NTO-R-0175

Spear Report

XE-Prime

EP-'8 A.

PHYSICS AND STARTUP TESTS

ENGINE CHILL & PHYSICS

OPEN LOOP

OPEN LOOP, HOT CORE

DAMP, AMBIENT CORE, θ NOMINAL +10

WET, WARM CORE, HIGH SOURCE POWER

WET, HOT CORE

AUGUST 1969

DISCLAIMER

XE-PRIME
EP-8A

NTO-R-0175

INFORMATION CATEGORY

UNCLASSIFIED

K. R. Conn 8/27/69
K. R. Conn Date
Authorized Classifier

DISTRIBU

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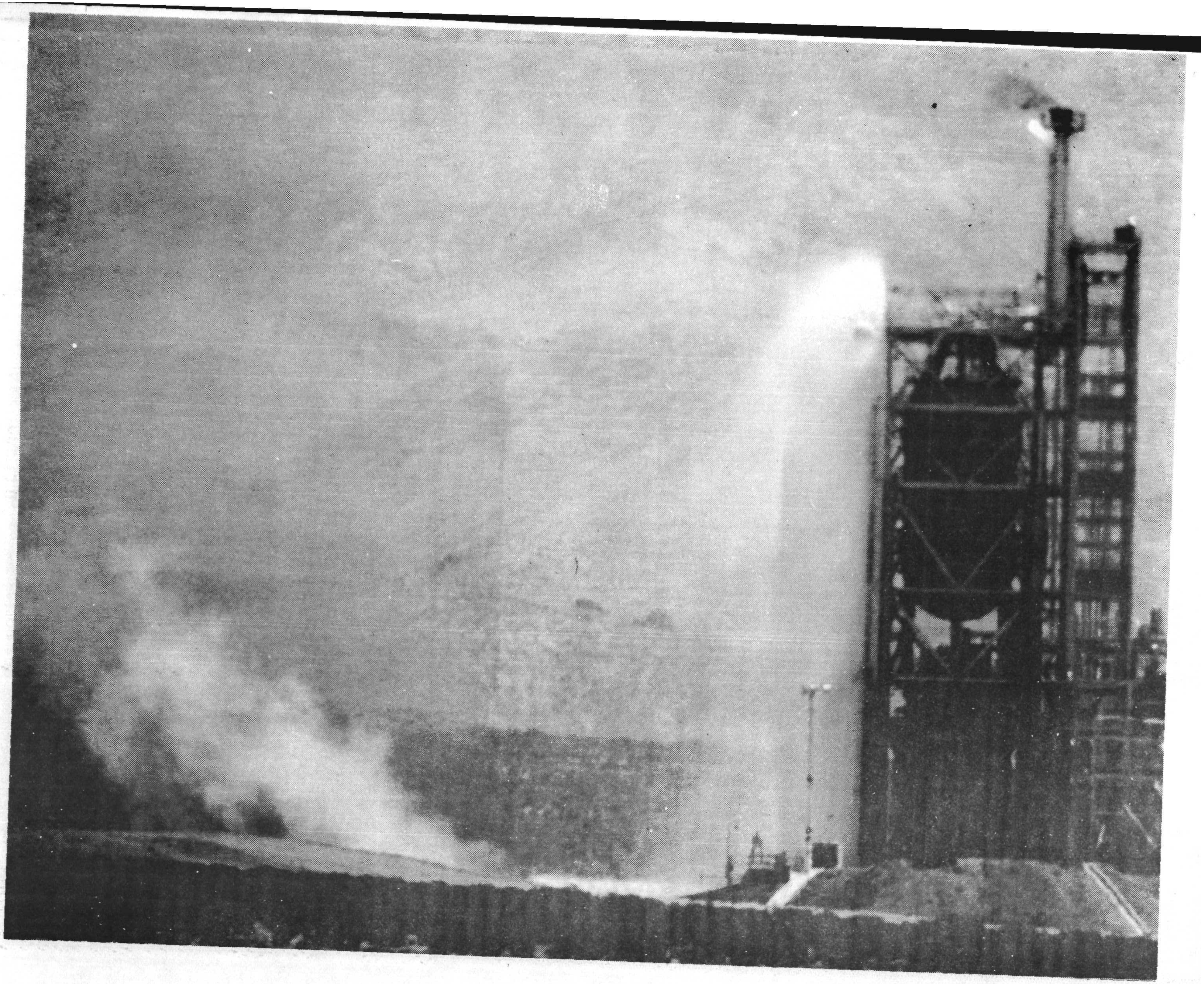

XE-PRIME EP-8A

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NOTE: * This memo was not available at time of publication.

ERRATA SHEET

The following should be added as Recommendation 6 on Page 4 of SPEAR Memo No. 1:

> During conditioning of the core to "cold core" conditions, the minimum drum position should be limited to 80° if a 2$ shutdown margin is to be insured.

The following should be added to the end of SUMMARY paragraph four in Memo No. 16, Page 1:

> Hence, in the absence of supporting analysis the data must be accepted and it is concluded that, to insure a 2$ shutdown margin in subsequent testing under these specific conditions, the minimum drum angle must be limited to 80°.

SPEAR Memo No. 1
K. R. Conn:jh
K. R. Conn

XE-PRIME

EP-8A

Subject: SUMMARY OF SPEAR ANALYSIS

The objectives of XE-Prime EP-8A were:

1. Obtain engine chilldown characteristics at a reduced run tank pressure.
2. Obtain information on reactivity effects with low temperature engine conditions.
3. Obtain information on engine startup and shutdown characteristics with open loop control.
4. Obtain information on characteristics of ON/OFF temperature controller.
5. Obtain information on sensitivity of (core) temperature autostarts to drum program profile.
6. Obtain information on sensitivity of (chamber) temperature autostarts to source power level and intial core temperatures.
7. Obtain engine dynamic response data for TPCV and drum position demand perturbations.
8. Evaluate engine operating characteristics with reduction of TPCV position.

To meet these objectives, the following tests were planned:

1. <u>Engine Chilldown and Engine Physics Tests</u>

   a. Engine and pump inlet line (below PSV) chilldown to 60^oR reflector inlet temperature with a run tank pressure of 25 psia and no steam generator operation.

   b. Reflector thermal reactivity coefficient and core thermal reactivity coefficient data measurement, measurement of drum worth at reduced reflector temperatures, and measurement of hydrogen worth.

2. <u>Run No. 1</u> - <u>Open Loop Startup - AC/AR, and Transfer Functions</u>

   Open loop startup from ambient conditions to T_c of 3000^oR. TPCV and drum transfer measurements performed at T_c/P_c of $2400^oR/300$ psia. Open loop engine mapping and shutdown.

Summary of SPEAR Analysis (Cont'd)

3. Run No. 2 - Open Loop Startup - HC/CR, and Transfer Functions

Open loop startup from hot core (1200^{o} to $1300^{o}R$ T_c) and cold reflector conditions to $1700^{o}R$. Drum transfer function measurements performed at T_c/P_c of $1000^{o}R$ and 60 psia.

4. Run No. 3 - (DAMP) Temperature Autostart - AC/AR/ ⊖ AWN + 10

Temperature autostart to T_c/P_c of $1700^{o}R$ and 120 psia (using core material temperature for control feedback) from ambient core and cold reflector conditions with drum program exponential to ambient wet critical position + 13 degrees. PDSV opened at Start Reactor.

5. Run No. 4 - (WET) Temperature Autostart - WC/CR/HSP

Temperature autostart to T_c/P_c of $1700^{o}R$/120 psia (using chamber temperature as control feedback) from warm core ($1000^{o}R$) and cold reflector conditions and high source power level (1 to 5 Mw).

6. Run No. 5 - (WET) Temperature Autostart - HC/CR

Temperature autostart (chamber temperature) to T_c/P_c of $1700^{o}R$/120 psia from hot core ($1300^{o}R$ to $1500^{o}R$) and cold reflector conditions. TPCV stepped closed incrementally during shutdown with engine in temperature control (core material T.622) at $1000^{o}R$.

All tests were completed. Although there were deviations from the planned conditions and test operations all of the objectives of EP-8A were met. A description of the pre-run operational difficulties and the chilldown and Physics Tests is presented in Memo No. 2. Summary plots of the startup tests (Runs 1 through 5) are also included. Descriptions of the individual startup tests are given in the respective Control System and Engine Performance memos.

The results of the Chilldown and Physics Tests are discussed in Memos No. 12 and 16. A chilldown of the engine system from ambient conditions (TPA was also at ambient) and a run tank pressure of 25 psia was completed. Approximately 152 seconds were required for the reflector inlet temperature to decrease to $60^{o}R$. The Physics Test provided data to estimate:

1. Reactivity effects with a below ambient, dry system.
2. Core and reflector temperature effects, with a dry system, on drum worth.
3. Effects of cold core and reflector conditions, with flow, on drum worth.

This data is presented in Memo No. 16.

Summary of SPEAR Analysis (Cont'd)

The first open loop startup was made from near ambient conditions (except for a chilled turbopump). The test performed essentially as predicted. The second startup was from restart conditions. In this test an anomaly in the drum exponential demand resulted in a deviation from the normal drum exponential profile. The startup was completed and the operations planned for the run performed. The cause of the anomaly is not known at the present time. Engine operation mapping and control with open loop, constant drum and TPCV ramp rate control and with ON-OFF temperature control was demonstrated. Transfer functions with TPCV and drum position demand perturbations were conducted. The first test was conducted with an open loop shutdown with the drums manually closed and the TPCV ramped closed at a fixed rate. The Control System and Engine Performance during these tests is presented in Memos No. 4 and 5.

The (DAMP) Temperature Autostart with a drum exponential setting of drum critical ambient wet position plus 13 degrees was planned but not successfully carried out in EP-7A. A new estimate of the ambient wet critical drum position of 85 degrees was obtained during the Physics Test of EP-8A. The exponential pot setting was based on this value; therefore, the drum program exponential setting for this test was only 6 degrees greater than the "nominal" setting for EP-7A instead of the 10 degree differential that was planned prior to EP-7A. The Control System and Engine Performance during the (DAMP) Temperature Autostart is discussed in Memos No. 6 and 7.

The (WET) Temperature Autostarts with the first from an initial high source power level and the second with a hot core provided information on the sensitivity of the startup to source power and temperature that supplements the (WET) temperature startup in EP-6A. The results indicated that the bootstrap time (drum program initiation to temperature loop closure) is not affected significantly by increasing the initial source power but was fairly sensitive to the initial core temperature condition. Memos No. 8 and 9 discuss the Control System and Engine Performance during these tests.

The ambient critical drum bank position measured for EP-8A was 93.2 degrees. This indicated an increase in critical drum position during EP-7A of 0.4 degrees for a loss in drum worth of -2.6 cents.

The evaluation of the nuclear sub-systems (Memos 4 and 15) established that the performance of these components was normal during EP-8A with the temperatures and pressures remaining within the established limits.

The engine valves, turbopump, lines, thrust structure and pressure vessel performance and the engine system vibration data were evaluated and it was established that these components were in satisfactory condition for continued testing. The cumulative spin time on the TPA is now approximately $87\frac{1}{2}$ minutes with 23.3 minutes in excess of 10,000 rpm and 3.7 minutes in excess of 20,000 rpm.

The integral neutronics power for EP-8A (IPWALIN) was 4.36×10^5 Mw - sec (121.1 Mw-Hr).

Summary of SPEAR Analysis (Cont'd)

The Nuclear Exhaust System satisfactorily supported the EP to the planned conclusion of the EP. Two generators were operated at full steam for 60.5 minutes at a nominal steam temperature of 1290°R. The post-test inventory indicated a maximum of seven minutes of operating time remaining when the SGS was shutdown. Leakage at full steam operation was observed on two of the generators. The leaks resulted in the shutting down to idle after full steam was achieved on two generators, restarting the third generator to idle, and then using it during the sustained full steam operation. A sufficient chamber pressure was achieved in Run 1 for duct pull-in. The duct aerodynamic performance was within the acceptable limits. The Performances of the Nuclear Exhaust System is discussed in Memo No. 25.

The facility fluid systems operated satisfactorily and supported the test to the planned conclusion of the EP. Because of the duration of the EP (4-3/4 hours of pre-run and 4 hours of engine test operation) the fluid minimum inventory limits were being reached. The performance of these systems is discussed in Memo No. 17A.

Based on the analysis conducted by SPEAR following EP-8A the engine and facility systems are considered to be in acceptable condition for continued testing in EP-9A.

RECOMMENDATIONS

Following are the SPEAR recommendations from EP-8A:

1. The SPEAR Report was completed without final resolution of the nuclear autostart drum program exponential anomaly observed in Run No. 2 or the drum actuator torque motor current anomaly.

Operations and Source Engineering personnel were continuing the investigation of these anomalies. The TRB, prior to EP-9, should review the results of the investigations and ascertain that the test can be conducted satisfactorily.

2. Any post-test analysis of engine system and individual component performance at low power conditions should include a detailed evaluation of the data values to attempt to remove any offset errors and calibration shifts.

3. Replace the Teflon gaskets in the SGS LOX propellant system with Durabla gaskets.

4. The estimated maximum Steam Generator run time should be reevaluated to consider the data from EP-8A.

5. The "Real Time" reactivity calculation was demonstrated to be effective in determining the nuclear condition of the engine during operation particularly during childown and conditioning phases. Operations and Test Planning should consider additional use of this information during the run, either digitally displaying it in the Control Room or by obtaining from the TDC.

SPEAR Memo No. 2
W. F. Booty:jh

XE-PRIME

EP-8A

Subject: SUMMARY PLOTS AND TEST DESCRIPTION

SUMMARY/INTRODUCTION

This memo contains summary plots of EP-8A, Runs 1 through 5 and a brief discussion of the pre-run operational problems. Detailed discussion of particular tests, operations, component and subsystem performance is contained in other memos.

TECHNICAL DISCUSSION

A. Pre-Operations

The standard facility and engine pre-run operations were performed satisfactorily with the following exceptions:

1. PCV-472 Step Setting

   The pre-test checkout of the step mode of PCV-472 operation disclosed that it stepped open to 23% instead of 30%. This was readjusted to 28.5% and checked ok.

2. V-5002 Preset Pressure and Overpressure Detector Setpoints

   The prerun checkout on V-5002 showed that the preset pressure demand was 201 psig instead of 150 psig and the overpressure detector was greater than 305 psig instead of 225 psig. These were readjusted to 155 and 220 psig and checked OK.

3. The 3900 area hydraulic supply system failed; however, all the valves supplied by this system were placed in their run configuration before hydraulic pressure decayed so that the run was not affected.

4. Several other operational problems occurred during the runs. These were: erroneous high torque motor current indications on drums 3, 4, and 11; double drum program exponential on Run 2, and anomalous TPCV and TBV position indications after the test.

Technical Discussion (Cont'd)

Numerous drum program exponential and linear checkouts were performed at various console pot settings.

B. Physics Test

Drum 1 was bumped between 173 and 7 degrees twice with the reactor at 1.05 Kw in position control to establish an ambient dry drum bank worth reference. Duct flow of 6900 gpm, 7.25 pps ETC GN_2 purge, and .2 pps He UTS purge flowrates were established. Run tank pressure was increased to 25.0 psia and PSV opened which allowed LH_2 to flow through the engine. When reflector inlet temperature reached $40^{o}R$ (TARIP) PDSV was closed. The drum 1 bumps were then repeated to get the cold reflector worth. It was believed that the cold reflector worth would be less than the ambient worth. Power was then increased in power control on a 1.8 sec period to 1.25 Mw and held until TACS3 reached $856^{o}R$. The drums were then fixed and Drum #1 cycled again. When TACS3 reached $1032^{o}R$ power was reduced to 1 Kw. PDSV was then opened four times and closed when the drums reached 72, 70, 68, and 68 degrees. Drum #1 was once more bumped out and in twice with the rest of the bank in position control.

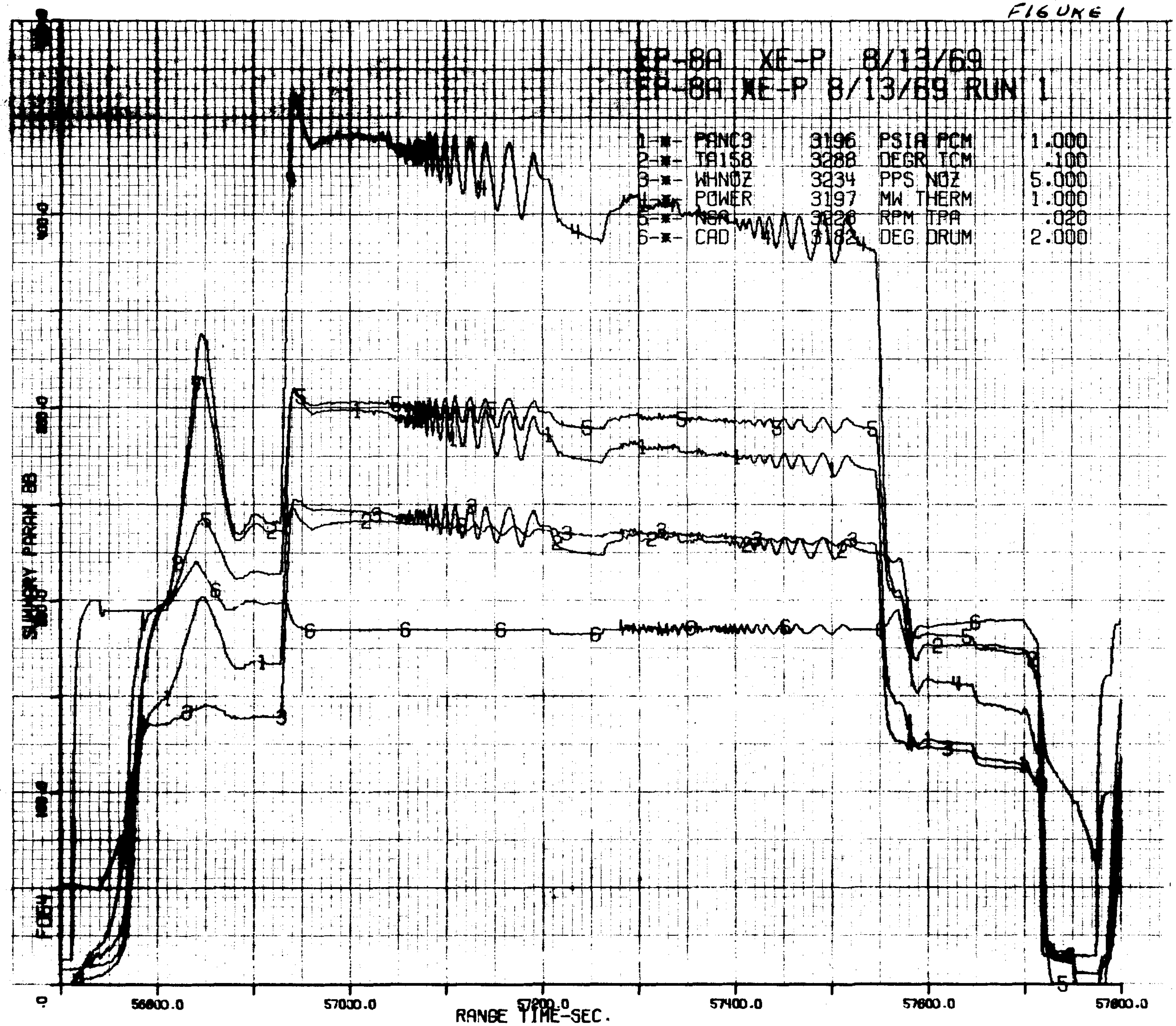
Dewar pressure was increased to 35.0 psia and power raised to 12.2 Mw. PDSV was opened establishing 5.7 pps LH_2 flowrate. A run tank topping checkout at low outflow was then performed with RSV 128 and RSV 129. Operation was nominal. Drum #1 bumps were again performed. Power was then reduced to 330 Kw and PDSV closed. Power was reduced to 100 Kw and Drum #1 bumped out and in twice.

9.5 Mw, with flow, was established and the worth test repeated. The engine was then warmed up with GHe.

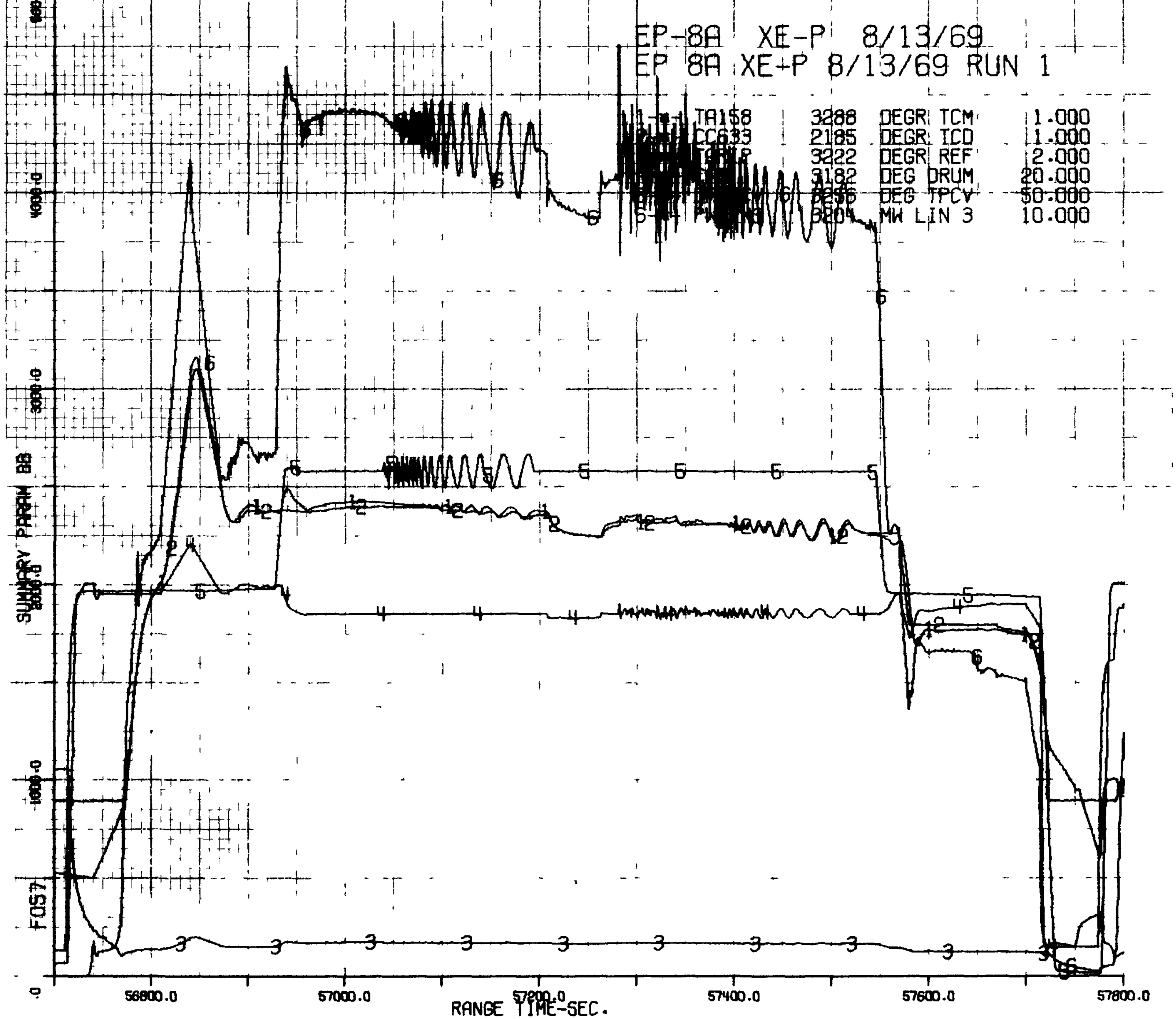
Duct flow and gas purges were shut off, the run tank refilled to 100%, and 4-LH-6 line chilled in. The final pre-run operation of establishing 23,000 gpm duct flow, shield flow and starting steam generators 1 and 3 were done.

Run descriptions will not be given here as they are included in other memos. Figures 1 - 7 show Run 1; Figures 8 - 15 show Run 2; and Figures 16 - 23 show Runs 3, 4, and 5.

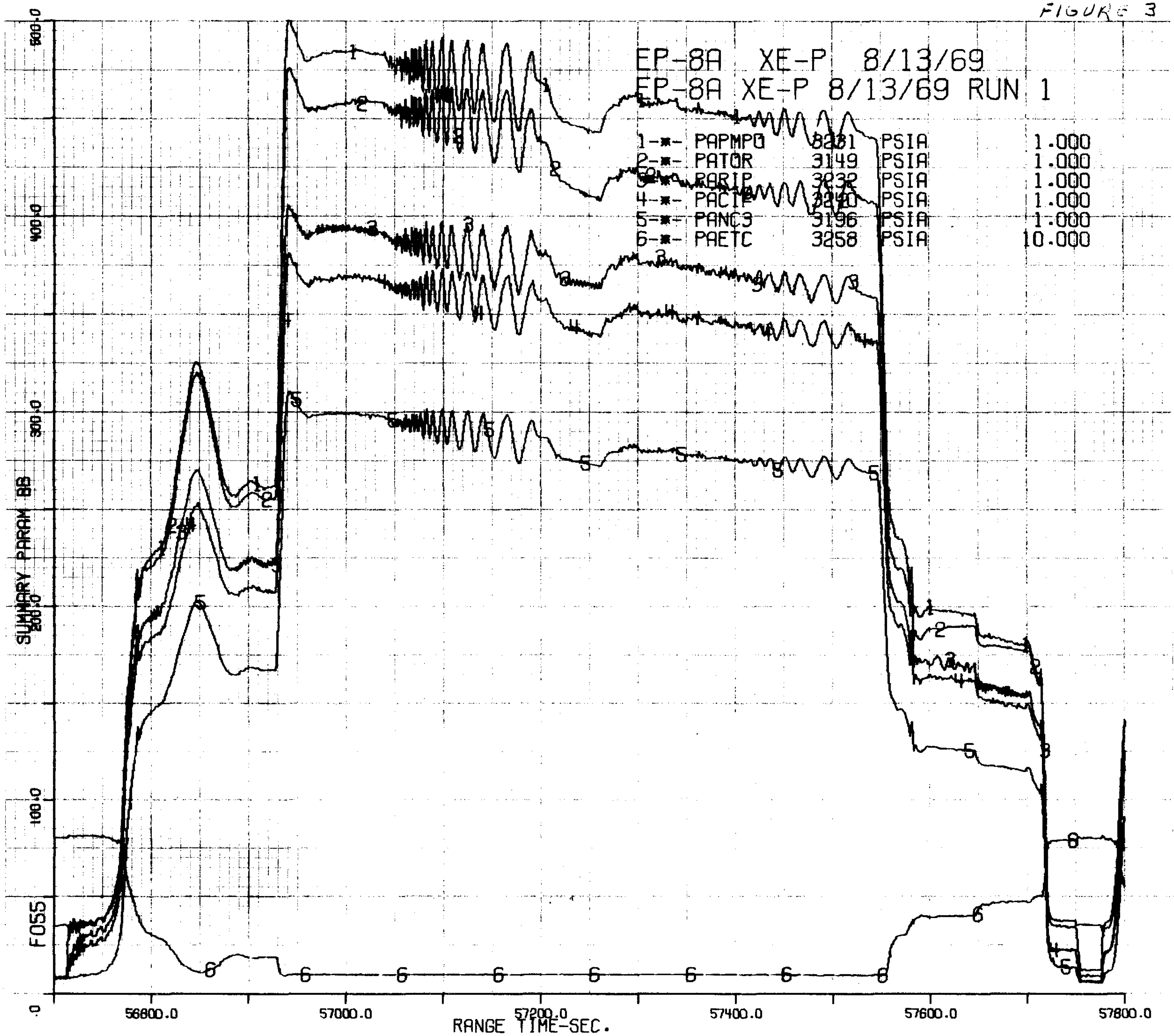
MEMO # 2
FIGURE 1



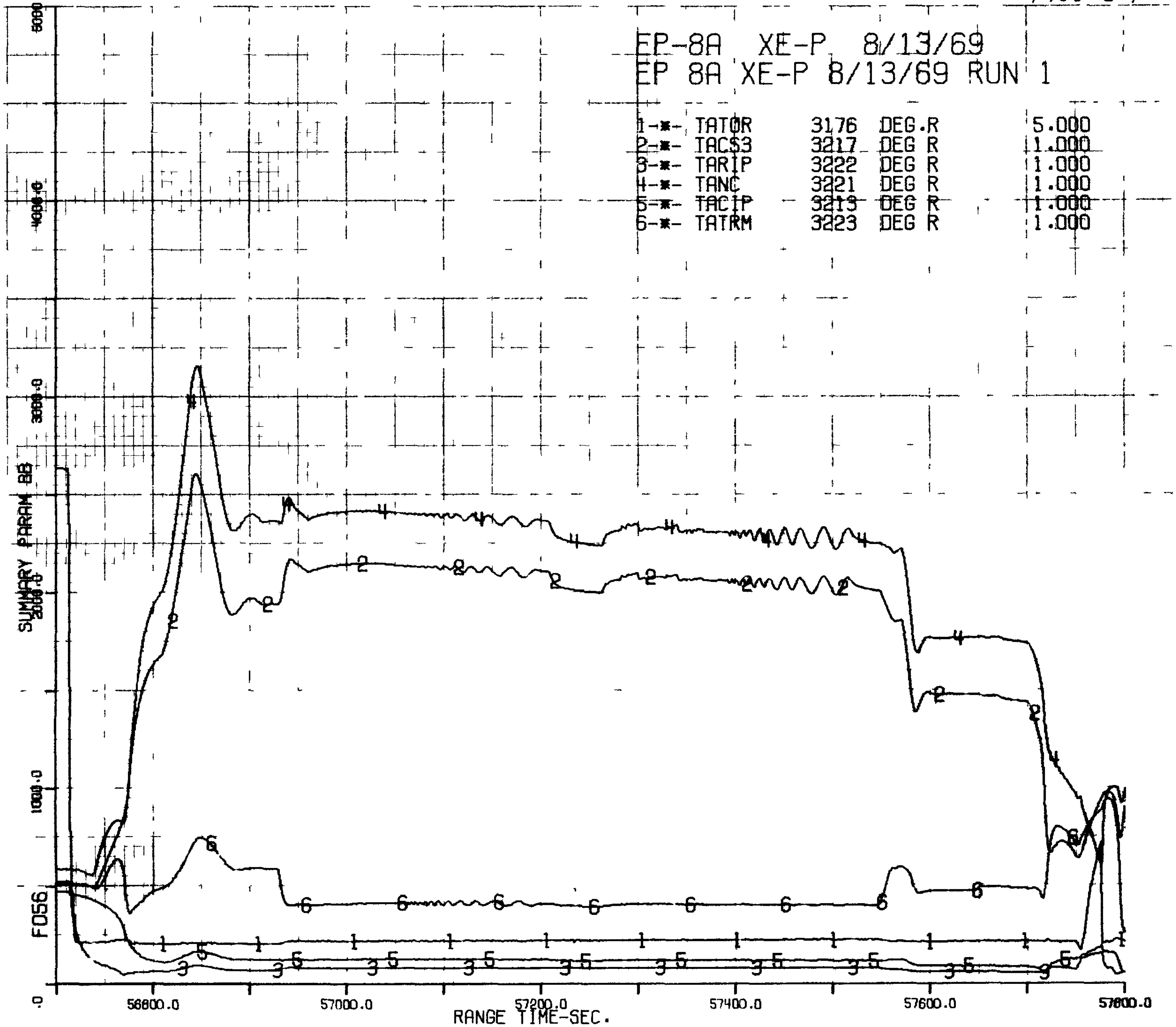
MEMO #2
FIGURE 2



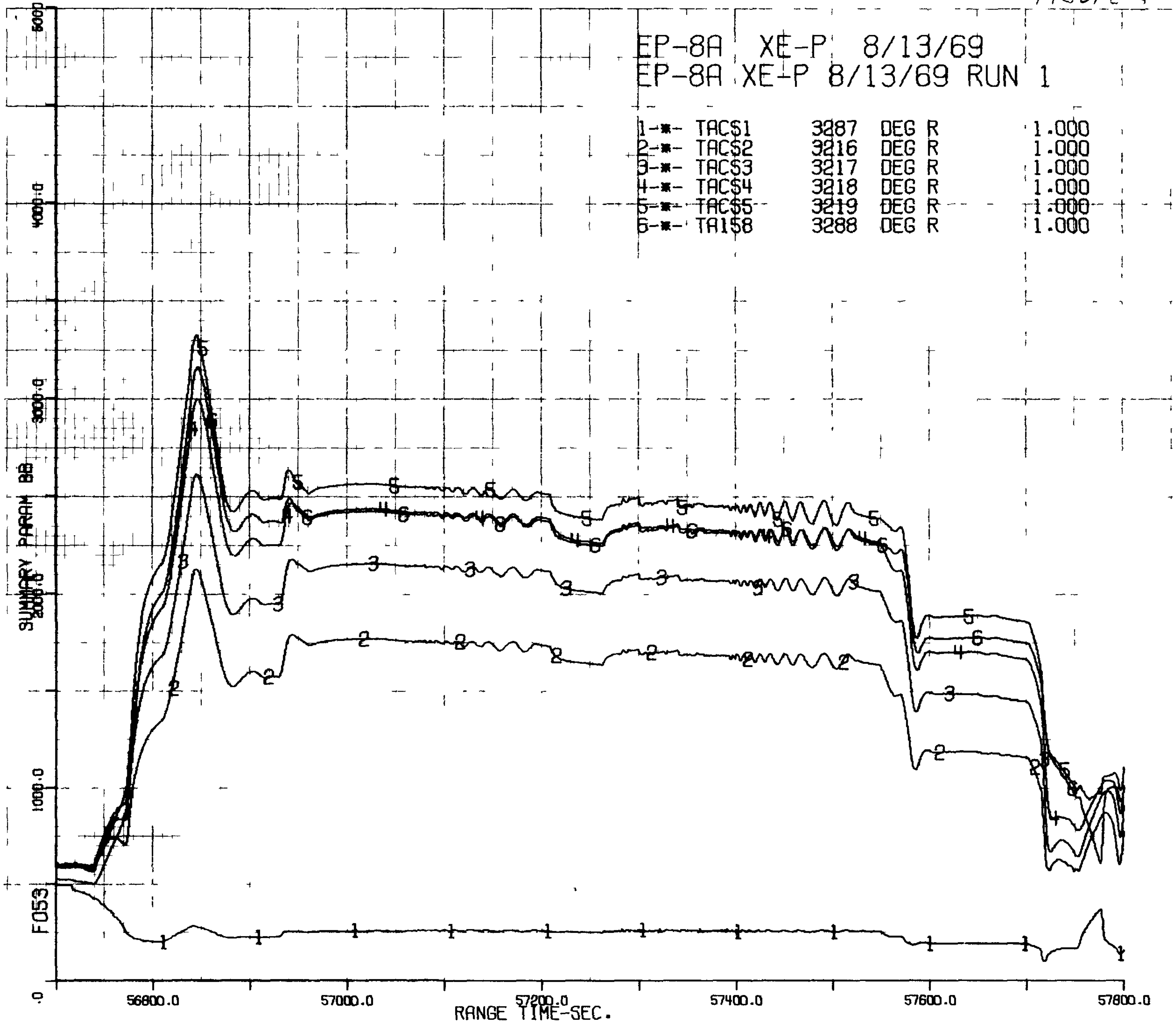
MEMO # 2
FIGURE 3

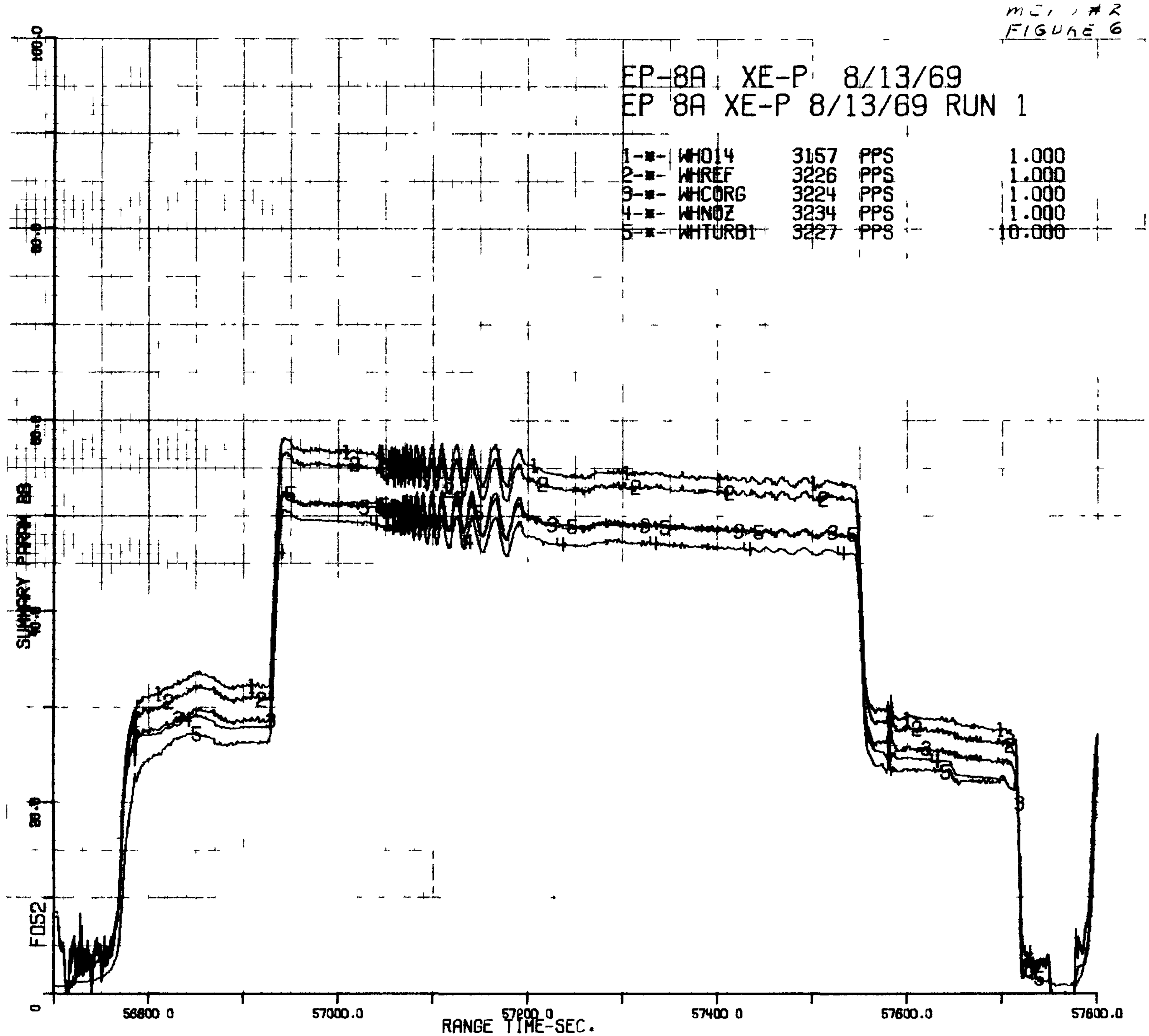


MCL # 4
FIGURE 4



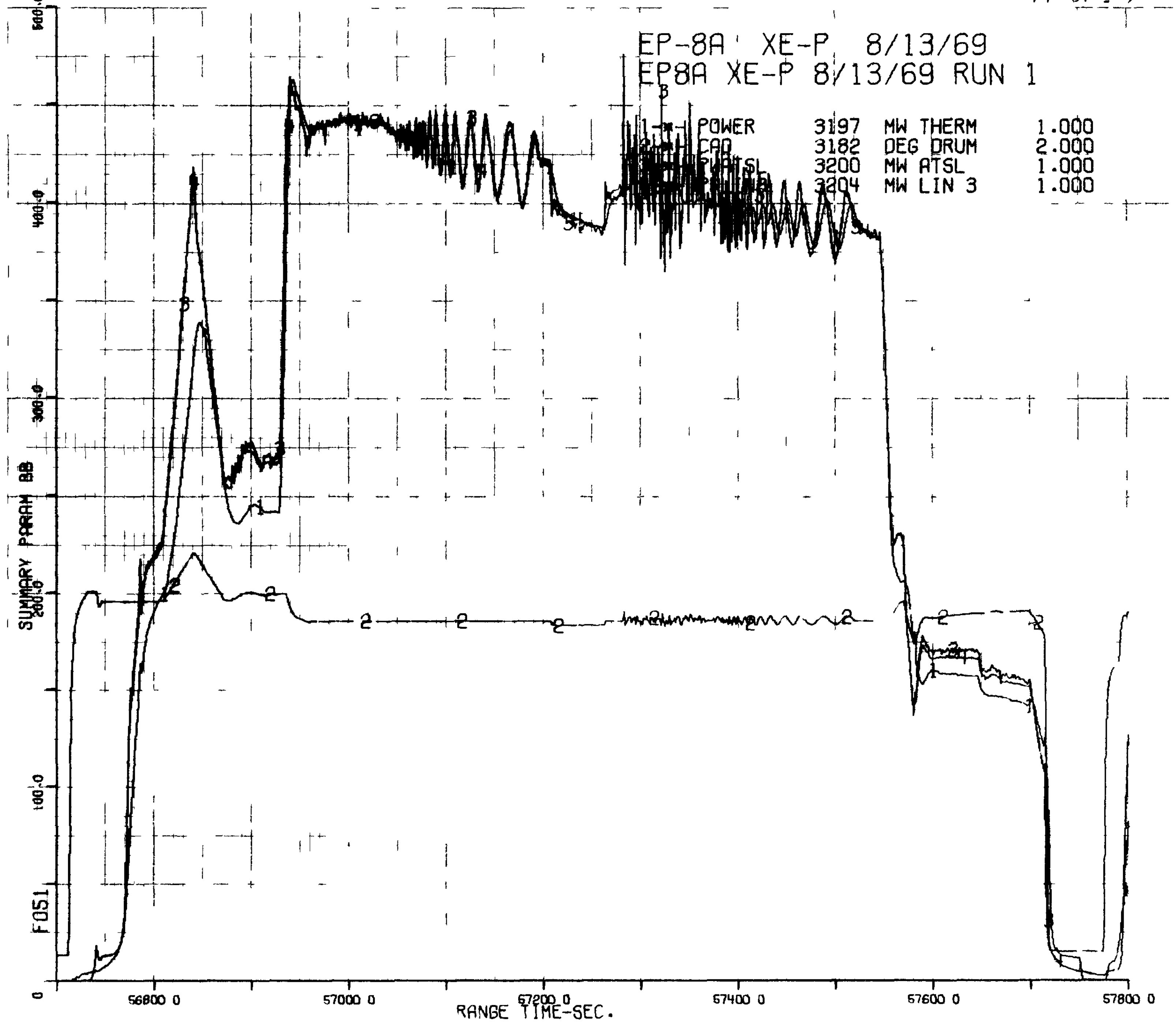
MCR #x
FIGURE 5





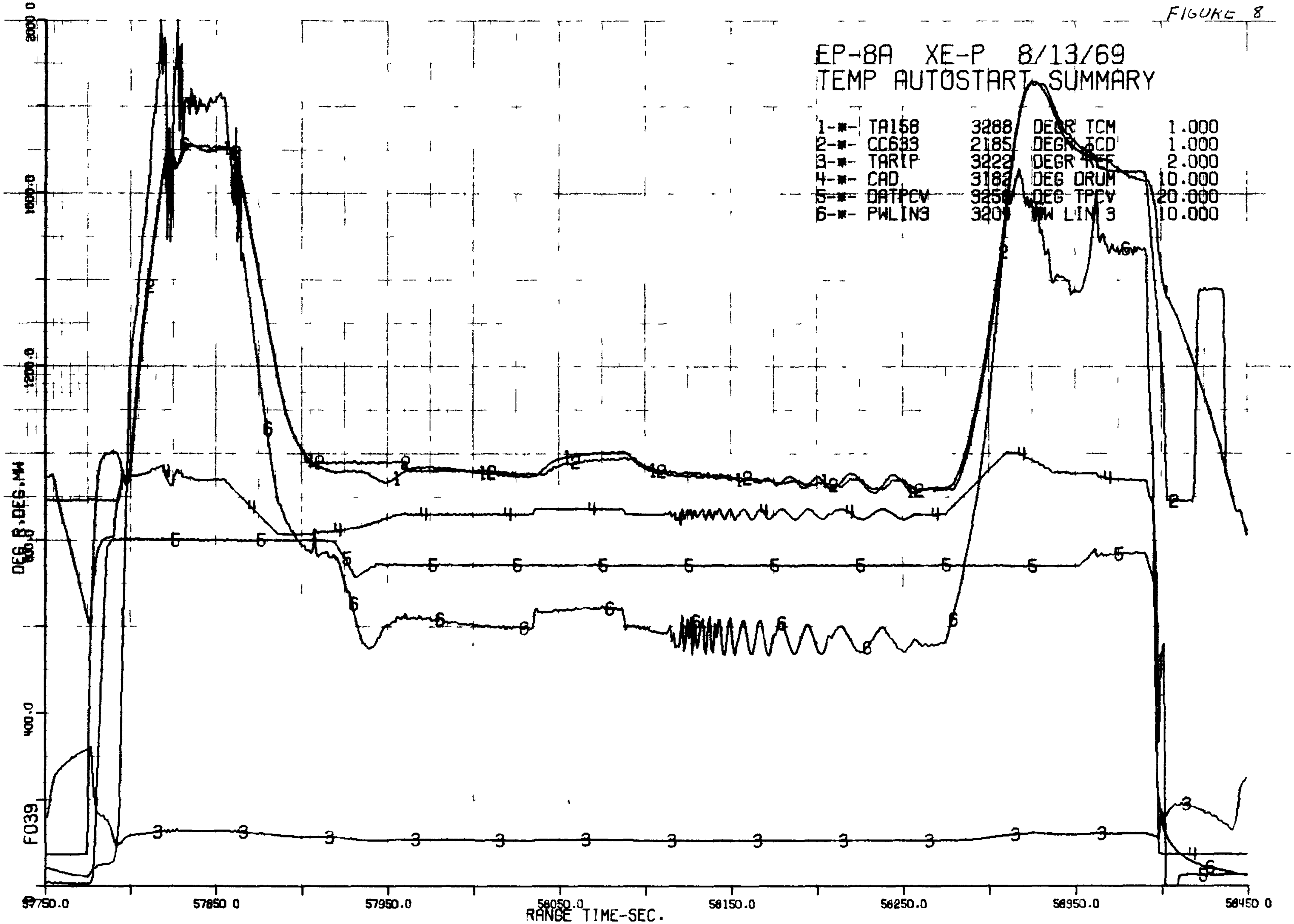
MCI #2
FIGURE 6
EP-8A XE-P 8/13/69
EP 8A XE-P 8/13/69 RUN 1
1-*- WH014 3157 PPS 1.000
2-*- WHREF 3226 PPS 1.000
3-*- WHCORG 3224 PPS 1.000
4-*- WHNOZ 3234 PPS 1.000
5-*- WHTURB1 3227 PPS 10.000
SUMMARY PARAM 83
F052
RANGE TIME-SEC.
56800.0
57000.0
57200.0
57400.0
57600.0
57800.0

FIGURE 7

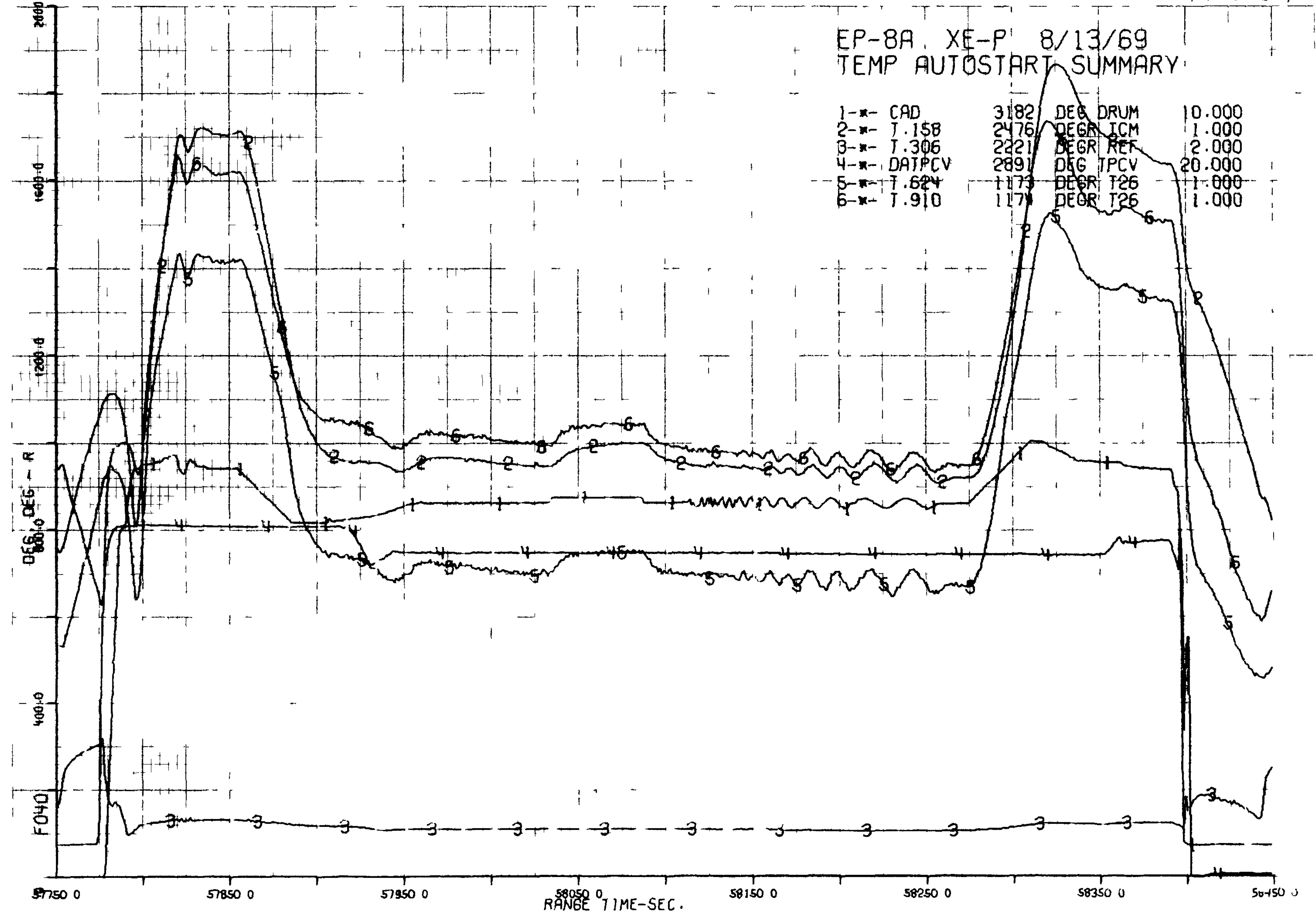


EP-8A XE-P 8/13/69
EP8A XE-P 8/13/69 RUN 1
1 POWER 3197 MW THERM 1.000
2 CAD 3182 DEG DRUM 2.000
3200 MW ATSL 1.000
3204 MW LIN 3 1.000
SUMMARY PARAM 88
F051
0
100.0
200.0
300.0
400.0
500.0
56800 0
57000 0
57200 0
57400 0
57600 0
57800 0
RANGE TIME-SEC.

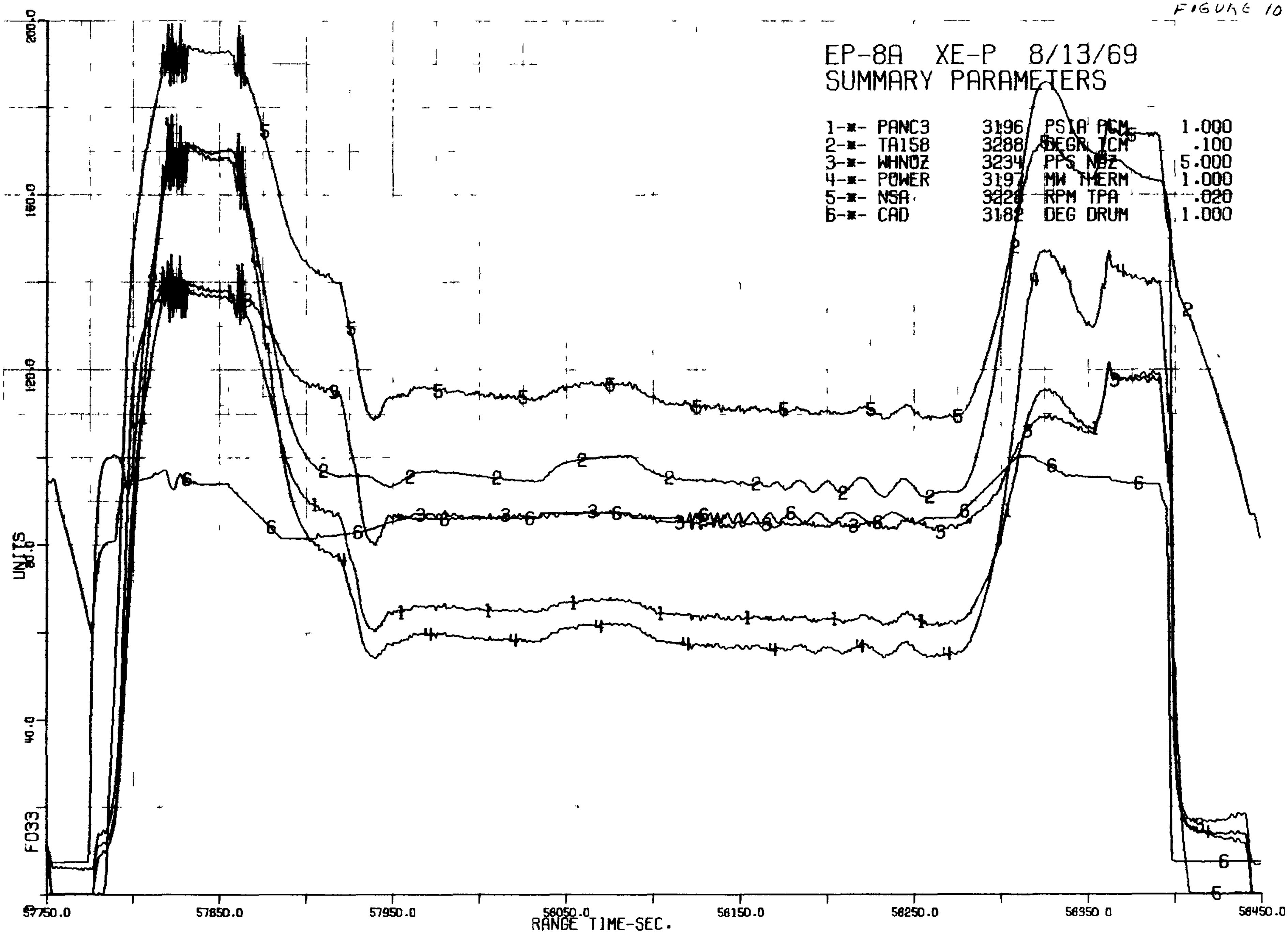
MEMO # 2
FIGURE 8



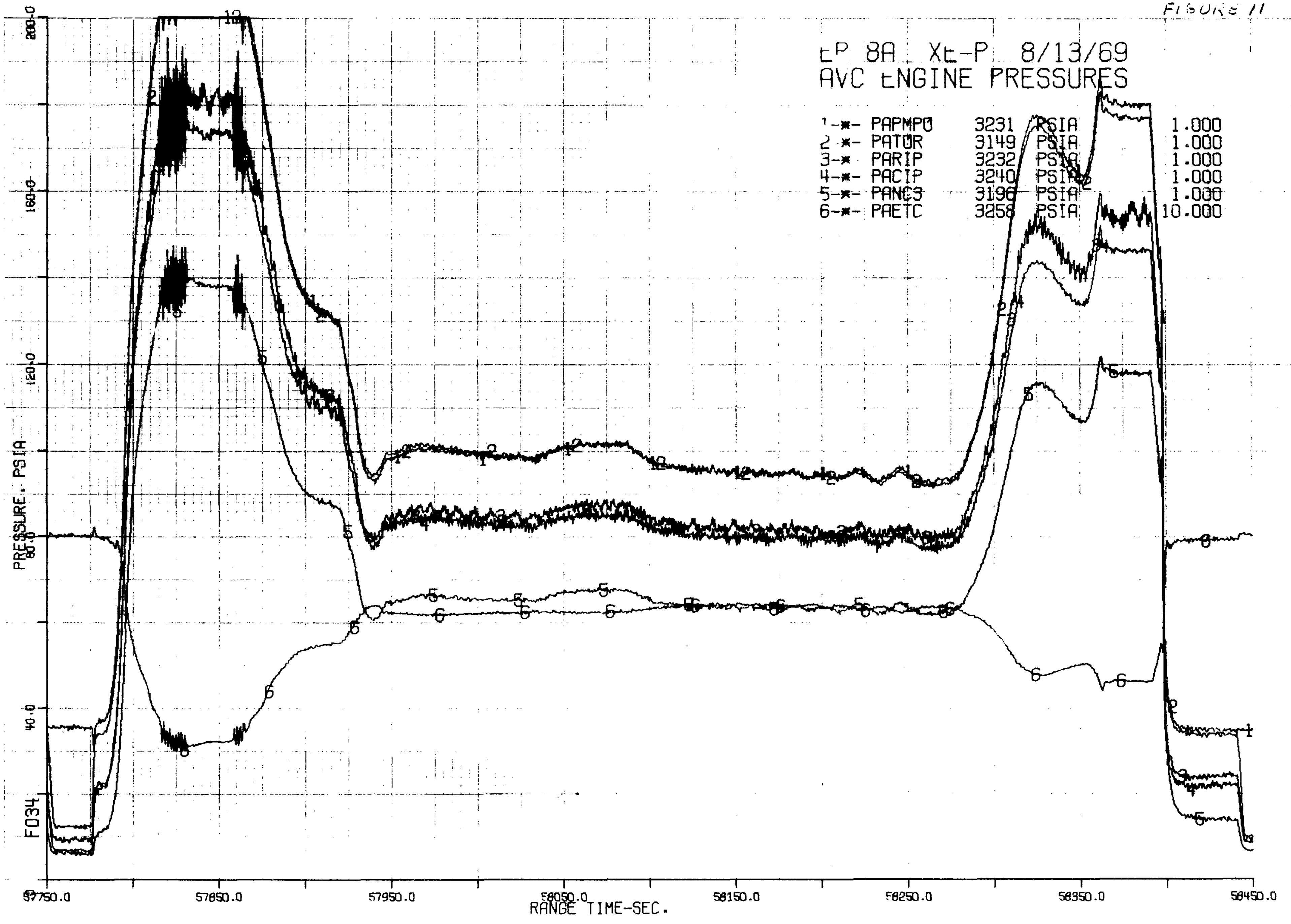
MEMO # 2
FIGURE 9



MEM. #2
FIGURE 10



MEMO # 2
FIGURE 11



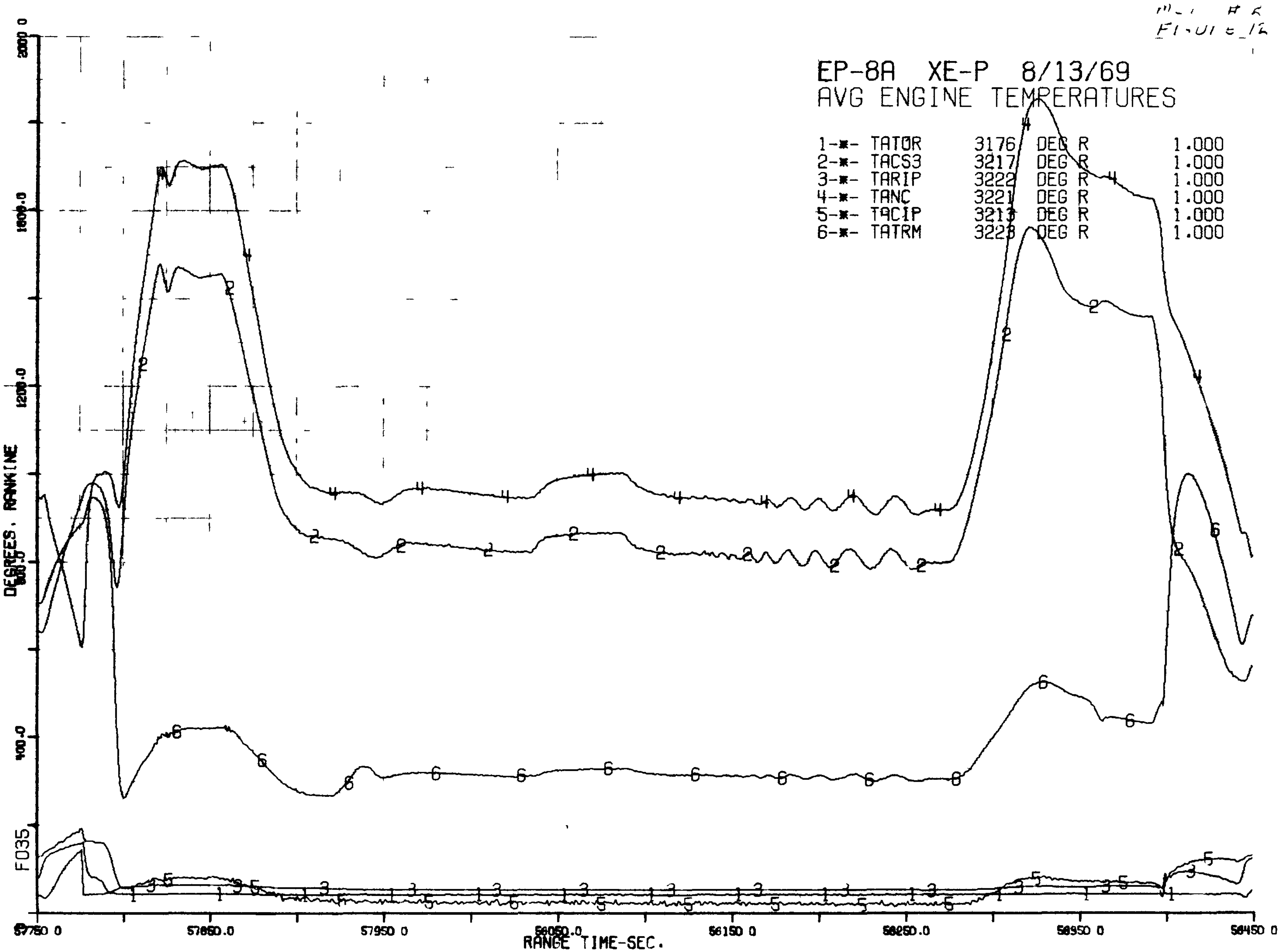
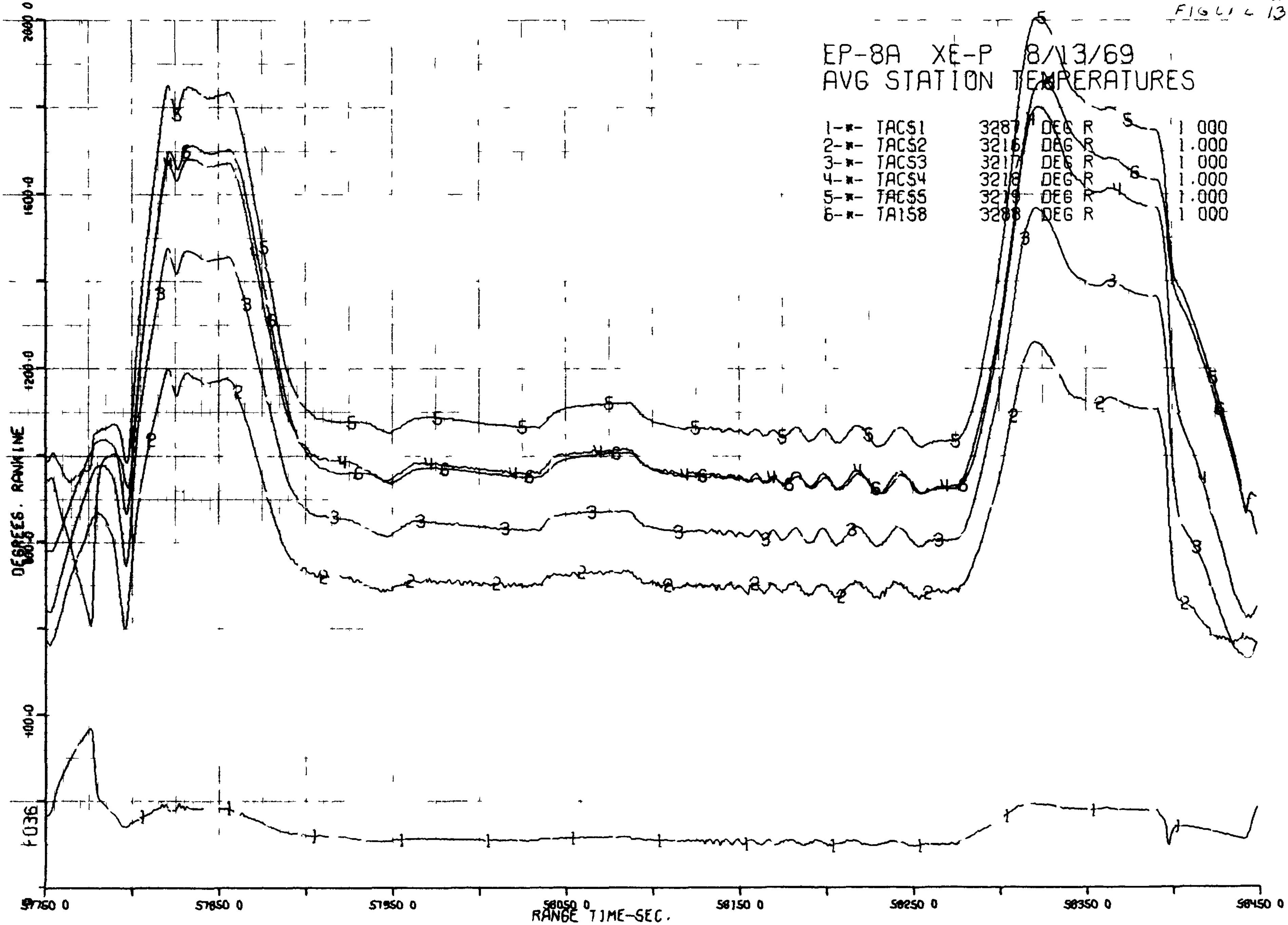
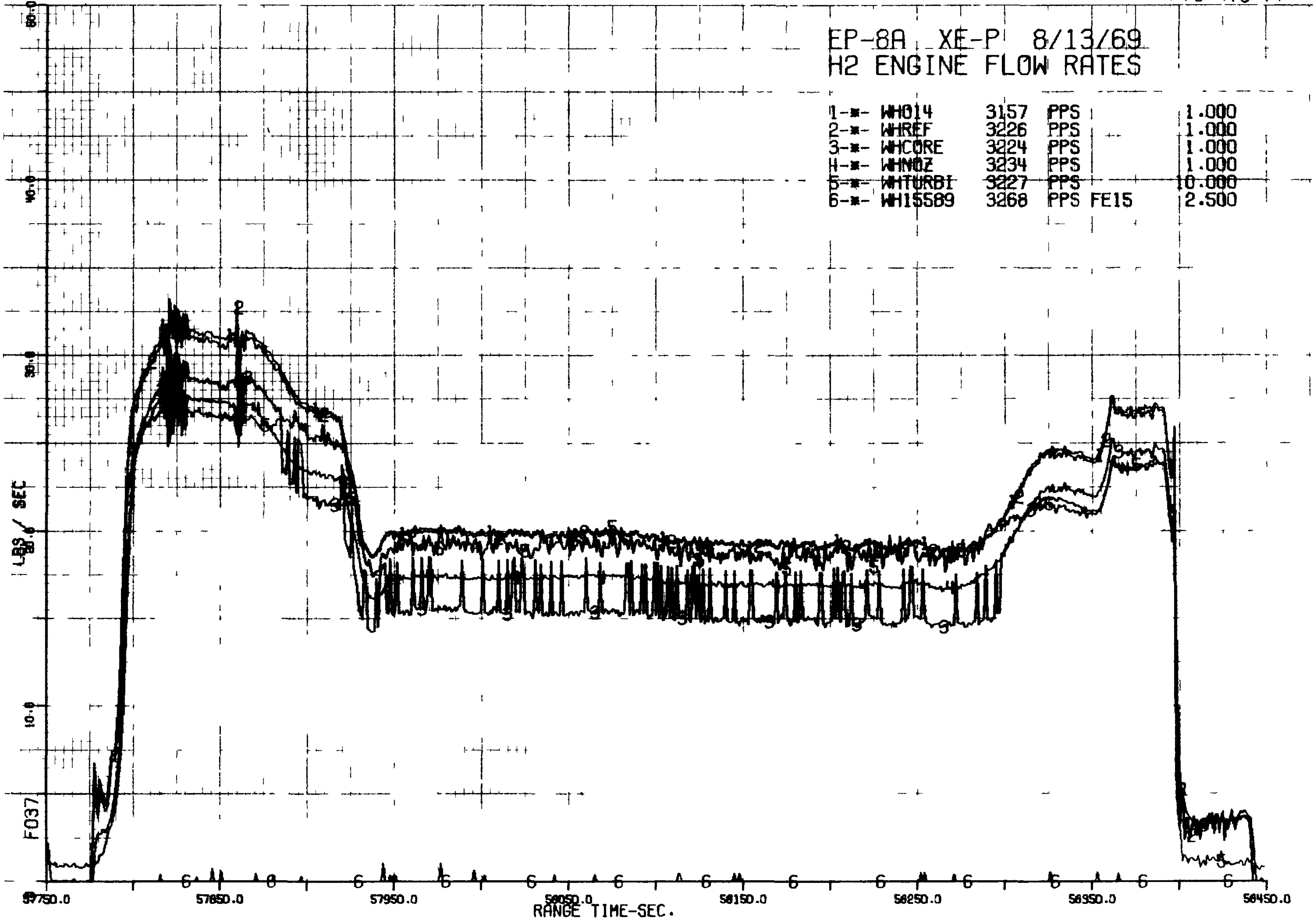

EP-8A XE-P 8/13/69
AVG ENGINE TEMPERATURES
1-*- TATOR 3176 DEG R 1.000
2-*- TACS3 3217 DEG R 1.000
3-*- TARIP 3222 DEG R 1.000
4-*- TANC 3221 DEG R 1.000
5-*- TACIP 3213 DEG R 1.000
6-*- TATRM 3223 DEG R 1.000
DEGREES, RANKINE
RANGE TIME-SEC.
F035
2000.0
1600.0
1200.0
800.0
400.0
57750.0
57850.0
57950.0
58050.0
58150.0
58250.0
58350.0
58450.0

FIGURE 13

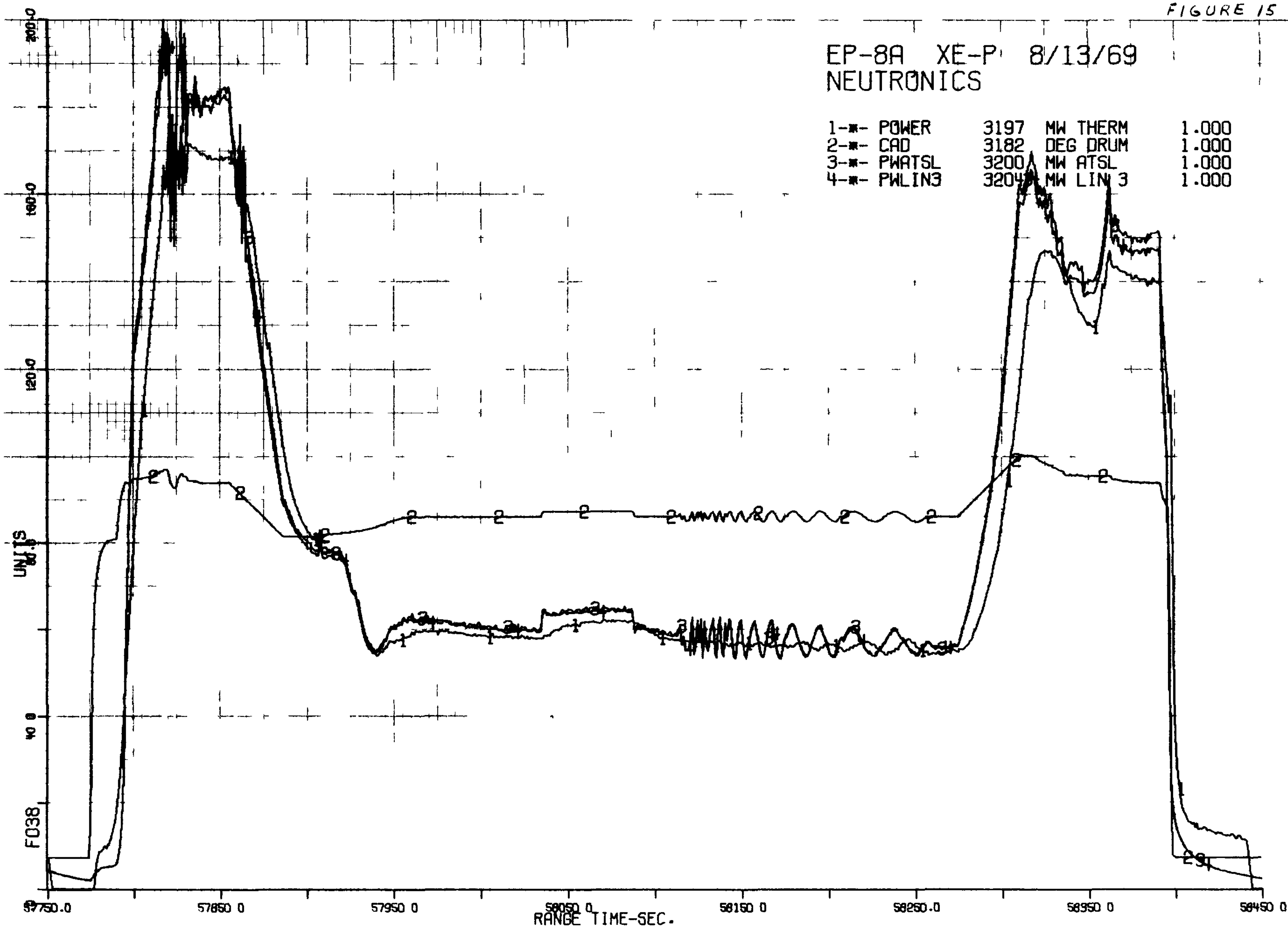


EP-8A XE-P 8/13/69
AVG STATION TEMPERATURES
1-*- TACS1 3287 DEG R 1.000
2-*- TACS2 3216 DEG R 1.000
3-*- TACS3 3217 DEG R 1.000
4-*- TACS4 3218 DEG R 1.000
5-*- TACS5 3219 DEG R 1.000
6-*- TA158 3288 DEG R 1.000
DEGREES. RANKINE
2000.0
1600.0
1200.0
800.0
400.0
+036
57750 0
57850 0
57950 0
58050 0
58150 0
58250 0
58350 0
58450 0
RANGE TIME-SEC.

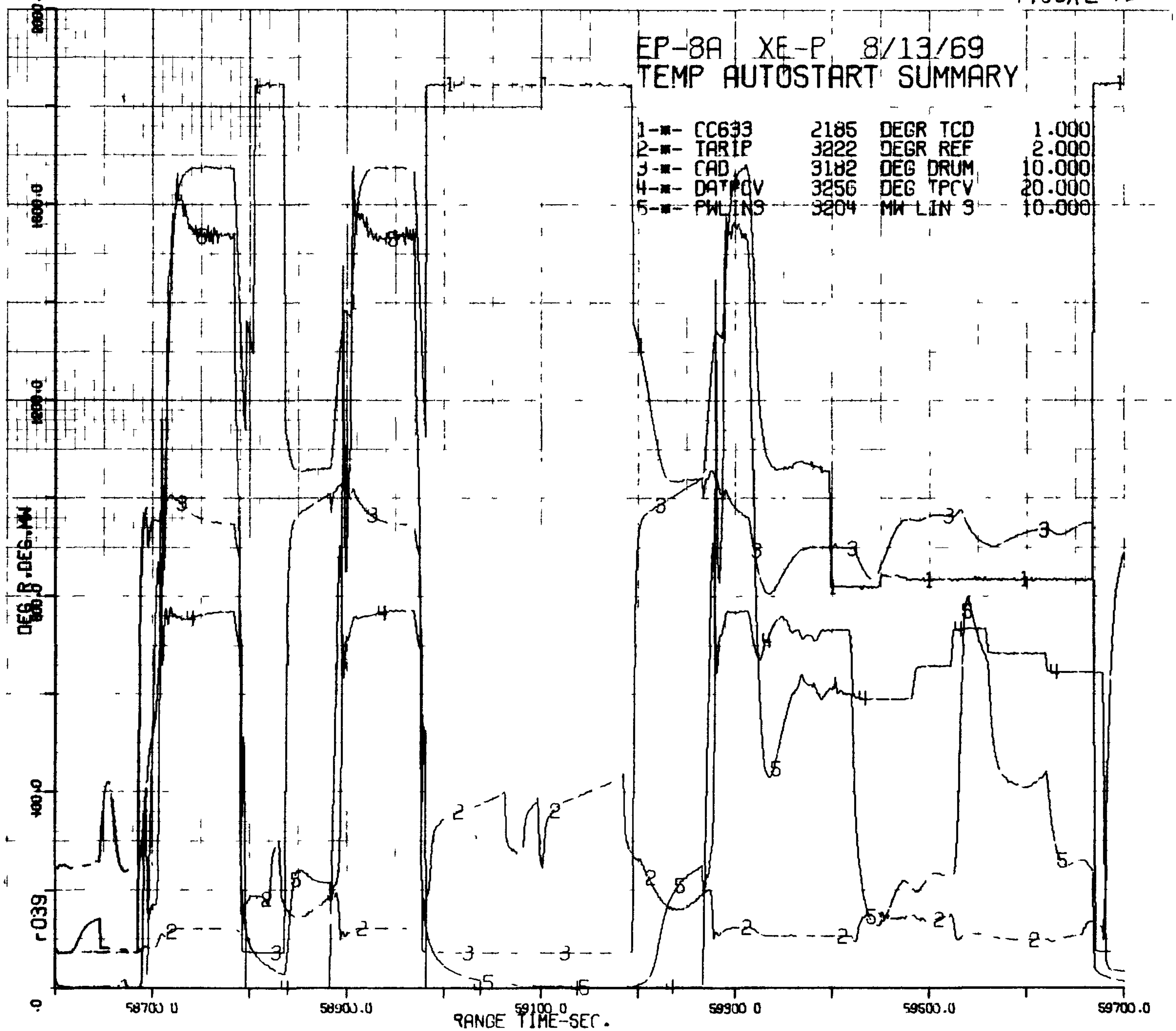
MCH) # 2
FIGURE 14



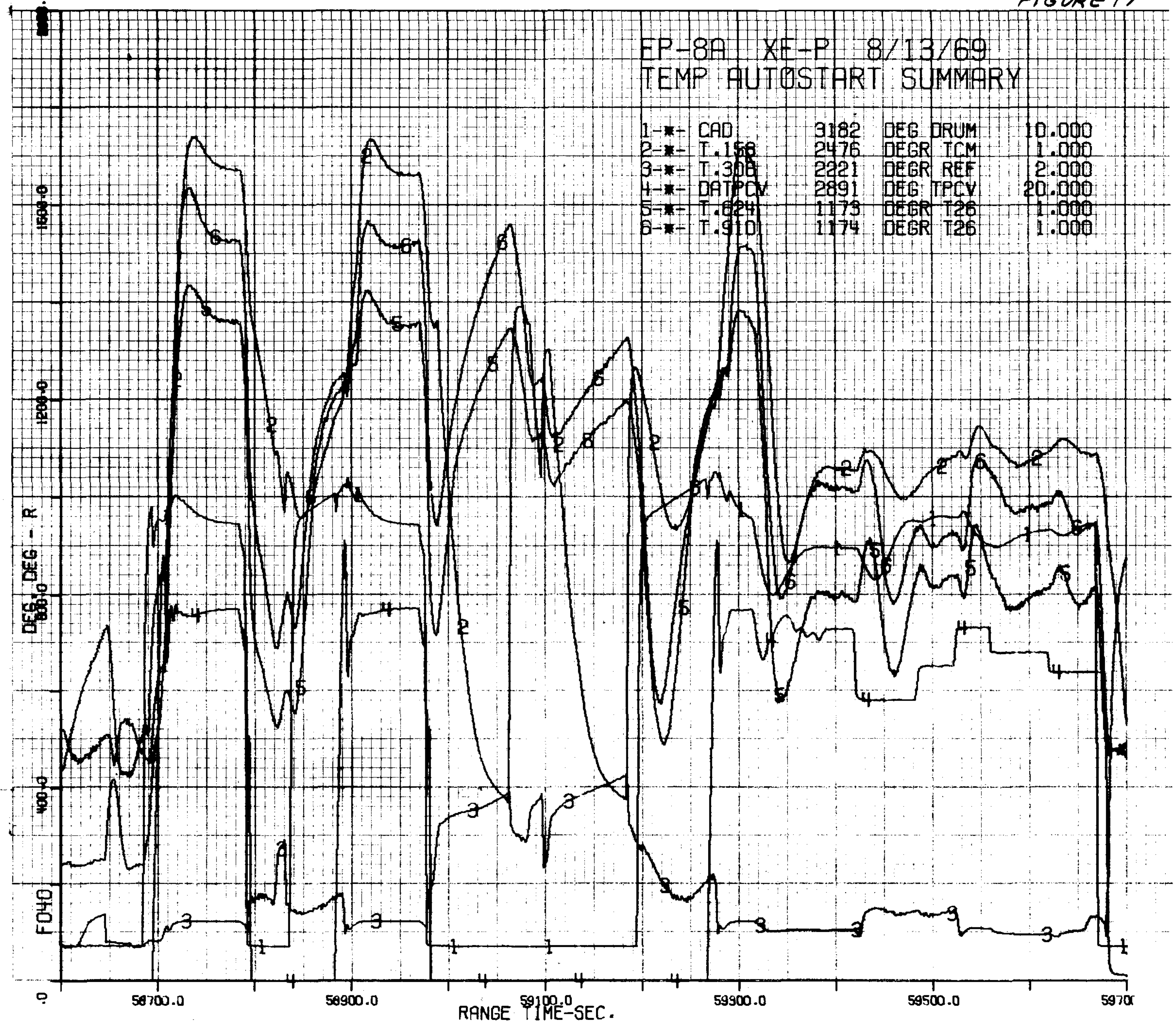
MEMO #2
FIGURE 15



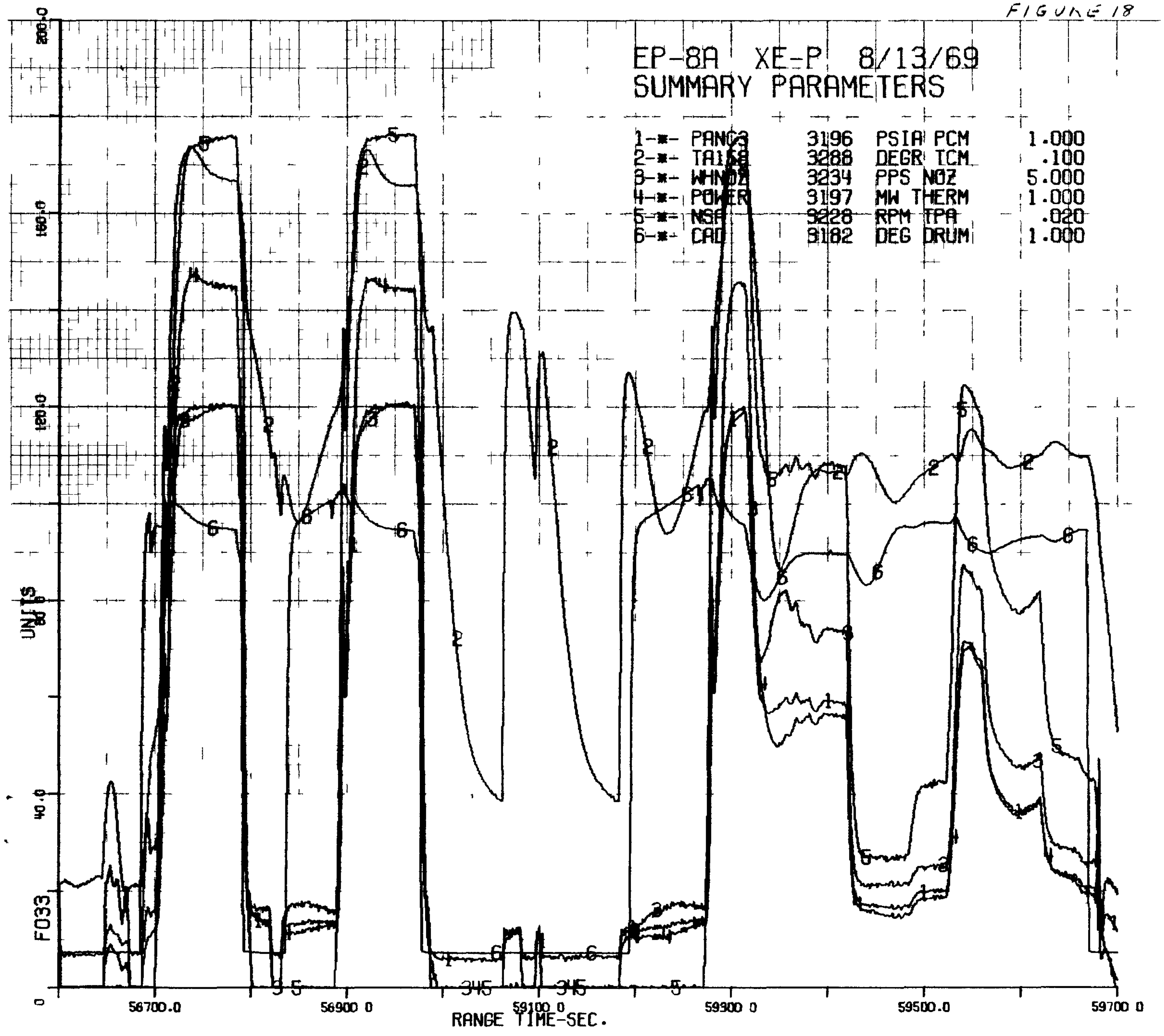
MEMO # K
FIGURE 16



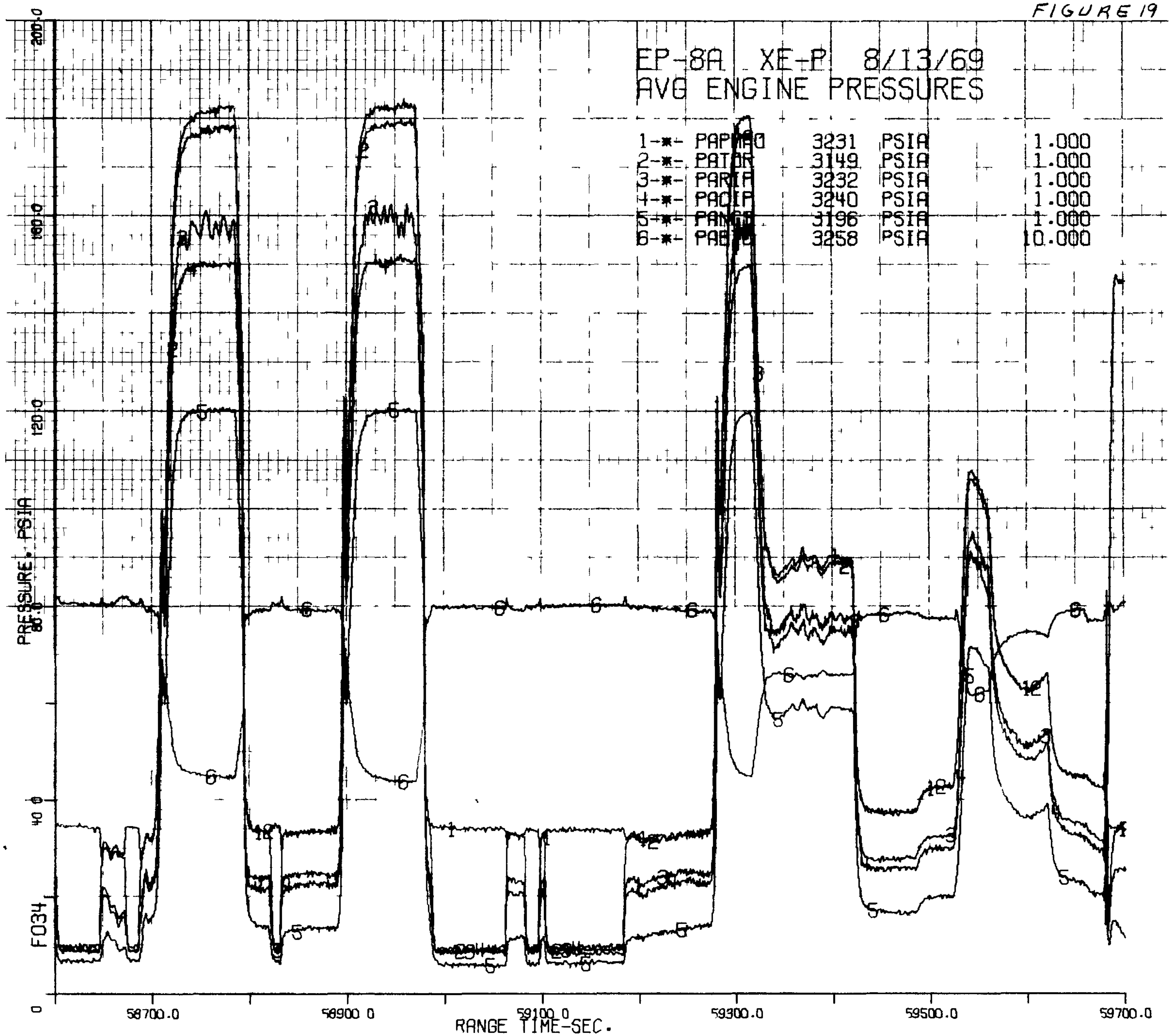
MEMO #2
FIGURE 17



MEMO # 2
FIGURE 18



MEMO #2
FIGURE 19



MEMO #2
FIGURE 20

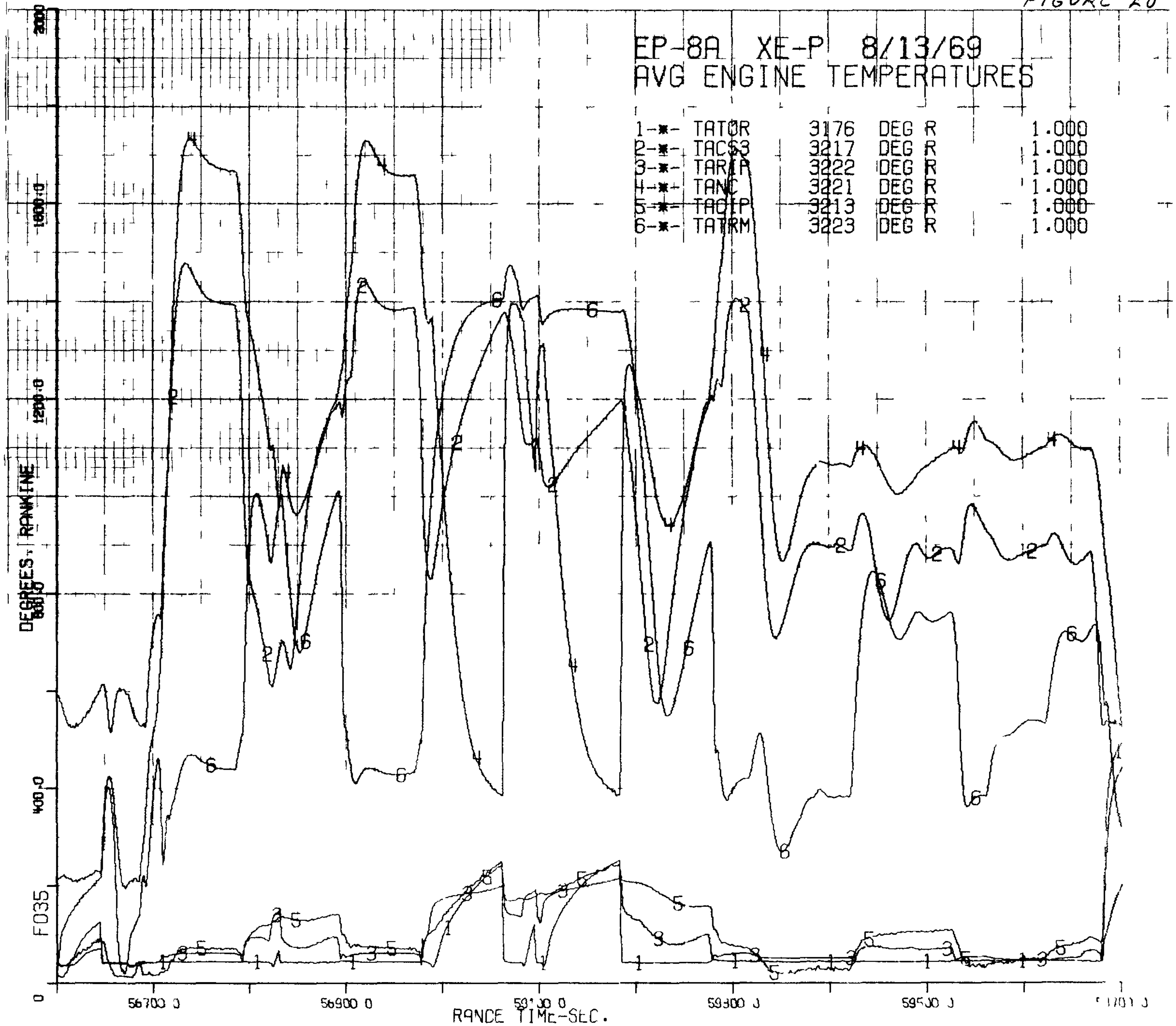
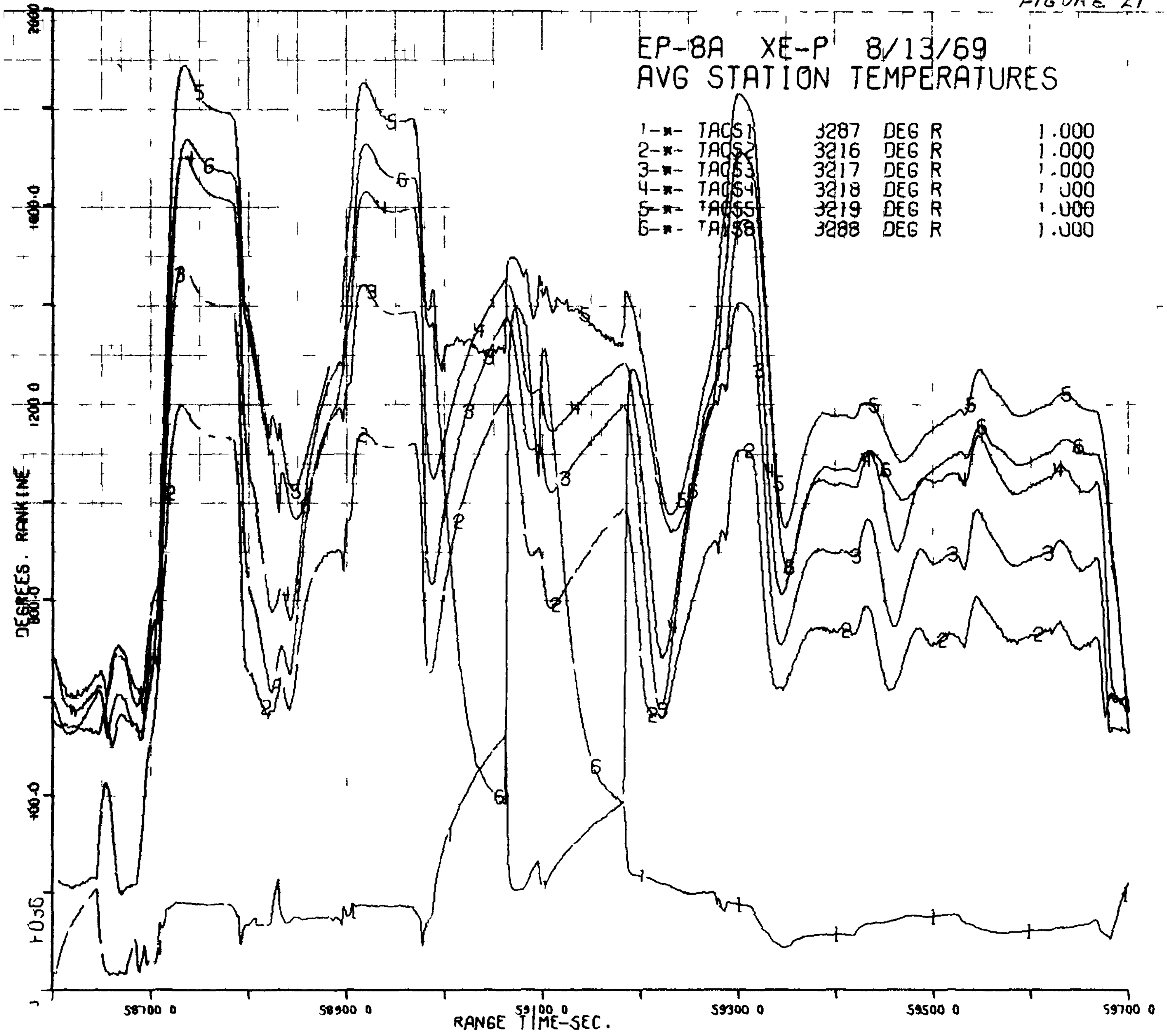
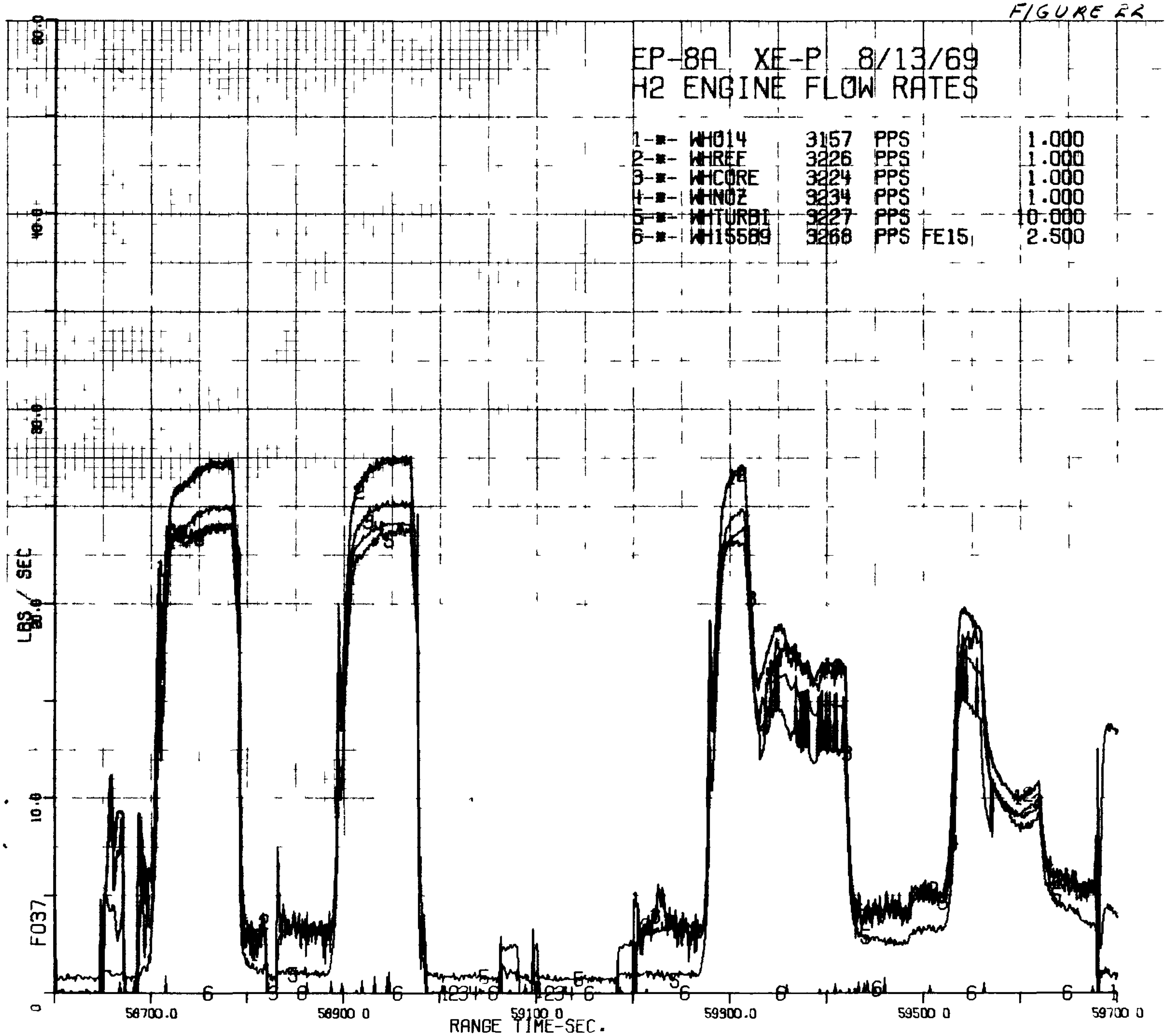


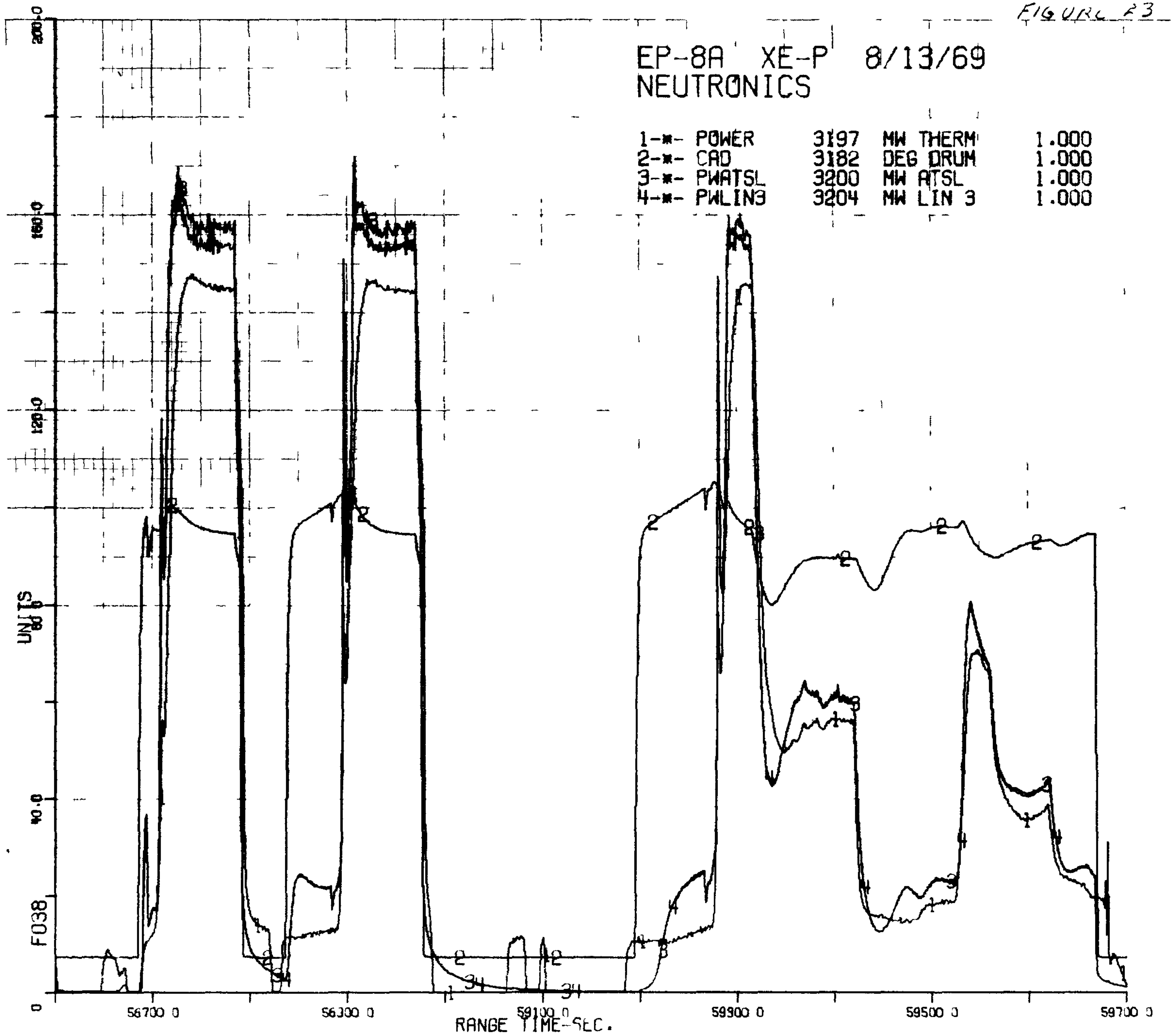
FIGURE A1


EP-8A XE-P 8/13/69
AVG STATION TEMPERATURES
1-*- TACS1 3287 DEG R 1.000
2-*- TACS2 3216 DEG R 1.000
3-*- TACS3 3217 DEG R 1.000
4-*- TACS4 3218 DEG R 1.000
5-*- TACS5 3219 DEG R 1.000
6-*- TANS8 3288 DEG R 1.000
DEGREES. RANKINE
RANGE TIME-SEC.
58700 0
58900 0
59100 0
59300 0
59500 0
59700 0
1200 0
800 0
400 0

MEMO H ~
FIGURE 22



MEI #2
FIGURE 23



SPEAR Memo No. 3

J. K. Endo
K. E. per J. K. E.

XE-PRIME

EP-8A

Subject: CRITICALITY MEASUREMENTS

SUMMARY:

The ambient critical drum bank position for EP-8A was 93.2 degrees.

TECHNICAL DISCUSSION:

Data for this memo was obtained from the NTO Thinned Digital Data Listings and TDC CALCOMP Plots.

The ambient critical drum bank position measurement was taken at CRT of 34836.6 to 34876.6 seconds at a constant average power level of 530 watts (average of PWLIN-1 and PWLIN-3). No temperature corrections were made because the outer reflector temperature coefficient of 0.119 cents/$^{\circ}$R and the core temperature coefficient of -0.13 cents/$^{\circ}$R essentially compensate for each other at ambient conditions. Since the power level was constant, the reactivity was Zero. Therefore, no correction to the measured ambient critical drum bank position was necessary. The above mentioned core and reflector temperature coefficients are being evaluated from test data obtained during this EP. SPEAR Memo No. 16 (Physics Test) evaluated this in detail.

TABLE I

SUMMARY OF OUTER REFLECTOR AND AVERAGE CORE TEMPERATURES

Average Outer Reflector Temperature (Average of TE-301, TE-302, TE-303 and TE-304)	=	562°R
Average Core Temperature (Average of TACS1C1 and TANC)	=	559°R

The critical bank position at the start of EP-8A was 93.2 degrees based on the computed average drum position (CAD). This is 0.4 degrees greater than the pre-test ambient critical drum bank position.

The difference of 0.4 degrees between EP-7A and EP-8A represents a drum worth of - 2.6 cents. This indicates that the corrosion effects are now predominant and the effects caused by the loss of X and Niobium coating are now small.

The loss or gain in reactivity worth during EP-8A will be determined from the pre-test criticality measurement of EP-9A.

The reactivity gain for the X and Niobium coating loss for each EP up to EP-7A and the pre-test cold dritical drum position is listed below. However, this neglects the predicted reactivity loss (Reference 1) caused by the loss of carbon primarily during the full power run (EP-5C) and the intermediate power run of EP-8A.

		Pre-test Average Ambient Critical Drum Bank Position
EP-2A	23 cents	100.1 degrees
EP-3	2 cents	95.6
EP-5C	16 cents	95.4
EP-4A *	2 cents	92.8
EP-6A *	- 2 cents	92.6
EP-7A *	- 2.6 cents	92.8
EP-8A **		93.2

It should be noted that the control drum meter on the ATE console indicates drum bank position of 0.9 to 1.0 degrees less than the digital (CAD) data that was used in this memo. This difference was noted in the EP-5C SPEAR memo, and continues to exist.

* Low Power Testing, T_c approximately 1700^{o}R

** Intermediate and Low Power testing, T_c approximately 2400^{o}R and 1700^{o}R, respectively.

Reference 1: XE-2 Nuclear Subsystem Thermal and Nuclear Design Data Book, TME-1805, Page J-28.

SPEAR Memo No. 4
B. S. Maxon/D. C. Rardin:jh

XE-PRIME

EP-8A

Subject: ENGINE PERFORMANCE DURING OPEN LOOP TESTS

SUMMARY

The test objective of obtaining information on engine startup characteristics in open loop control with TPCV ramped open at initiation of engine flow was successful except for anomalous performance of the drum programmer on Run No. 2 which caused this startup to be significantly different from that planned.

The first open loop startup test performed during EP-8A, with near ambient engine system temperatures but chilled pump, went essentially as planned and predicted. The ramp opening of TPCV in conjunction with PDSV opening did not result in any significant system pressure oscillations, and reduced the time required to obtain reflector inlet temperatures (T.306) near the 100°R region by approximately 10 seconds. The beginning of engine bootstrap, as evidenced by increasing pump head rise, occurred approximately 36 seconds after TPCV reached 39° when the chamber temperature reached 650°R with reflector inlet temperature at 90°R, TPCV at 40°, and the run tank pressurized to 35 psia. Pressure null occurred approximately 18 seconds after this event. Although the initial drum ramp was stopped at a 1 second period during this test, evaluation of test data and predictions showed that an acceptable open loop startup would have been achieved if the drum ramp had not been stopped before the drum step.

Temperature and pressure throttling, using constant drum (± 0.4° sec) and TPCV (± 1.25°/sec) ramp rates, were successfully demonstrated with results essentially as predicted by the CAM. The overall performance of the ON-OFF temperature controllers also was essentially as predicted.

Shutdown of the engine using essentially constant drum (-20°/sec) and TPCV (-2.5°/sec) in open loop control, was successfully demonstrated. Although the temperature cooldown rates were higher than predicted due to difference in decay heat levels, no test limits were approached.

Although the engine was started successfully during the second open loop startup performed during EP-8A without any of the test limits being approached, anomalous operation of the drum programmer caused the test to be significantly different from that planned.

Summary (Cont'd)

The beginning of engine bootstrap, as evidenced by increasing pump head rise, occurred when TPCV reached 35° with chamber temperature at 1000°R, reflector inlet temperature at 85°R, and run tank pressurized to 35 psia. Pressure null (40 psia) occurred approximately 8 seconds after this event. As a result of lower than expected drum position at bootstrap, the chamber temperature decreased initially by approximately 80°R.

Figure 14 shows the chamber temperature and pressure on the engine map for the first open loop test through shutdown.

TECHNICAL DISCUSSION

1. Open Loop Startup (Run No. 1)

a. Test Description

The purpose of this run was to obtain information on engine startup characteristics in open loop control with TPCV ramped open at initiation of engine flow, with engine near ambient temperature conditions but the turbopump chilled.

Figure 1 shows the relationship between the drum position, power, TPCV position, pump speed, chamber temperature, and chamber pressure. Figure 2 shows the relationship between the reactor temperatures and drum position. Table No. I gives the chronology of the significant events during the open loop startups. Prior to engine start the run tank pressure was set at 35 psia, and the engine system, except for the pump, reconditioned to near ambient temperatures.

At "Start Reactor", the control drum program was initiated followed by PDSV opening to start propellant flow through the engine, and TPCV ramp to nominal 40° at 5°/sec to provide for engine bootstrap when engine conditions permitted.

The drums were programmed open using exponential and ramp controls in the "Nuclear Autostart Mode." The exponential and ramp potentiometers were set to provide a drum position of ambient drum critical plus 2° (94°) at approximately 10 seconds after "Start Reactor," with a continuing linear (0.4°/sec) ramp. This planned drum program was essentially obtained during the test. The control drums were switched to position control and maintained at a position of 100° when the reactor period reached approximately 1 second. When the power level reached 19 Mw, the drums were set in 2.5° (100° to 97.5°) corresponding to a drum position of 4.3° above ambient drum critical (93.2°) This reduced the nuclear

Technical Discussion (Cont'd)

power level to approximately 13 Mw which remained essentially constant until engine bootstrap phase. (The switch of the control drums to position control was performed in order to quickly accomplish a drum step-in in the event engine bootstrap occurred prior to the planned drum step-in which was to occur at 25 Mw. This was the first test in which the TPCV was opened to a throttled position (40°) at initiation of engine chilldown flow. Although the pre-test predictions with CAM showed that bootstrap would not occur until after the drum set-in at 25 Mw, a simulation or CAM of CFDTS, Test No. -015 showed that a bootstrap might occur significantly earlier than predicted with CAM.

PDSV open and TPCV ramp opening to 39.7° at 5°/sec was initiated within 2 seconds of the start of the drum program. Although an rpm indication (EN800)(i.e., excess of 100 rpm) was obtained when TPCV reached 39°, the start of engine bootstrap, as evidenced by acceleration in pump head was obtained about 30 seconds later when chamber temperature (T.158) was 650°R and the reflector inlet temperature (T.306) was 90°R. It is to be noted in Figure 2, that the reflector inlet temperature leveled out at 90°R due to rise in chamber temperature, until an acceleration in pump head condition was obtained. Pressure null (40 psia) was obtained 48 seconds after TPCV reached 39° when chamber temperature reached 850°R. Within 5 seconds after pressure null, the maximum chamber temperature rise rate of 62°R/sec was reached. A 0.41°/sec drum ramp was initiated after chamber temperatures began to stabilize near 2000°R resulting in a subsequent chamber temperature rise of 40°R/sec. Although earlier initiation of the drum ramp was not planned, it appears that this could have been done within 20 seconds of pressure null.

A comparison between the initial engine chilldown characteristics with and without TPCV open at PDSV opening is shown in Figure 3. This correlation shows that with the pump initially chilled in, opening TPCV in conjunction with PDSV as performed during this test decreases the time required to reduce reflector inlet temperature (T.306) to the 100°R region by approximately 10 seconds.

The chamber pressure oscillations shown in Figure 1 in the 125 to 140 psia range are similar to those experienced during previous XE-P's[1] and NRX/EST tests. The power spike shown in PWALIN is not real and was not evident in any of the individual power channels.

Ref. 1: NTO-R-0169, SPEAR Report, XE-Prime EP-III, Memos No. 3 and 25.

Technical Discussion (Cont'd)

b. Comparison of Predicted and Measured Data

Figure 4 shows a comparison between the measured and predicted power and period during the first open loop test. The CAM prediction chosen for this comparison was Run 20, performed on 31 July 1969. For comparison purposes, the CAM drum profile was adjusted for the difference in drum ambient dry critical position (i.e., 99° for CAM vs. 93° for XE-Prime, EP-8A).

The difference in the predicted and measured drum position and time required to reach a 1-second period is thought to be due primarily to a lower than actual H_2 reactivity feedback affect used in CAM.

The difference in the predicted and measured time (12 seconds) to drum step is due to both the shorter time required to reach a 1 second period and the higher source level (40 watts vs. 100 milliwatts) in the actual test.

Based on extrapolation of test data to a shutdown power of 100 milliwatts (instead of an actual shutdown power of 40 watts) and use of a continuing drum ramp, it is predicted that a minimum reactor period of 0.3 seconds and drum position of 103° would have been obtained prior to a control drum step at 25 Mw. This extrapolated prediction compares to a minimum period of 0.4 seconds and corrected drum position of 107° based on CAM Run 16 performed on 31 July 1969.

The minimum reactor period obtained during bootstrap was 2.7 seconds as compared to a predicted period of 2.3 seconds based on CAM.

Figure 5 shows a comparison between the measured and predicted engine chamber temperature, chamber pressure, pump speed, drum position, and TPCV position. The CAM prediction chosen for this comparison was Run 20 performed on 31 July 1969.

Although the measured nuclear power after the drum step was higher than predicted (13 vs. 7 Mw), the measured chamber temperature rise rate prior to pressure null was lower than predicted (10°R/sec vs. 20°R/sec). Although the measured chamber temperature at pressure null was about as predicted (820°R vs. 850°R), the measured time to pessure null was greater than predicted by approximately 6 seconds. The measured chamber temperature rise after pressure null was approximately as predicted (i.e., 62°R/sec).

Technical Discussion (Cont'd)

2. Open Loop Mapping (Run No. 1)

The purpose of the mapping performed during Run 1 was to evaluate the capability of 1) engine high temperature control using a constant drum ramp rate with a fixed TPCV position and 2) engine pressure control using a constant TPCV ramp rate with temperature being maintained using the ON-OFF Temperature Controller.

Figures 6 and 7 show the relationship between the drum position, power, TPCV position, pump speed, chamber temperature, chamber pressure, and reactor temperatures during the initial portion of the mapping test. Figures 8 and 9 show the relationship of these parameters for the final portion of the mapping tests performed after the transfer function tests.

With TPCV position maintained at 39.5°/a constant drum ramp rate of +0.41°/sec was initiated when chamber temperature (TANC) began to stabilize near 2000°R following the open loop bootstrap. This ramp rate was maintained until the chamber temperature exceeded 3000°R, and then reversed to obtain a negative drum ramp of -0.41°/sec. Chamber temperature increased at +40°R/sec (between 2500 and 3000°R) reaching 3050°R when the drum ramp was reversed, and then overshot to 3160°R (i.e., 110°R). The chamber temperature then decreased at -30°R/sec (between 3000°R and 2500°R). The CAM (Run 16, 7/31/69) predicted chamber temperature rates of +60°R/sec and -30°R/sec and temperature overshoot of approximately 100°R for drum ramp rates of ± 0.4°/sec and constant TPCV position of 44°.

With chamber temperature in ON-OFF Temperature control at 2370°R (TANC), a constant TPCV ramp rate of +1.2°/sec was initiated from 39.5°. This ramp rate was maintained until the chamber pressure reached 294 psia (PANC3) and then TPCV was maintained at 51.8°. The chamber pressure and temperature increased from a steady-state condition of 167 psia/2370°R to 294 psia/2468°R when TPCV reached 51.8°. The chamber pressure/temperature reached peak values of 310 psia/2480°R approximately 48 seconds later. The chamber pressure and temperature then stabilized at 299 psia/2400°R with TPCV at 51.5° and drums at 92.5°. The chamber pressure increased at a maximum rate of 16 psi/sec (200 to 250 psia) while TPCV ramped at +1.2°/sec. The chamber temperature remained within ± 5°R and drums remained within ± 0.2° over this pressure range.

The chamber temperature overshoot of approximately 100°R due to the action of the ON-OFF temperature controller was the main cause of the chamber pressure overshoot of approximately 16 psi. This behavior was in good agreement with CAM predictions (Run 16, performed on 7/31/69).

Technical Discussion (Cont'd)

Following transfer functions tests, a constant TPCV ramp rate of -1.2°/sec was initiated from 51.5° with chamber temperature in ON-OFF temperature control at 2250°R. This ramp rate was maintained until TPCV reached 39.0°. The chamber pressure and temperature decreased from a steady-state condition of 268 psi/2250°R to 157 psia/ 2226°R when TPCV reached 39.1°. The chamber pressure decreased at a maximum rate of -12 psi/sec (250-200 psia) during the TPCV ramp. The minimum chamber temperature reached as a result of this operation was 2200°R. This behavior was in excellent agreement with CAM predictions.

The ON-OFF temperature controller was then used to reduce the chamber temperature to 1766°R at -50°R/sec with TPCV maintained at 39.0°.

3. Open Loop Shutdown (Run No. 1)

The purpose of the shutdown during Run 1 was to evaluate the capability of engine shutdown in open loop control using constant TPCV and drum ramp rates.

Figures 10 and 11 show the relationship between the drum position, TPCV position, pump speed, chamber temperature, reactor temperature, and chamber pressure during the open loop shutdown.

The open loop shutdown was performed from steady-state operation at 1740°R/115 psia by ramping drums in at -0.4°/sec with TPCV maintained at 38.7° until chamber temperature reached 1550°R. At 1550°R, the drums were run-in in position control and TPCV ramped in at -2.5°/sec. The average drum run-in rate during manual drum run-in was -21°/sec which was as used in the pre-test CAM predictions.

During the open loop shutdown, the maximum rate of temperature change, which occurred only once over a two second interval were -60°R/sec and -100°R/sec based on chamber (TANC) and in-core (TACS-3) measurements. The maximum tie rod average temperature (TATRM) peak after shutdown was 800°R which occurred approximately 16 seconds after shutdown. Since the pre-test CAM predictions did not include the 120 second hold at nominal 1800°R experienced prior to the open loop shutdown, the predictions indicated lower temperature cooldown rates and higher peak temperatures.

4. Open Loop Restart

The purpose of this run was to obtain information on engine startup characteristics in open loop control with TPCV ramped open at initiation of drum program with engine temperatures and nuclear decay power near restart conditions.

Technical Discussion (Cont'd)

Figure 12 shows the relationship between the drum position, power, TPCV position, pump speed, chamber temperature, and chamber pressure. Figure 13 shows the relationship between the reactor temperatures and drum position. The chronology of the significant events during this open loop restart are given in Table 1.

This restart was planned to occur as soon as possible following the open loop shutdown, as long as the engine chamber temperature and core station temperatures were greater than 1000°R. PDSV was closed 21 seconds after closure of TPCV during the open loop shutdown test when it appeared that the chamber temperature would decrease below 1000°R.

For the restart test,the drum program was initiated about 45 seconds after TPCV closure from the previous open loop shutdown test, followed by PDSV reopening and TPCV ramp to 40° at 5°/sec. Although it was planned to have the drums programmed open identical to the first (Run 1) open loop start, this did not occur as shown in Figure 12. The drums apparently programmed out on an exponential and became fixed at 80.5°.A reinitiation of an exponential to 94° occurred with a lag in time to a given drum position of approximately 12 seconds. At this point pressure null occurred, and as planned, the drums were switched to position control, and subsequently opened to maximum setting of 96.9° to reach the planned 1700°R chamber temperature.

Due to the anomalous performance of the drum programmer, the engine was in the bootstrap phase when the "second" exponential drum program was initiated. The beginning of engine bootstrap as evidenced by acceleration in pump head rise occurred when TPCV reached 35° with the control drums at 80.5°, chamber temperature at 1000°R, and reflector inlet temperature at 85°. Although the chamber temperature and nuclear power was essentially stable at 1000°R and 5.5 Mw, the chamber pressure had increased to 18 psia, and the pump speed had increased to 2300 rpm when the "second" exponential drum program was initiated. The chamber temperature began to decrease below 1000°R during the "second" exponential drum program and reached a minimum level of 923°R with the drums at 93.7°. A minimum period of 1.4 seconds occurred at near minimum chamber temperature. The maximum chamber temperature rise after pressure null was 50°R/sec with the drums at 94.8°.

Due to significantly different initial conditions and the anomalous performance of the drum programmer, no major comparison to the pre-test CAM predictions could be made.

CONCLUSIONS

Except for the anomalous performance of the drum programmer during Run No. 2, all open loop test objectives planned for EP-8A were met.

TABLE I

OPEN LOOP START CHRONOLOGY

EP-8A STARTUP	Run No. 1 Pred-icted	Run No. 1 AMBIENT TEST		Run No. 2 HOT STARTUP TEST	
Drum Program Start	0	56712	0	57774	0
PDSV Open	0	56713	1	57776	2
TPCV Ramp Start	0	56713.5	1.5	57778	4
Drums Pass Ambient Critical (93.2°)		56720	8	57794	20
RPM Indicates above 100 rpm per EN800	9	56722	10	57784	10
TPCV Open to 39°	9	56722	10	57786	12
Drum Position Control	28	56732	20	57795	21
Drum Step	41	56741	29		
Positive Pump Head Rise	-	56752	40	57785	11
Pump rpm Exceeds 2000	22	56756	44	57788	14
Pressure Null(40 psia)	51	56770	58	57794	20

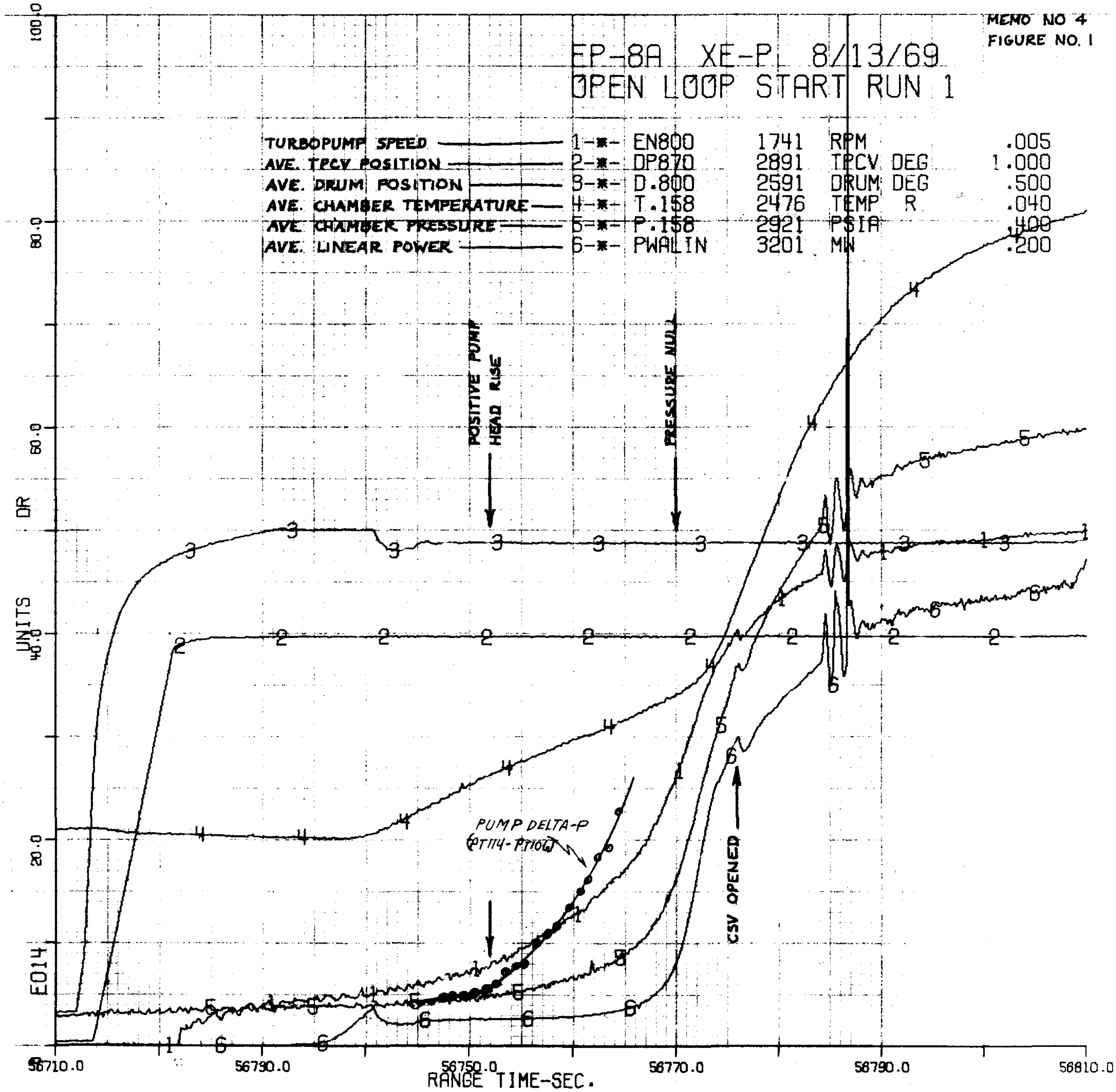
TABLE II

OPEN LOOP START-UP, MAPPING, AND SHUTDOWN EVENTS

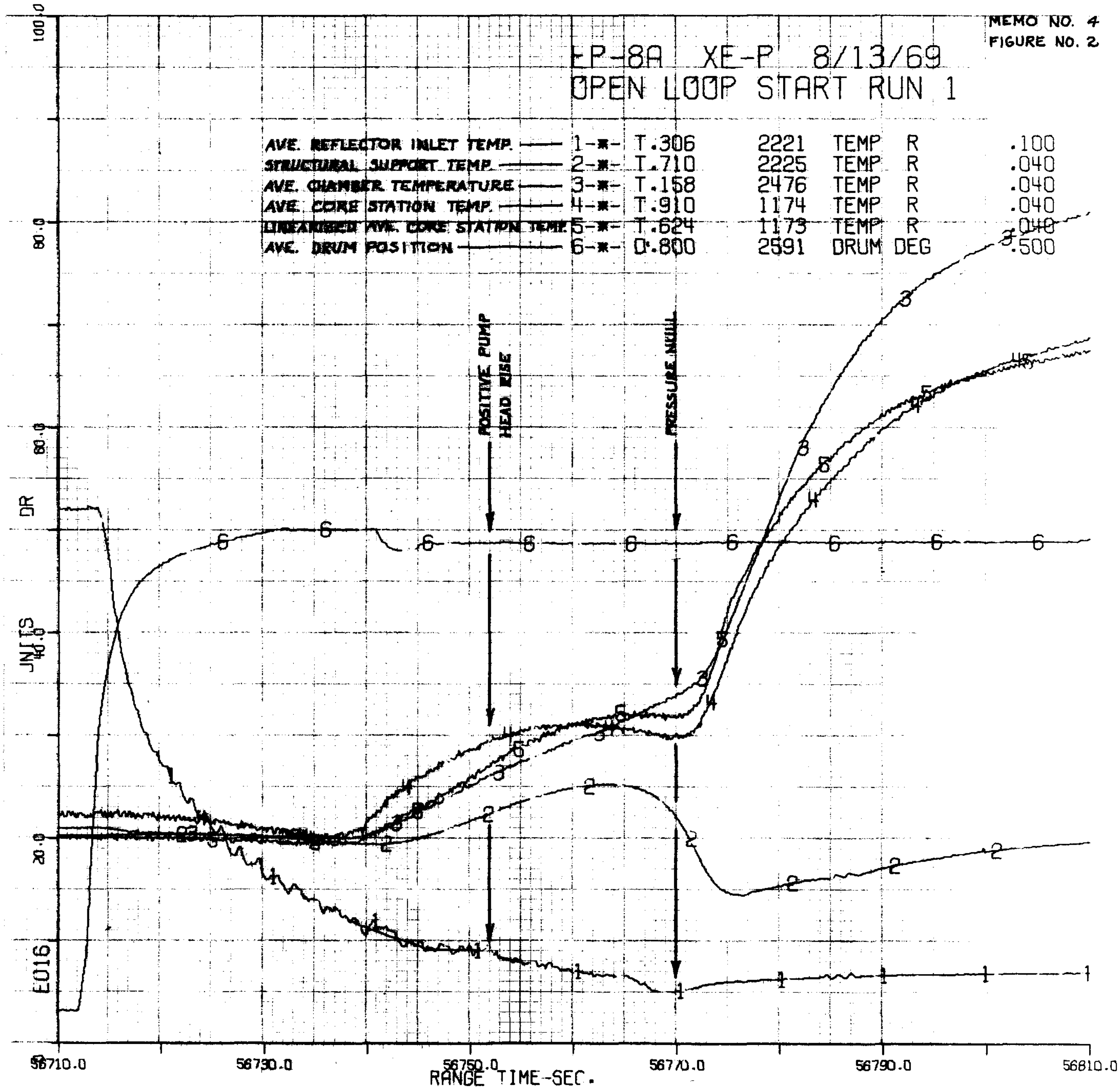
Reference: Figure 14

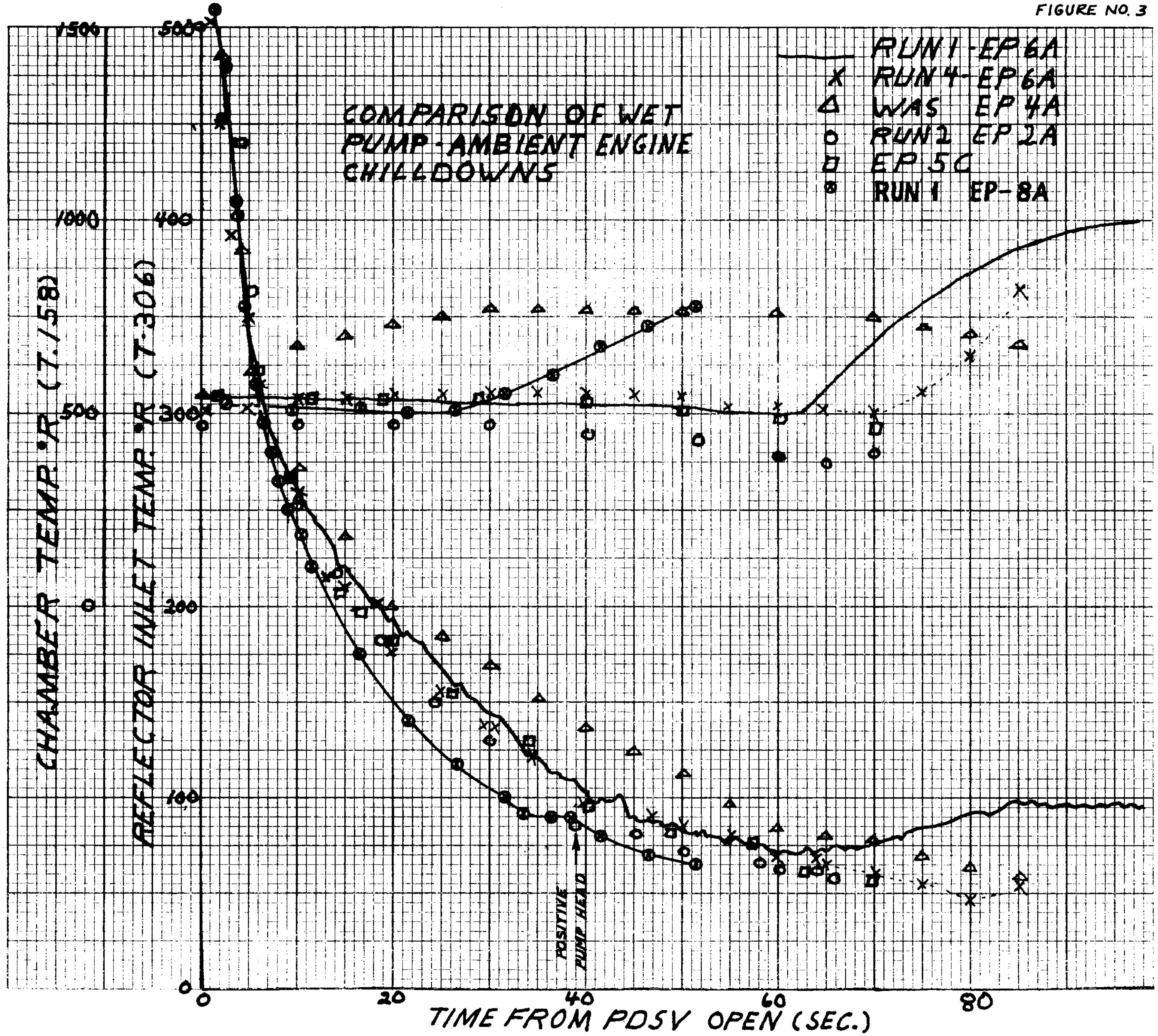
Point	Event
1	Start Engine..TPCV Ramp to 39.4°
2	Start Drum Ramp...TPCV at 39.4°
3	Drum Ramp Reversed
4	Drum Ramp Stopped
5	Start TPCV Ramp from 39.4° in ON-OFF Temperature Control
6	TPCV Stopped at 51.8°
7	Drums to Position Control for Transfer Functions
8	Start TPCV Ramp from 515° in ON-OFF Temperature Control
9	TPCV Stopped at 39.1°
10	Start Shutdown in ON-OFF Temperature Control with TPCV at 39.0°
11	Drums to Position Control
12	Start Drum and TPCV Ramp
13	To Shutdown From TPCV at 38.7° PDSV CLOSED

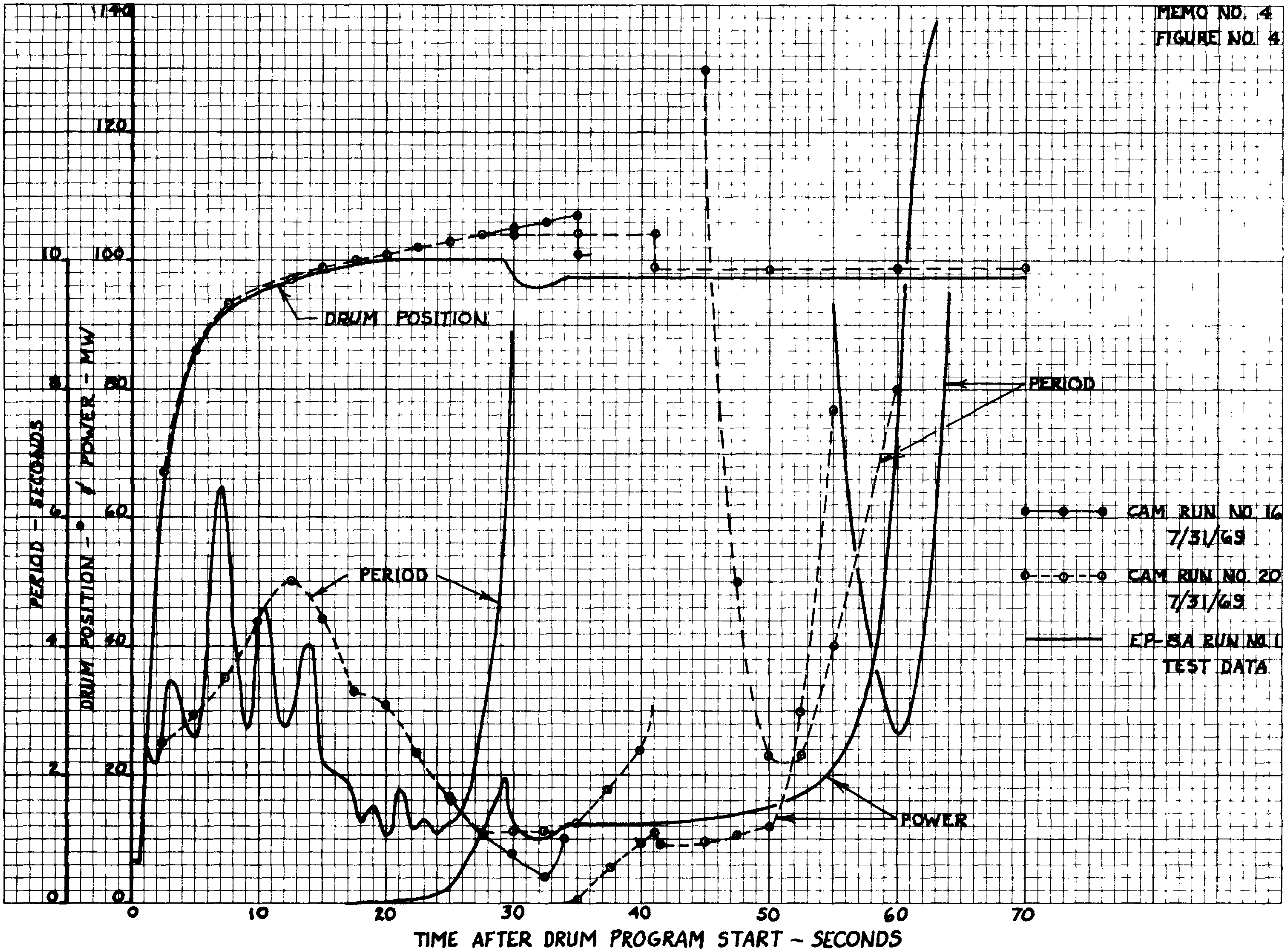
MEMO NO 4
FIGURE NO. 1



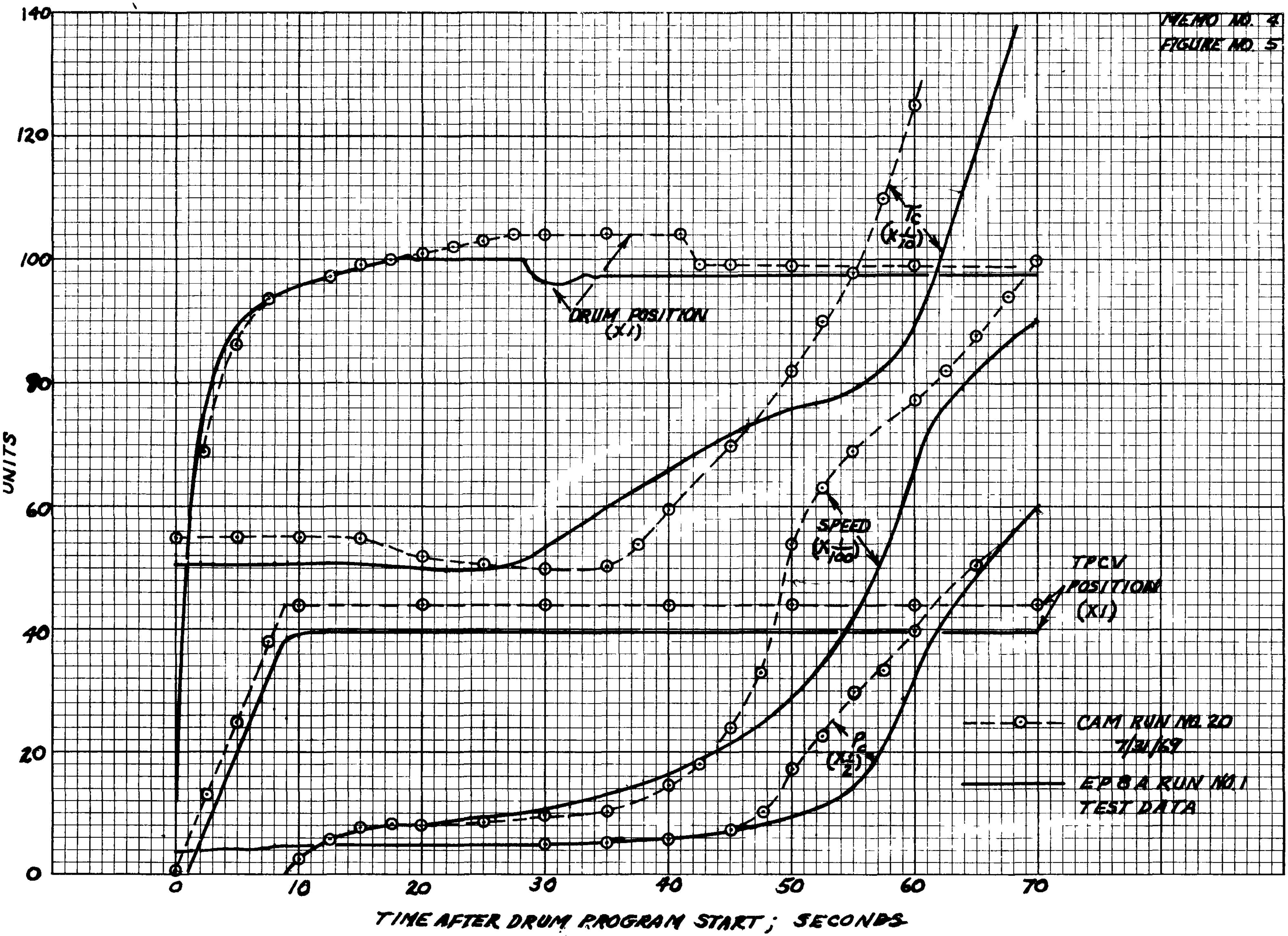
MEMO NO. 4
FIGURE NO. 2

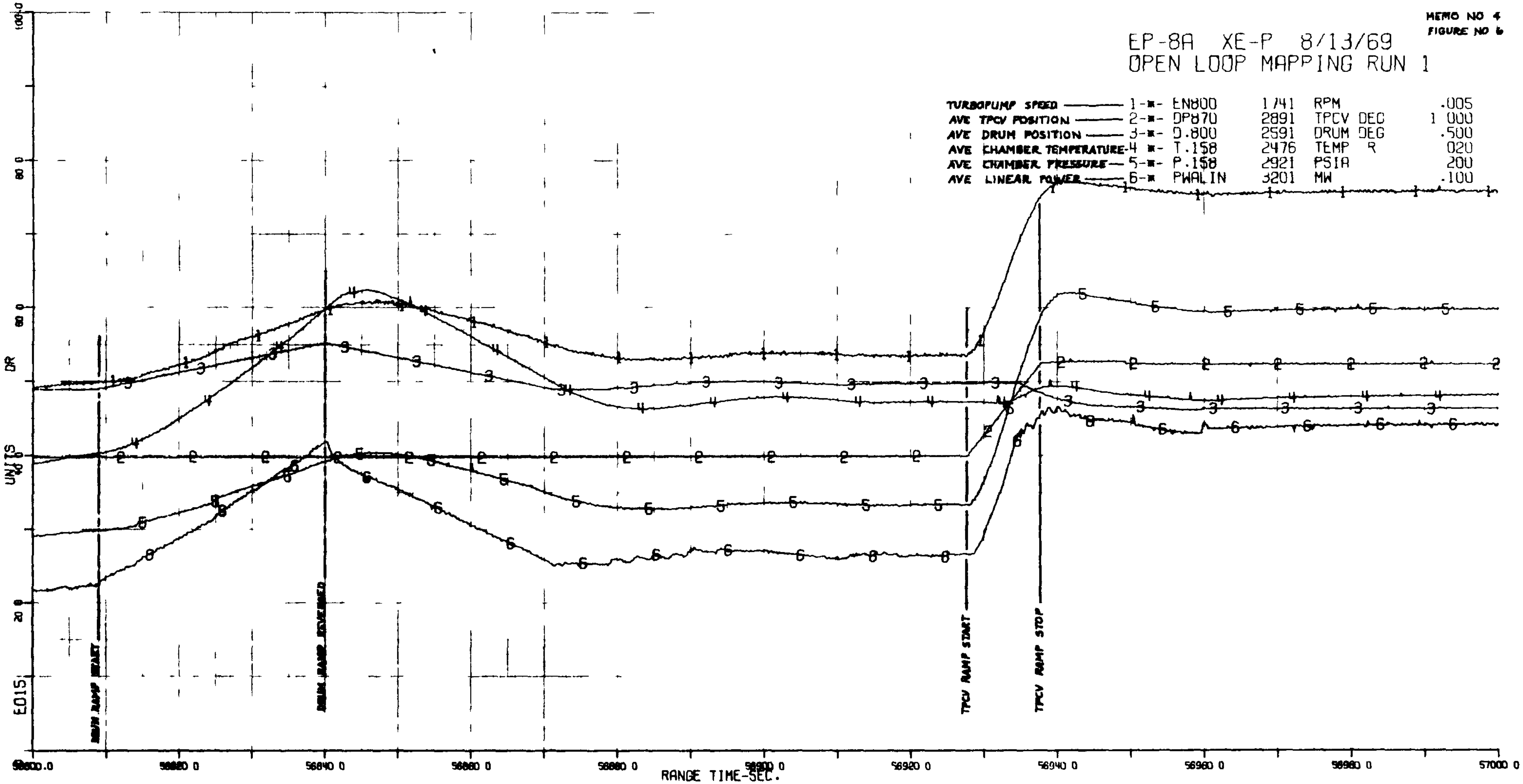



COMPARISON OF WET PUMP-AMBIENT ENGINE CHILLDOWNS
RUN 1 - EP 6A
RUN 4 - EP 6A
WAS EP 4A
RUN 2 EP 2A
EP 5C
RUN 1 EP-8A
CHAMBER TEMP. °R (T-158)
REFLECTOR INLET TEMP. °R (T-306)
1500
1000
500
500
400
300
200
100
0
0
20
40
60
80
POSITIVE PUMP HEAD
TIME FROM PDSV OPEN (SEC.)


MEMO NO. 4
FIGURE NO. 4
DRUM POSITION
PERIOD
PERIOD
POWER
CAM RUN NO. 16
7/31/69
CAM RUN NO. 20
7/31/69
EP-8A RUN NO. 1
TEST DATA
PERIOD - SECONDS
DRUM POSITION - ° / POWER - MW
TIME AFTER DRUM PROGRAM START ~ SECONDS
0
10
20
30
40
50
60
70
2
4
6
8
10
20
40
60
80
100
120
140

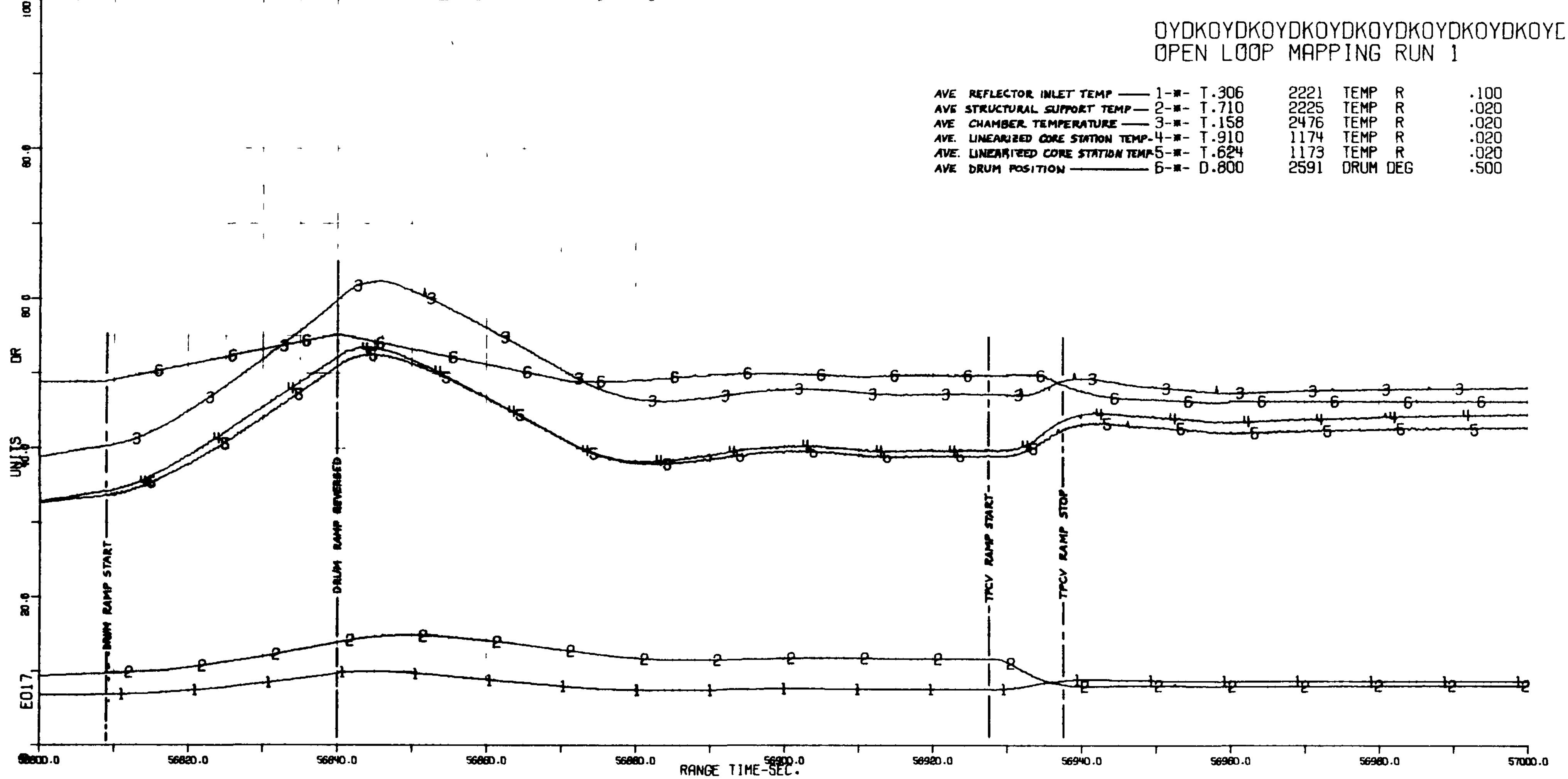
[redacted]

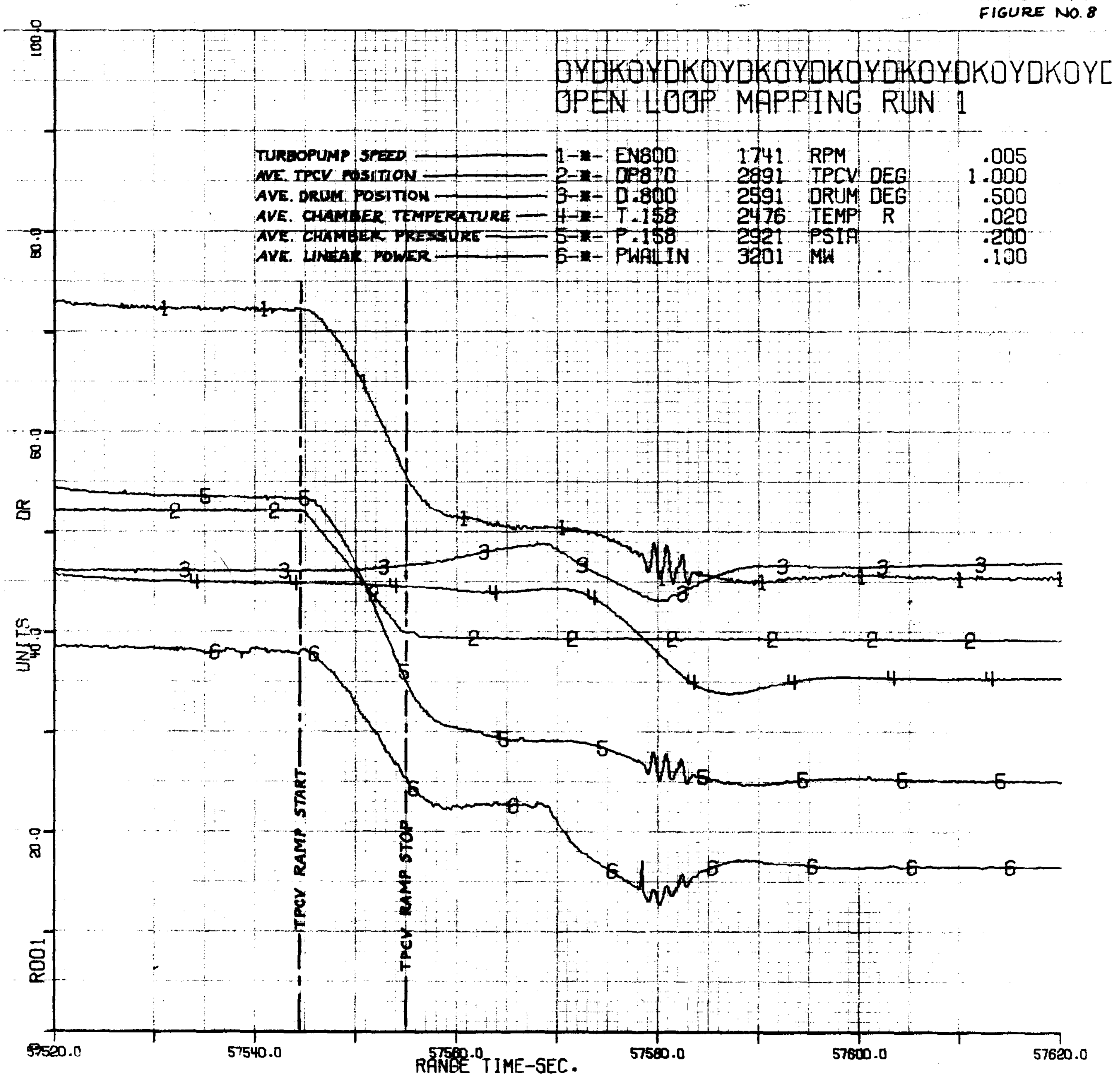

MEMO NO. 4
FIGURE NO. 5
UNITS
TIME AFTER DRUM PROGRAM START ; SECONDS
DRUM POSITION (X1)
T_C $(X \frac{1}{10})$
SPEED $(X \frac{1}{100})$
TPCV POSITION (X1)
P_C $(X \frac{1}{2})$
CAM RUN NO. 20 7/31/67
EP 8 A RUN NO. 1 TEST DATA
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70



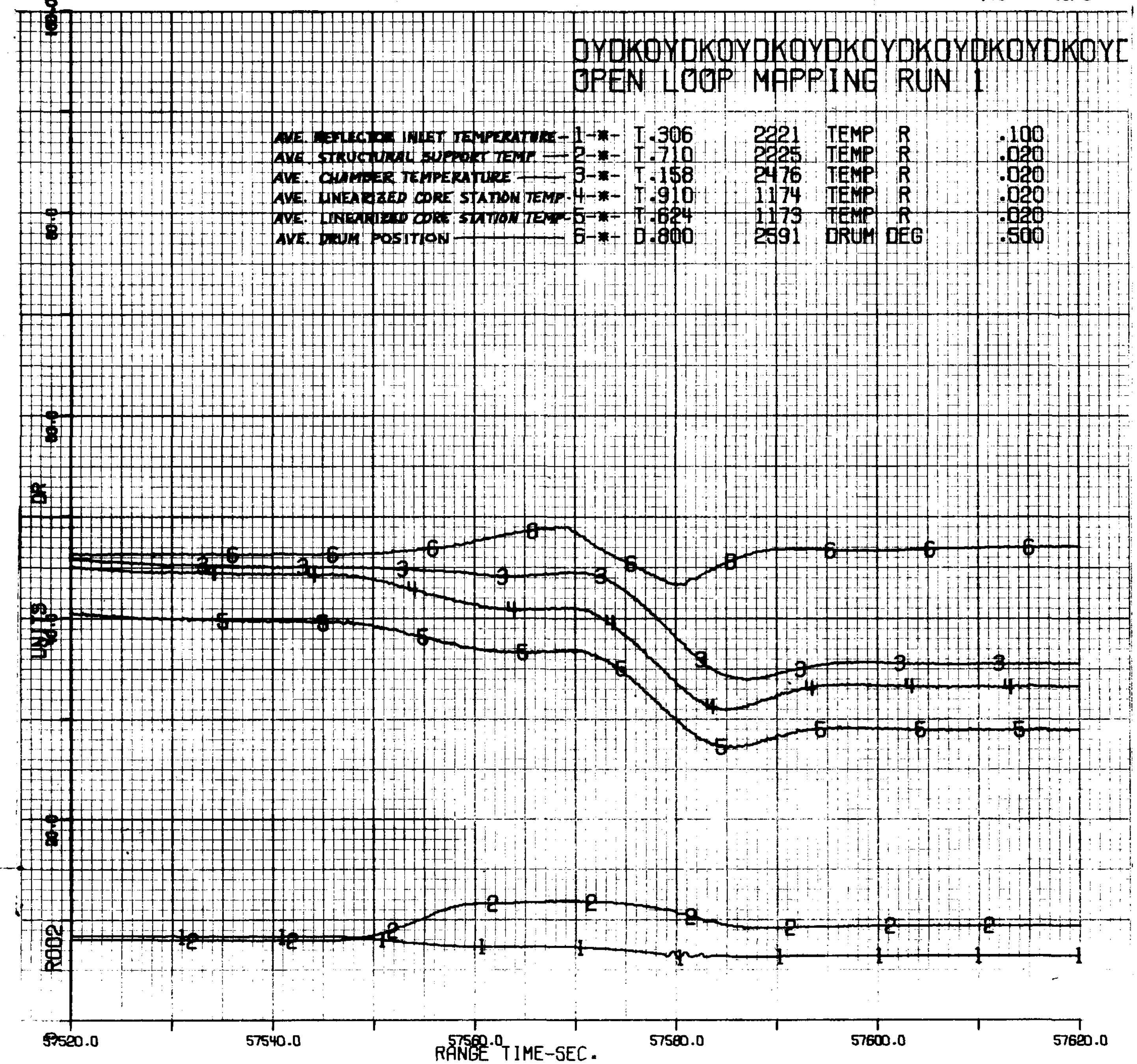
MEMO NO 4
FIGURE NO 6
EP-8A XE-P 8/13/69
OPEN LOOP MAPPING RUN 1
TURBOPUMP SPEED 1-*- EN800 1741 RPM .005
AVE TPCV POSITION 2-*- DP870 2891 TPCV DEG 1 000
AVE DRUM POSITION 3-*- D.800 2591 DRUM DEG .500
AVE CHAMBER TEMPERATURE 4 *- T.158 2476 TEMP R 020
AVE CHAMBER PRESSURE 5-*- P.158 2921 PSIA 200
AVE LINEAR POWER 6-* PWALIN 3201 MW .100
DRUM RAMP START
DRUM RAMP REVERSED
TPCV RAMP START
TPCV RAMP STOP
UNITS
DR
E015
RANGE TIME-SEC.
56800.0
56820 0
56840 0
56860 0
56880 0
56900 0
56920 0
56940 0
56960 0
56980 0
57000 0

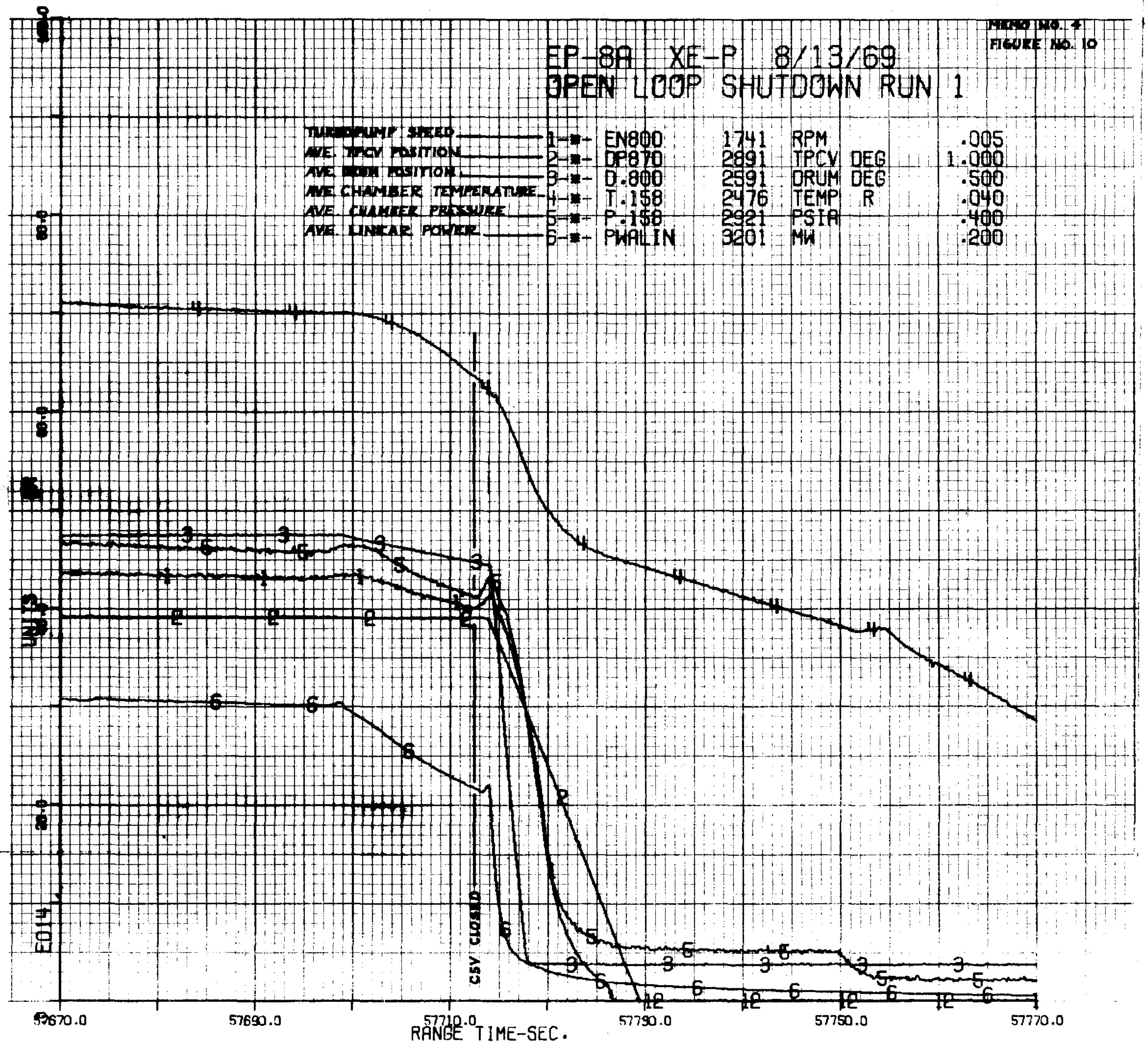
MEMO NO 4
FIGURE NO 7

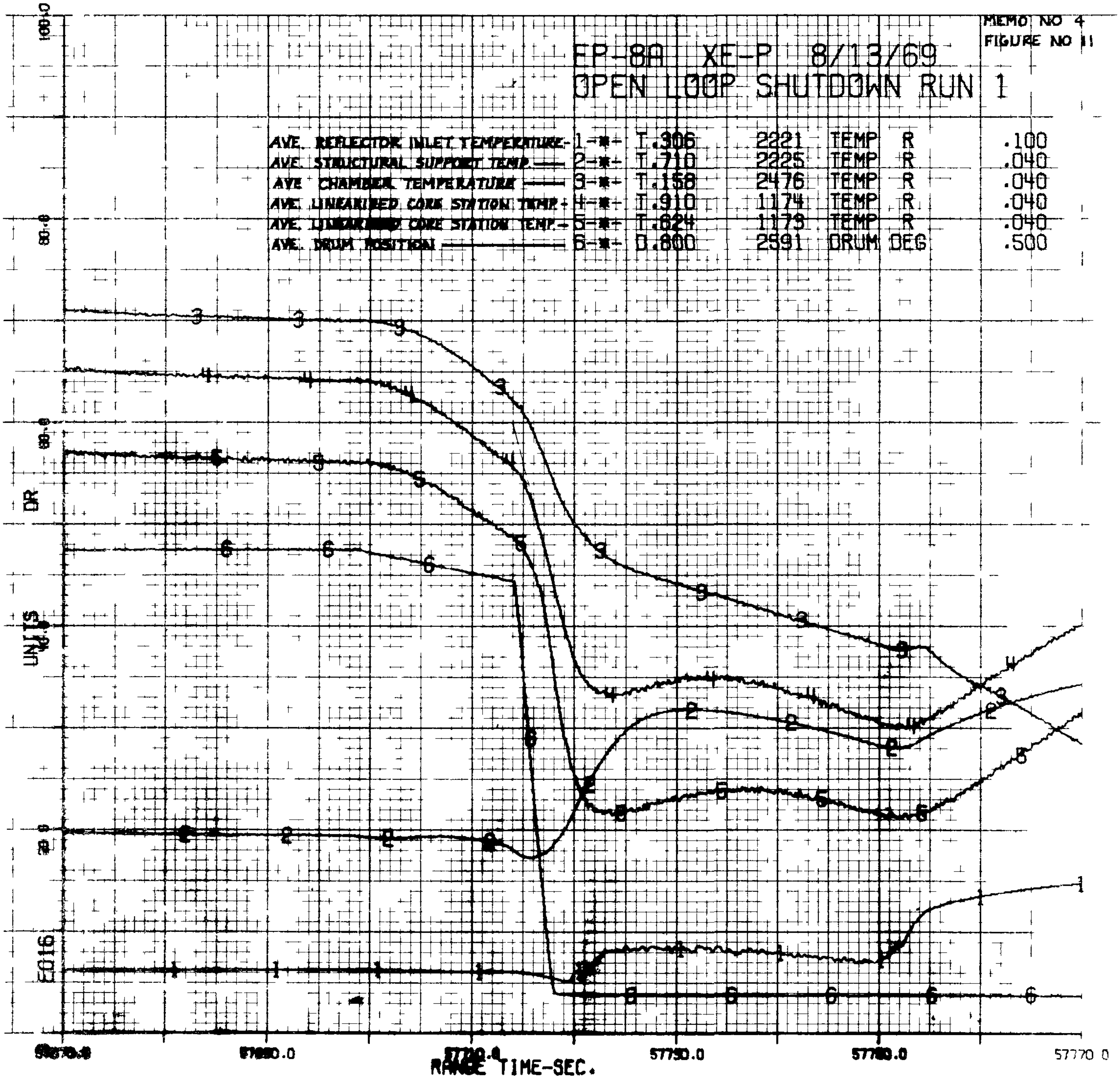



DYDKOYDKOYDKOYDKOYDKOYDKOYDKOYD
OPEN LOOP MAPPING RUN 1
TURBOPUMP SPEED — 1-*- EN800 1741 RPM .005
AVE. TPCV POSITION — 2-*- DP870 2891 TPCV DEG 1.000
AVE. DRUM POSITION — 3-*- D.800 2591 DRUM DEG .500
AVE. CHAMBER TEMPERATURE — 4-*- T.158 2476 TEMP R .020
AVE. CHAMBER PRESSURE — 5-*- P.158 2921 PSIA .200
AVE. LINEAR POWER — 6-*- PWALIN 3201 MW .100
TPCV RAMP START
TPCV RAMP STOP
100.0
80.0
60.0
40.0
20.0
R001 UNITS OR
57520.0
57540.0
57560.0
57580.0
57600.0
57620.0
RANGE TIME-SEC.

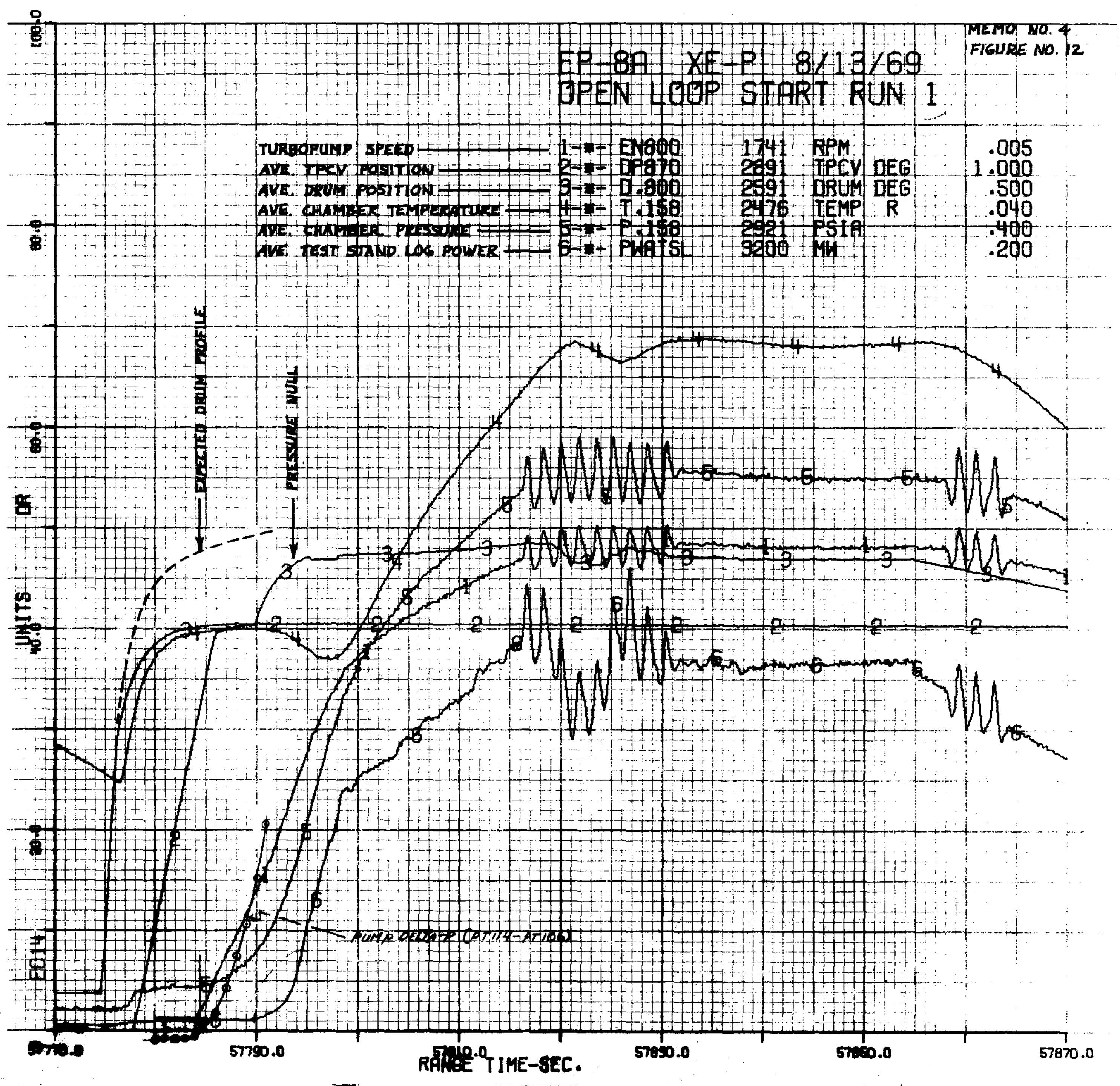
MEMO NO. 4
FIGURE NO. 9



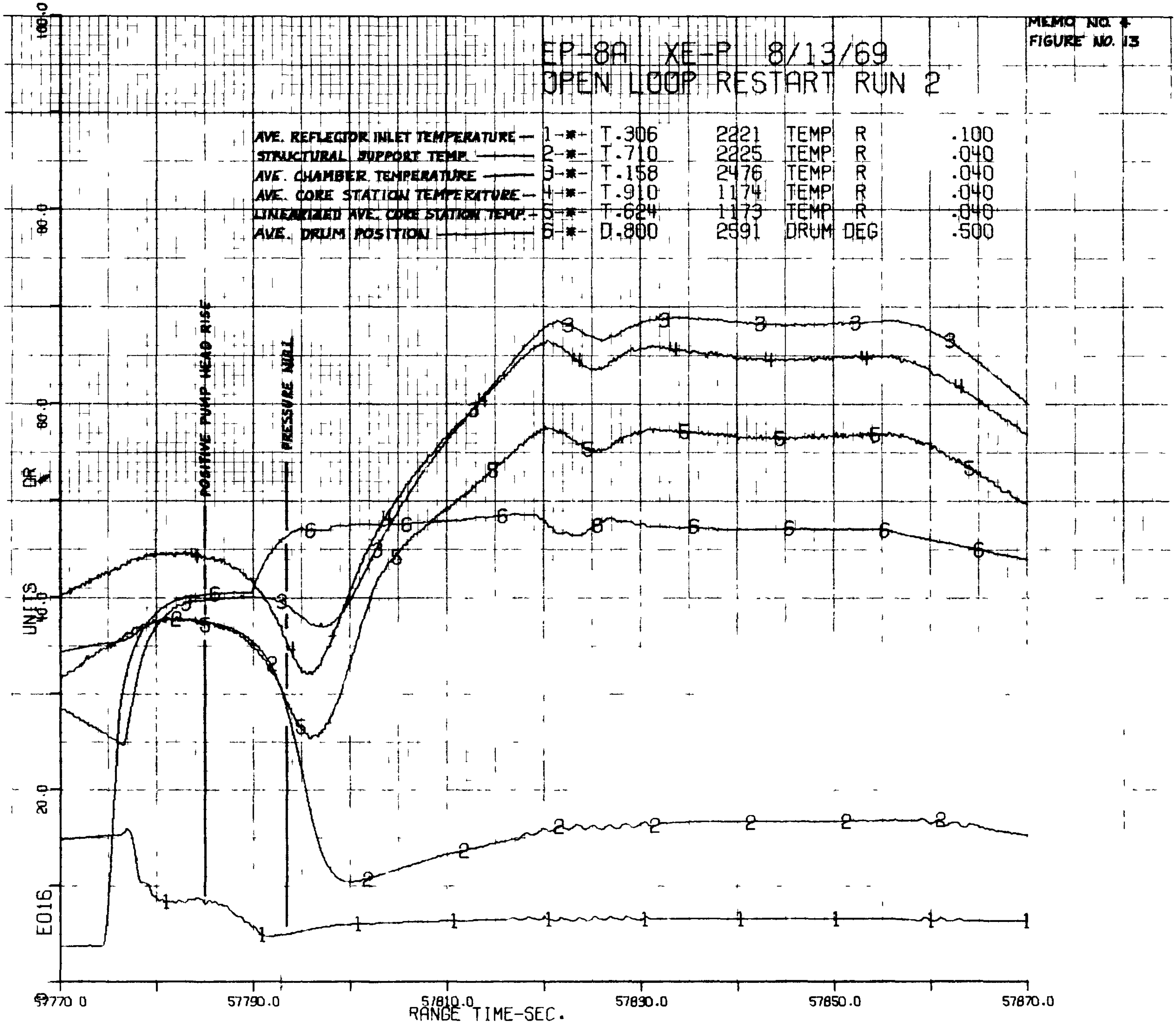

MEMO NO. 4
FIGURE NO. 10
EP-8A XE-P 8/13/69
OPEN LOOP SHUTDOWN RUN 1
TURBOPUMP SPEED 1-*- EN800 1741 RPM .005
AVE. TPCV POSITION 2-*- DP870 2891 TPCV DEG 1.000
AVE. DRUM POSITION 3-*- D.800 2591 DRUM DEG .500
AVE. CHAMBER TEMPERATURE 4-*- T.158 2476 TEMP R .040
AVE. CHAMBER PRESSURE 5-*- P.158 2921 PSIA .400
AVE. LINEAR POWER 6-*- PWALIN 3201 MW .200
CSV CLOSED
UNITS
E014
57670.0
57690.0
57710.0
57730.0
57750.0
57770.0
RANGE TIME-SEC.



MEMO NO 4
FIGURE NO 11
EP-8A XE-P 8/13/69
OPEN LOOP SHUTDOWN RUN 1
AVE. REFLECTOR INLET TEMPERATURE 1 T.306 2221 TEMP R .100
AVE. STRUCTURAL SUPPORT TEMP. 2 T.710 2225 TEMP R .040
AVE CHAMBER TEMPERATURE 3 T.158 2476 TEMP R .040
AVE. LINEARIZED CORE STATION TEMP. 4 T.910 1174 TEMP R .040
AVE. LINEARIZED CORE STATION TEMP. 5 T.624 1173 TEMP R .040
AVE. DRUM POSITION 6 D.800 2591 DRUM DEG .500
DR
UNITS
E016
RANGE TIME-SEC.
57770.0



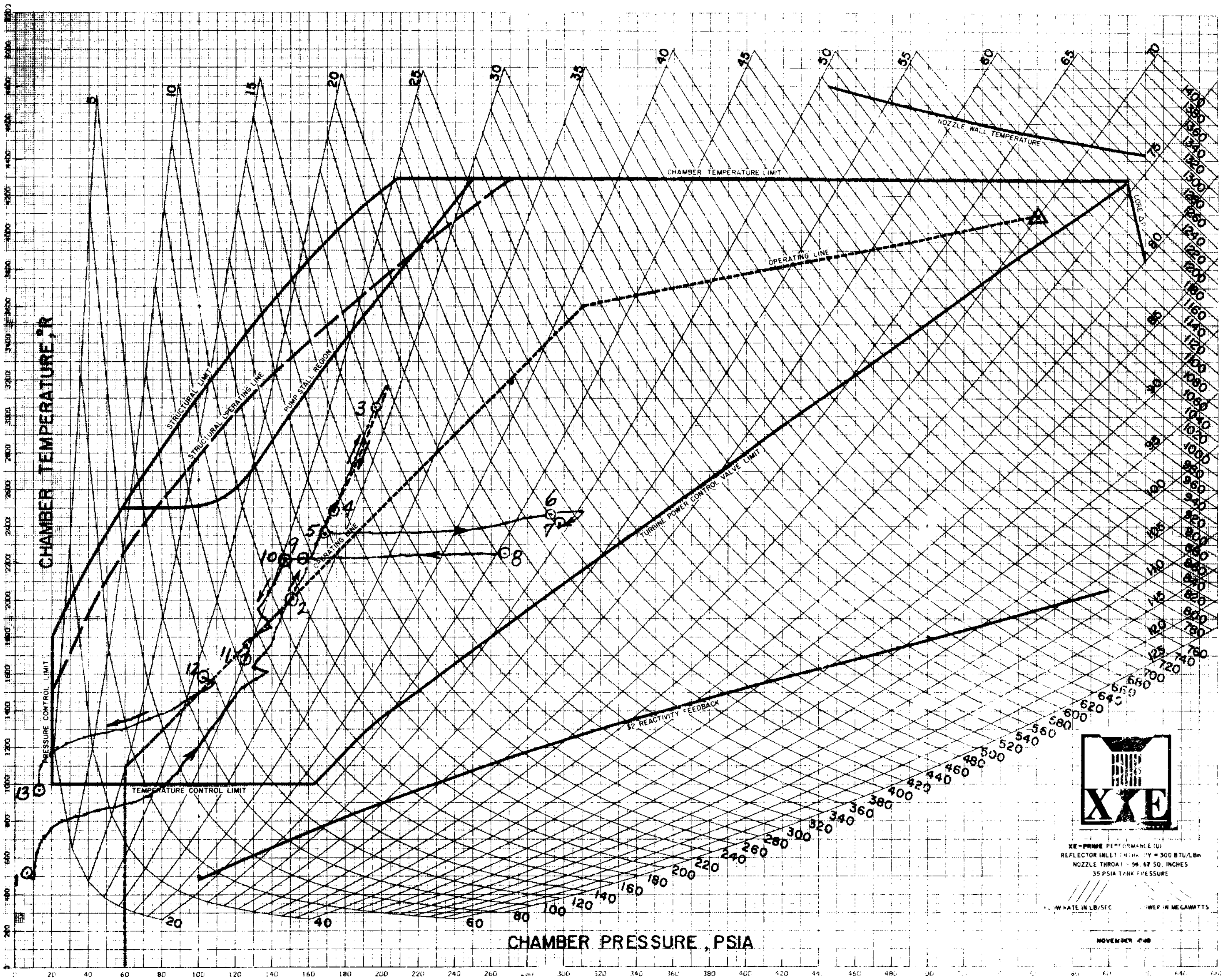
MEMO NO. 4
FIGURE NO. 12
EP-8A XE-P 8/13/69
OPEN LOOP START RUN 1
TURBOPUMP SPEED 1-*- EN800 1741 RPM .005
AVE. TPCV POSITION 2-*- DP870 2891 TPCV DEG 1.000
AVE. DRUM POSITION 3-*- D.800 2591 DRUM DEG .500
AVE. CHAMBER TEMPERATURE 4-*- T.1S8 2476 TEMP R .040
AVE. CHAMBER PRESSURE 5-*- P.1S8 2921 PSIA .400
AVE. TEST STAND LOG POWER 6-*- PWATSL 3200 MW .200
EXPECTED DRUM PROFILE
PRESSURE NULL
PUMP DELTA-P (PT114-PT106)
UNITS DR
E014
100.0
80.0
60.0
40.0
20.0
57790.0
57810.0
57830.0
57850.0
57870.0
RANGE TIME-SEC.



MEMO NO. 4
FIGURE NO. 13
EP-8A XE-P 8/13/69
OPEN LOOP RESTART RUN 2
AVE. REFLECTOR INLET TEMPERATURE — 1-*- T.306 2221 TEMP R .100
STRUCTURAL SUPPORT TEMP. — 2-*- T.710 2225 TEMP R .040
AVE. CHAMBER TEMPERATURE — 3-*- T.158 2476 TEMP R .040
AVE. CORE STATION TEMPERATURE — 4-*- T.910 1174 TEMP R .040
LINEARIZED AVE. CORE STATION TEMP. — 5-*- T.624 1173 TEMP R .040
AVE. DRUM POSITION — 6-*- D.800 2591 DRUM DEG .500
POSITIVE PUMP HEAD RISE
PRESSURE NULL
UNITS
DR
E016
100.0
80.0
60.0
40.0
20.0
0
57770.0
57790.0
57810.0
57830.0
57850.0
57870.0
RANGE TIME-SEC.

FIGURE 14

OPEN LOOP START-UP, MAPPING, AND SHUTDOWN



SPEAR MEMO NO. 5
R. F. Schenz
RFS

XE-PRIME

EP-8A

Subject: CONTROL SYSTEM PERFORMANCE DURING OPEN LOOP STARTUPS

SUMMARY

This memorandum covers the operation of the engine control system for the first two runs on EP-8A. The runs consisted of open loop starts, mapping transfer function measurements, and open loop shutdowns.

The only anomaly noted was an unexpected difference in the nuclear auto-start exponential drum demand signal between the first two runs.

The new drum and TPCV ramp controllers performed satisfactorily, as well as the ON-OFF temperature controller. The transfer function measurements produced excellent results.

TECHNICAL DISCUSSION

The open loop starts were accomplished by means of drum and TPCV ramp controllers which were installed prior to EP-8A. The controllers permit the CTE to independently ramp the drums and TPCV in or out at the pre-set rate, or to hold them in a constant position. The operation of the controllers is covered later in more detail.

The first bootstrap in EP-8A was an open loop startup from ambient conditions. The drums were demanded exponentially by a set level of 700 divisions (96 degrees) on the exponential pot, and with a set level of 300 divisions on the linear ramp pot (0.4°/sec). At the same time the TPCV was ramped at a demand rate of 5.0°/sec to a nominal 40°. The reactor period decreased to one second, at which point the drums were switched to manual position control with the demand set to 96°. When reactor power reached 19 MW the drums were manually stepped in 6°. After engine stabilization, the drums were ramped out at 0.4°/sec until Tc reached 3020°R (T.158, RT56842.6) (3000°R planned), then ramped back until Tc reached 2471°R (RT56871.7) (2400° planned). The drums were then placed in the ON-OFF temperature control mode and the TPCV ramped out at 1.2°/sec to obtain nominal chamber conditions of 2400°R and 300 psia. Transfer function measurements on the TPCV and drums were then performed. The drums were then placed in the ON-OFF temperature control mode and TPCV in ramp control. The temperature was reduced to a nominal 1800°R at 50°R/sec. An open loop shutdown was then performed by ramping the drums in with the drum ramp control at 0.4°/sec. At 1600°R (T.158 of 1618°R at RT57710.9) position control was selected and the drums run full in. Coincident with the manual closing of the drums, the TPCV was ramped closed at - 2.5°/sec.

The second bootstrap was similar to the first except that the core was hot (T.622 at 932^{o}R). After engine stabilization at a chamber temperature of 1696^{o}R and chamber pressure of (T.158, RT 57858.9), the drums were ramped in to obtain a nominal chamber temperature of 1000^{o}R (942^{o}R actual) and the TPCV was set to 37.2^{o} to obtain a nominal chamber pressure of 60 psia (64 actual). Transfer function measurements were made by perturbing the drums. The drums were then ramped out until T_c reached a nominal 1700^{o}R. The program error was nulled. The TPCV and drums were then placed in program control (nominal T_c/P_c of 1700^{o}R and 120 psia) and the engine shutdown with the normal shutdown controller.

1. Ramp Controller

The operation of the drums amd TPCV ramp control circuits are the same, and can only be selected while in the manual position control mode. The ramp control circuit is an electronic integrator, the output of which is a position demand signal to the drum or TPCV loop control. While in control modes other than ramp, the ramp control integrator tracks the position of the drum or TPCV in order to allow ramp control to be selected without introducing a transient into the system. When ramp control is selected, the integrator is taken out of the track mode and permitted to integrate up, down, or to hold. The rate of integration is determined by the rate pot on the CTE console, and the direction by the ramp switches. The maximum design rates are 1 degree per second for the drum and 10 degrees per second for the TPCV.

Both ramp controllers performed satisfactorily throughout Runs No. 1 and 2. Figure 1 shows a plot of the drum demand ramp during the first open loop start run. The points are Channel CC800.. from the ECO1 thinned data pass. The solid line shows the desired ramp rate of 0.4^{o}/sec. An example of the output of the TPCV ramp controller is shown in Figure 2. The points are Channel CP624.. from the ECO1 thinned data pass.

2. Temperature Control

A. ON-OFF Temperature Controller

The ON-OFF temperature controller provides drum control in a manner in which its name implies. The control drum demand is either fixed or changing at a constant rate. If the temperature error is within the temperature error deadband of the controller, the demand is fixed. When the temperature error becomes larger than the controller's error deadband, the drums are demanded to rotate with constant velocity in the direction to reduce the error. A functional block diagram of the ON-OFF temperature controller is shown in Figure 8.

The lead compensation, with the appropriate roll off, the deadband width and the pseudo rate feedback are shown in this functional drawing along with their available adjustment ranges. All of these adjustments are located in the Experimental Controller Chassis.

The ON-OFF temperature controller was used twice during Run No. 1. AT RT56901, at nominal chamber conditions of 2400^{o}R and 300 psia, the temperature loop was closed by the CTE. The drum position was controlled by the ON-OFF controller until RT 56960. The controller was being used to maintain steady-state operation while P_c was increased to a nominal

300 psia. The action of the controller in attempting to maintain a constant temperature during this disturbance (to the T_c loop) can be seen by inspecting Figures 3 and 4. Figure 3 shows the temperature error (T.604 - which is the difference between the demand and measured temperature). It can be seen that T.158 increases 68°R above the demanded temperature and the controller reduces the error to Zero in 18 seconds (which is acceptable). The roll-in of the drums caused by the controller can be seen in Figure 4.

The ON-OFF controller was used again after the transfer function measurements to bring the chamber temperature from a nominal 2400°R to 1800°R to prepare for the open loop shutdown. It performed satisfactorily at all times that it was in use.

B. State Program Temperature Controller

Temperature control during the second run, when selected, was with the state program temperature controller. The controller performed satisfactorily and was analyzed in SPEAR Report, EP-3, Memo No. 24.

3. Transfer Function Measurements

Open loop transfer functions were made during EP-8A on Runs No. 1 and 2. During Run No. 1,RT 57040 at nominal chamber conditions of 2400°R and 300 psia, transfer functions were made by applying sinusoidal perturbations to the TPCV. At RT 57210, measurements were made by applying step, pseudo-random, and sinusoidal perturbations to the drums, in that order.

The results of the transfer function measurements were in general very good. Figure No. 5 shows the results of the chamber pressure (P.158) vs. measured TPCV position (DP870) measurements with an over-plot of CAM test predictions taken from RN-S-0418, 1 April 1969. Figure No. 6 shows the results of the chamber temperature (T.158) vs. measured drum position (D.800) reduced from the sinusoidal perturbation data. The over-plot is again from the cited reference.

During Run No. 2, RT 58035, transfer function measurements were initiated at nominal chamber conditions of 1000°R and 60 psia (actual 944°R and 64.6 psia) by perturbing the drums in the same manner as in Run No. 1. The plots were not available for SPEAR.

Response plots were also made from the pseudo-random data. They showed acceptable results over a generally narrower frequency range than the sinusoidal results. Results from the step data were not available.

4. Run No. 2 Drum Demand Anomaly

During the second open loop start the nuclear autostart drum control demand generator did not perform as expected. The demand profile was supposed to be identical to the one for Run No. 1. The demand generator was to be set to increase exponentially to 96 degrees and ramp out at a rate of 0.4°/sec.

Inspection of Figure 7 shows that the drum demand went exponentially to 80°, with no evidence of a ramp, and then at a range time of 57790, 16 seconds after start engine, the demand again started to increase exponentially toward a higher value (about 95°). All control drum position data indicated that the drums followed the demands indicating that the drums were receiving and responding. The drums were placed in manual position control at RT 57794.7, some 4 seconds after the drums started out the second time.

The exponential and ramp pot set points were supposed to be 700 and 300 divisions, respectively. It was verified by the audio recording of the run that the command to set the pots were given to the LRE and acknowledged.

In an effort to isolate the cause of the anomaly, data from the "Verify Exponential and Ramp Pot Set Points" portion of EP-8A, NTO-TOP-0031, was examined in detail. Plots were made of the exponential drum demand signals for ten of the single drum "Reactor Starts". The exponential and ramp pot settings for these starts were verified by checking the net audio recordings for the time period. The results show that the drum demand was a smooth exponential for all of the runs plotted. Table I is a summary of the pot settings, range times, and nominal exponential final values. The drum demand circuit was functioning properly for these checkouts - also for the start in Run No. 1.

NTO controls performed a functional checkout of the circuit after the test and reported that it was functioning correctly. An attempt to duplicate the drum demand profile of Run No. 2 was made by manipulating the exponential and linear ramp demand pots. It was not possible to duplicate the profile with the pots alone.

If the load on the nuclear autostart drum demand integrator were increased enough (by a short circuit or some other malfunction) and then gradually removed, the behavior of the demand would be similar to the demand profile in Run No. 2.

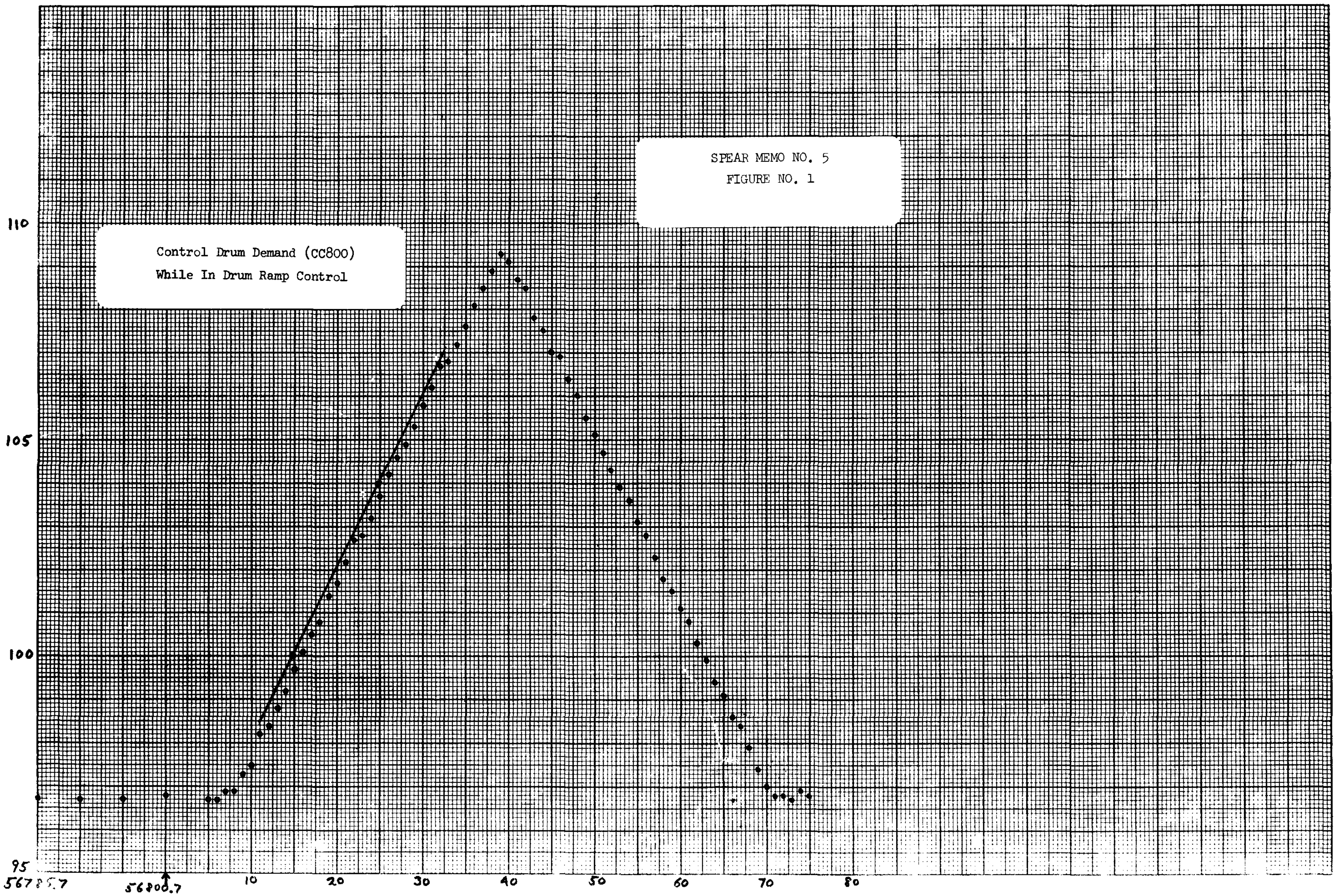
CONCLUSIONS:

No reason for the anomaly on the nuclear autostart drum demand circuit could be found. It is recommended that investigation be continued in an effort to find an explanation for the anomaly.

The TPCV and drum ramp controllers, as well as the ON-OFF temperature controller, performed satisfactorily throughout the test.

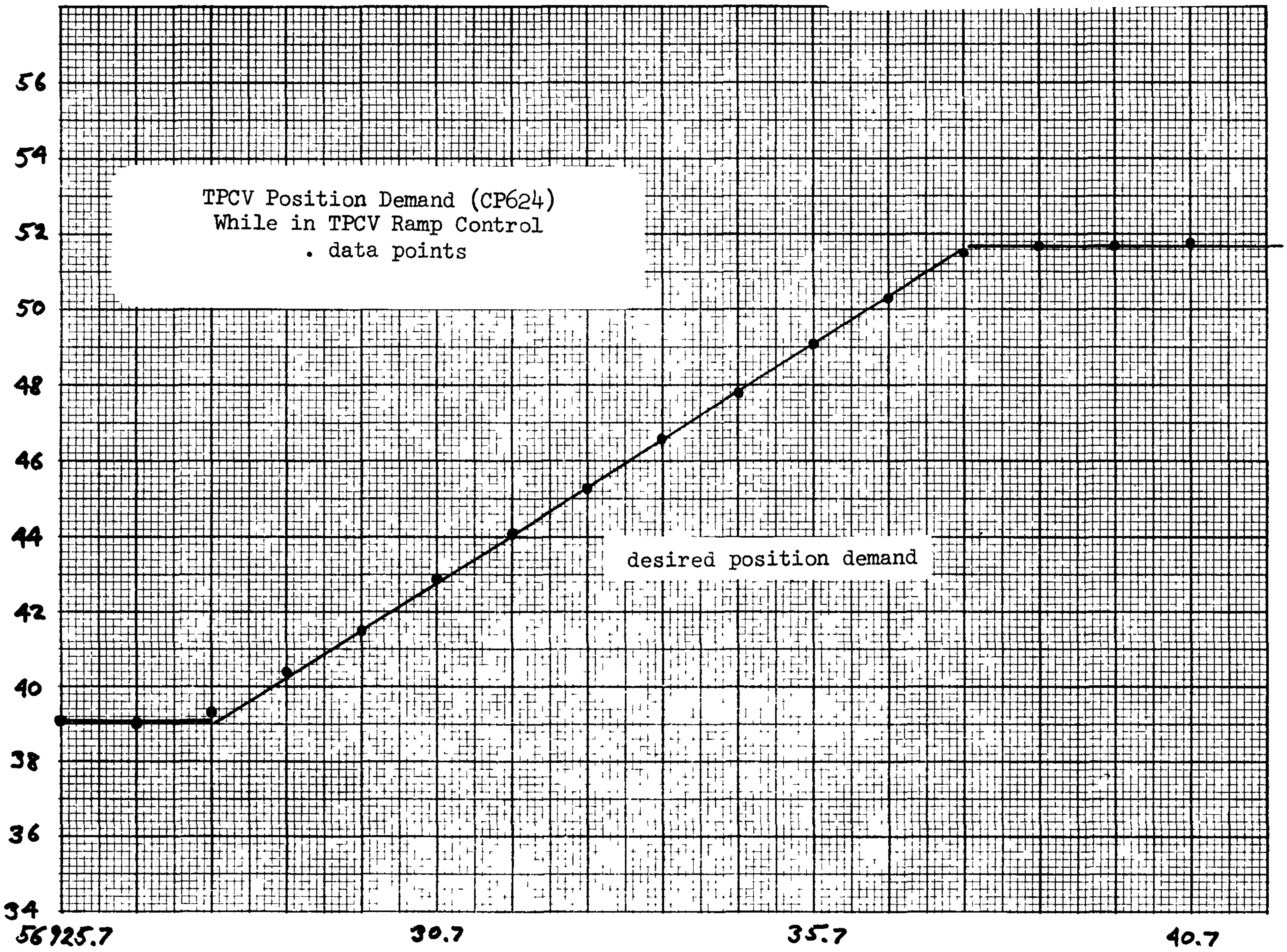
TABLE 1

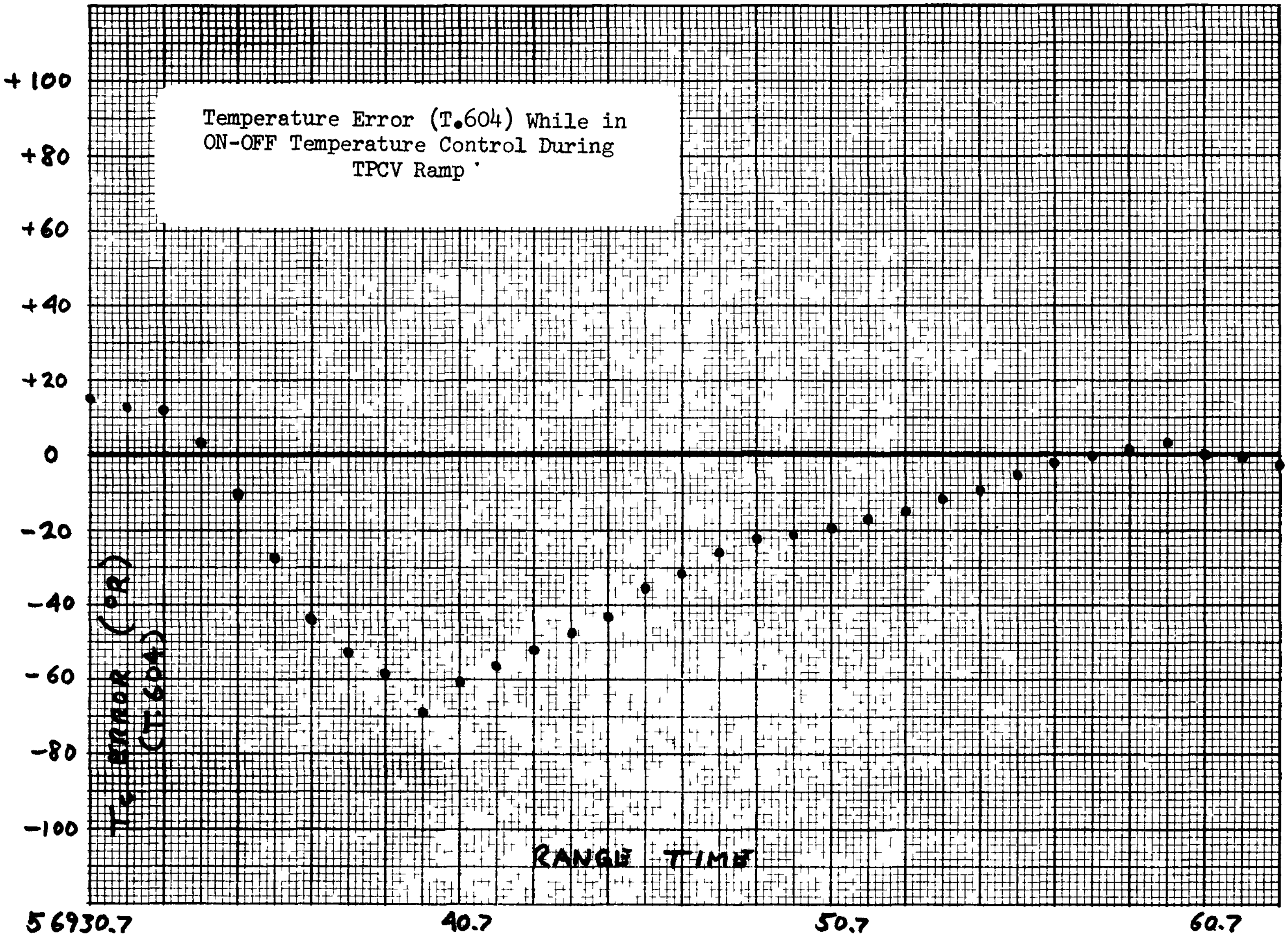
	Range Time	C.800 Final Value (Nominal) Degree	Linear Ramp Rate Deg/Sec	Exponential Pot Setting Command	Exponential Pot Setting Command
1	35618.3	80	.18	460 div.	45 div.
2	35781.0	80	.15	460 div.	45 div.
3	36159.2	80	.16	460 div.	45 div.
4	36232.2	90	.10	626 div.	45 div.
5	36283.2	100		800 div.	45 div.
6	38950.0	80	.16	460 div.	45 div.
7	39052.0	100	.26	800 div.	45 div.
8	39185.0	90	.18	626 div.	155 div.
9	39327.0	90	.48	626 div.	366 div.
10	40349.7	100	.39	750 div.	336 div.


SPEAR MEMO NO. 5
FIGURE NO. 1
Control Drum Demand (CC800)
While In Drum Ramp Control
110
105
100
95
56785.7
56800.7
10
20
30
40
50
60
70
80

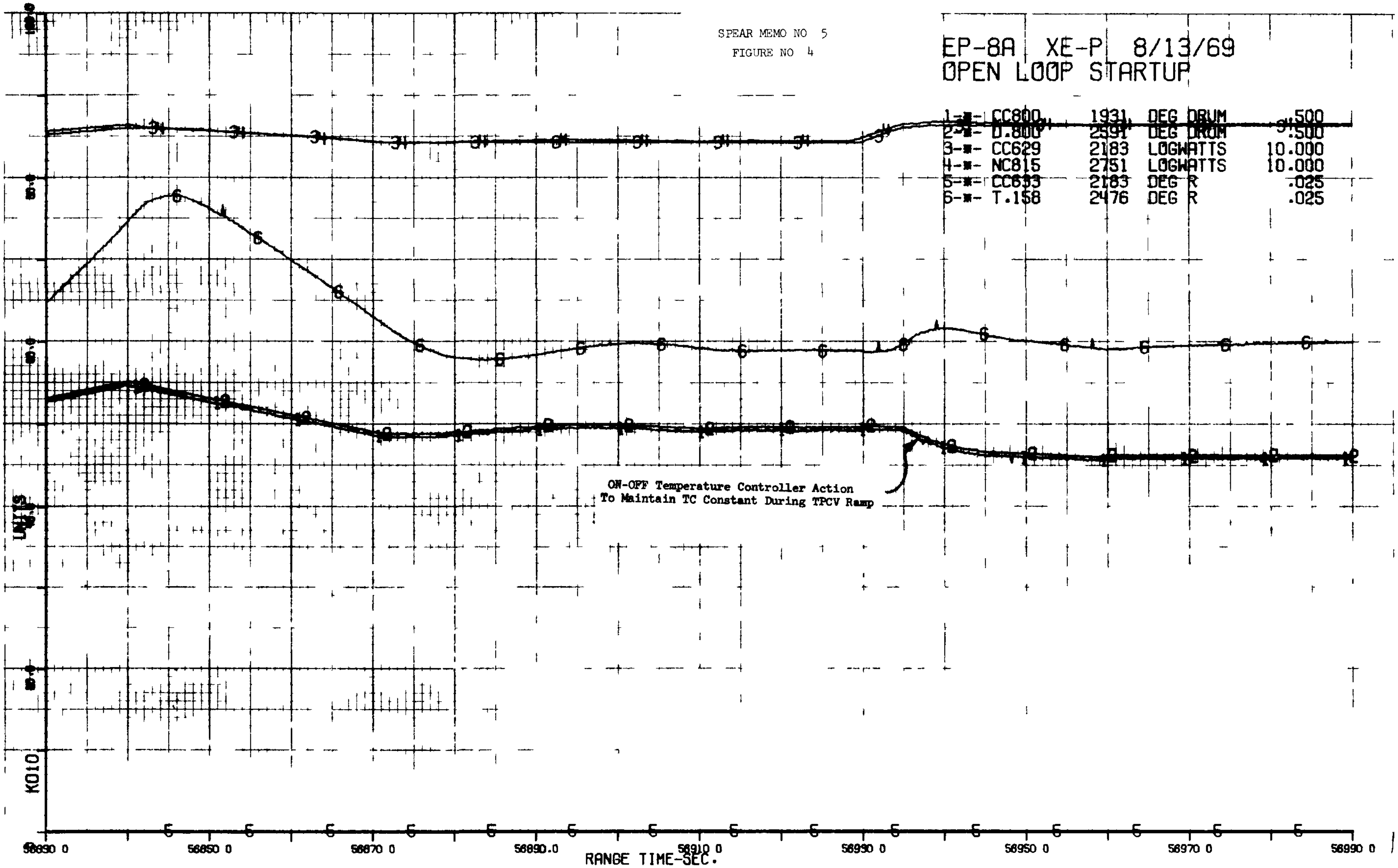
SPEAR MEMO NO. 5

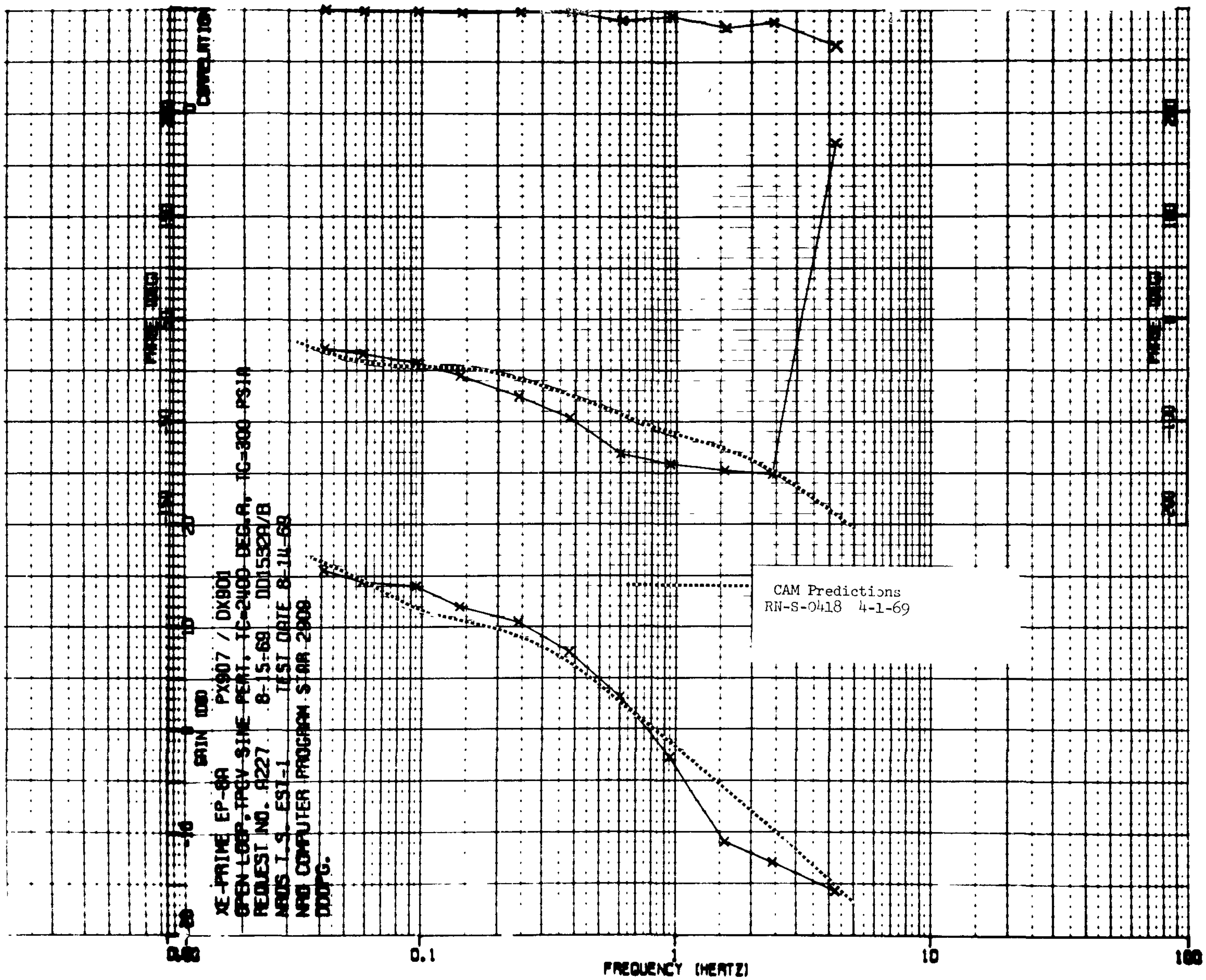
FIGURE NO. 2




Temperature Error (T.604) While in ON-OFF Temperature Control During TPCV Ramp
+100
+80
+60
+40
+20
0
-20
-40
-60
-80
-100
T.C. ERROR (°R)
(T.604)
RANGE TIME
5 6930.7
40.7
50.7
60.7

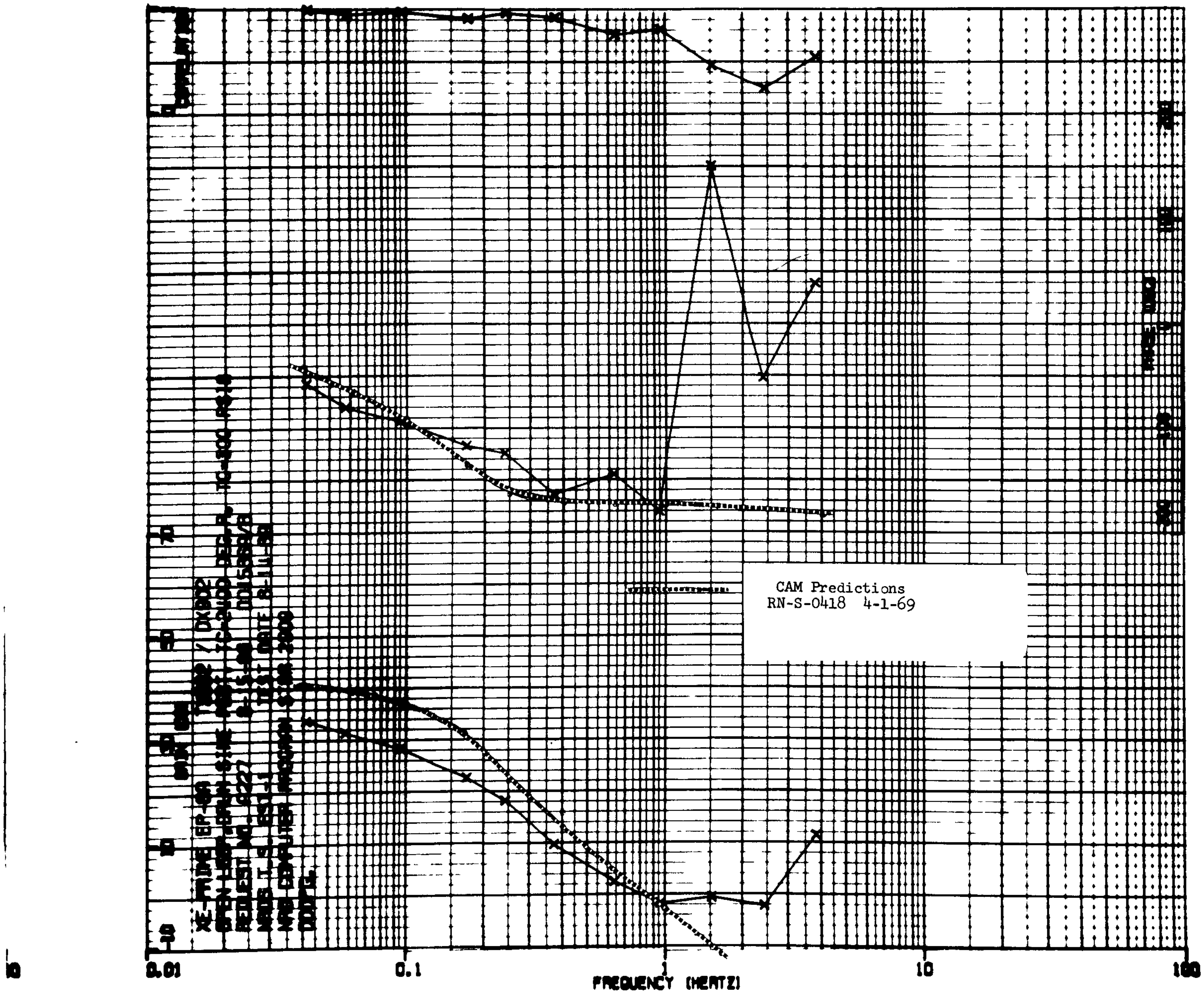
SPEAR MEMO NO 5
FIGURE NO 4

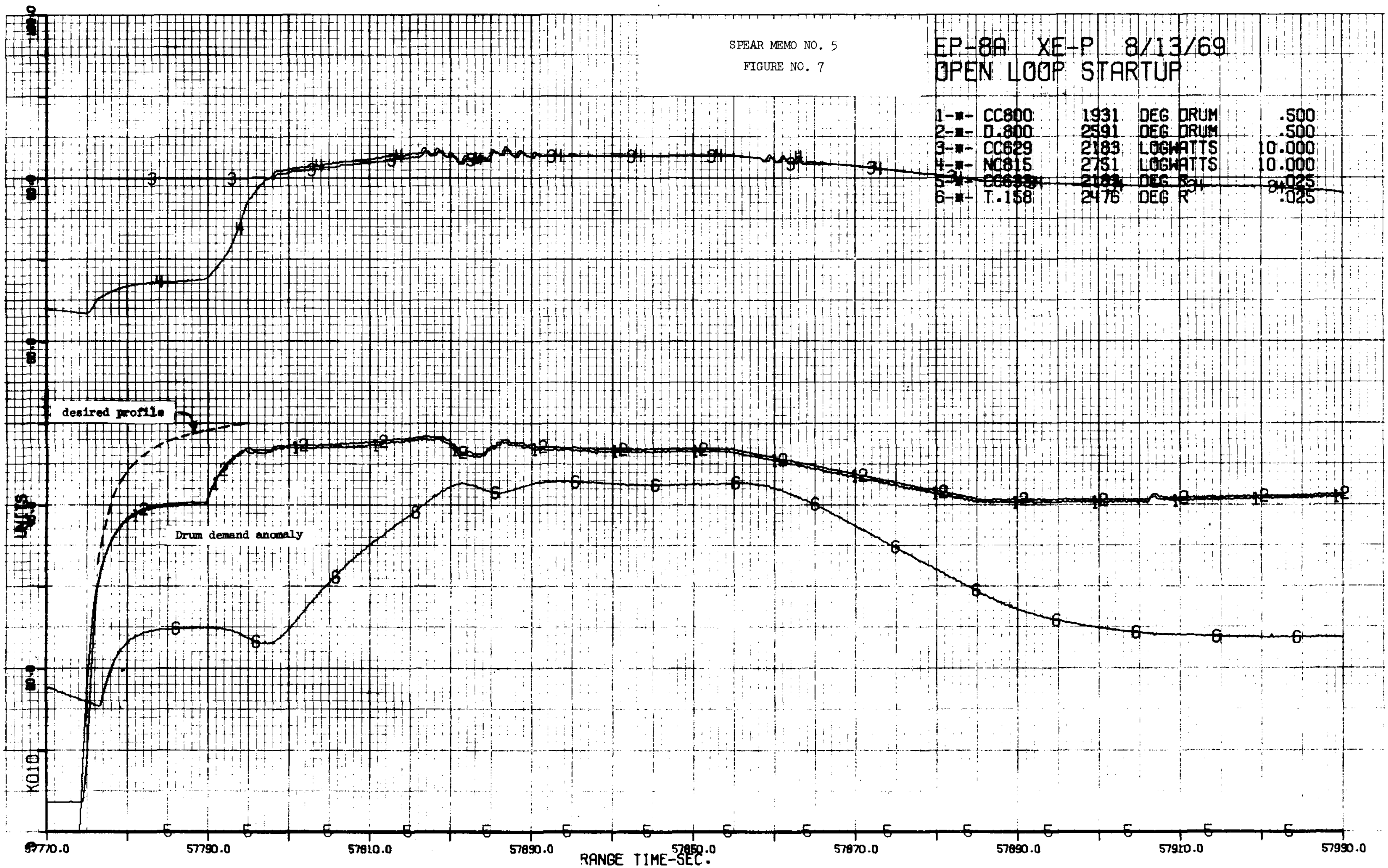



XE-PRIME EP-6A PX907 / DX901
OPEN-LOOP, TPCV-SINE PERT. TC-2400 DEG.R. TC-300 PSIA
REQUEST NO. A227 8-15-68 DD1532A/B
NRDS T.S. EST-1 TEST DATE 8-14-68
NRB COMPUTER PROGRAM STAR 2909
DODPG.
GAIN (DB)
PHASE (DEG)
COHERENCE
CAM Predictions
RN-S-0418 4-1-69
0.1
1
10
100
FREQUENCY (HERTZ)

SPEAR MEMO NO. 5

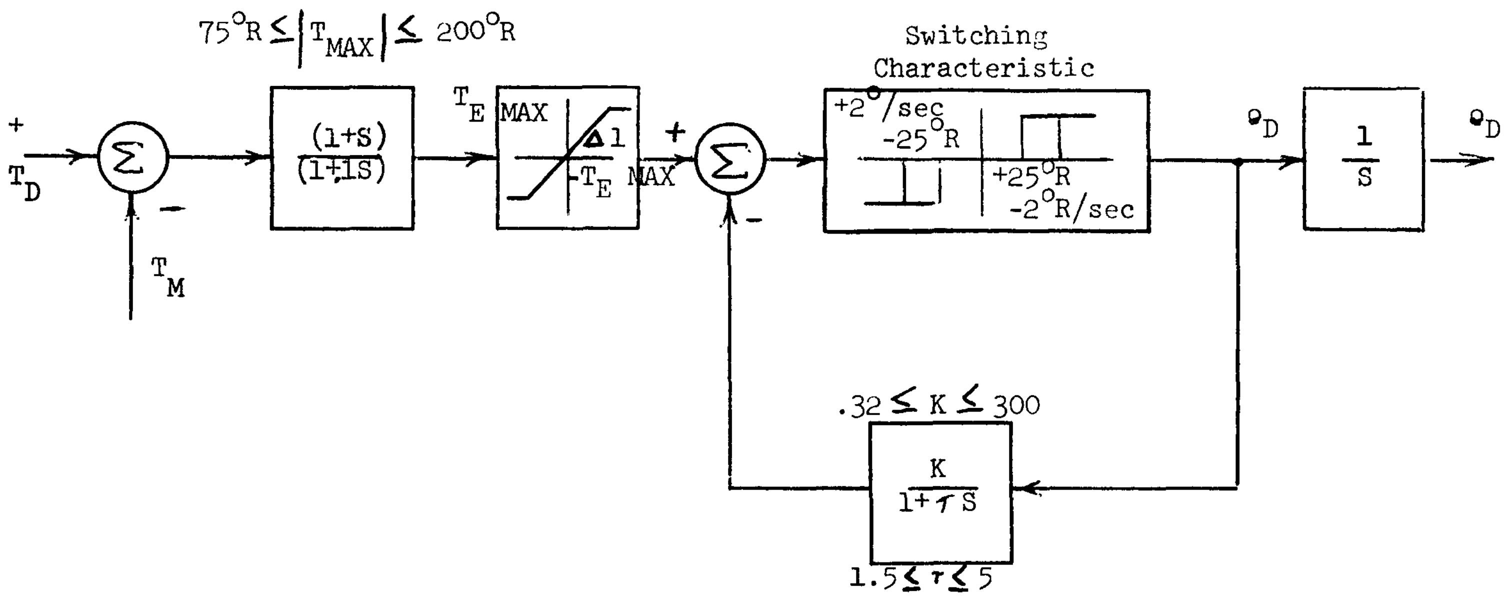
FIGURE NO. 6





SPEAR MEMO NO. 5
FIGURE NO. 7
EP-8A XE-P 8/13/69
OPEN LOOP STARTUP
1-*- CC800 1931 DEG DRUM .500
2-*- D.800 2591 DEG DRUM .500
3-*- CC629 2183 LOGWATTS 10.000
4-*- NC815 2751 LOGWATTS 10.000
6-*- T.158 2476 DEG R .025
desired profile
Drum demand anomaly
UNITS
K010
57770.0
57790.0
57810.0
57830.0
57850.0
57870.0
57890.0
57910.0
57930.0
RANGE TIME-SEC.

ON-OFF Temperature Controller



SPEAR Memo No. 6

R. J. Williams RJW
P. W. Coupland

XE-PRIME

EP-8A

Subject: ENGINE PERFORMANCE DURING (DAMP) TEMPERATURE AUTOSTART

SUMMARY:

A successful engine startup was achieved using the (DAMP) temperature autostart system with the drum exponential set point purposely adjusted to raise the drum program profile 5.6 degrees above the first test conducted. This test was the third of a series of three tests intended to investigate the effects of significantly undershooting or overshooting the nominal exponential drum program ramp. The main objective of this series of three tests appears to have been accomplished although the range investigated was not as great as planned. Satisfactory engine starts were obtained over an exponential set point range of 15.6 degrees. Quantitative interpretation of the effect of changing the exponential set point is somewhat obscured by the fact that the initial conditions were not exactly the same for each of the three tests.

Engine system performance appeared to be normal throughout the test. The engine responded to the autostart program in a logical manner.

Memo No. 7 discusses the control system performance during the damp autostart test.

TECHNICAL DISCUSSION:

1. Introduction

It was intended that a series of three tests be conducted to establish the range over which the exponential set point of the drum program could be varied and still produce an acceptable engine startup. Based on analysis made prior to the first test it was planned to cover a set point range of 20° (i. e., a nominal case ± 10°). This information was desired to establish the degree of accuracy required in estimating the critical position of a reactor to ensure a successful temperature autostart. Prior to each EP the ambient critical (i.e., ambient reactor-no flow) drum position is measured. However, for the autostart system employed for these tests, the desired exponential set point is intended to be determined with respect to existing critical position rather than the ambient critical position. This requires an adjustment of the set point to allow for the reactivity feedback effects of the existing reactor material temperatures and hydrogen flow. It was further intended that prior to each test the engine system be brought to the same set of initial conditions (by control of the pulse cooling). Hence the difference between ambient critical and existing critical should be the same for each test.

2. Test Description

This test was originally planned to be the nominal + 10° case. As run, it probably constituted something less than a nominal + 10° case. During EP 7A the ambient critical was taken by test operations to be 92°, and the difference between ambient critical and ambient wet critical to be -3° (89°). Thus the exponential used for the "nominal case" was ambient wet critical + 3° or 92°, and for the undershoot case to be $92^\circ - 10^\circ = 82^\circ$. Had the overshoot case been run during EP-7A as planned, the overshoot case would have been set for $92^\circ + 10^\circ = 102^\circ$. The ambient critical from measured data was listed in SPEAR Memo No. 3 of EP-7A as 92.8°.

For EP-8A the ambient critical was taken by test operations to be 92°. During the reactor physics test conducted prior to Run 3, the difference between ambient critical and ambient wet critical was apparently re-evaluated to be -7°. On this new basis the "nominal case" would have been $92^\circ - 7^\circ + 3^\circ = 88^\circ$, and so the exponential set point used was $88^\circ + 10^\circ = 98^\circ$. Hence there now appears to be a question of what constitutes a "nominal case," depending on whether ambient wet critical is based on EP-7A or EP-8A.

The major parameters of engine characteristics during the (DAMP) temperature autostart are presented in Figures 1 and 2, and a chronology of events is shown in Table 1. Conditions required for childown complete were satisfied prior to the initiation of the drum program. Due to the high exponential set point used, the drums were rapidly rolled out, passing through the ambient critical position (93.2 degrees) approximately 5.5 sec. after first motion of the drums. Reactor power (PWLIN 1) increased rapidly as expected, reaching 36 Mw about 8 sec. after first motion of the drums. This rapid increase in power, produced a rapid increase in reactor temperatures which resulted in the drum program being terminated within 10 sec. of drum first motion. The inward drum step at this time reduced the power to about 13 Mw. One-half second later the TPCV started to open, and engine bootstrap proceeded in an orderly fashion. The maximum rate of chamber temperature increase following bootstrap was about 55 degrees/sec.

3. Comparison of (DAMP) Temperature Autostart Drum Exponential Sensitivity Tests

A calculation was performed to establish the range of drum exponentials actually run. Figure 3 presents a comparison of some significant parameters for the three tests conducted with the range times adjusted to bring the first motion of the control drums into coincidence. Drum program complete occurred most promptly in the last test conducted. During that test the drums reached a maximum position of 98 when the inward step occurred. The drum position for the corresponding time from first motion of the drums during the nominal case and the "undershoot" case were determined to be 92° and 82° respectively. However, a shift in cold critical drum position of 0.4° had occurred between EP-7A and EP-8A, (See Memo No. 3, SPEAR Reports EP-7A and EP-8A) therefore, the position in EP-8A was adjusted to 97.6° to put it on a comparable basis with the tests of EP-7A. Since the exponential ramp was nearly completed at nine seconds after the drum programs start, the relative drum positions at this time were taken as a reasonable measure of the as-run exponential set point. On this basis the "undershoot" case represented a change from the first test of -10°, and the "overshoot" case represented a change from the first test of +5.6. The total range covered was 15.6°.

The engine material temperatures at initiation of the three tests are compared in Table 2. It may be observed that the desire to have identical initial conditions was not satisfied and in general the third test conducted was started from lower engine system conditions. During pulse cooling immediately prior to the test, the in core temperature T.910 kept increasing to greater than 700°R and thereby causing a "drum program terminate" signal (Fig. 4). In order to remove this condition prior to starting the test, additional cooling pulses were made. This appears to have resulted in the temperature distribution shown in Table 2 in which T.910 is about the same for all three tests, but the remaining temperatures were colder for the third test. The extent to which the discrepancies in initial conditions contributed to the results obtained from these tests is beyond the scope of SPEAR analysis and any analysis of these effects should consider the knowledge gained during the reactor physics test conducted as part of this EP.

With reference to Figure 3 it may be seen that there is a greater difference in several important parameters between the first test and the +5.7° cases than between the first test and the - 10° cases. Particularly, the initial rise in reactor power and T.910 temperature after drum program termination appear to be increasing at an accelerating rate. Hence it appears that the degree of drum "overshoot" that can be tolerated by the system is rapidly approaching a limit. For example the initial power rise indicates a very short period is being approached.

A comparison of event intervals for the three tests is shown in Table 3, and comparison of conditions at the time of drum program terminate and at pressure null are presented in Tables 4 and 5 respectively.

CONCLUSIONS:

A successful engine startup was achieved using the (DAMP) temperature autostart system with the drum exponential set point of 5.6° above that of the first test conducted.

This together with two (DAMP) temperature autostart tests previously conducted has demonstrated the ability to start successfully over a set point range of 15.6° <u>for the conditions tested</u>. Data from this test shows evidence that for these conditions the upper limit of the exponential set point is rapidly being approached.

Differences in initial conditions for the three drum sensitivity tests conducted obscures evaluation of the data to some extent. While it is not recommended that these tests be rerun, it is suggested that if this type of study is desired during testing of future engine systems, the tests should be controlled to provide more uniform initial conditions. This may readily be accomplished by performing each test as the first test of succeeding EP's, or by reconditioning the system between each test by flowing ambient gas through the engine system.

TABLE 1

EP-8A Run 3, Chronology

Channel Number Used to Establish Event	Event	Range Time
SC 616	Start Reactor	58684.6
D.800	Start Drum Rollout	58685.1
DR 100	Start of PDSV Opening	≃ 58685.3
BC 915	Chilldown Complete	Condition satisfied prior to opening PDSV
BC 911	Drum Prog. Term.	58694.6
SC 617	Start Engine (Press. Loop Closed)	58695.6
DP 870	Start of TPCV Opening	58695.7
BC 916	Press Null	58707.2
BC 912	Bootstrap Complete	58707.2
BC 655	Tc Temp. Loop Closure	58707.3

TABLE 2

COMPARISON OF ENGINE MATERIAL TEMPERATURES (^{o}R) PRIOR TO START OF RUN

Parameter and Channel No.	EP-7A Run No. 4	EP-7A Run No. 5	EP-8A Run No. 3
Nozzle Flange Bolt			
TE128	271	275	186
Nozzle External Wall			
TE131	191	203	111
TE136	224	234	153
Inner Reflector			
TE401	323	303	140
TE402	332	403	162
TE403	319	351	98
Ave. Outer Reflector			
T.300	171	196	95
Ave. In Core Station			
T.600	207	219	102
Ave. Tie Rod			
T.710	716	792	125
Ave. In Core Station			
T.910	466	647	506

TABLE 3

COMPARISON OF EVENTS DURING DAMP AUTOSTARTS

Channel No. Used for Event	Event	Times Relative to Start of Drum Rollout: EP-7A Run No. 4	EP-7A Run No. 5	EP-8A Run No. 3
D.800	Start Drum Rollout	0	0	0
DR 100	Open PDSV	0.7	1.2	$\simeq$ 0.2
BC 915	Chilldown Complete (When T.306 reaches 80^{o}R)	4.5	4.6	Condition satisfied prior to opening PDSV
BC 911	Drum Program Terminate (When T.910 reaches 700^{o}R)	27.4	75.0	9.5
DP 870 SC 617	Start of TPCV Opening and Pressure Loop Closed	28.2	76.3	10.6
BC 916 BC 912	Pressure Null & Bootstrap Complete (P_c = 40 psia)	40.0	88.2	22.1

TABLE 4

COMPARISON OF ENGINE CONDITIONS AT DRUM PROGRAM TERMINATE

Drum Program Terminate Attained When T.910 = 700°R

Parameter, Channel No., Units	EP-7A Run No. 4	EP-7A Run No. 5	EP-8A Run No. 3
Drum Position (D.800), deg.	91.9	92.4	98.3
Linear Power (PWLIN 1), Mw	23.1	19.6	36
In Core Temp. (T.910), °R	695	706	694
In Core Temp. (T.624), °R	630	577	502
Tie Rod Temp. (T.710), °R	421	465	232
Refl. Inlet Temp. (T.306), °R	41.4	40.8	41.6
Chamber Temp. (T.158), °R	692	724	424
Chamber Press. (P.158), psia	15.2	16.0	15.5
Pump Disch. Press. (PT114), psia	35.5	35.5	35.0
Engine Flow (WH014), lb/sec	4.8	4.7	5.2

TABLE 5

COMPARISON OF ENGINE CONDITIONS AT PRESSURE NULL

Pressure Null Attained When P_c = 40 psia

Parameter, Channel No., Units	EP-7A Run No. 4	EP-7A Run No. 5	EP-8A Run No. 3
Drum Position (D.800), Deg.	93.6	91.6	95.3
Linear Power (PWLIN 1), Mw	44.9	40.2	42
In Core Temp. (T.910), ^{o}R	650	640	825
In Core Temp. (T.624), ^{o}R	590	540	630
Tie Rod Temp. (T.710), ^{o}R	428	419	408
Chamber Temp. (T.158), ^{o}R	766	675	751
Chamber Press (P.158), ^{o}R	38.8	39.8	39.8
Pump Disch. Press. (PT114), psia	72.2	70.9	70.1
Engine Flow (WH014), lb/sec	17.3	17.7	19.5
TPCV Position (DP870), deg.	41.5	41.2	42.8
Pump Speed (EN800), rpm	4,300	4,200	4,200

SPEAR Memo No. 6

Figure 1

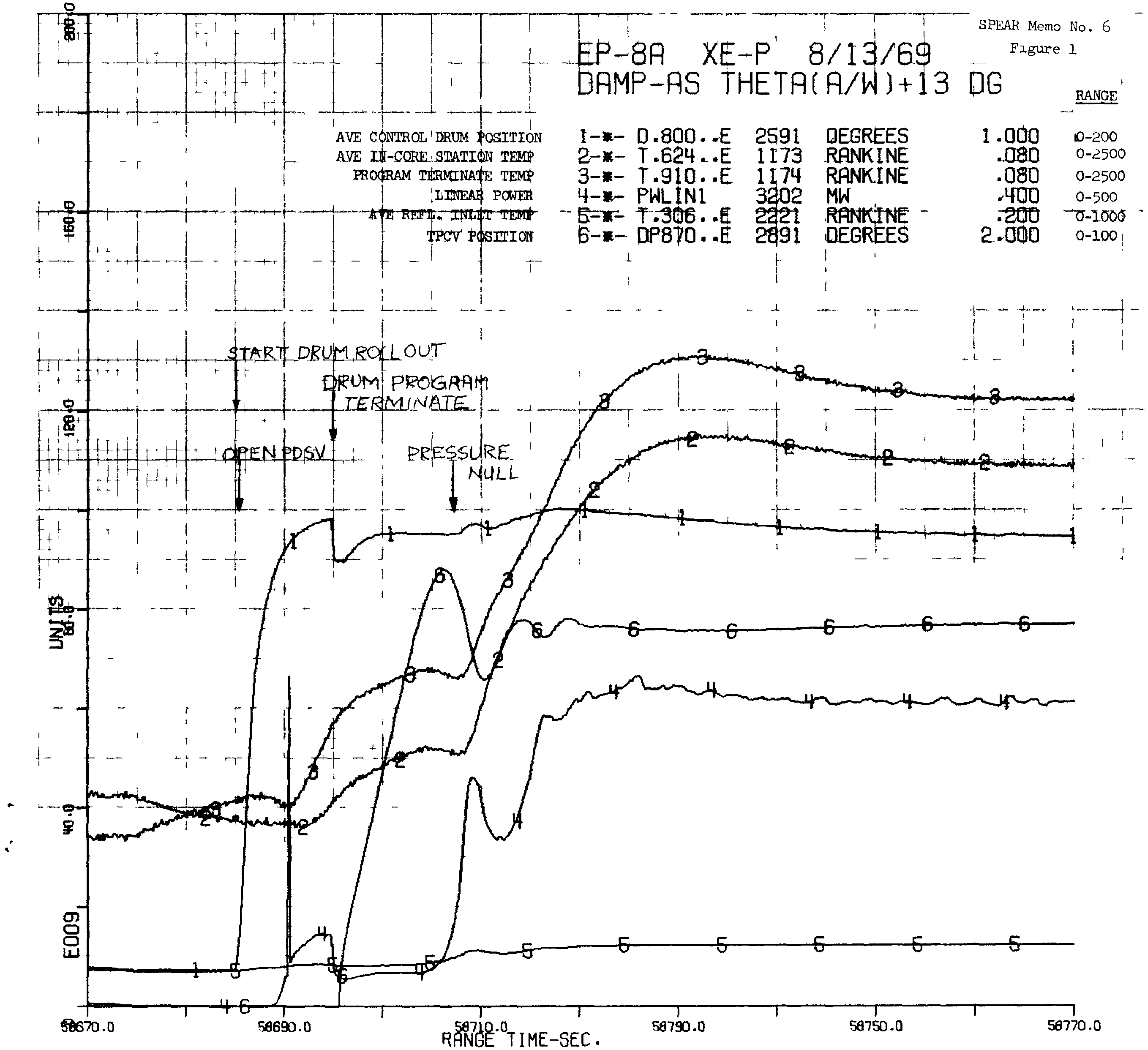
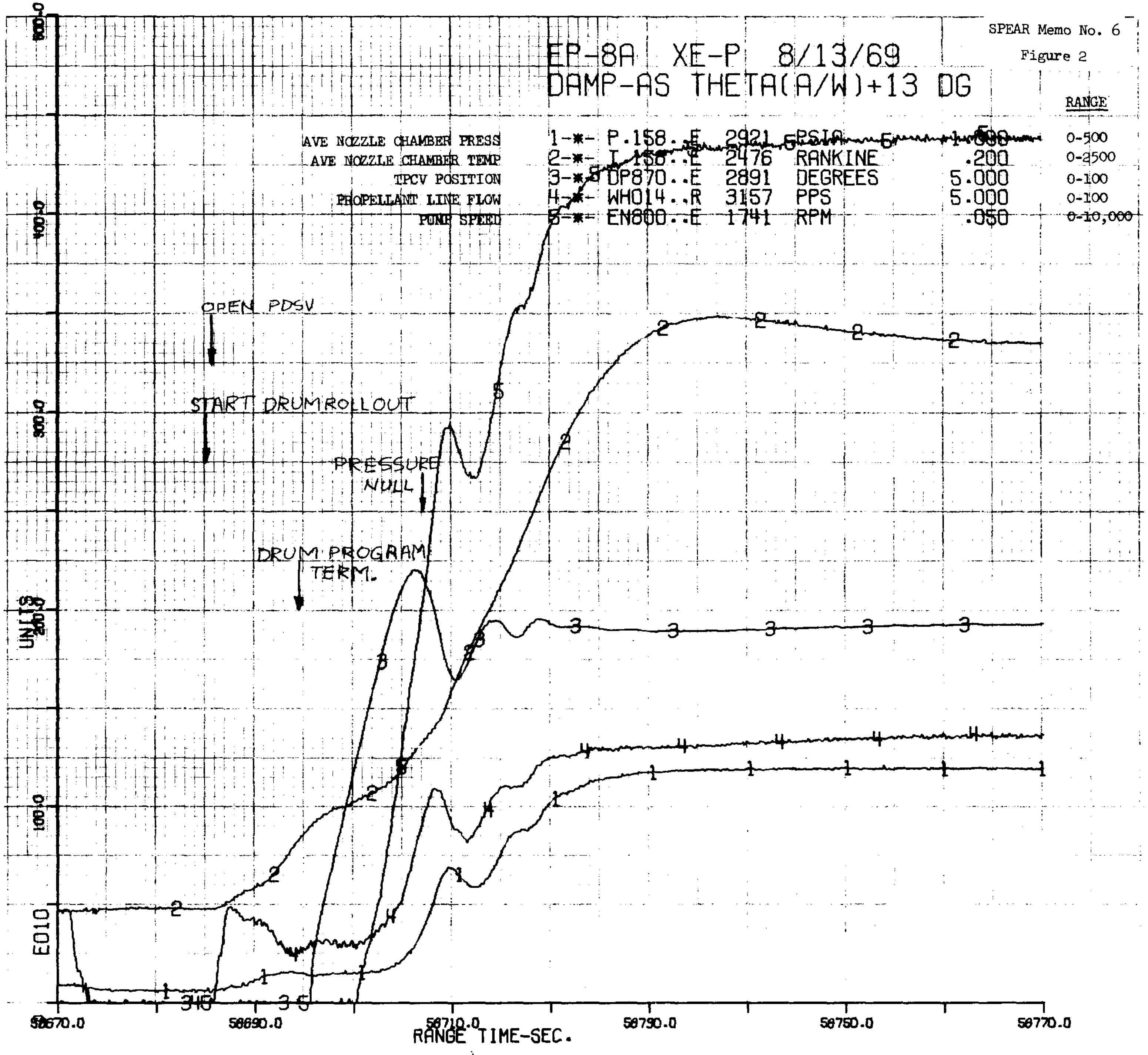


Figure 2


EP-8A XE-P 8/13/69
DAMP-AS THETA(A/W)+13 DG
RANGE
AVE NOZZLE CHAMBER PRESS 1-*- P.158..E 2921 PSIA 1.000 0-500
AVE NOZZLE CHAMBER TEMP 2-*- T.158..E 2476 RANKINE .200 0-2500
TPCV POSITION 3-*- DP870..E 2891 DEGREES 5.000 0-100
PROPELLANT LINE FLOW 4-*- WH014..R 3157 PPS 5.000 0-100
PUMP SPEED 5-*- EN800..E 1741 RPM .050 0-10,000
OPEN PDSV
START DRUM ROLLOUT
PRESSURE NULL
DRUM PROGRAM TERM.
UNITS
E010
RANGE TIME-SEC.
58670.0
58690.0
58710.0
58730.0
58750.0
58770.0

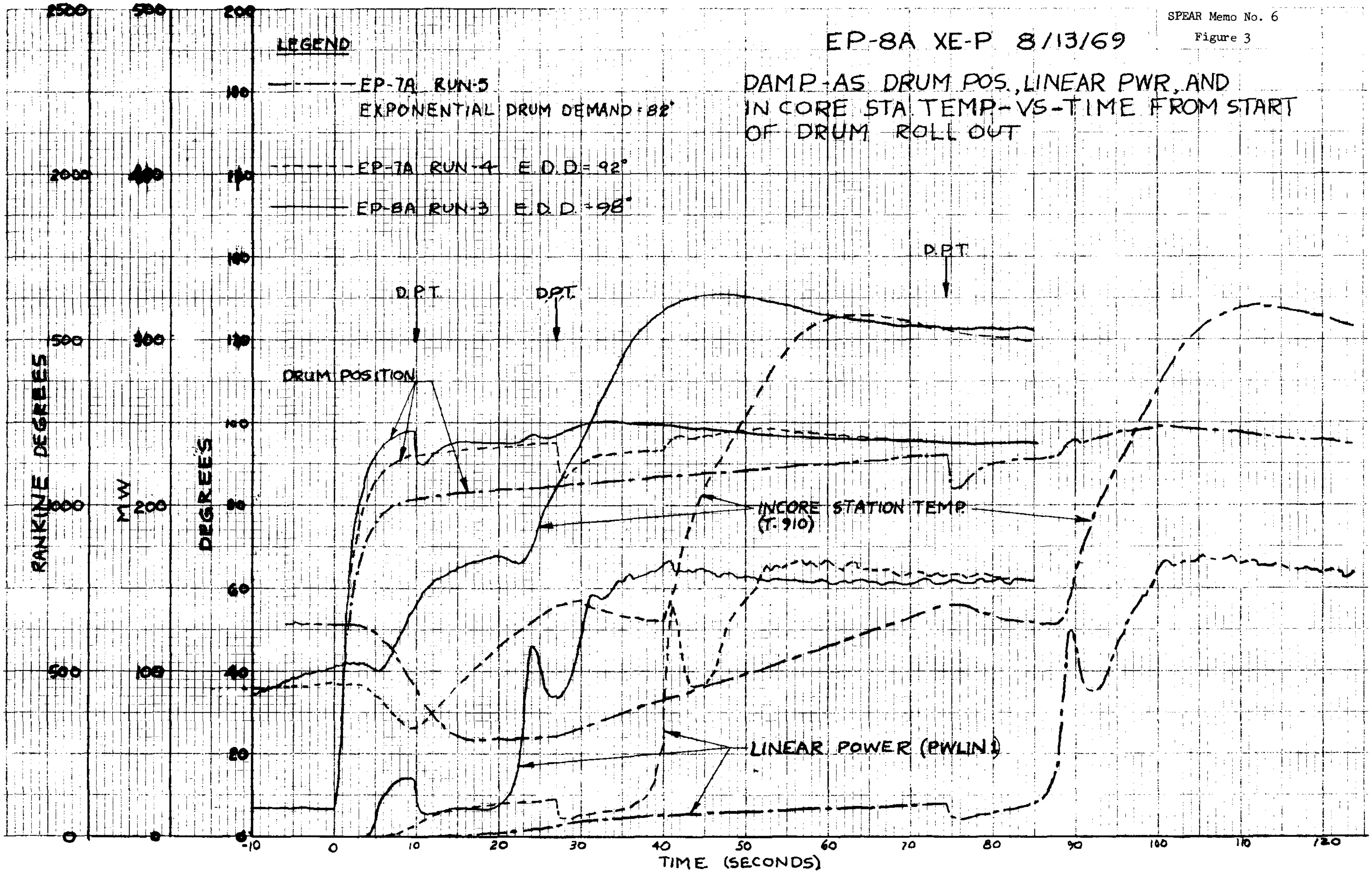
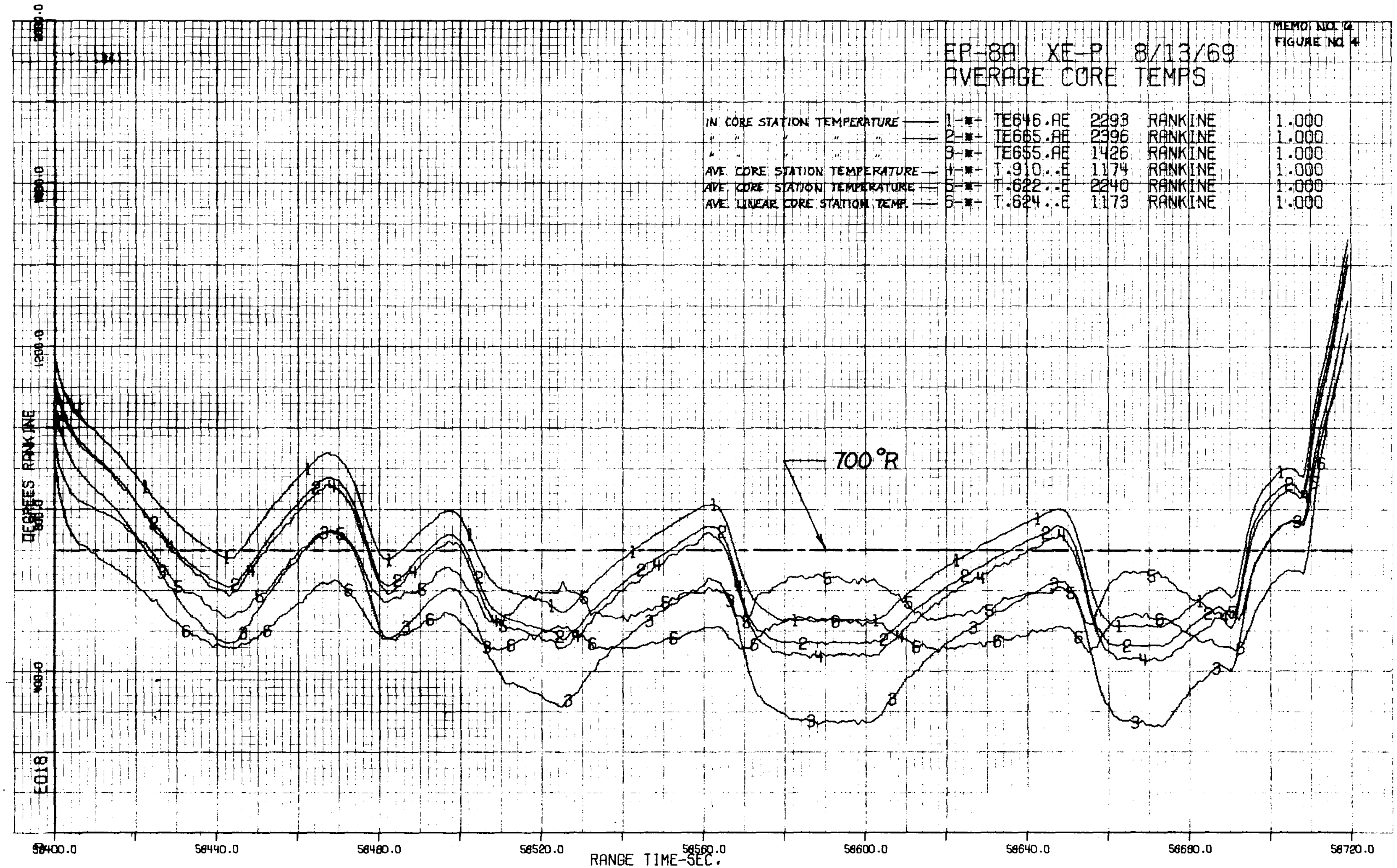

EP-8A XE-P 8/13/69
DAMP-AS DRUM POS., LINEAR PWR, AND IN CORE STA TEMP-VS-TIME FROM START OF DRUM ROLL OUT
LEGEND
EP-7A RUN-5 EXPONENTIAL DRUM DEMAND-82°
EP-7A RUN-4 E.D.D.=92°
EP-8A RUN-3 E.D.D.=98°
D.P.T.
D.P.T.
D.P.T.
DRUM POSITION
INCORE STATION TEMP (T-910)
LINEAR POWER (PWLIN1)
RANKINE DEGREES
MW
DEGREES
2500
2000
1500
1000
500
0
500
400
300
200
100
0
200
180
160
140
120
100
80
60
40
20
0
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (SECONDS)

Figure 3



MEMO NO. 4
FIGURE NO. 4
EP-8A XE-P 8/13/69
AVERAGE CORE TEMPS
IN CORE STATION TEMPERATURE — 1-*- TE646.AE 2293 RANKINE 1.000
" " " " " — 2-*- TE665.AE 2396 RANKINE 1.000
" " " " " — 3-*- TE655.AE 1426 RANKINE 1.000
AVE. CORE STATION TEMPERATURE — 4-*- T.910..E 1174 RANKINE 1.000
AVE. CORE STATION TEMPERATURE — 5-*- T.622..E 2240 RANKINE 1.000
AVE. LINEAR CORE STATION TEMP. — 6-*- T.624..E 1173 RANKINE 1.000
700 °R
DEGREES RANKINE
1200.0
800.0
400.0
58400.0
58440.0
58480.0
58520.0
58560.0
58600.0
58640.0
58680.0
58720.0
RANGE TIME-SEC.

SPEAR Memo No. 7
W. Bailey:jh

XE-PRIME

EP-8A

Subject: Control System Performance During (DAMP) Temperature Autostart

SUMMARY

This memo contains information on the performance of the (DAMP) Temperature Autostart Control System (Run No. 3) EP-8A.

In a (DAMP) temperature autostart the opening of the PDSV coincides with the initiation of the start reactor. Bootstrapping of the engine to the chamber temperature and pressure conditions of 1700°R and 120 psia was accomplished as on EP-7A, Runs 4 and 5.

The test objective was to obtain information for an engine startup from ambient core, cold reflector condition with a drum program exponential to the ambient wet critical position +13 degrees. The exponential setting was based on measurement of the cold critical drum angle earlier in the EP.

TECHNICAL DISCUSSION

A block diagram of the (DAMP) temperature autostart logic used on Run 3 of EP-8A is shown in Figure 1. A Chronology Listing for the run is given in Table I. Parameter values were obtained from the short digital data printout (10 samples), Passes EC01 and EC02. Operational event times were determined from the digital events listing, EV01 and EV02.

The "Start Reactor" command was given at RT 58684.6, followed by the PDSV open command 0.4 seconds later. The drum program phase in this test lasted only 10.0 seconds. The exponential portion of the drum program behaved as expected; however, it was terminated prior to reaching the exponentail set point because the condition for drum program terminate (DPT) was achieved. Due to the early DPT time a ramp was not included in the drum program.

DPT was effected at a value of T.910 of 693.7°R which is approximately 6°R below design, but well within system tolerance. At DPT the drums stepped in 8.5 degrees as in previous EP's. The drum position at DPT was 98.3 degrees.

Technical Discussion (Cont'd)

The "Start Engine" signal was given 1.0 seconds after DPT. The Childown Complete (CDC) signal also appeared at this time as the reflector inlet temperature (T.306) was below 80°R. At start engine T.806 was 41°R.

Figure 2 shows the response of the core temperature demand generator (CC621) and the control drum demand (CC800). Due to the simultaneous occurrence of "Start Engine" and CDC (RT 58695.5) the temperature demand generator did not experience a hold following drum program terminate but continued increasing on an exponential of a one second time constant to a final value of 1100°R.

Figure 3 shows the TPCV response (DP870) for the test. The response, resulting from pressure loop closure, is characteristic of other EP's.

At pressure coincidence (pressure null), the temperature loop closure occurs simultaneously with the start of the program to control the drums with Tc. However, operation of the drum control program is not contingent upon temperature loop closure as in past EP's. Pressure null occurred at RT 58707.2. The value of chamber pressure was 39.6 psia, (40.0 psia predicted). Chamber temperature loop closure followed 0.1 second later. Drum response to this action can be noted in Figure 2. The temperature ramp to 1700°R begins at this time. The ramp was characteristic of other EP's, ramping at about 50°R/sec, to 1780°R and settling to 1670°R (1700°R expected). The total elapsed time from "Start Reactor" until chamber temperature demand reached 1670°R was 55.5 seconds.

CONCLUSIONS

The (DAMP) temperature autostart controls and control logic performed as required. The early opening of PDSV, for the damp temperature autostart, caused several of the logic steps to be initiated immediately in the logic sequence, thus demonstrating the flexibility of the control functions. The control system is adequate for subsequent EP testing. No data anomalies were observed.

TABLE I

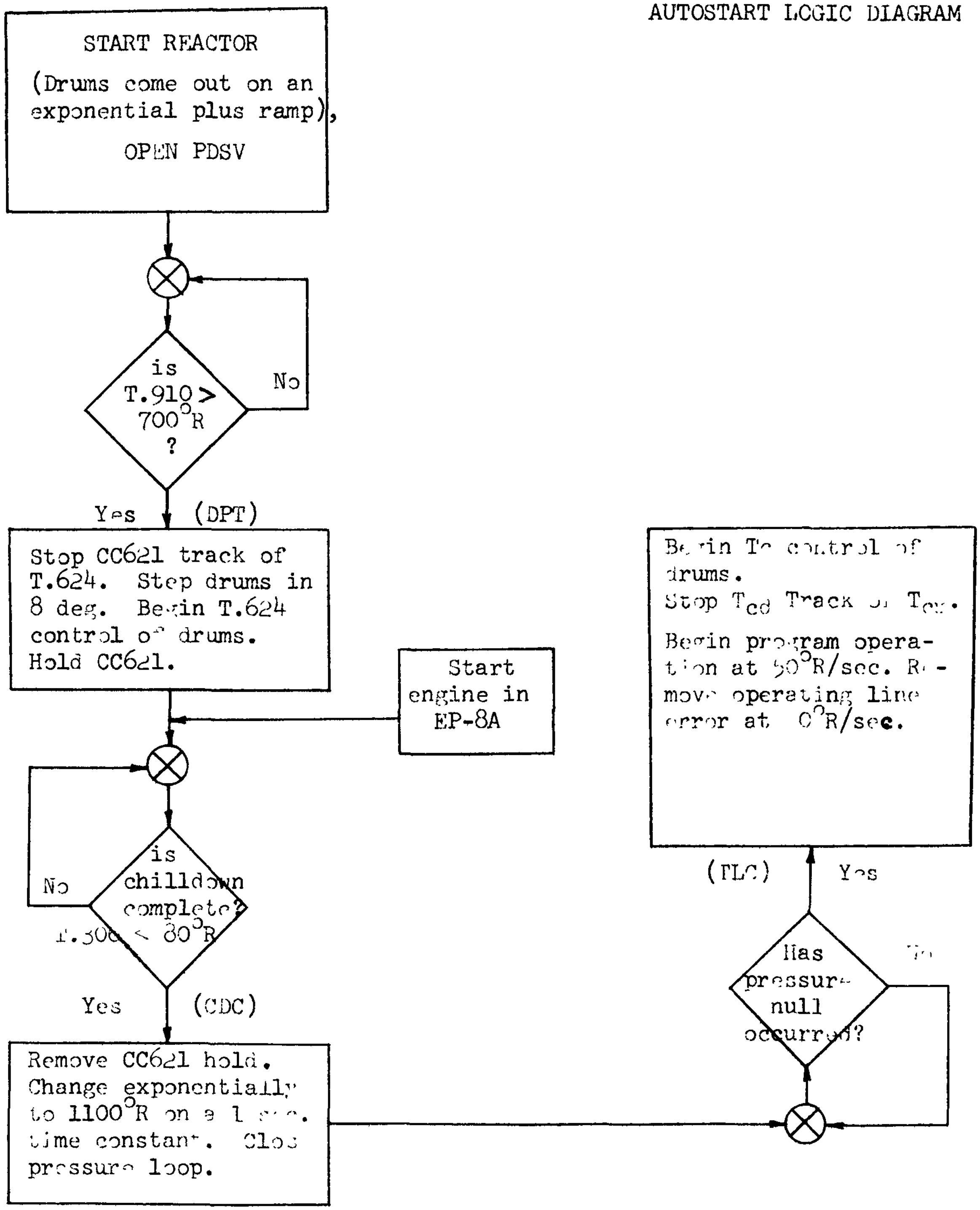
CHRONOLOGY LISTING (RUN 3)

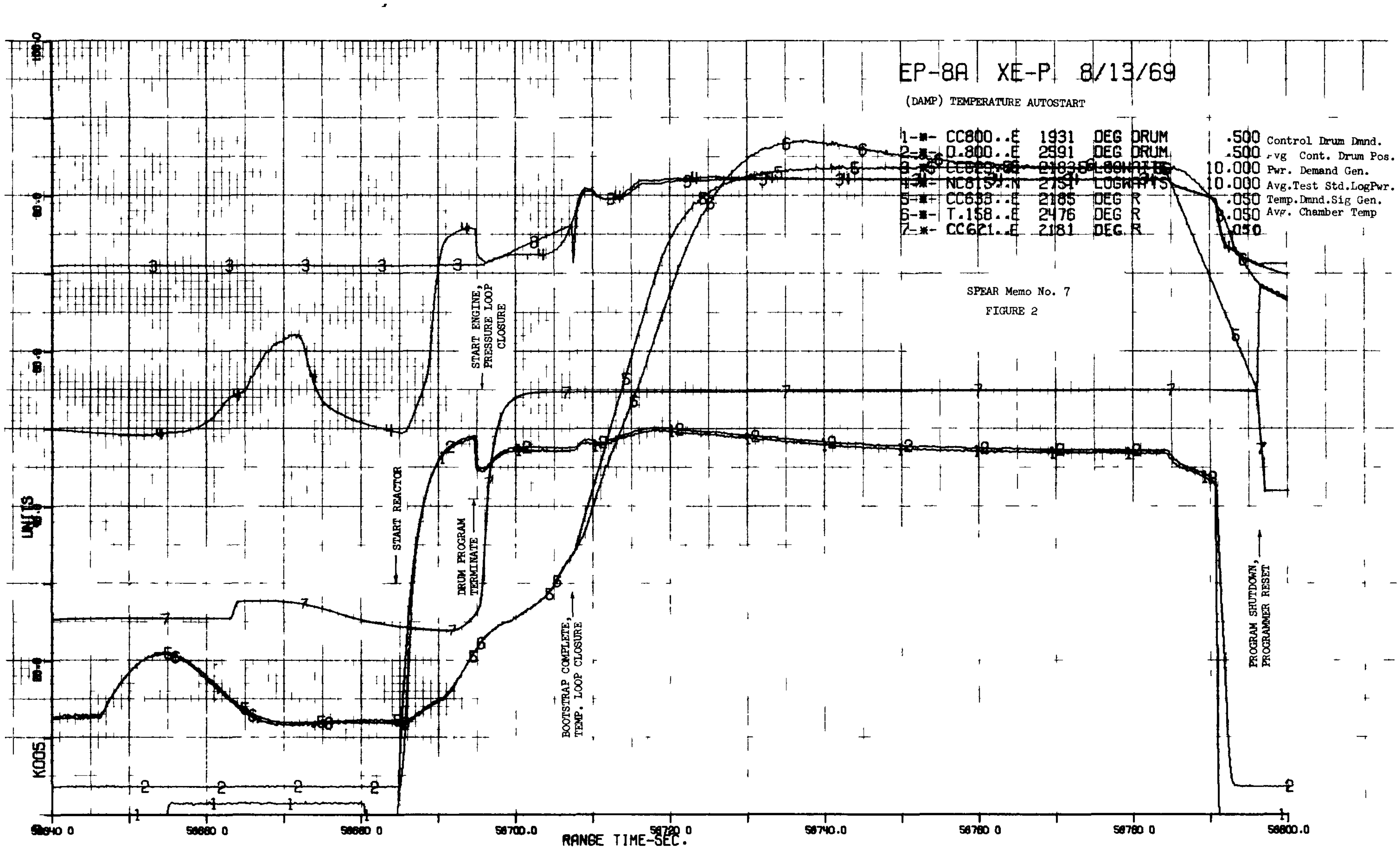
I.D.	Event	RT	Pass
SC 616	Start Reactor	58684.6	EV01
SR 641	PDSV Open	58685.0	EV01
BC 911	Drum Program Terminate	58694.6	EV02
BC 915	Chilldown Complete	58695.5	EV02
SC 617	Start Engine	58695.6	EV01
BC 657	Pressure Loop Closed	58695.6	EV01
BC 916	Pressure Null	58707.2	EV01
BC 912	Bootstrap Complete	58707.2	EV02
BC 655	Temp Loop Closure	58707.3	EV01
SC 616	Program Shutdown	58796.2	EV01
BC 655	Programmer Reset	58796.2	EV01

Event "Drum Ramp Start" is not applicable for Run 3 because the exponential portion of the drum program was not finished before T.910 exceeded 700°R.

SPEAR Memo No. 7
FIGURE 1

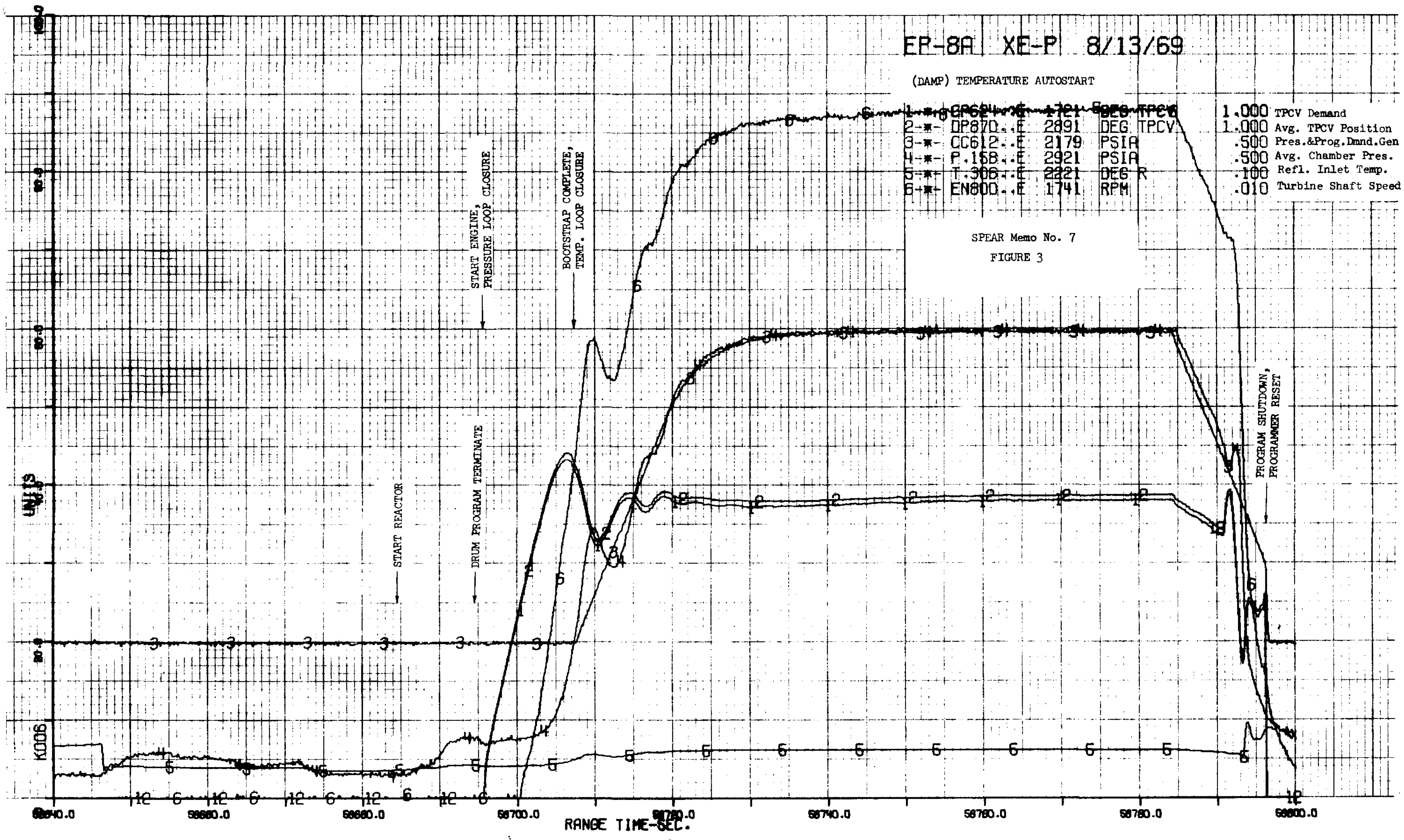
EP-8A (DAMP) TEMPERATURE
AUTOSTART LOGIC DIAGRAM





SPEAR Memo No. 7

FIGURE 2



EP-8A XE-P 8/13/69
(DAMP) TEMPERATURE AUTOSTART
1 DEG TPCV 1.000 TPCV Demand
2 DP870 E 2891 DEG TPCV 1.000 Avg. TPCV Position
3 CC612 E 2179 PSIA .500 Pres.&Prog.Dmnd.Gen
4 P.158 E 2921 PSIA .500 Avg. Chamber Pres.
5 T.306 E 2221 DEG R .100 Refl. Inlet Temp.
6 EN800 E 1741 RPM .010 Turbine Shaft Speed
SPEAR Memo No. 7
FIGURE 3
START ENGINE, PRESSURE LOOP CLOSURE
BOOTSTRAP COMPLETE, TEMP. LOOP CLOSURE
START REACTOR
DRUM PROGRAM TERMINATE
PROGRAM SHUTDOWN, PROGRAMMER RESET
UNITS
RANGE TIME-SEC.
58700.0
58740.0
58760.0
58780.0

SPEAR MEMO NO. 8
C. J. Naretto RJW

XE-PRIME

EP-8A

Subject: ENGINE PERFORMANCE DURING (WET) TEMPERATURE AUTOSTARTS

SUMMARY:

An engine (wet) temperature autostart with an initial high source power and an engine (wet) temperature autostart with a hot core were completed successfully. The turbopump was in a chilled condition prior to both autostarts.

TECHINICAL DISCUSSION:

A. Introduction

During EP-6A, a (wet) temperature autostart was made with an initial source power of 60 Kw and an initial core temperature (T.622) of 970^{o}R. The purpose of the two (wet) temperature autostarts performed during EP-8A was to expand upon the start made during EP-6A. The first autostart was intended to be made at a higher source power, 2.77 Mw, but with essentially the same chamber temperature (it was actually 90^{o}R higher). The second autostart was intended to be made at the same source power but at a higher core temperature. The core temperature was intended to be 1420^{o}R, but it was actually 1082^{o}R. SPEAR Memo No. 6, EP-6A, documented the system behavior during the earlier run.

Data sources for this memo were NRO Data Plots, NTO Thinned Digital Data Listings, and NTO CALCOMP Plots of short data listings.

A discussion of the Control System operation during the (wet) temperature autostarts is presented in Memo No. 9.

B. (WET) Temperature Autostart with an Initial High Source Power

Time based plots of pertinent parameters for the overall startup and bootstrap phase are shown in Figures No. 1 and 2, respectively.

This restart was begun immediately following a normal shutdown from a short duration, steady-state hold of T_c/P_c of 1700^{o}R and 120 psia. At Range Time 58836.4 seconds the control drums began rotating out on a 2-second exponential toward ambient-critical position plus 3^{o} (95^{o}*). Flow was being maintained from the run tank and the

NOTE: * Ambient-critical drum bank position was assumed from the CTE console to be 92^{o}. Post-test analysis showed θ_{cc} was actually 93.2^{o}.

chamber temperature was decreasing through 1040°R at the time of initial drum movement. The cold-critical position was reached in approximately 7 seconds, which compared well to the 8 seconds predicted by the CAM.

Closure of the temperature control loop took place approximately 48 seconds after initial drum roll out at an average chamber temperature of 1167°R and 36 seconds after the chamber temperature reached a minimum of 958°R. At the time of closure of the temperature control loop, the average chamber temperature was 209°R above the minimum T_c. The control drums rotated inward approximately 3° at this time. The CAM predicted 18 seconds to temperature control loop closure from initial drum rollout. This difference is probably due to the higher initial source power (3.5 Mw) assumed for the CAM run.

Closure of the temperature control loop activated the pressure control loop because chilldown complete conditions had already been satisfied. The TPCV began to open immediately after temperature loop closure in response to a 40 psia chamber pressure demand. Chamber pressure null (i.e., P_c=40 psia) occurred 10 seconds after closure of the temperature and pressure control loops. TPCV gate position reached a maximum of 45.5° at this time. Attainment of pressure null initiated a pressure demand ramp of 5 psia/sec toward the hold point chamber pressure of 120 psia. Chamber pressure null also initiated a temperature demand ramp of 30°R/sec.

Significant pump acceleration started approximately 4 seconds after temperature loop closure at a TPCV gate position of 21 degrees - pressure coincidence occurring 6 seconds later. Chamber pressure continued to rise; peaking at 75 psia 12 seconds after temperature loop closure. After a brief pressure correction downward, chamber pressure rose along the demand line, stabilizing at about 119 psia, 39 seconds after temperature loop closure.

Chamber temperature rose to a peak of 1734°R, 35 seconds after closure of temperature control loop and then stabilized at 1700°R. As pressure rose, average linear power increased from 22 Mw to 146 Mw in 6 seconds, corrected down to approximately 85 Mw and then stabilized to a nominal power of 155 Mw. A steady-state hold of approximately 50 seconds duration was followed by a normal shutdown.

C. <u>(Wet) Temperature Autostart with an Initial High Core Temperature</u>

Time based plots of pertinent parameters for the overall startup and bootstrap phase are shown in Figures No. 3 and 4, respectively.

After a normal shutdown from the high source power temperature auto-start and hold, the engine system was pulse-cooled as required to obtain a high core temperature (T.622). The planned station 3 temperature was 1450^{o}R; the actual temperature at drum program initiation was 1082^{o}R.

During a cooling pulse, with Station 3 temperature decreasing through 1075^{o}R, the control drums were started out on an exponential ramp toward ambient critical plus 3^{o} (RT 59193.5). A linear ramp of 0.14^{o}/sec was added to the exponential ramp automatically when the average reflector inlet plenum temperature dropped below 125^{o}R, approximately 14 seconds after drum initiation. The ambient-critical drum angle was reached approximately 6.5 seconds after drum program initiation, and ambient-critical plus 3^{o} was reached 3 seconds later. Minimum chamber temperature (T.158 = 936^{o}R) occurred 38.5 seconds after initial drum roll out. Temperature loop closure occurred 72 seconds after drum program initiation (CAM predicted 77 seconds) at an average chamber temperature (T.158) of 1136^{o}R and 33.5 seconds after the chamber temperature minimum. The control drums rotated inward approximately 4^{o} at this time. Closure of the temperature control loop activated the pressure control loop because chilldown complete conditions were already satisfied and the TPCV began to open immediately. Chamber pressure null occurred 11 seconds after the closure of the temperature and pressure control loops. TPCV gate position reached a maximum of approximately 45^{o} at this time. At pressure null, a pressure demand ramp of 5 psia/sec and a temperature demand ramp of 30^{o}R/sec toward the hold point chamber conditions of 1700^{o}R and 120 psia was initiated. The temperature demand ramp was changed to zero when the T_c program error removal rate was changed to 50^{o}R/sec and then became 50^{o}R/sec when the chamber operation on the operating line was required.

Significant pump acceleration started approximately 6 seconds after temperature loop closure at a TPCV gate position of 26.5 degrees - pressure coincidence occurring 6 seconds later. Chamber pressure continued to rise; peaking at 74 psia, 13.5 seconds after temperature loop closure. After a brief pressure correction downward, chamber pressure rose along the demand line; stabilizing at 118 psia about 37 seconds after temperature loop closure. As pressure rose, average linear power increased from approximately 23 Mw to 143 Mw in 8 seconds, corrected down to approximately 81 Mw, and then stabilized at a nominal power of 153 Mw. Chamber temperature rose to a peak of 1717^{o}R, 37.5 seconds after closure of the temperature loop. A short steady-state hold, during which chamber temperature did not fully stabilize, was followed by a normal shutdown.

D. Comparison to (WET) Temperature Autostart of EP-6A

A tabulation of selected parameters is presented in Table I. The initial conditions at initial drum rotation for EP-6A - Run No. 5, EP-8A - Run No. 4, and EP-8A - Run No. 5 are presented, as are the times required for particular events to occur.

The relatively long delay between temperature loop closure and initial TPCV movement (9 seconds) during EP-6A - Run No. 5, was due to the fact that the requirement for chilldown complete was a reflector inlet temperature (T.306) of 60^{o}R; this was not achieved and a manual by-pass was required. This was made 9 seconds after temperature loop closure. Prior to EP-8A, the requirement for chilldown complete was increased to 80^{o}R.

The total elapsed time from drum initiation to closure of temperature control loop for the higher source power (WET) temperature autostart was nearly the same as the (WET) temperature autostart performed during EP-6A even though the initial source power in the former was considerably higher than in the latter (2.77 Mw vs. 0.06 Mw). The autostart performed during EP-6A required approximately 47 seconds after initial drum movement for the temperature control loop to close. Due to the higher initial source power of EP-8A - Run No. 4, it was expected that this time would be considerably shorter; in fact, the CAM predicted 18 seconds.

Figure 5 is presented in an attempt to explain the effects of initial system conditions on the time required for temperature loop closure. As noted in Table I, the time required to obtain temperature loop closure (TLC) during EP-8A - Run No. 4 was not significantly different from EP-6A - Run No. 5, even though the former was run with a higher initial source power. The phenomenon observed may be explained by the higher chamber temperature associated with the high source power startup. The rapid increase in average linear power caused the chamber temperature to "turn around" sooner after drum program initiation. Increasing negative feedback reactivity due to the higher temperature, caused the linear power to level and actually begin to decrease, beginning approximately 15 seconds after drum program initiation as seen in Figure 5. Hence, due to this increasing negative feedback reactivity, the drum bank critical position during this time interval obviously was increasing at a greater rate than the drum ramp and exceeded the actual drum position. The decreasing power level, plus the fact that it started to decrease from a lower level, reduced the rate of chamber temperature increase sufficiently to cause the coincidence in the time required for temperature loop closure.

The structural support temperatures at initiation of Run No. 5 were close to their limit values. The limit for starting the test was 1450^{o}R, measurement of T.710. The measured T.710 was 1305^{o}R and one of the individual measurements (TE714) providing input to the T.710 averager was 1520^{o}R at test initiation. Examination of the engine bootstrap during this run, in comparison with EP-6A, Run No. 5, showed no evidence that the engine system was approaching a limit insofar as ability to bootstrap is concerned. Hence, it appears that the limitation on restarting at elevated temperatures using the (WET) temperature autostart would be established by the structural support limit rather than by the ability of the engine to bootstrap.

CONSLUSIONS:

The high source power and high initial temperature (WET) temperature autostarts were both demonstrated as being feasible.

The time required to close the temperature loop after drum initiation was not affected significantly by increasing the initial source power from 0.06 Mw (EP-6A, Run 5) to 2.77 Mw (EP-8A, Run 4), but seems to be more sensitive to initial chamber temperature.

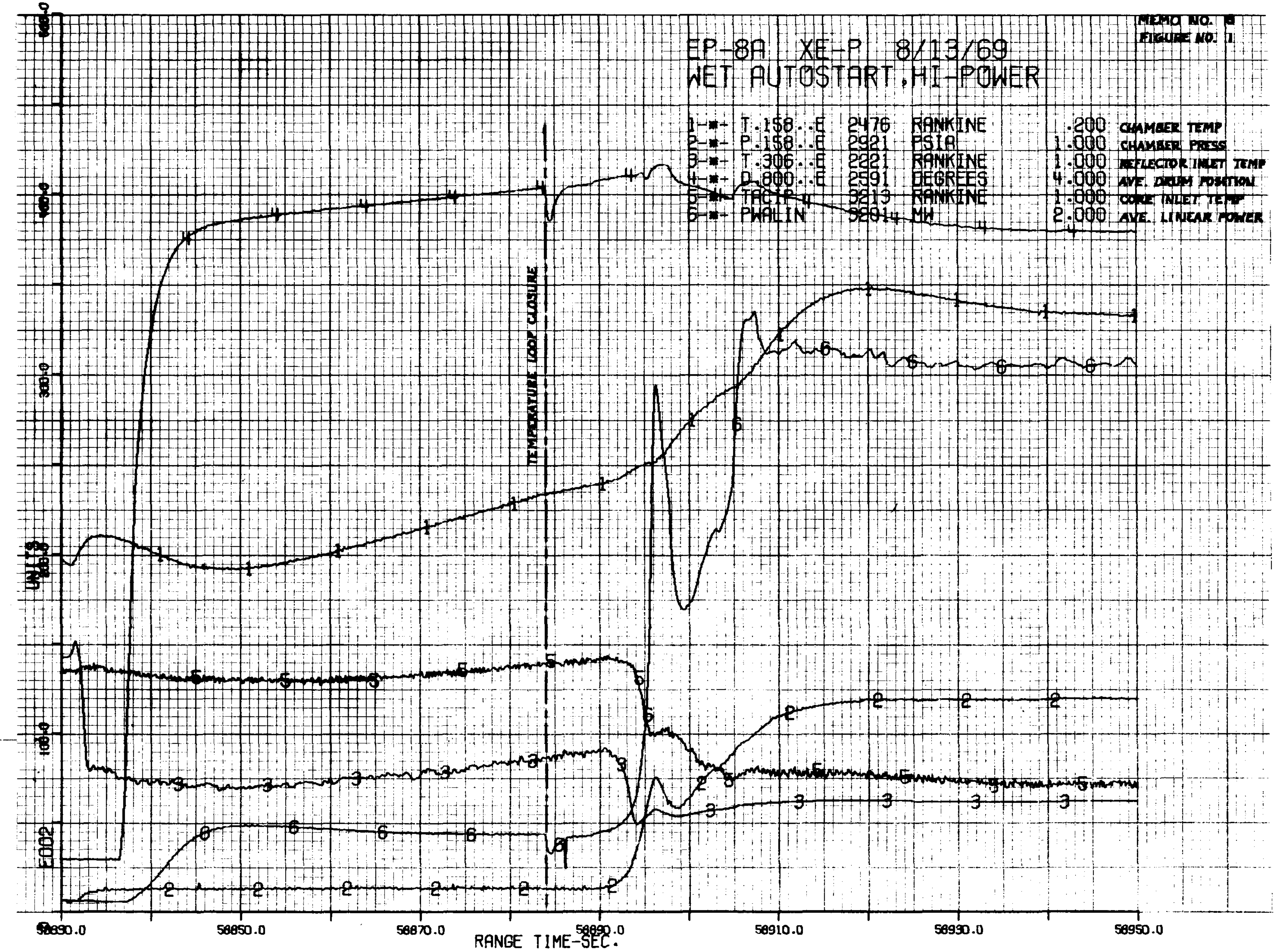
Comparison of data from EP-8A, Run 5 to that from EP-6A, Run 5 indicated that limitation on restarting at elevated temperatures using (WET) temperature autostart is established by the structural support limit rather than by the ability of the engine to bootstrap.

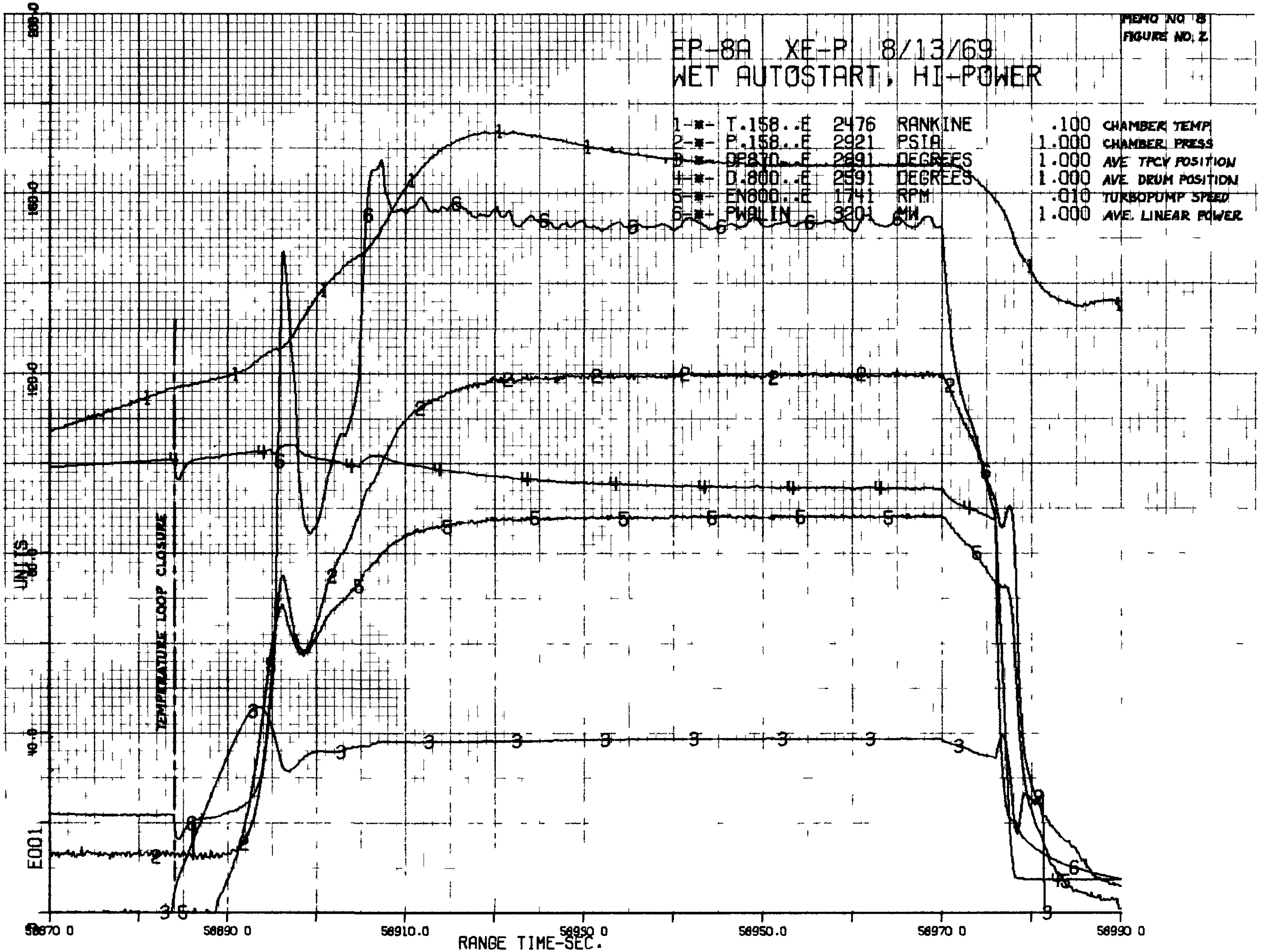
TABLE I

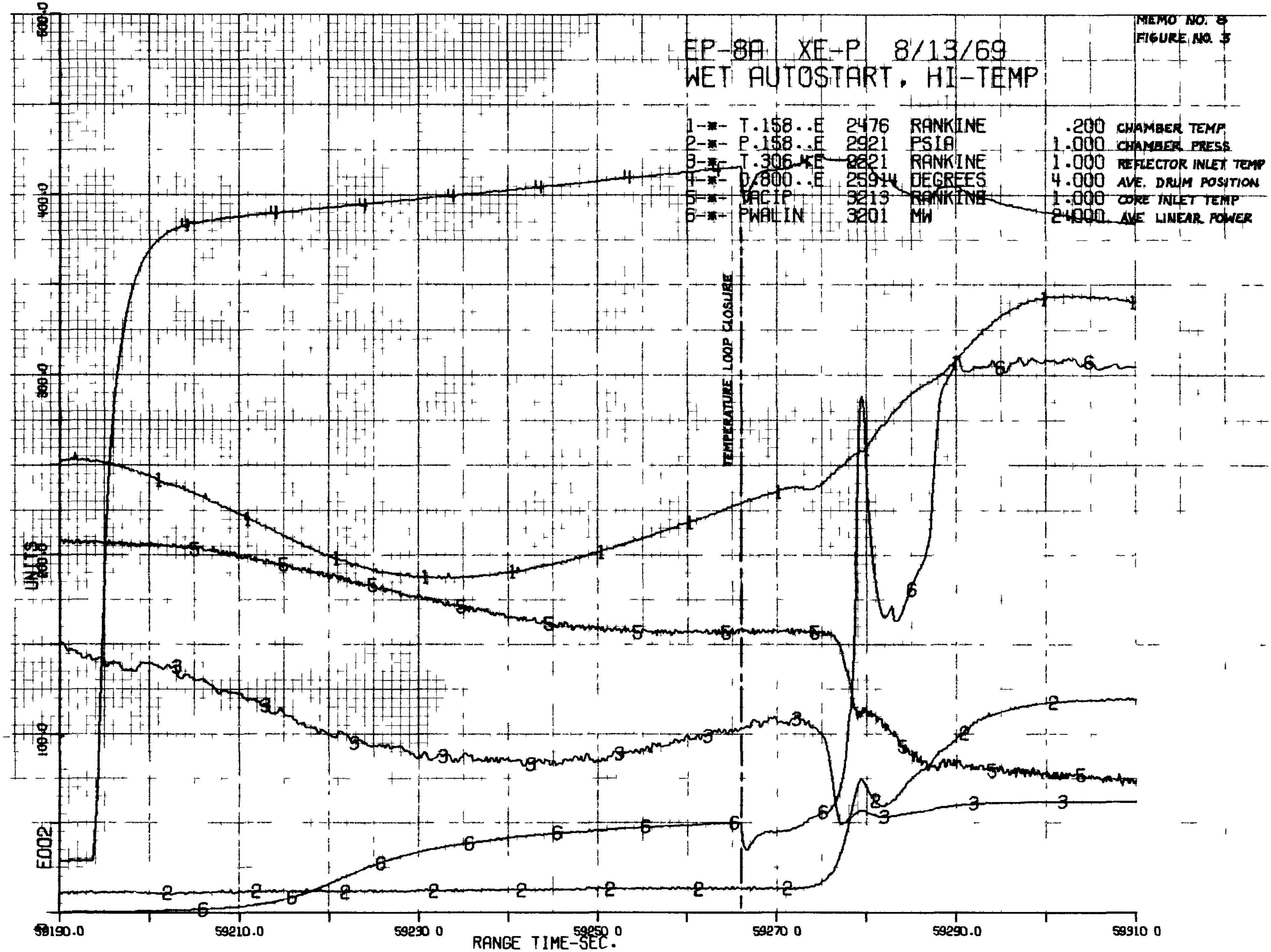
COMPARISON OF (WET) TEMPERATURE AUTOSTARTS, EP-6A AND EP-8A

PARAMETERS		EP-6A WAS (Restart)	EP-8A WAS (Restart) High Source Pwr.	EP-8A WAS (Restart) High Init. Temp.
Initial Conditions				
Core Temp. (T.622)	°R	956	721	1082
Chamber Temp. (T.158)	°R	952	1042	1261
Chamber Press. (P.158)	psia	14	12	11
Reflt. In. Temp. (T.306)	°R	96	74	145
Power (PWALIN)	Mw	0.06	2.77*	0.0875*
Tank Press. (PT099)	psia	35	35	35
Min. Chamber Temp. (T.158)	°R	800	958	936
Chamber Temp at TLC (T.158)	°R	1050	1167	1136
Min. Reflector Inlet (T.306)	°R	125	70	83
Time from Initial Drums Movement to:				
T_c Min.	sec	25	10.5	28
TLC Closure	sec	47	48	72
TPCV Start to Move	sec	56	49	73
TPA Start Significant Acceleration	sec	61	52	78
TPCV Maximum Position	sec	66 (44°)	57 (45.5°)	83 (44.5°)
TPA Peak Speed	sec	69 (6500 rpm)	60 (6807 rpm)	86 (6820 rpm)
Pressure Null	sec	67	58	84

* Average of PWLIN I and PWLIN 3


MEMO NO.
FIGURE NO. 1
EP-8A XE-P 8/13/69
WET AUTOSTART, HI-POWER
1-*- T.158..E 2476 RANKINE .200 CHAMBER TEMP
2-*- P.158..E 2921 PSIA 1.000 CHAMBER PRESS
3-*- T.306..E 2221 RANKINE 1.000 REFLECTOR INLET TEMP
4-*- D.800..E 2591 DEGREES 4.000 AVE. DRUM POSITION
5-*- TACIP 4 3213 RANKINE 1.000 CORE INLET TEMP
6-*- PWALIN 32014 MW 2.000 AVE. LINEAR POWER
TEMPERATURE LOOP CLOSURE
UNITS
500.0
400.0
300.0
200.0
100.0
58830.0
58850.0
58870.0
58890.0
58910.0
58930.0
58950.0
RANGE TIME-SEC.


MEMO NO 8
FIGURE NO. 2
EP-8A XE-P 8/13/69
WET AUTOSTART, HI-POWER
1-*- T.158..E 2476 RANKINE .100 CHAMBER TEMP
2-*- P.158..E 2921 PSIA 1.000 CHAMBER PRESS
3-*- DP870..E 2891 DEGREES 1.000 AVE TPCV POSITION
4-*- D.800..E 2591 DEGREES 1.000 AVE. DRUM POSITION
5-*- EN800..E 1741 RPM .010 TURBOPUMP SPEED
6-*- PWALIN 3201 MW 1.000 AVE. LINEAR POWER
TEMPERATURE LOOP CLOSURE
UNITS
E001
RANGE TIME-SEC.
58890 0
58910.0
58930 0
58950.0
58970 0
58990 0


MEMO NO. 8
FIGURE NO. 3
EP-8A XE-P 8/13/69
WET AUTOSTART, HI-TEMP
1-*- T.158..E 2476 RANKINE .200 CHAMBER TEMP
2-*- P.158..E 2921 PSIA 1.000 CHAMBER PRESS
3-*- T.306 KE 2221 RANKINE 1.000 REFLECTOR INLET TEMP
4-*- D/800..E 25914 DEGREES 4.000 AVE. DRUM POSITION
5-*- TACIP 3213 RANKINE 1.000 CORE INLET TEMP
6-*- PWALIN 3201 MW 24.000 AVE LINEAR POWER
TEMPERATURE LOOP CLOSURE
UNITS
E002
RANGE TIME-SEC.
59190.0
59210.0
59230 0
59250 0
59270 0
59290.0
59310 0

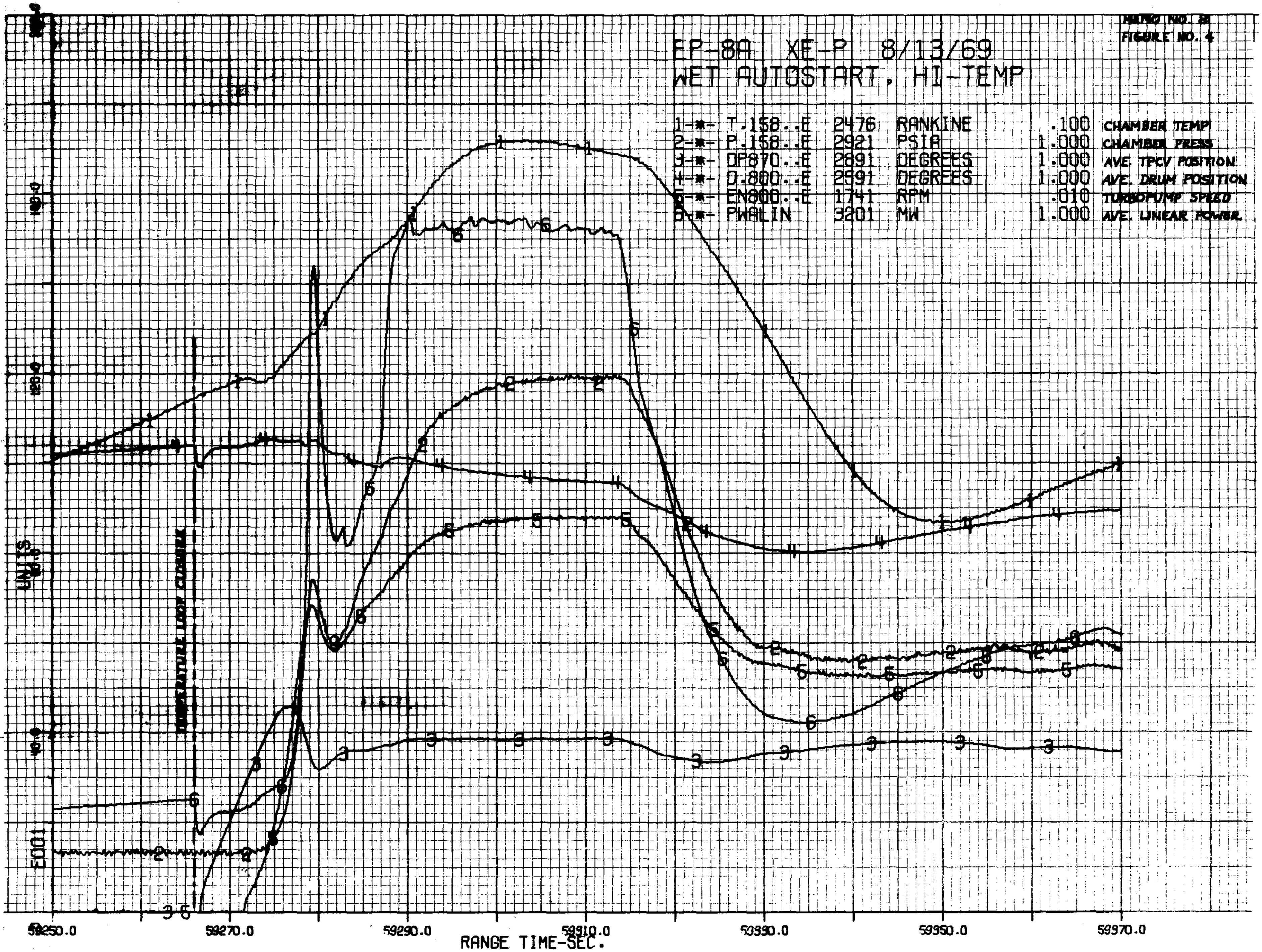
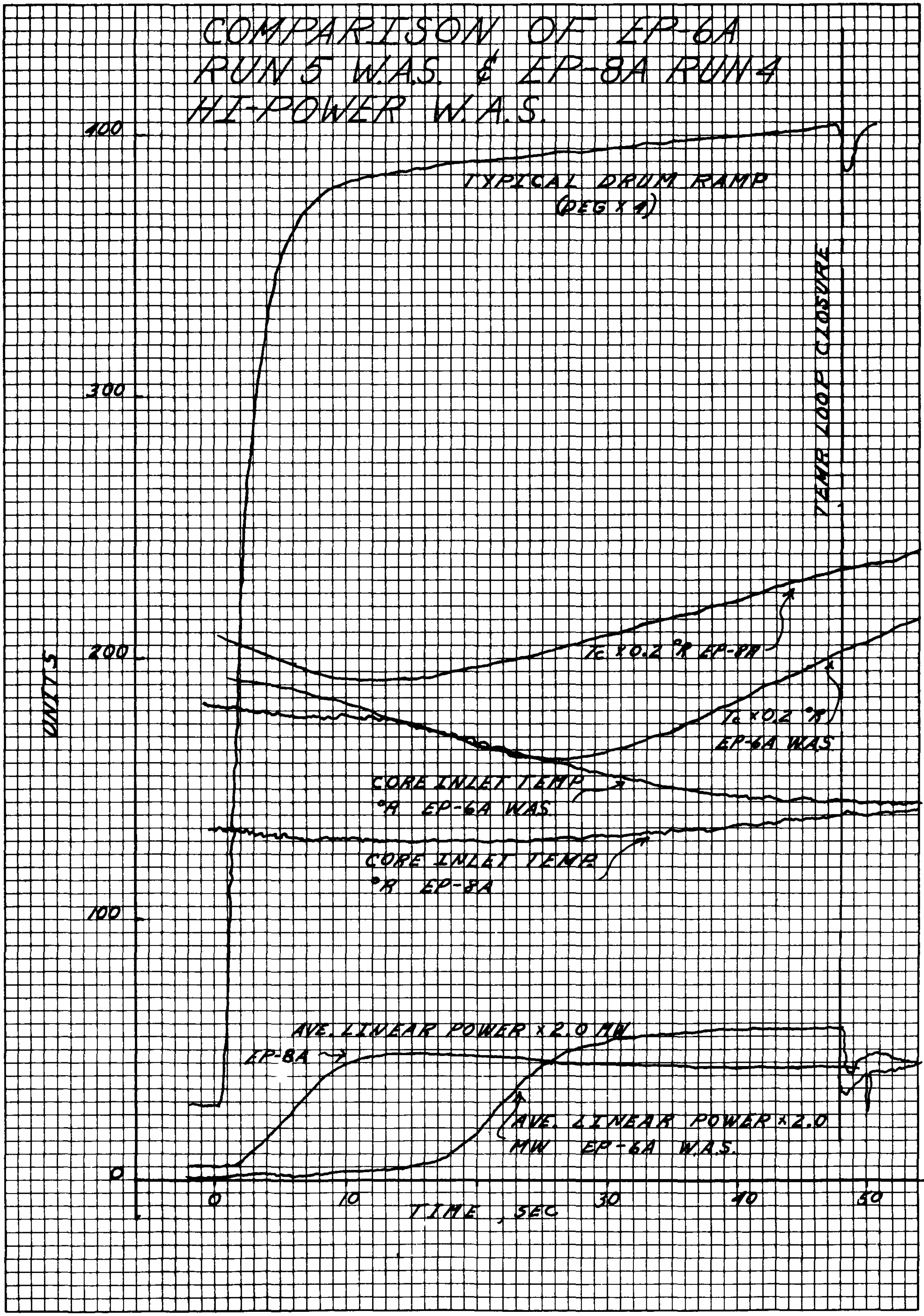


FIGURE NO. 4
EP-8A XE-P 8/13/69
WET AUTOSTART, HI-TEMP
1-*- T.158..E 2476 RANKINE .100 CHAMBER TEMP
2-*- P.158..E 2921 PSIA 1.000 CHAMBER PRESS
3-*- DP870..E 2891 DEGREES 1.000 AVE. TPCV POSITION
4-*- D.800..E 2591 DEGREES 1.000 AVE. DRUM POSITION
5-*- EN800..E 1741 RPM .010 TURBOPUMP SPEED
6-*- PWALIN 3201 MW 1.000 AVE. LINEAR POWER
TEMPERATURE LOOP CLOSURE
UNITS
E001
59250.0
59270.0
59290.0
59310.0
59330.0
59350.0
59370.0
RANGE TIME-SEC.


COMPARISON OF EP-6A RUN 5 W.A.S. & EP-8A RUN 4 HI-POWER W.A.S.
400
300
200
100
0
UNITS
TYPICAL DRUM RAMP (DEG X 4)
TEMP LOOP CLOSURE
Tc X 0.2 °R EP-8A
Tc X 0.2 °R EP-6A WAS
CORE INLET TEMP °R EP-6A WAS.
CORE INLET TEMP °R EP-8A
AVE. LINEAR POWER X 2.0 MW EP-8A
AVE. LINEAR POWER X 2.0 MW EP-6A W.A.S.
0
10
20
30
40
50
TIME, SEC

SPEAR Memo No. 9
G. W. Story
GWS

XE-PRIME

EP-8A

Subject: CONTROL SYSTEM PERFORMANCE DURING (WET) TEMPERATURE AUTOSTART

SUMMARY

This memo contains information and test data on the performance of the Control System during two (wet) temperature autostarts, one from high decay power (Run No. 4) and with a hot core (Run No. 5) conducted during EP-8A. Run No. 4 was initiated with a power level of 2.77 Mw and with the average core station temperature (T.622) at 721°R; Run No. 5 was a repeat of Run No. 4, except that the restart was initiated at a reactor power level of 87.5 Kw and with an average core station temperature of (T.622) of 1082°R.

The objectives of Runs No. 4 and 5 were to demonstrate, and gather performance data on the utilization of a (wet) temperature autostart starting from a high decay power point and with a hot reactor core. Tables No. 1 and 2 provide the chronology and a summary of the key parameters, respectively.

Each run was successfully carried out and the data shows no anomalies. The control subsystem is considered ready for the next EP test.

TECHNICAL DISCUSSION

EP-8A was the third EP test series in which (wet) temperature autostarts have been performed. In EP-4A, preliminary tests of the (wet) control system up to the bootstrap point were performed. During EP-4A a control drum profile design error was discovered and corrected prior to EP-6A tests. EP-6A successfully tested the (wet) temperature autostart control system, starting from ambient conditions through bootstrap and then restarted the engine, using the (wet) sequence with a hot core and a cold reflector.

Technical details of these tests, modifications and the current logic are shown in EP-4A SPEAR Memo No. 8 and EP-6A SPEAR Memo No. 5. Changes in circuitry since the EP-6A test includes resetting the ramp rate temperature limit between Temperature Loop Closure (TLC) and Bootstrap Complete (BSC) from 1400°R to 1600°R and changing the Chilldown Delay Complete (CDC) point from 60°R to 80°R.

Parameter values and operational event times were obtained from the following data:

Digital Events, Passes EV01 and EV02	8-13-69
Digital Data Thin (1 sec), Passes EC01, EC02 & EC03	8-13-69
TDC CALCOMP Plots, EP-8A	8-13-69
Special CALCOMP Plots, EP-8A	8-13-69

High Decay Power (Run #4)

Chilldown was started with PDSV opening at RT 58831 with a 2.77 Mw power level. This was followed by a "Start Engine" command 5 seconds later after chamber peaked out. The drums were moved exponentially to a measured 95.5 degrees on a two-second time constant (See Figure 1) and then continued to open with a ramp of 0.139 degrees/second (0.15°/sec planned).

During the Run No. 4 chilldown, the measured chamber temperature (Tcm) decreased approximately 80°R to a minimum of 960°R with the Chamber Temperature Demand (Tcd) following it down 100°R higher and then holding with negligible drift at 1054°R (See Figure 2). When Tcm increased 102°R above Tcd, TLC occurred. These events occurred as expected.

At TLC, the Tcd began increasing at 25°R/sec until BSC. CDC had occurred prior to TLC; therefore, only the 25°R/sec ramp occurred (no 15°R/sec ramp period).

The TPCV reached a maximum position of 45.5° during bootstrap, slightly below the 47° position clamp (See Figure 2).

During bootstrap the Tcd is monitored to determine the deviation from the normal operating line (900°R) at BSC. When program operation begins at BSC the Tcd deviation from the operating line is normally removed at 20°R/sec. The operating line error (existing at BSC) can be removed at 0, 10, 20, or 50°R/sec by CTE command. The program normally ramps Tc at 50°R/sec. However, if Tcd is above the operating line (greater than 900°R) at BSC, the error is corrected at 20°R/sec, thus the net Tcd linear ramp rate is 30°R/sec; likewise, if Tc is below the operating line, the net Tcd demand rate is 70°R/sec. When the error becomes Zero, the Tcd rate becomes 50°R/sec to the programmed operating point.

In Run No. 4, the Tcd was 420°R above the operating line (900°R) at BSD. The 420°R error was removed at 20°R/sec for 2 sec then switched by CTE command to 50°R/sec, until the Tcd reached the normal operating line. During the 50°R/sec error removal period (when Tcd demand should have been Zero) Tcd drifted downward 2.3°R/sec (See Figure 1) indicating that a minor voltage error existed between the program generator and the error removal generator. This is within normal tolerances, however, and is considered to be acceptable.

Hot Core (Run #5)

The engine parameters at "Start Engine" for Run No. 5 were: power level of 87.5 Kw, core station temperature of 1082°R, T_{RI} (T.306) was 144°R. As in Run No. 4, the drums ramped open exponentially to 95.5° on a two-second time constant and then continued to open with a ramp of 0.14°R/sec (See Figure 3, sheet 1 of 2). The T_{RI} (T.306) < 125°R condition was satisfied at the end of Run No. 4 RT 58981.8.

Tcm (T.158) decreased approximately 325°R to the minimum of 934°R with Tcd tracking down (+100°R) to a hold. The hold of Tcd when Tcm increased was as predicted. When Tcm was 102°R above Tcd, TLC occurred and Tcd ramped up at 25°R/sec until BSC occurred.

CDC was manually bypassed at RT 59266.6 (1 sec after TLC) because TRI (T.306) had not decreased to the 80°R set point and accounts for the lack of a 15°R/sec ramp rate.

At BSC, Tcd was 414°R above the operating line (900°R); this error was removed at 50°R/sec (a net Tcd demand of Zero) until Tcd reached the normal operating line.

TPCV opened to 45.6° maximum during the bootstrap phase, 1.4° short of the clamp (See Figure 5, sheet 1 of 2).

The Run No. 5 section of the EP-8A Test Operating Procedure called for the temperature controller input signal to be transferred to T.622. However, the input relay contacts to the temperature controller only have two signals available, T.158 and T.624. The T.624 is a linearized version of the T.622 signal. Therefore, the input to the temperature controller is actually T.624, rather than the T.622 specified.

At RT 59397 the input signal to the temperature controller was transferred from T.158 (average measured chamber temperature) to T.624 (average core station temperature, T.622 linearized). The error was manually Zeroed on the CTE console and the engine was transferred from drum and TPCV control to temperature and TPCV control (RT 59402).

The TPCV was manually stepped inward from 36.4° to 29.5° at RT 59418 (See Figure 5, sheet 2 of 2). This produced a maximum negative control temperature error (T.602) of 66°R in the temperature controller, 15 seconds after TPCV was stepped. The temperature controller error then returned to Zero 9 seconds later and continued to a maximum positive temperature error of 132°R approximately 40 seconds after TPCV was stepped. These excursions of the temperature controller caused a maximum temperature swing in the in-core temperature (T.624) of 143°R about a nominal of 650°R and a swing of $\pm$ 50°R in the chamber temperature (T.158). SPEAR Memo No. 8 expands this analysis of the temperature controller and provides conclusion as to its relative performance.

CONCLUSIONS:

The (wet) temperature autostart controls operated satisfactorily during engine startup from the high source power limit and from a hot core. The use of T.624 dor input to the temperature controller also appeared to operate as expected. The controls are satisfactory for subsequent EP's. No data anomalies were noted.

TABLE I

CHRONOLOGY OF EP-8A (WET) TEMPERATURE AUTOSTARTS

Run No.	Event	Source	Range Time
4	PDSV Open	SR641	58819.1
	Start Engine	SC617	58836.1
	Drum Linear Ramp Start (DRS)	BC914	58805.0 *
	Temperature Loop Closure (TLC)	BC655	58883.9
	Chilldown Complete (CDC)	BC915	58836.0
	Pressure Loop Closure (PLC)	BC657	58883.9
	Pressure Null (PN)	BC916	58894.5
	Bootstrap Complete (BSC)	BC912	58894.5
	Program Shutdown	SC618	58969.6
	Programmer Reset	SC618	58981.5
5	PDSV Open	SR641	59182.1
	Start Engine	SC617	59193.3
	Drum Linear Ramp Start	BC914	58981.8 *
	Temperature Loop Closure	BC655	59265.9
	Chilldown Complete	BC915	59266.6
	Pressure Loop Closure	BC657	59266.6
	Pressure Null	BC916	59277.6
	Bootstrap Complete	BC912	59277.6
	Program Shutdown	SC618	59667.8
	Programmer Rest	SC618	59668.4

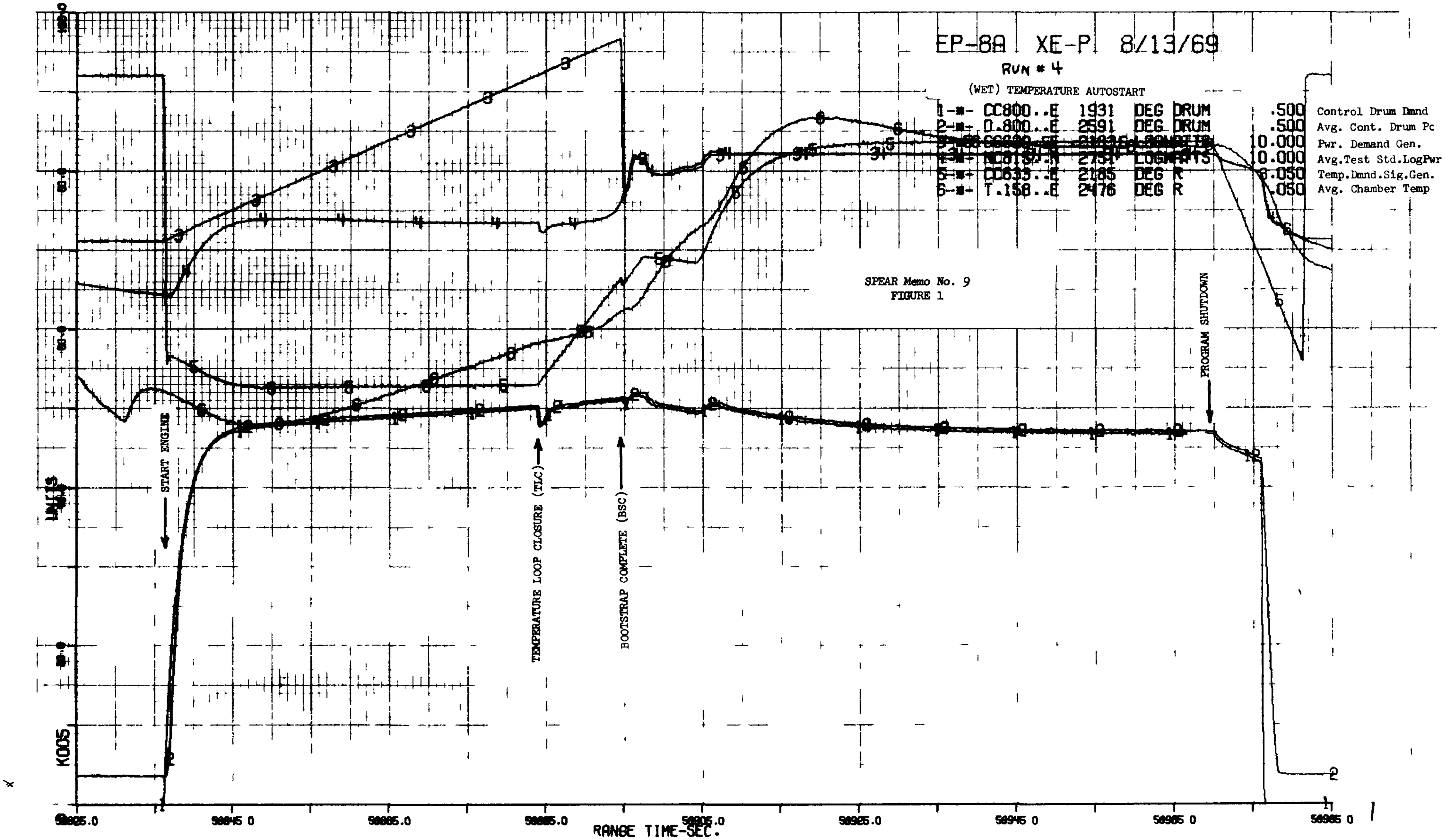
* Drum Ramp Start (DRS) indicates that the T_{RI} constraint for the beginning of the drum linear ramp has been relived (i.e., $T_{RI} < 125^oR$). Drum programs are constrained by definition until Start Reactor circuits operate.

TABLE II

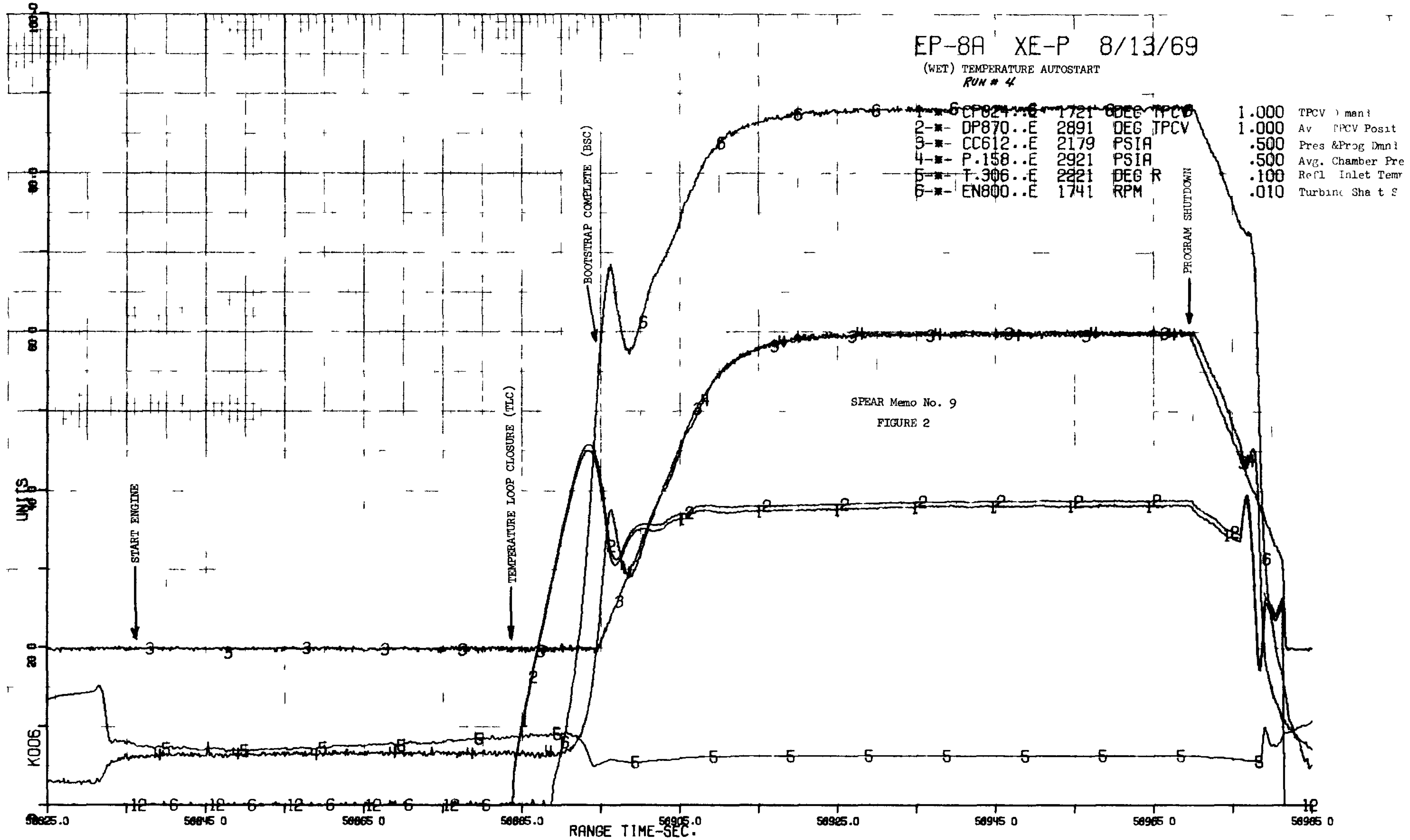
(WET) TEMPERATURE AUTOSTART PARAMETER SUMMARY

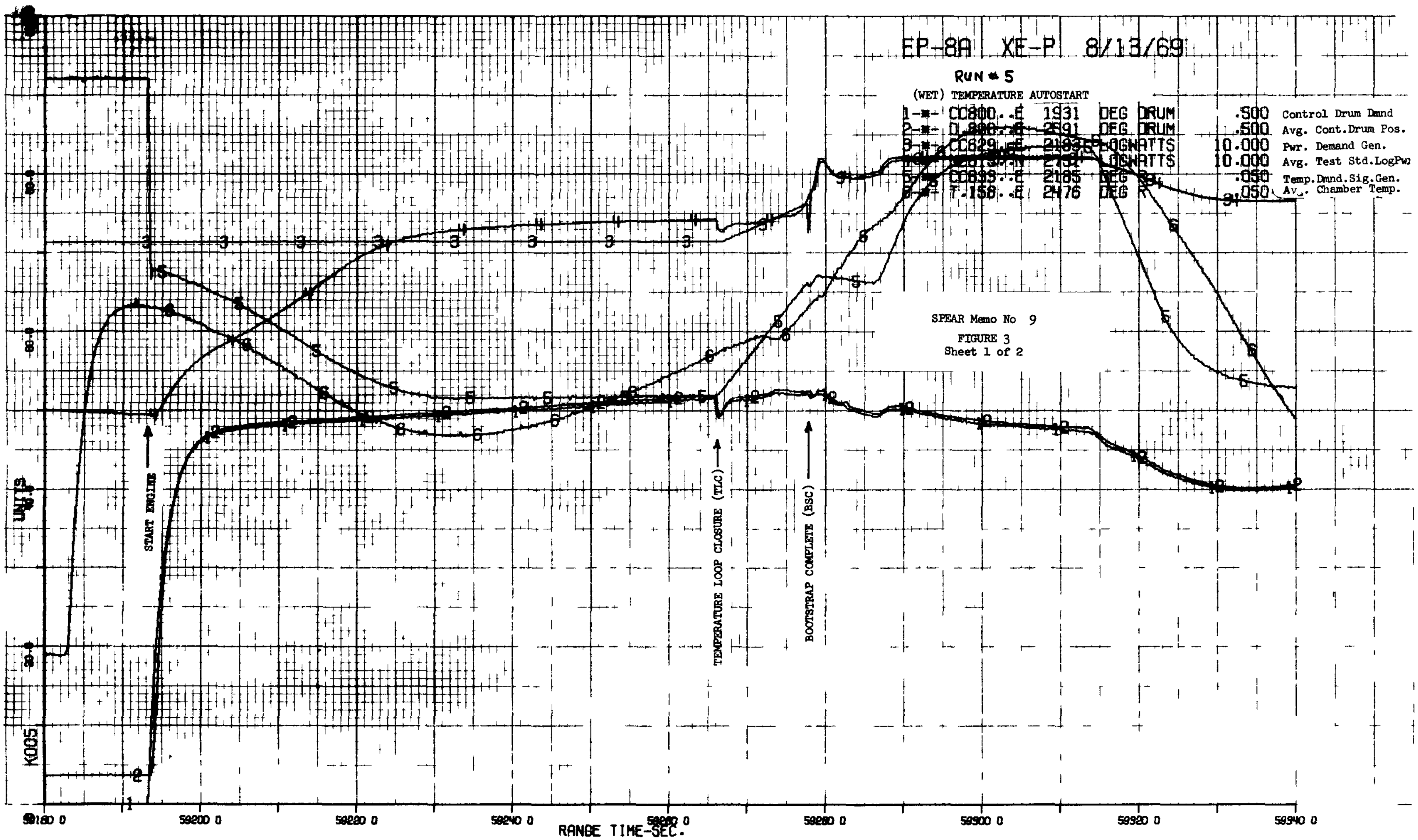
	Run No. 4	Run No. 5
DRUM CONTROL		
Exponential Value at DRS	95.5 Degrees	95.5 Degrees
Time Constant, Sec	2 sec (2 planned)	2 sec
Ramp	0.139 deg/sec (0.15 sec planned)	0.14 deg/sec
REFLECTOR INLET TEMPERATURES		
At Drum Ramp Start	85°R @ 58805.0	85°R @ 58981.8
Tri Minimum	49°R @ 58894.2	49°R @ 59277.3
Tri at CDC	75°R @ 58836.0	104°R @ 59266.6 (Manual CDC)
TPCV		
Maximum position during bootstrap (PLC to BSC)	45.5 Degrees	45.6 Degrees
Chamber Temperature Demand		
Track (Start Engine to $\dot{T}cm > 0$)	96°R	96°R
Hold ($\dot{T}cm > 0$ to TLC)	Negligible Drift (± 2°R)	Negligible Drift (± 5°R)
Tcm - Tcd (at TLC)	102°R	102°R
Tcd Ramp (TLC to CDC)	CDC occurred at or prior to TLC therefore no 15°R/sec ramp rate	
Tcd Ramp (CDC* to BSC)	25°R/sec	25°R/sec
Tcd BSC Error (Removal Rate)	20/50°R	50°R
Tcd Error at BSC	420°R	414°R

NOTE: * CDC occurred prior to TLC so ramp did not start until TLC.



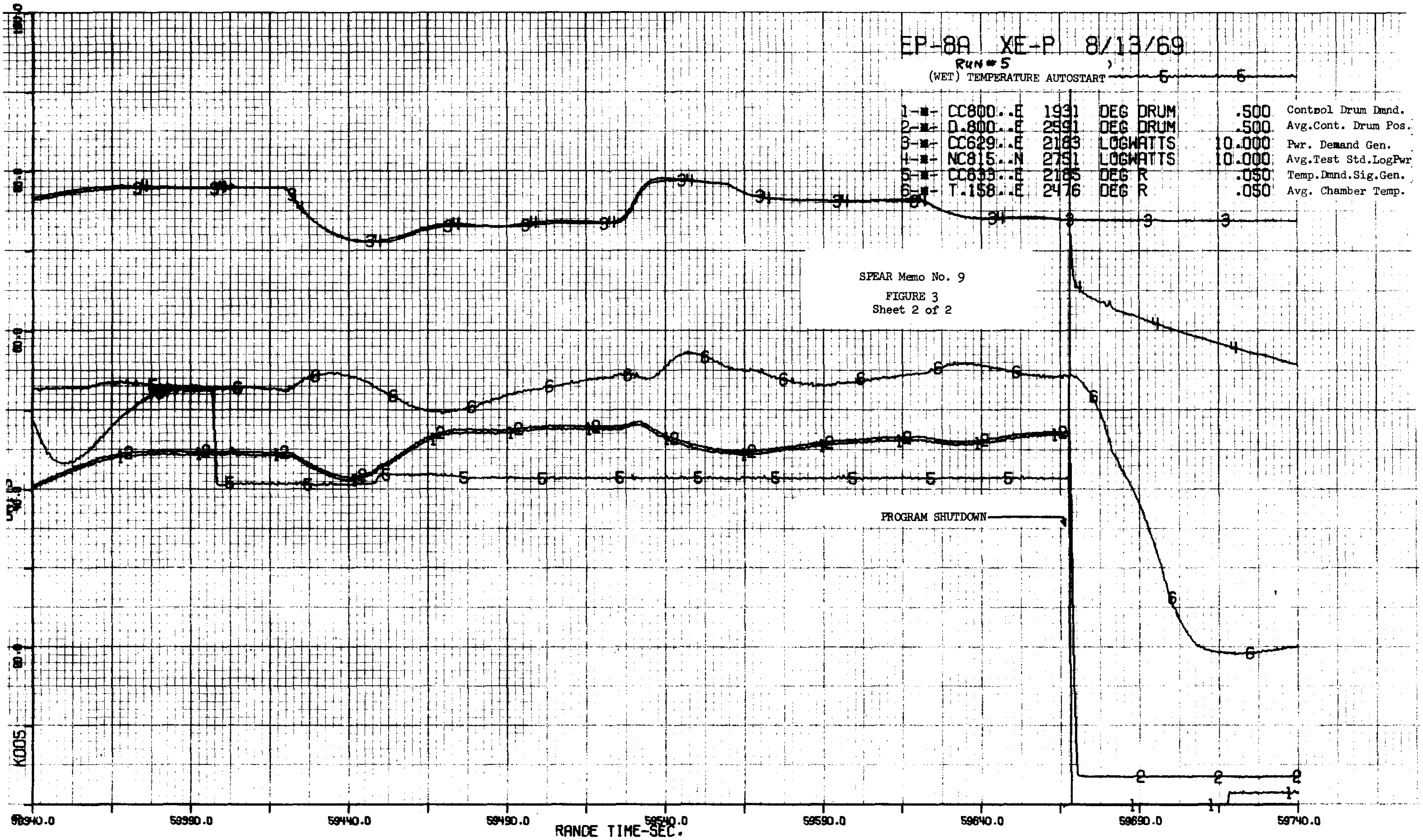
SPEAR Memo No. 9
FIGURE 1


EP-8A XE-P 8/13/69
(WET) TEMPERATURE AUTOSTART
RUN # 4
1-*- CP024..E 1721 DEG TPCV 1.000 TPCV Demand
2-*- DP870..E 2891 DEG TPCV 1.000 Av TPCV Posit
3-*- CC612..E 2179 PSIA .500 Pres &Prog Dmnd
4-*- P.158..E 2921 PSIA .500 Avg. Chamber Pre
5-*- T.306..E 2221 DEG R .100 Refl Inlet Temp
6-*- EN800..E 1741 RPM .010 Turbine Shaft S
SPEAR Memo No. 9
FIGURE 2
START ENGINE
TEMPERATURE LOOP CLOSURE (TLC)
BOOTSTRAP COMPLETE (BSC)
PROGRAM SHUTDOWN
UNITS
K006
RANGE TIME-SEC.
58825.0
58845.0
58865.0
58885.0
58905.0
58925.0
58945.0
58965.0
58985.0



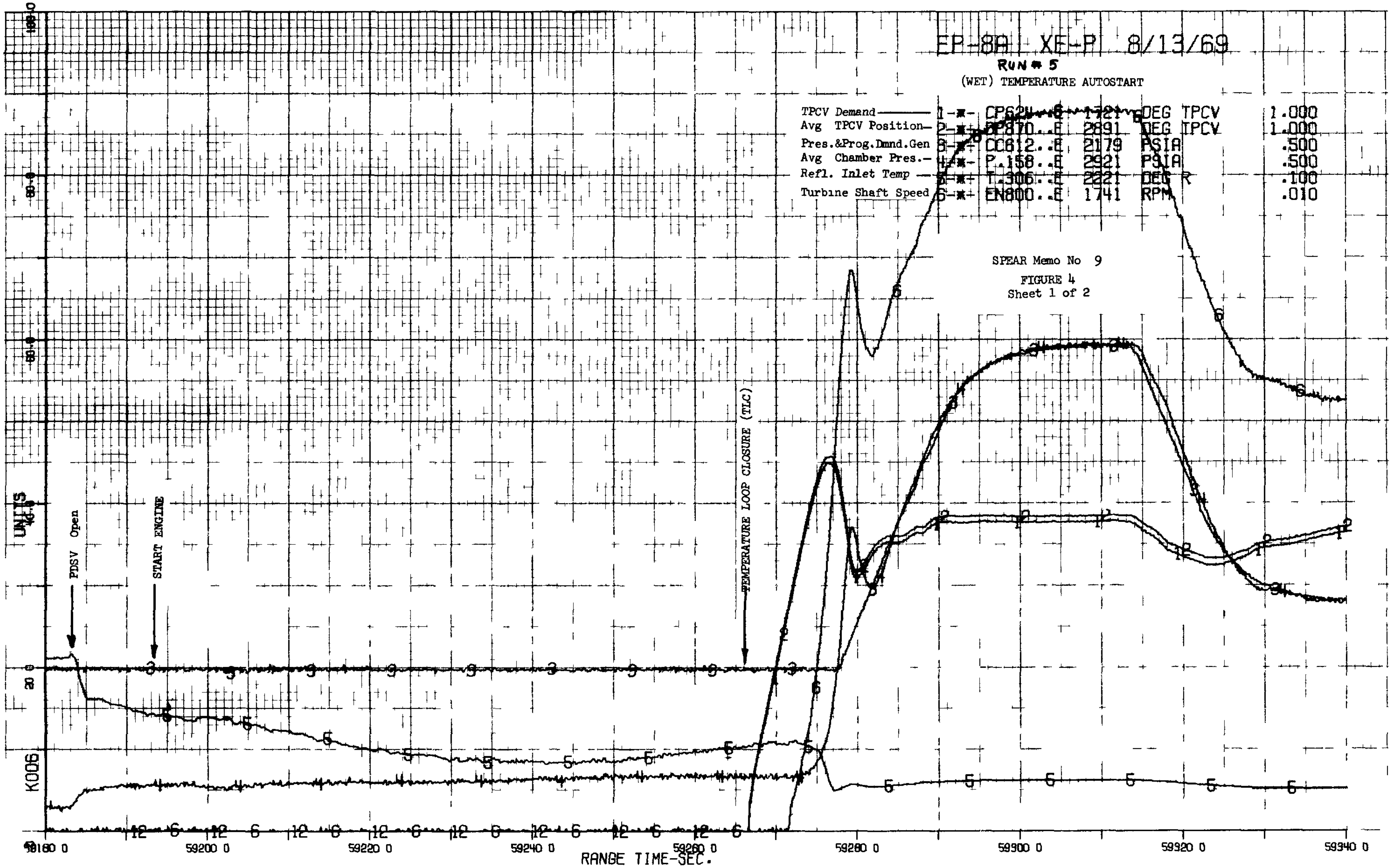
SPEAR Memo No 9

FIGURE 3
Sheet 1 of 2

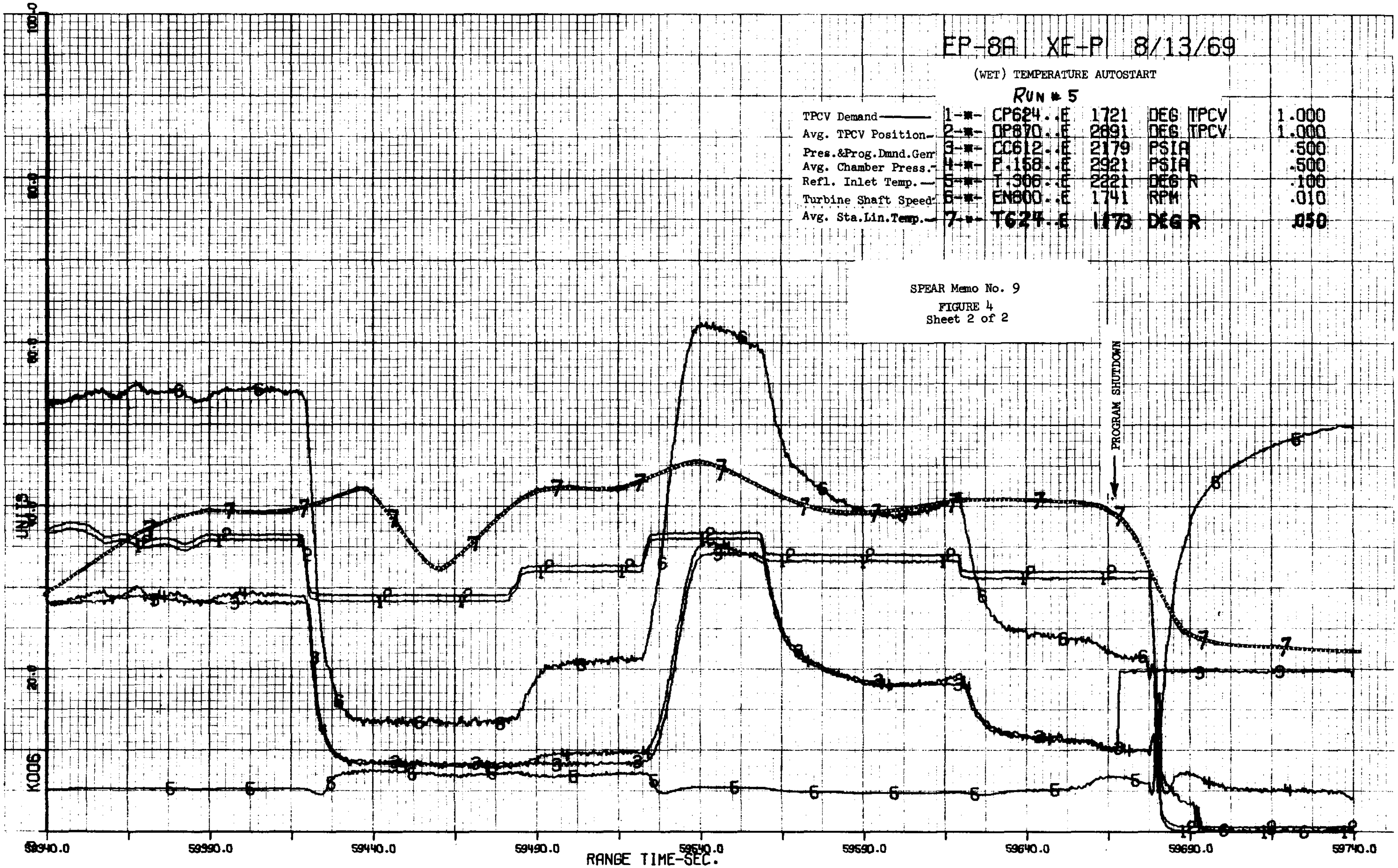


SPEAR Memo No. 9

FIGURE 3
Sheet 2 of 2



EP-8A XE-P 8/13/69
RUN # 5
(WET) TEMPERATURE AUTOSTART
TPCV Demand 1 CP62U..E 1721 DEG TPCV 1.000
Avg TPCV Position 2 BP870..E 2891 DEG TPCV 1.000
Pres.&Prog.Dmnd.Gen 3 CC612..E 2179 PSIA .500
Avg Chamber Pres. 4 P.158..E 2921 PSIA .500
Refl. Inlet Temp 5 T.306..E 2221 DEG R .100
Turbine Shaft Speed 6 EN800..E 1741 RPM .010
SPEAR Memo No 9
FIGURE 4
Sheet 1 of 2
PDSV Open
START ENGINE
TEMPERATURE LOOP CLOSURE (TLC)
UNITS
K006
RANGE TIME-SEC.
59180 0
59200 0
59220 0
59240 0
59260 0
59280 0
59300 0
59320 0
59340 0



SPEAR Memo No. 9

FIGURE 4
Sheet 2 of 2

SPEAR Memo No. 10
J. Archer:dl
J. Bock

XE PRIME

EP-8A

Subject: GENERAL CONTROL SYSTEM PERFORMANCE

SUMMARY

This memo briefly summarizes the performance of the control systems which warranted a detailed evaluation and which are not discussed in memos number 5, 7, and 9.

The following controls are covered in this memo:

1. TBV Position Control
2. TPCV Position Control
3. Shutdown Controller
4. Program Power Scram
5. V5002 Over-Pressure Detector
6. PCV 472 Step Control
7. Drum torque motor current
8. Exponential plus Ramp Drum Demand
9. Drum Program Terminate Detector

TECHNICAL DISCUSSION

TBV Position Control

A Turbine Blocking Valve (TBV) data anomaly in valve position channel (DR110) was noted after the EP-8A tests were completed. The TBV was commanded closed at RT 61356.5 and the valve closed immediately. The valve actuation pressure (PT 785) was approximately 60 psia at this time. Some 160 seconds later (RT2510) the data (DR110) indicated that the valve had partly reopened to 15%. A check of the valve open command channel (SR646) revealed no open command signal. The actuating pressure (PT896) was approximately 56 psia at this reopening. The data indicated that the valve reclosed to a 5% open position over a 100 second period, and remained at this position for approximately 900 seconds, then reopened (RT63468) with gas pressure (PT896) at 169 psia, followed by gradual closing at 169 psia. The data indicates that the TBV then gradually closed to approximately 4% open for the remainder of the data listing, with gas pressure staying around 167 psia.

Investigation into the possible cause of this anomaly has revealed that the circuit connector passing through the shield on top of the engine compartment shows existence of moisture.

TBV is a binary valve operated from low resistance solenoids and requires a low resistance source to operate. Since valve openings greater than 15% were not indicated by the data, it is concluded that the valve did not operate. Also, tests after the connector was dried out indicated that the valve and valve position channels were operating normally. Therefore, it is concluded that the abnormal position readings were caused by water from the deluge system in the connector.

TPCV Position Control

During the post-operational phase the TPCV position appeared to drift randomly. This phenomenon was witnessed by several of the operators and is shown in Figure 1 for RT 61970 through RT 62130. The actuation gas (PT897) at this time was approximately 14.0 psia, well below the pressure needed to drive the TPCV. The average position signal (DP870) was found to be following no. 1 position input (DP867) and not computing the average of the three (DP867, DP868 and DP869). DP868 and DP869 indicate some drift, see Figure 1, but not to the degree indicated on Channel DP867.

Subsequent testing revealed two problems: 1) water in a connector at the top shield and 2) TPCV position channels (DP868 and DP869) were found to be incorrectly wired internal to the TPCV controller chassis. The wiring error was corrected, the connector dried out, and functional tests performed showing normal operation. A review of EP-7A thinned data listing pass EC01 failed to reveal any erratic action of the three position signals; therefore, it is concluded the anomaly was caused by water from the deluge system in the connector at the top shield and the wiring error in the TPCV controller chassis.

Shutdown Controller

The existing shutdown controller has been used in EP-5C and EP-4A and was successfully demonstrated in both EP's.

Of the five runs conducted during EP-8A, only Numbers 2, 3, and 4 were terminated with the TPCV shutdown controller. The shutdown temperature demand (CP625) data was compared with the average chamber temperature (T.158) to provide an error signal and this in turn was compared with TPCV action to evaluate the shutdown controller performance for the three aforementioned tests.

In each of these tests the response of the TPCV position (DP870) was compared with the condition of the error signal and was found to be in agreement. The TPCV was properly positioned to eliminate the error. Therefore, the shutdown controller is considered to be operating properly.

Program Power Scram

During the initial phase of the Reactor Physics Tests, a Scram occurred at RT 45786.95. The drums were manually positioned to 93.2^{o}, then drum #1 was placed in individual control and rotated to 165^{o} (actuation position 173.7^{o}). The Peak Test Stand Log Power (NC815) was 1970 watts at the point of Program Power Scram initiation (see Figure 2).

The Program Power setpoint was 2 KW. The scram initiation was very close to the predicted setting and is considered to be well within tolerance.

The Program Power setpoint was changed to 10 KW and the test was continued without interruption.

V5002 Over-Pressure Detector

The V5002 over-pressure detector failed to operate at the expected pressure level during the pre-operational phase. The detector was adjusted and rechecked. The detector operated at approximately 230 psia and remained energized until the tank pressure (PT097X) dropped to approximately 150 psia. The exact dead band could not be determined from the data because the over-pressure detector event was not patched to data. Subsequent testing on 8/20/69 and 8/21/69 revealed a dead band of 56 psi.

Special short digital data listings for pass LCS1 were used for this analysis.

PCV 472 Step Control

During the pre-operational checkout of PCV 472 step control, the valve position meter indicated 23% open when it should have indicated 30%. The valve was operated and the signal conditioner properly spanned. On the subsequent checkout the thinned data listings indicated 28.5% and the valve position meter indicated approximately 30%, which is within acceptable limits.

No problems were experienced with the valve or the controller.

Drum Torque Motor Current

During the physics test at RT46400 while the control drums were stationary at 93^{o}, the drum torque motor current detector for control drum number 11 indicated a step from approximately 40 ma D.C. bias to 100+ ma D.C. bias current in a direction to drive the drum out. The thinned 1/10 listings and 100 sample/sec data were reviewed to determine movement of the drum. If there was movement of drum 11, it was within the noise level of the data and inconclusive. Also, the drum velocity signal was reviewed to determine the presence of a corrective signal. Here again, if there was a corrective signal, it was within the noise level of the data.

Subsequent to the test, the connectors at the top shield were inspected and moisture was found in P32 through which the control for drum 11 passes. The connector was dried out and potted to prevent further moisture problems. Drum tests performed on 8/21/69 showed no problems with drum 11 torque motor current.

Apparently, the moisture in the connector was furnishing a current path from a separate source to the 5 ohm resistor in the controller indicating a much higher current in the torque motor than was actually there.

This evidence is inconclusive and AGC and WANL Controls are continuing to investigate the cause.

Exponential Plus Ramp Drum Demand

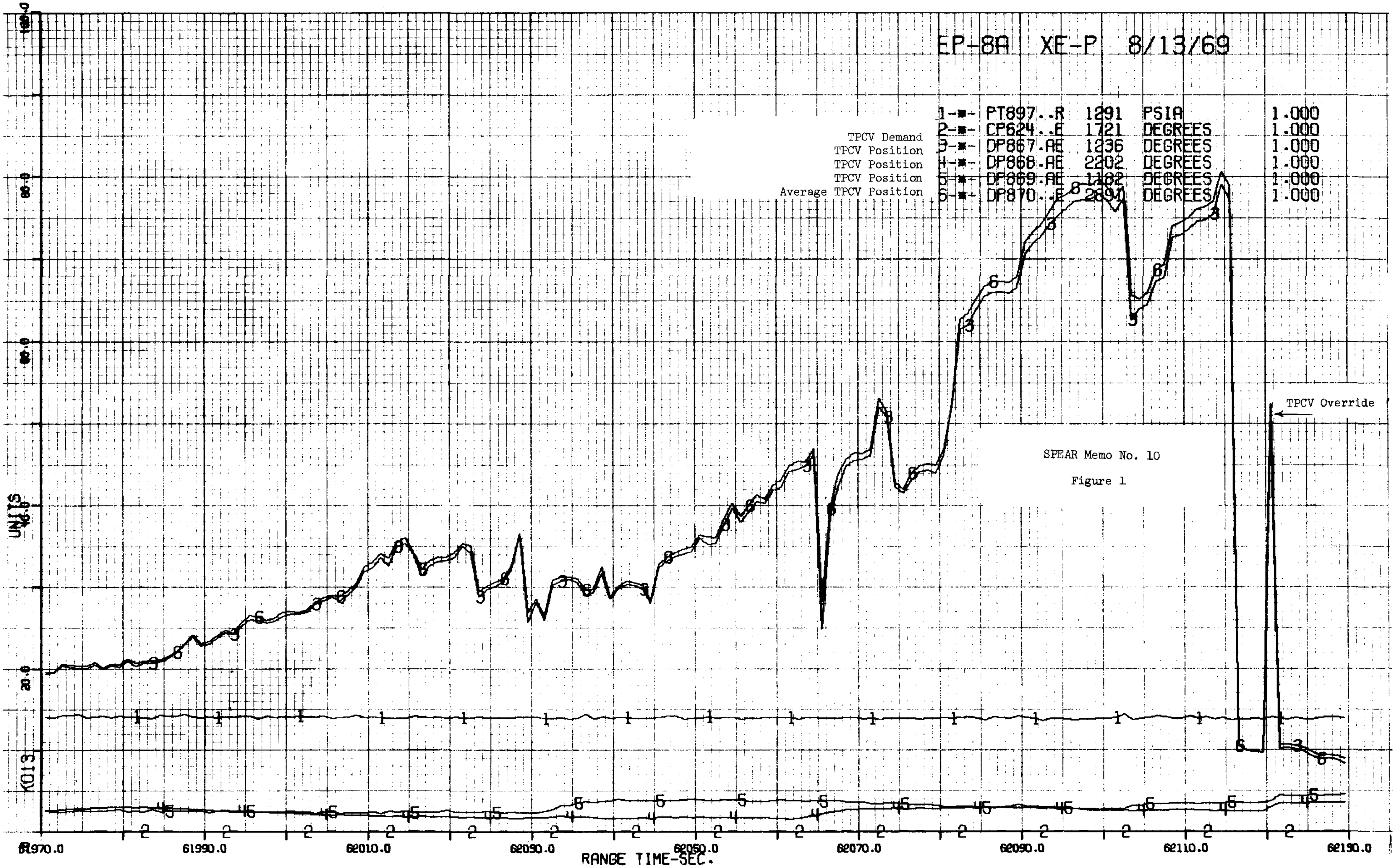
During the physics test prior to run #1, a problem was encountered with the exponential plus ramp drum position demand controller. The demand profile did not correlate with previous demand profiles for the same exponential and ramp potentiometer settings. Also during run # 2 the demand profile was not a smooth exponential plus ramp. See Figure 7 of memo no. 5.

On 8/21/69, investigation of the chassis connectors on the controller chassis 40R048A1 disclosed pin w in connector J4 was bent and possibly making a high resistance connection with pin DD. This evidence is not conclusive and further investigation is being conducted by AGC and WANL Controls personnel.

Drum Program Terminate Detector

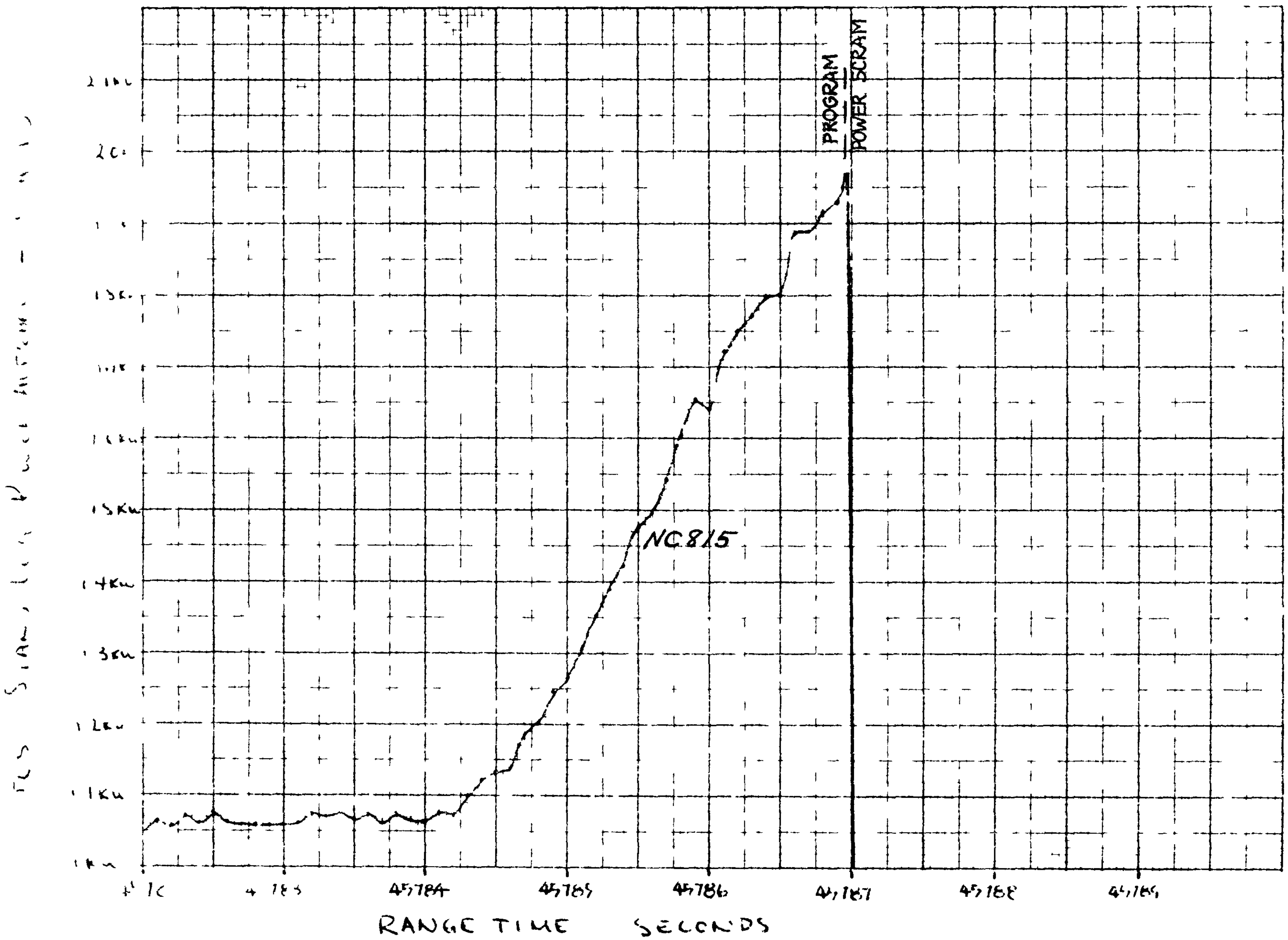
After the open loop startups, runs number 1 and 2, and prior to the damp autostart, run number 3, the drum program terminate (DPT) relay closed at RT 58452, RT 58554.3, and RT 58640.1 due to temperature rise in the core (T.910). The PDSV was pulsed open four times during this period to bring the temperature (T.910) down to ambient conditions.

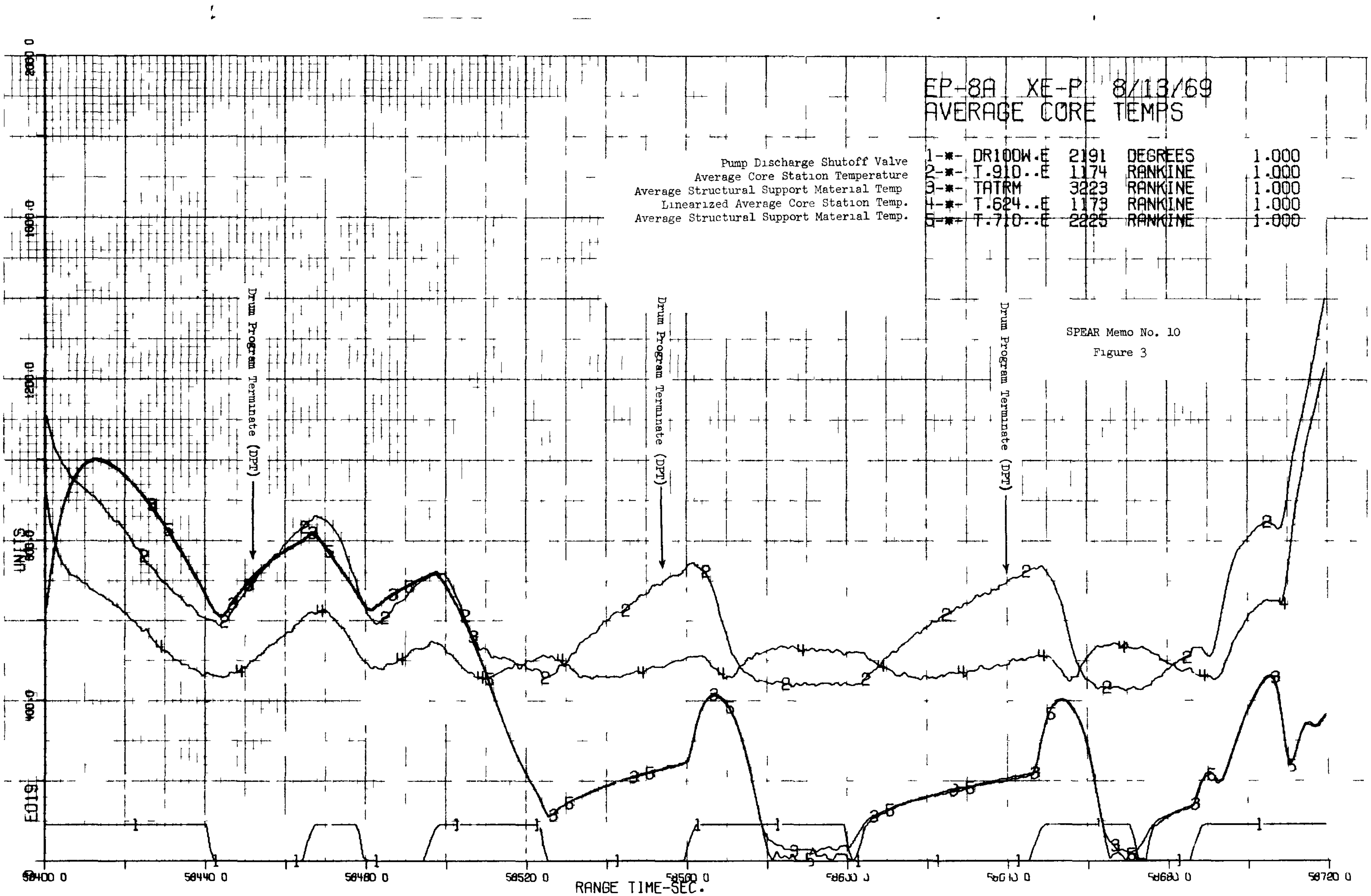
As can be seen from Figure 3, the drum program terminate signal (BC911) coincides with the increase of T.910 to 700^{o}R as expected.



SPEAR Memo No. 10

Figure 1


PROGRAM
POWER SCRAM
NC815
RANGE TIME SECONDS



EP-8A XE-P 8/13/69
AVERAGE CORE TEMPS
Pump Discharge Shutoff Valve 1-*- DR100W.E 2191 DEGREES 1.000
Average Core Station Temperature 2-*- T.910..E 1174 RANKINE 1.000
Average Structural Support Material Temp 3-*- TATRM 3223 RANKINE 1.000
Linearized Average Core Station Temp. 4-*- T.624..E 1173 RANKINE 1.000
Average Structural Support Material Temp. 5-*- T.710..E 2225 RANKINE 1.000
Drum Program Terminate (DPT)
Drum Program Terminate (DPT)
Drum Program Terminate (DPT)
SPEAR Memo No. 10
Figure 3
UNITS
E019
RANGE TIME-SEC.
58400 0
58440 0
58480 0
58520 0
58720 0

SPEAR Memo No. 11

A. L. Anderson/mg

ALA EJW

XE-PRIME

EP-8A

Subject: ENGINE STEADY STATE PERFORMANCE

SUMMARY:

The objective in obtaining the steady-state conditions of P_c = 300 psia and T_c = 2400°R on Run No. 1 of this EP was to take transfer function measurements in a position of relatively low power near the TPCV limit line on operating map. The rest of the steady-state hold points were at the nominal hold of P_c = 120 psia and T_c = 1700°R on the normal operating line during Runs No. 3 through 5. This hold point was selected as the highest practical operating temperature with the emergency cooldown system "off line".

There was relatively good agreement with digital predictions and good repeatability between EP's was obtained during the low power hold points, thus indicating no problems with proceeding to the next EP.

TECHNICAL DISCUSSION:

There were four steady-state hold time periods selected during EP-8A. These time slices were selected from the TDC plots and were generally chosen near the last five to ten seconds of the holds in order that the temperatures would have as much time as possible to stabilize. The time periods selected were as follows:

Run No. 1 - (Open Loop Startup from Ambient Conditions)	RT 57015 to 57025
Run No. 3 - (Damp Temperature Autostart)	RT 58777 to 58782
Run No. 4 - (Wet Temperature Autostart - Warm Core)	RT 58960 to 58970
Run No. 5 - (Wet Temperature Autostart - Hot Core)	RT 59308 to 59313

The values selected for the plenum pressures, temperatures and flow rates were generally obtained from the AGC NERVA Steady State Data Summary Program (E-57105). Program input was 1 sample/second data. Steady state summaries are shown in Tables I and II. This data was verified by looking at individual channels and comparing them with other measurements taken in the same plenums. Where differences occurred, as in the case of some of the pressures, Δ P readings were used to calculate backup data. There were some questionable measurement readings but, in most cases, these were also reported and discussed in earlier SPEAR Memos. A discussion of some of the differences between the summary program and the values selected in Tables I and II follows:

1. The turbine power control valve position pots DP 867, -868, -869 and the averager, DP 870, were not used in Tables I and II. The

averager showed a higher reading than the numerical average of the three pots as in past tests. An alternate method of taking the TPCV demand (CP.624..E) and subtracting the TPCV position error (D.627..E) was used. These two circuits were checked out recently and are known to be good between the valve potentiometers and the control room recorders.

2. Reactor power (thermal) was hand calculated, using the chamber pressure (PANC5) and chamber temperature (TANC). This method compared closely with the published P_c/T_c steady state map values of power.

3. The pressure in the ETC was predicted to be higher than the actual test data. This was assumed to be due to the difference in the ETC purge flow. The digital steady-state predictions assumed a 2-4 lbs/sec purge flow rate based on EP-III data. However, there was little or no ETC purge during this EP. Therefore, the steam generators were able to pull the pressure in the ETC down to a lower pressure.

4. The net positive suction pressure (NPSP) was lower than predicted during the bootstraps to $1700^{o}R$ due to the increase in run tank (V-5001) temperature. Tank topping was initiated immediately prior (RT 56907) to conducting the initial transfer function test (RT 57035). Tank outlet temperature increased from 36.6 ^{o}R at (RT 57015) to 40.0 ^{o}R at 59313. This higher temperature caused the lower NPSP during the bootstraps to low power (Runs No. 2 through 5).

Flow rates were obtained by using the following calculated parameters:

WHTURBI	-	Computed Turbine Inlet
WHBP	-	Computed Hot Bleed
WHDIL	-	Computed Diluent
WHNOZ	-	Computed Nozzle Chamber
WACTCL	-	Drum Actuator Coolant
WH847W	-	Accumulator H_2 Vent
WHBLTCL	-	Computed Bolt Coolant (X3)
WBECL3	-	Calculated (orifice) Bearing Coolant

From these, all other plenum flow rates were calculated. Good agreement (within 0.5 lb/sec) was obtained between the calculated pump inlet flow rate and the measured (density corrected) flow rate (WH014).

All plenum pressures were obtained by averaging what was considered to be the accurate measurements in each plenum. The exception to this was the reflector outlet pressure where the only transducer (PT304) was inoperative. However, in cross checking plenum pressure averages with the ΔP readings, an acceptable value was obtained. This method was used in verifying the reliability of many of the values of pressures used from the summary program.

Temperatures at the tank and the nozzle manifold were higher than predicted due to the tank topping taking place during a good portion of the test. After the hydrogen had passed through the nozzle tubes, the temperatures fell back in line with those obtained on EP-7A. There were some erroneous temperature readings throughout the system but, as with the pressures and flow rates, they were screened for validity.

CONCLUSIONS:

There was very good agreement between the past EP's and this test on the temperatures, pressures, and flow rates. The engine system at steady-state is following the predicted values very closely and there is no apparent reason that the engine cannot be further tested.

TABLE I

XE-PRIME EP- 8A STEADY-STATE HOLD POINT

P_c = 298 psia T_c = 2418 °R   Range Time = 57015 to 57025

	Predicted	Actual	
TURBINE POWER CONTROL VALVE POSITION	55.7	51.1	Degrees
REACTOR POWER	450	430	Megawatts
TURBOPUMP SHAFT SPEED	15423	15133	RPM
AMBIENT PRESSURE (ENGINE TEST COMPARTMENT)	1.72	.99	PSIA
NET POSITIVE SUCTION PRESSURE	17.4	20.0	PSI

STATION	FLOW (lb/sec)		PRESSURE (psia)		TEMPERATURE (Deg R)	
	Predicted	Actual	Predicted	Actual	Predicted	Actual
PROPELLANT TANK OUTLET	56.1	56.2	35.0 Δ	35.1	36.5	36.6
PUMP INLET	56.1	56.2	32.5	34.0	36.6	36.8
PUMP OUTLET	55.6	55.7	491	483	43.5	42.9
NOZZLE MANIFOLD INLET	54.9	54.7	464	458	43.8	44.3
NOZZLE TUBE OUTLET	52.8	50.1	388	393	82	-
REFLECTOR INLET	54.9	54.7	388	393	80	85.8
REFLECTOR OUTLET	54.9	54.7	373	377	115	-
SHIELD I OUTLET (DOME)	54.9	54.7	371	373	116	109
CORE INLET	50.7	50.4	368	368	124	130
CORE EXIT	50.7	50.4	300	298	2424	-
NOZZLE CHAMBER (T_c)	49.7	49.3	300	298	2400	2418
DILUENT BLEED INLET (DOME)	4.19	4.11	371	373	116	109
DILUENT BLEED OUTLET	4.19	4.11	355	351	125	119
HOT BLEED PORT	1.02	1.11	300	298	2400	2418
TPCV INLET	5.22	5.22	270	281	556	531
TURBINE INLET	5.22	5.22	209(T)	216(T)	559(T)	531(T)
TURBINE 2nd STAGE ROTOR EXIT	5.70	5.74	27	22.6	386	370
TURBINE EXHAUST NOZZLE	5.70	5.74	9.1	15.4	360	390

Δ = Ullage Pressure

(T) = Total

TABLE II

XE-PRIME EP-8A STEADY-STATE HOLD DATA

(Nominal Chamber Conditions - T_c = 1700°R, P_c = 120 psia)

	Predicted	RT 58777 to 58782	RT 58960 to 58970	RT 59308 to 59313
Turbine Power Control Valve Position, deg.	41.3	37.6	37.7	37.5
Reactor Power, Mw	149	144	143	144
Turbopump Shaft Speed, rpm	8760	8777	8798	8770
Ambient Pressure (ETC), psia	5.53	4.46	4.38	4.49
Net Positive Suction Press., psi	20.0	12.6	12.5	10.2
TEMPERATURES - °R				
Propellant Tank Outlet	36.8	39.3	39.5	40.0
Pump Inlet	36.9	39.5	39.7	40.3
Pump Outlet	39.3	41.7	41.9	42.4
Nozzle Manifold Inlet	39.4	43.8	44.0	44.7
Reflector Inlet	59	60.9	61.0	60.9
Reflector Outlet	82	-	-	-
Shield I Outlet (Dome)	83	66	65	64
Core Inlet	83	74	70	72
Nozzle Chamber	1700	1664	1656	1693
Diluent Bleed Inlet (Dome)	83	66	65	64
Diluent Bleed Outlet	88	74	76	80
Hot Bleed Port Inlet	1700	1664	1656	1693
TPCV Inlet	248	201	206	210
Turbine Inlet	248(T)	208 (T)	210 (T)	214 (T)
Turbine Exhaust	174	136	143	145
Turbine Exhaust Nozzle	184	149	152	162

(T) = Total

TABLE II - Cont'd

	Predicted	RT 58777 to 58782	RT 58960 to 58970	RT 59308 to 59313
PRESSURES - Psia				
Propellant Tank Ullage	35.0	35.1	35.1	35.1
Propellant Tank Outlet	36.2	35.3	35.3	35.2
Pump Inlet	35.6	35.6	35.7	35.5
Pump Outlet	184	184	184	182
Nozzle Manifold Inlet	176	178	179	176
Nozzle Tube Outlet	156	155	160	157
Reflector Inlet	156	155	160	157
Reflector Outlet	151	152	153	151
Shield I Outlet (Dome)	150	150	151	150
Core Inlet	152	150	149	149
Nozzle Chamber	120	119	120	119
Diluent Bleed Inlet (Dome)	150	150	151	150
Diluent Bleed Outlet	143	143	144	142
Hot Bleed Port Inlet	120	119	120	119
TPCV Inlet	118	118	118	117
Turbine Inlet	118 (T)	61.4(T)	61.8(T)	60.6(T)
Turbine 2nd Stage Rotor Exit	8	6.7	6.7	6.7
Turbine Exhaust Nozzle	5.53	5.1	5.1	5.1
FLOW RATES - lb/sec				
Propellant Tank Outlet	26.7	26.8	26.8	26.3
Pump Inlet	26.7	26.8	26.8	26.3
Pump Outlet	26.4	26.6	26.6	26.2
Nozzle Manifold Inlet	26.4	26.6	26.6	26.2
Nozzle Tube Outlet	25.4	24.1	24.1	23.6
Reflector Inlet	26.4	26.6	26.6	26.2
Reflector Outlet	26.4	26.6	26.6	26.2
Shield I Outlet (Dome)	26.4	26.6	26.6	26.2
Core Inlet	24.4	24.4	24.4	24.0
Nozzle Chamber	24.2	24.2	24.2	23.8
Diluent Bleed Inlet (Dome)	2.04	2.18	2.16	2.09
Diluent Bleed Outlet	2.04	2.18	2.16	2.09
Hot Bleed Port Inlet	0.21	0.23	0.23	0.23
Turbine Inlet	2.24	2.41	2.39	2.32
Turbine Exhaust	2.54	2.58	2.59	2.48
Turbine Exhaust Nozzle	2.54	2.58	2.59	2.48

SPEAR Memo No. 12
R. J. Williams
R J Williams

XE-PRIME

EP-8A

Subject: ENGINE CHILLDOWN AT REDUCED TANK PRESSURE

SUMMARY:

A successful engine chilldown at a run tank pressure of 25 psia was conducted in conjunction with the engine physics test. The TPA and engine were at ambient temperature at initiation of the chilldown and reactor power was maintained constant at about 1 Kw. Approximately 152 seconds were required to decrease the reflector inlet temperature (T.306) to 60^{O}R.

TECHNICAL DISCUSSION:

Data on engine chilldown characteristics at reduced tank pressure was considered desirable information because it is believed that the NERVA engine will operate at a lower tank pressure than 35 psia. Previous tests have shown that the XE system is capable of bootstrapping at tank pressures as low as 23 psia, however, since these were engine restarts, no chilldown data was obtained. The primary use intended for low tank pressure chilldown data is to provide a low pressure check case for the mathematical engine models to determine whether the fluid flow and heat transfer equations are sufficiently representative at these conditions of low pressure and flow rate. The application of the data obtained is beyond the scope of SPEAR. The data obtained was examined for reasonableness, and appears to be satisfactory. No anomalies were readily discernable. Plots of the system plenum fluid temperatures as a function of time are presented in Figure 1. The time required at a run tank pressure of 25 psia, for the reflector inlet temperature to decrease to 60^{O}R was approximately 152 seconds. The corresponding chilldown time at 35 psia was between 75 and 80 seconds. A tabulation of some plenum temperatures at the time that the reflector inlet reached 60^{O}R is compared to those obtained during EP-III in Table 1. (EP-III chilldown was conducted at similar conditions except the tank pressure was 35 psia and the ETC pressure was 8.2 psia). The reactor power level during both of the tests was low enough to be negligible with respect to thermal effects. It may be seen from the table that the dome and nozzle chamber temperatures are only moderately different.

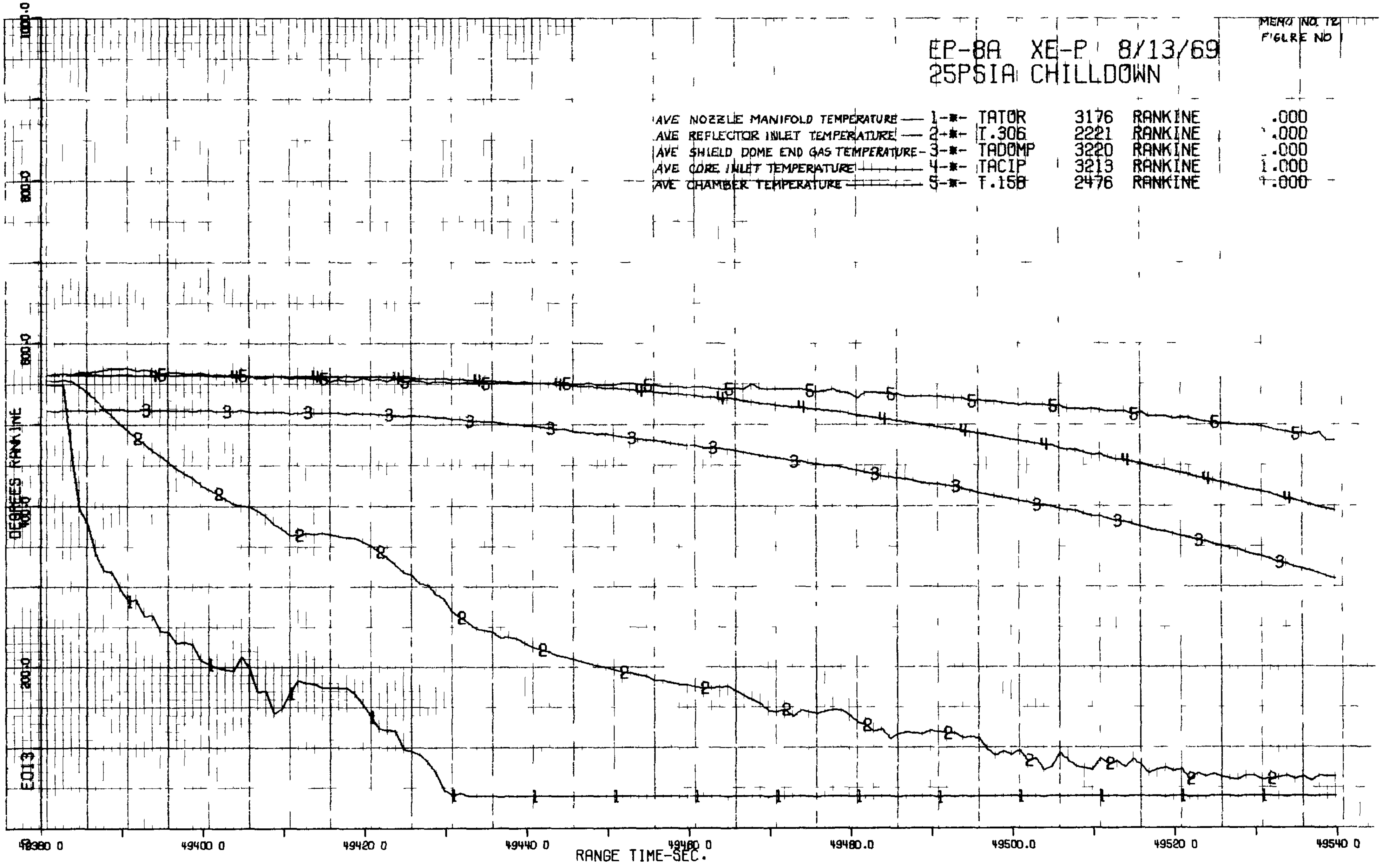
CONCLUSIONS:

Data was obtained on engine chilldown at a run tank pressure of 25 psia. As expected, the time required to chill the system to a reflector inlet temperature of 60^{O}R is considerably greater than it is with the run tank pressure at 35 psia.

TABLE 1

COMPARISON OF ENGINE PARAMETERS AT CHILLDOWN COMPLETE

EP	III	8A
P. Tank (PT099)	35.3	25.1
P. ETC (PT292)	8.2	12.7
T. Tank (TT032)	35.5	34.8
T. Reflt. In (T.306)	60.1	58.2
T. Dome (TDOMP)	334	318
T. Noz. (T.158)	469	486
Power (Approximate)	33 Kw	1 Kw



MEMO NO. 12
FIGURE NO 1
EP-8A XE-P 8/13/69
25PSIA CHILLDOWN
AVE NOZZLE MANIFOLD TEMPERATURE — 1-*- TATOR 3176 RANKINE .000
AVE REFLECTOR INLET TEMPERATURE — 2-*- T.306 2221 RANKINE .000
AVE SHIELD DOME END GAS TEMPERATURE — 3-*- TADOMP 3220 RANKINE .000
AVE CORE INLET TEMPERATURE — 4-*- TACIP 3213 RANKINE 1.000
AVE CHAMBER TEMPERATURE — 5-*- T.158 2476 RANKINE 1.000
DEGREES RANKINE
1000.0
800.0
600.0
400.0
200.0
E013
RANGE TIME-SEC.
49380 0
49400 0
49420 0
49440 0
49460 0
49480.0
49500.0
49520 0
49540 0

SPEAR Memo No. 13
R. J. Williams
R. J. Williams

XE PRIME

EP-8A

Subject: LOW POWER TPCV MAPPING

SUMMARY:

During Run 5, quasi steady-state engine operating characteristics were obtained at a chamber temperature of approximately 1100°R and discreet TPCV positions ranging from 37 to 29 degrees.

TECHNICAL DISCUSSION:

Just prior to shutdown during Run 5, TPCV was set to 36.5° (DP-870) in position control and the drums adjusted to provide a chamber temperature (T.158) of 1060°R. The "in core" temperature demand was adjusted to zero error and temperature control switched to the "in core" temperature (T.624) control loop. With the temperature demand held constant, the TPCV was ramped successively to 29°, 33°, 37°, 34°, and 32°. The resulting system response to these changes in TPCV position is presented in Figures 1 and 2. With respect to these figures, the following general characteristics of the engine system are noted:

1. At a chamber temperature of 1100°R (T.158) a TPCV position of 29° does not provide significant pumping action.

2. At a chamber temperature of 1100°R (T.158) a TPCV position of greater than 33° is required to obtain a chamber pressure of 40 psia (i.e. pressure null).

3. The system pressure level may overshoot and undershoot considerably when operated in this mode of control, (i.e. the chamber pressure at RT 59540 is 13 psia or 22.4% greater than at RT 59415 although TPCV position is 37° at both times).

4. At these conditions the system requires a long time to stabilize. Starting at RT 59550, the TPCV position was held constant for about 30 sec without attaining equilibrium.

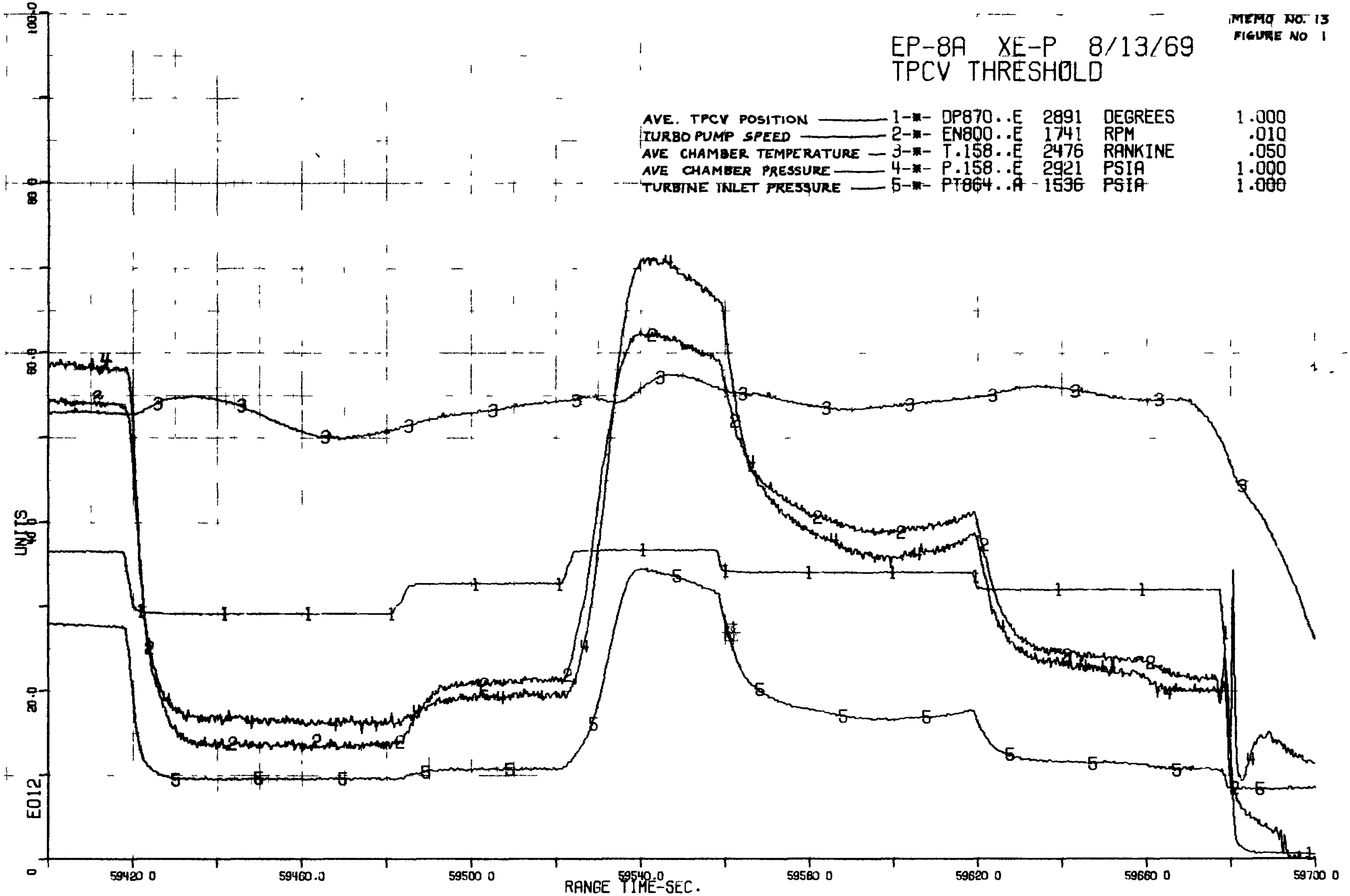
5. The pronounced decrease in pressures starting at RT 59660 was apparently caused by a shift in fluid properties in the nozzle tubes. Evidence of this is the marked increase in reflector inlet temperature starting at RT 59657.

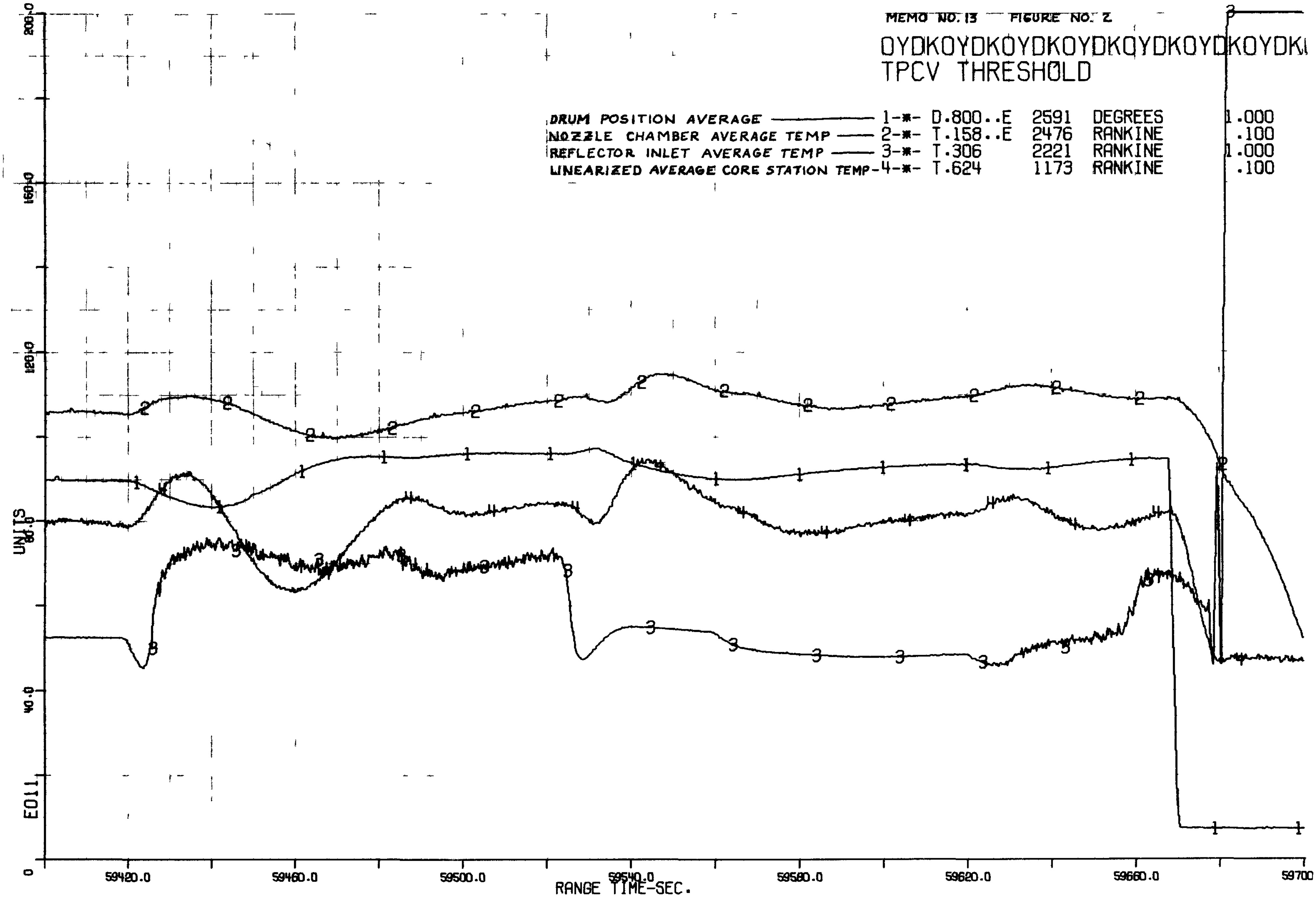
6. The "in-core" temperature control loop maintained chamber temperature within a band width of 150°R throughout this phase of testing. It is also interesting to note that the corresponding band width of the "in-core" temperature (T.624) used for the controller feedback was 300°R.

CONCLUSIONS:

Data was obtained with respect to engine system characteristics at low power and TPCV positions from 37 to 29 degrees.

Because the system pressures and flow rates were in the lower end of their instrumented range throughout this phase of testing, special attention should be given means of avoiding offset errors if this data is to be utilized in systems analysis.


MEMO NO. 13
FIGURE NO 1
EP-8A XE-P 8/13/69
TPCV THRESHOLD
AVE. TPCV POSITION —1-*- DP870..E 2891 DEGREES 1.000
TURBO PUMP SPEED —2-*- EN800..E 1741 RPM .010
AVE CHAMBER TEMPERATURE —3-*- T.158..E 2476 RANKINE .050
AVE CHAMBER PRESSURE —4-*- P.158..E 2921 PSIA 1.000
TURBINE INLET PRESSURE —5-*- PT864..A 1536 PSIA 1.000
UNITS
E012
RANGE TIME-SEC.
0
20.0
40.0
60.0
80.0
100.0
59420 0
59460.0
59500 0
59540.0
59580 0
59620 0
59660 0
59700 0


MEMO NO. 13 FIGURE NO. 2
OYDKOYDKOYDKOYDKOYDKOYDKOYDK
TPCV THRESHOLD
DRUM POSITION AVERAGE 1-*- D.800..E 2591 DEGREES 1.000
NOZZLE CHAMBER AVERAGE TEMP 2-*- T.158..E 2476 RANKINE .100
REFLECTOR INLET AVERAGE TEMP 3-*- T.306 2221 RANKINE 1.000
LINEARIZED AVERAGE CORE STATION TEMP 4-*- T.624 1173 RANKINE .100
200.0
160.0
120.0
80.0
40.0
0
UNITS
E011
59420.0
59460.0
59500.0
59540.0
59580.0
59620.0
59660.0
59700
RANGE TIME-SEC.

SPEAR Memo No. 14

G. Ross/J. K. Endo

XE-PRIME

EP-8A

Subject: REFLECTOR, SHIELD AND SUPPORT PLATE THERMAL AND FLUID PERFORMANCE

SUMMARY:

No apparent conditions exist that would prevent further testing of the nuclear subsystem components. All of the temperatures and pressures remained within the established limits as a result of the intermediate and low power and flows attained during EP-8A.

TECHNICAL DISCUSSION:

The data for this memo were obtained from NTO Thinned Digital Data and CALCOMP Plots, the WANL Multiplots, and WANL Listing of Data and Calibration Results.

The Zero calibration point for the shield dome-end gas and core inlet plenum thermocouples is 8°R. However, after the first run, during reflector childown operations below 60°R, they tended to be erratic. During some of the steady-state hold points TE501 and TE506 were below 60°R and erratic, thus, they are not listed in Table I. Table I lists the majority of the NSS parameters during four steady-state hold points. T_c was approximately 2400°R for the first steady-state hold (Run No. 1) and T_c was approximately 1700°R for the last three steady-state hold points (Runs No. 3, 4, and 5.).

The thermocouple, TE505 (shield dome-end gas temperature) calibrated properly; however, the parameter did not respond when the calibration signal was removed and indicated approximately 300°R at ambient conditions and throughout the entire run.

The pressure transducers, PD603 (core axial pressure drop) and PT706 (core exit pressure) were calibrated to a full scale of 53.4 psid and 163 psia, respectively. Therefore, during the first run (2400°R, 300 psia) they saturated at the above values. This data is not shown in Table I. However, during the subsequent four runs at the lower powers (1700°R/120 psia) they did not exceed the maximum calibration value and functioned properly.

Pressure Oscillations

The reflector inlet and outlet data indicated pressure oscillations during the low power hold points. This pressure oscillation has occurred in all of the previous EP's at low power hold points and does not appear to be detrimental to the nuclear subsystem.

CONCLUSION:

The nuclear subsystem components and instrumentation performed as expected.

TABLE I

N.S.S. COMPONENT PRESSURES AND TEMPERATURES AT FOUR STEADY-STATE HOLD POINTS

(Average data taken over 5 and 10-second intervals from WANL listings of data & calculation results)

LOCATION	CHANNEL		CRT, Seconds 57020 ± 5	58779.5 ± 2.5	58965 ± 5	59310.5 ± 2.5
NOZZLE CHAMBER	TC1 *	°R	2418.	1665.	1656.	1690.
	P.Chamb	psia	298.	119.	120.	119.
	FE014	lb/sec	55.8	27.6	27.7	27.5
REFLECTOR INLET PLENUM TEMPERATURE	TT217	°R	84.7	58.9	58.9	58.7
	TT218		81.6	58.8	58.9	58.7
	TT219		81.3	58.7	58.7	58.7
	TT371		90.0	63.8	63.3	63.4
	TT372		84.0	60.7	60.7	60.6
	TT373		88.5	62.9	63.0	62.8
	T.306		87.2	61.9	62.0	61.9
PRESSURE VESSEL ANNULUS EXIT TEMPERATURE	TE223	°R	91.6	69.6	70.4	80.7
	TE226		97.4	68.4	69.8	92.1
SHIELD DOME-END GAS TEMPERATURE	TE501	°R	105.1			
	TE502		111.1	64.4	64.7	66.2
	TE503		117.8	65.2	64.8	65.6
	TE504		108.7			60.4
	TE505		(N.G.)	(N.G.)	(N.G.)	(N.G.)
	TE506		101.0			60.2
CORE INLET PLENUM TEMPERATURE	TE776	°R	134.5	77.5	77.9	82.9
	TE777		129.2	80.8	81.3	87.4
	TE778		126.8	78.4	80.2	85.6
	TE779		131.8	73.7	73.2	66.5
	TE780		130.8	67.0	67.9	72.2
	TE781		124.8	69.0	67.9	70.8
	TE782		134.3	77.1	76.6	77.4
	TE783		133.9	65.2	64.6	57.5
	TE784		133.5	61.4	61.9	62.5
	TE785		127.7	60.2	62.2	74.3
	TE786		123.8	68.3	67.7	69.4
REFLECTOR INLET PLENUM PRESSURE	~~PT210~~	psia	~~392.2~~	~~159.0~~	159.8	157.8
	PT300		391.7	156.5	157.5	155.9
PRESSURE VESSEL ANNULUS PRESSURE	PT212	psia	394.2	157.3	158.2	156.3
	PT214		391.2	157.0	157.6	155.5
OUTER REFLECTOR, OUTER PLENUM PRESSURE	PT304	psia	(NG)	(NG)	(NG)	(NG)
SHIELD DOME END GAS PRESSURE	PT500	psia	373.1	149.9	150.7	149.3
DILUENT LINE ENTRANCE PRESSURE	PT225	psia	373.7	152.0	152.9	151.0
CORE INLET PLENUM PRESSURE	PT604	psia	373.3	152.0	152.9	151.5
	PT606		362.9	147.4	148.6	147.5
CORE EXIT PRESSURE	PT702	psia	297.1	118.7	119.4	118.5
	PT704		295.6	117.4	118.2	117.4
	PT706		(NG)	120.3	120.8	119.5
SUPPORT RING PRESSURE DROP	PD205	psid	16.9	5.5	5.7	5.8
OUTER REFLECTOR PRESSURE DROP	PD301	psid	16.1	5.2	5.3	5.5
SEAL CHAMBER II TO CORE EXIT PRESSURE DROP	PD423	psid	50.4	20.3	20.8	20.9
SHIELD PRESSURE DROP	PD501	psid	6.0	2.5	2.5	2.9
CORE AXIAL PRESSURE DROP	PD603	psid	(NG)	30.1	30.2	29.8
	PD605		72.5	29.1	29.3	29.2
REACTOR PRESSURE DROP	PD607	psid	93.4	36.1	36.5	36.3
	PD609		(NG)	(NG)	(NG)	(NG)
CORE INLET TO INTERSTICE	PD611	psid	5.7	2.7	2.9	3.8
	PD613		-.9	-.9	-.7	-.4
	PD615		4.2	1.3	1.4	1.7
	PD617		3.0	-.6	-.6	-.6
	PD619		5.3	1.7	1.7	2.1
	PD621		1.4	-1.5	-1.4	-1.0

NOTE: * Numerical average of four chamber thermocouples.

SPEAR Memo No. 15
J. K. Endo/G. Ross

JKE.

XE-PRIME

EP-8A

Subject: REACTOR THERMAL PERFORMANCE

SUMMARY

The thermal performance of the reactor core during EP-8A was essentially as expected, and within the temperature limits. No significant anomalies were observed.

Thermocouple TE658 (core element) gave an erroneous reading during the entire test.

The faulty multiplexer card which caused TE690 to give erroneous readings during EP-7A was replaced and TE690 performed satisfactorily during EP-8A.

TECHNICAL DISCUSSION

In performing EP-8A the core was subjected to five thermal cycles. The core temperatures reached a peak of approximately 3000°R and were then lowered to 2400°R in the first cycle and 1700°R in the other four cycles. The run profiles are illustrated in the Summary Plots (Figures No. 1, 2, 4, 5, 7, 8, 10 and 11). The power, core station temperature, structural support material temperature, and the chamber temperature, pressure and flow are shown in the above figures. The average core temperatures are presented in Figures No. 3, 6, 9, and 12.

The structural support material temperatures remained below the established limits during the entire run. However, Figure No. 9 indicates that the average temperature recorded by TATRM was approaching the limit during the period between Run No. 4 and Run No. 5 (CRT 59093). Reviewing the data for the individual structural support material thermocouples indicates that between Runs No. 4 and 5 one thermocouple, TE714, was within 40° of the maximum permitted.

Figures 9 and 12 also show that during this same period (CRT 59875-59180) the TATRM temperature became higher than the in-core temperature. While the in-core temperatures are normally higher than the structural material temperatures, it appears that during a shutdown period the reverse can be true where short pulses are used for cooldown purposes. The short pulses used during this period allowed the LH_2 coolant to reduce the in-core temperatures. However, the pulses were not long enough for the coolant to reach and reduce the structural support material temperatures. This is clearly seen in Figures No. 7, 8, and 9 at a CRT of 59065 seconds.

During the Physics Test, H_2 flow through the engine was initiated to provide data on the chilldown characteristics at reduced tank pressure (25 psia). The reflector inlet was also chilled to $60^\circ R$ during the test to determine the effect of the cold reflector on the core and reflector reactivity. This is evaluated in SPEAR Memo No. 16, in detail.

An open loop startup and shutdown was performed to determine the characteristics of engine operation with open loop control. This included an open loop startup from ambient conditions (Run No. 1), and a startup (Run No. 2) with a hot core (1200° to $1300^\circ R$ T_c), with cold reflector conditions. TPCV and drum transfer function measurements were made at T_c/P_c of $1000^\circ R$ and 60 psia on the second run.

Three temperature autostarts were performed. On the first (DAMP) autostart (Run No. 3) to $1700^\circ R$ and 120 psia, the in-core material temperature was used for control feedback. The start of the (DAMP) autostart was with an ambient core and cold reflector. The drums were then programmed exponentially to an ambient wet critical + 13 degrees and PDSV was opened at Start Reactor.

The last two (WET) temperature autostarts to a T_c/P_c of $1700^\circ R$ and 120 psia were made using the chamber temperature as control feedback. Run No. 4 was started with a warm core ($1000^\circ R$) and the other, (Run No. 5) with a hot core (1300° - $1500^\circ R$). Both autostarts were made with a cold reflector.

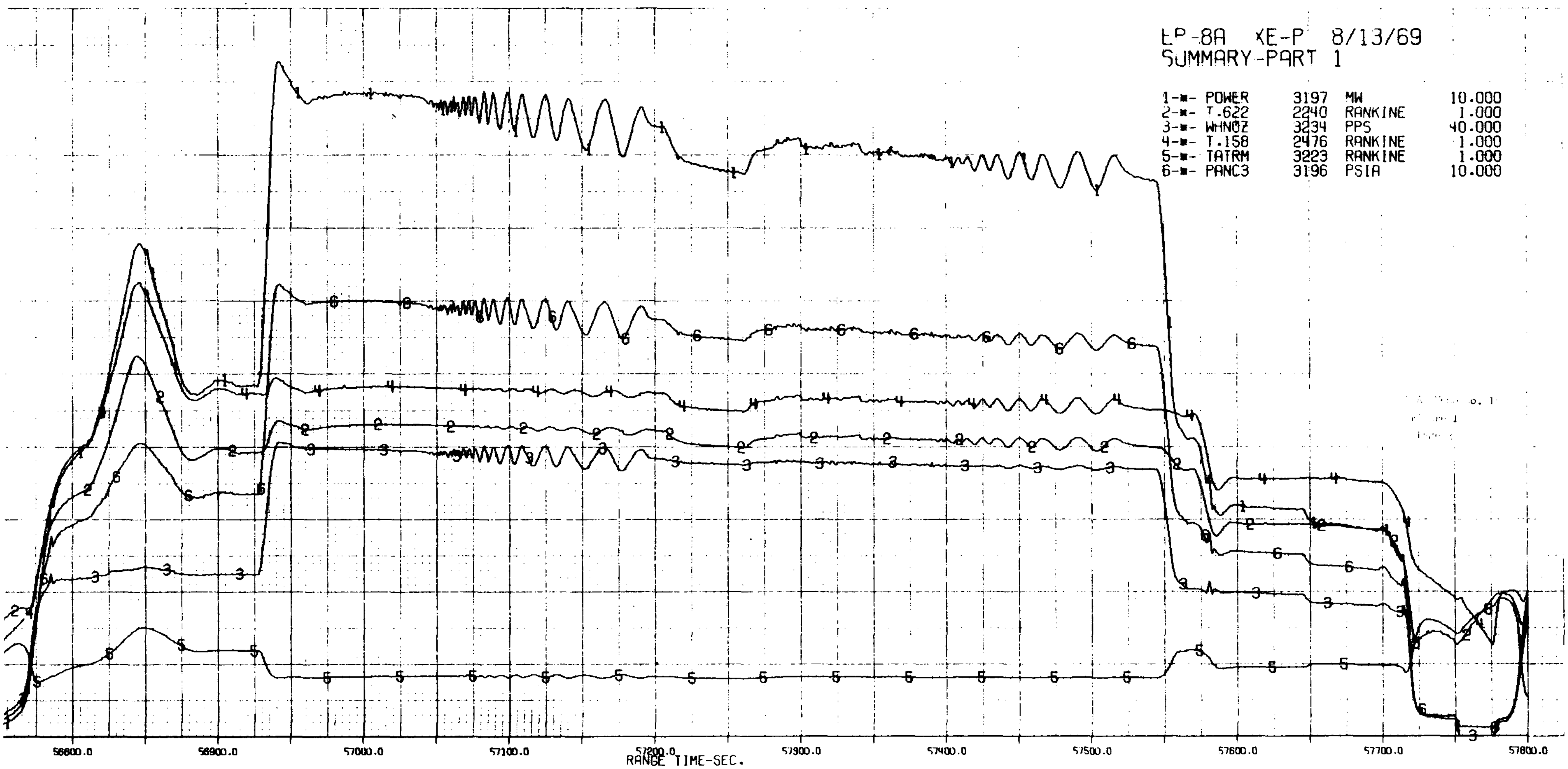
Thermocouple TE658 was very erratic during the entire run and was not considered in this memo.

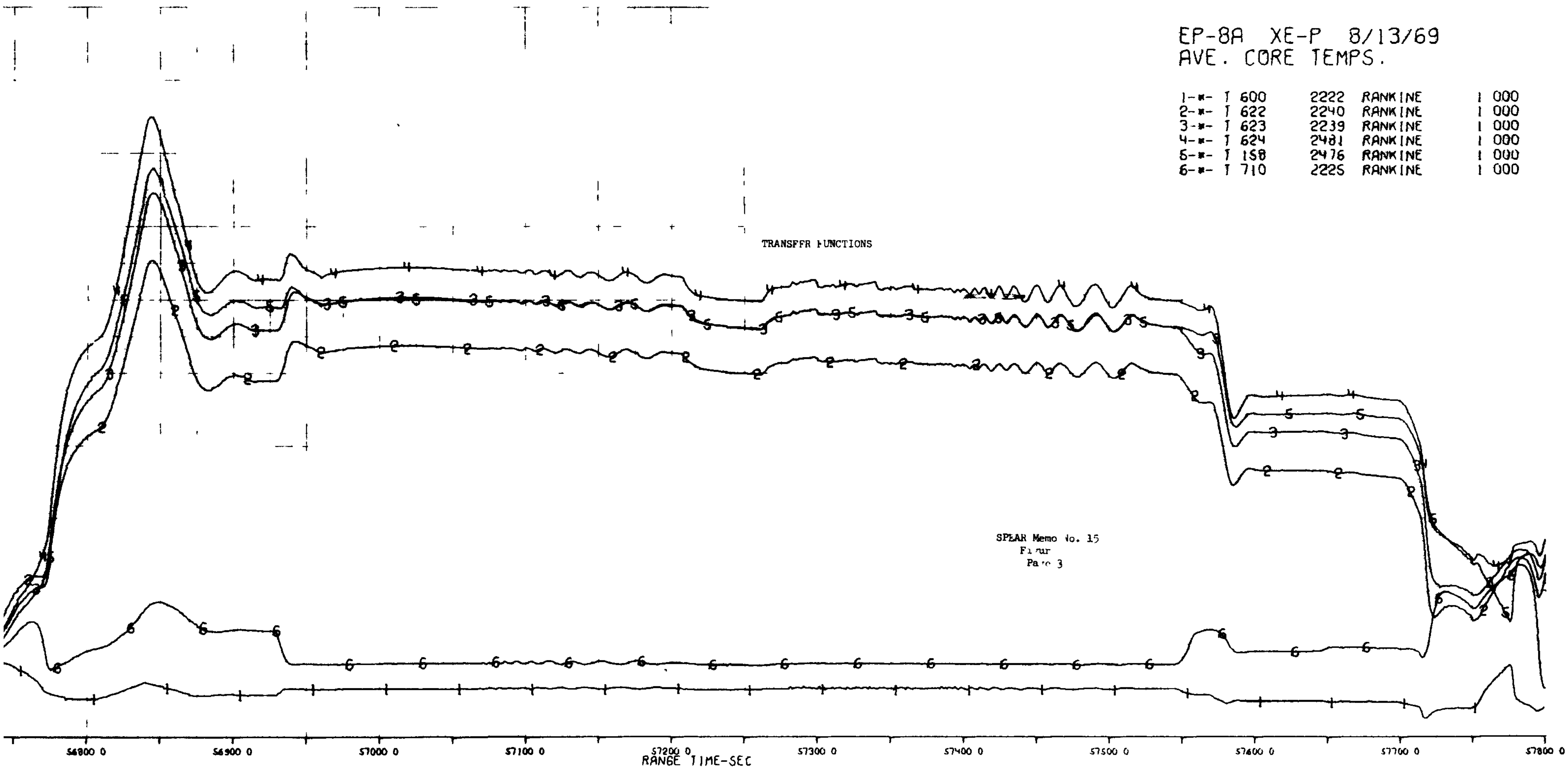
During the intermediate and low power operating periods, the flow distribution through the core remained satisfactory, with no apparent unacceptable cross-sectional variation in temperature.

Also shown in Figure 4, Run No. 2, is the system pressure oscillation experienced at P_c of 140 psia and T_c of approximately $1680^\circ R$. This has occurred in past EP's and has been reported in previous SPEAR memos.

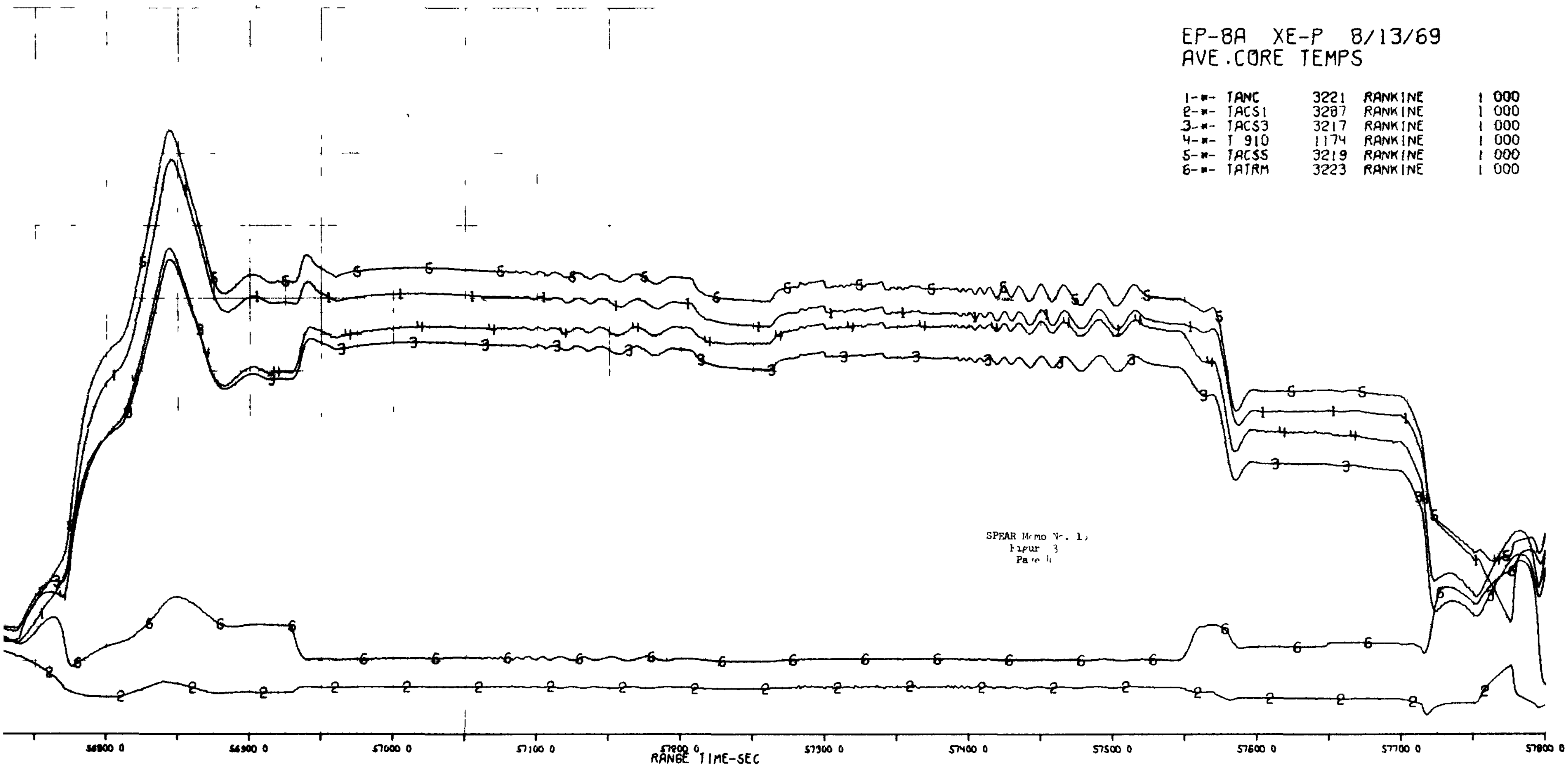
<u>CONCLUSIONS</u>

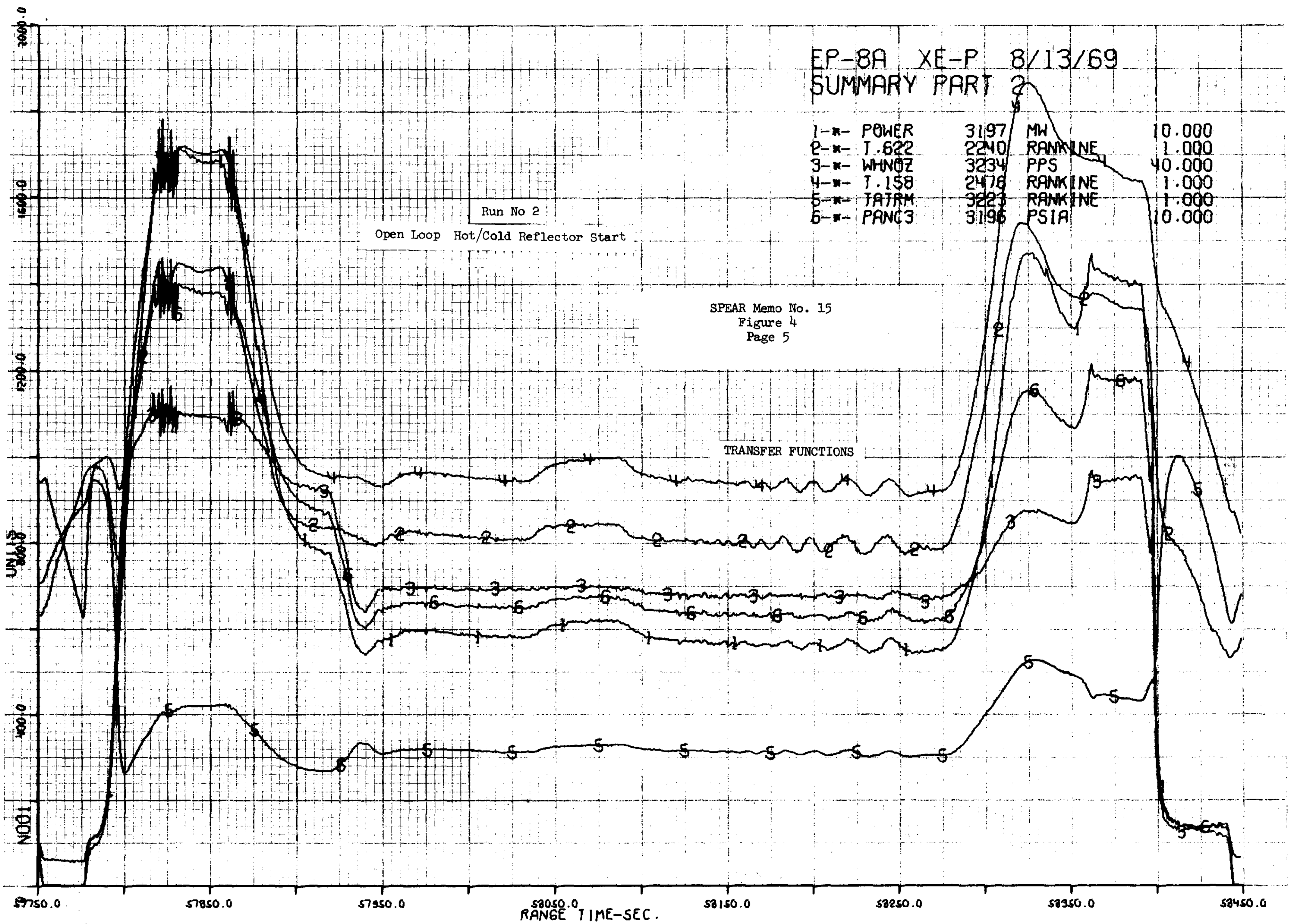
The core temperatures and pressures responded as expected and remained within established limits.

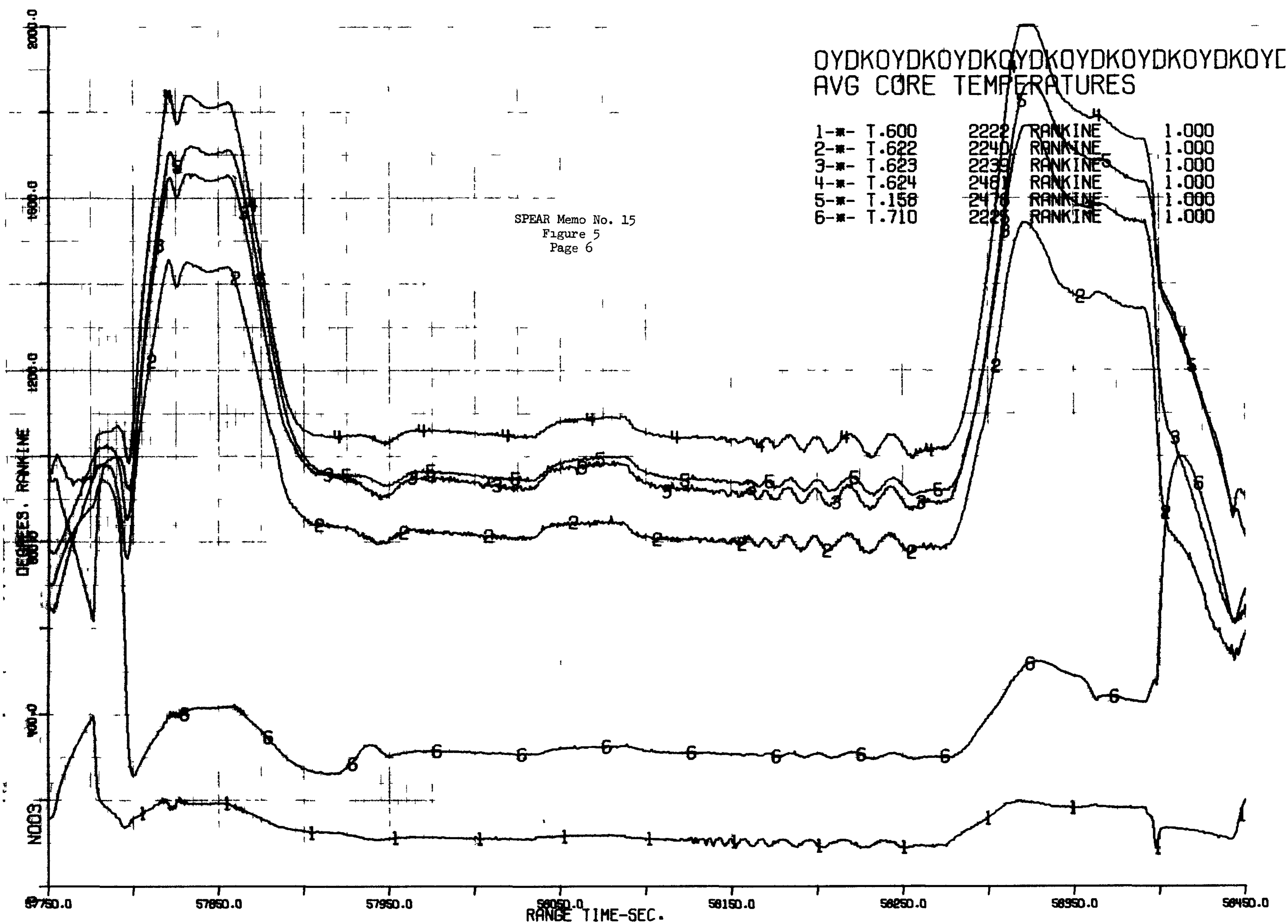

EP-8A XE-P 8/13/69
SUMMARY-PART 1
1-*- POWER 3197 MW 10.000
2-*- T.622 2240 RANKINE 1.000
3-*- WHNOZ 3234 PPS 40.000
4-*- T.158 2476 RANKINE 1.000
5-*- TATRM 3223 RANKINE 1.000
6-*- PANC3 3196 PSIA 10.000
56800.0
56900.0
57000.0
57100.0
57200.0
57300.0
57400.0
57500.0
57600.0
57700.0
57800.0
RANGE TIME-SEC.



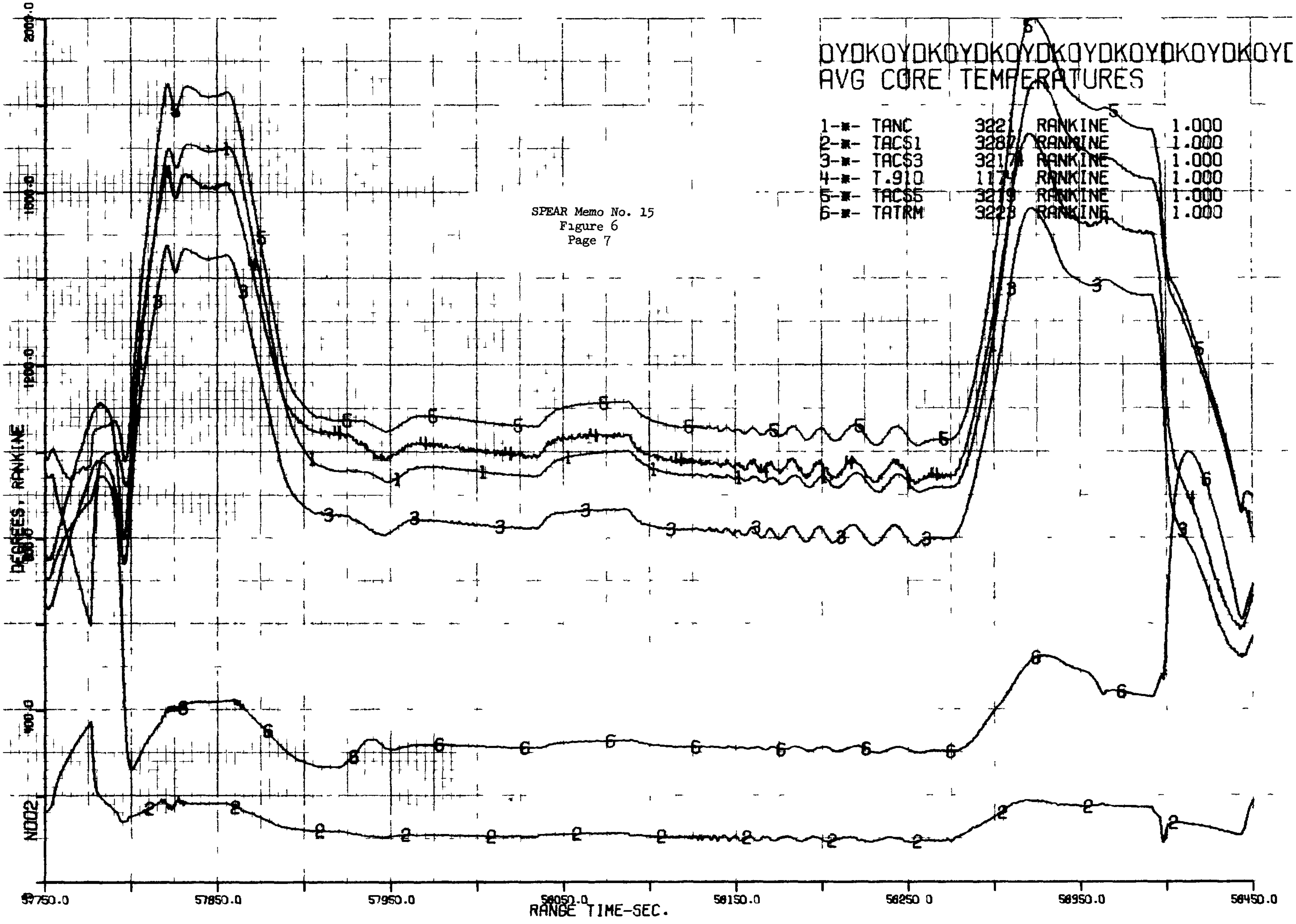
SPEAR Memo No. 15
Figur
Page 3


EP-8A XE-P 8/13/69
AVE.CORE TEMPS
1-*- TANC 3221 RANKINE 1 000
2-*- TACS1 3287 RANKINE 1 000
3-*- TACS3 3217 RANKINE 1 000
4-*- T 910 1174 RANKINE 1 000
5-*- TACS5 3219 RANKINE 1 000
6-*- TATRM 3223 RANKINE 1 000
SPEAR Memo N-. 1,
Figur 3
Pa e 4
56800 0
56900 0
57000 0
57100 0
57200 0
57300 0
57400 0
57500 0
57600 0
57700 0
57800 0
RANGE TIME-SEC

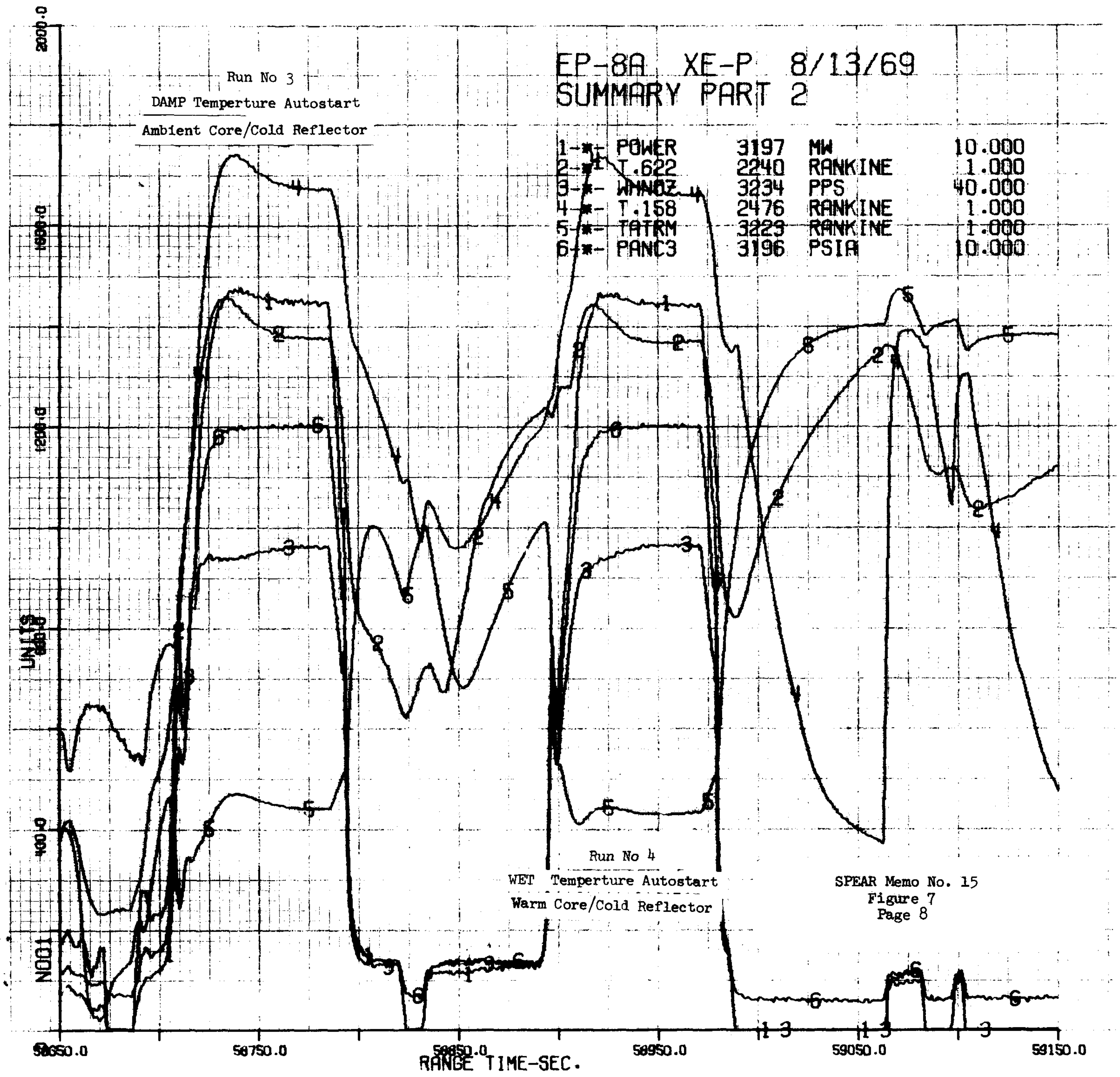

EP-8A XE-P 8/13/69
SUMMARY PART 2
1-*- POWER 3197 MW 10.000
2-*- T.622 2240 RANKINE 1.000
3-*- WHNOZ 3234 PPS 40.000
4-*- T.158 2476 RANKINE 1.000
5-*- TATRM 3223 RANKINE 1.000
6-*- PANC3 3196 PSIA 10.000
Run No 2
Open Loop Hot/Cold Reflector Start
SPEAR Memo No. 15
Figure 4
Page 5
TRANSFER FUNCTIONS
UNITS
57750.0
57850.0
57950.0
58050.0
58150.0
58250.0
58350.0
58450.0
RANGE TIME-SEC.

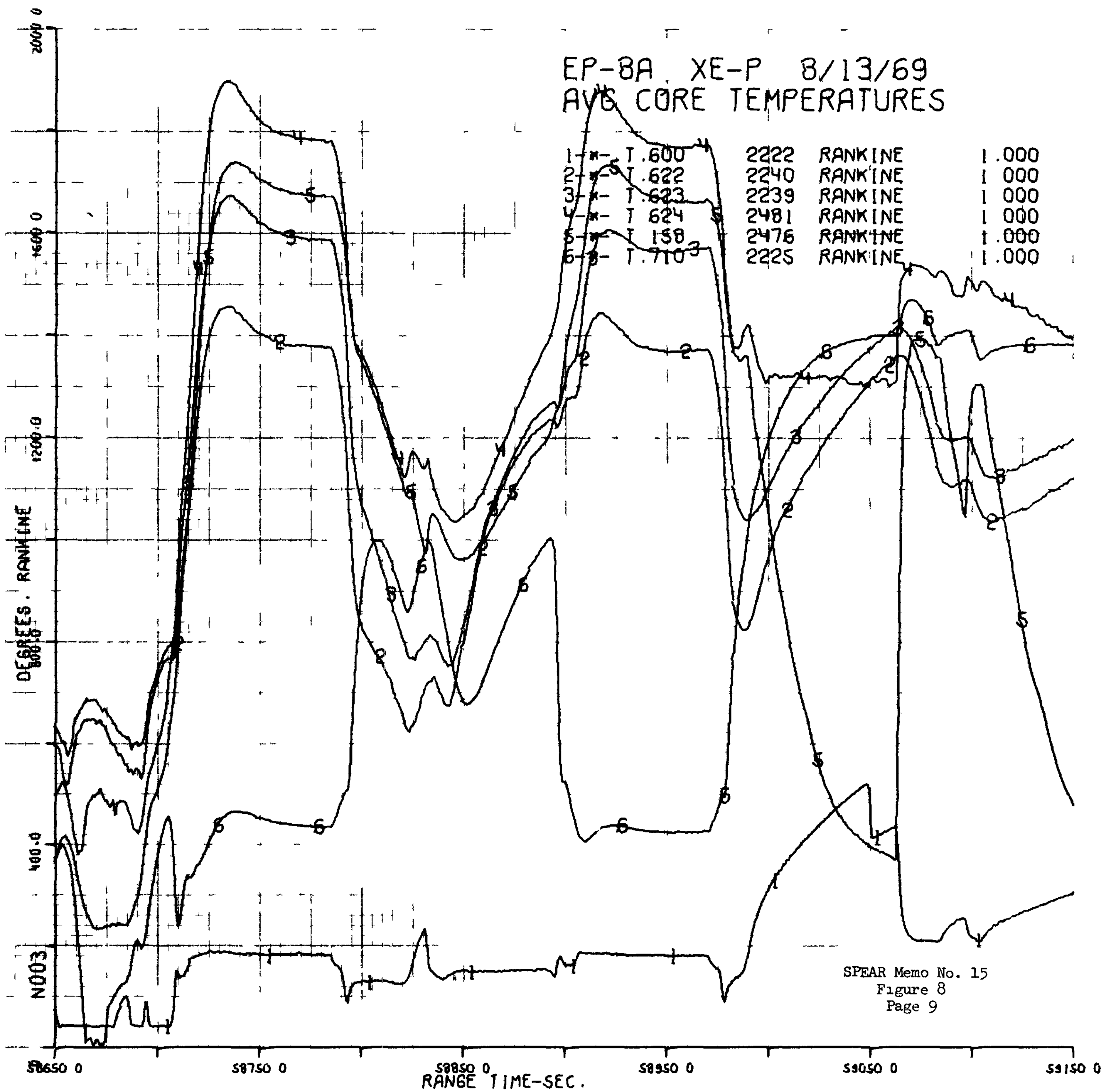


SPEAR Memo No. 15
Figure 5
Page 6

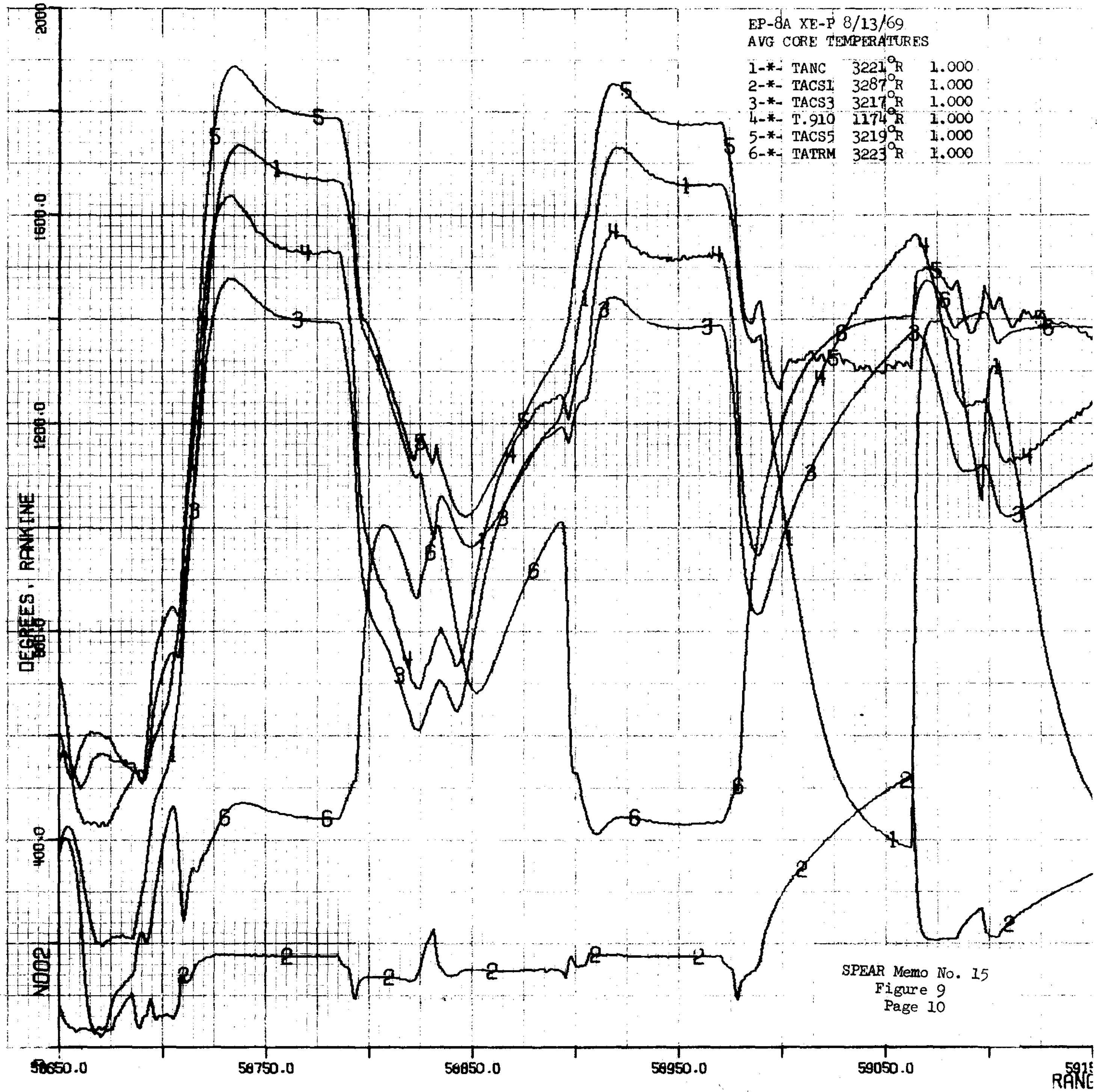


SPEAR Memo No. 15
Figure 6
Page 7

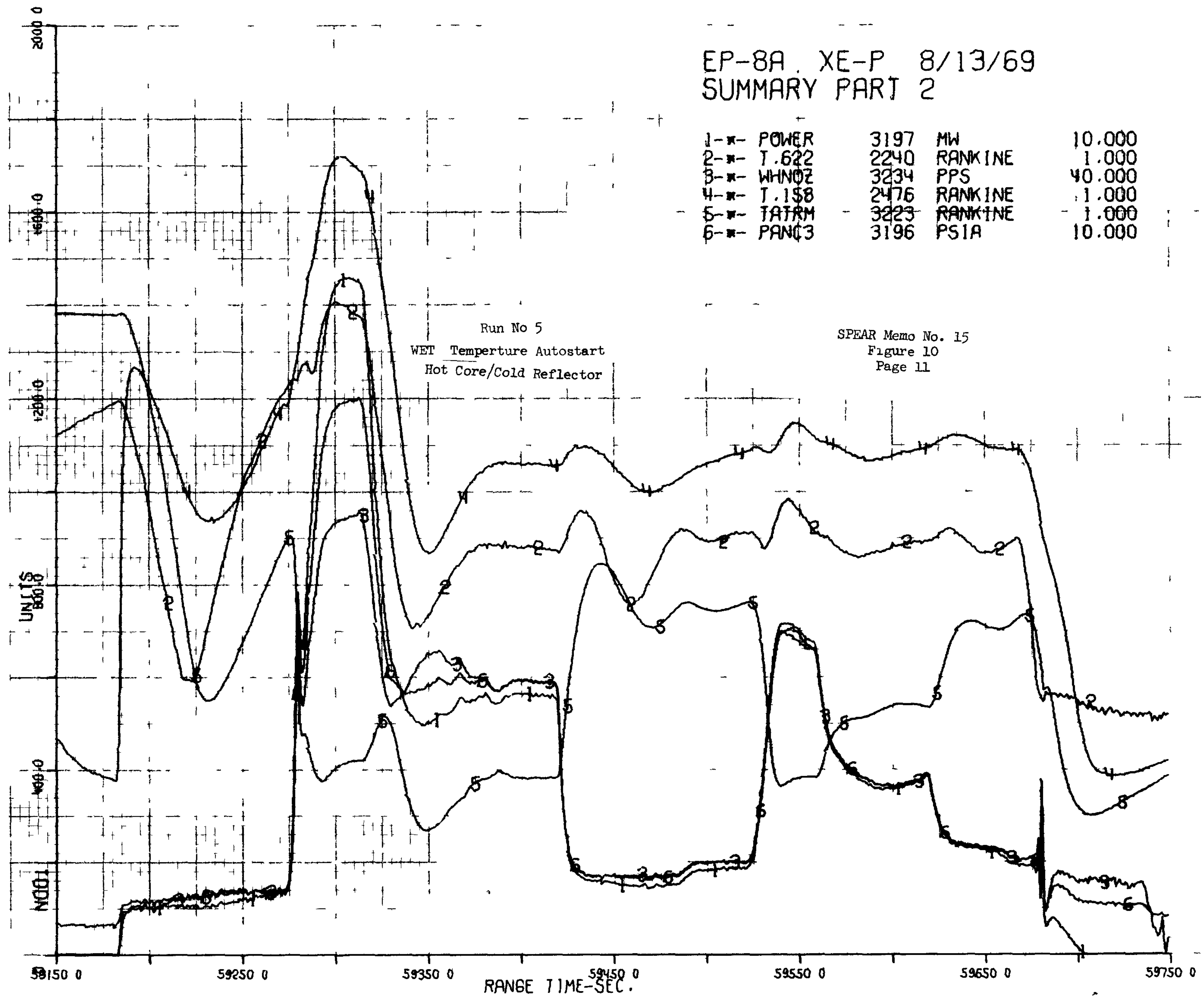

EP-8A XE-P 8/13/69
SUMMARY PART 2
1-*- POWER 3197 MW 10.000
2-*- T.622 2240 RANKINE 1.000
3-*- WHNOZ 3234 PPS 40.000
4-*- T.158 2476 RANKINE 1.000
5-*- TATRM 3229 RANKINE 1.000
6-*- PANC3 3196 PSIA 10.000
Run No 3
DAMP Temperture Autostart
Ambient Core/Cold Reflector
Run No 4
WET Temperture Autostart
Warm Core/Cold Reflector
UNITS
N001
2000.0
1600.0
1200.0
800.0
400.0
58650.0
58750.0
58850.0
58950.0
59050.0
59150.0
RANGE TIME-SEC.



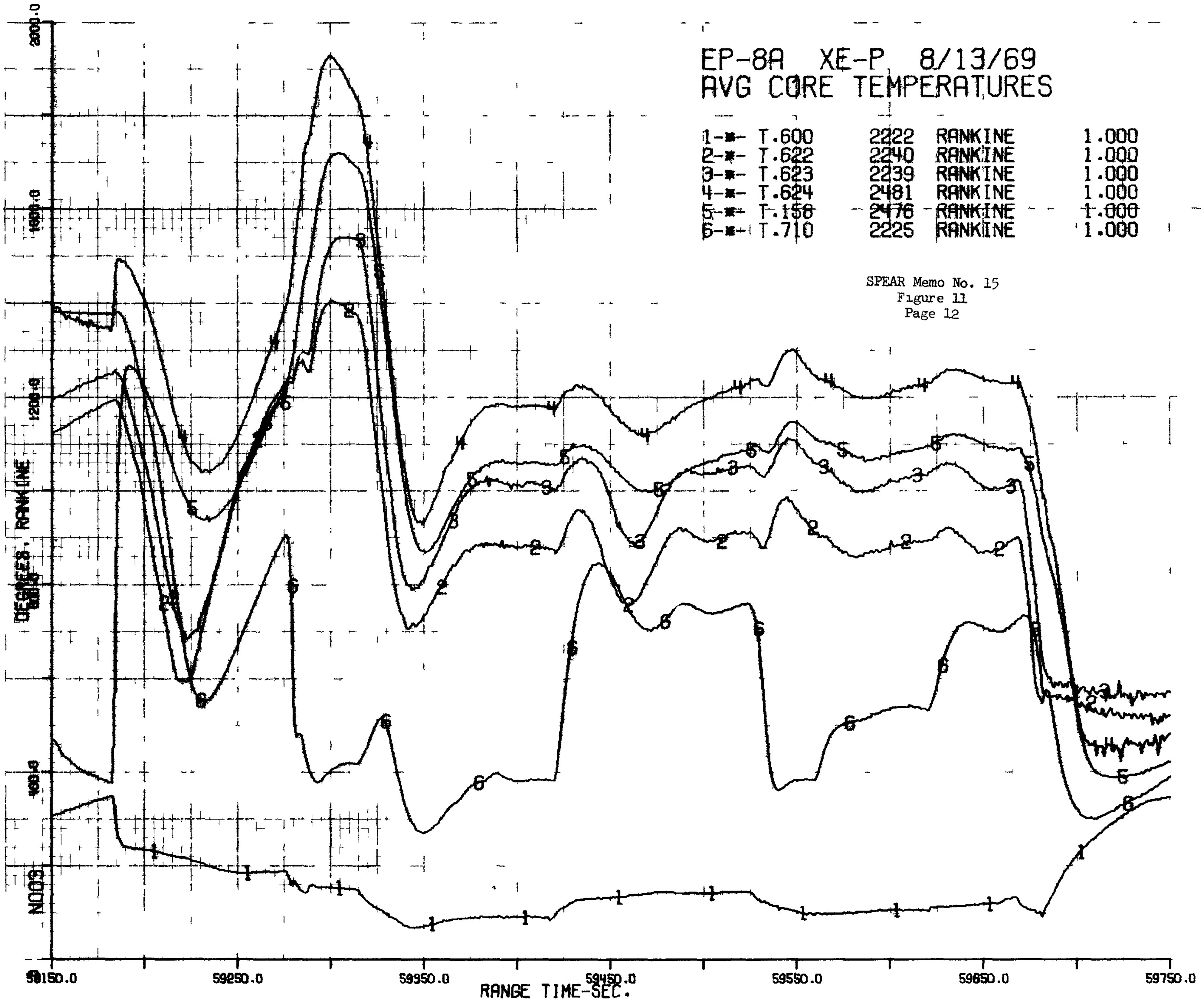
SPEAR Memo No. 15
Figure 8
Page 9



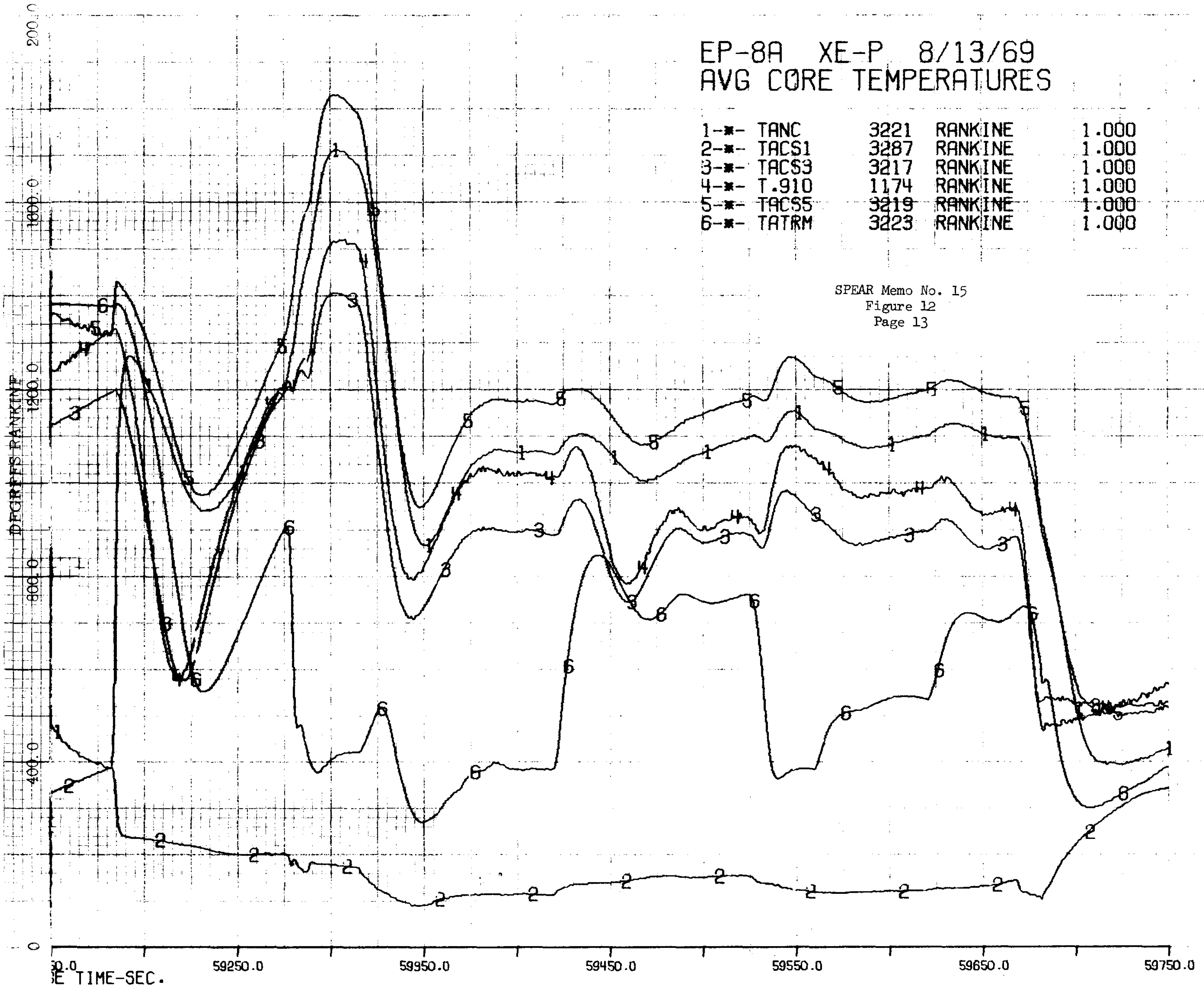
SPEAR Memo No. 15
Figure 9
Page 10



EP-8A XE-P 8/13/69
SUMMARY PART 2
1-*- POWER 3197 MW 10.000
2-*- T.622 2240 RANKINE 1.000
3-*- WHNOZ 3234 PPS 40.000
4-*- T.158 2476 RANKINE 1.000
5-*- TATRM 3223 RANKINE 1.000
6-*- PANC3 3196 PSIA 10.000
Run No 5
WET Temperture Autostart
Hot Core/Cold Reflector
SPEAR Memo No. 15
Figure 10
Page 11
UNITS
RANGE TIME-SEC.



SPEAR Memo No. 15
Figure 11
Page 12



SPEAR Memo No. 15
Figure 12
Page 13

SPEAR Memo No. 16
A. L. Mowery/L. F. Miller:jh

XE-PRIME

EP-8A

Subject: PHYSICS TEST ANALYSIS

SUMMARY

The purpose of the Physics Test was to determine the thermal effects on reactivity and drum span when the reflector is below ambient temperature.

The test successfully provided data to estimate:

1. A map of the dry core/reflector reactivity effects below ambient (Figure No. 1).
2. A map of the dry core/reflector temperature effects on drum worth (Figure No. 2).
3. The effects of extremely cold reflector/core on drum worth with 35 psia Dewar flow (Figures No. 3 and 4).

Core reflector hydrogen worth was not determined because of the analysis problem to determine the contents and the distribution and condition of the hydrogen throughout the Reactor System. The data does appear to be sufficiently consistent so that hydrogen worths may subsequently be determined.

The wet drum worth data shows an apparent substantial reduction in drum worth and shutdown capability. These results are summarized in Figures No. 4 and 5. Though some fall-off in drum worth based on previous test programs and analyses was expected, the thermal conditions of the reflector were lower in EP-8A than had been previously analyzed.

In theory, the drum worth fall-off is proportional to reflector/barrel hydrogen content. The test conditions were such that these regions may have contained a significant quantity of liquid hydrogen even though the measured temperatures indicate conditions and values above saturation. It is considered that no liquid would be present above reflector temperatures of 200°R; therefore, the dry shutdown levels should exist for most transient conditions where the reflector temperature remains above this level.

TECHNICAL DISCUSSION

1. Description of Physics Test

The Physics Test was initiated by determination of a critical bank angle, under ambient dry conditions, at 1 Kw. This was 93.2° at CRT = 45786. To normalize the new reactivity computation, an ambient drum bump test was performed at CRT = 46420.

Technical Discussion (Cont'd)

The reactor was then cooled to perform the core temperature coefficient test. Initial conditions were an average core temperature of 350°R and an average reflector temperature of 270°R. After the cooling was completed the power was raised to 1 Mw and held constant. Starting at CRT = 49700, the effect on critical drum bank of core temperature at reduced reflector temperature was determined. When Station 3 reached 900° a drum bump test was performed. This occurred at CRT = 49920 while the core continued to warm slowly. At CRT = 50500, the test was terminated and Station 3 had reached approximately 1100°R.

The power level was reduced and a sequence of cooling pulses were initiated to bring the core and the reflector down to extremely low temperatures. Data was obtained on the low core and reflector reactivity between and after the cooling pulses (reactor assumed dry). At initial conditions of core temperature = 160°R and reflector temperature = 115°R at CRT = 51180, a drum bump test was performed.

Power was then brought to 12 Mw with tank flow at a dewar pressure of 35 psia to perform the first wet reflector drum worth test. By CRT = 51720, the reactor had stabilized sufficiently at a critical bank angle of 83.2°. The initial conditions were core temperature = 420°R, reflector temperature = 50°R when the wet bump was performed.

Power was reduced to ~100 Kw, without flow, and the final dry drum bump was performed. The conditions were: core temperature = 630°R and reflector temperature = 250°R at CRT = 52300.

Power was then brought to 9 Mw with flow from the tank at 35 psia. Drums stabilized at 74.3 at CRT - 52700 and the final wet drum bump was performed.

Power was reduced and the reflector was warmed by He flow to attempt to bring the reflector back to ambient.

The drum worth determination depended entirely on the reactivity computation since integral worth tests were performed by rapid drum rollout from bank to 165° (~2 seconds), followed by a roll-in to 15° (~4 seconds), a rollout to 165° (~4 seconds), then a return to the bank. The entire procedure required approximately 30 seconds from a stable critical before the drum bump to a stable critical after the drum bump.

Thermal effects on reactivity were determined by mapping of the critical bank angle against effective average core temperature and average reflector temperature. The effective average temperatures were defined by weighting the core temperature distribution by the worth distribution. The axial worth distribution used for the weighting function is shown in Figure 6 and approximate corrections were used for radial profile variations when necessary.

Technical Discussion (Cont'd)

2. Integral Drum Worth

Integral drum worths were determined from the "real time" reactivity computation. Since Drum No. 1 gave consistent worths in EP-1A between standard methods and the reactivity calculation, it was selected for the physics test drum bumps. However, there are two potentially significant differences in the computation of reactivity between EP-1A and EP-8A:

a. A new program was employed.

b. Data sampling rate was 100/sec in EP-1A and only 5/sec in EP-8A.

For these reasons Drum No. 1 was recalibrated at ambient conditions. From Table I the EP-8A drum worth from 0° to 180° was 63.5¢ with a spread of less than 1¢ in the measurements. The best value for this drum worth from EP-1A was 66.2¢. Thus, the reactivity computer appears to be low by about 4%, which is a satisfactory accuracy for making drum worth comparisons. A comparison of the reactivity computation of Drum No. 1 and the expected worth is shown in Figure 7. Some "hysteresis" is evident, but the drift at the end points is not excessive.

Table I compares the dry drum worths at the various test conditions. To correct the worth values to a 0° to 180° basis from a 15° to 165° test range, a 0.96 correction factor was applied. The drum bump at RT=49922 required small corrections of 1 to 2¢ because of variations in average core temperature. The variation of the worths was small indicating good reproducibility except for the case where core temperature was extremely low at RT=51180. For this case further analysis may be necessary since small change in core temperature may cause significant reactivity changes due to the greatly enhanced temperature coefficient at these temperatures. These results are displayed in Figure 2. There appears to be a small variation in drum worth which increases with both increasing core and reflector temperatures. Further analytical analysis will be required to verify the results and determine, quantitatively, the functional dependence on core and reflector temperature.

The two wet drum bump results are substantially more difficult to interpret. A large hysteresis effect was observed in these two cases as a result of the variation in core temperature and concomitant variation in core hydrogen content. This effect is illustrated in Figure 5.

To attempt to minimize the effect of core temperature variation, the computed reactivity of the drum bump while the drum was stationary at either the full in or full out position, was plotted against the core temperature. An example is shown in Figure 8 for the drum bump at the 12 Mw hold. On the initial drum motion to full out and hold, the core temperature increased and the computed wet reactivity dropped off as shown in the positive cure. When the drum rolled in

Technical Discussion (Cont'd)

and held, the core temperature dropped and the computed reactivity increased as shown in the negative curve. The drum worth was estimated to be the sum of these reactivities at the initial core station temperature, 413°R. The data was reproducible in that both drum swings are consistent and the sum of the curves is approximately constant. The apparent drum worth is 42¢ at the core initial temperature of 413°. Correcting to 0° to 180° yields a worth of approximately 44¢. From the initial drum position of 85°, the worth to full out should be 55% of the worth and to full in, 45%. Based on the total span of 42¢, outward rotation should be worth 23¢ and the inward rotation, 19¢. This compares well with the observation at the initial temperature of 23.5¢ and 18.5¢.

A similar analysis for the 9 Mw hold drum bump is shown in Figure 9. The worth is 30¢ for test conditions and 31¢ for 0° to 180°. Using an initial Drum No. 1 angle of 76°, the relative roll out reactivity should be 19.5¢ and the roll in, 11.5¢. This compares with the measurements at the core station initial temperature of 321° of 19¢ and 11¢.

3. Thermal Mapping Test

The data used to derive the critical bank map was obtained in several phases of the test. The results have not been converted into reactivity because of the variation in drum worth which, though relatively minor, will require further analysis. Interpretational difficulties stem from the paucity of reliable temperature measurements below ambient and the sensitivity to the precise shape of the axial temperature profile.

The best data was obtained from the warm up at 1 Mw from below ambient core and reflector temperature conditions. A summary of this data is shown in Table II. Corresponding central axis temperature profiles were weighted by the axial worth profile to obtain the effective average temperatures in Table II. A temperature offset of +40°R was found in the Station 2 temperature measurement and +30°R in Station 4. These offsets were subtracted from the measurements to obtain the reported values. Representative radial temperature profiles have not been used pending comparison with the EP-1A data reduction procedure. Critical bank position versus effective average core temperature is shown in Figure 10. Spotted on the curve is the variation of average reflector temperature. To determine the cold reflector effect the average of thermocouple readings TE 646, 655, and 665 were used to compare with the results of the EP-1A thermal calibration test. The critical bank position versus Station 3 temperature is shown in Figure 11, for both EP-1A and EP-8A tests. EP-1A results were corrected to the 8A critical bank position of 93.2° when the effective average core temperature was 570°. Station 3 must be at ~ 590° to realize a 570° with the existing axial temperature profile.

The difference in critical angle between the EP-1A and EP-8A and the two reflector conditions versus average core temperature is shown in Figure 12 with average cold reflector temperatures spotted.

Technical Discussion (Cont'd)

Using an ambient reflector temperature of 560°R and a bank worth of 6.5¢/°, Figure 13 shows the estimated variation of the temperature coefficient of the reflector with average core temperature.

Cold reflector/core effects data was obtained after the termination of the four cooling pulses that brought the reflector to its minimum temperature. Data from these test periods is summarized in Tables III and IV. A drum bump test was performed between the two time periods.

To smooth the data, the important parameters were plotted versus range time: critical angle, reflector temperature, and core temperature. The electrical average reflector temperature was low by some 5°R and was not used. Effective average temperatures were derived from the representative axial temperature profiles. Tie rod exit temperature was employed for the core outlet temperature estimate. This data appears to be ~ 40° low, but the discrepancy could not be resolved. Cross-plotting the data yielded the smoothed results in Figure 3 showing the variation in critical angle versus temperature. Average core temperatures are spotted on the curves.

Data taken during the core warmup after the termination of the 9 Mw run is summarized in Table V. A similar analysis was performed on this data as on the 12 Mw run. A cross-plotted summary of the smoothed data is shown in Figure 14.

Thermal effects results are summarized in Figure 1. From the data discussed in the previous sections an attempt was made to map the dry critical bank angle variation with effective average core temperature (parametric in reflector temperature). The data appears reasonably consistent noting that the uncertainty in core average temperature can be 5% or more due to the profile variations.

CONCLUSIONS

A wide variety of information was gained from this test that will be useful in support of the NERVA design:

1. There is a small, but clear, dependence of dry drum worth on core/reflector thermal conditions. The drum worth increases with increasing core and reflector temperatures.
2. The reflector coefficient is negative down to core/reflector temperatures of 100°R. A strong dependence on core temperature was found such that the reflector effect increases sharply at low core temperatures. At elevated core temperatures (~ 1000°R) the reflector effect becomes negligible.

Conclusions (Cont'd)

3. Wet reflector drum worths reduce substantially below the drum case at similar temperatures. This is doubtless due to the near LH_2 thermal conditions of the reflector, but quantative analysis will have to be performed at WANL.

4. The reactivity computation provided the key to the analysis of the test data.

RECOMMENDATION

Should testing in the region of completely chilled down reflector be desirable in future tests, several procedures are suggested. If the reactor approached a short period such that a retreat is indicated, every effort should be made to bring the reactor back to ambient conditions. Thus, a scram is not indicated. Power should be maintained at the highest practicable level during the chilldown, and if a short period is approached, an attempt should be made to bring the reactor to, and maintain, 10 to 50 Mw. Flow from the dewar should be terminated and pressures lowered in the reflector. The stored hydrogen in the lines and reflector will then simply boil off and shutdown capability will increase. At ambient, scram can be initiated. No pressurization (e.g., GN_2 flow) should be initiated until the reactor is at least ambient.

Since the reactivity computation will provide an immediate indication of reactivity increases, it is recommended that it be displayed digitally on the CTE console during the chilldown tests.

TABLE I

DRY INTEGRAL DRUM WORTH RESULTS

Range Time	$\overline{T}_c$ (°R)	$\overline{T}_R$ (°R)	Critical Angle (°)	Drum #1 Angle (°)	Raw Worth (°)	Raw Span (°)	Corrected Span (°)	Variation (%)	Average Span (°)
TEST 1									
46420	570	555	93.2	94.3					
25.6				166	28.6	61.2	63.0		
34.7				6.7	32.6	63.0	63.7	1.2	63.5
44.1				174	30.4	63.2	63.8		
48.5				8	32.8				
TEST 2									
49616	355	266	84.8	86.2					
20.5				173	31.4	60.7	61.3		
28.9				7	29.3	60.6	61.2	0.2	61.3
37.1				173	31.3	60.7	61.4		
44.7				9	29.4				
TEST 3									
49922.3	870	282	97.1	97.5					
25.9				173	22.9	63.3	62.6		
33.7				7	40.4	60.6	62.5	0.6	62.7
42.5				173	20.2	63.1	62.9		
47.7				12	42.9				
TEST 4									
51180.5	180	99	72.0	72.9					
85.2				173	33.1	55.6	57.0		
94.5				20	22.5	56.1	58.0	5	58.4
51202.4				171	33.6	59.3	60.2		
11.1				7	25.7				
TEST 5									
52303	790	238	94.8	96.7					
06				173	24.7	60.2	62.0		
14				16	35.5	59.9	61.7	1.4	61.6
21				170	24.4	60.4	61.1		
27				7	36.0				

TABLE II

SUMMARY OF REACTOR WARMUP DATA

FROM BELOW AMBIENT INITIAL REACTOR CONDITION

RANGE TIME	CRITICAL ANGLE	ACTUAL ANGLE	COMPUTED REACTIVITY	°R AVERAGE CORE TEMP.	°R AVERAGE REF. TEMP.	°R BARREL TEMP. (ID)	BARREL TEMP. (OD)
49704.9	84.7	84.7	0.0	360	269	233	218
49742.5	88.2	90.3	0.14	455	271	252	236
49774.1	90.7	91.7	0.065	565	273	278	250
49798.1	92.3	92.9	0.04	625	276	302	260
49836.7	94.0	94.4	0.028	700	279	338	284
49880.3	95.7	96.0	0.018	795	283	376	304
49922.1	97.2	96.6	-0.039	880	287	409	322
49956.3	98.1	96.5	-0.102	940	291	436	337
50003.9	99.2	99.0	-0.015	1015	300	469	356

TABLE III

SUMMARY OF COLD CORE/REFLECTOR
WARMUP DATA (RT 51080 - 51180)

RANGE TIME	CA	T_c	T_r	T_B I.D.	T_B O.D.
51080	69.2	159	61.5	50	50
51085	69.5	159.3			
51090	70.0	160.3	70.6	50	44
51095	70.4	160.5			
51100	70.7	167.0	79.9	54	48
51105	70.8	165.0			
51110	71.1	166.3	83.2	52	60
51115	71.0	166.3			
51120	71.2	169.0	89	61	70
51125	71.3	170.3			
51130	71.6	169.3	92.4	68	73
51135	71.9	171.3			
51140	71.7	170.0	95.2	69	69
51145	71.7	174.0			
51150	72.2	171.3	99.6	75	73
51155	71.8	170.3			
51160	71.8	172.3	102.2	83	77
51165	72.0	174.6			
51170	72.6	176.3	103.2	81	80
51175	72.0	175.9			
51180	72.0	176.3	105.2	88	85

TABLE IV

SUMMARY OF COLD CORE/REFLECTOR WARMUP DATA (RT 51220-51380)

Range Time	Degrees Critical Angle	°R Average Core Temp	°R Average Ref. Temp	Barrel Temp ID	Barrel Temp OD
51220.0	72.5	181	113	93	91
51230.0	72.4	178	116.2	97	95
51240.0	73.0	181	119	103	95
51250.0	72.6	180	121.4	98	101
51260.0	72.9	178	121.7	103	99
51270.0	72.9	179	123.7	104	98
51280.0	72.9	182	125.5	102	107
51290.0	72.9	182	127.5	107	108
51300.0	73.3	182	129.2	108	105
51310.0	73.3	182	129.6	108	109
51320.0	73.3	183	131.3	110	106
51330.0	73.3	183	132.1	110	113
51340.0	73.3	183	132.7	109	111
51350.0	73.3	183	133.3	114	112
51360.0	73.2	179	136.4	116	115
51370.0	73.3	184	137.2	116	113
51380.0		187		118	117

TABLE V

SUMMARY OF FINAL REACTOR WARMUP DATA

Range Time	CA	$\overline{T}c$	$\overline{T}_R$
53650	87.4	372	403
53700	87.8	382	413
53750	87.9	388	422
53800	88.0	393	430
53850	88.4	397	436
53900	88.2	408	443
53950	88.9	415	449
54000	88.6	425	455
54050	89.2	430	460
54100	89.3	435	465
54150	89.6	440	469
54200	89.7	460	471
54250	90.2	472	472
54300	87.2		477
54350	89.6	488	500

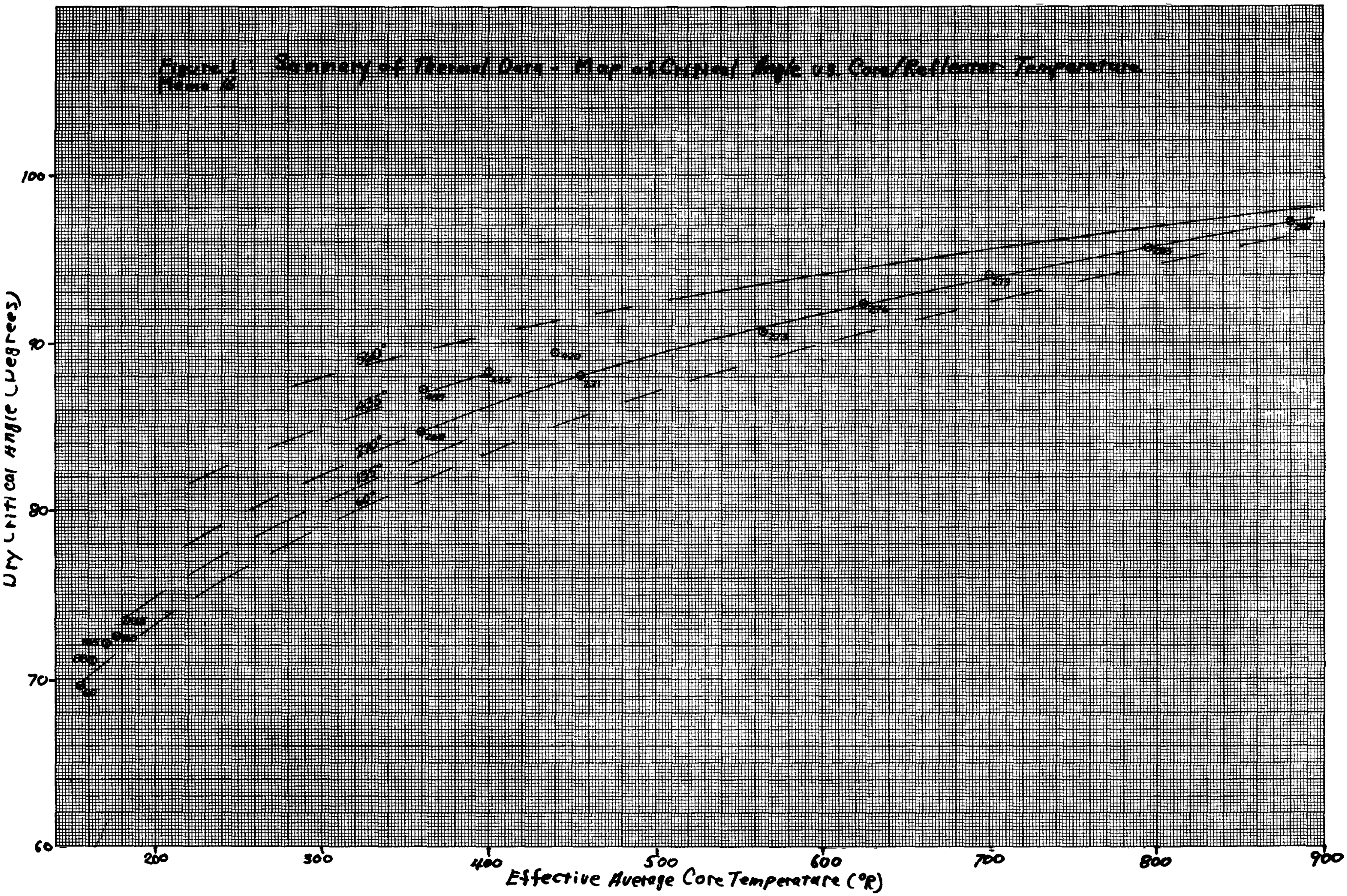


Figure 1: Summary of Thermal Data - Map of Critical Angle vs. Core/Reflector Temperature
Memo 16
Dry Critical Angle (Degrees)
100
90
80
70
60
200
300
400
500
600
700
800
900
Effective Average Core Temperature (°R)

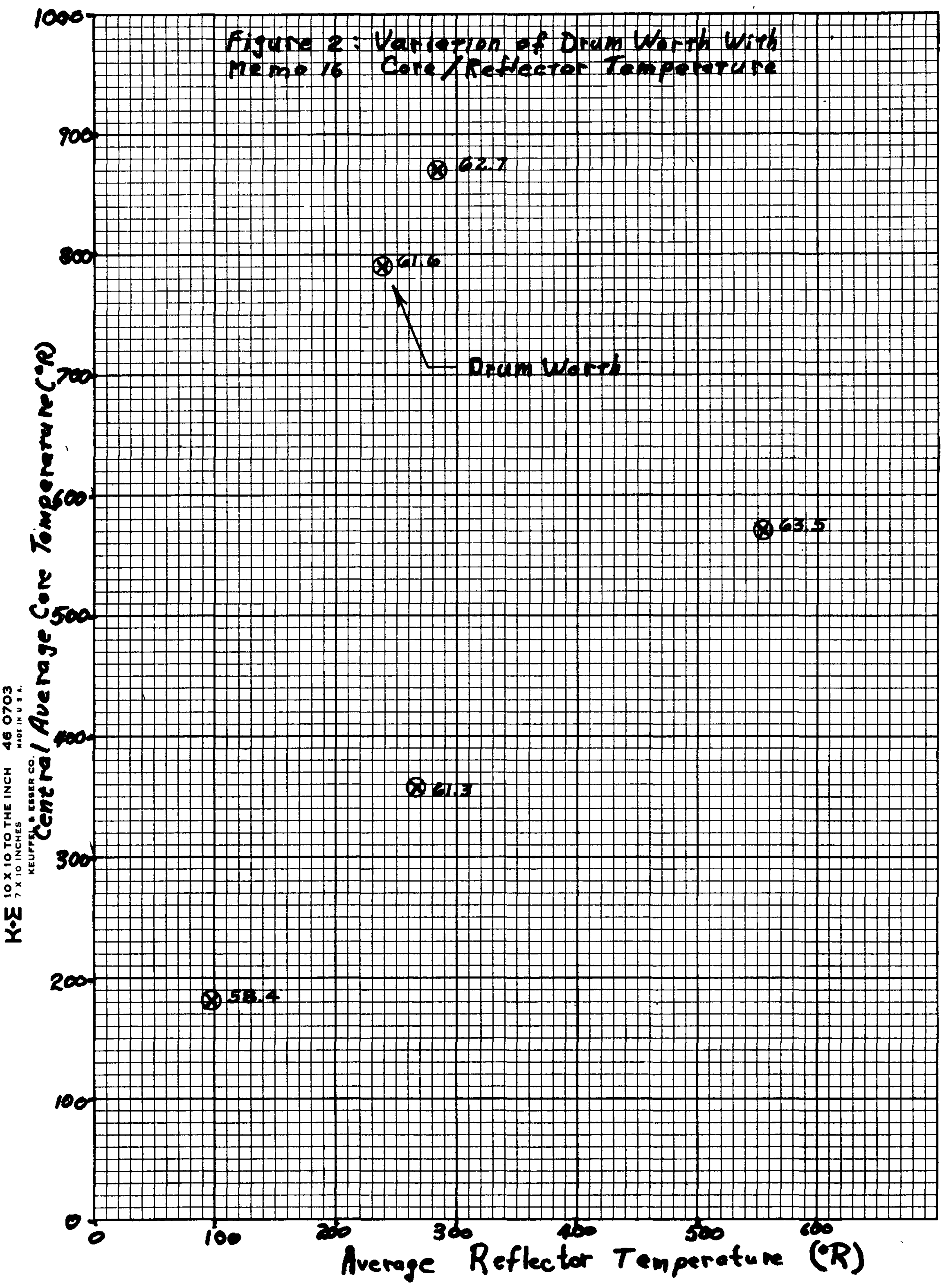


Figure 2: Variation of Drum Worth With
Memo 16 Core/Reflector Temperature
62.7
61.6
Drum Worth
63.5
61.3
58.4
Central Average Core Temperature (°R)
Average Reflector Temperature (°R)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
K+E 10 X 10 TO THE INCH 7 X 10 INCHES KEUFFEL & ESSER CO. 46 0703 MADE IN U.S.A.

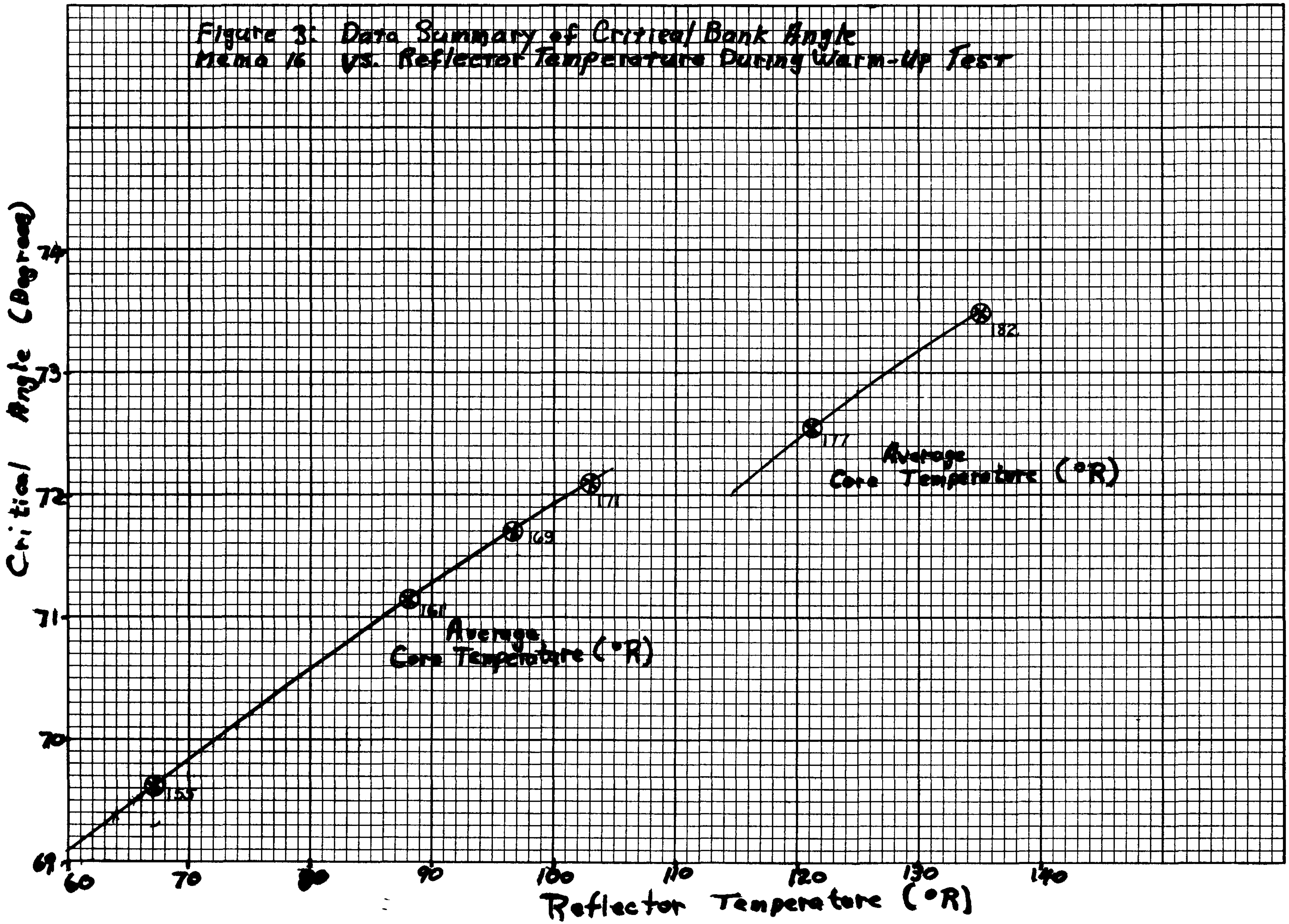
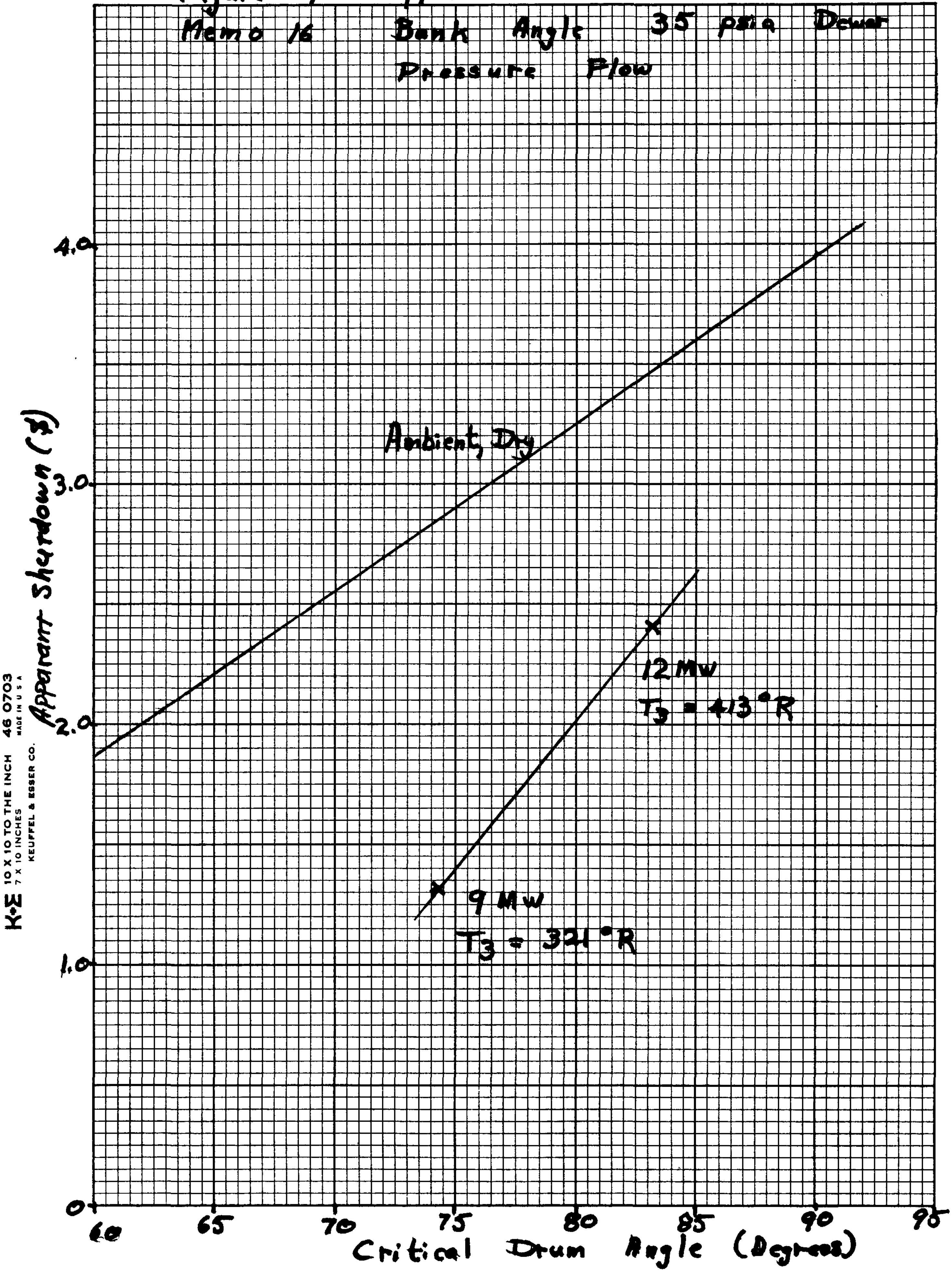


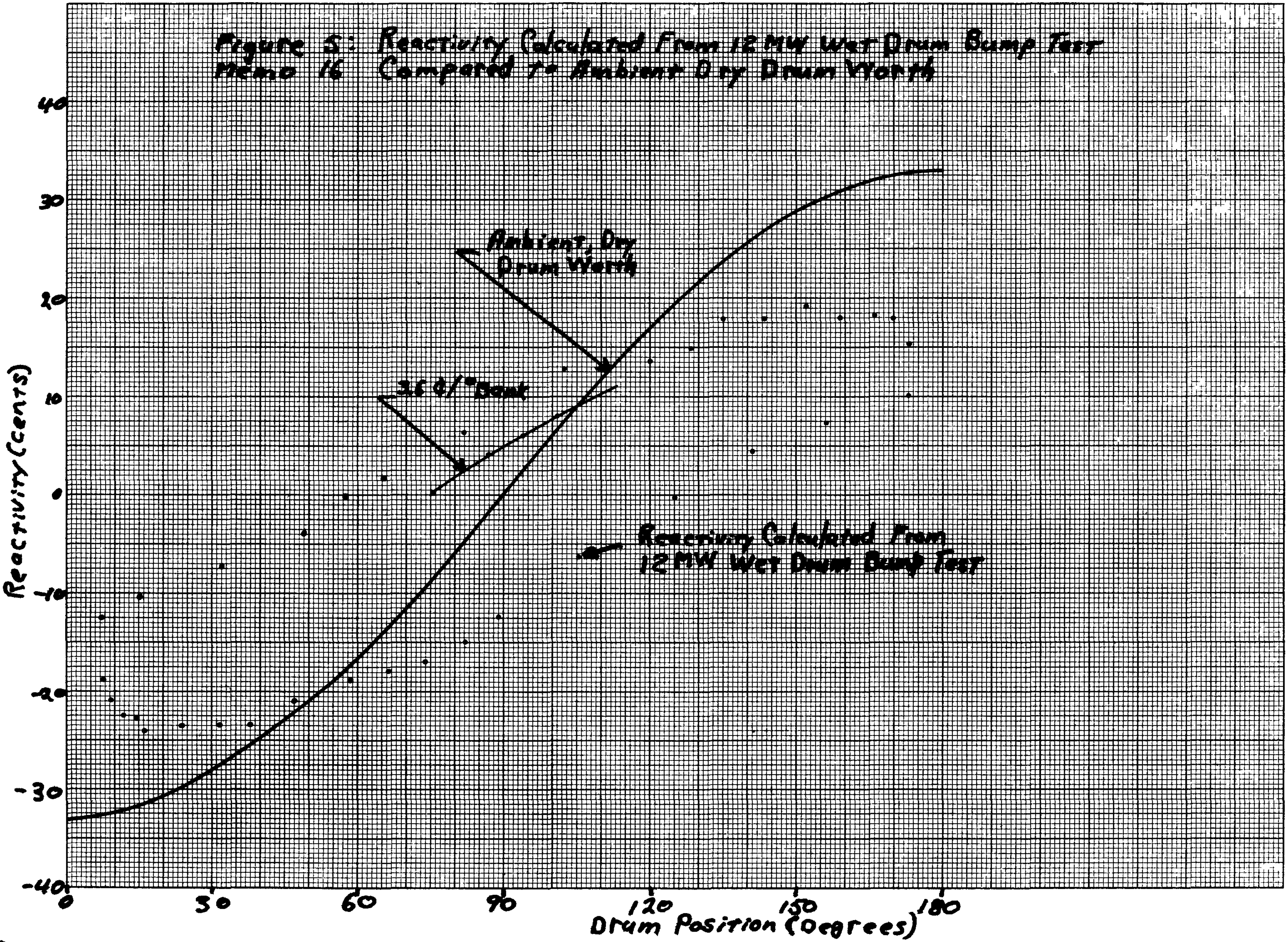
Figure 3: Data Summary of Critical Bank Angle
Memo 16 vs. Reflector Temperature During Warm-Up Test

Figure 4: Apparent Shutdown vs Critical Bank Angle 35 psia Dewar Pressure Flow

Memo 16

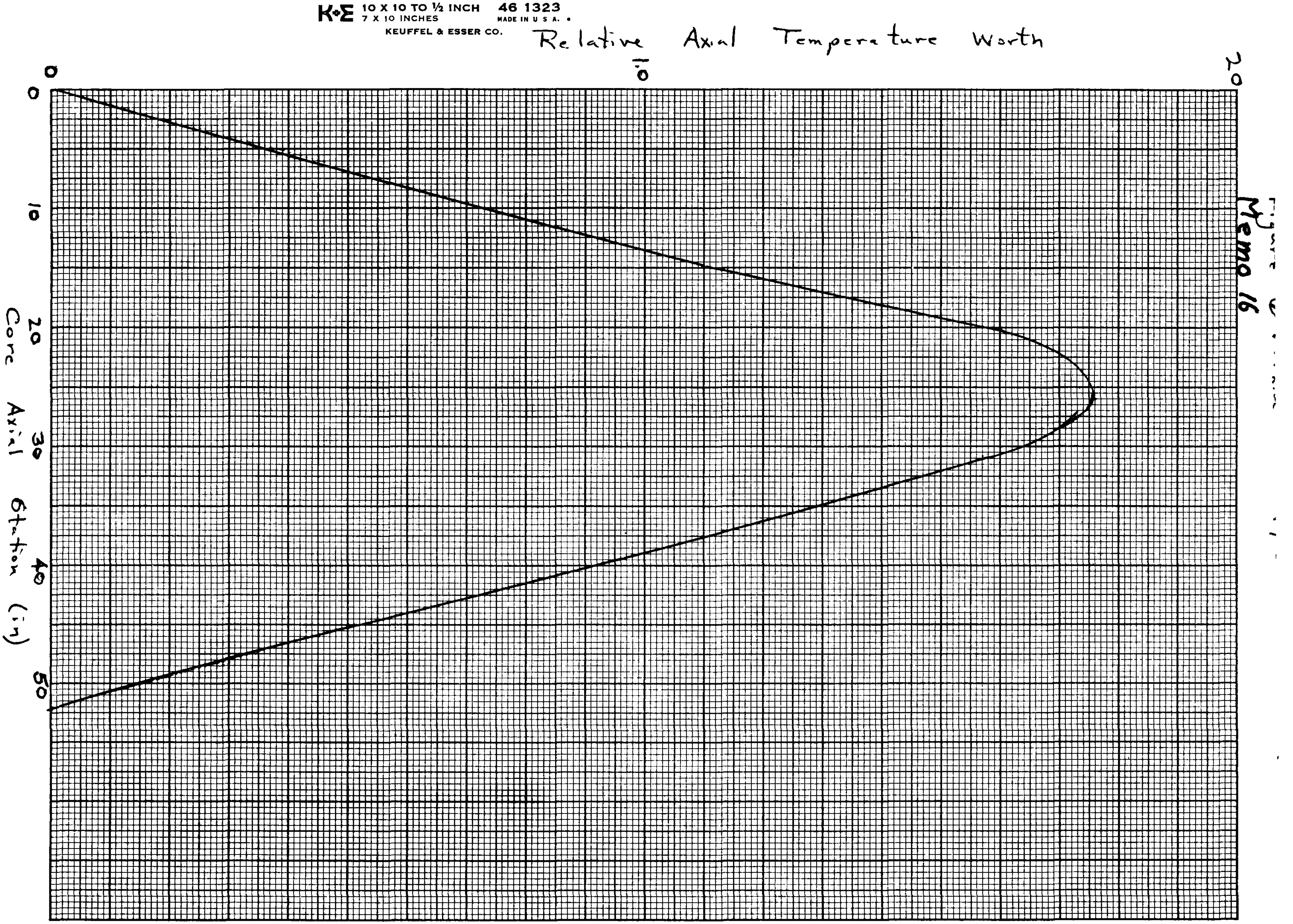


KEUFFEL & ESSER CO.



[redacted]

Relative Axial Temperature Worth



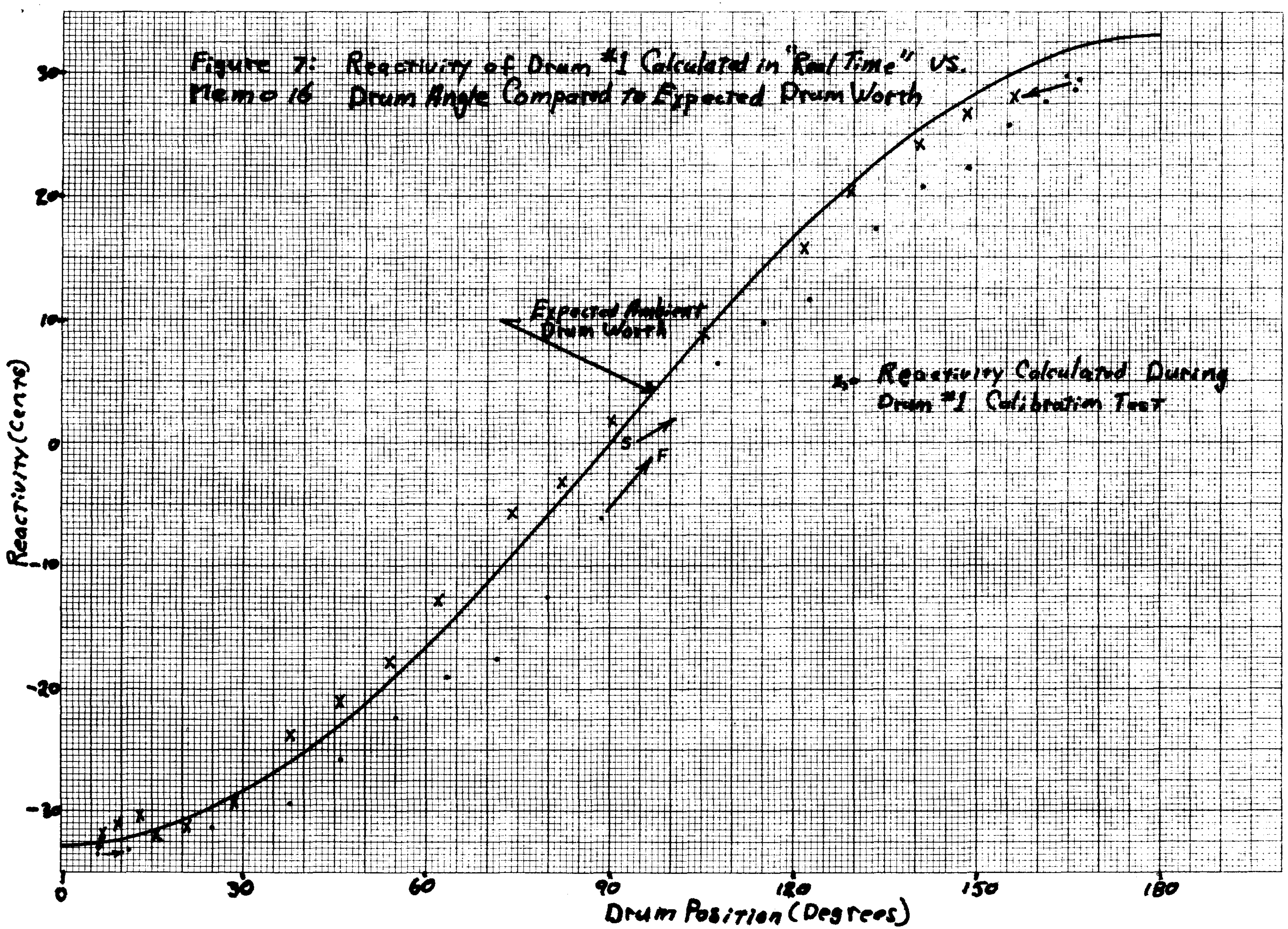
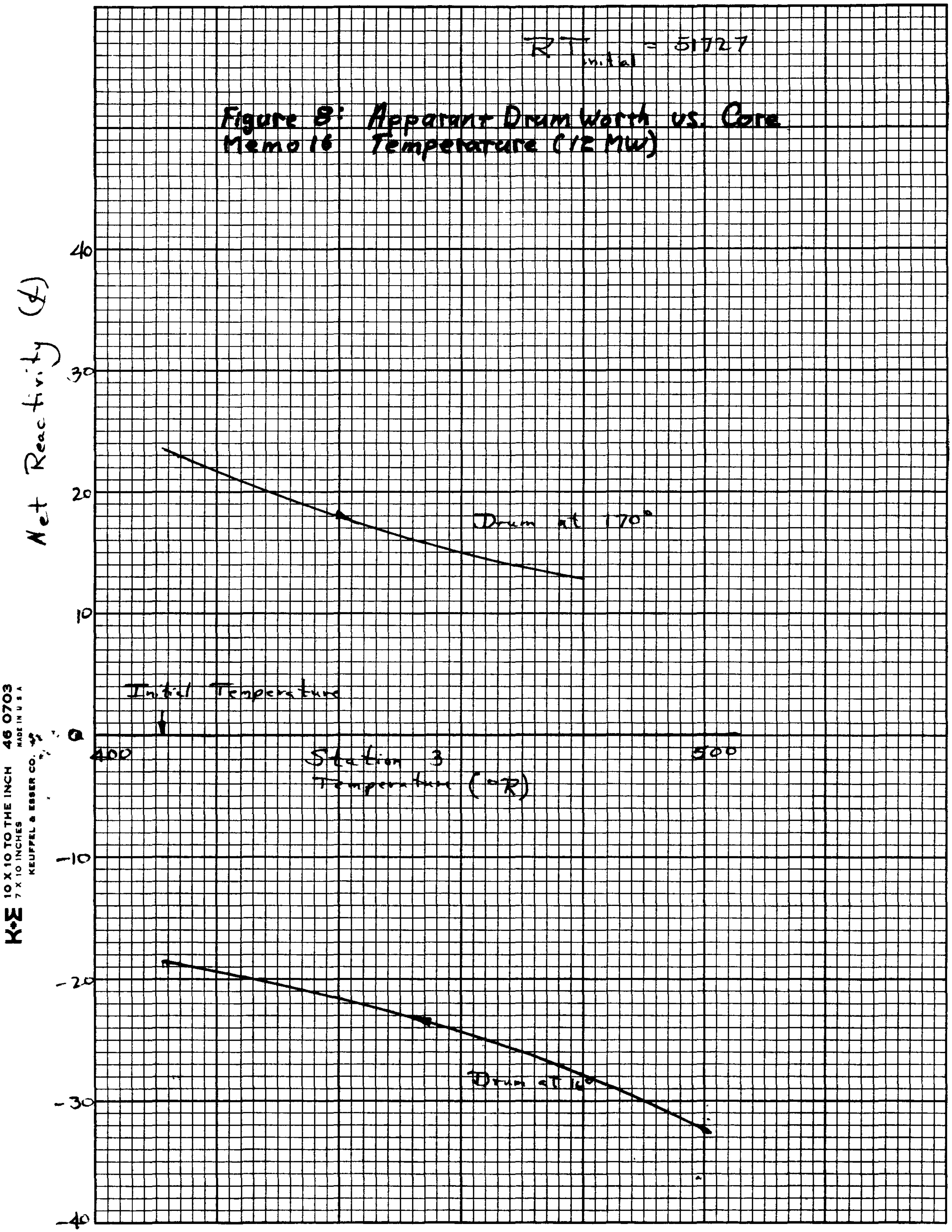
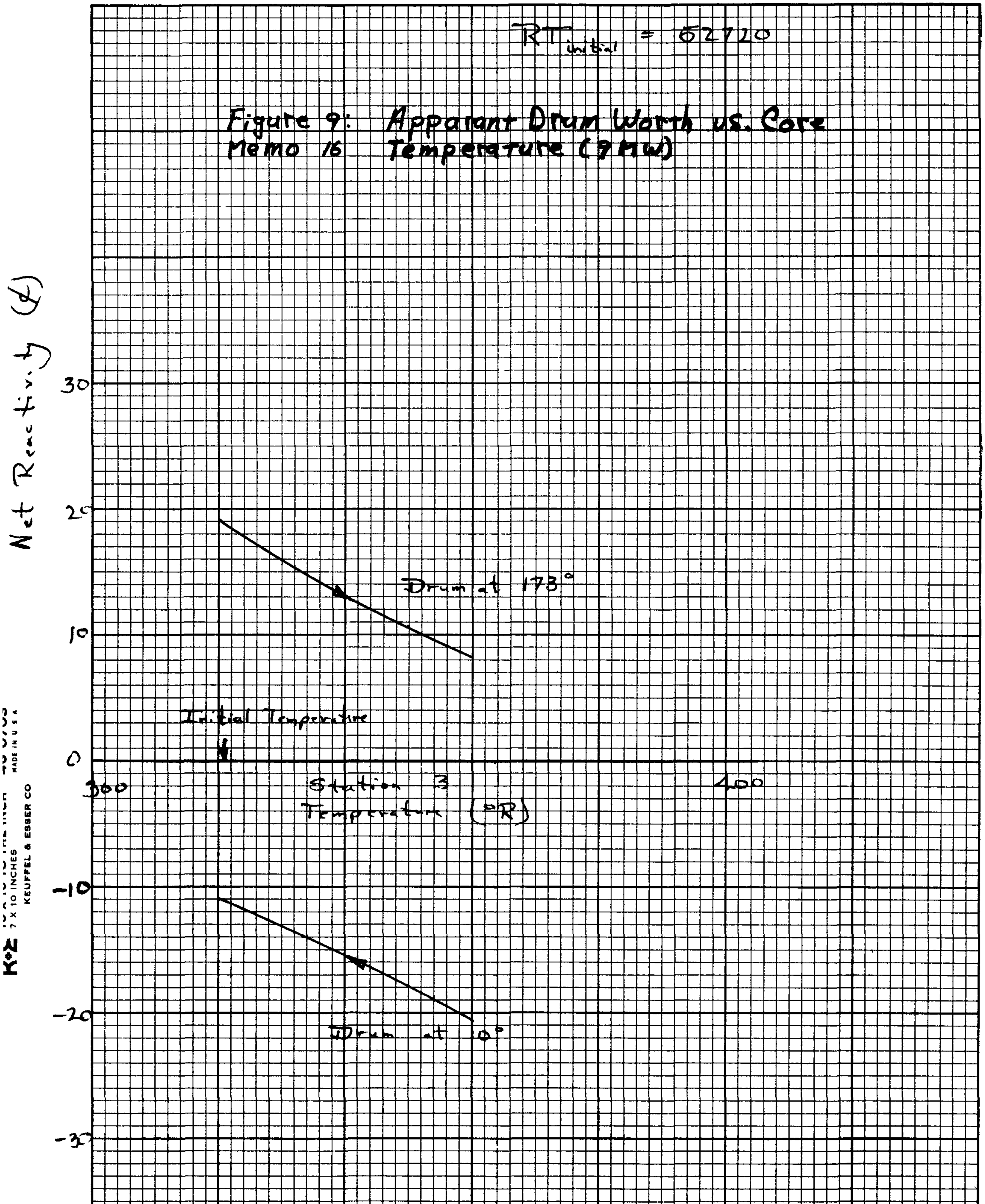


Figure 7: Reactivity of Drum #1 Calculated in "Real Time" vs.
Memo 16 Drum Angle Compared to Expected Drum Worth
Expected Ambient Drum Worth
x - Reactivity Calculated During Drum #1 Calibration Test
S
F
Reactivity (Cents)
30
20
10
0
-10
-20
-30
0
30
60
90
120
150
180
Drum Position (Degrees)


RT initial = 51727
Figure 8: Apparent Drum Worth vs. Core
Memo 16 Temperature (12 MW)
Net Reactivity (¢)
40
30
20
10
0
-10
-20
-30
-40
Drum at 170°
Initial Temperature
400
500
Station 3
Temperature (°R)
Drum at 10°
K+E 10 X 10 TO THE INCH 7 X 10 INCHES 46 0703
KEUFFEL & ESSER CO. MADE IN U.S.A.



$RT_{initial}$ = 52720
Figure 9: Apparant Drum Worth vs. Core
Memo 16 Temperature (9 MW)
Net Reactivity (¢)
30
20
10
0
-10
-20
-30
Drum at 173°
Initial Temperature
300
400
Station 3
Temperature (°R)
Drum at 10°

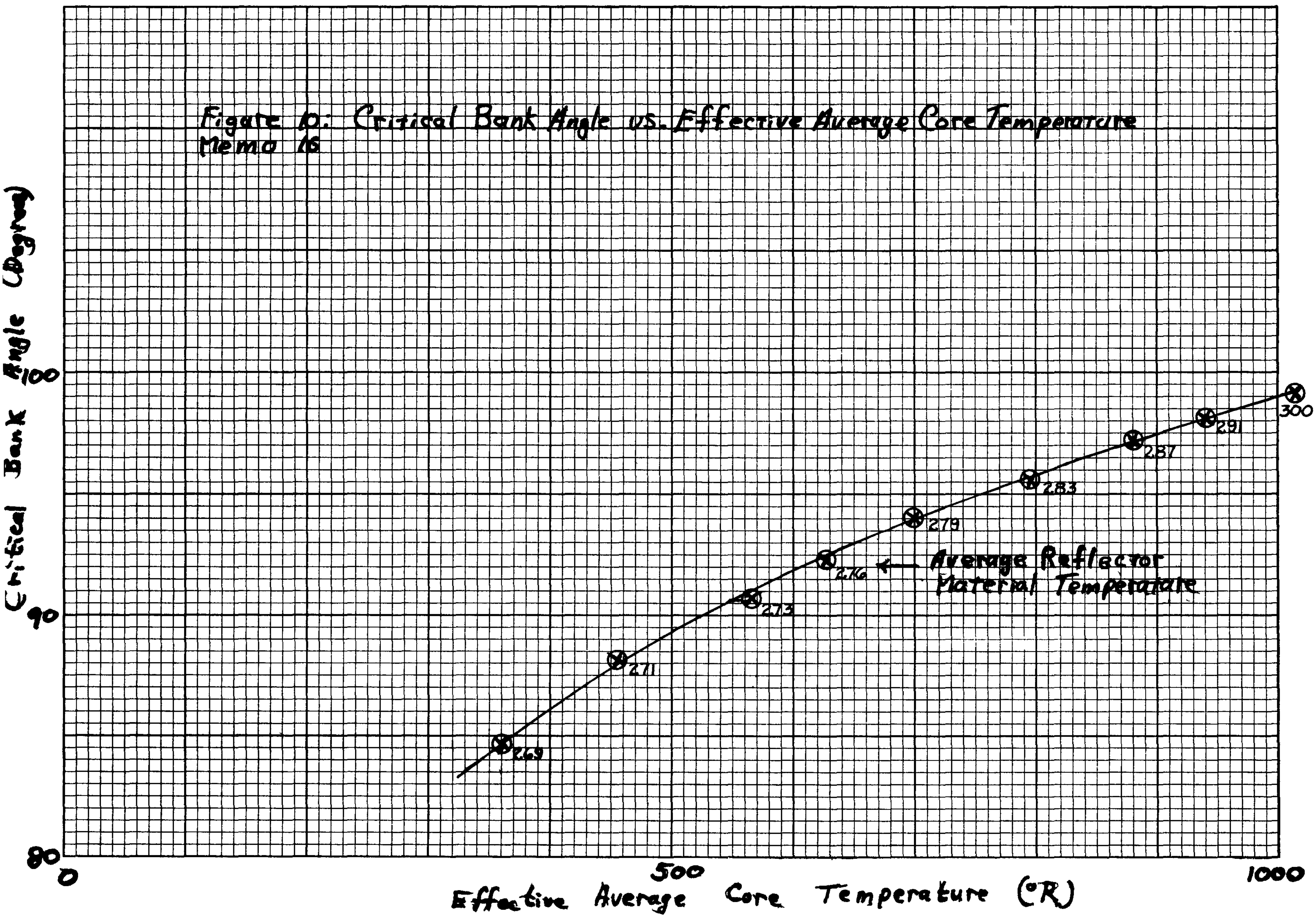


Figure 10: Critical Bank Angle vs. Effective Average Core Temperature
Memo 16
Critical Bank Angle (Degrees)
Effective Average Core Temperature (°R)
80
90
100
0
500
1000
269
271
273
276
279
283
287
291
300
Average Reflector Material Temperature

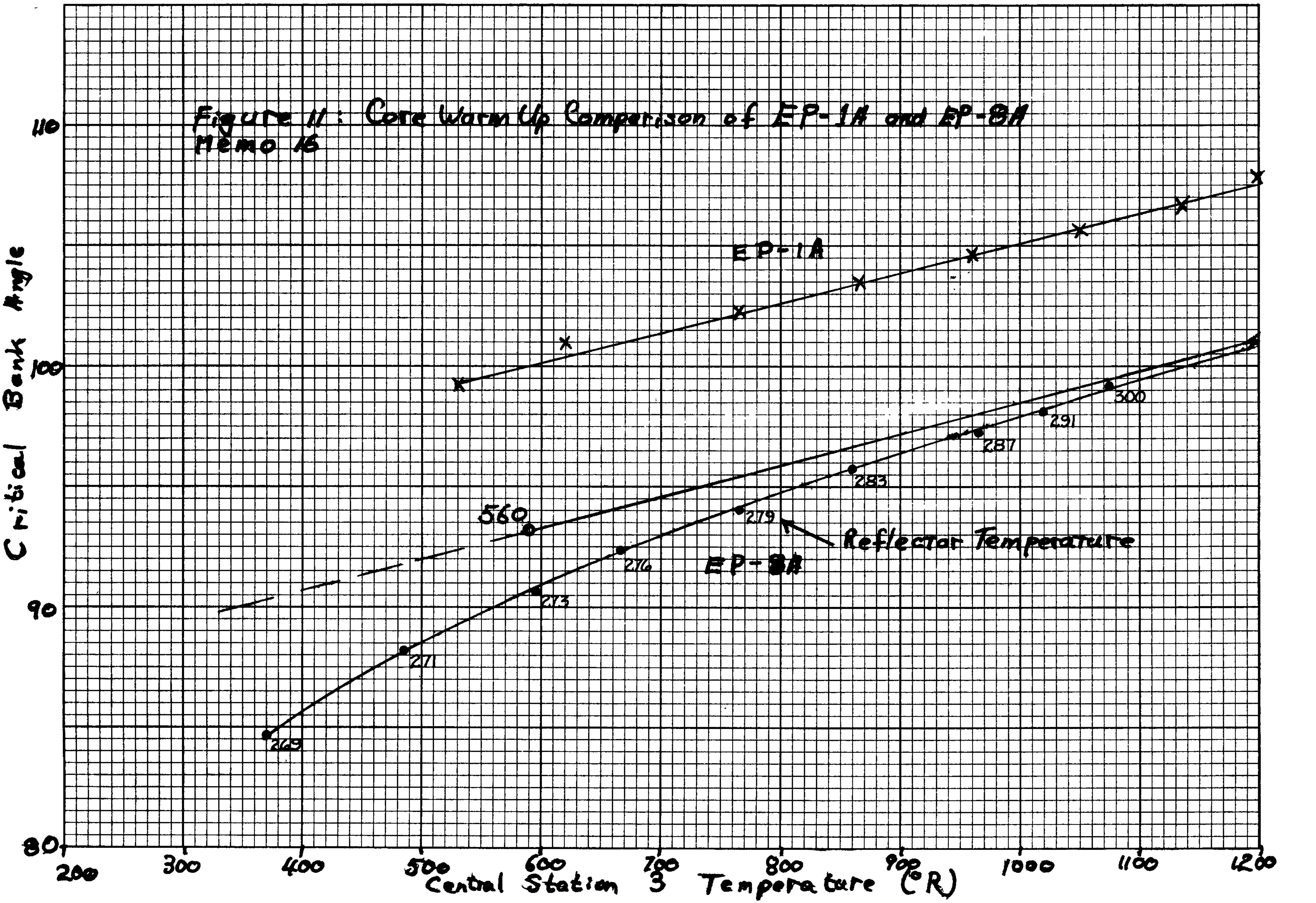


Figure 11: Core Warm Up Comparison of EP-1A and EP-8A
Memo 16
EP-1A
EP-8A
560
Reflector Temperature
269
271
273
276
279
283
287
291
300
Critical Bank Angle
80
90
100
110
Central Station 3 Temperature (°R)
200
300
400
500
600
700
800
900
1000
1100
1200

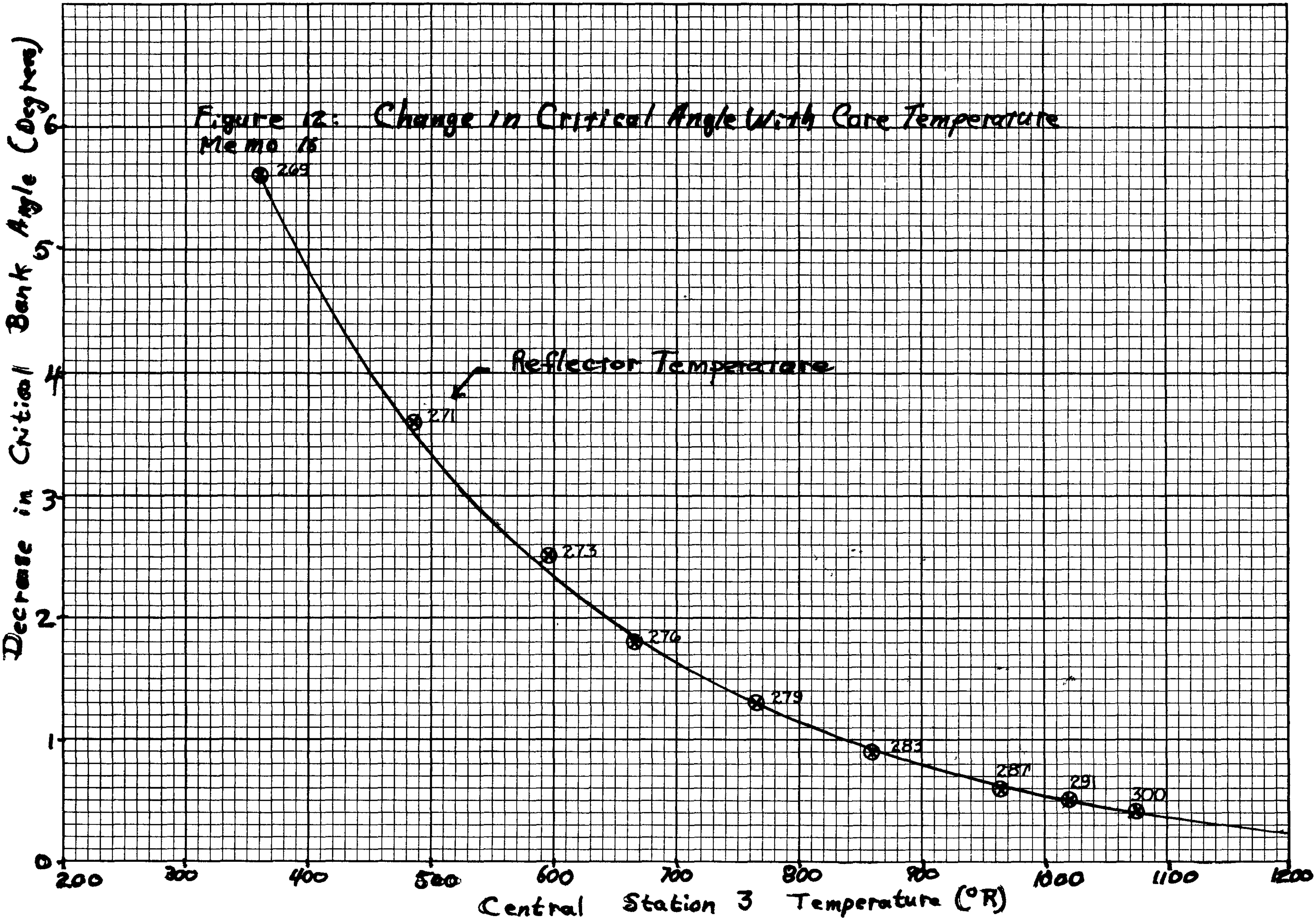
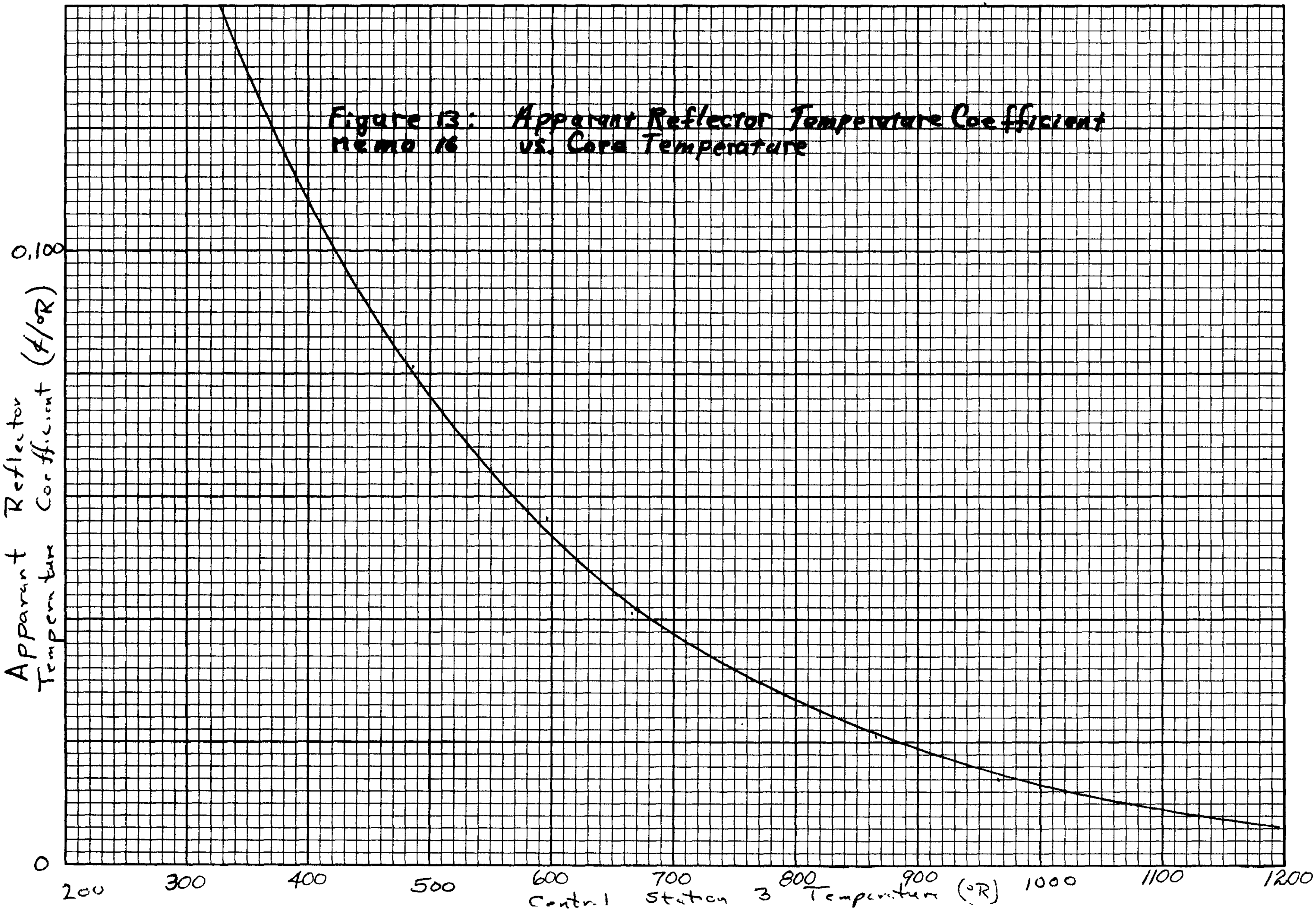


Figure 12: Change in Critical Angle With Core Temperature
Memo 15
Reflector Temperature
269
271
273
276
279
283
287
291
300
Decrease in Critical Bank Angle (Degrees)
0
1
2
3
4
5
6
200
300
400
500
600
700
800
900
1000
1100
1200
Central Station 3 Temperature (°R)

K+E 10 X 10 TO THE INCH 46 0703
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.



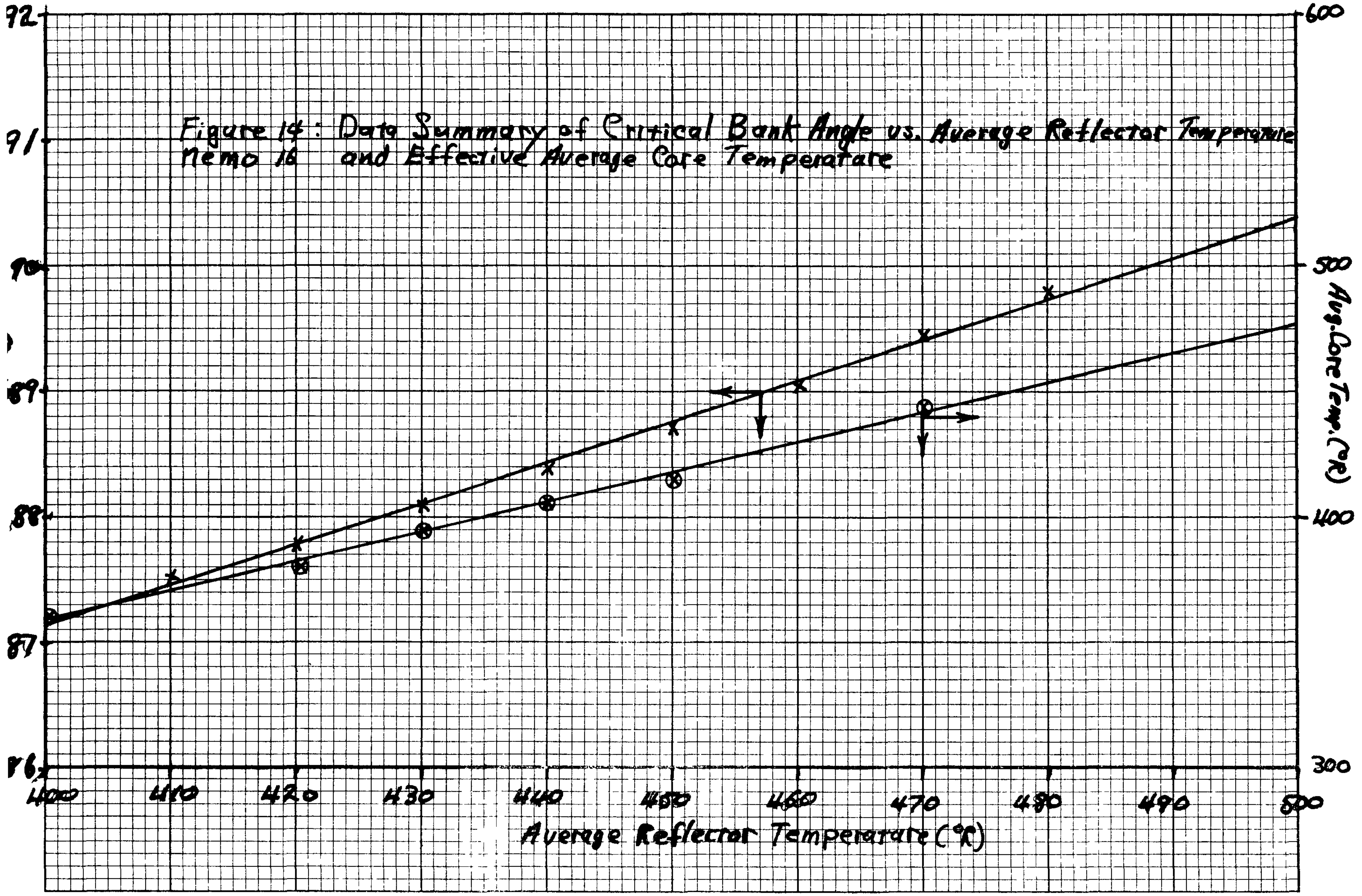


Figure 14: Data Summary of Critical Bank Angle vs. Average Reflector Temperature
Memo 16 and Effective Average Core Temperature
92
91
90
89
88
87
86
600
500
400
300
Avg. Core Temp. (°R)
400
410
420
430
440
450
460
470
480
490
500
Average Reflector Temperature (°R)

SPEAR Memo No. 17

XE-PRIME

EP-8A

Subject: NON-NUCLEAR ENGINE COMPONENT PERFORMANCE SUMMARY

It was necessary to omit this memo because it was not available at time of publication.

In addition to those components covered in specific memos this memo also summarized the results of post-test review and analysis of the following:

1. TPA and engine system vibrations during the test.

2. Lines, thrust structure and pressure vessel.

It was verified that these evaluations disclosed no problems with the components and all engine components evaluated are considered to be in satisfactory condition for the next EP.

K. R. Conn
K. R. Conn
Acting SPEAR Chairman

SPEAR Memo No. 17A
J. W. Holaday:jh

XE-PRIME

EP-8A

Subject: FACILITY SYSTEMS PERFORMANCE

SUMMARY

All the facility systems, which were evaluated performed satisfactorily, with the exception of the problems noted below:

1. The most significant anomaly was the possible interaction between the operation of the test stand cooling system and inner engine compartment electrical systems. Apparently one of the three TPCV position pot channels (DP867) and the TBV position channel may have been affected by moisture present in some electrical connectors in the top shield penetration. These engine electrical systems will be checked out prior to the next EP.

2. The hydraulic supply system, which supplied the hydraulically operated valves in the V-3900 GN_2 storage and supply system, experienced a malfunction during the pre-operational phase. Proper setup of the valve by the T15 console operator after the failure resulted in an operational configuration of the V-3900 storage and supply system. Post-test investigation revealed leakage at a vessel shut-off valve and a defective coupler. The system has been restored to an operational configuration.

3. The V-5002 overpressure detector trip point required adjustment during the pre-operational phase; however, after adjustment the system performed satisfactorily.

The highlights of the facility system operation were:

1. The facility fluids were utilized in an optimum manner and supported 4.72 hours of pre-run operations and 4.05 hours of engine test operations.

2. There were no significant run tank (V-5001) pressurization system problems during topping operations including the period when the LH_2 inflow into V-5001 exceeded the outflow.

   The data sources were NTO listings (thin and short) and CALCOMP Plots.

TECHNICAL DISCUSSION

1. ETC H_2 Sensors

There are two sensors, KT003 and KT004, associated with the H_2 sensing system. The sensing lines which "sniff" the gas above the intermediate shield (KT003B) and near the nozzle (KT004D) were used during the majority of EP-8A. The sensors performed satisfactorily event though they appeared to be erratic at times. During the inverting pulses they responded normally.

2. ETC Shield Seal Purge System

The ETC shield seal pressures, convolute buffer pressures, and blade real pressures remained above ambient. Some decrease (less than 0.19 psi, except for PT631) was evidenced when the ETC pressure was decreased from 12.8 psia to 8.0 psia during startup of the steam generators. The S-4 bottom blade purge pressure (PT631) decreased from 15.95 psia to 15.75 psia when the ETC pressure was decreased to 8.0 psia and decreased from 15.75 psia to 14.69 psia when the ETC pressure was reduced to 0.95 psia during pull-in. This decrease was observed during previous EP's and apparently is not detrimental.

3. GH_2 Supply System

The GH_2 supply system was used twice during EP-8A. The first time was prior to the first bootstrap (open loop startup from ambient conditions) in which 4.8 lbs/sec was flowed for 30.0 seconds. The second was after the last bootstrap in which 5.4 lbs/sec was flowed for 81.0 seconds. Figures 1 and 2 show the GH_2 supply system pressures for the entire run.

4. Fluid Utilization

The net fluids utilization during EP-8A tabulated in Table 1. The inventory and usage versus time profiles are plotted in Figures 3, 4, 5 and 6. The GN_2 trailer inventory (LBGNTR) is not plotted but equals approximately 1/3 the V-3200 series vessels storage capacity. In general, the fluids inventories had reached the minimum levels at the termination of the engine test phase.

The helium supply system pressures are shown in Figures 7 and 8. The tube trailer discharge line pressure (PT874) reflects the UTSM inerting usage, which is generally a nominal .1 pps during the pretest phase and a nominal .2 pps during the run phase; due to the length of this test the flow was reduced to .09 pps during the run phase. Even at this low flow the helium tube trailer dropped to 333 psia by the end of the test.

All three He storage vessels were on-line for this test.

Technical Discussion (Cont'd)

The V-3900 bottle GN_2 storage and supply system pressure versus time profile is shown in Figures 9 and 10. The initial inerting of the duct vault and pipe chase using V-3901, 02 and 03 and subsequent inerting maintenance with vessel V-3904 is clearly shown.

5. V-5001/V-3801/PSL Performance

V-3801 was pre-pressurized to 85 psia with helium to conserve H_2. The initial V-3801 inventory was 138,160 lbs (LT002 = 92% HT). Approximately 56,600 lbs were utilized to fill and chill V-5001 and V-5002. The initial V-3801 fluid temperature was 37.7°R at 85 psia, (NPP = 67 psi) and the find temperature was 38.8 at 20 psia. The total LH_2 usage was 121,000 lbs. The pertinent initial V-5001 fill data is present in Figures 11 and 12.

V-5001 topping was performed during the physics test to determine the characteristics of the V-5001 pressurization system during low outflow (approximately 6 pps) topping operations. The pertinent V-5001 data during this topping operation is shown in Figure 13. The dewar pressurization valve, PCV-165, closed from 21% to 1% after topping was initiated through RSV-128. The dewar level (LT499) increased slowly and PCV-165 oscillated between 0.5 and 4% open during the RSV-128 topping operation. The dewar pressure increased from 35.0 to 35.5 psia when RSV-129 was opened. It then decayed back to 35.0 over the 35 sec that PCV-180 was open. The dewar level (LT499) increased at .086%/sec after RSV-129 was opened. The V-5001 vent valve, PCV-180, opened to 25-30% to hold the pressure to the demanded 35 psia. There was no alternate PCV-165 and PCV-180 cycling or other system instabilities (except for PCV-180 limit cycles) therefore, this topping procedure can be utilized, if necessary. At the 6 pps outflow, the net fill reates (at a V-3801 to V-5001 pressure differential of 44.6 psid), were 6.8 and 34.6 pps for RSV 128 and 129. The topping rates were thus 12.5 and 40.3 pps.

V-5001 topping was accomplished during Run No. 1 at the T_c = 2400°R and P_c = 300 psia operating point. The pertinent V-5001 topping data is presented in Figures 13, 13A, 14 and 15. RSV-128 was opened after stabilization at the 2400°R/170 psia operating point. RSV-129 was opened when LT499 reached 85% and V-3801 was allowed to flow down from 71 psia to 61.5 psia to conserve GH_2. The V-3801 pressure was maintained at 61.5 psia during the remainder of the test. RSV-129 was closed at RT 57528; however, the topping data acquired during the physics test indicates that RSV-129 could have been left open and PCV-180 would have maintained the V-5001 pressure at 35 psia in a stable fashion.

Technical Discussion (Cont'd)

"Pulse" topping was performed during Run No. 2 as shown in Figure 16. Figures 17 and 18 show additional V-5001 parameters during Run No. 2. Figures 19, 20 and 21 show pertinent V-5001 parameters during Run No's. 3, 4, 5 and 6. In summary the V-3801, V-5001 and propellant supply systems performed satisfactorily.

CONCLUSIONS

The facility fluid systems performed satisfactorily during EP-8A and are in acceptable condition to support the next EP.

TABLE I

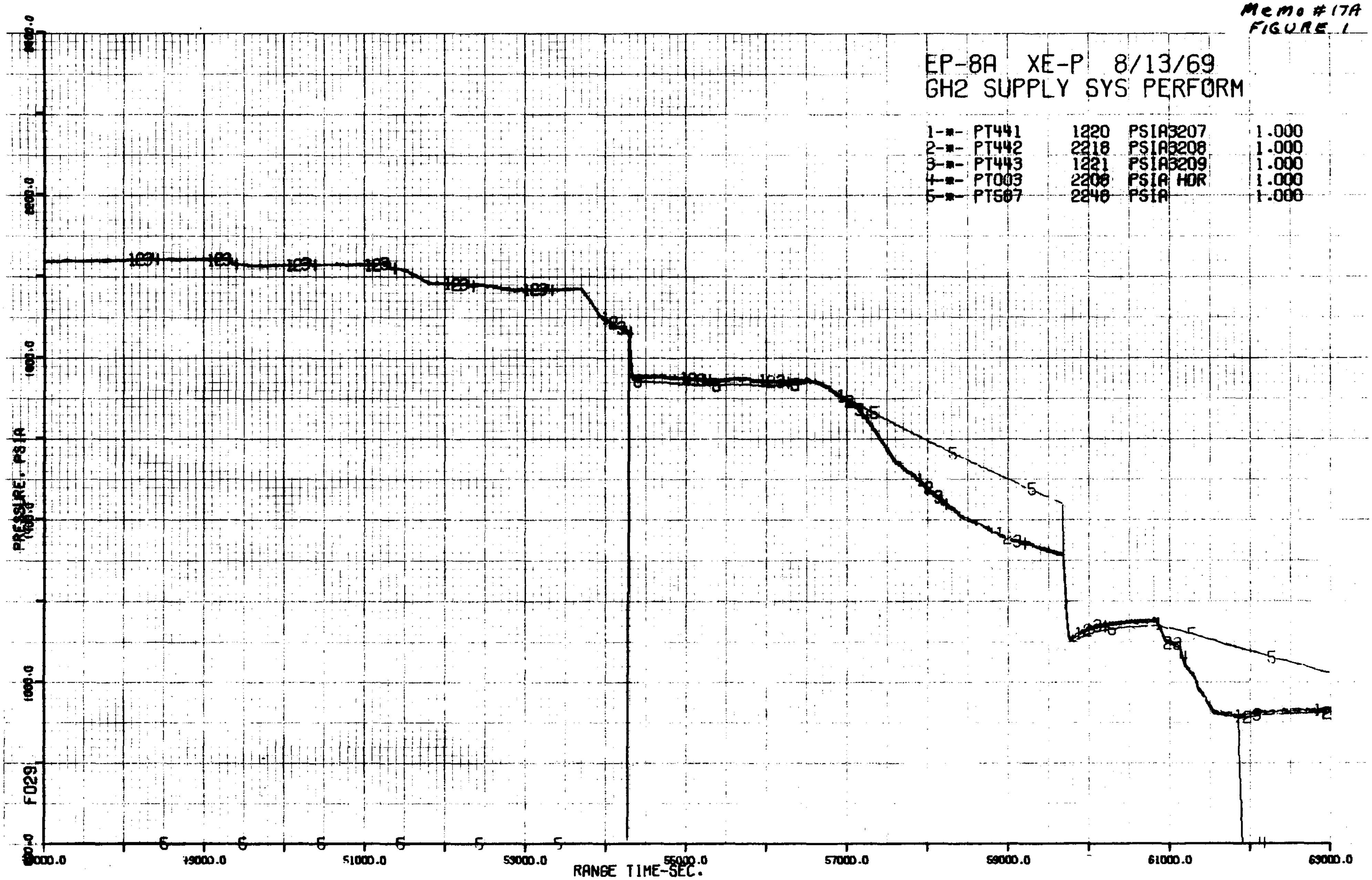
FLUID UTILIZATION

XE-Prime EP-8A

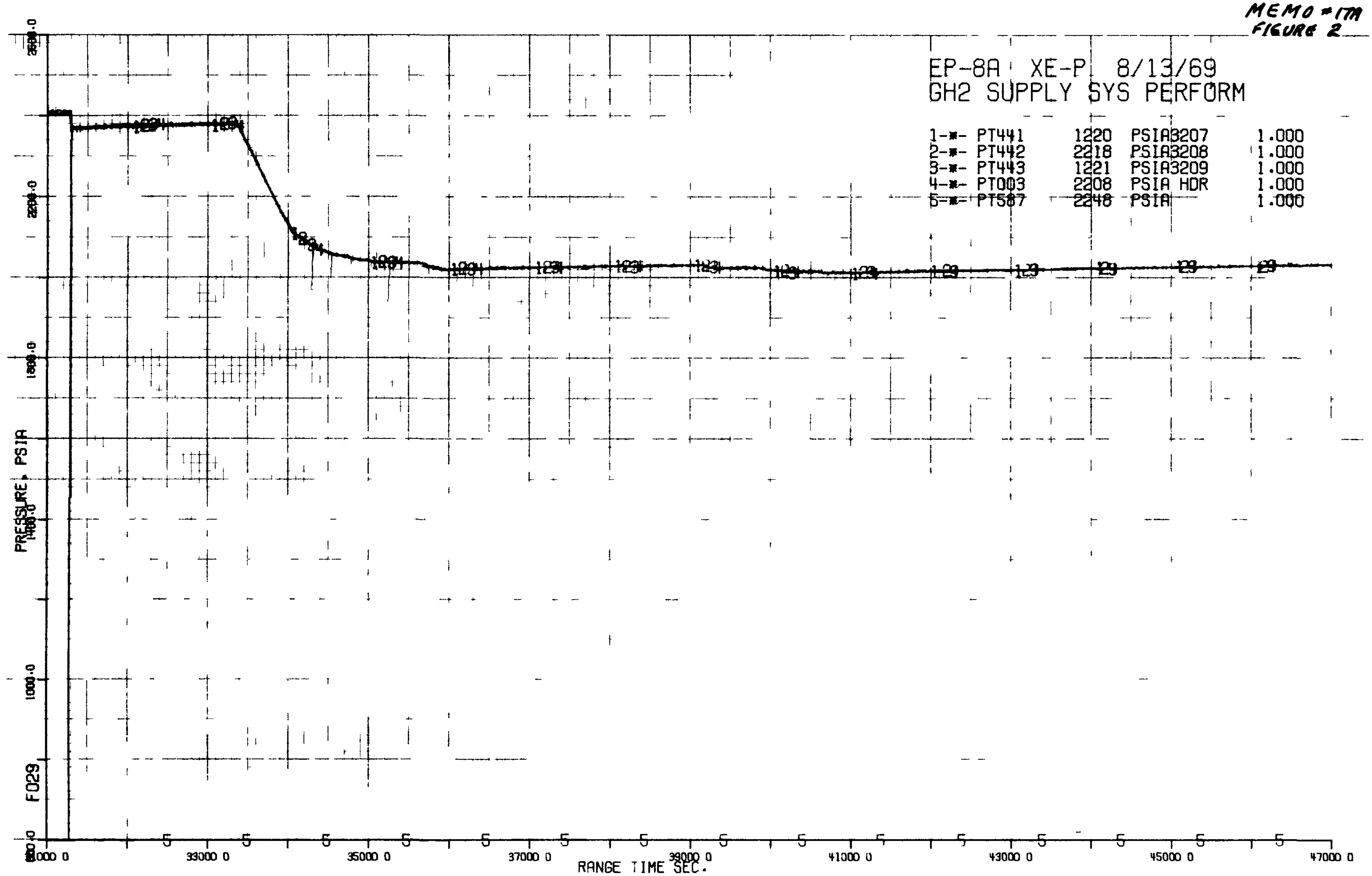
Fluid		Initial Inventory (lbs)[1]	Inventory At Start of Run (lbs)[1]	Final Inventory (lbs)[1]	Usage (lbs)[1]	
	Range Time, Secs	31000	44950	63000		
	ΔT	0	3.9 hrs	8.9 hrs		
GN_2	V-3201, 02, 03	55,000	45,700	20,000	35,000	
	V-3901, 02, 03, 04	110,000	76,000	30,000	80,000	
	Tube Trailers	20,326	16,794	7,361	12,965	
					127,965	TOTAL
GH_2	V-3207, 08, 09	5,320	4,600	2,210	3,110	
He	V-3204, 05, 06	8,100	7,490	5,650	2,450	
LH_2	V-3801	138,160	80,000	16,200	121,960	
LN_2	V-3601	168,266	147,012	113,953	55,313	
H_2O	T-3302	2.56×10^6	2.54×10^6	$.05 \times 10^6$ gal	2.51×10^6	
He(UTSM)	Tube Trailer	3,310	2,439	44	3,266	
C_3H_8	V-3401	15,400 gal	---	1,400 gal	14,000 gal	
LO_2	V-2801	20,700 gal	---	4,250 gal	16,450 gal	

1 Unless otherwise noted, usage is in lbs.

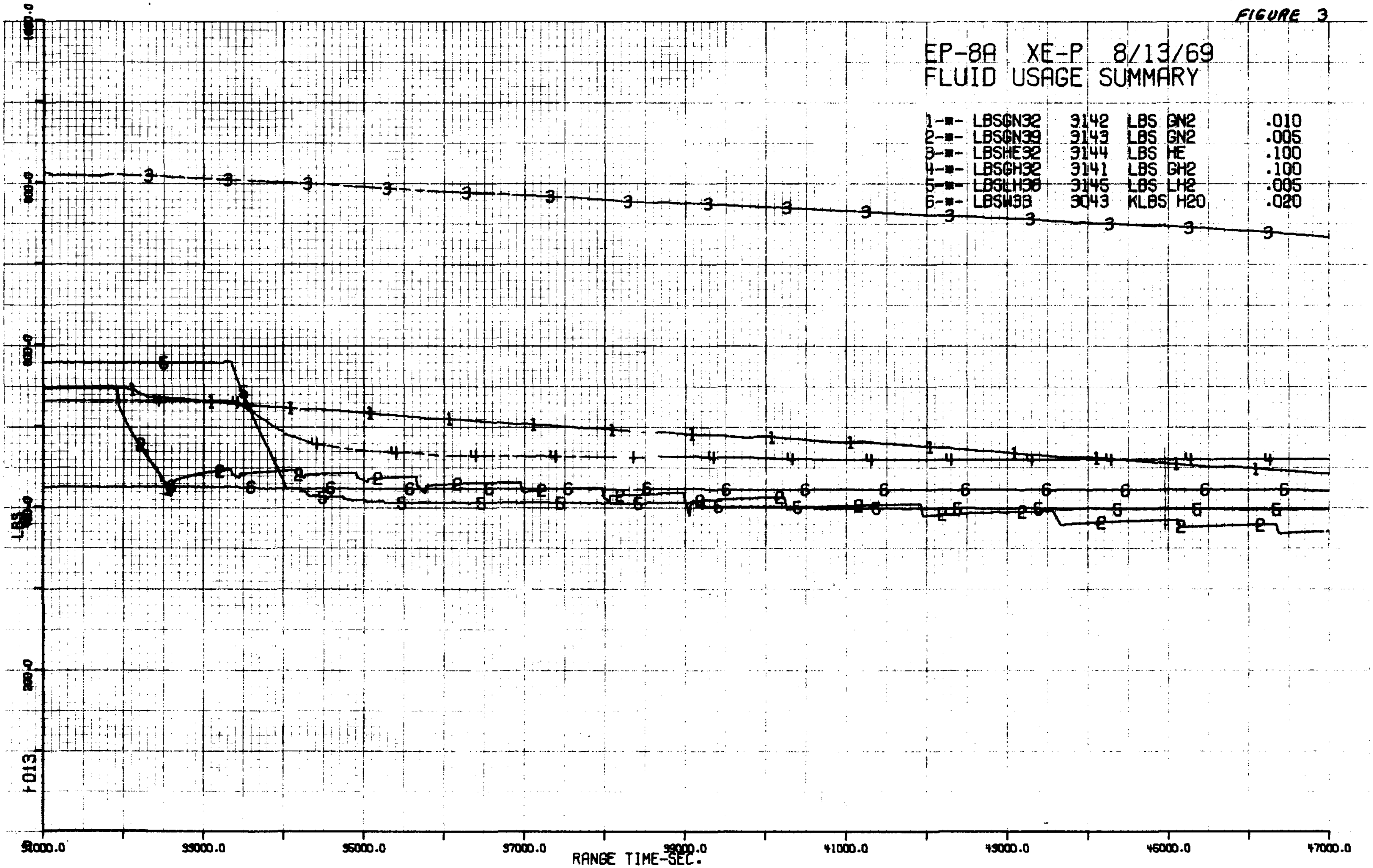
Memo #17A
FIGURE 1

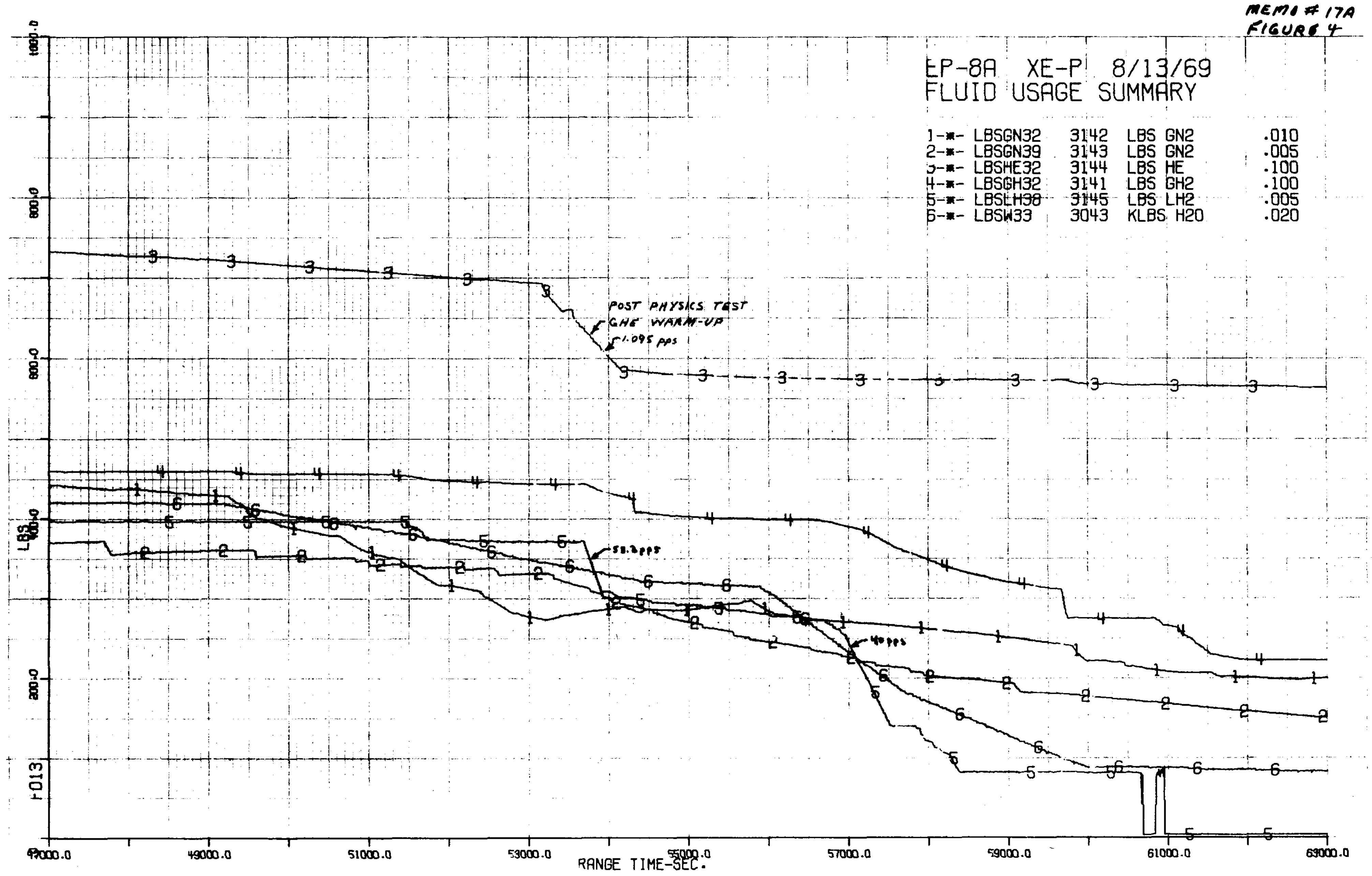


MEMO #ITM
FIGURE 2

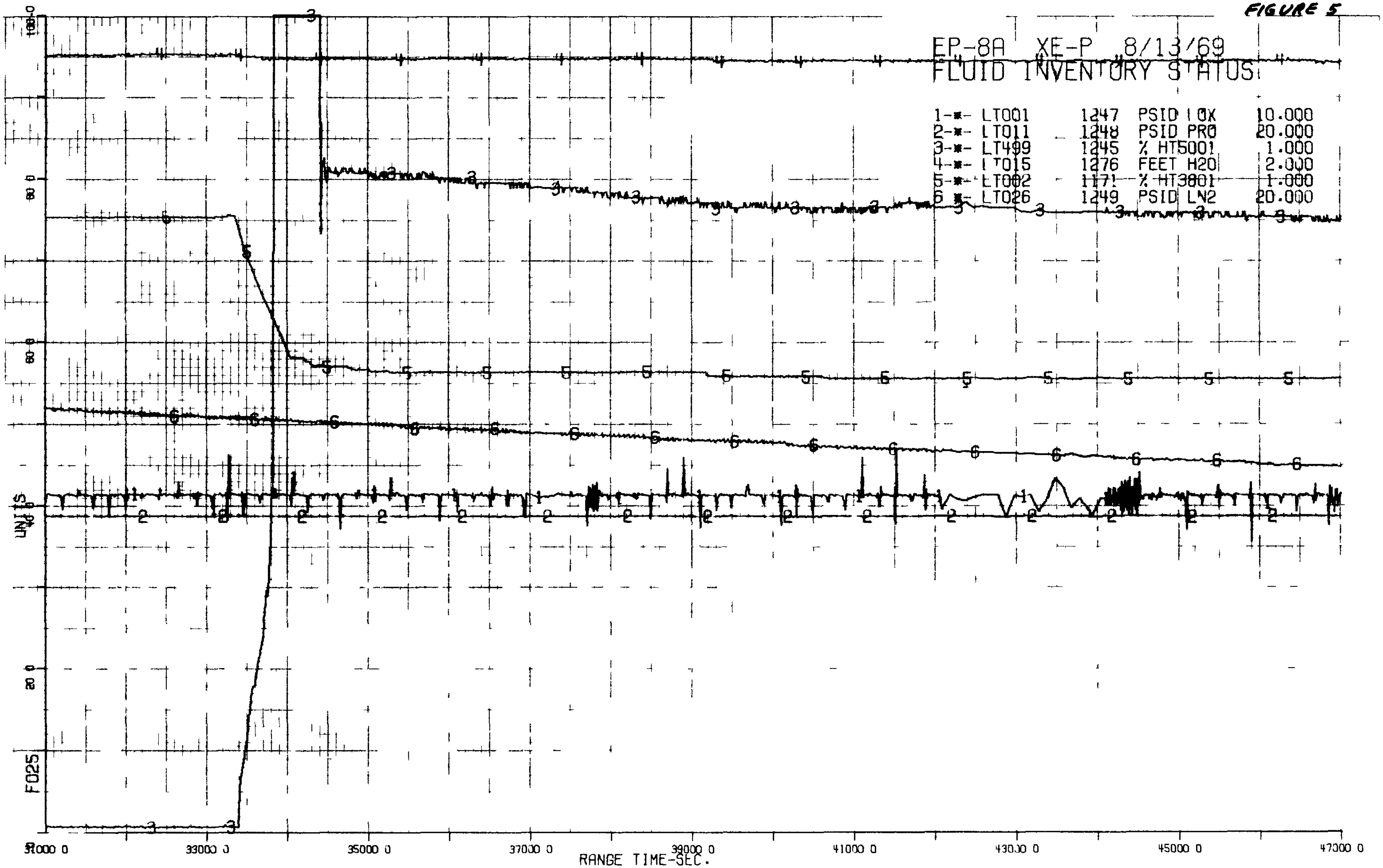


MEMO # 17A
FIGURE 3

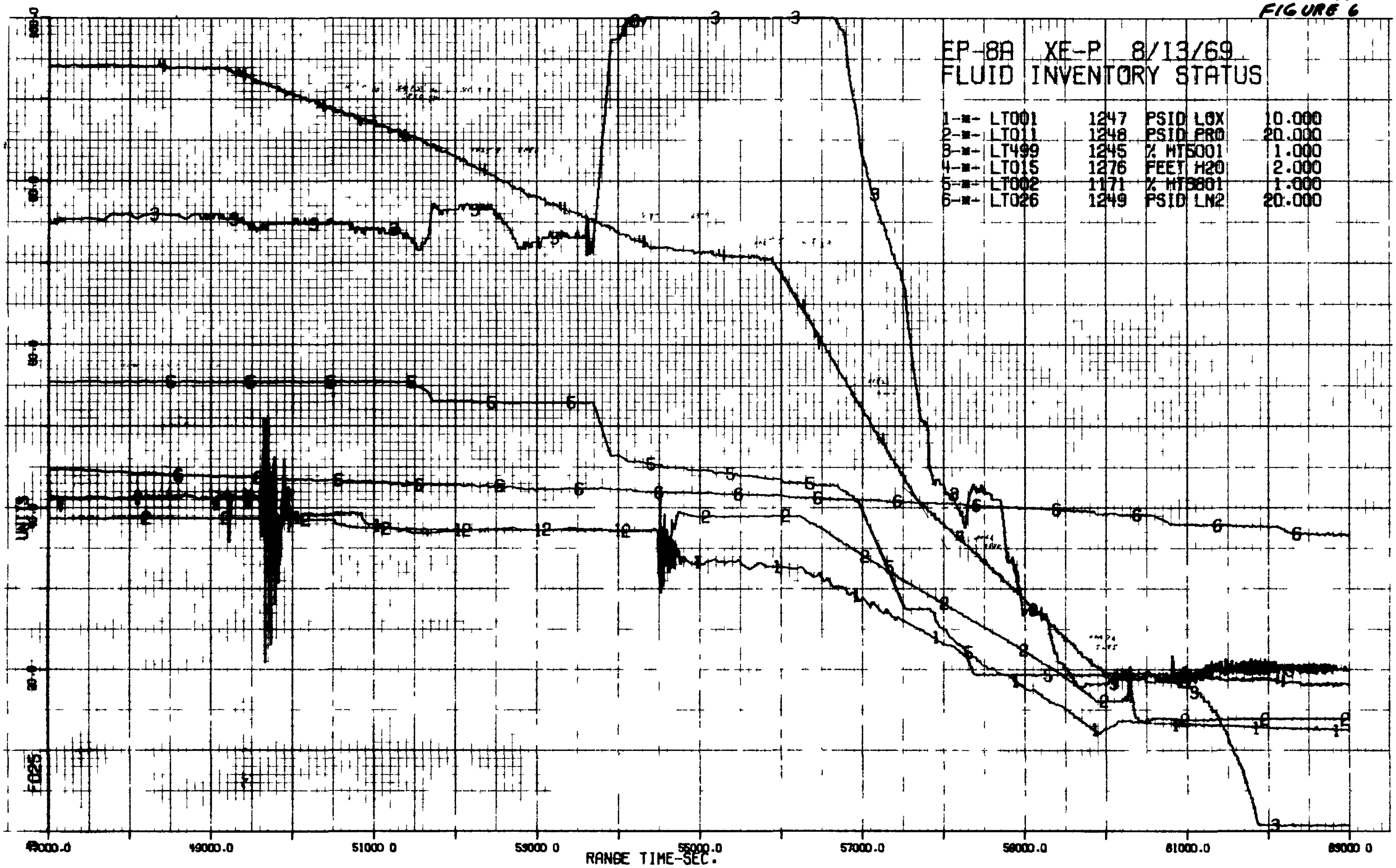



MEMO # 17A
FIGURE 4
EP-8A XE-P 8/13/69
FLUID USAGE SUMMARY
1-*- LBSGN32 3142 LBS GN2 .010
2-*- LBSGN39 3143 LBS GN2 .005
3-*- LBSHE32 3144 LBS HE .100
4-*- LBSGH32 3141 LBS GH2 .100
5-*- LBSLH38 3145 LBS LH2 .005
6-*- LBSW33 3043 KLBS H2O .020
POST PHYSICS TEST
GHE WARM-UP
1.095 pps
53.2 pps
40 pps
LBS
RANGE TIME-SEC.
47000.0
49000.0
51000.0
53000.0
55000.0
57000.0
59000.0
61000.0
63000.0
1000.0
800.0
600.0
400.0
200.0
F013

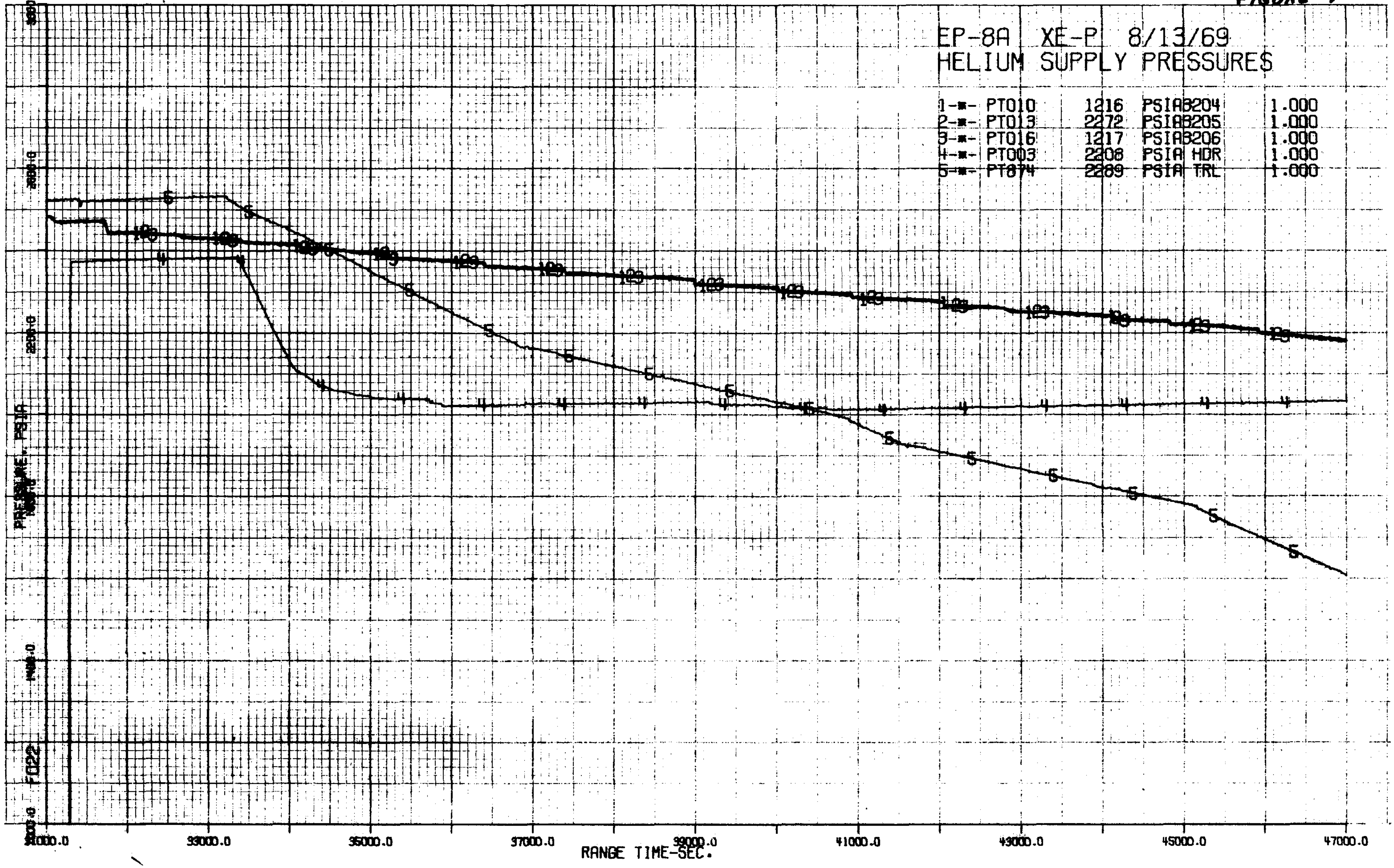
MEMO # 17A
FIGURE 5



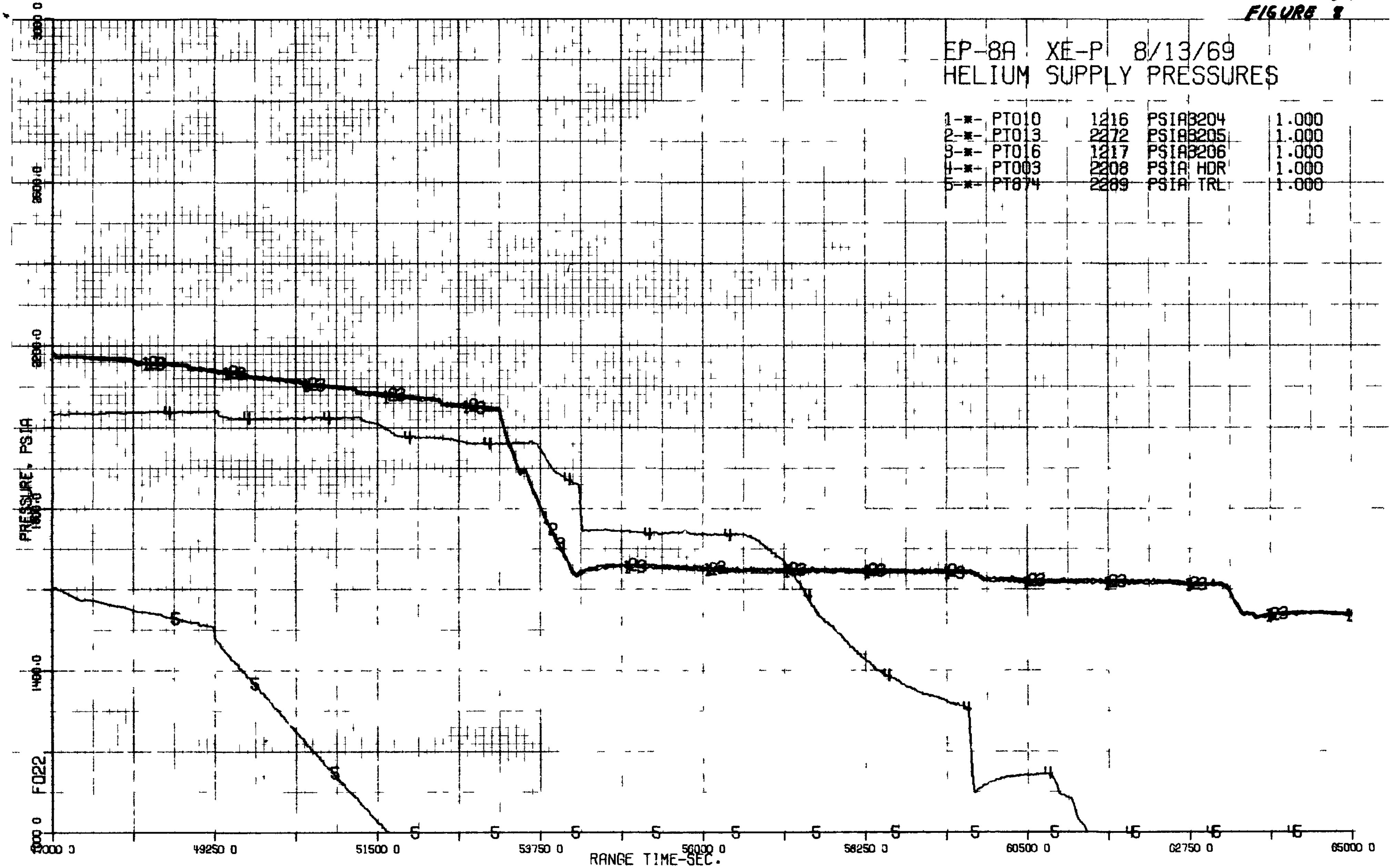
MEMO # 17A
FIGURE 6



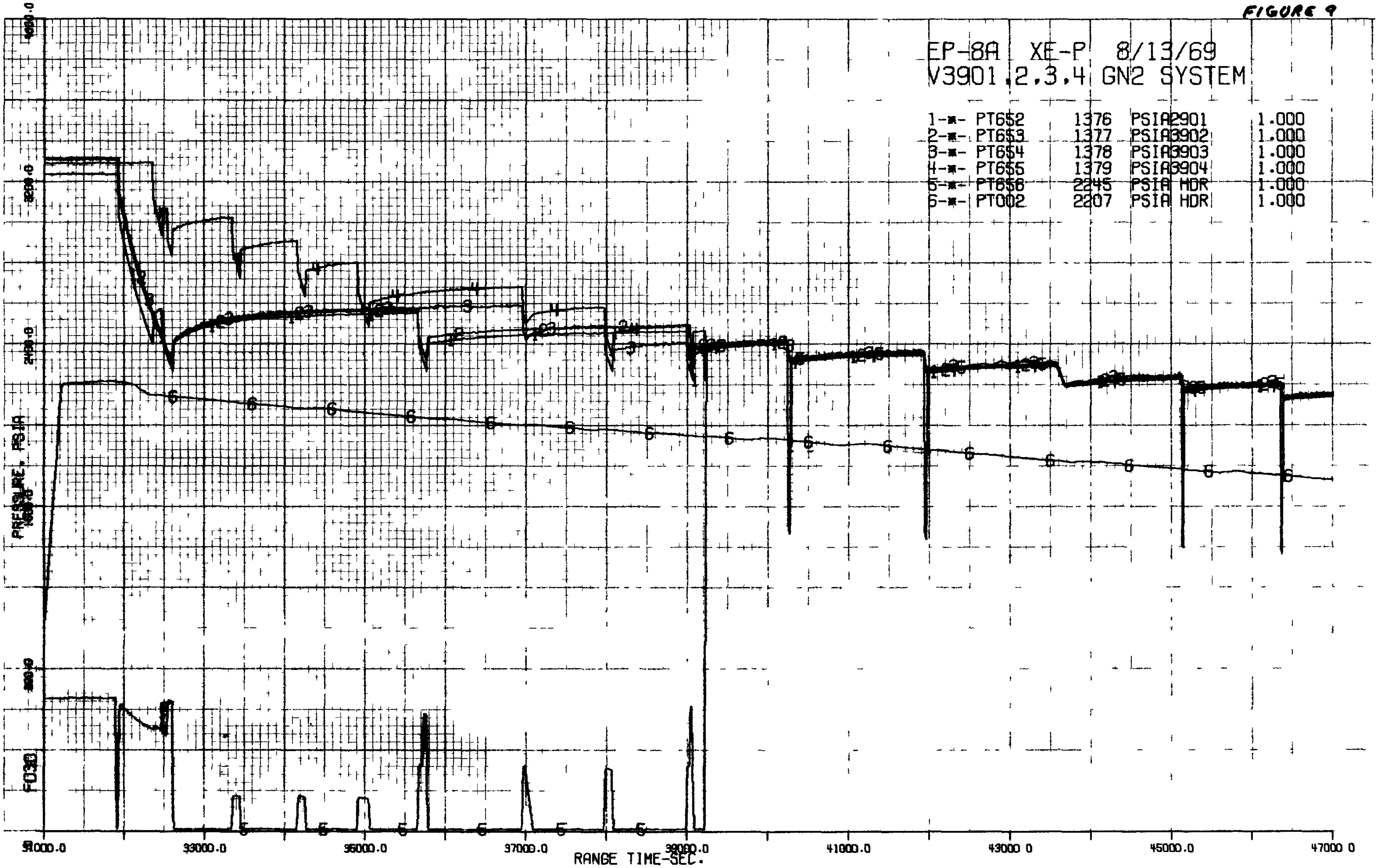
MEMO # 17A
FIGURE 7



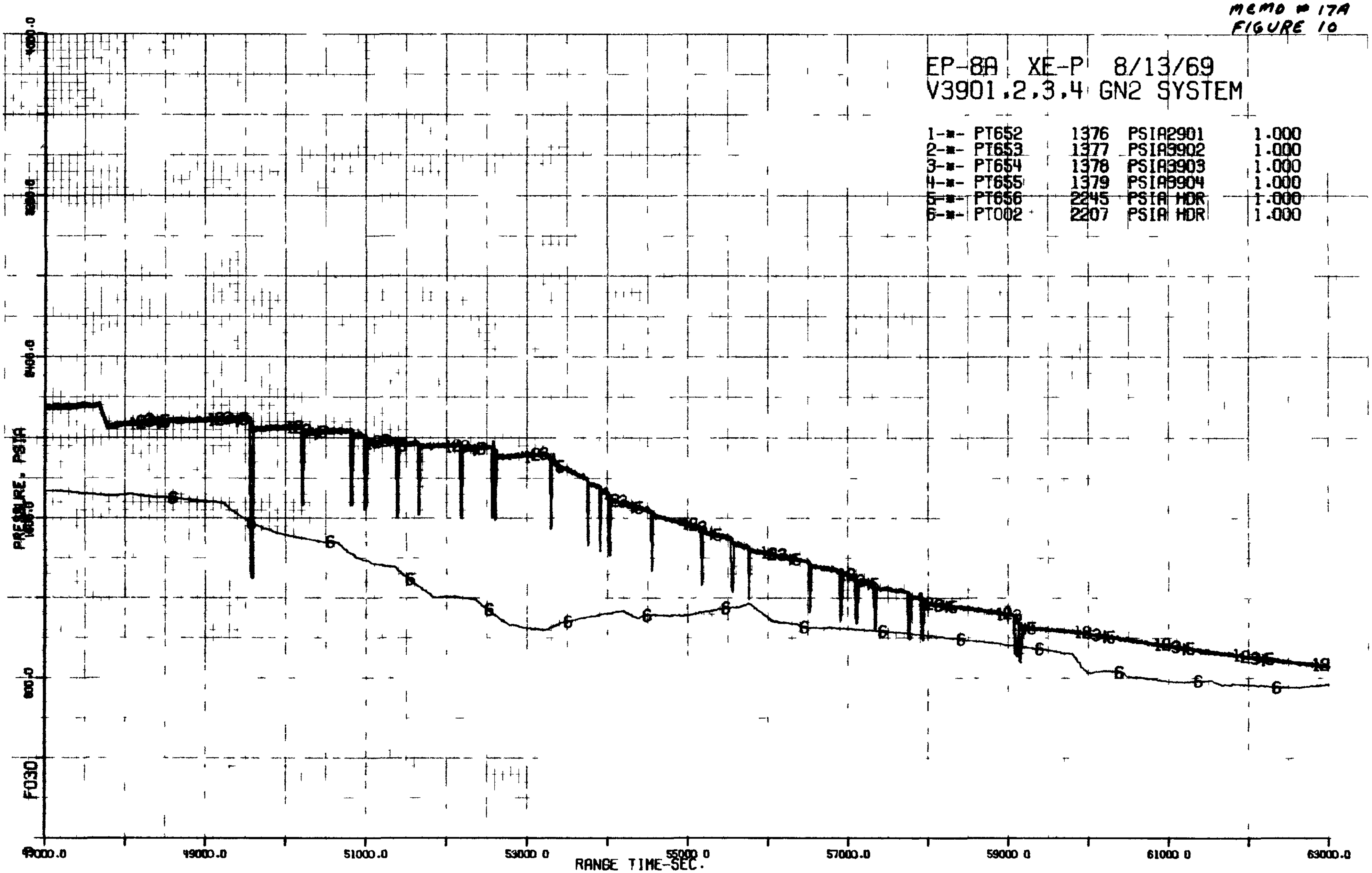
memo #17A
FIGURE 8



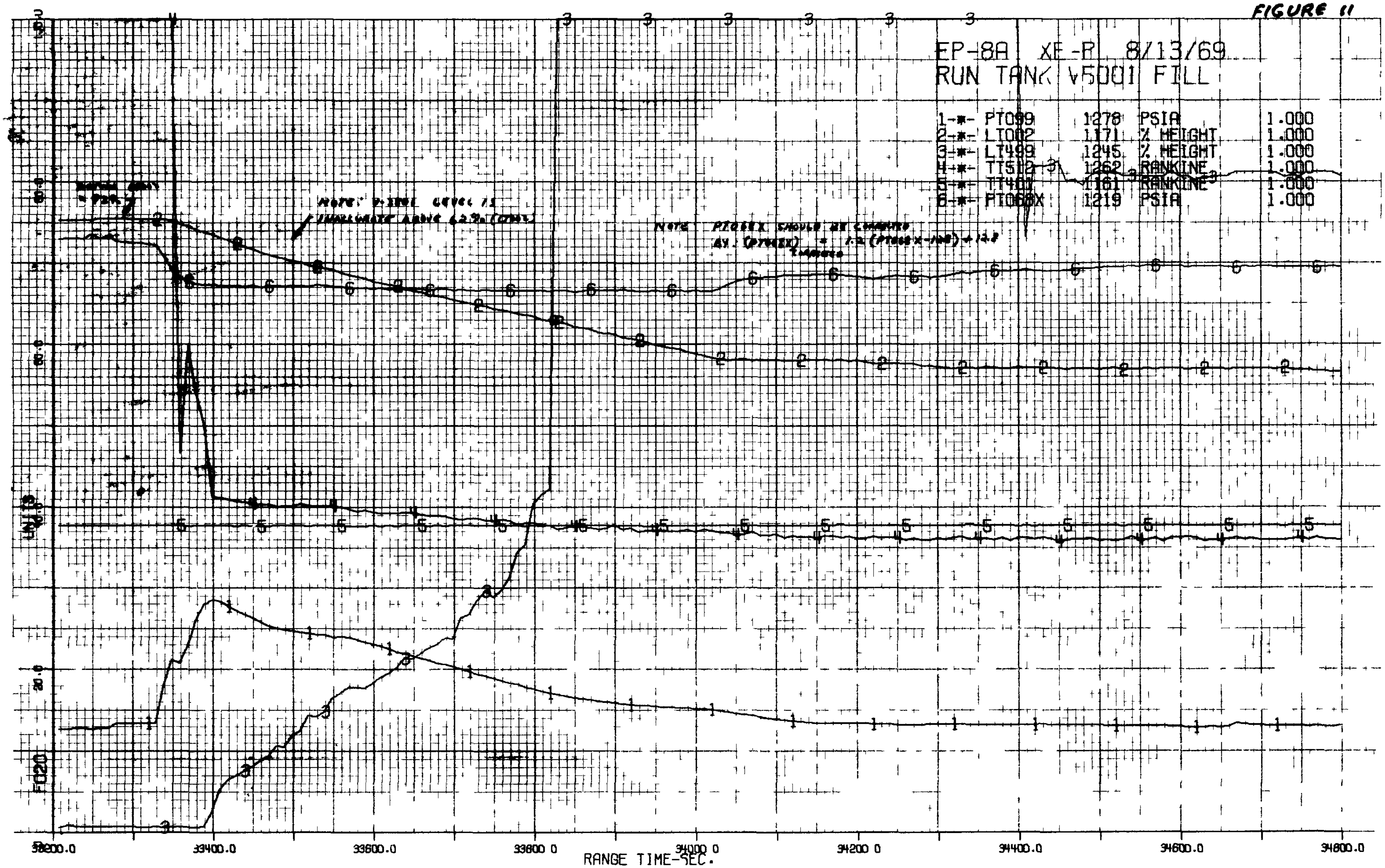
MEMO # 17A
FIGURE 9



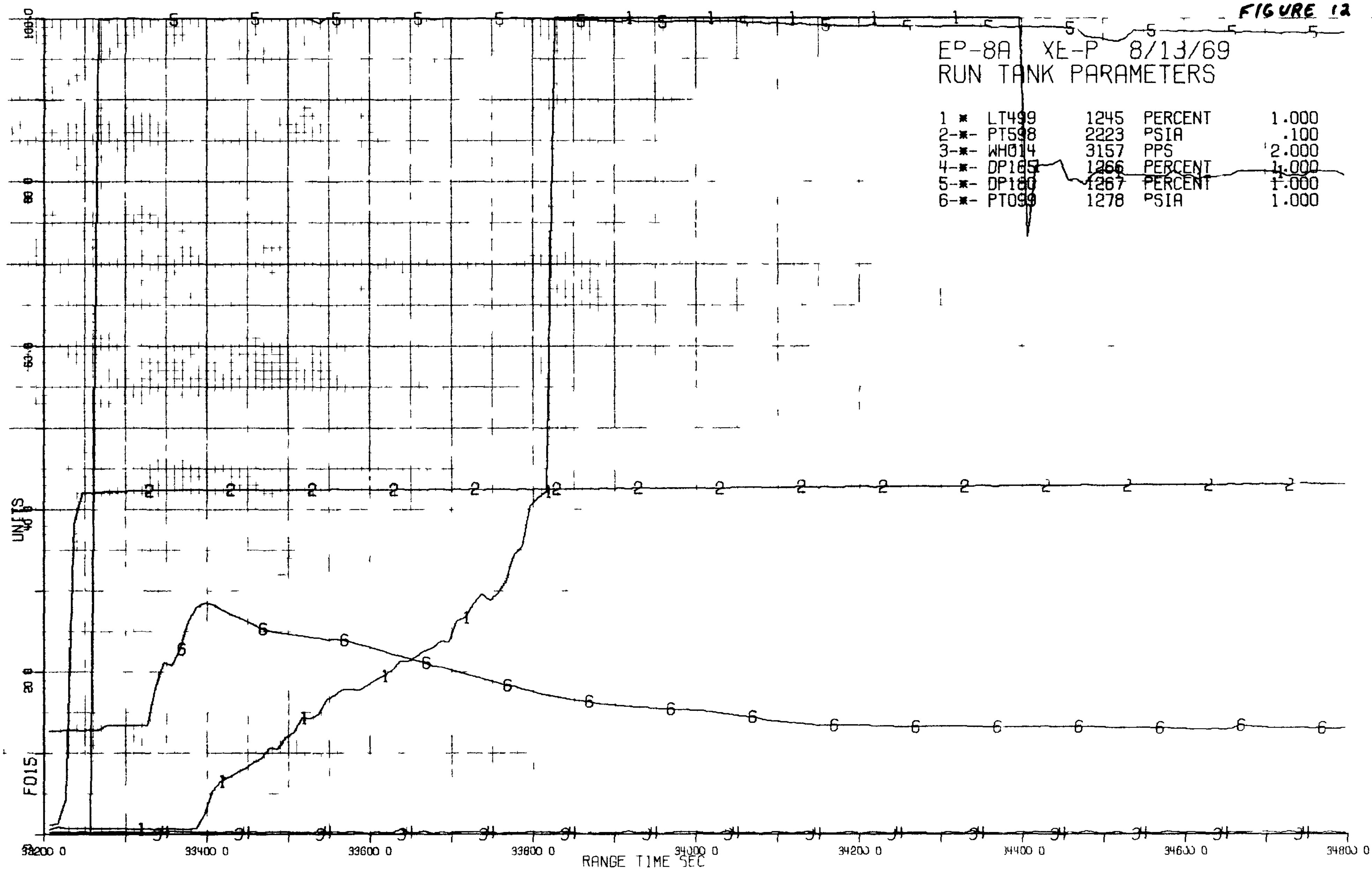
memo # 17A
FIGURE 10



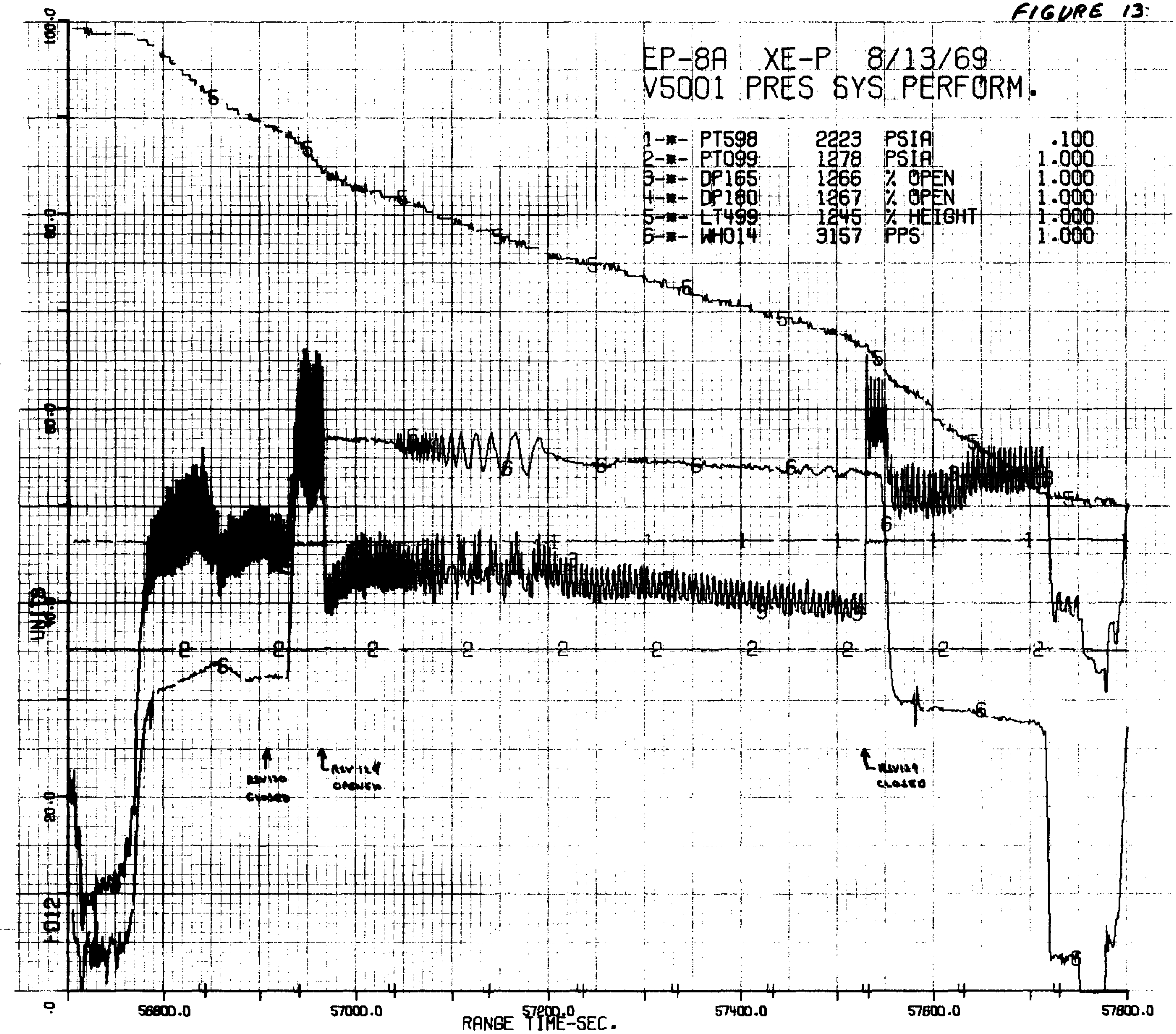
MEMO # 17A
FIGURE 11



MEMO # 17A
FIGURE 12



MEMO #17A
FIGURE 13



[redacted]70 'A

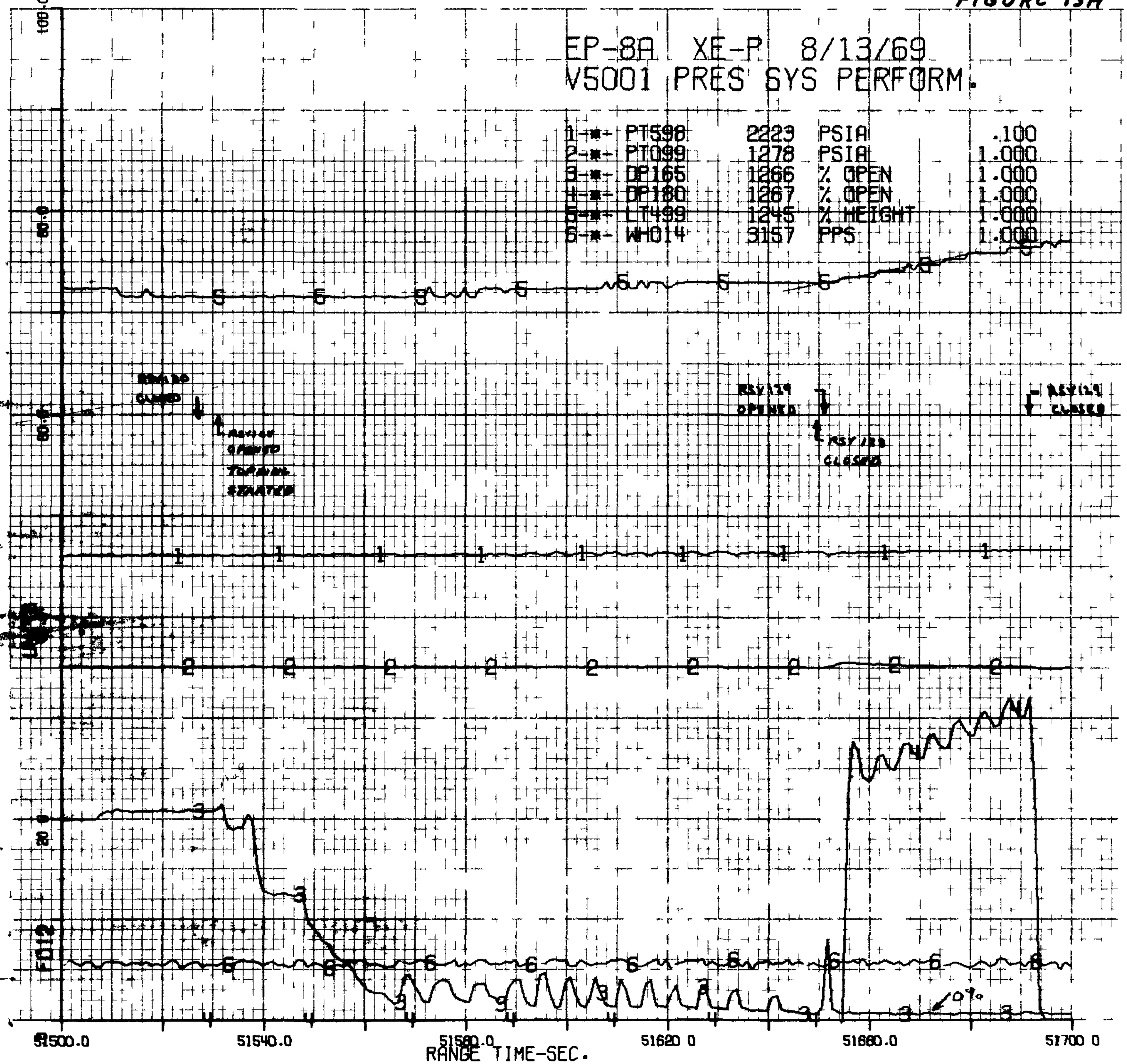


FIGURE 13A

MEMO #17A
FIGURE 14

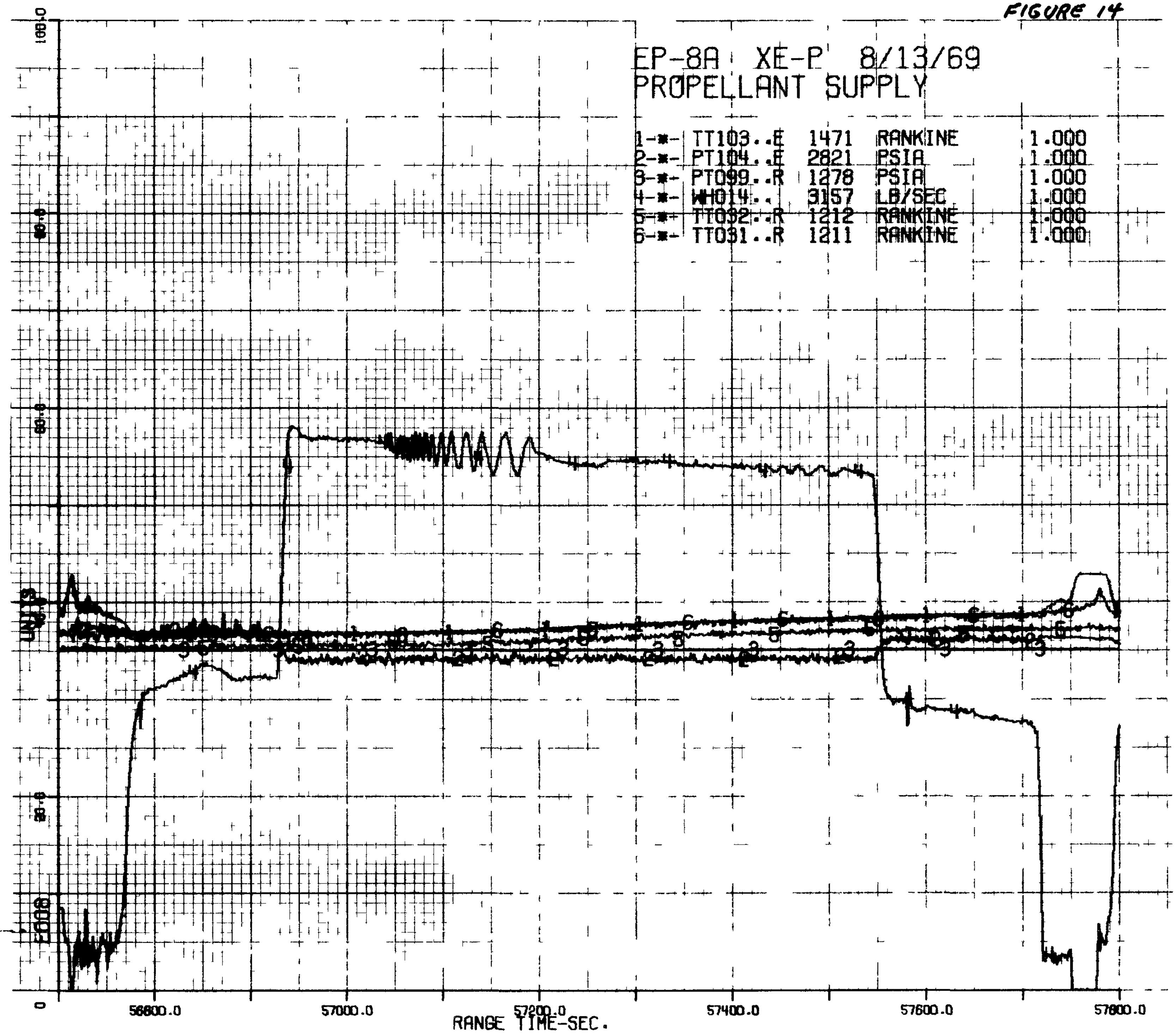
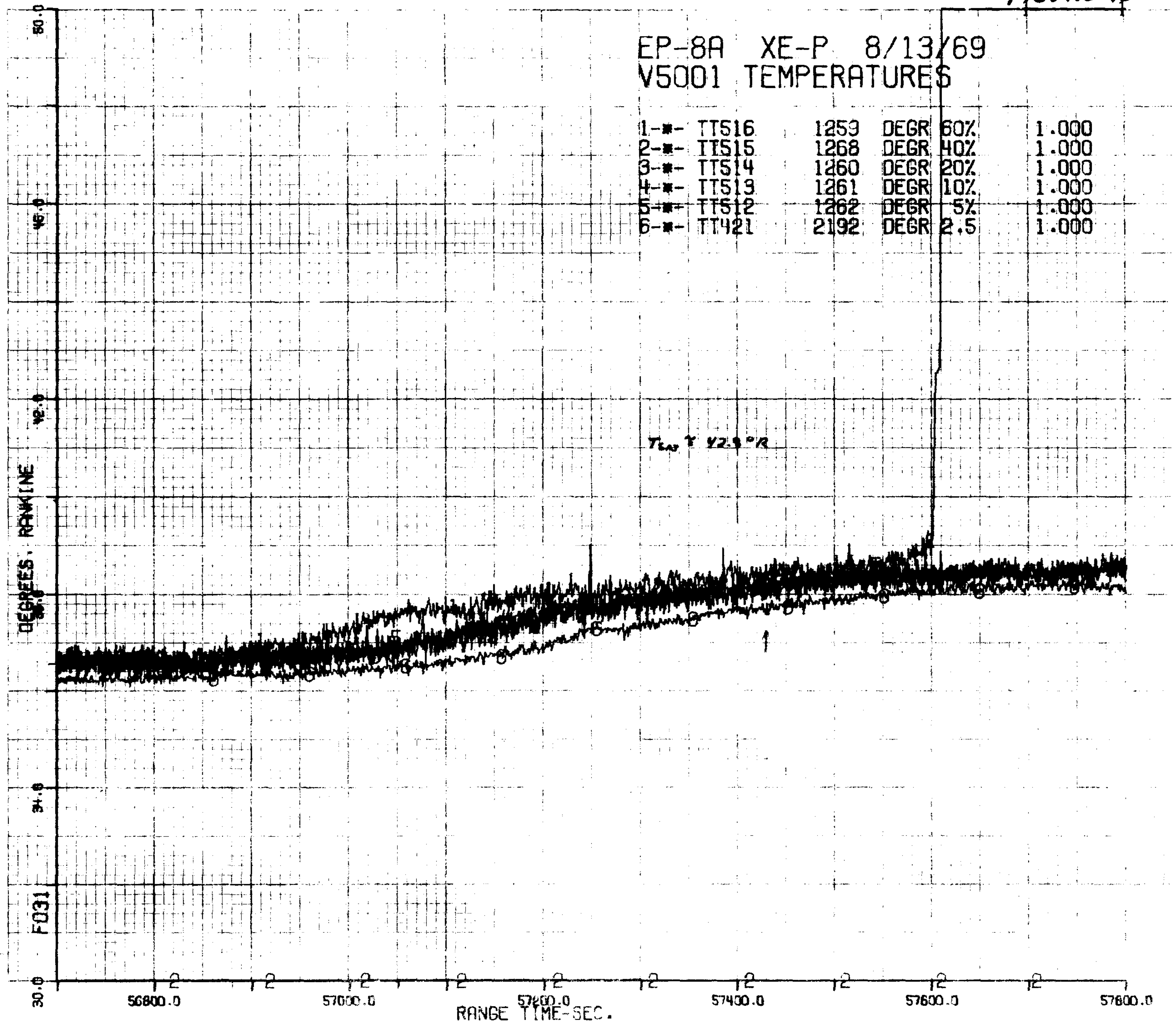
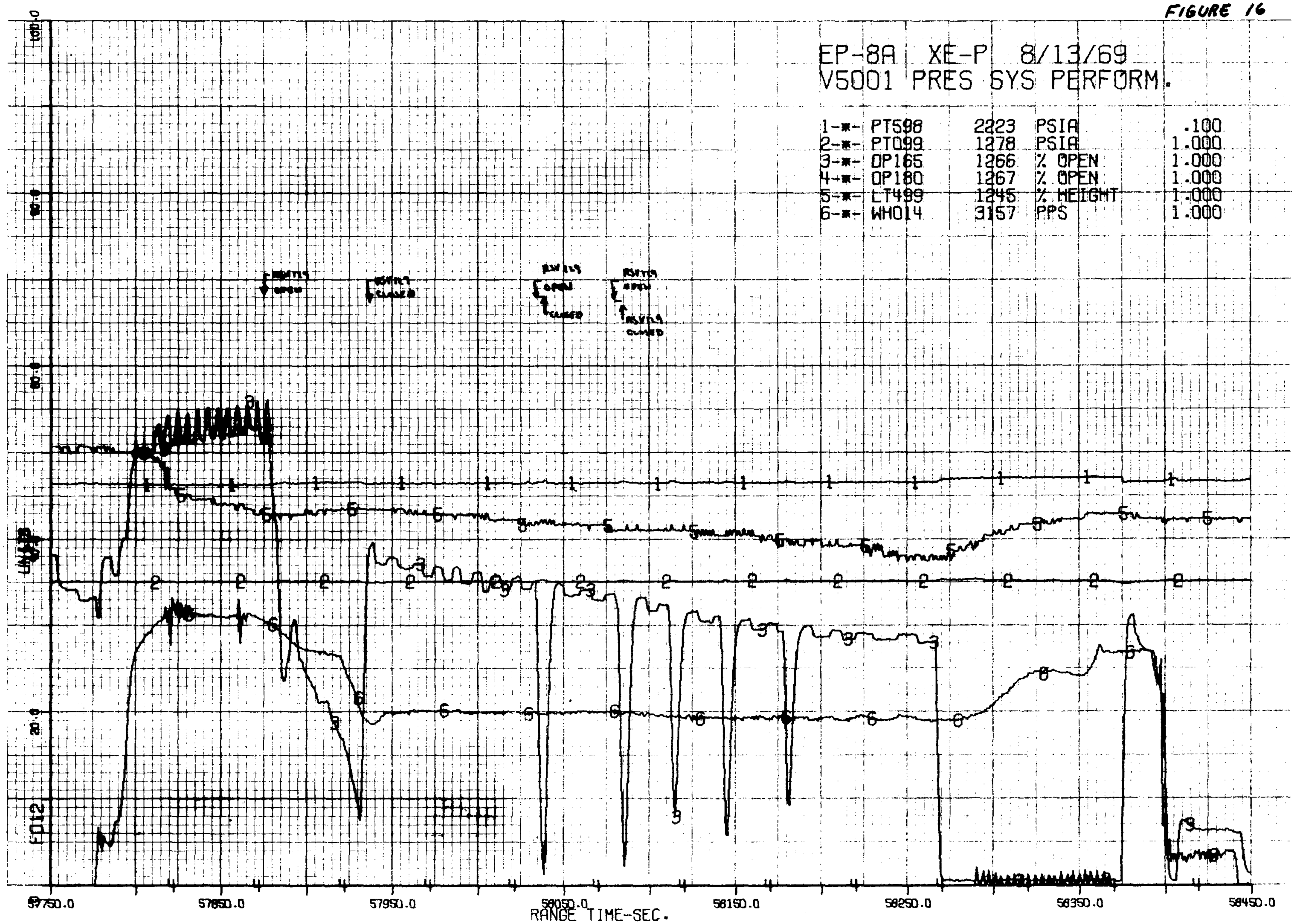


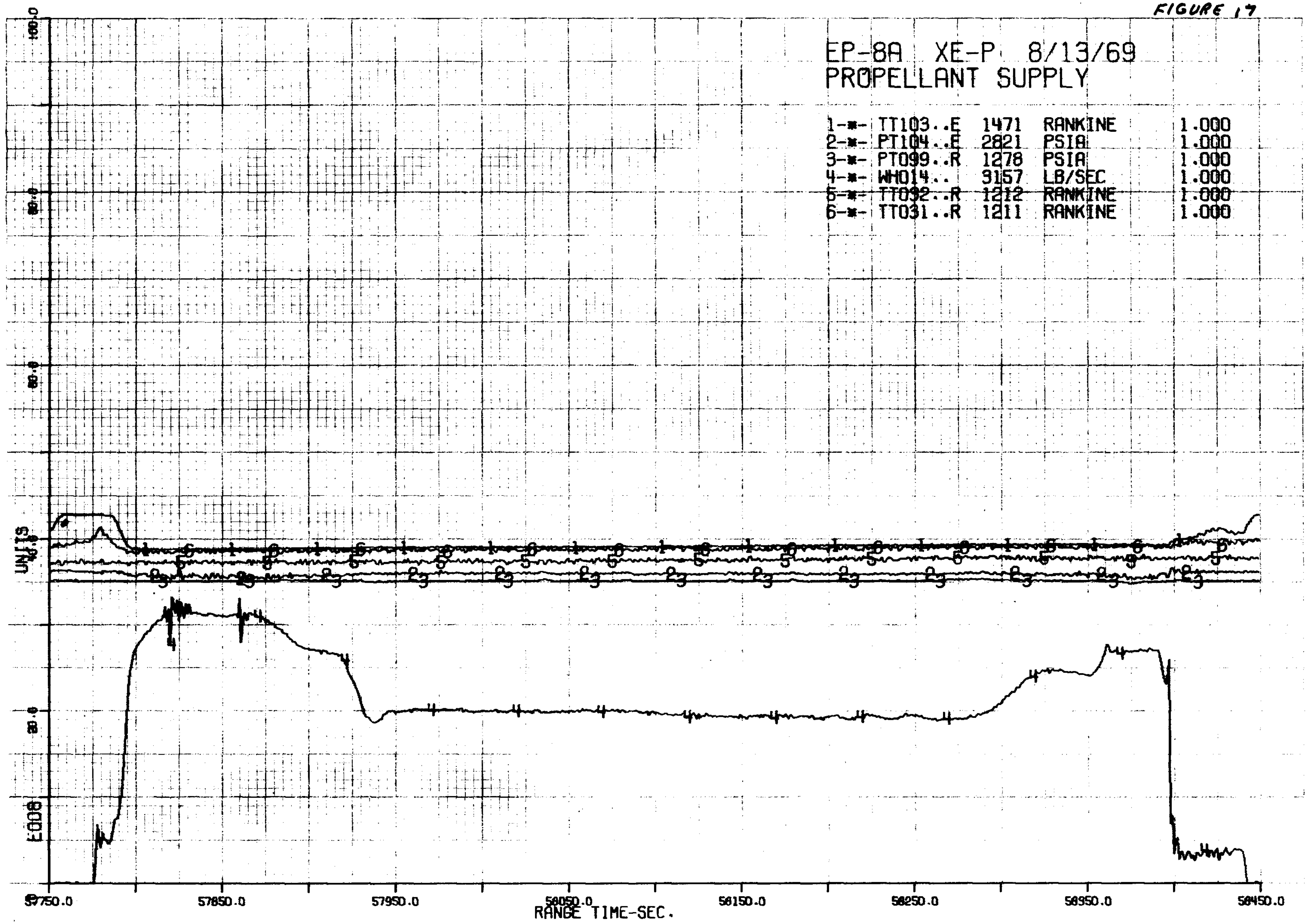
FIGURE 15

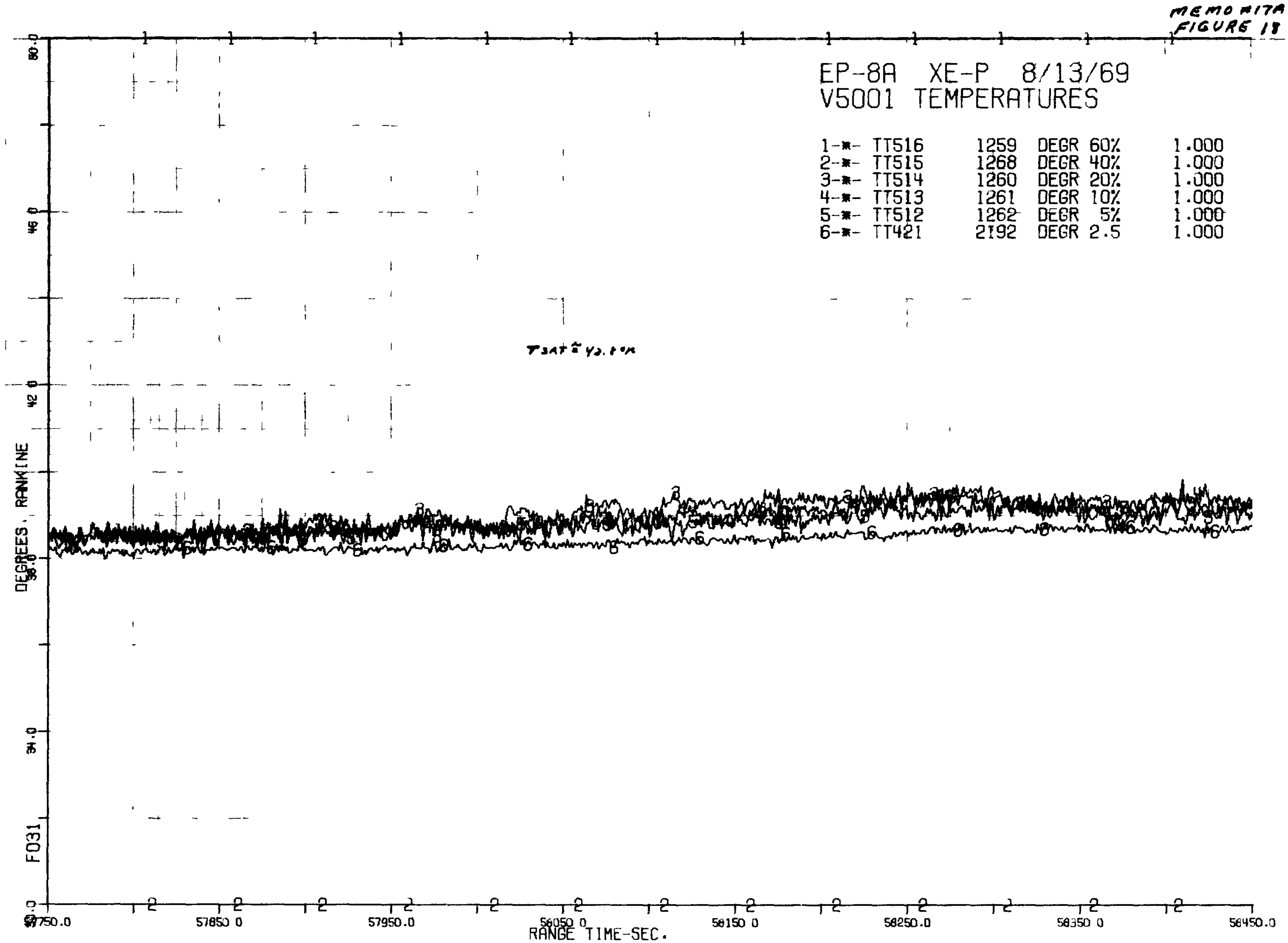

EP-8A XE-P 8/13/69
V5001 TEMPERATURES
1-*- TT516 1259 DEGR 60% 1.000
2-*- TT515 1268 DEGR 40% 1.000
3-*- TT514 1260 DEGR 20% 1.000
4-*- TT513 1261 DEGR 10% 1.000
5-*- TT512 1262 DEGR 5% 1.000
6-*- TT421 2192 DEGR 2.5 1.000
DEGREES, RANKINE
RANGE TIME-SEC.
56800.0
57000.0
57200.0
57400.0
57600.0
57800.0
30.0
34.0
42.0
46.0
50.0
F031

MEMO #17A
FIGURE 16

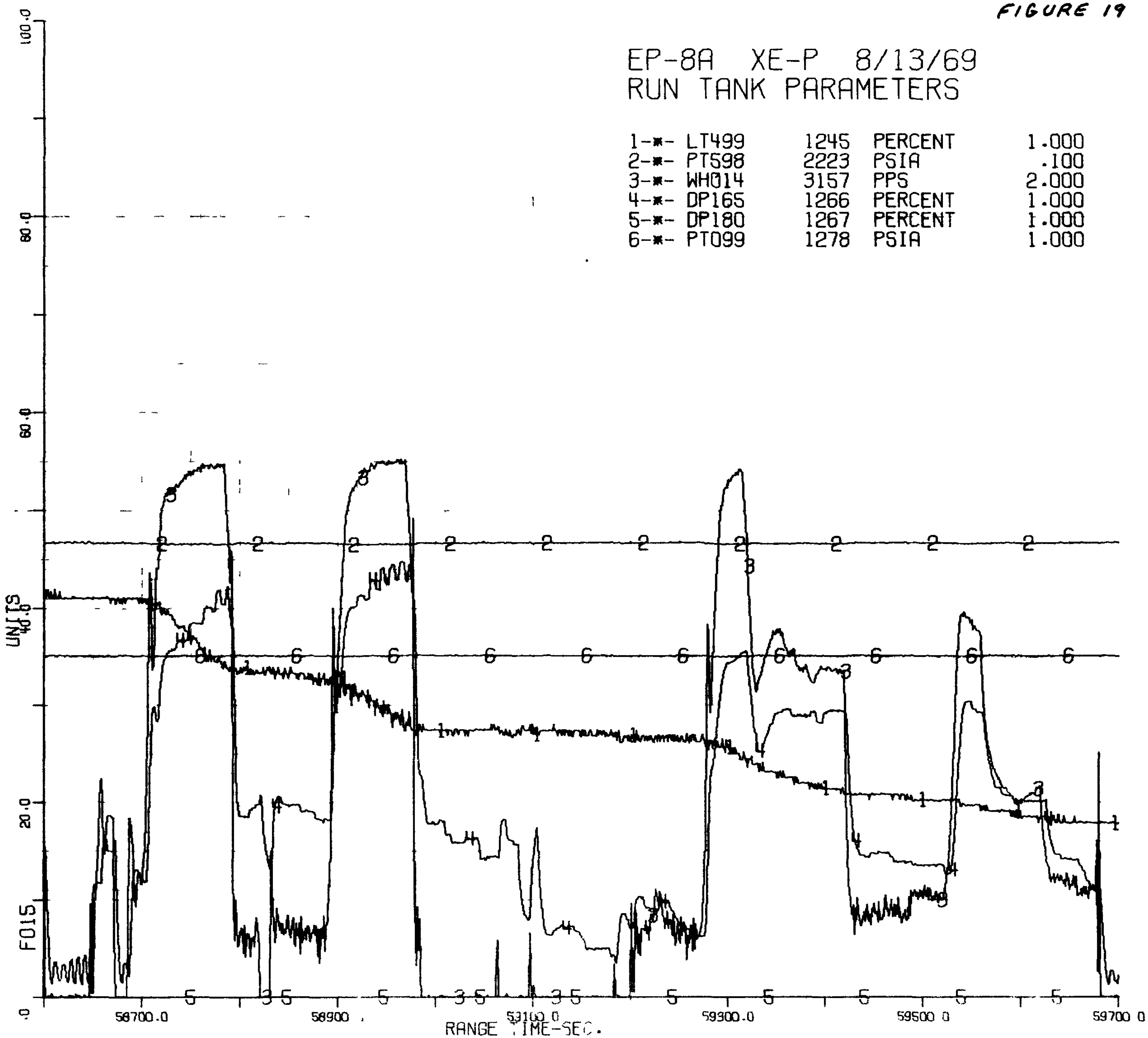


MEMO # 17A
FIGURE 17

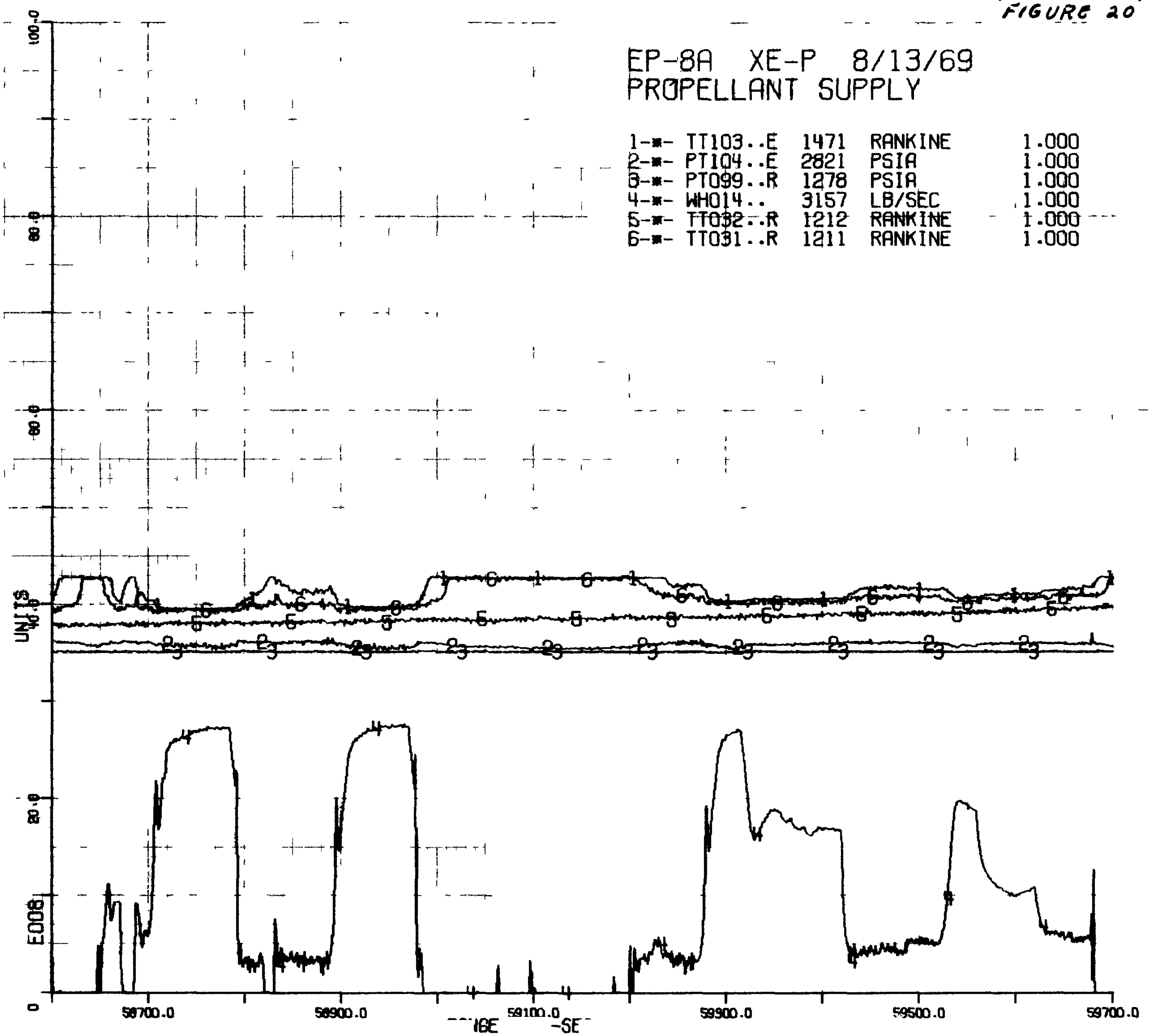



MEMO #17A
FIGURE 18
EP-8A XE-P 8/13/69
V5001 TEMPERATURES
1-*- TT516 1259 DEGR 60% 1.000
2-*- TT515 1268 DEGR 40% 1.000
3-*- TT514 1260 DEGR 20% 1.000
4-*- TT513 1261 DEGR 10% 1.000
5-*- TT512 1262 DEGR 5% 1.000
6-*- TT421 2192 DEGR 2.5 1.000
DEGREES, RANKINE
F031
RANGE TIME-SEC.
50.0
46.0
42.0
38.0
34.0
57850.0
57950.0
58050.0
58150.0
58250.0
58350.0
58450.0

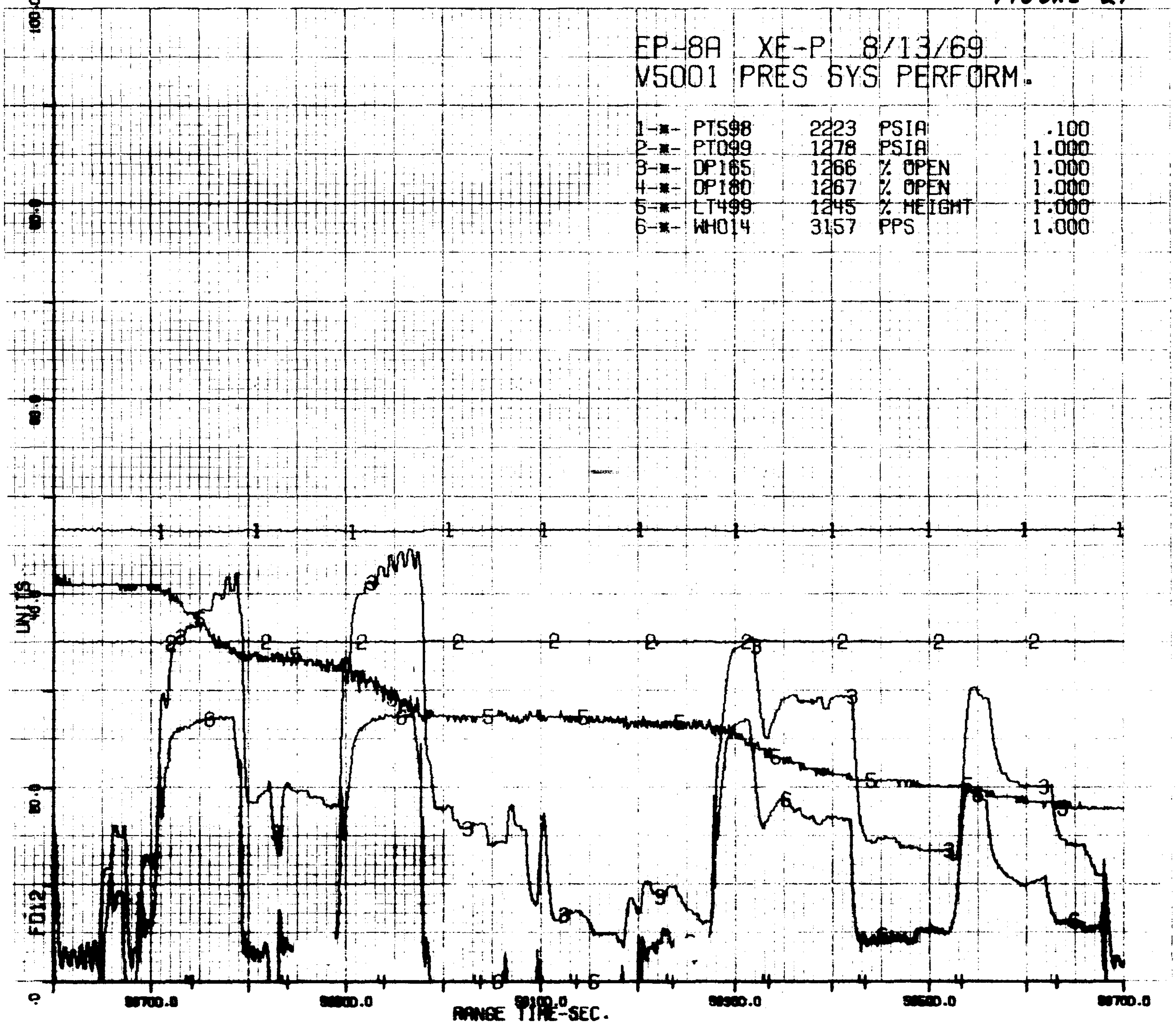
MEMO #17A
FIGURE 19



MEMO # 17A
FIGURE 20



MEMO # 17A
FIGURE 21



SPEAR Memo No. 18
J. P. Mathews:jh

XE-PRIME

EP-8A

Subject: ENGINE FOUR-INCH BUTTERFLY VALVES

SUMMARY

This report presents the Turbine Block Valve and Turbine Power Control Valve (less actuator) performance evaluation.

The Turbine Block Valve (TBV) was subjected to 1-1/2 open-close cycles using 60-65 psia actuation pressure. This brings the cumulative total TBV open-close cycles to 12 at normal (500 psia) actuation pressure; 28 cycles at low (50-70) psia actuation pressure; and 1 open-close cycle at 165 psia actuation pressure.

TPCV and TBV butterfly position indication drift, observed during post-test facility securing operations, was attributed to erroneous valve position readout rather than actual valve movement. This anomaly is discussed in EP-8A SPEAR Memo #10.

The TPCV and TBV successfully performed their respective design functions during engine operation.

TECHNICAL DISCUSSION

A. Turbine Power Control Valve

The following parameters and data listings were utilized to evaluate the valve performance:

Data Channel	Pass No.	Parameter	Units
DP-870	BFS-7	Actuator Output Shaft Position	Degrees Open
PT-815	TS02	Inlet Pressure	psia
PD-802	TS02	Delta P: TPCV Inlet to TBV Outlet	psid
TE-832	TS01	Inlet Temperature	^{o}R
WTURBI	TS03	Turbine Drive Fluid Flow	lb/sec

At an approximate Range Time (RT) of 32212, the TPCV was subjected to pre-test operation during the Flow Shutdown Chain (FSD) checkout. The valve was opened to approximately 42 degrees and then closed by command via the FSD circuit.

Technical Discussion (Cont'd)

The TPCV operated satisfactorily each time and consistently achieved a full closed position when commanded.

Figures 1 through 5 present plots of the TPCV shaft position vs. time for each of the five (5) respective engine bootstraps.

The TPCV operation chronology is shown in Table I of SPEAR Memo No. 17, "Non-Nuclear Engine Component Performance Summary."

The TPCV loss coefficient (K) was calculated based on data obtained during Runs 1 and 3 hold periods at RT 57015/57025 and RT 58777/58782 respectively. The results, shown in Figure 6, indicate good agreement between predicted and actual loss coefficient values.

B. Turbine Block Valve

The following parameters and data listings were utilized to evaluate TBV performance:

Data Channel	Pass No.	Parameter	Units
DR-110W	BFS-7	TBV Shaft Position	% Open
SR-646	EV01	TBV Position Command - Manual	Binary
SC-620	EV01	TBV Position - Close Command - SCRAM	Binary
PT-896	BFS-7	Valve Pneumatic Actuation Supply Pressure - GHe	psia
WHE432V	BFS-7	Valve Pneumatic Actuation System Flow - GHe	lb/sec

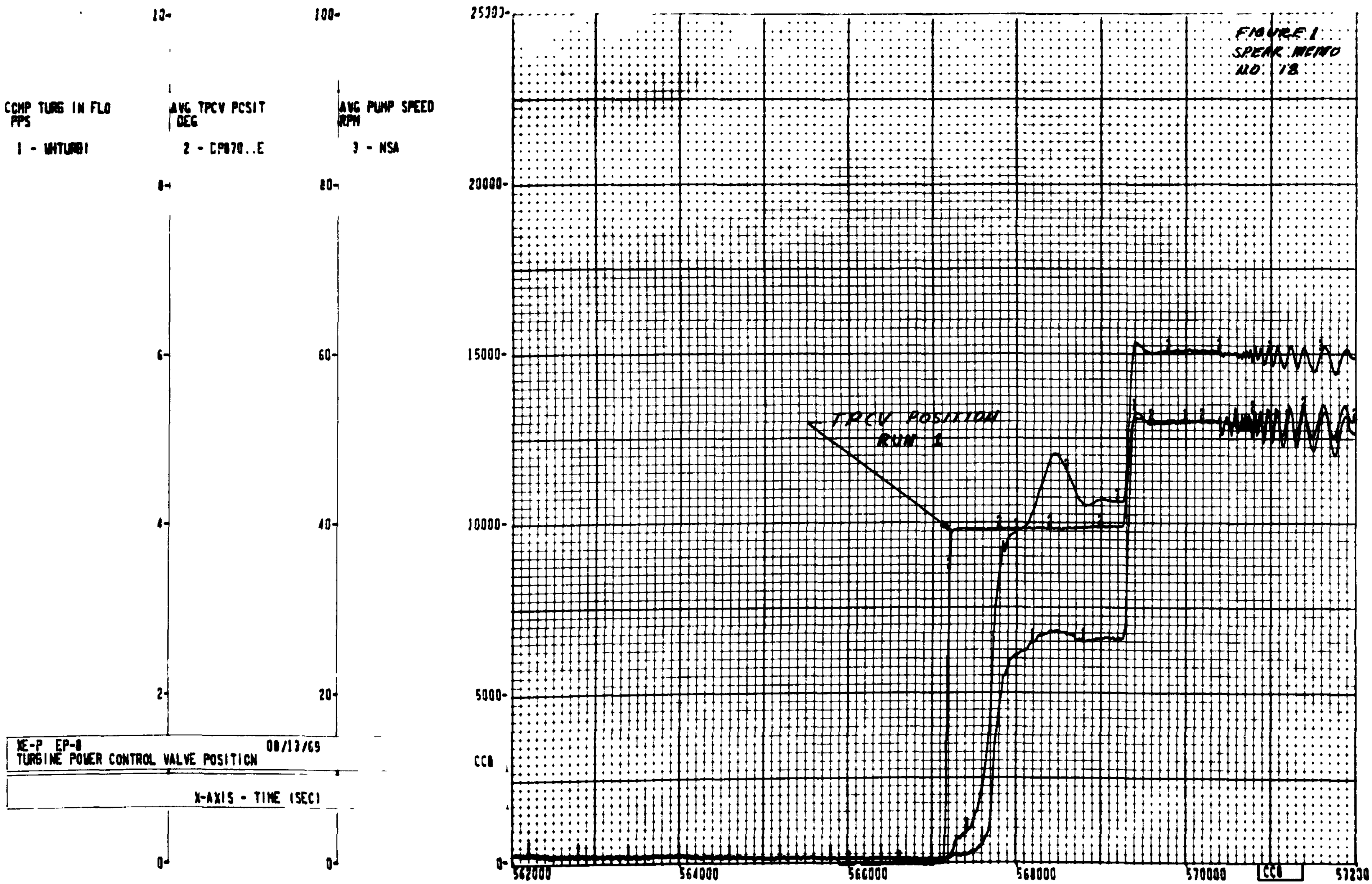
The TBV closed to the 18% (11.8°) position using low (66 psia) actuation pressure during the Flow Shutdown Chain checkout (RT 32212) and achieved full closure upon increasing actuation pressure to 118 psia. This actuation pressure is considerably less than was required during EP-7A (190 psia) and EP-6A (160-200 psia - See Ref. 1) FSD chain checkouts.

The TBV was opened at RT 56593.6 (actuation pressure 509 psia) and remained open throughout the five (5) bootstraps. The valve fully closed on command (actuation pressure 60 psia) at RT 61358.5 following the last engine bootstrap.

Ref. 1: XE-Prime, EP-6A, SPEAR Memo No. 11, "Engine Four-Inch Butterfly Valves"

CONCLUSIONS

The TPCV and TBV performed their design functions during the engine test and are acceptable for the next EP.



CCMP TURB IN FLO
PPS
1 - WHTURBI
AVG TPCV PCSIT
DEG
2 - CP070..E
AVG PUMP SPEED
RPM
3 - NSA
XE-P EP-8 08/13/69
TURBINE POWER CONTROL VALVE POSITION
X-AXIS - TIME (SEC)
FIGURE 1
SPEAR MEMO
NO. 18
TPCV POSITION
RUN 1
562000
564000
566000
568000
570000
572300

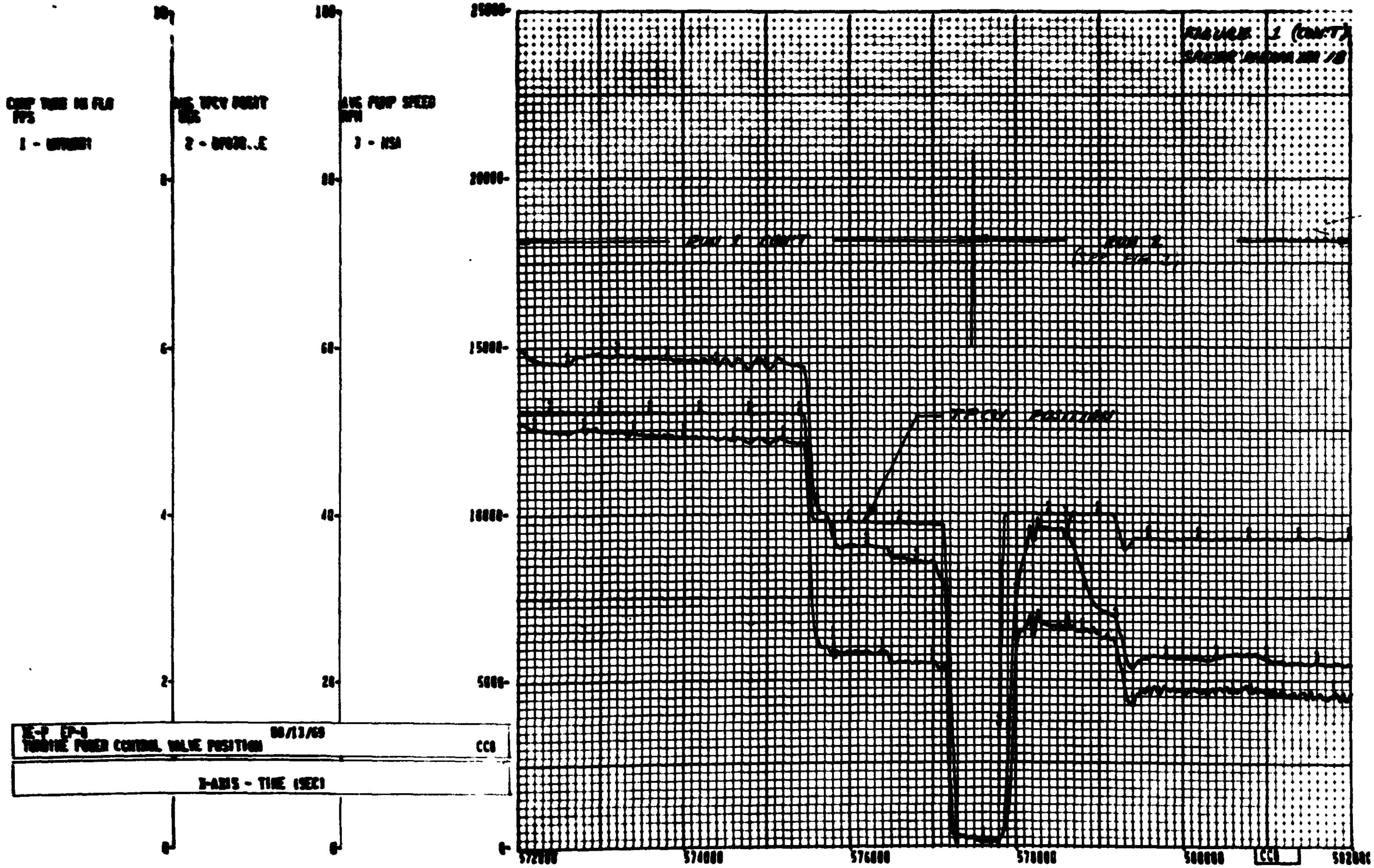
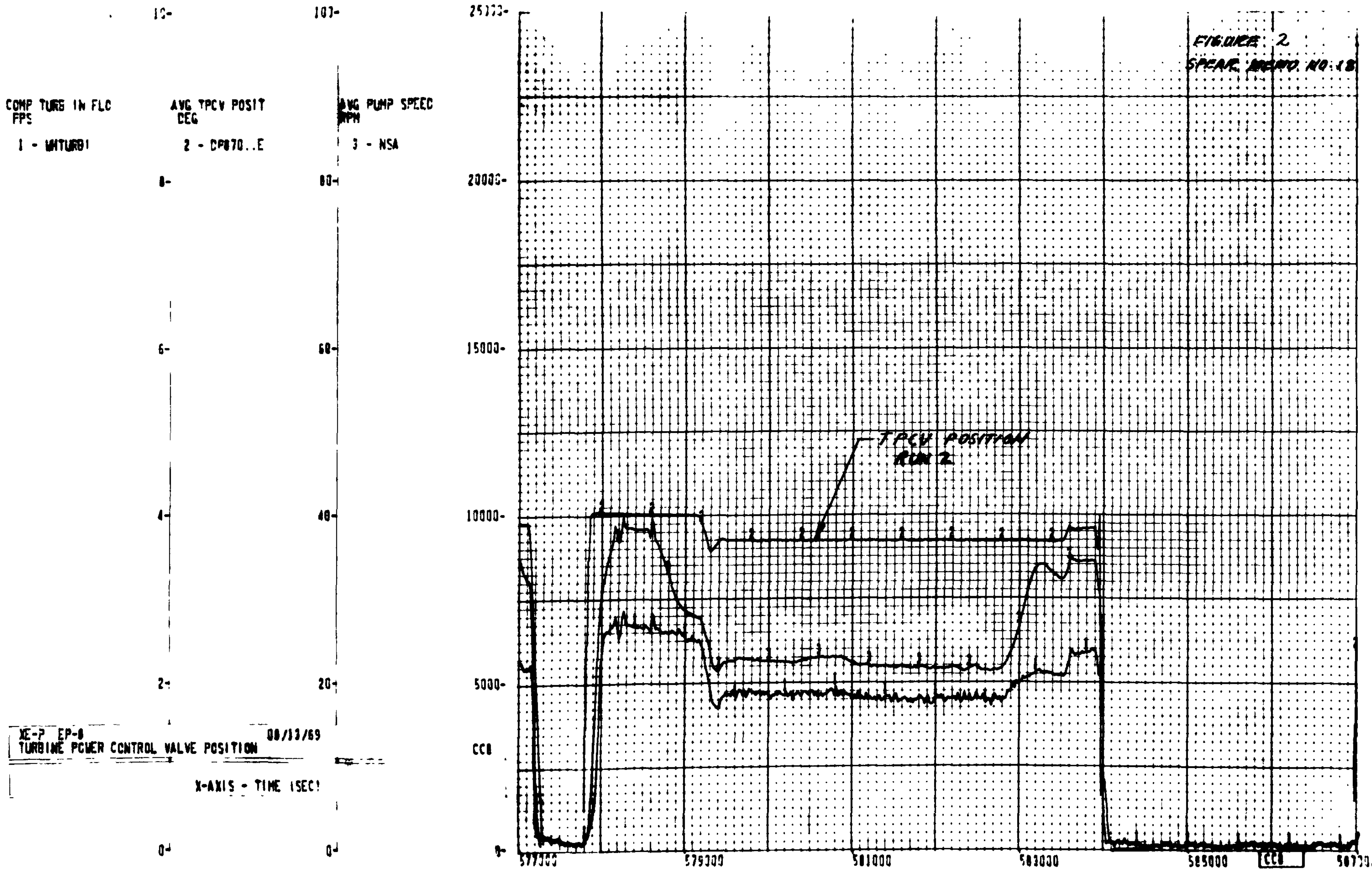
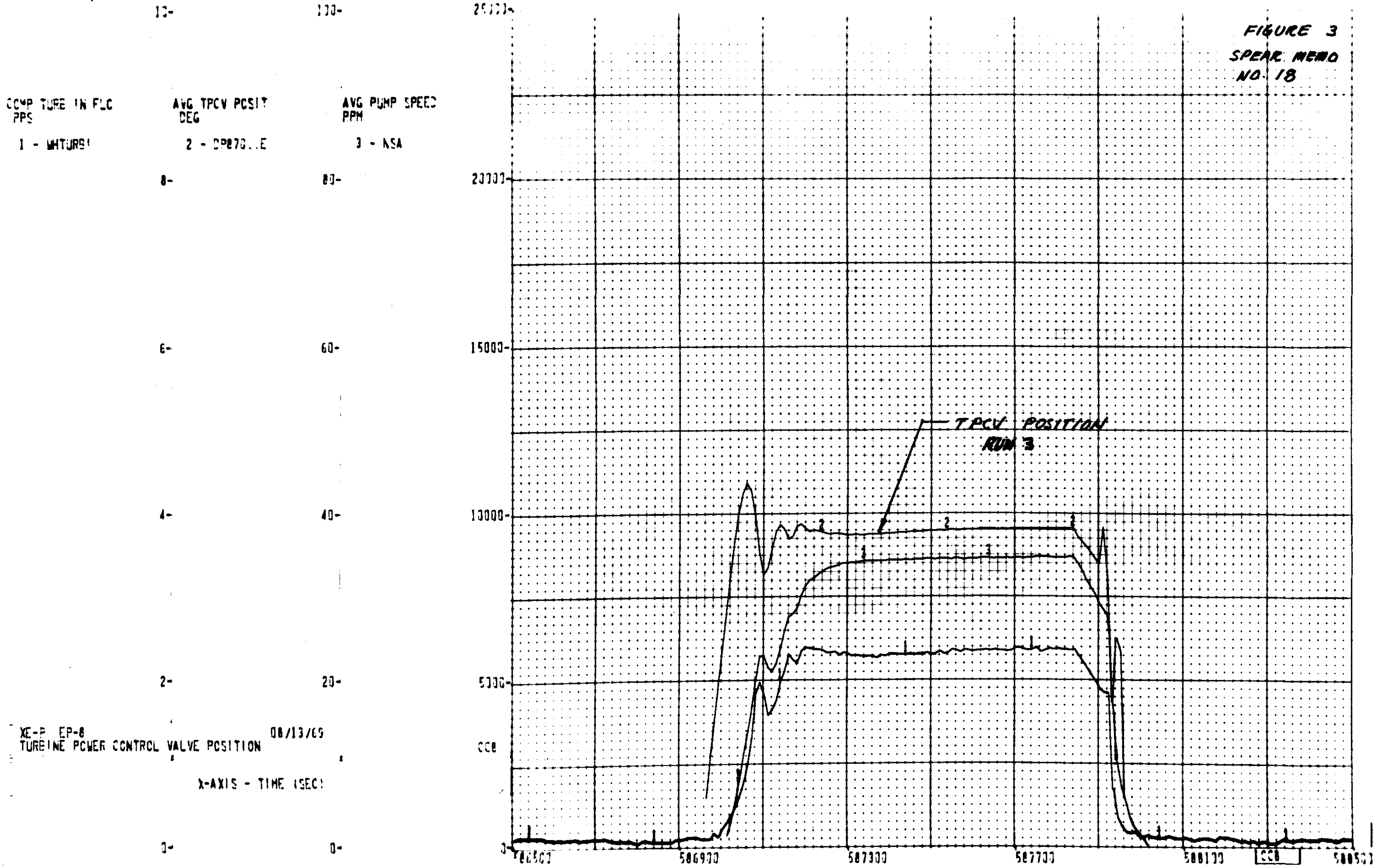


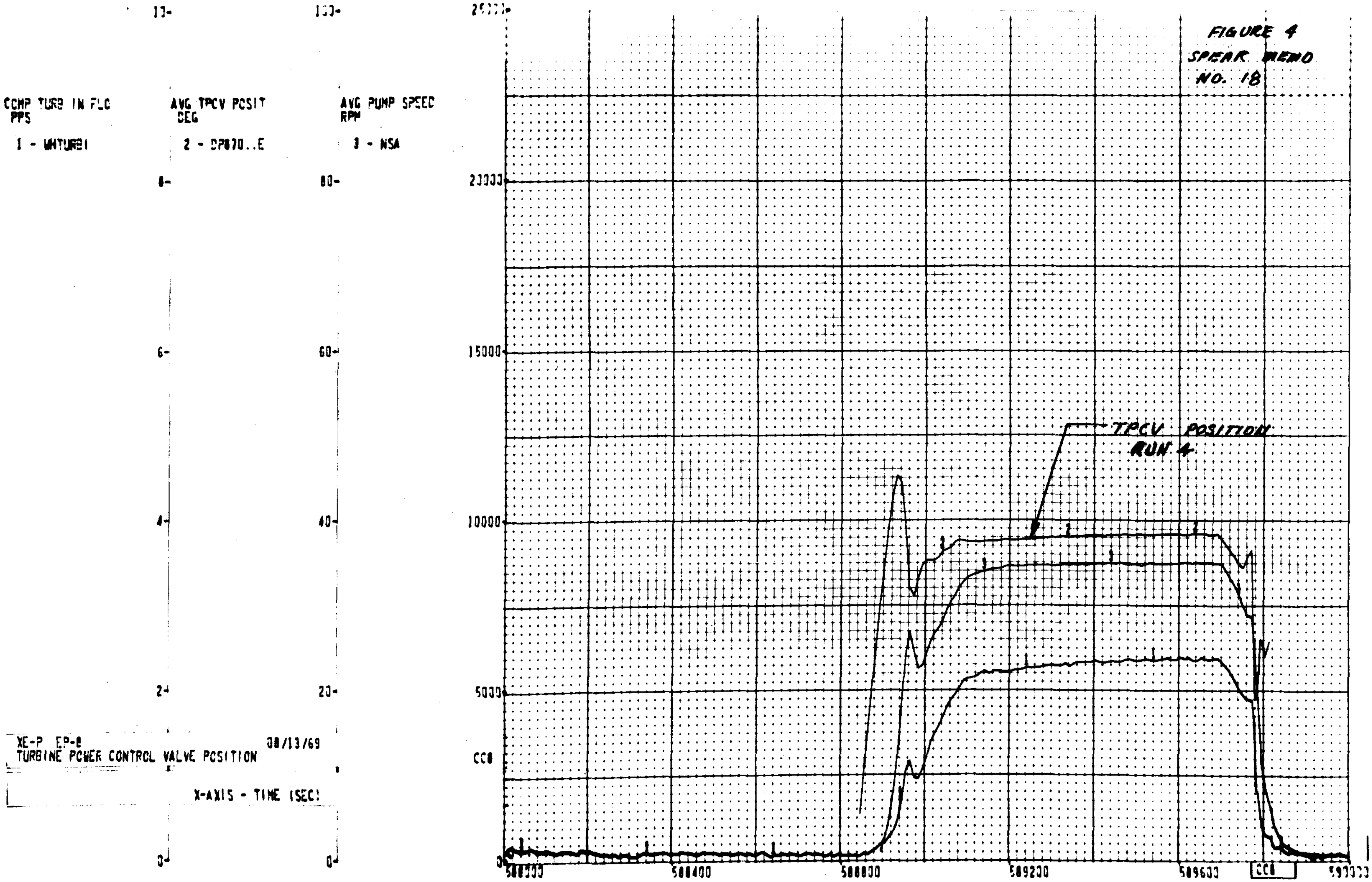
FIGURE 1 (CONT)
AVG PUMP SPEED
RPM
3 - NSA
RUN 1 CONT
RUN 2
TPCV POSITION
XE-P EP-8 08/13/69
TURBINE POWER CONTROL VALVE POSITION
CC8
X-AXIS - TIME (SEC)



COMP TURB IN FLC
FPS
1 - WNTURB1
AVG TPCV POSIT
DEG
2 - DP870..E
AVG PUMP SPEED
RPM
3 - NSA
FIGURE 2
SPEAR MEMO NO. 18
TPCV POSITION
RUN 2
XE-P EP-8 08/13/69
TURBINE POWER CONTROL VALVE POSITION
X-AXIS - TIME (SEC)

FIGURE 3
SPEAR MEMO
NO. 18




COMP TURB IN FLO
PPS
1 - WNTURB1
AVG TPCV POSIT
DEG
2 - DP070..E
AVG PUMP SPEED
RPM
3 - NSA
XE-P EP-8
TURBINE POWER CONTROL VALVE POSITION
08/13/69
X-AXIS - TIME (SEC)
FIGURE 4
SPEAR MEMO
NO. 18
TPCV POSITION
RUN 4
588000
588400
588800
589200
589600
590000
25000
20000
15000
10000
5000
0
100
80
60
40
20
0
10
8
6
4
2
0

TPCV POSITION
(+ AVG) DEGREES

1 - DP865.AE
2 - DP870..E

PSV POSITION
PERCENT

3 - DR102..E

TBV POSITION
PERCENT

4 - DR110W.E

CSV POSITION
PERCENT

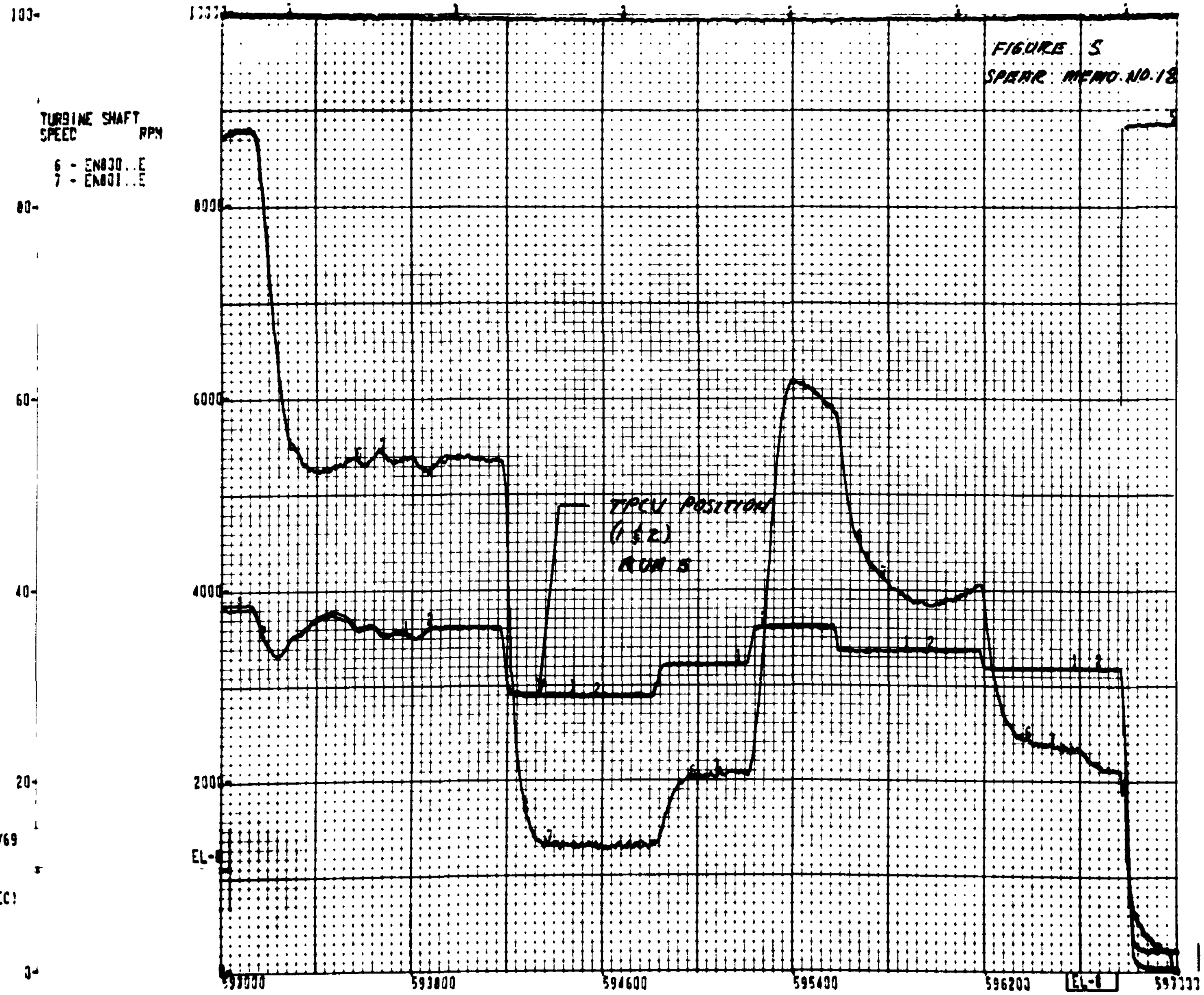
5 - DR106W.E

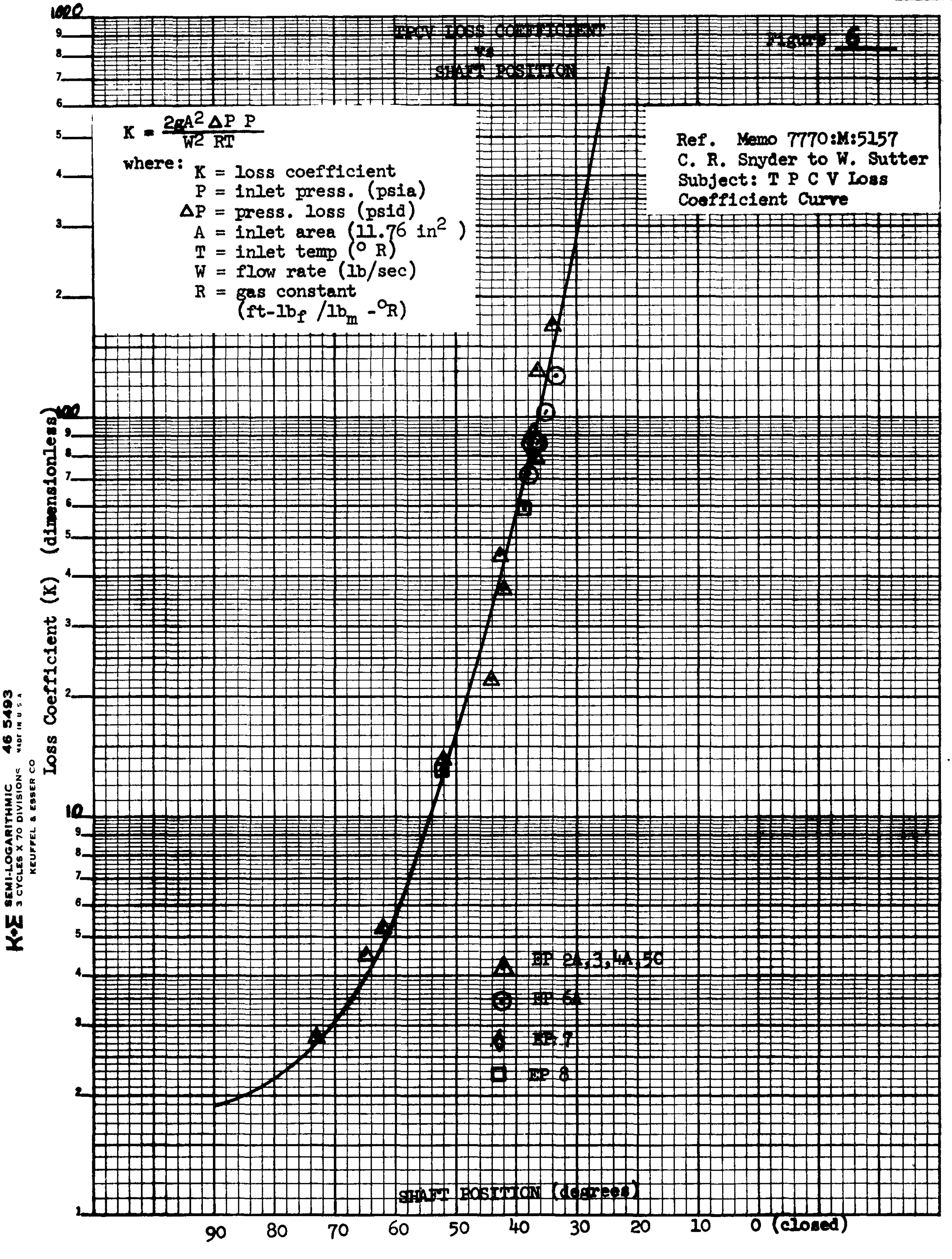
TURBINE SHAFT
SPEED RPM

6 - EN830..E
7 - EN831..E

XE-P EP-8 08/13/69
ENGINE PERFORMANCE PLOT-LOW POWER

X-AXIS - TIME (SEC)




TPCV LOSS COEFFICIENT
vs
SHAFT POSITION
Figure 6
$K = \frac{2gA^2 \Delta P\ P}{W^2\ RT}$
where: K = loss coefficient
P = inlet press. (psia)
ΔP = press. loss (psid)
A = inlet area (11.76 in²)
T = inlet temp (° R)
W = flow rate (lb/sec)
R = gas constant (ft-lbf /lbm -°R)
Ref. Memo 7770:M:5157
C. R. Snyder to W. Sutter
Subject: T P C V Loss Coefficient Curve
Loss Coefficient (K) (dimensionless)
SHAFT POSITION (degrees)
90 80 70 60 50 40 30 20 10 0 (closed)
EP 2A,3,4A,5C
EP 6A
EP 7
EP 8
K+E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO

SPEAR Memo No. 19
D. W. Berry:jh

XE-PRIME

EP-8A

Subject: ENGINE FIVE-INCH BUTTERFLY VALVES

SUMMARY

This report presents a description and the results pertaining to the functional performance evaluation of the XE-Prime engine, five-inch butterfly valves, i.e., PDSV, PDVV, CSV and CVV as relevant to the EP-8A test series. Additionally, performance evaluation of each five-inch butterfly valve's respective pilot valve was conducted. All valves operated satisfactorily throughout the test and no anomalies which would be detrimental to engine performance were noted.

Cycles on all five-inch butterfly valves during EP-8A were conducted at nominal 500 psig actuation pressure with the exception of PDVV which on the final closing cycle was commanded close following venting of PT-896 and thus was pressurized at 328 psia. The PDSV was cycled a total of 18 times during EP-8A, increasing the accumulated number of actuation cycles at 500 psig nominal actuation pressure to 62 cycles. The PDVV was cycled twice during all phases of testing bringing the accumulated total number of cycles at 500 psig to 26. The CSV being cycled three (3) times during the EP-8A series of runs, brought the accumulated total at 500 psig to $37\frac{1}{2}$ cycles. The CVV was cycled 21 times at a nominal 500 psig pressure for a cummulative total of 128 cycles. Table I presents the accumulated total number of cycles on each valve at various actuation pressures above 150 psia.

TECHNICAL DISCUSSION

The following parameters and data listings were utilized in the valve performance evaluation:

Data Channel	Pass No.	Parameter	Units
PT-896	BFS-7	GHe Actuation Supply Pressure	psia
WHE-432V	AS-03	GHe Actuation Flow Rate	lb/sec
PT-891	LCC-1	CSV Upstream Pressure	psia
PT-110	PM-02	PDSV and PDVV Upstream Pressure	psia
TT-881	LCC-1	CSV Upstream Fluid Temp.	°R
TT-110	PM-02	PDSV and PDVV Upstream Fluid Temp.	°R

Data Channel	Pass No.	Parameter	Units
DR-100	BFS-7	PDSV Butterfly Position	Degrees Open
DR-104	BFS-7	PDVV Butterfly Position	Degrees Open
DR-106	BFS-7	CSV Butterfly Position	Degrees Open
DR-108	BFS-7	CVV Butterfly Position	Degrees Open
FE-432	AS-03	Engine Valve Actuation Supply Flow	Hertz
SR-641	EV-01	PDSV Position Command Switch Trace	Binary
SR-642	EV-01	CSV Position Command Switch Trace	Binary
SR-643	EV-01	PDVV Position Command Switch Trace	Binary
SR-644	EV-01	CVV Position Command Switch Trace	Binary
SC-618	EV-01	Shutdown Command Switch Trace	Binary

A review of GHe actuation supply pressure and flow rate data (PT-896 and WHE-432V, respectively) during each five-inch butterfly valve travel indicated with the exceptions noted below, normal peak actuation gas flow at the nominal 500 psia level of .01 to .028 lb/sec. Additionally, when valve travel terminated the actuation gas flow rate returned to its initial value, i.e., its value prior to the five-inch valve command, indicating no excessive leakage in either the five-inch valve actuator and/or associated pilot valves. The sustained GHe valve actuation flow rate as determined from WHE-432V during periods of no valve activity was $\leq$ .0005 lb/sec throughout EP-8A.

Typical data relevant to EP-8A five-inch butterfly valve cycling time are summarized in Table II. Individual valve operation and test sequencing of all actuated engine valves is presented in Table I of the "Non-Nuclear Components," SPEAR Memo No. 17.

A. Pump Discharge Shutoff Valve

The PDSV was cycled a total of 18 cycles during EP-8A. Actual valve travel time indicated no anomaly; however, indication of opening gas usage on both the raw signal FE-432 and the integrated signal WHE-432V was either non-existent or negligible for 13 of the 18 cycles conducted during EP-8A. Not noted in earlier tests, but present in EP-8A, the same low GHe actuation flow rate was indicated twice on two separate PDSV closings , RT 50770 and 57748. The actual flow rate was approximately 50% of that expected in both cases. During the closing cycles, the actuator is working against the actuator spring (PDSV is N.O.). This indicated inconsistency in actuation gas consumption is attributed to instrumentation anomalies as no significant deviation in valve travel time was noted. The above anomaly was also noted in EP-6A and EP-7A, SPEAR Memos No. 18 and 17, respectively.

Technical Discussion (Cont'd)

The valve was cycled closed and opened eighteen (18) times during EP-8A. Each of the cycles was conducted at cryogenic temperatures with a nominal 500 psig actuation pressure. No abnormal operation of the valve was noted. The PDSV data presented in Table I reflects typical valve cycling during similar conditions of all prior EP's. Opening and closing valve traces are plotted on Figure 1 which are indicative of normal valve operation.

B. Pump Discharge Vent Valve

No anomalies were noted regarding the PDVV during EP-8A operation. Figure 2 is a valve cycle position trace which displays a cryogenic PDVV open-close cycle of EP-8A. The valve was cycled two (2) times; both at cryogenic temperature conditions, once at 512 psia actuation pressure and the final closing cycle at 328 psia.

C. Cooldown Shutoff Valve

The CSV was cycled a total of three (3) times during flow shutdown checkout and EP-8A. The first two close-open cycles occurring prior to TPA chilldown and thus were conducted at ambient temperature conditions. The third cycle was conducted at cryogenic temperature conditions; closed at RT 56775 and cycled open at RT 57711. No abnormal operation of the CSV was noted; however, as reported following EP-7A, (SPEAR Memo No. 17) SR-642, Pass EV-01 did not indicate pilot valve commands for either the close or open cycles. This problem was again reported as a data anomaly.

Figure 3 presents a typical open/close cycle trace from the EP-8A test data.

D. Cooldown Vent Valve

The CVV was cycled twenty-one (21) times during the EP-8A series, no anomalies being noted. Each cycle was conducted at a nominal 500 psig actuation pressure; two cycles were conducted at ambient temperature conditions ($473^{\circ}R$ - $539^{\circ}R$) and the remaining 19 cycles performed at reduced cryogenic temperatures.

Figure 4 presents a cryogenic open-close cycle, Valve Position vs. Time, which was typical of all cycles during EP-8A.

CONCLUSIONS

The five-inch butterfly valves are acceptable for the next engine test.

TABLE I

FIVE-INCH BUTTERFLY OPERATIONAL CYCLE RECORD

VALVE	Cumulative Number of Cycles			
	Act. Press. 500 ± 50 psia	Act. Press 400 ± 50 psia	Act. Press. 300 ± 50 psia	Act. Press. 200 ± 50 psia
PDVV	26	0	3½	2½
CSV	37½	0	5	4½
CVV	128	0	4	6
PDSV	62	0	2	4

[redacted] [redacted]

TABLE II

EP-8A ENGINE FIVE-INCH BUTTERFLY VALVES
TYPICAL CYCLING DATA

Valve	Activity	Switch Event	Delay Time to Start of Stroke	Range Time at Start of Stroke (sec)	Duration of Travel (sec)	Actuation Pressure (psia)	Valve Main Stream Inlet Conditions: Press. (psia)	Valve Main Stream Inlet Conditions: Temp. (°R)	Actuation Flow Rate (lb/sec)	Total Cycles During EP-8A	Total Cycles During EP-8A @ 500 psig Act
PDVV	Opening	59743.7	0.2	59743.9	1.1	507	13.6	40	.023	2	1-1/2
	Closing	56702.9	0.4	56703.4	2.3	509	34	41			
PDSV	Closing	59100.8	0.3	59101.1	2.0	507	36	40	.020	18	18
	Opening	59182.1	0.3	59182.4	2.9	510	31	41	.013		
CVV	Opening	56521.9	.2	56522.1	1.1	511	71	47	.023	21	21
	Closing	56527.2	1.5	56528.7	2.4	509	57	47	.024		
CSV	Closing	NOT AVAILABLE	--	57712.0	1.2	508	158	47	0	3	3
	Opening		--	59676.4	1.8	508	43	41	.020		

EP-8A PDSV, POSITION TRACE VS. TIME

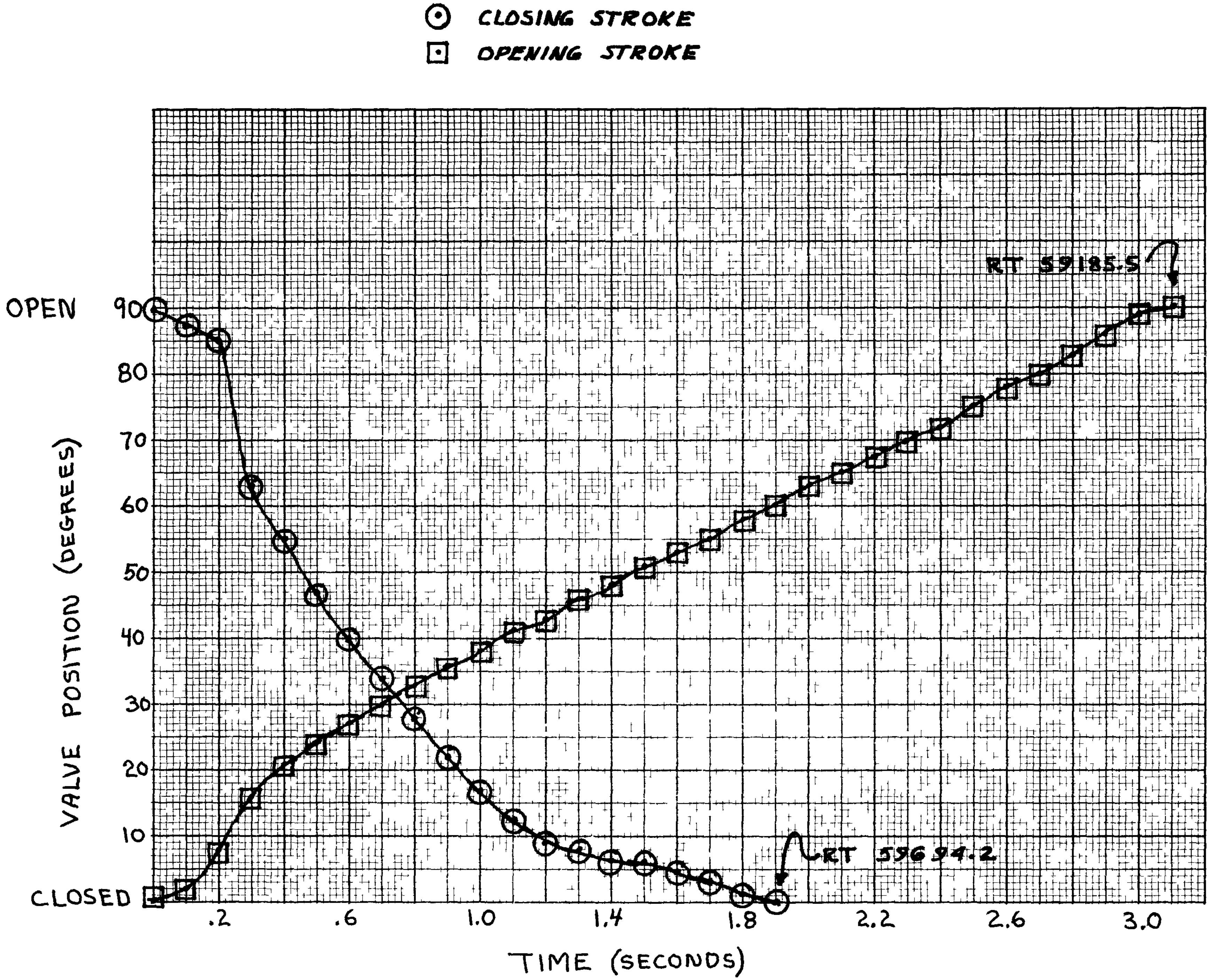


FIGURE 1
SPEAR MEMO. NO. 19

EP-8A PDVV, POSITION TRACE VS. TIME

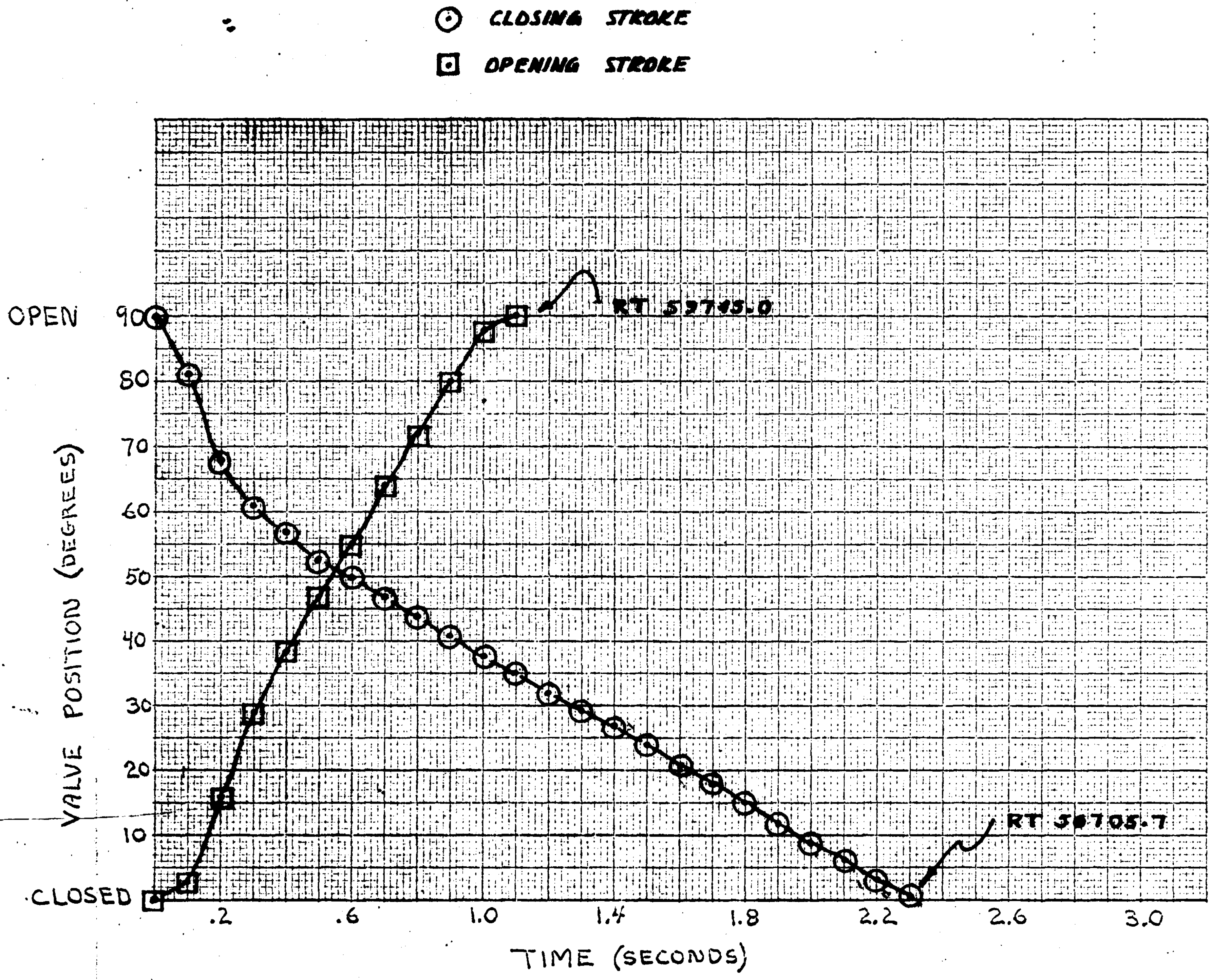


FIGURE 2
SPEAR MEMO. NO. 19

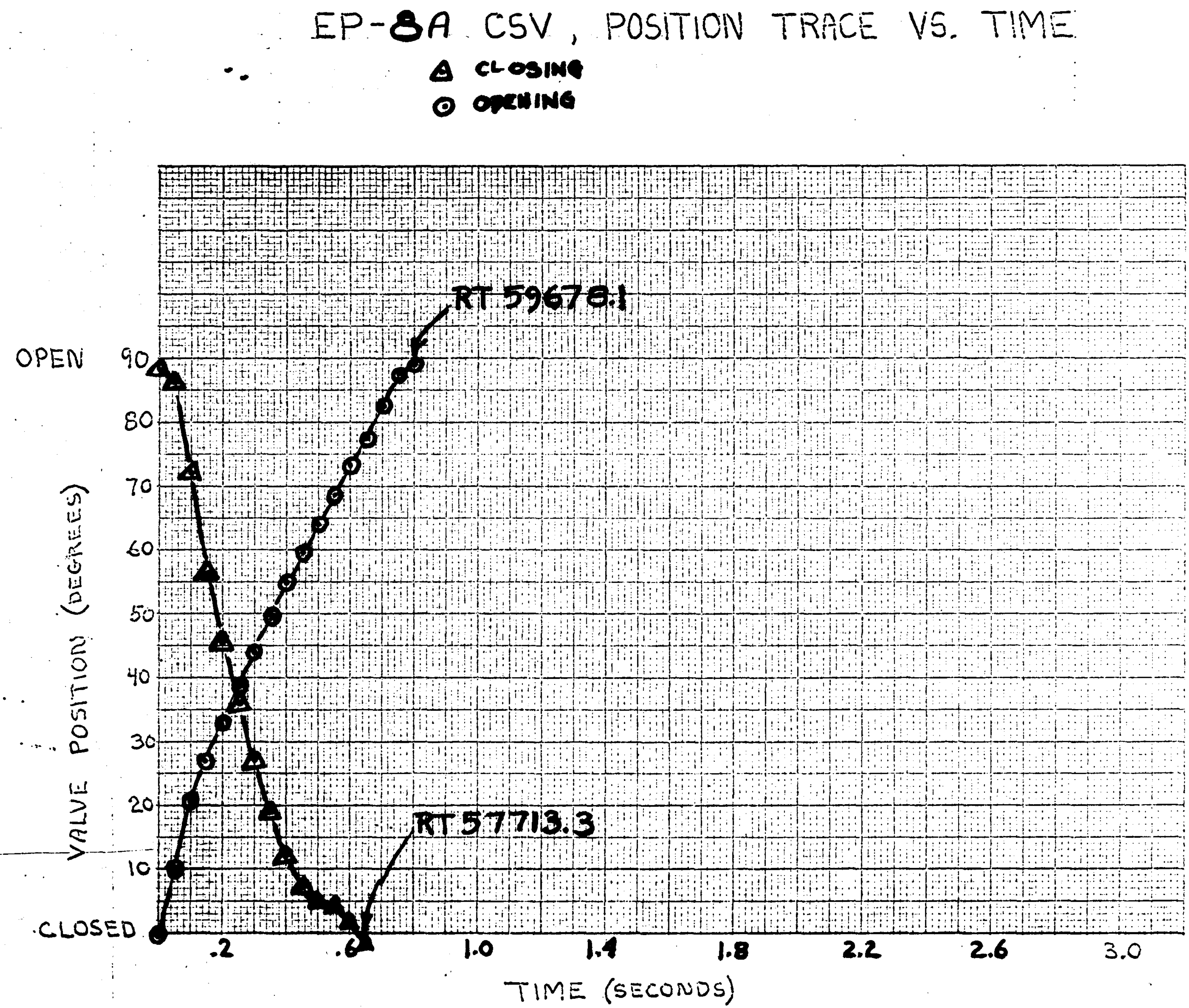


FIGURE 3
SPEAR MEMO NO. 19

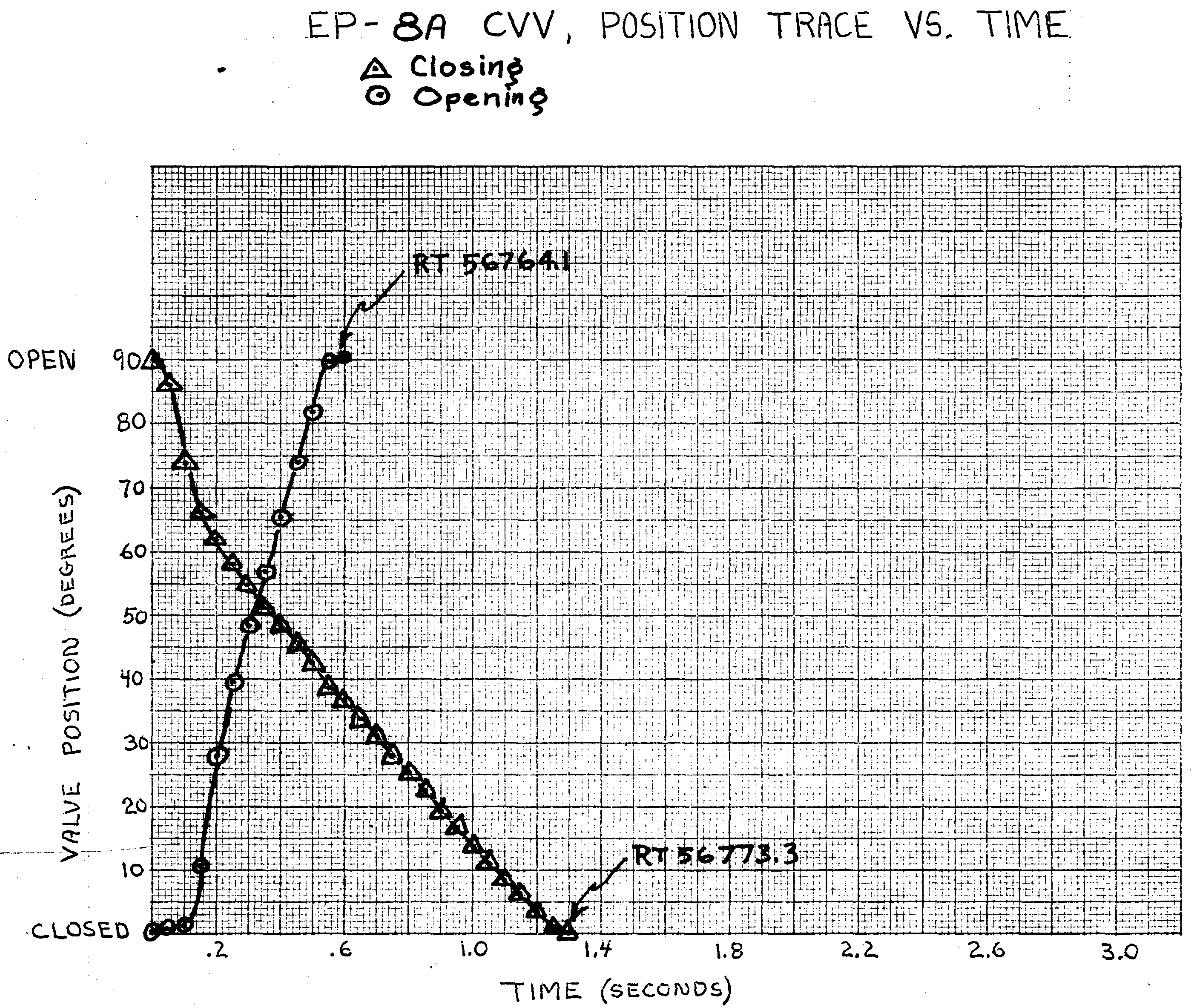


FIGURE 4
SPEAR MEMO. NO. 19

SPEAR Memo No. 20
D. W. Berry/jh

XE-PRIME

EP-8A

Subject: ENGINE PROPELLANT SHUTOFF VALVE

SUMMARY

This memorandum presents the results of the functional performance evaluation of the poppet type, eight inch propellant shutoff valve (PSV) and its associated pilot valve during EP-8A operation.

The PSV and pilot valve were cycled five (5) times during the EP-8A test. Of the five cycles, the first was conducted at ambient temperature and reduced actuation pressure of 66 psia. The remaining four cycles were conducted at cryogenic temperatures and nominal design actuation pressure. This increases the accumulated number of cycles to 82 of which 25 have been at operating temperature and pressure.

The eight inch poppet valve and pilot valve performed satisfactorily during the EP-8A test with no anomalies noted with respect to functional operation.

TECHNICAL DISCUSSION

Performance of the eight inch valve was ascertained from digital data of the following noted channels:

Data Channel	Pass No.	Parameter	Units
SR-637	EV-01	PSV Command Switch	Binary
SC-620	EV-01	SCRAM Command Switch	Binary
DR-102	BFS-07	PSV Poppet Position	% Open
WHE 432V	BFS-07	GHe Actuation Flow Rate	lb/sec
FE-432	AS-03	Engine Valve Actuation Supply Flow	Hertz
PT-896	BFS-07	GHe Actuation Pressure	psia
PT-485	LR-03	Valve Inlet Pressure	psia
TT-475	LR-03	Valve Inlet Temperature	°R

Technical Discussion (Cont'd)

Rapid sample, short data (10 samples per second) was used in analyzing the third open/closed cycle, Range Times 56472.5 and 59749.4 respectively. All prior and subsequent cycles were analyzed using 1 sample per second data.

The PSV was cycled open and closed once at ambient temperature, (550°R) and reduced actuation pressure of 66 psia. The four cryogenic temperature cycles were conducted at temperatures ranging from 41.0°R to 248°R and nominal 500 psia GHe actuation pressures on each opening cycle. Performance data from the five cycles is summarized in Table I. Valve chronology, placing the PSV operation sequence in perspective to overall engine operation is tabulated in Table I, of "Non-Nuclear Components", SPEAR Memo No. 17.

Figure 1, using rapid sample data, presents a typical cryogenic valve Position vs. Time trace for a complete PSV open/closed cycle. The stepped closing noted (RT 59748.9 to 59753.1) is representative of the phenomena noted in prior EP's, References 1-3.

Actuation gas flow rate data for each PSV opening cycle conducted at nominal operating temperature and pressure conditions indicated no significant deviations from EP-7A cycles at corresponding conditions. Evidence that the PSV piston stop, seal assembly is still operative was indicated from WHE-432V GHe actuation flow rate data which returned to its normal, no-valve activity level following the PSV opening cycle. GHe flow decayed to an insignificant level ($\leq$ .0005 lb/sec) concurrent with PSV opening to the 100% position. At this condition only does the stop seal make contact with its seat and contain the actuation gas. Similarly, as WHE-432V returned to its normally sustained level ($\leq$ .0005 lb/sec) during all periods of valve inactivity following both opening and closing PSV cycles, it is determined that the 806235-3 pilot valve operated as predicted with no discernible leakage.

CONCLUSIONS

Analysis of the operation of the PSV and its associated pilot valve revealed no discrepancies detrimental to either the valve or engine system. Therefore, the PSV and pilot valve are ready for further testing.

References: XE-Prime, EP-IIA, SPEAR Memo No. 34, "Propellant Shutoff Valve"
XE-Prime, EP-III, SPEAR Memo No. 18, "Propellant Shutoff Valve"
XE-Prime, EP-7A, SPEAR Memo No. 18, "Eight-Inch Poppet Valve"

TABLE I

PROPELLANT SHUTOFF VALVE ACTUATIONS

CRT (START OF CYCLE)	(CYCLE)	VALVE ACTUATION TIME-SEC.	TIME PERIOD (EVENT SWITCH to VALVE MOVEMENT-SEC	ACTUATION PRESSURE PSIA	VALVE INLET CONDITIONS	
					PRESSURE, psia	TEMP. °R
32201.9	OPENING	---	-------	66.5	12.4	549
32212.2	CLOSING	2	-------	66	12.7	551
49382.8	OPENING	---	-------	510	26.0	41
52764.5	CLOSING	5	-------	511	36.2	42.3
56472.5	OPENING	0.5	0.1	512	36.2	43.1
59749.4	CLOSING	4.2	6.3	511	35.4	42.8
60289.5	OPENING	---	-------	512	39.8	43.4
60461.5	CLOSING	5	-------	510	12.5	248
62542.5	OPENING	---	-------	68	15.6	129
62678.5	CLOSING	4	-------	68	11.5	43

REMARKS

Total number of cycles, EP-8, was five (5); including one (1) ambient temperature, low pressure cycle and four (4) cycles at cryogenic conditions.

Total number of cycles to date include 33 at operating temperature. The PSV design criteria allows 100 cycles at operating conditions.

EP-8 PSV, POSITION TRACE VS. TIME

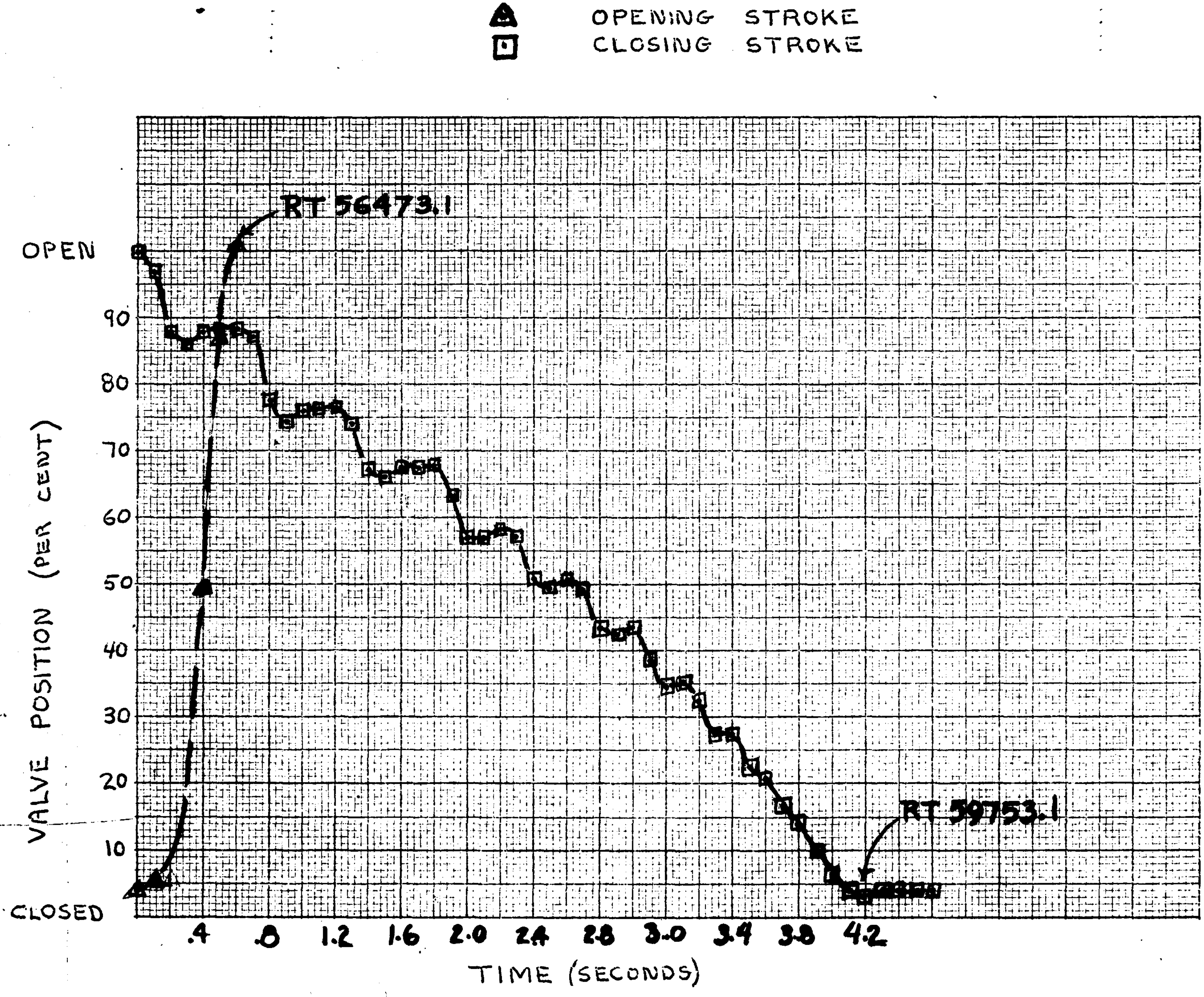


FIGURE 1
SPEAR MEMO. NO. 20

SPEAR Memo No. 21
A. L. Armitage:jh

XE-PRIME

EP-8A

Subject: PUMP DISCHARGE CHECK VALVE

SUMMARY

This memorandum describes the functional performance evaluation of the five-inch flapper type pump discharge check valve (PDKV) during EP-8A. The five-inch check valve performed satisfactorily during EP-8A test and no anomalies were noted with respect to functional operation.

TECHNICAL DISCUSSION

The following parameters were investigated for evidence as to check valve operation. Data used were from the thinned (one sample per second) listing as follows:

1. PT110--Pump discharge line pressure located just downstream of the turbopump assembly, obtained from Pass PM02.
2. PT126--Nozzle torus pressure located in the nozzle torus near the inlet flange, obtained from Pass NZ02.
3. PD801--Delta pressure across bearing coolant labyrinth obtained from Pass TS03.
4. PT891--Cooldown supply line pressure located upstream of the cooldown shutoff valve obtained from Pass LCC1.
5. PT104--Pump inlet pressure located just upstream of the turbopump assembly obtained from Pass PM01.
6. EN800-Pump speed obtained from Pass PM01.
7. WHP-BC--Pump labyrinth flow rate obtained from Pass BFS2.
8. TT108, TT110--Pump discharge fluid temperature obtained from Pass PM02.
9. TT103, TT105--Pump inlet fluid temperature obtained from Pass PM01.
10. FE14, Pump inlet flow rate obtained from Pass PM01.

Technical Discussion (Cont'd)

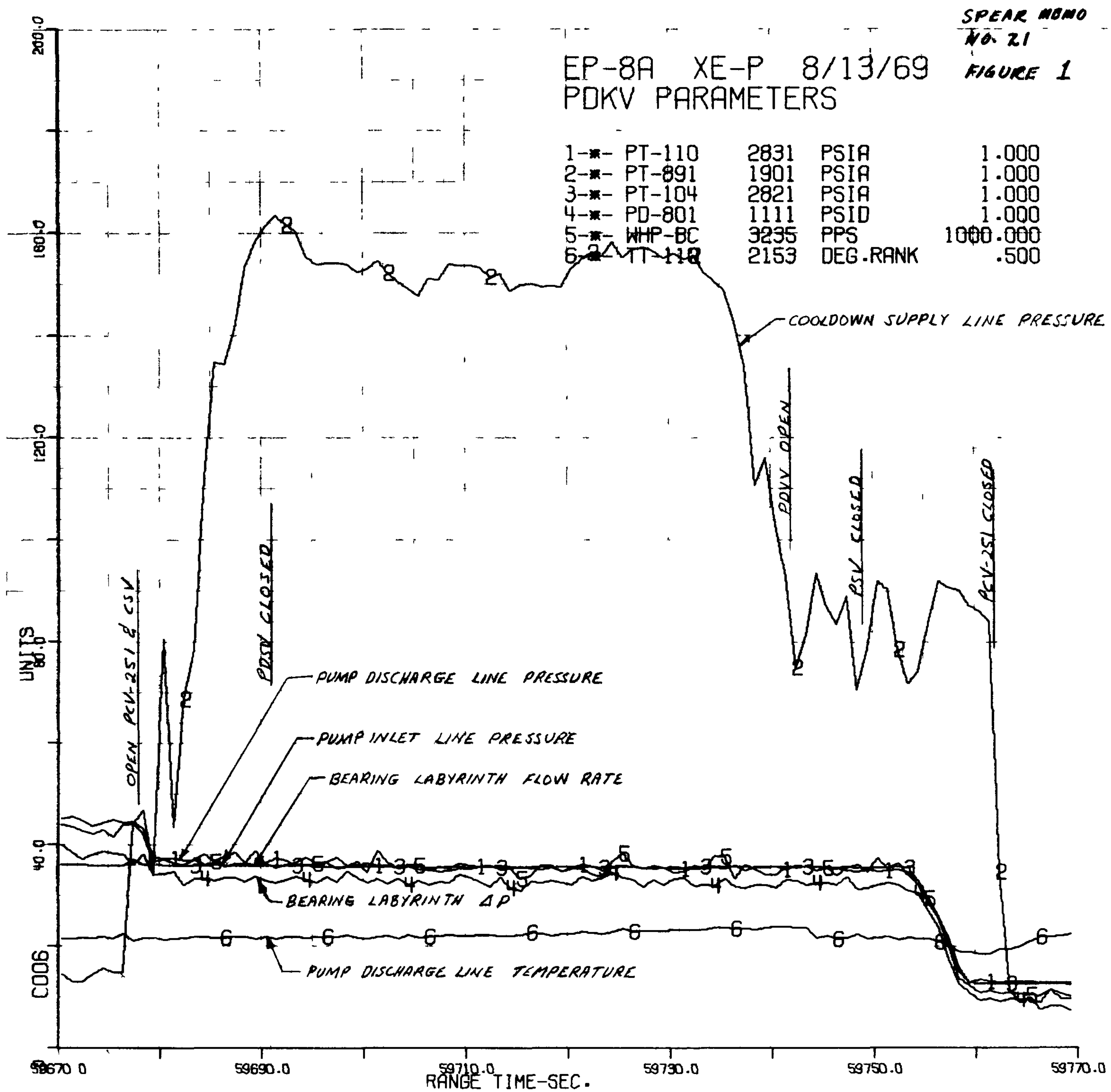
During post test pulse cooling of the engine, conditions did allow partial evaluation of the PDKV.

At time 59677 PCV-251 and CSV were opened to allow insertion of 465°R GH_2. PDSV was closed at time 59690. However, during the above times PSV was open allowing a through path to the run tank. A check of FE-14 pump inlet flow between times 59681 and 59690 shows that pump flow stopped (with the exception of bearing labyrinth coolant flow of approximately .038 lb/sec). The stoppage of pump flow is a result of a negative ΔP across PDKV, thus checking coolant flow and stopping pump discharge flow.

Since the cooldown gas GH_2 was at 465°R and the pump discharge remained at a constant temperature of 43.5°R (TT-110), this substantiates that no gross leakage occurred in the reverse direction through PDKV. PDKV, therefore, functioned as required.

CONCLUSION

The pump discharge check valve is functioning as designed and is ready for the next test.



SPEAR MEMO
NO. 21
FIGURE 1
EP-8A XE-P 8/13/69
PDKV PARAMETERS
1-*- PT-110 2831 PSIA 1.000
2-*- PT-891 1901 PSIA 1.000
3-*- PT-104 2821 PSIA 1.000
4-*- PD-801 1111 PSID 1.000
5-*- WHP-BC 3235 PPS 1000.000
6-*- TT-110 2153 DEG.RANK .500
COOLDOWN SUPPLY LINE PRESSURE
PUMP DISCHARGE LINE PRESSURE
PUMP INLET LINE PRESSURE
BEARING LABYRINTH FLOW RATE
BEARING LABYRINTH ΔP
PUMP DISCHARGE LINE TEMPERATURE
OPEN PCV-251 & CSV
PDSV CLOSED
PDKV OPEN
PSV CLOSED
PCV-251 CLOSED
UNITS
C006
200.0
160.0
120.0
80.0
40.0
59670.0
59690.0
59710.0
59730.0
59750.0
59770.0
RANGE TIME-SEC.

SPEAR Memo No. 22
A. L. Armitage:jh

XE-PRIME

XE-8A

Subject: ENGINE PURGE CHECK VALVES

SUMMARY

The EP-8A run data was reviewed with respect to the operation of the 3/8" purge check valves.

TECHNICAL DISCUSSION

The data investigated regarding purge valve operation are listed below:

1. PT895 (Pass BFS-7) purge manifold line pressure.
2. PT894 (Pass PM01) Pressure upstream of the flow control orifice in the bearing housing purge line.
3. PT890 (Pass TS03) Bearing housing pressure.
4. TE890 (Pass TS03) Bearing housing temperature.
5. PT815 (Pass TS02) Turbine inlet pressure upstream of TPCV.
6. PT225 (Pass TS01) Diluent line pressure near pressure vessel dome.
7. WHE433P (Pass AS03) Purge line flow meter reading in pounds per second.
8. TE848 (Pass BFS-7) Purge line gas temperature.
9. TE832 (Pass TS01) Turbine inlet line venturi inlet temperature.
10. BR446 (Pass EV03) RSV-446 purge valve switch event.

Purge flow was secured at time 49170 prior to the first run and re-established at the completion of the fifth run at time 59825. The data indicates that the purge check valves are performing their primary functions i.e., allowing purge flow to the engine and preventing significant fluid backflow into the purge line during the engine runs.

Purge manifold pressure (PT895), bearing housing purge line pressure upstream of the control orifice (PT894), bearing housing pressure (PT890), and total purge flow rate (WHE433P) are shown in Figure 1 for the time period when purge flow to the engine is initiated following the completion

Technical Discussion (Cont'd)

of the test. The calculated purge flow (based on purge manifold pressure and temperature, the sum of the purge flow orifice areas, and the measured back pressure) is in agreement with the measured flow (.0042 lb/sec for both calculated and measured) indicating the valves are opening properly.

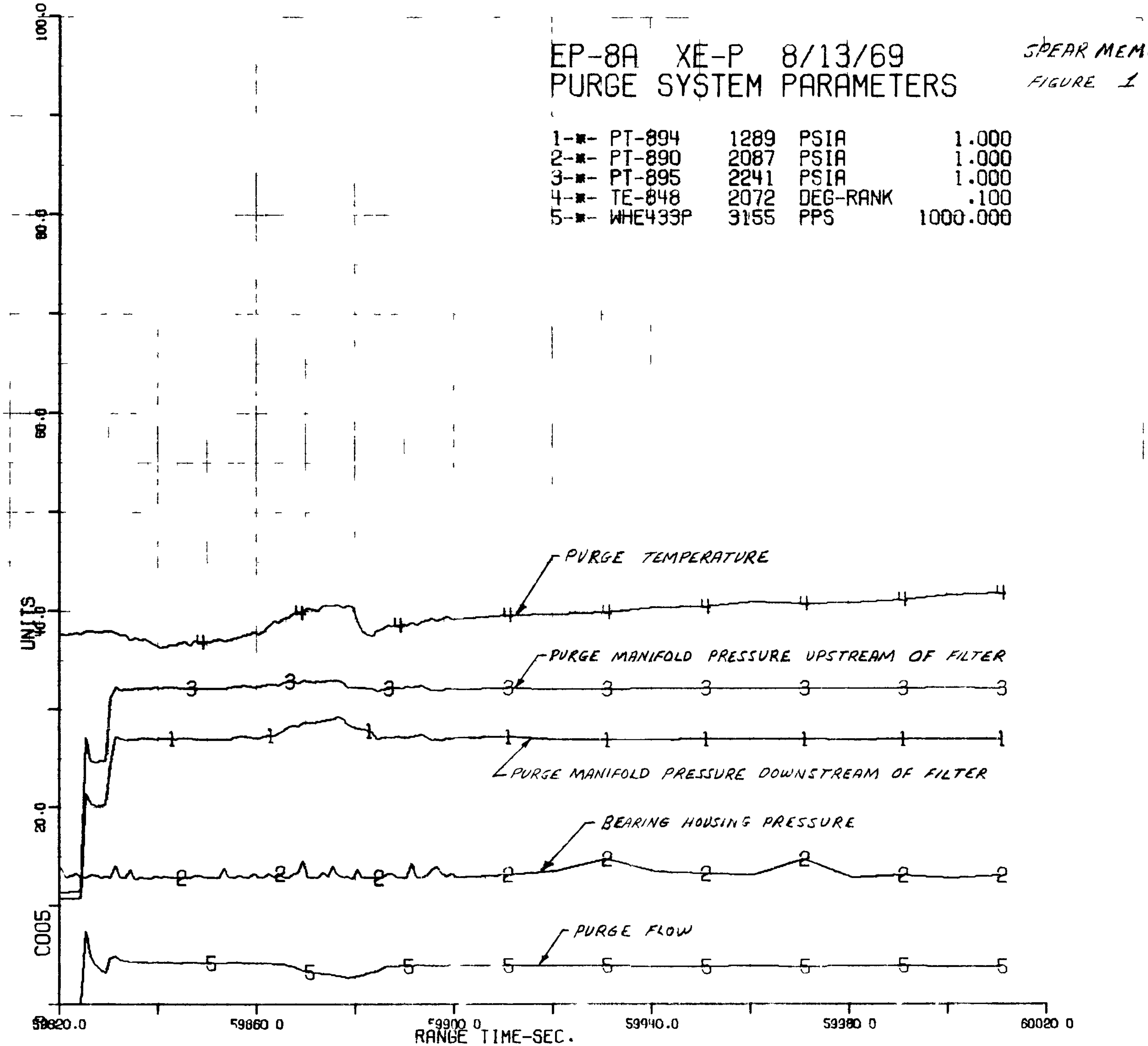
The above listed purge system parameters are shown on Figure 2 for the time period during which engine Runs 4 and 5 were conducted (time 58880 - 59680). Leakage of the check valves in the check direction during engine operation is indicated by the slight rise (7 psia) in purge manifold pressure (PT895) for Run 4 and (1.5 psia) rise in purge manifold pressure for Run 5. By the method outlined in Reference 1, the maximum leakage of the valve was determined to be .0009 lbs/sec, an insignificant amount.

CONCLUSION

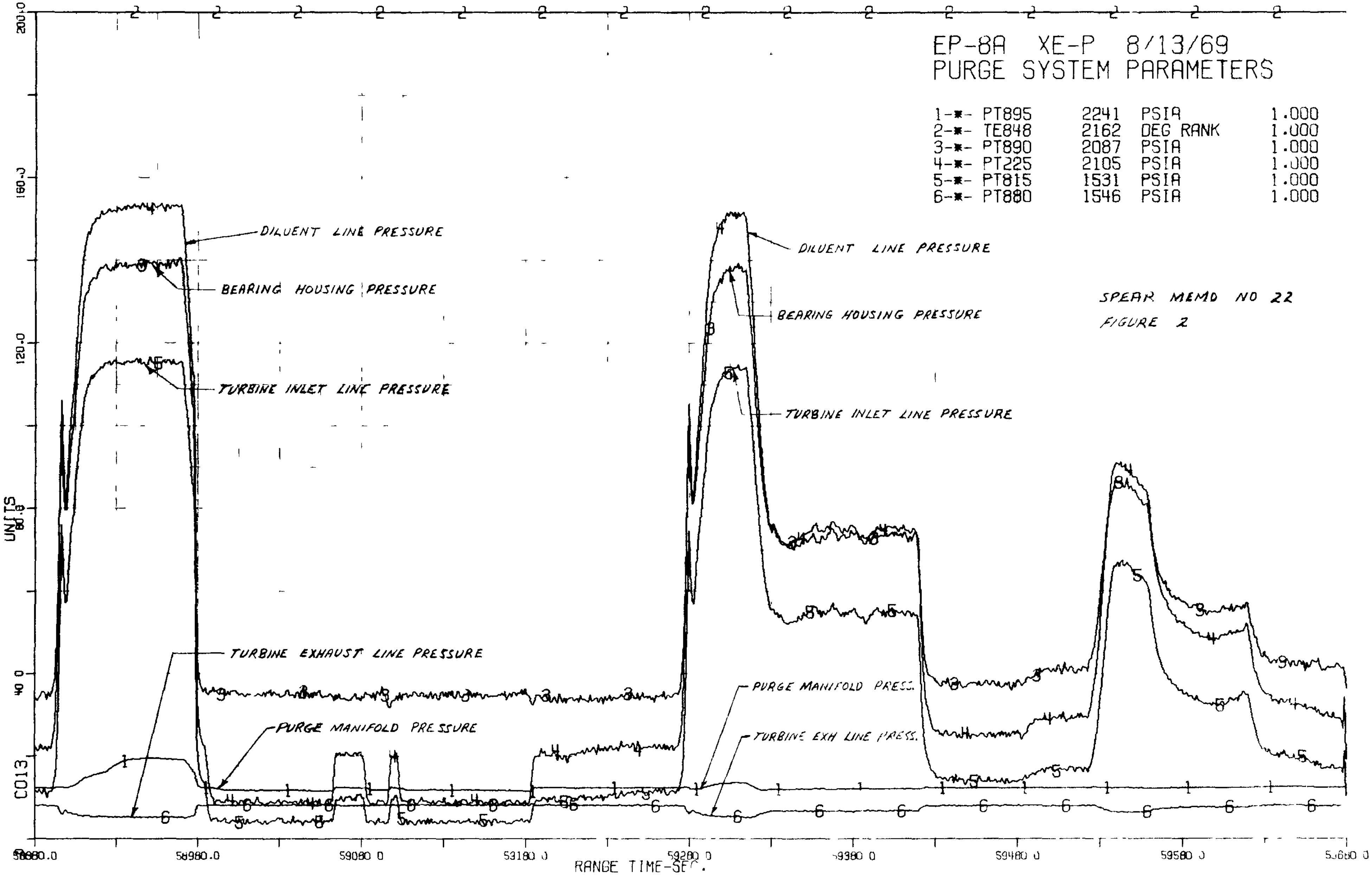
The data indicates the 3/8" purge check valves are performing their design function.

Ref. 1: NTO-R-0169, SPEAR Report XE-Prime, EP-IIIA, "Intermediate Power Demonstration Test and Restart".

[redacted]



SPEAR MEMO NO. 22
FIGURE 1



EP-8A XE-P 8/13/69
PURGE SYSTEM PARAMETERS
1-*- PT895 2241 PSIA 1.000
2-*- TE848 2162 DEG RANK 1.000
3-*- PT890 2087 PSIA 1.000
4-*- PT225 2105 PSIA 1.000
5-*- PT815 1531 PSIA 1.000
6-*- PT880 1546 PSIA 1.000
SPEAR MEMO NO 22
FIGURE 2
DILUENT LINE PRESSURE
BEARING HOUSING PRESSURE
TURBINE INLET LINE PRESSURE
TURBINE EXHAUST LINE PRESSURE
PURGE MANIFOLD PRESSURE
PURGE MANIFOLD PRESS.
TURBINE EXH LINE PRESS.
UNITS
RANGE TIME-SEC.
200.0
160.0
120.0
80.0
40.0
58980.0
59080.0
59180.0
59280.0
59480.0
59580.0
C013

SPEAR Memo No. 23
T. Y. Shigemoto:jh

TYS 017

XE-PRIME

EP-8A

Subject: ENGINE TURBOPUMP

SUMMARY

The engine test data were analyzed to determine the turbopump performance during the five starts of EP-8A.

The turbopump successfully started on each occasion. One start was initiated under conditions of zero NPSP (Net Positive Suction Pressure).

The total cumulative spin time after EP-8A, Runs 1 through 5, was 87.58 minutes; 23.29 minutes were at speeds in excess of 10,000 rpm (3.66 minutes in excess of 20,000 rpm from prior tests).

TECHNICAL DISCUSSION

The engine turbopump underwent five (5) consecutive startups during EP-8A with a total spin duration of 41.10 minutes, 12.67 minutes in excess of 10,000 rpm.

The turbopump started successfully on each occasion. The turbopump conditions at initial indicated rotation are presented in Table I. As shown by the tabulated values, the turbine total to static pressure ratio was approximately one. Since a pressure ratio of 1.005 is required to produce a 2 in-lb torque (Reference 1), the measured values are indicative of the low starting torque requirements of the turbopump, although exact values of turbine pressure ratio have questionable validity at these low values. Table I also indicates that NPSP was adequate to suppress cavitation on startup for all of the runs except Run 2. Startup on Run 2 was initiated with zero NPSP. Table II indicates that Run 2 had only 4.1 seconds of flow duration prior to initial indicated rotation. This is similar to EP-6A, Run 6 (Ibid.), where there was only 2.4 seconds of flow duration prior to initial indicated rotation and the NPSP was zero. There was little vapor ingestion during startup for Run 2 (startup was smooth, no large oscillations were observed). A zero or low NPSP (less than 7 psi) start is not necessarily harmful to the turbopump as discussed in Reference 2. Some 10 seconds after rotation indication (@ CRT 57786.6), at 1346 rpm a positive NPSP was recorded.

Ref. 1: Report on XE-Prime, EP-6A, SPEAR Memo No. 22
Ref. 2: Report on XE-Prime, EP-7A, SPEAR Memo No. 15

Technical Discussion (Cont'd)

The overall performance of the turbopump is presented on Figures 1 through 5 for each of the startups. The parameters of shaft rotational speed (EN 800 and EN 801), turbine inlet total pressure (PT 864), pump discharge pressure (PT 110), and turbine second stage rotor exit pressure (PT 878) are presented as functions of time (CRT). Figure 5 also displays turbine power control valve (TPCV) position (DP 870). The turbopump performance can thus be related to the TPCV position.

Figures 6 and 7 depict the start performance of the turbopump. The pump performance (Figure 6) is seen to be the same as obtained during previous tests. The turbine performance (Figure 7) is similar to that of previous tests except that during runs 1 and 4 several data points indicated that the required inlet pressure was some 10% less than obtained during prior tests. These data were for conditions where the second stage rotor exit pressure was approximately 6.5 psia, whereas the majority of the data were taken for an exit pressure of 7.5 psia. Since the available energy is dependent on the pressure ratio, a lower inlet pressure would correspond to a lower exit pressure at the same rotational speed, assuming the same pump conditions.

Figure 8 illustrates the low speed pump performance upon startup for each of the five runs. For shaft speeds less than 1500 rpm Enclosure (1) of Reference 3 should be utilized in determining the pump performance.

Table III presents the turbopump parameters for designated steady-state hold times. These parameters are presented for the tabulated as well as other steady-state conditions on Figures 9, 10, and 11. The pump efficiency from previous EP's is seen to be somewhat higher than obtained during component testing - this is due to the low temperature rise across the pump at the low rotational speeds. The data for the other parameters is seen to be similar to that obtained during previous tests. The turbine efficiency is seen to be somewhat low during Run 2. A study of these points (U/C_o = 0.10 to 0.103) disclosed a turbine inlet temperature of approximately 100°R. These low temperatures may have had an effect on performance as seen with the flow parameter.

Figure 12 depicts turbine flow parameter as a function of total inlet to static exit pressure ratio. As discussed in Reference 1, it was believed that deviations from the mean data line were due to the finite data involved and the inaccuracies in the measurements. Figure 13 shows that if this reasoning was correct there is fair consistency in the data inaccuracies. Figure 13 gives the choked flow parameter as a function of turbine inlet temperature for EP-4A through 7A. As seen, the flow parameter varies (decreases) linearly with temperature down to approximately 200°R.

Ref. 3: Memo, T. Y. Shigemoto to O. I. Ford, Usage of XE-Prime Data for Low Speed and Bootstrap Turbopump Performance Analysis, 7740:M0351, dated 11 August 1969

Technical Discussion (Cont'd)

Figures 14 and 15 present the initial bearing childown data. Figure 14 is a display of bearing temperatures (TE 836, 838, 841 and 871) and bearing housing temperature (TE 890) as functions of time. Figure 15 presents pump discharge pressure (PT 110), pump inlet pressure (PT 104) and bearing housing pressure (PT 890) as functions of time. Figures 16 and 17 indicate the same parameters as Figures 14 and 15 respectively, but depict the bearing childown just prior to Run 1. The general childown characteristics are in accord with that observed during EP-7A (Reference 4).

Figure 18 is a presentation of bearing coolant flow as a function of pump total pressure rise. The flow rate is seen to correlate with that of previous tests. As in other EP's, the values of flow rate may be in error since it is greatly dependent on the coolant density at the labyrinth seal gap.

Table IV presents the time and pump conditions at which slight rotation occurred, as determined from the RDP-3 trace (strip chart record 'P').

The coastdown data for all five runs is presented on Figures 19 and 20. In each instance the coastdown was smooth to zero rpm.

Stall may have occurred, using pump prediction data, at the following times and rotational speeds during the shutdown phase of each run.

Run No.	CRT	Rotational Speed
1	57718.9	4766 rpm
2	58397.9	5636 rpm
3	58792.8	5860 rpm
4	58978.2	5612 rpm
5	59677.8	2011 rpm

The occurrence of stall at these low rotational speeds should not present any mechanical problems, as discussed in previous SPEAR turbopump memorandums.

CONCLUSIONS

The data analyzed indicated that the turbopump operation was normal and that the turbopump did not undergo any adverse conditions.

Ref. 4: Report on XE-Prime EP-7A, SPEAR Memo No. 21.

TABLE I

TURBOPUMP CONDITIONS AT INITIAL INDICATED ROTATION*

EP-8A

Run No.	Time* (CRT)	P_{TTi} (psia)	P_{2Tre} (psia)	T_{Ti} (^oR)	W_t (lb/sec)	T_s (^oR)	P_s (psia)	NPSP (psi)	P_d (psia)	T_d (^oR)
1	56714.4	8.6	8.6	324.8	0.09	40.5	35.9	8.7	35.9	41.8
2	57780.8	8.3	8.3	172.5	0.13	42.8	36.2	0	35.6	42.5
3	58697.4	8.3	8.2	222.0	0.13	40.5	35.2	9.7	34.0	40.9
4	58884.6	8.2	8.2	186.0	0.11	41.4	36.0	9.5	34.5	41.7
5	59267.9	8.2	8.2	215.5	0.09	42.0	36.3	3.1	35.1	42.3

* Initial rotation after TPCV commanded open as determined from strip chart record RDP3.

P_{TTi} = Turbine inlet total pressure (NR), PT864 (from TS02, 10 s/s).
P_{2Tre} = Turbine second stage exit static pressure, average of PT876 and PT878 (from TS02, 10 s/s).
T_{Ti} = Turbine inlet temperature, average of TE834 and TE835 (from TS02, 10 s/s).
W_t = Turbine inlet flow rate, W_{HTURBI} (from TS03, 10 s/s).
T_s = Pump suction temperature, average of TT103 and TT105 (from PM01, 10 s/s).
P_s = Pump suction pressure, average of PT104 and PT106 (from PM01, 10 s/s).
NPSP = Net Positive Suction Pressure = P_s - vapor pressure
P_d = Pump discharge pressure, PT110 (from PM02, 10 s/s).
T_d = Pump discharge temperature, TT109 (from PM02, 10 s/s).

TABLE II

CONDITIONS DURING PUMP CHILL

EP-8A

Run No.	*Flow Duration Just Prior to N Indication: CRT	*Flow Duration Just Prior to N Indication: Duration	Wp Variation During Final Chill	Ts Prior to Start of Final Chill	Ps During Final Chill	NPSP at First N Indication
1	(56537.6 to 56714.4)	176.8 sec	0 to 8.51 lb/sec	40.5°R	35.9 psia	8.7 psi
2	(57776.7 to 57780.8)	4.1 sec	0 to 6.75 lb/sec	42.8°R	36.2 psia	0
3**	(58685.1 to 58697.4)	12.3 sec	0 to 8.49 lb/sec	40.5°R	36.2 psia	9.7 psi
4	(58832.2 to 58884.6)	52.4 sec	0 to 7.43 lb/sec	41.4°R	36.0 psia	9.5 psi
5	(59198.3 to 59267.9)	69.6 sec	0 to 4.68 lb/sec	42.0°R	36.3 psia	3.1 psi

* From PM01 Thin Data and RDP-3
** Flow durations of 18, 29, 41 and 26 seconds with pauses of 16, 35, 46 and 3.6 seconds prior to final chill.

Wp = Pump flow rate, WH014, from PM01
Ts = Pump inlet temperature, average of TT103 and TT105, from PM01
Ps = Pump inlet pressure, average of PT104 and PT106, from PM01
NPSP = Ps - Vapor pressure

TABLE IV

TURBOPUMP CONDITIONS DURING SLIGHT ROTATION

EP-8A

Time (CRT)	Shaft Speed (rpm)	Pump Flow (lb/sec)	Turbine Pressure Ratio
56052.4 to 56054.0	3 max.	0	1.003
56560.0 to 56624.0	30 max.	0.4 to 8.3	1.000 to 1.025
56625.0 to 56640.0	3 max.	7.6	1.000
59874.0 to 59884.0	5 max.	0	1.000

Shaft Speed = Average of EN 800 and 801, from PM01 thin data
Pump Flow = WH014, from PM01 thin data
Turbine Pressure Ratio = PT864/PT878, from TS02 thin data

FIGURE 1 SPEAR Memo No 23

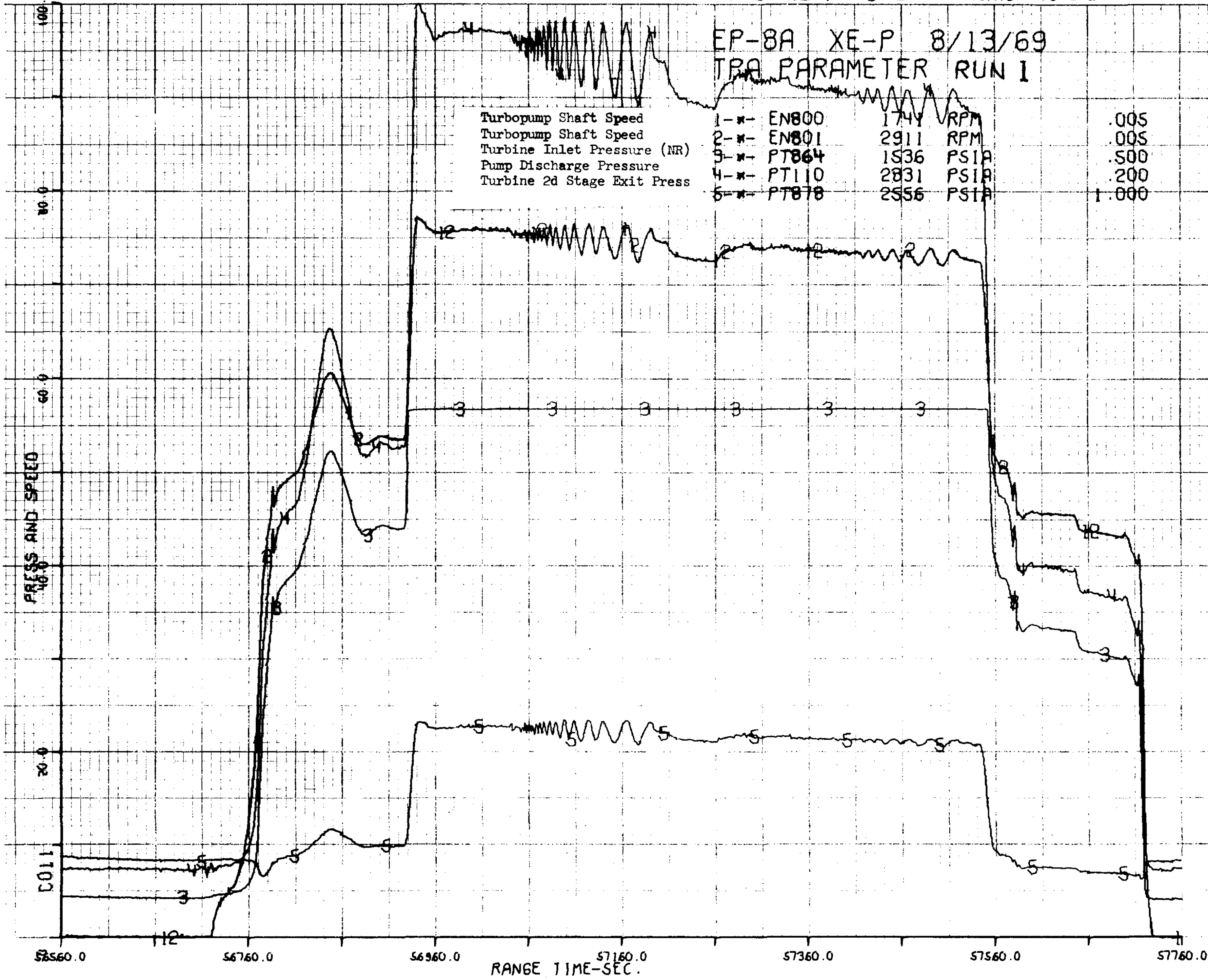


FIGURE 2 SPEAR Memo No. 23

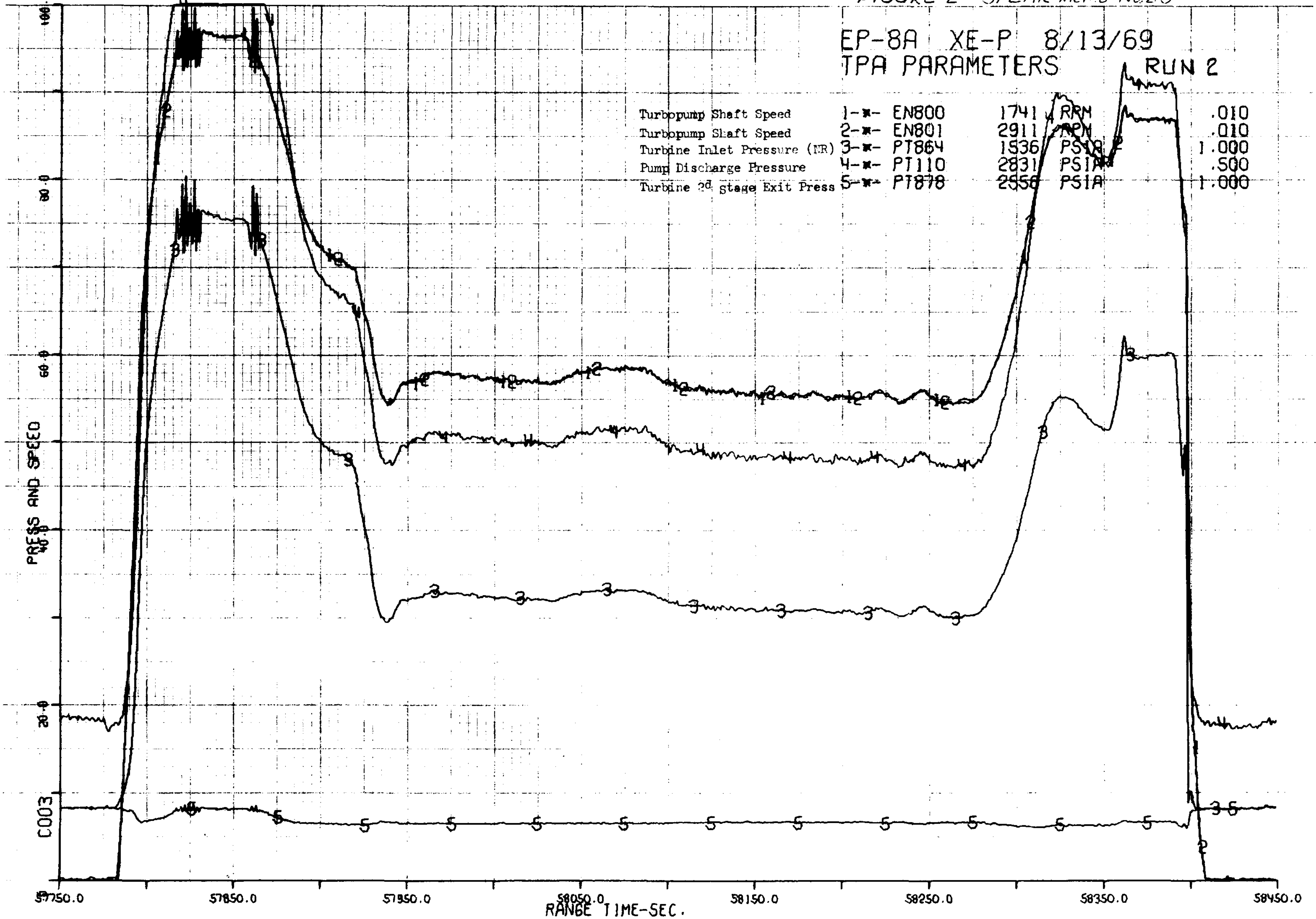
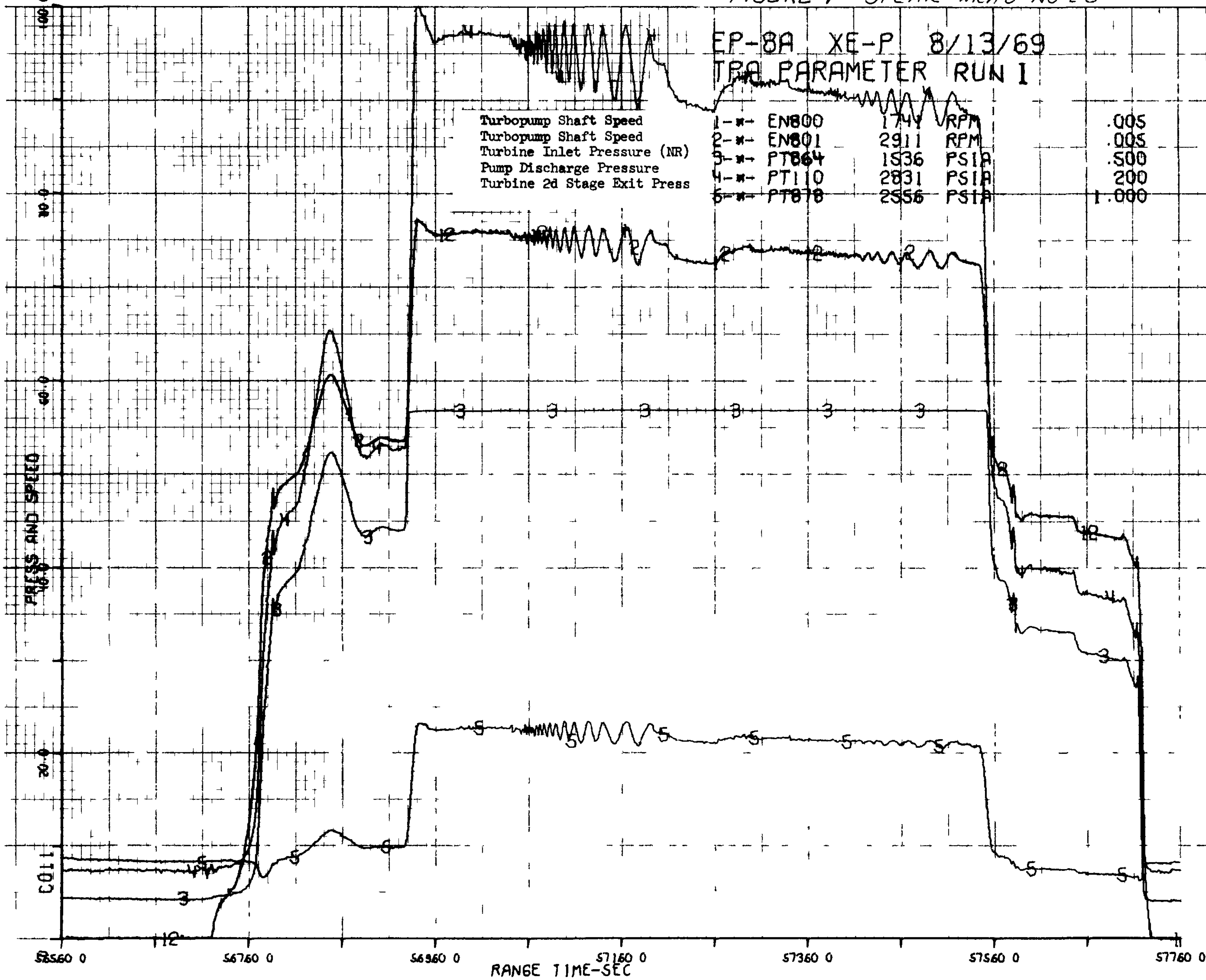


FIGURE 1 SPEAR Memo No 23



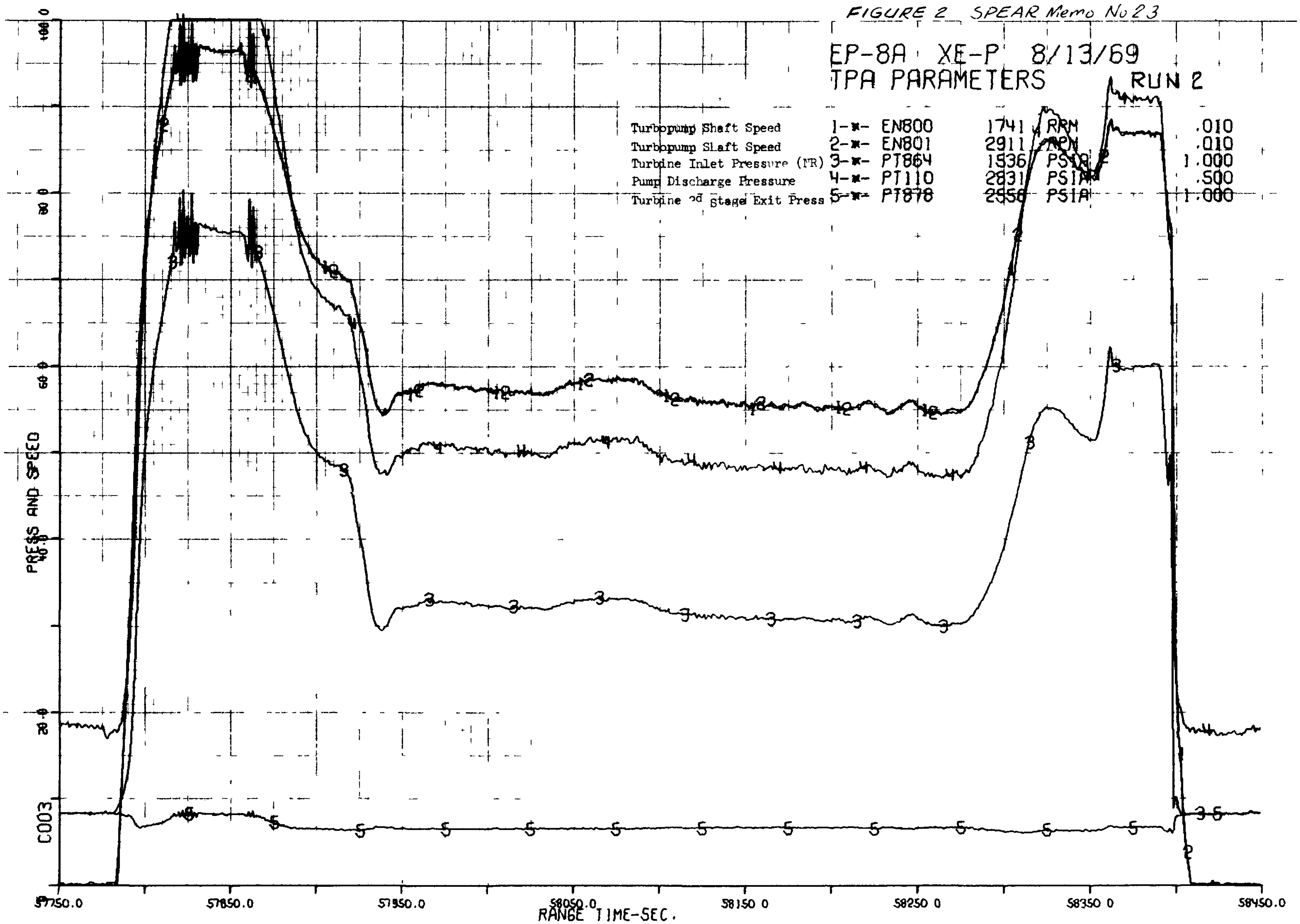


FIGURE 2 SPEAR Memo No 23
EP-8A XE-P 8/13/69
TPA PARAMETERS RUN 2
Turbopump Shaft Speed 1-*- EN800 1741 RPM .010
Turbopump Shaft Speed 2-*- EN801 2911 RPM .010
Turbine Inlet Pressure (NR) 3-*- PT864 1536 PSIA 1.000
Pump Discharge Pressure 4-*- PT110 2831 PSIA .500
Turbine 2d Stage Exit Press 5-*- PT878 2556 PSIA 1.000
PRESS AND SPEED
C003
RANGE TIME-SEC.
57750.0
57850.0
57950.0
58050.0
58150 0
58250 0
58350 0
58450.0

FIGURE 3 SPEAR Memo No 23

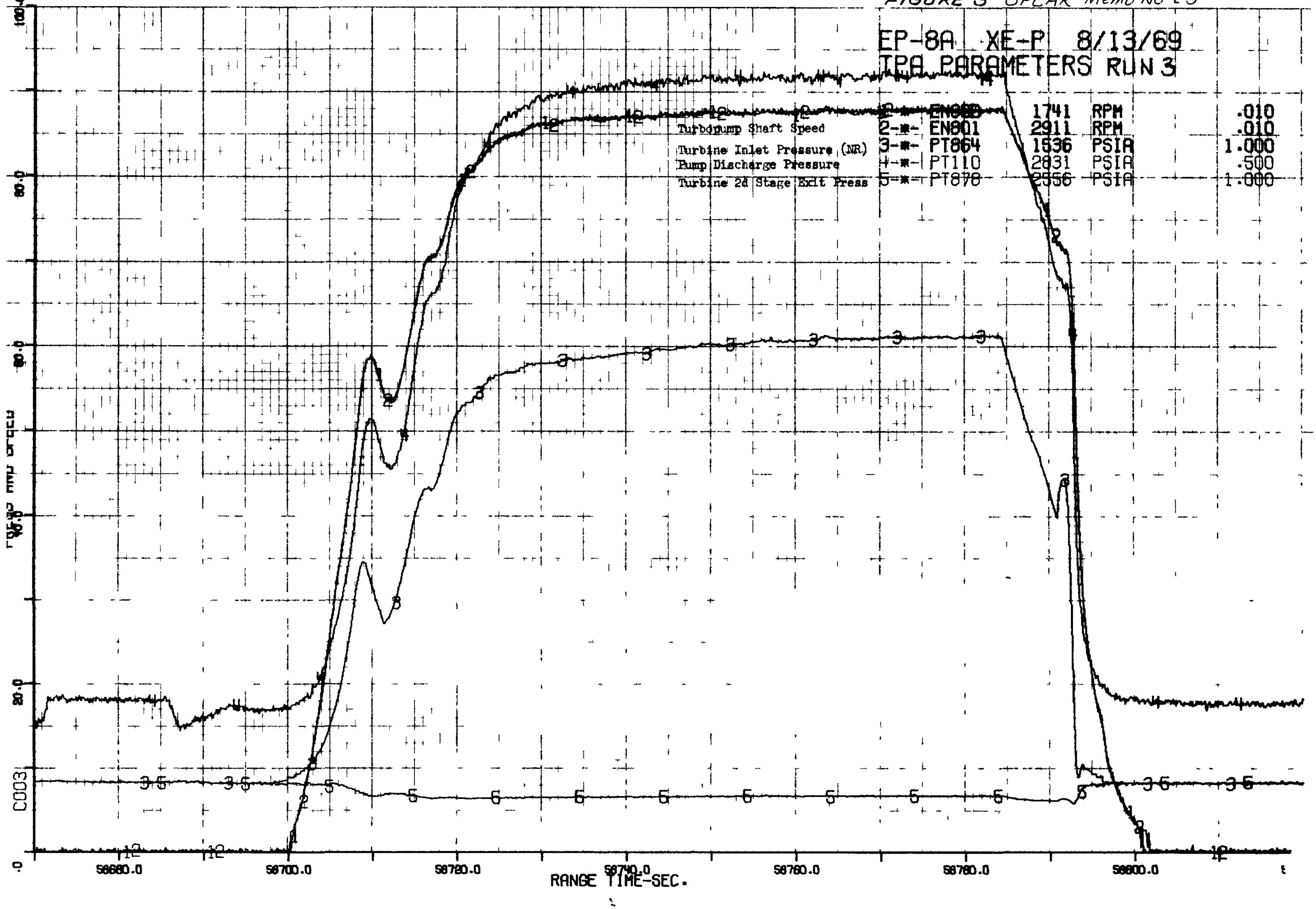
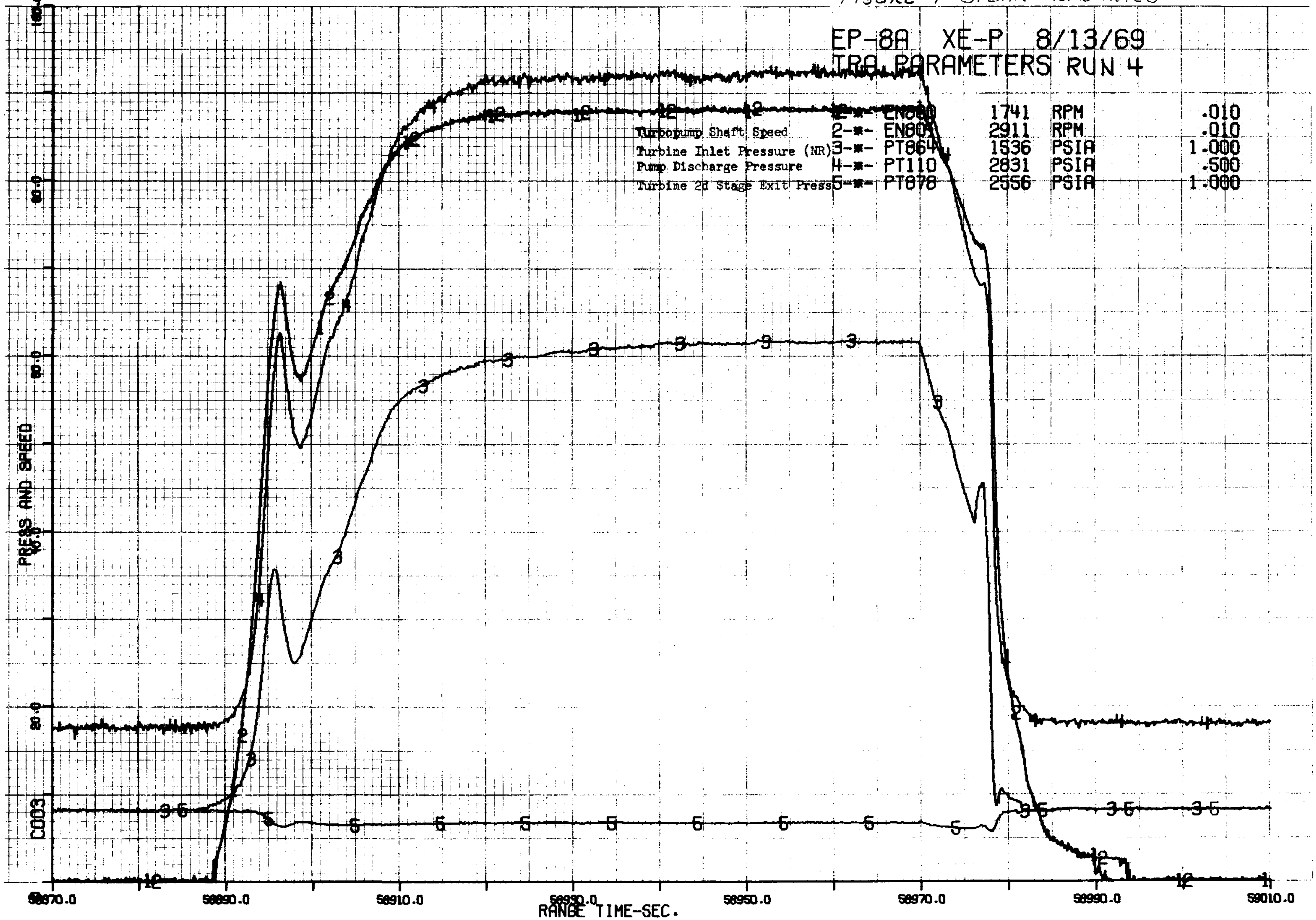
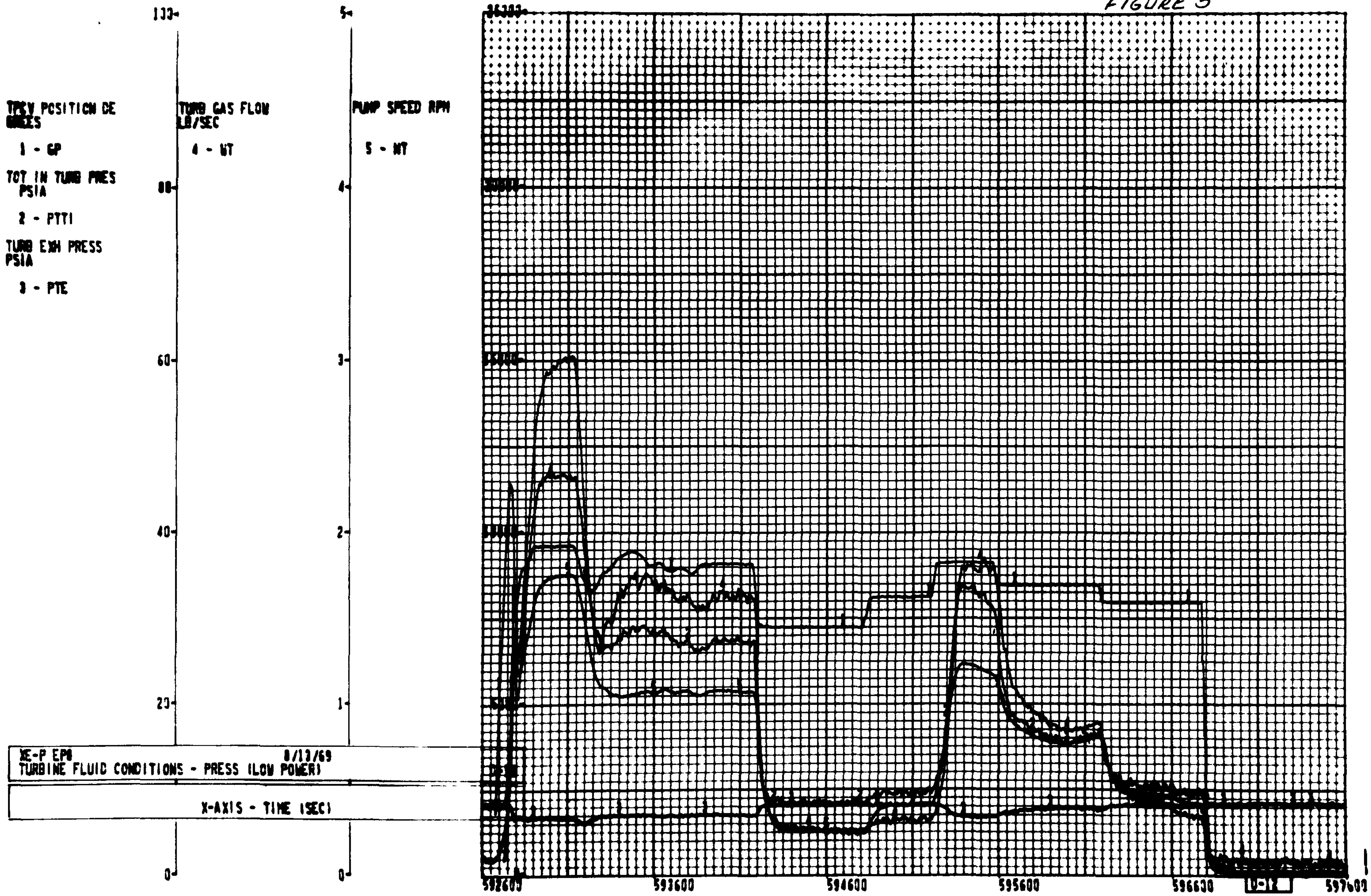


FIGURE 4 SPEAR Memo No. 23



SPEAR Memo No. 23
FIGURE 5



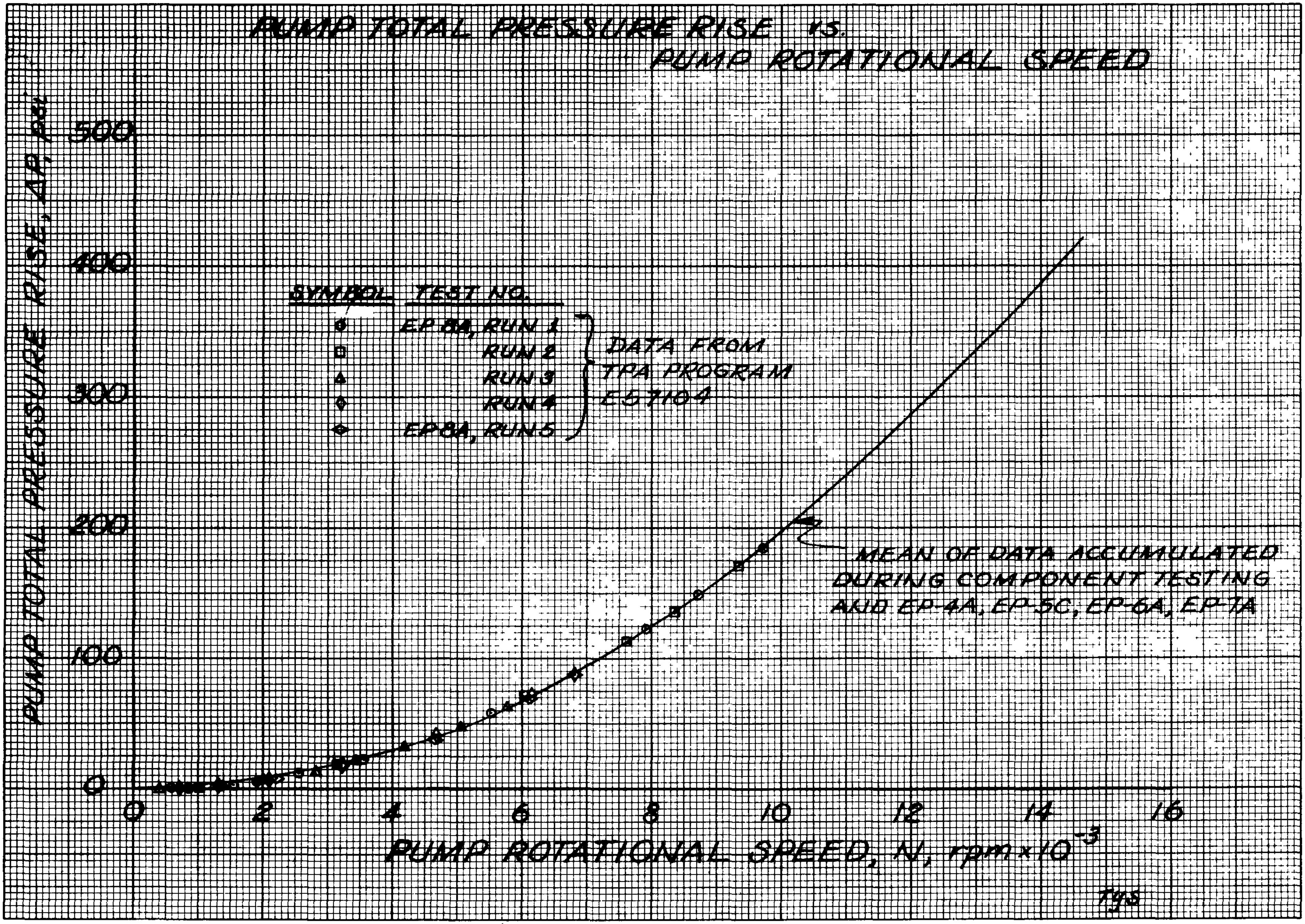
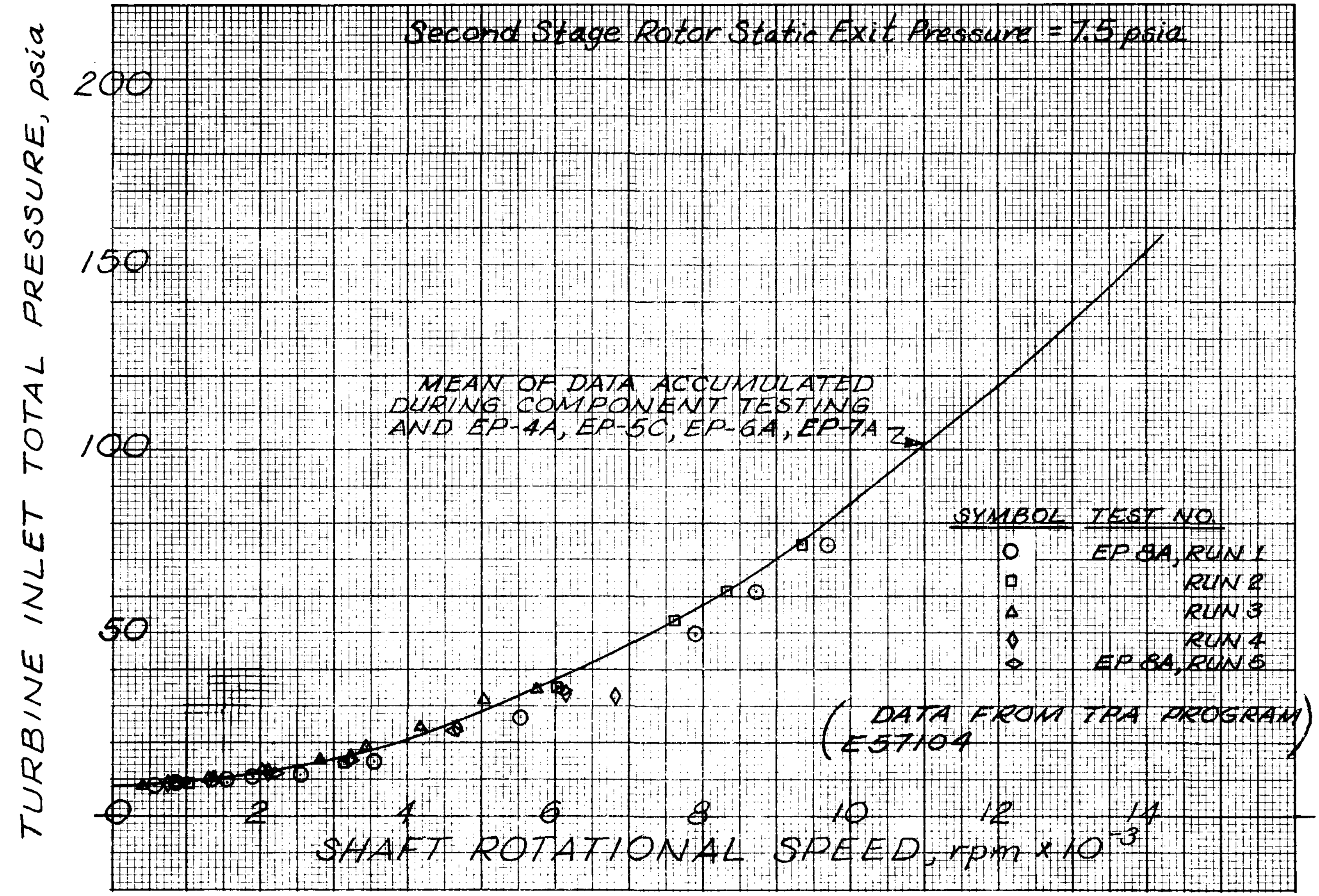


FIGURE 6

SPEAR Memo No 23

TURBINE INLET TOTAL PRESSURE
VS.
SHAFT ROTATIONAL SPEED



SPEAR Memo No. 23
FIGURE 7

FIGURE 8

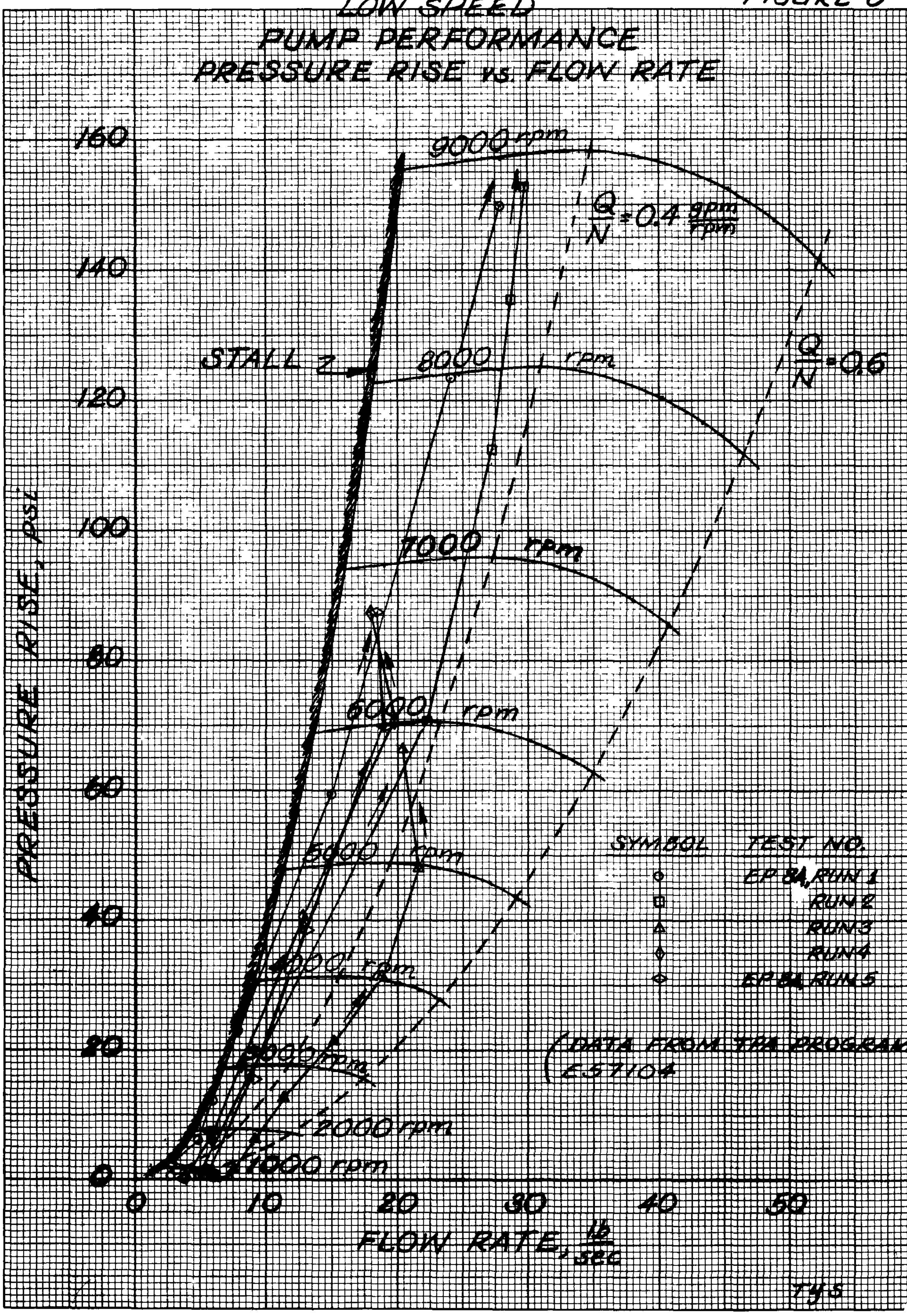
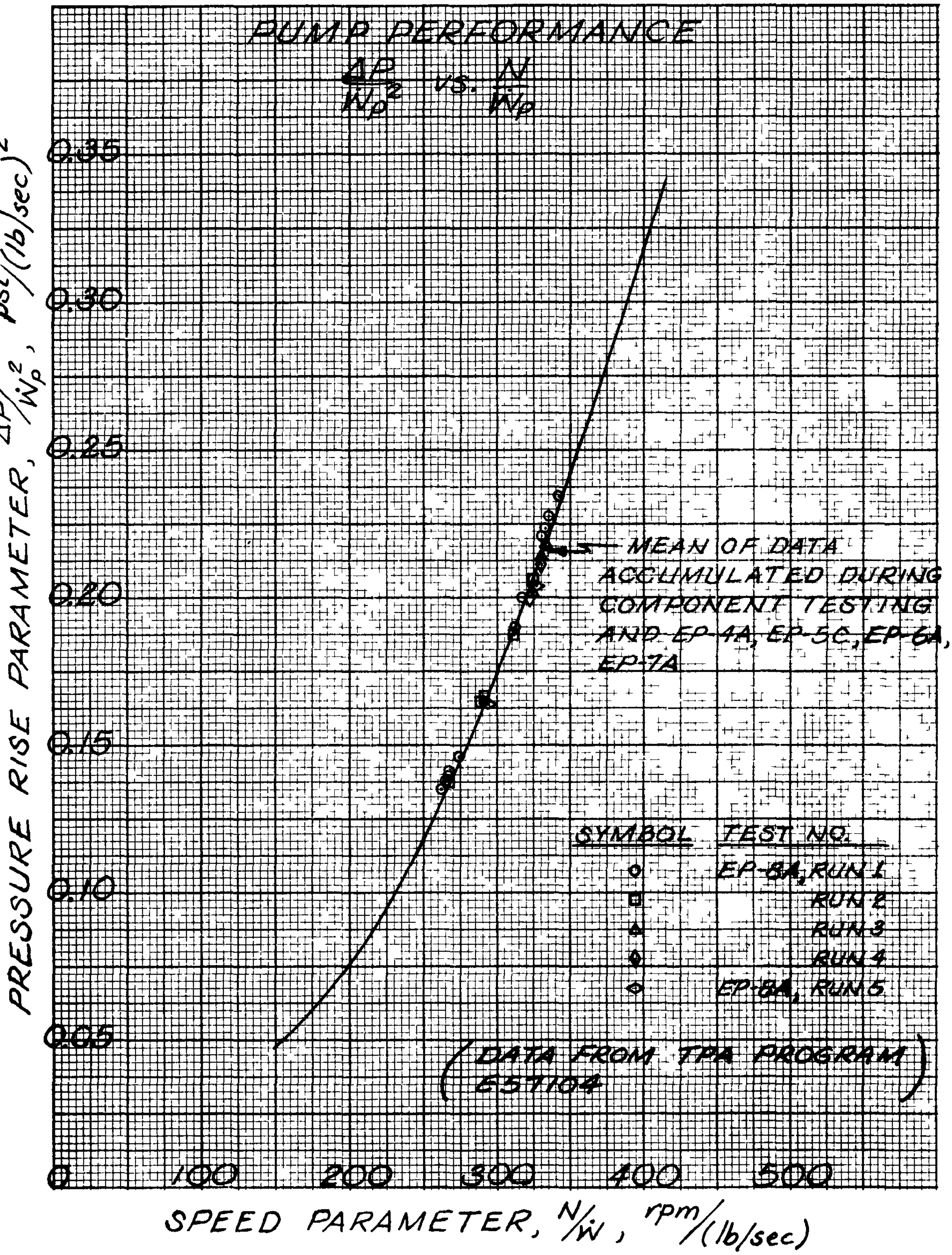
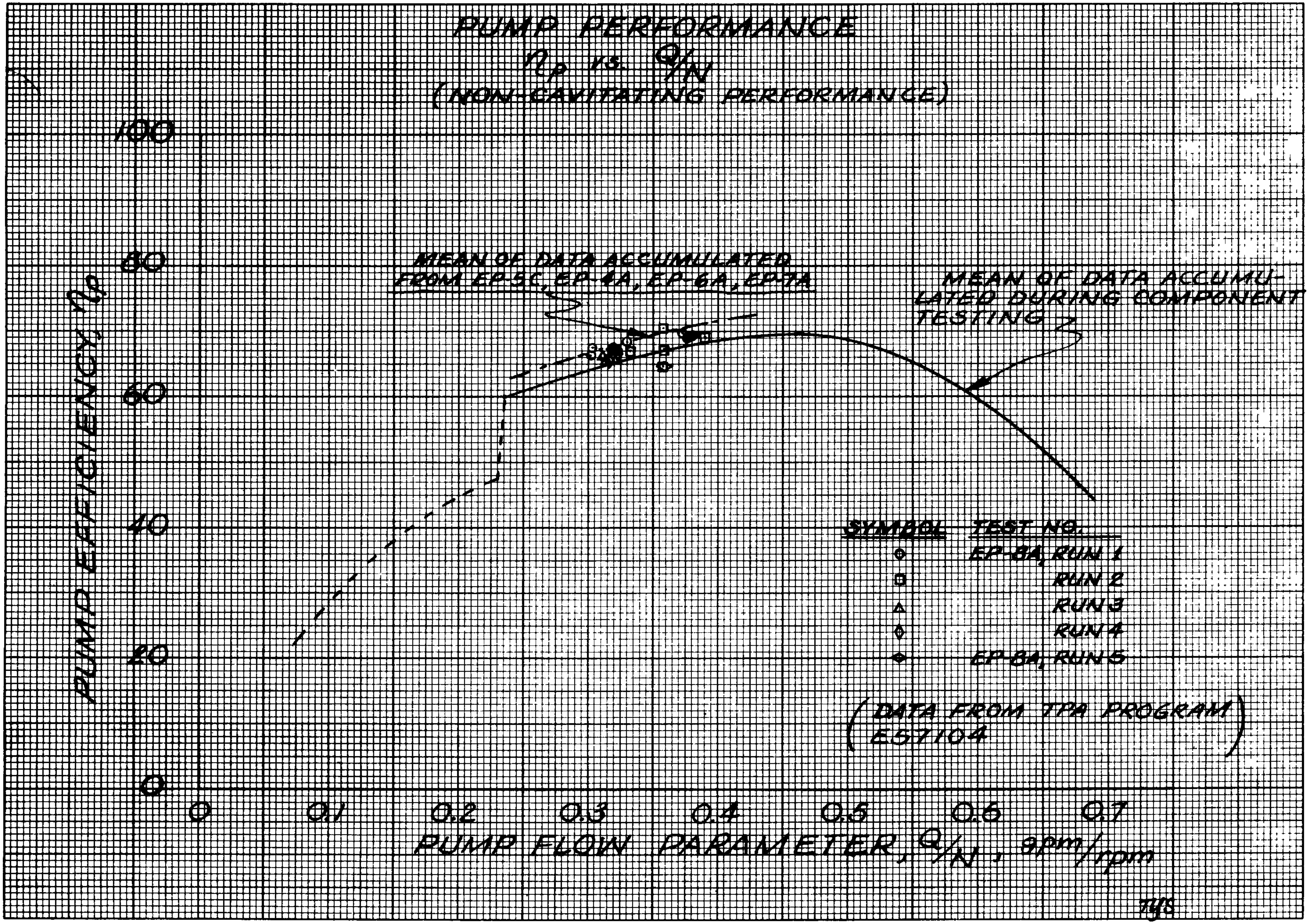

LOW SPEED
PUMP PERFORMANCE
PRESSURE RISE vs. FLOW RATE
PRESSURE RISE, PSI
FLOW RATE, lb/sec
0
10
20
30
40
50
0
20
40
60
80
100
120
140
160
9000 rpm
8000 rpm
7000 rpm
6000 rpm
5000 rpm
4000 rpm
3000 rpm
2000 rpm
1000 rpm
STALL
Q/N = 0.4 gpm/rpm
Q/N = 0.6
SYMBOL
TEST NO.
EP 84, RUN 1
RUN 2
RUN 3
RUN 4
EP 84, RUN 5
(DATA FROM TPA PROGRAM E57104)
TYS

FIGURE 9


PUMP PERFORMANCE
ΔP/Ẇp² vs. N/Ẇp
PRESSURE RISE PARAMETER, ΔP/Ẇp², psi/(lb/sec)²
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
100
200
300
400
500
SPEED PARAMETER, N/Ẇ, rpm/(lb/sec)
MEAN OF DATA ACCUMULATED DURING COMPONENT TESTING AND EP-4A, EP-5C, EP-6A, EP-7A
SYMBOL
TEST NO.
EP-8A, RUN 1
RUN 2
RUN 3
RUN 4
EP-8A, RUN 5
(DATA FROM TPA PROGRAM E5T104)

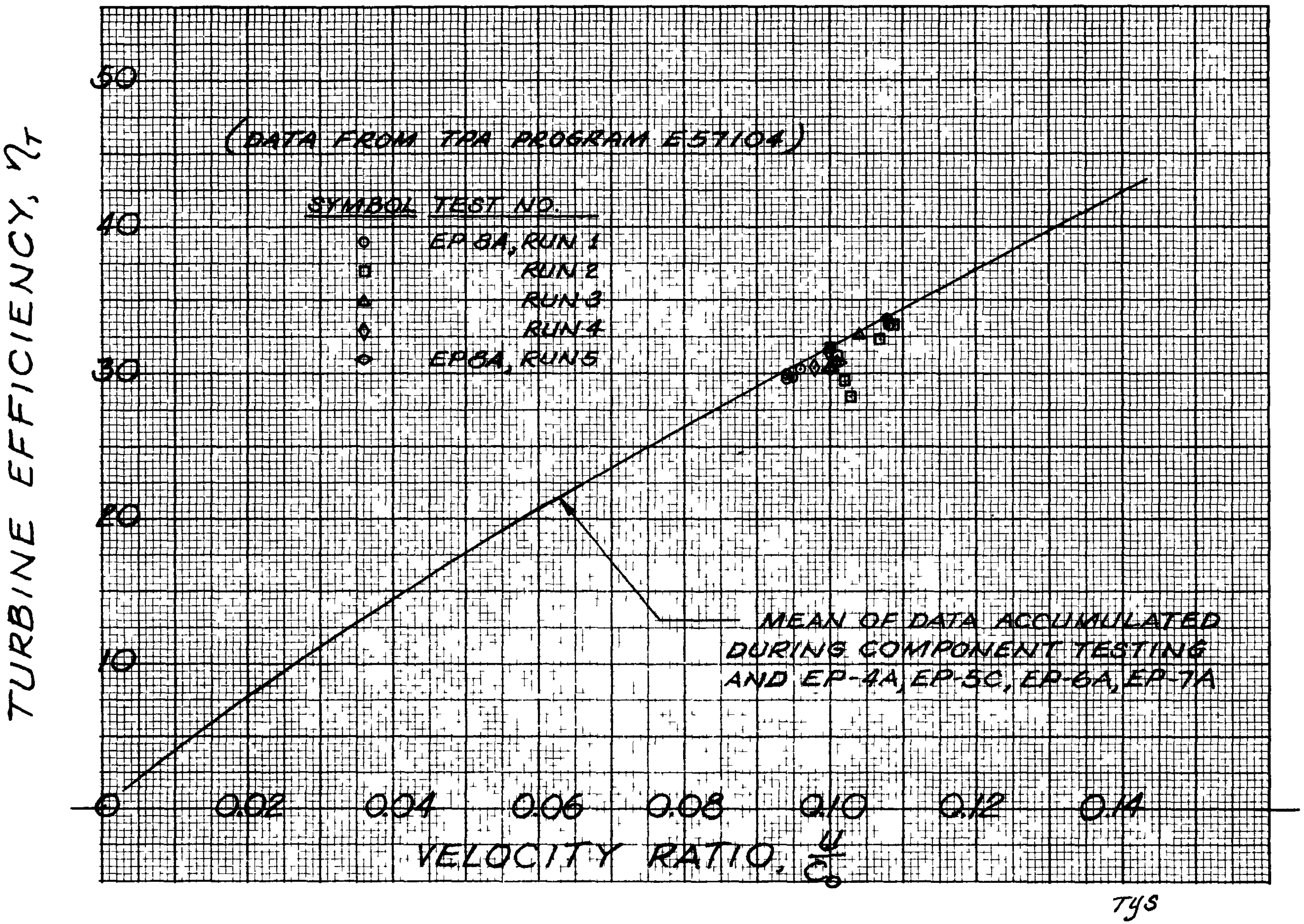
TYS



SPEAR Memo No.
FIGURE 10

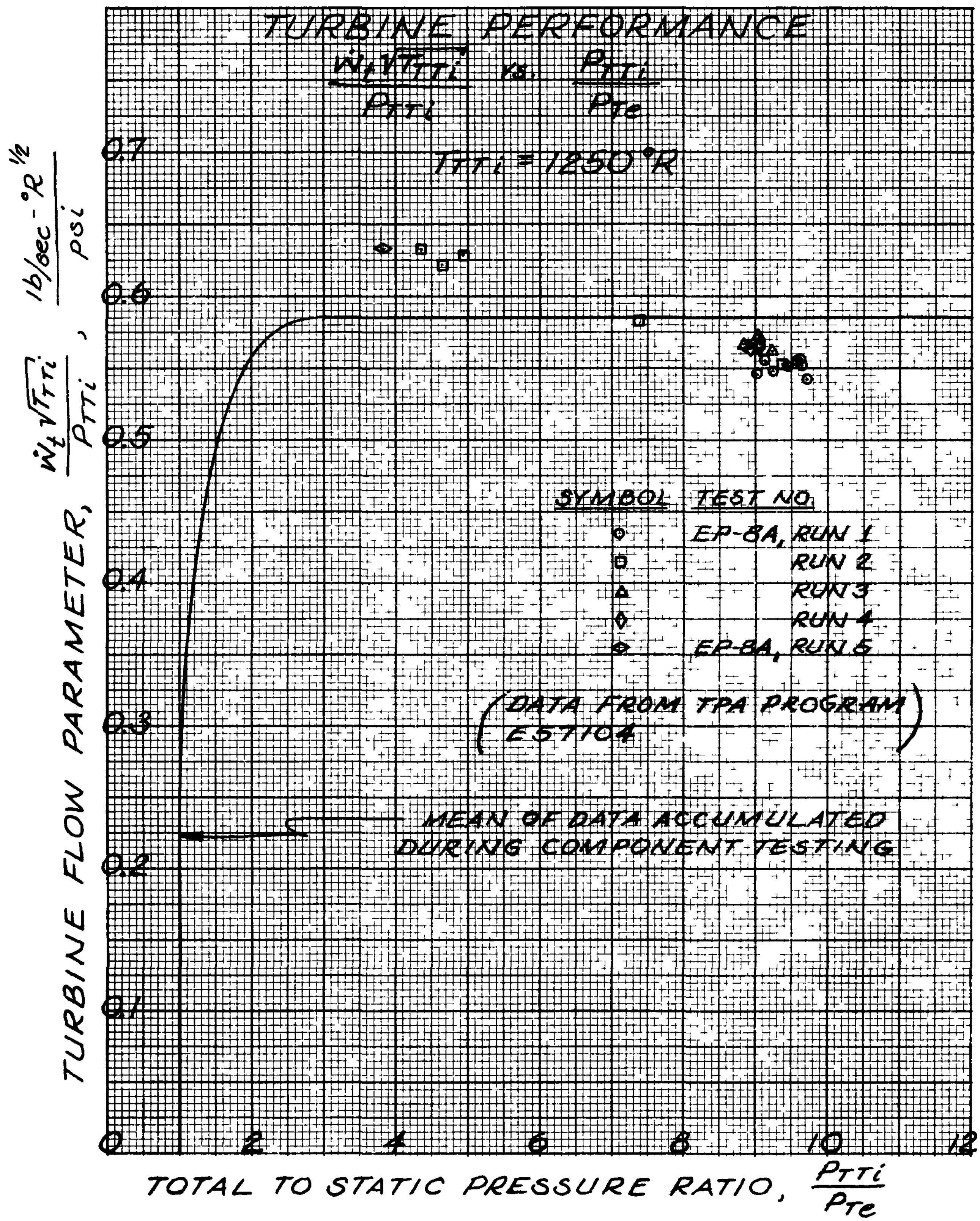
TURBINE PERFORMANCE

η_T vs. $\frac{U}{C_o}$



SPEAR MEMO No. 23
FIGURE 11

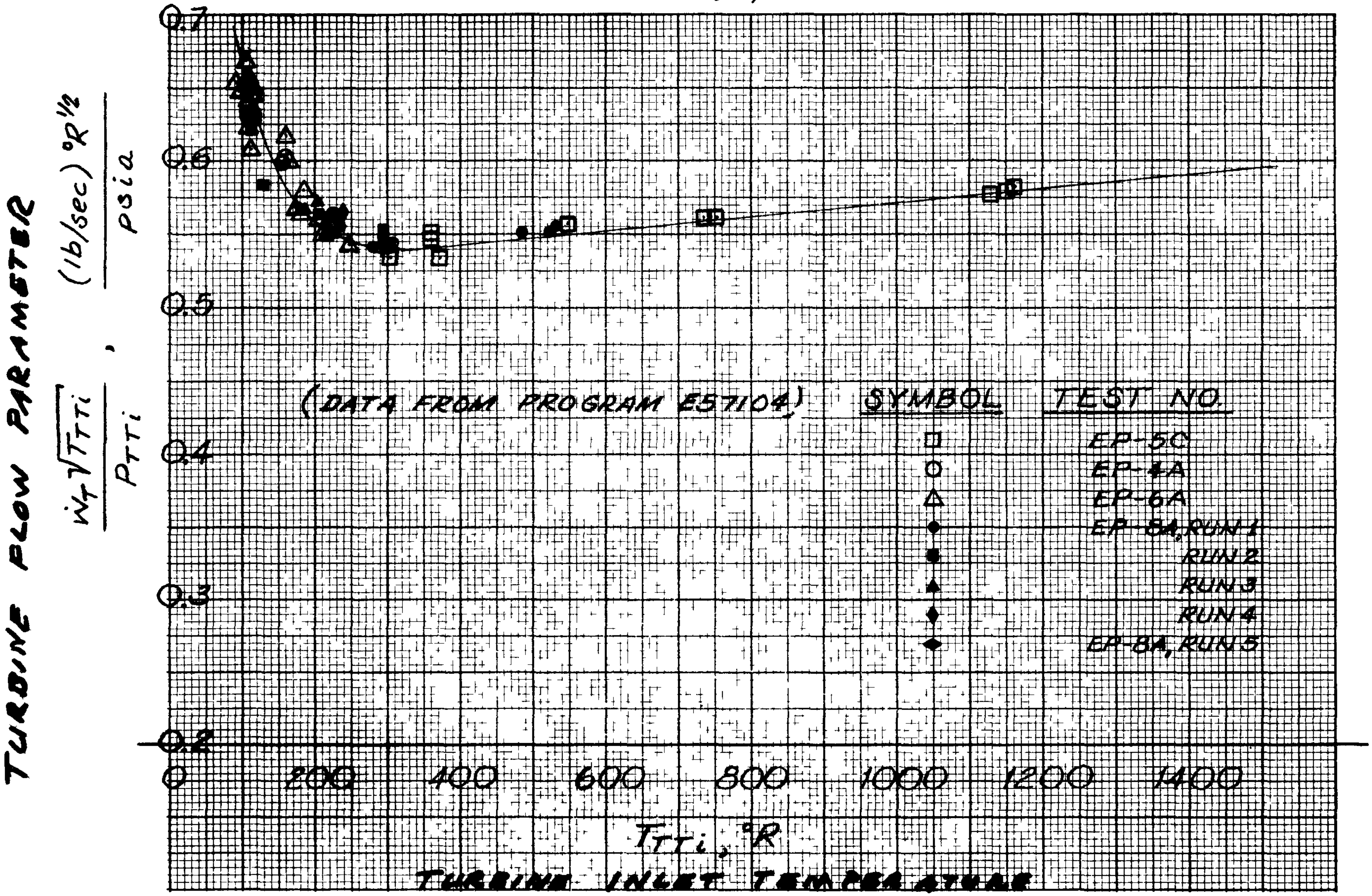
SPEAR Memo No. 23
FIGURE 12



TYS

TURBINE FLOW PARAMETER (CHOKED) AS A FUNCTION OF TURBINE INLET TEMPERATURE

XE TURBOPUMP, S/N 889023



TYS
8-14-69

SPEAR Memo No. 23
FIGURE 13

FIGURE 14 SPEAR Memo No. 23

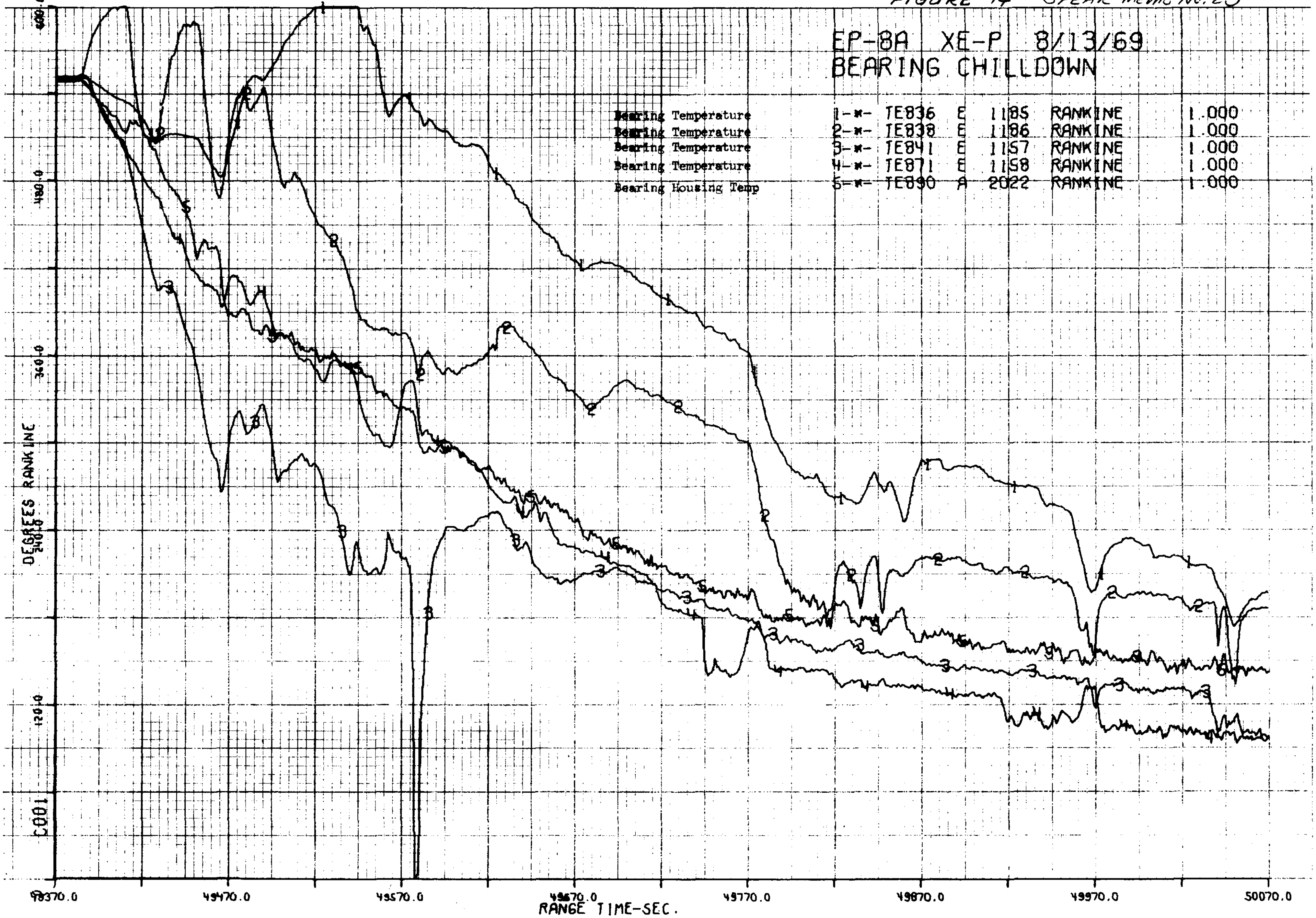


FIGURE 15 SPEAR Memo No. 23

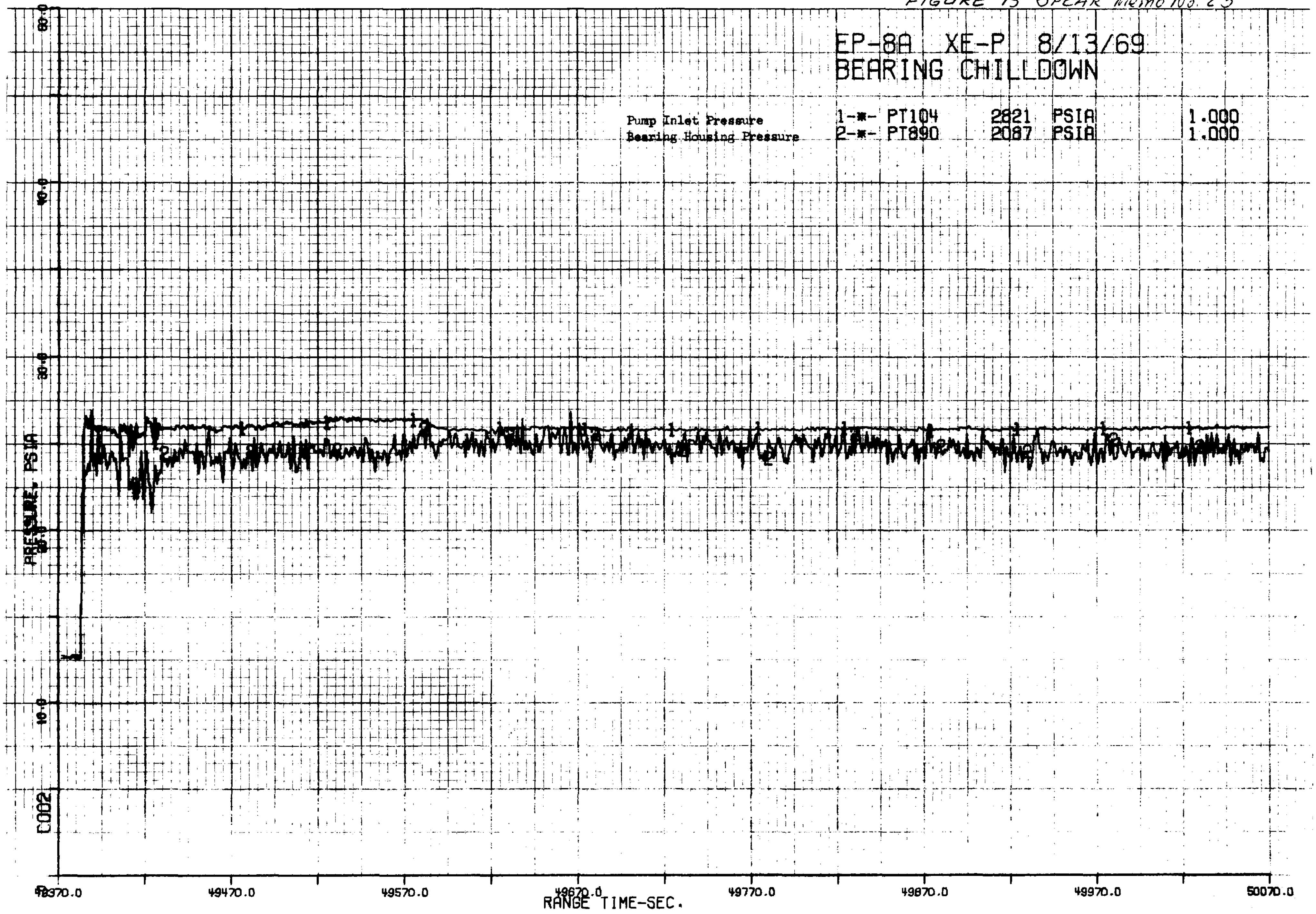


FIGURE 16 SPEAR Memo No. 23

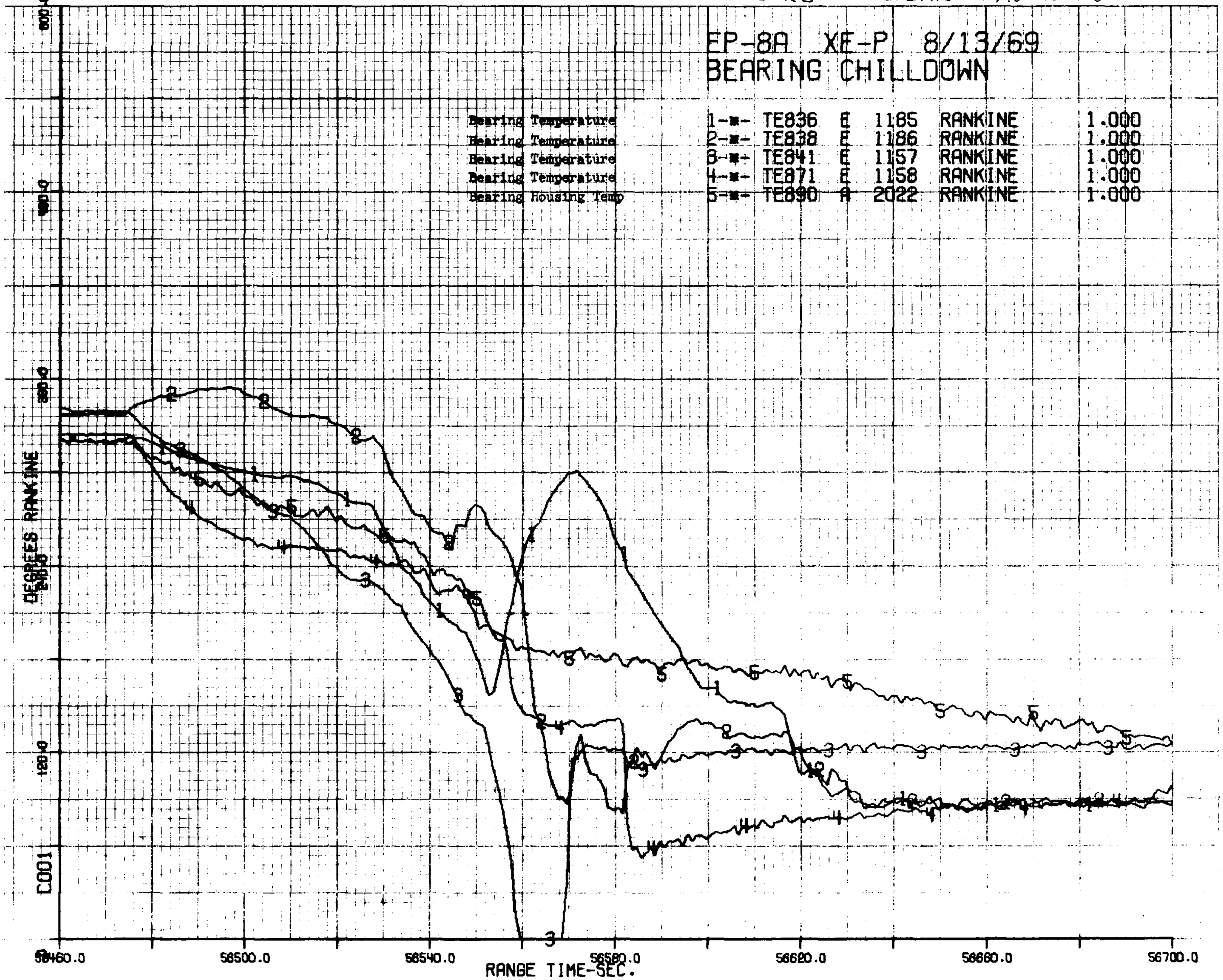
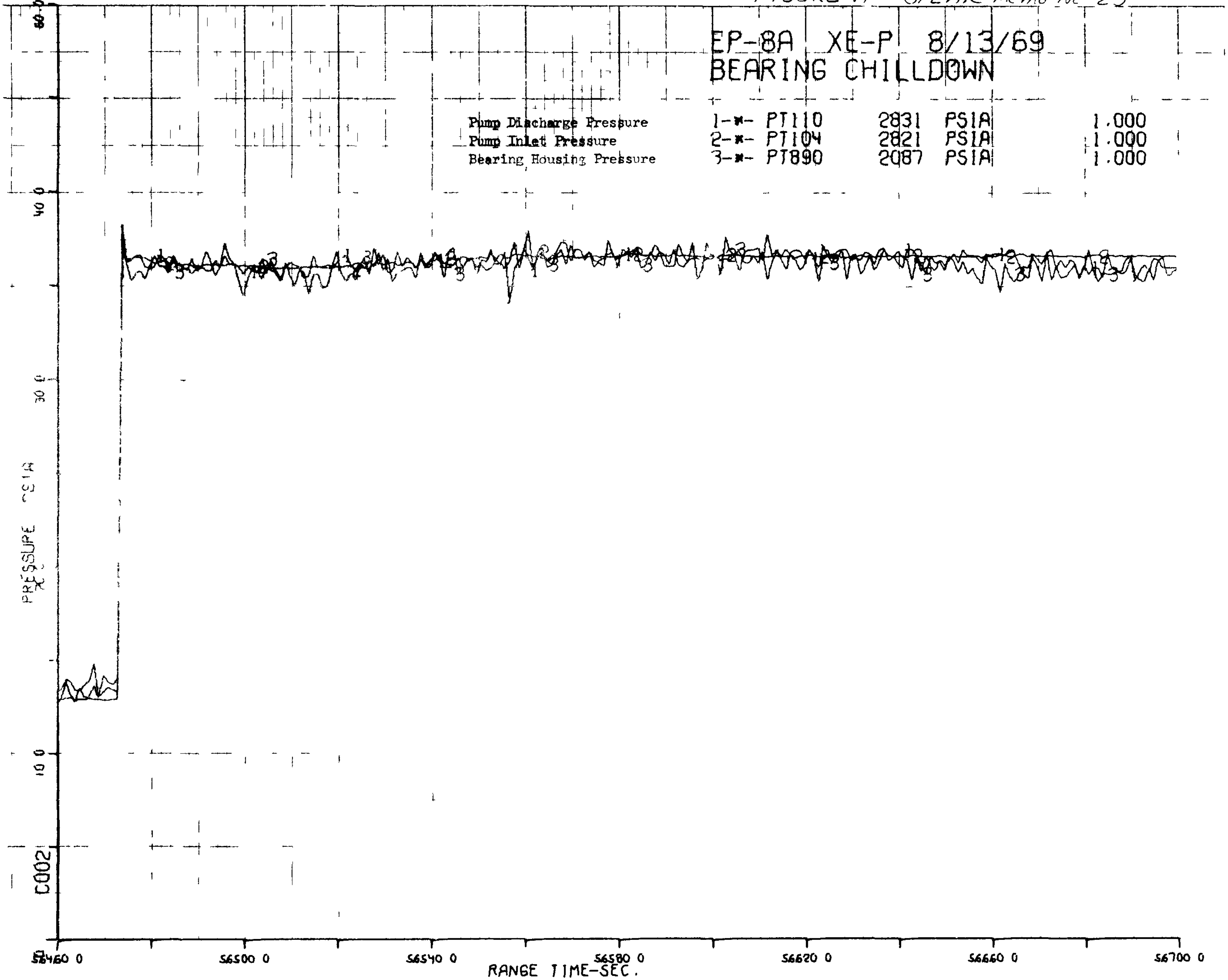
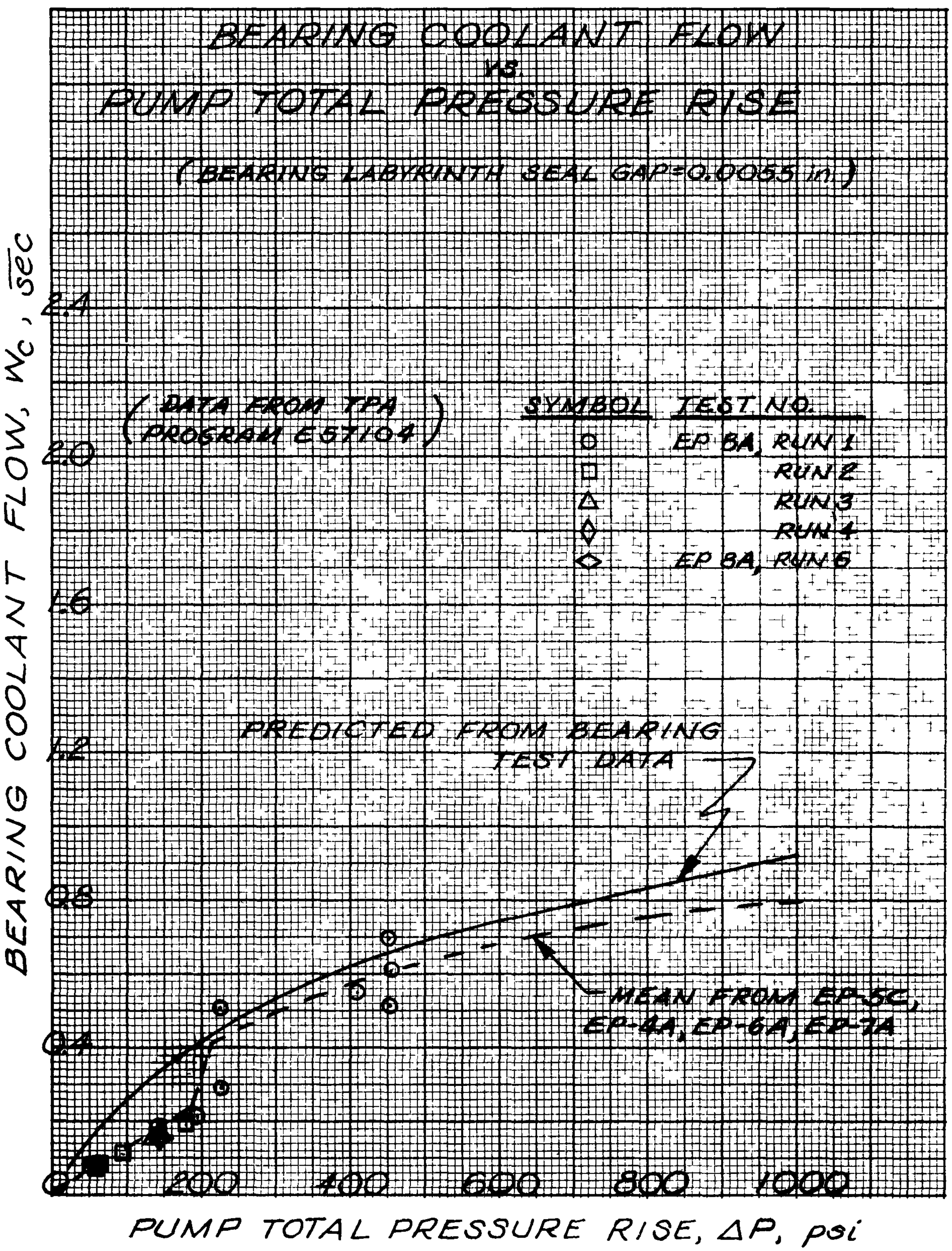


FIGURE 17 SPEAR Memo No. 23




BEARING COOLANT FLOW
VS.
PUMP TOTAL PRESSURE RISE
(BEARING LABYRINTH SEAL GAP=0.0055 in.)
(DATA FROM TPA PROGRAM E57104)
SYMBOL TEST NO.
EP 8A, RUN 1
RUN 2
RUN 3
RUN 4
EP 8A, RUN 6
PREDICTED FROM BEARING TEST DATA
MEAN FROM EP-5C, EP-4A, EP-6A, EP-7A
BEARING COOLANT FLOW, $\dot{W}_c$, lb/sec
2.4
2.0
1.6
1.2
0.8
0.4
0
200
400
600
800
1000
PUMP TOTAL PRESSURE RISE, ΔP, psi

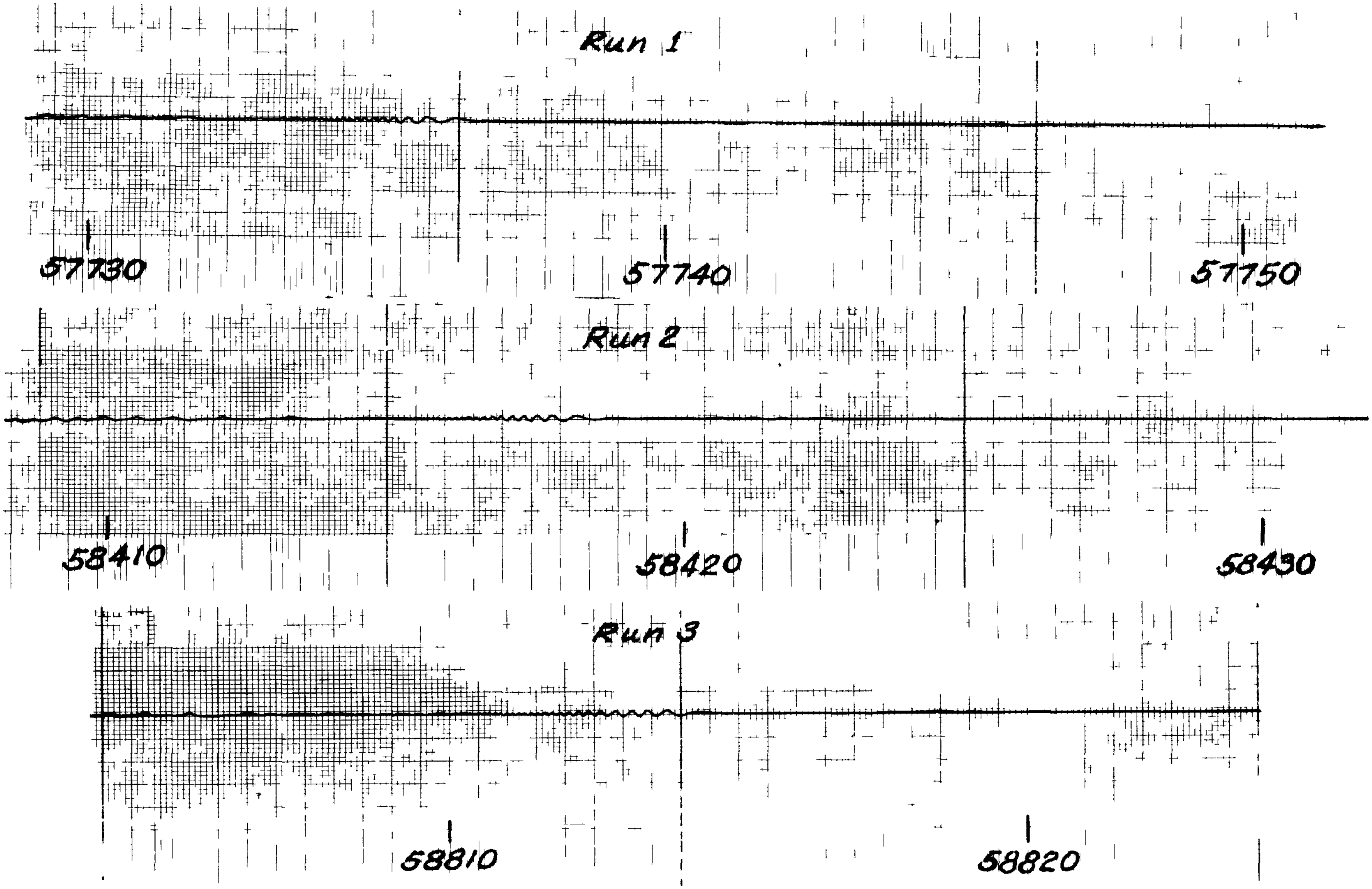
TYS

RECORDER P TRACE (RDP-3)

SHUTDOWN PHASE

ROTATIONAL SPEED vs. CONTROL ROOM TIME (CRT)

EP-8A, Runs 1,2,3



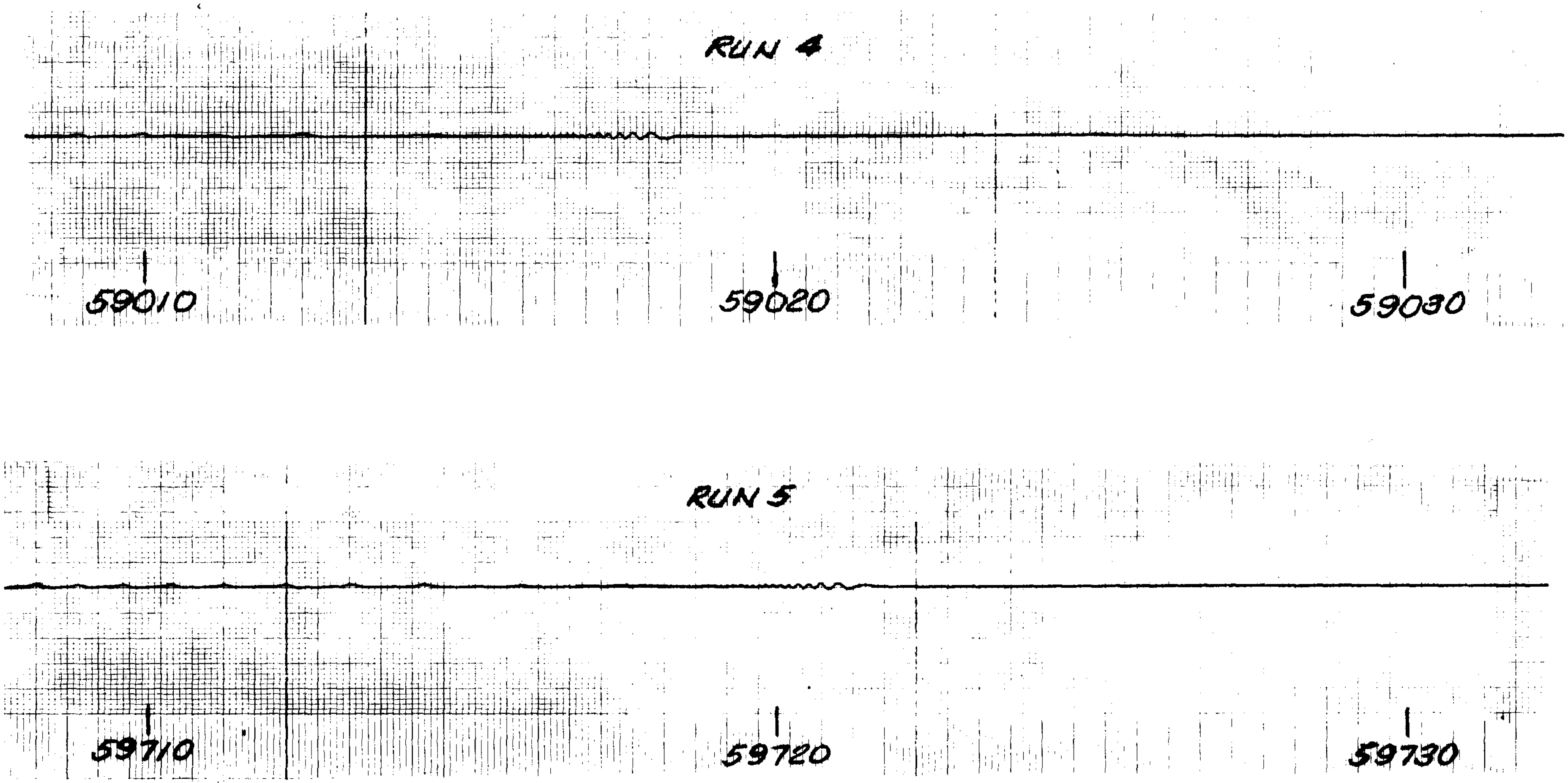
SPEAR Memo No 23, FIGURE 19

RECORDER P TRACE (RDP-3)

SHUTDOWN PHASE

ROTATIONAL SPEED vs. CONTROL ROOM TIME (CRT)

EP-8A, Runs 4 and 5



SPEAR Memo No 23, FIGURE 20

SPEAR Memo No. 24
PAA/NTO Health & Safety
MKWu:ck

XE-PRIME

EP-8A

Subject: RADIOLOGICAL REPORT

Radiological support for EP-8A included area monitoring surveillance of NRDS during run and post-run periods, and radiation and contamination survey support for re-entry and post-run activities at ETS-1.

A. Area Monitoring Surveillance

1. The maximum reading obtained from the Remote Area Monitoring System was from Unit #9 located 475 feet from the reactor on an azimuth of 303 degrees. This unit indicated 500 R/hr at a reported reactor power of 440 MW. At test termination this unit indicated 1.8 R/hr, decreasing to 90 mR/hr at 4.1 hours.

2. Air Sampling

   Air sampling was performed during EP-8A at the following locations: R-MAD, E-MAD, Test Cell "C," NRDS Main Gate, Road "H&K" Junction, and the Central Support Area. Analysis of the air samples indicated no significant activity above background.

3. Particle Deposition

   Post-run surveys were conducted on Road "K" and within ETS-1. There were no indications of particle deposition resulting from the test.

B. Test Cell Radiation and Contamination Surveys

1. Radiation Surveys

   Table I contains select pre- and post-run radiation dose rate information.

2. Contamination Surveys

   Contamination surveys of the Facility, including the drainage ditch, and of post-test re-entry personnel indicated background results.

   A water sample taken from the retention basin on R+1 indicated trace fission-product and sodium - 24 activity.

C. Personnel Radiation Exposure

The total estimated radiation exposure received by test personnel on run day, i.e., NTO, EG&G, and Pan Am, was 185 mR. The total estimated exposure for these personnel during R-day, R+1, and R+2 was 375 mR.

TABLE I

SELECT SURVEY DATA
EP-8A
Date: August 13, 1969

Time After Shutdown (Hours)	Location	Dose Rate mR/hr
Pre-test	40' SW/NE from reactor	10
	14' SW/NE from reactor	1000
	Contact with S-1 shield	300
1.1	Outside West Test Cell Building Tunnel Exit/Entrance	30
	South Edge of Test Stand Pad at Grating on Access Road Center Line	80
	Level 3840-0	30
	Level 3848-8 on Stairs	200
2.3	Center of Roadway at Electrical Shop	10
	Level 3848-8 at Elevator	240
4.3	Level 3848-8 at Elevator	36
	Level 3810 at Elevator	6
6.3	Valve Pit #1	22
6.5	70' NE/SW from Reactor	3000
15.3	350' NE/SW from Reactor	10
	125' NE/SW from Reactor	100
	30' NE/SW from Reactor	1000
	18' NE/SW from Reactor	5000
	Catwalk 3848 level	40
39.0	160' NE/SW from Reactor	10
	50' NE/SW from Reactor	100
	20' NE/SW from Reactor	1000
	Contact S-1 Shield	3600
	Contact S-2 Shield	4600
	Catwalk 3848-8 Level	10
	Duct Vault Inside Maximum at Exhaust Elbow below Reactor	50
	Duct Vault Inside Average	10
111.0	120' NE/SW from Reactor	10
	32' NE/SW from Reactor	100
	4' NE from S-3 Shield	1000
	2' SW from S-1 Shield	1000
	Contact S-1 Shield	1600
	Contact S-2 Shield	2400
	Catwalk 3848-8 Level	5

SPEAR Memo No. 25

J. Holaday/T. Keasling/mg

XE-PRIME

EP-8A

Subject: NUCLEAR EXHAUST SYSTEM

SUMMARY:

The Nuclear Exhaust System (NES) supported the XE-Prime EP-8A tests without any major problems. The Steam Generator System (SGS) was operated at full steam for 60.5 minutes with two modules. The nominal full steam temperature was 1290°R. There was no evidence of any major steam line anomalies.

The NES Duct aerodynamics performance was within acceptable limits during the first engine startup. During the open loop startup (ambient conditions), the duct pull-in occurred at 0.95 psia ETC pressure at which time the engine chamber pressure was 190.0 psia. As the engine chamber pressure was increased to 310 psia, the ETC pressure increased to 1.0 psia. No evidence of "buzzing" was observed during either pull-in or drop-out of the duct. During the remaining four bootstraps, the engine chamber pressure was never increased high enough to pull-in the duct.

The NES Duct coolant system and the Test Stand Coolant System successfully supported the test. The maximum flow through the duct was approximately 23,800 gpm with 10,700 gpm of this flow then going to the Test Stand Coolant System; this flow occurred during the first bootstrap and then was reduced to lower flow rates. The duct coolant temperature increase was well below the allowable change in temperature.

No condition exists that should preclude the initiation of the Experimental Plan.

TECHNICAL DISCUSSION:

A. Introduction

The source of the data used for the evaluation reported in this memo were 1 SPS and 10 SPS Digital Data Listing.

B. SGS Performance

1. Facility Operations

The liquid oxygen system, the propane system and the process water system all functioned satisfactorily during the SGS operation. All pressures and temperatures compared favorably with preceding test data. A tabulation of the support systems parameters and SGS data is presented in Table I.

2. System Performance

During EP-8A, all SGS modules were started to the idle condition and Modules No. 2 and 3 were brought to full steam. From television observation, Module No. 2 had a LO_2 leak around the LOX Propellant Line so Modules No. 2 and 3 were returned to idle. Module No. 1 was brought back to idle and then Modules No. 1 and 3 were brought to full steam. From television observation, Module No. 1 also had a slight LO_2 leak around the LOX Propellant Line, but it was no worse than #2 and not enough to stop the test. Full steam operation was continued with Modules No. 1 and 3.

The steam generators were run for approximately 60.5 minutes. This is the longest the SGS has operated at one time at full steam. The Facility limit for SGS operation was set at 72 minutes (reference SPEAR Memo No. 12, EP-6A) but a post-test reading on the propane tank (1400 gallons) indicatedthere was approximately 7 minutes left; this allows for the 5% inventory cut point.

The SGS Chronology for EP-8A is shown in Table II.

The SGS operational times for EP-8A, together with accumulated operating times since the last inspection, are listed in Table III.

3. Steam Generator System (SGS) Inspection

a. EP-8A Pre-Test Activities

The following activities were carried out on the steam generator system between EP-7A and EP-8A:

1. Combustion chambers S/N 880051 and 880052 were installed in Modules No. 1 and 2, respectively, replacing the chambers which had developed cracks in welds on the preceding test. (See SPEAR Report EP-7A.)

2. The "long" water injection pintles were replaced with new pintles in all combustion chambers.

3. The main stage injectors and igniter (topworks) assemblies were installed in each module. The major components installed in the SGS for EP-8A are listed as follows:

Item	Module No. 1	Module No. 2	Module No. 3
Igniter	77	880001	880008
Injector	880001	880002	0017
Chamber	880051	880052	0019

NOTES: (A) Injector, S/N 880003, formerly installed in Module No. 2, and found to be in good condition after Test EP-7A, was removed from service for cleaning and additional inspection before further use.

(B) Igniters, S/N 880001 and S/N 7, were inadvertently switched between Modules No. 1 and 2 during re-assembly, and final position is as noted above.

4. The propane line filter element (50-LF-436) was replaced with

a new item. A very small amount of rust-like material was found in the element removed.

5. A pressure transducer was installed to monitor Module No. 2 main stage "upper" chamber pressure; this measurement data is to be used in evaluating the performance of the combustion chamber differential pressure switch (50-PDS-480-2).

6. The first and second igniter stage's propellant line filters on all modules were inspected and all were found to be clean.

7. Leak tests of the SGS propellant piping and hot gas system were satisfactorily completed.

8. Electromechanical (functional) tests were successfully performed.

9. Module No. 2 second-stage igniter pressure switch (50-PDS-407-2) failed to operate during initial functional tests and was replaced.

b. EP-8A Post-Test Activities

The following activities have been performed since EP-8A and in preparation for EP-9A:

The SGS coolant water circuits were flushed with demineralized water to remove any residual "raw" water in the system.

Modules No. 1 and 3 were disassembled for inspection and the following observations were made:

1). <u>Module No. 1</u>

Injector S/N 880001 was found to have two eroded areas on the cylindrical surface adjacent to the injector face, each being near a "LOX spud" assembly. The larger eroded area was about 2-1/2 inches long (circumferential length) and 1-1/8 inches wide, and the circumferential face-plate to cylindrical weld was burned away over 2-1/4 inches length; the second eroded area was 1-1/4 inches long and 3/4 inch wide and did not appear to have burned completely through the weld depth. The injector face did not appear to have been damaged.

The combustion chamber, S/N 880051, had an eroded area in the inner liner at a location which was adjacent to the larger injector erosion noticed above. This "burn-out" was about one-inch below the top of the liner, was 2 inches long (circumferential length) and 1-inch wide, and the liner was burned through at the center leaving about a 1/4 inch diameter hole.

The "long" water injection pintles were found to have burned tips and were replaced.

Inspection of the igniter, S/N 7, by a boroscope, and a pressure test of the coolant water circuits did not reveal any abnormalities.

Module No. 1 was reassembled using Igniter, S/N 7, Injector, S/N 880003, and Chamber, S/N 00101.

2). Module No. 2

This module, which had been operated at full steam during the preceding test for only about 2 minutes, was not disassembled. The "long" water injection pintles were replaced (along with pintles on the other modules) even though no damage was noted on the items removed.

3) Module No. 3

The injector, S/N 0017, and combustion chamber, S/N 0019, were found to be in good condition. A boroscope inspection and coolant water circuits pressure test was made on the ignitor, S/N 880008, and no abnormalities were noted.

The "long" water injection pintles tips were found to be eroded and new pintels were installed.

The module was reassembled with the same components as noted above.

4). The modules injector-bolts "breakaway" torque values recorded after EP-8A are noted below. The pre-test torque on these bolts was 500 ft-lb.

1) Module No. 1.- Average breakaway torque was 260 ft-lb, and varied over a range from 200 to 300 ft-lb.

2) Module No. 2.- The bolt torque varied from 100 to 250 ft-lb, and the average breakaway torque was 180 ft-lb.

3) Module No. 3.- The average bolt torque was 370 ft-lb, and varied from 300 to 450 ft-lb.

Inspection of the steam plenum from Modules No. 1 and 3 chamber locations indicated the plenum was in good condition.

The Teflon gaskets in the SGS Modules main liquid oxygen piping were removed and replaced with Durabla gaskets. Considerable LOX leakage was noted at flanges during the preceding test, apparently due to "cold flow" of the Teflon gaskets and the resultant decrease in tightness of the piping connections.

The SGS pressure switches were checked and all functioned satisfactorily within the prescribed limits.

C. Steam Line Performance

1. Data Acquisition

Data acquisition for XE-Prime EP-8A remained in the reduced level as described in SPEAR Memo No. 12., EP-6A. Location of instrumentation was shown in Figure No. 2, SPEAR Memo No. 8, EP-1, EP-SL-2.

2. Data Analysis

The steam line was subjected to a nominal full steam condition for about 60.5 minutes during EP-8A. It performed satisfactorily throughout the test. The data compares well with the results of the previous tests.

a. Steady State Temperature and Pressure

The maximum steam temperature reached was 1304°R. A representative steady-state full steam condition taken at RT 59074.2 seconds was as follows:

Steam Plenum Pressure	PT 425	126.9 psia
Separator Outlet Pressure	PT 865	118.2 psia
Steam Ejector Pressure	PT 239	115.8 psia
Avg. Steam Temp. Separator Outlet		1301°R
Avg. Pipe Wall Temperature at Hanger H-4		1226°R
Avg. Pipe Wall Temperature at Hanger H-2		1196°R

b. Maximum Line Movement

Maximum line movements due to thermal expansion are shown below:

Top Elbow, DT 707		Bottom Elbow, DT 708	
X	- 1.09	X	3.61
Y	0.66	Y	2.59
Z	- 3.87	Z	Not Taken

c. Transient Temperature

During shutdown, the steam temperature at the bottom of the separator outlet did not go below the saturation point indicating no carry-over of wet mixture.

d. Transient Line Movement

The maximum jerk of the line indicated by DT 707 and -708 during startup and shutdown of the steam generator was .03 inches.

3. Steam Line Inspection

1. The steam line flange bolt breakaway torques were measured after Run EP-8A and are recorded below:

a. Plenum Steam Flange.- Average breakaway torque was 245 ft-lb., with torque range varying from 100 to 300 ft-lb. Pre-test bolt torque was 447 ft-lb.

b. Separator Inlet Flange.- The bolt torque ranged from 400 to 600 ft-lbs and averaged 510 ft-lbs. The pre-test bolt torque was 737 ft-lb.

c. Separator Outlet Flange.- The bolt breakaway torque average was 950 ft-lb, and varied from 800 to 1100 ft-lb. The torque prior to the test was 1190 ft-lb.

d. Separator Outlet Elbow Downstream Flange.- The bolt torque varied from 850 to 1050 ft-lb and the breakaway average torque was 950 ft-lb.

2. All flanges were retorqued to the specified "pre-test" values as noted above.

3. Visual inspection of the steam line did not reveal any abnormalities, and the steam line position has not changed significantly.

4. The Steam Line Measurements are shown in Table VI.

D. Duct/ETC Aerodynamics Performance

1. Diffuser Performance

The first bootstrap of the EP was the only one in which the nozzle chamber pressure was high enough to pull the duct in. The ETC pressure decreased from the initial value (after SGS pull-in) of 8.0 psia to a pull-in value of 0.95 psia when the engine chamber pressure was 190.0 psia.

Figure No. 1 is a plot of the diffuser performance for EP-5C and EP-8A. It can be seen that the pull-in conditions (ETC pressure and the nozzle chamber pressure) are almost identical. The UTS helium purge flow for EP-5C was equivalent to 1.6 lb/sec of GN_2 and for this EP, it was nearly zero. This explains why the ETC pull-in pressure is slightly lower.

Further review of Figure I shows how closely the rise in EP-8A ETC pressure for values of engine chamber pressure above pull-in pressure follows that of EP-5C. The curve further shows that the nozzle was flowing full from approximately 1800 psia engine chamber pressure and higher.

Buzzing was not detected during either pull-in or drop-out of the diffuser.

The diffuser back pressure (severance plane pressure) is shown as a function of nozzle chamber pressure in Figure No. 2. The severance plane pressure increased from 8.0 psia to 14.2 psia during the first bootstrap. The change in slope is a manifestation of the steam slowing down the hydrogen gas causing energy to be transferred to the steam. This action is discussed in Para. D. of SPEAR Memo No. 17, EP-2A.

Table IV is a tabulation of the significant duct aerodynamic performance parameters during EP-8A.

2. <u>Steam Ejector Performance</u>

The ETC pressure decreased as the steam ejector pressure increased and compares exactly with previous runs.

E. Duct and Test Stand Coolant Performance

1. <u>Duct Coolant and Test Stand Coolant Performance</u>

During the first bootstrap of EP-8A, the total duct flow was approximately 23,000 gpm, and the flow was then reduced to approximately 9,000 gpm for the remainder of the EP. The temperature rise for the bootstraps are shown in Table V and all sections were considerably less than the limit because of the excess amount of water flowed. The minimum total duct water flow for these conditions is 7,000 gpm.

During the post-test cooldown, the duct was pressurized and only the drain valves were opened (RSV-738 and RSV-739). The temperature rise in any section of the duct was less than 2 degrees.

The lower test stand coolant flow during the first bootstrap was set at 10,700 gpm and was then reduced to approximately 8,800 gpm for the remainder of the EP. A separate supply of coolant water to the top of the test stand was flowing 1500 gpm (RSV-937). From inspection, there was no damage to the stand. Temperature rise on one of the two thermocouples on the stand was approximately 10°R.

2. <u>NES Duct and Test Stand Inspection</u>

a. After Test EP-8A, the NES duct water system was flushed with demineralized water, thereby removing any residual "raw" water which may have remained in the coolant circuits.

b. Examination of the duct vault door, of the drainage ditch floor, of the ditch water-cooled side walls, and of the stand concrete areas, (all of which were being exposed to the duct exhaust hydrogen flame) indicated no damage occurred as a result of Test EP-8A.

c. On the gunite-covered, uncooled, east-side wall of the drainage ditch, about 120 feet in front of the stand, two large ruptures of the gunite surface are evident. These "buckled" areas in the concrete surface, 10 to 20 feet above the ditch floor, have developed during the period of the last several tests.

d. Following Test EP-8A, a large hole was observed in the drainage ditch south-side wall, around the curve from the stand and below the retaining wall located near the end of the shield carriage rails. The hole is about 12 feet wide, 20 feet deep into the side of the ditch, and 10-12 feet high at the back. The condition causing the hole has apparently been developing over a relative long period of time. Water draining from the test stand and released from a small ditch immediately above the hole, washed away the dirt-sand from under the gunite wall surface, thereby undermining the gunite, which finally collapsed during the last test.

Corrective action is planned to prevent further erosion of the wall at this location.

F. ETC Repressurization System

During EP-8A, the PCV-449 emergency purge system was not tripped and analysis of the test data indicates no condition developed which should have activated the valve control system. Examination of the steam line pressure (PT-425) and the control circuit tracking pressure (CP-449YS) indicates that the system up-track rate was 1.19 psi/sec, and the down-track rate was 5.34 psi/sec; this data is the same as observed during previous tests.

CONCLUSIONS

The SGS performed satisfactorily throughout the EP. The steam line returned to its pre-test position and the test data does not indicate any major anomalies.

The diffuser performance was well within acceptable limits. The ETC pressure was maintained at a minimum value after pull-in.

The duct coolant system and test stand coolant system successfully supported the engine operation. No test stand damage was noted as a result of this test.

As a result of the data analysis and inspection performed, the following recommendations are made:

1. Replace the Teflon gaskets in SGS LOX propellant tanks with Durabla gaskets.

2. The maximum Steam Generator run time should be re-evaluated with respect to the data from this last test.

TABLE I

XE-PRIME EP- 8A — STEAM GENERATOR SYSTEM TEST DATA TABULATION — Range Time: 5/982.9

		FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO_2 Tank Press. (P-49)	psia	315.1				
LO_2 Manifold Press. (P-421)	psia	303.1				
LO_2 Manifold Temp. (T-479	^oR	162.8				
Propane Tank Press. (P.118)	psia	298.3				
Propane Tank Temp. (T-483)	^oR	500.0				
Propane Manifold Press. (P-420)	psia	289.6				
Propane Manifold Temp. (T-478)	^oR	502.1				
Water Supply Press. (P-168)	psia	223.5				
Water Manifold Press. (P-427)	psia	212.4				
Main Stage Propane Venturi (F-405)	psia		288.6		286.5	
Main Stage Propane Flow	lb/sec		7.08		7.04	
Main Stage LO_2 Venturi (F-409)	psia		289.7		291.[illegible]	
Main Stage LO_2 Flow	lb/sec		16.76		16.[illegible]	
Injection Water Venturi (F-406)	psid		209.4		211.2	
Injection Water Bypass Flow	lb/sec		6.54		6.27	
Total Injection Water Flow	lb/sec		41.83		41.79	
Water Film Cooling	lb/sec		3.41	3.53	3.40	
First Stage Press. (P-416)	psia		179.4		183.5	
Second Stage Press. (P-417)	psia		177.7		179.8	
Main Stage Press. (P-438)	psia		134.1		135.0	
Plenum Press. (P-425)	psia					126.4
Separator Inlet Press. (P-864)	psia					128.3
Separator Outlet Press. (P-865)	psia					118.6
Separator Outlet Temp. (T-590)	^oR					129.4
Steam Line Press. (P-239)	psia					115.9
Steam Line Temp. (T-159)	^oR					1291.0
Total Steam Flowrate	lb/sec					135.0

TABLE II

STEAM GENERATOR SYSTEM CHRONOLOGY - EP-8A

	EVENT	RANGE TIME (Seconds)
1.	Idle Steam SG-1	55940
2.	Idle Steam SG-2	55951
3.	Idle Steam SG-3	55960
4.	Full Steam SG-3	56211
5.	Full Steam SG-2	56229
6.	Shutdown SG-1	56246
7.	LOX Leak observed on SG-2	
8.	Idle Steam SG-2	56363
9.	Idle Steam SG-3	56370
10.	Idle Steam SG-1	56381
11.	Full Steam SG-1	56386
12.	Full Steam SG-3	56409
13.	Stop SG-2	56432
14.	Stop SG-1	59880
15.	Stop SG-3	59885

TABLE III

STEAM GENERATOR SYSTEM OPERATING TIMES - EP-8A

MODULE	Idle Steam Operating Time (Seconds)	Full Steam Operating Time (Seconds)
1	3805	3494
2	481	134
3	3925	3635

Since last inspection

The operating times since last inspection are the same as above times since all three modules were inspected after XE-Prime, EP-7A.

TABLE IV

DUCT AERODYNAMIC PERFORMANCE DATA SUMMARY

RANGE TIME	ENGINE P_{anc3} (psia)	ENGINE T.158 (^oR)	STEAM EJECTOR P-239 (psia)	STEAM EJECTOR T_{asl} (^oR)	Duct Sever' Plane P-805 (psia)	ETC P_{aetc} (psia)	Press. Ratio P_{anc} / P-805	ETC GN_2 Purge W_{netc} (lb/sec)
56900	168.2		116.3	1274	12.13	1.7	13.87	0
58336	112.1		115.4	1276	10.54	4.83	10.67	0
58769					10.68			0
58930					10.77			0
59310					10.69			0

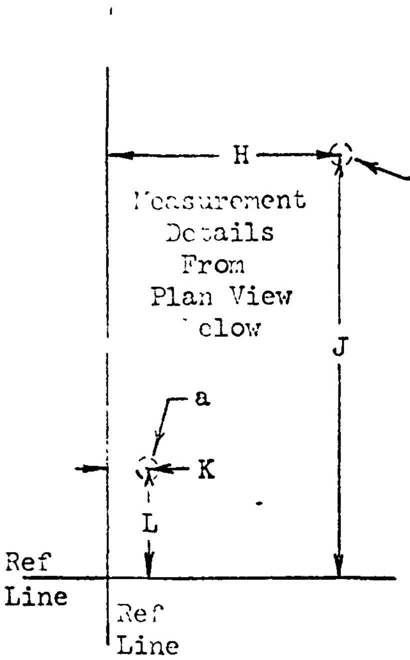
TABLE V

DUCT COOLANT SUMMARY

RANGE TIME		Ambient Open Loop Start up	Hot Core Open Loop Start up	Damp Autostart	Wet Autostart High Decay	Hot Core Wet Autostart
	RT	56900	58336	58769	58930	59310
TOTAL FLOW RATE (gpm)		221,558	8,901	9,241	8,662	8,952
Section 1						
Actual Temp. Rise	^oR	19	32	28	29	28
Limit Temp. Rise	^oR	(55)	(55)	(55)	(55)	(55)
Section 2 UPPER						
Actual Temp. Rise	^oR	12	17	16	16	16
Limit Temp. Rise	^oR	(70)	(70)	(70)	(70)	(70)
Section 2 LOWER						
Actual Temp. Rise	^oR	17	23	22	22	22
Limit Temp. Rise	^oR	(70)	(70)	(70)	(70)	(70)
Section 3						
Actual Temp. Rise	^oR	10	22	21	21	21
Limit Temp Rise	^oR	(50)	(50)	(50)	(50)	(50)
Maximum Strain Mv	In/In	612	355	357	344	321

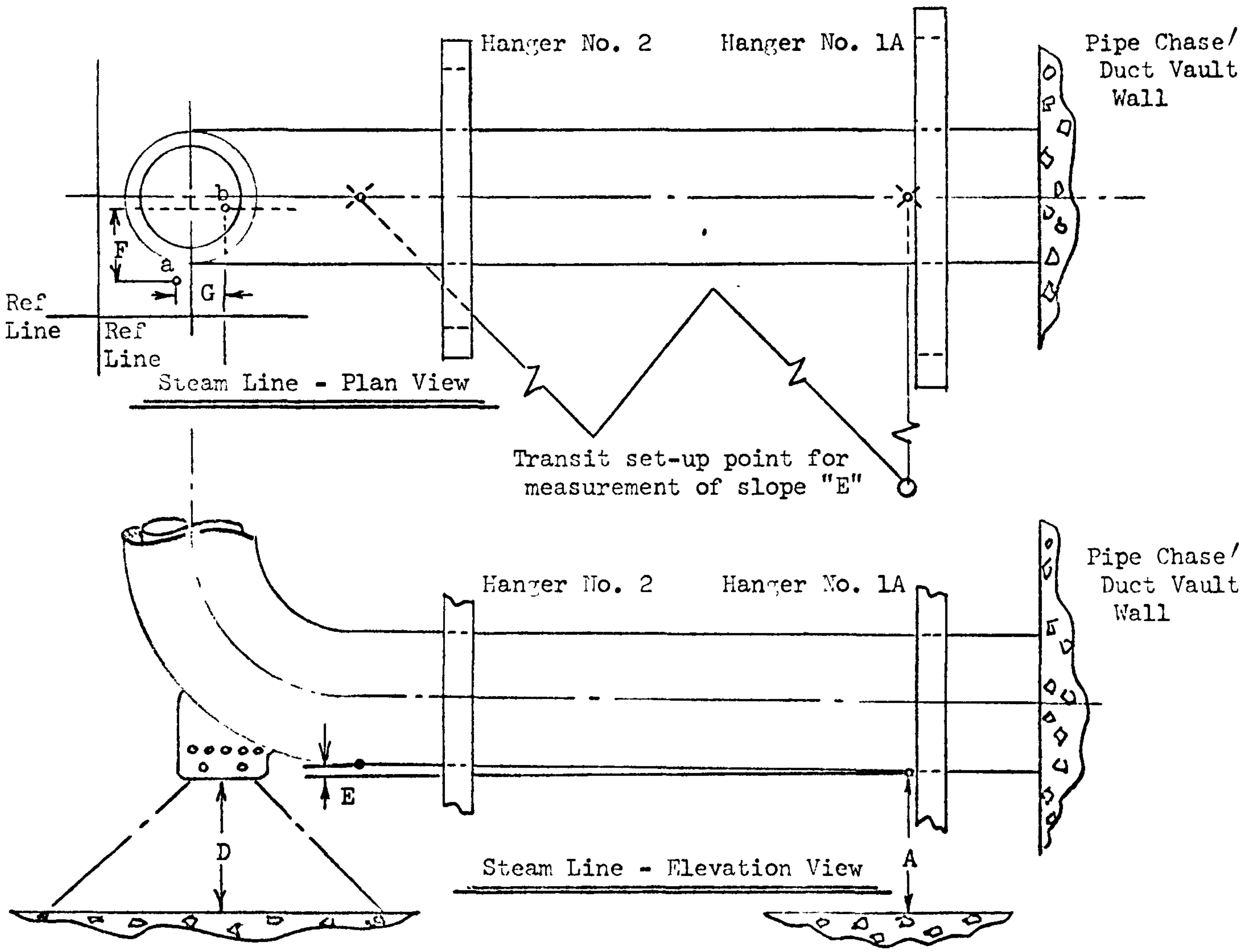
TABLE V - Cont'd

STEAM LINE POSITION MEASUREMENTS (Continued)



a -- Point "a" is a plumb bob point on the Pipe Chase floor from a mark on the upper elbow (gimbal) deflection pots bracket.

b -- Point "b" is a plumb bob point on the Pipe Chase floor from a mark on the lower elbow snubber attachment plate.



Steam Line Measurements in Pipe Chase

TABLE VI

[illegible]

Pre-test EP-8A	$40\frac{1}{2}$	$11\frac{7}{16}$	*	$41\frac{1}{2}$	$1\frac{5}{16}$	** ←			→	**
Post-test EP-8A	40	⁑	⁑	$41\frac{3}{8}$	⁑	** ←			→	**

[illegible] with steel tape.

[illegible] various locations on the steam line in the Pipe [illegible] are described below and in the sketches on Page 2.

[illegible] line elevation [illegible] hanger No. 1, [illegible] to bottom of insulation.

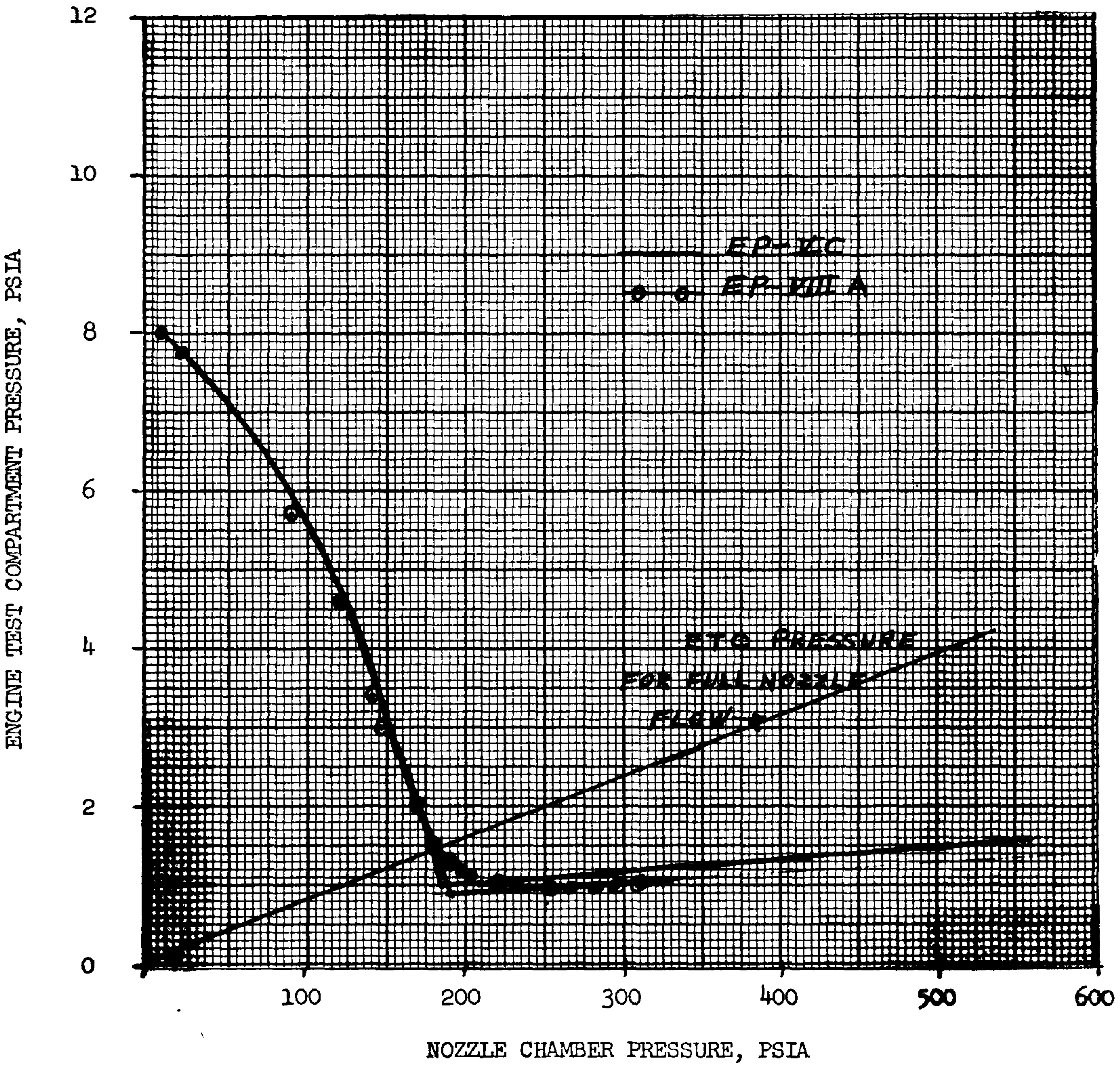
[illegible] line elevation at hanger No. 3, ceiling to top of insulation.

[illegible] line elevation [illegible] hanger No. 4, ceiling to top of insulation.

* Scafford removed and cannot measure.

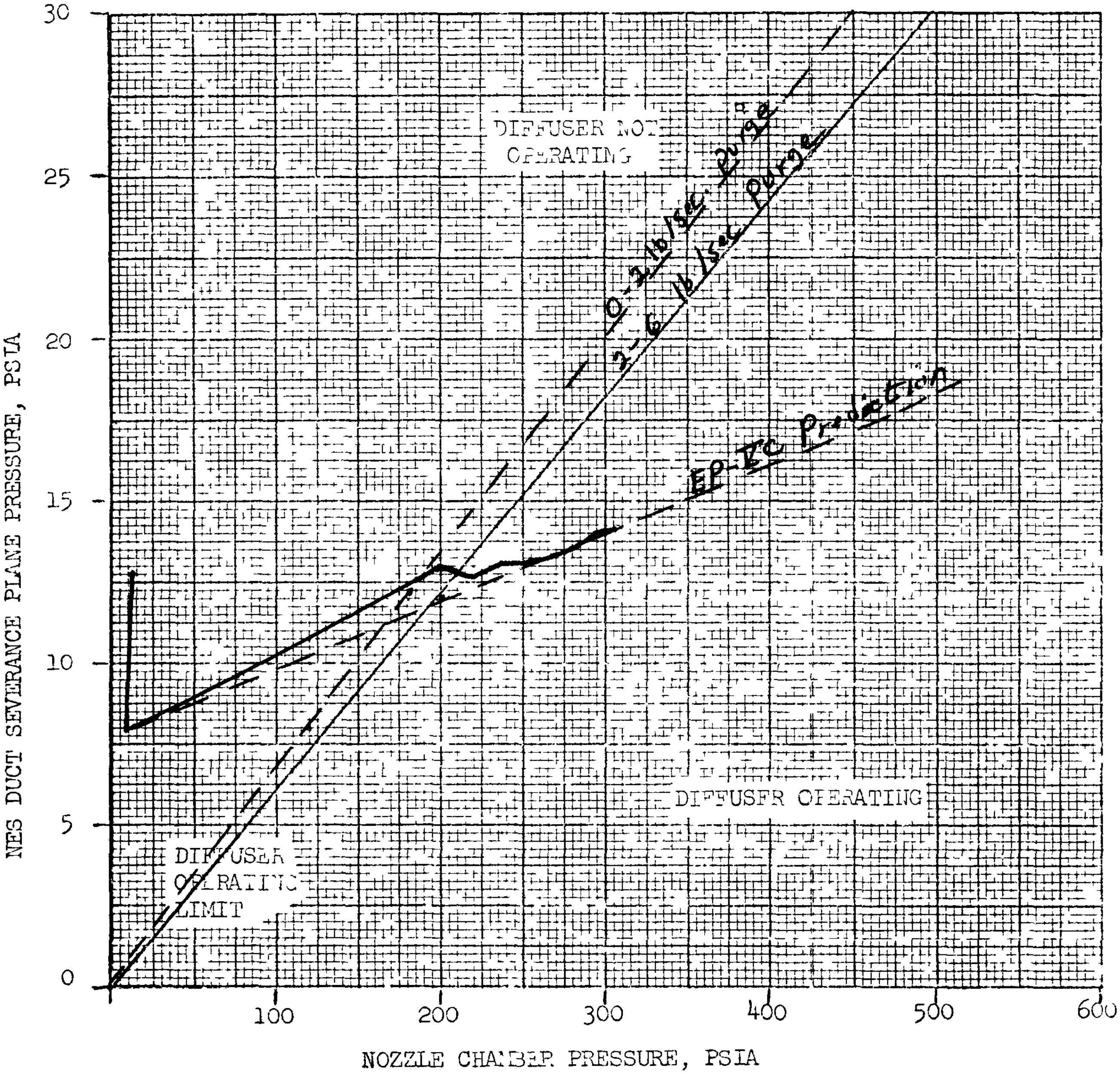
** Requirements for these measurements deleted.

⁑ Measurements not yet taken at time of writing.



ENGINE TEST COMPARTMENT PRESSURE VS NOZZLE CHAMBER PRESSURE

FIGURE I



NES DUCT SEVERANCE PLANE PRESSURE VS XE NOZZLE CHAMBER PRESSURE

FIGURE 2

SPEAR Memo No. 26
RWS R. Samuelson/J. Barrick/
R. Hoff/L. Stone:jh

XE-PRIME

EP-8A

Subject: MEASUREMENT SYSTEM PERFORMANCE

SUMMARY

The drift and step changes detected in the digital data system during EP-7A have been greatly reduced in magnitude. The nozzle manifold temperature problem produced by the presence of thermoelectric voltages in the transducer cables has been reduced to insignificance. Small temperature induced pressure data drifts were encountered during and just after the end of the first transfer function test. Data channels providing suspect data, as characterized by data anomalies, are summarized in Table IV. A summary of cancelled data channels is provided in Table V. A data system performance summary is presented in Table VI. Appendix A explains the entries of Table VI.

TECHNICAL DISCUSSION

Following EP-7A, numerous digital and analog system ground leads in the Test Cell Building, Forward Control Room, and Recorder Room were found to be loose. These ground connections were tightened prior to EP-8A. As a result, the problems with the digital data system mentioned in the EP-7A SPEAR Report, Memo No. 26, have been diminished in magnitude. The step changes have been cut in half (from 0.4% to 0.2% of full scale). As before, the step changes correlate with PDSV actuation. The slow drift problem now appears insignificant (Reference Figures 1, 2 and 3). ETS-1 personnel will continue to investigate the problem.

The data system uncertainty of Pace reference block temperature data channels (TT262..F and TT263..F) ranges from -0.255°R to +1.105°R (per RN-S-0495) so that the data system uncertainty for these channels may be expressed as 0.440 ± 0.665°R. The temperature stability of the Pace reference block temperature controller is ± 0.5°R. Therefore, by applying RSS summation techniques, the total variability of Pace reference block temperatures would be 0.440° ± 0.832°R. Thus, the operation of the engine mounted Pace reference unit can be considered as being normal if the data obtained from channels TT262..F and TT263..F falls within the span 609.3 to 611.0°R. Figure 4 shows that the average Pace reference block temperature (average of TT262..F and TT263..F), the ambient UTS gas temperature near the Pace module (TE988..F), and the temperature of the purge gas entering the UTS (TE557..F) all vary significantly as a function of time. The

Technical Discussion (Cont'd)

Pace reference block temperature is seen to exceed the 611°R upper uncertainty limit by no more than 0.2°R until CRT 60250 seconds, which is about 500 seconds after completion of the last power run. The rise to 612.3°R at CRT 63000 seconds was caused by the increase in the UTS purge gas temperature which, in turn, produced a rise in ambient gas temperatures about the Pace unit. The Pace reference junction block can be heated, but not cooled. As a result, the block temperature was driven upward above the 610°R set point temperature. In this case, the excessive rise was inconsequential as the engine power test had been completed.

Thrust chamber thermocouples (TE138.AE, TE140,AE, TE141.AE, and TE144.AE) were calibrated prior to engine installation to the LN_2 point (139.3°R) and calibration curves have been established for XE-Prime to allow valid data reduction from 200°R to 4700°R. Measurements obtained with these channels are valid throughout this range if sufficient gas flow (1 lb/sec or more) is present to overcome stem conduction heat losses. Similarly, the calculated average of these channels, as provided by TA158 and TANC, will yield accurate data from 200°R to 4700°R. However, the linearized average chamber temperature channels (T.158..E and T.602..E) are ranged from 492°R to 4700°R and should not be used below 492°R as their accuracy degrades as temperatures below 492°R are encountered. Channel T.158..E data is used primarily for control purposes and is obtained by directly averaging and linearizing the thermocouple outputs while channels TA158 and TANC provide calculated averages. Extensive changes in the control circuitry needed to extend the range of T.158..E down to 200°R were not considered warranted especially since TANC provides an accurate average. The fact that T.158..E is not set up for use below 492°R accounts for differences of up to 100°R between measured and calculated average temperature in the low ranges.

During EP-3A, EP-5C, and EP-4A, nozzle manifold temperature channels occasionally indicated higher temperatures than did the reflector inlet plenum temperature channels. This anomaly resulted from the presence of thermoelectric voltages that were generated by the interaction of copper and nickel-clad copper wires in the transducer cables. The effect of thermoelectric voltages was effectively suppressed for channels TT120..A and TT122..A by increasing the transducer excitation current and decreasing the measurement range from 35 - 610°R to 35 - 60°R. As a result, these two channels yielded valid data for EP-6A, EP-7A and EP-8A.

The measurement range had to be maintained at 35 - 610°R for nozzle manifold temperature channels TT121..A and TT123..A to provide cooldown information. Thus, other techniques had to be adopted to eliminate the thermoelectric induced data errors for these channels. Although the location of the thermoelectric voltages were not known, it was hoped that the voltages were being generated on both sides of the transducer's resistance element and could be made to oppose (cancel) if the excitation and output leads were reversed on one side of the resistance element. A

Technical Discussion (Cont'd)

review of EP-7A data indicated that this technique successfully suppressed the thermoelectric error for channel TT123..A, but not for TT121..A. A second technique was then employed to improve the data from TT121..A. This technique consisted of shunting the resistance element with a fixed resistor and increasing the excitation current, thereby increasing the data signal level relative to the thermoelectric noise signal level when cryogenic temperatures are being measured. A review of EP-8A data for TT121..A, indicates that the technique was successful. Thus, all nozzle manifold temperature data is now considered to be correct. A comparison of individual nozzle manifold data channel outputs are presented in Table I, while a comparison of average engine station temperatures are summarized in Table II.

Small temperature induced pressure data errors were encountered during the first transfer function test when nozzle pressure and temperature levels were being maintained near 300 psia and 2400°R, respectively. The nature of the transient low temperature excursion in the Upper Thrust Structure (UTS) is illustrated in Figure 5. Temperature channel TE986..A measures gas temperatures above the shield between Control Drum Actuators No. 2 and 3. Channel TE988..A measures gas temperatures adjacent to the pressure transducers that are mounted on transducer bracket SN 1134043. Channel TE981..E is the temperature of a transducer (PT500..A) that is mounted on bracket SN 1134043 while TE985..A is the temperature of nozzle chamber pressure transducer PT149.AE.

The rapid gas temperature decline as indicated by TE986..A and TE988..A was not caused by variations in the UTS purge line temperature (TE557..F) as this temperature was essentially constant at 550°R. Nitrogen condensation is an unlikely cause as helium was the only purge gas used. There were variations in the purge flow rate, but these occurred before the transient temperature excursions appeared. There is, however, a correlation with nozzle chamber pressure. Although it is not shown in Figure 5, nozzle chamber pressure was ramped upward from 165 psia, attaining its steady-state point (300 psia) at 56940 seconds. This is the same time point at which channel TE986..A starts to drift downward from a previously steady-state temperature of 540°R. At time 57550 seconds, a negative nozzle chamber pressure ramp was initiated and UTS gas temperatures began to rise. Thus there appears to be some correlation between engine system pressures and UTS gas temperatures.

The existence of UTS gas temperature transients is responsible for the appearance of transducer temperature variations (TE981..A and TE985..A). A rapid variation in the temperature of a pressure transducer will cause the transducer output to deviate (drift) from the correct output level. To determine the magnitude of temperature induced pressure data drift for this test, reference was made to pressure data from transducers used to monitor the same parameter where the transducers were mounted on different brackets (located in slightly different temperature zones). As an example, pressure transducers PT124..E, PT126..E, PT128..E, and PT130..E are measuring nozzle manifold pressures. Transducer PT128..E is mounted on bracket SN 1118614

Technical Discussion (Cont'd)

while the others are mounted on bracket SN 1134043 whose gas temperature environment is given by TE988..A, Figure 5. By referring to Figure 6, it is seen that the three transducers mounted on bracket SN 1134043 consistently indicate lower pressure levels than PT128..E which is located on bracket SN 1118614. All four pressure transducers are in excellent agreement for all time periods occurring before and after the time interval containing the transient UTS temperature excursion. The absolute magnitude of temperature induced drift in pressure data is not known but is not expected to exceed 2 percent of the pressure transducers full scale range, based upon the data of Figure 6 and other related data sources. The pressure transducers most affected by temperature transients are located on bracket SN 1134043 and are identified in Table III.

CONCLUSIONS

The digital data system continues to perform in an excellent manner and is ready for the next test. However, the digital data system noise level must be closely watched as it appears to be slowly increasing. Although no major wide band system problems were noted, the evaluation of the system must be continued to identify the sources of existing problems and to implement the necessary corrections.

TABLE IV

MEASUREMENT ANOMALIES

XE-P EP-8A

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
1	HT-701L.A	Core Support Plate	Excessive 60 HZ noise on oscillographic records, Run Time 50220 seconds	Post-test investigations indicates that noise is generated in the LVDT chassis. Data should be considered questionable. No further action taken.
2	KT004..F	H2 Con Etc Ch2-EMF	Excessive Pre-cal noise levels. Exceeds 1.3 % of full scale measurement range.	Post-cal noise level normal (less than 0.1% of F.S.). No action taken.
3	PD208..A	Diluent Orifice	Excessive channel nonlinearity, exceeded 3% of full scale. Noise on oscillograph calibration data is significant and increases with cal. level.	Post-test calibration linearity error is less than 0.12% of F.S. No action taken. Noise absent during Post-test check.
4	TE317..F	SI Intmed. Shld H20-Temp	Excessive ambient noise, 6.5% of full scale	Post-test noise level is normal (less than 0.15% of F.S.). No action taken.
5	TE505..A	Shield Dome End Gas	Recorded digital went up to 300°R and then saturated (remained at 300°R) for remainder of test. Pre and Post calibrations look good.	Dirty signal conditioner connectors were observed. Channel operation appeared normal after connector was cleaned.
6	TE811..A	DRM Torque XDCR TEM 11	Engineering unit data read 0.7°R throughout run	Channel appears normal during Post-test investigations. No action taken.

SPEAR Memo No. 26

TABLE V

DELETED MRL CHANNELS

Prior to	Channel	Title	Reason
EP-1	TT215..A	Ref. Inlet Plen.	Hardware Failure
	MG258L.A	P.V. Closure	Hardware Failure
	MG220L.A	Press Vessel	Hardware Failure
	MG221T.A	Press Vessel	Hardware Failure
	MG228L.A	Press Vessel	Hardware Failure
	MG229T.A	Press Vessel	Hardware Failure
	MG243T.A	P.V. Forward	Hardware Failure
	PT837..R	TPCV Acts Exhaust Gas	Hardware Failure
	U.801..V	UTS TV Camera	Not Used
	TE921..A	Temp on HT805	Not Used
	BR454..R	C.D. Gas Syst SV Bypass	Not Used
	BR460..R	C.D. Gas Syst SOV	Not Used
	F.012..R	LH CD Syst FLW-Calc	Not Used
	BR544.DR	C.D. Gas Syst SV VV	Not Used
	BR721..OR	Byps CD LN Blk Vlv	Not Used
	CP576..R	Byps CD LN Con Vlv	Not Used
	DP576..R	Byps CD LN Con Vlv	Not Used
	SC650..E	CD Actr Press Scrm PS957	Not Used
	TT488..R	He DN Strm He Htr	Not Used
	T.880..A	Pv Fwd Flg Gam Htg Rats	Not Used
	T.883..A	Pv Fwd Flg Gam Htg Rats	Not Used
	VC901..E	Timing or Clock Sig	Not Used
	PT837..R	Drum Act Exh Gas	Hardware Failure
	TE821..A	Drum Act Lock Sol	Hardware Failure
	HT803R.A	Turb Inlet Line Accel	Hardware Failure
	TE671..E	Core Element	Hardware Failure
	TE679..E	Core Element	Hardware Failure
	NX901..E	Zero Supp NC818..N	Not Used
	TT036..R	V-5002 HP LH Dewar	Hardware Failure
EP-1A	BC660..E	Log Pwr Ovrd	Not Used
	TE712.AE	Tie Rod Mat	Hardware Failure
EP-2A	MG259T.A	P.V. Closure	Hardware Failure
EP-3	MG806L.A	UTS	Hardware Failure
	TE913..A	EMND Cas #3	Not Used
	TE914..A	EMND Cas #3	Not Used
	TE916..A	EMND Cas #3	Not Used
	N.842..A	UTS Det #3	Hardware Failure
	N.840..A	UTS Det #1	Hardware Failure
	N.841..A	UTS Det #2	Hardware Failure
EP-5C	TE843..E	Turb Bearing	Hardware Failure
	YT803..A	Cont Drum Tq 3	Hardware Failure
	TE809..A	Drum Tq Xducer Temp 7	Hardware Failure

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Deleted MRL Channels - Cont'd

Page 2

Prior to	Channel	Title	Reason
EP-5C (Cont'd)	TE840..E	Turb Bearing	Hardware Failure
	N.845..A	ETC U-238 N-Det Low	Hardware Failure
	MG710..A	Tie Rod	Hardware Failure
	MX910..A	AC Coup MG710..A	Not Used
	AT803..A	Interm Shld Lvl Mike	Hardware Failure
	AT804..A	Interm Shld Lvl Mike	Hardware Failure
EP-4A	BC658..E	Pwr Mode Inhibit	Not Used
	NC801.AE	Eng Log Pwr 1	Hardware Failure
	TE112..R	Pump Discharge Ln	Hardware Failure
	N.844..A	ETC Gamma Det	Hardware Failure
	YT805..A	Cont Drum Tq 5	Hardware Failure
	YT807..A	Cont Drum Tq 7	Hardware Failure
	MG403..A	Inner Ref Spring	Hardware Failure
	HT703..A	Core Sup Plate	Hardware Failure
EP-6A	TE723..N	T-STD Neut. 1 Canister	Hardware Failure
	TE139.AE	Nozz Chamber Temp	Hardware Failure
EP-7A	YT810..A	Control Drum Torque - 10	Hardware Failure
	YT811..A	Control Drum Torque - 11	Hardware Failure

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TABLE VI

MEASUREMENT SYSTEM REVIEW SUMMARY

SPEAR MEMO NO. 26

XE-P EP-	1B	2A	3A	5	5C	4A	6A	7A	8A
AVERAGE NB AMBIENT NOISE (COUNTS)	16	9	9	9	9	10	11	11	12
NUMBER OF NB CHANNELS SET UP	864	870	861	873	884	878	869	867	868
NUMBER OF NB CHANNELS REVIEWED	864	870	861	873	884	878	869	867	868
PERCENT OF REVIEWED NB CHANNELS WITH LOST DATA	1.9	1.6	3.5	0.8	2.4	0.3	0.6	1.3	0.2
AVERAGE FM WB CALIBRATION NOISE (COUNTS)	30	30	22	39	77	49*	40*	26*	45*
NUMBER OF FM WB CHANNELS SET UP	100	120	129	130	132	131	129	129	129
NUMBER OF FM WB CHANNELS REVIEWED	30	120	32	31	49	0	0	0	0
PERCENT OF REVIEWED FM WB CHANNELS WITH LOST DATA	0	1	41	19	16	N/A	N/A	N/A	N.A.
NUMBER OF OSCILLOGRAPH CHANNELS SET UP	41	51	53	50	50	50	47	49	50
NUMBER OF OSCILLOGRAPH CHANNELS REVIEWED	41	51	0	50	50	50	47	49	50
PERCENT OF REVIEWED OSCILLOGRAPH CHANNELS WITH LOST DATA	10	2	N/A	4	16	4	4	~0	2
NUMBER OF STRIP CHART CHANNELS SET UP	81	98	75	82	82	82	81	82	80
NUMBER OF STRIP CHART CHANNELS REVIEWED	0	0	0	16	6	64	81	82	80
PERCENT OF REVIEWED STRIP CHART CHANNELS WITH LOST DATA	N/A	N/A	N/A	0	0	2	1	0	0
NUMBER OF LOST AND IRREPARABLE CHANNELS (EACH EP)	1	4	6	2	7	2	2		
NUMBER OF LOST AND IRREPARABLE CHANNELS (CUMULATIVE)	1	5	11	13	20	22	24		

Note: * Based on the R-3 Pre-test Data System Calibration

EXPLANATION OF ENTRIES IN MEASUREMENT SYSTEM REVIEW SUMMARY

1. AVERAGE NB AMBIENT NOISE (COUNTS)

All ambient 2-sigma level values in the Digital Data System Diagnostic Routine are summed and averaged, 9999 counts being equal to full-scale. Exceptions to this are those channels whose noise level exceeds 100 counts. The digital data system is currently so quiet that a noise level greater than 100 counts indicates a significant channel problem.

2. NUMBER OF NB CHANNELS SET UP

This is the number of narrow band channels believed to be set up and functioning properly at the start of an experimental plan and, therefore, does not include channels reported on the "Not Set Up" list provided by ETS-1 Instrumentation personnel.

3. NUMBER OF NB CHANNELS REVIEWED

Time does not always permit the reviewing of all recorded data during the limited SPEAR effort. This value is an attempt to put the number of reported anomalies in its proper perspective.

4. PERCENT OF REVIEWED NB CHANNELS WITH LOST DATA

If data, but not necessarily a transducer, is irretrievably lost during an experimental plan, the corresponding channel is included in this calculation. If data can be salvaged by re-processing or by using special data reduction techniques, it is not considered as lost and is not included. Channels having lost data or data requiring special data reduction are included in the Data Anomaly Table.

5. AVERAGE FM WB CALIBRATION NOISE (COUNTS)

All noise level values derived from the Wide-Band System Calibration Diagnostic Routines are summed, averaged, and normalized to yield an overall 2-sigma noise value that may be compared to the 2-sigma value derived from the Narrow-Band Calibration Diagnostic Routine. When calculating the noise level of FM WB channels, a 2-sigma noise level of 100 counts is considered excessive and channels possessing this noise level are not used when calculating the average FM WB noise level.

6. The definitions of the line items through PERCENT OF REVIEWED STRIP CHART CHANNELS WITH LOST DATA are similar to those of the narrow-band system as applicable to the indicated systems.

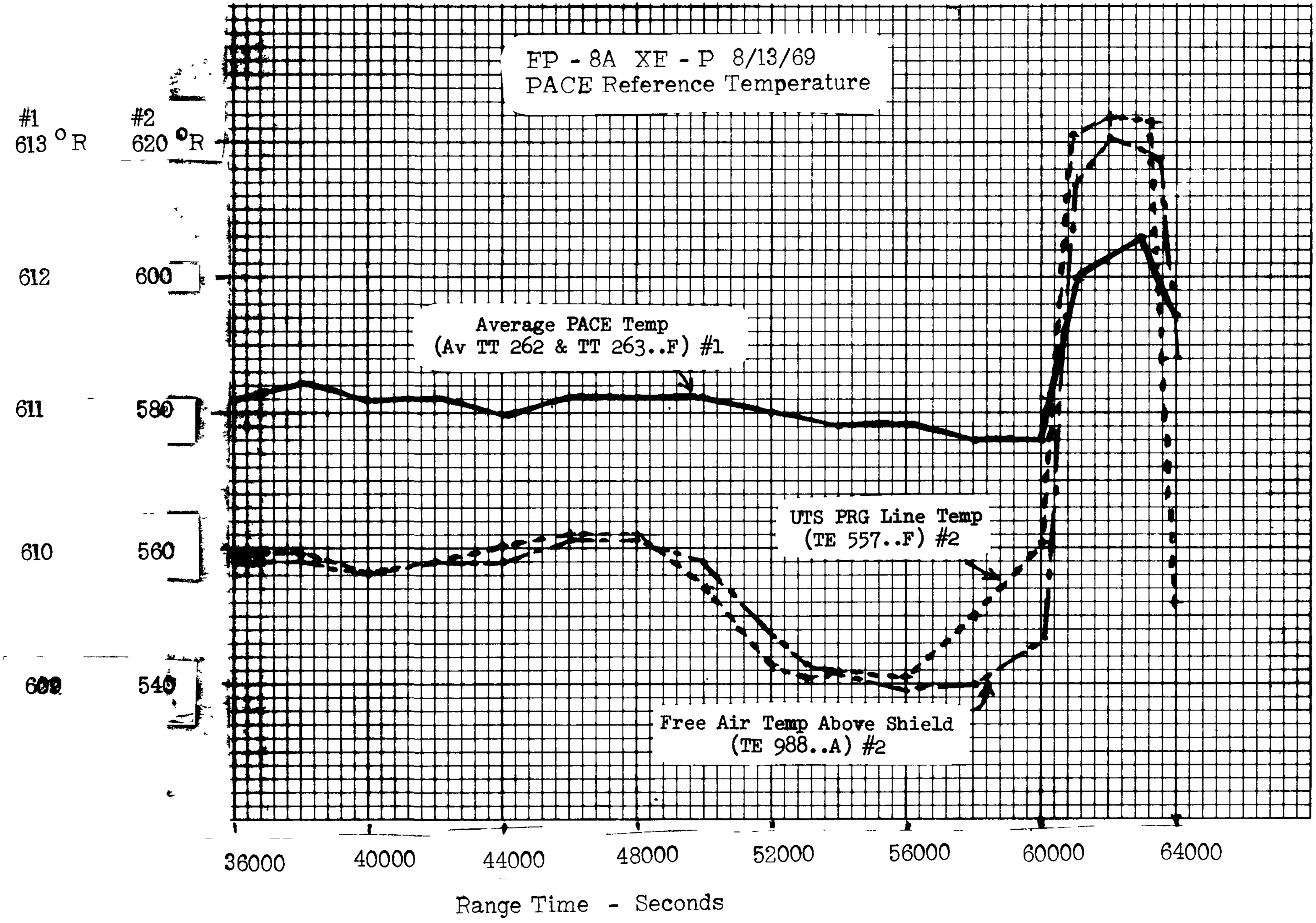
7. NUMBER OF LOST AND IRREPARABLE CHANNELS (EACH EP)

The loss of a measurement channel due to hardware failure (transducer, connector, cable, etc.) which cannot be repaired with the engine installed at ETS-1 will be summarized here for each EP.

8. NUMBER OF LOST AND IRREPARABLE CHANNELS (CUMULATIVE)

A cumulative total of items reported under the definition of Paragraph 7.

SPEAR Memo No. 26, Figure 4



-10-

TABLE I

Nozzle Manifold Temperatures

CHANNEL	RANGE TIME (Seconds)			
	57020	58780	58960	59310
TT120..A	44.3°R	43.4°R	43.7°R	44.2°R
TT121..A	44.2°R	43.1°R	43.4°R	43.9°R
TT122..A	44.8°R	45.0°R	44.7°R	45.1°R
TT123..A	43.2°R	44.0°R	44.2°R	45.4°R

TABLE II

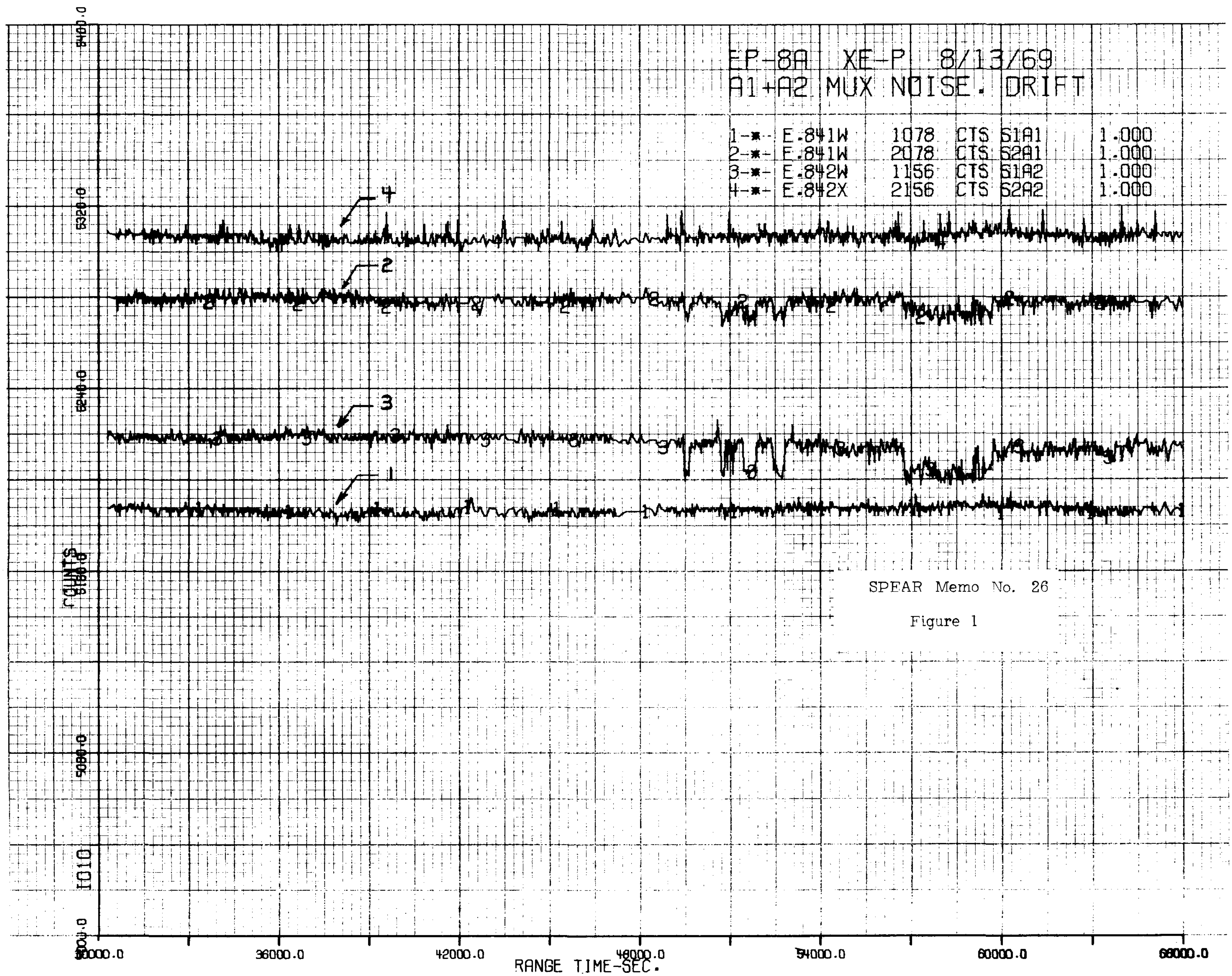
Average Engine Station Temperatures

ENGINE STATION	RANGE TIME (Seconds)			
	57020	58780	58960	59310
Pump Inlet	36.8°R	39.6°R	39.7°R	40.2°R
Pump Outlet	43.2°R	41.8°R	42.3°R	42.7°R
Nozzle Manifold	44.1°R	43.9°R	44.0°R	44.7°R
Ref. Inlet Plenum	85.8°R	60.9°R	61.0°R	60.9°R

TABLE III

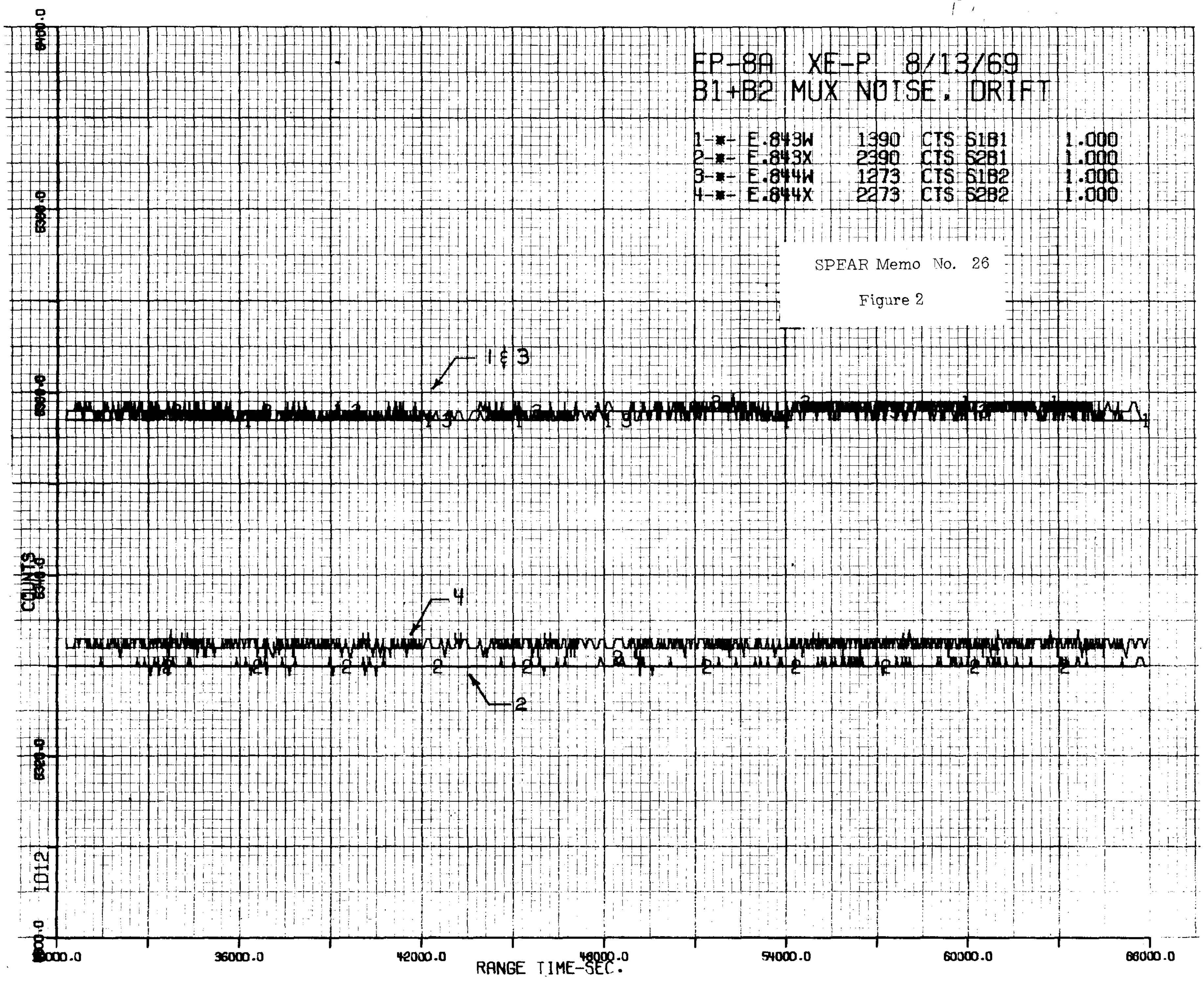
Pressure Transducers Mounted on Bracket, S/N 1134043

PD301..A	PD609..A	PD621..A	PT304..A	PT706..A
PD423..A	PD611..A	PT124..E	PT500..A	PT802..A
PD501..A	PD613..A	PT126..E	PT604..A	PT804..A
PD603..A	PD615..A	PT130..E	PT606..A	PT806..A
PD605..A	PD617..A	PT300..A	PT702..A	PT808..A
PD607..A	PD619..A	PT302..A	PT704..A	



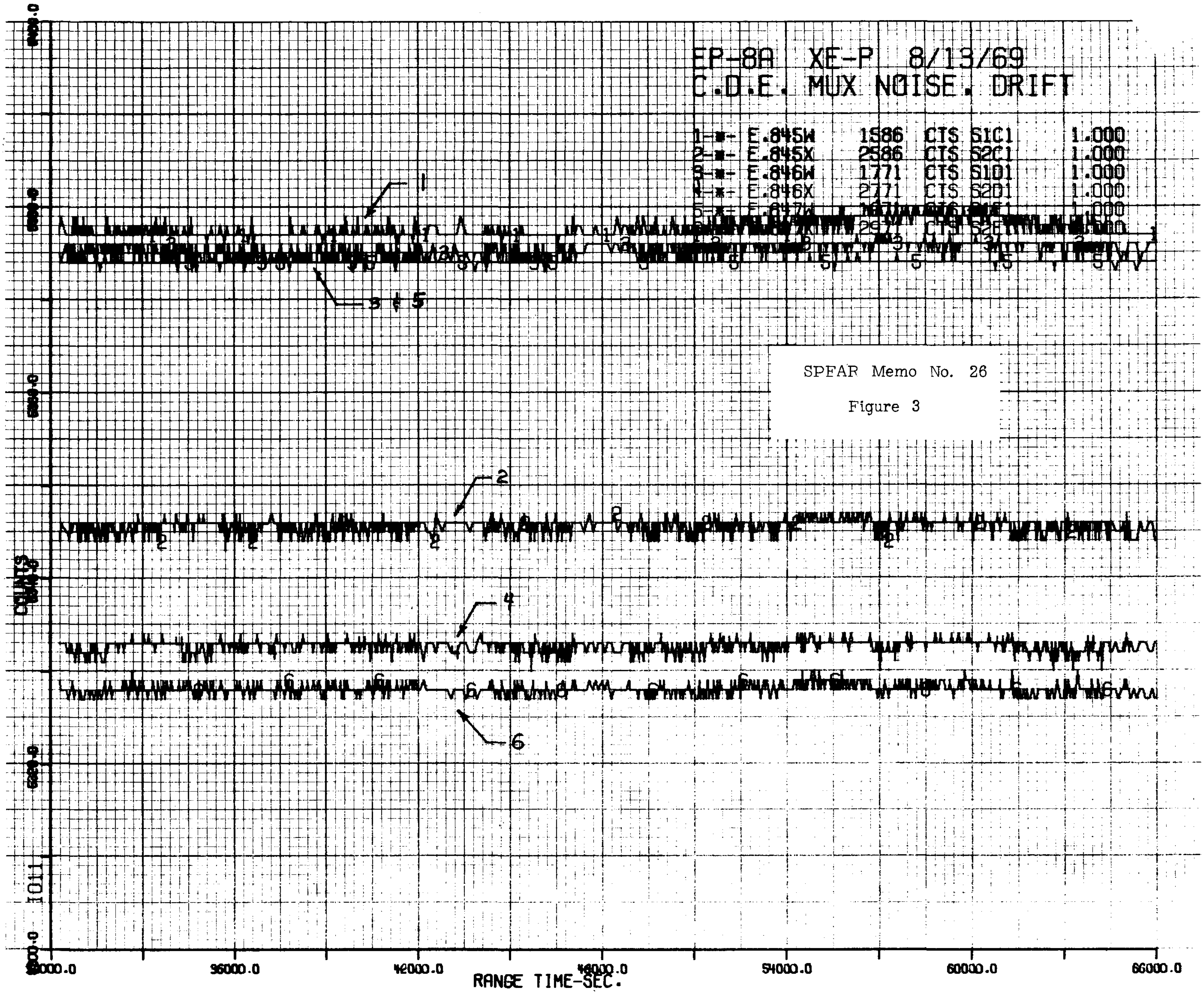
SPEAR Memo No. 26

Figure 1



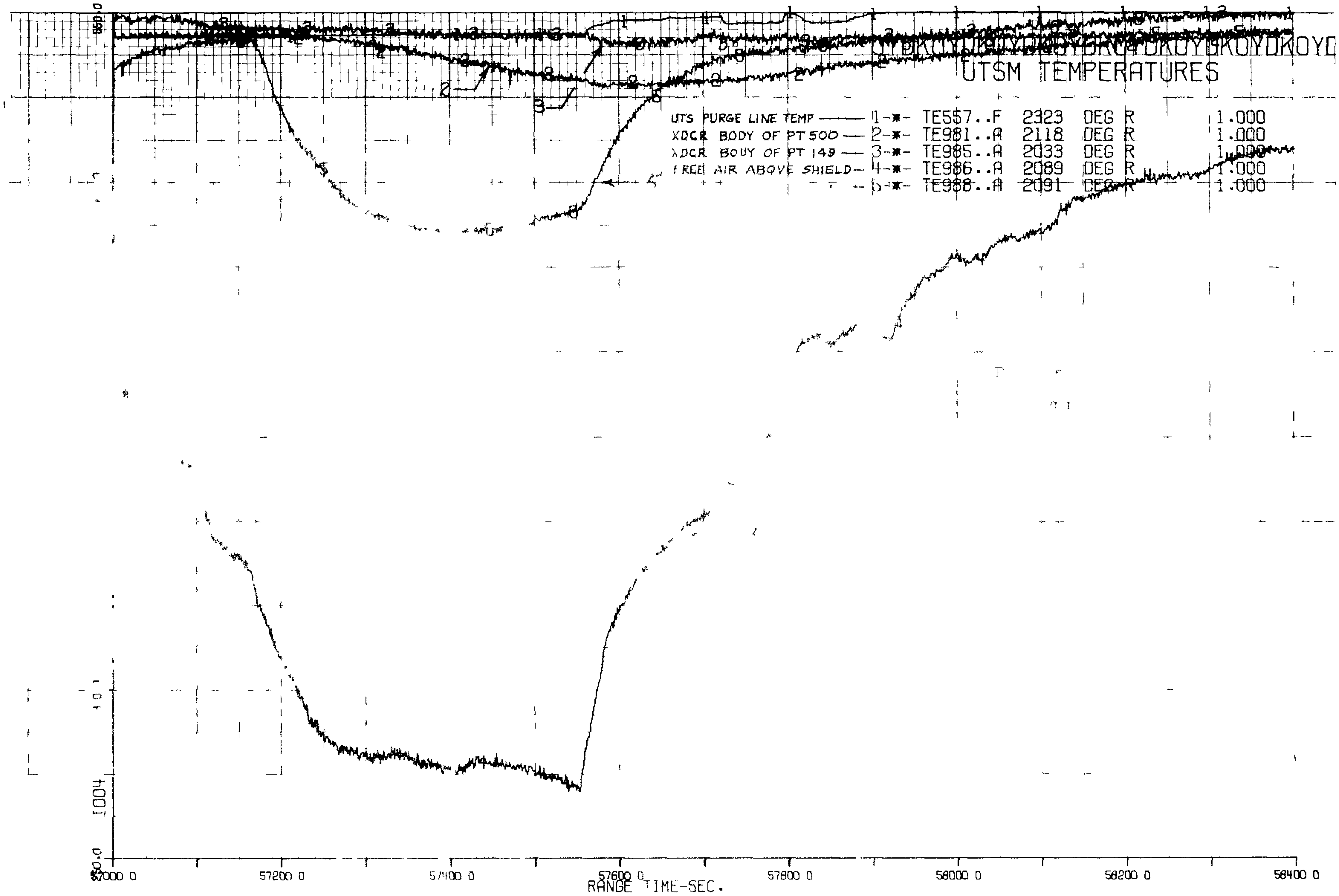
SPEAR Memo No. 26

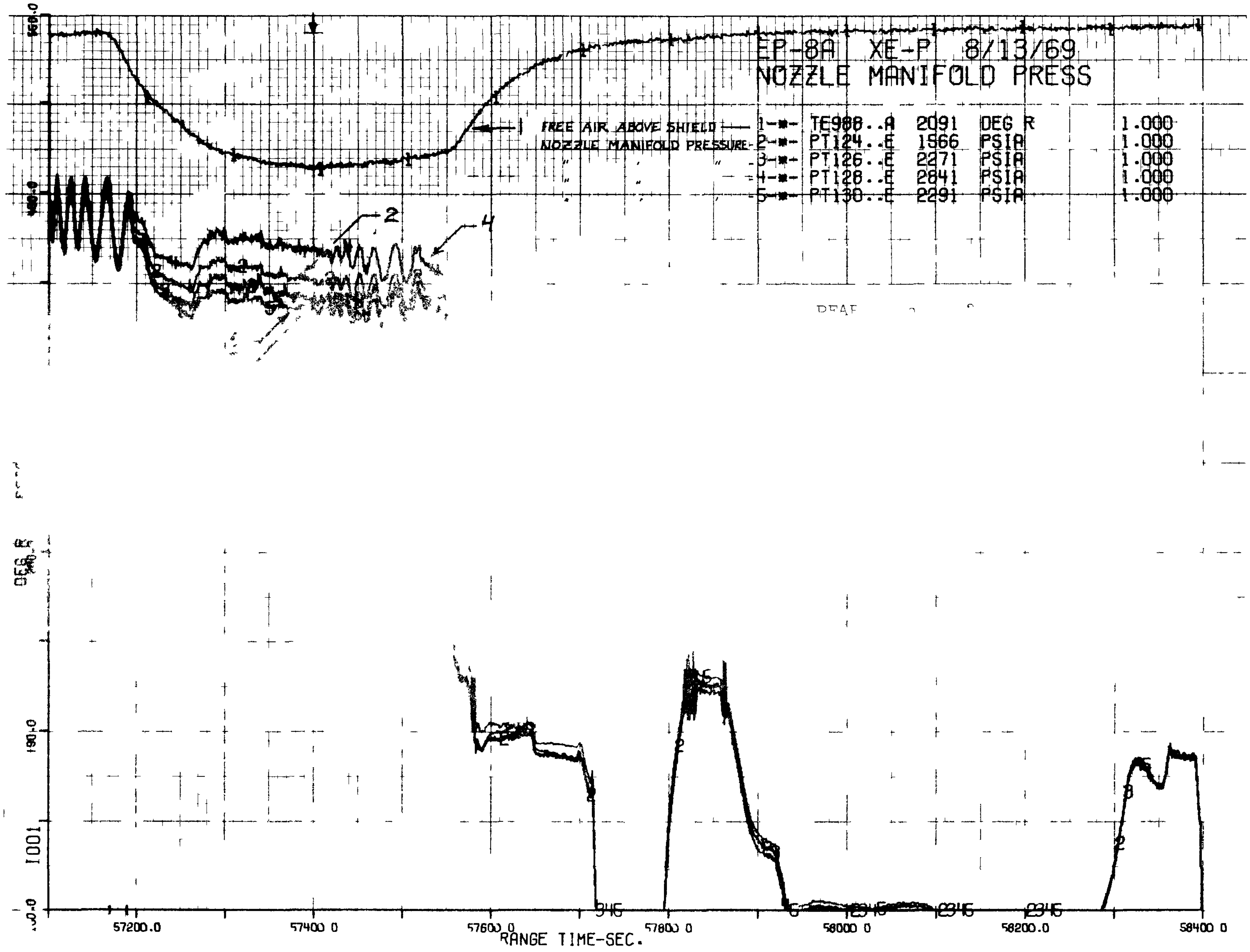
Figure 2



SPFAR Memo No. 26

Figure 3


UTSM TEMPERATURES
UTS PURGE LINE TEMP — 1-*- TE557..F 2323 DEG R 1.000
XDCR BODY OF PT 500 — 2-*- TE981..A 2118 DEG R 1.000
XDCR BODY OF PT 149 — 3-*- TE985..A 2033 DEG R 1.000
FREE AIR ABOVE SHIELD — 4-*- TE986..A 2089 DEG R 1.000
5-*- TE988..A 2091 DEG R 1.000
57000 0
57200 0
57400 0
57600 0
57800 0
58000 0
58200 0
58400 0
RANGE TIME-SEC.



EP-8A XE-P 8/13/69
NOZZLE MANIFOLD PRESS
FREE AIR ABOVE SHIELD
NOZZLE MANIFOLD PRESSURE
1 TE988..A 2091 DEG R 1.000
2 PT124..E 1566 PSIA 1.000
3 PT126..E 2271 PSIA 1.000
4 PT128..E 2841 PSIA 1.000
5 PT130..E 2291 PSIA 1.000
57200.0
57400.0
57600.0
57800.0
58000.0
58200.0
58400.0
RANGE TIME-SEC.

SPEAR Memo No. 27
R. S. Fitzroy

TEST CHRONOLOGY
XE-PRIME
EXPERIMENTAL PLAN 8A

I. PRE-OPERATIONAL PHASE

A. 27800 CHECKED THE CONTROL ROOM NET (USED NET # 9).

B. 27849 ESTABLISHED AREA CONTROL.

C. 28046 STARTED TO PERFORM DATA SYSTEM CALIBRATION.

28059 OPENED RSV-666.

28274 OPENED RSV-296.

28428 Secured engine purge.

28525 Switched consoles to ENABLE and verified demand pots were normal.

28533 Switched all groups except # 7 to ENABLE.

29269 to 30145 Performed Manual Data System Calibration.

29290 Conducted a one point remote calibration of the log and linear neutronics system and recorded 64 frames of Digital Data.

29316 Re-established engine purge.

29323 Switched source drive control to EXPOSE.

29327 Recorded 64 frames of Digital Data.

30358 Returned all groups to INHIBIT.

30437 Returned consoles to INHIBIT.

30378 Shielded the Source.

30382 Switched source drive to OFF.

30390 CLOSED RSV-296 and RSV-666.

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

28445 Verified MASTER KEY (# 4) to OPERATE.

28450 CLOSED RSV-868.

28473 Verified P-478 ZERO psig.

28493 Unlocked RSV-444 and rotated the Manual Override hand wheel to the FULL OPEN (UP) position.

28697 Switched RSV-444 and RSV-877 to OPERATE.

28709 Exercised RSV-444 CLOSED.

28718 Exercised RSV-877 CLOSED.

28800 Locked SVB-11.

UNLOCKED 50-BV-2332 and manually CLOSED.

28820 Proceeded to the LN_2 DEWAR.
28848 Reported P-181 60 psig.
28853 CLOSED PCV-517.
28866 OPENED RSV-326.
29197 Placed OPEN collar on RSV-326.
29882 Installed Key # 1 and switched to CP control.
29905 Verified ZERO position demand on gang drum demand.
29912 Installed Key # 5 and switched to drum OPERATE.
29924 Switched TPCV to OPERATE.

II. CTE PRE-OPERATIONAL PHASE

A. PRESSURIZED V-3601, CHILLED DOWN 225-LN-6 AND SET UP CRYOTRAP CHILLER.

30479 DDS to 1/1.
30508 OPENED RSV-325.
30523 Pressurized V-3601 to 150 psig using PRV-108.
30529 In MANUAL slowly OPENED PCV-517 to 90%.
30570 OPENED RSV-879.
30585 Cycled RSV-879 as required to establish LN_2 in the cryotrap.
30594 Used PCV-517 and PCV-754 to maintain chill at T-510.
30610 After chill established at T-510, reduced P-580 to less than 60 psig using PCV-517.

B. EXERCISED THE PCV's

31290 Exercised PCV-456 CLOSED.
31313 Exercised PCV-543 CLOSED.
31341 Exercised PCV-472 CLOSED.
31350 Verified P-587 is ZERO and ARMED PCV-251.
31375 Exercised PCV-251 CLOSED.
31418 Verified P-586 is ZERO and ARMED PCV-471.
31430 Exercised PCV-471 CLOSED.
31476 PLACED PCV-251 and PCV-471 in SAFE.
31326 Exercised PCV-579 CLOSED.
31382 Exercised PCV-250 CLOSED.
31484 Exercised PCV-165/180 to the CLOSED positions.
31581 Exercised FCV-50 OPEN.

C. SET UP CONTROL DRUM PNEUMATIC SYSTEM (GH_2 HEADER PRESSURIZED GN_2 HEADER PRESSURIZED ETC INERTED)

31647 OPENED RSV-867.

31657 Used PRV-402 to establish 40 ± 20 psig at P-618.

31680 OPENED RSV-881.

31693 When T-571 indicated 165°R CLOSED RSV-881.

31784 Cycled RSV-879 as required to maintain less than 165°R at T-571.

31816 Used PRV-402 to establish 700 psig at P-618.

31820 OPENED RSV-877.

31831 OPENED RSV-444.

31832 Used PRV-200 to slowly increase P-478 to 200 psig.

32035 OPENED RSV-868.

32048 Used PRV-403 to establish 750 psig at P-618.

32136 CLOSED RSV-868.

D. CHECKED OUT THE FSD CHAIN

32150 Reported P-896 (50 psig).

32166 Verified Engine Safety System Reset

32186 In POSITION control, OPENED TPCV.

32194 OPENED TBV.

32202 Verified PSV OPEN. (Valve was CLOSED and commanded OPENED).

32208 DDS to HIGH.

32212 SCRAMMED.

32216 DDS to LOW.

32252 Placed CLOSED demand on TBV.

32258 Placed CLOSED demand on PSV.

32262 Reset FSD chain.

32270 Increased P-896 to 500 psia.

32295 Reported TBV fully CLOSED.

32365 CLOSED CSV and placed in ENABLE.

32914 Selected PCV-472 step mode.

32918 DDS to HIGH.

32921 SCRAMMED.

32924 DDS to LOW.

32930 Reported position of CSV (OPENED) and PCV-472 (30%).

32934 INHIBITED CSV.

32940 Switched PCV-472 to MANUAL and CLOSED.

E. PRESSURIZED V-3801 AND SWITCHED TO AUTO CONTROL

31060 CLOSED RSV-258 and RSV-257.

31073 OPENED RSV-87 and RSV-276.

31084 In AUTO increased V-3801 pressure to 70 psig.

F. FILLED V-5001, V-5002 AND CHILLED PSL (TSER, DV AND PC WERE INERTED PRIOR TO THIS SECTION).

33201 OPENED PCV-447 and established 65 psig at P-643 (0.1 lb/sec Helium).

33223 Used PRV-426 to establish 400 psig at P-598.

33244 OPENED RSV-83.

33250 OPENED RSV-252.

33256 CLOSED RSV-130.

33260 OPENED RSV-390 and PCV-180.

33274 OPENED RSV-128.

33282 OPENED RSV-455.

33290 OPENED RSV-132.

33306 to 34361 Used RSV-128, RSV-129, RSV-390 and PCV-579 as necessary to fill and chill V-5001 to 80% and obtain bulk temperature of less than 37°R.

33347 OPENED RSV-110 and RSV-109.

33354 OPENED RSV-106 and filled V-5002 to 100%.

33366 CLOSED PCV-472.

33374 OPENED RSV-384 until T-28 indicated LH_2, then CLOSED.

33382 OPENED PCV-456.

33387 OPENED RSV-107 X.

33393 OPENED RSV-107 Y.

33402 OPENED RSV-185 and RSV-186.

G. SET SCRAM SETTINGS

33459 The following scram inputs were set up:

a. Select Program Power - 1 KW (160 Div.) ACTIVE

b. Floating Power - BYPASSED

c. Period .25 sec/50% - ACTIVE

33486 The following inputs were set up and the listed conditions verified:

a. 24 VDC - ACTIVE

b. 115 VAC - ACTIVE

c. RPM - ACTIVE (20,000)

d. dp/dt - ACTIVE

e. TPCV Actuator Pressure - ACTIVE

f. CSV AUTO BYPASS

g. Drum Override Bypass Command Removed (8-1/2° threshold).

h. TPCV Override ACTIVE

i. Pressure Mode Inhibit ACTIVE.

333535 The following scram inputs were set up:

a. Max Drum Position - 40° (220 Div.) - ACTIVE

b. Drum Roll-in Detector - BYPASSED.

H. CONDUCTED INDIVIDUAL DRUM ROTATION AND MAX DRUM SCRAM CHECKOUT

33565 Deactivated criticality alarm system.

33572 Verified Individual Drum Select switch was OFF, all individual pots were ZERO and Lock Switches were not Active.

33582 Verified gang position demand pot was ZERO.

33618 Verified CSV was INHIBITED.

33623 Verified drums indicated LOCKED.

33631 One at a time, the individual drums were rotated to 165° and SCRAMMED.

Drum # 1	90.8°	Drum # 5	91.1°	Drum # 9	91.0°
Drum # 2	91.2°	Drum # 6	91.1°	Drum # 10	91.0°
Drum # 3	91.1°	Drum # 7	91.0°	Drum # 11	91.0°
Drum # 4	91.2°	Drum # 8	90.9°	Drum # 12	90.8°

34261 Safety System was reset.

34271 In Position Control, drums were set against locking pins.

34386 Max Drum Position SCRAM pot was slowly lowered until SCRAM occurred.

34418 Position demand was set to ZERO.

I. VERIFIED DRUM EXPONENTIAL AND RAMP POT SET POINTS

44075 Max Drum SCRAM was set to 220 Div. (40°) ACTIVE .

44097 Exponential Pot was set to 700 Div. (91°).

44108 Ramp pot was set to 300.

44124 Verified gang drum demand was ZERO.

44126 Safety System was reset.
44129 Placed all drums except # 8 in individual control.
44155 Unlocked drum # 8.
44160 Power Demand was set to 1 KW.
44164 Selected Power Control.
44178 STARTED REACTOR.
44230 SHUTDOWN.
39440 Disabled gang drum key.
40904 Selected Dry Autostart.
40909 Selected temperature Autostart.
40913 Set Program Demand Pot to 0 Div.
40917 Selected Program Control.
40938 Set Exponential Pot to 353 Div. (80°).
40947 Set Ramp Pot to ZERO Div.
40995 STARTED REACTOR.
41016 SHUTDOWN.
41031 Set Exponential Pot to 60°.
41170 STARTED REACTOR.
41312 Set Ramp Pot to 300 Div. (0.40°/sec.).
Selected Position Control.
41316 Selected Wet Autostart.
41343 Set Exponential Pot to 353 Div. (80°).
41351 Set Ramp Pot to ZERO Div. (45 Div.)
41368 Started Engine.
41400 Set Exponential Pot to 515 Div. (90°).
41428 Set Exponential Pot to 675 Div. (100°).
41471 SCRAMMED.
41478 Disabled Gang Key.
41479 Locked Drum # 8.
41482 Selected Drum Control ZERO DEMAND.
41484 Selected Nuclear Autostart.
41490 Set Exponential and Ramp Pots to ZERO.

J. ESTABLISHED REACTOR CRITICALITY AND CONDUCTED PROGRAM POWER AND PERIOD SCRAM CHECKS

34460 Reported Startup count rate above background.

1 95 # 2 105 # 3 95

34475 Verified Program Power Scram at 160 Div. (1 KW) and ACTIVE.

34480 Verified Period 0.25/50% and ACTIVE.

34495 Set Max Drum Position SCRAM to 565 Div. (102°) and ACTIVE.

34509 Reset Engine Safety System.

34521 UNLOCKED all Control Drums.

34534 In Position Control initiated Start Reactor and established 500 watts. (0 cc)

34910 DDS and drum recorders to HIGH.

34920 In Position Control initiated a Program Power SCRAM at 1 KW.

34931 Disabled gang key and verified all drums were LOCKED.

34935 Data Systems to LOW.

34940 BF_3 Power ON.

35011 Reset Engine Safety System, then enabled gang key.

35021 In Position Control, initiated Start Reactor, established Reactor Power at 300 w.

35318 BYPASSED Max Drum SCRAM.

35326 Data Systems to HIGH.

35330 RECORDERS to HIGH.

35333 Initiated a Period SCRAM.

35340 Disabled gang key and verified all drums were LOCKED.

35343 Data Systems to LOW.

35347 ACTIVATED Max Drum SCRAM.

K. OVERPRESSURIZED DETECTOR CHECKOUT V-5002

35570 Verified PCV-472 is CLOSED.

35585 Verified overpressure detector was activated and turned on RSV-109 Control Power.

35617 CLOSED RSV-106, RSV-109 and RSV-110.

39840 In AUTO established 100 psig in V-5002.

39890 DDS to HIGH.

39893 Selected P-97 preset and reported P-97 150 psig.

39933 Set Auto Pot to 150 psig.

39999 Selected P-97 pot.

40451 Reduced P-97 to 150 psig and switched to AUTO.

40463 Selected P-97 preset.

40473 Set Auto Pot to 100 psig.

40481 Selected P-97 pot and reported P-97 psig.

40495 Switched PCV-250 to MANUAL and closed.

40570 Vented V-5002.

III. LFE PRE-OPERATIONAL PHASE

A. PRESSURIZED THE GN_2 HEADER AND INERTED ETC

30801 DDS 1/1.

30809 Verified RSV-1, RSV-6 and RSV-11 were OPENED and RSV-2, RSV-7 and RSV-12 were CLOSED.

30825 OPENED RSV-861 and reported P-666.

30835 OPENED RSV-273.

31240 When P-2 stabilized, OPENED RSV-245 and CLOSED RSV-273. Reported P-2 2150 psig.

31360 OPENED RSV-853.

31365 OPENED RSV-222.

31369 CLOSED RSV-853.

31390 OPENED PCV-447 and established 150 psig at P-643 (0.2 lb/sec. Helium), then CLOSED.

31451 Reported O A-1 and O A-2. Used PCV-621 as necessary to reduce O A-1 and O A-2 to less than 3%, then CLOSED.

B. PRESSURIZED THE GN_2 HEADER

31250 OPENED RSV-286 and RSV-283.

31256 OPENED RSV-274 and MONITORED P-3.

31265 OPENED RSV-246 and CLOSED RSV-274.

31283 OPENED RSV-523, RSV-519 and RSV-515.

31300 When P-3 stabilized, OPENED RSV-524, RSV-520, RSV-516, and CLOSED RSV-523, RSV-519 and RSV-515. Reported P-3 2350 psig.

C. INERTED THE TSER

31820 OPENED RSV-927.

D. INERTED DUCT VAULT AND PIPE CHASE

31843 STARTED Duct Vault and Pipe Chase Circulating Fan.

31869 OPENED Duct Vault louvers.

31894 OPENED RSV-899 and RSV-900.

E. EXERCISED PCV-449 EMERGENCY SYSTEM

30480 Verified P-904 was ZERO.

30485 Verified PCV-449 was reset.

30489 Switched PCV-449 to OPERATE.

30498 Exercised PCV-449 CLOSED in MANUAL control.

30567 Switched console to ENABLE.

30580 Placed PCV-449 preset command pot to 450 Div.

30603 Armed PCV-449.

30613 I.C. PCV-449.

30614 ACTIVATED RATE DETECTOR.

30625 DDS to HIGH.

30631 Removed calibration step.

30640 DDS to LOW.

30642 CLOSED PCV-449 using preset command pot.

30665 Switched console to INHIBIT.

30673 BYPASSED Rate Detector.

30676 Switched PCV-449 to SAFE.

30680 Reset PCV-449.

F. ENGAGED TSA/ENGINE BOLTS AND CLAMPS AND PRESSURIZED EXTERNAL SHIELD

31531 OPENED RSV-221.

31540 Established 14 psig at P-480 with PRV-405.

31570 Engaged TSA/Engine bolts and clamps.

G. PRESSURIZED THE HELIUM HEADER

31672 OPENED RSV-247 and CLOSED RSV-275.

31680 Verified RSV-16, RSV-21 and RSV-26 were OPENED and RSV-17, RSV-22 and RSV-27 were CLOSED.

31687 OPENED RSV-54 and used to maintain P-5 between 1000 and 1500 psig.

H. BLED IN LIQUID OXYGEN

49575 Turned SGS enclosure fan ON.

49580 OPENED RSV-436, RSV-68 and RSV-496.

49599 CLOSED RSV-69 X and Y.

49600 OPENED RSV-92 X and Y.

49626 Pressurized LO_2 tank to 80 psig.

51419 CLOSED RSV-436 and RSV-481.

I. BLED IN PROPANE

49665 OPENED RSV-329 for 3 seconds and CLOSED.

49679 OPENED RSV-731.

50487 CLOSED RSV-731 when propane was bled in.

50493 OPENED RSV-494.

50508 When P-420 reached 100 psig, CLOSED RSV-494.

50513 OPENED RSV-329 X and Y.

50523 OPENED RSV-482.

50550 OPENED RSV-435 and CLOSED after T-478 indicated less than 520°R.

J. PRESSURIZED PROCESS WATER SYSTEM

46490 OPENED RSV-666.

46800 OPENED RSV-296. Reported when duct was bled in. (Duct bled in at 46855).

46861 OPENED RSV-297 and RSV-298.

46871 Verified RSV-439 was de-energized OPEN.

K. PRESSURIZED PROPANE AND LO_2 TANK

54421 OPENED RSV-330.

IV. OPERATIONAL PHASE

A. REPORTED FLUID INVENTORY

44960 Reported:

PT 002 <u>1750 psig;</u> PT 003 <u>2050 psig;</u> PT 005 <u>2250 psig</u>.

44980 Reported LT15 47 ft. P-874 1950 psig.

44987 Reported LT026 2.2 psig LT 002 69%.

44999 Reported LT011 1.9 psig LT001 4.2 psid.

45010 Reported PT652 2200 psig.

45022 Reported LT499 75% LT453 75%
LT009 95%

B. FINAL ENGINE SETUP

45036 Reported the following:

PSV (C) - CLOSED TBV (C) - CLOSED

PDVV (C) - CLOSED TPCV (C) - CLOSED

PDSV (O) - OPEN Function Analyzer INHIBIT

TPCV POSITION CONTROL

Drum Position Control Zero Demand

Temp Trim 500 Div.

T.158 - 580°R   P.120 - ZERO psig
T.306 - 510°R   P.158 - 10 psia
T.710 - 550°R   F-14 - ZERO pps
SHUTDOWN COMPLETE
Gang Drum Switch Disabled.

45116 BF_3 Power ON.

45121 Reported the following:
RSV-530(O) - OPEN   P-17 - 500 psig   PT832 - 205 psig
P-618 - 750 psig   T.300 - 560°R   T-108 - >60°R

45150 Reported:
CSV (C) and INHIBIT
CVV (O) - CLOSED - Commanded OPEN
PCV-251 SAFE/MANUAL/CLOSED
PCV-471 SAFE/MANUAL/CLOSED
PCV-472 MANUAL/CLOSED
PCV-543 MANUAL/CLOSED
PCV-456 - 10%

45194 Reported:
PCV-479 - CLOSED   P-97 - ZERO
RSV-390 - OPEN   RSV-109 - OPEN
P-99 - ZERO   RSV-110 - OPEN
V-5001 Press Control: MANUAL
PCV-180 - OPEN
PCV-165 - CLOSED
RSV-128/129 (C) - CLOSED
V-5002 Press Control: MANUAL
PCV-250 - CLOSED

45234 Verified Data System 1/1.

45240 Selected:
Drum Ramp Control OFF
Nuclear Autostart
Power Loop Pot to 0 Div.
2 second period

TPCV Ramp Control OFF
Pressure Loop CLOSED
Experimental Temperature Controller

ON-OFF Temperature Controller
Temperature Rate: 50^{o}/sec.
Pressure Rate: 5 psi/sec.

45281 Set up the following inputs:
Program Power (10 KW) _____Div. ACTIVE
Period .25/50% - ACTIVE

45296 Selected:
Max. Drum at 600 Div. (108^{o}) ACTIVE
Drum Roll-in BYPASSED

45312 Set up the following inputs:
TF Input to TPCV
RPM EN-800 and EN-801 ACTIVE
dp/dt ACTIVE
TPCV Actuator Pressure - ACTIVE
TPCV Override - BYPASS
Pressure mode INHIBIT - ACTIVE
Drum Override - BYPASS Command and pot setting at 412 Div. (8.5^{o}).

C. CONDUCTED LOW TANK PRESSURE CHILLDOWN AND REACTOR PHYSICS TEST

45425 CLOSED all Process Water Fire Protection RSV's.

45430 Reset Safety System.

45441 13 VDC Power ON.

45449 ENABLED Gang Key.

48910 In Position Control, STARTED REACTOR, established 1 KW and switched to Power Control.

49122 Selected Drum Control.

49412 Placed Drum # 1 in individual control.

49425 All Data Systems to HIGH.

49446 Rapidly rotated Drum # 1 to 165^{o}, to 15^{o}, to 165^{o} and to 15^{o}, then returned to bank position.

49150 Secured Engine Purge.

49170 Used FCV-31 to establish 7000 GPM duct flow.

49218 SGS Manual purge ON.

49230 Used PCV-621 to establish 7 pps GN_2 flow.

49260 CLOSED RSV-390.

49268 In MANUAL, pressurized V-5001 to 12.2 psig and switched to AUTO.

49375 All Data Systems to HIGH.

49380 OPENED PSV.

49556 When T-306 indicated 60°R, CLOSED PDSV (T.300 = 300°).

Selected Drum Control.

49601 Rapidly rotated Drum # 1 to 165°, to 15°, to 165° and to 15°, then returned to bank position.

49655 Returned to Power Control and switched Drum # 1 to Gang Control.

49710 Selected RUN. When T.622 indicated 900°R, selected drum position control.

49912 Selected Drum Control.

49916 Placed Drum # 1 in individual control.

49920 Rapidly rotated Drum # 1 to 165°, to 15°, to 165° and to 15°, then returned to bank position.

49956 Returned to Power Control and switched Drum # 1 to gang control.

49965 When T.622 indicated 1100°R, reduced power to 1 KW.

50633 OPENED PCV-621 to establish 7 pps.

50641 OPENED PDSV and CLOSED when drums indicated 72°.

50838 OPENED PCV-621 to establish 7 pps.

50852 OPENED PDSV and CLOSED when drums indicated 70°.

50925 OPENED PCV-621 to establish 7 pps.

50934 OPENED PDSV and CLOSED when drums indicated 68°.

51035 OPENED PCV-621 to establish 7 pps.

51042 OPENED PDSV and CLOSED when drums indicated 68°.

51160 Selected Drum Control.

51164 Placed Drum # 1 in individual control.

51179 Rapidly rotated Drum # 1 to 165°, to 15°, to 165° and to 15°, then returned to bank position.

51220 Returned to Power Control and switched Drum #1 to gang control.

51229 Set Program Power SCRAM to 745 Div. (50 MW).

51246 Increased V-5001 pressure to 35 psia.

51346 Selected HOLD and set power demand to 12 MW.

51360 OPENED PCV-621 to establish 7 pps.

51372 SELECTED RUN. At 12 MW OPENED PDSV.

a. Reported when system stabilized - 82.3°

b. Reported T.710 - 300°R)
T.300 - 100°R)
T.600 - 60°R)
T.158 - 600°R)

Ambient Core Indicators

51430 OPENED RSV-130 and bled in Transfer Line.

51525 CLOSED RSV-130.

51531 OPENED RSV-128.

After V-5001 pressure stabilized, CLOSED RSV-128.and OPENED RSV-129. (V-5001 stabilized at 51650).

After Dewar Pressure stabilized, CLOSED RSV-129. (Dewar stabilized at 51694).

51706 Selected Drum Control.

51714 Placed Drum # 1 in individual control.

51723 Rapidly rotated Drum # 1 to 165°, to 15°, to 165° and to 15°, then returned to bank position.

51763 Returned to Power Control and switched Drum # 1 to gang control.

Reported Power Level (12 MW).

Reduced Power to 300 KW and CLOSED PDSV when temperatures dropped below ambient. (Temperature drop occurred at 51804).

51830 20 seconds after PDSV closed, CLOSED PCV-621.

52282 Selected Drum Control.

52293 Placed Drum # 1 in individual control.

52301 Rapidly rotated Drum # 1 to 165°, to 15°, to 165° and to 15°, then returned to bank position.

52338 Returned to Power Control at 100 KW and placed Drum # 1 in gang position control.

52356 OPENED PCV-621 and established 7 pps.

52366 In Power Control established 9 MW and OPENED PDSV.

a. Reported when system stabilized - 74.2°

b. Reported T-710 - 200°R

T.300 - 100°R

T.600 - 60°R

T.158 - $<$500°R

52686 Selected Drum Control.

52694 Placed Drum # 1 in individual control.

52703 Rapidly rotated Drums # 1 to 165°, to 15°, to 165° and to 15°, then returned to bank position.

52740 Returned to Power Control and switched Drum # 1 to gang control.

52754 CLOSED PDSV, PSV and OPENED PDVV.

52776 20 seconds after PDSV was closed, CLOSED PCV-621.

52780 Established 900° ambient core temperatures.

52792 Reduced Power to 100 KW.

52800 ENABLED CSV and OPENED.

Reported He bottle pressures - 2050 psig.

54295 ARMED PCV-471 and used to establish 200 psig at P-475.

53418 On TD command CLOSED PCV-471 and switched to SAFE.

54352 CLOSED CSV and INHIBITED.

54357 Shutdown, disabled gang key and selected Drum Control.

54380 CLOSED FCV-31.

54382 CLOSED PCV-621.

54386 Secured S. G. Purge.

53513 Used PCV-180 to vent V-5001, then OPENED RSV-390.

53655 Used RSV-128 and RSV-129 to fill V-5001 to 100%.

53460 Reduced UTS Purge to 0.1 pps.

D. COMPLETED CHILLDOWN OF 4-LH-6 AND PRESSURIZED HE HEADER

54425 OPENED CVV.

54430 OPENED PCV-543.

54435 OPENED PCV-472 to 30%.

54458 Used PCV-472, CVV and PCV-543.to maintain chill.

54464 OPENED RSV-54 and reported when P-5 stabilized. (1600 psig)

54506 OPENED RSV-53 and CLOSED RSV-54.

E. FINAL NES SETUP

55440 Obtained less than 180° at T-479 and less than 517°R at T-478.

55575 Reset Steam Generators.

55584 Depressed ready switches.

55590 Positioned inject valve pots to 1000.

F. CONDUCTED OPEN LOOP STARTUP (AMBIENT CONDITIONS) (TEST # 1)

55625 Selected:

Nuclear Autostart

Power Loop pot to 1000 Div.

Power Demand 100 MW.

Power Control.

2 Second Period

Drum Ramp Control OFF

Drum Ramp Rate 0.4°/sec.

TPCV Position Control

TPCV Ramp Control ON

TPCV Ramp Rate 5.0°/sec.

55679 Set up the following inputs:
Program Power (850 MW) - 900 Div. - ACTIVE
Period 0.1/25% - ACTIVE
Ramp Pot 300 Div. ($.4^{\circ}$/sec)
Exp. Pot 700 Div. (θ cc + 2°).
55705 Drum Override - ACTIVE
Max. Drum 600 Div. (θ cc (108°) + 16°) - ACTIVE
Drum Roll-in - ACTIVE
55726 Placed PCV-471 in AUTO Sequence mode.
54220 OPENED RSV-539 and RSV-322.
54260 CLOSED RSV-322 and RSV-539.
54272 OPENED RSV-201.
Reported P-2 (1200 psig) and P-587 (1750 psig).
55760 In MANUAL, pressurized V-5001 to 22.2 psig and switched to AUTO.
55773 Used PCV-621 to maintain H_2 concentration below 2%.
55824 OPENED RSV-738, RSV-739, RSV-858 and RSV-859.
55839 OPENED FCV-31 to 100% and OPENED FCV-32 to establish 5.2 psid at P-56 and P-57 (23,000).
55884 OPENED RSV-937.
55935 MANUAL SGS Purge ON.
55940 STARTED S.G. 1 to IDLE.
55951 STARTED S.G. 2 to IDLE.
55960 STARTED S.G. 3 to IDLE.
55995 OPENED RSV-303, RSV-304, RSV-305 and RSV-306.
56173 All Data Systems to HIGH.
56390 FULL STEAM S.G. 1.
56403 FULL STEAM S.G. 3.
56241 CLOSED RSV-439 after T-591 was greater than 760°R.
56410 STOPPED S.G. 2.
56256 Adjusted FCV-423-2 and 3 until T-534 indicated $1260^{\circ} \pm 50^{\circ}$R.
Reported P-904 (1600 psig) and pot setting (645 Div.)
Set PCV-449 preset demand pot to 645 Div.
56279 Activated PCV-449 rate trip.
56283 I.C.'ed PCV-449.
56290 Armed PCV-449 and switched to OPERATE.
56296 CLOSED PCV-621.
56473 OPENED PSV and established TPA chill.

56483 OPENED RSV-868, CLOSED RSV-867.

56510 OPENED PCV-472 to 30%.

56530 Started Engine Shield Flow.

56577 When T_c was 1600°R, BYPASSED Max. Drum SCRAM.

56583 Reset PCV-449 when P_c was greater than 60 psia.

56586 ENABLED Gang Drum Key.

56590 13 VDC Power ON.

56593 OPENED TBV.

56613 CLOSED RSV-106 and in AUTO, pressurized V-5002 to 100 psig.

56628 ENABLED CSV and set PCV-543 to 15%.

56641 CLOSED PCV-579 when PDSV opened.

56666 OPENED RSV-130 and maintained V-3801 pressure above _____ psig.

56703 CLOSED PDVV.

56709 STARTED REACTOR, STARTED ENGINE, BYPASSED CHILLDOWN AND OPENED PDSV.

56714 Ramped TPCV at 5°/sec to 40°.

56721 When power indicated 25 MW, selected drum control and set to 96° (Θ cc + 4°).

56804 Drum Ramp Control - ON.

56814 When T_c stabilized, ramped drums out until T_c was 3000°, then ramped in until T_c was 2400°R.

56901 Selected T_c Control.

56907 OPENED RSV-128.

56909 CLOSED RSV-130.

56912 Drum ramp control - OFF

56917 Set TPCV Ramp rate at 1.25°/sec.

56925 Ramp TPCV out until P_c was 300 psia.

56944 TPCV Ramp Control - OFF.

56960 Selected Drum Position Control.

56983 CLOSED RSV-128 and OPENED RSV-129 when V-5001 level fell below 80%.

57035 Conducted Transfer Function Tests and reported completion at 57522.

57530 CLOSED RSV-129.

57534 Selected T_c Control.

57540 TPCV Ramp Control - ON.

57543 Ramped TPCV to 40°.

57566 Set T_c demand to 287 Div. (1800°R).

57593 Armed PCV-449.

57600 Programmed Power SCRAM 858 Div. (400 MW).

57606 Set Exponential Pot to 700 Div. (Θ cc + 2).

57620 Max. Drum SCRAM 600 Div. (Θ cc + 16) - ACTIVE.

57640 CLOSED PCV-472 and placed in step mode. OPENED PCV-543.

57656 Reduced duct flow to 9000 GPM.

57668 Selected Drum Position Control.

57673 Drum Ramp Control - ON.

57678 At Shutdown Complete, used PDSV to maintain T_c above 1000°R.

57680 Selected SHUTDOWN.

57692 Ramped Drums to T_c = 1600°. Switched to drum position control and ran drums full in.

57698 Ramped TPCV to ZERO at 1600°R.

57725 In MANUAL, vented V-5002 to ZERO.

G. CONDUCTED HOT CORE, OPENED LOOP STARTUP (TEST # 2)

57731 Selected or reported:

Drum Position Control, Zero Demand

Shutdown Complete

Power Loop OPEN

Power Demand 100 MW

Power Control

Drum Ramp Control - OFF

TPCV Ramp Rate 5.0°/sec

State Program Control.

57772 Started Reactor, started Engine, bypassed chilldown and OPENED PDSV.

57781 Ramped TPCV at 5°/sec. to 40°.

57799 At pressure null, selected Drum Control.

57793 Used drums to maintain T_c of 1700°R.

57820 Reported V-5001 level at 48%. Topping began.

57840 Drum Ramp Control - ON.

57860 Ramped Drums in to T_c of 1000°R and switched to temperature control.

57914 TPCV Ramp Control - OFF.

57947 Set pressure to 60 psia.

57955 Drum ramp control - OFF.

57960 Selected Drum position control.

58027 Conducted Transfer Function Tests and reported completion at 58260.

58270 Drum Ramp Control - ON.

58272 Ramped drums out to T_c = 1700°R.

58345 Drum Ramp Control - OFF.

58353 Nulled Program Error and switched to Program Control.

At SHUTDOWN COMPLETE, switched drums and TPCV to Position Control.

At SHUTDOWN COMPLETE, CLOSED PDSV and used to maintain T_{26} between 500 and 600°R.

58390 SHUTDOWN.

H. CONDUCTED DAMP AUTOSTART (θ AMB WET + 13°) (TEST # 3)

58409 Reported the following:

Error Correction rate 20°R/sec.

Drum Position Control, ZERO Demand

Temp. Loop OPEN.

58426 SELECTED:

Dry Autostart

Temperature Autostart

Set Program Demand Pot to 148 Div. (120 psi) 1700°R

Program Control

Drum and TPCV Ramp Control - OFF.

58510 SET UP:

Ramp Pot 142 Div. (0.20°/sec.)

Exp. Pot 645 Div. (θ amb wet + 13°).

58531 Set Max. Drum Scram to 575 Div. (θ amb wet + 19°) - ACTIVE - 104°.

ENABLED Gang Key.

TPCV Override - ACTIVE.

Verified drum program terminate clear.

13 VDC Power ON.

58633 Reported power was 100 KW.

58686 Started Reactor and OPENED PDSV.

58690 At Drum Program Terminate, started Engine.

Reported when T_c = 1700°R.

Set Ramp Pot to 120 Div. (0.15°/sec.)

Set Exponential Pot to 595 Div. (θ cc + 3) - 95°.

Set Max. Drum Scram at 600 Div. (θ cc + 16°) - ACTIVE - 110°.

58769 BYPASSED TPCV override. Activated at SHUTDOWN COMPLETE. After SHUTDOWN COMPLETE, CLOSED PDSV at T_c of 1100°.

58784 SHUTDOWN.

I. CONDUCTED WET AUTOSTART HIGH DECAY POWER (TEST # 4)

58804 Reported the following:
SHUTDOWN COMPLETE
Drum Position Control Zero Demand
Temperature Loop OPEN

58816 SELECTED:
Wet Autostart
Set Program Demand Pot to 148 Div. (120 psia) (1700°R)
Program Control

58821 SET UP:
Period .25/50% - ACTIVE.

58824 Reported power was 5 MW (1 MW minimum).

58832 OPENED PDSV. When T_c peaked out, STARTED ENGINE.

58916 Reported T_c was 1700°R.

58930 BYPASSED TPCV Override. ACTIVATED at SHUTDOWN COMPLETE. After SHUTDOWN COMPLETE, CLOSED PDSV and maintained T_{26} between 1300 and 1500°R.

58968 SHUTDOWN

J. CONDUCTED HOT CORE WET AUTOSTART (TEST # 5)

58984 Reported the following:
SHUTDOWN COMPLETE
Drum Position Control ZERO Demand
Temperature Loop OPEN

58988 SELECTED
Set Program Demand Pot to 148 Div. (120 psia) 1700°R
Program Control

59178 Reported power was 100 KW.

59180 OPENED PDSV. When T_c peaked out, STARTED ENGINE.

59300 Reported T_c was 1700°R.

59310 Set Program Demand to 58 Div. (1000°R) and reported stable at 59372.

59386 Selected drum and TPCV control.

59396 Selected T.622 control.

59402 Selected Temperature Control.

59412 While holding T.622 constant, stepped TPCV at 5° increments to 25° and 2° increments thereafter.

59696 After SHUTDOWN COMPLETE, at $T_c = 800^{\circ}R$, CLOSED PDSV.

59668 SHUTDOWN.

Disabled Gang Drum Key.

59677 OPENED CSV.

Armed PCV-251 and established 200 psig at P-475.

59710 OPENED PCV-456.

59714 OPENED RSV-948.

Reported when T-881, T-555 and T-474 were above 350°R.

Selected T_c Control.

Verified TPCV CLOSED.

59742 OPENED PDVV, CLOSED PSV.

Reported reflector and dome end temperatures were above 350°R and T_c was below 800°R.

59762 CLOSED PCV-251 and SAFE.

Reported T-474 (300°R).

59772 CLOSED PCV-456.

59780 CLOSED PCV-517.

Reported P-580 at 40 psig.

59790 OPENED RSV-545.

59803 CLOSED PCV-543 and PCV-754.

Used PCV-517 to maintain Engine within cooldown limits.

59814 OPENED RSV-867, CLOSED RSV-868.

59818 OPENED RSV-550.

59825 Re-established engine system purge.

59870 Switched PCV-449 to SAFE.

59872 Reset PCV-449.

59873 BYPASSED Rate Trip.

59879 STOPPED S.G. 1.

59884 STOPPED S.G. 3 MANUAL Purge OFF after 2 minutes.

59893 CLOSED RSV-948 and RSV-550.

59896 Data System to LOW.

59904 CLOSED RSV-433/949 and RSV-434.

59914 CLOSED: RSV-937 RSV-303
RSV-738 RSV-304
RSV-739 RSV-305
RSV-858 RSV-306
RSV-859
FCV-31

59956 CLOSED PCV-447 and OPENED RSV-882.

59976 OPENED PCV-447 and established 385 psig (1 pps).
Secured trough cooling and external shield flow.

60000 OPENED all Process Water Fire Protects RSV's.
LOCKED all drums, removed Gang Key and returned to TD.

60010 Switched PCV-471 to MANUAL.

V. CTE POST OPERATIONAL PHASE

A. 60074 DRUM AND TPCV ACTUATION SYSTEM SECURED

60076 BYPASSED TPCV ACTUATOR Pressure SCRAM

60080 CLOSED RSV-867.

60092 OPENED RSV-443. Reported when P-618 indicated ZERO.

60132 Vented PRV-402, PRV-200 and PRV-403.

60143 CLOSED RSV-444 and RSV-877.

60149 CLOSED RSV-879.

B. 60156 PUMP DISCHARGE LINE CLEANED UP

60158 CLOSED RSV-132 and RSV-455.

60166 Reset Safety System.

60293 OPENED PSV.

60300 OPENED RSV-142.
Reported when T-108 was greater than 60°R.

60451 CLOSED RSV-142.

60459 CLOSED PSV.

60468 Vented PRV-485 to 50 psig at P-896.

60483 CLOSED PDVV and OPENED PDSV.

60494 CLOSED TBV.

C. 60515 V-5001 LH_2 REMOVED AND PSL CLEANED UP

60516 Verified the following:
RSV-129 (C) - CLOSED RSV-128 (C) - CLOSED
RSV-132 (C) - CLOSED RSV-252 (O) - OPEN
PCV-579 (C) - CLOSED RSV-455 (C) - CLOSED

59386 Selected drum and TPCV control.

59396 Selected T.622 control.

59402 Selected Temperature Control.

59412 While holding T.622 constant, stepped TPCV at 5^{o} increments to 25^{o} and 2^{o} increments thereafter.

59696 After SHUTDOWN COMPLETE, at $T_c = 800^{o}R$, CLOSED PDSV.

59668 SHUTDOWN.

Disabled Gang Drum Key.

59677 OPENED CSV.

Armed PCV-251 and established 200 psig at P-475.

59710 OPENED PCV-456.

59714 OPENED RSV-948.

Reported when T-881, T-555 and T-474 were above $350^{o}R$.

Selected T_c Control.

Verified TPCV CLOSED.

59742 OPENED PDVV, CLOSED PSV.

Reported reflector and dome end temperatures were above $350^{o}R$ and T_c was below $800^{o}R$.

59762 CLOSED PCV-251 and SAFE.

Reported T-474 ($300^{o}R$).

59772 CLOSED PCV-456.

59780 CLOSED PCV-517.

Reported P-580 at 40 psig.

59790 OPENED RSV-545.

59803 CLOSED PCV-543 and PCV-754.

Used PCV-517 to maintain Engine within cooldown limits.

59814 OPENED RSV-867, CLOSED RSV-868.

59818 OPENED RSV-550.

59825 Re-established engine system purge.

59870 Switched PCV-449 to SAFE.

59872 Reset PCV-449.

59873 BYPASSED Rate Trip.

59879 STOPPED S.G. 1.

59884 STOPPED S.G. 3 MANUAL Purge OFF after 2 minutes.

59893 CLOSED RSV-948 and RSV-550.

59896 Data System to LOW.

59904 CLOSED RSV-433/949 and RSV-434.

59914 CLOSED: RSV-937 RSV-303
RSV-738 RSV-304
RSV-739 RSV-305
RSV-858 RSV-306
RSV-859
FCV-31

59956 CLOSED PCV-447 and OPENED RSV-882.

59976 OPENED PCV-447 and established 385 psig (1 pps).
Secured trough cooling and external shield flow.

60000 OPENED all Process Water Fire Protects RSV's.
LOCKED all drums, removed Gang Key and returned to TD.

60010 Switched PCV-471 to MANUAL.

V. CTE POST OPERATIONAL PHASE

A. 60074 DRUM AND TPCV ACTUATION SYSTEM SECURED

60076 BYPASSED TPCV ACTUATOR Pressure SCRAM

60080 CLOSED RSV-867.

60092 OPENED RSV-443. Reported when P-618 indicated ZERO.

60132 Vented PRV-402, PRV-200 and PRV-403.

60143 CLOSED RSV-444 and RSV-877.

60149 CLOSED RSV-879.

B. 60156 PUMP DISCHARGE LINE CLEANED UP

60158 CLOSED RSV-132 and RSV-455.

60166 Reset Safety System.

60293 OPENED PSV.

60300 OPENED RSV-142.
Reported when T-108 was greater than 60°R.

60451 CLOSED RSV-142.

60459 CLOSED PSV.

60468 Vented PRV-485 to 50 psig at P-896.

60483 CLOSED PDVV and OPENED PDSV.

60494 CLOSED TBV.

C. 60515 V-5001 LH_2 REMOVED AND PSL CLEANED UP

60516 Verified the following:
RSV-129 (C) - CLOSED RSV-128 (C) - CLOSED
RSV-132 (C) - CLOSED RSV-252 (O) - OPEN
PCV-579 (C) - CLOSED RSV-455 (C) - CLOSED

60532 In MANUAL Vented V-3801.
60830 OPENED RSV-129 and RSV-128.
60939 CLOSED RSV-128 and RSV-129.
60948 CLOSED RSV-252 and OPENED RSV-130.
60960 OPENED RSV-455.
60971 OPENED RSV-132.
61110 OPENED PCV-579; drained V-5001. Reported when empty.
62430 CLOSED RSV-132 and RSV-455.
62440 OPENED RSV-142.
Maintained ETC GH_2 concentration below 2%.
62463 OPENED PSV.
62473 CLOSED PCV-579.
62594 CLOSED RSV-142.
62674 CLOSED PSV and SCRAMMED.
63083 CLOSED RSV-283.
63092 OPENED PCV-180 and vented V-5001 to ZERO psig.
63097 OPENED RSV-390.
63110 OPENED PCV-165 and reported P-598 was ZERO psig.
63120 Vented PRV-426.
63124 CLOSED: PCV-165 RSV-186
PCV-180
63139 OPENED RSV-261.
63144 CLOSED PCV-447.

D. COOLDOWN SYSTEM LH_2 REMOVED

60991 Reported the following:
PCV-472 (C) - CLOSED
RSV-107 (C) - CLOSED
RSV-384 (O) - OPEN
61010 Reported the following:
RSV-106 (C) - CLOSED
PCV-250 (C) - CLOSED
RSV-109 (C) - OPEN
61024 OPENED RSV-106 to blowback the LH_2 in V-5002.
61033 OPENED RSV-107 (X and Y)
61503 CLOSED RSV-106.
61534 CLOSED RSV-83 and OPENED RSV-386.

CLOSED RSV-107 (X and Y).

62415 Reported H_2 Concentration in TSER (0%).

62424 CLOSED RSV-927 (SECURED TSER INERTING).

E. COOLDOWN SYSTEM INERTED

63170 CLOSED RSV-286 and OPENED PCV-250.

63179 Used RSV-110 to vent any remaining pressure in V-5002, then CLOSED.

63184 RSV-109 Control Power OFF.

63190 OPENED RSV-255.

63220 After 20 seconds CLOSED RSV-386.

63261 OPENED RSV-252.

63266 OPENED RSV-105.

63304 CLOSED RSV-384.

When P-101 reached 90 psig, OPENED RSV-384 to vent down, then CLOSED RSV-384.

63470 CLOSED RSV-105.

63480 CLOSED RSV-130.

63519 OPENED and CLOSED RSV-386.

63588 OPENED and CLOSED RSV-130.

63700 CLOSED RSV-252.

63706 OPENED RSV-130.

63715 CLOSED RSV-255.

Vented PRV-485.

63771 CLOSED RSV-276.

63782 OPENED RSV-87 and PCV-248.

63823 CLOSED PCV-248 and RSV-87.

63848 OPENED RSV-258 and RSV-257.

VI. LFE POST OPERATIONAL PHASE

A. 60110 VENTED LOX SYSTEMS

60111 CLOSED RSV-92X and RSV-92Y.

OPENED RSV-436.

OPENED RSV-389.

OPENED RSV-387.

CLOSED RSV-496.

CLOSED PRV-9.

OPENED RSV-69X and RSV-69Y.

CLOSED RSV-68 when P-49 approached 0 psig.

60141 OPENED RSV-495.

When purge was completed, RSV-495 CLOSED.

CLOSED RSV-436.

B. 60170 VENTED PROPANE SYSTEM

60171 CLOSED PRV-104.

OPENED RSV-331.

When P-118 indicated 90 psig, CLOSED RSV-330 and RSV-331.

CLOSED RSV-482.

60218 Cycled RSV-435 OPEN AND CLOSED until manifold pressure was ZERO, then left RSV-435 OPEN.

60415 OPENED RSV-494.

When purge was completed, CLOSED RSV-494.

CLOSED RSV-435.

Turned OFF enclosure fan.

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SPEAR TEAM REPORT

23 August 1969
KRC:jh

TO: TEST REVIEW BOARD / TEST DIRECTOR
F. B. Damerval, J. J. Schinkle, M. Horn

FROM: SPEAR Team

SUBJECT: SPEAR Report, XE-Prime, EP-8A (NTO-R-0175)

Enclosures: SPEAR Memoranda (1) through (27) for EP-8A

Enclosed are the SPEAR Team memos for XE-Prime EP-8A, Chilldown, Physics and Startup Tests conducted on 13 August 1969.

The memos cover analysis of the Engine, Facility Systems, and the Data Systems by the Engine System, Component, Nuclear, Facility, Controls, and Instrumentation Groups of the SPEAR Team.

K. R. Conn

K. R. Conn, Acting Chairman
SPEAR Team