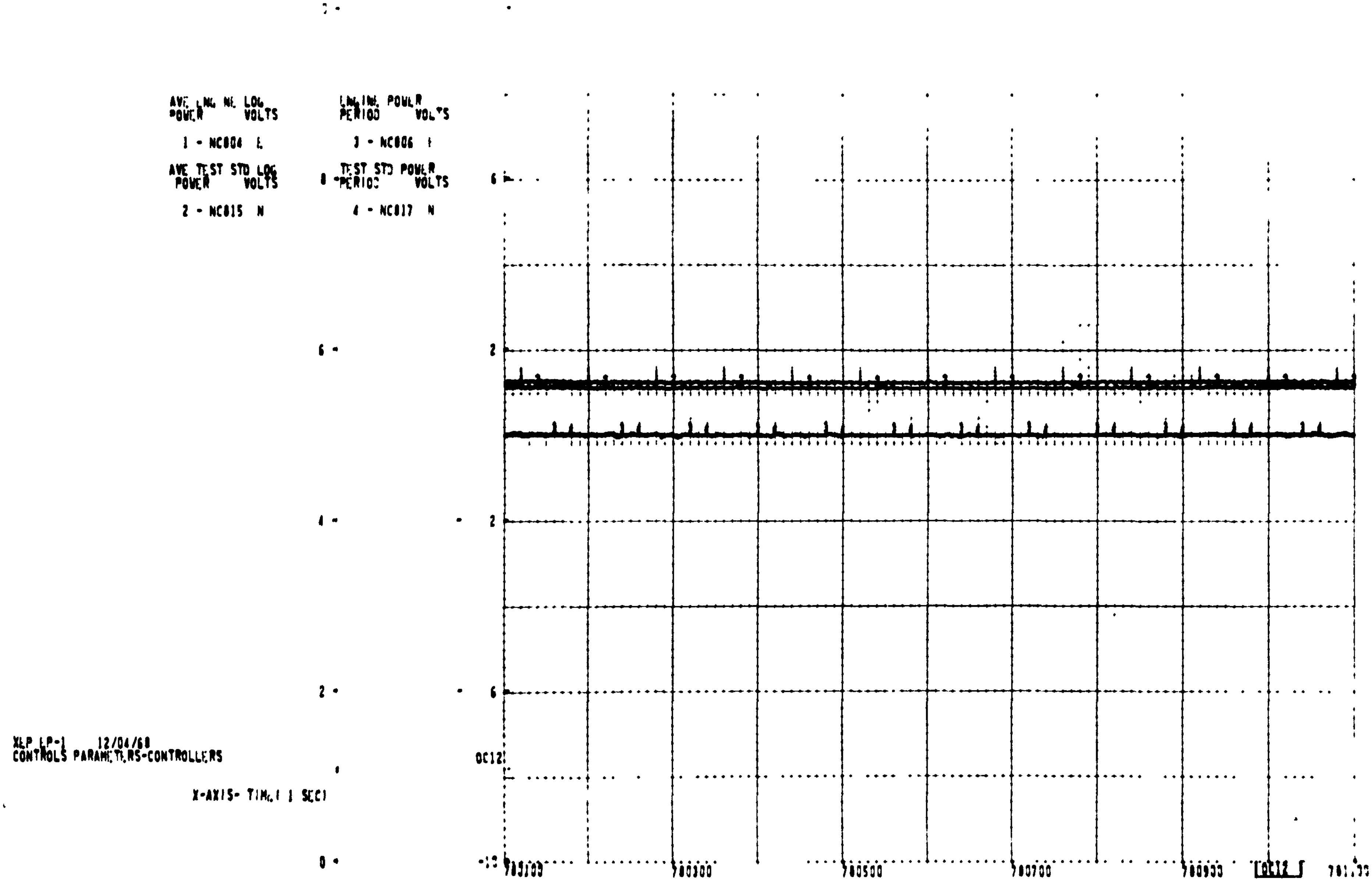
△——△ EP-I FROM STEP RESPONSE

FIGURE 3

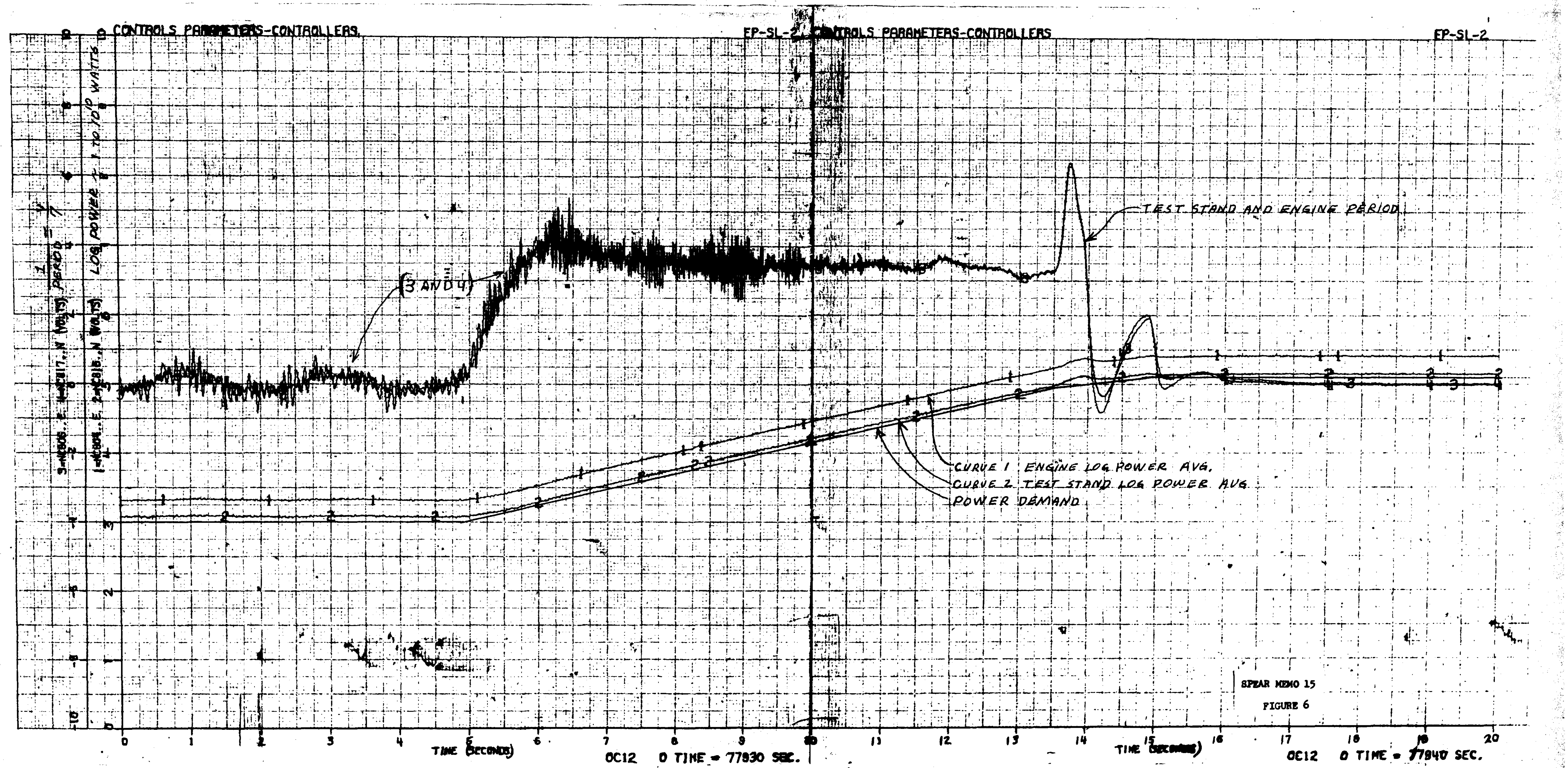
SPEAR MEMO 15



SPEAR MEMO 15 FIGURE 4

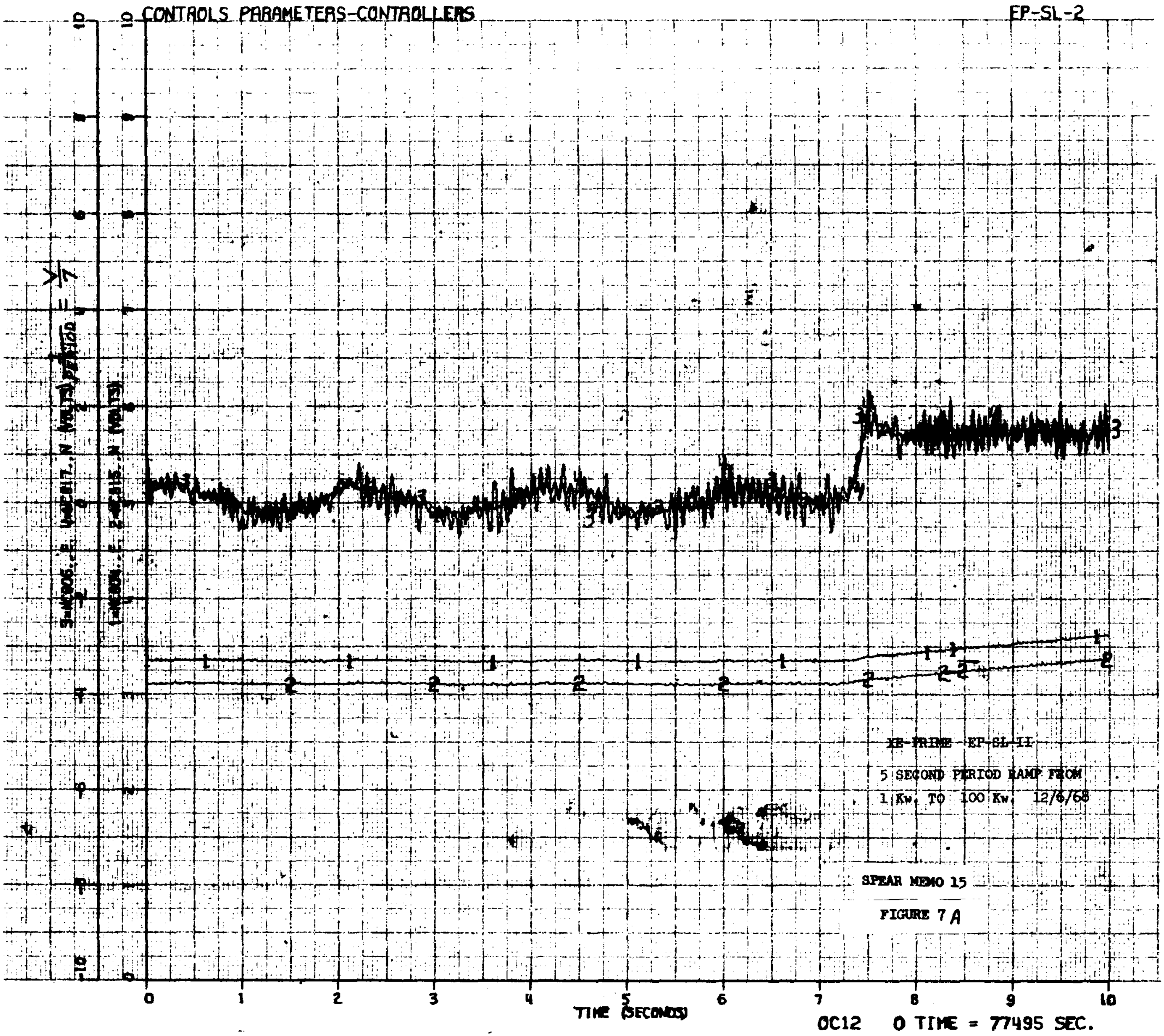


SPEAR MEMO 15 FIGURE 5



SPEAR MEMO 15

FIGURE 6



SPEAR MEMO 15

FIGURE 7A

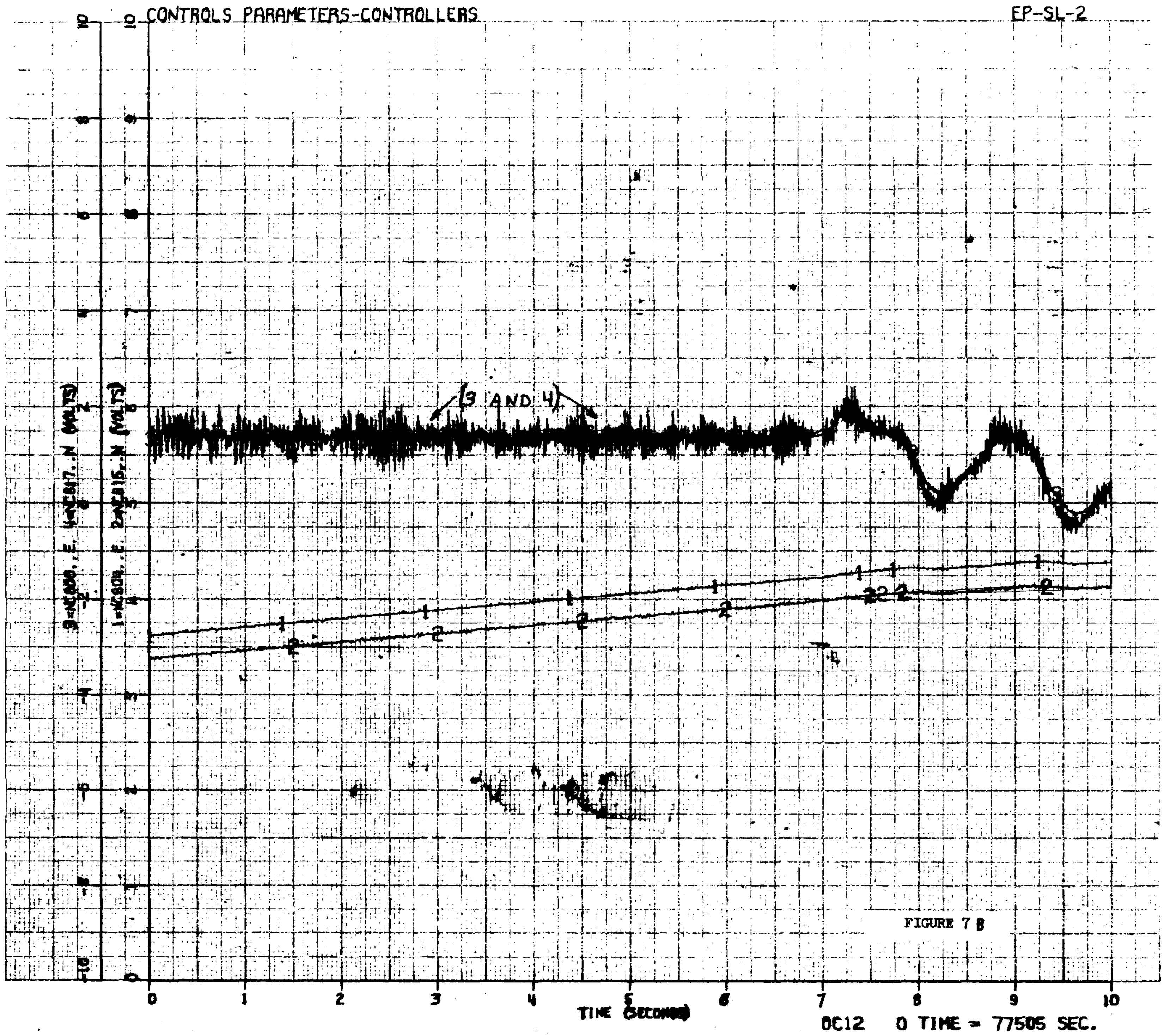

CONTROLS PARAMETERS-CONTROLLERS
EP-SL-2
(3 AND 4)
TIME (SECONDS)
0C12 0 TIME = 77505 SEC.

FIGURE 7 B

CONTROLS PARAMETERS-CONTROLLERS

EP-SL-2

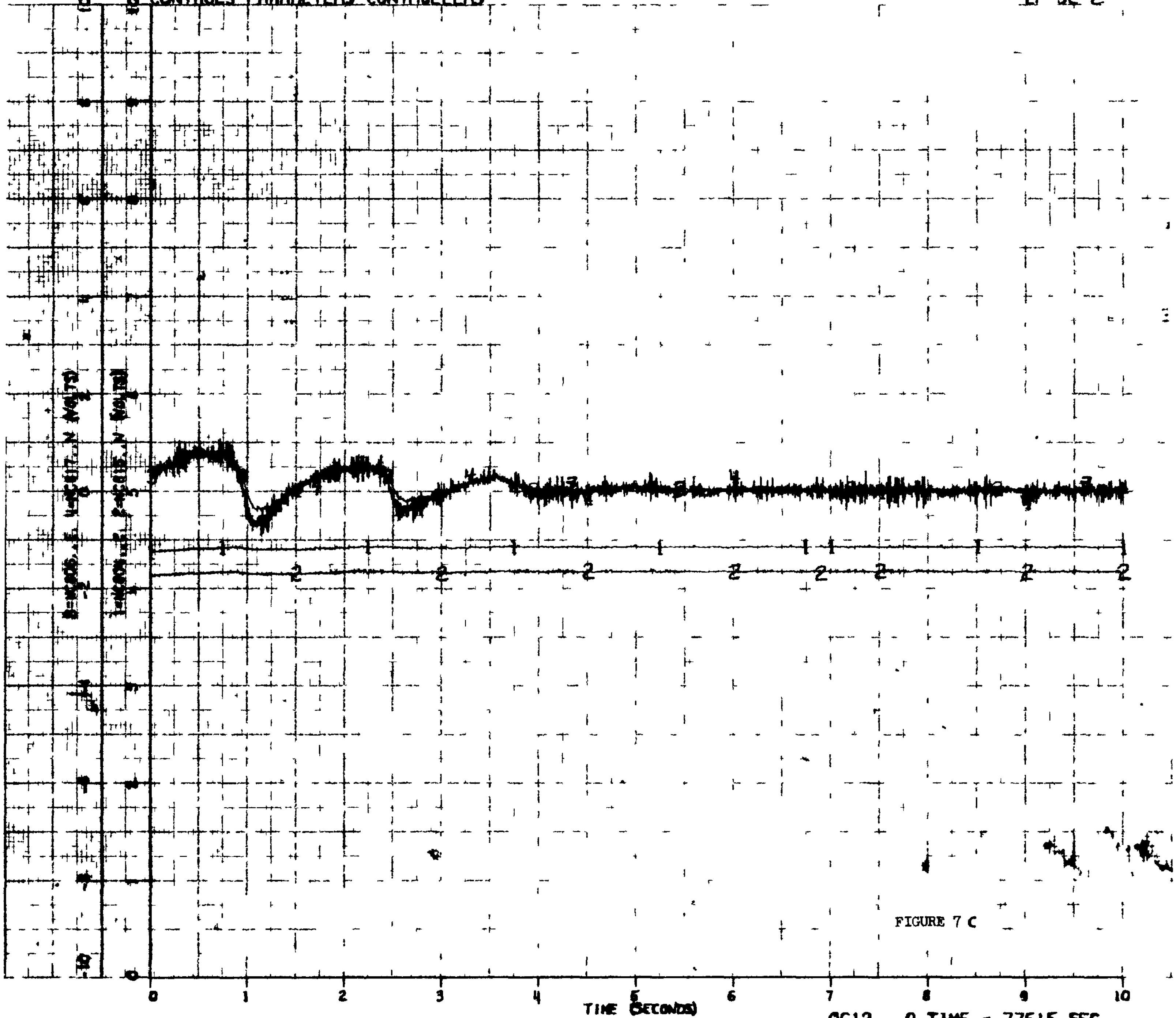


FIGURE 7 C

OC12 0 TIME = 77515 SEC.

SPEAR Memo No. 16
J. D. Miller: ssm

XE-PRIME

EP-I and EP-SL2

Subject: DRUM POSITION CONTROL AND OVERRIDE EVALUATION

INTRODUCTION

This memo is concerned with the static accuracy and the dynamic control characteristics of the drum position control loop and the operation of the drum demand override.

Drum position dwells, regardless of whether power or position control was being exercised, suitable for evaluating static accuracy occurred numerous times in EP-I and EP-SL2.

Step and sine wave responses in position Control were measured at two different points in EP-I: 1) At a subcritical drum position of approximately 47 degrees near 42000 seconds and 2) at the 98.2^{O} indicated critical position near 75000 seconds.

SUMMARY

The static error (measured exceeding demanded) in the drum position Control loop, based on measured data, apparently had a well defined maximum which varied from 1 degree at 10 degree drum position to 3.4 degrees at 100 degree drum position. This error is sufficiently outside the specified static accuracy of $\pm 1^{o}$ so as to require evaluation prior to the next test.

Step responses in position control can accurately be described as first order exponential behavior. Average time constants are .140 - .180 sec and average time delays from demand to measured position are .180 - .220 sec.

Frequency response measurements were within tolerances, repeatable and showed a bandwidth of 1.1 cps and adequate gain and phase margins.

Drum overrides occurred only in position control and could not be evaluated because of inoperative data channels.

TECHNICAL DISCUSSION

1. Static Accuracy

There are twelve drum actuator control position loops. In operation a ganged drum position demand CC800 is compared against either feedback position potentiometer cup "A" or "B" on each actuator, and the actuator moves to minimize the error. In operation, the operator adjusts the ganged drum command until he obtains the desired average of the positions. The static accuracy evaluation is made by comparing the ganged drum position demand with the computed average drum position.

The position error data shown in Figure 1 for drum angles up to 100° was determined from EP-I and EP-SL2 for long dwell periods in either position or power control.

The drum demand, CC800, was averaged over 5 consecutive thinned listing times (generally 1 second apart) and the average drum position computed from individual drum positions at the center of the 5 point interval. The spread in drum demand over the 5 times was typically 0.3 degrees and the range in individual drum positions at a given time averaged 2.3 degrees in EP-I and 1.6 degrees in EP-SL2. While the computed average drum position is, of course, actually only that available from the individual position measured, it is inherently a better value than the electronically computed average, channel D 800.

The characteristic drawn in Figure 1 is actually the best fit for all the EP-SL2 data and as such is well defined.

The EP-I data approaches this characteristic as a maximum but in several areas of the position range drops below it in a well defined manner.

The indicated static error shown in Figure 1 exceeds the specified static accuracy of $\pm 1^{\circ}$. Investigation of this discrepancy is beyond the scope of the Spear effort and source engineering will evaluate the problem prior to the next test.

2. <u>Step Response</u>

Figures 2 and 3 illustrate drum demand, drum #1 position and average position response for successive in and out steps in position control during EP-I. The reactor was critical and drums were stepped in 2 degrees at 75680 seconds and out 2 deg at 75685 seconds. The plots are from zero-suppressed (bias eliminated and scale expanded) wide band data processed through a 23 cps filter and are relatively noise free.

The function generator yielded a relatively clean step which settled out in 5-10 milliseconds. The generator output is summed with the manual drum demand in a circuit with a 0.1 sec time constant. This indicates that the drum demand should move to the new level in an exponential manner with 63.3% of the change accomplished in 0.100 sec. The actual drum demand shows a time constant within 5% of this value. The actuator transfer function (drum demand to drum position) does not include the summer effect because both input and output are measured downstream of the summer. Since the summer is bypassed in power control, the only reason for considering its effect is to explain the shape of the drum demand step response.

Both the #1 and the average positions show first order responses with time constants and time lags behind the drum demand tabulated in Table. 1. Both position channels show larger time constants and slightly greater delays for the outward step. The average (of the 2 steps) time constants are .140 - .180 sec and the average delays are .180 - .220 sec.

Both position channels show a 0.1 - 0.2 degree creep back towards the pre-step position 1 to 2 seconds after the exponential rise.

Frequency response computed from these steps by AGC program 2909 did not provide usable data due to noise problems.

3. Frequency Response

Sine wave response in position control was measured in EP-I at 1) 47 deg drum position near 42000 sec and 2) at the 98.2° critical position near 75000 seconds.

The first transfer function measurements were made at 10 frequencies in the 0.1 - 16.0 cps range. The peak to peak demand amplitude was 2 deg for the 0.1 and the 0.25 cps frequencies, 4 deg at .63 and 1.0 cps and decreased with increasing frequency thereafter because of the summer transfer function previously discussed. The second transfer function measurements were for 5 frequencies ranging from 0.25 to 2.5 cps with a low frequency amplitude of 3 degrees. This series was terminated on the basis of insufficient response indicated on control room strip charts. As determined later, the higher resolution of the wide band system and the frequency analysis program permitted usable data to be obtained.

Figures 4 and 5 show the zero-suppressed demand, drum #1 position and average drum position responses for 0.25 and 0.63 cps, respectively, in the later series of sine wave studies. The actuator back lash characteristics are shown to be more dominant for drum #1 than for the average drum position.

Figures 6 and 7 show the log magnitude and phase (Bode) plots for the drum #1-to-demand and the average position-to-demand transfer functions, respectively. The data were determined from the wide band zero suppressed channels by AGC Program 2909. Meaningful signal strength, in comparison to noise, exists only up to 1.6 - 2.5 cps. Excellent agreement is shown between the first and second response tests and between drum #1 and average position transfer functions. The transfer function bandwidth (response down 3 db) are 1.1 cps for both responses.

Figure 8 gives a Nichols chart presentation of open and closed loop position control stability for the average drum position transfer function. Gain is plotted against phase for the two sine wave tests. The open loop characteristics are given by the rectangular gain - phase grid and the closed loop characteristics by the curved grids. The gain margins (gain at 180° phase lag, open loop) are 19 and 10 db for the first and second tests, respectively. The phase margins (phase at 0 db, open loop) are 62 and 59 degrees for the first and second tests, respectively.

These margins are very close to the commonly specified values and are therefore considered adequate to demonstrate closed loop position control stability.

It should be noted that the drum control system is non-linear and that dynamics characteristics would be expected to be different for other amplitudes.

4. Drum Demand Override

The drum override is set to track the drum demand at a rate which increases with the error between demand and tracker up to a maximum of 1.25 deg/sec at a 2.5 deg error. When the demand exceeds the tracked value by more than 8.5 deg the tracked value replaces the demand as the required drum position.

This operation is complemented by sending the manual position demand pot output to the drums when an override has occurred. Since this pot follows the override tracker when in power or temperature control, the override becomes effective at the drums to reduce the drum demand if an override has occurred.

In position control the manual demand pot is hand-set and does not follow the override tracker. The pot output in this mode goes to the drums by both the normal and the override paths. A drum override therefore can occur in position control without affecting the drums.

While numerous drum overrides were observed in position control, none were observed to occur in power control. Operator observations were relied upon since BC-662, drum override, did not indicate any override during either test and was apparently inoperative.

The operation of the drum demand tracker could not be determined because wide band channel CC631, drum override, was apparently not functioning, at least during EP-I.

Since channel CC 631 records the manual demand pot, it would not have shown the operation of the tracker in the position control mode which is the only one which significantly exercised the system. This could be remedied by recording this channel directly from the tracker output.

RECOMMENDATIONS

1. Average drum position should be computed and included in the digital listing.

2. The indicated discrepancy between the drum demand and the computed average drum position should be corrected before the next test.

3. Transfer function measurements should not be aborted on the basis of control room strip charts which may not have enough resolution.

4. The wide band drum override channel should be recorded at the tracker output rather than at the manual position demand output in order to show tracker functioning in the position control mode.

ANOMALIES

1. Zero suppressed channel CX902, DX902 and DX903 ranges were incorrectly specified as ± 4. 5 per cent instead of 4. 5 degrees.

2. Channel BC-662, drum override, and CC631, drum override were not functioning.

3. Drum demand, channel CC800, was plotted as negative on AGC narrow band plots for EP-SL2 and was not plotted at all for EP-I because of the polarity error.

TABLE 1

POSITION CONTROL STEP RESPONSE CHARACTERISTICS

QUANTITY	ZERO-SUPPRESSED CHANNEL	STEP	TIME CONSTANT SEC	TIME LAG BEHIND DRUM DEMAND
Drum Demand	CX902	IN	.105	
		OUT	.105	
Drum # 1 Position	DX903	IN	.132	.218
		OUT	.163	.232
Avg Drum Position	DX902	IN	.145	.175
		OUT	.220	.187

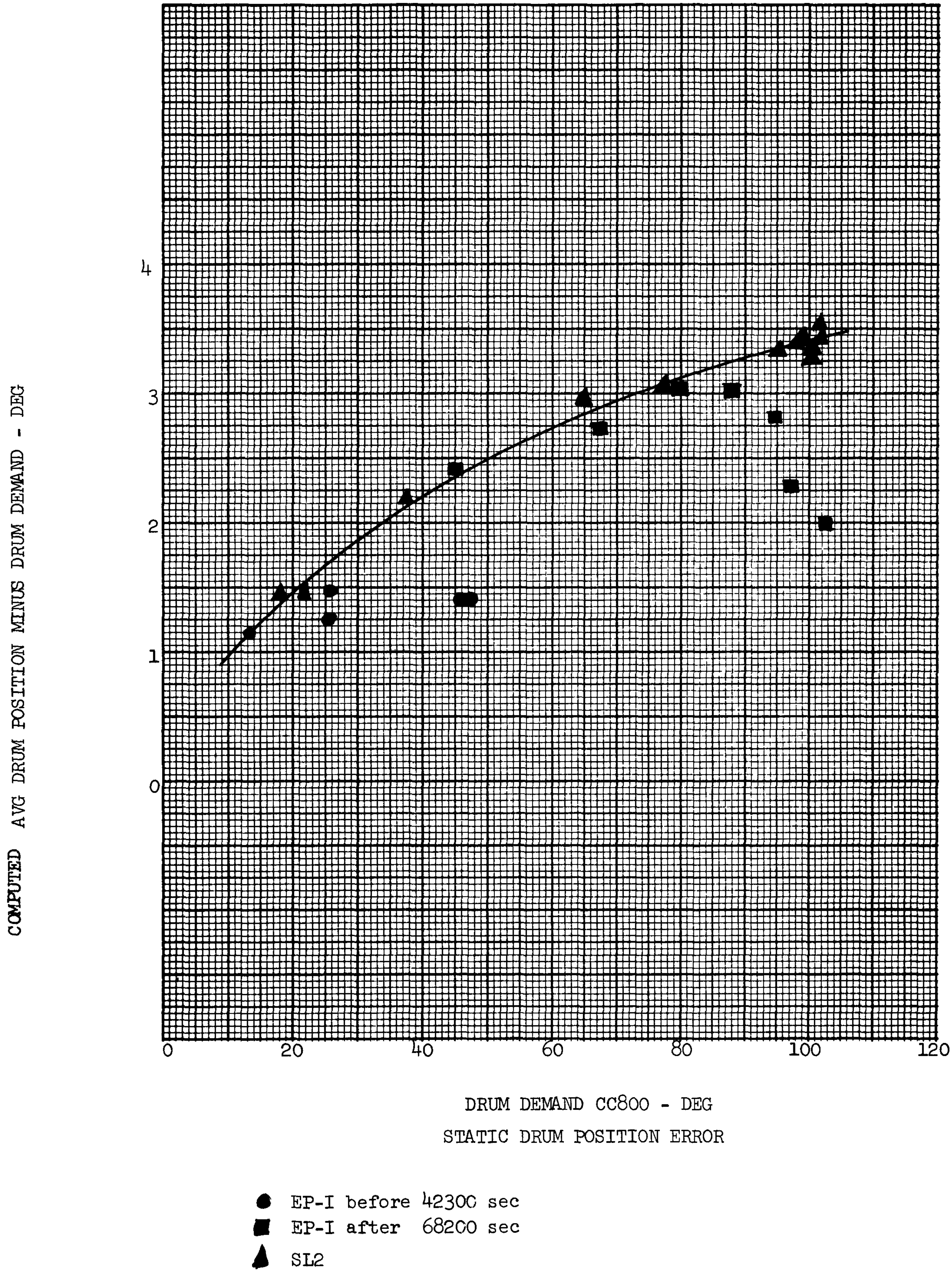

COMPUTED AVG DRUM POSITION MINUS DRUM DEMAND - DEG
4
3
2
1
0
0
20
40
60
80
100
120
DRUM DEMAND CC800 - DEG
STATIC DRUM POSITION ERROR
EP-I before 42300 sec
EP-I after 68200 sec
SL2

FIGURE 2

DRUM STEP RESPONSE

REACTOR CRITICAL

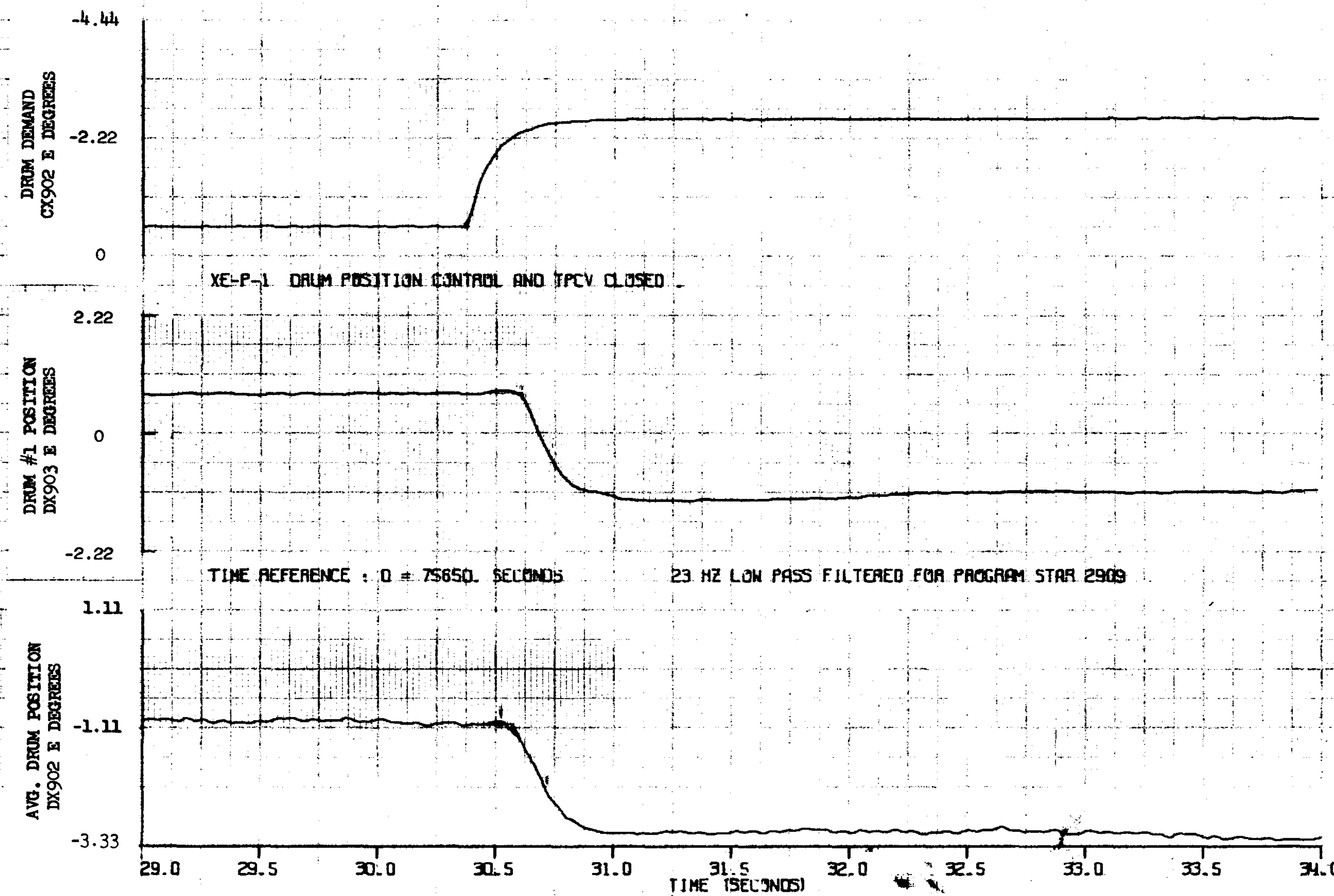


FIGURE 3
DRUM STEP RESPONSE
REACTOR CRITICAL

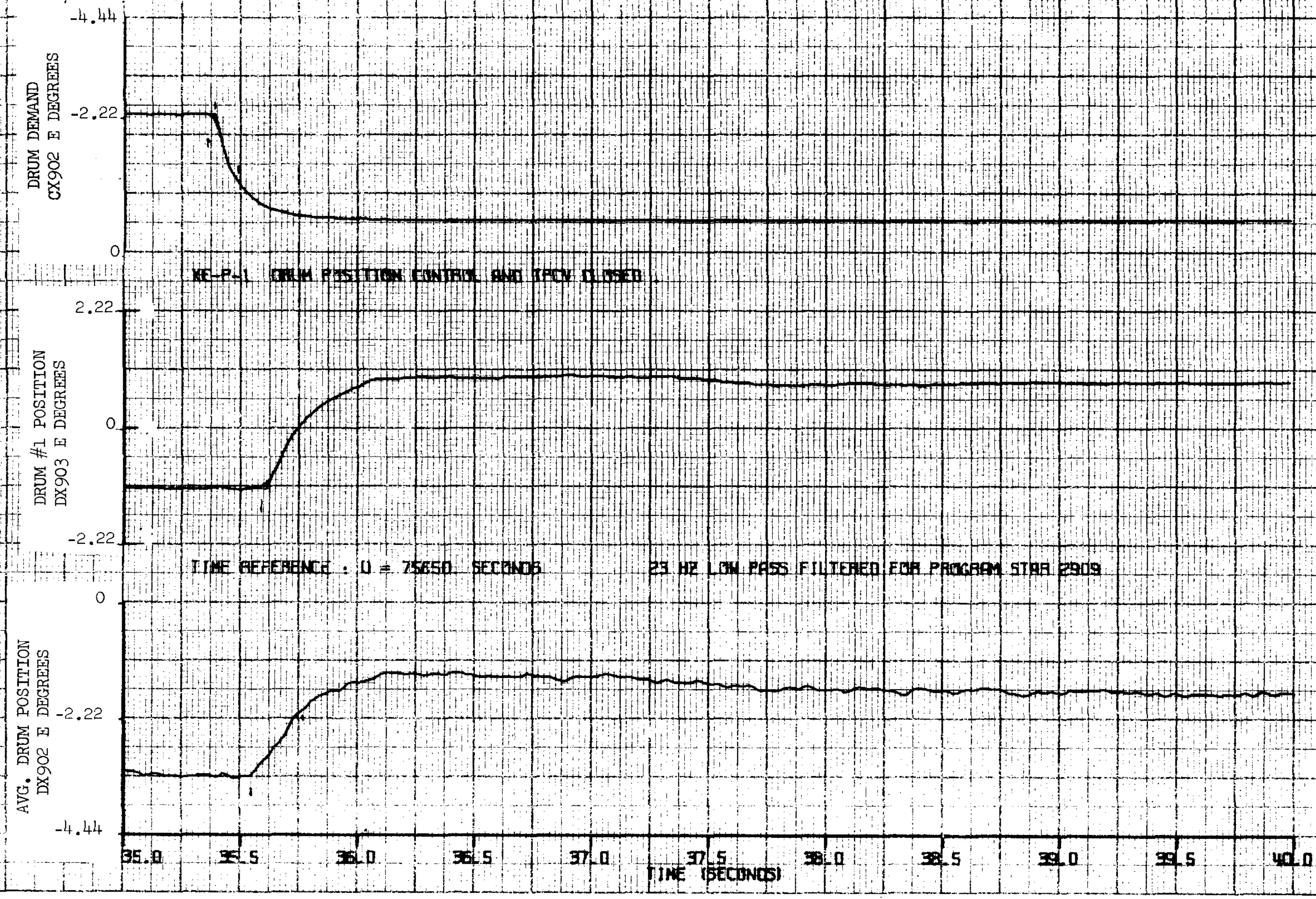


FIGURE 4

DRUM SINE WAVE RESPONSE

0.25 CPS

REACTOR CRITICAL

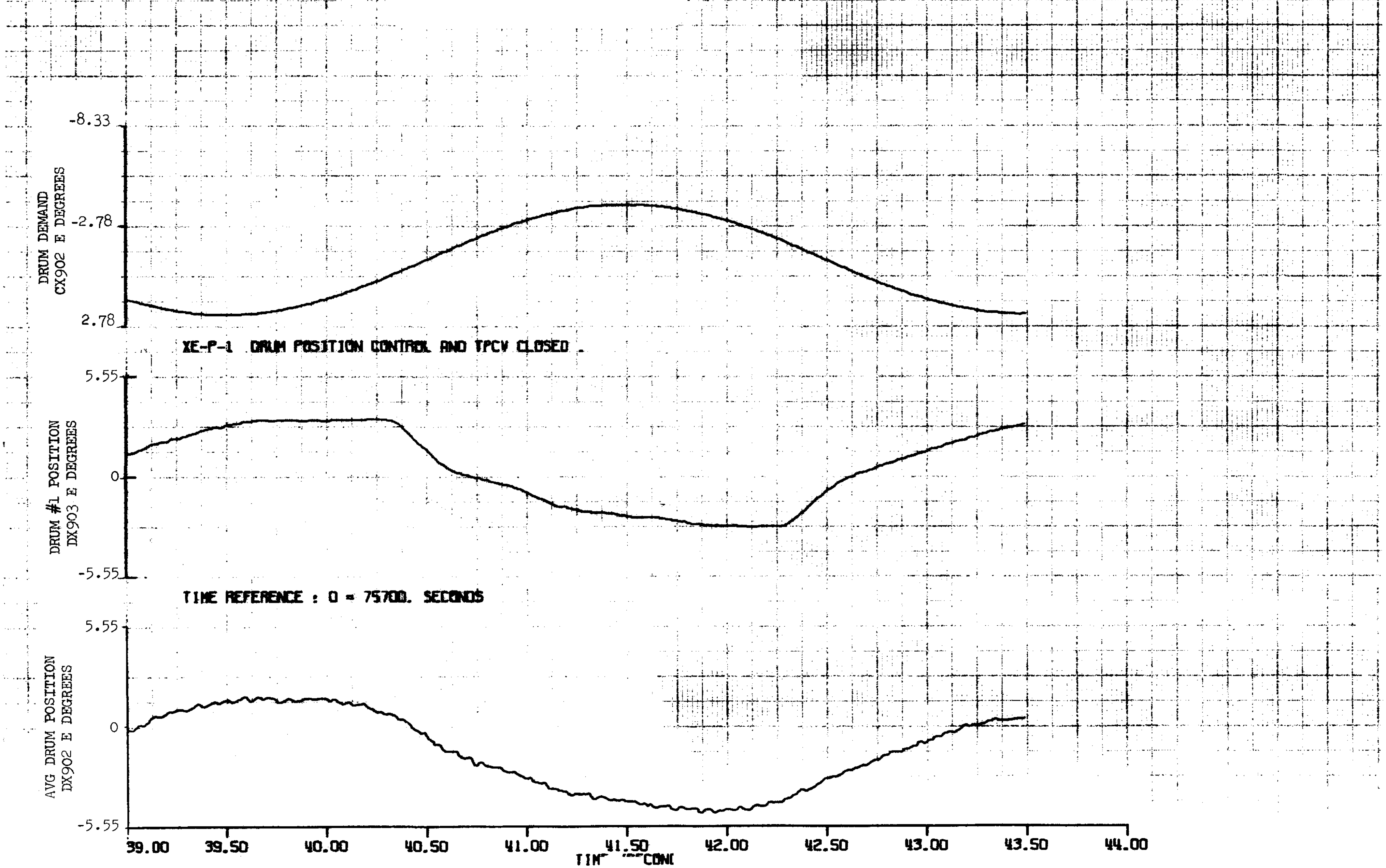
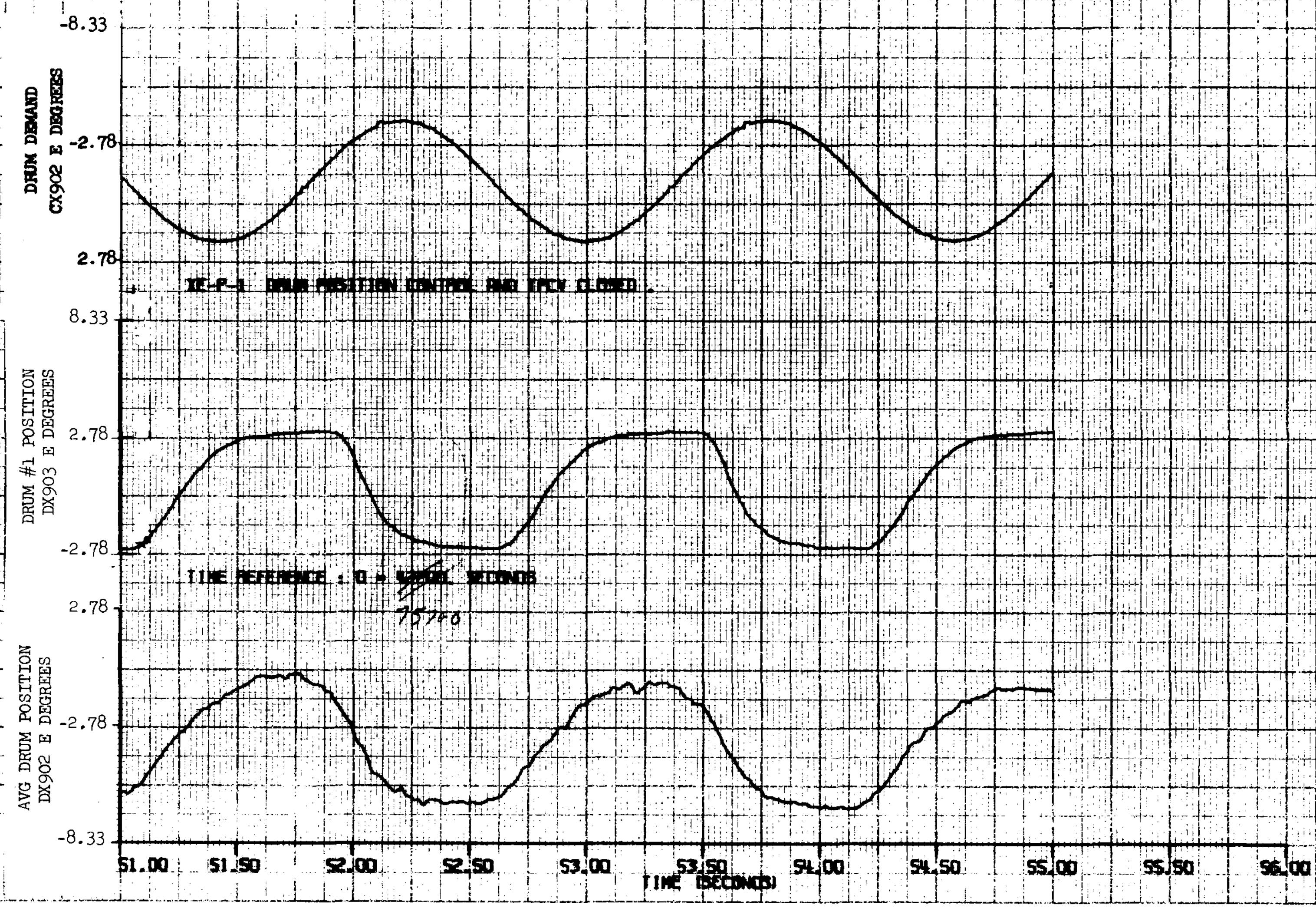


FIGURE 5

DRUM SINE WAVE RESPONSE

0.63 CPS

REACTOR CRITICAL



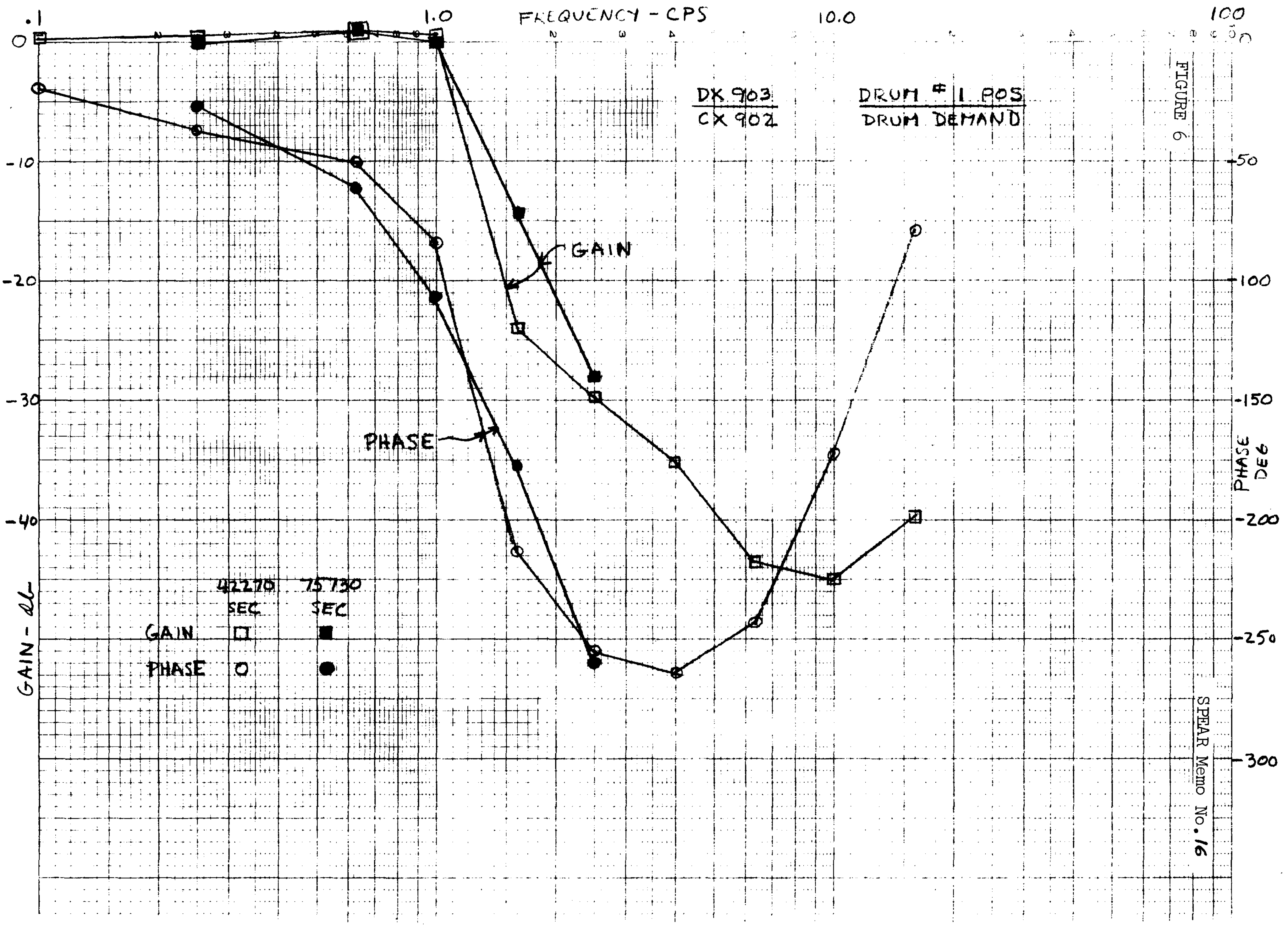


FIGURE 6

SPEAR Memo No. 16

NO 3400 L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

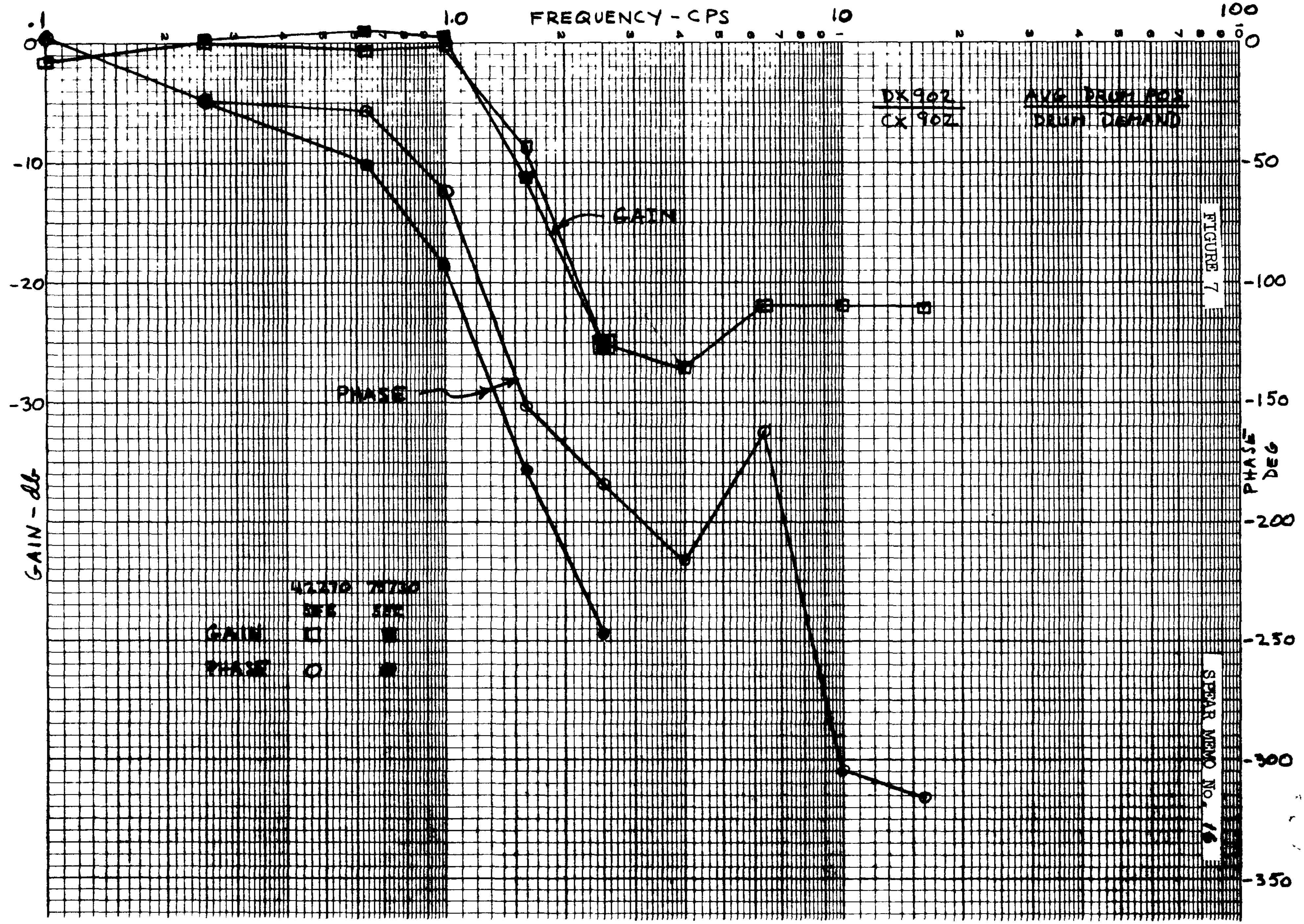


FIGURE 7

SPEAR MEMO No. 16

SPEAR Memo No. 16

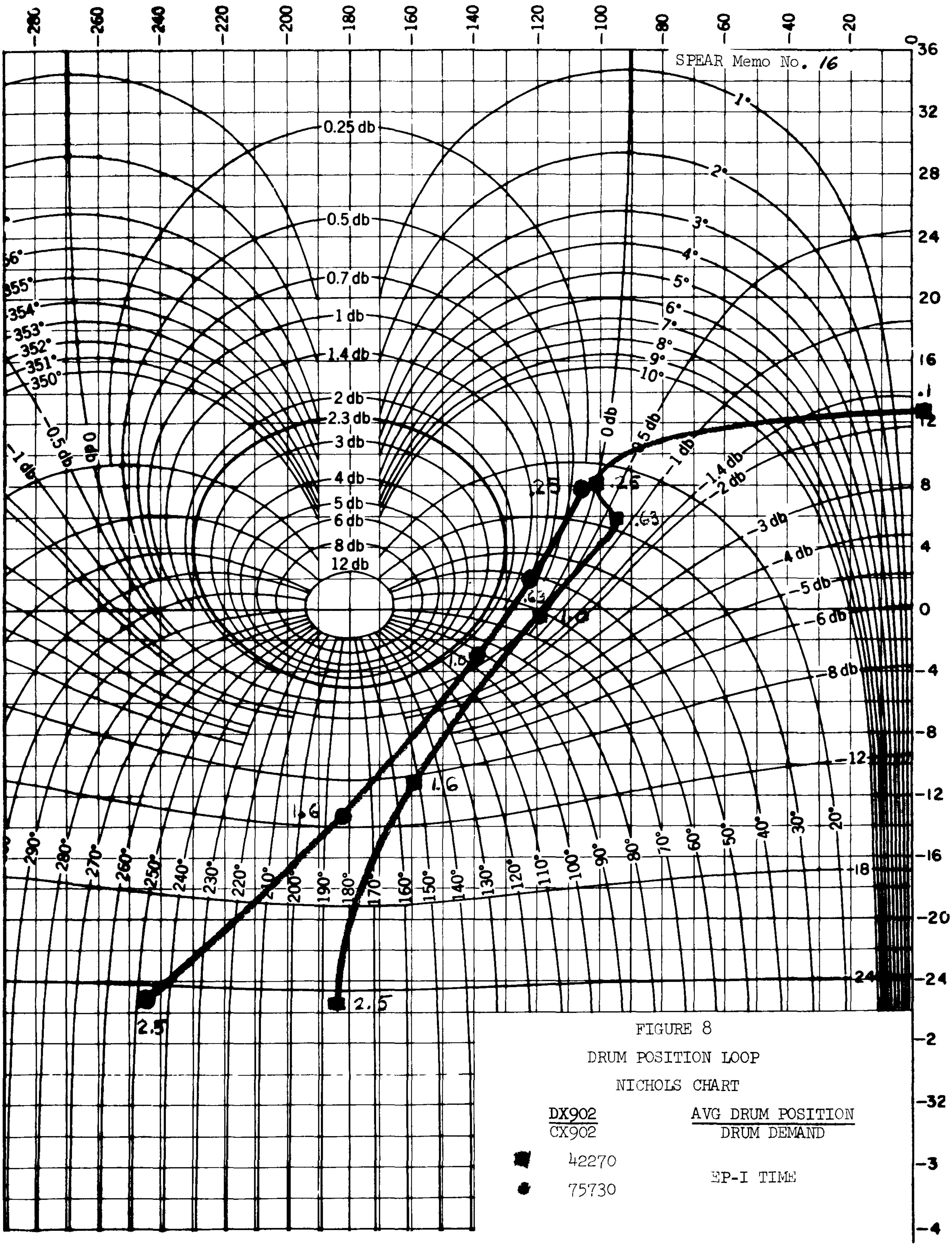


FIGURE 8

DRUM POSITION LOOP

NICHOLS CHART

$\frac{\text{DX902}}{\text{CX902}}$	$\frac{\text{AVG DRUM POSITION}}{\text{DRUM DEMAND}}$
■ 42270	EP-I TIME
● 75730	

SPEAR Memo No. 17

T. A. ~~Keasling~~ TAK, /NH/BSM

XE-PRIME

EP-I AND EP-SL2

Subject: PHASE II NES STEAM LINE AND STEAM GENERATOR SYSTEM TEST INSPECTION OBSERVATIONS

INTRODUCTION

Pre-test and post-test inspections of the NES steam supply system were performed for the Phase II tests. The observations related to these inspections and measurements are reported herein.

SUMMARY

Inspections and measurements of the steam generators, water separator and steam line to the NES duct were made before and after the Phase II test. The positions of the several steam system elements, relative to fix facility points, were determined. Torque measurements were made on bolts in the steam line flanges and also for the generators injectors stud bolts.

Several discrepancies were noted in the steam generators components during the testing activities.

The steam line installation does not appear to have suffered any detrimental effects during the Phase II test.

TECHNICAL DISCUSSION

Pre-test Activities

Following the conduct of the Phase I NES Steam Line Demonstration Tests, completed on 9 October 1968, and the subsequent inspection which was covered in SPEAR Team Report NTO-R-0161, activities performed preparatory for the Phase II test included the items listed below:

1. The steam generator modules steam plenum Station (Module) No. 1, which was found to have several cracks in a circumferential weld, was repair welded.

2. The steam generator modules were re-assembled utilizing several new major components, as described in Table No. 1.

3. All of the generator modules first stage ignitor pressure switches (50-PDS-413) were replaced with newly serviced items.

4. The individual generator module control box electrical connectors were "potted" with RTV-11 compound to get an improved water-tight connector installation.

5. The steam generators injection water control system was modified for improved water flow control, as described elsewhere in this report.

6. The steam separator was disconnected from adjacent piping and moved about 18 inches to allow entrance through the inlet flange. The four internal wall-mounted brackets (Drawing NRO-1135263-18), which formerly restrained the heat shields, were removed. (The heat shields were removed prior to EP-II-2, as reported earlier.) The carbon flakes residue was removed from the bottom of the separator and the water drain line.

7. The separator water drain valve 50-RSV-439 was inspected subsequent to the publication of the Phase I Tests SPEAR Report. This inspection revealed a 1/8-inch to 1/4-inch thick coating of carbon was present on the inlet and outlet ports and around the plug and on the valve stem; carbon was noted between the seat and plug, holding the valve open; several pieces of carbon were found above and below the valve seat. The valve was cleaned, re-assembled and re-installed in the separator drain line.

8. The new NES steam line installation was completed by the PMI contractor. NTO personnel installed the temporary steam line instrumentation and adjusted the several steam line "constant-load" hangers.

10. Satisfactory SGS hot gas system leak tests were performed by installing a blind disk between the separator inlet flanges.

11. The final steam piping closures were completed and the several 18-inch and 20-inch diameter flanges were engaged using the bolt torques listed below: (Note: The bolt threads and nuts flange-contact face were lubricated.)

    a. Plenum steam outlet flange 447 ft-lb.
    b. Separator inlet flange 737 ft-lb.
    c. Separator steam outlet flange 1190 ft-lb.
    d. Separator outlet 20-inch elbow downstream flange 1190 ft-lb.

12. A pre-test inspection of the steam system was made; measurements of the positions of the steam generator plenum, separator and steam line were taken and recorded. Close examination of Modules No. 2 and 3 ignitors (Nos. 880007 and 880008, respectively) revealed that the first stage fuel pressure and cooling water pressure sensing (1/4-inch) taps positions were "approximately interchanged" when compared to previously used ignitors; this condition required re-plumbing to correctly connect 50-PS-422-2 and -3 coolant water pressure switches, in order to acquire the proper indication for coolant "Water OK" lights for these modules.

Post-Test Inspection

The NES Steam Line Phase II Test was conducted on 6 December 1968. During the testing activity inspections of the steam generator system included the items below:

1. Liquid oxygen leakage was observed (by the TV camera coverage) from Module No. 1, second stage LO_2 shutoff valve inlet fitting. The fitting "O" ring was replaced and no further leakage occurred.

2. The injection water control valve of Module No. 1 would not respond to commands from the FEL control console. A transistor in the valve control circuit was found to have failed and was replaced, and satisfactory valve operation was obtained.

3. Module No. 3 failed to start on several attempts because ignition of propellants in the second stage ignitor was not obtained. Functional checks indicated the second stage LO_2 shutoff valve was not opening (actuation gas pressure was present), but after warming the valve and additional operating cycles were performed, the valve functioned normally. During succeeding test operations, the module was started successfully.

4. Observations (by TV camera coverage) of the steam line in the duct vault during the test revealed that the water from an ETC shields discharge line was being sprayed on the steam line cover and Gimbal No. 1, and also on the steam line to NES duct severance plane coupling.

Following the Phase II Test, inspections were made of the steam generators and plenum, the water separator and steam line. Observations made during these inspections are described as follows:

1. The steam generator modules pressure switches were checked for actuation at specified pressures with the following results:

   a. Module No. 1 Switch 50-PDS-480 operated slightly out of specification (at 8.2 make, 3.9 break) and was readjusted to required limits of 7 ± 1 psig make, 5 ± 1 psig break.

      All other Module No. 1 pressure switches operated within the prescribed limits.

   b. Module No. 2 Switches 50-PDS-406 and 50-PDS-480 operated slightly out of specification; 50-PDS-406 operated at 11.6 psig make, 5.8 psig break, and was re-adjusted to specification of 12 $^{+0}_{-2}$ psig make, 8 ± 2 psig break; 50-PDS-480 actuated at 7.9 psig make, 5.7 psig break, then 8.2 psig make, and was then readjusted to operate per specification at 7 ± 1 psig make, 5 ± 1 psig break.

      Switch 50-PS-422 was found to have a cracked fitting in the case, and was replaced with a new switch.

      All other Module 2 pressure switches operated within the prescribed limits.

c. Module No. 3 Switches 50-PS-422 and 50-PDS-480 operated out of specification; 50-PS-422 actuated at 16.2 psig make, 11.4 psig break, and was re-adjusted to operate within the required $20 {}^{+5}_{-0}$ psig make, 15 $\pm$5 psig break; 50-PDS-480 operated at 8.4 to 8.1 psig make, 6.1 to 6.2 psig break, and was re-adjusted to operate within specification of 7 $\pm$1 psig make, 5 $\pm$1 psig break.

All other Module No. 3 pressure switches operated within the specified limits.

2. The steam generator modules injector bolts "breakaway" torque was checked as noted below. Prior to the Phase II test, all modules injector bolts had been torqued to 500 ft-lbs.

   a. Module No. 1. Injector bolts breakaway torque varied from 100 ft-lb minimum to 260 ft-lb maximum, with average torque of 175 ft-lb; all bolts were then re-torqued to 500 ft-lb.

   b. Module No. 2. Three injector bolts could be turned by hand, two were noted to have 5 ft-lb breakaway torque, and remaining bolts breakaway torque was 100 ft-lbs or less; all bolts were re-torqued to 500 ft-lbs.

   c. Module No. 3. The injector bolts breakaway torque varied from 170 ft-lb minimum to 425 ft-lb maximum, with the average of 310 ft-lb; all bolts were re-torqued to 500 ft-lbs.

3. The steam generators propellants supply plumbing was leak tested; Module No. 1 second stage LO_2 shutoff valve was found to be leaking through the valve seat, and the LO_2 bleed line thermocouple was found to also be leaking. No other leakage was observed in either the propane or oxygen supply systems.

4. The second stage LO_2 shutoff valves in Modules No. 1 and 3 are scheduled to be replaced; the hot gas and propellant manifolds will be leak tested after the component replacement is accomplished.

5. The propane supply line filter 50-LF-436 was inspected and the filter element was found visually clean.

6. The plenum steam outlet flange bolts breakaway torque was found to vary from 150 to 400 ft-lb; the average breakaway torque was 250 ft-lb; all bolts were re-torqued to 447 ft-lb, which was the prescribed pre-test torque value.

7. The spearator inlet flange bolts breakaway torque was noted to vary from 150 to 450 ft-lb; the average breakaway torque was 230 ft-lb. These bolts had been torqued to 737 ft-lb before the Phase II test.

8. The separators outlet steam flange bolts breakaway torque was found to vary from 200 to 600 ft-lbs, with the average torque of 350 ft-lbs. These bolts had originally been torqued to 1190 ft-lbs.

9. The separator-outlet 20-inch elbow downstream-flange bolts were found to have breakaway torque valves of 200 to 400 ft-lbs; the average breakaway torque was 280 ft-lbs. The original torque on these bolts was 1190 ft-lbs.

10. The water separator drain valve (50-RSV-439) was removed and dis-assembled for inspection and servicing. A very light deposit of carbon was noted in the valve inlet passage; the internal surfaces of the valve body were clean and free of carbon. Several small localized areas on the valve plug and seat assembly had very light soot deposits; no carbon was deposited on the valve seat, and the valve in general was clean.

11. Inspection of the gas stream thermocouple probes found all to be tight. Prior to the Phase II test, all probes were installed using metal ferrules, replacing the ceramic ferrules, and no loosening of the thermocouple fittings occurred.

12. Position measurements were made of the steam plenum, separator and steam line, as recorded in Tables II, III and IV.

    a. The steam plenum position was not significantly changed from the pre-test location.

    b. The water separator position appears to have changed slightly, being a little closer to the shadow wall by about 1/8 inch.

    c. The steam line "cold" position after the Phase II test was, in general, lower than the pre-test position, and at the pipe chase lower elbow the decrease in elevation was 11/16 inch; the vertical steam line section in the pipe chase was also displaced toward the shadow wall approximately 1/4 inch when compared to the pre-test location.

13. During the post-test inspection of the steam piping and separator flanges and adjacent weld areas, and of the steam line supports and insulation, no abnormalities were noted. The steam line installation is basically unchanged.

14. The inspection of the internal condition of the NES duct has not been accomplished at the time of writing of this report. This inspection is expected to be performed before additional steam system tests are performed.

RECOMMENDATIONS

1. Incorporate as part of the operating procedure the closing of the separator water drain valve (RSV-439) when operating two generators at full steam temperatures over 760°R, thereby minimizing the carbon deposition in the valve.

2. Several of the steam generators pressure switches actuation pressures changed and the switches required re-adjustment. The replacement of these switches with switches of higher reliability should be made.

3. Post-test torque checks and bolt tightening as necessary should be made a standard procedure for the steam line flanges, since significant decreases in bolt tightness occurred as a result of the test.

4. The steam line position lowered as a result of the test, and if left as is, thermal expansion on a succeeding test will cause snubbers and load hangers to approach or exceed limits of travel. The "constant-load" hangers supporting the steam line in the pipe chase should be re-adjusted to support a greater load, such that the steam line at the lower elbow will be raised approximately one inch, establishing a new support condition for reference on a succeeding test.

5. The water from the shield discharge which sprayed on the steam line in the duct vault during testing should be diverted such that the steam line gimbal and severange plane connector are not deluged during the test.

ANOMALIES

1. The Ignitors S/N 880007 and 880008, first stage fuel pressure and coolant water pressure sensing taps positions are inconsistent with all previously used ignitors.

2. The Module No. 1 second stage liquid oxygen shutoff valve inlet fitting "O" ring seal failed during test operations.

3. A Module No. 1 injection water valve control circuitry transistor failed during test operations.

4. The Module No. 3 second stage liquid oxygen shutoff valve stuck closed and failed to operate during initial generator start-up attempts.

5. Several pressure switches operated out of specified limits during post-test actuation checks and were then re-adjusted:

50-PDS-480-1	50-PS-422-3
50-PDS-406-2	50-PDS-480-3
50-PDS-480-2	

6. Pressure switch 50-PS-422-2 was found to have a cracked body fitting.

7. The generators injector bolt torque was significantly decreased as a result of the test.

8. The steam line 18-inch and 20-inch flanges bolt torques were significantly decreased as a result of the test.

9. The Module No. 1 second stage liquid oxygen shutoff valve leaked through the seat on a post-test leak test. Leakage was also noted at the Module No. 1 liquid oxygen bleed thermocouple on the leak test.

10. The steam line did not return to its pre-test "cold" position.

TABLE I

STEAM GENERATOR SYSTEM MAJOR COMPONENTS

The major components installed in the steam generator modules during the NES Steam Line Demonstration Tests are listed below.

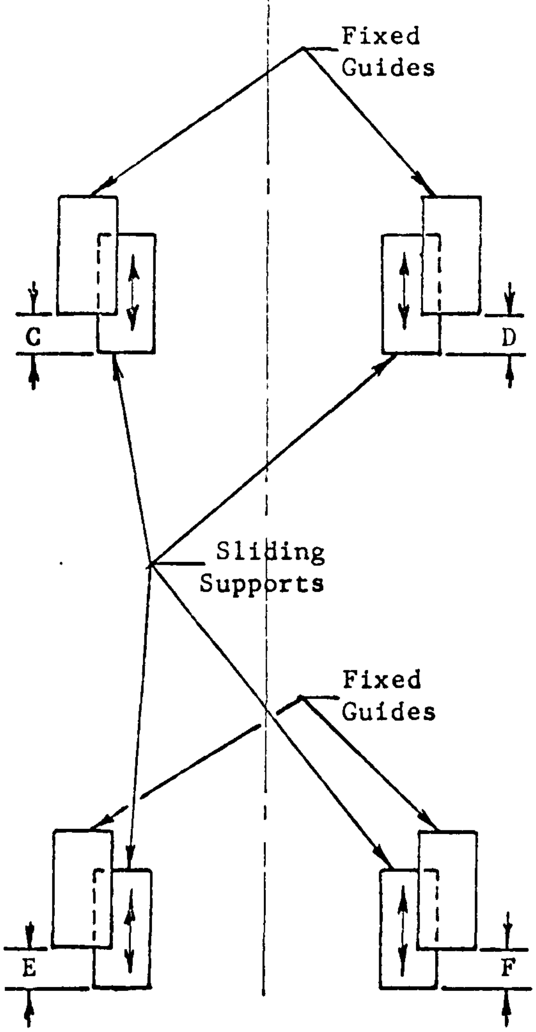
	Phase I Tests	Phase II Test
Module No. 1		
Ignitor	0017	880002
Injector	880001	880002
Chamber	880051	880053
Module No. 2		
Ignitor	880004	880007
Injector	001	0016
Chamber	0017	00101
Module No. 3		
Ignitor	880003	880008
Injector	0017	0017
Chamber	0019	0019

TABLE II

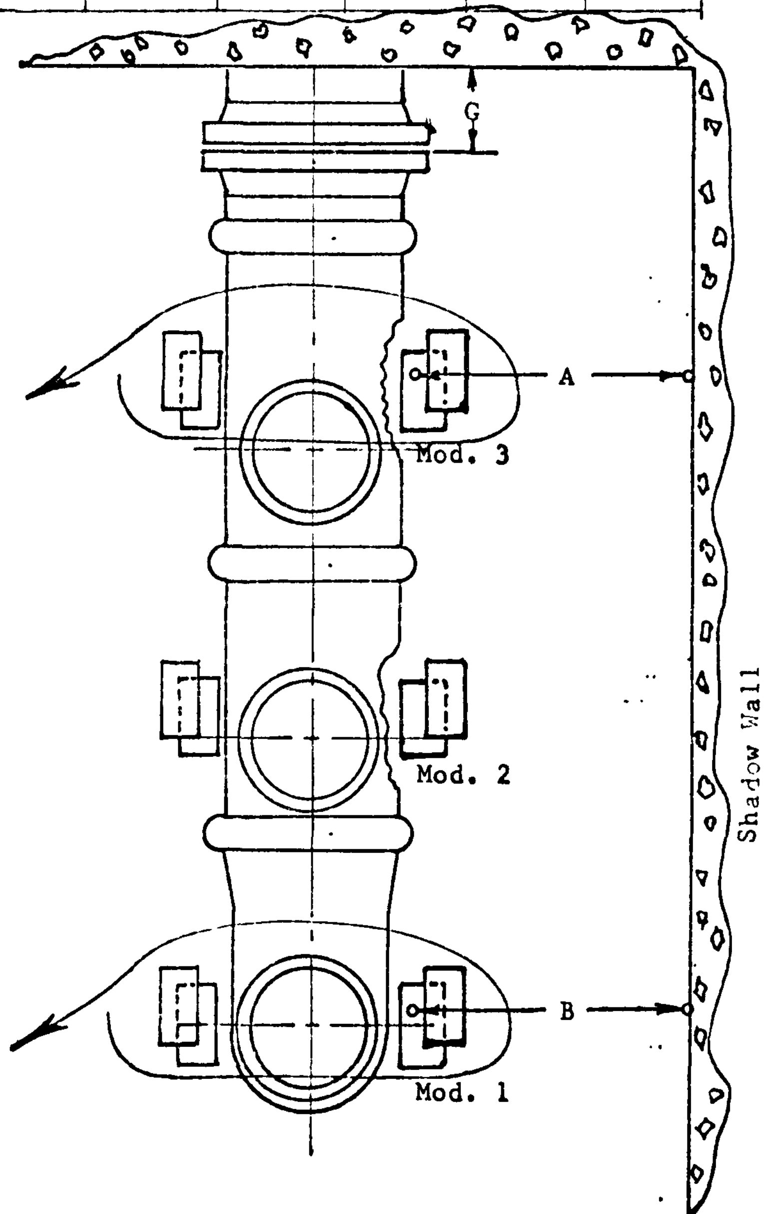
STEAM GENERATOR SYSTEM PLENUM MEASUREMENTS

	A	B	C	D	E	F	G	
Before Phase II Test	$39\frac{1}{16}$	$39\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{7}{16}$	$\frac{3}{8}$	11	
After Phase II Test	39	$39\frac{3}{16}$	---	$\frac{7}{32}$	$\frac{13}{32}$	$\frac{13}{32}$	$10\frac{7}{8}$	

Measurements taken with steel tape.
All measurements in inches.



Sliding Supports
Measurement Details



Plenum Measurements
on Sliding Support

Plenum Plan View

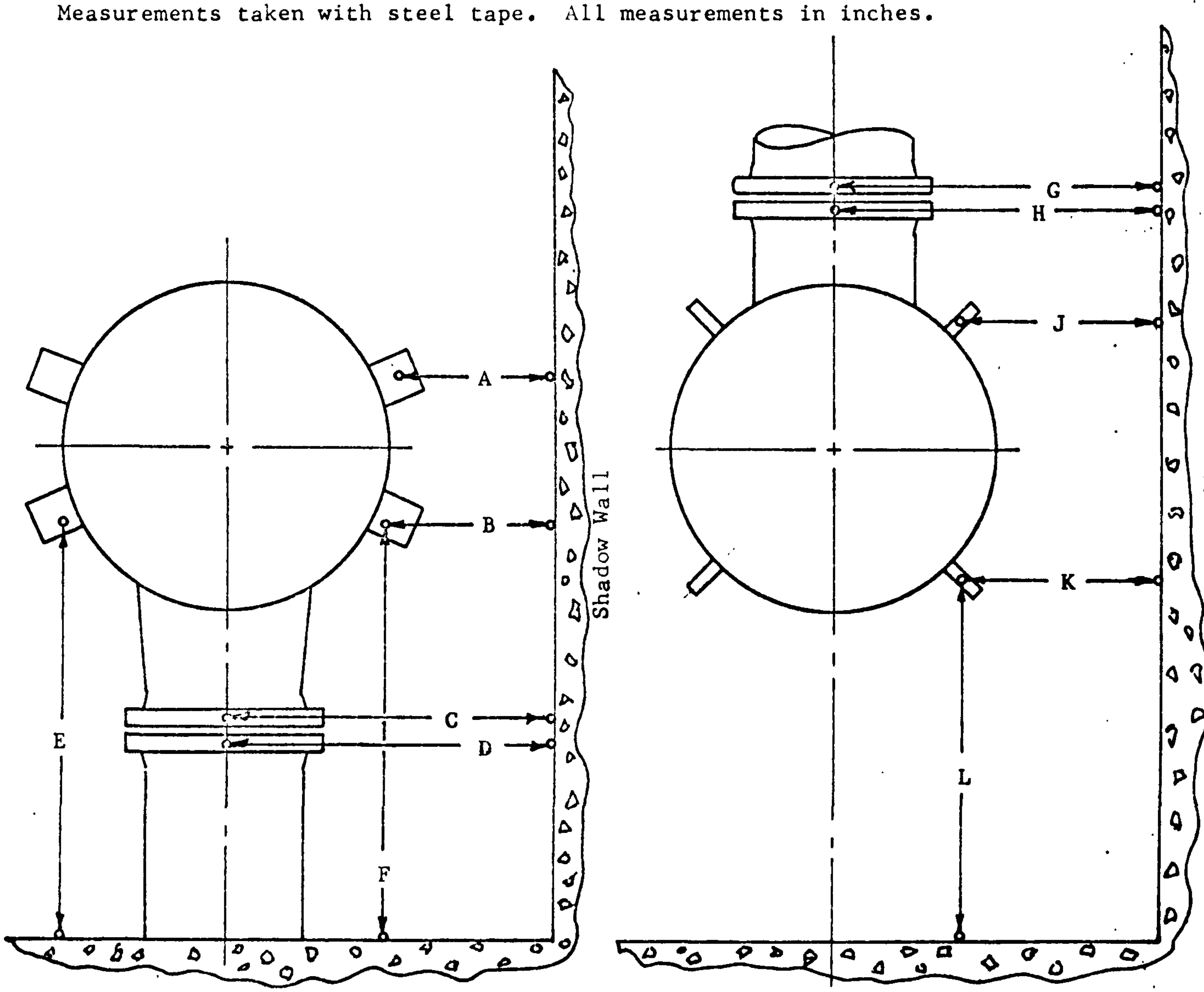
TAK 11-68

TABLE III

STEAM GENERATOR SYSTEM SEPARATOR MEASUREMENTS

	A	B	C	D	E	F	G	H	J	K	L
Before Phase II Test	$34\frac{15}{16}$	$41\frac{13}{16}$	$65\frac{7}{8}$	$65\frac{13}{16}$	$68\frac{3}{8}$	$68\frac{3}{4}$	---	$65\frac{1}{2}$	$44\frac{1}{2}$	$44\frac{7}{8}$	$62\frac{7}{8}$
After Phase II Test	$34\frac{7}{8}$	$41\frac{7}{8}$	$65\frac{13}{16}$	$65\frac{3}{4}$	$68\frac{1}{4}$	$68\frac{7}{16}$	---	$65\frac{1}{4}$	$44\frac{1}{16}$	$44\frac{13}{16}$	$62\frac{15}{1}$[illegible]

Measurements taken with steel tape. All measurements in inches.



Separator Measurements
Near Bottom

Separator Measurements
Near Top

Separator Plan Views

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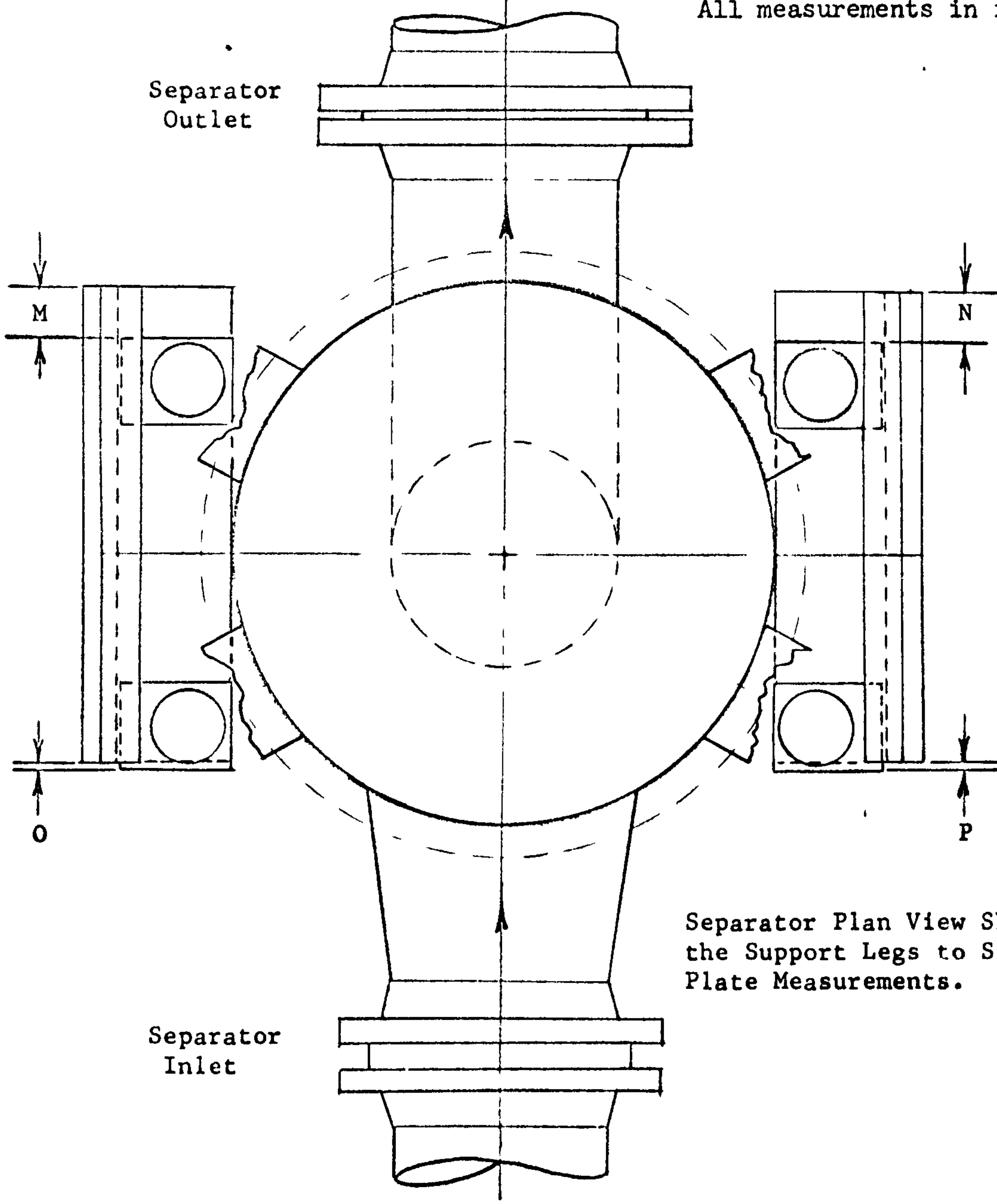
STEAM GENERATOR SYSTEM SEPARATOR MEASUREMENTS (Continued)

	M	N	O	P	
Before Phase II Test	$6 \frac{15}{16}$	$6 \frac{11}{16}$	$\frac{7}{8}$	$\frac{15}{32}$	
After Phase II Test	$6 \frac{15}{16}$	$6 \frac{11}{16}$	$\frac{7}{8}$	$\frac{7}{16}$	

All measurements in inches.



Separator Plan View Showing the Support Legs to Slide Plate Measurements.

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TABLE IV

STEAM LINE POSITION MEASUREMENTS

	A	B	C	D	E	F	G	
Before Phase II Test	40 $\frac{7}{16}$	11 $\frac{3}{16}$	9 $\frac{7}{16}$	41 $\frac{7}{8}$	$\frac{15}{16}$	16 $\frac{1}{2}$	10 $\frac{1}{8}$	
After Phase II Test	40	11 $\frac{5}{8}$	9 $\frac{3}{4}$	41 $\frac{3}{16}$	$\frac{7}{8}$	16 $\frac{1}{2}$	10	

Measurements taken with steel tape. All measurements in inches.

Steam line measurements, taken at various locations on the steam line in the Pipe Chase, are described below and in the sketches on Page 2.

Measurement	Description
A	Steam line elevation at Hanger No. 1A, deck to bottom of insulation.
B	Steam line elevation at Hanger No. 3, ceiling to top of insulation.
C	Steam line elevation at Hanger No. 4, ceiling to top of insulation.

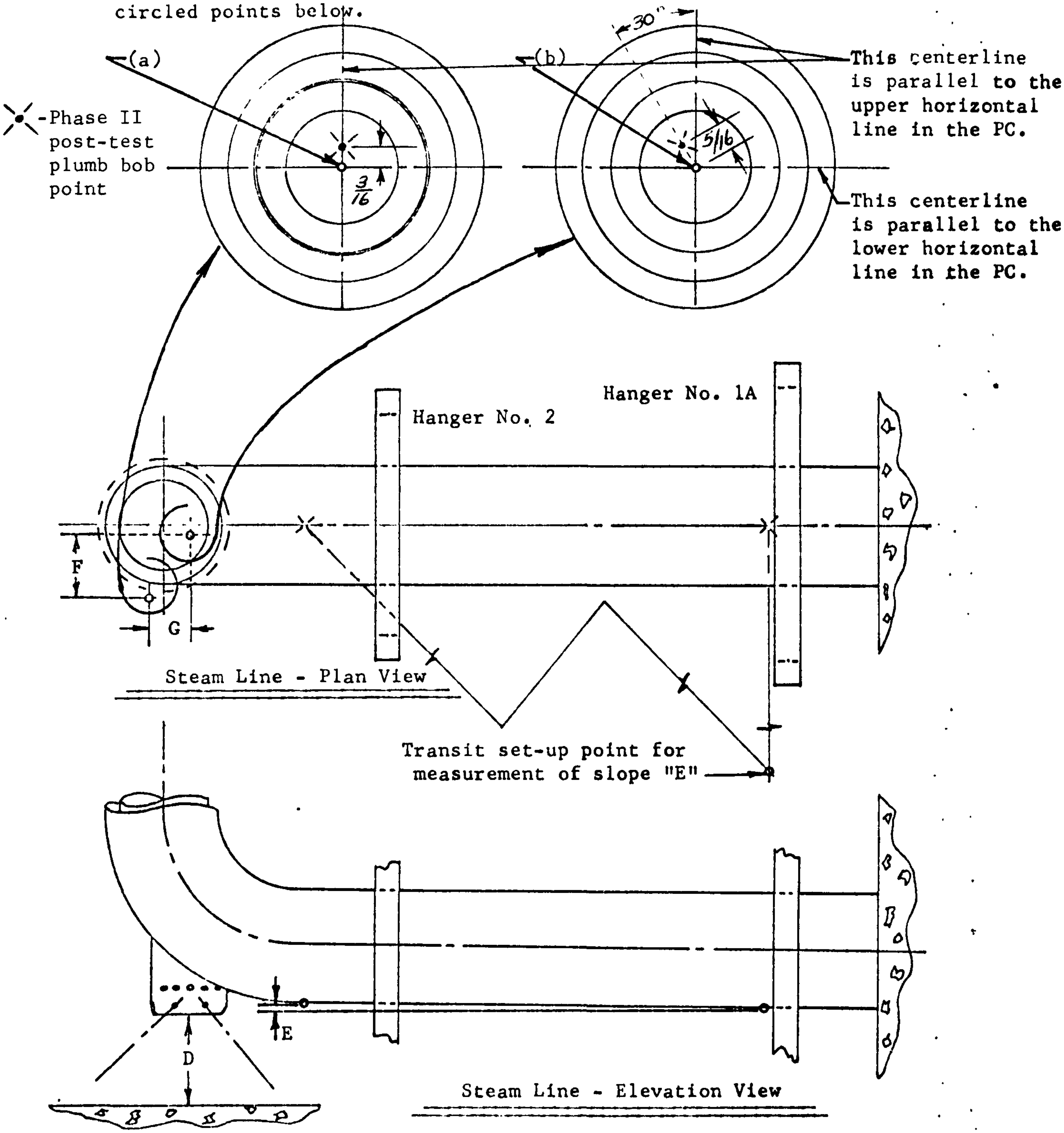
TABLE IV

STEAM LINE POSITION MEASUREMENTS (Continued)

(a) The center point is the "original" plumb bob point from a mark on the upper elbow (gimbal) deflection pots bracket.

(b) The center point is the "original" plumb bob point from a mark on the lower elbow snubber attachment plate.

NOTE: Changes of the plumb bob points from test-to-test will be noted on the circled points below.



Steam Line Measurements in Pipe Chase

SPEAR Memo No. 18
W. L. McCarty W. L. M/AH/BSM

XE-PRIME

EP-I AND EP-SI2

Subject: STEAM GENERATOR SYSTEM PERFORMANCE DURING PHASE II NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

The Steam Generator System (SGS) was tested to evaluate recent modifications to the SGS and installation of the new steam line. Oscillations in steam pressure and temperature had been experienced in the Steam Line Phase I Tests (9 October 1968) and a modification to the SGS Water System had been installed to alleviate the oscillations.

This memorandum will discuss oxygen, propane, and hot gas performance. The performance of the new SGS Water System will be discussed in Memo No. 7.

SUMMARY

The Steam Generator System was run for approximately 740 seconds (two module operation). Several anomalies occurred during the test, the majority of which were due to component failure. The SGS was subjected to an extremely long liquid oxygen bleed-in which contributed to several problems. Also, three times a unit at full steam malfunctioned because of a faulty pressure switch.

TECHNICAL DISCUSSION

Test Outline

Because of various anomalies in the SGS, the conduct of the Steam Generator Test was altered. Table 1 is a brief chronology of the SGS events.

SG-1 and -2 started to idle steam normally. When SG-1 started to full steam, there was a 9-second delay before the sequence started. This was because the water in the high side of PDS-406 was frozen and sensing only 13 psia. Prior to starting, the pressure switch had a negative 194 psi across it. When commanded to full steam, the low side or cavitating venturi throat dropped to 2 psia (10 psid across the switch) and actuated PDS-406, thus starting the sequence. It took 9 seconds for the differential to go from -194 psid to +10 psid. SG-2 was brought to full steam and an attempt made to throttle the water flow through FCV-423-1-2. Because of the frozen line problem, previously mentioned, FT-406-1 was reading around 10 psid on the FEL console. This, along with the operator's indications that the FCV-423-1 indicating potentiometer was not working, caused the Test Director to stop SG-1 and -2.

It was then decided to try SG-2 and -3. SG-2 was brought to idle steam, however, SG-3 was started to idle steam three times without success. There was an indication of a second stage cutout along with no second stage pressure signifying a non-operating second stage propellant valve. SG-2 was then started to full steam and the temperature increased to 950°R and then stopped.

A re-entry was made and the PDS-406/FT406 sensing lines were moved away from the LOX manifold and the second stage propellant valves exercised using the "cold checkout controls." The second stage LOX valve was thought to be hanging up and repeated cycles freed it. A bad transistor was found in the FCV-423-1 potentiometer and was replaced and all three units were subjected to several checkouts using the cold checkout controls. The propellant tanks were then bled-in and re-pressurized and the water manifold pressurized. During this operation there was no indication of "water flow OK" on any of the three units. This indication comes from three pressure switches on the first, second and third stage coolant jackets of each unit, connected electrically in series. The water manifold was depressurized and repressurized. This apparently dislodged the frozen line on SG-1 and -3. Therefore, SG-1 and -3 were brought to idle steam.

SG-1 was brought to full steam but when SG-3 was brought to full steam, SG-1 malfunctioned to stop because of a low steam cutout. This is initiated by the pressure switch PDS-480, connected from the top to bottom of the third stage, deactivating. By this time SG-2 "water flow OK" light had come on. SG-2 was then attempted to start to idle steam twice followed by SG-1. The first stage pressure switch failed to close because of the high pressure (50 psia) present in the combustion chamber as a result of SG-3 at full steam. SG-3 was stopped.

It was desirable to run SG-1 and -2 because of some special instrumentation on their water manifolds. SG-1 and -2 were brought to idle and SG-1 was brought to full steam. SG-2 was brought to full steam and four seconds later SG-1 malfunctioned because of a low steam cutout, the same anomaly experienced earlier. SG-2 was stopped and SG-2 and -3 were brought to full steam and the steam temperature increased to 1260°R and 1560°R, then lowered to 1460° and 1260°R. The duct flow was decreased causing the water flow to the SGS to increase and as a consequence the steam temperature decreased. When the units were being re-adjusted to 1460°R, SG-3 malfunctioned to stop because of a "low steam cutout"; SG-2 was stopped shortly thereafter.

Liquid Oxygen System

The liquid oxygen flow rates to the modules at full steam were very close to the desired 16.4 lb/sec actual versus 16.7 lb/sec required. The LO_2 temperature started at 170°R and dropped to 165°R during the test which is well within the 180°R maximum limit. The LOX usage presented in Memo No. 25 for bleed-in, pressurization and depressurization prior to the long full steam period was 12,000 gallons for 11 hours. During bleed-in some difficulty in obtaining less than 180°R in the manifold was experienced after the manifold was pressurized to 300 psia. This would be expected if, as in this test, a long hold period is experienced after pressurization because the corresponding saturation temperature at 300 psia is 241°R.

Again, the contingency checklist for venting the LOX System was used for this test which involved purging the LOX surge tank and manifold with gaseous nitrogen, and there was no sign of pressure fluctuation in the manifold during steady-state SGS operation.

The vent on the LOX tank RSV-69 took approximately 30 seconds to open at one point in the test. The conditions prior to this were that RSV-69 was opened and the tank was vented from 300 psia to 100 psia and the valve was closed. A re-entry took place and the tank was pressurized. Approximately $3\frac{1}{2}$ hours after the valve was closed another re-entry took place and at this point the valve delayed in opening. It is recommended that this valve be re-worked.

Liquid Propane System

The liquid propane flow rates to the modules was exactly correct at 7 lbs/sec. There were no problems experienced with this system except that RSV-329 was leaking past the seat prior to the test. This should be corrected prior to the next test.

Coolant Water System

The coolant water system which consists of the coolant circuit to the first, second, and third stage plus the plenum was adequate. The maximum temperature recorded was during startup of the second module to full steam (range time 79730) and the outlet temperature for Modules 2 and 3 were 557°R and 537°R and the plenum outlet was 539°R.

As stated earlier, the sensing lines to the coolant water pressure switches PS-422 and PS-423 were frozen along with the sensing line to the high side of PDS406/FT406. The lines should be insulated and, if necessary, re-routed away from the liquid oxygen lines.

SGS Operation

Tables 2 and 3 present some selected parameters for the steam generator system. All values are normal. Table 4 is a list of operating times for the various units.

During the operation of SG-1, FCV-423-1 valve did not respond (range time 59400). A transistor at the console was found to be shorted out. After the problem was corrected, SG-1 was brought to full steam and shutdown twice and FCV-423-1 responded correctly. Apparently, the problem has been solved.

The next anomaly was when SG-3 was attempted to start to idle steam (range time ~ 61401) three times and a second stage cutout was experienced. The cause of this was no second stage combustion. During a subsequent re-entry, the second stage LOX valve was thought to be hanging, thus causing the cutout. Repeated operation freed the valve. SG-2 was run singularly (range time 61605) and the temperature increased to about 950°R.

Another anomaly was when SG-1 was at full steam and SG-3 was brought to full steam (range time 79440) and SG-1 stopped because of a "low steam cutout". This malfunction was similar to the one which happened later when SG-1 was at full steam and SG-2 was brought to full steam (range time 79609) and SG-1 again stopped. Also, when SG-2 and -3 were at full steam (range time 80461), a slight pressure surge caused SG-3 to stop. All three malfunctions were initiated by the de-actuation of PDS-480 which is the differential pressure switch from the top of the third stage to the bottom. The pressure switch is set to de-actuate at 5 ±1 psid. There is no instrumentation on the units to measure the pressure at the top of the chamber; PT-438-1, -2, and -3 measure the pressure at the bottom of the chamber, therefore, there is no data to indicate that there was a differential pressure of 6 psid or less. A post-test inspection revealed that PDS-480-1, 02, and -3 were close to the specified values. However, this is the first time that a module has shut down when another module was brought to full steam which is obviously a normal operation; the pressure surge which was approximately 36 psi/sec was lower than the 54 psi/sec experienced during Phase I steam line checkout test (9 October 1968, range time 57870) and no shutdown was experienced. It is concluded that the pressure switchsPD-480-1 and -3 tended to de-actuate during increasing steam pressure because they were faulty. The switch on Units 1 and 3 should be replaced with either one from spares or a new type. It is also recommended to change the low side sensing point from the bottom of the combustion chamber to the plenum exit flange. (PT-425 location). One sensing line should be connected to all three switches and to a spare port at the plenum rather than PT-425 or PT-426 sensing ports. This change would not compromise the safety aspect of the switch which is to protect the units from a propellant valve closure. Some temporary instrumentation should be installed to sense the chamber differential pressure during the next SGS test.

The three unsuccessful attempts to bring a module to idle steam when one is at full steam (range time 79465) proves the point that it cannot be done. This, however, does bring out the fact that there is an advantage to bringing all three units to idle steam and shutting down the spare module after the other two are at full steam.

RECOMMENDATIONS

1. Rework RSV-69 so that it will not freeze up.

2. Rework RSV-329 so that it will not leak.

3. Insulate and, if necessary, re-route the water sensing lines away from the liquid oxygen lines in the SGS.

4. New type pressure switches should be procured and installed. If this is not done, a new differential pressure switch, PDS-480, should replace the existing switches on Units 1 and 3. The low side port of each switch should be manifolded to a common 1/4-inch sensing line and the line connected to a port on the plenum exist flange. The sensing location should not use the same port as PT-425 and PT-426.

5. The pressure transducers used for PT407X..FSG and PT408X..FSG (first and second stage propane pressure on Module 2) should be temporarily installed to the top of the combustion chamber of Modules 1 and 3 to evaluate the differential pressure during the next test.

6. During engine tests, all three modules should be started to idle steam and the spare module shut down after the other two are at full steam.

7. The second stage LOX valve on Module 3 should be removed, evaluated at cryogenic temperatures and disassembled to determine why the valve hung up.

ANOMALIES

The hardware anomalies for the Steam Generator System are listed in Memo No. 17. In addition, RSV-69 (LOX tank vent valve) hesitated in opening for approximately 30 seconds and RSV-329 (propane tank shutoff valve) leaked past the seat.

The data and instrumentation anomalies are listed in Memo No. 9 . Briefly, the digital data for the SGS parameters was good. The strip chart traces showing BC701W.FSG, BC701X.FSG and BC701Y.FSG (SGS startup traces) were very poor. The traces on BC701W and X went off scale at full steam and BC701Y was off scale when the unit was off. These traces can easily be checked during the conduct of the Electro-mechanical Checklist NTO-SOP-0120.

TABLE 1

	EVENT	RANGE TIME (seconds)
1.	Idle Steam SG-1	59167
2.	Idle Steam SG-2	59176
3.	Full Steam SG-1	59309
4.	Full Steam SG-2	59345
5.	Stop SG-1	59697
6.	Stop SG-2	59705
7.	Idle Steam SG-2	61399
8.	Unsuccessful attempt Idle Steam SG-3 (Second Stage Cut-out)	61409
9.	Unsuccessful attempt Idle Steam SG-3 (Second Stage Cut-out)	61431
10.	Unsuccessful attempt Idle Steam SG-3 (Second Stage Cut-out)	61547
11.	Full Steam SG-2	61605
12.	Stop SG-2	61946
	H O L D	
13.	Idle Steam SG-1	79320
14.	Idle Steam SG-3	79327
15.	Full Steam SG-1	79419
16.	Full Steam SG-3 and SG-1 malfunctioned to stop (Low combustion chamber pressure)	79440
17.	Unsuccessful attempt Idle Steam SG-2 (First Stage Cutout)	79465
18.	Unsuccessful attempt Idle Steam SG-2 (First Stage Cutout)	79482
19.	Unsuccessful Attempt Idle Steam SG-1 (First Stage Cutout)	79493
20.	Stop SG-3	79503
21.	Idle Steam SG-1	79549
22.	Idle Steam SG-2	79557
23.	Full Steam SG-1	79585
24.	Full Steam SG-2	79609
25.	SG-1 Malfunctioned to Stop (Low combustion chamber pressure)	79613
26.	Stop SG-2	79623
27.	Idle Steam SG-2	79640
28.	Idle Steam SG-3	79646

TABLE 1

	EVENT	RANGE TIME (seconds)
29.	Full Steam SG-2	79680
30.	Full Steam SG-3	79721
31.	SG-3 Malfunctioned to stop (Low combustion chamber pressure)	80461
32.	Stop SG-2	80500

TABLE 2

STEAM GENERATOR SYSTEM TEST DATA TABULATION

STEAM SEPARATOR - PHASE II - RANGE TIME 80078.7

PARAMETERS	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO_2 Tank Press. (P-49) psia	307.6				
LO_2 Manifold Press. (P-421) psia	295.4				
LO_2 Manifold Temp. (T-479) ^oR	164.9				
Propane Tank Press. (P-118) psia	298.9				
Propane Tank Temp. (T-483) ^oR	502.4				
Propane Manifold Press. (P-420) psia	291.3				
Propane Manifold Temp. (T-478) ^oR	504.				
Water Supply Press. (P-168) psia	212.4				
Water Manifold Press. (P-427) psia	199.7				
Main Stage Propane Venturi (F-405) psia			287.5	288.1	
Main Stage Propane Flow (lb/sec)			7.02	7.02	
Main Stage LO_2 Venturi (F-409) psia			281.2	282.6	
Main Stage LO_2 Flow (lb/sec)			16.4	16.4	
Injection Water Venturi (F-406) psid			198.3	199.7	
Injection Water Bypass Flow (lb/sec)			5.2	5.0	
Total Injection Water Flow (lb/sec)			40.7	40.7	
Water Film Cooling (lb/sec)		3.33	3.14	3.17	
First Stage Press. (P-416) psia			174.8	179.5	
Second Stage Press. (P-417) psia			171.9	177.5	
Main Stage Press. (P-438) psia			133.8	132.6	
Plenum Press. (P-425) psia					124.9
Steam Line Press. (P-239) psia					116.2
Steam Line Temp. (T-159) ^oR					1432
Total Steam Flow Rate (lb/sec)					131.5

TABLE 3

STEAM GENERATOR SYSTEM TEST DATA TABULATION

STEAM SEPARATOR - PHASE II - RANGE TIME 80020.7

PARAMETERS	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO_2 Tank Press. (P-49) psia	309.6				
LO_2 Manifold Press. (P-421) psia	297.7				
LO_2 Manifold Temp. (T-479) ^{o}R	165.2				
Propane Tank Press. (P-118) psia	298.3				
Propane Tank Temp. (T-483) ^{o}R	502.4				
Propane Manifold Press. (P-420) psia	290.5				
Propane Manifold Temp. (T-478) ^{o}R	504				
Water Supply Press. (P-168) psia	212.7				
Water Manifold Press. (P-427) psia	197.8				
Main Stage Propane Venturi (F-405) psia			285.9	287.1	
Main Stage Propane Flow (lb/sec)			6.97	6.97	
Main Stage LO_2 Venturi (F-409) psia			283.9	283.9	
Main Stage LO_2 Flow (lb/sec)			16.4	16.4	
Injection Water Venturi (F-406) psid			199.5	200.2	
Injection Water Bypass Flow (lb/sec)			4.2	4.4	
Total Injection Water Flow (lb/sec)			39.6	39.8	
Water Film Cooling (lb/sec)		3.09	2.94	2.94	
First Stage Press. (P-416) psia			179.7	184.9	
Second Stage Press. (P-417) psia			177.7	180.6	
Main Stage Press. (P-438) psia			140.1	140.2	
Plenum Press. (P-425) psia					129.2
Steam Line Press. (P-239) psia					121.6
Steam Line Temp. (T-159) ^{o}R					1585
Total Steam Flow Rate (lb/sec)					129.3

TABLE 4

SGS OPERATING TIMES

	IDLE STEAM OPERATION TIME	FULL STEAM OPERATION TIME
MODULE 1	714 seconds	437 seconds
MODULE 2	2000 seconds	1535 seconds
MODULE 3	991 seconds	803 seconds

SPEAR Memo No. 19
J. W. Holaday / JWH/BSH/18.4

XE-PRIME

EP-I AND EP-SL2

Subject: NES DUCT COOLING SYSTEM PERFORMANCE DURING PHASE II NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

The NES duct water coolant system has not been modified since prior to Phase I tests, but the test stand coolant system which operates from the discharge water of the duct was modified slightly decreasing the back pressure at FCV-31.

SUMMARY

The duct was bled in and initial flow was established by opening FCV-31. With FCV-31 100% open, the total duct flow was approximately 12,500 gpm.

RSV-738, RSV-739, RSV-858 and RSV-859 were opened 100%. FCV-32 was then opened approximately 38% establishing a total flow of 39,700 gpm thru the duct. The NES duct cooling system functioned satisfactorily during the test.

TECHNICAL DISCUSSION

The maximum flowrate now obtainable with FCV-31 in 100% open position is approximately 12,500 gpm as opposed to 11,700 gpm obtained during the last test (SL Phase I). During the last test an orifice was installed in the inerting wall coolant line to simulate the required flow and during this test the inerting wall coolant system was operational.

The duct inlet and outlet pressures and the total flows were compared with previous runs and the tabulated results (Table 1) show that the system operates approximately the same as before at full flow conditions.

The maximum strain recorded was during SGS operation (approximately 367 microinches per inch) at strain gage GG017 located on top of Section 3 just downstream of the steam line attachment (Station 746). This reading is approximately 23% lower than the highest previous reading

During SGS operation, the increase in coolant water temperature was approximately the same (10° to $20^{\circ}R$) as for previous tests.

During the water flow test the upper left flare on the duct exit went out and remained out during most of the test. It did re-light without the assistance of the operator after being out approximately 5 hours. The lower left flare also went out but during the last SGS test it didn't relight. There are two separate systems for the flares, one system supplies the top two flares and the other system supplies the bottom two. Therefore, both systems will have to be checked out.

Visual observations of the water tank level indicator during the test indicated that the water level continued to drop when the water systems were inactive. After examination of the data it appears that approximately 126,000 gallons of water at a rate of 620 gpm leaked past one or more of the duct inlet water valves (RSV-296, 297 or 298) with the valves closed. This loss is equivalent to 3 minutes of rated duct coolant flow.

RECOMMENDATIONS

1. It is recommended that those leaking duct coolant water inlet valves be repaired as soon as spare parts are available.

2. The duct flare systems should be re-evaluated prior to the next test to determine if modifications or adjustments can be incorporated to increase their operational reliability.

3. All instrumentation anomalies listed below should be corrected prior to the next test.

4. Criteria for evaluation of duct strain data should be provided by source engineering prior to the next test.

ANOMALIES

1. DF-031 was not properly reporting FCV-031 valve position.

2. Strain Gage STG-004 had a large negative reading at all times.

3. Two of the four duct flares were inoperative during certain phases of the test.

4. TE-068 was reading approximately 145° high at all times.

5. One or more of the duct supply valves (RSV-296, 297 and 298) are leaking.

TABLE 1

DUCT WATER FLOW COMPARISON

				SECTION 1			SECTION 2			SECTION 3				
TEST NUMBER	DATE	DUCT INLET PRESS psig	DUCT OUTLET PRESS psig	ACTUAL FLOW gpm	% TOTAL FLOW	MIN. REQ'D FLOW gpm	ACTUAL FLOW gpm	% TOTAL FLOW	MIN. REQ'D FLOW gpm	ACTUAL FLOW gpm	% TOTAL FLOW	MIN. REQ'D FLOW gpm	TOTAL FLOW gpm	DUCT kw
NEP-III	2/2/67	198	58	12340	31.4	11756	11470	28.9	11152	15770	39.7	15126	39660	3350
NEP-IV	2/7/67	199	61	12400	31.9	11756	10990	28.3	11152	15490	39.8	15126	38880	3310
SL PHASE I EP-2	10/9/68	204	76	11836	31.6	11756	10903	29.1	11152	14700	39.3	15126	37439	3310
PHASE II	12/6/68	198	53	12628	32.2	11756	11262	28.8	11152	15304	39.0	15126	39194	3265

SPEAR Memo No. 20
J. W. Holaday

XE-PRIME

EP-I AND EP-SL2

Subject: TEST STAND COOLANT WATER SYSTEM PERFORMANCE DURING PHASE II NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

A water flow test was conducted to determine the adequacy of coolant water coverage to the test stand, the duct vault door, the test stand weather door, the east duct vault wall, the stairway, the concrete/granite pads, the west duct vault wall and the duct vault inerting wall. This test was a repeat of the steam line Phase I test conducted on 9 October 1968 with the exception that the duct vault inerting wall and west duct vault wall coolant systems simulated with an orifice in the previous test were in operation during this test.

SUMMARY

As in the previous test, the coolant flow to the test stand was established in three distinct steps in order to plot the flow profile. The test stand coverage and the flow profile (Figure 1) at each step was approximately the same as the previous test.

With FCV-31 opened 100%, FCV-32 was then opened to establish 39,667 gpm through the NES duct. Water coverage was adequate for all levels up to and including the top of the test stand weather door. After 20 seconds, RSV-937 was opened completing the coverage to the upper test stand.

The test stand coolant water system is satisfactory with the exception of re-directing some of the coolant nozzles.

TECHNICAL DISCUSSION

After a normal duct bleed-in the coolant water flow to the test stand was gradually established in the following manner:

1. FCV-31 was opened establishing 45 psia at P-863; this is a flow of approximately 7724 gpm.
2. FCV-31 was opened to establish 53.0 psia at P-863; this is a flow of approximately 9535 gpm.
3. FCV-31 was then opened 100% establishing 61.0 psia at P-863; this is a flow of approximately 12,495 gpm.

These flow rates established through the duct are the actual flowrates for the test stand coolant system. The plot (Figure 1) of PT-863 pressure and water flow rate for SL Phase II may be used for future estimation of flow to the test stand coolant system.

With the duct flowing at 39,667 gpm and RSV-937 open, the test stand weather door, the test stand, the concrete apron, the duct vault inerting wall, the east duct vault wall and stairway had excellent coverate. At this time the pressure at PT-863 was 27 psig. During the previous test (SL-Phase I) this pressure was 33 psig. The change to the duct vault inerting wall spray system accounts for the difference in pressure.

The duct vault door has good coverage but the nozzles on the east edge vertical coolant line appear to force the water flowing down the door, away from the door surface. The west duct door edge does not have sufficient coverage but the upper portion would have sufficient coverage if the nozzles on the duct vault door vertical line were directed away from the duct vault door and on the west duct door edge. Water coverage in the lower portion of the west duct door edge can not be determined. Figure 2 shows the deficient coverage.

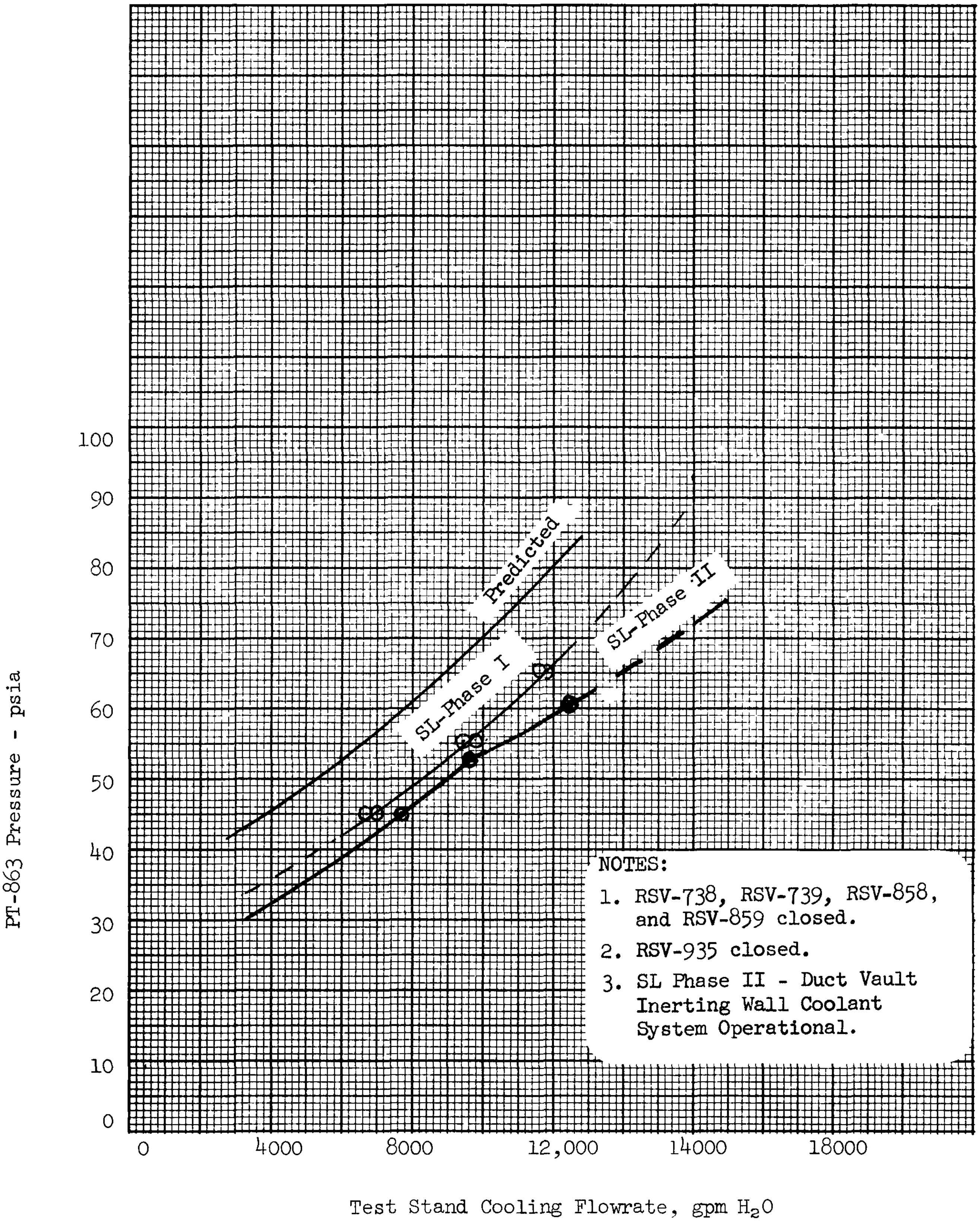
RECOMMENDATIONS

1. Re-direct the nozzles on the duct vault door vertical coolant line to spray on the side wing of the west duct door.

2. The one line from the discharge manifold of the bottom eight tubes of Section 3 of the duct should be used to cool the lower part of the side wing of the west duct door. At present, this line just discharges onto the floor of the drainage ditch.

ANOMALIES

None.



PT-863 PRESSURE VS TEST STAND COOLING WATER FLOWRATE

FIGURE 1

ETS-1 COOLING WATER COVERAGE

FIGURE 2

SPEAR Memo No. 21

H. S. Kresny HSK/BSM

XE-PRIME

EP-I AND EP-SL2

Subject: ETC AND SECONDARY EJECTOR PERFORMANCE DURING PHASE II NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

The ETC and Secondary Ejector performance during XE-Prime EP-SL2 has been examined to determine performance repeatability from previous tests and any noteworthy improvements in such areas as shield water flow, seal system performance or secondary ejector performance.

SUMMARY

The shield water flow rates were comparable to previous tests but do not satisfy the flow requirement of RN-S-0418. The ETC seal pressures remained above atmospheric throughout the test. The ETC and secondary ejector performed satisfactorily during steam generator full steam operation. The ETC pressure with two modules at full steam was somewhat higher than those obtained during previous tests.

TECHNICAL DISCUSSION

ETC Shield Water Flow Rates

Table 1 shows the water flow rates together with individual shield supply pressures, steam generator flows and duct flow for several operating times. In addition, a comparison with previous flow data is shown.

Shield flow rates, although slightly lower than during previous tests, are nevertheless comparable. The flow rates do not satisfy the requirements given in RN-S-0418, XE-P Test Predictions.

An effort has been made to determine the effect of duct flow and steam generator flow on shield flow rates. Table 1 shows that shield supply pressures are virtually those of P-168, the process water header pressure located upstream of the duct supply line junction, when duct flow is about 40,000 gal. with no S.G. or shield flow. When the shields and S.G. are demanding approximately 4400 gallons through the common 24-inch header, the shield supply pressure is about 22 psi lower than the process water header pressure, with or without duct flow. For 4000 gpm through a 24-inch line, the pressure drop should be about 0.1 psid. This discrepancy is not yet understood.

ETC and Secondary Ejector Performance

Table 2 shows the steady-state data for two points during full steam operation of S.G. Modules 2 and 3. The top ETC pressures (P290 and 291) read atmospheric pressure throughout the test which indicates that a transducer line may have been open to atmosphere. It has not been possible to verify this conclusion. The bottom ETC pressures (PT292, 293) seemed to read correctly.

Figure 1 shows the ETC (P_{ETC}) and Secondary Ejector (P-239) pressures as a function of time during steam generator operation. With one module (#2) operating, the ETC pressure decreased to 10.5 psia. When both modules (2 and 3) went to full steam, the ETC pressure decreased to 7.75 psia and then increased to 8 psia and remained steady until the steam generators were shut down. The seal and purge flow rate W 434 is shown as a matter of secondary interest on this figure. Figure 2 presents the ETC and S.E. pressures during the steam generator shutdown transients.

ETC GN_2 Sealing System

The ETC sealing system provided adequate air exclusion during steam generator operation. The lowest seal pressure encountered was the Convolute Buffer Purge which decreased to 14.0 psia. Whereas, during XECF-EPII the Bottom Seal Blade Purge showed the largest pressure decrease (therefore leakage), during XE-P-EP-SLII the Top Seal Blade Purge indicated the largest pressure decrease. It is likely that each subsequent shield mate-up will determine where the points of greatest leakage are. Table 3 shows the seal pressures for XECF-EP-II and XE-P-SL2 with and without steam generators at full steam. Note that:

1. Some decrease in leakage (top and bottom seals) is implied for XE-P-SL2 compared to XECF-EP-II.

2. None of the seal or buffer pressures decreased below 14.0 psia and, therefore, no air inleakage into the ETC through the seals was possible.

Figure 3 shows the ETC pressure, top and bottom seal blade purge pressures and seal and purge flow. No noticeable increase in seal purge flow (W-434) was detected when ETC pressure was decreased. The flow of 0.25 pps constitutes seal purge, latch tension flow (should be 0) and solenoid box purge. Of these, the known users during S.G. operation were the Convolute Buffer Zone Purge and the large (5 ft x 5 ft x 1 ft) solenoid boxes located on the ETC shields (50IB1 & 2). The increases of W-434 flow starting just prior to steam generator shutdown are unexplained.

The ETC oxygen and hydrogen detector data channels were inoperative during this test. However, the O_2 meter on the LFE Console was operative and indicated 0.5 percent oxygen when the steam generator came up to full steam. A 4 pps GN_2 purge was established which reduced O_2 concentration. The cause of this increase in oxygen concentration may have been leakage through the top seal blade purge transducer line if, in fact, that line is found to be open to atmosphere.

ETC and Secondary Ejector Correlation

Several additional data points were established for ETC pressure versus Secondary Ejector steam pressure, in an attempt to establish a correlation of these parameters. Figure 4 shows these points together with those of NES-EPN-1.

RECOMMENDATIONS

ETC Shield Flow

The seemingly excessive pressure drop in the shield water flow supply header should be further evaluated. If no explanation is possible, then water flow rate requirements should be re-evaluated to determine whether the present requirements are too conservative.

ETC Pressure Transducers

The PT-290 and 291 transducer lines should be checked for either open lines or hand valves that may have been left open.

ANOMALIES

Data

O_2 and H_2 detector data channels were not set up.

Instrumentation

PT-290 and PT-291 read atmospheric pressure throughout the test.

TABLE 1

ETC SHIELD WATER FLOW RATES,
STEAM GENERATOR FLOW AND DUCT FLOW

CRT	38250	79300*	79760*	81924
P-168F, psia	225	230	215	224
Duct Flow, gpm	39500	903	38000	353
Steam Generator Flow, gpm	~ 0	1090	1680	303
S-1 Flow, PT-278 / gpm	224/0	208/1210	192/1150	223/0
S-2 Flow, PT-284 / gpm	225/0	213/1130	198/1080	224/0
S-4 Flow, PT-262 / gpm	225/0	212/550	196/520	223/0

COMPARISON WITH PREVIOUS TESTS

	XECF-EP-I	XECF-EP-II	SL-II	REQUIRED FLOW(1)
S-1		1200 gpm	1150 gpm	1290
S-2	1150 gpm	1150	1080	1290
S-4	550	550	520	604

* Shield Water Valves open at this time.

(1) RN-S-0418

TABLE 2

ETC AND SECONDARY EJECTOR STEADY STATE DATA

S.G. MODULES	2&3	2&3
TIME	80020.7	80078.7
PT-239 (Pse) psia	121.6	116.2
TE-159 (Tse) °R	1585	1432.4
PT-706 (Pc) psia	8.7	8.96
TE-700 (Tc) °R	536.1	548.2
P-292 Petc(BOT) psia	7.93	8.04
*P-290 Petc(TOP) psia	(12.37)	(12.35)
FT-15 $\dot{W}$ (chamber) pps	9.99	10.6
PT-474 $\dot{W}$(ETC Purge) pps	4	4
FE-430 $\dot{W}_{He}$(Drums) pps	0	0
FE-433 $\dot{W}_{GHe}$(Eng.Purge) pps	0.007	0.007
PT-632 Petc(BOT Seal) psia	14.2	14.2
PT-633 Petc(BOT Seal) psia	14.2	14.2
PT-634 Petc(TOP Seal) psia	14.0	14.0
FE-434 $\dot{W}_{GN_2}$(Purge & Latch System) pps	.25	.25

*290 and 291 read about 12.36 throughout the run.

() Data is anomalous.

10 pps Primary Nozzle Flow (GN_2)
4 pps ETC GN_2 Purge

FIGURE 1

ETC AND SECONDARY EJECTOR STEAM PRESSURE VS TIME

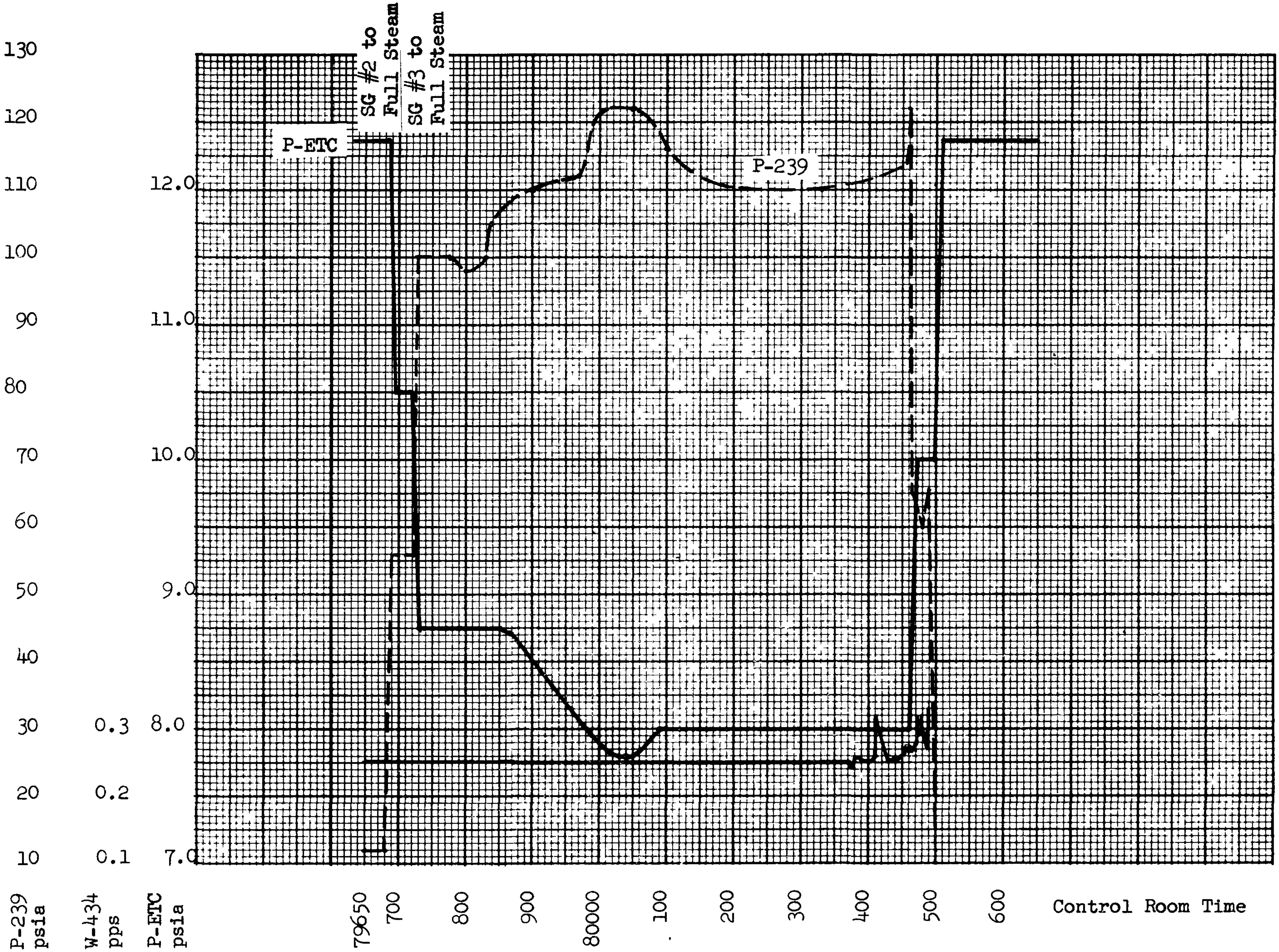


FIGURE 2

ETC PRESSURE DURING SG#3 AND SG#2 SHUTDOWN VS TIME

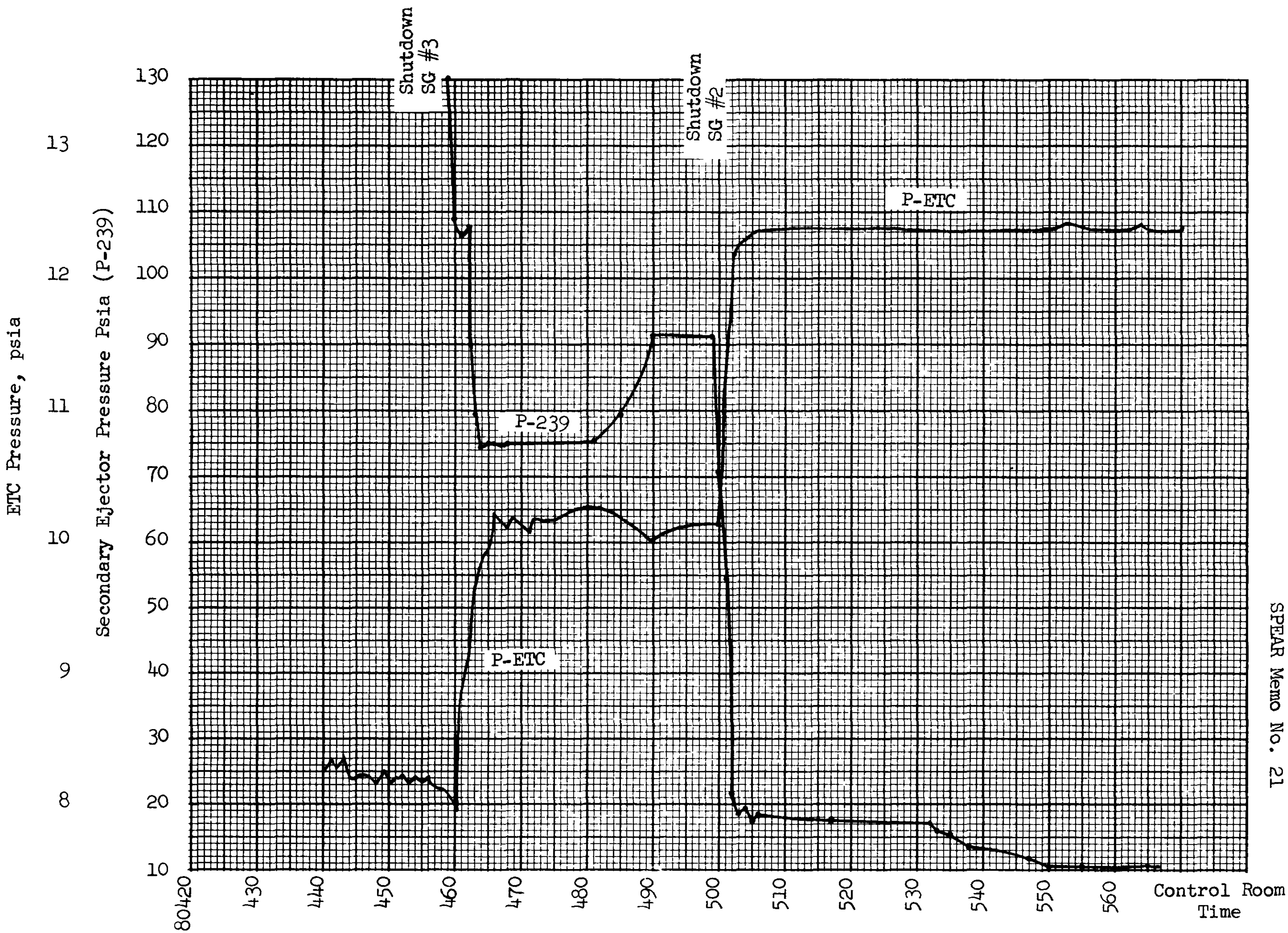


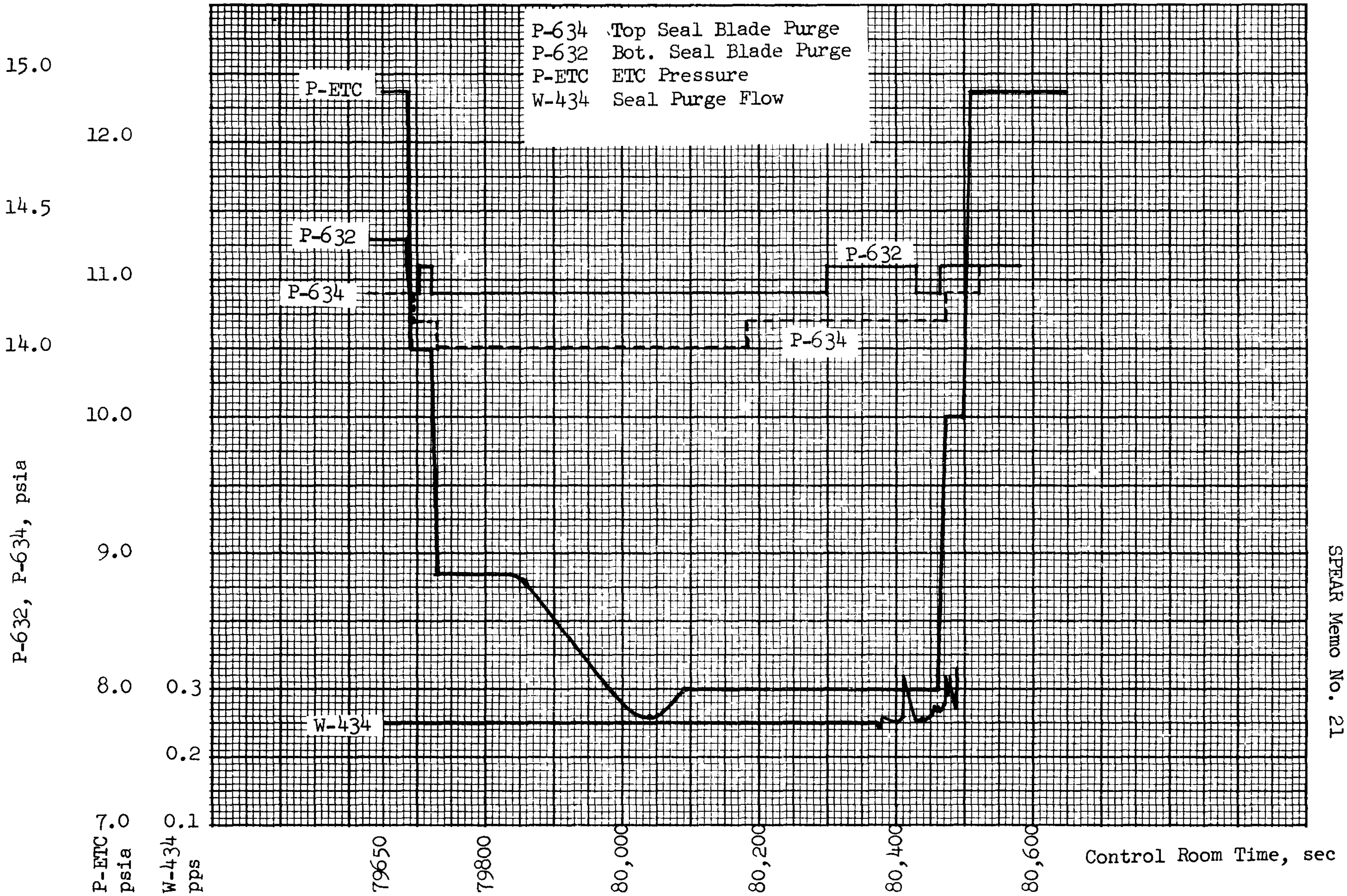
TABLE 3

SHIELD SEALING PRESSURES BEFORE AND AFTER STEAM GENERATOR OPERATION

PARAMETER	DESCRIPTION		XECF-EP-II SG's NOT OPERATING	XECF-EP-II SG's AT FULL STEAM	XECF-EP-II ΔP		XE-SL-II SG's NOT OPERATING	XE-SL-II SG's AT FULL STEAM	XE-SL-II ΔP
PT-625	GASKET PURGE	CAVITY (WEST)	14.15	14.12	.03		14.4	14.1	.3
PT-626	GASKET PURGE	CAVITY (EAST)	14.14	14.11	.03		14.4	14.1	.3
PT-627	CONVOLUTE BUFFER	PURGE	14.35	14.17	.18		14.3	14.2	.1
PT-628	CONVOLUTE BUFFER	PURGE	14.29	14.12	.17		14.1	14.0	.1
PT-629	S-1 CONVOLUTE SEAL	PURGE	17.10	17.07	.03		15.5	15.4	.1
PT-630	S-1 CONVOLUTE SEAL	PURGE	17.10	17.07	.03		15.2	14.9	.3
PT-631	S-4 BOTTOM BLADE	PURGE	14.43	13.95	.48		14.4	14.3	.1
PT-632	S-1 BOTTOM SEAL BLADE PURGE		14.51	14.12	.39		14.3	14.2	.1
PT-633	S-1 BOTTOM SEAL BLADE PURGE		14.02	13.67	.25		14.3	14.2	.1
PT-634	TOP SEAL BLADE PURGE		14.12	14.09	.03		14.3	14.0	.3
PT-636	TOP BELLOWS		—	—	—		42.6	42.3	.3
PT-293	ETC PRESSURE		12.40	7.5	4.90		12.40	8.00	4.40

FIGURE 3

ETC AND SEAL BLADE PURGE PRESSURE AND SEAL BLADE PURGE FLOW



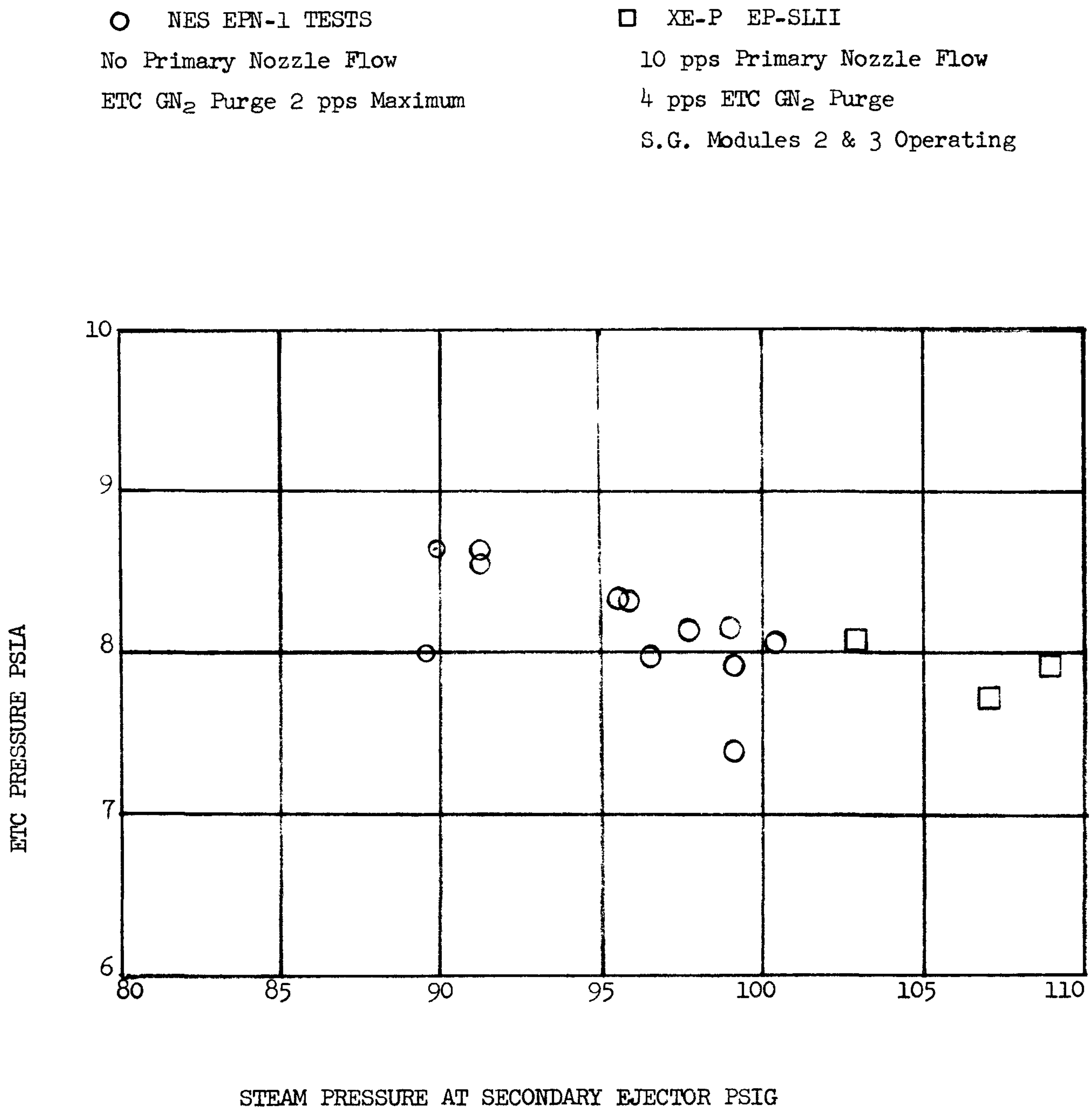


FIGURE 4

ETC PRESSURE VERSUS STEAM PRESSURE AT SECONDARY EJECTOR

SPEAR Memo No. 22
G. A. Davis GAD/BSM

XE-PRIME

EP-I AND EP-SL2

Subject: TEST STAND AUXILIARY SYSTEM PERFORMANCE DURING PHASE II NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

The control drum actuator helium supply system and the nitrogen/helium engine purge supply systems were utilized during XE-EP-I and XE-SL PHASE II testing. Discussed herein are the results of analysis of each system performance and helium gas utilization during the testing period.

SUMMARY

The control drum actuator supply system and the engine purge system performed as expected. Engine purge was 36 SCFM GN_2 during EP-I and 31 SCFM helium during SL2. Control drum actuators flowrate was .021 lb/sec helium for the drums against the 6 degree soft stop and .044 lb/sec helium whenever there was an inward or outward movement or when the drums were stable at some position (20 to 160 degrees). The helium usage rate during EP-I was 115 lbs/hr and 100 lbs/hr during SL2.

TECHNICAL DISCUSSION

Engine Purge System Performance

During EP-I the engine was purged with 36 SCFM of nitrogen through RSV-446 (FE-433). Figure 1 shows the system pressures (PT-622, PT-895) vs GN_2 flowrate based on test data from EP-I and SL2. Prior to SL2 testing, a switch from 39.5 SCFM GN_2 to 31 SCFM helium was made. The system pressures versus helium flowrate are also shown in Figure 1. Table 1 lists some representative data for the engine purge system.

Control Drum Actuator System Performance

Table 1 lists representative pressures, temperatures and flowrates for several control drum positions. In general, for 12 drum actuation, the helium flowrate was .044 lb/sec whenever there was a control drum command supplied, whether the drums were in transit, in or out, or at some stable position. With all 12 drums locked and a command applied, the flowrate was .039 lb/sec. With no command to the control drums, the helium flowrate was about .021 lb/sec. The supply line actuator pressure was maintained within the required 215 $\pm$10 psia. The temperature, T-535, was well within the required 430 to 560°R (RN-S-0400).

Helium Usage

Table 2 lists the gross facility helium usage, based on helium contained in the helium vessel(s) before and after test run completion. Also listed are usages from the engine purge system, the control drum actuator system and the "estimated" usage to the top water shield penetrations.

EP-I

The gross helium usage was calculated to be 1350 lbs and the usage rate was 115 lb/hr based on helium vessel outflow. The control drum actuator system used 1125 lbs helium, based on flow through FE-430, and the estimated (no flow measurement available) top water shield usage is 59 lbs helium, based on 5 lb/hr. The difference between the gross helium vessel usage and the individual system usages is 166 lbs. Much of the excess vessel usage can be attributed to the helium vented during the cryotrap setup operations. This flow is not directly measurable. It should be noted that GN_2, and not helium, was used for EP-I engine purge.

SL-2

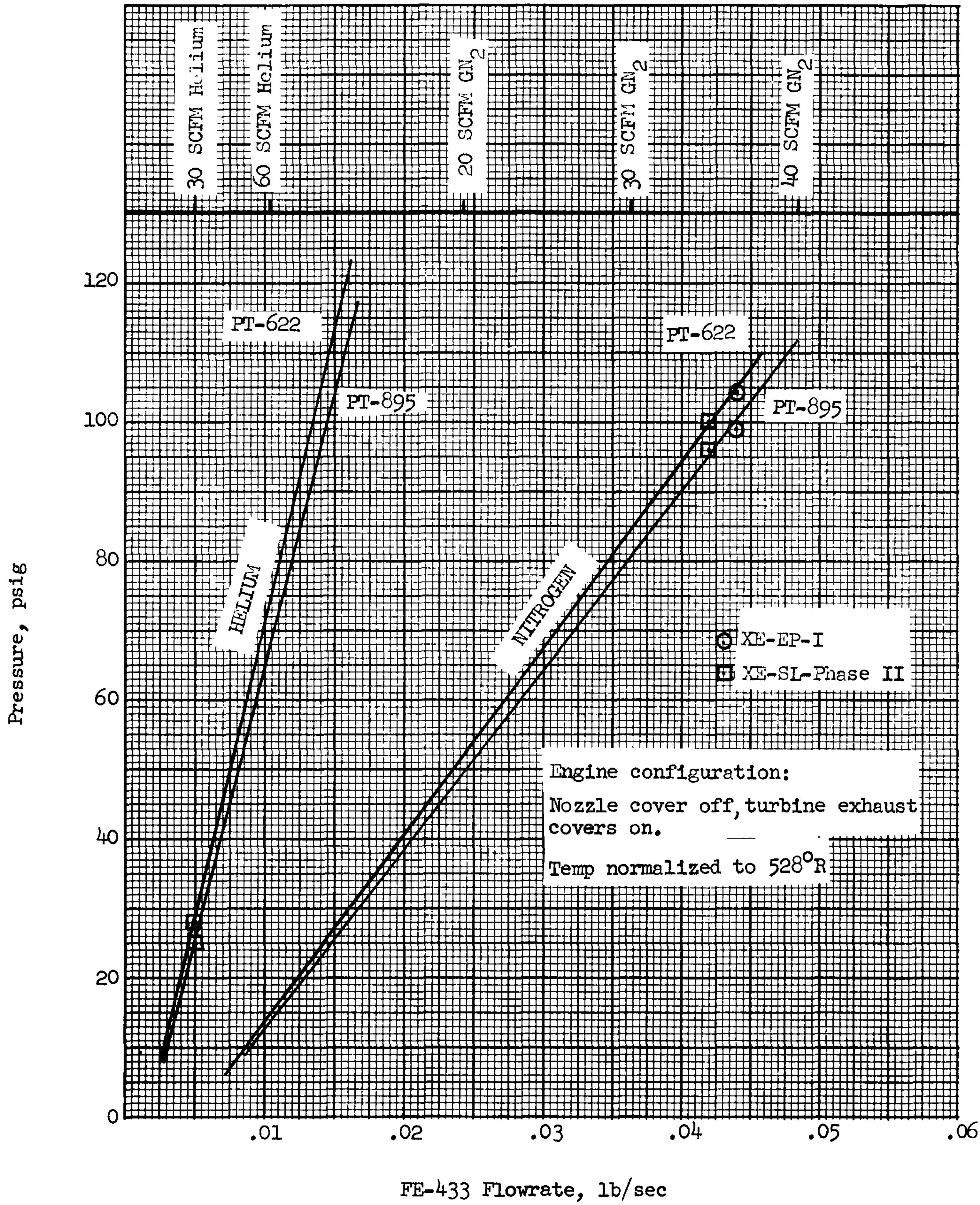
The gross helium usage was 1200 lbs and the usage rate was about 100 lbs/hr. The control drum actuator system used 836 lbs helium and the engine purge system used 210 lbs helium, based on flow through FE-433. The estimated top water shield penetrations usage is 64 lbs. Thus, the excess helium usage from the helium vessels of 90 lbs can be attributed to helium venting during the cryotrap setup operations.

RECOMMENDATIONS

In order to conserve helium, flow to the control drum actuators should be terminated during hold periods of any significant length.

ANOMALIES

None.



PRESSURE VS FE-433 FLOWRATE FOR XE ENGINE PURGE

FIGURE 1

TABLE 1

DATA, ENGINE PURGE AND CONTROL DRUM ACTUATOR SYSTEMS

	ENGINE PURGE SYSTEM								CONTROL DRUM ACTUATOR SYSTEM								
	CRT	FE-433	PT-622	PT-895	TE-538	W-433	W-433 Normalized to 528°R		CRT	D.800	FE-430	PT-615	PT-832	T-535	T-813	WHE430	
	sec	cps	psia	psia	°R	lb/sec	lb/sec		sec	degrees	cps	psia	psia	°R	°F	lb/sec	
EP-I	76920	182	117	112	488	.0475 N_2	.044 N_2	EP-I	41817	47	496	207	208	521	517	.044	(1)
									42479	8.5	235	208	208	521	521	.021	(2)
									44657	17.8	437	208	208	520	520	.039	(3)
SL 2	37732	182	113	109	508	.044 N_2	.042 N_2		72399	104	477	208	206	498	505	.044	(1)
									78000	101	474	206	205	499	504	.044	(4)
	41297	411	41	38	520	.005 He	.005 He										
								SL-II	45540	102.6	493	210	210	526	524	.044	(1)
									57320	9.8	226	210	210	521	521	.020	(2)
									63150	110.4	483	208	208	506	509	.044	(4)

(1) POSITION CONTROL
(2) NO COMMAND
(3) DRUMS LOCKED
(4) POWER CONTROL

TABLE 2

HELIUM USAGE

TEST XE-PRIME	Control Drum Actuator, FE-430	Engine Purge FE-433	*Estimated Usage To Top Water Shield Penetrations	Lbs He Used Vessel Decay Method	Overall Helium Usage Rate (Vessels) lb/hr	He Usage Diff Between Vessel Decay Method And Individual Flow Calculations
EP-I	1125	---------	59	1350	115	166
EP-SL2	836	210	64	1200	100	90

* Based on 5 lb helium per hour

SPEAR Memo No. 23

H. W. Brandt/AS /BSM

XE-PRIME

EP-I AND EP-SL2

Subject: LN_2/CRYOTRAP SYSTEMS PERFORMANCE DURING PHASE II NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

The LN_2 system was activated during EP-I and EP-SL2 to chill and fill the LN_2 cryotrap, which was used to filter the control drum actuation gas (He). This memo presents the results of an evaluation of the pertinent data related to the LN_2 and cryotrap performance during EP-SL2. The EP-I data was reviewed and no significant system problems were evidenced; however, the EP-SL2 test data was selected for detailed evaluation since the EP-SL2 test conditions closely approached actual future EP test conditions.

SUMMARY

There was no leakage past RSV-545 with the LN_2 system pressurized to approximately 250 psig. Leakage had been experienced past RSV-545 during previous facility/engine tests and the valve had been refurbished prior to EP-I.

The initial fill and chill of the 225-LN-6 line and the cryotrap required approximately 4000 lbs of LN_2 and the operation took approximately 21 minutes. There was very poor correlation between the V-3601 usage based on the liquid level sensor (LT016) and the integral FE-052 flowrate. The poor correlation is attributed to the inaccuracy of the liquid level gage when the dewar is being pressurized.

Thirty-four minutes were required to pressurize V-3601 from 3 to 250 psig with a 64% ullage (2600 cu.ft.). Approximately 6940 lbs of GN_2 were used to pressurize V-3601 and the collapse factor was calculated to be 1.9.

The measured LN_2 boil-off rates in the cryotrap chiller were 200 lbs/hr and 130 lbs/hr with He flowrates of 0.044 pps and 0.021 pps, respectively, and with the cryotrap chiller level between 77% full and 47% full. The boil-off rate increased significantly at higher chiller levels (>75%) due to the increased heat conduction paths and inadequate initial chill of the top of the LN_2 heat exchanger. A heat balance indicated that the LN_2 loss due to heat conduction through piping, walls, tubing, etc., was approximately 42 lbs/hr when the level was between 77% and 47% full. In general, the cryotrap required refilling every 30 minutes.

TECHNICAL DISCUSSION

The schematic of the LN_2 and the control drum actuation system is presented in Figure 1. RSV-545 was mechanically blocked and actuation gas pressure was applied to the closed side of the valve actuator during both EP-I and EP-SL2. He flowed through the cryotrap to the control drums only since GLV-2337 was closed during both EP-I and EP-SL2.

Initial 225-LN-6 and Cryotrap Chilldown and Fill

The LN_2 system initial chill and fill was initiated at 36510 seconds when PRV-108 was adjusted to pressurize V-3601 to 250 psig. The line volume between RSV-326 and PCV-517 was initially chilled by flowing out through RSV-392 with PCV-517 closed. PCV-517 was opened at 37192 seconds to chilldown the line between PCV-517 and RSV-545. The line pressure (PT194) increased from 16 psia to 84 psia during this time span (36510 to 37192 seconds); however, TT055 did not decrease below the upper range limit of 215°R. Saturated conditions were initially evidenced at the FE052 inlet 17 minutes after pressurization was initiated. Saturated liquid (PT580=143 psia, TT510=187°R) was observed at RSV-545 inlet (PT580, TT510) approximately 21 minutes after pressurization began. Thirty-four minutes were required to pressurize the dewar from 16 psia to 255 psia with a 64% ullage (2600 cu.ft.).

The amount of LN_2 used to initially fill and chill the 42 cu.ft. volume between RSV-326 and RSV-545 (5500 lbs of stainless steel piping and valves) and the 5 cu.ft. chiller could not be determined accurately since the V-3601 liquid level indicator (LT026) indicated unreliable data during the dewar pressurization operation. The FE052 integral flow data showed that approximately 2000 lbs of LN_2 was used to fill and chill the line volume between PCV-517 and RSV-545; therefore, since the line volume and metal mass between RSV-326 and PCV-517 is approximately the same as the PCV-517 downstream volume and metal mass, it appears that approximately 4000 lbs is required to initially fill and chill the 225-LN-6 line and the cryotrap. This usage is consistent with previous test data.

Comparison of the integral FE052 flowrate and the usage, based on LT026 change during chill maintenance flow operations through PCV-517, resulted in very poor correlation because of the inaccurate level readings over the relatively short chill maintenance periods ($<$ 100 seconds).

RSV-545 Performance

Leakage past RSV-545 was experienced during previous test operations, which required use of the LN_2 system and RSV-545 was disassembled and refurbished prior to EP-I. The temperature data (TT511) downstream of RSV-545 was reviewed and there was no abnormal temperature decrease noted when the inlet pressure was increased to 250 psia. The temperature at TT511 did gradually decrease 47°R during the 13.3 hour test period; however, this decrease was due to the 25°R change in ambient temperature and chilldown of the piping downstream of RSV-545 through conduction. The valve is adequate for future testing.

LN_2 Usage

The LN_2 usage for the cryotrap chiller varied during EP-SL2 and the usage was related to the following parameters: the ambient temperature, the helium flowrate through the cryotrap, the chiller level, and the amount of time that the chiller was filled. In general, the cryotrap refilling operation was performed every 30 minutes.

The pertinent usage data is presented in Table 1. The LN_2 boil-off rate increased as a function of level due to the increased and shorter heat conduction paths to ambient and also because the top of the chiller was not initially chilled down completely. Without conduction losses the expected boil-off rate would be approximately 158 lbs/hr with a helium flowrate of 0.044 pps; however, the actual LN_2 boil-off rate was approximately 200 lbs/hr, when the level was between 77% and 47%. Figure 2 is a reference plot of the chiller level differential pressure (PD852) reading and the % volume. As expected, the difference in boil-off rate was 73 lbs/hr when the He flowrate was decreased from 0.044 pps to 0.021 pps. Therefore, the heat leak through the walls, piping, etc., was approximately 3560 btu/hr during the time period evaluated. The boil-off rate or the usage should increase by a factor of 2.0 (assuming the cryotrap inlet and exit gas temperatures remain the same) with hydrogen flow to the control drums only.

225-LN-6 Chill Maintenance

PCV-517 was closed and PCV-754 was opened to 80% after the 225-LN-6 line and cryotrap chiller was initially chilled and filled. The LN_2 was allowed to boil-off through PCV-754 until LN_2 was required for the cryotrap. One typical fill cycle will be described. At 59355 seconds the LN_2 chiller level had decreased to 51% (PD852=.283 psid) and RSV-879 was opened to refill the chiller. It should be noted that the chiller level decreased to a minimum level of 42% (PD852=.170) with a He flow of .021 pps and the chiller exit gas temperature was 143°R, which is well below the upper limit of 175°R. Therefore, it is recommended that the requirement that the chiller level be maintained at 0.5 psid (69%) be deleted and that the operational requirement be changed to maintain the chiller exit gas temperature below 165°R during chiller use.

Approximately 23 minutes had elapsed since the previous chiller fill and the RSV-545 inlet pressure (PT580) and temperature (TT510) were 22 psia and 145°R. PCV-754 was open to 70% and PCV-517 was opened at 59362 seconds to increase the line pressure and provide LN_2 for the cryotrap fill. PCV-517 was open between 5.7 to 6.7% during this operation.

The indicated FE.52 LN_2 flowrate was approximately 12.6 pps with 254 psia at PT194 and 30 psia at PT580 and 9.3 pps with 254 psia at PT194 and 132 psia at PT580. A flow split was determined during this cryotrap fill operation. The calculated flowrate through PCV-517 was 9.0 lbs/sec as compared to the FE.052 calculated flowrate of 9.3 lbs/sec. The flowrate into the chiller was approximately 2.5 pps with 130 psia at PT580; therefore, flowrate through PCV-754 at 70% open was approximately 6.5 pps. This flowrate yields a vent line Cv value of 5 at the 70% opening. This value appears low since the full open vendor-quoted Cv is 14. The calculated impedance, K, of the 3/4 inch cross-over line between the 225-LN-6 line and the cryotrap is 29.3, whereas the theoretical, based on line size, valve Cv's, etc. is 26.

When PCV-517 was closed, the line pressure decreased rapidly to approximately 40 psia and sub-cooled liquid was evidenced in the line. The pressure and temperature reached saturation values approximately foru minutes after PCV-517 was closed. The line pressure (PT580) decreased to steady-state value of 22 psia.

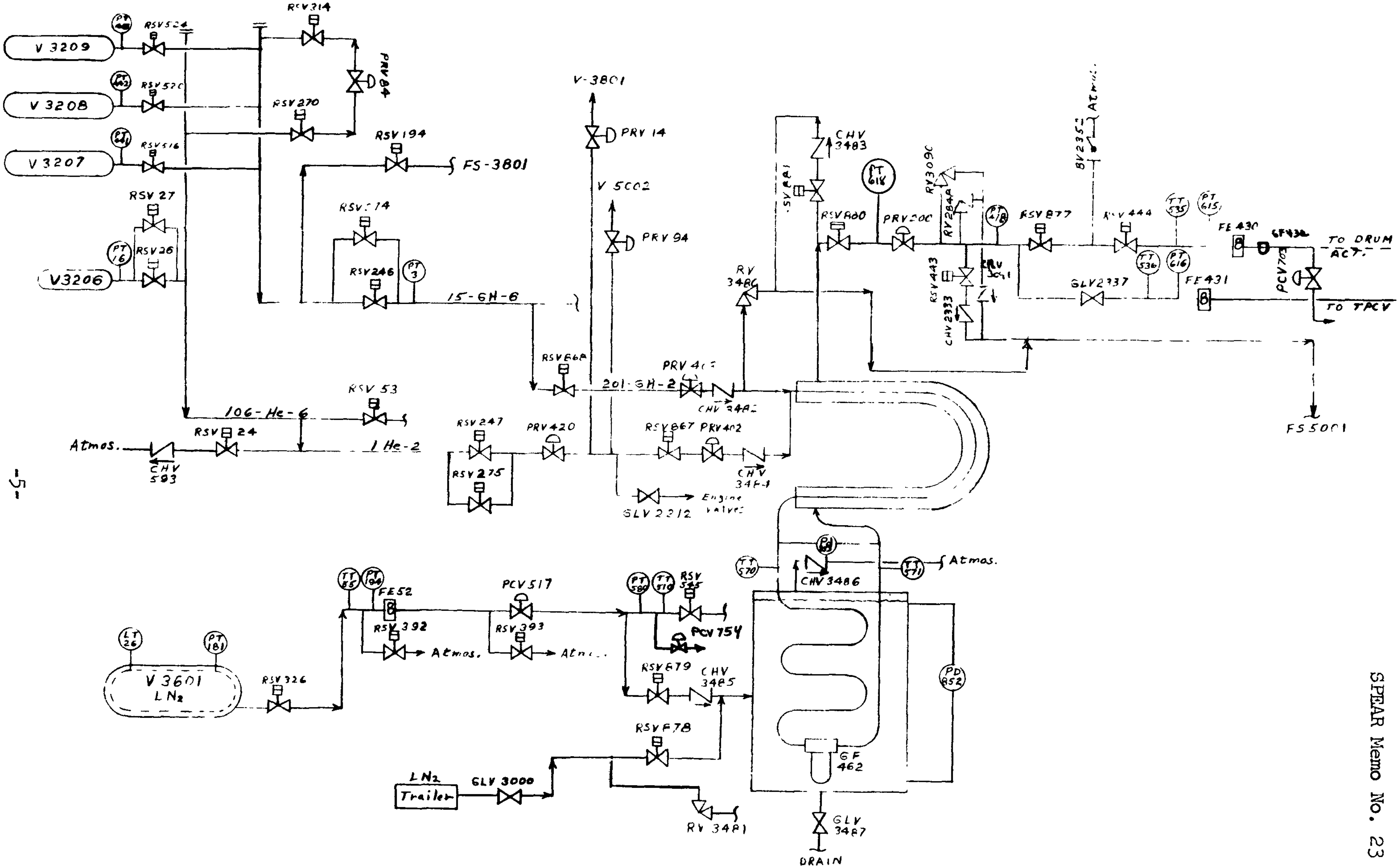
It is to be noted that there is an alternative method of maintaining the 225-LN-6 line in a chilled condition. PCV-517 could be cracked open and PCV-754 used to maintain the line pressure (PT580) below 75 psig and line temperature (TT510) below saturation prior to the gas to LN_2 switch for engine cooling.

RECOMMENDATIONS

The requirement that the chiller level indication (PD852) be maintained at .5 psid should be deleted and the operational requirement should be changed to maintain the exit gas temperature below 165^{o}R during cryotrap operations.

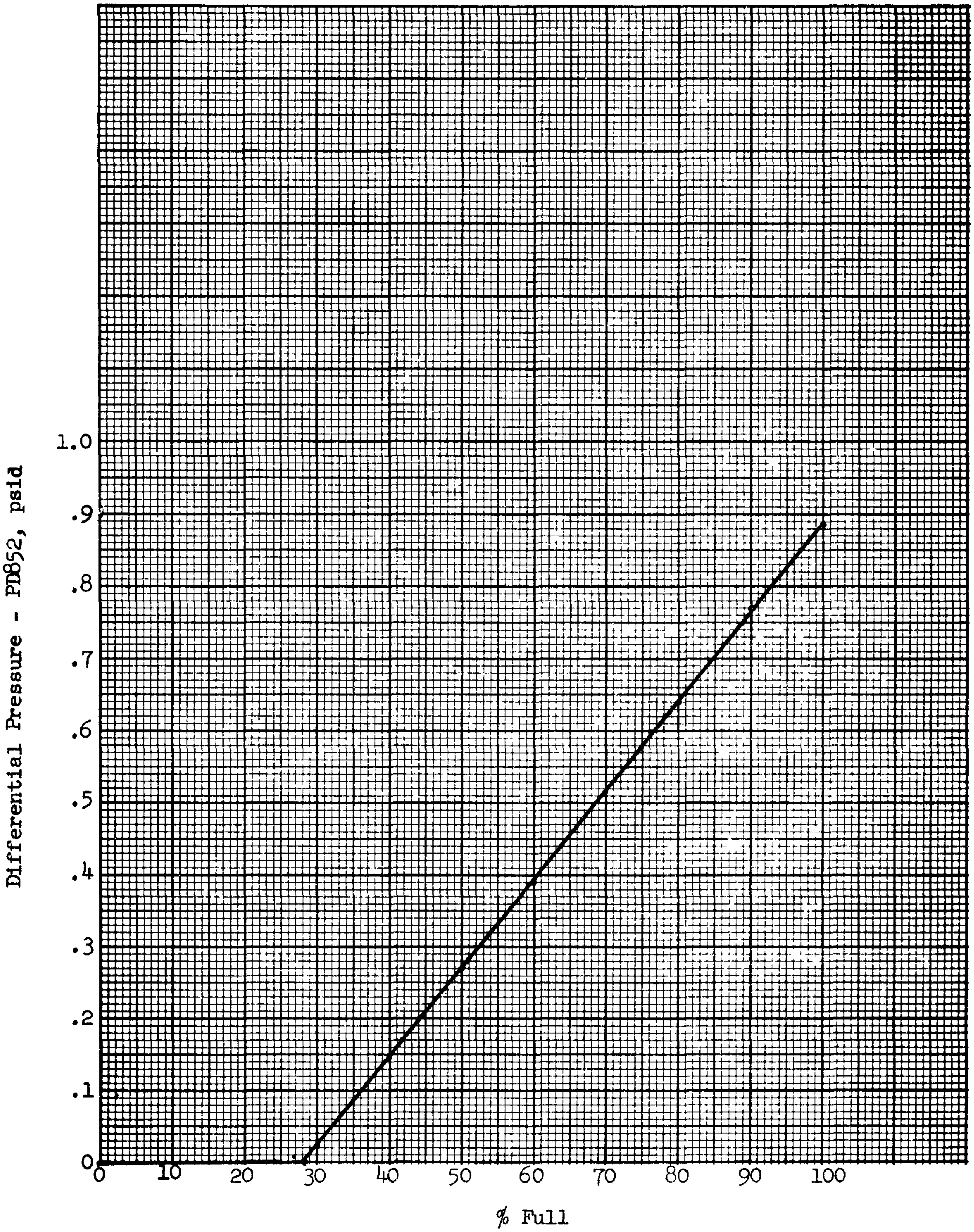
ANOMALIES

None.



SCHEMATIC OF THE GH_2 AND GHe SUPPLY SYSTEMS TO THE DRUMS AND TPCV ACTUATORS

FIGURE 1



CHILLER DIFFERENTIAL PRESSURE (PD852) VS CHILLER INVENTORY

FIGURE 2

100% Full = 250 lbs at
48 lbs/cu.ft.
100% Full = 5.1 cu.ft.
100% Full = 44.5 inches
78.5% Full = 35 inches

TABLE 1

LN_2 USSAGE SUMMARY TABLE

Range Time	PD852	Inventory lbs	Boil-off Rate lbs/hr	WF430 pps	
57697	.746	221	-1410		TE570 Initial/Final = 211°R/204°R
57720	.700	212	-264		TE571 Initial/Final = 145°R/142°R
58006	.600	191	-185	.044	TE535 Initial/Final = 519°R/515°R
58396	.500	171	-200		
58756	.400	151	-188		
59138	.300	131	-200		
59354	.244	119			
79784	.671	206	-172		TE570 Initial/Final = 209°R/211°R
80100	.600	191	-128		TE571 Initial/Final = 142°R/141°R
80662	.500	171	-127	.021	TE535 Initial/Final = 505°R/505°R
81213	.400	151	-131		
81505	.353	141			

SPEAR Memo No. 24
D. C. Rardin DCR/BSM

XE-PRIME

EP-I AND EP-SL2

Subject: ENGINE GN_2 SUPPLY SYSTEM PERFORMANCE DURING PHASE II NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

The GN_2 Supply System via PCV-251 was used during EP-SL2 conducted on 6 December 1968, to prevent steam from entering the engine when the steam generators shut down. It is the intent of this memo to verify that steam did not enter the engine and that the GN_2 System performed as expected. The data used in this analysis consisted of 1 sample per second and 10 sample per second NTO digital data.

SUMMARY

1. Steam did not enter the engine during the steam generator shutdowns.

2. The steady-state system performance was as expected and agreed with previous tests.

TECHNICAL DISCUSSION

Table I presents the system steady-state data for the three time periods that the system was flowed. During each of the runs a nominal 10 pps was flowed which resulted in a PCV-251 downstream pressure of about 105 psia which was estimated to be above the pressure required to prevent the system oscillations seen previously. There were no significant system pressure oscillations observed during either of the test runs. The system flow and pressure data presented in Table 1 is in agreement with previous test data and are as expected. PCV-543 was open during these flow periods to prevent CHV-3364 and CHV-3365 from chattering in the event that system oscillations occurred.

Figures 1 and 2 show the engine GN_2 purge performance during a typical steam generator shutdown. Figure 1 shows the chamber pressure (PT706), the bottom ETC pressure (PT292) and the core differential pressure (PD605) as a function of time for the shutdown of SG No. 3 during the last flow period. It is seen that about 1 psi differential pressure is maintained between the chamber pressure and the ETC pressure during the shutdown with the chamber pressure always above the ETC pressure indicating no steam flow into the engine. Also, the core differential pressure indicates GN_2 flow during the shutdown. When PCV-251 is closed, the chamber pressure and the ETC pressure equalize indicating that the 1 psi differential seen during the test is actual and not an offset in one of the instruments. The chamber temperatures also indicated that steam did not enter the engine during the shutdown transients.

Figure 2 is a cross plot of the chamber pressure (PT706) and the bottom ETC pressure (PT292) for the shutdown of SG No. 3 then the shutdown of SG No. 2 and finally the closing of PCV-251. It is seen that the chamber pressure is maintained above the ETC pressure during the steam generator shutdown transients and is equalized when PCV-251 is closed.

It was noted that CHV-2302 leaked during these flow periods but the leakage rate (.006 pps) is well within the value criteria and therefore of no concern.

RECOMMENDATIONS

None.

ANOMALIES

None.

TABLE I

ENGINE GN_2 SUPPLY SYSTEM STEADY-STATE DATA

RUN TIME SECONDS	59120.7 to 59739.1	61354.9 to 61978.0	79259.7 to 80550.4
HEADER PRESSURE (PT-002) PSIA	1810 to 1540	1638 to 1373	1650 to 1088
FLOW METER INLET PRESSURE (PT-587) PSIA	1650	1489	1228
GN_2 FLOW RATE (WN 15589) PPS	10.2	9 7	10.1
PCV-251 POSITION (DP-251) %	8.2	9.0	12
PCV-251 DOWNSTREAM PRESSURE (PT-475) PSIA	108	105	103
CHV 1721 UPSTREAM PRESSURE (PT-814) PSIA	99	95	94
COOLDOWN INTERFACE PRESSURE (PT-846) PSIA	88	85	84
PCV-543 INLET PRESSURE (PT-851) PSIA	61	59	58
PCV-543 POSITION (DP-543) %	99	99	99
PCV-543 VENT FLOW RATE PPS	.5	.5	.5
CSV UPSTREAM PRESSURE (PT-891) PSIA	84	80	78
NOZZLE TORUS PRESSURE (PT-124) PSIA	80	76	—
GN_2 USAGE LBS	6800	*	*
CHV-2302 LEAKAGE RATE PPS	.006	.006	.005

* 3900 AND 3200 AREA VESSELS USED

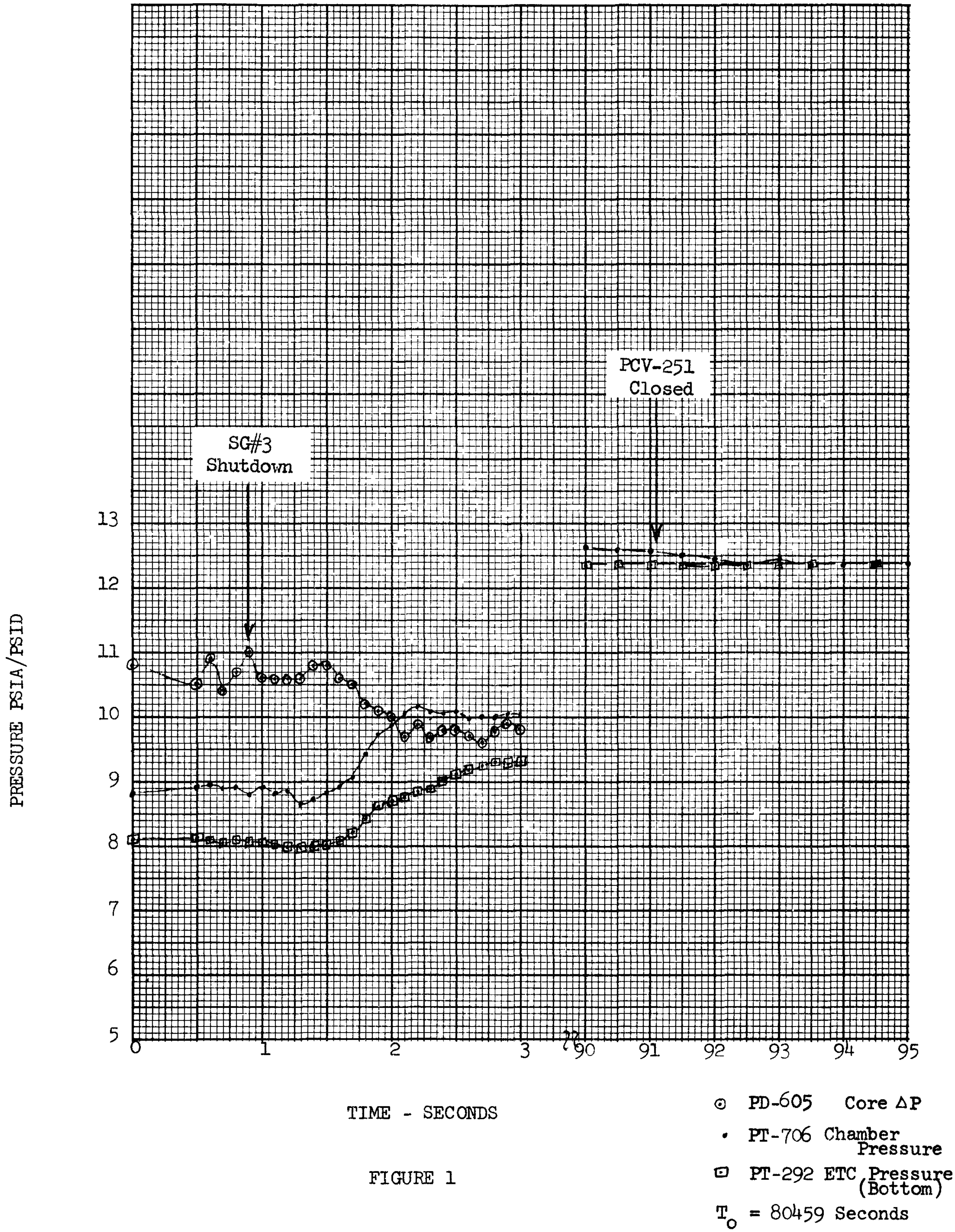

PRESSURE PSIA/PSID
13
12
11
10
9
8
7
6
5
0
1
2
3
90
91
92
93
94
95
SG#3
Shutdown
PCV-251
Closed
TIME - SECONDS
PD-605 Core ΔP
PT-706 Chamber Pressure
PT-292 ETC Pressure (Bottom)
T_o = 80459 Seconds

FIGURE 1

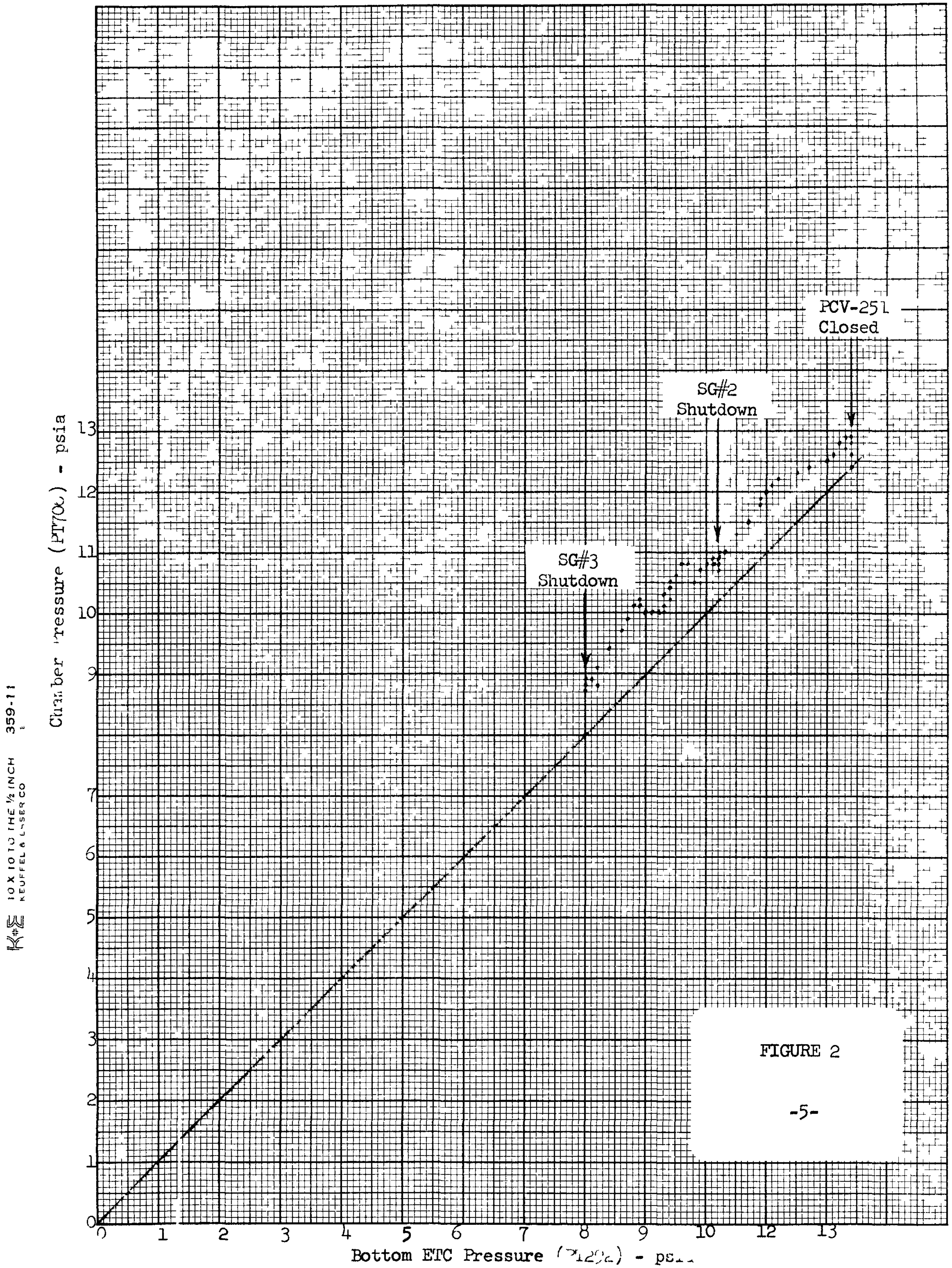

PCV-251
Closed
SG#2
Shutdown
SG#3
Shutdown
Bottom ETC Pressure
psia
359-11

FIGURE 2

SPEAR Memo No. 25
J. W. Holaday H/BSM/HA

XE-PRIME

EP-I AND EP-SL2

Subject: FLUID UTILIZATION DURING PHASE II
NES STEAM LINE DEMONSTRATION TEST

INTRODUCTION

The fluids considered in this report will be liquid oxygen and propane used for the SGS and the water used for the duct flow (includes test stand coolant through FCV-31) SGS operation, ETC cooling and test stand coolant (RSV-937).

SUMMARY

1. The total water used was 1,730,460 gallons.

2. The total liquid oxygen used was 15,000 gallons.

3. The total propane used was 6,900 gallons.

DISCUSSION

The water usage has been divided into the following two phases: 1) water used during the test (test stand coolant, duct coolant flow, SGS operation and side shield coolant flow); and 2) water used due to leakage when the water supply valves were closed.

The total water used for the test period was 1,604,400 gallons. The water lost due to leakage through the NES duct supply valve over a 3.4 hour period was 126,060 gallons. This could support the duct at full coolant flow for over three (3) minutes and could mean the difference between completing a test or shutting down early.

The liquid oxygen and propane usage has been divided into the following two phases: 1) propellant required to bleed in the systems; and 2) propellant used during the three tests.

During the propellant bleed in, tank pressurization, depressurization and system securing 4,000 gallons of propane and 12,000 gallons of liquid oxygen were used. This seems like an excessive amount of LOX to be used for bleed-in but according to the SGS operator there were no extra long bleed-in times or other abnormal operations.

During the 800 seconds of two module SGS operation, 2900 gallons of propane and 3000 gallons of liquid oxygen were used.

RECOMMENDATIONS

1. The duct water supply valves should be repaired as soon as possible.

2. The SGS operating procedures and the cooldown temperature requirement should be reviewed for possible means of reducting LOX useage during bleed-in.

ANOMALIES

Leakage past one or more of the NES duct water supply valves.

SPEAR MEMO No. 26
C.A. DeLorenzo:cb

XE-PRIME

EP-I AND EP-SI2

Subject: ON-SITE RADIOLOGICAL REPORT

INTRODUCTION

XE-Prime, EP-I was conducted the same day that the PEWEE I full power reactor test was run two miles east of ETS-1. The winds were light and variable and generally from the west, which reduced complications that could have resulted from the PEWEE I's effluent passing over or near ETS-1. On the evening of EP-I, there was an indication of airborne radioactivity at ETS-1 which presumably was effluent release from PEWEE I. The information in this memo is from Pan Am Report PAA 33-32.

TECHNICAL DISCUSSION

Radiological support for EP-I and EP-I, Phase II, included: area monitoring surveillance during the runs and post-run periods; and radiation and contamination survey support for re-entry teams and post-run activities.

A. Area Monitoring Surveillance

1. Remote Area Monitoring

Pan Am's five remote area radiation monitoring detectors were located at various distances - 150 feet to 1350 feet - from the XE-Prime engine and at different azimuths. Some detectors were in line of site of the reactor and others had significant intervening shielding. But at no time was a significant radiation level detected on any of the monitors during either test.

2. Air Sampling

At about 1910 hours on 12/4/68, the LSF reported an increase on their air monitoring equipment. A Hi-Vol air sample using a MSAR composite charcoal impregnated filter mat was taken in the ETS-1 tunnel area with negative results. Subsequent samples taken at 2000 hours and 2035 hours indicated 0.01 and 0.04 MPC's, respectively, compared to the iodine-131 MPC of 9×10^{-9} microcuries per milliliter.

The LSE air monitoring indications then returned to background. The activity detected was considered relatively insignificant and was not specifically identified other than to know it was net activity above the background radon-thoron activity in the tunnel.

Because of the operating configuration of the XE-Prime engine, the airborne radioactivity was considered to have resulted from PEWEE I effluent radioactivity which had returned with drainage winds.

B. ETS-1 Radiation and Contamination Surveys

1. Radiation Surveys

Table II presents selected information obtained during re-entry team and post-run radiation surveys. The data include approximate power integrals, team designations, mid-time of surveys, times after shutdown, survey locations, and measured radiation levels.

2. Contamination Surveys

The contamination surveys which were conducted for re-entry teams on R and R+1 days were negative. One incident of a contaminated shoe occurred following EP-I. The contamination level was only 1.0 mR/hr and decontamination was successful. Efforts to identify the source of the contamination were unsuccessful. No other personnel contamination was detected after EP-I or Phase II.

C. Personnel Radiation Exposures

1. Radiation Exposure

Radiation exposure information from pocket dosimeters is presented in Table I for re-entry teams following both runs. Only re-entries with exposures greater than 10 mR individually or 20 mR collectively as a team have been listed.

TABLE I

RE-ENTRY TEAM INFORMATION

Re-entry Team	Dosimetry Recovery	Dosimetry Preparation
No. Participants**	5	3
Total Team Dose, mR*	660	110
Max. Individual Dose, mR*	220	60
Average Dose, mR*	132	37
No. of Monitors	2	N. A.
Monitors' Dose, mR*	205	N. A.
Actual Job Time, Minutes	7-8	30
Max. Dose Rate, mR/hr	7,000	--
Re-entry Date	12/4	12/5

*Pocket Dosimeter Results
**Excludes Monitor
N. A. - Not Assigned Specifically

TABLE 2

Selected Survey Results -- EP-I
Date: December 4, 1968

Preliminary Power Integral of 60 Megawatt-Seconds

Re-entry Team	Mid-Time	Survey Location	Dose Rate mR/hr (C.W.)**
Special Electronics Support	2203 (0.3*)	Forward Tunnel of Test Cell Bldg.	Background
Initial Survey	2250 (1.1*)	W. End Shadow Wall, shielded	2.0
		Outside Shed, N. of H_2O shield opening	2000
		Outside Rx. shield @ opening	7200
		Rx. nozzle @ 2'	20000
Drums Lock	2338 (1.9*)	W. End, Shadow Wall, shielded	1.0
		Between levels 2&3 of Test Stand	2.0
		LO_2 Dewar	1.0
Dosimetry Recovery	2348 (2.1*)	Max. Dose Rate Inside H_2O Shield @ 3'	7000
		Ave. Dose Rate Inside H_2O Shield @ 3'	6500
		Max. Rdg. on Dosimetry	80/110***

Date: December 5, 1968

Isodose Line	0125 (3.7*)	30' West	10
		30' East	10
		3rd Level catwalk atop Rx. Shield Opening	10

*Time after shutdown, hours.
**C.W. -- Closed Window measurement.
***Open Window.

Re-entry Team	Mid-Time	Survey Location	Dose Rate mR/hr (C.W.)**
Special	0915 (11.5*)	15' from Rx., unshielded	90
		At Shield Opening	200
		Contact with Press. Vessel Midplane	8000
		Ave. Dose Rate approx. 3' from Rx. in compartment	600
		Within H_2O Shield away from Opening	10
Special	0938 (11.9*)	Duct Vault	1.2
		Pipe Chase	0.4

PHASE II -- Preliminary Power Integral of 35.2 Megawatt-Seconds
DATE: December 6, 1968

Re-entry Team	Mid-Time	Survey Location	Dose Rate mR/hr (C.W.)**
Special	1448 (----)	W. End Shadow Wall, unshielded	1.0
Steam Generator, LOX, Pipe Chase, & Duct Vault	1850 (----)	High Pressure Gas Area	Bkgd.
		Steam Generator Enclosure	1.0
		E. Wing Wall, unshielded	4.0
		E. Wing Wall, shielded	1.0
		TSER	Bkgd.
		Pipe Chase Rm., Levels 1&2	<1.0
		Door to Duct Vault	5.0
		E. Edge, Pad	Bkgd.
		Pad Smears	Bkgd.
Drums Lock	2338 (1.1*)	Test Stand, 3rd Level	<1.0
		Within Shield Structure	10
		Pad Smears	Bkgd.

Date: December 7, 1968

Re-entry Team	Mid-Time	Survey Location	Dose Rate mR/hr (C.W.)**
Special	0650 (8.3*)	Duct Vault, Max. Rdg.	2.0
		Pipe Chase, Max. Rdg.	2.0
		Pad, Max. Rdg.	2.0
		Contact with Shield	5.0

---

*Time after shutdown, hours.

**C.W. -- Closed Window measurement.

Re-entry Team	Mid-Time	Survey Location	Dose Rate mR/hr (C.W.)**
		Date: December 9, 1968	
Special	0800 (57.5*)	Contact with Shield	2.0
Special	1450 (64.3*)	With W. Shield Closed & 6' above Pad; at 20'	0.12
		at 30', 40', & 50'	0.06
		Contact with W. Shield	0.4
		E. Shield Open 4' & 6' above Pad:	
		At 3'	100
		At 4'	80
		At 5'	65
		At 6'	55
		At 7'	50
		At 20'	0.15
		At 30', 40', & 50'	0.06
		Contact with E. Shield, outside	0.35
		Contact with E. Shield, inside	30
		Contact with Pressure Vessel	640
		Date: December 10, 1968	
Pad	0815 (81.7*)	Personnel Stand, 3rd Level, max.	8
		Personnel Stand, 2nd Level, max.	40
		Personnel Stand, Pad Level in Crit. Zone at work area	200
		Pad Level in Crit. Zone General Area	40
		S-3 Personnel Platform	10

*Time after shutdown, hours.

**C.W. -- Closed Window measurement.

SPEAR Memo No. 27

W. F. Booty
D. C. Rardin

TEST CHRONOLOGY

FOR

XE-PRIME EXPERIMENTAL PLAN I

4 December 1968

I. PRE-OPERATIONAL PHASE

A. FACILITY SET UP

B. 33700 CHECKED THE CONTROL ROOM NET (NET #9).

D. ESTABLISH AREA CONTROL

33835 Reported area secure for testing.

E. UNLOCKED CONTROL DRUM PNEUMATIC DOUBLE BLOCK AND BLEED SYSTEM AND SWITCHED CONTROL DRUM POWER.

33950 Verified Criticality Alarm System ACTIVE.

34190 Obtained Key #1, Key #5, SVB-11 Key and the Pneumatic System Keys. Proceeded to the RSV-877/444 Area and reported in.

34207 Verified P-478 indicated ZERO psig.

34250 Unlocked RSV-444 and rotated the Manual Override hand wheel to the FULL OPEN (UP) position.

34279 Unlocked RSV-877 and rotated the Manual Override Hand wheel to the FULL OPEN (UP) position.

34500 Unlocked SVB-11 and OPENED the Jamesbury supply valves for RSV-444 and RSV-877.

34596 Switched RSV-444 and RSV-877 to OPERATE.

34620 RSV-444 CLOSED.

34630 RSV-877 CLOSED.

34648 SVB-11 LOCKED.

34684 50-BV-2332 UNLOCKED and manually CLOSED.

34980 Proceeded to the TCB and reported in.

34989 Installed Key #1 and switched to CP control.

34998 Verified CP Control.

35005 Verified ZERO position demand on gang drum demand.

34020 Installed Key #5 and switched to drum OPERATE.

34021 Verified Drum Operate indication.

34250 Returned to the Control Point and reported in.

35547 Deactivated Criticality Alarm System.

F. PERFORM DATA SYSTEM CALIBRATION.

33045 Switched consoles to ENABLE.

33055 Switched all groups except #7 to ENABLE.

33065 Performed Automatic Data System Calibration, recorded ambient data and reported completion

33184 Complete.

33193 Returned all groups to INHIBIT.

33199 Returned consoles to INHIBIT.

33206 DATA SYSTEM TO LOW.

33253 Conducted a one point remote calibration of the log and linear neutronics system and reported completion.

33358 BF-3 power ON.

33364 All scaler power channels ON.

33369 Selected AUTO on all scaler channels.

33389 Switched source drive control to EXPOSE and verified operation of power increase timer.

33415 Verified .

33425 Verified operation of all scaler channels.

33536 Sequentially selected startup Channels 1, 2, and 3 for display on ATE console and verified operation.

33584 Shielded the source and verified shielded.

33618 Switched source drive to OFF.

G. PRESSURIZE V-3601, CHILLDOWN 225-LN-6 AND SET UP CRYOTRAP CHILLER.

35071 OPENED RSV-325.

35088 OPENED RSV-392.

35106 CLOSED PCV-517.

35115 CLOSED RSV-327.

35130 OPENED RSV-326

35150 Pressurized V-3601 to 100 psig using PRV-108.

35174 Slowly OPENED PCV-517 to 90% in MANUAL.

35270 OPENED RSV-879.

35321 Cycled RSV-879 as required to maintain a minimum LN_2 level of .5 psid.

35325 Used PCV-754 to chill until T-510 indicated 140 to 150^{O}R.

36267 When T-55 stabilized, CLOSED RSV-392.

36585 OPENED PCV-754.

36586 Used PCV-517 to maintain chill at T-510.

H. CONDUCT MANUAL SCRAM AND INPUT SCRAM SETTINGS.

35363 Set Master Key (#4) to OPERATE.

35371 Reset Engine Safety system.

35374 Initiated Manual Scram.

35390 Set Fixed Power Scram at 160 divisions (1 KW).

35395 Selected Fixed Power Scram and ACTIVATED.

35402 Bypassed Floating Power Scram.

35414 Activated 115 VAC Neutronics Instrumentation Power.

35419 Activated $\pm$ 24 VDC Power Supply.

35428 Selected Period Trip of 1.0 seconds.

35435 Selected interval of 25%.

35440 Activated Period Scram.

35473 Set Max. Drum Position Scram at 360 divisions (64° drum position).

35478 Activated Max. Drum Position Scram.

35485 Bypassed Drum Roll-in Scram.

35490 Bypassed pump discharge pressure loss (dp/dt).

35496 Bypassed loss of TPCV actuator pressure.

35503 Bypassed TPA Speed Scram Input.

35510 Bypassed TPCV position override.

35514 Activated Drum Position Override.

35521 Bypassed Pressure Mode INHIBIT.

I. SET UP CONTROL DRUM PNEUMATIC SYSTEM.

36908 OPENED RSV-867.

36914 OPENED RSV-880.

36918 CLOSED RSV-881.

36946 Used PRV-402 to establish 40 $\pm$ 20 psig at P-618.

36955 OPENED RSV-881.

37085 When T-571 indicated 160 $\pm$ 10°R, CLOSED RSV-881.

37125 Used PRV-402 to establish 800 psig at P-618.

37132 CLOSED RSV-443.

37138 OPENED RSV-877.

37143 OPENED RSV-444.

37170 Used PRV-200 to slowly increase P-832 to 200 psig.

37218 Established 200 psig at PRV-200.

II. OPERATIONAL PHASE

A. CONDUCT INDIVIDUAL DRUM ROTATION CHECKOUT.

37251 Verified Individual Drum Select Switch OFF and individual and gang pots at ZERO.

37274 Obtained Ganged Drum Key (Key #3) from TD and switched to ENABLE.

37280 Verified drums indicated LOCKED, and Drum Lock switches NOT ACTIVE.

37292 Reset Engine Safety System.

37300 Period Scram.

37318 Reset Engine Safety System.

37324 Selected Drum #1, UNLOCKED AND ACTIVATED individual control.

37335 DATA SYSTEMS TO HIGH.

37340 Withdrew Drum #1 to 165°.

37371 Initiated Manual Scram.

37378 DATA SYSTEM TO LOW.

37385 Set individual drum pot to ZERO, LOCKED AND DEACTIVATED individual control.

Repeated the above steps for Drums 2 thru 12.

37433 Drum #2 Scrammed.

37488 Drum #2 Scrammed.

37524 Drum #4 Scrammed.

37557 Drum #5 Scrammed.

37589 Drum #6 Scrammed.

37625 Drum #7 Scrammed

37654 Period Scram.

37676 Drum #8 Scrammed.

37703 Drum #9 Scrammed.

37731 Drum #10 Scrammed.

37761 Drum #11 Scrammed.

37770 50% Period Selected.

37798 Drum #12 Scrammed.

37811 DATA TO LOW.

B. CHECK MAX DRUM SCRAM.

37870 Adjusted PRV-200 from 210 psig to 190 psig.

37893 Set Max Drum Position Scram at 220 divisions (40°).

37900 Calibrated neutronics, back to 100% period.

38013 Drums set to 10° in POSITION Control.

38020 Reset Engine Safety System.

38026 Unlocked Control Drum #1.

38032 Selected Drum #1 and ACTIVATED individual control.

38028 DATA SYSTEMS TO HIGH.

38055 Withdrew Drum #1 to 165°.

38088 Slowly lowered Max Drum Position Scram Set Pot until Scram occurred - 120 degrees.

38093 DATA SYSTEMS TO LOW.

38098 Set Position Demand Pot to ZERO.

38100 Set Drum #1 demand to ZERO.

38105 Deactivated Individual Control.

38120 Set Max Drum Position Scram to 360 divisions (64°).

C. ESTABLISH INITIAL REACTOR CRITICALITY AND CONDUCTED FIXED POWER SCRAM.

38150 Set Fixed Power Scram at 160 divisions (1 Kw).

38155 Reset Engine Safety System.

38168 Patched transfer function generator to drums Position Loop.

38179 Unlocked control drums.

38198 Reported source count rate above 60 counts per minute.

38232 Printed out drum positions:

Drum #1	7.1	Drum #7	6.0	
Drum #2	5.8	Drum #8	5.6	
Drum #3	7.0	Drum #9	7.4	
Drum #4	6.3	Drum #10	6.8	
Drum #5	7.2	Drum #11	7.3	
Drum #6	8.0	Drum #12	6.0	Average: 6.6

38255 Reported Count Rates:

Scaler #1 343 cpm

Scaler #2 350 cpm

Scaler #3 449 cpm

38276 Verified POSITION Control is selected.

38283 DATA SYSTEMS TO HIGH.

38284 Initiated start reactor in POSITION Control, withdrew drums to 23.6°.

38318 Position of 23.6° achieved.

38329 Reported Count Rates:

Scaler #1 339 cpm

Scaler #2 386 cpm

Scaler #3 464 cpm

38640 Printed out drum positions:

Drum #1	27.0	Drum #7	23.9	
Drum #2	25.1	Drum #8	23.8	
Drum #3	27.4	Drum #9	23.8	
Drum #4	27.4	Drum #10	23.8	
Drum #5	22.3	Drum #11	23.8	
Drum #6	23.8	Drum #12	25.6	Average 23.7

38739 SCRAMMED

38747 Disabled Gang Key and verified all drums locked.

39083 Drum #9 high torque motor current defective recorder channel.

39820 Unlocked control drums.

39863 Initiated start reactor and in POSITION control, withdrew drums to 23.6°.

Reported Count Rates:

Scaler #1 380 cpm

Scaler #2 390 cpm

Scaler #3 487 cpm

Read drum positions:

Drum #1	23.2	Drum #7	23.0	
Drum #2	21.6	Drum #8	22.9	
Drum #3	23.6	Drum #9	23.6	
Drum #4	23.9	Drum #10	22.6	
Drum #5	24.2	Drum #11	23.8	
Drum #6	24.1	Drum #12	23.1	Average 23.3

40231 SCRAMMED.

40600 Checked difference in average drum position D.800 and calculated individual position - looked for #9 torque motor current noise.

41750 Reset Engine Safety System and enabled gang key.

41791 Initiated Start Reactor and in POSITION Control withdrew Drums to 47.2°.

41831 Position of 47.2 achieved.

41839 Reported Count Rates:

Scaler #1 498 cpm

Scaler #2 516 cpm

Scaler #3 738 cpm

42232 Printed out drum positions:

Drum #1	46.9	Drum #7	47.3	
Drum #2	45.6	Drum #8	47.4	
Drum #3	47.9	Drum #9	47.6	
Drum #4	47.6	Drum #10	46.1	
Drum #5	47.1	Drum #11	47.7	
Drum #6	47.2	Drum #12	47.4	Average 47.3

42259 ENABLED Transfer function input.

42260 Proceeded with sine transfer function measurements of .1 cps, .25 cps, .63 cps, 1.0 cps, 1.6 cps, 2.5 cps, 4.0 cps, 6.3 cps, 10 cps, and 16 cps.

42463 Inhibited transfer function input.

42472 DATA SYSTEMS TO LOW

42474 Drums in and locked.

42480 SCRAMMED.

HOLD FOR TORQUE MOTOR NOISE INVESTIGATION.

45661 Set maximum drum position scram to 410 divisions (74.0°).

45677 DATA SYSTEMS TO HIGH.

45694 Start Reactor.

45708 Withdrew the drums to 64.6°.

Noise back - decreased position.

Noise gone @ 28-30°.

Noise back @ 33°; torque motor current is 28-35 ma with ± 10 ma noise

45900 Drums at 40° ~40 ma noise

45920 All drums locked.

46050 Set max drum scram @ 360 pot divisions.

HOLD FOR DRUM NOISE INVESTIGATION.

52103 More drum tests, individually unlocked and rotated out to 40°, noise returned when last drum came out.

52965 Isolated drum position to data.

52994 Maximum position scram check.

53010 Individual drums rotated out to 40°.

54065 Ganged drums out to 38° with backup + 24 V power supply removed, noise returned.

54318 Ganged drums out to 38° with other +24V power supply removed, noise returned.

54390 SCRAM
57460 Drums run out to the stops individually.
58360 Drums back in, one +24 V supply removed.
58423 Ganged drums out to 38°, same problem.

58486 SCRAM

HOLD FOR TORQUE MOTOR CURRENT NOISE INVESTIGATION.

63276 Reset Engine Safety System.

63280 Drums 1, 5 and 9 rotated to 160°.

63510 Drum 9 in and locked.

63520 Drum 5 in and locked.

63562 Drum 2 to 160°.

63580 Drum 3 to 160°.

63653 Drums 1, 2 and 3 run in and locked.

63665 SCRAM

63688 Drum actuation system bleed-off and secured.

67410 Re-established 200 psig to drum actuator system.

68070 Reset Engine Safety System and enabled gang key.

68060 DATA TO HIGH

68137 Initiated Start Reactor and in POSITION Control withdrew drums to 47.2°.

68147 Count Rate Reported:

Scaler #1 303 cpm

Scaler #2 443 cpm

Scaler #3 373 cpm

68590 Printed out drum positions:

Drum #1	47.0	Drum #7	46.9	
Drum #2	45.4	Drum #8	46.8	
Drum #3	47.2	Drum #9	47.3	
Drum #4	47.5	Drum #10	46.4	
Drum #5	47.5	Drum #11	47.4	
Drum #6	47.2	Drum #12	46.6	Average 47.2

68888 Set maximum drum position scram to 410 divisions (74.0°).

68895 Withdrew the drums to 70.8°.

68962 Drums at 70.8°.

68990 Count Rate Reported:

Scaler #1 426 cpm

Scaler #2 613 cpm

Scaler #3 550 cpm

69010 Set max. scram at 440 divisions (80°).

69720 Printed out drum position:

Drum #1	69.7	Drum #7	69.7	
Drum #2	68.1	Drum #8	69.5	
Drum #3	69.8	Drum #9	69.7	
Drum #4	69.8	Drum #10	69.2	
Drum #5	69.8	Drum #11	69.9	
Drum #6	69.7	Drum #12	69.2	Average 70.2

70070 Set Max Drum Position Scram to 470 divisions (85°).

70072 Withdrew drums to 82.5°.

70090 Set Max Drum Position Scram to 500 divisions (90°).

70100 Drums set at 82.5°.

70125 Reported Count Rate:

Scaler #1 840 cpm

Scaler #2 1013 cpm

Scaler #3 994 cpm

70865 Printed out drum positions:

Drum #1	82.0	Drum #7	82.1	
Drum #2	80.7	Drum #8	82.0	
Drum #3	82.2	Drum #9	82.2	
Drum #4	82.2	Drum #10	81.5	
Drum #5	82.1	Drum #11	82.2	
Drum #6	82.0	Drum #12	81.7	Average 82.4

70906 Withdrew drums to 90.5°.

70908 Set Max Drum Position Scram to 530 divisions (95°).

70944 Set Max Drum Position Scram to 100°.

70945 Drums at 90.5°.

70968 Reported Count Rate:

Scaler #1 1611 cpm

Scaler #2 1805 cpm

Scaler #3 1738 cpm

71350 Printed out drum positions:

Drum #1	89.9	Drum #7	90.1		
Drum #2	88.9	Drum #8	90.2		
Drum #3	90.1	Drum #9	90.2		
Drum #4	90.1	Drum #10	89.3		
Drum #5	90.0	Drum #11	90.2		
Drum #6	90.0	Drum #12	89.7	Average	90.4

71548 Withdrew drums to 95.5°.

71605 Drums at 95.5°.

71610 Set Max Drum Position Scram at 105°.

71635 Reported Count Rate:

Scaler #1 6740 cpm

Scaler #2 7550 cpm

Scaler #3 7460 cpm

72230 Printed out drum positions:

Drum #1	95.8	Drum #7	95.9		
Drum #2	94.9	Drum #8	95.8		
Drum #3	96.3	Drum #9	96.8		
Drum #4	96.2	Drum #10	95.4		
Drum #5	95.7	Drum #11	95.9		
Drum #6	95.6	Drum #12	95.7	Average	96.3

72390 Established 10 watts in POSITION Control.

72496 Log #3 noisy.

72499 Rejected Log #2.

72514 Took fission chamber count rate (144.96 cps).

72626 Printed out drum positions:

Drum #1	97.3	Drum #7	97.3		
Drum #2	96.4	Drum #8	97.0		
Drum #3	97.8	Drum #9	98.6		
Drum #4	97.6	Drum #10	96.9		
Drum #5	97.3	Drum #11	97.2		
Drum #6	97.6	Drum #12	97.6	Average	98.2

72780 Established 50 watts.

72912 Took fission chamber count rate (738.32 cps).

72930 Established 100 watts.

Took fission chamber count rate (1406.81 cps).

73120 Established 1 KW.

73160 Initiated a fixed power scram in POSITION Control at 1 KW.

73178 SCRAM.

73191 Disabled Gang Key and verified all drums LOCKED.

73196 DATA SYSTEMS TO LOW.

73776 Reported fission chamber power correction factor (2.5).

D. CONDUCTED PERIOD SCRAM CHECK.

74080 Switched drum HE bottles V-3205 to V-3206.

74100 Set Fixed Power Scram to 160 divisions (1 KW).

74105 Set Period Trip 1.0 second and sample time 100%.

74126 Reset the Engine Safety System and Enabled Gang Key.

74128 DATA SYSTEMS TO HIGH.

74138 Initiated Start Reactor and in POSITION Control established reactor power at 100 W.

74297 100 W. established.

74377 25% Period Sample Time selected.

74415 Set Max Drum Scram to 630 divisions (113°).

74430 Reset drum override.

74424 Initiated a Period Scram.

74431 Disabled Gang Key and verified all drums LOCKED.

74434 DATA SYSTEM TO LOW.

E. CONDUCTED CONTROL SYSTEM PRELIMINARY CHECKOUT, LOW POWER DOSIMETRY TEST AND DRUM ROLL-IN SCRAM CHECK.

75210 Set Fixed Power Scram at 195 divisions (2 KW).

75226 Set Max Drum Scram at 600 divisions (108°).

Patched the transfer function generator to the Drum Position Demand.

75283 Reset Engine Safety System and Enabled Gang Key.

75287 DATA SYSTEMS TO HIGH.

75297 Selected POSITION Control and STARTED Reactor.

75299 Established reactor power at 1 KW in POSITION Control.

75473 1 KW established.

Fission chamber count rate (13,292 cps).

75618 Enabled transfer function input.

75680 Inserted -1° step.

75687 1° step removed.

75729 Proceeded with transfer sinc function measurements of .1 cps, .25 cps, .63 cps, 1.0 cps, 1.6 cps, and 2.5 cps.

75783 Inhibited transfer function input.

75812 Power drifted to 600 W - Brought back up to 1 KW.

75823 Switched to POWER Control.

75840 Switched transfer function input to the POWER Control Loop.

75847 ENABLED transfer function generator input.

75855 Step power demand to 900 watts, held for 5 seconds.

75861 Stepped to 1 KW and held 5 seconds.

75867 INHIBITED transfer function input.

75872 Removed transfer function input.

76000 Printed out drum positions:

Drum #1	97.2	Drum #7	97.5	
Drum #2	96.5	Drum #8	97.5	
Drum #3	98.0	Drum #9	99.0	
Drum #4	97.4	Drum #10	96.7	
Drum #5	97.1	Drum #11	97.6	
Drum #6	97.4	Drum #12	97.7	Average 98.1

76014 In POWER Control decreased the power level to on 20 sec period to 100 W.

76122 100 W established.

76215 Back up to 1 KW on 5 second period.

76242 1 KW established.

SCRAM.

76277 OPENED RSV-304.

76290 Monitored P-623 and reported when S-1 is full.

76520 Ran drums in, locked and scrammed.

77347 S-1 filled.

77370 CLOSED RSV-304.

77392 Reported S-1 Water Level, P-623 85%.

77437 Set Fixed Power Scram at 195 divisions (200 KW).

77540 Back up to 1 KW in POSITION on 10 second period.

77714 1 KW established.

77743 In POWER Control at 1 KW.

77870 Printed out drum positions:

Drum #1	97.4	Drum #7	97.3	
Drum #2	96.4	Drum #8	97.2	
Drum #3	97.8	Drum #9	98.8	
Drum #4	97.6	Drum #10	97.0	
Drum #5	97.4	Drum #11	97.4	
Drum #6	97.2	Drum #12	97.5	Average 97.6

77910 Fixed scram set at 480 KW. Back on 25% period.

77926 Increased power to 100 KW on a 5 second period.

77960 1 KW established.

78157 Activated Drum Roll-in Scram.

78167 In POWER Control, decreased power on a 2 second period to produce a drum roll-in SCRAM.

78171 SCRAM.

78179 Disabled Gang Key and verified all drums LOCKED.

78183 DATA SYSTEMS TO LOW.

78202 Bypassed Drum Roll-in SCRAM.

III. SECURE AND RE-ENTRY PHASE

A. SECURED CONTROL DRUMS.

78220 LOCKED all Control Drums.

78231 Verified Drum Position Demand ZERO.

78240 Verified Gang Drum Control Key (Key #3) in DISABLE, removed key and returned to TD.

78275 Set Max Drum Position Scram at 220 divisions (40°).

79184 Drum noise checks - added capacitance to #9 - seemed better.

B. SECURED CONTROL DRUM PNEUMATICS AND ENGINE PURGE.

79577 CLOSED RSV-867.

79655 CLOSED RSV-444 and RSV-877 when P-615 and P-832 were ZERO.

79618 OPENED RSV-443.

79664 CLOSED PRV-200.

79670 OPENED RSV-881.

79678 CLOSED PRV-402.

80995 CLOSED RSV-446.

C. MOVED S-1 BACK.

78926 Recorded S-1 shield water level obtained during S-1 fill. PT-623 85%.

78945 Dropped S-1 water level $1\frac{1}{2}$% lower than previous reading obtained by cycling RSV-356 as required.

78994 Level dropped $1\frac{1}{2}$%.

79000 Inched S-1 shield back for ETC access.

D. CLEARED THE RE-ENTRY TEAM INTO THE AREA FOR DOSIMETRY REMOVAL.

IV. POST-OPERATIONAL PHASE

79960 - 81170 FACILITY SECURED.

SPEAR Memo No. 28

W. F. Booty
D. C. Rardin

TEST CHRONOLOGY

FOR

XE-PRIME

PHASE II NES STEAM LINE DESIGN
DEMONSTRATION TEST
AND
INTERMEDIATE DOSIMETRY IRRADIATION

6 December 1968

I. PRE-OPERATIONAL PHASE

B. CHECKED THE CONTROL ROOM NET (Net #9).

D. 33840 ESTABLISHED AREA CONTROL.

E. 34165-35724 PERFORMED DATA SYSTEM CALIBRATION

F. 36089 SET UP THE PRE-OPERATIONAL NETS

II. CTE PRE-OPERATIONAL PHASE

A. 36341-38884 PRESSURIZED V-3601, CHILLED DOWN 225-IN-6, SET UP CRYOTRAP AND CHECKED FOR RSV-545 LEAKAGE

B. 38438-38555 CONDUCTED MANUAL SCRAM AND INPUT SCRAM SETTINGS.

C. 39315-40225 UNLOCKED CONTROL DRUM PNEUMATIC DOUBLE BLOCK AND BLEED SYSTEM, SWITCHED CONTROL DRUM POWER, AND SWITCHED FROM GN_2 TO GHe ENGINE PURGE.

D. 40300-40632 SET UP CONTROL DRUM PNEUMATIC SYSTEM.

E. CONDUCTED INDIVIDUAL DRUM ROTATION CHECKOUT.

41188 Verified Individual Drum Select Switch was OFF and all individual pots were ZERO.

41198 Verified gang position demand pot was ZERO.

41214 Obtained Ganged Drum Key (Key #3) from TD and switched to ENABLE.

41233 Verified drums indicated LOCKED, and Drum Lock switches were NOT ACTIVE.

41242 Reset Engine Safety System.

41250 Selected Drum #1, UNLOCKED AND ACTIVATED individual control.

41263 DATA SYSTEMS TO HIGH.

41265 Withdrew Drum #1 to 165°.

41294 Initiated Manual SCRAM.

41305 Set individual drum pot to ZERO, LOCKED AND DEACTIVATED Individual Control.

Repeated the above steps for Drums 2 thru 12:

Drum #2	41358	Drum #7	41880
Drum #3	41442	Drum #8	41922
Drum #4	41495	Drum #9	41969
Drum #5	Couldn't pull #5 - Tried several times	Drum #10	42009
		Drum #11	42054
Drum #6	41830	Drum #12	42101

42120 DATA SYSTEM TO LOW

HOLD to check #5 - found fuse burned out.

43450 DATA SYSTEM TO HIGH and re-checked drums:

Drum #5	43502	Drum #11	43636
Drum #9	43558	Drum #12	43680
Drum #10	43601		

43690 DATA SYSTEM TO LOW

F. CHECKED MAX DRUM SCRAM.

43742 Verified Max Drum Position Scram set at 220 divisions (40°).

43765 Reset Safety System.

43771 In POSITION Control, set drums to 10°.

43786 Unlocked Control Drum #1.

43797 Selected Drum #1 and ACTIVATED individual control.

43773 DATA SYSTEMS TO HIGH.

43830 Withdrew Drum #1 to 165°.

43842 Slowly lowered Max Drum Position Scram Set Pot until scram occurred.

43864 SCRAM.

43868 DATA SYSTEMS TO LOW.

43880 Set Position Demand Pot to ZERO.

43884 Set Drum #1 demand to ZERO.

43888 DE-ACTIVATED Individual Control.

G. ESTABLISHED REACTOR CRITICALITY AND CONDUCTED FIXED POWER AND PERIOD SCRAM CHECKS.

43900 Startup channels were less than 60 cpm.

43990 Set Max Drum Scram at 78°.

44038 Set Max Drum Scram at 40°.

44052 Set Fixed Power Scram at 1 kw.

Test Chronology for Phase II NES Steam Line Demonstration Test

44276 Reset Engine Safety System.

44287 UNLOCKED control drums.

44302 DATA SYSTEM TO HIGH.

44469 Drums to 40°.

44505 Max Drum Scram set to 78°.

44599 Drums to 68°.

45020 Max Drum Scram set to 90°.

45058 Drums to 80°.

45148 Max Drum Scram set to 108°.

45155 In POSITION Control initiated start reactor and established 500 watts.

45517 500 Watts established.

45537 In POSITION Control, initiated a Fixed Power Scram at 1 KW.

45556 SCRAM.

45562 Disabled Gang Key and verified all drums LOCKED.

45567 DATA SYSTEMS TO LOW.

45567 BF3 Power ON .

45920 Verified Period Trip 1.0 second and sample time 25% selected.

45927 Reset the Engine Safety System, then ENABLE gang key.

46112 DATA SYSTEMS TO HIGH.

45980 Set Fixed Power Scram to 282 Divisions (10 KW).

46089 Set Fixed Power Scram to 192 Divisions (2 KW).

46120 In POSITION Control Initiated Start Reactor established reactor power at 1 KW.

46317 1 KW established.

46342 Switched to power control.

46408 to 500 W on 5 second period.

46500 to 1 KW on 5 second period.

46631 Switched to Position Control.

46649 Bypassed max drum scram.

46675 Set Fixed Power Scram at 283 divisions (10 KW).

46685 Initiated a Period Scram, got drum override indication not scram - Scram did occur.

Disabled gang key and verified all drums LOCKED.

DATA SYSTEMS TO LOW.

ACTIVATED max drum scram.

BF3 power ON.

47215 Pushed Scram Button.

RECHECK OF PERIOD SCRAM

47362 Period Trip Set at 1 second and 25%.

47378 Reset the Engine Safety System, then ENABLE gang key.

47390 In POSITION Control initiated Start Reactor established reactor power at 1 KW.

47560 Power Loop closure.

47572 1 KW established.

47588 Bypassed max drum scram.

47615 Reset Fixed Drum Scram to 283 divisions (10 KW).

47641 Initiated a Period Scram.

47653 Disabled gang key and verified all drums were LOCKED.

47660 DATA SYSTEMS TO LOW.

47667 ACTIVATED Max Drum Scram.

47685 BF3 Power ON.

H. START TO 1 KW.

47835 Set Fixed Power Scram pot at 196 divisions (2 KW).

47848 Verified Period Scram at 1.0 seconds and 25% sample time.

47854 Reset Engine Safety System then ENABLE Gang Key.

47862 DATA SYSTEMS TO HIGH.

47866 STARTED Reactor in Drums Control to 1 KW.

47935 BF3 Power OFF when required.

48015 1 KW established.

48050 Switched to Power Control.

48114 CTE/ATE/LRE/CSE: Reported all Scram Signals.

III. LFE PRE-OPERATIONAL PHASE

A. 36413 - 37770 EXERCISED THE ESSENTIAL VALVES.

B. CONDUCTED TEST STAND COOLING SYSTEM WATER FLOW TEST.

37770 OPENED RSV-296 and bled in duct.

37805 OPENED RSV-297.

37946 OPENED RSV-298.

37966 DDS TO HIGH.

37800 Used FCV-31 to establish 30 psig at P-863.
38080 Used FCV-31 to establish 39 psig at P-863.
38120 OPENED FCV-31 to 100%.
48155 OPENED RSV-738
38156 OPENED RSV-739
38162 OPENED RSV-858
38164 OPENED RSV-859
38240 OPENED FCV-32 until F-56 or F-57 indicated 15.6 psid (40,000 gpm).
38272 OPENED RSV-937.
38304 CLOSED RSV-937.
38315 CLOSED FCV-32.
38475 CLOSED FCV-31.
38401 CLOSED RSV-738.
38402 CLOSED RSV-739.
38409 CLOSED RSV-858.
38410 CLOSED RSV-859.
38478 DATA SYSTEMS TO LOW
38520 LT-015 is 37.5 feet.
38520 Switched to the CTE Net (#9).

C. 40100 - 40180 BLED IN LIQUID OXYGEN.

D. 40305 - 40438 BLED IN PROPANE.

E. 40377 - 41100 PRESSURIZED THE GN_2 HEADER.
40377 OPENED RSV-1, RSV-6 and RSV-11.
40388 CLOSED RSV-2, RSV-7 and RSV-12.
40402 OPENED RSV-273.
41100 OPENED RSV-245 and CLOSED RSV-273 when P-2 stabilized.

IV. <u>OPERATIONAL PHASE</u>

A. SWITCHED BACK TO THE OPERATIONS NET (#9)

B. PRESSURIZED PROPANE AND LO_2 TANK.
48010 OPENED RSV-494.
48042 OPENED RSV-329X and Y.
48062 OPENED RSV-482.

48100 OPENED RSV-435. CLOSED after T-478 indicated less than 520°R.

48175 Engine Log 1 back in Average.

48325 CLOSED RSV-435.

48330 OPENED RSV-330.

48340 Pressurized propane tank to 295 psig.

48282 Pressurized LO_2 tank to 310 psig.

49437 Propane and LO_2 at 295 and 310 psig, respectively.

C. INERTED THE ETC.

48537 OPENED RSV-853

48555 OPENED RSV-222

48567 CLOSED RSV-853

48600 OA-1 and OA-2 were less than 0%.

49720 OPENED PCV-447 and established 397 psig at P-643 (1 lb/sec GN_2).

49751 Established 397 psig at P-643.

48640 Monitored ETC O_2 concentration.

D. ENGAGED TSA/ENGINE BOLTS ANC CLAMPS.

48642 OPENED RSV-221.

LT-15 is 37 feet.

48739 Established 14 psig at P-480 with PRV-405.

48743 Engaged TSA/Engine Bolts and Clamps.

48827 P-480 dropped - re-established to 14 psig.

49075 LN DM out on Brush.

E. SET UP STEAM GENERATOR AND ESTABLISHED COOLANT FLOW.

49763 Obtained less than 180°R at T-479.

50026 2nd Stage LOX Valve Leak, SG #2.

50100 Drums in and scrammed, drum actuation system secured, and SG secured for re-entry.

56350 - 59000 HOLD OVER AND RE-ESTABLISH CONTROL DRUM ACTUATION SUPPLY, LOX AND PROPANE BLEED IN AND PRESSURIZATION FOR STEAM GENERATORS.

56670 Drum Actuation System Established.

56714 Set FPS at 2 KW, 196 divisions.

56729 Set Max Drum Scram at 600 divisions (108.2°).

56735 Activate Max Drum Scram

56740 Re-set Engine Safety System and ENABLE Gang Key

56752 DATA SYSTEMS TO HIGH.

Test Chronology for Phase II NES Steam Generator Demonstration Test

56781 Started Reactor - In Manual Control to 1 KW.

56946 Established 1 KW.

56972 Switched to Power Control.

56990 Max Drum Scram set at 115°.

57026 Selected individual monitor and conducted relative drum worth measurements.

57039 Drum #1 selected.

57055 Drum #1 active control and scram (period).
Scram due to null offset.

57060 Drum nulls checked at 40°.

57540 Repeated relative drum worth measurements.

57550 Started Reactor.

57714 1 KW established in position control.

57740 Switched to power control.

Select Drum	Drum Null	Activate Control	Set to 15°	Set to 165°	Drum Null	Deactivate Control
1*		57841	57884	58025	58082	58240
2	58264	58315	58328	58420	58503	58518
3	58588	58589	58610	58672	58720	58722
4	58735	58736	58754	58825	58860	58877
5	58895	58900	58819	58964	59000	59005
HOLD FOR S.L. TEST						
6	59996	59947	60025	60077	60120	60122
7	60132	60144	60164	60204		60242
8	60284	60287	60307	60348	60375	60395
9	60407	60415	60432	60466	60515	60519
10	60526	60531	60550	60589	60625	60628
11	60868	60873	60893	60939	60961	60905
12	61025	61035	61055	61094	61130	61134
HOLD FOR S.L. TEST						

CONDUCTED DIFFERENTIAL DRUM WORTH TESTS

62355 Selected Drum Average Monitor.

62426 Set Fixed Power Scram at 570 divisions (2 MW).

62432 Switched to POSITION Control.

62448 Bypassed Max Drum Scram.

62489 Stepped Drum Position out 10° and held until power level indicated 900 KW.

62508 Re-established 1 KW.

62590 Switched to Power Control.

62797 Switched to Position Control.

62820 Stepped Drum Position out 10° and held until power level indicated 900 KW.

62832 Re-established 1 KW.

62932 Switched to Power Control.

63119 Switched to Position Control.

63135 Stepped Drum Position out 10° and held until power level indicated 900 KW.

63154 Rotated Drums in.

63162 SCRAM.

G. FIRST STEAM PROFILE

58999 OPENED RSV-324

59030 OPENED PCV-543

59130 PCV-251 used to establish 100 psig at P-475 (11 pps).

59145 DDS to HIGH and Recorders to LOW.

59156 Reported all PCV-449 rate trips.

59157 Turned on Manual SGS Purge.

59162 Started Camera Group A.
59170 Started SG-1 to IDLE.
59180 Started SG-2 to IDLE.
59297 OPENED FCV-31 to 100% and FCV-32 until F-56 or F-57 indicated 15.6 psid (40,000 gpm).

59229 Turned on Camera Group B for five seconds on each command to full steam.

59305 ANALOG TO HIGH

59325 Full Steam SG-1.

59350 Full Steam SG-2.

59405 RSV-439 OPENED

59425 Adjusted FCV-423-1 and -2 until T-534 indicated 1260 ±50°R.

59465 No Control on #1 water valve.

59600 Attempted to raise T-534 by closing water pots.

59685 OPENED water pots.
59697 Stopped SG#1 (449 rate trip)
59703 Stopped SG#2 (449 rate trip)
59736 CLOSED PCV-251.
59890 Duct water flow stopped.
59900 Completed relative Drum Worth measurements.

E. SET UP STEAM GENERATOR AND ESTABLISHED COOLANT FLOW.

69050 Verified RSV-439 de-energized OPEN.
60970 OPENED RSV-434.
60973 OPENED RSV-433/RSV-949.
60975 Verified water OK lights.
60980 Re-set steam generators.
60994 Depressed ready switches.
61012 Positioned injection water control valve pots to 1000.
61040 Trough cooling water valves OPENED.

F. SET UP ENGINE PURGE.

61715 Switched PCV-251 to arm.
61347 Used PCV-251 to establish 100 psig (11 pps) at P-475.

G. REPEATED FIRST STEAM PROFILE

61377 DDS to HIGH and Recorders to LOW.
61363 Reported all PCV-449 rate trips.
61384 Turned on Manual SGS Purge.
61392 Started Camera Group A.
61400 Started SG-2 to IDLE.
61408 Started SG-3 to IDLE, no 2nd Stage.
61412 Re-set SG-3
61431 Started SG-3 to IDLE, No 2nd Stage.
61579 OPENED FCV-31 to 100% and FCV-32 until F-56 and F-57 indicated .2 psid (6,000 gpm).
61608 Full Steam SG-2
61670 Water Valve in to 16% and out to 100%.
61705 Adjusted FCV-423-2 until T-534 indicated 900°R.
61850 FCV-423-3 OPENED dropping T-534 to 700°R.
61947 STOPPED SG-2.

61977 CLOSED PCV-251

62000 Secured for SG Check Out (HOLD).

E. (of EP-I) CONDUCTED INDIVIDUAL DRUM ROTATION CHECKOUT

74410 Cryotrap refilled, propane and LOX systems pressurized and bled in, and drum actuation system set up.

74783 Verified Individual Drum Select Switch was OFF and all individual pots were ZERO.

74797 Verified gang position demand pot was ZERO.

Obtained Ganged Drum Key (Key #3) from TD and switched to ENABLE.

74808 Verified drums indicated LOCKED, and Drum Lock switches were NOT ACTIVE.

74811 Re-set Engine Safety System.

74843 Selected Drum #1, UNLOCKED AND ACTIVATED individual control.

74855 Set Fixed Power Scram to 2 KW, Max Drum Scram set to 64° and 1 second period 50% selected.

74894 DATA SYSTEMS TO LOW.

74915 Withdrew Drum #1 to 165°.

74920 Initiated Manual Scram.

74928 Set individual drum pot to ZERO, LOCKED AND DEACTIVATED individual control.

Repeated Steps for Drums 5 and 11.

Drum #5 74981 Drum #11 75041

DATA SYSTEMS TO LOW.

F. CHECKED MAX. DRUM SCRAM

75057 Verified Max Drum Position Scram set at 220 divisions (40°).

75077 Reset Safety System.

75091 In POSITION Control set drums to 10°.

75108 UNLOCKED Control Drum #6.

Selected Drum #6 and ACTIVATED individual control.

75125 Withdrew Drum #6 to 90°.

75157 Withdrew Drum #6 to 165°.

75163 Slowly lowered Max Drum Position Scram Set Pot until scram occurred.

75175 No scram light, but drum went in.

G. CONDUCTED DRUM INTEGRAL WORTH TEST

75265 Verified Fixed Power Scram at 196 pot divisions (2 KW).

Test Chronology for Phase II NES Steam Line Demonstration Test

75275 Set Max Drum Position Scram to 605 divisions, 108.2°.

75283 Reset Engine Safety System.

75300 Unlocked control drums.

Verified period Scram set at 50% and 1 second.

75335 DATA SYSTEMS TO HIGH.

75321 In POSITION Control initiated start reactor and established 1 KW.

75529 1 KW established.

75620 Selected and Activated Drum #1

75678 Drum #1 to 15°

75749 Used #1 to re-establish 1 KW and switched back to gang.

75767 SCRAM.

CONDUCTED MOTOR CURRENT CHECK AND REPEATED DRUM INTEGRAL WORTH TEST

76197 Began running all drums to 90°, then to 165° and then back in to check torque motor currents since removal of capacitors.

Checked Max Drum Scram on #12 from 165°.

76700 Repeated Drum Integral Worth Test with Drum #6.

76895 Established 1 KW in Position Control.

77035 Rotated #6 to 15°.

77125 Rotated #6 back out to re-establish 1 KW. Switched to Power Control.

Log Channels Printed Out.

77460 Set Fixed Power Scram to 20 KW.

77501 Went to 10 KW on 5 second period.

77517 10 KW established.

77532 Back down to 1 KW in Power Control.

77508 1 KW established.

77593 Set Fixed Power Scram to 2 KW.

77870 Set Fixed Power Scram to 200 KW.

77935 Went to 100 KW on a 2 second period.

77945 100 KW established.

78047 Back down to 1 KW in Power Control.

78103 1 KW established.

78115 Set Fixed Power Scram at 2 KW, Max Drum Scram at 108.2°.

78203 SCRAM.

E. SET UP STEAM GENERATOR AND ESTABLISH COOLANT FLOW

79185 Verified RSV-439 was de-energized OPEN.

OPENED RSV-434.

79194 OPENED RSV-433/RSV-949.

79199 Verified water OK lights.

79203 Reset steam generators.

Depressed Ready switches.

79219 Positioned injection water control valve pots to 1,000.

79233 Established Trough Cooling Flow.

79280 OPENED: RSV-738, RSV-739, RSV-858, RSV-859, RSV-303, RSV-304, RSV-305, RSV-306.

F. SET UP ENGINE PURGE.

79242 Switched PCV-251 to arm.

79273 Used PCV-251 to establish 100 psig (11 pps) at P-475.

G. FIRST STEAM PROFILE

79285 DDS to HIGH and Recorders to LOW.

79294 Turned on Manual SGS Purge.

79314 STARTED Camera Group A.

79323 STARTED SG-1 to IDLE.

79331 STARTED SG-2 to IDLE.

79409 OPENED FCV-31 to 100% and FCV-32 until F-56 and F-57 indicated 15.6 psid (40,000 gpm).

79846 CLOSED RSV-439.

79414 ANALOG TO HIGH.

79426 Full Steam SG-1.

79440 Full Steam SG-2.

SG-1 Low Pressure Cutout when commanded #3 to full steam.

79465 Attempted to IDLE SG#2.

79482 Attempted to IDLE SG#2 again.

79493 Attempted to IDLE SG#1.

79505 Stopped SG#3.

79520 Re-set

79530 Oscillations observed on PT-420

79553 SG#1 to IDLE.

79562 SG#2 to IDLE.

79578 T-534 at 630°R.

Test Chronology for Phase II NES Steam Line Demonstration Test

79585	Full Steam SG#1.
	T-534 was 700°.
79609	Full Steam SG#2.
79613	SG#1 low pressure cutout.
79640	SG#2 to IDLE.
79646	SG#3 to IDLE.
79680	Full Steam SG#2
	T-534 is 725°R.
79721	Full Steam SG#3.
79753	Adjusted FCV-423-2 and -3 until T-534 indicated 1260 ±50°R.
79900	T-534 indicated 1260 ±50°R.
79938	Adjusted FCV-423-2 and -3 until T-534 indicated 1500 ±50°R.
80040	Trimming temperature at near 1560°R.
80071	LT-15 is 15.5 feet.
80090	Reported when T-602 stabilized.
80090	Adjusted FCV-423-2 and -3 until T-534 indicated 1460 ±50°R.
80140	LT-15 is 14.5 feet.
80170	Neutronics oscillations.
80180	Adjusted FCV-2 and -3 until T-534 indicated 1260 ±50°R.
80184	LT-15 is 14.0 feet.
80200	LT-15 is 13.5 feet.
80324	CLOSED FCV-32.
80340	CLOSED FCV-31 to obtain 0.5 psid. (6000 gpm) at F-56 and F-57.
80407	Readjusted FCV-423-2 and -3 until T-534 indicated 1260 ±50°R.
80420	T-534 up to 1460°R.
80461	SG #3 shut down malfunction, PCV-449 rate trip.
80500	STOPPED SG-2.
80518	CLOSED RSV/433/RSV-949.
80570	CLOSED RSV-434.
80680	DDS to LOW and Recorders to LOW.
81050	CLOSED duct and shield water valves.
80557	Turned OFF Camera Group A.
80553	CLOSED PCV-251
80988	Top seal control to PRESSURE.
80992	Bottom seal blade purge OFF.
80997	S-2 seal blade purge OFF.

81013 Convolute seal purge OFF.

81030 CLOSED RSV-857 and SV-864.

I. 80955 SET UP THE LFE POST-OPERATIONAL NET.

VI. LFE POST-OPERATIONAL PHASE

A. 80716 - 80805 VENTED LOX SYSTEMS.

B. 80834 VENTED PROPANE SYSTEM.

C. 81110 DISCONTINUED ETC PURGE.

TORQUE MOTOR CURRENT CHECK OUT.

81300 Torque Motor Current checkout with no ground wires.

81320 Pulled Drums 1, 5, and 11 to 90°, then 165° and then back in for Torque Motor Current noise check.

81438 Max. Drum Scram.

Period Scram 1 second at 50%.

81530 Reactor Startup to 1 KW in POSITION control. Very noisy Torque Motor Current at 49°.

81569 Deluge Zone #8.

81604 Drums to 70°.

81627 Drums in, scram and DEACTIVATED.

82315 Torque Motor Current checkout with 2 ground wires.

82390 Drums #1, 5, and 11 to 90°, then to 165°.

82545 Max Drum Scram.

82774 Reactor Startup to 1 KW in POSITION Control.

82802 Switched to Power Control.

82840 UTS Lights turned for interaction (none).

82855 SCRAM.

82930 Secured Control Drum Pneumatics.

Ah

NERVA TEST OPERATIONS — Nuclear Rocket Development Station

TO: R. G. Staker

FROM: E. H. Brooks

DATE: 7 January 1969
NTO-M-26232
EHB:jms

SUBJECT: Data System and Grounding Problems

DISTRIBUTION: J. Powell, R. Tounis, D. Vander Meer, P. D. Zaremba, E. H. Brooks, S. H. Kemp, J. M. Pilant, NTO File, FO File (6)

The Spear Report from EP-I and EP-I and SL lists data dropout as being a significant problem during the tests. Investigation has revealed that the problem was apparently due to parity errors in data processing due to dirty tape heads or tapes. Repeated processing of the data did not show losses of the same data points. This problem is being corrected by cleaning all used tapes on a routine basis and cleaning the tape heads of the recorders more frequently.

Confusion on the part of Data Processing, the Spear Team and other groups on the calibration to be used and exact channel ranges has been rectified by clearly defining the responsibilities of the various groups in meetings held on January ~~5~~, 1969 and January 7, 1969. This problem should not be present in the future.

Digital subsystem 1 was observed to operating improperly after starting up following the Denham Event. This was traced to a defective gate card. Replacing the card appears to have solved the problem.

Several individual channels were reported as discrepancies. These have been resolved and were partially caused by the fact that the decision was made not to complete setup and c/o of the entire data system prior to EP-I, but concentrate on only those channels required for EP-I.

The remaining problems are:

(1) Ampex recorders (2) Wide band noise problems and (3) Grounding problems.

A letter has already been written by P. D. Zaremba detailing the plans to insure better maintenance and c/o of the recorders by the lessor.

The wide band problem is believed to be related to the grounding problem and the two problems will be investigated concurrently. The plans are as follows:

(1) Investigate individually the various channels feeding the Wide Band System, particularly looking at the grounding and shielding configuration. One problem has already been uncovered in this area.

(2) Complete the investigation of the Wide Band recording system grounding configuration and correct as necessary to agree with the design grounding scheme at ETS-1.

(3) Investigate the overall grounding system problems at ETS-1 using data obtained in the recently completed grounding test and methodically correct the errors starting at the TCB and proceeding from there to the FCR and CP.

(4) After each change review data from both the WB and DDS Systems to insure that no additional problems are created.

(5) Install alarms between the various grounds to detect future errors if and when they occur.

Completion of this plan should restore the facility to the design configuration and eliminate the problems.

E. H. Brooks

E. H. Brooks, Deputy Manager
NTO Facility Operations

A Lokoff

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