NTO - R - 0180

Spear Report

XE-Prime
EP-10 A

(DRY)
TEMPERATURE AUTO STARTS

LAMINAR FLOW TESTS

SEPTEMBER 1969

DISCLAIMER

XE-PRIME
EP-10A

NTO-R-0180

INFORMATION CATEGORY

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XE-PRIME

EP-10A

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SPEAR Memo No. 1

K. R. Conn

KRC

XE-PRIME

EP-10A

Subject: SUMMARY OF SPEAR ANALYSIS

The concluding Experimental Plan, EP-10A, of the XE-Prime Test Program was conducted on 11 September 1969. The tests planned for this EP were:

1. Nine (Dry) Temperature Autostart Tests, without bootstrapping, as outlined in Table I.

2. Laminar Flow Tests with liquid and gaseous hydrogen flow to the engine.

The objectives of the Autostart tests were to:

1. Provide information on (Dry) Temperature Autostart characteristics to the point of bootstrapping with various initial engine conditions, drum exponential angles, drum program termination criteria, and chill-down delay times.

2. Provide information on engine pre-conditioning techniques.

The objectives of the Laminar Flow tests were to:

1. Investigate flow instability at NERVA maximum and minimum core inlet temperatures during cooldown.

2. Provide information on engine temperature asymmetries with low flow rates of LH_2 and GH_2.

Six of the nine planned Autostart tests (Runs No. 1, 2, 3, 4, 6, and 7), and the Laminar Flow tests were performed. Autostart Runs No. 5, 8, and 9 were omitted when it became apparent that the GN_2 inventory would be critical. The objectives of the EP were essentially met.

The Autostart tests are discussed in Memo No. 4. The results of these tests indicate that similar autostart characteristics can be achieved with Temperature Autostart reactor startups, without flow, from a wide range of initial engine thermal conditions, and with a significant error in the estimation of the critical drum position. It appears that the initial power level is the major factor in influencing the power level, the heat flux condition, and drum position at the termination of the drum program. The drum profile and program termination criteria are significant factors, but only in conjunction with the initial reactor power.

In three of the five cases where the engine chilldown was delayed following the reactor startup (termination of the drum program), it was necessary to introduce LH_2 flow during the hold when the core material temperatures exceeded the run limit. If the ability to hold the reactor in the startup condition is a criteria, then the influence of those factors that affect the power level, heat flux, and drum position at drum program termination must be minimized.

A hold of the engine system in a "ready to bootstrap" condition (reactor startup and Chilldown Complete achieved) for up to 200 seconds was demonstrated with chilldown re-established in 5 to 16 seconds.

Considerable fluid temperature asymmetries were noted through the reactor system during the LH_2 Laminar Flow test. The asymmetries were worse during decreasing temperature transients. Very little asymmetry was present during the GH_2 flow test. No instability conditions were apparent, although localized instability, that did not express itself in the individual measurements, could have existed. Also, equilibrium conditions were never achieved, thus, an evaluation of the flow stability under extended steady-state conditions could not be made. The Laminar Flow tests are discussed in Memo No. 5.

Since the EP consisted of only low flow and low power operating conditions with no TPA operation, the only engine components evaluated were the various valves that were actuated as a part of the Autostart and Laminar Flow tests. Valve operations were normal except for PDSV. During 22 of the 27 opening cycles of PDSV there was a significant delay between the open command (CTE Console) and the opening of the valve, ranging from about 6 seconds to 85 seconds. The cause of the delay has been attributed to an electrical short. The action of PDSV during this EP is discussed in Memo No. 7. No evidence of leakage through PDKV was indicated when the nozzle torus pressure was increased to 100 psia during post-test LN_2 cooling.

The EP was conducted without steam generator operation. A GN_2 purge of 6.5 lb/sec was maintained into the ETC during hydrogen flow to provide a positive dynamic pressure at the duct exit to prevent any air from entering the end of the duct.

The facility performance during EP-10A is discussed in Memo No. 8.

The measured ambient critical drum position for EP-10A, corrected to a reactor temperature of $560^\circ R$, was 97.9°. This was a change of 4.5° from the EP-9A pre-test critical position, indicating a loss of reactor reactivity worth of 29¢ during EP-9A.

The integrated power for EP-10A was 1.7 Mw sec.

Table II is attached to summarize the XE-Prime Test Series, test dates, maximum and integrated powers, and significant operating durations.

RECOMMENDATIONS

The recommendations from EP-10A SPEAR are:

1. Further detailed evaluation be made of the asymmetries that occurred during the LH_2 and GH_2 Laminar Flow tests.

2. Further detailed evaluation be made of the (Dry) Temperature Autostart tests.

3. Further examination be made to establish the exact cause and characteristics of the "short" in the circuit to the PDSV opening solenoid valve.

4. An inspection of the PDSV and PDKV be made following engine disassembly.

5. An analysis be performed to attempt to establish the cause of the apparent large reactor reactivity loss in EP-9A.

Acknowledgment is hereby made of the significant contributions to the EP-10A SPEAR effort by the following personnel:

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TABLE I

SUMMARY OF (DRY) TEMPERATURE AUTOSTART TEST CONDUCTED FOR EP-10A

Run No.	Drum Exponential	Initial Temp. Conditions Core	Reflector	T.910 settings for DPT, °R.	Delay of chilldown after DPT, sec.[2]	No-flow hold following chilldown complete[3]
1	θ_c+3	Ambient	Ambient	850	60	60 sec.
2	θ_c+3	Cold	Cold	700[4]	60	60 sec.
3	θ_c+3	Ambient	Cold	850	0	60 sec.
4	θ_c+3	Hot	Cold	Δ 200[4]	60	60 sec.
5	θ_c-7	Hot	Cold	Δ 200[4]	60	No hold
6	θ_c+13	Ambient	Cold	850	60	No hold
7	θ_c-7	Ambient	Cold	850	60	30 sec.
8	θ_c+13	Ambient	Cold	700	60	90 sec.
9	θ_c+13	Cold	Cold	700	60	120 sec.

1. Switch to drum position control at Drum Program Terminate.
2. All runs except 4 and 5 (hot core) pulse to maintain core temperature under 1000°R during no-flow periods. Runs 4 and 5, pulse to maintain core temperature under 1200°R during no-flow periods.
3. Chilldown complete at T.306 = 80°R.
4. Terminate drum program manually at T.624 of 700°R in Run 2 and after an increase in T.624 of 200°R in Runs 4 and 5.

XEP TEST SERIES SUMMARY

Experimental Plan	Date	Maximum Power	Integrated Power (10^5 Mw-Sec)	Time at Max. Power (sec.)	TPA Run Time (Min.)
EP-1	4 Dec. 1968	215 KW	.00039		
EP-SL2	6 Dec. 1968	1200 KW	.00023		
1A	24 Feb. 1969	900 Kw	.00876		
1B	27 Feb. 1969	10 KW	.00117		
2	13 Mar. 1969	50 Kw	.00041		
2A	20 Mar. 1969	200 Kw	.0928		3.3*
3C	17 Apr. 1969	445 Mw	1.48		10.1*
5C	11 June 1969	1070 Mw	4.25	100	11.8
4A	26 June 1969	58 Mw	.49		3.1
6A	10 July 1969	200 Mw	1.01		22.1
7A	24 July 1969	160 Mw	.541	160	9.5
8A	13 Aug. 1969	440 Mw	4.36	610	41.1
9A	28 Aug. 1969	610 Mw	3.38	340	14.3
10A	11 Sep. 1969	50 Mw	.171		
	Totals		15.81		115.3

NOTE: * Run time of XE-Prime TPA. This TPA was replaced prior to EP-5C

SPEAR Memo No. 3

J. K. Endo

J.K.E.

XE-PRIME

EP-10A

Subject: CRITICALITY MEASUREMENTS

SUMMARY

The ambient critical drum bank position for EP-10A was 97.9 degrees. This ambient critical drum bank position is based on reflector temperature coefficient data obtained during the physics test of EP-8A and is corrected to a reflector and core temperature of 560°R.

TECHNICAL DISCUSSION

Data for this memo was obtained from the NTO Thinned Digital Data listings.

The ambient (560°R) critical drum bank position was taken at CRT of 38092 to 38102 at a constant average power level of 446 watts (average of PWLIN-1 and PWLIN-3). PWLIN-2 was not considered because it is mounted two inches farther away than PWLIN-1 and PWLIN-3.

Using the data from the physics test of EP-8A, the apparent reflector temperature coefficient for station 3 temperature of 596°R is -0.054 cents/°R. The core temperature coefficient of - 0.13 cents/°R was not changed and is assumed to be still valid.

The measured critical drum bank position of 98.2 degrees (CAD) corrected to reflector and core temperature of 560°R is 97.9 degrees, based on the above constants. Table I lists the average temperatures used in this memo for the control room times given above. The correction to the measured critical drum bank position, based on the reflector coefficient used prior to EP-9A, would be negligible.

TABLE I

SUMMARY OF OUTER REFLECTOR AND AVERAGE CORE TEMPERATURES

Average Outer Reflector Temperature (Avg. of TE301, TE302, TE303 & TE304)	=	576°R
Average Core Temperature (Avg. of TACS1S1 and TANC)	=	569°R
Station 3 Temperature (TA910)	=	596°R

It should be noted that the meter on the ATE console indicated 97°, which is approximately 1.0° less than the digital data value of 98.2°, as measured by CAD. This difference is consistent with all the previous EP's

The loss in reactivity worth during EP-9A, based on the pre-test criticality measurements of EP-9A and EP-10A, was approximately 4.5° of drum bank position, or 29 cents (based on a drum bank worth of 6.5¢/°). The measured drum worth change of 4.5° between EP-9A and EP-10A pre-test control drum positions is substantially greater than expected. There was no indication that the pre-test criticality measurements of EP-9A and EP-10A were not valid. During both Steady-State holds at 4090°R and 300 psia there was no significant change in drum positions. However, the effect of any change in reactivity worth could have been masked by the system performance drift that was occurring during both holds. At the present time the cause of the problem is not known and should be further evaluated at WANL and also during post-test operations to be conducted at E-MAD.

CONCLUSIONS

It is recommended that the cause of the relatively high loss of reactivity worth during EP-9A be further investigated at source engineering and also at E-MAD during post-test operations.

SPEAR Team

KRC

XE-PRIME

EP-10A

Subject: ENGINE PERFORMANCE DURING (DRY) TEMPERATURE AUTOSTARTS

SUMMARY

Six of the nine (Dry) Temperature Autostarts planned for EP-10A were performed. These were performed from various initial core and reflector thermal conditions with various drum exponential pot settings and drum program termination criteria. Childown was initiated, both immediately and after a 60-second delay after DPT, in the various runs. In addition, a second,no-flow,hold period was introduced (in five of the runs) following the first "chill-down complete", with a second chilldown period to re-establish "Chilldown Complete".

The results of the autostart tests are summarized in Tables I and II and in Figures No. 1 through 12.

The reactor conditions at the termination of the drum program were fairly similar in the five runs with the major elements affecting the conditions being the very low power level at the beginning of Run No. 1 and the low temperature rise (140°R) to the drum program termination level in Run No. 2. In those runs (Nos. 3, 6, and 7) in which the initial conditions were the same, but the drum exponential setting varied +8 and -10° from a nominal value, the conditions at DPT were very similar in all three cases.

In the tests to demonstrate a delay of engine chilldown following drum program termination it was necessary to introduce LH_2 pulses in three of the five autostart tests when the core temperatures exceeded the test limits. Those factors that affect the reactor conditions at the termination of the drum program also affect the ability to hold the reactor in a ready condition. If the ability to maintain the reactor in a start-up condition, with engine chilldown delayed, is to be a feature of the system, then those factors that tend to result in a high power level and heat flux at DPT should be considered and minimized in selecting the startup criteria. Such factors are: a) the initial power, b) a drum exponential that rolls the drums out to a position significantly in excess of the critical position, c) the amount of temperature rise to the DPT trip level, and d) the temperature span between the DPT trip level and the temperature limit.

The flow was terminated at Chilldown Complete in five of the tests to demonstrate holding the entire engine system in a "Ready for Start-up" condition. Holds of up to 202 seconds were made with times to re-establish chilldown conditions of 5 to 16 seconds.

More detailed evaluation of these autostart tests is left to later efforts.

TECHNICAL DISCUSSION

A. INTRODUCTION

The (Dry) Temperature Autostarts demonstrated reactor start-ups and engine system conditioning to the point of bootstrapping. Initiation of bootstrapping at Chilldown Complete was prevented by maintaining TBV in a closed position. Also, the Start Engine command was not given, which inhibited TPCV opening, even though Chilldown Complete occurred. Chilldown Complete was set to occur at a reflector inlet temperature, T.306, of 80°R. Drum Program Terminate (DPT) was set to occur at a core temperature, T.910, of 850°R. At DPT, the drums were stepped in 8°. The drums were then switched to position control and held. In run No. 2, it was desired to terminate the drum program at a T.624 temperature of 624°R (initially planned for 700°R). This was achieved by a manual switch to drum position control followed by a step-in of 8° in position control. In Run No. 4, the test was initiated with a hot core. In this case, the (Wet) Temperature Autostart drum program was utilized to prohibit a DPT until the desired conditions for terminating the drum program were attained (increase in T.624 of 200°R). The drums were then manually switched to position control and stepped in 8°.

These autostarts were performed with a run tank pressure of 35 psia with the propellant line chilled down to PDSV. The steam generators were not utilized during this EP. A GN_2 purge flow of approximately 6.5 lb/sec was maintained into the ETC during all phases of the EP when hydrogen flow was established.

The initial conditions, conditions at termination of the drum program, engine chilldown times, and other factors for the completed autostart tests are summarized in Tables I and II.

B. DESCRIPTION OF AUTOSTARTS

1. Run No. 1

The initial conditions for Run No. 1 were an ambient reflector and core. The source power level was less than 0.5 watts. Figures No. 1 and 2 show various system parameters during the Autostart test. The autostart was initiated by the Start Reactor command. This started the drum program which rolled the drums out on an exponential to 99° (estimated critical position plus 3 degrees). The drums then continued on a linear ramp of 0.175°/sec (the linear ramp pot setting was at 0.20°/sec). Drum Program Terminate (DPT) occurred when T.910 reached the DPT trip level of 850°R and the drums were stepped in 8 degrees from their maximum position of 110°. The drums were then placed in position control and held constant at 102°. The elapsed time was 72 seconds from start of drum roll-out to DPT. At DPT, the average linear power (PWALIN) peaked at 44.5 Mw. It should be noted that this peak power at DPT was the highest of the six autostarts.

The second phase of this run was to demonstrate a nominal hold of 60 seconds following Drum Program Termination (conclusion of reactor startup) before flow was initiated to start engine childown. However, one of the conditions for this run was to maintain T.624 below 1000°R by pulsing LH_2 flow with PDSV as required. About 5 seconds after DPT, T.624 exceeded 1000°R and PDSV was commanded open. There was a 6.5 second delay following the open command before the valve started to open. This anomaly occurred in 22 of the 27 times that PDSV was commanded open during the EP and is further discussed in Memo No. 7. PDSV was not full open until about 10 seconds after T.624 exceeded 1000°R and about 17 seconds after DPT. The core temperatures continued to decrease with T.624 reaching a peak of 1210°R about 34 seconds after DPT. At the end of the 60-second hold T.624 was still above 1000°R. The amount of temperature overshoot beyond the 1000°R intended limit was influenced by the delay in PDSV opening, as well as the reduced effect of the initial flow (low flow rate and low cooling potential), as a result of the engine system from PDSV to the core inlet being at ambient temperatures, in removing heat from the core.

PDSV was left open and engine childown continued. The chill-down time of the engine system from ambient conditions (propellant line previously chilled to PDSV) to Childown Complete (CD) at T.306 equal to 80°R was approximately 106 seconds from the beginning of PDSV opening.

Following Childown Complete, PDSV was closed and a second 60-second hold made without flow; followed by a childown to reacquire Childown Complete. The purpose of this second hold was to evaluate the time and fluid usage required to re-establish Childown Complete, and thus the initiation of bootstrapping, following a hold period after the entire engine system had been pre-conditioned to a "ready-for-bootstrap" condition. During this hold period T.624 again exceeded 1000°R (28 seconds after PDSV was closed) and it was necessary to introduce a LH_2 flow pulse (for about 14 seconds) with PDSV. At the end of the hold, childown was again initiated and Childown Complete occurred about 21 seconds after PDSV began to open; however, the childown was essentially complete 8 seconds after PDSV began to open when T.306 reached a minimum of 82°R and increased back to 100°R before continuing to decrease.

At Childown Complete, the drums were manually ramped out 8° to simulate the action of the drums at Childown Complete when bootstrapping is initiated by CD. The drums were held for 20 seconds at that position. Power during this hold reached a maximum of 30 Mw. The drums were then run in; and PDSV was closed as the core temperatures decreased below 1000°R to end Run No. 1.

2. Run No. 2

The core and reflector were both cold at the beginning of the second run. The initial power level was approximately 550 watts. At Start Reactor, the drums were rolled out on an exponential to 85° (estimated dry critical position of 82° plus 3°), followed by a linear ramp of 0.175°/sec. (See Figures No. 3 and 4.) The drum program was terminated by a manual switch to position control when T.624 (average Station 3 linear temperature) reached 615^{o}R (the planned termination had been switched to 624^{o}R prior to the run). The drums were then stepped in 8^{o} from a maximum of 102^{o} and held at a constant position of 94^{o}. The time from Start Reactor to the termination of the drum program was 103 seconds. The average linear power (PWALIN) reached a peak of 5.3 Mw at termination of the drum program. Station 3 temperatures (T.910 and T.622) had increased to approximately 750^{o}R at that time.

When the drum program started the T.622 core station temperature averager was indicating a slight decay in temperatures, as shown in Figure No. 3 . When the T.910 temperature (mid-core measurements at the same station) began to increase, the T.622 temperature began decreasing from a level of 580^{o}R to a minimum of 490^{o}R at a similar rate. It then turned around and began increasing. The initial level of T.624 was higher than T.910 (580^{o}R compared to 380^{o}R) and the condition shown appears to be an adjustment of these temperatures toward the mean station condition. However, it is not presently understood why and how it occurs at that particular time during the run.

Following the termination of the drum program, a nominal hold of 60 seconds was initiated prior to the start of engine chilldown. During this hold, PDSV was to be cycled, as required, to maintain T.624 below 1000^{o}R. However, T.624 increased to a maximum of only 770^{o}R so that no cooling was required during this hold. After the hold, PDSV was opened and engine chilldown initiated. Chilldown Complete was achieved 6 seconds after PDSV started to open (there was an approximate 10-second delay from the open command until the valve started to open).

Following Chilldown Complete, PDSV was closed to terminate the LH_2 flow to the engine and a second 60-second hold initiated. During this hold, the reflector inlet temperature increased to about 125^{o}R. At the end of this hold, PDSV was opened and engine chilldown initiated again. Chilldown Complete was re-established 5 seconds after PDSV stared to open.

The drums were then ramped out 8^{o} after Chilldown Complete and held for 20 seconds. The power increased in 15 seconds to 20 Mw. The drums were then ramped in to end Run No. 2.

2. <u>Run No. 3</u>

Initial conditions for this run were a cold reflector and an ambient core. The power level at the beginning of the drum program was approximately 27 Kw. The exponential was set at 95^{o} (estimated dry critical position of 92^{o} plus 3^{o}). Run No. 3 is summarized in Figures No. 5 and 6. Start Reactor command was given and the drums rolled out on an exponential to 95^{o}. The drums then continued on a linear ramp at 0.175^{o}/sec to 106^{o}, at which point DPT occurred. The drums stepped in 8^{o} to 98^{o} and were then placed in position control. The total elapsed time from drum rollout to DPT was 71 seconds. The power increased from the initial level to a peak of 9.4 Mw at DPT.

In this run, engine chilldown was planned immediately after DPT. The command to open PDSV was given 5 seconds after DPT, but the valve did not start to open until 15 seconds after DPT. Chilldown Complete was attained in 7 seconds after PDSV began to open.

Following the first Chilldown Complete, PDSV was closed and a 60-second hold, without flow, was made. At the end of the 60-second hold, PDSV was opened to re-initiate engine chilldown and Chilldown Complete was attained 6 seconds after PDSV started to open.

The drums were then stepped out 8° and held for 20 seconds. The power increased to 28 Mw during this period. The drums were then run in and PDSV closed to end Run No. 3.

4. Run No. 4

The initial conditions for this test were a cold reflector and hot core. The power level at the beginning of drum program was approximately 36 Kw. The drum exponential was set at 102° (estimated dry critical of 99° plus 3°). Since this run was to be initiated with a hot core (900°R to 1000°R), the (Wet) Temperature Autostart drum program was utilized to prevent a DPT trip. In this program, the linear ramp demand is active when the reflector inlet temperature is 125°R, or less. However, the controller does not accept the demand until the exponential ramp is nearing the set level. The linear ramp is then initiated and the exponential inhibited. Figures No. 7 and 8 show various engine parameters for this run. Start Reactor was commanded and the drums rolled out on the exponential and then continued on a linear ramp of 0.175°/sec. The drum program was terminated manually at a drum position of 110° when T.624 reached 1050°R (the temperature criteria for terminating the drum program was increased from 850°R to an increase in T.624 of 200°R, due to the initial hot core condition) by switching to position control. The drums were then stepped in 8° to 102° and held at that position. The drum program was terminated 52 seconds after the beginning of drum roll-out. The power increased gradually to a peak of 9.3 Mw at the termination of the drum program.

Engine chilldown was delayed for a nominal hold of 60 seconds following the termination of the drum program. During this hold, the maximum limit of T.624 was increased to 1200°R, due to the initial hot core condition. T.624 was to be maintained below 1200°R by pulsing LH_2 flow as required. The temperatures increased slowly, however, and the planned hold was complete before it was necessary to introduce flow.

PDSV was then opened to initiate engine chilldown. The reflector inlet temperature decreased to about 84°R in 12 seconds after the valve started to open. However, it turned around and increased to 95°R and held steady at 90°R for 3 seconds before continuing to decrease. As a result, Chilldown Complete (at A

T.306 of 80^{o}R) did not occur until about 19 seconds after the valve started to open. The high (1000^{o}R) chamber temperature that occurred after flow was initiated, and the high core temperature (1200^{o}R) were apparently factors in causing the pause in reflector inlet chilldown which resulted in a 7-second delay in Chilldown Complete, although the temperature criteria had been essentially satisfied. A similar situation had occurred during the second chilldown period in Run No. 1.

At Chilldown Complete, the flow was terminated and a second 60-second hold started. At the end of this hold, PDSV was reopened and Chilldown Complete was re-established in about 9 seconds after the valve started to open. Again the reflector inlet temperature bottomed out (below 80^{o}R; therefore, in this case a prompt Chilldown Complete was achieved) and momentarily increased, indicating that the conditions of this run were approaching those where, although the engine is essentially chilled and ready for bootstrapping, the Chilldown Complete event could be delayed for a significant time if the CD reflector inlet temperature setting is too low.

Following Chilldown Complete, the drums were stepped back in 2^{o} as the power was increasing toward the program power Scram setting of 60 Mw. However, it should be noted that the power peaked and had already turned around before the drums were stepped in. The drums were then held at 108^{o} for 20 seconds. At the end of the 20-second hold, the drums were run in and PDSV was closed when the core temperatures (T.624) decreased to 700^{o}R.

5. Run No. 6

Initial conditions for this test were a cold reflector and ambient core. The power level at the beginning of the drum program was 2.9 Kw. The exponential was set at 103^{o} (estimated dry critical position of 92^{o} plus 11^{o}). Run No. 6 is summarized in Figures No. 9 and 10. The reactor was started and the drums rolled out exponentially to 103^{o} and continued on a linear ramp to a maximum of 108^{o} at DPT. At DPT, the drums were stepped in 8^{o} to 100^{o} and placed in position control. The total elapsed time from drum roll-out to DPT was 35.5 seconds. The power increased gradually and reached a peak of 18.5 Mw at DPT.

Following DPT, a 60-second delay of engine chilldown was started. During the hold, PDSV was to be opened, as required, to maintain T.624 below 1000^{o}R. Two short pulses were made with the first one (of 8 seconds duration) initiated about 8 seconds after DPT and the second one (of 5 seconds duration) about 28 seconds after DPT. After the hold, PDSV was opened and engine chilldown initiated. Chilldown Complete was attained in 8 seconds after PDSV started to open.

No hold following Chilldown Complete was made in this run.

Following Chilldown Complete, the drums were ramped out 8^{o} and held for 20 seconds. The drums were then run in to end the test. PDSV was closed when T.624 decreased to 700^{o}R. During the 20 second hold, power increased to 29 Mw.

6. Run No. 7

Initial conditions for this run were an ambient core and cold reflector. The power level at the beginning of the drum program was 65.3 Kw. Reactor startup began with an exponential drum roll-out to 85^{o} (estimated dry critical position of 92^{o} minus 7^{o}) followed by a linear ramp of 0.175^{o}/sec (see Figures No. 11 and 12). The drums reached a maximum position of 108^{o} at DPT. They were then stepped in 8^{o} to a position of 100^{o} and switched to position control. DPT occurred 140 seconds after the drum program was started. Power increased gradually to a maximum of 9.5 Mw at DPT.

Following DPT, a 60-second hold prior to engine chilldown started. PDSV was to be cycled, as required, to maintain T.624 below 1000^{o}R during the hold. PDSV was commanded open 15 seconds after DPT and started to open 15 seconds later. During the 15-second delay, T.624 had increased to 1050^{o}R. PDSV was left open for 7 seconds and then closed. PDSV was then commanded open to start engine chilldown 97 seconds after DPT. The core temperature (T.624) was about 1050^{o}R and increasing slowly at that time. PDSV started to open 26 seconds after the open command was initiated (T.624 at 1055^{o}R). Chilldown Complete occurred 15 seconds after PDSV started to open.

Following Chilldown Complete, PDSV was closed and a second no-flow hold period (120 seconds) was started. PDSV was commanded open after about 105 seconds (the early command was in anticipation of the delay in valve opening). The valve opened to about 4^{o}, after a delay of 10 seconds, and held in that position. After 85 seconds (from valve open command), it was assumed the valve was not going to open and it was decided to abort the run. A close command was given to the valve. At about that time, the valve did begin to move and opened to 60^{o} before the close command became effective and closed the valve. An open command was again given and the valve opened after about an 8 second delay. The total hold without flow was thus approximately 202 seconds. Chilldown Complete was achieved in 16 seconds after the valve started to open.

Following Chilldown Complete, the drums were stepped out 8^{o} to 107.5^{o} (the drums had been stepped in about 0.5^{o} during the "aborted" abort) and held for about 20 seconds. Power peaked to about 50 Mw as the drums were stepped out. The drums were then run in and the autostart phase of the EP terminated.

Planned Runs, Nos. 5, 8, and 9, were not conducted when it became apparent that the GN_2 supply would run short.

C. ANALYSIS OF AUTOSTARTS

The objectives of these autostarts were to:

1. Provide information for evaluating the effect of performing (Dry) Temperature Autostarts from various initial conditions, over a range of drum exponential ramp settings relative to the critical drum bank position, and with various temperature criteria for drum program termination.

2. Provide information for evaluating the ability to delay the engine childown and bootstrapping following a reactor startup in the (Dry) Temperature Autostart mode.

3. Provide information for evaluating the ability to start up the reactor and pre-condition the entire engine to point of initiating bootstrapping, and then perform a hold before beginning bootstrapping.

With the completion of six of the planned runs, the objectives were basically satisfied. Detailed analysis and evaluation of these Autostarts is left for later efforts in conjunction with the development of engine startup modes for NERVA. Only generalized evaluations were made by SPEAR.

The reactor startup and engine childown phases of the runs are summarized in Tables I and II.

Runs No. 1, 2, 3, and 4 give the reactor startup characteristics from various initial core and reflector temperature conditions. Runs No. 3, 6, and 7 illustrate the startups with an exponential drum program setting varying $+8^{\circ}$ and -10° from a nominal level. The drum program was terminated in Run No. 2 at T.910 of 700°R and in Run No. 4 at an increase in T.624 of 200°R. In the other runs, it was terminated by DPT trip at T.910 of 850°R. The drum angle at the termination of the drum program varied from 101.5° in Run No. 2 to 110° in Runs No. 1 and 4. The peak power level at drum program termination varied from 5.3 Mw to 18.5 Mw, with the exception of Run No. 1 in which it spiked to a peak of 44.5 Mw. In the five runs in which a 60-second hold was planned, following termination of the drum program, it was necessary to introduce LH_2 flow pulses in three of the cases when the core material temperature (T.624) exceeded the limit set for that run. These temperature overshoots were after-effects of the power level and heat flux at drum program termination.

Runs No. 1 and 3 were similar autostarts with the primary difference in start conditions being an ambient reflector condition in Run No. 1 with a cold reflector condition (147°R) in Run No. 3. Another major difference, however, was the initial power level. The power level for Run No. 1 was less than 0.5 watts; whereas, at the beginning of the drum program in Run No. 3 it was approximately 27 Kw.

The significant difference in the autostart characteristics was the gradual increase in core temperature and power in Run No. 3 vs. the delayed, but very rapid, temperature and power increase in Run No. 1. These two runs were examined to evaluate the possible effects of the large difference in power levels in the differences that existed at DPT. In the latter, the power spiked to 44.5 Mw from a level of about 1/2 Mw in 10 seconds; whereas, in Run No. 3, the power increased gradually from 1/2 Mw to a peak of 5.3 Mw in 49 seconds.

Apparently the major element in these two autostarts was the difference in the initial power level. With the very low power level of Run No. 1, it required a long time before the power increased to a level where sensible heating (evidenced by an increase in core temperatures) began to occur. During this time the drums were rolled out well in excess of critical and, as a result, a relatively short period occurred. Thus, when the power did increase to a level where the temperatures began to increase, the short period produced the resulting rapid power spike and corresponding rapid core temperature increase. With the high initial power level of Run No. 3, sensible heating began almost immediately. As the core temperatures increased, the critical angle was "pushed up" and the differential between actual drum position and critical position kept small. A short period, similar to that of Run 1, thus did not occur. The temperature and power thus increased gradually and no sharp power spike occurred. In Run No. 1, the power did not build up to the initial level that existed in Run No. 3 until 57 seconds after the beginning of the drum program. At that time the drums rolled out to 108^{o} (the position at DPT was 110^{o}) which is 12^{o} beyond the estimated critical position. An increase in power from 1/2 watt to 27 Kw requires an increase by a factor of "e" about 11 times. Thus, an average period of about 5 seconds would have been required to provide this power increase. It is estimated that a minimum period of less than 1.5 seconds existed in Run No. 1 at the time that sensible heating began. In Run No. 3, the estimated minimum period was only 13 seconds.

The other runs were initiated with power levels varying from 550 watts to 65 Kw. The initial power level would also have been a factor in these runs, but not of the magnitude demonstrated between Runs No. 1 and 3.

The reactor conditions at DPT were very similar in Runs No. 3, 6, and 7, although the drum program exponential settings were 95^{o}, 103^{o}, and 85^{o}, respectively. The drum positions and power levels at DPT were 106.5^{o}, 108^{o}, and 108^{o} and 9.4 Mw, 18.5 Mw, and 9.5 Mw, respectively. In Run No. 3, the engine cilldown was initiated soon after DPT. It is not clear whether LH_2 pulsing would have been necessary if a hold had been planned. In the other two runs, pulses were necessary during the hold following DPT when T.624 exceeded the run limit of 1000^{o}R. It appears that the relatively low initial power level of Run No. 6 (2.9 Kw) compared to Runs No. 3 and 7 (27 Kw and 65 Kw, respectively) may have also been a contributing factor in causing the higher peak power and greater temperature rise rate at DPT. The magnitude of any power effect is not known at this time. These three runs do demonstrate that considerable latitude is possible in selecting the drum program or in erring in the estimation of the critical drum position.

Following the termination of the drum program in five of the startup tests (Runs No. 1, 2, 4, 6, and 7), a nominal 60-second hold was to be made before the beginning of engine chilldown. During these holds the core temperature (T.624) was to be maintained* below a limit (150° above the drum program termination level) by pulsing with LH_2 flow. It was necessary to initiate LH_2 pulsing in three of the five runs. Since the response of the core material temperatures following the termination of the drum program results from the reactor conditions at program termination, those factors that influence the peak power level and temperature rise rate also affect the ability to delay engine chilldown following the reactor startup. The effect of initial power level was explained above. The exponential drum setting and linear ramp rate in conjunction with the initial power level will also affect the minimum period. A lower DPT level, as well as a high temperature limit, also allows a greater increase in temperature before the limit is reached.

In Runs No. 1, 2, 3, 4, and 7, a no-flow hold period was made following the engine chilldown to Chilldown Complete. A second chilldown was then re-initiated to re-establish Chilldown Complete. These holds demonstrated establishing and holding the complete engine system (including reactor) in a ready to bootstrap condition. The holds varied from 60 seconds to approximately 200 seconds. The time required to re-establish nominal Chilldown Complete conditions varied from 5 seconds to 21 seconds.

CONCLUSIONS

1. The autostart tests indicate that similar Temperature Autostart reactor startup characteristics, without flow, can be obtained from a wide range of initial engine thermal conditions and with a significant error in the estimation of the critical drum position.

2. The tests indicate that the initial reactor power level is the major factor influencing the power level, heat flux and drum position at the drum program termination. The drum profile and program termination criteria are also significant factors, but only in conjunction with the initial reactor power factor.

3. If the ability to have a no-flow delay following reactor startup is a criteria, those factors influencing the power, heat

* At T.024 of 1200°R in Run No. 4, however the drum program was terminated at 1050°R for an increment of 150°R.

flux and drum position at drum program termination must be considered and their influence minimized.

4. The engine system can be held in a "ready-to-bootstrap" condition for a significant period of time and chilldown conditions re-established in a fairly predictable time.

TABLE I

SUMMARY OF (DRY) TEMPERATURE AUTOSTART REACTOR STARTUPS

Run No.	INITIAL CONDITIONS: Reflector Temp. T.300 °R	Core Temp. T.910 °R	Power	Est. Dry Crit. Drum Posit.-Deg.	Exponential Setting Deg.	Linear Ramp Setting Deg/Sec	Time to DPT * Sec.	CONDITIONS AT TERMINATION OF DRUM PROGRAM: Core Temperatures T.910 °R	Core Temperatures T.624 °R	Drum Position Deg.	Power Mw	Est. Minimum Period** Sec.	Δ T.910 / Δ t °R/sec	Drum Posit. after Step-in Deg.
1	572	610	Less than 0.5 W	96	θc + 3 (99)	0.20	72	850*	740	110	44.5	1.4	53.3	102
2	125	275	550 W	82	θc + 3 (85)	0.20	103	750	615*	101.5	5.3	5	10.3	94
3	147	490	27 KW	92	θc + 3 (95)	0.20	71	850*	780	106.5	9.4	13	16.3	98
4	170	865	36 KW	99	θc + 3 (102)	0.20	51.5	1010	1050*	110	9.3	12	10.4	102
6	215	475	2.9 KW	92	θc + 11 (103)	0.20	35.5	850*	800	108	18.5	3	30.4	100
7	165	500	65.3 KW	92	θc - 7 (85)	0.20	140	850*	840	108	9.5	12	13.3	100

NOTE: * In Runs No. 2 and 4 the drum program was terminated by CTE by a switch to position control at T.624 of 615°R and 1050°R respectively. In the other runs it was terminated by DPT at T.910 of 850°R.

** Minimum period during drum program.

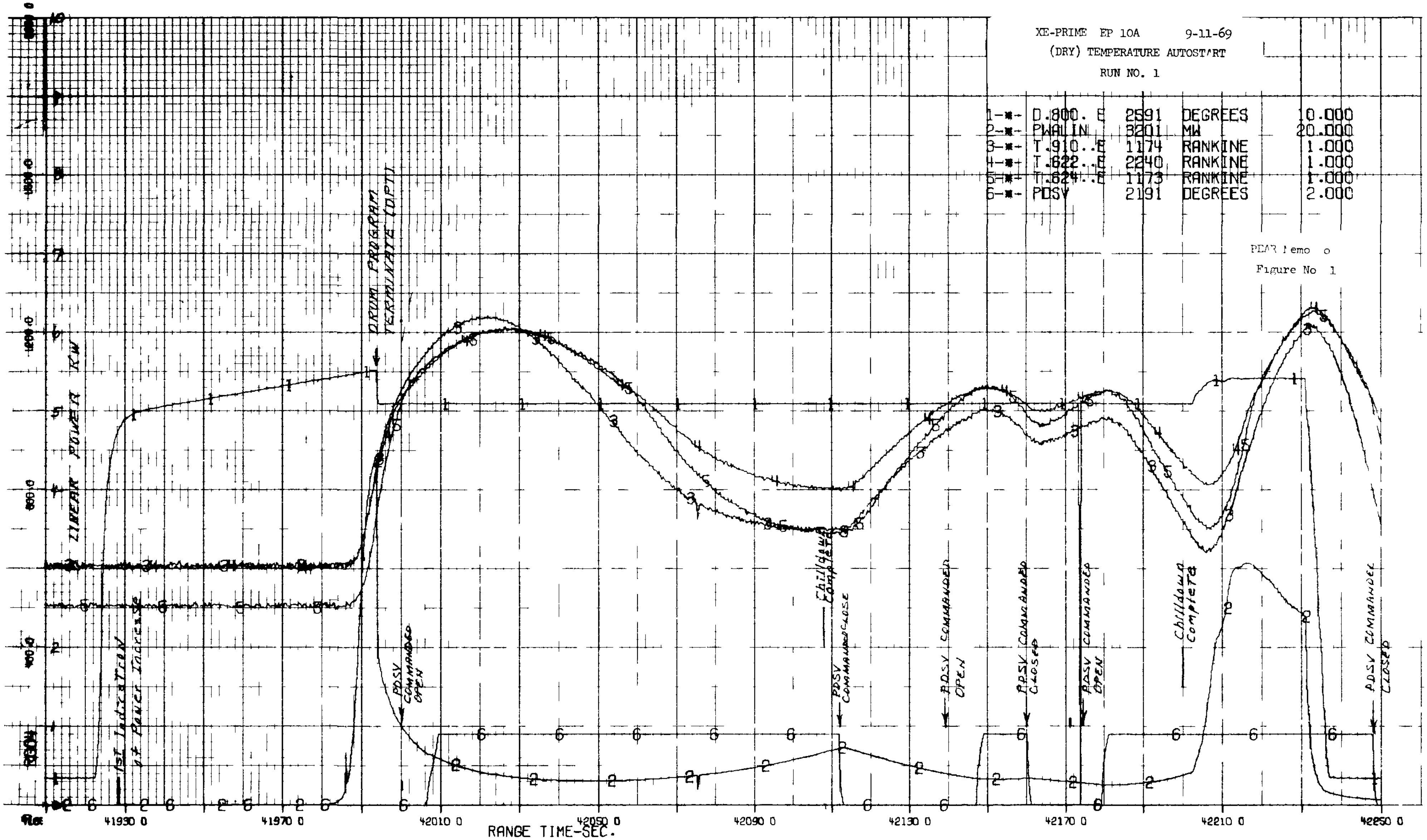
TABLE II

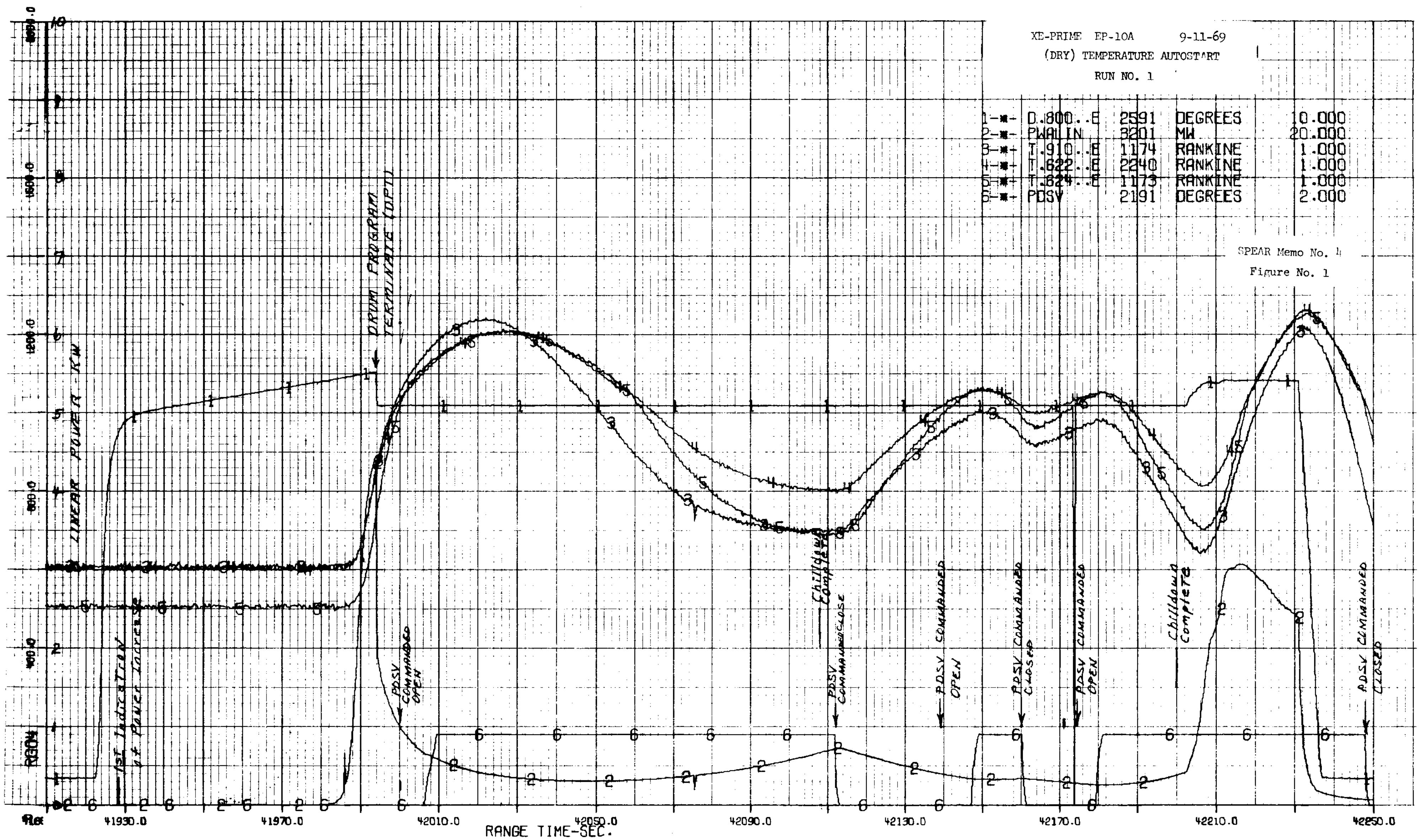
SUMMARY OF ENGINE CHILLDOWNS, HOLDS, AND RECHILLS

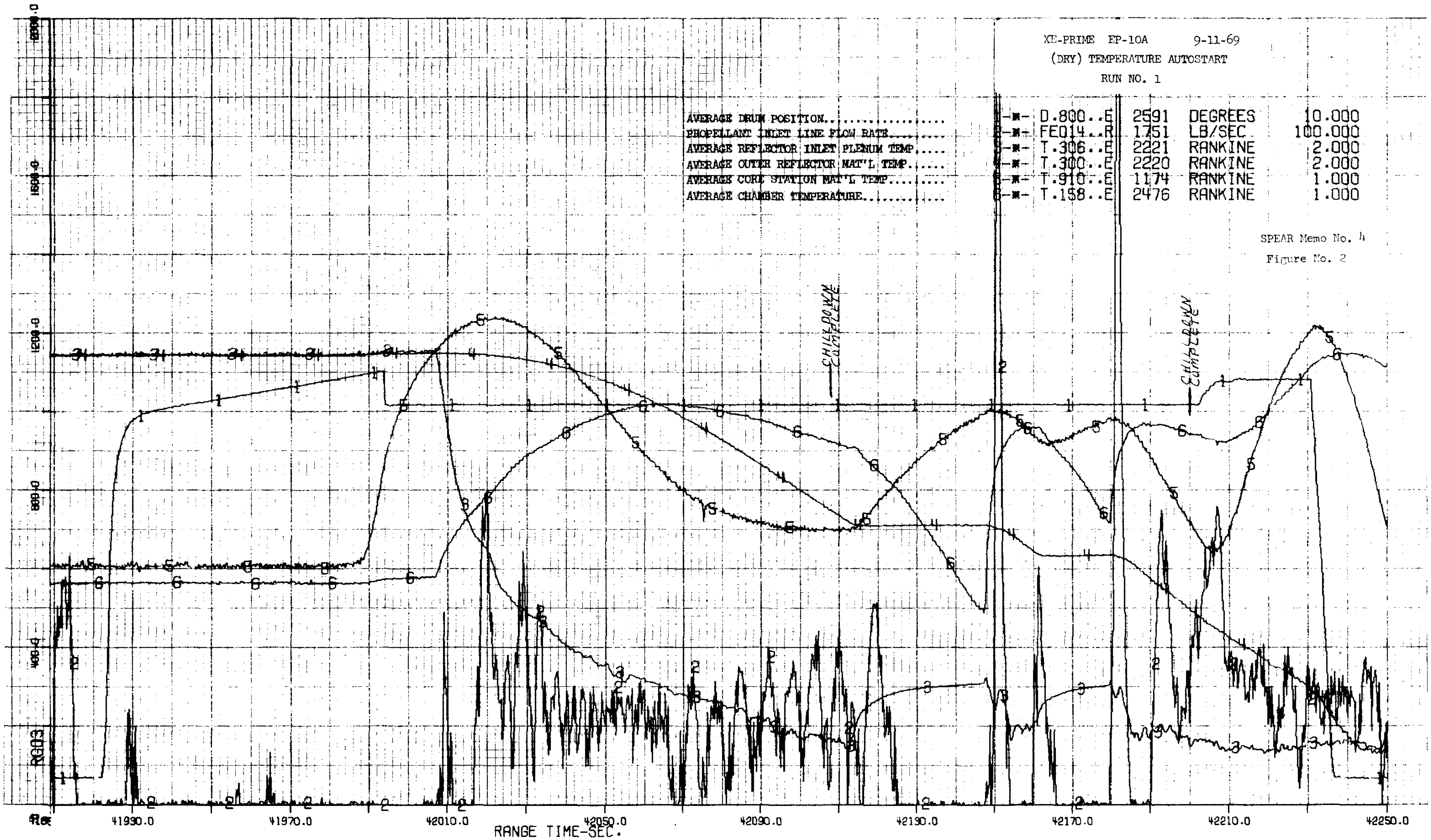
Run No.	Time[1] to Chilldown Complete (Sec)	Delay of Engine Chilldown Following Termination of Drum Program (Sec)	No Flow Hold Period[4] Following Chilldown Complete (Sec)	Time[1] to Re-establish Chilldown Complete (Sec)
1	106	12[5] (60 Planned)	66[2]	21[3] (8)
2	6	69	61	5
3	7	No Hold Planned	59	6
4	19[3] (12)	71	68	9
6	8	54[6]	No Hold	-
7	15	124[7]	202	16

NOTES:

1. From start of PDSV opening.
2. Four second LH_2 pulse was introduced during this hold when T.624 exceeded $1000^{\circ}R$.
3. Actual CD, although T.306 was less than $85^{\circ}R$ at time shown in ( ).
4. From end of PDSV valve closing to beginning of PDSV opening.
5. LH_2 flow was demanded 5 sec after DPT as T.624 exceeded the run limit of $1000^{\circ}R$. The flow was continued and chilldown completed.
6. Two LH_2 pulses during hold with total duration of 13 seconds.
7. One 7-second LH_2 flow pulse during run.

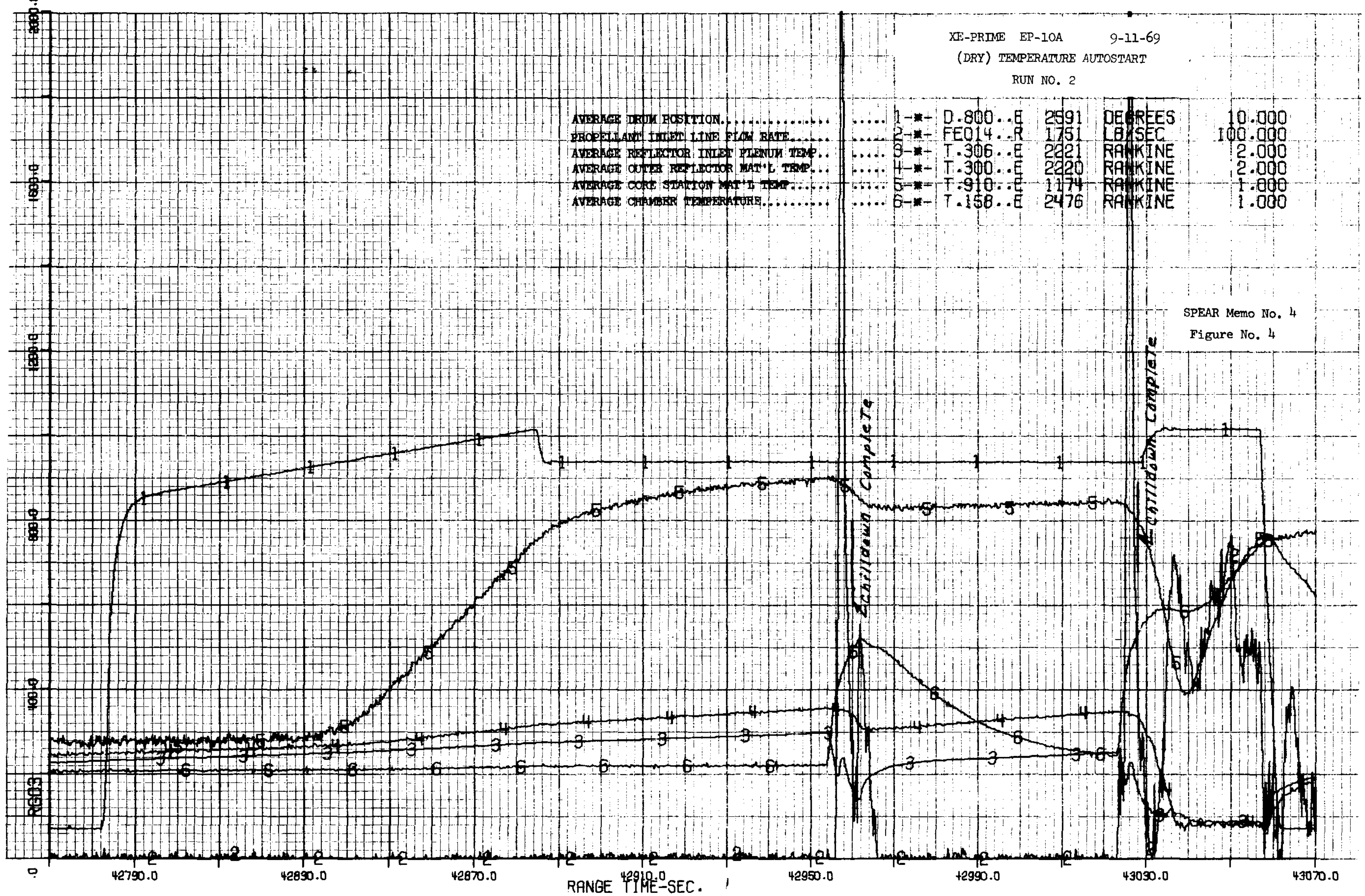

XE-PRIME EP 10A 9-11-69
(DRY) TEMPERATURE AUTOSTART
RUN NO. 1
1-*- D.800. E 2591 DEGREES 10.000
2-*- PWALIN 3201 MW 20.000
3-*- T.910..E 1174 RANKINE 1.000
4-*- T.622..E 2240 RANKINE 1.000
5-*- T.624..E 1173 RANKINE 1.000
6-*- PDSV 2191 DEGREES 2.000
Figure No 1
LINEAR POWER KW
DRUM PROGRAM TERMINATE (DPT)
1st Indication of Power Increase
PDSV COMMANDED OPEN
Chilldown Complete
PDSV COMMANDED CLOSE
PDSV COMMANDED OPEN
PDSV COMMANDED CLOSED
PDSV COMMANDED OPEN
Chilldown Complete
PDSV COMMANDED CLOSED
41930 0
41970 0
42010 0
42050 0
42090 0
42130 0
42170 0
42210 0
42250 0
RANGE TIME-SEC.


XE-PRIME EP-10A 9-11-69
(DRY) TEMPERATURE AUTOSTART
RUN NO. 1
1-*- D.800..E 2591 DEGREES 10.000
2-*- PWALIN 3201 MW 20.000
3-*- T.910..E 1174 RANKINE 1.000
4-*- T.622..E 2240 RANKINE 1.000
5-*- T.624..E 1173 RANKINE 1.000
6-*- PDSV 2191 DEGREES 2.000
SPEAR Memo No. 4
Figure No. 1
LINEAR POWER - KW
DRUM PROGRAM TERMINATE (DPT)
1st Indication of Power Increase
PDSV COMMANDED OPEN
Chilldown Complete
PDSV COMMANDED CLOSE
PDSV COMMANDED OPEN
PDSV COMMANDED CLOSED
PDSV COMMANDED OPEN
Chilldown Complete
PDSV COMMANDED CLOSED
41930.0
41970.0
42010.0
42050.0
42090.0
42130.0
42170.0
42210.0
42250.0
RANGE TIME-SEC.

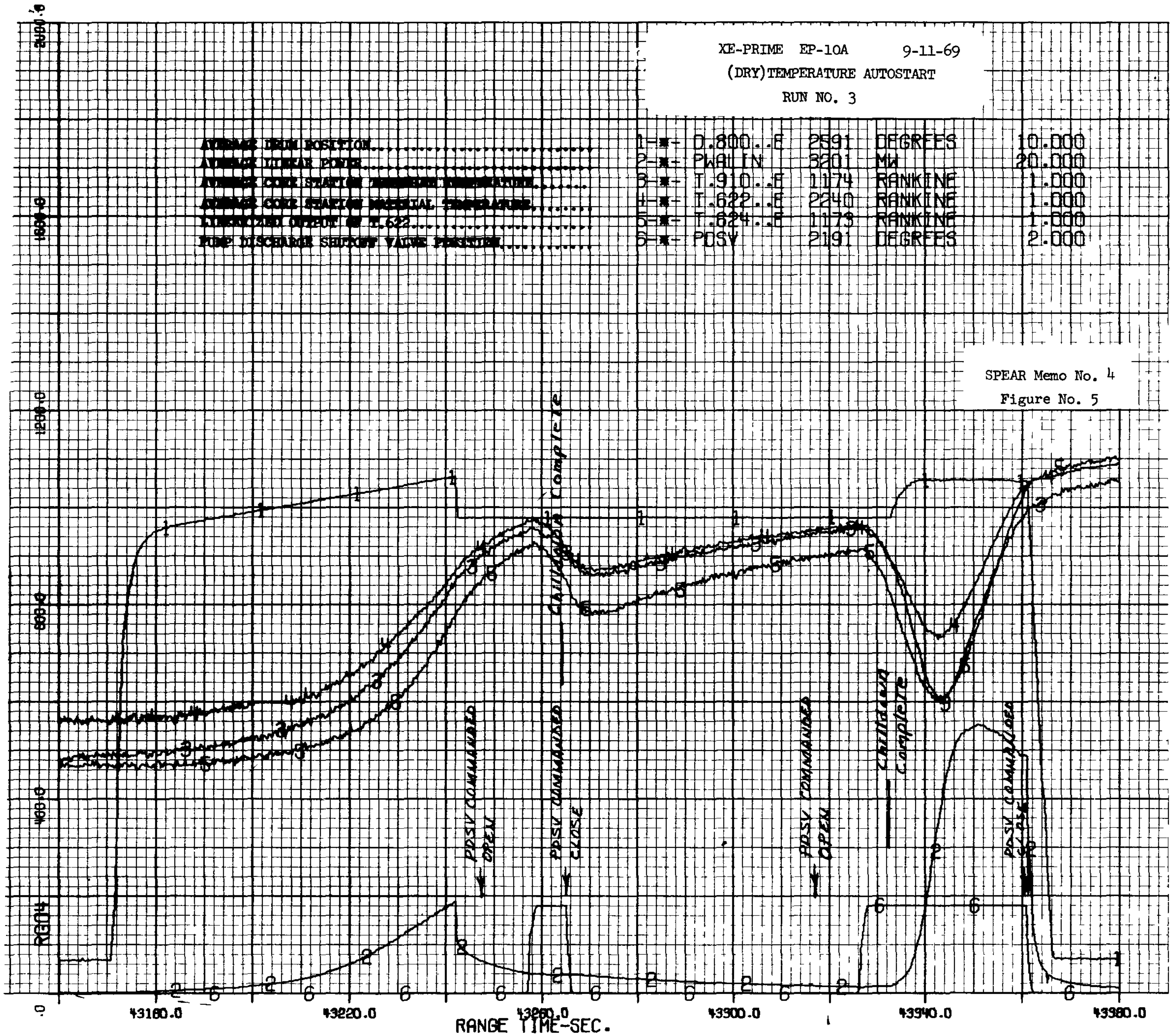


SPEAR Memo No. 4

Figure No. 2

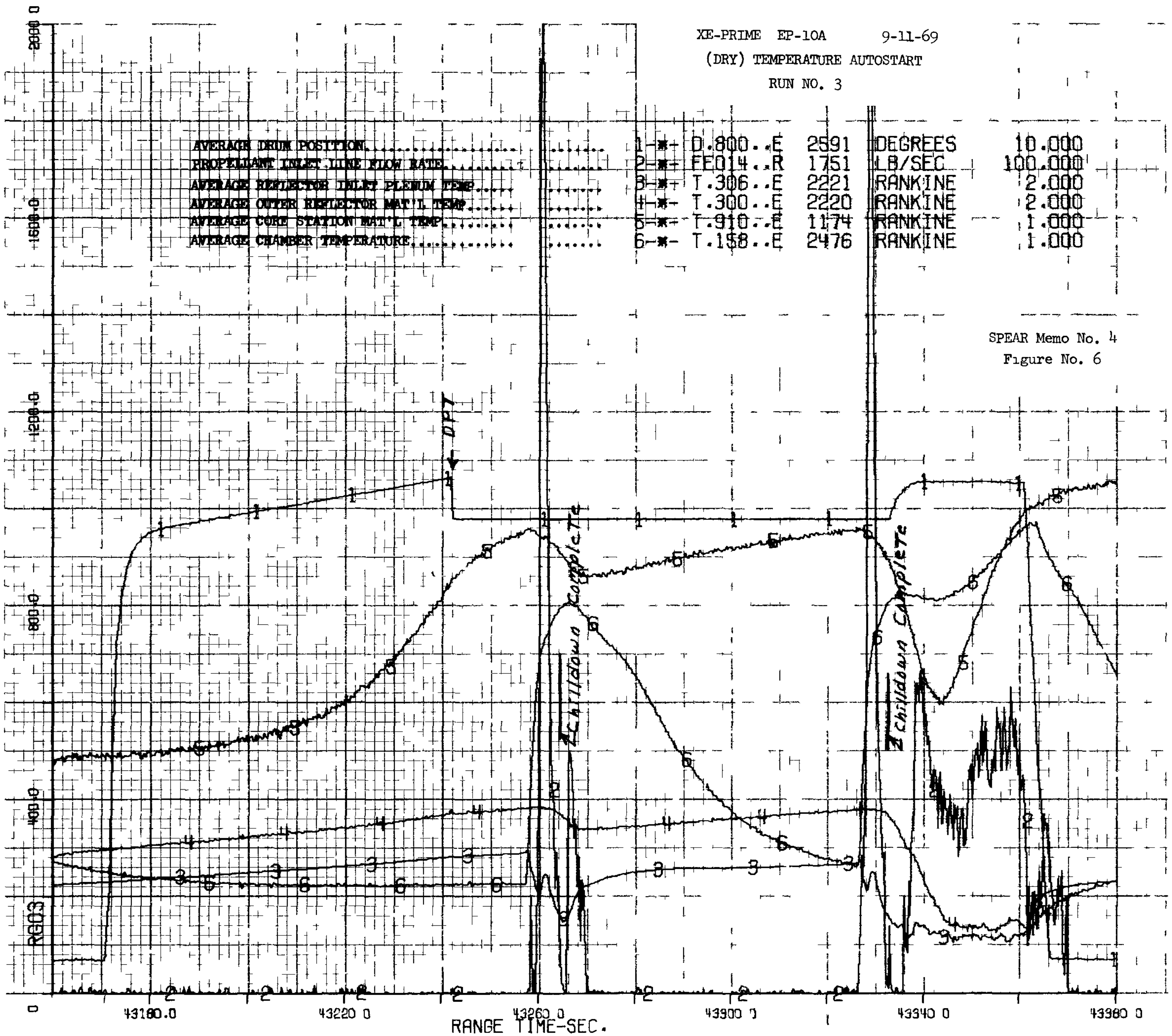


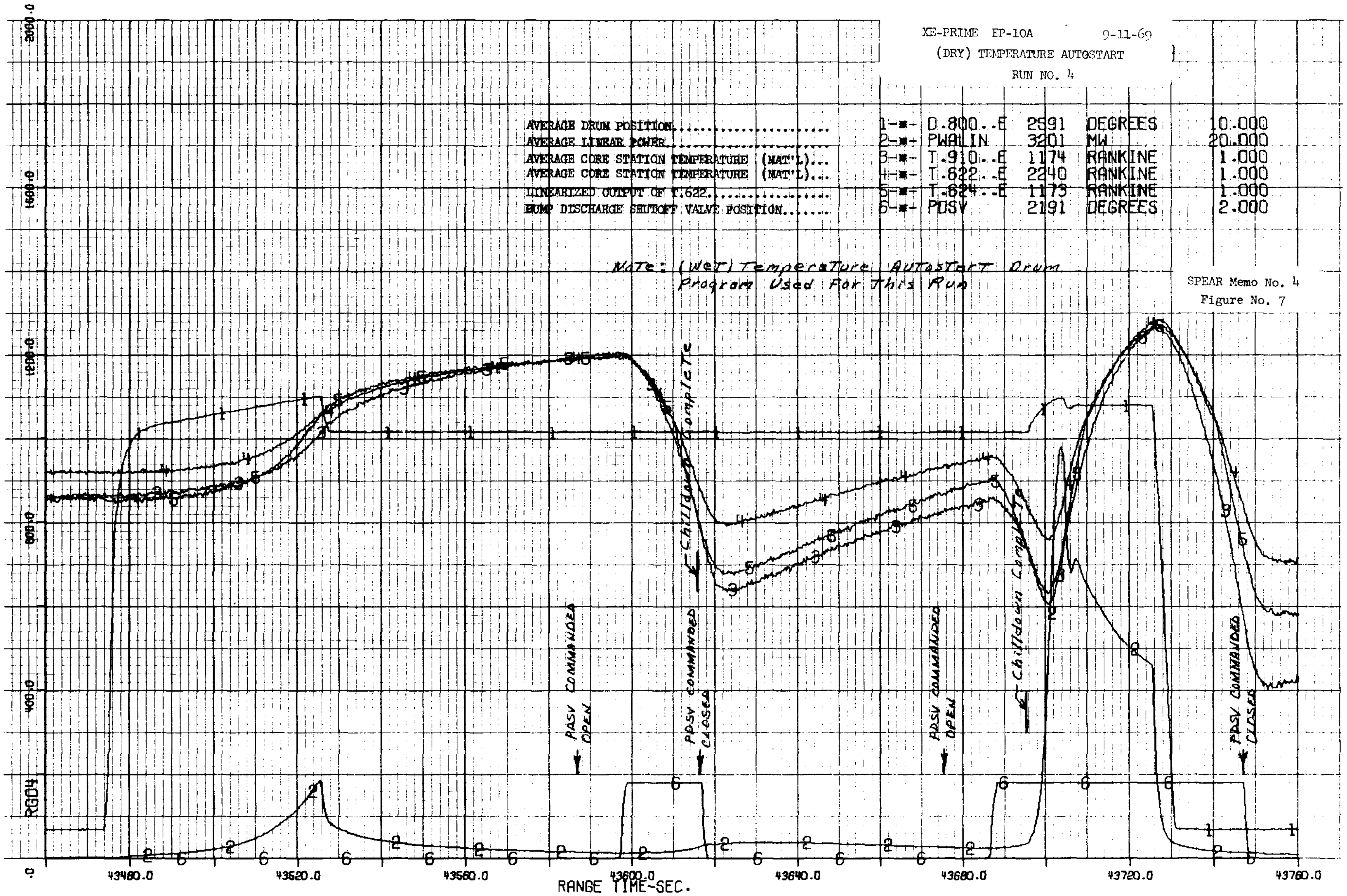
XE-PRIME EP-10A 9-11-69
(DRY) TEMPERATURE AUTOSTART
RUN NO. 2
AVERAGE DRUM POSITION........ 1-*- D.800..E 2591 DEGREES 10.000
PROPELLANT INLET LINE FLOW RATE...... 2-*- FE014..R 1751 LB/SEC 100.000
AVERAGE REFLECTOR INLET PLENUM TEMP.. 3-*- T.306..E 2221 RANKINE 2.000
AVERAGE OUTER REFLECTOR MAT'L TEMP.. 4-*- T.300..E 2220 RANKINE 2.000
AVERAGE CORE STATION MAT'L TEMP..... 5-*- T.910..E 1174 RANKINE 1.000
AVERAGE CHAMBER TEMPERATURE........ 6-*- T.158..E 2476 RANKINE 1.000
SPEAR Memo No. 4
Figure No. 4
Chilldown Complete
Chilldown Complete
0.
400.0
800.0
1200.0
1600.0
2000.0
42790.0
42830.0
42870.0
42910.0
42950.0
42990.0
43030.0
43070.0
RANGE TIME-SEC.



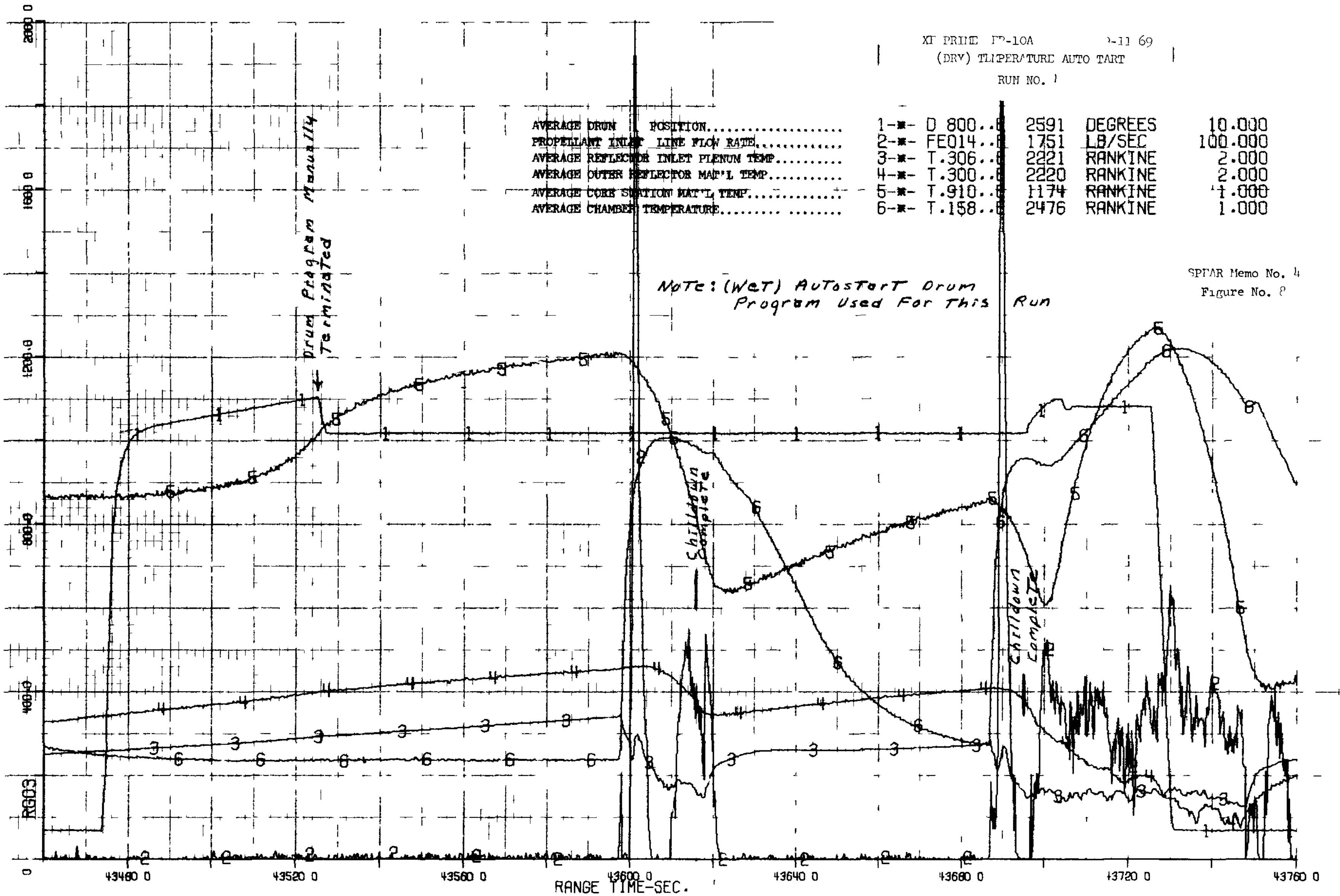
SPEAR Memo No. 4

Figure No. 5

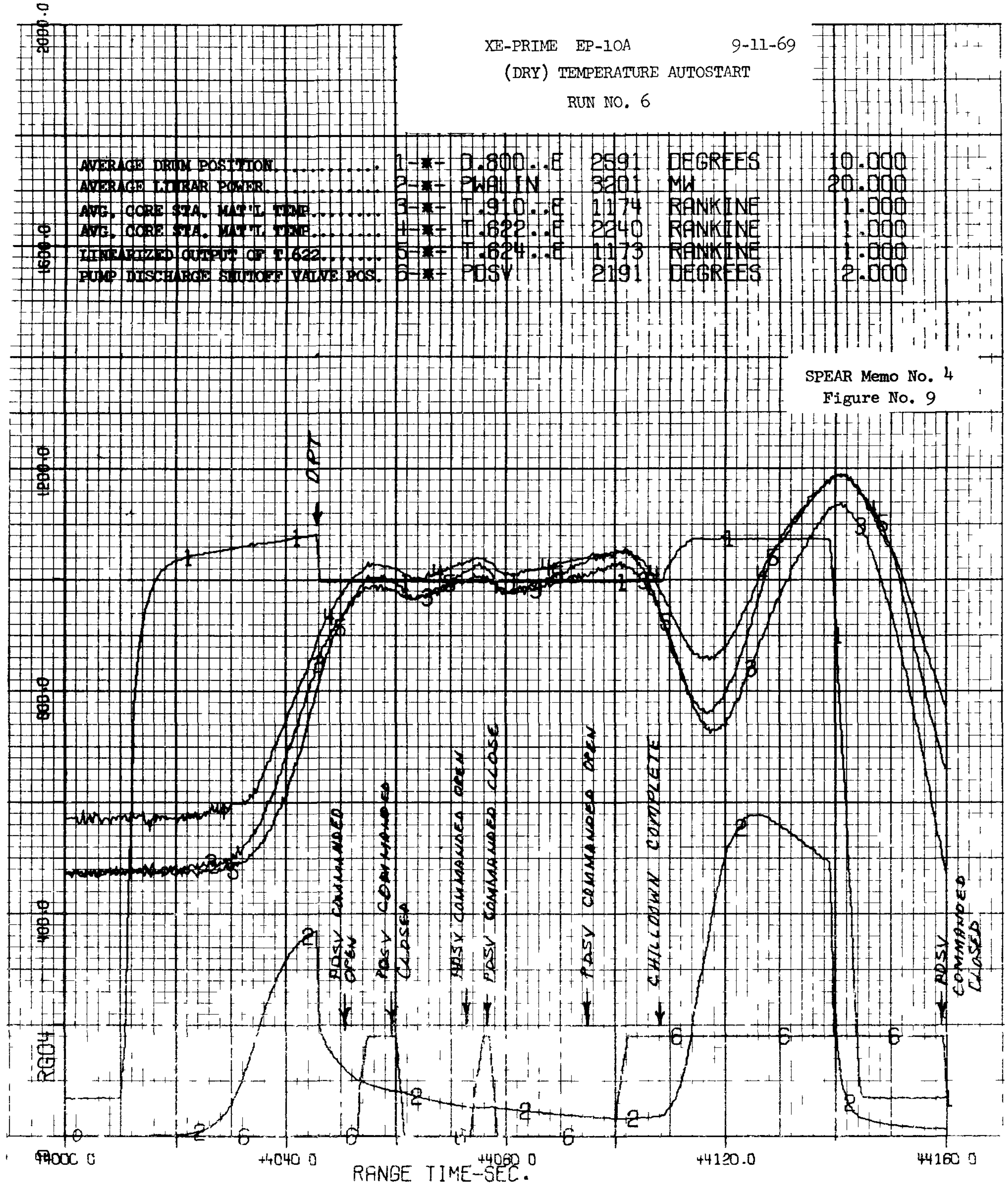

XE-PRIME EP-10A 9-11-69
(DRY) TEMPERATURE AUTOSTART
RUN NO. 3
AVERAGE DRUM POSITION 1-*- D.800..E 2591 DEGREES 10.000
PROPELLANT INLET LINE FLOW RATE 2-*- FE014..R 1751 LB/SEC 100.000
AVERAGE REFLECTOR INLET PLENUM TEMP 3-*- T.306..E 2221 RANKINE 2.000
AVERAGE OUTER REFLECTOR MAT'L TEMP 4-*- T.300..E 2220 RANKINE 2.000
AVERAGE CORE STATION MAT'L TEMP 5-*- T.910..E 1174 RANKINE 1.000
AVERAGE CHAMBER TEMPERATURE 6-*- T.158..E 2476 RANKINE 1.000
SPEAR Memo No. 4
Figure No. 6
DPT
Chilldown Complete
Chilldown Complete
2000.0
1600.0
1200.0
800.0
400.0
0
RG03
43180.0
43220.0
43260.0
43300.0
43340.0
43380.0
RANGE TIME-SEC.



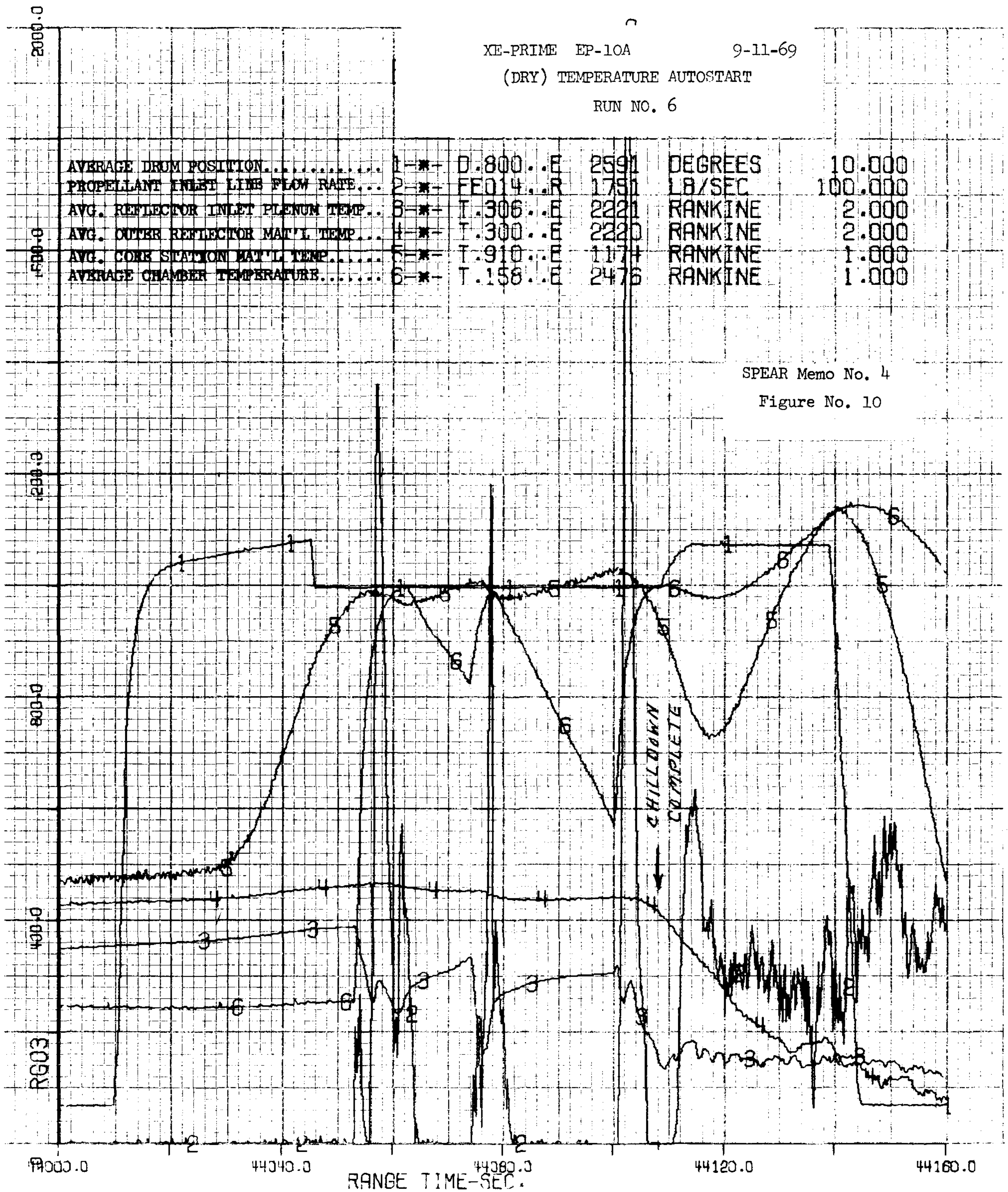
SPEAR Memo No. 4
Figure No. 7



XT PRIME EP-10A -11 69
(DRY) TEMPERATURE AUTO TART
RUN NO. 1
AVERAGE DRUM POSITION.................... 1-*- D 800..6 2591 DEGREES 10.000
PROPELLANT INLET LINE FLOW RATE............ 2-*- FE014..6 1751 LB/SEC 100.000
AVERAGE REFLECTOR INLET PLENUM TEMP.......... 3-*- T.306..6 2221 RANKINE 2.000
AVERAGE OUTER REFLECTOR MAT'L TEMP........... 4-*- T.300..6 2220 RANKINE 2.000
AVERAGE CORE STATION MAT'L TEMP.............. 5-*- T.910..6 1174 RANKINE 1.000
AVERAGE CHAMBER TEMPERATURE................ 6-*- T.158..6 2476 RANKINE 1.000
SPEAR Memo No. 4
Figure No. 8
NoTe: (WeT) AuToStarT Drum Program Used For This Run
Drum Program Manually Terminated
Childown Complete
Childown Complete
2000 0
1600 0
1200.0
800.0
400.0
0
RG03
43480 0
43520 0
43560 0
43600 0
43640 0
43680 0
43720 0
43760 0
RANGE TIME-SEC.

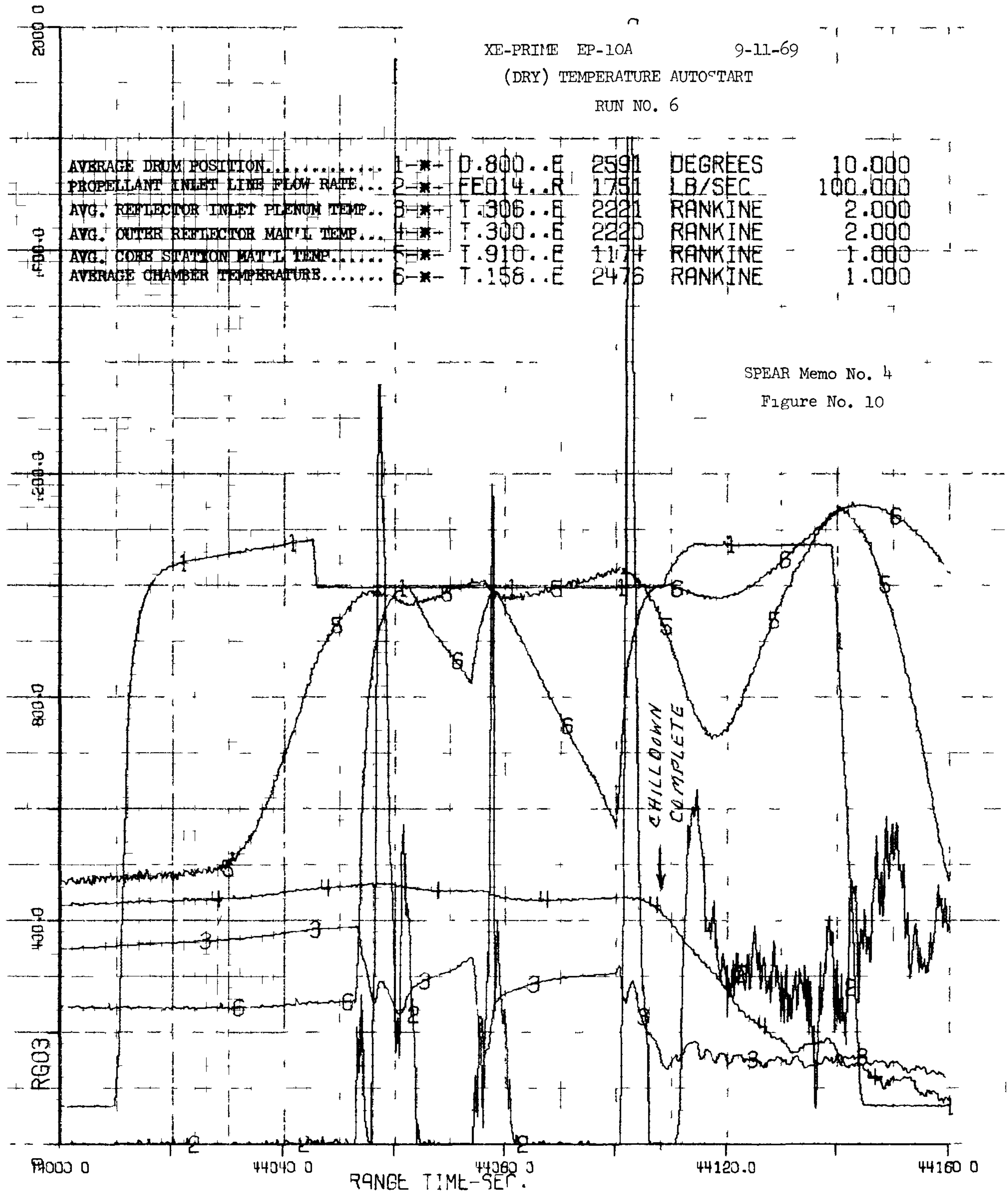


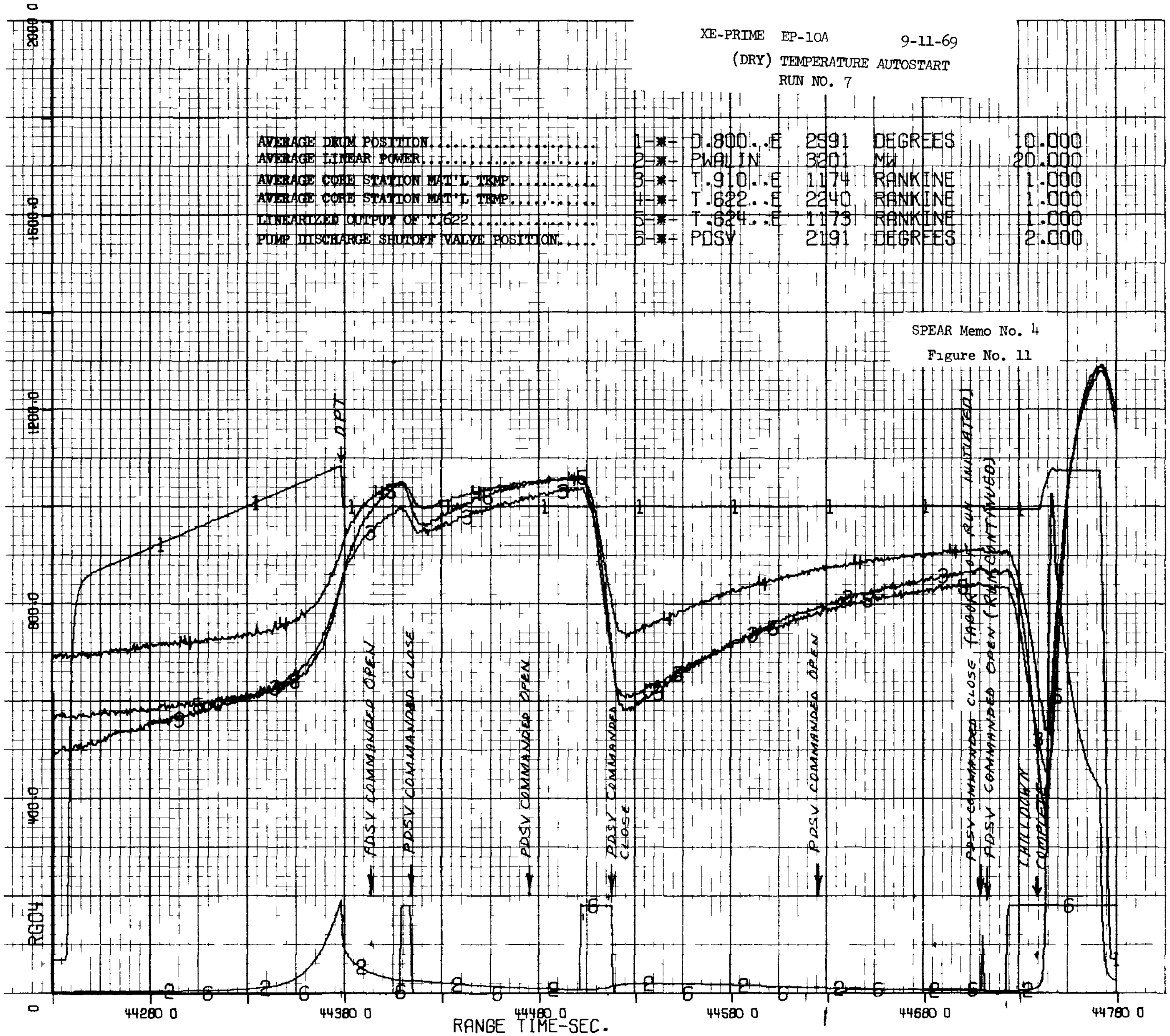
SPEAR Memo No. 4
Figure No. 9



SPEAR Memo No. 4

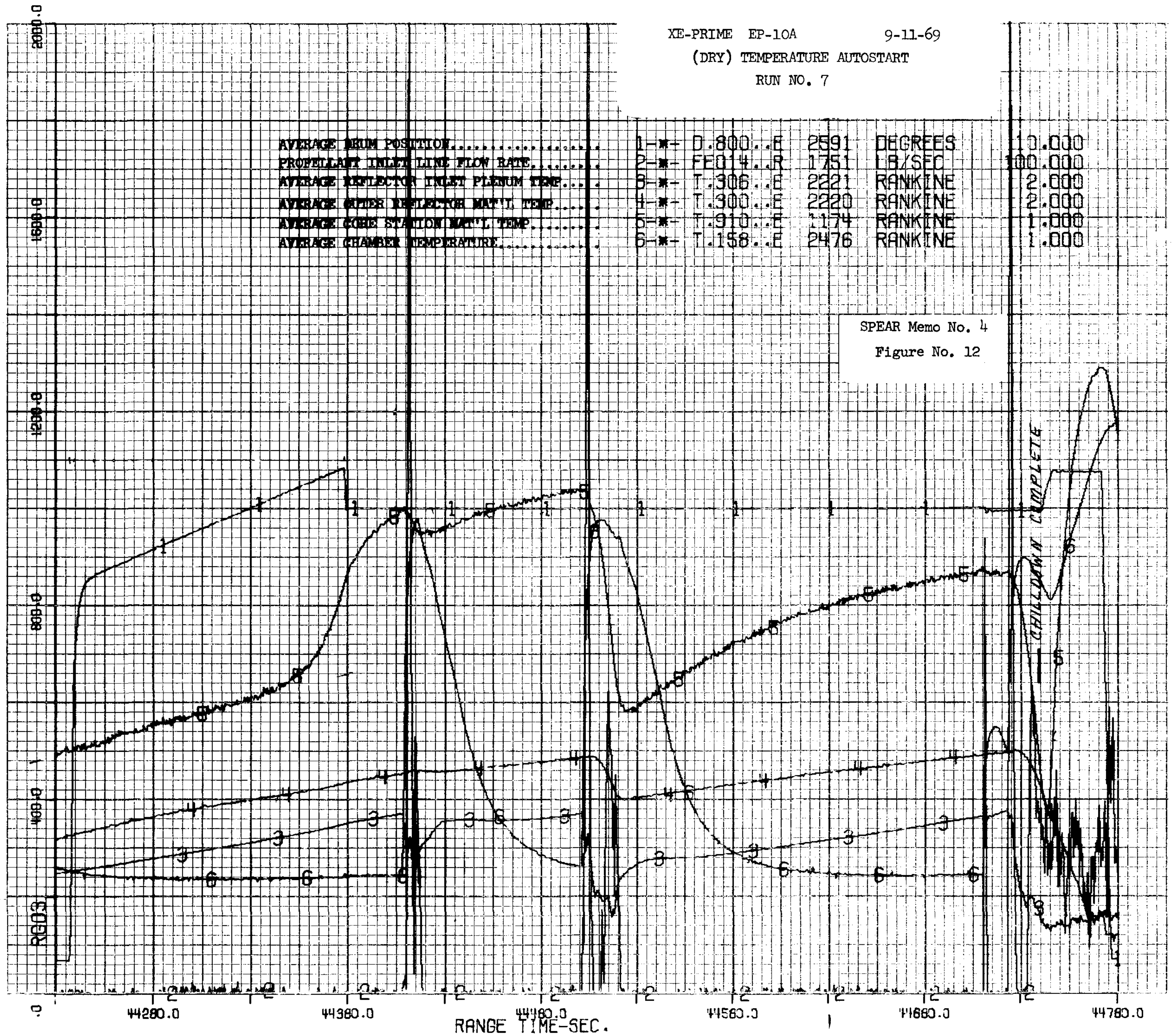
Figure No. 10


XE-PRIME EP-10A 9-11-69
(DRY) TEMPERATURE AUTOSTART
RUN NO. 6
AVERAGE DRUM POSITION............ 1-✱- D.800..E 2591 DEGREES 10.000
PROPELLANT INLET LINE FLOW RATE... 2-✱- FE014..R 1751 LB/SEC 100.000
AVG. REFLECTOR INLET PLENUM TEMP.. 3-✱- T.306..E 2221 RANKINE 2.000
AVG. OUTER REFLECTOR MAT'L TEMP... 4-✱- T.300..E 2220 RANKINE 2.000
AVG. CORE STATION MAT'L TEMP...... 5-✱- T.910..E 1174 RANKINE 1.000
AVERAGE CHAMBER TEMPERATURE....... 6-✱- T.158..E 2476 RANKINE 1.000
SPEAR Memo No. 4
Figure No. 10
CHILLDOWN COMPLETE
2000.0
1600.0
1200.0
800.0
400.0
RG03
44000.0
44040.0
44080.0
44120.0
44160.0
RANGE TIME-SEC.

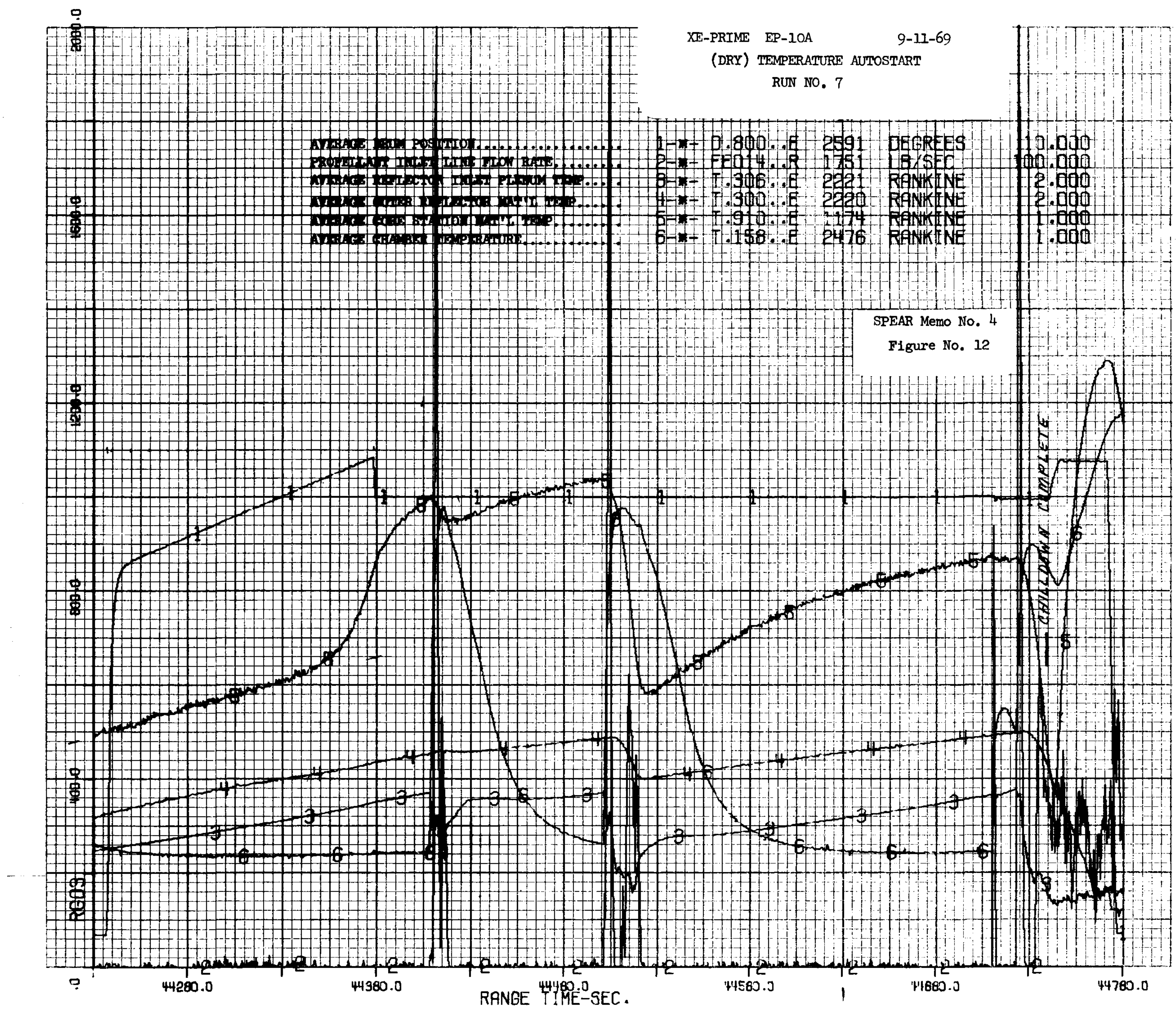


SPEAR Memo No. 4

Figure No. 11



SPEAR Memo No. 4
Figure No. 12



SPEAR Memo No. 4

Figure No. 12

SPEAR Memo No. 5

SPEAR Team

KRC

XE-PRIME

EP-10A

Subject: ENGINE AND REACTOR COMPONENT THERMAL PERFORMANCE DURING LAMINAR FLOW TESTS

SUMMARY

The Laminar Flow tests, conducted in two parts, one with LH_2 and one with GH_2 engine flows, were conducted to investigate reactor flow and temperature asymmetries and flow stability under low flow conditions. Considerable fluid temperature asymmetry was noted during the LH_2 test; very little noted during the GH_2 test. No instability conditions were apparent; although localized instability that did not express itself in the individual measurements could have existed. Also, equilibrium conditions were never achieved, thus, an evaluation of the flow stability under extended steady-state conditions could not be made. Detailed source engineering analysis and evaluation are required for a full understanding of the phenomena which occurred.

TECHNICAL DISCUSSION

A. Introduction

The objectives of the laminar flow tests were:

1. To investigate flow instability at NERVA maximum and minimum core inlet temperatures during cooldown.

2. To provide information on temperature asymmetries associated with LH_2 and GH_2 flow.

Laminar flow instability is a condition occurring under low flow, high heat flux conditions in which $(\partial \Delta P/\partial \dot{W})$ Q* may be zero or negative. In this situation, a decrease in flow would result in an increase in the temperatures which would result in further decreases in flow. Should such a condition exist in the core the flow in some passages will decrease and those areas will become increasingly warmer. Localized hot spots with temperatures in excess of the allowable limits could occur.

Phoebus test data and other experimental work have provided information for the calculation of the approximate flows, core inlet and core outlet temperatures in which this phenomena would occur. The runs of EP-10A were

* ΔP = Pressure Drop
W = Mass Flowrate
Q = Heat Flux

Technical Discussion (Cont'd)

planned to provide data both within and outside of this regime with LH_2 and ambient GH_2 flow to the engine.

Since the amount of instrumentation is small with respect to the number of flow channels, highly localized hot spots may not be detected from this test. Due to the other effects of two-phase fluid, impedance induced asymmetries, conduction, and transient functions, a positive determination of the existence of instability is beyond the scope of this analysis. Only a cursory evaluation of the results of the tests are made here. A detailed follow-on analysis should be made.

Data sources for this memo are NTO Thin Data Tapes, NRO Plots and WANL Plots.

B. LH_2 Flow Test

Liquid hydrogen was supplied to the engine for the LH_2 flow test from the cooldown system (V-5002) through a bypass around PCV-472. This bypass included a small capacity turbine flowmeter and a pressure control valve, PCV-910. The accuracy of the flow rates obtained from this meter are presently questionable. This meter and the method used for computer flow rate are discussed in Memo No. 8.

Both the LH_2 and GH_2 flow tests were run without the steam generator system. A GN_2 purge flow of about 6.5 lb/sec was maintained into the ETC to provide a positive dynamic pressure at the duct exit to prevent air intrusion.

The LH_2 flow test was initiated with a chilldown of the LH_2 cooldown system to the CSV. Flow was established and maintained through the cool-down system with PCV-472, PCV-543 and CVV to maintain the line chill.

The engine initial thermal conditions were: the mid-core material temperatures were about 450°R while the remainder of the system through the nozzle torus, nozzle, reflector (T.306 = 320°R and T.300 = 280°R), dome (210°R) and core inlet (210°R) was chilled. The core exit (core support temperature was 400°R) and nozzle chamber were also chilled (345°R, indicated). The initial power level was about 40 watts.

The reactor was started up manually in position control. At a power level of 10 Kw, the reactor was switched to power control and the power increased to 2.8 Mw. PCV-543 and PCV-472 were closed and PCV-910 opened. CSV was opened and CVV closed initiating LH_2 flow to the engine as the power increased through the 1 Mw level. A 300-second hold was initiated at 2.8 Mw to condition the reactor to a nominal core exit gas temperature (T.680) of 500°R.

Technical Discussion (Cont'd)

At the end of the 300-second hold the power was increased to a nominal level of 8 Mw and a 130-second hold, in power control, initiated. At the conclusion of the hold the power was reduced to 2.8 Mw. It was actually reduced to a minimum of about 0.7 Mw and adjusted up to 2.8 Mw. A hold of 300 seconds was to be made at this level to recondition the core to a nominal core exit gas temperature of 500°R. However, it was terminated after approximately 127 seconds when stable temperatures were achieved. The power was then increased to 11 Mw and a 95-second hold made. The power was again reduced to 2.8 Mw (as before, it was actually reduced to about 0.4 Mw and then adjusted up to 2.8 Mw). Stable core exit gas temperatures of 500°R were achieved after about 70 seconds and the hold terminated. The power was then increased to 14 Mw. A hold was made at this level for about 70 seconds. The power was then reduced to a minimum of about 0.6 Mw and then adjusted up to 2.8 Mw to recondition the core back to a nominal ambient condition. After a 90-second hold the drums were run in and the LH_2 flow stopped to conclude the LH_2 flow test. The flow, power, drum positions, and various plenum and core material temperatures during the LH_2 flow test are summarized in Figures 1, 2 and 3.

During the initial power hold (at 2.8 Mw), the system, through the core inlet, was being chilled and the core was being conditioned to a steady-state thermal level with a core exit gas temperature of 500°R. The average chamber temperature increased to a nominal level of about 450°R and held fairly steady.

The temperature measurements in the various system plenums (nozzle torus, reflector inlet, dome end) at the core exit and in the chamber are shown in Figures 4 through 10. The azimuthal location and the measurement values in various plenums are shown in Tables I, II and III for various times during the LH_2 flow test. The nozzle torus temperatures do not indicate any significant asymmetry. However, the temperature and pressure conditions in the torus tend to indicate (within the accuracy of the data) two-phase conditions. Thus, while the temperatures were nearly constant, there could have been a great density variance in the torus which would give a corresponding variance in flow rates into the nozzle tubes. The measurements in the reflector inlet (Figure 5 and Tables 1 through 3) show asymmetry in this region. During the low temperature periods it appears that some of the measurements are indicating two-phase fluid conditions. As mentioned above there can be a big variance under such conditions in the energy and density through the regions sampled by the measurements, even though the indicated temperatures are constant. One measurement, TT 373, taken at an angular location of 223 degrees, always reads higher than the others, indicating a warm region at that location.

Asymmetry developed in the dome end and core inlet plenums during the initial chilldown transient (Figure 6 and 7) with a maximum spread of about 100°R in the former plenum and 130°R in the core inlet plenum. During the subsequent transients, both increasing and decreasing, the asymmetries remained fairly constant, with a spread of 50° to 150°R. Within the core inlet plenum there was one measurement that tended to respond somewhat differently than the others. The degree of variation was not great however, and it did not indicate either of the extreme values.

Technical Discussion (Cont'd)

During the chilldown period the chamber temperature initially increased rapidly to about 420°R as flow was established, and then increased gradually to about 485°R (see Figure 10). From this point the four chamber temperature readings began to diverge indicating that an asymmetry pattern was being developed in the chamber plenum. Initially TE138 and TE140 continued to increase and then leveled out at about 525°R. The other two measurements, TE141 and 144, however, turned around and began decreasing, reaching an indicated minimum of 375°R when power was increased. The response of these thermocouples tends to indicate an unstable flow pattern out of the core. However, any instability is in the decreasing temperature direction. There was a difference in response characteristics of the four chamber temperatures during the later temperature transients with TE141 and TE144 (which also normally gave the colder readings) always turning around and going in the reverse direction in advance of the peaking or bottoming out of the other two. Variations between the four individual chamber temperatures of up to 700°R (400°R to 1100°R) were recorded. The four peripheral temperature samples represented by these four measurements can only provide a very broad overall indication of the temperature patterns emitted into the chamber plenum.

The response of the various thermocouples measuring the core exit gas temperatures was very similar to that displayed by the chamber temperature thermocouples. An asymmetry developed during the initial system chilldown and then this asymmetry developed and diminished during decreasing and increasing temperature transients, respectively. Some variation in response (with crossing over) is seen in these measurements. However, this apparently reflects a change in radial temperature distribution rather than an azimuthal variation.

The asymmetries in the core exit gas and chamber temperatures developed during the decreasing temperature transients but diminished, and the pattern became fairly uniform, during the increasing temperature transients. This was in opposition to the trend displayed in EP-4A (SPEAR Memo No. 4) where the asymmetry appeared to develop during increasing temperature transients. In this latter case the power adjustments were very gradual and the flow rate was greater (4 lb/sec); whereas, in the LH_2 flow test the power changes occurred very fast and the flow rate was 1.7 lb/sec. This difference in rate of power adjustment and flow rates may provide an explanation of the opposite trends displayed in the two EP's.

The temperatures indicate distinct hot and cold areas that appeared to extend from plenum to plenum. The asymmetry was fairly constant at the core inlet; whereas, it diminished during increasing temperature transients and developed during decreasing temperature transients at the core exit and in the chamber. A hold with equilibrium conditions was never achieved, however, so no conclusion can be drawn as to whether the asymmetry exhibited at the peak temperatures would have remained small or may have increased with time.

Technical Discussion (Cont'd)

A cursory examination was made of the core material temperature measurements. This data indicated the existence of temperature asymmetries at the various core stations. Figures No. 11, 12 and 13 show the temperature data at Station 3 during the LH_2 flow test. Typically, the warmest areas were in the 180° and 223 azimuthal locations with colder areas in the 315 to 0° locations. The existence of these conditions for both high and low heat generation (power) and a constant flow indicated that no unstable condition existed. Flow and temperature instability could have existed in localized areas which did not influence the areas sampled by the temperature measurements.

During the power increases, the data indicated a relative increase in the "nearer-center" material temperatures compared to the peripheral temperatures and little relative change in the azimuthal asymmetry.

Further evaluation of the system plenum temperature measurements and the various core station material temperatures should be made to establish the correlations and any interactions that may exist between plenum fluid and core material temperature distributions.

C. GH_2 Flow Test

The GH_2 flow test was conducted in a similar manner to the LH_2 flow test. The GH_2 was supplied from the storage bottles and was introduced into the engine through the V-5002 pressurization circuit and the LH_2 cooldown line. RSV-185 was replaced with an open spool. A calibrated orifice was added with the spool to obtain a measurement of the GH_2 flow rate.

The GH_2 flow test was initiated with a manual reactor startup. At 10 Kw the reactor was switched to power control and the power increased to 8 Mw (PWALIN of 7.5 Mw). CSV was opened and CVV closed. PCV-250 was then used to initiate a steady GH_2 flow of 1.5 lb/sec to the engine. A 130-second hold was made with this flow rate and power level. At the termination of the hold period the power was reduced to 100 Kw and the GH_2 flow stopped. LH_2 flow to the engine was pulsed with PSV (PDSV was not used because of the delayed opening characteristics it had displayed in the earlier tests of the EP) and the reactor power increased (to a peak of 1 Mw) to recondition the engine to cold reflector and ambient core conditions, similar to the initial conditions for the first GH_2 flow period.

The power level was brought up to 2.7 Mw, CSV opened, CVV closed, and PCV-250 opened to establish and maintain a steady GH_2 flow of 0.5 lb/sec to the engine. A 386-second hold was initiated. At the end of the hold time the power was reduced to 100 Kw. The GH_2 cooldown system was "readied" and the flow through from PCV-250 terminated. As GH_2 flows decreased, the power was increased to 7.6 Mw. A steady GH_2 flow of 3.0 lb/sec (3.8 lb/sec planned) was then established with PCV-251 and a hold of 80 seconds made. At the end of the hold the power was decreased to 1 Mw and the flow through PCV-251 was terminated. Flow through PCV-250 was reestablished at a steady level of 0.5 lb/sec. A hold of approximately 175 seconds was made at these conditions.

/

The power was then increased to 5 Mw and a hold initiated. It was necessary to terminate the hold after about 112 seconds when the Station 3 temperature hit the test limit of 1230^{o}R. The power was reduced to 100 Kw and flow continued to reduce the core exit gas temperature to about 1100^{o}R. The power was finally reduced to 15 Kw and the flow increased to about 1 lb/sec to bring the temperature down. The GH_2 flow rate was then reduced to 0.2 lb/sec and the power increased to 0.4 Mw. These conditions were held for about 215 seconds. The power was increased to 700 Kw and a 250-second hold initiated. The core exit gas temperature had earlier decreased to about 600^{o}R. After about 207 seconds the power was increased to 1 Mw. After another period of about 480 seconds, the power was further increased to 1.5 Mw. After another 150-second hold period, the GH_2 flow test was terminated with a normal shutdown (the drums run in immediately). After the chamber temperatures were reduced to about 750^{o}R, a Scram was commanded and the GH_2 flow through PCV-250 terminated. The flow, power, and various system temperatures during the GH_2 flow test are shown in Figures No. 14, 15, and 16.

Fluid temperatures in the various plenums are shown on Figures No. 17 through 21. As shown in these figures, there was negligible fluid temperature asymmetries during the GH_2 portion of the run. There were asymmetries present during the LH_2 chilldown of the reflector.

The nozzle chamber thermocouple, TE141, that was reading slightly lower than the others during GH_2 flow, was the highest reading chamber temperature during most of the LH_2 run. During previous EP's, this thermocouple had given lower readings during the higher power operating conditions. At low power and flow conditions, however, it has previously given higher readings.

The GH_2 test demonstrated much the same material temperature phenomena as the LH_2 test in that power or heat flux changes were seen to show up in a change in radial rather than azimuthal distribution, although on a lesser scale. That is, the material temperature at the center of the core peaks faster and higher than the periphery. Figures No. 19 and 20 illustrate this point as it is seen at the core exit gas thermocouples. With very low power and flow the temperatures converge with a spread of less than 100^{o}R. The Core Station 3 material temperatures during the GH_2 test are shown in Figures No. 22, 23, and 24.

CONCLUSIONS

During the LH_2 flow periods there were large azimuthal fluid temperature asymmetries and radial and azimuthal material temperature asymmetries throughout the system. The fluid asymmetries were worst during decreasing temperature transients and low power holds. There was no indication of any flow instability conditions; however, no conclusion can be made at this time as to the possibility of the existence of localized instability conditions.

No significant asymmetries or indications of flow instability occurred during the GH_2 flow periods.

Detailed analysis of this data, along with that of previous EP's and engine tests should be made by Source Engineering to further identify the cause and nature of engine asymmetries.

TABLE I

ENGINE FLUID TEMPERATURE AZIMUTHAL DISTRIBUTION — RT 47930 - 47935

LH$_2$ FLOW, DECREASING TEMPERATURE TRANSIENT

	AZIMUTHAL LOCATION DEGREES: 0–60	60–120	120–180	180–240	240–300	300–360	360–60
REFLECTOR INLET, °R	101 (TT371)		41 (TT374); 87 (TT217)	90 (TT373)	42 (TT218)	37 (TT372); 52 (TT219)	101 (TT371)
CORE INLET, °R	123; 152	95	72	171; 156	153; 76	53; 118	123
*CORE STA. 5, °R	350, 452, 585, 623, 690, 615	483; 396	394; 369	806; 738; 901	340	392; 397; 500; 569; 466	350, 452, 585, 623, 690, 615
NOZZLE CHAMBER, °R	816 (TE138)			895 (TE140)	329 (TE144)	324 (TE141)	816 (TC138)

*Not absolute temperatures, but difference from an arbitrary value.

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TABLE II

ENGINE FLUID TEMPERATURE AZIMUTHAL DISTRIBUTION RT 48170 - 48175

LH_2 FLOW, HIGH POWER PEAK

	AZIMUTHAL LOCATION DEGREES 0–60	60–120	120–180	180–240	240–300	300–360	360–60
REFLECTOR INLET, °R	X 68 (TT371)		X 72 (TT374); X 127 (TT217)	X 136 (TT373)	X 93 (TT218)	X 69 (TT372); X 93 (TT219)	X 68 (TT371)
CORE INLET, °R	143; 155	130	110; 169; 157	130	158; 110	138	
*CORE STA. 5, °R	436; 429; 417; 381; 379; 322; 20	265; 29	182; 322; 102	69; 422		150; 261; -33; 120	436; 429; 417; 381; 379; 322; 20
NOZZLE CHAMBER, °R	X 1122 (TE138)			X 1102 (TE140)	X 1132 (TE144)	X 1092 (TE141)	X 1122 (TE138)

*Not absolute temperatures, but difference from an arbitrary value.

TABLE III

ENGINE FLUID TEMPERATURE AZIMUTHAL DISTRIBUTION RT 48685 - 48690

LH$_2$ FLOW, LOW POWER

	AZIMUTHAL LOCATION DEGREE						
	0–60	60–120	120–180	180–240	240–300	300–360	360–60
REFLECTOR INLET, °R	X 72 (TT371)		X 37 (TT374) X 66 (TT217)	X 48 (TT373)	X 54 (TT218)	X 36 (TT372) X 55 (TT219)	X 72 (TT371)
CORE INLET, °R	100 118	59 41	147 131	133	64	20 99	100
*CORE STA. 5, °R	314 346 404 454 461 411 469	324 423	400 352 569	522 593	532	477 476 354 382	314 346 404 454 461 411 469
NOZZLE CHAMBER, °R	X 526 (TE138)			X 581 (TE140)	X 233 (TE144)	X 222 (TE141)	X 526 (TE138)

*Not absolute temperatures, but difference from an arbitrary value

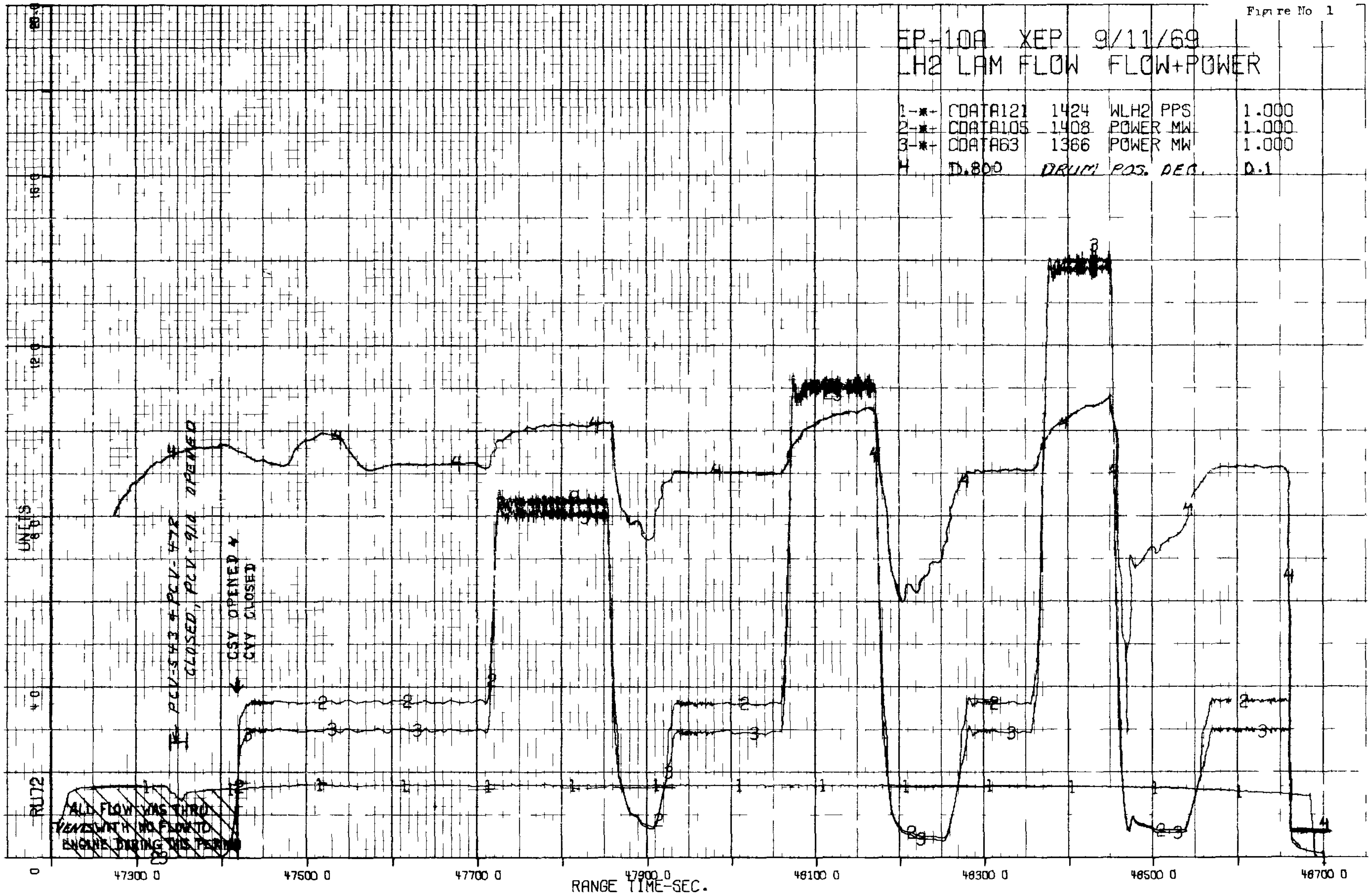
EP-10A XEP 9/11/69
LH2 LAM FLOW FLOW+POWER
1-*- CDATA121 1424 WLH2 PPS 1.000
2-*- CDATA105 1408 POWER MW 1.000
3-*- CDATA63 1366 POWER MW 1.000
4 D.800 DRUM POS. DEG. 0.1
PCV-543 + PCV-478 CLOSED, PCV-910 OPENED
CSV OPENED + CYV CLOSED
ALL FLOW WAS THRU VENTS WITH NO FLOW TO ENGINE DURING THIS PERIOD
UNITS
RANGE TIME-SEC.
47300 0
47500 0
47700 0
47900 0
48100 0
48300 0
48500 0
48700 0

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Figure No. 2

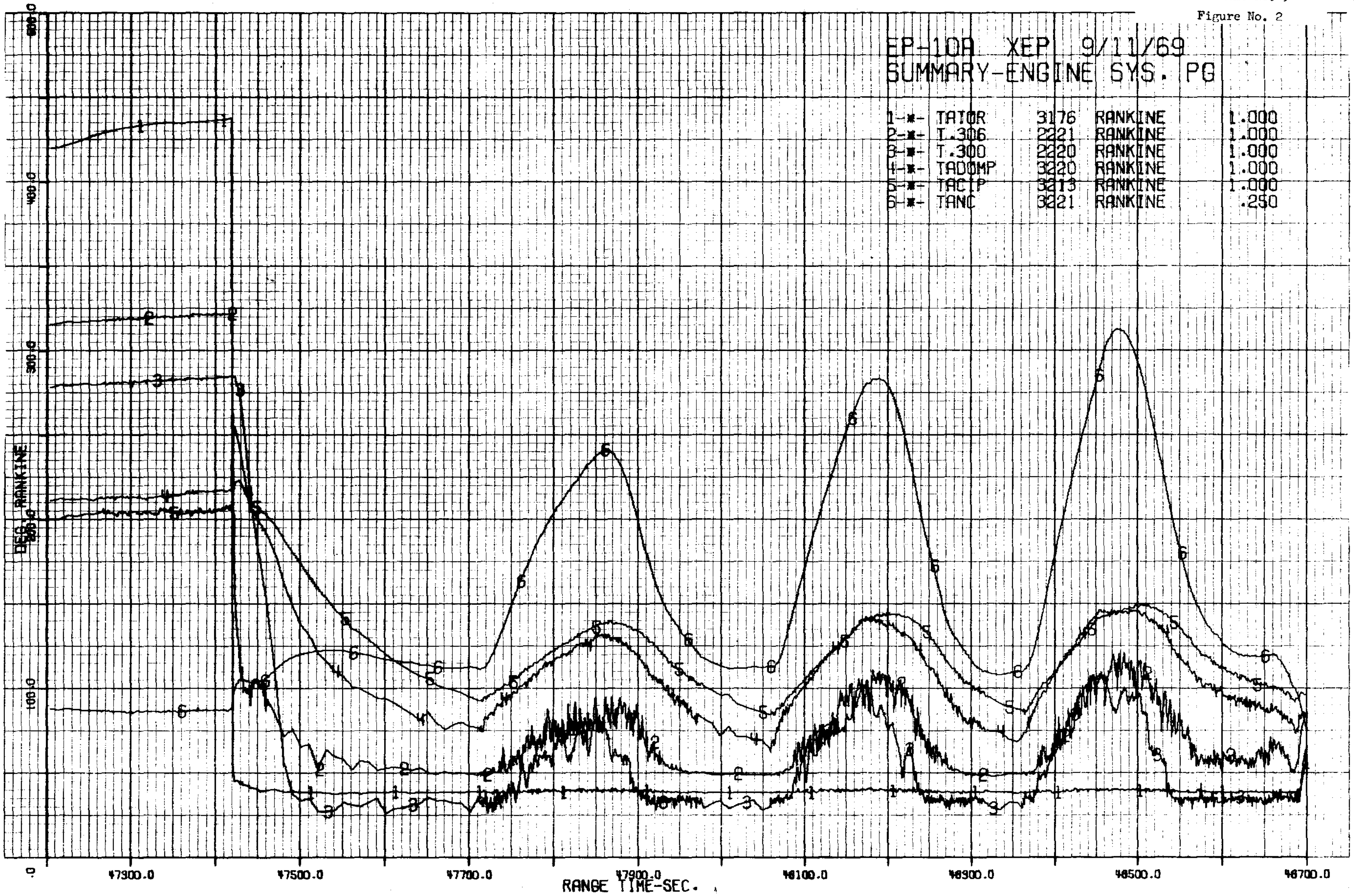

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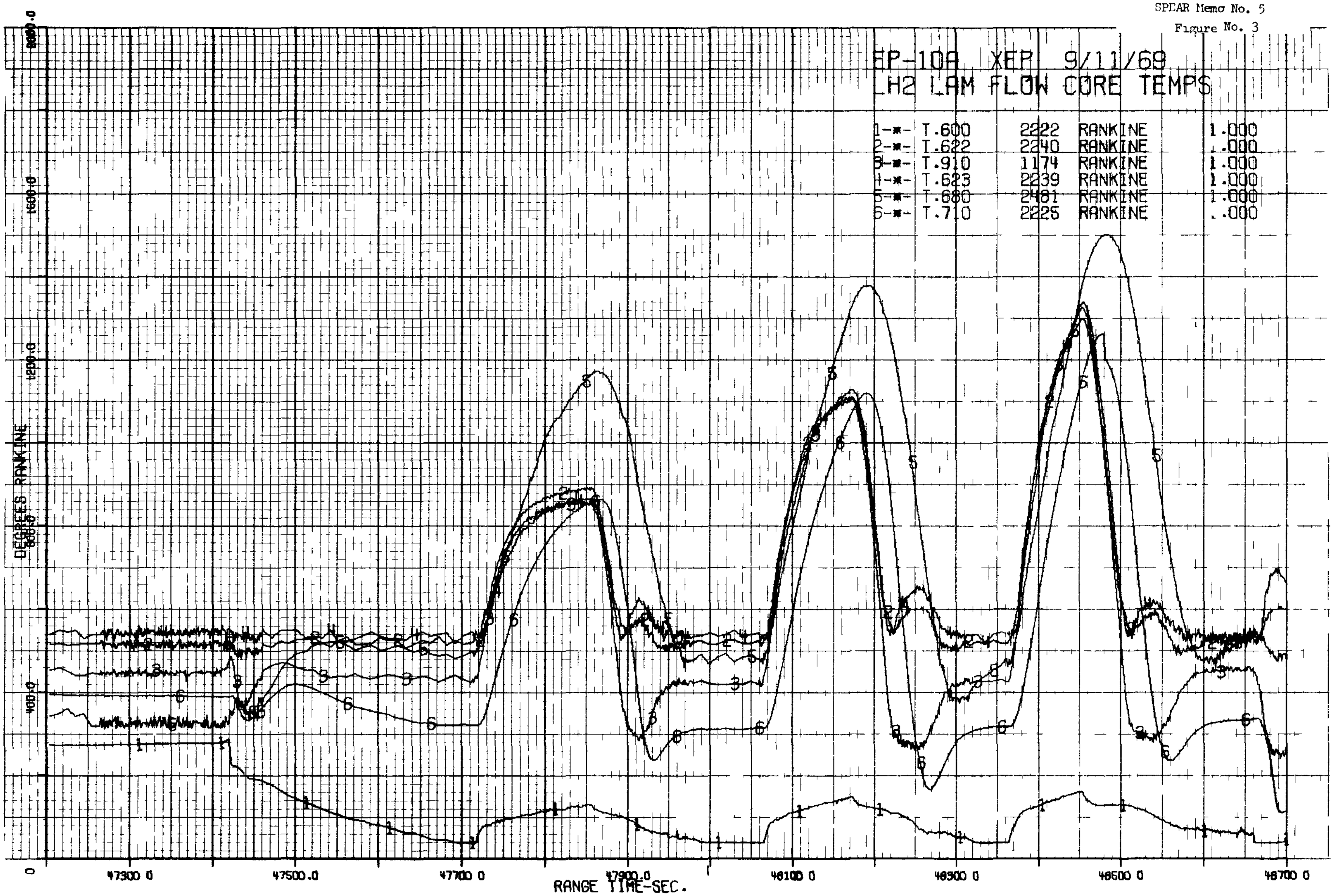
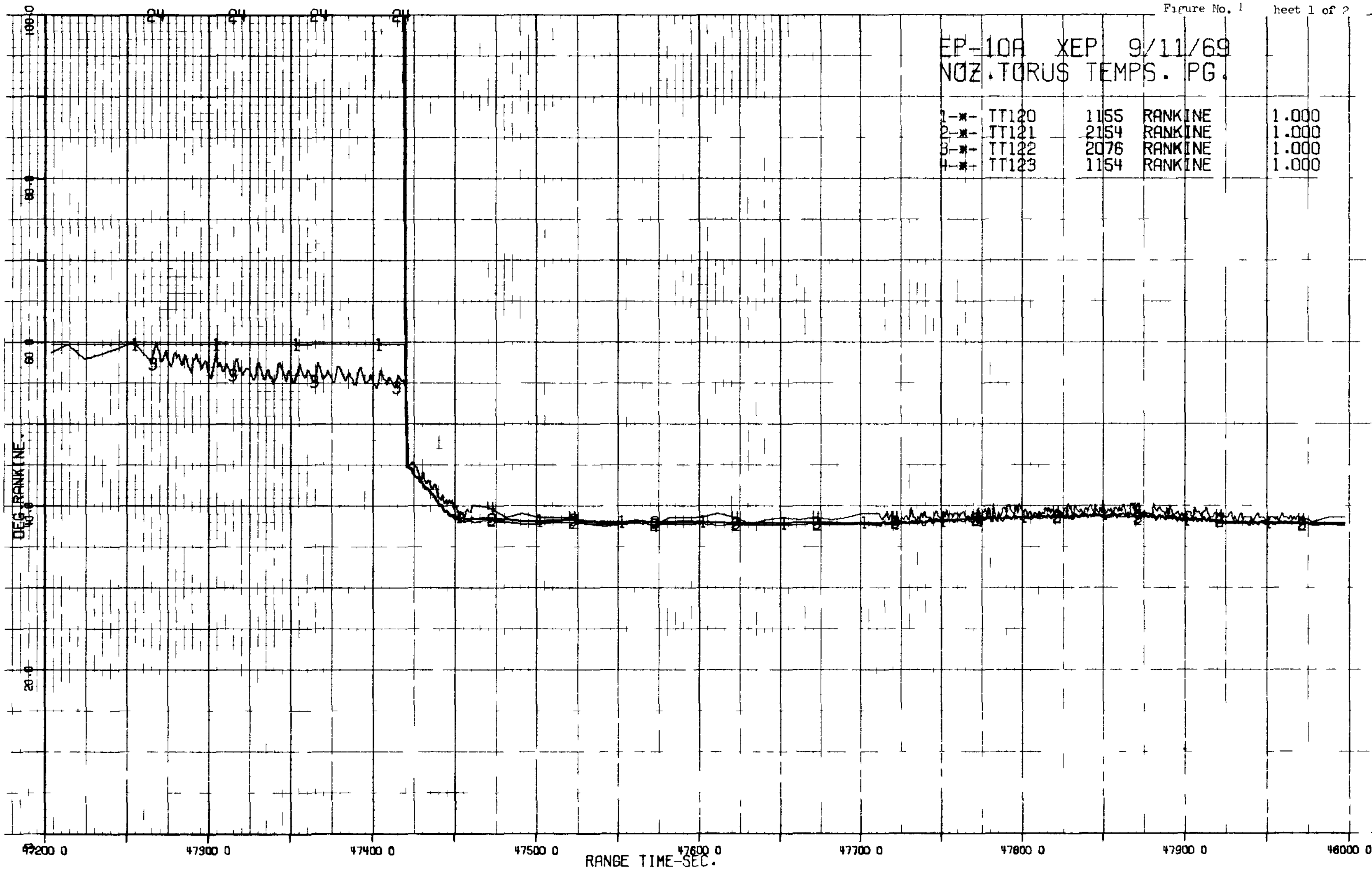
Figure No. 3



TP AP Memo No. 5

Figure No. 1 heet 1 of 2



SPEAR Memo No. 5

Figure No. 4 Sheet 2 of 2

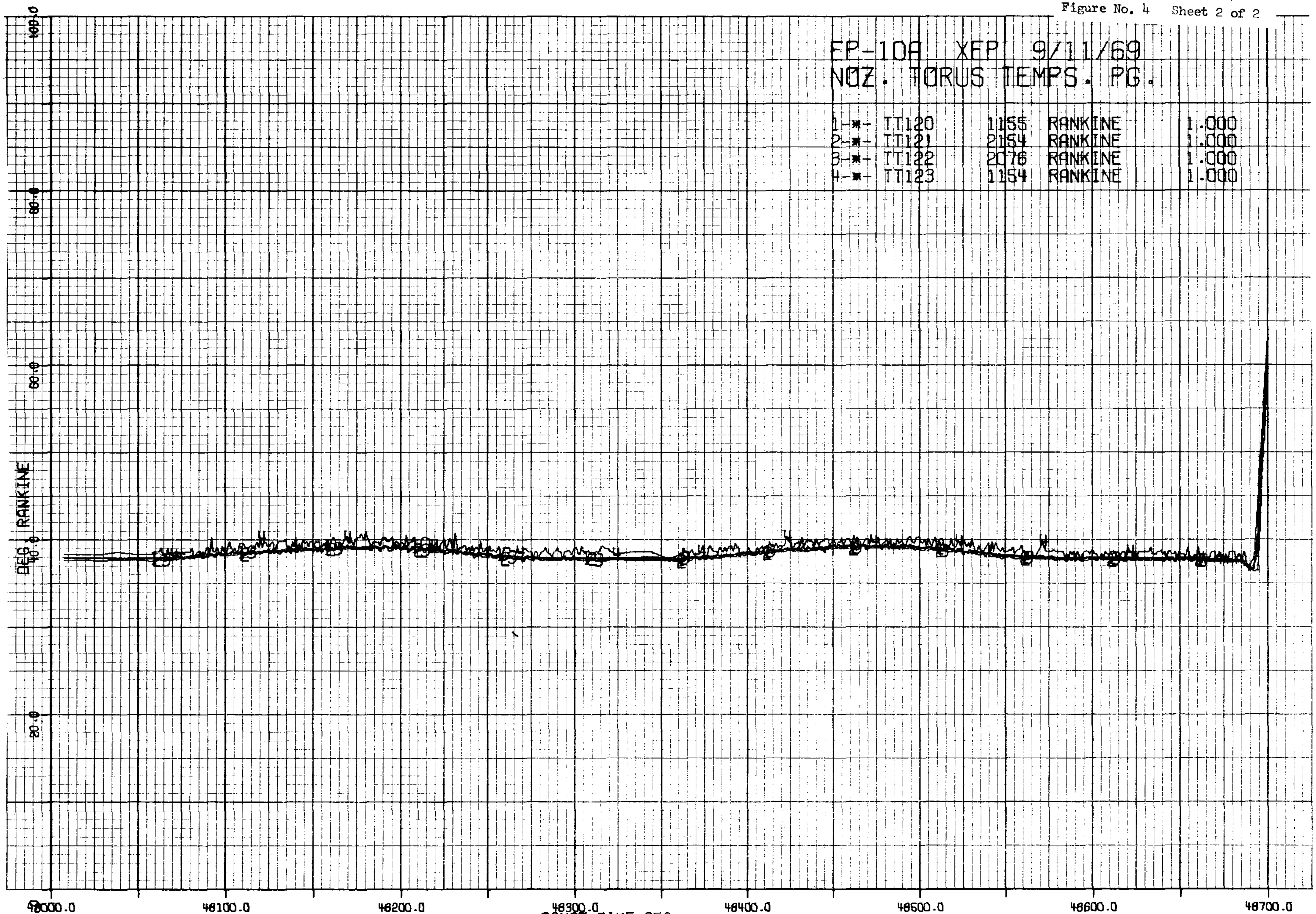


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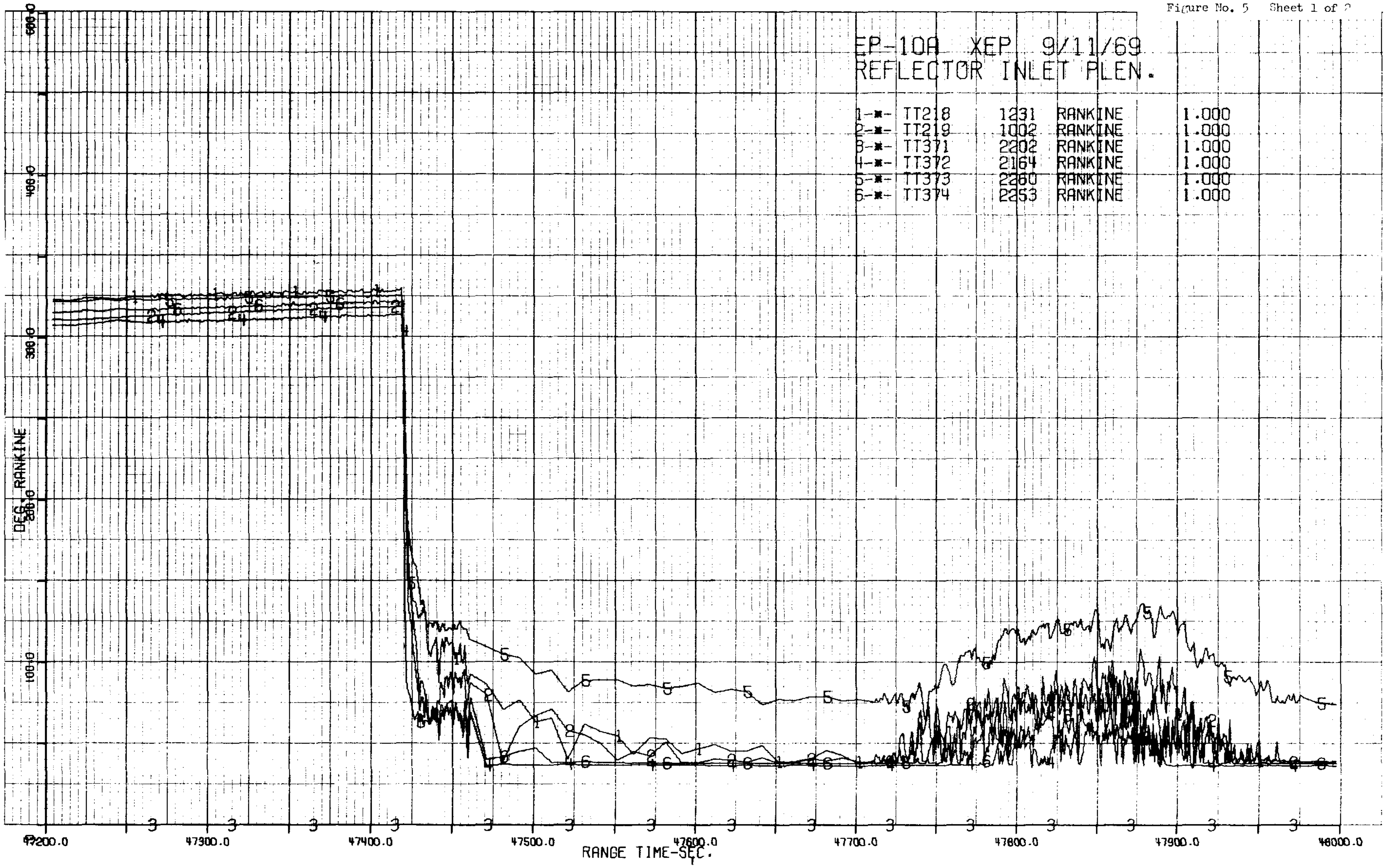
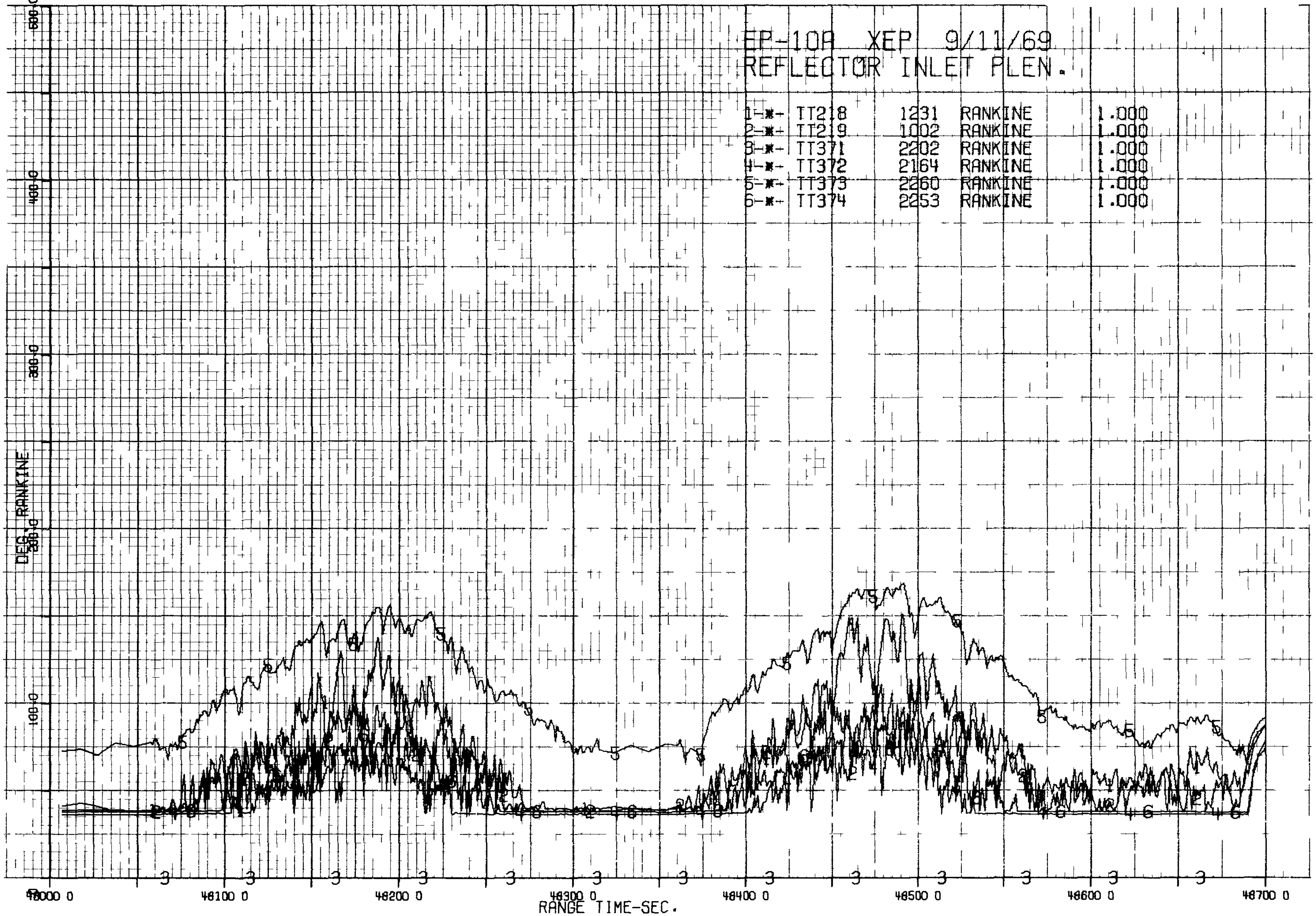
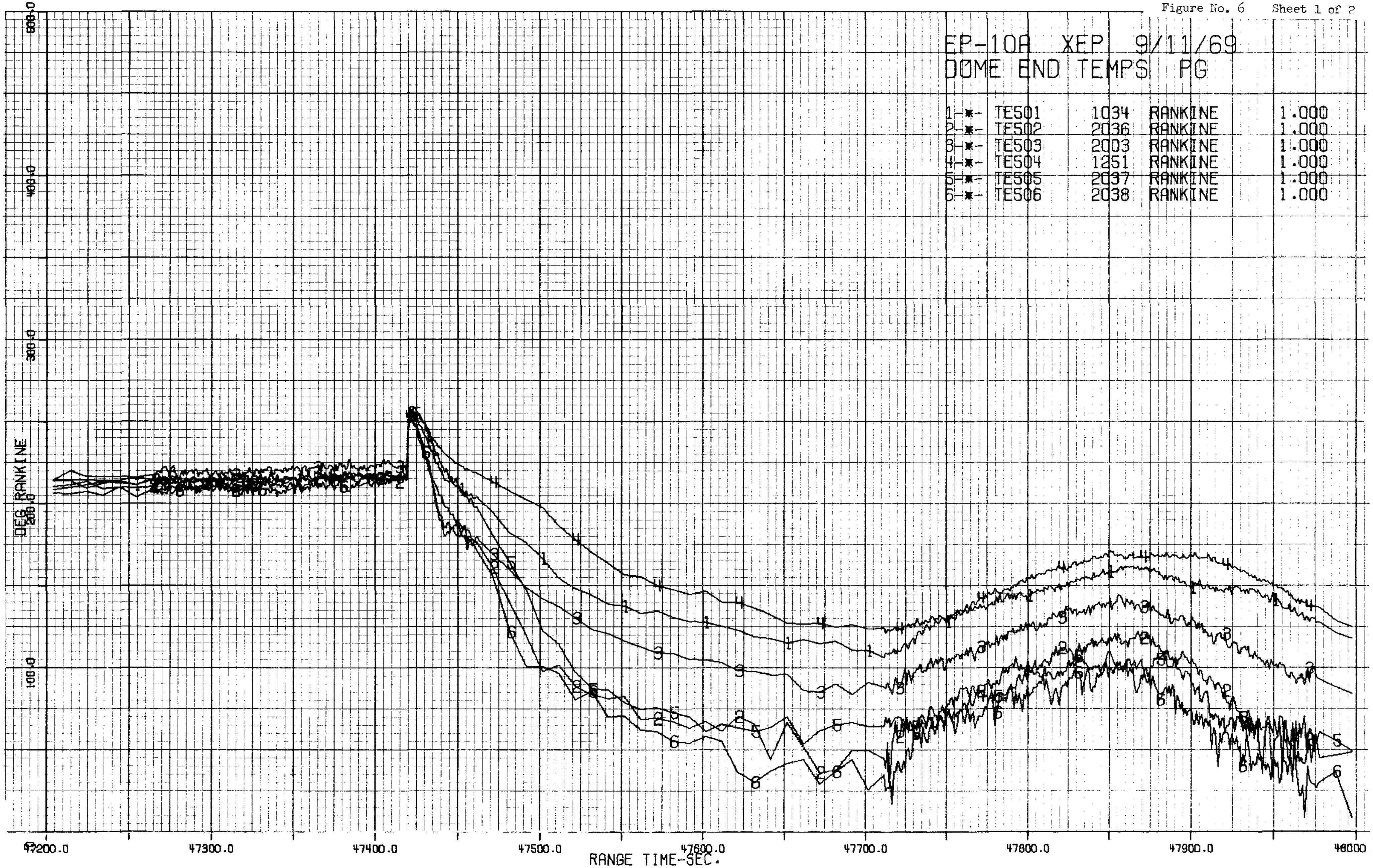
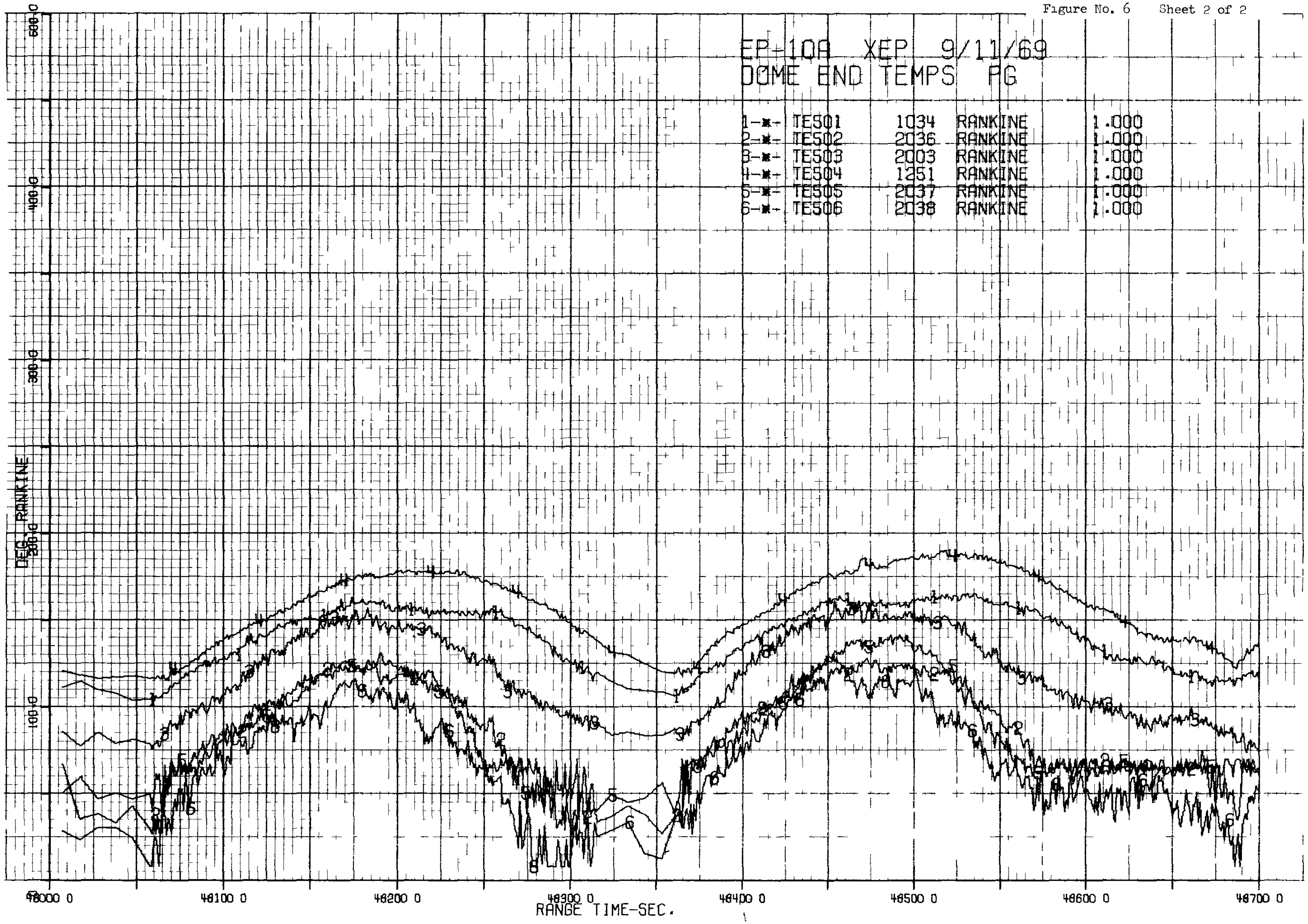
Figure No. 5 Sheet 1 of 2



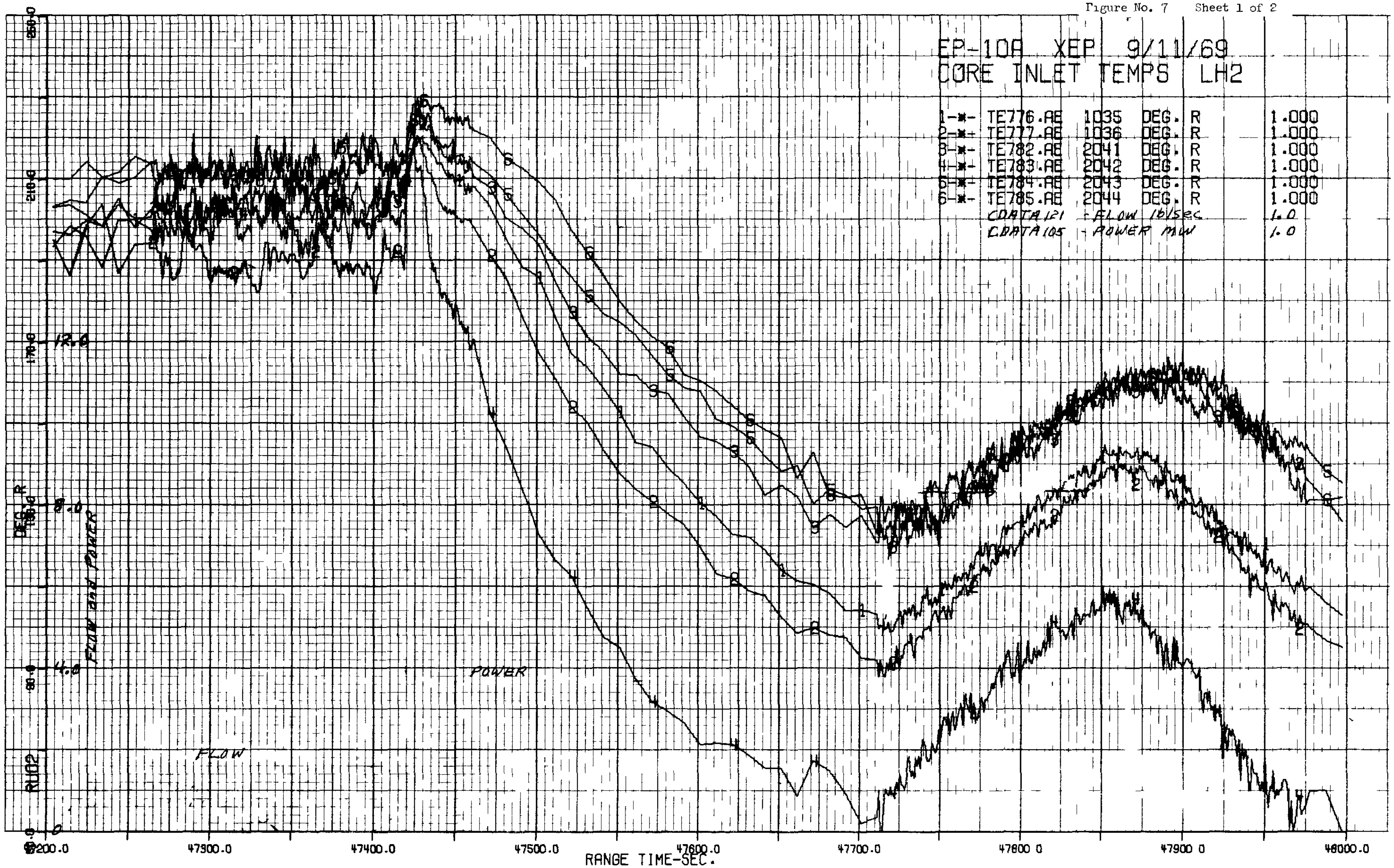

EP-10A XEP 9/11/69
REFLECTOR INLET PLEN.
1-*- TT218 1231 RANKINE 1.000
2-*- TT219 1002 RANKINE 1.000
3-*- TT371 2202 RANKINE 1.000
4-*- TT372 2164 RANKINE 1.000
5-*- TT373 2260 RANKINE 1.000
6-*- TT374 2253 RANKINE 1.000
DEG. RANKINE
500.0
400.0
300.0
200.0
100.0
48000 0
48100 0
48200 0
48300 0
48400 0
48500 0
48600 0
48700 0
RANGE TIME-SEC.

SPEAR Memo No. 5
Figure No. 6 Sheet 1 of 2




EP-10A XEP 9/11/69
DOME END TEMPS PG
1-*- TE501 1034 RANKINE 1.000
2-*- TE502 2036 RANKINE 1.000
3-*- TE503 2003 RANKINE 1.000
4-*- TE504 1251 RANKINE 1.000
5-*- TE505 2037 RANKINE 1.000
6-*- TE506 2038 RANKINE 1.000
DEG. RANKINE
500.0
400.0
300.0
200.0
100.0
48000 0
48100 0
48200 0
48300 0
48400 0
48500 0
48600 0
48700 0
RANGE TIME-SEC.

SPEAR Memo No. 5
Figure No. 7 Sheet 1 of 2



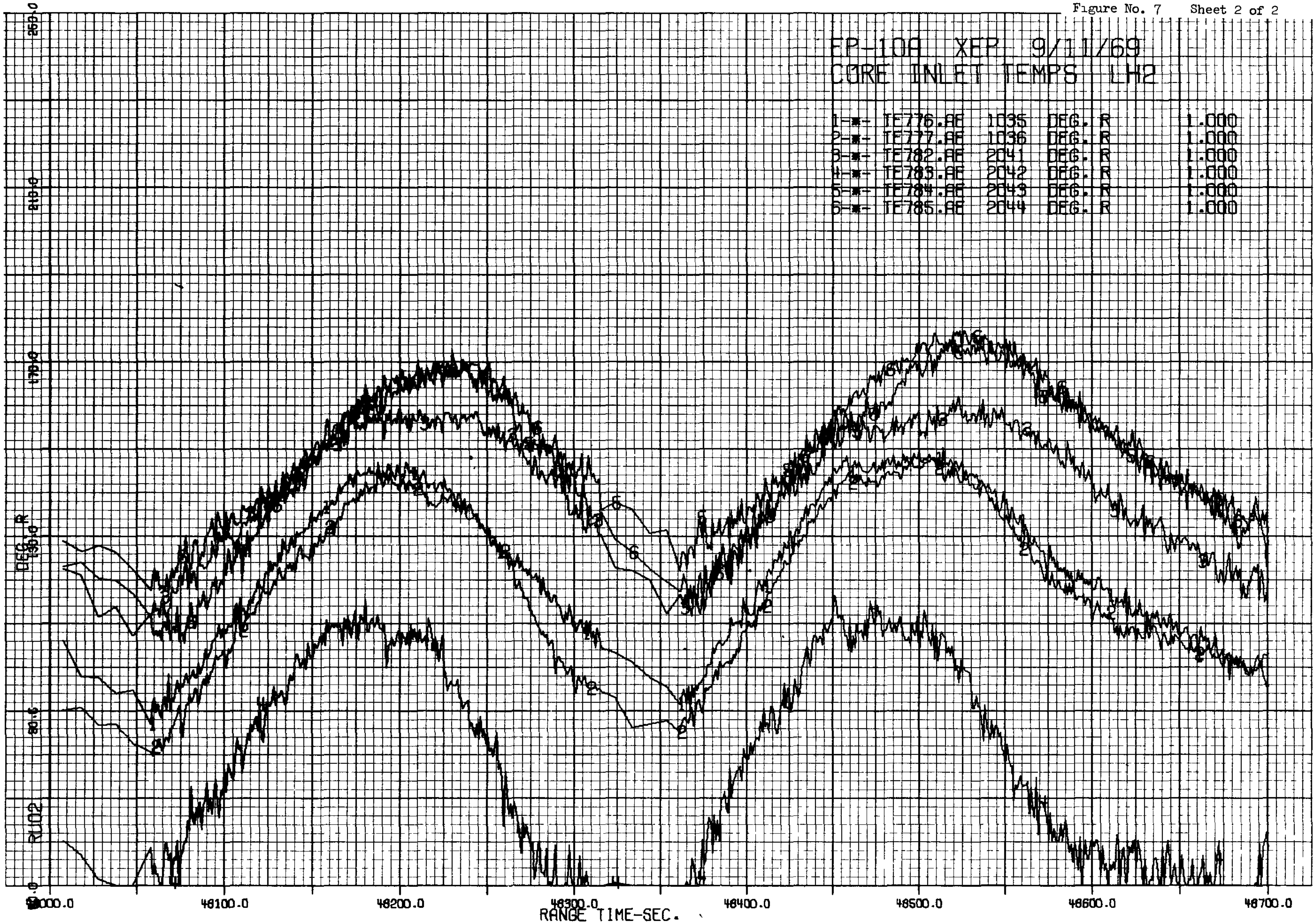

EP-10A XEP 9/11/69
CORE INLET TEMPS LH2
1-*- TE776.AE 1035 DEG. R 1.000
2-*- TE777.AE 1036 DEG. R 1.000
3-*- TE782.AE 2041 DEG. R 1.000
4-*- TE783.AE 2042 DEG. R 1.000
5-*- TE784.AE 2043 DEG. R 1.000
6-*- TE785.AE 2044 DEG. R 1.000
DEG. R
RUO2
RANGE TIME-SEC.
48100.0
48200.0
48300.0
48400.0
48500.0
48600.0
48700.0

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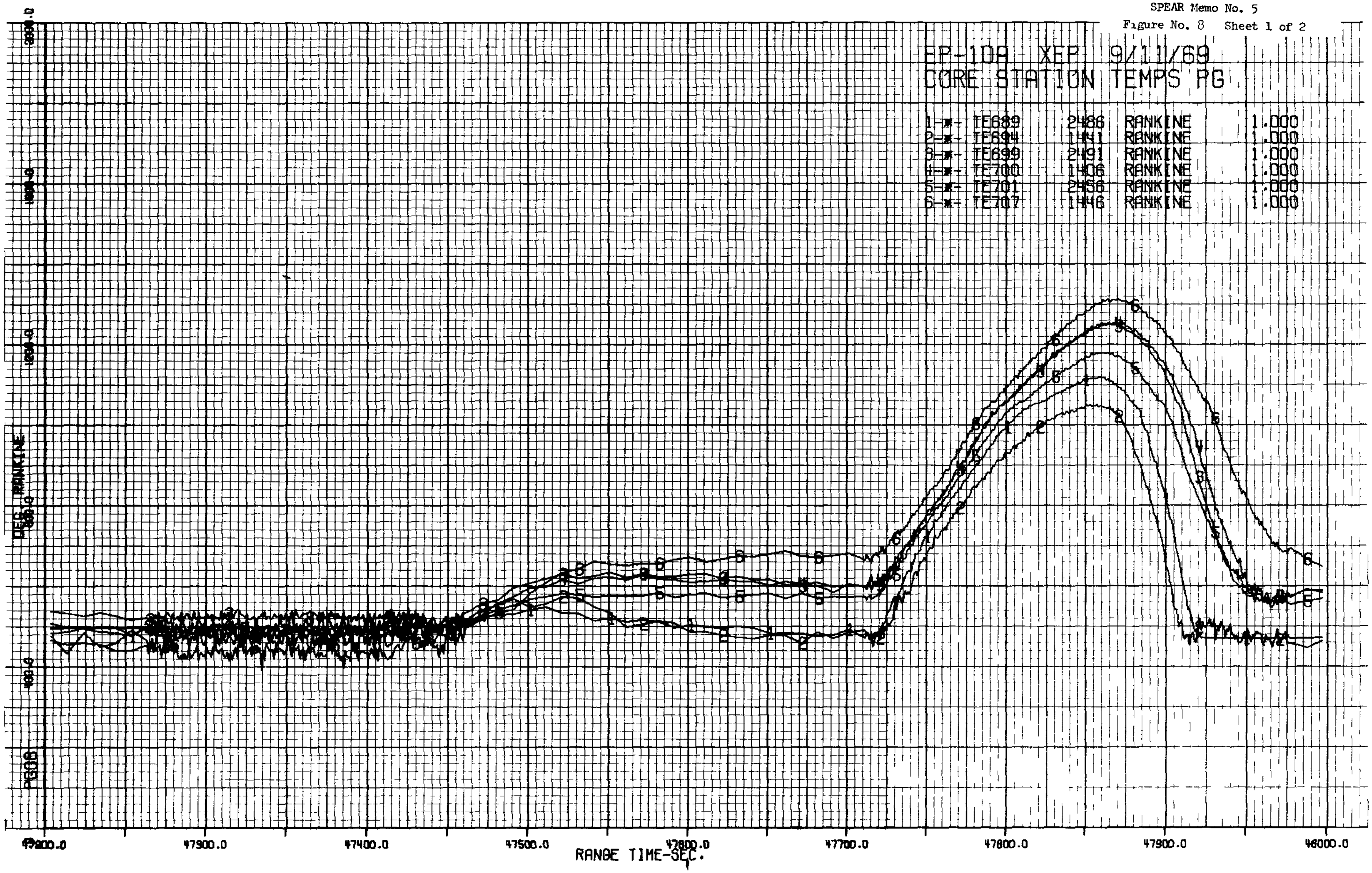
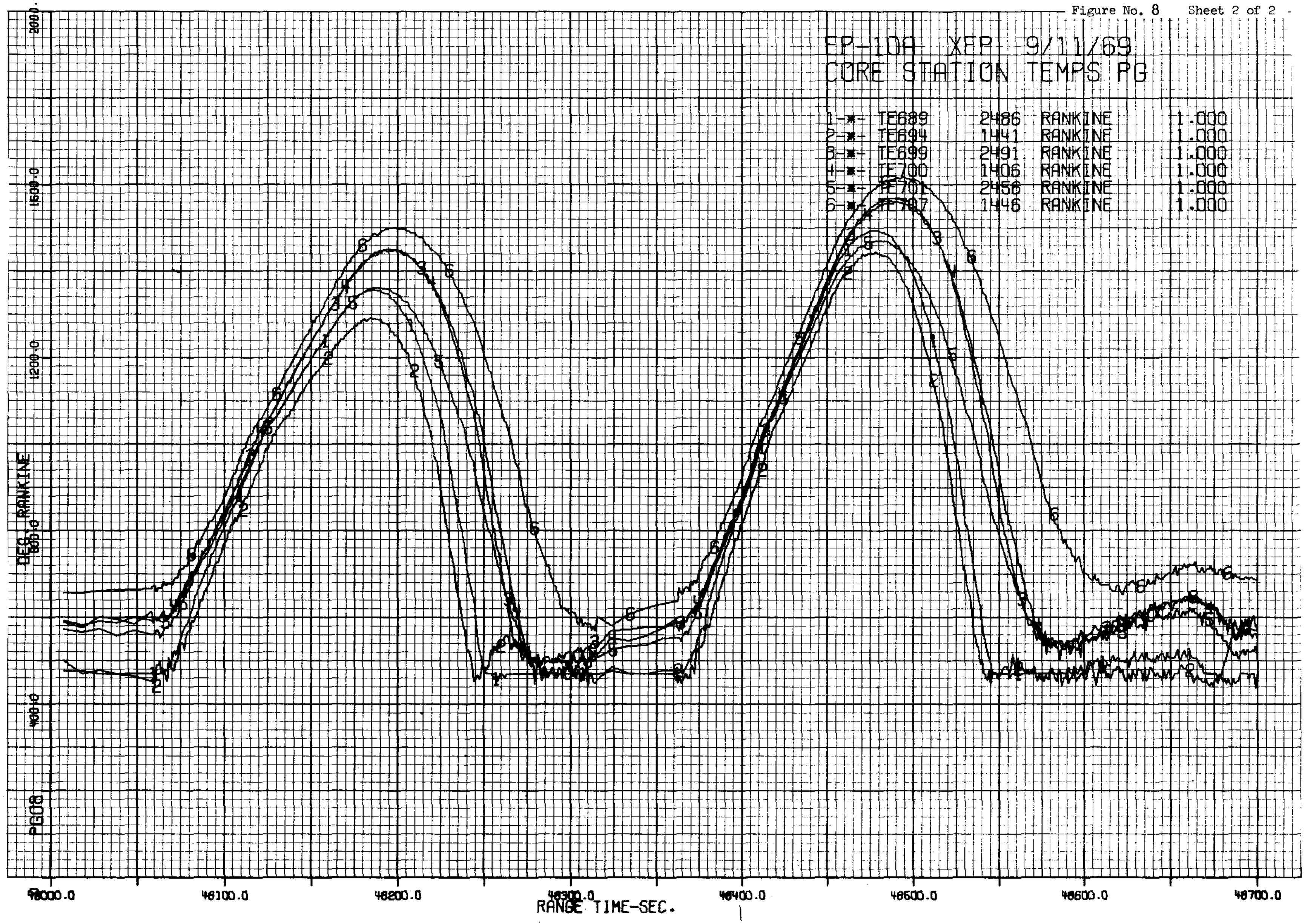
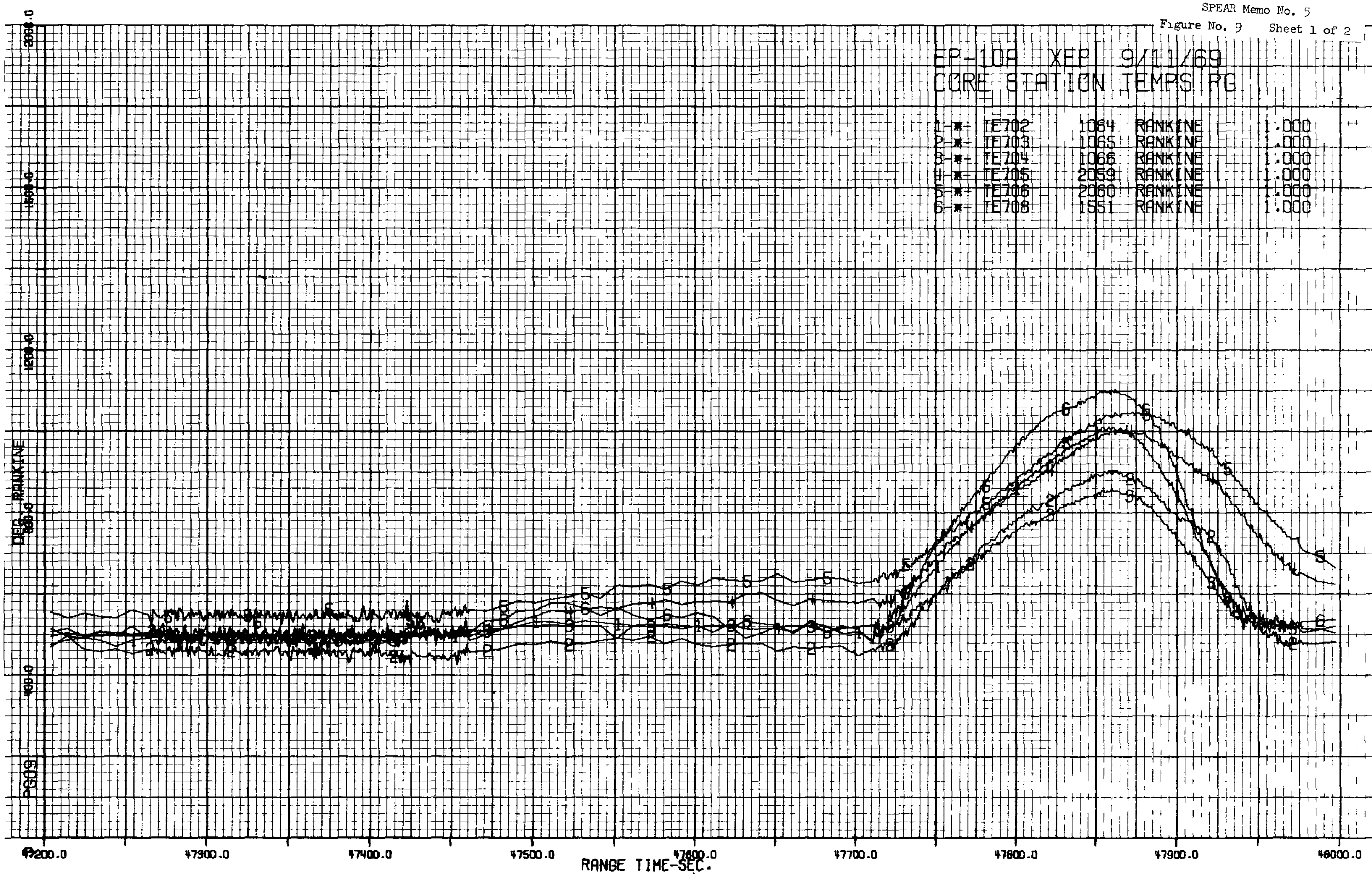
Figure No. 8 Sheet 1 of 2




FP-10A XFP 9/11/69
CORE STATION TEMPS PG
1-*- TE689 2486 RANKINE 1.000
2-*- TE694 1441 RANKINE 1.000
3-*- TE699 2491 RANKINE 1.000
4-*- TE700 1406 RANKINE 1.000
5-*- TE701 2456 RANKINE 1.000
6-*- TE707 1446 RANKINE 1.000
DEG. RANKINE
2000.0
1600.0
1200.0
800.0
400.0
PG08
46000.0
46100.0
46200.0
46300.0
46400.0
46500.0
46600.0
46700.0
RANGE TIME-SEC.

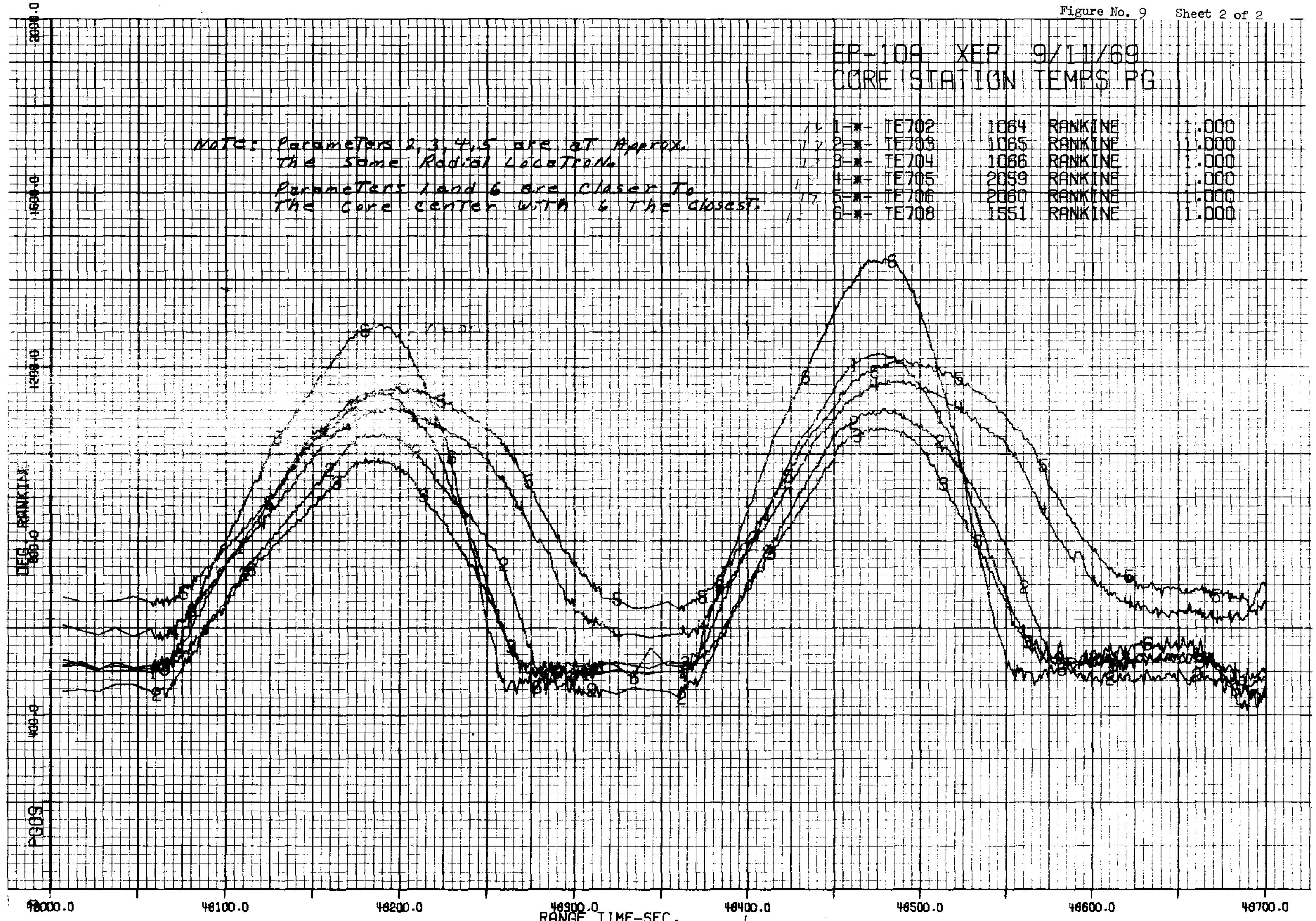
SPEAR Memo No. 5

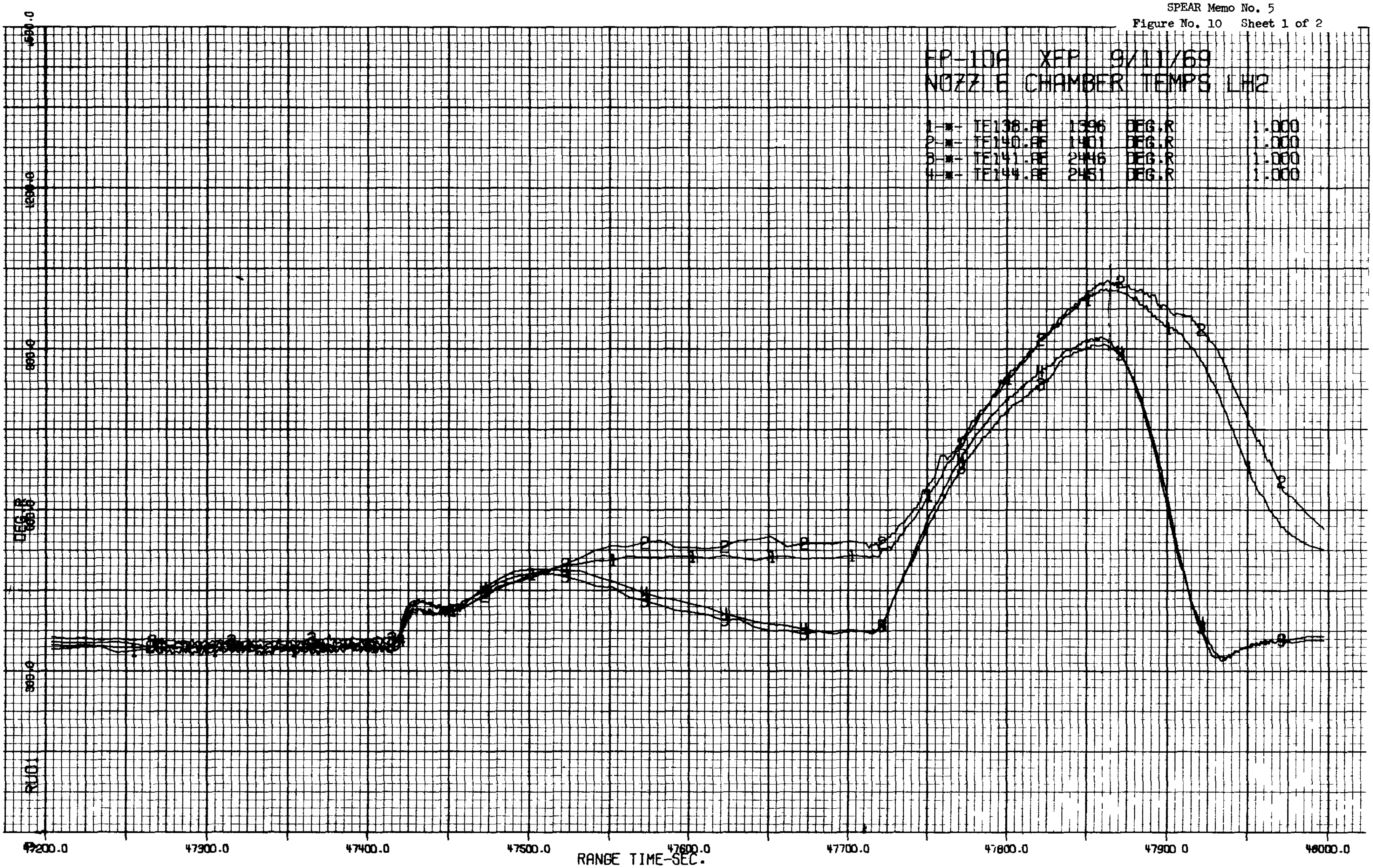
Figure No. 9 Sheet 1 of 2



SPEAR Memo No. 5

Figure No. 9   Sheet 2 of 2




FP-10A XFP 9/11/69
NOZZLE CHAMBER TEMPS LH2
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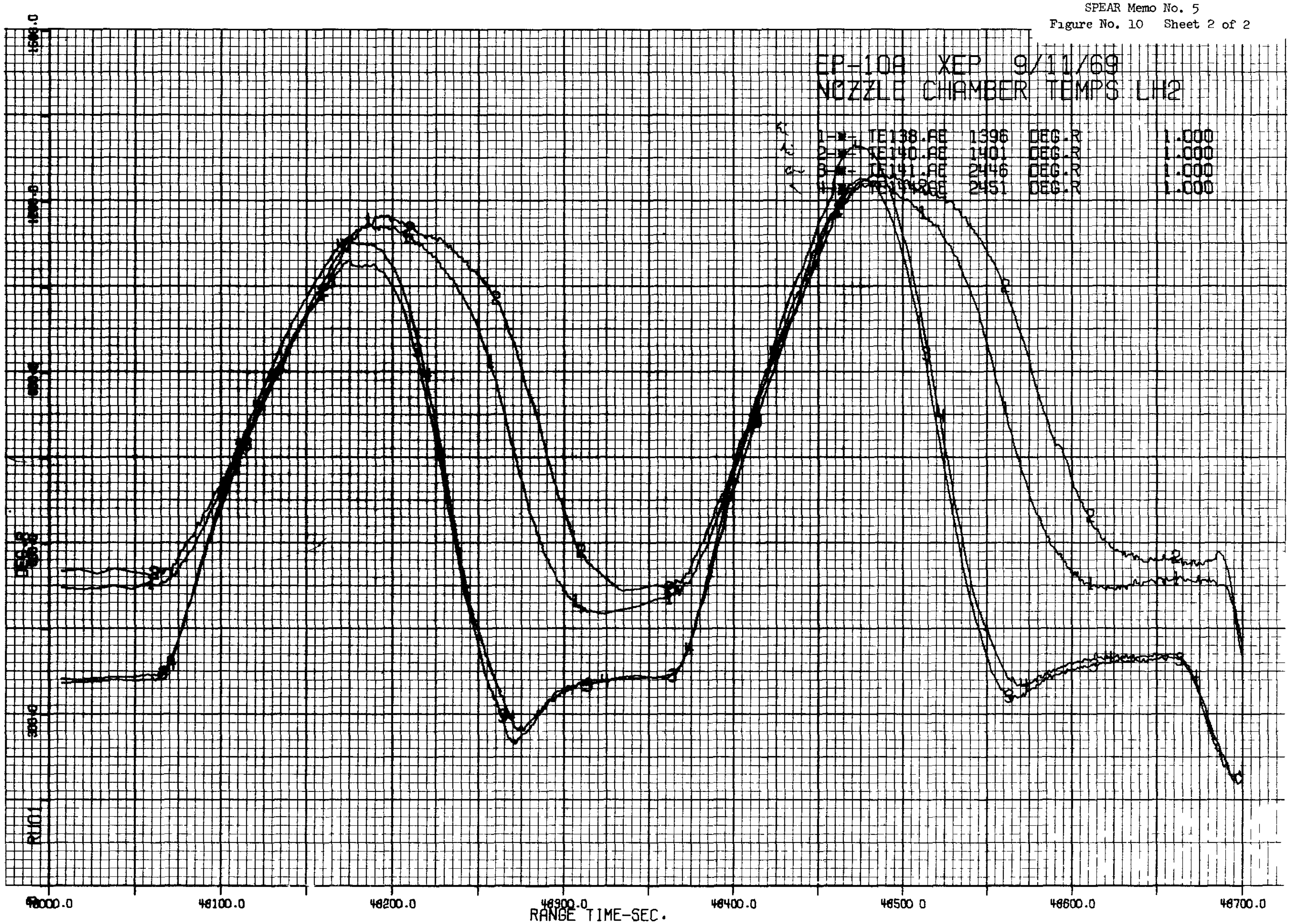
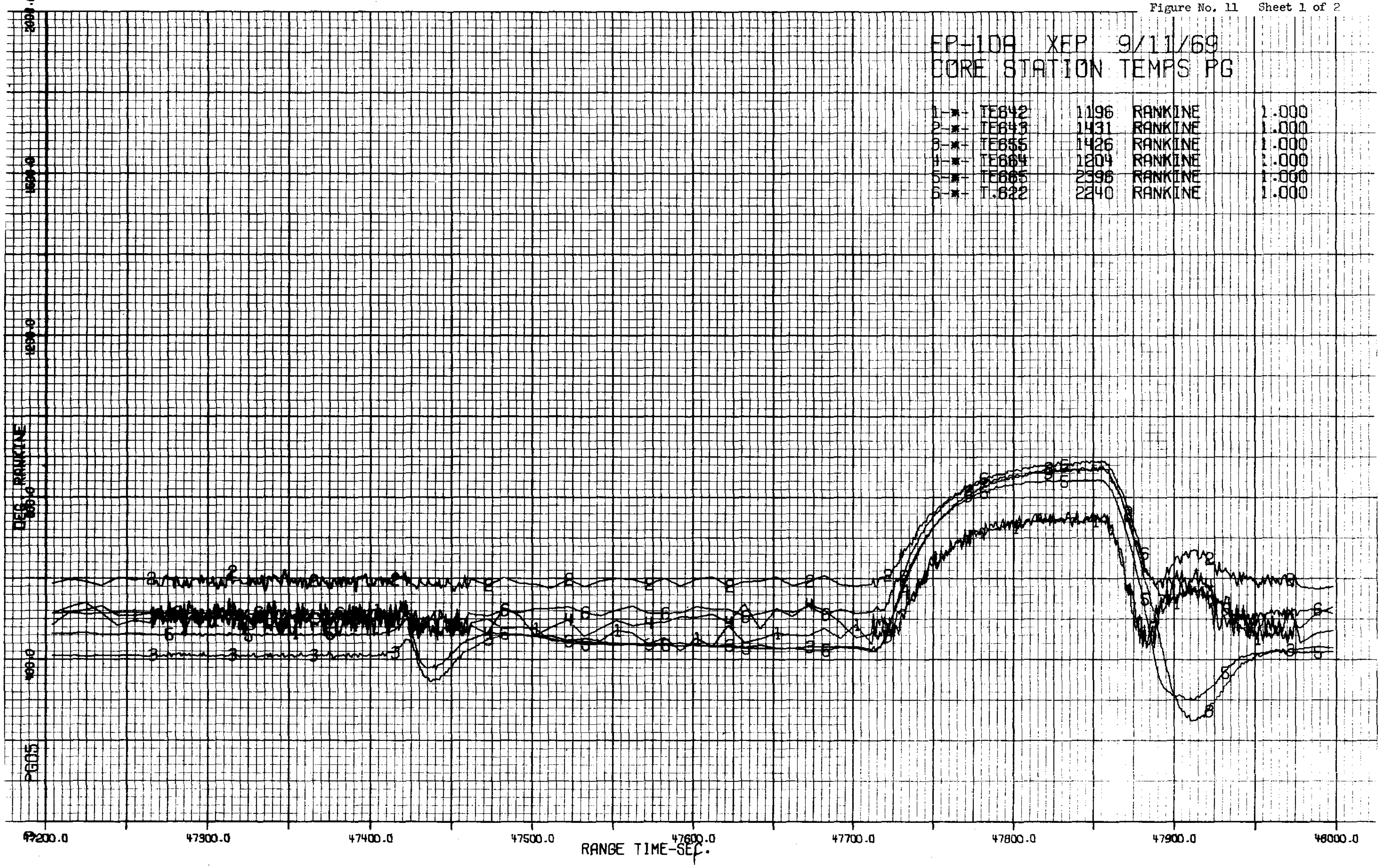
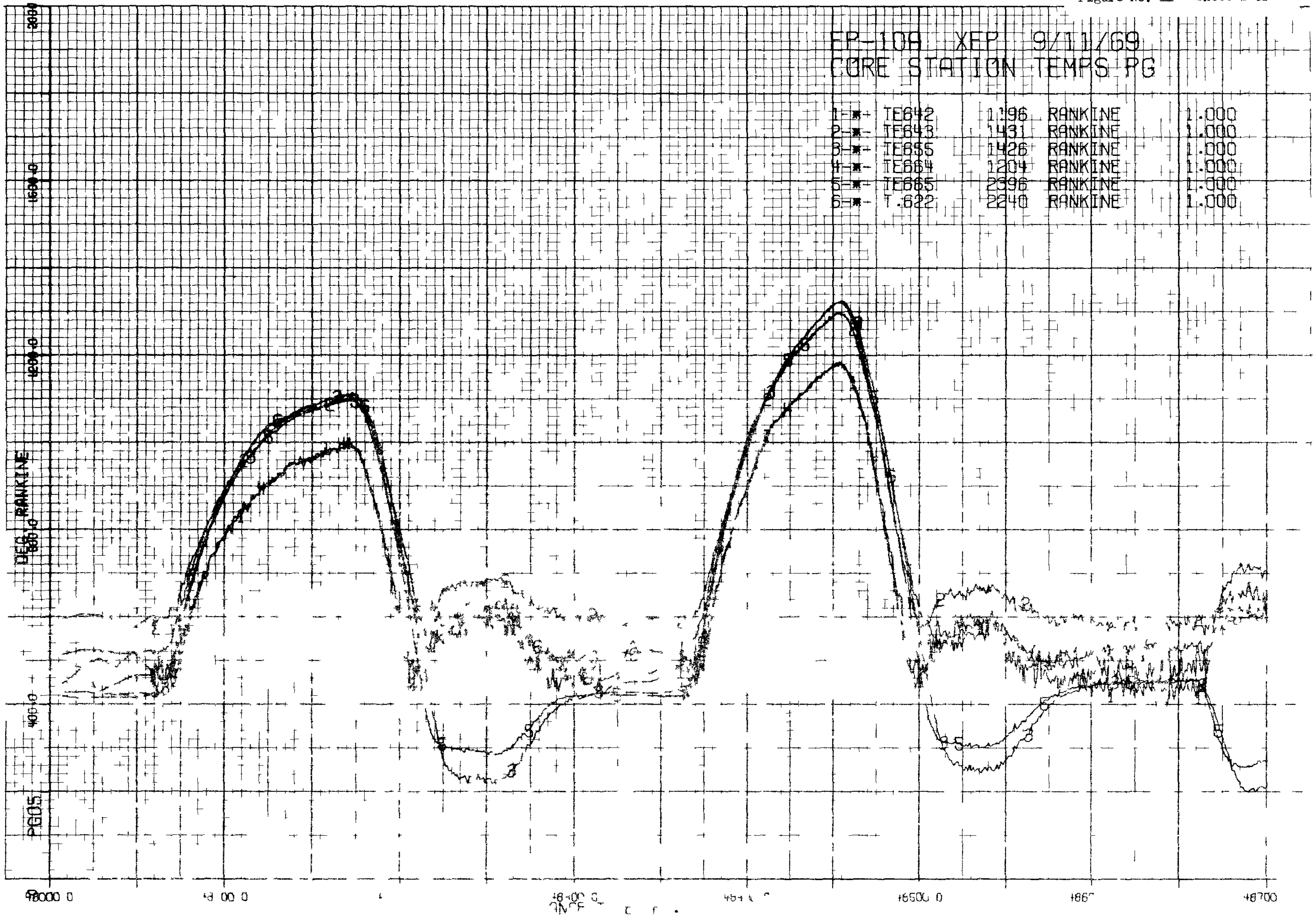
2-*- TE140.AE 1401 DEG.R 1.000
3-*- TE141.AE 2446 DEG.R 1.000
4-*- TE144.AE 2451 DEG.R 1.000
DEG.R
RU01
47200.0
47300.0
47400.0
47500.0
47600.0
47700.0
47800.0
47900.0
48000.0
RANGE TIME-SEC.


EP-10A XEP 9/11/69
NOZZLE CHAMBER TEMPS LH2
1 TE138.AE 1396 DEG.R 1.000
2 TE140.AE 1401 DEG.R 1.000
3 TE141.AE 2446 DEG.R 1.000
4 2451 DEG.R 1.000
DEG.R
RANGE TIME-SEC.
48100.0
48200.0
48300.0
48400.0
48500 0
48600.0
48700.0


EP-10A XEP 9/11/69
CORE STATION TEMPS PG
1-*- TE642 1196 RANKINE 1.000
2-*- TE643 1431 RANKINE 1.000
3-*- TE655 1426 RANKINE 1.000
4-*- TE664 1204 RANKINE 1.000
5-*- TE665 2396 RANKINE 1.000
6-*- T.622 2240 RANKINE 1.000
DEG RANKINE
PG05
47200.0
47300.0
47400.0
47500.0
47600.0
47700.0
47800.0
47900.0
48000.0
RANGE TIME-SEC.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CORE STATION TEMPS PG
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2-*- TE643 1431 RANKINE 1.000
3-*- TE655 1426 RANKINE 1.000
4-*- TE664 1204 RANKINE 1.000
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6-*- T.622 2240 RANKINE 1.000
DEG RANKINE
PG05

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Figure No. 12 Sheet 1 of 2

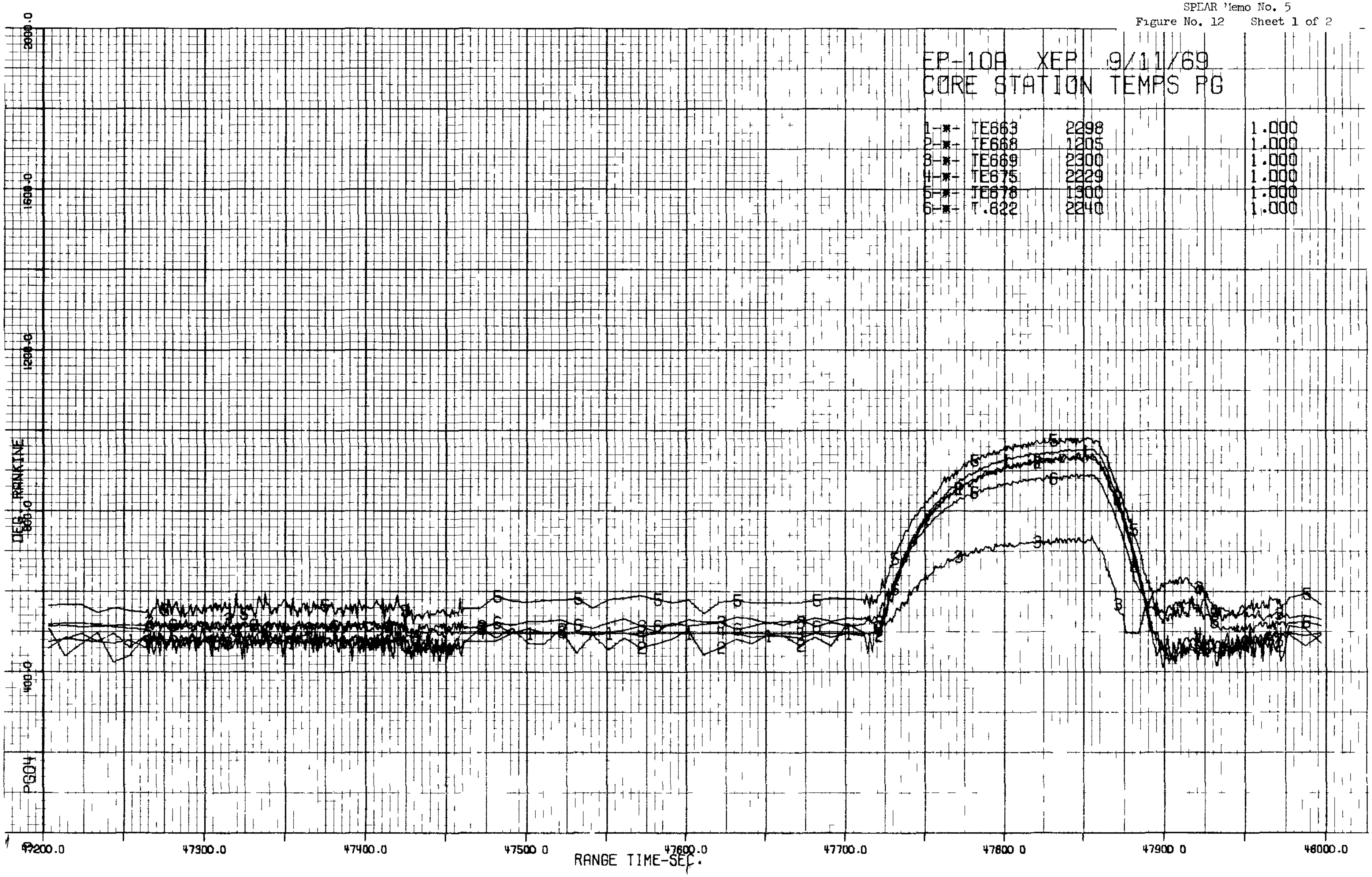
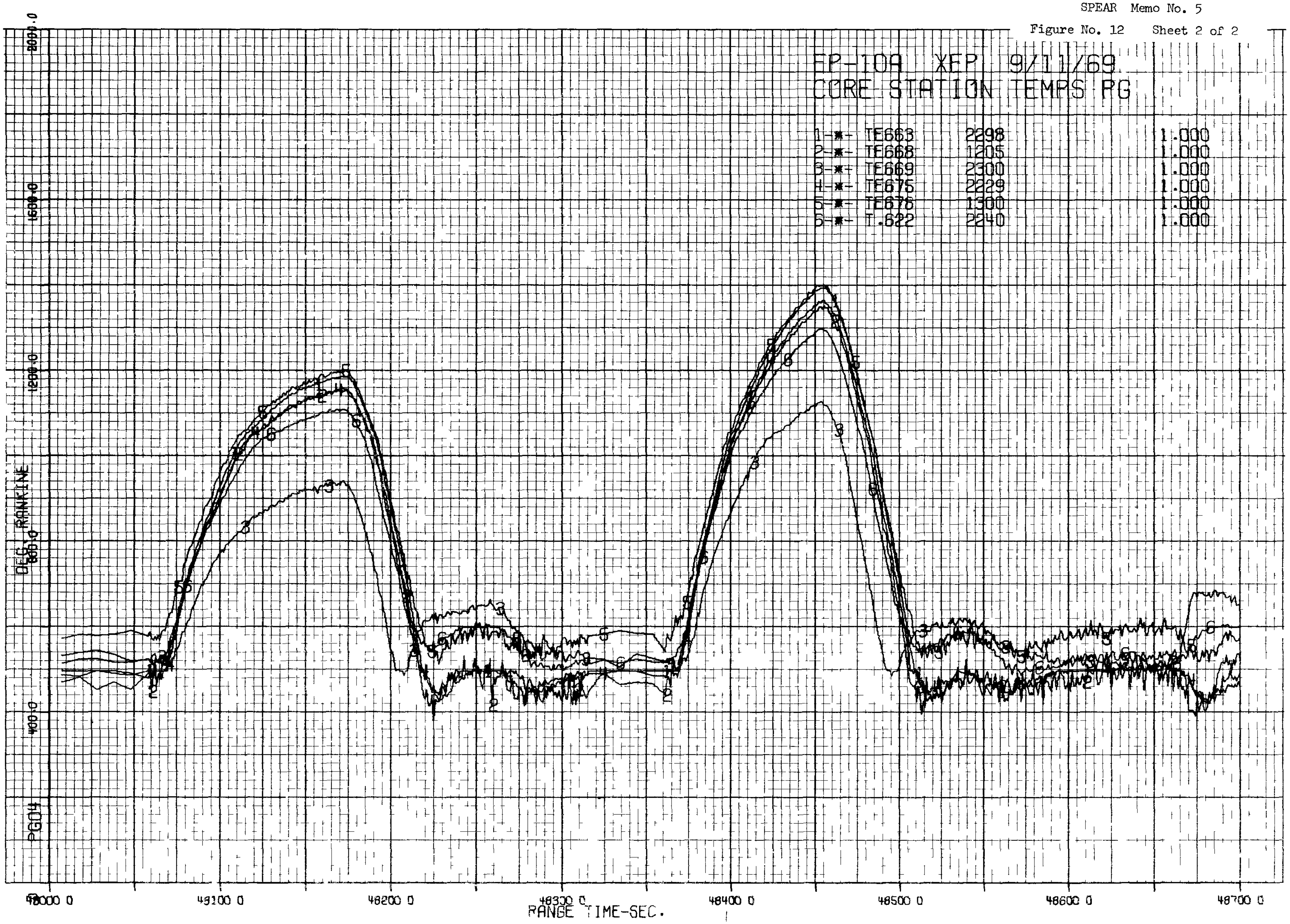
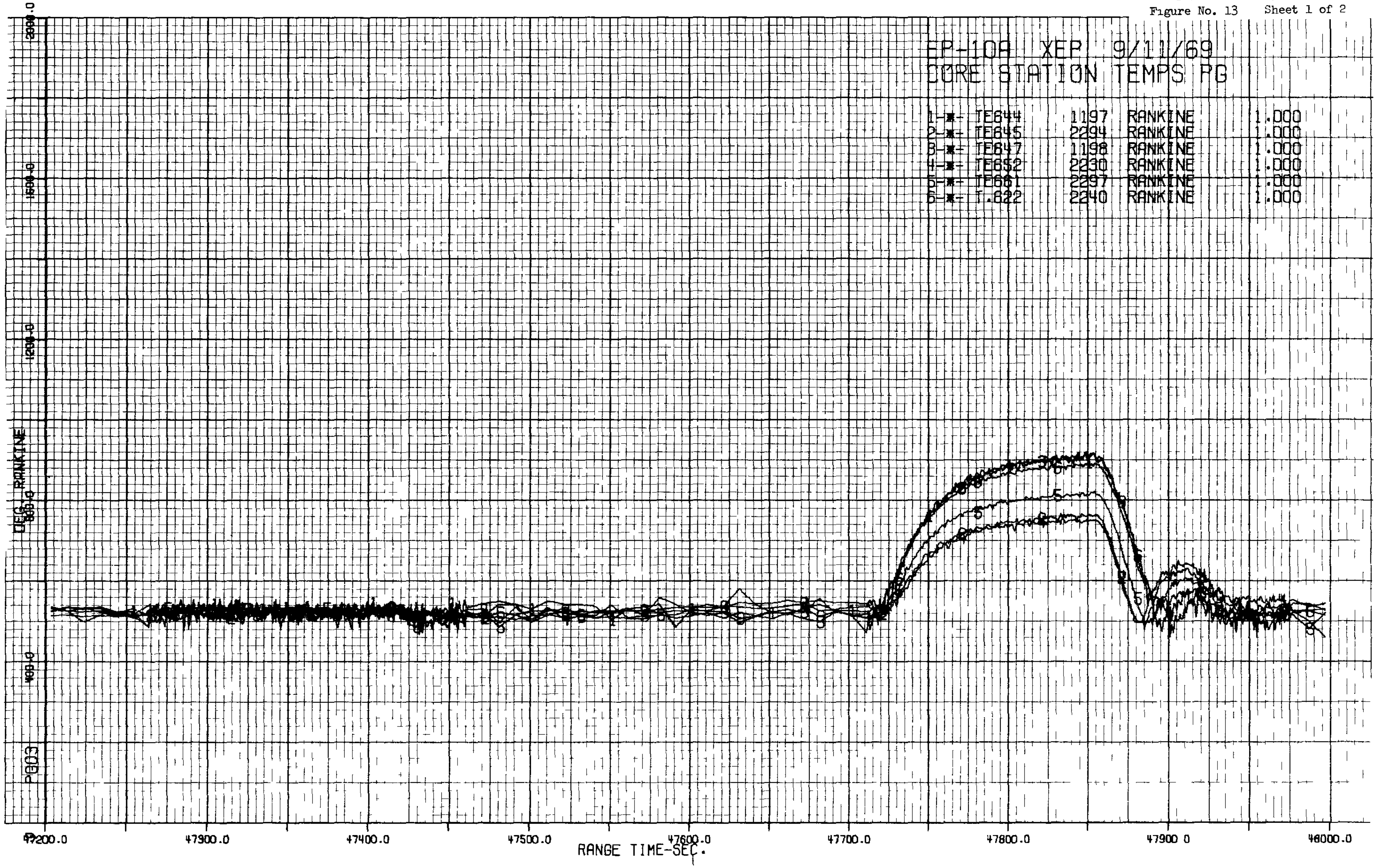


Figure No. 12 Sheet 2 of 2

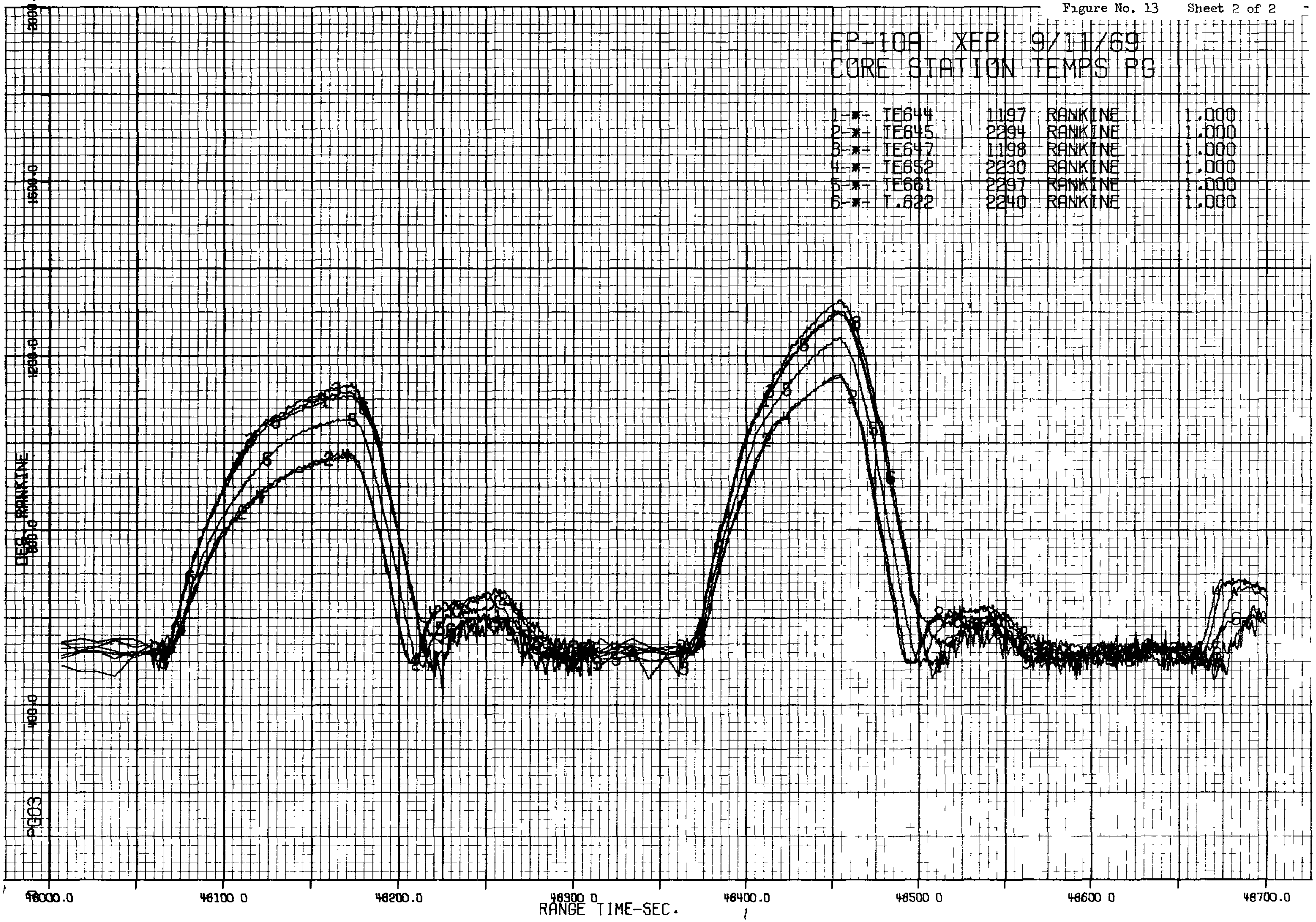


SPEAR Memo No. 5
Figure No. 13 Sheet 1 of 2



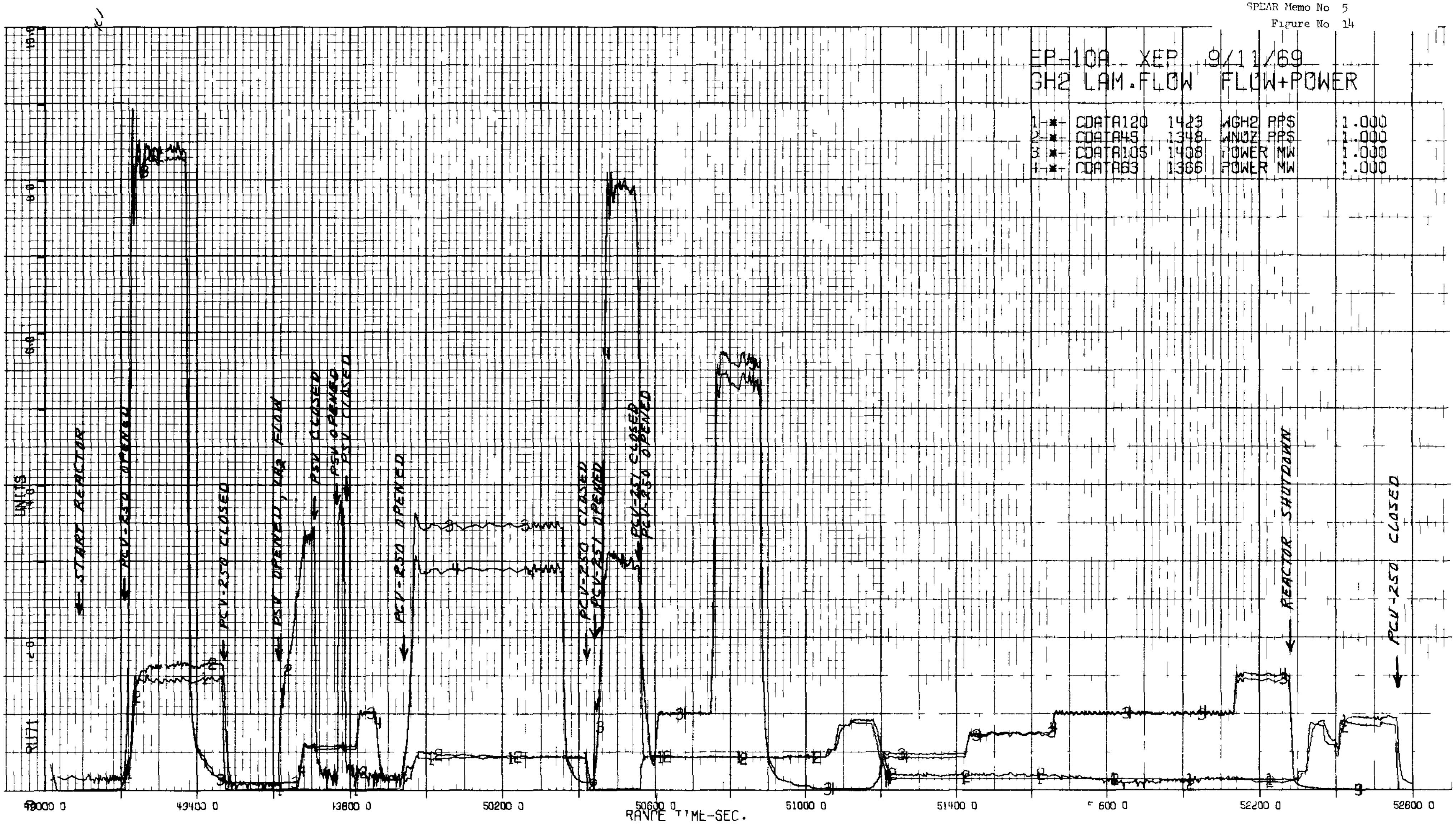
SPEAR Memo No. 5

Figure No. 13 Sheet 2 of 2

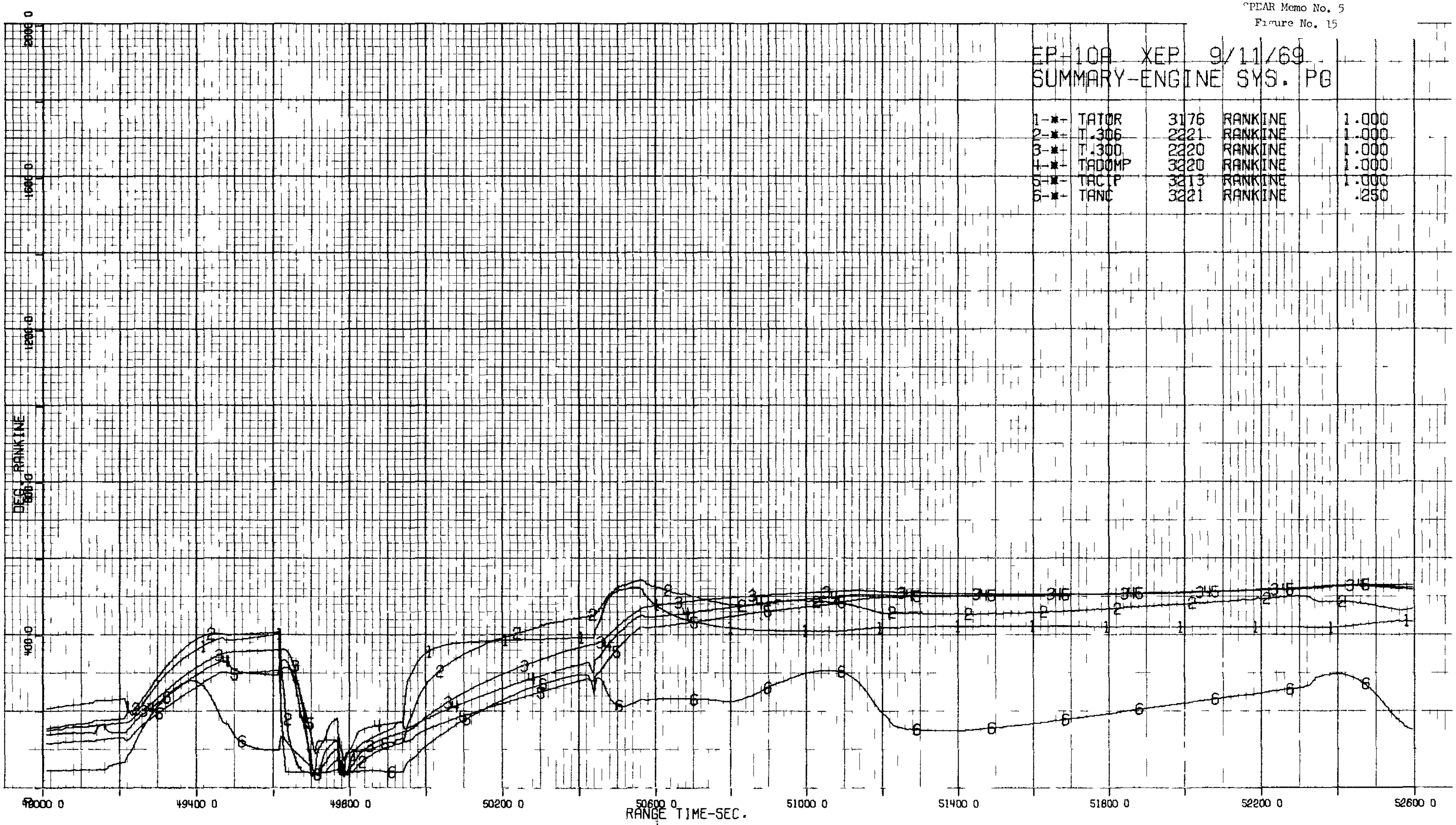


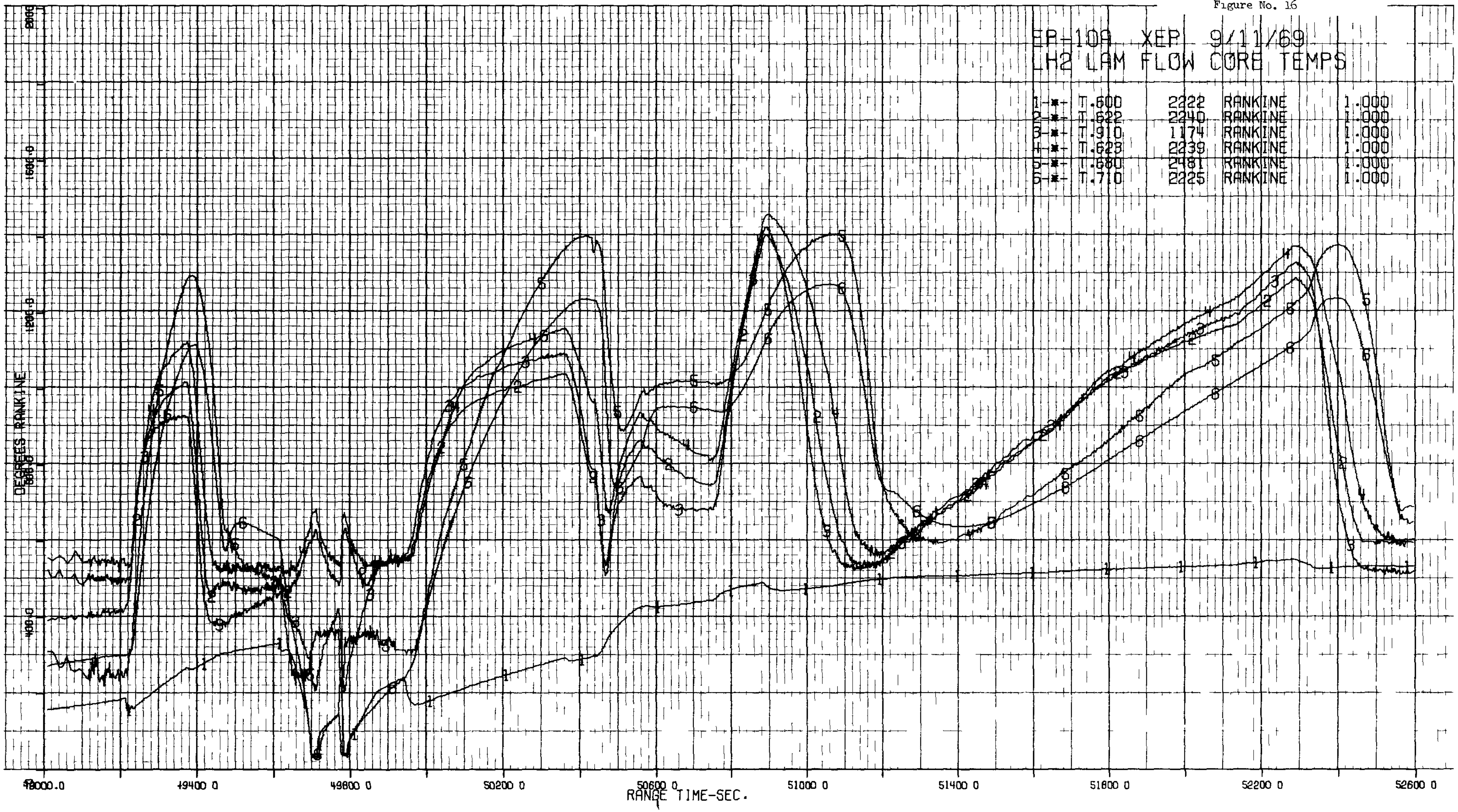
SPEAR Memo No 5

Figure No 14



SPEAR Memo No. 5
Figure No. 15

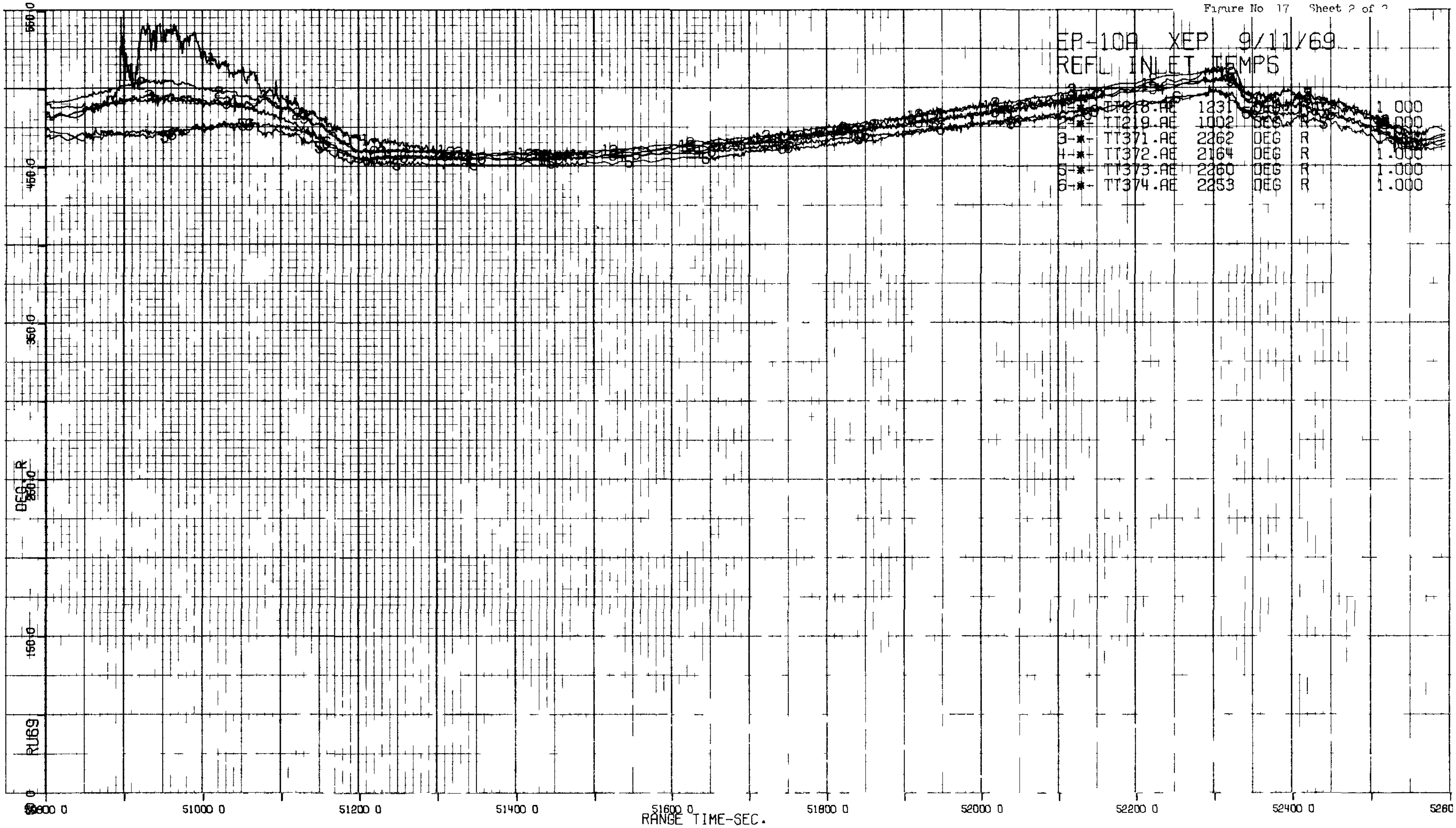



EP-10A XEP 9/11/69
LH2 LAM FLOW CORE TEMPS
1 T.600 2222 RANKINE 1.000
2 T.622 2240 RANKINE 1.000
3 T.910 1174 RANKINE 1.000
4 T.623 2239 RANKINE 1.000
5 T.680 2481 RANKINE 1.000
6 T.710 2225 RANKINE 1.000
DEGREES RANKINE
2000.0
1600.0
1200.0
800.0
400.0
0
49000.0
49400.0
49800.0
50200.0
50600.0
51000.0
51400.0
51800.0
52200.0
52600.0
RANGE TIME-SEC.

SPEAR Memo No. 5

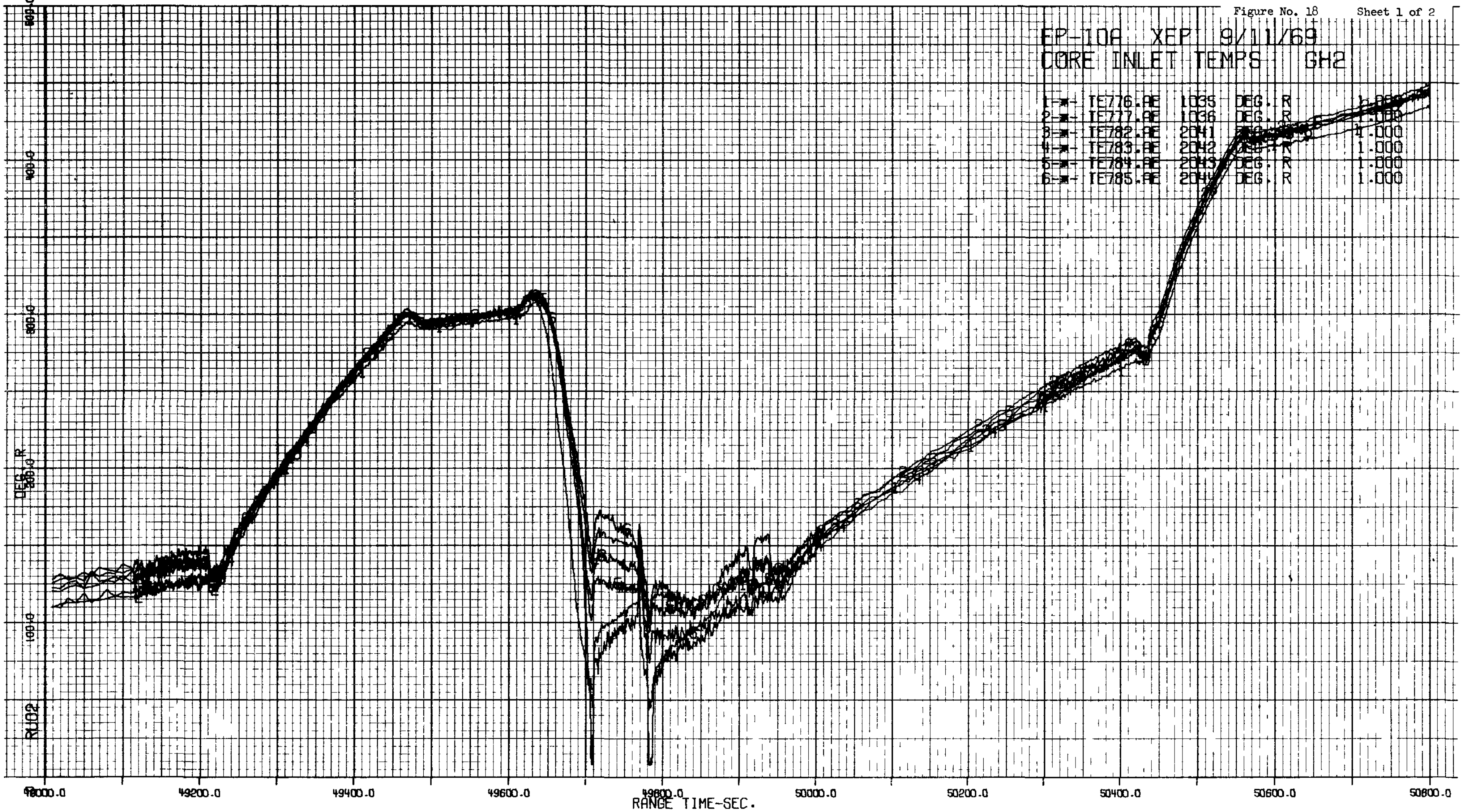
Figure No. 17 Sheet 1 of 2

SPEAR Memo No 5
Figure No 17 Sheet 2 of 2



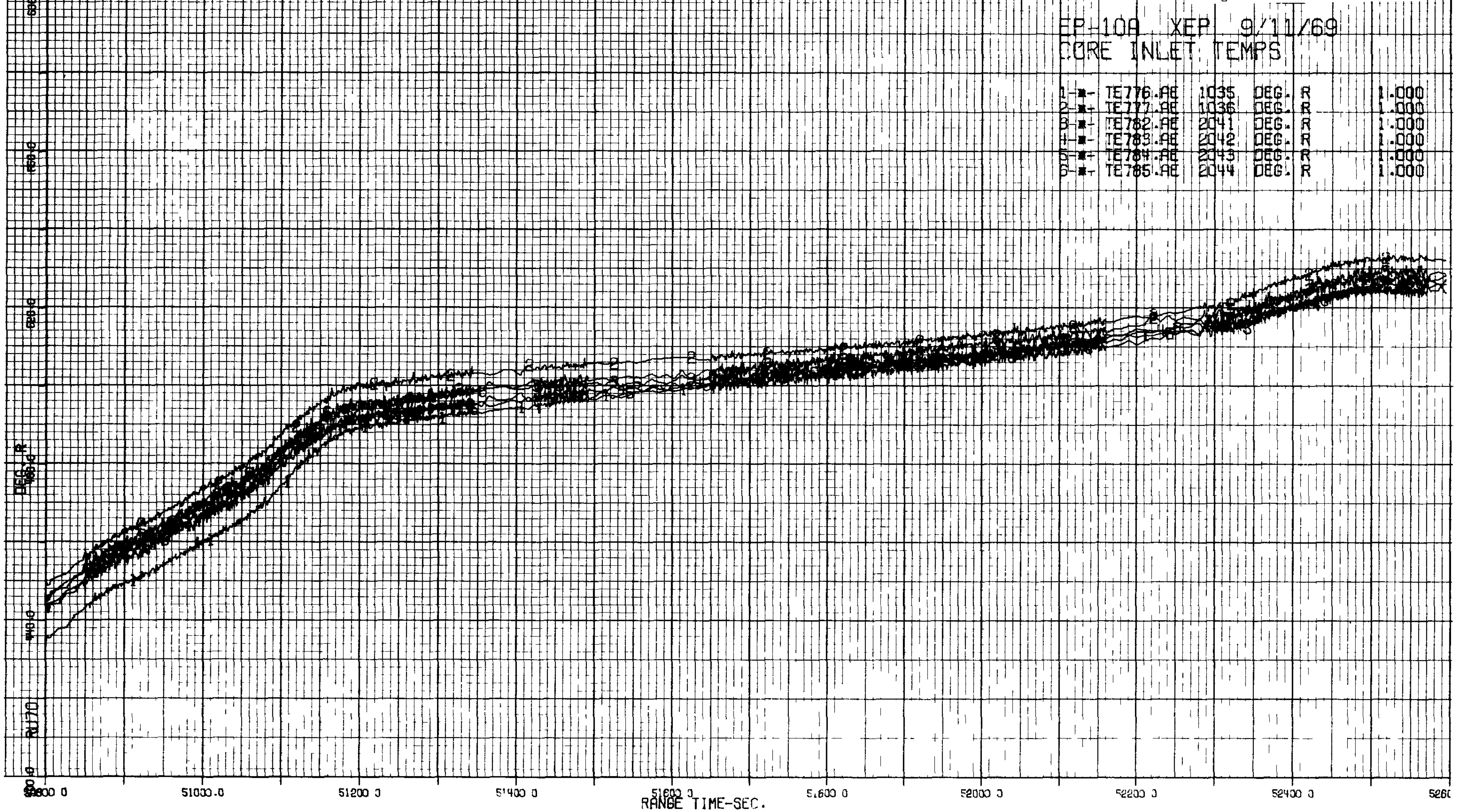
SPEAR Memo No. 5

Figure No. 18 Sheet 1 of 2

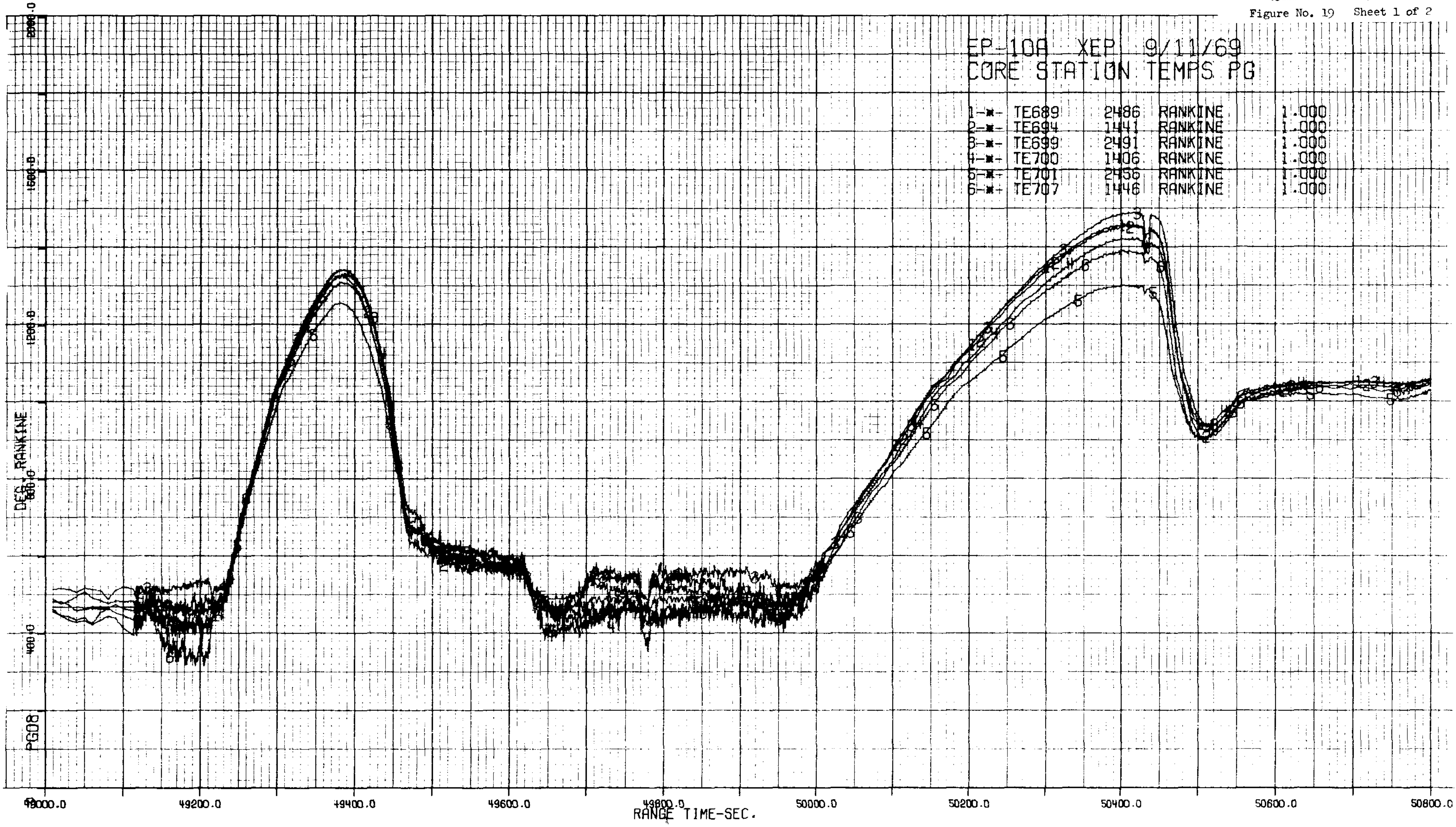


SPEAR Memo No. 5

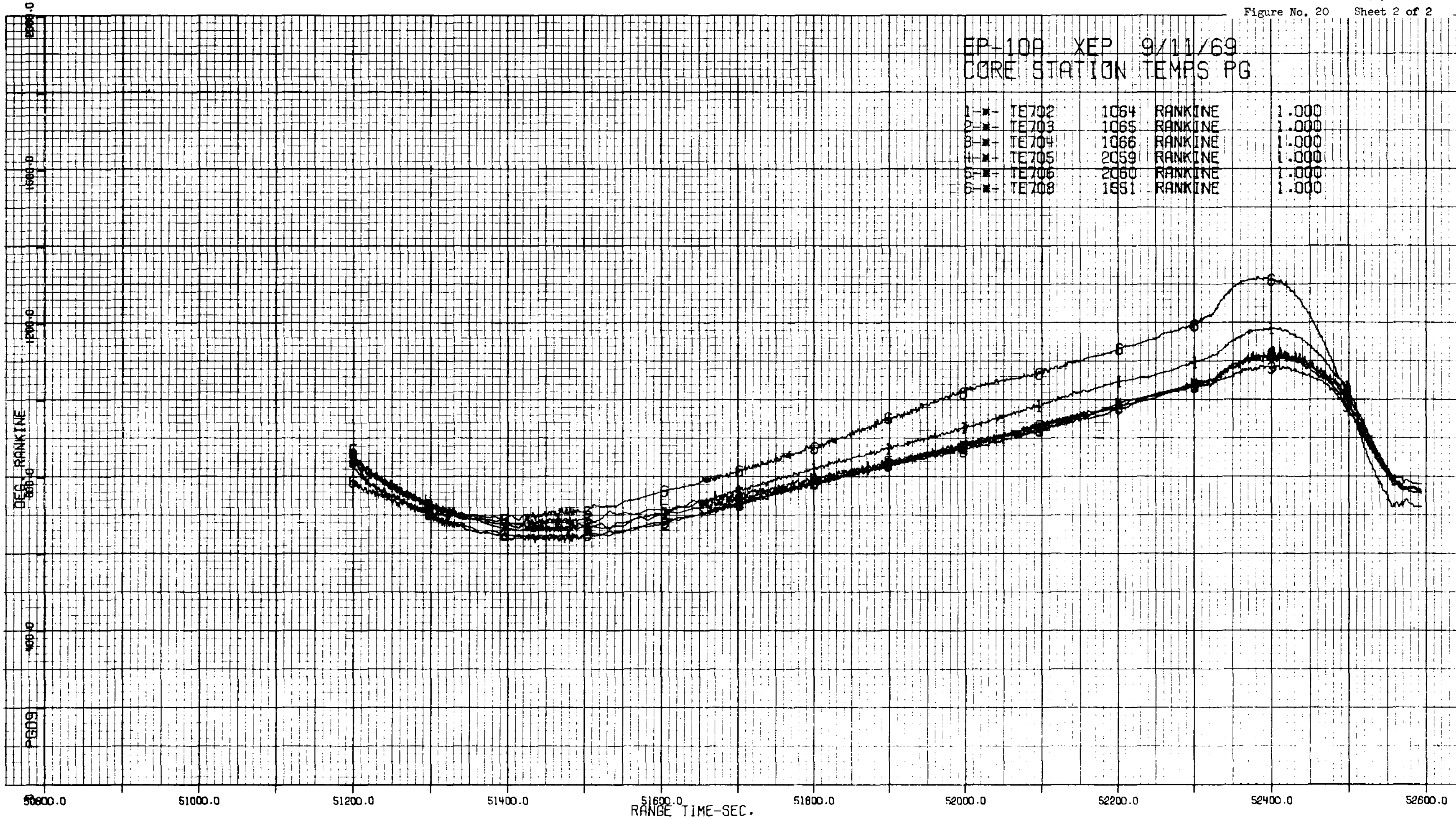
Figure No. 18 Sheet 2 of 2



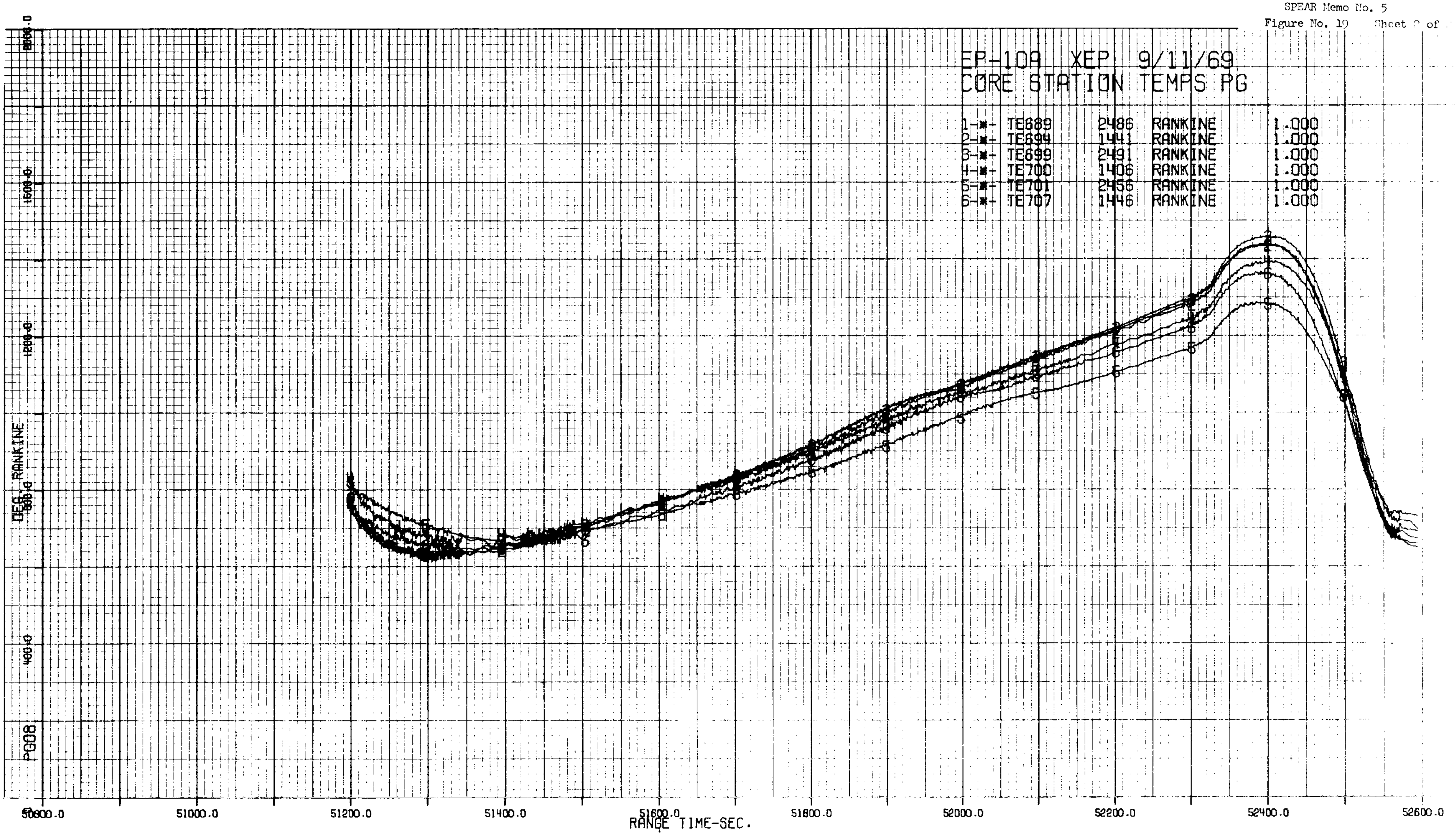
SPEAR Memo No. 5
Figure No. 19 Sheet 1 of 2

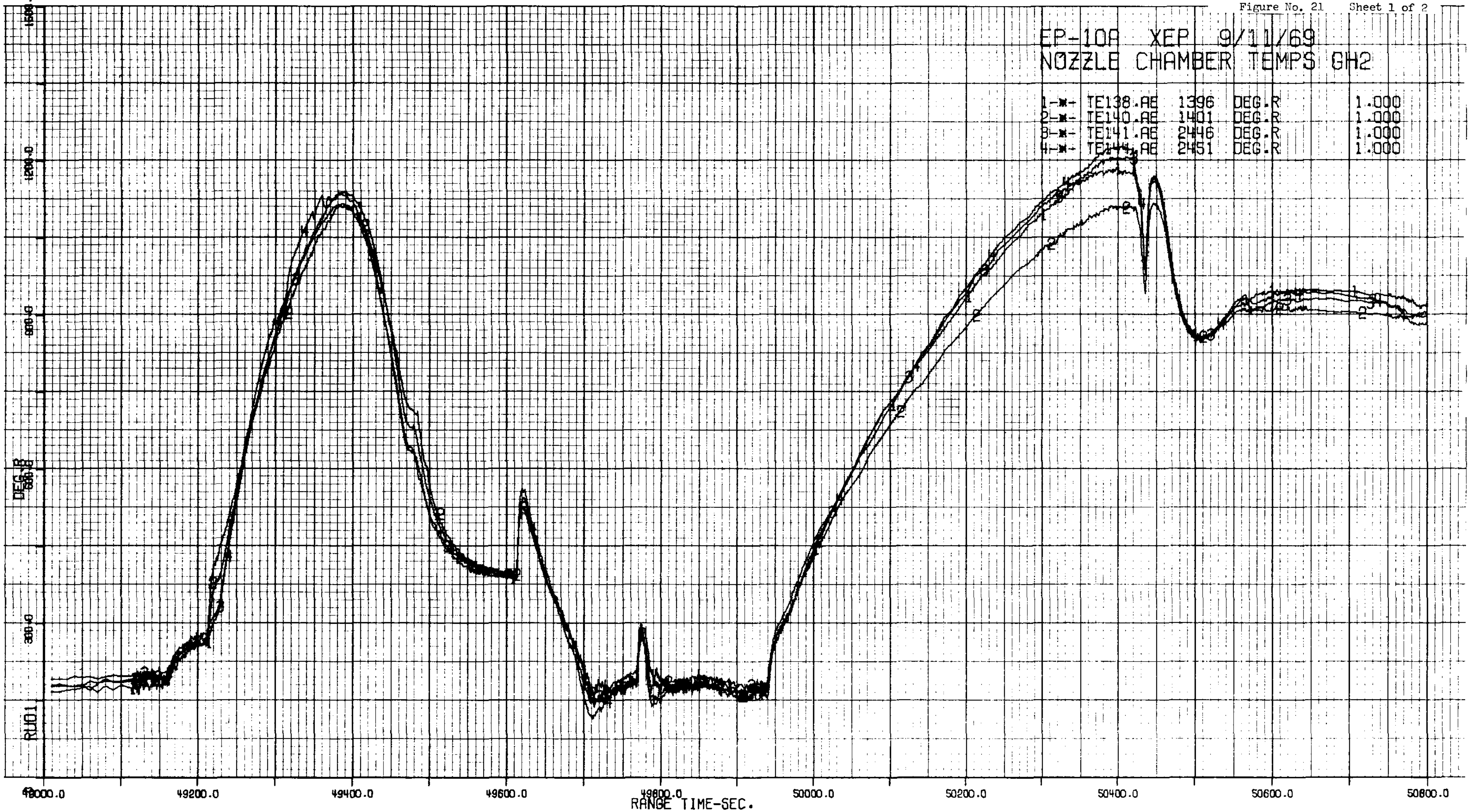


SPEAR Memo No. 5
Figure No. 20   Sheet 2 of 2



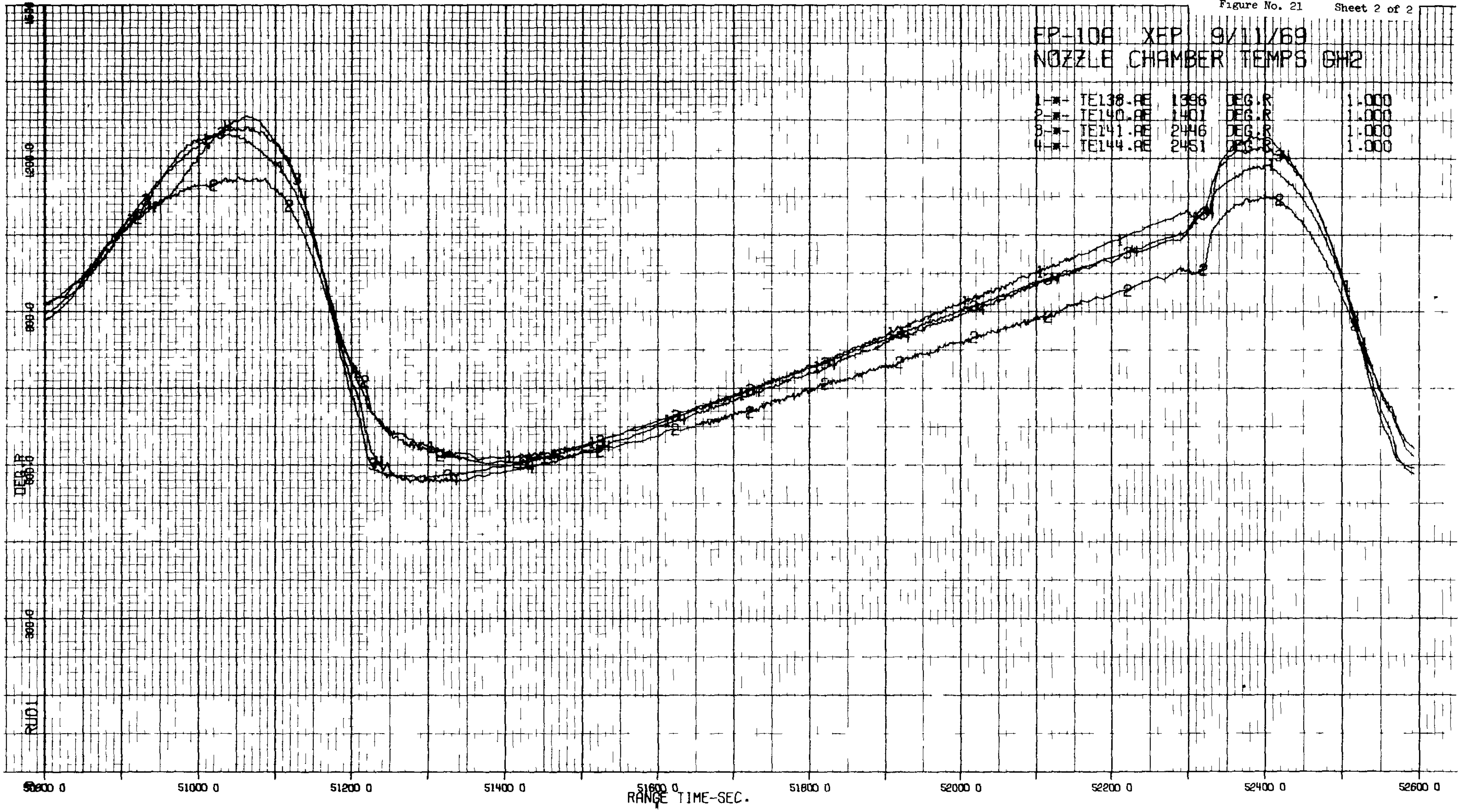
SPEAR Memo No. 5
Figure No. 19 Sheet [illegible] of [illegible]




EP-10A XEP 9/11/69
NOZZLE CHAMBER TEMPS GH2
1-✱- TE138.AE 1396 DEG.R 1.000
2-✱- TE140.AE 1401 DEG.R 1.000
3-✱- TE141.AE 2446 DEG.R 1.000
4-✱- TE144.AE 2451 DEG.R 1.000
DEG.R
RU01
49200.0
49400.0
49600.0
49800.0
50000.0
50200.0
50400.0
50600.0
50800.0
RANGE TIME-SEC.

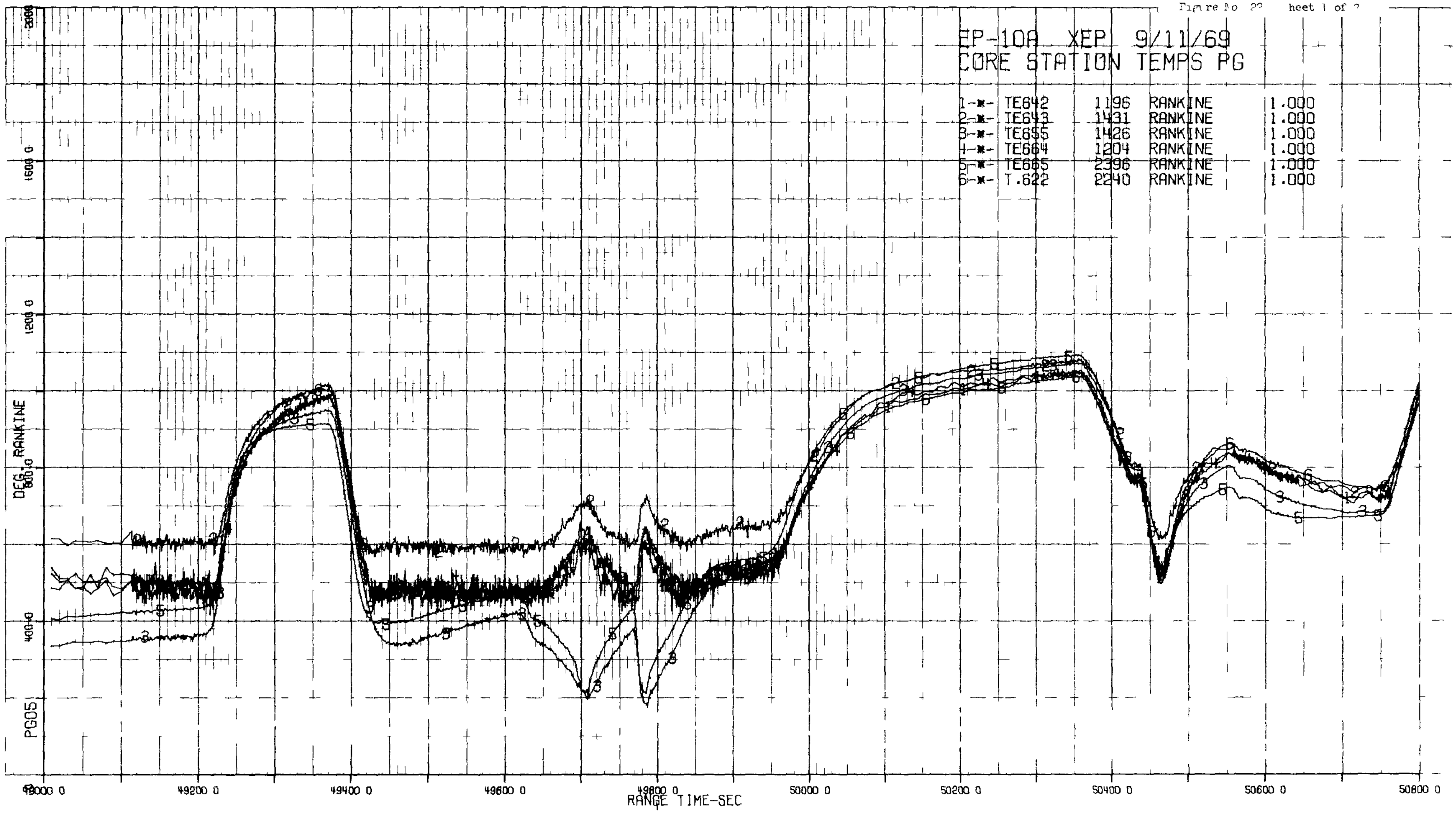
SPEAR Memo No. 5

Figure No. 21 Sheet 2 of 2



SPEAR Memo No

Figure No 22 Sheet 1 of 2



PTAR Memo No
Figure No Sheet of

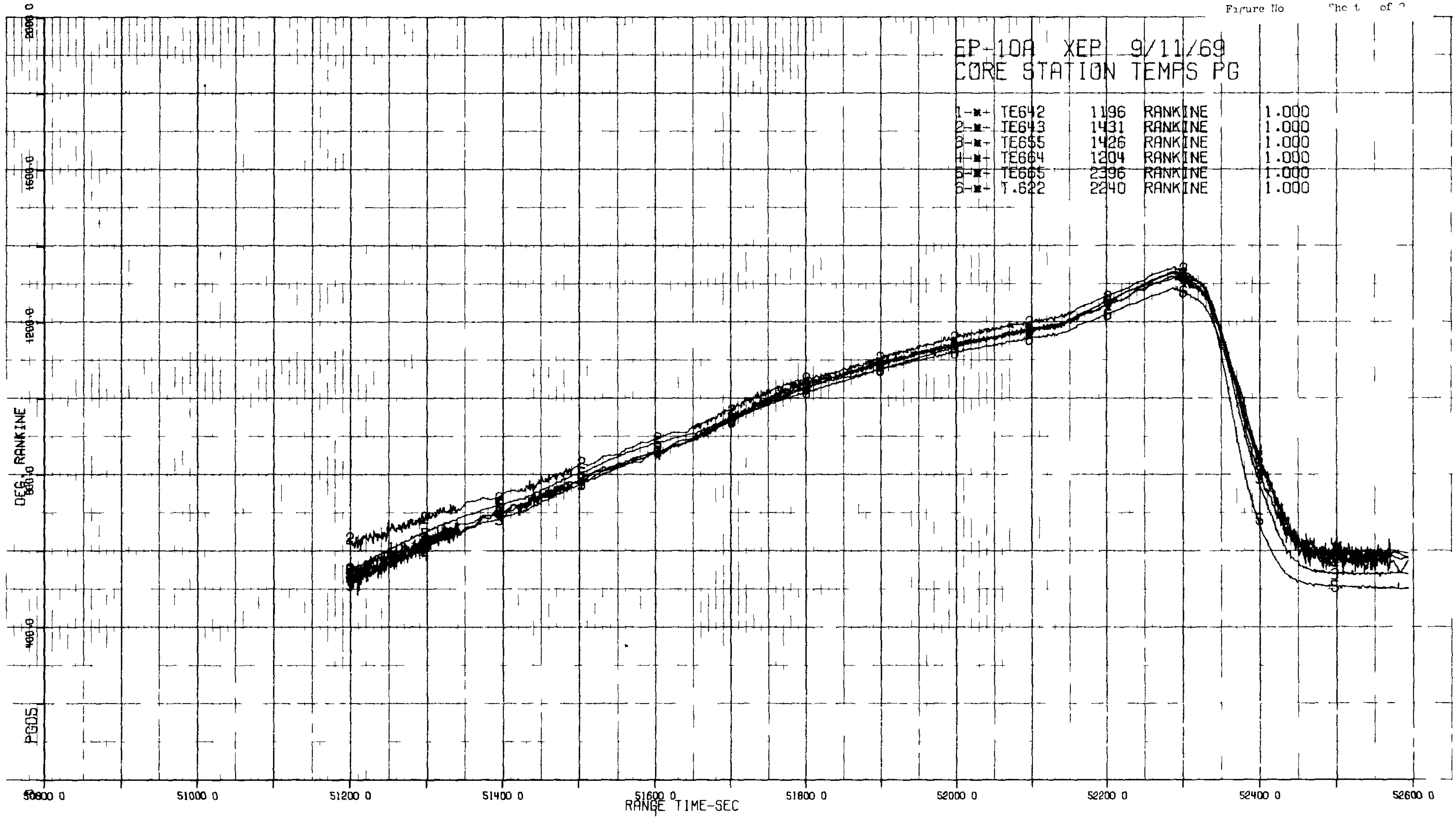


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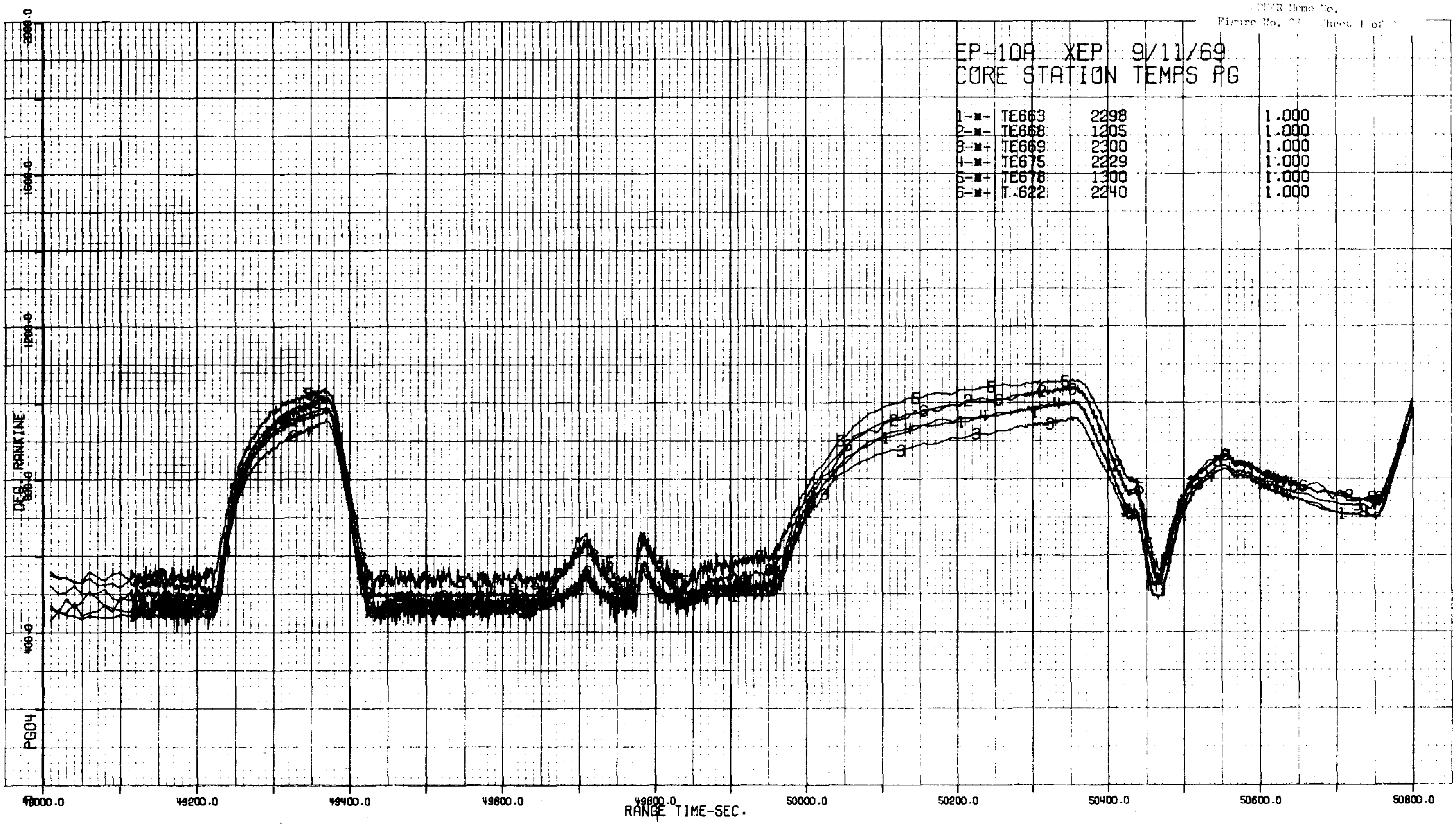
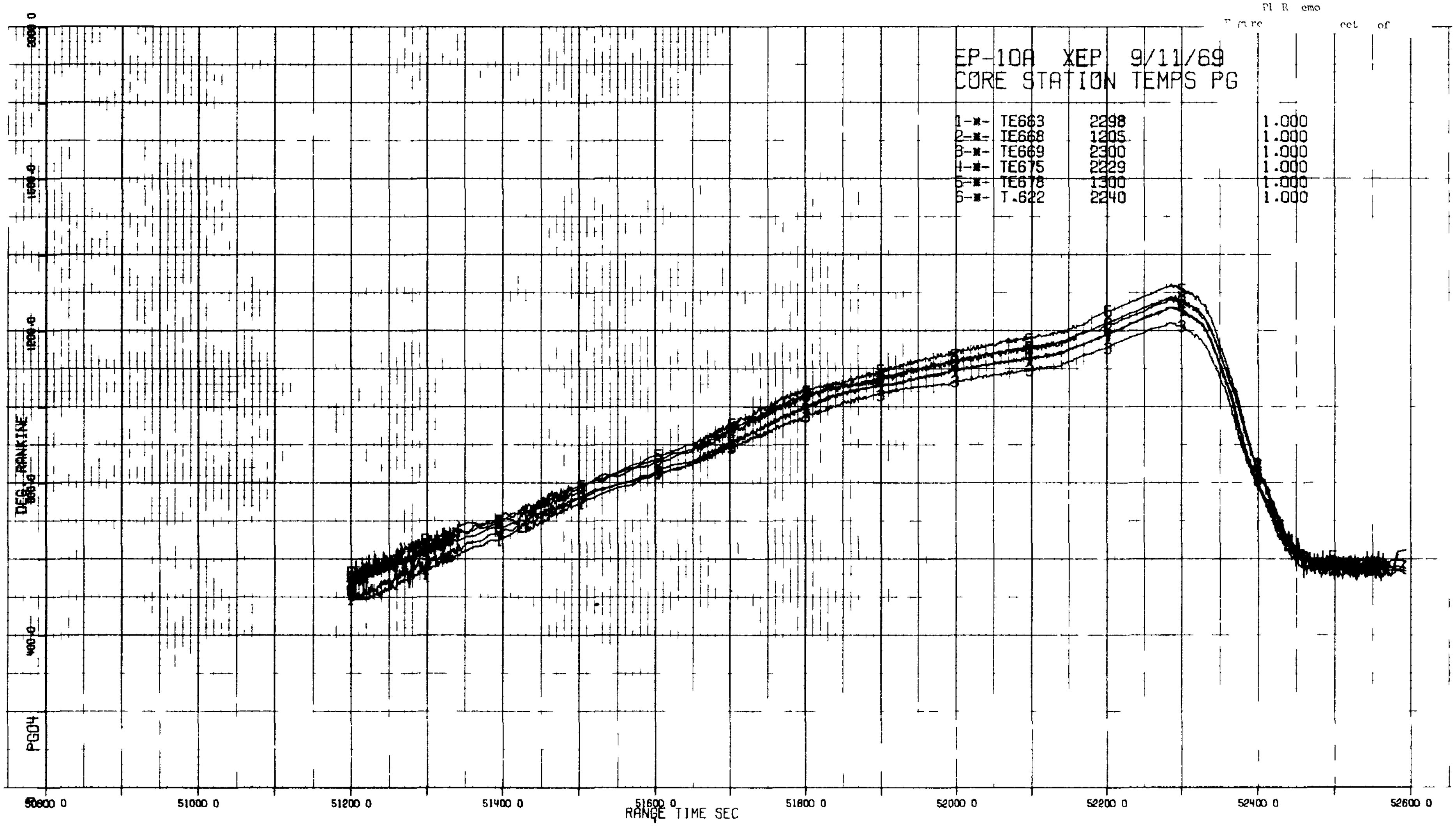
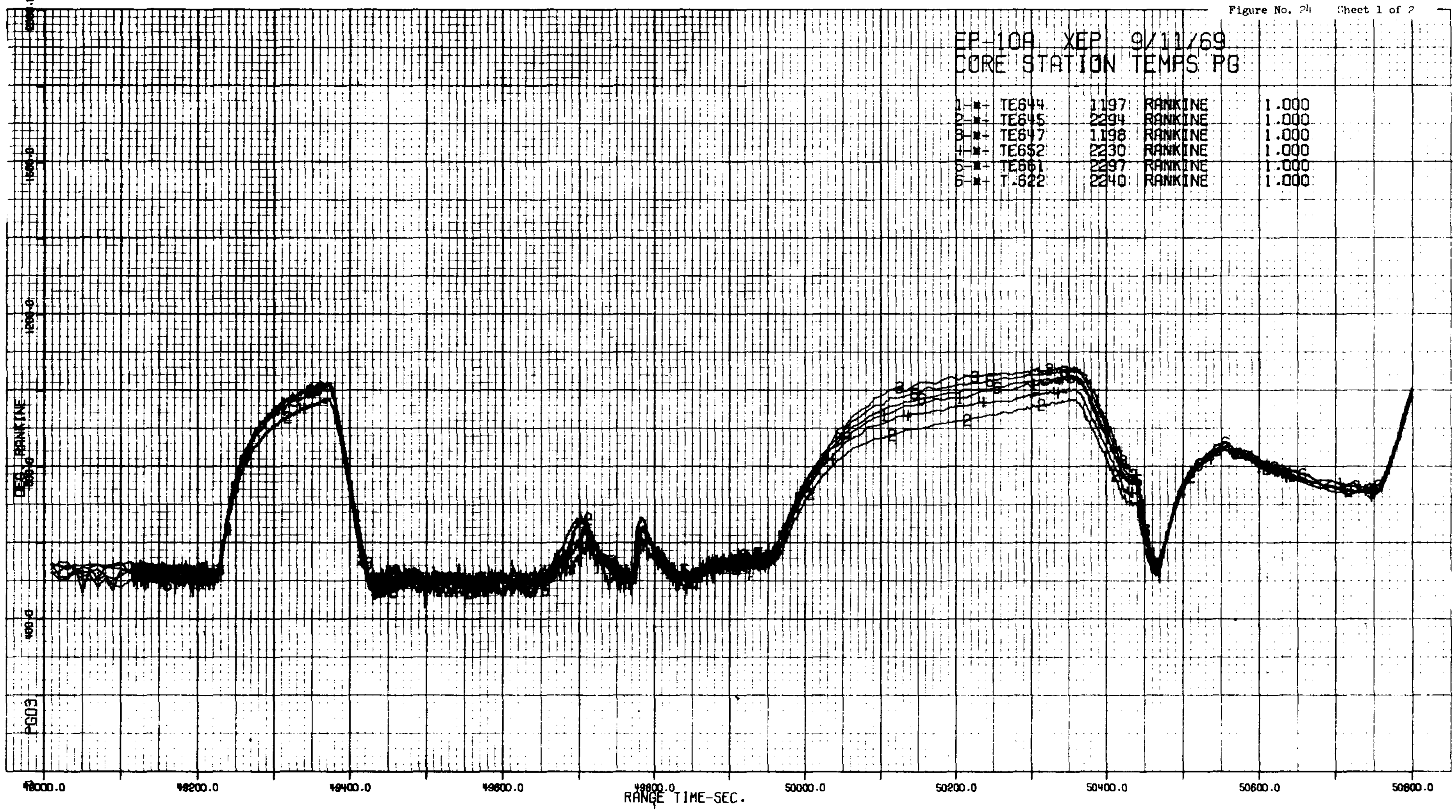
Figure No. [illegible] Sheet 1 of [illegible]



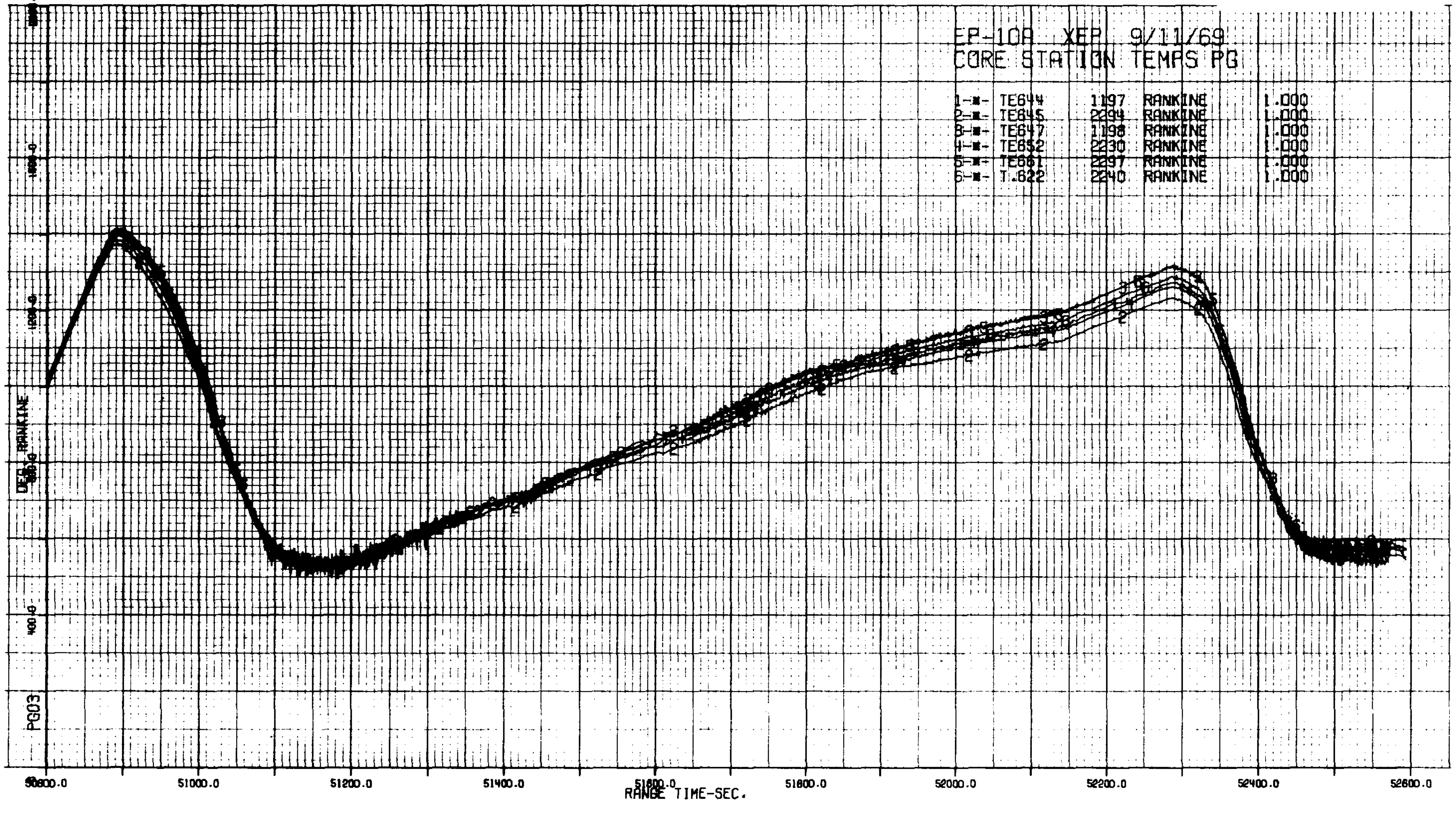

EP-10A XEP 9/11/69
CORE STATION TEMPS PG
1-*- TE663 2298 1.000
2-*- TE668 1205 1.000
3-*- TE669 2300 1.000
4-*- TE675 2229 1.000
5-*- TE678 1300 1.000
6-*- T.622 2240 1.000
DEG RANKINE
PG04
400.0
51000 0
51200 0
51400 0
51600 0
51800 0
52000 0
52200 0
52400 0
52600 0
RANGE TIME SEC

SPEAR Memo No. 5

Figure No. 24 Sheet 1 of 2



SPEAR Memo No. 5
Figure No. 24 Sheet 2 of 2



SPEAR Memo No. 6
R. Schenz/L. Burke

XE-PRIME
EP-10A

Subject: CONTROL SYSTEM PERFORMANCE

SUMMARY:

This memorandum covers the operation of the Engine Control System during EP-10A. The portions of the ECS that were analyzed were the exponential drum demand circuitry, drum position control loop, Drum Program Terminate temperature averager, and drum position averager. No anomalies were noted.

TECHNICAL DISCUSSION:

XE-Prime EP-10A consisted of six (Dry) Temperature Autostarts and two Laminar Flow tests. Controls used during the (Dry) Temperature Autostart tests consisted of the following:

(Dry) Temperature Autostart logic and drum demand profiles,

(Wet) Temperature Autostart drum demand profile generator, and

drum position control.

The logic of the (Dry) Temperature Autostart has been discussed in previous SPEAR Reports.

Controls used during the Laminar Flow tests were drum position and power control. They operated satisfactorily and have been thoroughly analyzed in previous EP's.

The data reviewed were the following:

1. (Dry) Temperature Autostart drum demand and response profiles.
2. (Wet) Temperature Autostart drum demand and response profiles.
3. Drum position control loop.
4. Drum Program Terminate temperature averager - T.910.
5. Individual drum position (D.801 - 812) vs. average drum position (D.800).

A. (DRY) TEMPERATURE AUTOSTART DRUM DEMAND AND RESPONSE PROFILES

CAL-COMP plots, Figures No. 1, 2, 3, 5 and 6, show the drum demand and response profiles for Runs No. 1, 2, 3, 6 and 7.

Table I is a reduction of the digital data and compares the actual temperature at which Drum Program Terminate occurred vs. the terminate set point (T.910), of 850°R. On Run No. 2, the drum program was terminated by a manual switch to drum position control at a T.624 of 624°R (actual value at time of switch was 608^{o}R). For information purposes, included also in Table I are exponential set points and range time at which drum terminate occurred. Inspection of the drum profiles in Figures No. 1 through 6 show that the drums were demanded out exponentially to the angle desired for the tests. The drum ramp rate was set at 0.2^{o}/sec, however, the actual rate was .17^{o}/sec in all the tests. The linear ramp began as the drum position neared the exponential set position. Drum Program Terminate initiated an immediate roll-in of 8^{o}. The maximum error from actual terminate vs. set point was -8^{o}R (842^{o}R - 850^{o}R), which is within acceptable values. The 8^{o} drum step at Drum Program Terminate was precise with no overshoot or undershoot.

B. (WET) TEMPERATURE AUTOSTART DRUM DEMAND AND RESPONSE PROFILES

(Wet) Temperature Autostart demand circuitry was used instead of the (Dry) Temperature Autostart logic on Run No. 4 because T.910 was above the 850^{o}R Drum Program Terminate set point.

Termination of the drum program and 8^{o} roll-in was accomplished by the Chief Test Engineer (CTE) by selecting drum position control when the visual monitor of T.624 indicated 1050^{o}R (200^{o} above the DPT set point of 850^{o}R). The actual temperature at which the switch from drum program to drum position control occurred are shown in Table II.

C. DRUM POSITION CONTROL LOOP

The drum position control loop was used after Drum Program Terminate on the six autostart tests. Nos. 1, 2*, 3, 4*, 6 and 7. Inspection of Figures No. 1 through 6 shows that actual average drum position (D.800) followed drum demand (CC.800) with a bias of 1 degree. This is comparable to bias on previous tests.

D. AVERAGER TEMPERATURES FOR DRUM PROGRAM TERMINATE (T.910)

T.910 is the output of an electronic "averager" and is representative of the average of the three in-core temperatures, TE646, 650 and 665. The operation of the averager was checked by calculating the arithmetic average of the three in-core temperatures at various range times. Table III compares T.910 with the calculated average.

E. DRUM POSITION AVERAGER

Drum position averager output (D.800), was compared to the arithmetic average of the individual drum positions(D.801 through D.812). The performance of the averager was checked at various range times by calculating the arithmetic average of the individual drum positions. These data are shown in Table IV.

CONCLUSIONS

The data review showed the portions of the Engine Control System used on EP-10A performed satisfactorily.

NOTE: (*) Drum position control was used by the CTE on Tests No. 2 and 4 to terminate the drum program and roll-in of 8^{o}.

TABLE I

SUMMARY OF DRUM PROGRAM PERFORMANCE DURING (DRY) TEMPERATURE AUTOSTART

RUN NO.	RANGE TIME AT DPT	EXPONENTIAL (2) SET POINT (degrees)	(1) (4) T.910 (°R)	(4) T.624 (°R)
1	41993.5	99	842	711
2	42883.9 (3)	85	742 (3)	608 (3)
3	43241.9	95	847	774
6	44045.4	103	846	804
7	44378.8	85	845	842

NOTE:
(1) Drum Program set to Terminate when T.910 equals 850°R
(2) Linear drum ramp for all runs was 0.2°/sec.
(3) Termination of Drum Program was to be accomplished by CTE by switch to drum control when the visual on T.624 = 624°R. SC608 discreet occurred at 42883.9.
(4) Values are interpolated from digital data.

TABLE II

SUMMARY OF DRUM PROGRAM PERFORMANCE DURING RUN NO. 4

RUN NO.	RANGE TIME AT DPT	EXPONENTIAL/ RAMP SET POINTS	T.910	T.624
4	42524.8	95°/(.2°/sec)	1005.3°R	1051.2°R

TABLE III

T.910 TEMPERATURE AVERAGER PERFORMANCE

RUN NO.	RANGE TIME	ARITHMETIC AVERAGE OF TE646, 650, & 665 (°R)	AVERAGER OUTPUT T.910 (°R)	DIFFERENCE BETWEEN AVERAGER OUTPUT AND ARITHMETIC AVERAGE Δ °R
1	41950.3	605.7	604.5	- 1.2
2	42950.6	893.3	889.9	- 3.4
3	43650.8	743.0	745.0	+ 2.0

TABLE IV

DRUM POSITION AVERAGER PERFORMANCE

RUN NO.	RANGE TIME	ARITHMETIC AVERAGE OF DRUM POSITIONS (degrees)	DRUM POSITION AVERAGER OUTPUT D.800 (degrees)	DIFFERENCE BETWEEN AVERAGER OUTPUT AND ARITHMETIC AVERAGE Δ (degrees)
4	43495.7	105.0	104.8	- 0.2
6	44065.4	99.6	99.6	± 0
Laminar Flow	47875.5	79.2	79.3	± 0.1
Drum Transient Run No. 1	41925.3	75.7	75.8	± 0.1

SPEAR Memo No. 7

SPEAR Team

KRC

XE-PRIME

EP-10A

Subject: ENGINE PUMP DISCHARGE CHECK VALVE, PROPELLANT SHUTOFF VALVE, AND FIVE-INCH BUTTERFLY VALVES

SUMMARY:

This report presents the results pertaining to the functional performance evaluation of the EP-10A engine valves, as listed above.

At RT 58377 the nozzle torus was pressurized to approximately 100 psia with LN_2 coolant flow. During this time PSV was closed, PDSV was open, and PDVV was closed. There was no indication of pressurization of the volume above PDKV, verifying that PDKV was closed and that any leakage through it was negligible.

The PSV and pilot valve were cycled four (4) times during EP-10A. Of the cycles, the first was conducted at ambient temperature and a reduced actuation pressure of 67 psia. The remaining three (3) cycles were conducted at cryogenic and a nominal actuation pressure of 507 psia. This increases the accumulated number of cycles to 95 of which 35 have been conducted at operating temperature and pressure. Valve chronology placing the PSV operating events in perspective to overall engine operation is tabulated in Table I. The eight-inch PSV and pilot valve performed satisfactorily during the EP-10A test with no anomalies noted with respect to functional operation.

All the five-inch butterfly valves were cycled at a nominal actuation pressure of approximately 500 psig during EP-10A. The PDSV was cycled 27 times for an accumulated total of 89 cycles using 500 psig nominal actuation pressure. The PDVV was cycled four times for an accumulated total of 36 cycles at 500 psig. The CSV was cycled five times at 500 psig for an accumulated total of 49 cycles and the CVV was cycled seven times for an accumulated total of 154 cycles. A summary of typical five-inch butterfly valve cycle data is presented in Table II including the total number of cycles on each valve at various actuation pressures greater than 150 psia. A valve chronology listing the PDSV, PDVV, CSV and CVV operating events with respect to overall engine operation is shown on Table I. Following each actuation of the PDSV, PDVV, CSV and CVV, when valve movement was terminated, the actuation gas flowrate (WHE-432) returned to the initial value recorded prior to the five-inch valve command signal. This indicates no excessive leakage in either the five-inch valve actuators or the associated pilot valves.

The PDVV, CSV and CVV operated satisfactorily during the test and no anomalies were noted. The PDSV operated normally with the exception of twenty-two opening cycles and three closing cycles. The condition that caused the abnormal operation of the cycles is noted in the PDSV discussion and is attributed to a short in the electrical system that operates the opening and closing pilot valves.

TECHNICAL DISCUSSION

Parameters investigated for evidence of performance of the above mentioned valves are noted in Reference 1, SPEAR Memos No. 19, 20 and 21.

A. PUMP DISCHARGE CHECK VALVE (PDKV)

An investigation of parameters pertaining to the PDKV revealed that evaluation of the valve could not be made. While pressure, temperatures and flow rates were investigated, a range time could not be found where proper positioning of the five-inch butterfly valves would allow an evaluation of PDKV checking function.

B. ENGINE PROPELLANT SHUTOFF VALVE (PSV)

The PSV was cycled open and closed once at ambient temperature and at a reduced actuation pressure of 67 psia. Two cryogenic cycles were conducted at a temperature averaging 44°R and one cycle was conducted at a temperature averaging 273°R. All three cycles were at a nominal 507 psia GHe actuation pressure. Figure No. 1, using rapid sample (short) data present a typical cyrogenic valve position vs. time trace indicating delay from pilot valve command (SR-637) to final valve movement.

Actuation gas flow rate data for each PSV opening cycle, conducted at nominal operating conditions, indicated no deviations from prior EP's. Data indicated that during EP-10A the PSV actuator, piston stop seal assembly, and the 806235-3 pilot valve operated in a satisfactory manner.

The eight-inch propellant shutoff valve performed satisfactorily and is acceptable for further testing.

Valve chronology placing the PSV operating events in perspective to over-all engine operation is shown in Table I.

C. PUMP DISCHARGE SHUTOFF VALVE (PDSV)

The PDSV was cycled a total of 27 times during EP-10A. Indications of delayed opening times of approximately 8 - 9 seconds (between command switch and initial valve movement) was apparent on 22 of the 27 cycles. Three of the closing cycles showed erratic delay times from command switch until initial valve movement.

Reference 1: NTO-R-0175, SPEAR Report for XE-Prime, EP-8A, Physics and Startup Tests

Three of the opening cycles which indicated evidence of both electrical and mechanical delay times are tabulated below for clarification:

OPENING CYCLE	EVENT SWITCH TIME	VALVE STARTED OPEN TIME	ACTUATION PRESS. psia	INLET PRESS. psia	INLET TEMP. °R
1	44394.2	44405	507	35	43
2	44474.8	44486	507	35	98
3	44625.7	44710	507	35	98

Approximately 11 seconds (Opening Cycle 1) elapsed from the event switch command until PDSV started to open. Cycles 2 and 3 had elapsed times of approximately 11 and 84 seconds, respectively, before PDSV showed indications of going full open (see Figures No. 2, 3, and 4). Data indicates that during the above three cycles, PDSV moved 2 - 4° after the electrical signal reached the pilot valve (that initiates venting of the closing actuator cavity) and venting of the actuator cavity took place. Once PDSV started to open (beyond the 2 - 4° characteristic) the valve travel actuation times were normal. This same initial travel of 2 - 4° has been experienced occasionally on some of the development valves when the venting of the pressurized actuator cavity occurs, but no opening actuation pressure is provided. As the cavity vents, the spring load will open the valve. In some instances, however, the valve would "hang up" for a period of time at the 2 - 4° position.

Post-test (R + 1) checks of the PDSV circuitry reveal that the PDSV opening solenoid coil was shorted from the facility 55 area out toward XE-P. At this time it is not know if the valve openings were by spring load after the pressurized cavity vented, or if the solenoid valve eventually cycled and the PDSV opening cycles were due to actuation pressure. Since the answer to this question is not known, it is also not known what the extent and significance is of the "binding up", after a small initial movement, displayed in three of the opening cycles.

The above short was reported on Quality Reliability Disposition Report No. 4849.

In addition, a request has been initiated to run complete electrical system checks prior to removal of the XE-Prime engine from the facility. It is recommended that PDSV and the solenoid valves be inspected following the engine disassembly.

D. PUMP DISCHARGE VENT VALVE (PDVV)

The PDVV operated satisfactorily during EP-10A. The valve was cycled a total of four times at cryogenic temperature during EP-10A for a total of 36 cycles at 500 psig nominal actuation pressure for all of the EP tests. A typical PDVV opening and closing cycle is shown in Figures No. 8 and 9.

E. COOLDOWN SHUTOFF VALVE (CSV)

The CSV was cycled a total of four times at cryogenic temperature and one time at ambient temperature during EP-10A and no anomalies were noted. The CSV was subjected to an accumulated total of 49 cycles at 500 psig actuation pressure during the EP tests. Figures No. 10 and 11 reveal a typical CSV opening and closing cycle.

F. COOLDOWN VENT VALVE (CVV)

No anomalies were noted during functional operation of the CVV during the EP-10A tests. The CVV was cycled a total of seven times at cryogenic temperature during EP-10A for an accumulative total of 154 cycles at 500 psig nominal actuation pressure during all the EP tests. A typical CVV opening and closing cycle is presented in Figures No. 12 and 13.

CONCLUSION

There were no anomalies associated with the functional operation of the PDVV, CSV, CVV, and PSV valves and associated pilot valves during EP-10A. During functional operations of PDSV, erratic opening and closing cycles were noted. Erratic operation is attributed to an electrical problem.

TABLE I

VALVE CHRONOLOGY - EP-10A

Code: S = Started   O = Open(d)
C = Completed   C = Close(d)

RANGE TIME	PSV	PDSV	PDVV	CSV	CVV
30934	SO				
31310	SC				
35026				SC	
35053		SC		SO	
35073				SC	
36541			SO		
41730	SO				
41870			SC		
41919			SO		
41913			SC		
42007		SO			
42144		SC			
42147		SO			
42160		SC			
42179		SO			
42247		SC			
42271		SO			
42275		SC			
42455		SO			
42497		SC			
42534		SO			
42546		SC			
42586		SO			
42594		SC			
42952		SO			
42960		SC			
43022		SO			
43056		SC			
43076		SO			
43079		SC			
43106		SO			

TABLE I (Continued)

RANGE TIME	PSV	PDSV	PDVV	CSV	CVV
43110		SC			
43256		SO			
43265		SC			
43325		SO			
43361		SC			
43391		SO			
43399		SC			
43596		SO			
43616		SC			
43685		SO			
43746		SC			
43847		SO			
43853		SC			
43878		SO			
43882		SC			
44028				SO	
44052		SO			
44059		SC			
44072		SO			
44076		SC			
44098		SO			
44159		SC			
44406		SO			
44414		SC			
44486		SO			
44518		SC			
44636		SO			
44712		SC			
44720		SO			
44814		SC			
44851		SO			
44875	SC		SO		
45015				SC	
45025					SO

TABLE I (Continued)

RANGE TIME	PSV	PDSV	PDVV	CSV	CVV
45618					SC
45928					SO
46108					SC
46188					SO
46438					SC
46478					SO
47114					SC
47204					SO
47417				SO	
47418					SC
48686					SO
48699				SC	
49124				SO	
49127					SC
49483				SC	
49486					SO
49500			SC		
49613	SO				
49702	SC				
49895		SC			
49898			SO		
49909				SO	
49915					SC
52833	SO				
52983	SC				
53003			SC		
53023		SO			

TABLE II

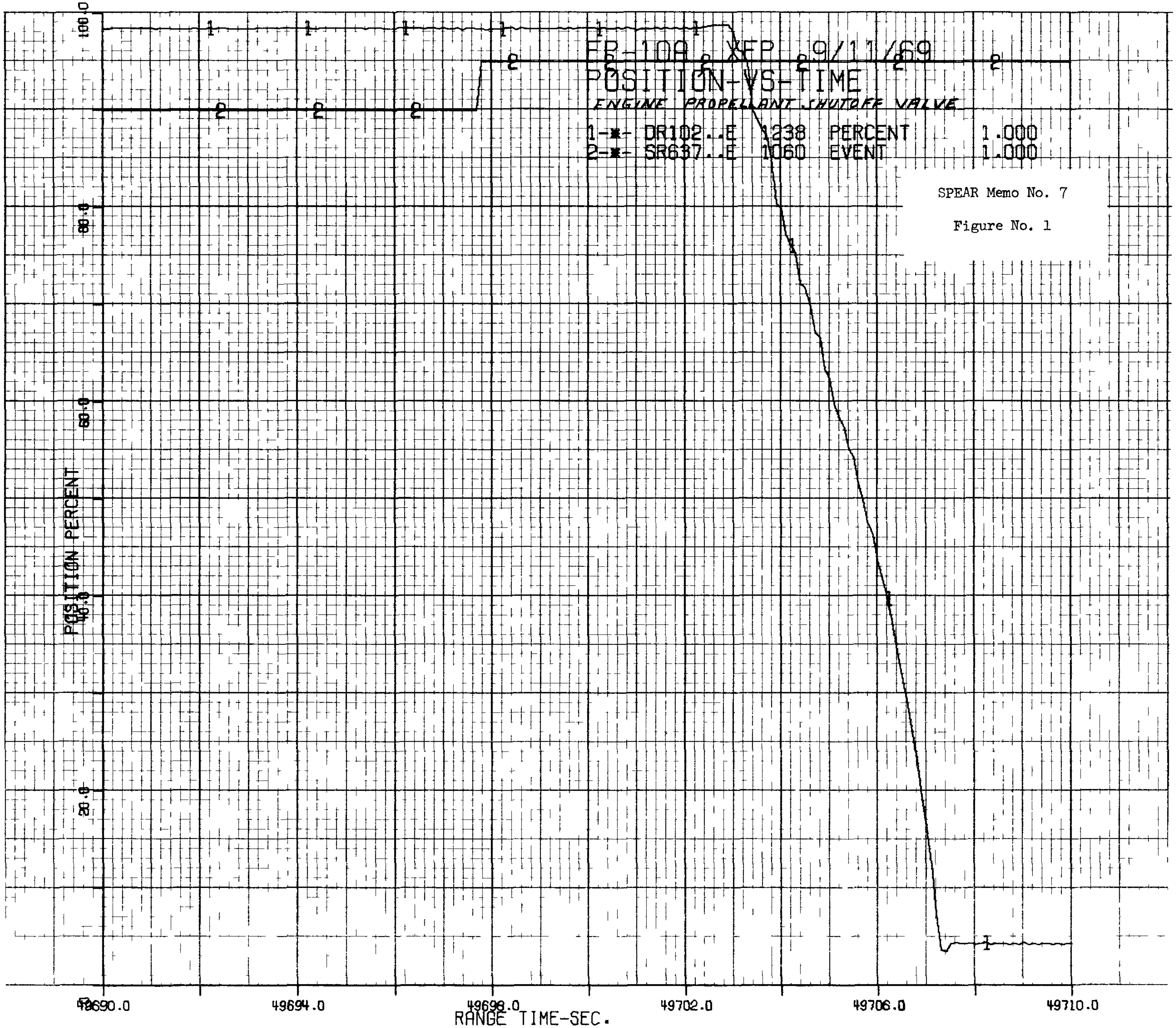
EP-10A ENGINE FIVE-INCH BUTTERFLY VALVES

TYPICAL CYCLING DATA

VALVE	ACTIVITY	SWITCH EVENTS (FROM PASS EV01)	DELAY TIME TO START OF STROKE	RANGE TIME AT START OF STROKE (sec)	DURATION OF TRAVEL (sec)	ACTUATION PRESS. (APPROX.) (psia)	VALVE MAIN STREAM INLET CONDITIONS PRESS. (PSIA)	VALVE MAIN STREAM INLET CONDITIONS TEMP. (°R)	ACTUATION FLOWRATE (MAX.) (lb/sec)	TOTAL CYCLES DURING EP-10A	TOTAL ACCUM. CYCLES-ALL EP TESTS
CVV	Closing	49914.8	.3	49915.1	2.7	507	14	144	*		
	Opening	49487.2	.1	49487.3	1.2	507	14	325	*	7	154
CSV	Opening	**	-	49910.1	2.1	507	14	144	*		
	Closing	**	-	49483.9	1.2	507	14	325	*	5	49
PDVV	Closing	49500.7	.4	49501.1	1.9	507	14	324	.017		
	Opening	49899.3	.1	49899.4	1.0	507	14	143	.022	4	36
PDSV	———	SEE DISCUSSION								27	89

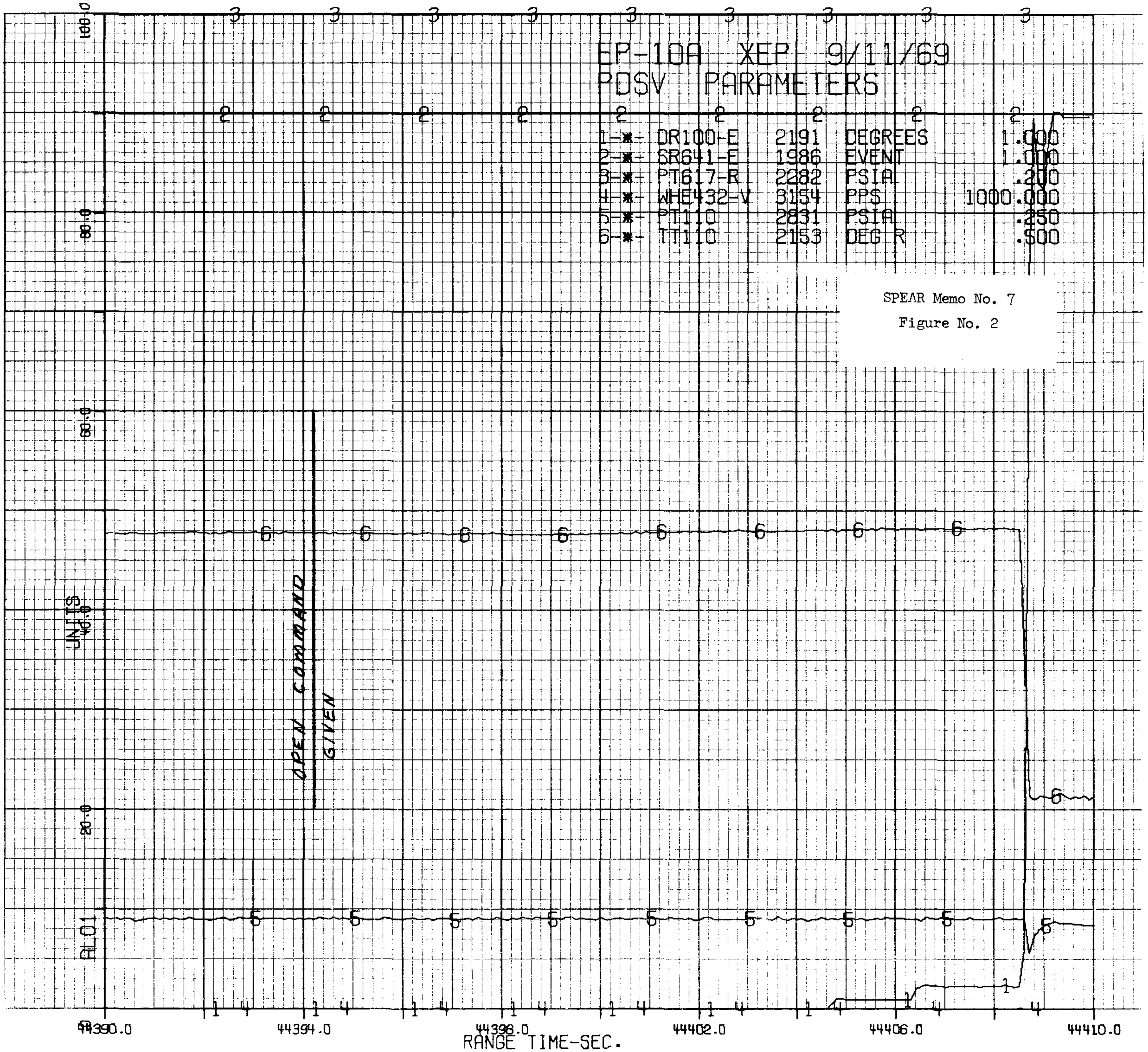
Code: * Actuation flowrate recording was sporadic.

** No event switch recording on PASS EV01.



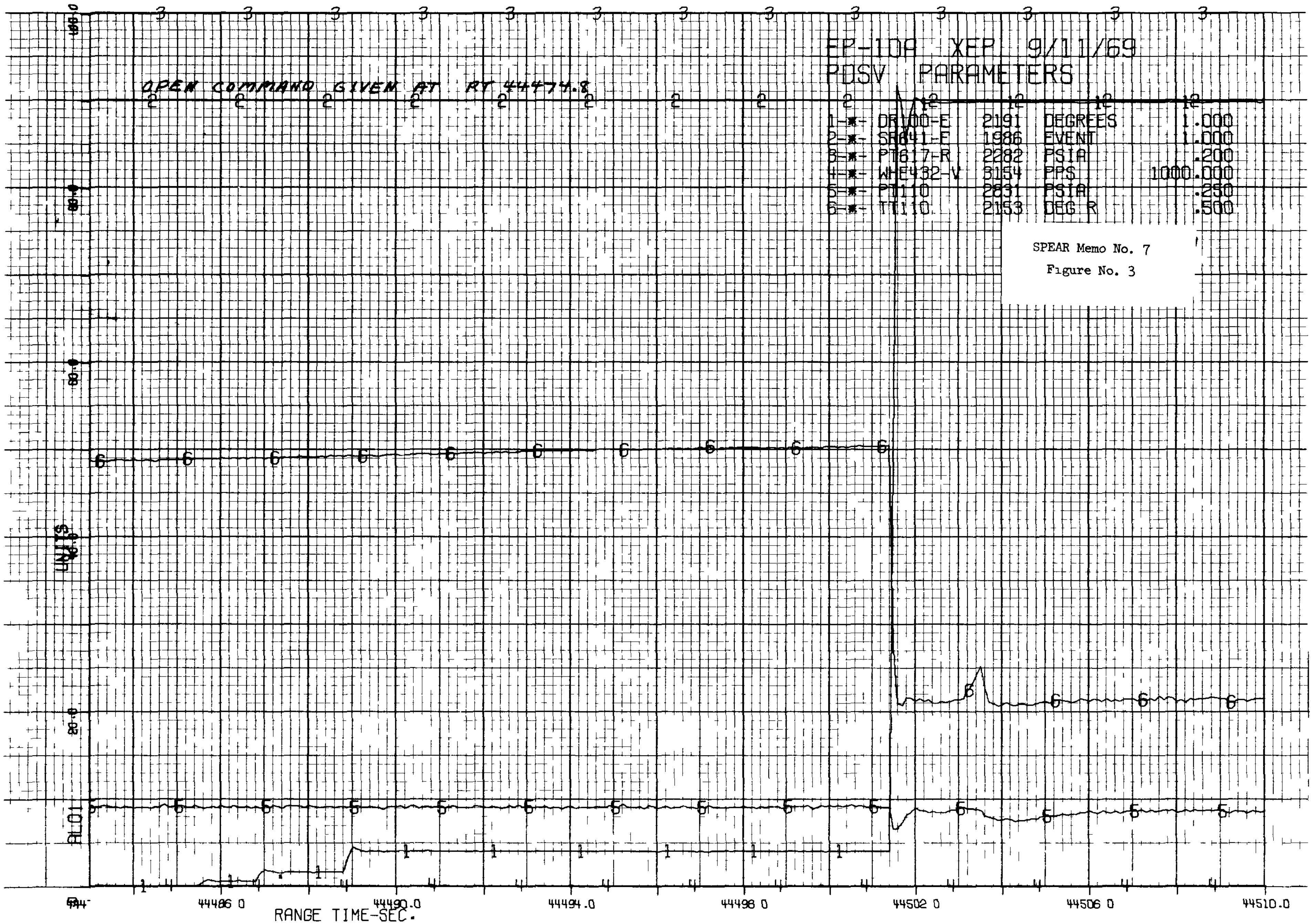
SPEAR Memo No. 7

Figure No. 1



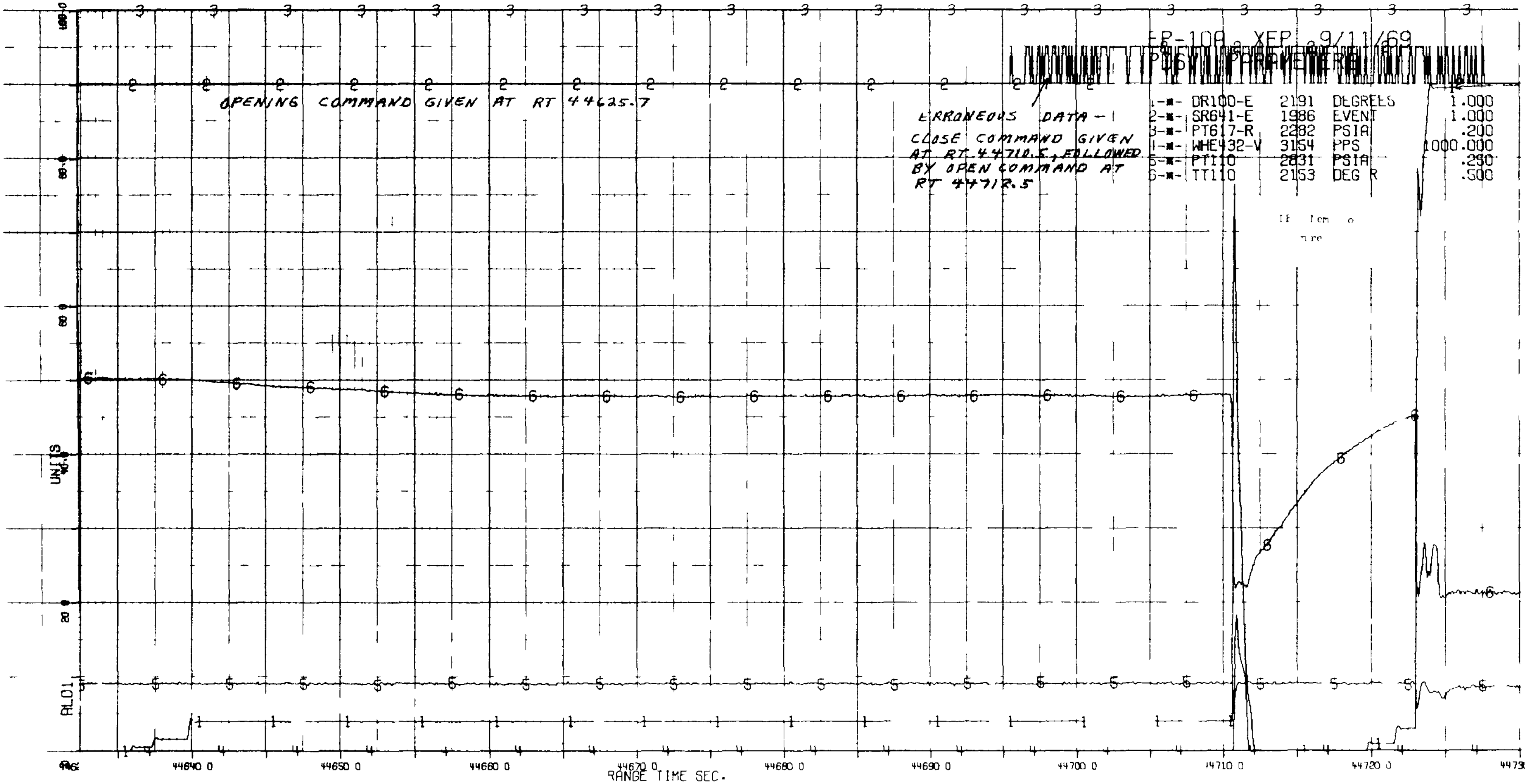
SPEAR Memo No. 7

Figure No. 2

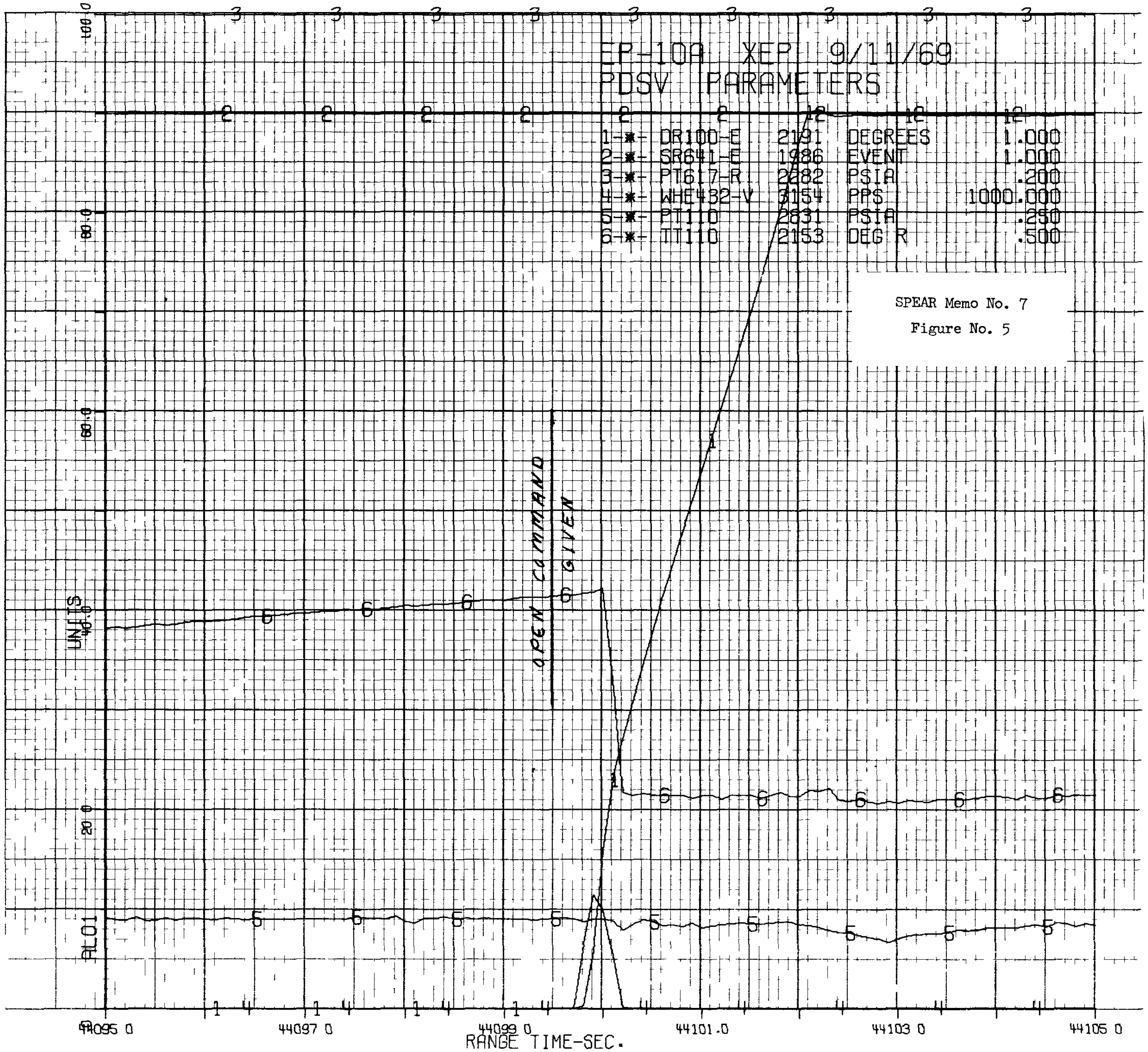


SPEAR Memo No. 7

Figure No. 3

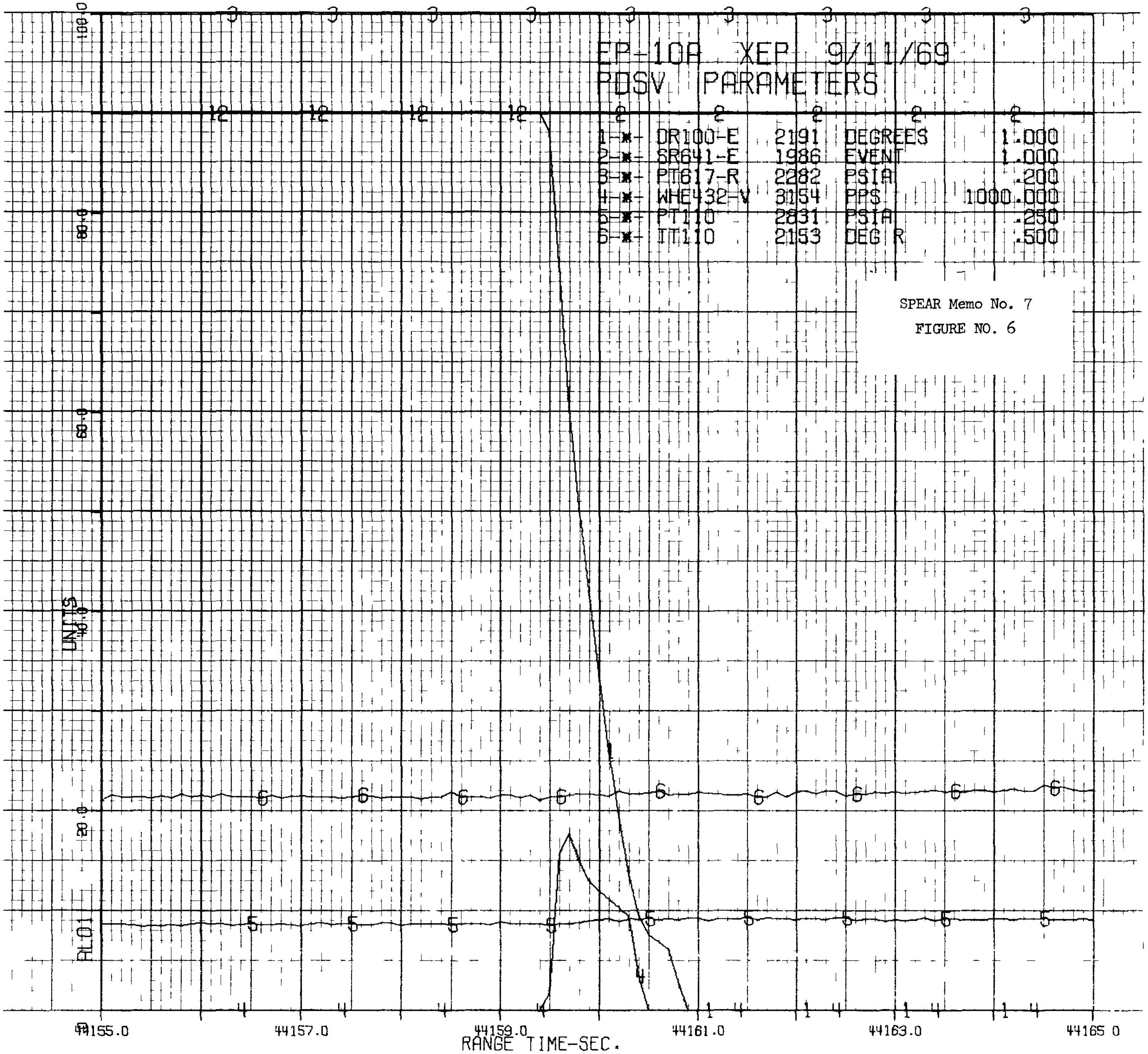


FP-10A XFP 9/11/69
PU6V PARAMETERS
1-*- DR100-E 2191 DEGREES 1.000
2-*- SR641-E 1986 EVENT 1.000
3-*- PT617-R 2282 PSIA .200
4-*- WHE432-V 3154 PPS 1000.000
5-*- PT110 2831 PSIA .250
6-*- TT110 2153 DEG R .500
OPENING COMMAND GIVEN AT RT 44625.7
ERRONEOUS DATA
CLOSE COMMAND GIVEN AT RT 44710.5, FOLLOWED BY OPEN COMMAND AT RT 44712.5
UNITS
ALD1
RANGE TIME SEC.
44640.0
44650.0
44660.0
44670.0
44680.0
44690.0
44700.0
44710.0
44720.0



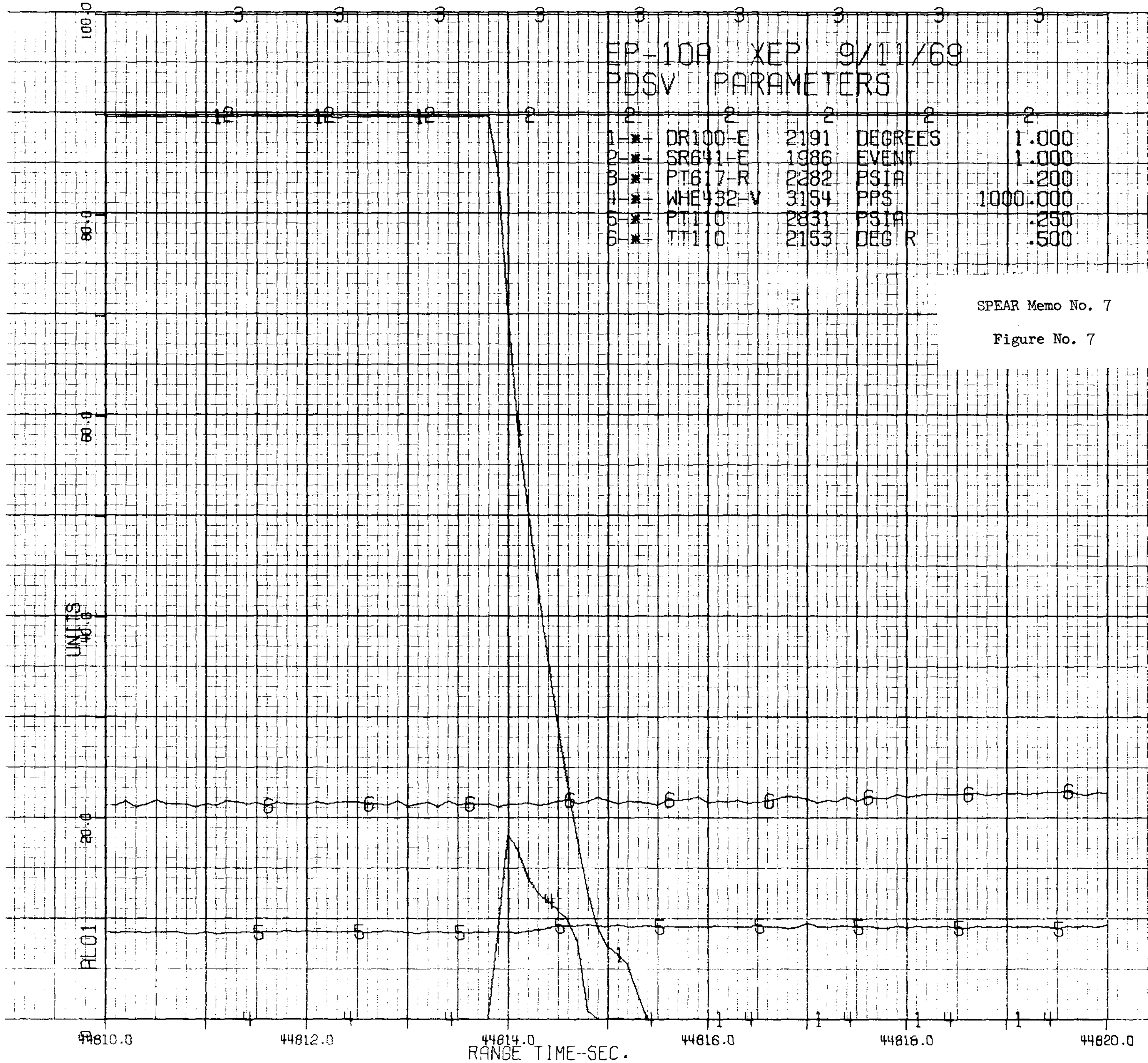
SPEAR Memo No. 7

Figure No. 5



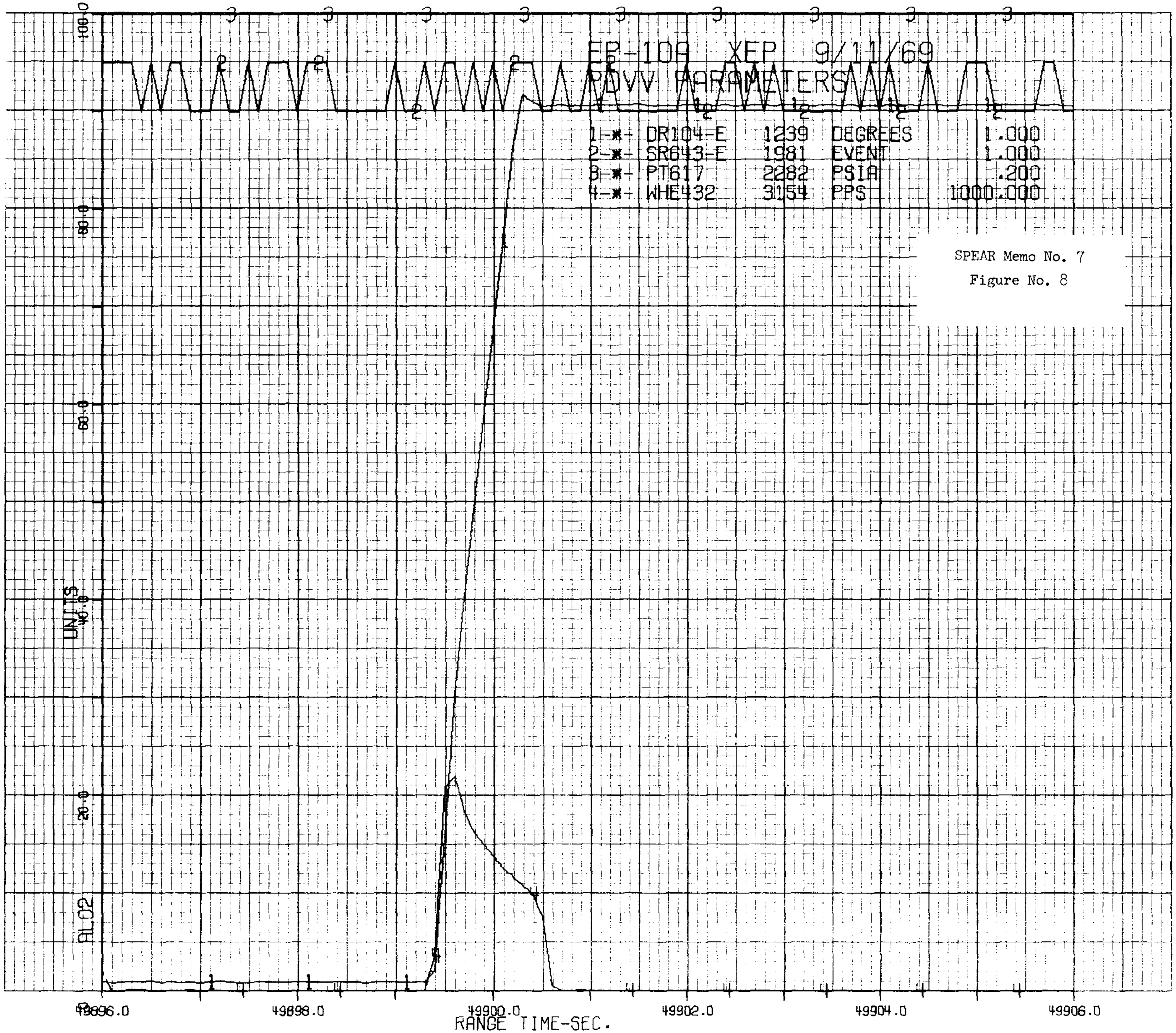
SPEAR Memo No. 7

FIGURE NO. 6

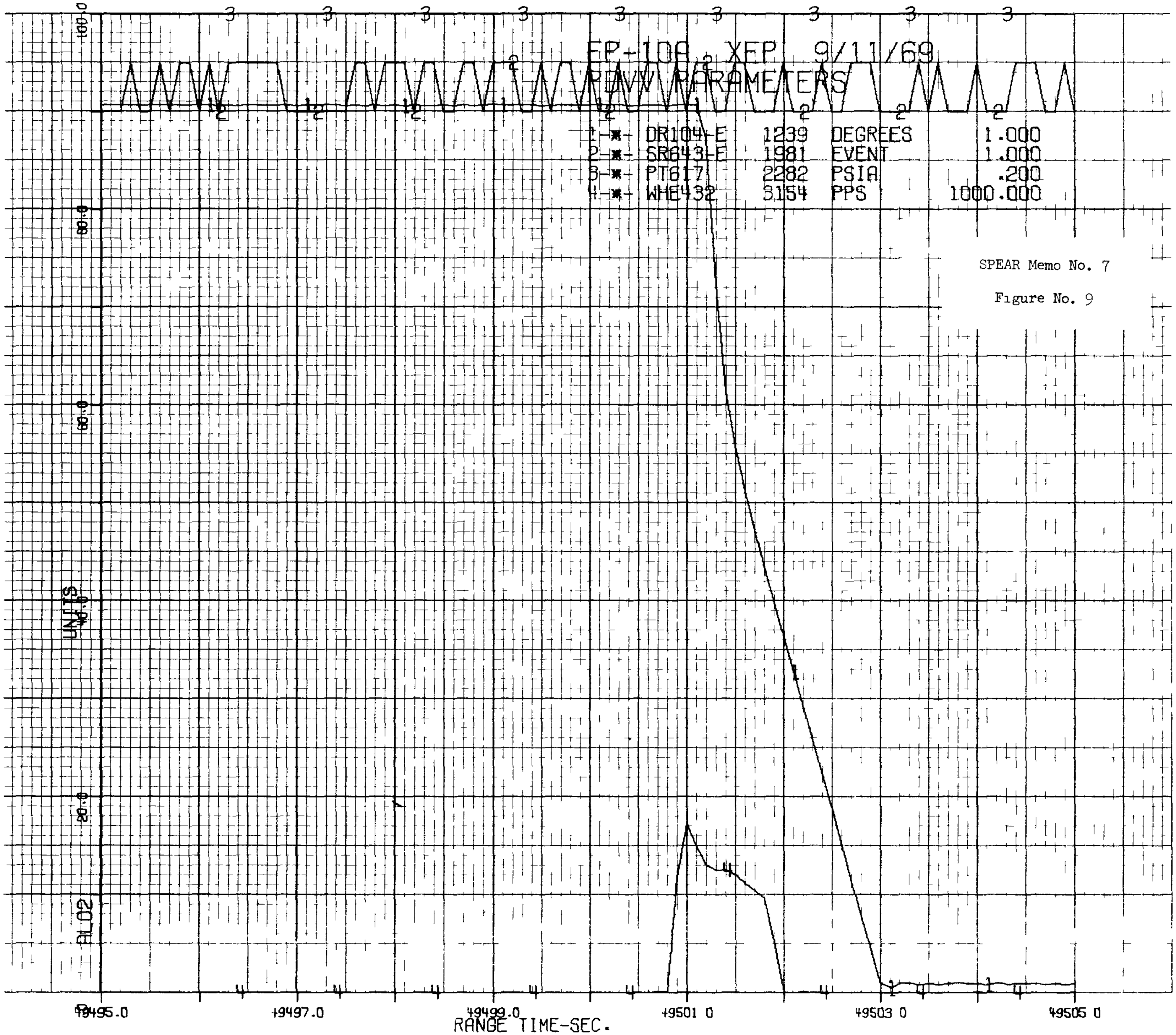


SPEAR Memo No. 7

Figure No. 7

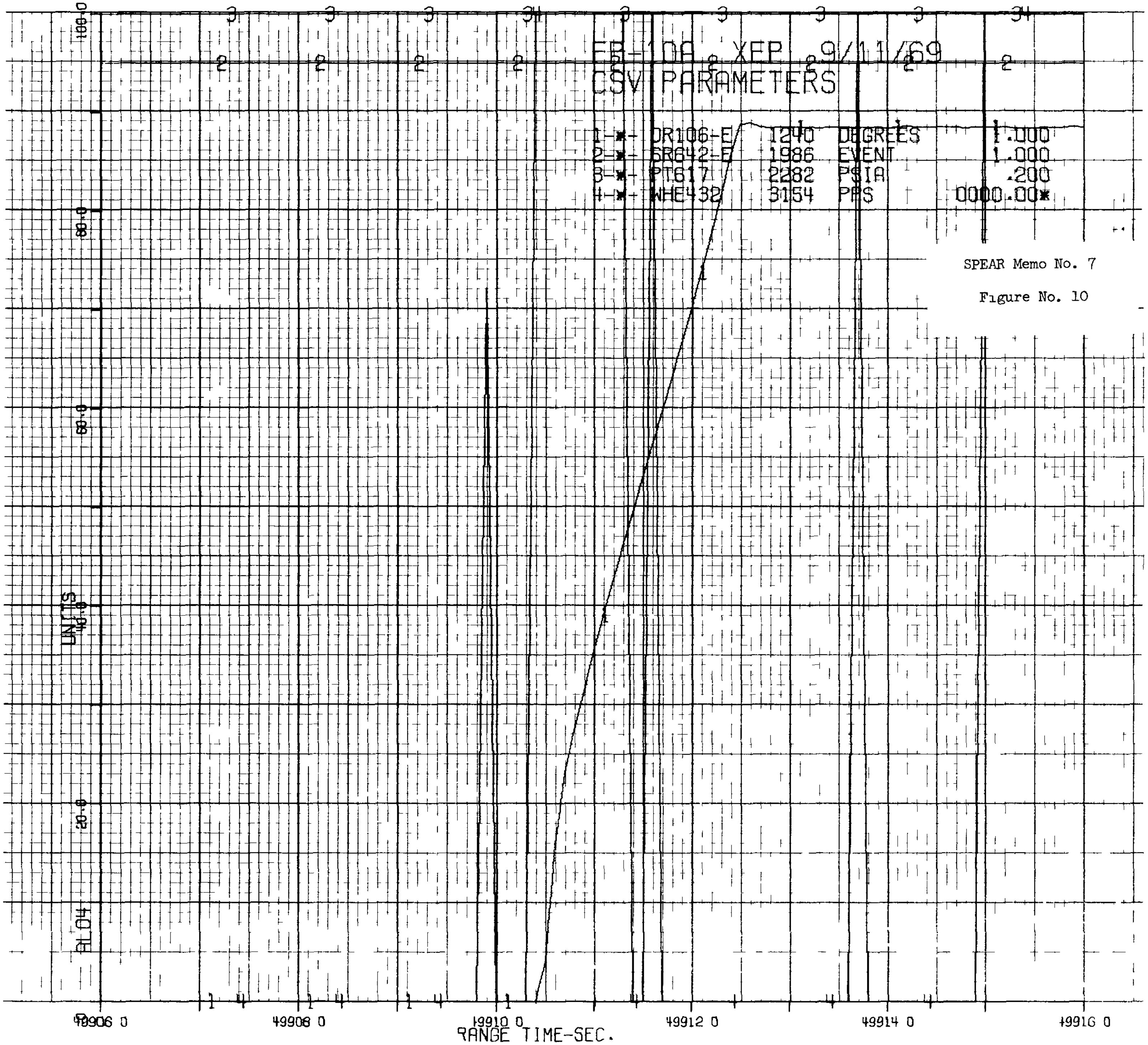


SPEAR Memo No. 7
Figure No. 8



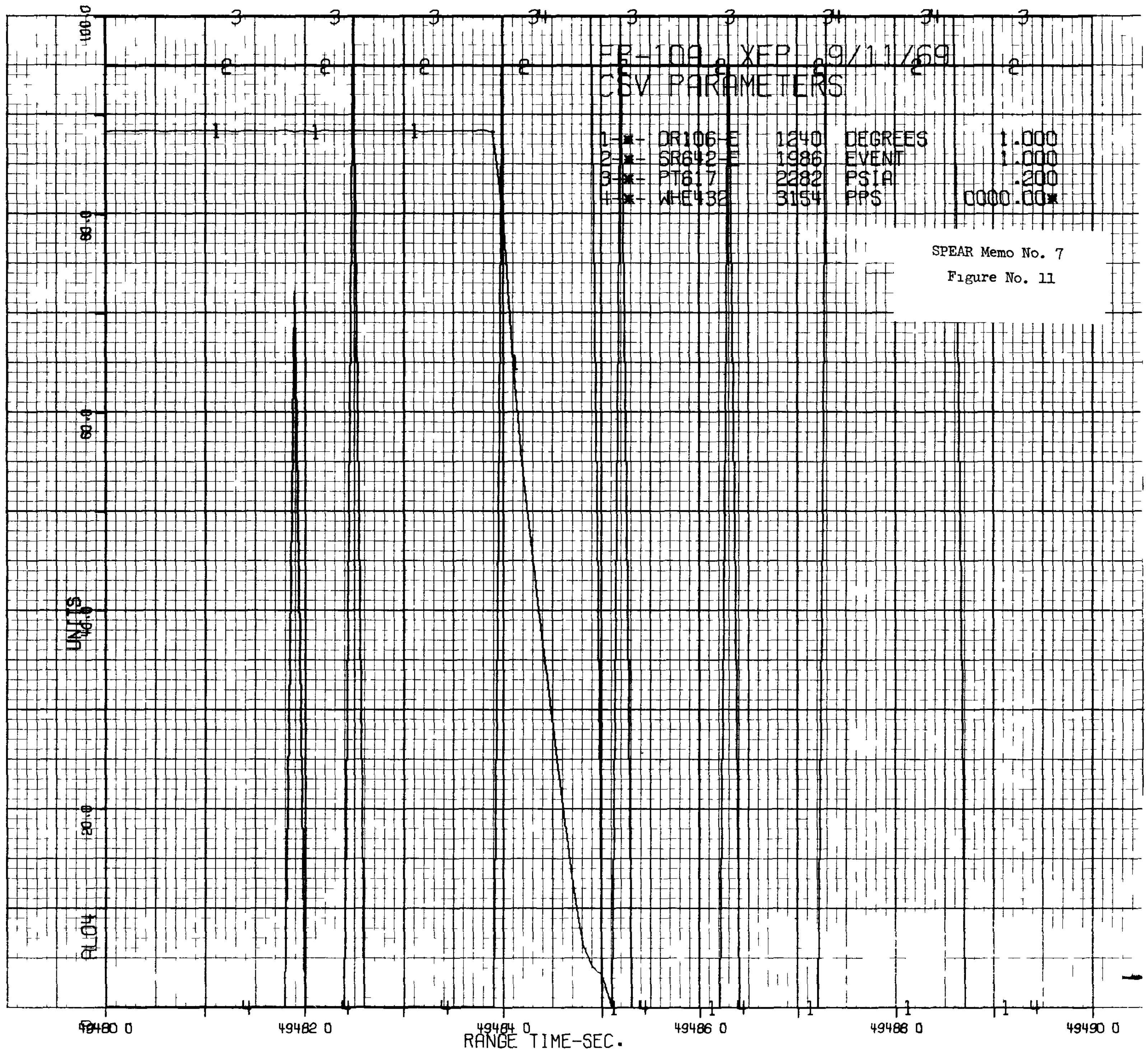
SPEAR Memo No. 7

Figure No. 9



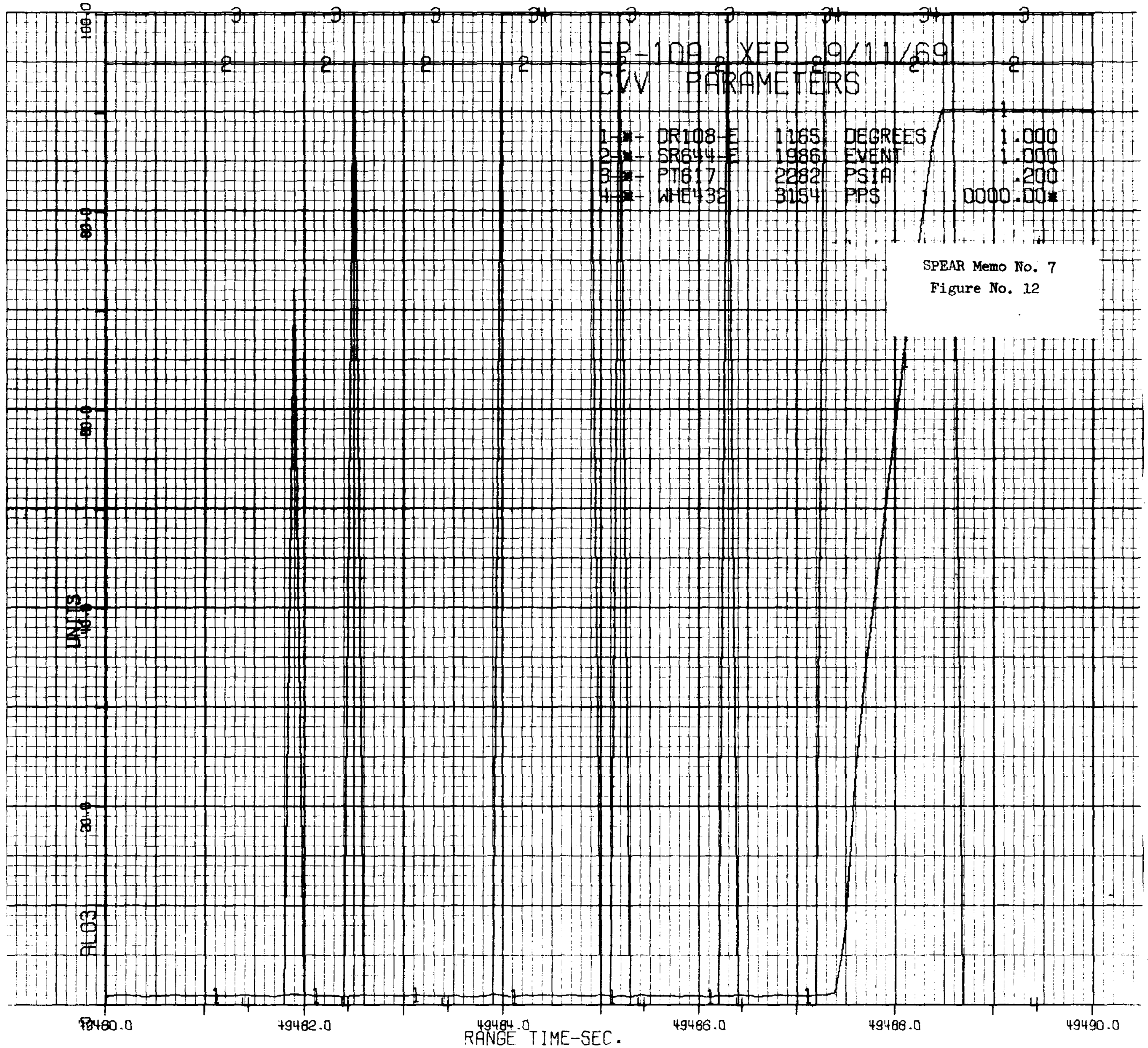
SPEAR Memo No. 7

Figure No. 10

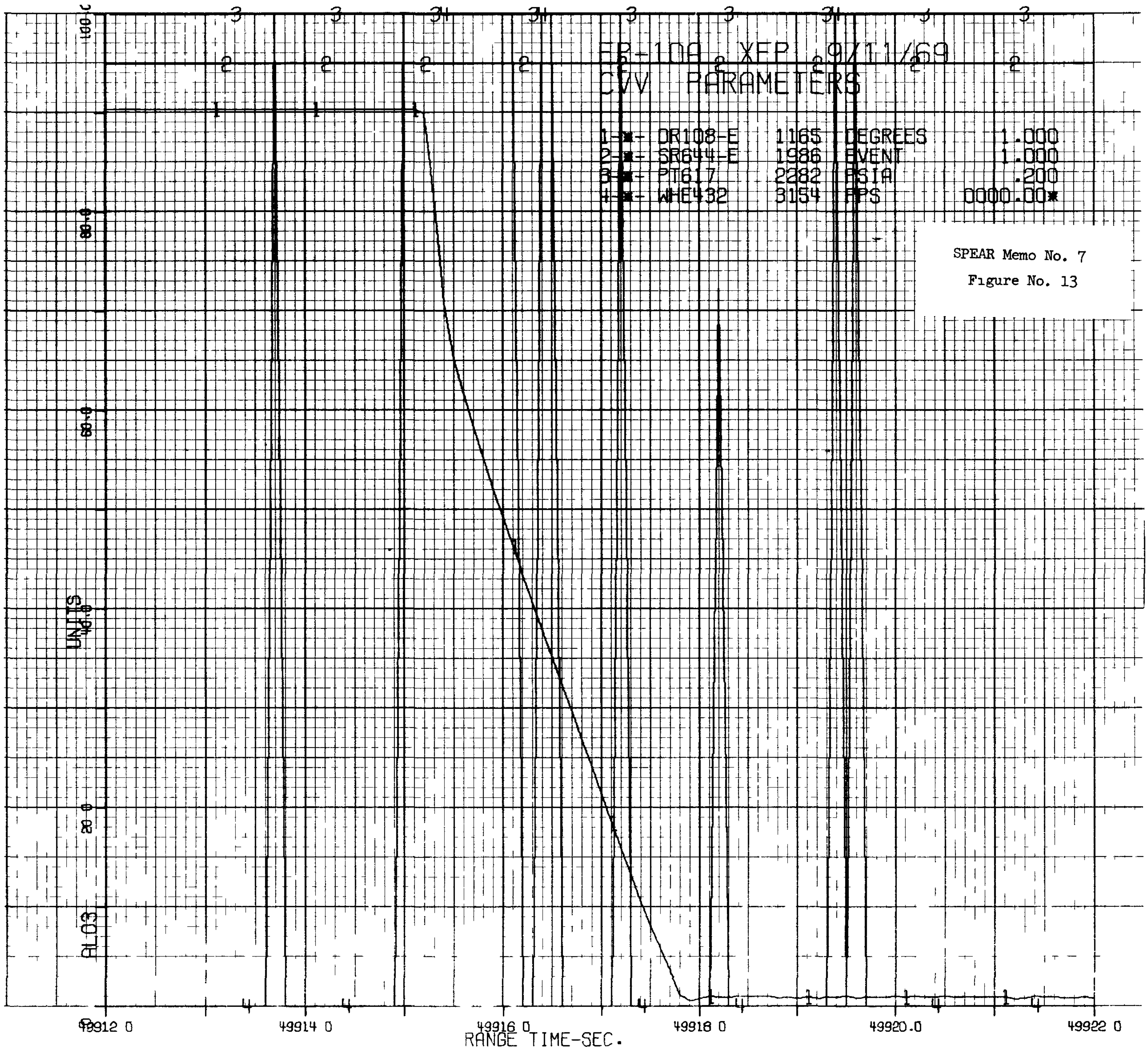


SPEAR Memo No. 7

Figure No. 11



SPEAR Memo No. 7
Figure No. 12



SPEAR Memo No. 7

Figure No. 13

SPEAR Memo No. 8
J. S. Goddard/W. F. Booty:sm

66

XE-PRIME

EP-10A

Subject: LOW LH_2 & GH_2 FLOWRATE MEASUREMENT SYSTEM PERFORMANCE

SUMMARY

Facility modifications were made between EP-9 & 10 to enable very low LH_2 and GH2 flowrates to be measured during the laminar flow instability (LFI) experiments. EP-10 was the first use of these two modifications. The LFI tests were done in two parts. The first was with LH_2 at 1.7 pps for 21 minutes at power levels of 2.8, 8.5, 11.1 and 14.0 mw. The second was with GH_2 at flowrates between .15 and 2.8 pps. Accurate GH_2 measurements were verified by comparison with bottle depletion but no good method was available for checking the LH_2 flowrate.

TECHNICAL DISCUSSION

1. Modifications

The two facility modifications to permit accurate low LH_2 and GH_2 flowrate measurements are described in NTO Change Proposal 109. Figures 1 and 2 show schematics of the LH_2 and GH_2 mods. Basically they were as follows:

a. LH_2 PCV472 Bypass System

A one inch line was installed between the RSV 384 vent line and the PCV 456 vent line. A two inch turbine flow meter, FE 440, was installed in this line together with a one inch, 15cv, linear, PCV 610. Pressure and temperature taps were installed upstream of the flow meter.

b. GH_2 Modified Supply System

The high pressure LH_2 dewar, V5002, pressurization supply system was modified by removing the PCV 250 downstream block valve RSV 185. In its place a spool was installed with a .954 diameter sharp edge orifice in it. Upstream pressure, temperature, and orifice differential pressure taps were provided.

2. Flow Calibrations

a. The turbine flowmeter used in the PCV 472 LH_2 bypass system was a two inch, Potter, Model 2-5757, S/N AJS 110. It was water flow calibrated on 27 August 1969, at the Sacramento Test Facility. A copy of the calibration data sheet is shown on Figure 3. The calibration constant K was 39.140 pulses/lb. of water at 68°F. The LH_2 flow equation is thus:

$$\text{WH 440} = \frac{\text{FE 440 pulses/sec} \times \text{DH 619}}{62.285 \text{ lbs/ft}^3\ H_2O\ @\ 68^\circ F \times 39.14 \text{ pulses/lb}}$$

$$= .0004102 \times \text{FE 440} \times \text{DH 619}$$

where DH 619 = Density of LH_2 @ TT619 & PT 876

Figure 4 shows WH 440 as a function of FE 440 for a family of densities.

b. The equation for the GH_2 orifice is:

WH 878 = .0822 (PT 878/TT 878) (Choke flow function, PT 097w downstream PT 878 upstream)

3. Performance

a. LH_2 472 Bypass System

Initial chilldown was accomplished through PCV 472, PCV 910, PCV 543 and CVV with CSV closed. V-5002 had been previously filled and chilled and V-3801 pressurized to 113.5 psia. It was difficult to obtain a chill of less than about 50°R until PCV 472 and PCV 910 were intermittently closed to allow the downstream pressure to decay and lower the saturation temperature. It is recommended that this method of chilldown be utilized on all cryogenic systems.

CSV was then opened and CVV/PCV 543 closed to initiate flow to the engine for 1263 seconds while engine power was stepped to power levels of 8.5, 11.1 and 14.0 mw (back to 2.8 mw between). PCV 910 was 100% open and PCV 472 closed. Figure 5 shows important LH_2 bypass system parameters during the engine flow period. The steady state values of supply system parameters are shown in Table I below at a flowrate of 1.69 pps (WH 440) during the first 75% of the flow period.

TABLE I

Steady State LH_2 Bypass
System Parameters @ 1.69 pps

Pressure	PSIA	Temperature	°R	Density	lbs/ft³
PT 068Y	113.5	TT 401/2	40.4	DH 401/2	4.31
PT 101	111.5	TT 028	43.3	DH 028	4.18
PT 876	97.9	TT 619	44.0	DH 619	4.13
PT 484	20	TT 495	39.0	DH 495	.10
PT 103	20	TT 474	38.3	DH 474	4.33
PT 846	20	TT 567	37.5	DH 567	4.35
PT 891	20	TT 881	37.5	DH 881	4.38
PATOR	18.5	TATOR	37.8	DH TOR	4.36/.10

The steady state flowrate of 1.69 pps was slightly less than expected partly because the bypass system K/A^2 was 59 based on test data compared to a calculated 39, and partly because the V3801 temperature was high. Note on Figure 5 that the flowrate starts to taper off at 48300 sec. until finally at the termination of the LH_2 LFI test it had decreased from 1.69 to 1.44 pps. This flowrate reduction resulted from the reduced density of the warm surface fluid from draining V3801 virtually dry. The system temperatures rose from the steady state values shown in Table I to 47.7 °R at TT 028 and 47.5 °R at TT 691. This was the first time that V3801 has been drained during a test below the bottom of the capacitance probe LT002.

A calibration check on FE 440 was performed by comparing the computed integral FE 440 LH_2 flowrate (IWH 440) with the LH_2 inventory change in V3801 over a period of 720 sec. (47480 to 48200). LT002 during this time decreased from 5.5 to 1.8 which is worth 1300 lbs of LH_2 at a density of 4.3 lbs/ft^3. The flowrate based on V3801 level change is thus 1.8 lbs/sec which is in reasonable agreement with WH 440. There is a large uncertainty in LT002 in this region; however, this was only done as a qualitative check. The carbon resistors did not function in this range, so LT002 was adjusted by an offset equivalent to the difference in the indication (11.0% hight) at a known height (10%), at which the RTT probes (TT 401 and 402) were uncovered. A very warm layer, which is still liquid between 41 and 53°R, exists in the top 1.2% height (about five inches).

b. GH_2 System

Figures, 6, 7, and 8 are plots of GH_2 supply system parameters during the GH_2 portion of the LFI tests which immediately followed the LH_2 tests. Figure 9 is a system pressure versus flowrate map for the modified system.

Flowrates of 1.47, .45, .46, .90, and .18 pps were established with PCV250. During the steady state hold portions at the various flowrates, a comparison was made with the integral orifice flow (IWH439) and vessel/header GH_2 inventory decrease. Excellent (closer than 1%) agreement was obtained in all cases.

After the first .45 pps flowrate test, PCV250 was closed while PCV251 was opened to establish 2.8 pps. It was not possible to provide this last minute flowrate requirement with PCV250 because the instrumentation had been ranged to provide accuracy at .2 pps and would be overranged at 1.8pps. It was planned to establish 3.7 pps and the PCV251 discharge pressure corresponding to this (143 psia) was set. CHV681 apparently did not open completely and created an additional impedance which resulted in a back-pressure 1.27 higher than normal. This is shown on Figure 10. All the other system pressures are slightly higher than on EP-9 (EP-9 performance is typical of past performance). Since CHV681 is the only component between PT475 and PT814, it is the prime suspect.

4. Miscellaneous Facility System Performance Problems

a. TSER Inerting

The TSER inerting valve RSV927 was opened at 1022 hours, and the O_2 concentration was down to 5% at 1036 hours. It was left open 100% of the time and closed after the test at 1450 hours. Toward the end, it was not possible to maintain TSER O_2 concentration below about 6 - 7%.

b. The duct flare air compressor reset switch failed again as discussed in EP-9 SPEAR Memo No. 2.

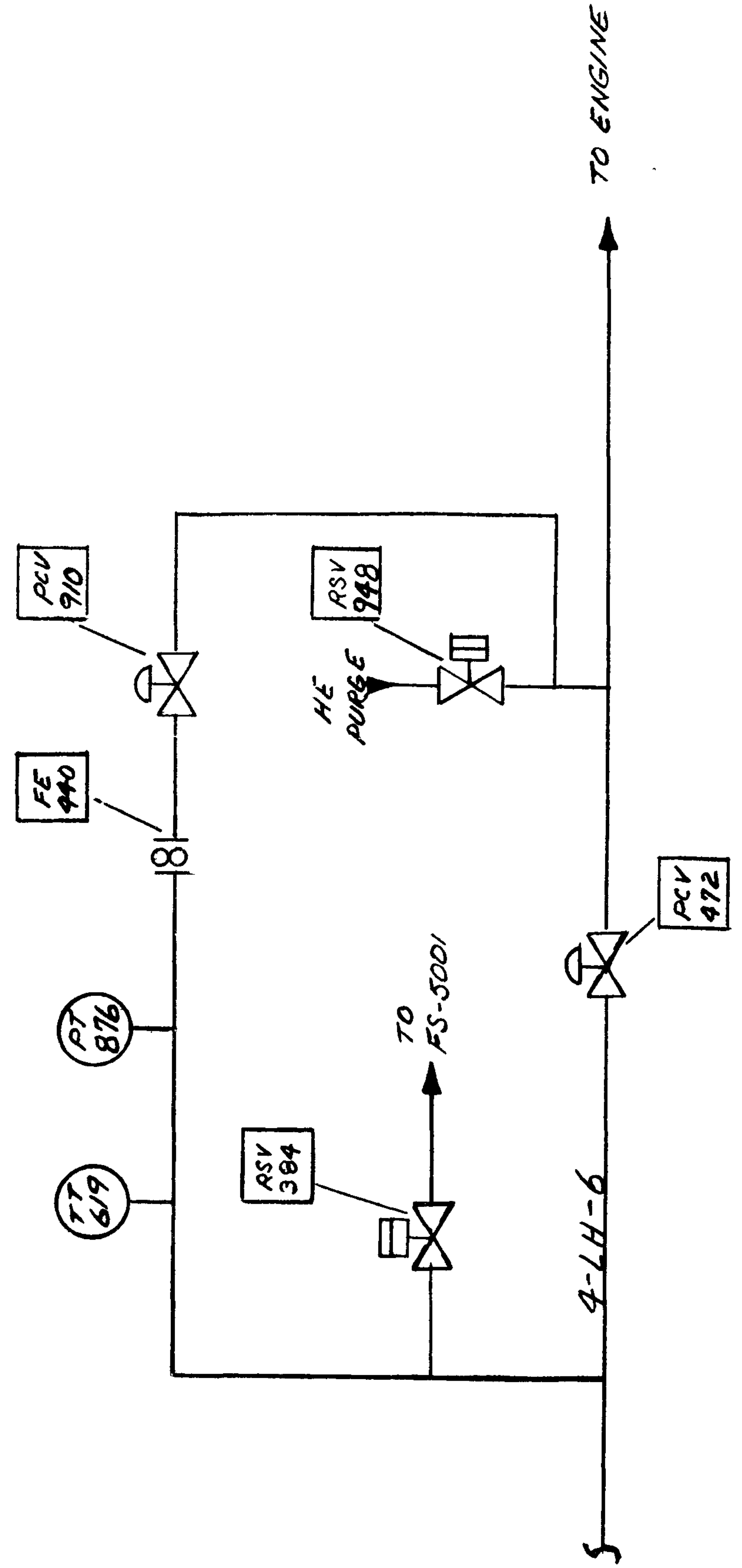
c. The engine valve actuator PRV200 pressurize switch stuck open several times. This was a console switch problem and caused no delays.

5. Recommendations

a. This was the first attempt during the NRX & XE programs to accurately determine low GH_2 and LH_2 engine flowrates. It points out the difficulty of providing accurate flow measurements with existing flowmeters over a large flow regime such as is planned for NERVA full power and cooldown. Permanently installed bypass systems should be provided for NERVA low flow measurements.

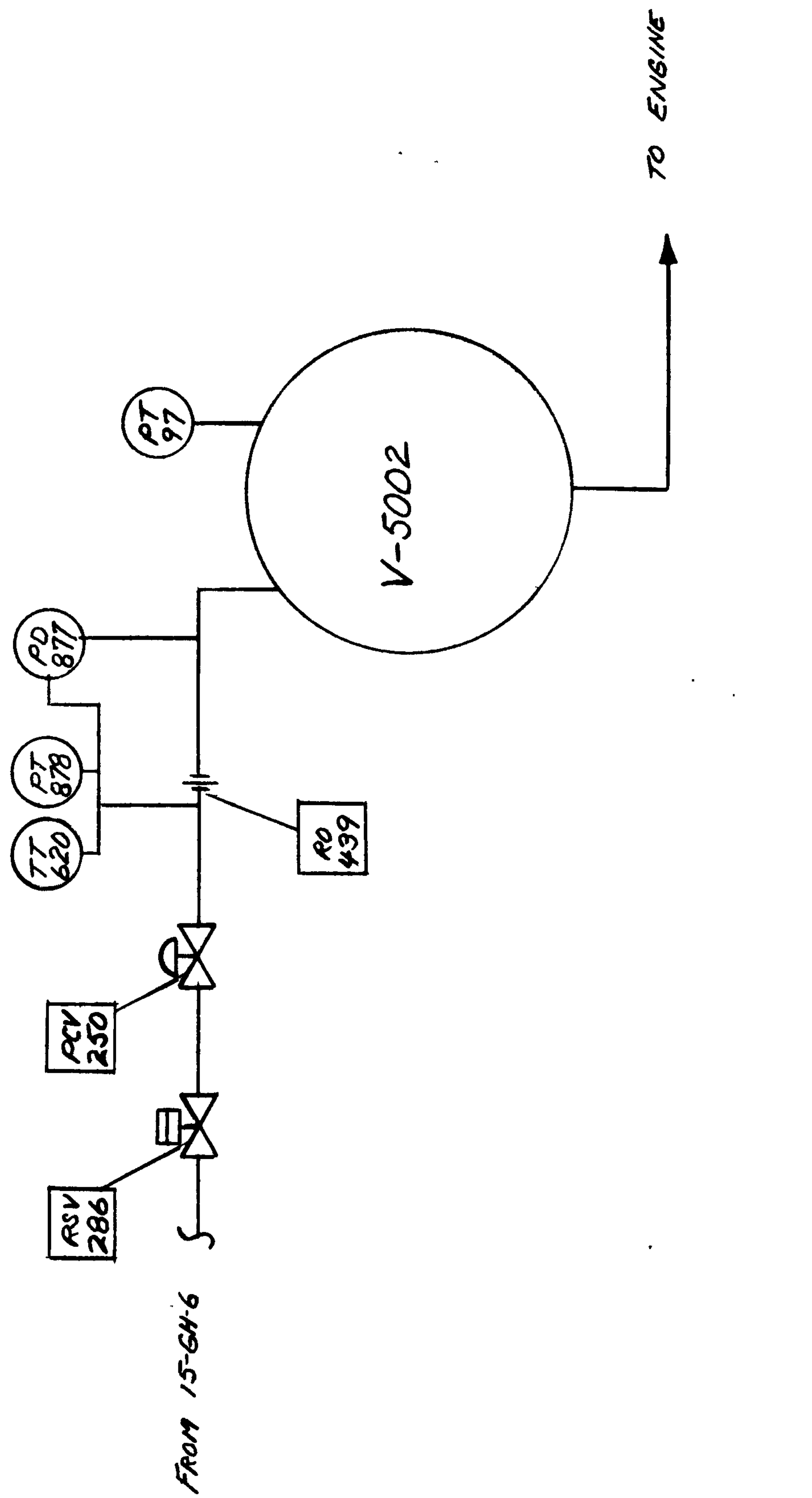
b. Inspect CHV681 for evidence of sticking.

c. As previously recommended in past SPEAR facility memos, inspect the TSER inerting system for gross leakage or impedance change.



PCV-472 BY-PASS SYSTEM FOR EP-10

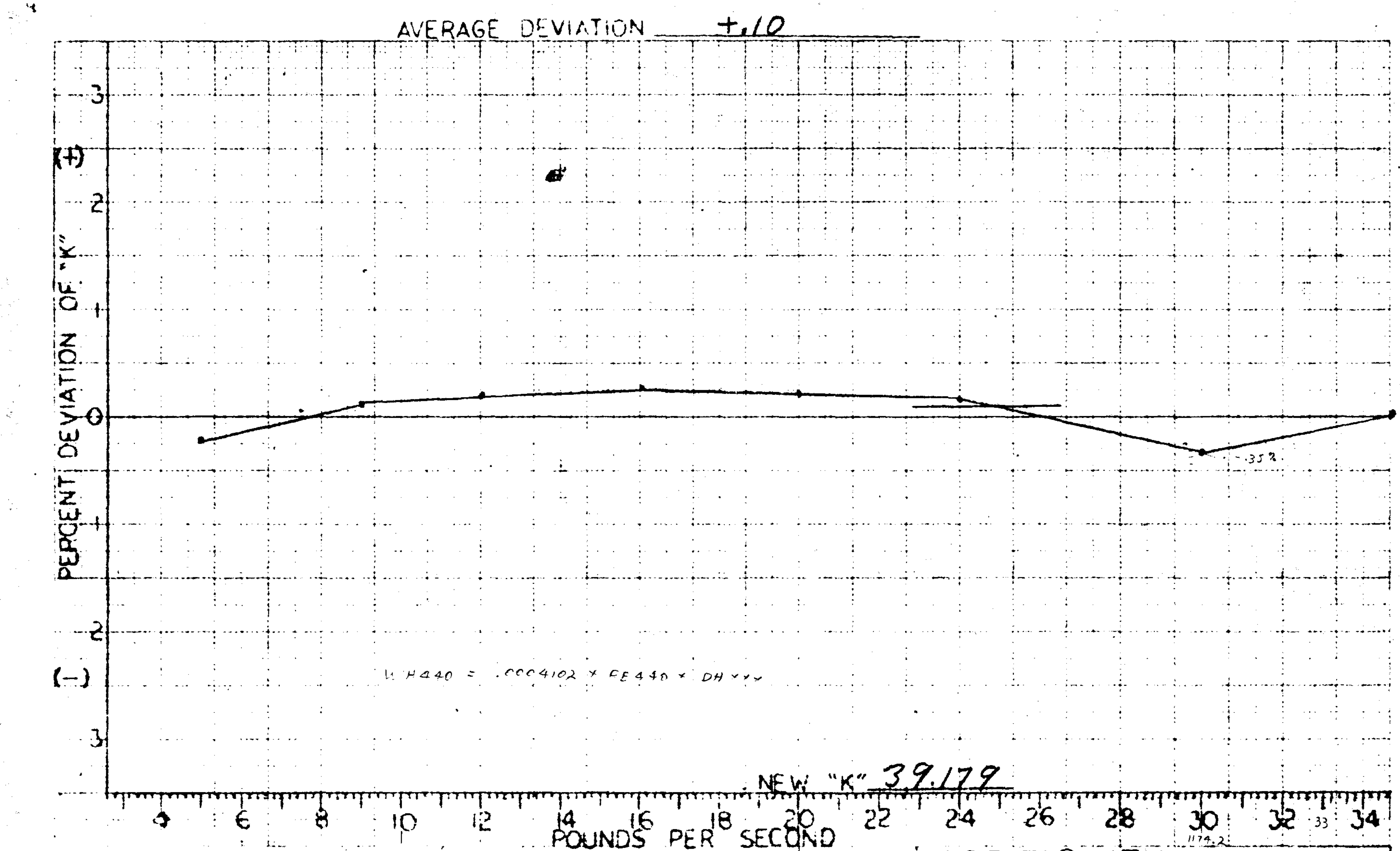
FIGURE 1



MODIFIED V-5002 PRESSURIZATION SYSTEM FOR EP-10

FIGURE 2

3 TO 34



△ 1ST
○ 2ND
□ 3RD

DATE FLOWED 2-27-61

BASE LINE "K" 39.140

TRANSDUCER LAB 8-27-64

TEST FACILITY H V-V

TEST FLUID H_2O STD 2-AV37+54

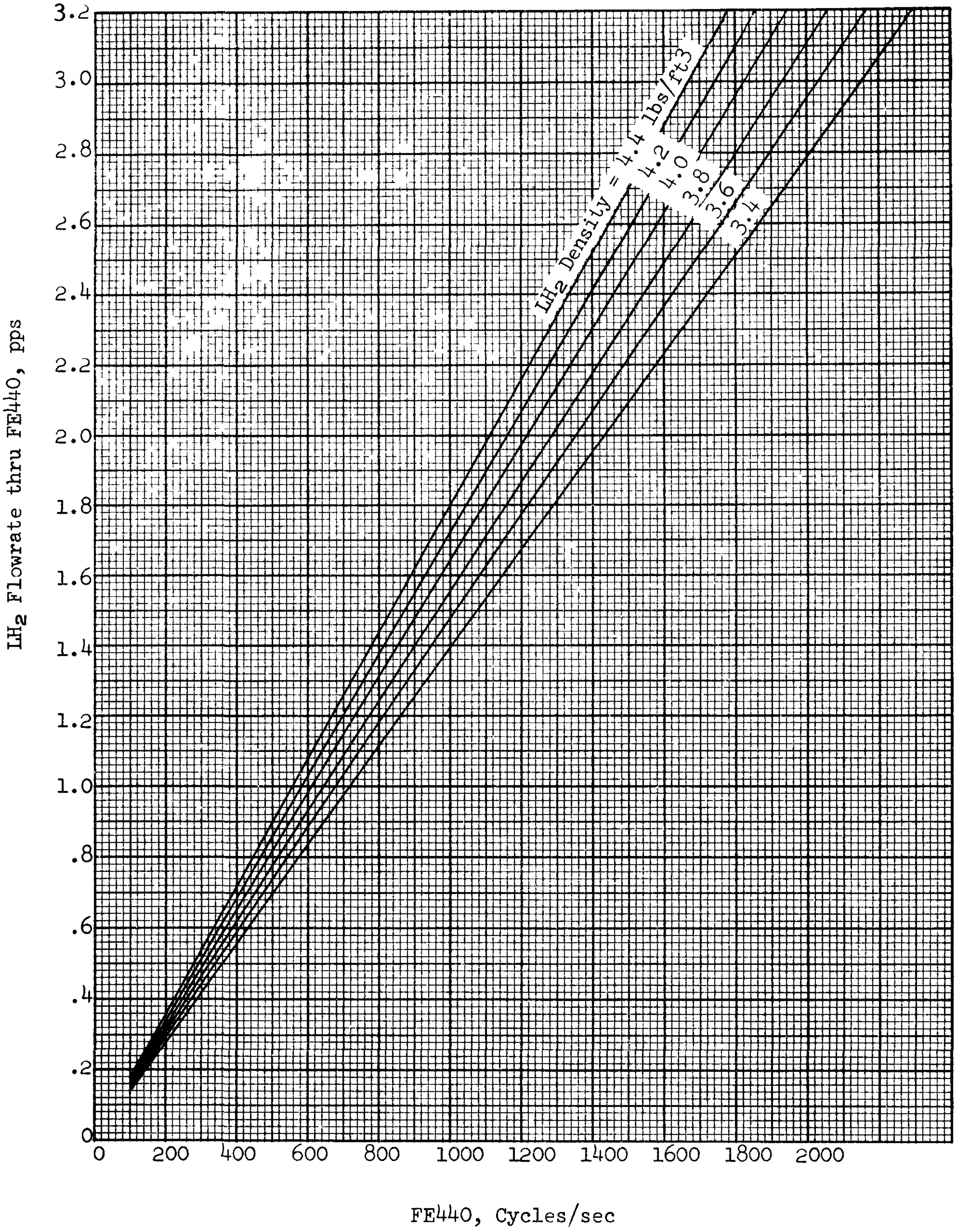
FLOWMETER 2-5757

AVS-110

PCA

JIM REVELINO 355-3504

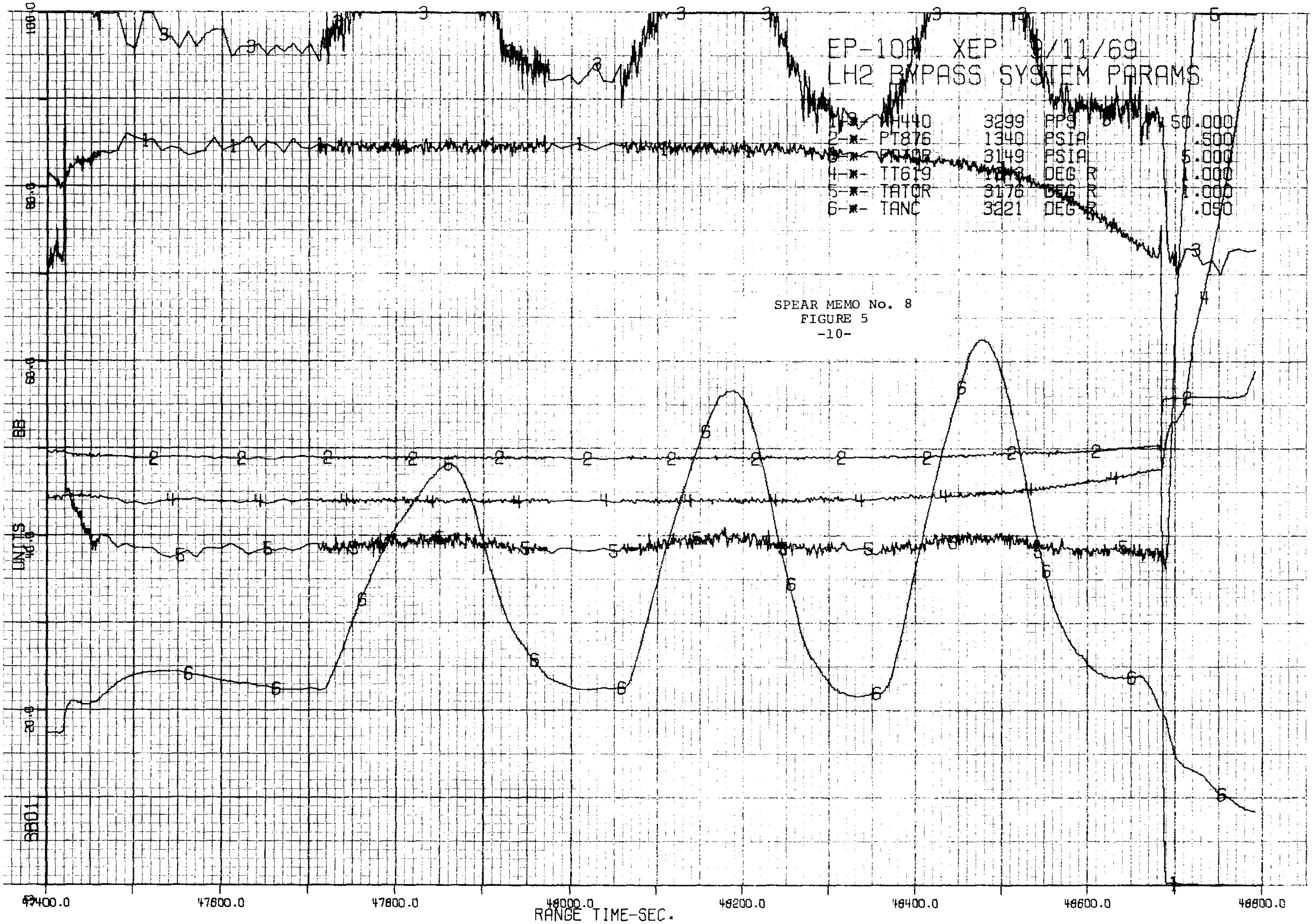
FIGURE 3



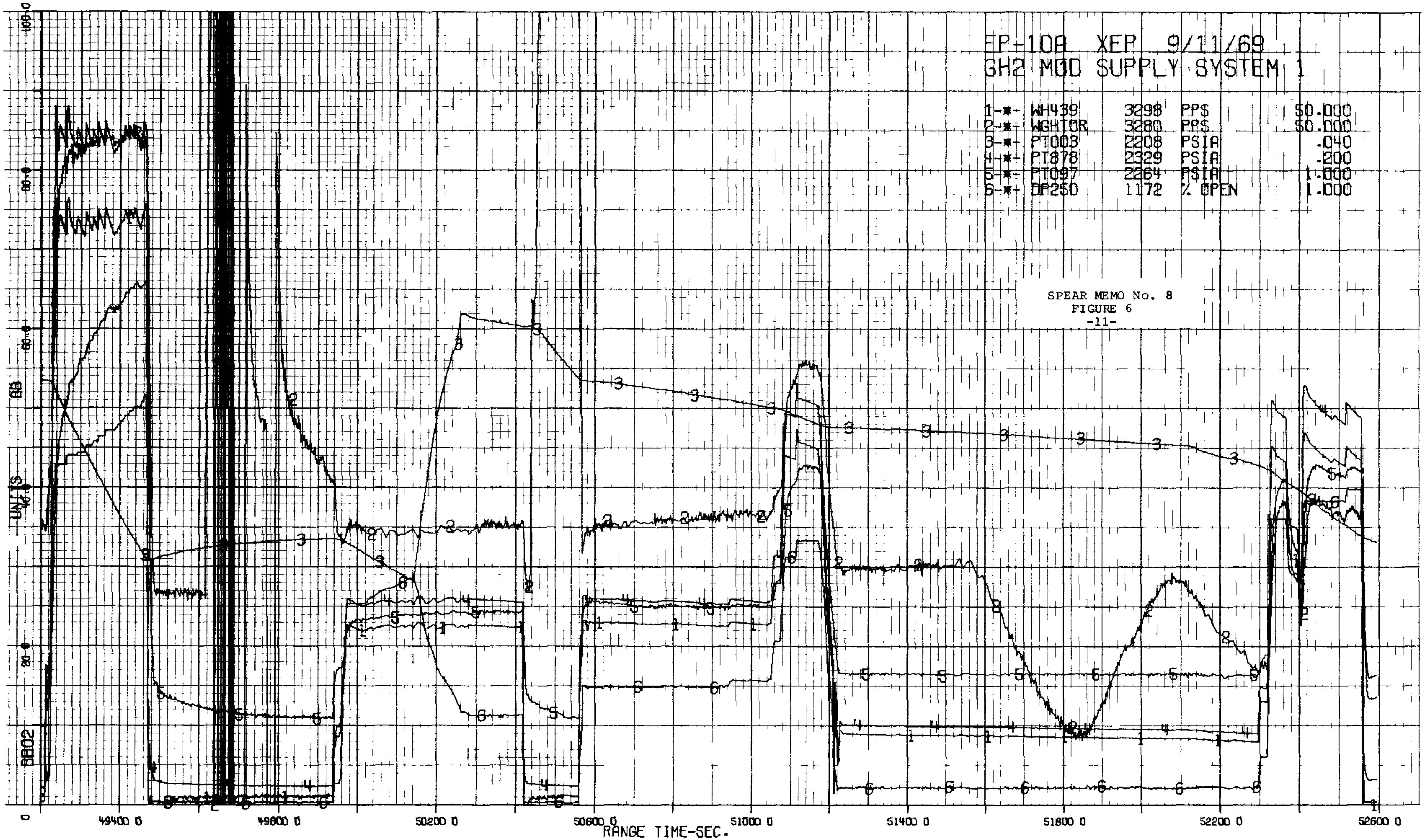
FE440 LH_2 FLOWRATE vs CYCLES/SEC
"K" FACTOR = 39.140 Cycles/lb H_2O (AT 68°F, ρ = 62.285)

FIGURE 4

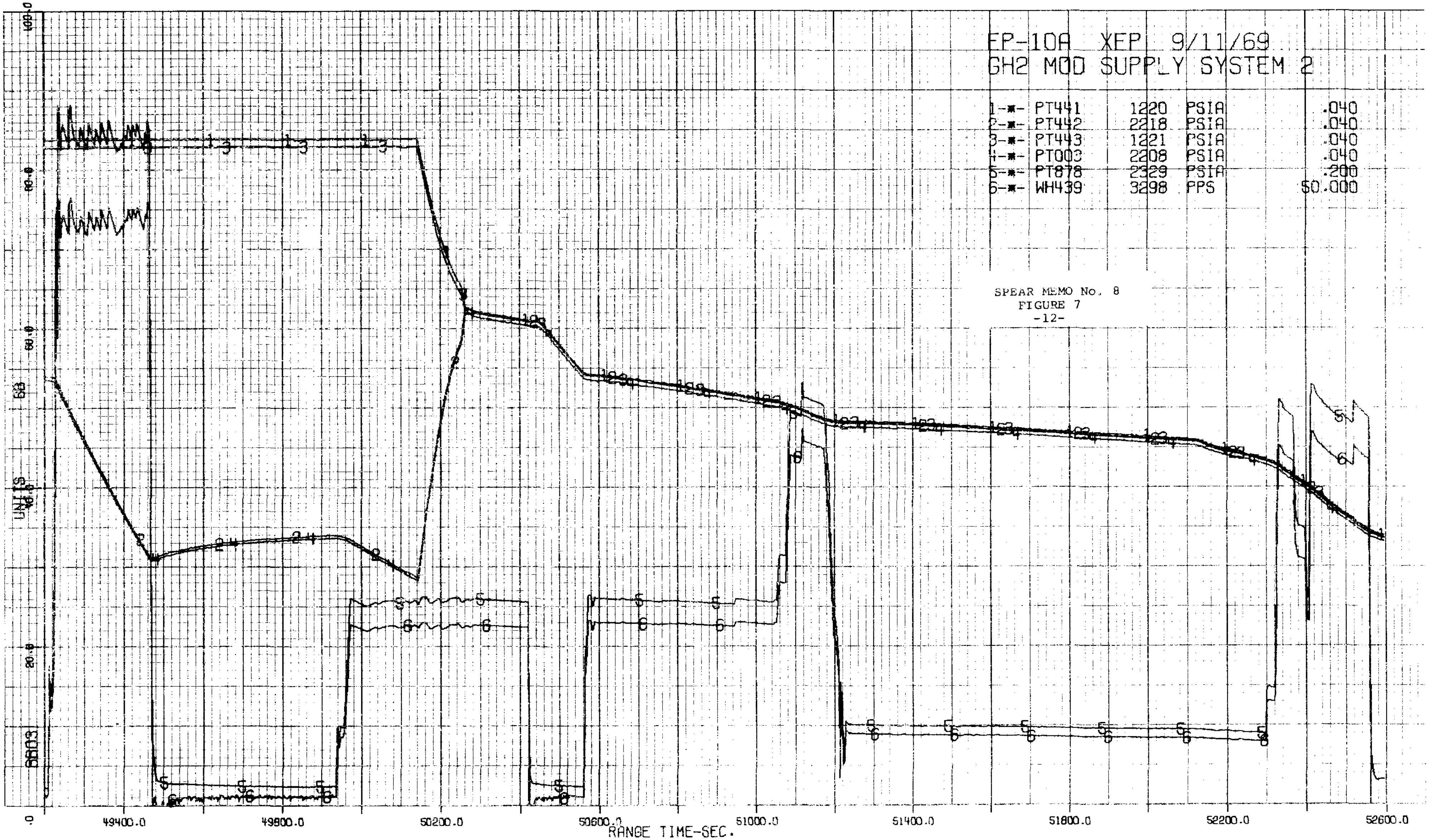
$$WH440 = \left(\frac{1}{62.285xK}\right)(FE440)(DH619)$$
$$= .0004102(FE440)(DH619)$$



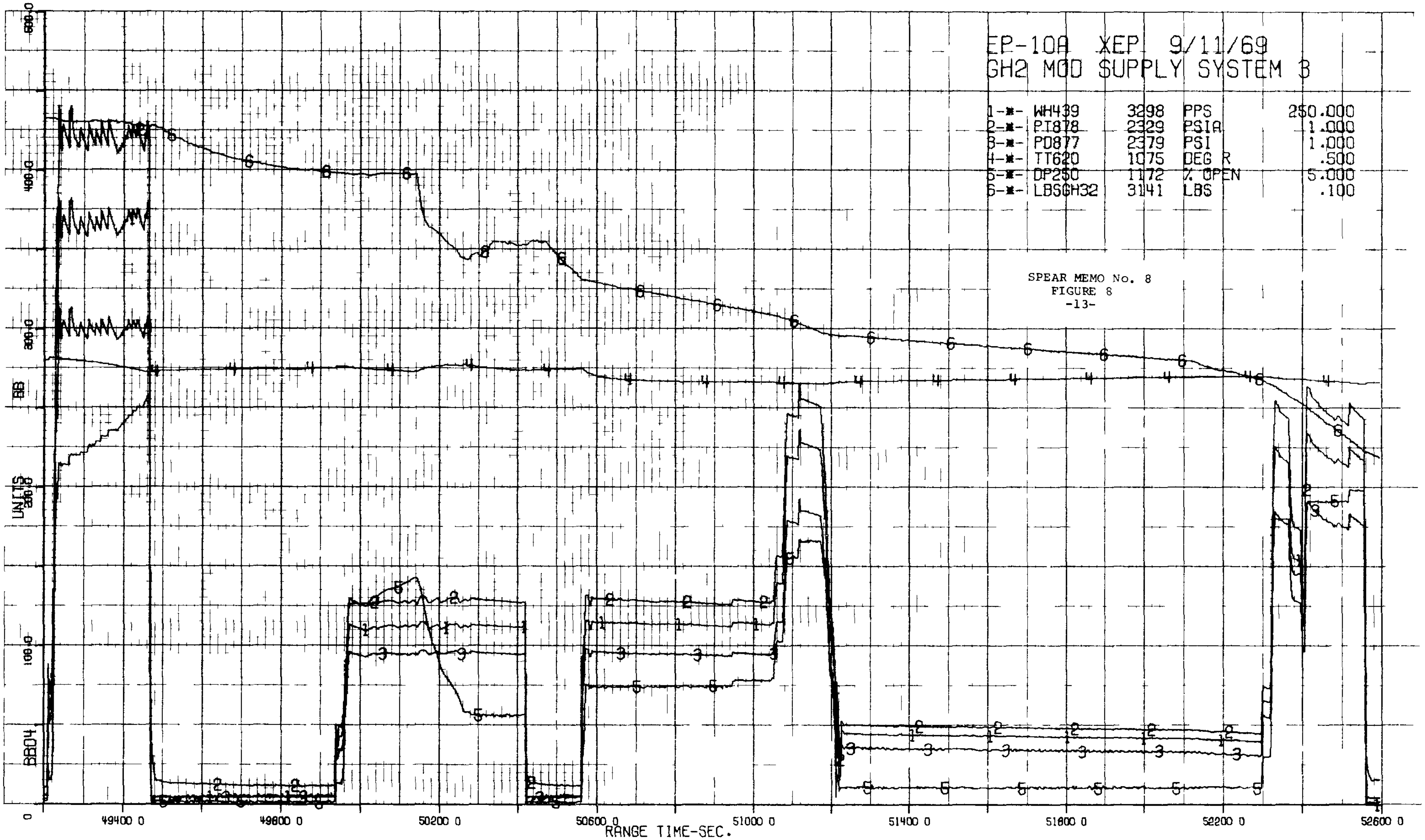
SPEAR MEMO No. 8
FIGURE 5
-10-



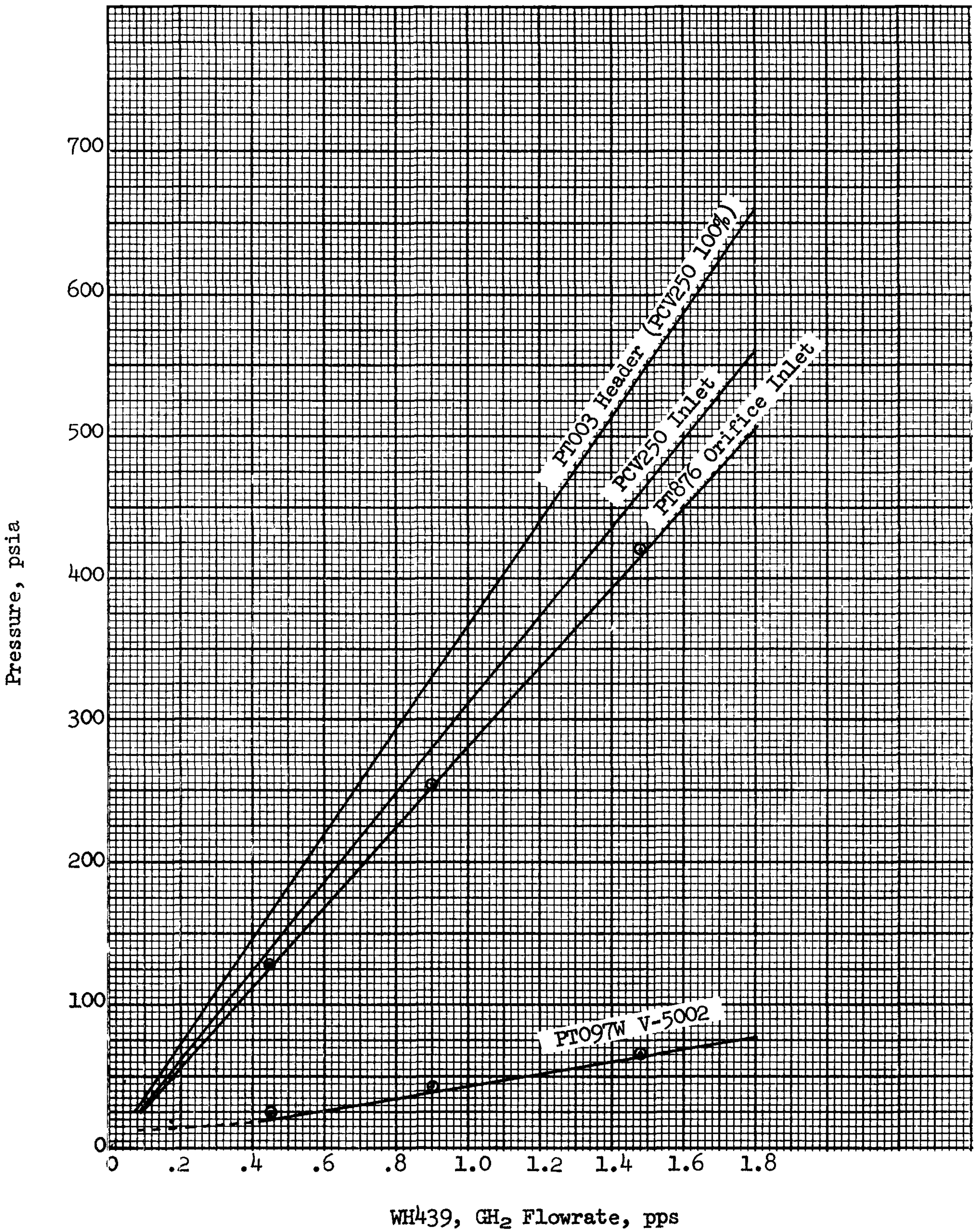
SPEAR MEMO No. 8
FIGURE 6



SPEAR MEMO No. 8
FIGURE 7
-12-



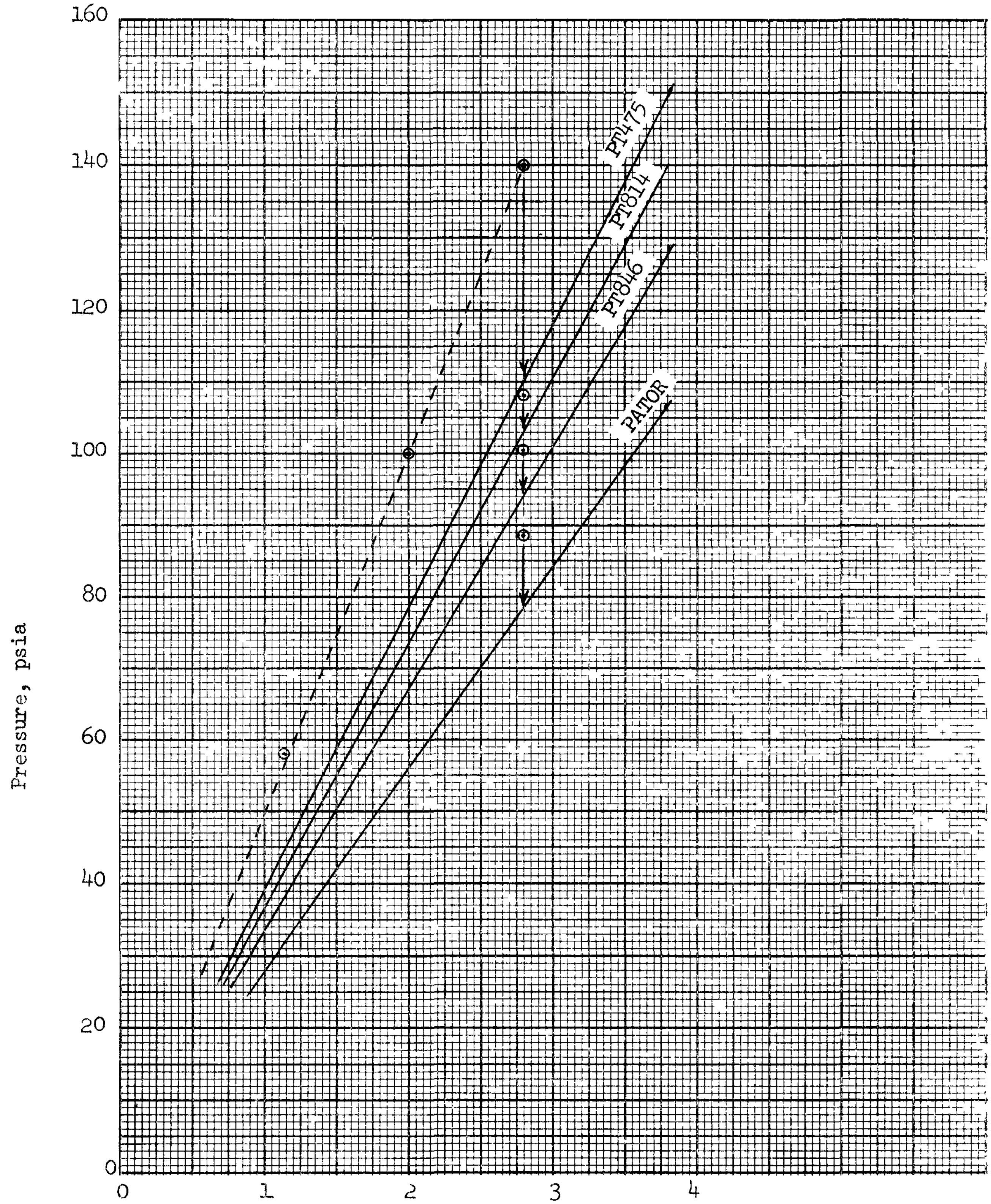
SPEAR MEMO No. 8
FIGURE 8
-13-



MODIFIED V-5002 GH_2 SUPPLY SYSTEM PRESSURES vs. FLOWRATE

FIGURE 9

—— Predicted
⊙ EP-10A Data



WH15778, FE015 GH_2 Flowrate, pps

GH_2 SYSTEM PRESSURE vs FLOWRATE

FIGURE 10

SPEAR Memo No. 9
RES R.D. Samuelson/
W.L. Babby/
L. Stone

XE-PRIME

EP-10A

Subject: MEASUREMENT SYSTEM PERFORMANCE

SUMMARY

No major measurement system anomalies were noted for this test. Data channels providing suspect data are summarized in Table I. A summary of cancelled data channels is provided in Table II. A data system performance summary is presented in Table III. Appendix A explains the entries of Table III.

TECHNICAL DISCUSSION

The digital data system has routinely had a constant voltage source applied to each multiplexer group to check for proper system performance. During EP-7A, slight upward voltage drifts and step voltage changes appeared that could be correlated to Control Room activities. Post-test data system ground corrections were performed and the voltage drifts were, essentially, eliminated while the amplitude of voltage step changes were cut in half (reduced from 0.4% to 0.2% of full scale) for EP-8A. A review of EP-10A data (Figures 1, 2, and 3) reveals that the step change has been reduced to 0.08% of full scale.

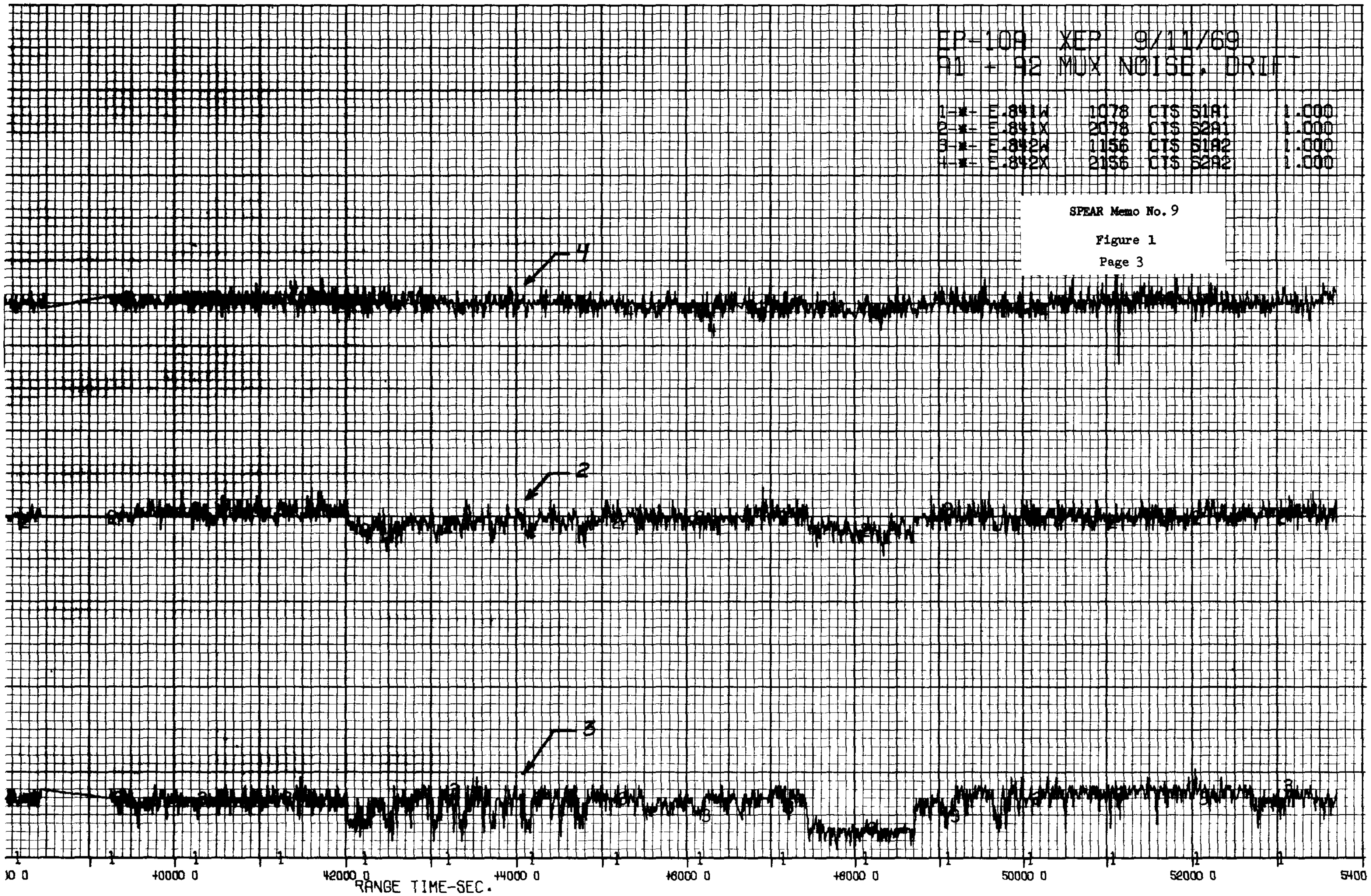
The digital data system noise level has stabilized at an acceptable level. The average 2-sigma noise level for the XE-Prime test series (EP-1A through EP-10A) is 10.3 counts or approximately 0.1% of the digital data system full scale range.

A review of UTS temperature data revealed slight temperature variations but they were not sufficient to produce significant pressure transducer data drifts.

The operation of the engine-mounted Pace reference unit is considered normal if the reference block temperature, as measured by data channels TT262..F and TT263..F, falls within the uncertainty span 609.3^{o}R to 611.0^{o}R. Data Channel TT262..F stabilized near 611.7^{o}R while Channel TT263..F varied from 612.8^{o}R to 613.7^{o}R during most of this test (see Figure 4). The data from TT263..F is considered suspect as the temperature excursions depicted for this channel in Figure 4 are not normal and the channel has a history of erratic performance (it failed completely during EP-5C). Thus, Channel TT262..F is assumed to be the only channel providing valid reference block temperatures for the engine-mounted PACE reference unit. Based upon the data supplied by TT262..F, the PACE reference block temperature exceeded its set point temperature by approximately 0.7°R. This deviation is not considered excessive.

CONCLUSION

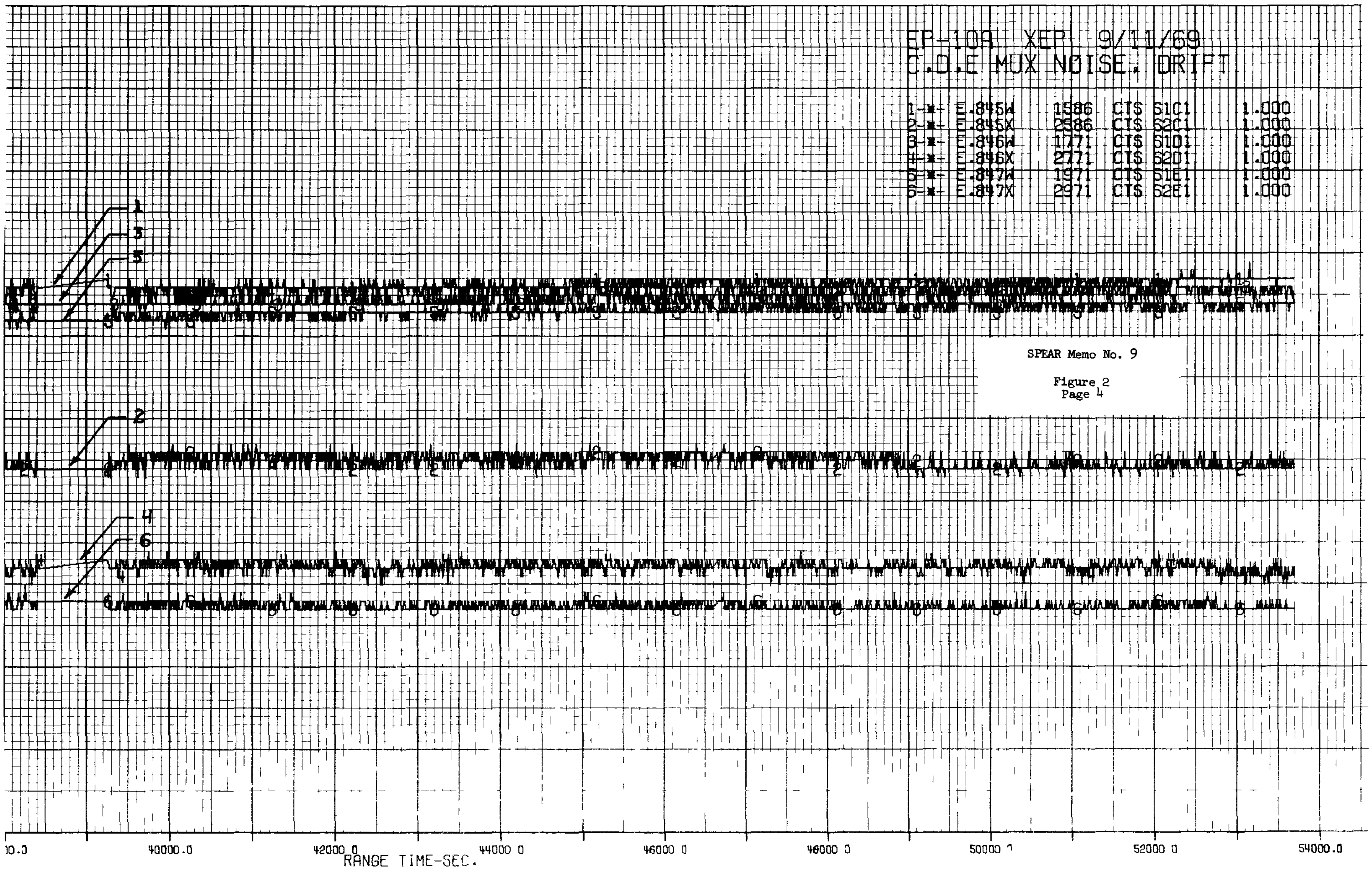
The measurement system continues to perform without degradation and is ready to support another test.



SPEAR Memo No. 9

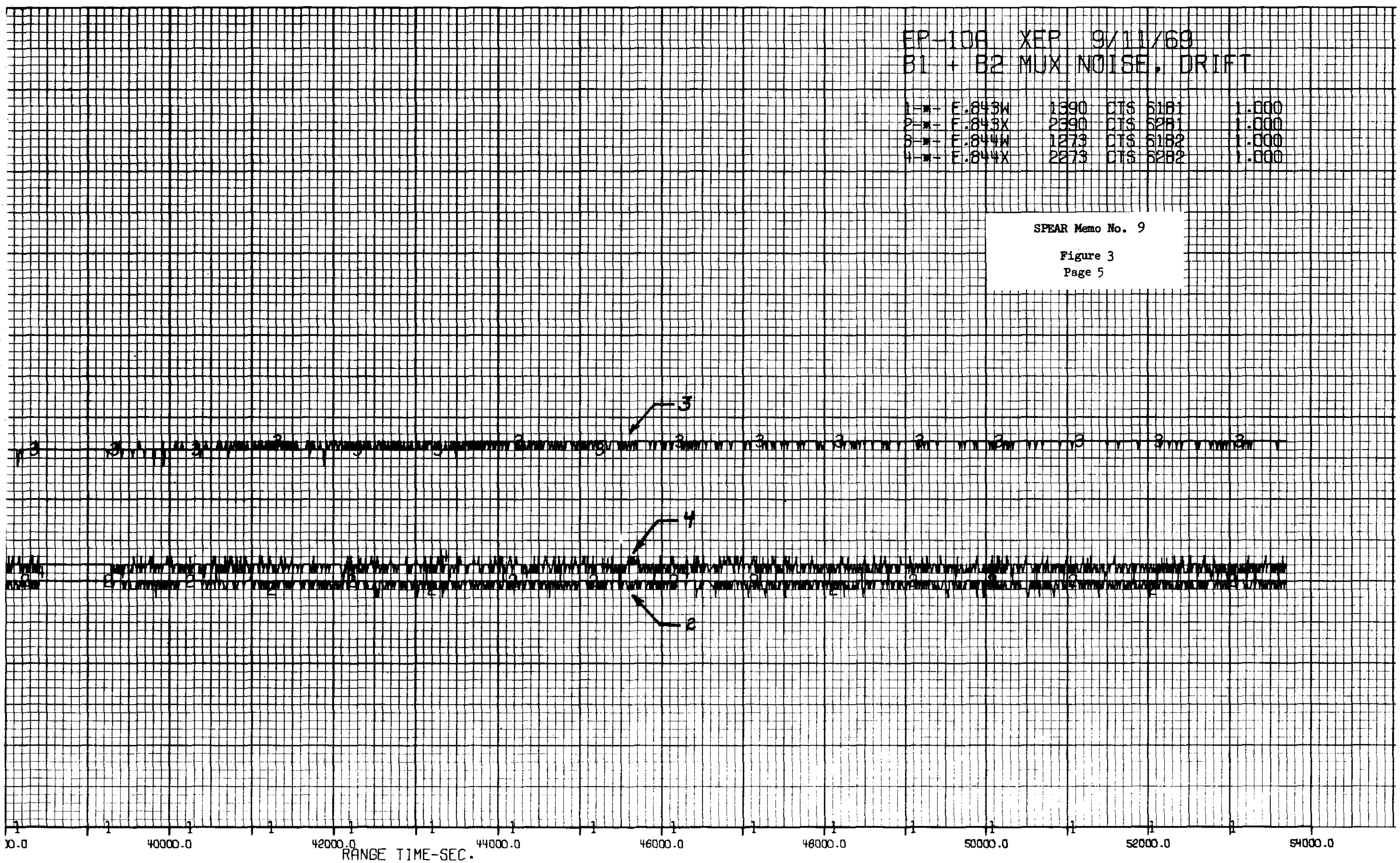
Figure 1

Page 3



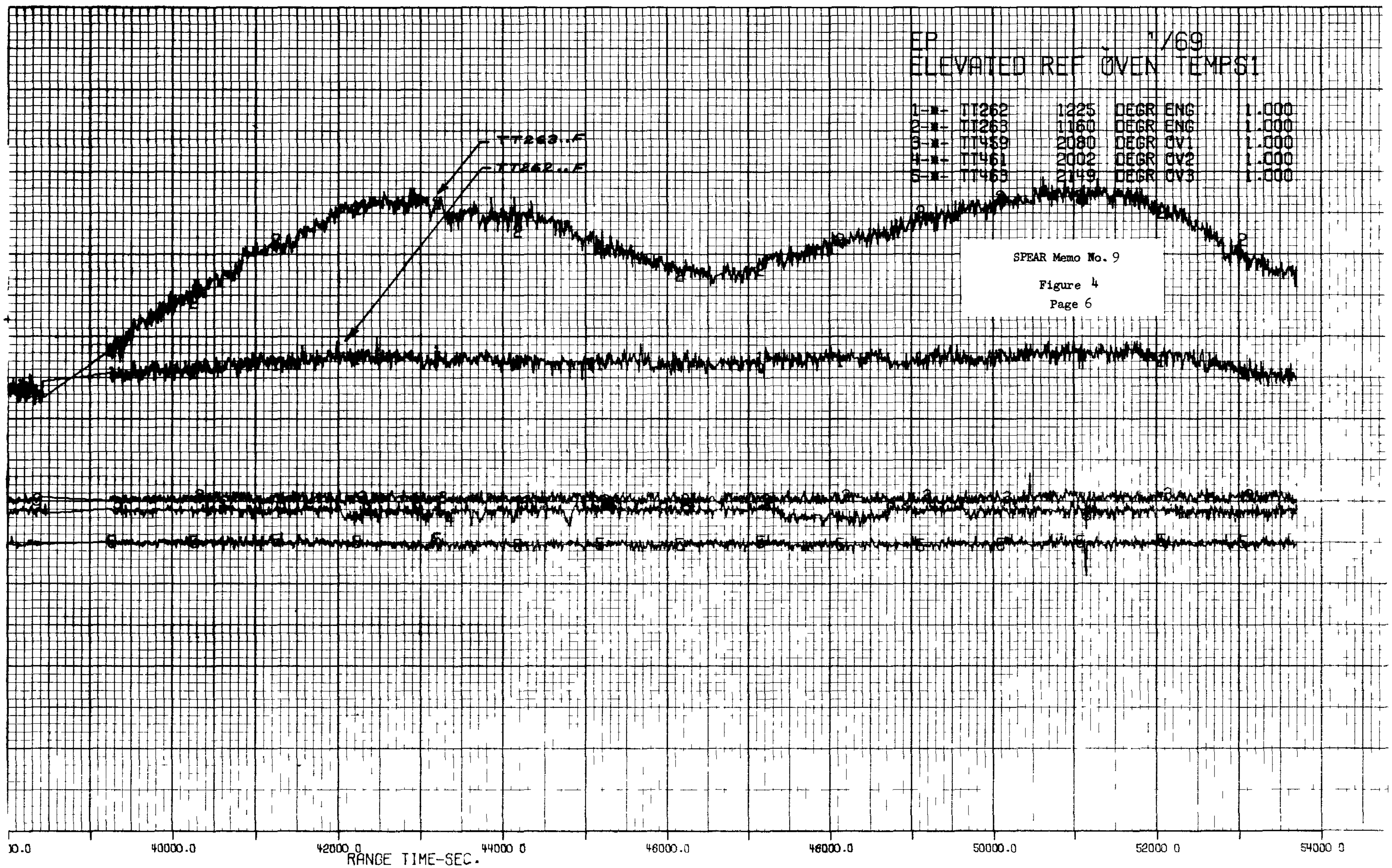
SPEAR Memo No. 9

Figure 2
Page 4



SPEAR Memo No. 9

Figure 3
Page 5



SPEAR Memo No. 9

Figure 4

Page 6

TABLE I

MEASUREMENT ANOMALIES

XE-P EP-10A

ITEM	MEAS. NUMBER	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
1.	E.800..E	TPA 1st Motion Detector	No pre-test calibration present on Digital Data System Calibration Diagnostic Routine	
2.	FT031..F	Duct H_2O Supply - Part - 12" Line	Full scale set-up range should be 5 psid on Digital Data System, was 4.33 psid.	
3.	FT032..F	Duct H_2O Supply - Total	Full scale set-up range should be 5 psid on Digital Data System, was 4.60 psid.	
4.	LT001..F	LO V-2801 Tank Level	Excessive channel noise level, 4% of full scale.	
5.	NC820..N	Linear Power 2	Excessive channel noise, 13% of full scale.	
6.	TE195..F	S2 H_2O Temperature	Excessive non-linearity, exceeds 3% of full scale.	
7.	TE811..A	Drum Torque Transducer, TEM 11	No engineering unit calibration, no engineering unit run data.	
8.	TT122..A	Nozzle Manifold	Excessive noise, exceeds 5% of full scale.	

TABLE II

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 System SV Bypass	Not Used
	BR460..R	C.D. Gas System 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

TABLE II (Cont'd)

PRIOR TO	CHANNEL	TITLE	REASON
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
	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
EP-8A	None		
EP-9A	None		
EP-10A	MG402..A	Inner Reflector Spring	Hardware Failure
	PT810..A	Turb Inlet Line Entr	Hardware Failure

TABLE III

MEASUREMENT SYSTEM REVIEW SUMMARY

XE-PRIME EP-10A	IA	IB	IIA	IIIA	5	5C	4A	6A	7A	8A	9A	10A
AVERAGE NB AMBIENT NOISE (COUNTS)	10	16	9	9	9	9	10	11	11	12	9	9
NUMBER OF NB CHANNELS SET UP	864	864	870	861	873	884	878	869	867	868	870	875
NUMBER OF NB CHANNELS REVIEWED	864	864	870	861	873	884	878	869	867	868	870	875
% OF REVIEWED NB CHANNELS WITH LOST DATA	2.4	1.9	1.6	3.5	0.8	2.4	0.3	0.6	1.3	0.2	0.7	0.2
AVERAGE FM WB CALIBRATION NOISE (COUNTS)	28	30	30	22	29	76.8	49*	40*	26*	45*	Not Avail.	Not Avail.
NUMBER OF FM WB CHANNELS SET UP	79	100	120	129	130	132	131	129	129	129	127	127
NUMBER OF FM WB CHANNELS REVIEWED	79	30	120	32	31	49	0	0	0	0	0	0
% OF REVIEWED FM WB CHANNELS WITH LOST DATA	11	0	0.8	41	5.1	16	NA	NA	NA	NA	NA	NA
NUMBER OF OSCILLOGRAPH CHANNELS SET UP	36	41	51	53	50	50	50	47	49	50	49	48
NUMBER OF OSCILLOGRAPH CHANNELS REVIEWED	0	41	51	0	50	50	50	47	49	50	49	0
% OF REVIEWED OSCILLOGRAPH CHANNELS WITH LOST DATA	NA	9.8	2.0	NA	4.0	16	4	4	0	2	4	NA
NUMBER OF STRIP CHART CHANNELS SET UP	81	81	98	75	82	82	82	81	82	80	80	80
NUMBER OF STRIP CHART CHANNELS REVIEWED	0	0	0	0	16	6	64	81	82	80	0	0
% OF REVIEWED STRIP CHART CHANNELS WITH LOST DATA	NA	NA	NA	NA	0	0	2	1	0	0	NA	NA
NUMBER OF LOST AND IRREPARABLE CHANNELS (EACH EP)	0	1	4	6	2	7	2	2	0	0	2	Not Avail.
NUMBER OF LOST AND IRREPARABLE CHANNELS (CUMULATIVE)	0	1	5	11	13	20	22	24	24	24	26	NA

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

APPENDIX A SPEAR Memo No. 9

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 reprocessing 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. 10
PAA/NTO Health & Safety
JRM:ck

XE-PRIME

EP-10A

Subject: RADIOLOGICAL REPORT

Radiological support for EP-10A 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 power integral for this test was 1.7×10^4 megawatt-seconds.

2. Air Sampling

   Air sampling was performed during EP-10A 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, except those listed in paragraph B.2 below.

B. Test Cell Radiation and Contamination Surveys

1. Radiation Surveys

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

2. Contamination Surveys

   Contamination surveys taken in the drainage ditch prior to EP-10A indicated a maximum contamination level of 1200 dpm/ft^2. Swipes taken on the pad were background. Following EP-10A, drainage ditch swipes indicated a maximum of approximately 9×10^5 dpm/ft^2. The northeast half of the reactor pad was contaminated with the swipes indicated a maximum of 5×10^4 dpm/ft^2. Surveys taken in the drainage ditch and on the reactor pad on September 15, 1969 -- four (4) days following EP-10A -- indicated a maximum level of 1.3×10^4 and 8×10^3 dpm/ft^2, respectively. The minimum anti-contamination clothing requirement established for entry into these areas is rubber shoe covers. Contamination within ETS-1 was limited to the above areas. On-site monitoring and air sampling indicated no activity in other NRDS facilities. A water sample taken from the retention basin on R + 1 indicated trace quantities of fission-product 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 80 mR.

TABLE I

SELECT SURVEY DATA
EP-10A
Date: September 11, 1969

Time After Shutdown (Hours)	Location	Dose Rate mR/hr
Pre-Test	105' SW/NE from reactor	10
	30' SW/NE from reactor	100
	Contact with S-1 shield	1300
	Contact with S-2 shield	1700
	Duct vault inside, below elbow	25
	Duct vault inside, average	5
	Catwalk, 3848-8 Level	3
2.5	225' SW/NE from reactor	10
	120' SW/NE from reactor	100
	80' SW/NE from reactor	200
	35' SW/NE from reactor	1000
	A-11 RAM (unshielded)	180
	A-12 RAM (unshielded)	1500
	Valve pit #1 at ladder	8
17.5	120' SW/NE from reactor	10
	35' SW/NE from reactor	100
	Contact with S-1 shield	1600
	Contact with S-2 shield	2200
89.5	105' SW/NE from reactor	10
	30' SW/NE from reactor	100
	Contact with S-1 shield	1200
	Contact with S-2 shield	1500

M. T. Dew

TEST CHRONOLOGY

FOR

XE-PRIME

EXPERIMENTAL PLAN 10A

I. PRE-OPERATIONAL PHASE

A. VERIFIED ALL STATUS BOARD SETUP CHECKLISTS RECEIVED AND APPROVED.

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

C. CHECKED THE TDC AND TRB NET (USED NET #10).

D. 29470 ESTABLISHED AREA CONTROL.

E. 29663 Switched PT-099 to Group 5.

29696 Opened RSV-666.

29705 Selected ETC sample system - 5% H2 range, 25% O_2 range.

29743 Opened RSV-296. Reported when duct was bled in.

30046 Secured Engine Purge

30054 Switched consoles to ENABLE and verified demand pots normal:

ASE, FEL, LFE, FER, GFS and CTE.

30071 Switched all groups except #7 to ENABLE

30079 Verified duct pressures had stabilized

30705 Performed Manual Data System Calibration

31217 Conducted a one-point remote calibration of the log and linear neutronics system and recorded 64 frames of Digital Data.

31264 Re-established engine purge

31278 Switched source drive control to EXPOSE

31284 Recorded 64 frames of Digital Data. Verified and reported operation of all scaler test stand log and linear channels.

31314 Returned all Groups to INHIBIT

31326 Returned the following consoles to INHIBIT
ASE, FEL, LFE, FER, GFS and CTE

31359 Shielded the source and verified SHIELDED.

31361 Switched source drive to OFF.

31365 CLOSED RSV-296 and RSV-666.

31371 Switched to ETC sample points.

31375 Switched PT-099 to Group #7.

F. UNLOCKED CONTROL DRUM PNEUMATIC DOUBLE BLOCK AND BLED SYSTEM AND SWITCHED CONTROL DRUM POWER

31399 Verified MASTER KEY (#4) to OPERATE

31417 CLOSED RSV-868

31419 KEY #1, KEY #5, SVB-11 KEY and PNEUMATIC SYSTEM Keys given to entry crew.

31778 Crew reported in.

31780 Verified that TD had Key #3.

31449 Verified that P-478 indicated ZERO psig .

31797 UNLOCKED RSV-444 and rotated the Manual Override hand wheel to the FULL OPEN (UP) position.

31804 UNLOCKED RSV-877 and rotated the Manual Override hand wheel to the FULL OPEN (UP) Position.

31807 UNLOCKED SVB-11 and OPENED the Jamesbury supply valves for RSV-444 and RSV-877.

32049 Switched RSV-444 and RSV-877 to OPERATE.

32088 Exercised RSV-444 CLOSED.

32098 Exercised RSV-877 CLOSED.

32117 LOCKED SVB-11.

32150 UNLOCKED 50-BV-2332 and manually CLOSED.

32183 Verified GLV-2337 was OPEN (TPCV actuation supply).

32606 Soaker System Turned ON

32610 CLOSED BV-3199

32636 OPENED RSV-17

32644 OPENED RSV-275

32708 CLOSED PSV

33048 Installed Key #1 and switched to COP Control

33075 Verified ZERO position demand on gang drum demand

33080 Installed Key #5 and switched to drum OPERATE

33095 Switched TPCV to OPERATE

34960 Returned all personnel to the Control Point and reported in.

II. CTE PRE-OPERATIONAL PHASE

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

33154 DDS to 1/1.

33163 OPENED RSV-325.

33166 CLOSED PCV-517.

33172 OPENED RSV-326.

33230 Pressurized V-3601 to 150 psig using PRV-108

33248 Monitored T-511

33250 In MANUAL slowly opened PCV-517 6o 90%

33256 OPENED RSV-879

33258 Monitored Cryotrap LN_2 vent

33262 Cycled RSV-879 as required to establish LN_2 in the cryotrap

33266 Used PCV-517 and PCV-754 to maintain chill at T-510.

B. EXERCISED THE PCV's

33283 Exercised PCV-910 CLOSED

33429 Exercised PCV-543 CLOSED

33482 Exercised PCV-472 CLOSED

33483 Verified P-587 was ZERO and Armed PCV-251

33527 Exercised PCV-251 CLOSED

33528 Verified P-586 was ZERO and armed PCV-471

33572 Exercised PCV-471 CLOSED

33580 Placed PCV-251 and PCV-471 in SAFE

33610 Exercised PCV-579 CLOSED

33665 Exercised PCV-250 CLOSED

33700 Exercised PCV-165/180 to the CLOSED Positions

C. SETUP CONTROL DRUM PNEUMATIC SYSTEM (GN_2 HEADER PRESSURIZED,ETC INERTED)

34241 OPENED RSV-867

34276 Used PRV-402 to establish 40 $\pm$ 20 psig at P-618

34280 OPENED RSV-881

34466 When T-571 indicated 165°R CLOSED RSV-881

34468 Cycled RSV-879 as required to maintain less than 165° at T-571

34509 Used PRV-402 to establish 700 psig at P-618

34545 OPENED RSV-877

34552 OPENED RSV-444

34554 CLOSED RSV-443

34556 Using PRV-200 slowly increased P-478 to 200 psig

36413 Repeated OPENING RSV-877

36415 Repeated OPENED RSV-444

36417 Repeated CLOSED RSV-443

36428 Repeated Using PRV-200 slowly increased P-478 to 200 psig

D. CHECKED OUT THE FSD CHAIN

34980 Increased P-896 to 500 psig

34987 Verified TBV fully CLOSED

35027 Verified Engine Safety System Reset

35030 CLOSED CSV and placed in ENABLE

35037 Verified PDSV OPENED

35048 DDS to HIGH

35053 SCRAMMED

35057 DDS to LOW

35060 Reported the position of PDSV

35063 Placed CLOSED Demand on PDSV

35068 Verified CSV OPENED

35073 Reset FSD Chain

35079 INHIBITED CSV

E. PRESSURIZED V-3801 and SWITCHED TO AUTO CONTROL

Reported V-3801 pressure (90 psig).

OPENED RSV-87 and RSV-383.

Maintained a minimum pressure of 30 psig.

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

38276 OPENED PCV-447 and established 375 psig at P-643(1.0 lb/sec GN_2) and turned ON purge heater

38282 CLOSED Zone 8 RSV

38308 USED PRV-426 to establish 400 psig at P-598

38386 OPENED RSV-83

38396 OPENED RSV-252

38401 CLOSED RSV-130

38426 OPENED RSV-128 and monitored P-99

38430 OPENED RSV-455 and monitored F-14

38450 OPENED RSV-132

38860 CLOSED RSV-455

39267 USED RSV-128, RSV-129, RSV-390 and PCV-579 as necessary to fill and chill V-5001 to 45% and obtained bulk temperature of less than 37°R.
Reported T-110 temp.

39343 OPENED RSV-110 and RSV-109

39350 OPENED RSV-106 and chilled V-5002

39357 CLOSED PCV-472 and PCV-910

39364 Maintained GH_2 concentration below 2%

39372 OPENED RSV-186

H. INPUT SCRAM SETTING

35106 Setup the following scram inputs:

35109 Program Power 1 KW (160 div) ACTIVE

35120 Floating Power - BYPASSED

35126 Period .25 sec/50% - ACTIVE

35150 RPM - BYPASSED

35154 dp/dt - BYPASSED

35157 TPCV Actuator Pressure - BYPASSED

35161 CSV Auto BYPASSED

35163 Drum Override BYPASSED Command removed (8-1/2° threshold)

35193 TPCV Override BYPASSED

35196 Pressure Mode Inhibit BYPASSED
Setup the following Scram inputs:

35201 Max Drum Position - 40° (220 div.) ACTIVE

35207 Drum Roll-in Detector - BYPASSED

I. CONDUCTED INDIVIDUAL DRUM ROTATION AND MAX DRUM SCRAM CHECKOUT

36571 CLOSED PDSV and OPENED PDVV

36585 Deactivated criticality alarm system

36609 Verified individual drum select switch OFF, all individual Pots Zero and locked switches not active.

36623 Verified gang position demand pot was ZERO

36630 Obtained ganged drum key #3 from TD and switched to ENABLE

36648 Verified CSV was INHIBITED

36652 Verified drums indicated LOCKED

36659 One at a time, rotated individual drums to 165° and SCRAMMED

36674 Reset Engine Safety System

36676 Selected drum, ACTIVATED and UNLOCKED individual control.
Withdrew drums to 165° at 500 pot div and reported DVM reading SCRAMMED.

Set individual drum pot to ZERO, LOCKED and DEACTIVATED:

Drum #1	36715	Drum #5	36883	Drum #9	37053
Drum #2	36757	Drum #6	36925	Drum #10	37093
Drum #3	36800	Drum #7	36971	Drum #11	37135
Drum #4	36839	Drum #8	37011	Drum #12	37177

37236 Reset Safety System

37266 In POSITION CONTROL, set drums against locking pins.
Printout Drum Position
Recorded DDS reading for each drum

37341 Slowly lowered Max Drum Position SCRAM pot until SCRAM Occurred.

37358 Reported Pot Div.

37364 Set Position Demand to ZERO

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

37396 Reported startup count rate above background

#1 6000 #2 6000 #3 6000

37409 Verified Program Power SCRAM at 160 Div. (1 KW and ACTIVE)

37433 Verified Period 0.25/50% and ACTIVE

37449 Set Max Drum Position SCRAM to 571 divisions (102°) and ACTIVE

37456 Reset Engine Safety System

37458 Verified Nuclear Autostart selected

37462 UNLOCKED all Control Drums

37476 In Position Control initiated Start Reactor and established 500 watts (0 cc)

37483 BF_3 Power OFF when required and verified exponential pot to ZERO

37489 During approach to 500 watts produced a drum override

37829 Selected Power Control when stable at 500 watts

38115 DDS and drum recorders to HIGH

38123 In Position Control, Initiated Program Power SCRAM at 1 KW

38154 Disabled gang key and verified all drums were LOCKED

38156 Data System to LOW

38158 BF_3 Power ON

38166 Reset Engine Safety System then enabled gang key

38174 In Position Control, Initiated Start Reactor

38356 Reactor Power Established at 100 w.

BF_3 Power Off when required

38363 BYPASSED Max Drum SCRAM

38370 Data Systems to HIGH

38372 Recorders to HIGH

38377 Initiated a Period SCRAM

38382 Disabled gang key and verified all drums LOCKED

37389 Data Systems to LOW

37392 ACTIVATED Max Drum Scram

K. DRUM TRANSFER FUNCTION TESTS

38420 Set Max Drum SCRAM to 85° - 470 Div. and ACTIVE

38664 Verified Program Power SCRAM at 1 KW and ACTIVE

38670 Verified Period SCRAM at .25/50% and ACTIVE

38673 Verified Nuclear Autostart selected

38678 Reset SCRAM and ENABLED Gan Key

38695 In Position Control initiated START REACTOR and run drums out to 80°

38751 Data System to HIGH

38754 ENABLED Transfer Functions

38760 Proceeded with Transfer Functions and reported completion

39199 INHIBITED Transfer Functions

39205 SCRAMMED - Disabled GangKey

39209 Data System to LOW

39211 Verified all drums LOCKED

L. VERIFIED DRUM EXPONENTIAL AND RAMP POT SET POINTS

39298 LOCKED all Drums

39308 Set Max Drum SCRAM to 220 divs. (40° ACTIVE)

39316 Selected Dry Autostart and temperature AUTOSTART

39391 Set Exponential Pot to 595 Divs. (95°)

39411 Set Ramp Pot to 142 div. ($.2^{\circ}$/sec)

39444 Verified gang drum demand was ZERO

39449 Reset Safety System

39454 Placed all drums except #5 in INDIVIDUAL CONTROL

39489 UNLOCKED DRUM #5

39496 Selected Program Control

39530 STARTED REACTOR

39539 Reported Drum Angle at 10 (93.6), 30 (98.0) and 40 sec (99.8)

39580 SHUTDOWN

39586 SCRAMMED

39588 Disabled Gang Key

39723 Placed Drums in Position Control

39763 UNLOCKED all Drums

III. LFE PRE-OPERATIONAL PHASE

A. PRESSURIZED THE GN_2 HEADER AND INERTED ETC

33904 DDS 1/1

33912 OPENED RSV-7 and RSV-273

33924 OPENED RSV-861 and reported P-666

33928 When P-4 stabilized, OPENED RSV-1, RSV-6 and RSV-11 and CLOSED RSV-2, RSV-7 and RSV-12

33957 When P-2 stabilized, OPENED RSV-245 and CLOSED RSV-273.

34144 Monitored P-587 for rise in pressure

34201 OPENED RSV-853

34304 OPENED RSV-222

34316 CLOSED RSV-853

34326 OPENED PCV-447 and established 375 psig at P-643 (1.0 lb/sec. GN_2) then CLOSED

33456 Monitored ETC O_2 concentration

33498 Reported OA-1 and OA-2. USED PCV-621 as necessary to reduce OA-1 and OA-2 to less than 3% then CLOSED

33503 Monitored buffer Gas Pressures.

B. PRESSURED THE GH_2 HEADER

33989 OPENED RSV-286 and RSV-283

33992 OPENED RSV-274 and Monitored P-3

34000 OPENED RSV-246 and CLOSED RSV-274

34021 OPENED RSV-519

34055 When P-3 stabilized OPENED RSV-520 and CLOSED RSV-519. Reported P-3 2325 psig.

C. INERT THE TSER

37327 OPENED RSV-927

37331 Reported and maintained TSER O_2 concentration below 5%

D. INERT DUCT VAULT AND PIPE CHASE

37379 Started Duct Vault and Pipe Chase circulating fan.

37391 Reported P-656

37400 OPENED Duct Vault Louvers

37415 OPENED RSV-899 and RSV-900

37418 Reported when Duct Vault and Pipe Chase O_2 concentrat below 5%

37430 CLOSED Duct Vault Louver.

E. ENGAGED TSA/ENGINE BOLTS AND CLAMPS and PRESSURIZE EXTERNAL SHIELD

34489 OPENED RSV-221

34592 Established 14 psig at P-480 with PRV-405

34611 Engaged TSA/Engine bolts and clamps

34729 Pressurized external shield to 13 psig

34800 Verified external shield level.

F. PRESSURIZED THE He HEADER

33660 OPENED RSV-247 and CLOSED RSV-275

33670 CLOSED all helium bottle valves

33714 OPENED RSV-54 and reported when P-5 stabilized

33726 Monitored P-836

33741 OPENED RSV-53 and CLOSED RSV-54

33750 Reported P-5 350 psig

33772 When P-5 was below 1500 psig,used the bottle bypass valves to maintain P-5 between 1000 and 1500 psig (1250 psi)

33801 OPENED RSV-78

G. PRESSURIZED PROCESS WATER SYSTEM

40112 OPENED RSV-666

40200 OPENED RSV-296. Reported when duct bled in.

40281 OPENED RSV-297 and RSV-298.

IV. OPERATIONAL PHASE

A. Reported Fluid Inventory

39800 PT 002 350 psig

PT 003 2400 psig

PT 005 1250 psig

39852 Reported LT15 46 Ft.

39857 Reported LT026 1.6 psid, LT 002 28%

39866 Reported PT652 2500 psig

PT655 2500 psig

41083 Reported LT499 45% LT453 45%

B. FINAL SETUP:

41098 Reported the following:

PSV (C)
PDVV (C)
PDSV (O)
TBV (C)
TPCV (C)
Function Analyzer INHIBITED

41665 Reset Safety System

Reported the following:

TPCV Position Control, Drum Position Control, Zero Demand, Temp Trim 500 Div. T.158, 590°R, T.306 - 520°R, T.710 - 580°R, P.120 - 0 psig, P.158 - 12 psia, F-14 - 1 pps.

41182 SHUTDOWN COMPLETE

41184 Gang Drum Switch Disabled.

41222 BF_3 Power ON

41227 Reported the following:

RSV-503 OPEN, P-17, 832 190 psig, P-618 750 psig, T.300 580°R and T-108 60+°R.

41247 Reported the following:

CSV CLOSED AND INHIBITED

CVV CLOSED

PCV-251 SAFE? MANUAL/CLOSED

PCV-471 SAFE/MANUAL/CLOSED

PCV-472 MANUAL/CLOSED

PCV-543 MANUAL/CLOSED

PCV-910 CLOSED

41287 Reported the following:

PCV-579 OPEN, RSV-390 OPEN, P-99 1 psi, V-5001 Press Control MANUAL, PCV-180 OPEN, PCV-165 CLOSED, RSV-128/129 CLOSED, RSV-109, 110 OPEN, RSV-106 CLOSED

41324 Verified Data System 1/1

41329 Verified the following:

Pressure Loop OPEN, Temp Control Experimental, State Program Control, Power Loop Closure Pot to 10 Div. Program Demand Pot to 65 Div. (60 psia, 1100°R), Dry Autostart, Temperature Autostart, Drum Ramp Control OFF, Drum Ramp Rate 0°/sec., -TPCV Ramp Control OFF, TPCV Ramp Rate 0°/sec., 13 VDC Power ON,

41694 Selected Program Control

41379 Setup the following Inputs:

Program Power 756 Div. (60 MW) ACTIVE

Period 0.10/25% ACTIVE

Ramp 142 Div. (0.20° sec)

Exponential 660 div. (θcc + 3°)

41424 Selected:

Max Drum at 621 Div. (θ 16°) ACTIVE

Drum Roll-in BYPASSED

41466 Setup the following Inputs:

41670 RPM EN-800 and EN-801 BYASSED

41474 dp/dt BYPASSED

41479 TPCV Actuator Pressure BYPASSED

41484 TPCV Override - BYPASSED

41487 Pressure mode INHIBITED - bypassed

41491 Drum Override - BYPASSED

41494 Verified T-139 rejected

41503 Established trough cooling

41508 In Manual pressurized V-5001 to 22.2 psig and switched to AUTO

41513 Secured Engine Purge

41523 Used FCV 31 to establish 7000 gpm

41705 Verified PDSV was closed and PDVV Opened

41709 Used PCV-621 to establish 6.5 pps GN_2 flow

41726 Turned on SGS Manual Purge

41749 OPENED PSV and reported when LH_2 conditions existed at PDSV

C. DRY AUTOSTART TEST #1) AMB CORE & REFLECTOR).θ+3)

41770 OPENED:

RSV-738, RSV-858, RSV-937, RSV-739, RSV-859 and RSV-306

41813 BF_3 Power OFF when required

41818 When PDSV OPENED CLOSED PCV-579

41825 CLOSED CSV and ENABLED.
Report on PDL Chill - 43°

41870 CLOSED PDVV

41875 Data System to HIGH

41878 ENABLED Gang Key

41915 STARTED REACTOR

41921 At Drum Program Terminate selected Position Control

42000 USED PDSV to maintain T-624 below 1000°R

42060 OPENED PDSV. Then T-306 was 80° CLOSED PDSV

42231 Ran Drums in and CLOSED PDSV

42236 USED PDSV and maintained T-624 below 1000°R

42252 SHUTDOWN. Verified SHUTDOWN COMPLETE

42256 Disabled Gang Key

D. DRY AUTOSTART (TEST #2) COLD CORE - COLD REFLECTOR Θ c + 3)

42315 Set Program Power SCRAM to 470 Div. (20 KW)

42330 Selected Nuclear Autostart

42344 Enabled Gang Key

42359 In Drum Position control START REACTOR

42362 At 150 KW Switch to Power Control

42438 OPENED and CLOSED PDSV on TD command

42533 OPENED and CLOSED PDSV on TD command (Repeat)

42579 OPENED and CLOSED PDSV on TD command (Repeat)

42639 Switched to Position Control. Ran drums in to ZERO

42644 SHUTDOWN. Reported SHUTDOWN COMPLETE

42646 Disabled Gang Key

42660 Selected Temperature Autostart

42687 Setup:

Program Power 756 Div. (60 MW)

Ramp Pot Div. (0.20°/sec) Dry

Exp. Pot Div. (Θ c # 3°)

42717 Max Drum SCRAM 566 Div. (Θ c + 19°)

42734 Verified Drum Program Terminate Clear

42737 Selected Program Control

42741 13 VDC Power ON

42743 Enabled Gang Key

42772 START REACTOR

42774 When T-624 was 620°R switched to Position Control and stepped drums in 8 degrees

42891 Used PDSV to maintain T-624 below 1000°R

42941 OPENED PDSV. When T-306 was 80° CLOSED PDSV

43014 OPENED PDSV. When T-306 was 80° ramped drums out 8 degrees

43055 Ran drums in and CLOSED PDSV

43062 Used PDSV to maintain T-624 at 490°R

43069 SHUTDOWN. Verified SHUTDOWN COMPLETE

43077 Disabled Gang Key

E. DRY AUTOSTART (TEST #3) AMB. CORE - COLD REFLECTOR Θ c + 3

43106 Selected:

Program Power (60 MW)

Exponential Pot 595 Div. Θ c + 3) 95°

Ramp Pot 142 Div. (.20°/sec)

43140 Max Drum SCRAM 600 Div. (Θ c + 16°) 108°

43149 Verified drum program terminate clear

43153 Selected Program Control

43156 13 VDC Power ON

43159 Enabled Gang Key

43166 START REACTOR

43168 At Drum Program Terminate Select Position Control

43245 OPENED PDSV. When T-306 was 80°, ramped drums out 8 degrees

43360 Ran drums in and CLOSED PDSV

43364 Used PDSV to maintain T-624 between 900°R and 1000°R

43368 SHUTDOWN. Verified SHUTDOWN COMPLETE

43372 Disabled Gang Key

F. DRY AUTOSTART (TEST #4) HOT CORE - COLD REFLECTOR Θ c + 3)

43388 Max Drum SCRAM 652 Div. (Θ c + 16°) (117°)

43390 Selected: Program Power (60 MW)

Ramp Pot (0.20°/sec) WET

Exp. Pot 710 Div. (Θ c + 3) (102°)

43425 Selected:

Drum Position Control, ZERO DEMAND

SHUTDOWN COMPLETE

Temperature Autostart

Wet Autostart

Temperature Loop Open

Program Control

43448 13 VDC Power ON

43453 Enabled Gang Key

43466 STARTED ENGINE

43468 When T-624 was 1050 (T-624 + 200) switched to position control and stepped drum in 8 degrees

43534 Used PDSV to maintain T-24 below 1200°R

43581 OPENED PDSV. When T-306 was 80°R, CLOSED PDSV

43591 OPEN PDSV. When T- 306 was 80° ramped drums out 8 degrees

43726 Ran drums in and CLOSED PDSV

43738 Used PDSV to maintain T-624 between 900° and 1000°R

43749 SHUTDOWN. Verified SHUTDOWN COMPLETE

43753 Disabled Gang Key

H. DRY AUTOSTART (TEST #6) AMB. CORE - COLD REFLECTOR Θ c + 13)

43778 Selected: Program Power (130 MW)
Exp. Pot (0.20°/sec) DFY

43801 Max Drum Scram 615 Div. (Θ c + 19°)

43810 Selected: Temperature Autostart
Dry Autostart
Program Control

43821 Verified Drum Program Terminate Clear

43826 13 VDC Power ON

43899 ENABLED Gang Key

44000 STARTED REACTOR

44010 At Drum Program Terminate Selected Position Control

44050 Used PDSV to maintain T-624 below 1000°

44097 OPENED PDSV - When T-306 was 80°R ramp drums out 8 degrees

44138 Ran drums in and CLOSED PDSV

43149 Used PDSV to maintain T-624 at 490°R

43167 SHUTDOWN. Verified Shutdown Complete

43170 Disabled Gang Key

I. DRY AUTOSTART (TEST #7) AMB CORE - COLD REFLECTOR Θ c -7)

44181 Selected: Program Power (60 MW)
Exp. Pot 435 Div. (Θ c -7) (85°)

44196 Max Drum SCRAM 600 Div, (Θ c + 16°) (108°)

44206 Verified Drum Program Terminate Clear

44210 Selected Program Control

44211 13 VDC Power ON

44215 ENABLED Gang Ky

44233 STARTED REACTOR

44235 At Drum Program terminate select Position Control

44380 Used PDSV to maintain T-624 below 1000°R

44498 OPENED PDSV. When T-306 was 80°R, CLOSED PDSV

44623 OPENED PDSV. When T-306 was 80°R ramped drums out 8 degrees.

44727 OPENED PDSV. When T-306 was 80°R ramped drums out 8 degrees (REPEAT)

44772 Ran drum in and CLOSED PDSV.

44830 SCRAMMED

44836 USED RSV-948 and RSV-550 to maintain engine temperatures

44839 CLOSED PCV-472

44841 Data System to 1/1

44845 CLOSED: FCV-31, RSV-937 , RSV-858, RSV-859, RSV-306

44857 Disabled Gang Key

44864 CLOSED PSV and OPENED PDVV

44890 Maintained ETC hydrogen concentration below 2% and then CLOSED PCV-621

44913 CLOSE SGS PURGE -

L. 44933 CONDUCTED LH_2 FLOW TEST

44934 CLOSED RSV-383 and PCV-248

44954 OPENED RSV-276. Established 100 psig in V-3801 and switched to AUTO

44970 OPENED RSV-110 and RSV-109

44973 OPENED RSV-106 and chilled V-5002
Monitored LT-9 and dewar temperatures
Reported Engine Temperatures

45026 INHIBITED CSV

45028 Placed CLOSED Command on CSV and OPENED CVV

45037 OPENED RSV-107 X

45046 OPENED PCV-472

45055 OPENED PCV-910

45057 OPENED PCV-543

45065 USED PCV-472, PCV-910, PCV-543 and CVV as required to chill 4-LH-6

45084 Reported when Chilldown was complete

46750 OPENED RSV-523 and RSV-515

47051 Reported V-3801 pressure 100 psig

47062 OPENED RSV-106 and CLOSED RSV-109 and RSV-110

47070 OPENED PCV-543 and CLOSED CVV and PCV-472

47074 On TD command used PCV-910 to determine max LH_2 flow rate

47080 Re-chilled the 4-LH-6 Line and reported when complete

47105 Reset Safety System

47107 Selected:

SHUTDOWN COMPLETE
NUCLEAR AUTOSTART
Power Loop Closure pot to 10 divs. (300 W)
5 Second Period
13 VDC Power ON

47125 USED FCV-31 to establish 7000 gpm

47133 Used PCV-621 to establish 6.5 pps GN_2 flow

47149 Turned on SGS Manual Purge

47155 OPENED RSV-858/859 and RSV-306 and RSV-937

47185 Set Program Power to (22 MW) 702 Div.

47207 Selected:

Max Drum at 621 Div. to (112°) ACTIVE
Drum Roll-in BYPASSED

47230 Data System to HIGH during power increases, DDS 1/1 other times

47238 ENABLED Gang Key

47243 In Postion Control STARTED REACTOR

47247 At 10 KW, switched to Power Control and increased power to 2.8 MW (500°R) Tex

47337 At 10 KW sat max drum at 676 Div. (121°)

47339 CLOSED PCV-543 and PCV-472

47356 At 1 MW ENABLED and OPENED CSV. CLOSED CVV and OPENED PCV-910.
Reported Flow Rate 1.7 pps

47709 Increase Power to 8 MW (1350°R)

47851 Decrease power to 2.8 MW (500°R) Tex

48167 Increase power to 11 MW (1800°R) Tex

48262 Decreased power to 2.8 MW (500°R)

48356 Increased power to 14 MW (1800°R)

48454 Decreased power to 2.8 MW (500°R) Tex

48656 SHUTDOWN. Verified SHUTDOWN COMPLETE
Reported Engine Temperatures

48682 CLOSED PCV-910 and OPENED CVV

48690 Disabled Gang Key

48695 Data System 1/1

48698 CLOSED CSV and INHIBITED

48706 CLOSE: FCV-31, RSV-937, RSV-858, RSV-859, RSV-306

48747 Maintained ETC GH_2 concentration below 2%. Then CLOSED PCV-621

48756 CLOSED SGS Purge

M. CONDUCTED GH_2 FLOW TEST

48770 In Manual Vent V-3801

48779 CLOSED RSV-107

48785 USED PCV-250 blow back LH_2 thru RSV-106

48788 OPEN: PCV-543, PCV-472, CVV, RSV-948, RSV-105

48810 Slowly OPENED PCV-910 and monitored FE-440

48814 Reported when V-5002 and cooldown system was dry

48869 OPENED PDSV and PDVV

48939 Set Program Power to 16 MW (685) Div. ACTIVE

48945 Set Max Drum SCRAM 621 Div. (Θ c + 16°)

48988 USED FCV-31 to establish 7000 gpm

49018 OPENED RSV-858 AND RSV-306

OPENED RSV-859 and RSV-937

Reported Source Power

49034 CLOSED RSV-106 and PCV-250

49045 CLOSED RSV-105, RSV-948, PCV-910 and PCV-543

49055 OPENED RSV-107

49062 Used PCV-621 to establish 6.5 pps GN_2 flow

49066 Turned on SG Manual Purge

49082 ENABLED Gang Key

49088 In Position Control STARTED REACTOR

49098 Set Max Drum SCRAM to 676 Div. (121°) Θ c + 25° ACTIVE

49108 Data System to HIGH

49125 ENABLED and OPENED CSV

49129 CLOSED CVV

49201 Used PCV-250 to establish 410 psig at P-878 (1.5 pps)

49358 Reduced Power to 100 KW

49462 CLOSED PCV-250

49473 CLOSED CSV and INHIBITED

49488 OPENED CVV

49491 Verified PDSV was OPEN

49496 CLOSED PDVV

49507 OPENED AND CLOSED PSV on TD Command
Reported reflector temperatures
CLOSED PSV at a drum angle of 80°

49772 CLOSED PDVV (Repeat)

49788 OPENED and CLOSED PSV on TD Command (Repeat)
Reported reflector temperatures
CLOSED PSV at a drum angle of 80°

49890 CLOSED PDSV and PSV. OPENED PDVV

49902 During the increase in GH2 flow increased power to 2.7 MW

49909 ENABLED and OPENED CSV

49916 CLOSED CVV

49923 USED PCV-250 to establish 120 psig at P-878 (0.5 pps)

50364 Reduced Power to 100 KW

50140 OPENED RSV-515 and RSV-523

50182 Verified that P-587 was ZERO

50184 OPENED RSV-539 and RSV-322

50226 CLOSED RSV-322 and RSV-539

50256 OPENED RSV-516 and RSV-524. CLOSED RSV-515 and RSV-523
Report P-3 -1550 psig

50274 OPENED RSV-201

50417 CLOSED PCV-250

50421 During increase in GH_2 flow increased power to 7.6 MW (1100°R)

50428 Armed PCV-251 and established 133 psig at P-475 (3.8 pps)

50540 During the decrease in GH_2 flow, decrease power to 1 MW (1100°R)

50546 CLOSED PCV-251 and SAFE

50550 Used PCV-250 to establish 120 psig at P-878 (0.5 pps)

50743 Increased Power to 5.0 MW (1900°R)

51162 Used PCV-250 to establish 33 psig at P-878 (.2 pps)

51166 Adjusted Power to 0.4 MW (1100°R)

51649 Increased Power to 1.5 MW (1800°R)

52284 SHUTDOWN. Verified SHUTDOWN COMPLETE

52292 Used PCV-250 to maintain engine temperatures

52546 After SCRAM used RSV-948 and RSV-550 engine temperatures

52552 SCRAMMED

52557 CLOSED PCV-250

52560 Verified all drums were in and disabled gang key

52565 Data System to 1/1

52568 Re-established engine system purge

52572 CLOSED: RSV-858, RSV-859, FCV-31, RSV-306, RSV-297, RSV-298

52592 Maintained ETC hydrogen concentration below 2% and then CLOSED PCV-621

52604 CLOSED SGS Manual Purge

52605 Secured trough cooling

52611 LOCKED all drums, removed gang key and returned to TD

N. SETUP LN_2 COOLDOWN SYSTEM

52656 CLOSED PCV-517

52660 OPENED PCV-754 and RSV-879

52669 When P-580 was less than 10 psig OPENED RSV-545

52683 CLOSED PCV-754 and RSV-879

52691 USED PCV-517 to maintain engine temperatures within cooldown limits.

V. <u>CTE POST OPERATIONAL PHASE</u>

A. DRUM AND TPCV ACTUATION SYSTEM SECURE

52723 CLOSED RSV-867

52736 OPENED RSV-443. Reported when P618 indicated ZERO

52790 Vented PRV-402 and PRV-200

OPENED RSV-443

CLOSED RSV-444 and RSV-877

52805 CLOSED RSV-879

B. 52907 PUMP DISCHARGE LINE CLEAN-UP

CLOSED RSV-579

52910 CLOSED RSV-132 and RSV-455

52924 Verified PDSV had a CLOSED Command and PDVV was OPEN

52936 OPENED PSV

52941 OPENED RSV-142

52956 Reported when T-108 was greater than 60°R

52987 CLOSED RSV-142

52990 CLOSED PSV

52998 Vented PRV-485 to 50 psig at P-896

53007 Reset Safety System

53019 CLOSE PDVV and OPEN PDSV

C. V-5001 LH_2 REMOVAL and PSL CLEAN-UP

52045 Verified the following:

RSV-129 CLOSED	RSV-128 CLOSED
RSV-132 CLOSED	RSV-252 OPENED
PCV-579 OPEN	RSV-455 CLOSED

52071 In Manual Vented V-3801

52076 OPENED RSV-129 and RSV-128

52086 Reported when T-44 indicated Gas Conditions

52629 CLOSED RSV-128 and RSV-129

52632 CLOSED RSV-252 and OPENED RSV-130

52638 CLOSED RSV-83 and OPENED RSV-386 - PSV CLOSED

53057 OPENED RSV-455

53061 OPENED RSV-132

53064 OPENED PCV-579 and rained V-5001. Reported when empty

D. V-5002 LH_2 SECURE

52070 Reported the following:

RSV-107 OPENED	PCV-472 CLOSED	RSV-384 OPENED

53120 Reported the following:

RSV-106 CLOSED	PCV-250 CLOSED	RSV-109 CLOSED
RSV-110 CLOSED		

53133 CLOSED RSV-107 X & Y

53143 CLOSED RSV-286 and OPENED PCV-250

53157 Used RSV-109 to vent any remaining pressure in V-5002 then CLOSED

53171 CLOSED: :CV-250, RSV-109 and RSV-110

E. COOLDOWN SYSTEM AND LH_2 TRANSFER LINE INERTING

53209 OPENED RSV-255

53217 After 20 seconds CLOSED RSV-386

53252 OPENED RSV-105

53275 CLOSED RSV-105

53296 CLOSED RSV-384

53358 CLOSED RSV-130 and OPENED AND CLOSED RSV-386

53440 OPENED AND CLOSED RSV-130

53446 CLOSED RSV-252

53452 OPENED RSV-130

53456 CLOSED RSV-255
53460 Secured TSER inerting
53463 CLOSED RSV-276
53474 OPENED RSV-87 and PCV-248
53500 CLOSED PCV-248 and RSV-87
53515 OPENED RSV-258 and RSV-257

F. PSL CLEANUP AND V-5001 SECURED

54340 Secured Duct Vault and Pipe Chase Inerting
54348 CLOSED RSV-132 and RSV-455
54354 Maintained ETC GH_2 concentration below 2%
54386 OPENED PSV
54409 OPENED RSV-142
54418 CLOSED PCV-579
54421 CLOSED RSV-142
54490 CLOSED PSV
54504 CLOSE PDSV and OPEN PDVV
54521 CLOSED RSV-283
54529 OPENED PCV-180 and vented V-5001 to ZERO psig
54595 OPENED RSV-390
54651 OPENED PCV-165 and reported when P-598 was ZERO psig
54659 Vented PRV-426
54665 CLOSED: PCV-165, PCV-180, RSV-186
54681 CLOSED PCV-447 and secured heater

G. GASEOUS COOLDOWN SYSTEM INERTING AND HEADER BOTTLE SECURE

54794 CLOSED RSV-201
54798 OPENED RSV-539 and reported when P-587 was ZERO
54823 OPENED RSV-322
54827 CLOSED RSV-59 and reported when P-587 stabilized
54833 OPENED RSV-539
54873 CLOSED RSV-539
54877 Monitored ETC GH_2 concentration
54880 OPEN RSV-941
54887 OPENED PCV-251
54969 CLOSED RSV-322 and reported when P-587 was ZERO
54972 CLOSED PCV-251 and RSV-941

54989 SECURED all Hydrogen Bottles

54996 OPENED RSV-194, vented P-3 to ZERO then CLOSED

55078 OPENED PCV-449 and Vented P-904 to ZERO

55090 OPENED RSV-275 and CLOSED RSV-247

55186 OPENED RSV-868

55192 CLOSED RSV-246

55196 CLOSED RSV-53

55202 DDS to 1/10

55208 CLOSE RSV-221

55212 Vent PRV-405

55224 TOP SEAL Control to PRESSURE

55230 Bottom seal blade purge OFF

55240 S-2 seal blade purge OFF

55247 Convolute seal purge OFF

I. TPCV CHECKED OUT AND SWITCHED CONTROL DRUM POWER

53654 BYPASSED TPCV override and pressure mode inhibit

53661 Reset Engine Safety System

53690 CLOSED RSV-443

53695 Verified TPCV closed and set TPCV pot to 50% demand
Reported when TPCV started to move

53721 OPENED RSV-867

53726 USED PRV-402 to establish 800 psig at P-618

53915 DDS to HIGH

53927 Slowly regulated PRV-200 to establih 200 psig at P-897
Reported when TPCV started to move

53974 OPENED TPCV to 90°

53983 Vented PRV-200

53989 OPENED RSV-443

53997 When P-478 was ZERO CLOSED RSV-443

54000 Set TPCV pot to 500 Div.

54007 DDS to HIGH

54015 Slowly regulated PRV-200 to establish 200 psig at P-897
Reported P-897 5 psig pressure when TPCV started to move

54064 ENABLED Function Generator

54074 Wide Band to HIGH

54256 With the TPCV at 45 degrees, introduced a 0.1 cps sine wave and increased the peak to peak amplitude until there was a measureable change in valve position

54310	With a TPCV at 45° and a demand of 4° peak to peak introduced sinusoidal input of:
	0.1, 0.2, 0.4, 0.8, 1.0, 2.0, 4.0, 6.0, 8.0, 10.0, 15,0, 20.0, 30.0 cps.
54410	INHIBITED Function Generator
54424	DDS and wide band to LOW
54429	CLOSED TPCV
54435	Activated TPCV Override
54439	Switched to Pressure Control
54640	Set TPCV Position pot to 630 div. (47°)
54674	DDS to HIGH
54688	Selected TPCV Position Control
54690	After 5 seconds reset TPO override
54705	SET TPCV at 35°. Waited 2 seconds and SCRAMMED
54715	DDS to LOW and Wide Band OFF
55253	Placed CLOSEDDemand on TPCV
55272	Vented PRV-200
55279	OPENED RSV-443. Reported thwn P-478 read ZERO

J. FUNCTIONAL CHECKOUT OF ENGINE VALVES

55341	Regulated RL-485 to establish 50 ± 5 psig at P-896
55350	DDS to HIGH
55355	Cycled TPV OPEN/CLOSED three times
55368	Cycled PSV OPEN/CLOSED three times
55467	DDS to LOW
55474	Regulated RL-485 to establish 500 ± 10 psig at P-896
55515	DDS to HIGH
55520	Cycled PDVV and PDSV three times
55600	OPENED AND CLOSED TBV
55608	Cycled CSV AND CVV three times and left CSV OPEN
55666	DDS to LOW
55669	OPENED PDSV and CLOSED PDVV
55676	Vented PRV-485

K. SETUP CONTROL DRUM PNEUMATIC SYSTEM

55323	Chilled in cryotrap and reported when filled
55502	Cycled RSV-879 as required and maintained less than 165°R at T-571
55702	CLOSED RSV-443
55712	OPENED RSV-877
55716	OPENED RSV-444
55719	Used PRV-200 to slowly increase P-478 to 200 psig.

L. P-19 CONTROL DRUM CHECKOUT

55790 CSEA Reported to Test Cell Building

55799 Set Drum Demand to 12°

55830 BYPASSED the individual Control Dum Null Circuit

55836 Reset the Engine Safety System and Unlocked Drum #1

55862 Set Drum #1 Individual Pot to 750 Div.

55888 DDS to HIGH

55892 Switched Drum #1 to Individual Control. When Drum #1 stabilized at 90° switched Drum #1 to Ganged Control

55909 DDS to LOW

56002 Set Max Drum SCRAM to 16° and ACTIVATED

55021 DDS to HIGH

55027 Switched Drum #1 to Individual and reported closed loop SCRAM

55055 DDS to LOW

55068 Switched Drum #1 to Ganged Control

56075 Reset the Engine Safety System

56122 When Drum #1 reached 50° produced an Open Loop SCRAM by momentarily depressing +15 VDC "power monitor switch -ESS"

56156 DDS to HIGH

56169 Switched Drum #1 to Individual Control and reported OPEN LOOP SCRAM

56229 DDS to LOW

55250 Switched Drum #1 to Ganged Control and locked. Returned pot to ZERO Divisions.

56335 Switched Drum #1 to Individual Control. When Drum stabilized at 90° switched drum #1 to Ganged Control

56378 Switched Drum #1 to individual control and reported closed loop SCRAM

56430 Switched Drum #1 to Individual Control and reported Open loop SCRAM

56489 Switched Drum #1 to Individual Control and when drum stabilized at 90° switched drum #1 to Ganged Control

56512 Switched Drum #1 to individual and reported closed loop SCRAM

56570 Switched Drum #1 to Individual Control and reported OPEN loop SCRAM

56620 Switched Drum #1 to Individual Control. When Drum stabilized at 90° switched drum #1 to Ganged Control

56646 Switched Drum #1 to Individual and reported closed loop SCRAM

56682 Switched Drum #1 to Individual Control and reported OPEN Loop SCRAM

56736 Switched Drum #1 to Individual Control. When drum stabilized at 90° switched drum #1 to Ganged Control

56759 Switched Drum #1 to individual and reported closed loop SCRAM

56791 Switched Drum #1 to Individual Control and reported Open loop SCRAM

56839 Switched Drum #1 to Individual Control. When drum stabilized at 90° switched Drum #1 to ganged control

56858 Switched Drum #1 to individual and reported closed loop SCRAM

56904 Switched Drum #1 to Individual Control and reported open loop SCRAM

56942 Switched Drum #1 to Individual Control. When Drum stabilized at 90° switched Drum #1 to Ganged Control

56961 Switched Drum #1 to Individual and reported closed loop SCRAM

56991 Switched Drum #1 to Individual Control and reported Open Loop SCRAM

57039 Switched Drum #1 to Individual Control. When Drum stabilized at 90° switched Drum #1 to Ganged Control

57062 Switched Drum #1 to individual and reported closed loop SCRAM

57086 Switched Drum #1 to Individual Control and reported open loop SCRAM

57150 Switched Drum #1 to Individual Control. When drum stabilized at 90° switched Drum #1 to Ganged Control

57166 Switched Drum #1 to individual and reported closed loop SCRAM

57192 Switched Drum #1 to Individual Control and reported open loop SCRAM

57219 Switched Drum #1 to Individual Control. When drum stabilized at 90° switched Drum #1 to Ganged Control

57236 Switched Drum #1 to individual and reported closed loop SCRAM

57253 Switched Drum #1 to Individual Control and reported open loop SCRAM

57281 Switched Drum #1 to Individual Control. When drum stabilized at 90° switched Drum #1 to Ganged Control

57295 Switched Drum #1 to individual and reported closed loop SCRAM

57313 Switched Drum #1 to Individual Control and reported open loop SCRAM

57343 Switched Drum #1 to Individual Control. When drum stabilized at 90° switched Drum #1 to Ganged Control

57358 Switched Drum #1 to individual and reported closed loop SCRAM

57372 Switched Drum #1 to Individual Control and reported open loop SCRAM.

57399 Slowly lowered Ganged Drum Demand to ZERO degrees then slowly set drums against locking pins.

57512 SCRAMMED

VII. PERFORMED A DATA SYSTEM CALIBRATION

57761 Secured Engine Purge

57771 Operators FER, GFS, ASE, FEL, CTE and LFE switched their consoles to ENABLE.

57795 Switched all groups except Group #7 to ENABLE

57884 Conducted a one point calibration of the Log and Linear channels. Reported Completed. 64 frames recorded

Returned all groups to INHIBIT

58903 Operaors FER, GFS, ASE, CTE, FEL AND LFE switched consoles to INHIBIT

58917 Re-established engine purge

58129 OPENED PCV-517 and pulsed

58195 CLOSED RSV-545

VIII. SWITCHED CONTROL DRUM POWER CONTROL AND LOCKED CONTROL DRUM PNEUMATIC DOUBLE BLOCK AND BLEED.

57940 Proceed to the TCB

58354 Switched Key #5 to grounded and removed

58360 Switched Key #1 to OFF and removed

57368 Verified P-897 was ZERO

57374 Switched TPCV power to Stand BY

57379 Activated Criticality Alarm Systems when radiation levels permitted

56384 Proceeded to the RSV-877 area and reported in at 56627

58641 Verified that P-478 indicated ZERO psig

58656 Rotated the Manual Override Hand Wheel on RSV-444 to the CLOSED (DOWN) Position

Rotated the Manual Override Hand Wheel on RSV-887 to the CLOSED (DOWN) Position

Locked the actuators on RSV-444 and RSV-877 and removed keys

Manually OPENED 50-BV-2332

Locked the handle on 50-BV-2332 and removed the key

CLOSED GLV-2337

UNLOCKED SVB-11 and CLOSED the Jamesburgy supply valves to RSV-444 and RSV-877

Switched RSV-444 and RSV-877 to SAFE

58928 LOCKED SVB-11

Returned to the CP and returned all keys to TD

59365 Removed CLOSED Command on RSV-877 and RSV-444

59369 CLOSED RSV-443

IX. POST COOLDOWN PHASE

A. 56225 CLOSED RSV-222 and PCV-621

56255 CLOSED: RSV-666, RSV-299, RSV-738, RSV-297, RSV-296, RSV-739

B. SECURE THE LN_2 SYSTEM

58283 CLOSED PCV-51y and RSV-545

58285 OPENED PCV-754

58291 Reduced PRV-108 Dome Pressure to 60 psig and activated.

61115 CLOSED RSV-861 and verified RSV-862 was OPEN

61118 FAC Assumed Facility Control