RN-DR-701

**SPEAR TEAM REPORT
XECF EP-1
2 APRIL 1968**

XF

MASTER

NERVA TEST OPERATIONS
Jackass Flats, Nevada

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April 1968

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RN-DR-701
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FROM: SPEAR Team

SUBJECT: SPEAR Reports, XECF-EP-1

ENCLOSURES: (1) Through (28) SPEAR Memoranda (See Table of Contents and Daily TWX's)

Enclosed are the final SPEAR Team Memoranda for XECF EP-1 which was conducted on April 2, 1968. The memoranda cover detailed analyses of the XECF engine, the ETS-1 facility and measurement system review by individual SPEAR Team members of the Engine System, Nuclear Components, Non-Nuclear Components, Controls, Dynamic and Instrumentation, Facility and Technical Assistance Groups. The SPEAR Team members participating in the activity were:

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SPEAR TEAM REPORT

XECF EP-1

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XECF EP-1 - SPEAR Memo No. 1 - B. Mandell

Subject: SUMMARY OF SPEAR ANALYSIS, EP-1, XECF

INTRODUCTION

This report summarizes the SPEAR Analyses for XECF EP-1 conducted on April 2, 1968. This was the first test of an engine system at ETS-1 and was intended to demonstrate that all facility systems and procedures were satisfactory for engine testing. The XECF Engine contains an inert core and four tests were planned for EP-1 to obtain additional X Engine bootstrap information. In addition, a hydrogen transfer test was conducted. A summary of the planned tests, results and chronology are shown in Enclosures (1) and (2).

Only one of the planned bootstraps was conducted during EP-1. A malfunction of the pump discharge shutoff valve on R-1 limited the testing to dry pump bootstraps and an adverse wind on Run Day caused the test stand wall temperature limits to be exceeded after only one bootstrap. To reduce the test stand wall temperature, the engine was warmed up with helium and the steam generators were shutdown. The engine warm up reduced the helium bottle pressure to too low a level for continued testing and operations were terminated for the day.

This was the first time a full SPEAR Team including all its groups evaluated data following a test.

SUMMARY OF ANALYSES

The test was very successful in its main objective, to operate all of the ETS-1 systems in conjunction with an engine. All systems including the LH₂ System, the GH₂ System, the GN₂ System, the GHe System, the Steam Generators, the Duct, the Engine Test Compartment, and the Data Systems were operated in their intended manner. With all these systems functioning the cold flow engine was started and data were obtained. The test operating team demonstrated a capability to operate the facility and react swiftly in a safe manner when unexpected events occurred. A number of anomalies were encountered and the following summarizes the SPEAR analyses relative to the test objectives.

A. DEMONSTRATION OF ENGINE BOOTSTRAP CAPABILITY

The capability of bootstrapping an engine in ETS-1 was successfully demonstrated but the test as run did not represent an intended X Engine startup. The TPA reached a peak speed of 5400 RPM and was in the process of accelerating when the TPCV was closed because of a chamber temperature limit.

The engine went through a series of oscillations similar to those observed on CFDTIS prior to bootstrapping. The test was not directly applicable for X Engine startup analysis because of chilling the nozzle prior to flowing hydrogen through the engine and a sharp increase in turbine back pressure which occurred during the bootstrap. These events gave compensating results but are difficult to separate and interpret. The data, however, are useful in developing a more complete understanding of engine bootstrap in follow-on computer analysis. It cannot be determined at present if similar oscillations would have occurred had the nozzle not been pre-chilled.

B. NOZZLE CHILL PRIOR TO BOOTSTRAP

Prior to bootstrap the nozzle was chilled to the range of 100°R at the inlet to 300°R at the outlet while the remainder of the engine, including the turbopump, was at ambient temperature. This condition occurred when the hydrogen used to chill the pump suction line was pulled into the engine. The pump discharge vent valve was open and when the steam generators were started, the cold hydrogen was pulled into the engine and exhausted through the duct. When the vent valve was closed, only the nozzle had been pre-chilled.

C. ETC PRESSURE RISE DURING BOOTSTRAP (Inadvertent Trip of the Steam Generator Shutdown Safety System)

The ETC pressure increased during bootstrap from 8 to 9.5 PSI. This occurred when a pressure spike in the steam line tripped PCV-449 and 30 lbs/sec of helium entered the ETC. A preliminary analysis of the pressure spike indicates the most likely cause was a change in the water valve position, but follow-on analyses are necessary to verify this. The operation of the PCV-449 was reviewed and determined to be as expected for the pressure oscillation that occurred in the steam line.

D. XECF ENGINE AVERAGERS

Five (5) engine averagers were used in XECF EP-1. The following summarize analyses on each:

1. CHAMBER TEMPERATURE

Only one thermocouple was sent to the averager. The output agreed with the data channel but there is no assurance averaging will be done properly when more than one signal is provided.

2. REFLECTOR INLET TEMPERATURE

The averager output appeared close to the value expected but did not agree with the input channels which appeared to be reading low.

3. CHAMBER PRESSURE

The averager output agrees closely with expected pressures but the individual input signals appear incorrect and low.

4. PUMP DISCHARGE PRESSURE

The averager output appears correct but the input to data are reversed in sign and read low.

5. TPCV

The output of the averager reads 90 degrees while the individual inputs read 30 degrees. Engine performance indicated the individual inputs are too low.

It is felt the averagers were working properly but the input signals are somehow being reduced going to data. Of the five (5) averagers it is important that the TPCV averager be checked before XECF EP-2 and the remaining averagers before XE-1.

E. ENGINE PRESSURE CONTROL

The engine pressure control system appeared to operate satisfactorily but data discrepancies prevented firm conclusions. The uncertainty in TPCV position indication (See Averager Summary) and a discrepancy in the indicated pressure demand versus the indicated actual pressures prevented firm conclusions.

F. V-5001 CONTROL SYSTEM

The V-5001 Control System operated satisfactorily but an approximate 1.8 PSI pressure bias caused a valve oscillation when switching from manual to automatic control.

G. ENGINE INTEGRITY

A review of the nozzle, TPA, reflector, core, engine lines and valves indicated all are ready for EP-2. Following EP-1 35 volts were applied to PDV and the valve operated. It is now ready for EP-2.

H. DATA SYSTEM PERFORMANCE

Approximately 96% of the 1034 data channels reviewed performed satisfactorily. There were several serious anomalies however. Twenty-eight seconds of data were lost from subsystem #1 during engine bootstrap due to an oversize tape and fourteen seconds were lost later on subsystem #2 due to a tape handling problem. The redundant recording of data on both subsystems allowed most but not all of the analyses to be completed. When the microwave system with the data link is verified as operational, the resulting dual recording capability should alleviate the problem.

The discrepancy in data leaving the engine system averagers is a problem requiring a solution before XE-1.

I. DATA REDUCTION

NRO CRT plots were received on R+2 to the specification requirement and NTO produced one (1) sample per second digital listings on R+1 to the specification requirement. Plots of the one (1) sample per second data were waived by the SPEAR director to go directly to special requests. Analog graphs were provided to SPEAR without headers attached and this must be corrected in support of future EP's.

J. STEAM GENERATOR PERFORMANCE

The steam generators performed satisfactorily with several anomalies noted. The manual water valve on unit #3 moved and caused a pressure spike in the steam line which in turn tripped the helium safety system. The propane manifold filter plugged with sand and reduced the manifold pressure. The reduced manifold pressure did not cause any apparent damage to the injector face due to overheating.

K. DUCT PERFORMANCE

The duct coolant water flow was increased in the elbow section and successfully kept the water temperature at a reasonable level with cold hydrogen flowing in the duct. The duct flares performed satisfactorily but an ignition problem was noted when liquid propane froze the pressure regulator.

L. ETC PERFORMANCE

The shield water flow system has not been modified and the water flows were again below XE-1 requirements as was noted on NEP-He-2. It was not possible to check the seal system GN_2 use because of a flowmeter malfunction.

There were leaks into the ETC from the bottom blade purge and bottom seal blade purges. No safety limits were exceeded but this has been a consistent problem.

M. PLUME HEATING DUCT EXIT AREA

One of the thermocouples on the concrete adjacent to the duct plume went to 288° F (limit 250° F). The engine was purged with GHe and the steam generators were shutdown to prevent additional heating of the concrete. The time was omitted from the analog traces on which the data were recorded and a good analysis of flows and wind velocities was not possible. Follow-on analyses are required to better assess this problem.

N. V-5001 LIQUID LEVEL MEASUREMENTS

The point capacitance probes did not function and the point carbon resistor probes were erratic and not usable. The continuous point resistors and the new reflectometer operated satisfactorily and when adjusted should give accurate level readings.

O. INERTING SYSTEMS

The TSER, duct vault, and pipe chase O_2 concentrations were maintained between 4 and 5% at all times after initial inerting. The usage of GN_2 was above normal due to wind conditions but it is concluded the systems are satisfactory for EP-2.

The UTSM purge and ETC purge systems performed satisfactorily but PCV-621 did not operate and FCV-50 had to be used for control.

P. STEAM LINE PERFORMANCE

The steam line had an acceptable level of movement and skin temperature differentials were within the allowable limit. It is concluded the line is ready for EP-2.

Q. LH_2 PROPELLANT SUPPLY SYSTEM

The LH_2 propellant supply system performed satisfactorily. A successful transfer was made flowing hydrogen back into dewar V-3801 from the run tank V-5001. The tank can be reduced to about the 23% level and then the remainder must be blown to the flare.

R. FLUID USAGES

EP-1 was terminated when the helium pressure dropped below 1500 PSIG, the minimum requirement for safe operation of the loss-of-steam safety system. The GN_2 pressure was also close to the minimum allowable for normal operation. The GH_2 inventory was satisfactory.

For EP-2 it is recommended hydrogen be intermittently used for engine warmup to conserve helium if the concrete wall temperature limit of $250^\circ F$ is not exceeded. A series of recommendations are included in Memo No. 26 to help conserve nitrogen. If these are incorporated, it is felt there is sufficient gas for EP-2.

S. OXYGEN INDICATION IN ETC

After PCV-449 was closed, there was a rise in indicated oxygen on the temporary oxygen analyzers attached to the nozzle. This was probably a faulty reading obtained when steam was pulled into the ETC as a result of pressure oscillations. The analyzers will indicate oxygen if water deposits on the probes.

SUMMARY ANOMALIESReference Memos

1) The pump oscillated during bootstrap.	#2, #4, #9, #8
2) The nozzle was pre-chilled prior to bootstrap.	#2, #3, #10
3) The loss of steam safety system was tripped during bootstrap.	#2, #4, #9, #16, #18
4) The chilldown circuit detector output was not sent to data.	#5
5) Pump flow was not corrected for available density.	#7
6) Two of three chamber pressures (PT-148 and PT149) were invalid on digital printouts. This also resulted in an invalid calculation of nozzle flow rate based on average chamber pressure on CRT plots.	#10
7) The venturi delta P for determining diluent flow-rate gave a negative reading and it appears that the transducer was plumbed in reverse.	#10
8) The pump discharge valve did not operate.	#11
9) UTSM temperature TE-858 dropped off and became erratic at time 63295. This temperature is on the turbopump support panel.	#12
10) The strain gages in the UTSM were recorded in the wide band data system and not recorded in the narrow band digital data system and the CRT plots.	#12
11) TT-144.A not included in chamber temperature averager circuit.	#13
12) Large temperature difference between TT-139.A and TT-144.A.	#13
13) Poor agreement of the reflector inlet temperature averager as compared to the individual RTT's at high temperatures while there was excellent agreement at the lower temperatures which were plotted.	#13
14) PT-148.A and PT-149.A do not compare with PT-141 and further they indicate negative pressures during certain times.	#13

SUMMARY ANOMALIES (Cont'd)Reference Memos

15) PT-110.A and PT-112.A apparently have the wrong sign and their magnitude is low.	#13
16) Two TPCV position indications disagree with averaged value.	#13
17) There was an apparent 1.8 psi bias in the V-5001 pressure control circuitry.	#14
18) There was a discrepancy in the data from the engine pressure control output.	#15
19) The manual demand for DP-449.M is scaled 0 to 25% instead of 0 to 100%. The XECF data log lists the range as 0 to 25% and this agrees with the calibration.	
20) The valve position DP-449 is listed in the data log as ranged from 0 to 100%, however, the calibration shows that the actual range was 0 to 200%.	#16
21) At an approximate range time of 62858 the command to PCV-449 was switched from automatic to manual demand. Data shows a resultant increase in auto demand and a reduction in manual demand suggesting the possibility of loading in the circuit.	#16
22) There is a difference between the measured and commanded position of PCV-449. The position demand is approximately 10% greater than the measure position.	#16
23) A number of data anomalies are outlined in Memo #17.	#17
24) There were pressure spikes in the steam line.	#18
25) The propane filter delta P increased due to sand in the filter.	#18
26) There were pressure oscillations in the steam generator LOX system.	#18
27) There was a LOX leak	#18
28) The first stage propane valve on module #3 did not shut.	#18
29) There were spikes in the water supply pressure to the steam generators.	#18

SUMMARY ANOMALIES (Cont'd)Reference Memos

30) The fire deluge system tripped.	#18
31) There was moisture in the conduit from Steam Generator #1 causing it not to operate.	#18
32) Unequal water flow occurred between steam generator modules #2 and #3.	#18
33) The command to the water valve on unit #3 changed for unknown reasons during bootstrap, causing a pressure spike.	#18
34) Liquid propane froze the duct flare regulator and delayed ignition.	#19
35) The ETC shield water flow was inadequate.	#20
36) The ETC bottom seals leaked.	#20
37) The GN ₂ flow meter FT-434 was not operable.	#20
38) The concrete near the duct exhaust exceeded the test limit.	#25
39) A series of anomalies are reported by NTO QC and are described in Memo No. 27.	#27
40) Not all V-5001 level indicators worked properly.	#24
41) There was a 10% error in indicated hydrogen inventory is transferring back and forth from V-3801 to V-5001.	#23
42) A faulty oxygen reading was indicated in the ETC after PCV-449 was closed apparently due to steam backflow.	#1

SUMMARY RECOMMENDATIONSReference Memo No.

- 1) Based on a review of the engine system objectives attained it is recommended that the tests scheduled for EP-I should be conducted during a subsequent EP. (2)
- 2) Further analysis of the engine characteristics under the unusual conditions that existed during this test should be made using the transient computer program to perform the mass and energy balances required. (2)
- 3) There should be no direct access from the engine into the flare system when the steam generators are operating (i.e. PDVV or PDV must be closed). Check valves are not considered adequate protection against air backflow to system. #3
- 4) The test should not be terminated while the pump is still accelerating because of the measured chamber temperature. The test should only be terminated after maximum pump speed is obtained and pump speed is decreasing. #4, #19
- 5) The completion of chilldown signal from the comparator should be sent to data. #5
- 6) All data circuits from the engine controllers and averagers should be end to end checked after completion of XECF to determine the cause of the data discrepancies. The T.P.C.V. position should be checked prior to EP-2. #5, #7, #10, #13, #15
- 7) The N.R.O. computer program for computing T.P.A. parameters should be corrected. #9
- 8) The PDSV closing pilot valve, S/N 124, should be removed from the UTSM and inspected and re-tested for acceptance after XECF. This inspection and test is necessary to attempt to isolate the cause of the malfunction and to ascertain that the valve is acceptable for future usage. Replacement of the unit should be considered for XE-1 but is not necessary for completion of XECF. (#11)
- 9) The strain gages in the UTS MG 801, 802, 803, 804, 805, 806 and 115 should be recorded in the narrow band Digital Data System and reproduced on CRT plots. #12

SUMMARY RECOMMENDATIONS (Cont'd)Reference Memo No.

- 10) At least two signals should be input to the chamber temperature averager. #13
- 11) The pressure rate detector should be modified to incorporate a positive rate limit before XE-1 to lower the probability of an inadvertent helium flow if the cause of the pressure oscillation cannot be found and corrected. #16
- 12) The scaling on the parameters CP449.M and DP449 should be checked and corrected as required. The apparent overloading of the control circuit and the difference between the actual and demanded position should be investigated in follow on analyses. #16
- 13) A series of data recommendations are defined in the indicated memos. #7, #10, #17
- 14) Steam generator liquid oxygen system pressurization system regulator PRV-9 should be serviced. #18
- 15) First stage propane valve on steam generator module 3 should be removed and functionally checked because it malfunctioned. #18
- 16) The steam generator propane manifold supply filter should be cleaned and checked after future runs until the whole system can be cleaned. The pressure drop between the propane tank and manifold should be closely monitored and not allowed to exceed approximately 70 psid. #18
- 17) All shield water valves, duct water valves and fire protection system deluge valves that most likely will open should be opened prior to arming the ETC repressurization system (PCV-449) to avoid a false trip of PCV-449. #18
- 18) If recommendation No. 17 cannot be accomplished, a water accumulator should be installed on the SGS manifold. #18
- 19) Maintain equal water flow to each SGS module. #18
- 20) Set the module water injection valves and do not touch the controller after PCV-449 is armed. #18

SUMMARY RECOMMENDATIONS (Cont'd)Reference Memo No.

- 21) Install a 75 Cv trim in all water injection valves. #18
- 22) Install ten turn potentiometers on the controllers of each water injection valve. #18
- 23) Install a back pressure regulator to prevent liquid from collecting downstream of the atmospheric propane vaporizer for the duct flare. #17
- 24) The ETC water shields require modification to meet minimum flow requirements. #20
- 25) FT-434 should be isolated during operations of the side shield latching mechanism. FT-434 should be checked out and, if possible, determine why it indicated a constant negative pressure differential during NTO-I-320. It should also be checked out to determine if the readings during EP-1 were valid. This should be done prior to EP-2. #10
- 26) The possibility of installing turbine meters in the low pressure GN_2 lines (less than 500 PSIG) to determine GN_2 flow should be evaluated. Or the possibility of installing another orifice meter in parallel with FT-434 should also be investigated, such that flow can be diverted through either flow orifice. #20
- 27) It is recommended that meters for FT-434 and PT-844 be installed on the RIC Console so that the RIC Console Operator can monitor any sudden changes in GN_2 flow. #20
- 28) The O_2 concentrations in the duct vault and pipe chase areas should be maintained between 4.8 and 5.0% to conserve GN_2 . #21
- 29) The duct exit area thermocouples which are test limits should be made a part of the digital data. #25
- 30) To conserve nitrogen, a series of recommendations are outlined in Memo No. 26. #26
- 31) To conserve GHe engine warmup should intermittently use GH_2 as long as no duct exit area temperature limits are exceeded. #25

SUMMARY RECOMMENDATIONS (Cont'd)Reference Memo No.

- 32) A series of recommendations for monitoring IH_2 level in V-5001 are outlined in Memo #24. #24
- 33) Care should be exercised in closing PCV-449 when the steam generators are running, particularly below 3%, to keep steam out of the E.T.C. #1

B Mandell

SUMMARY RESULTS XECF-EP-I

PLANNED TESTSRESULTSI. Hydrogen Transfer

Liquid hydrogen was to be transferred from storage dewar V-3801 to the run tank V-5001 and then back to the dewar by pressurizing the run tank.

The test was successful. V-5001 was filled to approximately 90% and then was emptied to approximately 23%.

II. Engine Bootstraps

1) The first bootstrap was a dry pump bootstrap with the tank pressure at 35 psia. Hydrogen was to be flowed through the engine until the reflector inlet temperature dropped to 70°R or the dome dropped to 100°R and then the TPCV was to be opened.

The test deviated from the plan for two reasons:

1) The ETC pressure increased from 8 to 9.5 psia during bootstrap when line pressure spike tripped the helium safety system. 2) Prior to bootstrap the nozzle was inadvertently cooled when cold hydrogen was sucked into the engine from an open vent valve.

2) Test #2 was to be identical to test #1 except the pump was to be pre-chilled.

This test was dropped on R-1 when the pump discharge valve would not close.

3) & 4) Test #3 and #4 were to be similar to test #1 except the tank pressure was to be reduced. 27 psia was to be tried for test #3 and the test conditions in the fourth test were to be determined from results of the third test.

Tests #3 and #4 were not conducted because of a depletion of the helium supply. One of the duct vault temperatures exceeded its limit and the engine was purged with helium and the steam generators were shutdown. The warmup of the engine with helium depleted its pressure to an unsatisfactory level for additional testing.

SUMMARY RESULTS XECF-EP-I

CHRONOLOGY

The chronology for the test is included in the Three Day Report, NTO-R-0142, and is not repeated in these SPEAR memoranda except for the major events listing below:

<u>EVENT</u>	<u>CONTROL ROOM TIME</u>
1. SG #2 to IDLE	62449
2. SG #3 to IDLE	62454
3. SG #2 to FULL STEAM	62477
4. SG #3 to FULL STEAM	62489
5. PSV OPEN	62802
6. TPCV Starts OPEN	62832.9
7. PCV-449 OPEN	62849.8
8. PCV-449 CLOSED	62867.0
9. TPCV CLOSED	62868
10. PCV-471 OPENED to 449 for Warmup	62997.9
11. SG #2 to IDLE	63445
12. SG #3 to IDLE	63448
13. PCV-471 CLOSED Warmup Complete	63558
14. SG OFF	63592

The steam generators ran at full steam for approximately 1000 seconds; the TPCV opened 31 seconds after PSV; PCV-449 introduced He into the ETC while bootstrap was in process; the He flowed to the ETC for 17 seconds; and TPCV was closed one (1) second after the He flow to the ETC was terminated. Approximately 250 lbs of hydrogen flowed through the turbopump from PSV OPEN to TPCV Shutdown plus five (5) seconds, from CRT 62802 to 62873.

SUBJECT: ENGINE SYSTEM PERFORMANCE SUMMARY

INTRODUCTION

This memorandum summarizes the results of the Engine Analysis group effort for XECF, EP-I. The test was conducted on April 2, 1968, to demonstrate a warm pump start at a run tank pressure of 35 psia. It was anticipated that engine performance during this test would be similar to that obtained during CFDTS Test No.-019 which was a warm pump start at a run tank pressure of 35.4 with initial engine material temperatures of 530°R and a back pressure of 7.5 psia, and to the computed test prediction performance which assumed a run tank pressure of 35 psia, initial engine material temperatures of 540°R and a back pressure of 7.5 psia. For the test prediction TPCV opening was set for 29 sec. after opening of PSV when the nozzle tube outlet temperature reached 100°R. During CFDTS-19 TPCV was opened 18 sec. after opening of PSV at a nozzle tube outlet temperature of about 300°R. Two anomalies occurred during the test which affected the start characteristics of the engine making a direct comparison with CFDTS test -019 or the test prediction difficult. (1) Prior to engine startup, cold hydrogen being vented from the pump inlet line flowed into the engine through PDVV and partially chilled some engine components. (2) During the startup the helium ETC purge system actuated causing an increase in ETC pressure reducing the pressure ratio and performance of the turbine. In evaluating the performance characteristics of the engine system during EP-I, comparison was made primarily to CFDTS Test - 19 rather than to the test prediction.

The test was successful to the extent that bootstrap was achieved and the effects of opening TPCV at a reflector inlet temperature of about 85°R were discernable.

SUMMARY

The following summarizes the test results with respect to the six EP-I test objectives identifiable to the Engine Analysis group.

1) Evaluate Warm Pump Starts Using the Technique of Chilling Down the Engine System

During the test the TPCV was maintained closed until the nozzle tube outlet temperature decreased to about 85°R. This procedure was intended to eliminate the system oscillations that occurred during CFDTS warm pump startups. However, examination of the test data showed that typical oscillation did occur from the time TPCV opened until bootstrap. Due to the unexpected initial engine conditions and the sudden increase in ETC pressure the occurrence of oscillations under normal conditions was not proven. However, the fact that the oscillations that occurred were typical of CFDTS warm pump starts is evidence that further chilldown of the pump is required prior to opening TPCV in order to avoid oscillations during engine startup.

2) Compare CFDTS and XECF Data

XECF engine performance appears to be qualitatively comparable to CFDTS providing allowances are made for the anomalies which occurred during the test. Direct comparison is difficult and further analysis will be required to detail the effects of the conditions that existed.

3) Evaluate Minimum Tank Pressure for Engine Bootstrap

This objective was not achieved because the planned tests at lower tank pressures were not performed.

4) Evaluate Differences Between Warm Pump and Prechilled Pump Starts

This objective was not achieved because the planned chilled pump test was not conducted and the warm pump test conducted was not a typical engine startup.

5) Evaluate the Warmup of the Engine System Using the Facility Supply System

This objective was partially achieved. Warmup of the engine was accomplished using GHe instead of GH_2 as planned. However, the data obtained can be extrapolated for GH_2 usage.

6) Obtain Data for Improvement of Analytical Models

Data obtained from the test will be useful in checking the analytical models. The unusual test conditions experienced will serve as a check on the extrapolation capability of the models.

DISCUSSION

Engine startup was initiated by opening of the PSV at a range time of approximately 62802 sec. The initial conditions of the engine were not as planned. Prior to engine startup, cold hydrogen being vented from the pump inlet line flowed into the engine through PDVV and partially chilled the pump discharge line downstream of PDVV, the nozzle and part of the reflector. A further discussion of the initial engine conditions is presented in SPEAR Memo No. 3. Due to the partial chilldown of the nozzle and reflector, the dome temperature decreased more rapidly than anticipated. It had decreased 100° R at about 62833 at which time the Pc loop was manually activated causing TPCV opening to be initiated. The TPCV opening time was approximately 12 sec. Opening of TPCV initiated flow to the turbine and the TPA accelerated from 0 to 3000 rpm in approximately 7.5 sec. at which time oscillations in pump speed began. Pump speed continued to increase in an oscillatory manner until 62849.8 sec. when PCV-449 opening resulted in a sudden increase in ETC pressure from 8 psia to 10.2 psia. The increase in turbine back pressure apparently reduced the shaft power output of the turbine causing a decrease in average pump speed. Oscillations in speed at an essentially constant average value continued until 62862.5 sec. at which time bootstrap of the

system occurred. System oscillations appeared to be typical of those encountered during CFDTs testing (see SPEAR Memo No. 4). At 62868 sec., when the pump speed was at about 5800 RPM and still increasing engine startup was terminated by manual closing of the TPCV when the control room nozzle chamber temperature display reached the test limit of 200°R. During subsequent warmup of the engine, temperature measurements on the facility increased to the point where the warmup fluid was switched from GH₂ to GHe in order to extinguish the flame at the outlet of the duct.

Two unanticipated conditions occurred during the test which could be expected to influence the length of time required for the engine system to bootstrap after opening of PSV. These conditions apparently produced compensating effects so that the time from opening of PSV to start of bootstrap was about the same as for CFDTs Test No. 019.

1) The prechill of the nozzle and part of the reflector reduced system impedance during the initial phase of engine chilldown and would probably have resulted in bootstrap occurring sooner than expected. In fact, the pump speed had increased to about 4800 RPM at 62850 sec. and may have continued to bootstrap at this time if the ETC pressure had remained constant.

2) Opening of PCV-449 caused an increase in ETC pressure which resulted in reducing turbine performance and pump speed. This delayed the onset of bootstrap.

CONCLUSION

This test was a successful means of operator training, and disclosed several correctable problems with respect to operation of the ETS-1 facility.

RECOMMENDATIONS

1) Based on a review of the engine system objectives attained it is recommended that, if possible, all the tests scheduled for EP-I should be conducted during a subsequent EP.

2) Further analysis of the engine characteristics under the unusual conditions that existed during this test should be made using the transient computer program to perform the mass and energy balances required.

A. J. Williams
DM

Subject: INITIAL ENGINE SYSTEM CONDITIONS

INTRODUCTION

The purpose of this memorandum is to summarize the engine system conditions at initiation of the engine start. Some earlier data is also presented because of the unexpected chilling of parts of the engine.

SOURCE OF DATA

1. Initial engine system temperatures - thinned digital data, No. 1
2. Core element temperature - CRT plots, No. 1
3. Nozzle inlet temperature - thinned digital data and CRT plots, No. 1
4. PDVV and PCV579 valve position - thinned digital data, No. 1

DISCUSSION

The only engine system valve opened between V-5001 fill operations and the start of the run (PSV open) was PDVV. PDVV was opened at range time 61850.6, 50 seconds prior to opening PCV579, and remained open until range time 62766.3. PCV579 also remained open and closed at range time 62778.3. Figure 1 is a plot of PDVV and PCV579 valve positions from start to open PCV579 through completion of the run. The nozzle manifold fluid temperature is also shown in Figure 1.

The nozzle manifold temperature started to cool about 219 seconds after the initial opening of PCV579 and chilled to 55°R at range time 62766.3 when PDVV was closed and then warmed to 166°R at the start of the run.

Figure 2 shows the engine system initial run temperatures on a simplified sketch. The extent of the pre-run chill is indicated from the skin temperature downstream of PDKV to reflector metal temperatures.

Figure 3 is a sketch of the vent system above the facility shield showing the direct connection of the vent lines from PCV579 and PDVV.

ANOMALY

The only anomaly with respect to the initial run conditions was the chilling of the pump discharge line, the nozzle assembly and part of the reflector below the planned 500 to 560°R ambient engine system temperature. This pre-run chilling occurred during the propellant supply line chilldown when LH₂ flow is vented through PCV579 to the FS-5001 vent system. During this

period the pump discharge vent valve (PDVV) was open which resulted in a direct path between PCV579 to the engine downstream of this pump. The steam generators were operating during this period which reduced the ETC and engine pressures below ambient providing a pressure differential between PCV579 outlet and the ETC. It is, therefore, concluded that this anomaly was caused by PDVV being open during the chillover of the propellant supply line.

RECOMMENDATION

To prevent chilling the engine system or possible ingestion of air prior to dry pump startup runs, it is required that PDVV, PDSV and cooldown vent valve (CSV) be closed.

W. L. K. Hump *RJH*
Bm

INITIAL RUN CONDITIONS

RANGE TIME - 62801.3

MEMO 3, FIL 2

LKH

RUN TANK		PSV	ETC
PRESS OUT -	35.9 PSIA	TEMP IN - 42°R	TOP CHAMBER - 7.7 PSIA
TEMP (10% LEAK) -	37.03 °R		BOTTOM CHAMBER - 8 PSIA

MEMO 3, FIG 3

LK14

XECF-EP-I - SPEAR Memo No. 4 - P. W. Coupland

Subject: ENGINE SYSTEM OSCILLATIONS

INTRODUCTION

During CFDTS warm pump startup tests, low frequency oscillations with relatively large amplitudes occurred in pump speed and system pressures. For XECF EP-I the opening of the TPCV was delayed until the nozzle tube outlet fluid temperature was approximately 85°R. The intent of this delay was an attempt to eliminate pump speed and system pressure oscillations by providing sufficient pre-chilling of the pump and nozzle tubes.

SUMMARY

The first XECF test showed large pump speed oscillations even though the pump and nozzle were pre-chilled prior to opening the TPCV. Analysis of these oscillations showed that they were typical of oscillations which occurred during CFDTS warm pump tests. Table I compares CFDTS Run No. 019 and XECF EP-I test conditions.

SOURCE OF DATA

1. Pump Speed Data -- XY on-line plotter
2. Pump Discharge Data -- CRT plots

TECHNICAL DISCUSSION

A warm pump test was conducted with a tank pressure of approximately 35 psia. The engine test compartment (ETC) pressure was 8 psia. During the XECF EP-I test the TPCV opening was delayed until the nozzle tube outlet fluid temperature reached approximately 85°R. The time delay was utilized in an attempt to eliminate pump speed and pressure oscillations by providing sufficient pump pre-chill. A review of the on-line X-Y plotter data revealed that the pump chill was marginal at best and that oscillations did occur from time point 62802 to 62867 as shown in Figure 1.

A comparison of the XECF data with the CFDTS data showed similar oscillations. During the XECF EP-I test, the chillover delay time was 31 sec followed by a smooth exponential increase in pump speed to 3000 rpm in approximately 8 seconds (see Figure 1). At this time, low frequency speed oscillations were incurred which had a period of around 3 seconds and an amplitude of approximately 1500 rpm. The mean value of these oscillations increased to 4000 rpm. From a comparison of CFDTS data with XECF data it appears that the system might have bootstrapped within the next few seconds with possibly only one more speed oscillation. It did not, however, since the ETC He purge system came on at this time and the ETC pressure was increased to 10.2 psia. Increasing the ETC pressure decreases the pressure ratio across the turbine thus decreasing mean pump speed back to 2000 rpm as shown in Figure 1.

X-1

Figure 1 compares the pump speed oscillations of XECF EP-I with those that occurred during CFDTS, Run No. 019. The time scales have been shifted in Figure 1 so that the valleys of the last pump speed oscillation prior to bootstrap are aligned.

It may be seen in Figure I that the speed oscillations are essentially equal in frequency and similar in amplitude for the period just prior to bootstrap.

Figure 2 presents a plot of pump speed and pump discharge pressure for the period prior to bootstrap during XECF EP-I and Figure 3 presents a similar plot of these parameters during CFDTS. It is apparent that during both tests the pump discharge pressure is out of phase with respect to the pump speed oscillations and shifts into phase with pump speed when bootstrap occurs.

CONCLUSION

Based on the data presented in Figures 1 through 3 it may be concluded that the system pressure oscillations that occurred during XECF EP-I were similar to those of warm pump CFDTS startups and would appear to be in no way associated with interaction of the engine with the ETS-1 test facility.

RECOMMENDATIONS

1. The test should not be terminated while the pump is still accelerating regardless of the measured chamber temperature. The test should only be terminated after maximum pump speed is obtained and pump speed is decreasing.
2. The next XECF test should be a repeat of Test 1, because the engine system objectives for this test were not achieved due to the anomalies that occurred during the test.

Lyok
PW Coupland
BN

TABLE I
TEST CONDITIONS

	CFDTS RUN No.019	XECF EP-I
Tank Pressure	35 psia	35 psia
Back Pressure	7.4 psia	8.0 psi
Pump Condition at PSV Opening	Warm	Warm
TPCV Program	Stepped and ramped the TPCV to the 80° position after an 18 second chilldown delay.	Opened TPCV on a chamber pressure error after a 31 second chilldown delay
Engine Hardware Temperatures at PSV Opening	525°R (Ambient)	(SPEAR Memo No. 3, Figure 2)

Figure-1 PWC
9/4/68

KEEP EP-1
PUMP DISCHARGE PRESSURE
RPM
VS
TIME

PUMP DISCHARGE PRESSURE - PSIA

RANGE TIME - SEC

PWC
4/1/68

FIGURE-2

SUBJECT: NOZZLE TUBE EXIT TEMPERATURES

INTRODUCTION

The chilldown completion signal circuit is as follows. Individual signals from RTT's TT207, TT210, and TT216 are input to the temperature averager. The averager signal, T.306, is input to the temperature comparator which is programmed for completion of chilldown. When the completion of chilldown set point is reached, a signal from the comparator actuates the pressure control loop.

The original purpose of this analysis effort was to verify that the nozzle tube exit temperature averaging circuit was operating properly at the time the temperature comparator circuit was to have actuated (i.e., completion of chilldown and initiation of TPCV opening) and to analyze the temperature distribution at the time of this event.

SOURCE OF DATA

1. Nozzle Tube Exit Temperature RTT's - Thinned Digital Data, No. 1
2. Nozzle Tube Exit Temperature Average Signal Data - Thinned Digital Data No. 2 and Control Room Sanborn Analog Recorder

DISCUSSION

The test specification established completion of chilldown at 70°R average nozzle tube exit temperature. However, this control parameter was bypassed and the pressure control loop manually activated when the dome temperature dropped 100°R. Therefore, verification of proper operation of this circuit was not demonstrated.

Analysis of the temperature comparator system is most significant during the time period when the temperature approaches the chilldown completion set point of the comparator system. Analysis of the data from the three RTT's that input to the averager, the averager signal, and verification that the completion of chilldown signal was available to the pressure control loop was limited because of the following reasons:

- 1) The digital data from RTT's TT207 and TT216 were on Sub-system 1, which was lost during the time period from 11 seconds before until 17 seconds after opening of TPCV. Only RTT TT210 digital data from Sub-system 2 was available.
- 2) The digital data T.306 from the averager from Subsystem 2 was not available during SPEAR evaluation, however, this data will be available later.
- 3) The completion of chilldown signal from the comparator was not sent to data.

XI

Analysis of the available data indicated good agreement between the arithmetical average of the three individual temperatures and the averager temperature. This data is shown in the following table.

NOZZLE TUBE EXIT TEMPERATURE

<u>Range Time</u>	<u>TT207</u>	<u>TT210</u>	<u>TT216</u>	<u>Arith. Avg.</u>	<u>T.306 (Avg)</u>
62821.3	133.1	141.8	120.2	131.7	134.7
62822.1	136.3	141.1	123.2	133.5	136.8
62833.0*	Lost	96.8	Lost	-----	**
62850.5	52.5	62.3	42.1	52.3	44.9
62851.5	43.1	43.3	43.5	43.3	43.4

* Time of TPCV initial opening

** Not available at time of SPEAR evaluation

The average signal data was available from the Control Room Sanborn Analog Recorder during this time period. Although this trace did show the trend of this average temperature, it was unsatisfactory for obtaining the magnitude of the temperature. This is believed to be due to the use of mode card ST03 in the signal conditioning equipment. This mode card is very non-linear. Approximately 50% of its output is obtained over the temperature range from 36°R to 68°R while the remaining 50% covers a temperature range in excess of 500°R.

The incorporation of mode card ST03 was made less than a week before XECF, EP-I. It is believed that there were two reasons for this late change. The first reason was to enable the operator to obtain a more accurate reading when the nozzle tube exit temperature was near 70°R. The second reason was to provide a higher level signal to operate the chilldown completion trip circuit to actuate the pressure control loop.

CONCLUSIONS

Verification of the chilldown completion circuit actuation at 70°R nozzle tube exit temperature was not demonstrated. Determination that the completion of chilldown signal was available to the pressure control loop could not be made. A comparison of the data from the three RTT's and the averager data could not be made during the time period when the nozzle exit temperature approached the chilldown completion set point.

RECOMMENDATION

It is recommended that the completion of chilldown signal from the comparator be sent to data.

Long K. Humpson
A/2 Bm

Subject: VERIFICATION OF ENGINE INTEGRITY

SUMMARY AND CONCLUSION

A comparison was made of XECF and CFDTS key engine parameters. A check was made also comparing flow impedances of major engine components.

The results of these comparisons revealed no anomalies relative to the integrity of major engine components and there appears to be no reason for not continuing testing.

DISCUSSION

Comparison of Key Engine Parameters Between XECF and CFDTS

As part of the examination of data to establish engine integrity, a comparison was made between XECF and CFDTS key engine parameters. Table I shows this comparison. Values were taken at the peak chamber pressure of 36 psia for the XECF run. These were compared with CFDTS Run 019 at the time of equal chamber pressure. These values were then used in calculating the K factors discussed in the following paragraphs.

The sources of the data for the comparisons were the thinned digital listings, Computer Run No. 1, and CRT plots, Computer Run No. 1 for XECF, and CalComp plots of CFDTS Run No. 019.

Pump speed in XECF was 5400 to 5460 rpm as compared to 5800 rpm in CFDTS. This difference was not considered significant. There were also differences in system pressures up to the nozzle chamber. These are shown in Table I. The greatest difference in parameter values were found in system temperatures. This was attributed primarily to the pre-chilled condition of the nozzle and part of the reflector at the time of engine startup. The most significant difference of Table I is nozzle chamber temperature which in XECF ranged from 170 to 287°R compared with 445 to 475°R in CFDTS. A similar difference is also reflected in turbine inlet temperatures which were 317 to 335°R in XECF and approximately 445°R in CFDTS.

Another significant difference appeared in nozzle flow rates. In XECF the flow was 19.4 #/sec compared to 14 #/sec in CFDTS. This difference is expected because of denser fluid due to lower temperature at the same chamber pressure.

A further comparison of data showed that in the XECF run, pump speed and system pressures appeared to be rising rapidly when the chamber temperature was 250°R. At this same chamber temperature in the CFDTS run, pump speed and system pressures had peaked about 2 seconds previously and were decaying. Further analysis should be made to explain this difference.

XE

It was concluded that the differences in temperature could be primarily attributed to the difference in initial test conditions and did not indicate that engine system integrity was involved.

Component Impedance

The flow impedances of the major components in XECF were calculated and compared with the flow impedances of the components in CFDTS. Although there are differences between the run conditions of the two tests, any gross differences in flow impedances could indicate that the integrity of a component had been lost. Table II gives a summary of the engine stations chosen and the measured parameters that enter the calculation of the flow coefficient K. The formula used for the calculation of K was:

$$K = \frac{\dot{W}}{\sqrt{\rho \Delta P}}$$

where $\dot{W}$ = Flowrate (lbs/sec)

ρ = Density (lb/ft³)

ΔP = Pressure differential across component

The diluent and turbine flows were calculated from the measured parameters at the venturi in the respective lines. The chamber flow was calculated from the choked equation using the average of the three chamber thermocouples. The flow through the various components was obtained by assuming a flow balance. This assumption is not strictly valid for this transient condition. However, the intent of comparing the K values of XECF and CFDTS is to look for gross differences.

The densities at the station points were determined by their temperatures and pressures. Nozzle inlet and outlet densities were averaged for the nozzle K calculation. The dome density was used for the reflector inlet to core inlet K. Since most of the pressure drop across the core is at the core inlet orifices, the core inlet density was used for the K calculation of the core.

The differential pressure measurements were obtained by subtracting the best estimates of the inlet and outlet pressures.

The CFDTS data (Run 019) in Table II was taken at a time such that the CFDTS chamber pressure was the same as the peak chamber pressure in XECF (36 psia).

A comparison of the K values in Table II indicates acceptable agreement. The agreement could not be expected to be any better because of the inaccuracies of the flow calculations, flow balances, measurements at low pressure and low pressure drops, and estimates of the proper density. For example, the difference between the calculated K's decreases as the ΔP across the component increases. The maximum difference (about 25%) occurs in the nozzle which has the lowest ΔP (about 7 psid). The minimum difference, 7%, is in the core which has the largest ΔP (about 33 psid).

[Handwritten signatures and initials]
Bm

TABLE I

COMPARISON OF KEY ENGINE PARAMETERS - XECF and CFDTS

PARAMETER	XECF-EP-I (Pc = 36 psia) *	CFDTS Run 019 (Pc = 36 psia)
1. Time from PSV Opening - sec	65.5	62
2. Pump Speed - RPM	5400-5460	5800
3. Pressure, Pump Discharge - psia	83	103
4. Pressure, Nozzle Tube Outlet-psia	65-76	91
5. Pressure, Core Inlet - psia	63-67	77
6. Pressure, Nozzle Chamber - psia	36	36
7. Temperature, Nozzle Manifold - °R	44	45
8. Temperature, Nozzle Tube Outlet - °R	49	50
9. Temperature, Nozzle Chamber - °R	170-287	445-475
10. Temperature, Turbine Inlet - °R	317-335	455
11. Flow, Nozzle - lb/sec	19.4	14
12. Flow, Turbine - lb/sec	1.0	0.75
13. Flow, Diluent - lb/sec	0.7	0.4

* At peak.

Subject: VERIFICATION OF ENGINE SYSTEM MEASUREMENTS (Thinned Digital Data)

INTRODUCTION

The engine system measurements were reviewed to verify that from the time PSV opens till TPCV closes: 1) all pressures, temperature and averaging measurements appear reasonable; 2) multiple measurements of particular functions correlate with adjacent measurements upstream and downstream of the engine system; and 3) the ΔP 's measurements correlate with corresponding ΔP 's based on available upstream and downstream pressure data, where available.

SUMMARY

In reviewing the thinned digital data, five pressure readings and four temperature readings were found to be in error. Twenty-one temperature readings were not listed with Run 1 printouts. One of the averaging and one ΔP measurement were in error. In general, most of the thinned digital data were satisfactory, since only 11 of 175 readings were in error.

DISCUSSION

The digital data were reviewed to verify that the pressure and temperature measurements obtained looked reasonable with respect to upstream and downstream parameters. Correlation between like parameters were also reviewed. Where pressure and temperature data averaging circuits were utilized, the average value of the parameter considered was checked against the averager printout. With the exception of five pressures and twenty-five temperature measurements, including 21 non-listed values, all pressures and temperatures recorded on the digital data sheets looked satisfactory. Correlation between like parameters also looked satisfactory. All of the pressure and temperature averager parameters were satisfactory except one which was considered suspect (nozzle chamber temperature averager - T158).

Table I is a listing of the parameters considered to be anomalies.

Pressure drop ΔP measurements were also reviewed. Where upstream and downstream measured pressures were recorded, the ΔP 's were obtained by difference and checked against the differential pressure transducer values. The measured pressure drop of the diluent line venturi (PD209) was suspect and considered unusable data.

In reviewing the pump inlet line flow (FE014) it was found that a constant density factor of 4.4 #/cu.ft. was used and incorrect digital data readings were obtained ($\dot{W}_p = \rho K \text{ FE014}$). However, this was not considered to be an anomaly since flowrate could be corrected by using the density obtained from

pump inlet temperature conditions. In addition, the data indicates that TPCV position (DP867 and DP868) was reading 30° while TPCV position average indicates the position to approximately 90° , (DP870).

RECOMMENDATIONS

1. Check electrical circuitry for possible malfunction.
2. Check thermocouple measurement hookup and continuity.

Attaviani

(Signature) in
15/24

TABLE I

<u>PARAMETER</u>	<u>TITLE</u>	<u>REMARKS</u>
PT110	Pump Discharge Pressure	Negative Readings
PT112	Pump Discharge Pressure	Negative Readings
PT148	Nozzle Chamber	Negative Readings
PT149	Nozzle Chamber	Negative Readings
PT894	TPA Purge	Negative Readings
TT031	FE014 Inlet Temperature	Reading Off-scale
TE160	Pump Inlet Line Skin	Reading High
TE161	Pump Inlet Line Skin	Reading High
TT109	Pump Discharge	Negative Readings
PD209	Diluent Line Venturi	Negative Readings
T158	Nozzle Chamber Average	Averager reads lower than input

Subject: NUCLEAR SUBSYSTEM PERFORMANCE

SUMMARY

The nuclear subsystem (NSS) measurements were examined and compared where possible with CFDTS data. Analysis of the data confirmed that the NSS performance is similar to CFDTS and that the NSS is capable of performing XECF-EP-II.

The inadvertent pre-chill of the engine only slightly reduced the NSS sensible heat. These components can be considered to be at ambient temperature.

DISCUSSION

Fluid Temperatures

Before PSV opened the propellant feedline vented LH₂ flow was sucked back through the open PDVV and inadvertently pre-chilled the reactor. Figure 1 taken from XECF multiplots illustrates the average nuclear subsystem (NSS) plenum temperatures. Fluid plenum temperatures at and after the dome plenum were at ambient temperature.

The apparent decrease in nozzle chamber temperature below ambient during inadvertent pre-chill was a thermocouple conduction problem. The cold nozzle wall conducted heat from the thermocouple faster than the convective heat input from the ambient gas. When the flow was increased the thermocouple read the proper gas temperature.

Figure 1 shows comparative cold flow test data for CFDTS, Run 1.2-02-NNS-019, a 35 psi tank pressure dry pump startup. The CFDTS reference run time to correlate with XECF data was taken starting at a reflector inlet equal to the pre-chilled XECF reflector inlet temperature. This CFDTS reference starting time compensates for XECF inadvertent pre-chill.

Correlation is excellent up to the time CFDTS bootstrapped. CFDTS Run 019 bootstrapped 16 seconds ahead of XECF EP-I Run 1. Comparative XECF start of bootstrap time for CFDTS is 62845 secs. After this time CFDTS fluid temperature dropped faster than XECF temperatures.

The delay in bootstrap time was caused by the inadvertent increase in ETC pressure by helium insertion. The resultant turbine pressure drop reduction delayed bootstrap.

Significant azimuthal and radial temperature distribution existed in the NSS plenums. Figure 2 taken from thinned digital listings shows the temperature distributions at the end of bootstrap.

The lowest azimuthal temperature for all plenums occurred at the position of flow inlet into the nozzle torus.

A cold region existed at the periphery of the flow passage and a hot one existed in the center. This trend is illustrated by the core inlet temperature distribution for the two radii shown. It is interesting to note that the center core inlet temperature was slightly higher than the peripheral chamber temperature. Again, this illustrates the presence of a radial temperature distribution. The effect of the radial temperature distribution on chamber temperature gives a negative bias on measured chamber temperature due to the peripheral radial location of the chamber temperature thermocouples.

The temperature distributions are not considered significant. Similar distributions were encountered in the CFDTS test, Number 1.2-02-NNS-019. Figure 3 shows a similar nozzle temperature and core inlet distribution for CFDTS. Any startup flow asymmetry is propagated and magnified as the test proceeds. In a power test, these asymmetries are considerably less severe.

Material Temperatures

Material temperatures within the NSS were normal for the XECF run. The inadvertent pre-chill only slightly reduced the NSS sensible heat. Axial temperature distribution of the reflector and core at end of pre-chill in Figure 4 confirms that the pre-chill sensible heat loss was small.

Figures 5 and 6 show, respectively, inner reflector and outer reflector time history. The inner reflector was completely chilled 66 seconds after PSV opened and the outer reflector was almost completely chilled.

Core material temperatures are shown in Figure 6. They decreased smoothly as a function of time but toward the end of bootstrap the core temperatures at the inlet and exit were greater than those at the center. The anomalous temperature distribution is believed to be caused by the thermocouples. At low temperatures the thermocouple measurements are in their low range and are considered inaccurate. However, at higher core temperatures the thermocouples behaved as expected.

Pressure Levels and Differentials

Analysis of XECF EP-I shows that the impedance of the NSS has not changed since CFDTS testing.

Selected plenum pressures and component differential pressures are shown, respectively, in Figures 8 and 9. Plotted data were obtained from the XECF multiplots.

The figures show the six pressure oscillations between TPCV open and bootstrap. Oscillations are normal for a startup where TPCV is open before a complete nozzle chilldown. Start of bootstrap at 62861.5 seconds is noted by the rapid increase in pressure. At 62868 seconds chamber temperatures

reached 200°R, the planned termination limit, TPCV was closed and pressure subsequently decayed rapidly.

XECF and CFDTS, Test No. 1.2-02-NNS-019, nuclear subsystem pressure levels and pressure differentials compare favorably. No change of reactor impedance was found. A comparison of XECF and CFDTS peak flows and pressures are tabulated in Table I. These parameters were ratioed to detect a change in reactor impedance. A constant ratio denotes an unchanged reactor impedance. All ratios in Table I were constant except shield pressure drop. The lower shield ratio is not considered significant.

TABLE I
COMPARISON OF XECF AND CFDTS PEAK PARAMETERS

<u>PARAMETERS</u>	<u>XECF</u>	<u>CFDTS</u>	<u>XECF</u> <u>CFDTS</u>
Flow - lb/sec	14.9	24.5	0.6
Pressures - psia			
Reflector Inlet	74	133	0.6
Nozzle Chamber	37.5	59.5	0.6
Pressure Differentials			
Reflector	0	0	-
Shield	6	15.5	0.4
Core	37.5	73.5	0.6

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Bm

FIGURE 1

REACTOR PLENUM TEMPERATURES DURING
 XECF EP-1, RUN1 BOOTSTRAP
 DATA FROM XECF MULTIPLOTS

M. WOODS 4/4/68

FIGURE 2

XECF EP-1
AZIMUTHAL TEMP.
DISTRIBUTION
RUN 1

AZIMUTHAL TEMPERATURE IN REACTOR
PLENUMS DURING XECF EP-1, RUN 1 BOOTSTRAP
DATA FROM THINNED DIGITAL DATA
LISTINGS SUBSYSTEM 1, RUN 1
W 4-5-68

BY.....DATE.....
CHKD. BY.....DATE.....
.....

SUBJECT.....
.....
.....

SHEET NO.....OF.....
JOB NO.....
.....

FIGURE 3

CFDTS AZIMUTHAL TEMP.
DISTRIBUTION

TEST NO 1.2-02-NNS
019 PLOT NO 15
TIME 128

N 4-5-68

FIGURE 4

XECF EP-1 RUN 1
PRECHILL EFFECT ON
REFLECTOR MATL.
TEMPS.
TIME 62802

FIGURE 5

INNER REFLECTOR
 MATERIAL TEMPS

XECF EP-1 RUN 1
 19.2 RAD. $\theta = 70^\circ$

DATA FROM XECF
 MULTIPLOTS

M 4-5-68

OUTER REFLECTOR SECTOR MATERIAL TEMPS XECF EP-1 RUN 1

FIGURE 6

11/4-5-68

FIGURE 7

FUEL ELEMENT TEMPERATURES DURING XECF
EP-1, RUN 1 BOOTSTRAP

DATA FROM THINNED DIGITAL DATA

LISTINGS SUBSYSTEM 1, RUN 1

M.W. 4-4-68

BY M. WOODS DATE 4/4/68

SUBJECT

SHEET NO OF

CHKD. BY DATE

JOB NO.

FIGURE 8

REACTOR PLENUM PRESSURES DURING XECF
EP-1, RUN 1 BOOTSTRAP

DATA FROM XECF MULTILOTS

FIGURE 9

REACTOR PRESSURE DROPS DURING XECF
EPI, RUN1 BOOTSTRAP

DATA FROM XECF MULTIPLOTS

SUBJECT: TURBOPUMP ASSEMBLY COMPONENT EVALUATION, EP-I

SUMMARY

The turbopump component performed predictably during the time interval 60.5 seconds after PSV opened to TPCV closure. From all indications the turbopump is ready to be run again.

At CRT 62802, the PSV opened, some 31 seconds later TPCV was opened, and at 60.5 after PSV opened, the pump began to bootstrap. During the time interval between PSV open and bootstrap, vapor existed in the inlet and caused oscillations in the system. Also, PCV-449 opened at time 62849.8 and caused turbine back pressure to increase from 8 to 10.2 psia. Although increasing back pressure at constant inlet pressure tends to decrease rotational speed, it does not appear to have a measurable effect on performance when liquid conditions exist at the pump inlet at low rotational speeds (2000 to 3000 RPM). The major effect of increasing the turbine back pressure appears to be a delay in attaining maximum bootstrap conditions.

PERFORMANCE AND DISCUSSION

The startup conditions for EP-I, Run 1 were:

Run Tank (PFTO)	= 35 psia
TPCV Open at TRI	= 70°R

Pump and turbine parameters for the time interval between PSV open to TPCV closed are shown on Figures 1 through 5. The time interval between CRT 62822 to 62850 is not shown for some data, but is not pertinent to this discussion.

From Figures 1 through 5 (representing one sample/sec digital data) it is seen that vapor existed in the pump inlet line up to CRT 62862.5. Up to this time, and from the time TPCV was opened, the pump produced pressure oscillations in the system. The turbine inlet pressure (PT866, PT868) is seen to oscillate with the pump discharge pressure (PT114). This performance is typical of that experienced during CFDTS during dry pump tests. SPEAR Memorandum No. 4 compares the results of EP-I, Run 1 with CFDTS.

From time 62862.5 to 62867.5 the pump operated in predictable fashion. One sample per second digital and related calculations are shown on Table I. Figures 6 and 7 represent pump data from CFDTS and NRX/EST. As can be seen, the XECF data corresponds quite well. This indicates that the pump was operating properly during this time period.

XF

Figure 8 indicates turbine inlet pressure required to achieve certain rotational speeds during CFDTS. The XECF data corresponds favorably with this data.

The deviation between XECF and CFDTS data is probably due to the turbine exhaust pressure (PT876). Although there is a decrease in rotational speed with an increase in back pressure, it is seen that, at the low speed condition, such back pressures (deviation from 7.5 to 9.1 psia) do not have measurable effects at the condition where liquid exists at the pump inlet.

Figure 9 depicts the time delay in attaining maximum bootstrap conditions for increasing turbine back pressures at constant tank pressure (PFTO).

It is also seen that secondary effect is to decrease the maximum obtainable rotational speed.

When PCV-449 came open, it released helium into the engine chamber and caused the turbine back pressure (PT876, 878) to increase from 8 to 10.2 psi (see Figure 5). The delay in bootstrapping to maximum rotational speed, according to Figure 9, would be some 8 seconds. What maximum rotational speed would have resulted is not known since the test was terminated when TC reached 200°R. The turbopump was still accelerating when TPCV was closed.

MECHANICAL ASSEMBLY DISCUSSION

Prior to testing the turbopump, some sand was found in the strainer above the PSV. It was thought that some sand might have found its way into the bearing coolant passageways. Figure 10 indicates that this probably did not occur. The pressure drop across the filters (PT114-PT890) are within the range expected at the liquid pumping conditions. The bearing coolant flow-rates also correspond with those expected at these conditions.

From all indications, it appears that the turbopump did not undergo any deleterious conditions.

TURBOPUMP DEVELOPMENT HISTORY

The turbopump assembly consists of a single stage, radial bladed, centrifugal impeller directly coupled to a two stage turbine.

An assembly similar to the one utilized in XECF underwent thirty-one (31) successive bootstrap tests during CFDTS at the H-5 facility, AGC-Sacramento, without detrimental effects. The modifications to that CFDTS configuration were to the impeller back vanes to reduce axial thrust; to the turbine inlet manifold to reduce turbine inlet pressure; and to the turbine rotor to relieve stress concentrations. Three buildups of this design were each successfully operated at conditions in excess of nominal XE requirements for total accumulated periods greater than forty (40) minutes.

DATA REDUCTION RECOMMENDATIONS

The computer program at NRO should be corrected so that data from that program will be available on subsequent EP's.

W. J. Shigenaga *ken*
rw

TABLE I

CRT	*FE014 lb/sec	PD114 psi	EN800 rpm	$\frac{PD114}{(FE014)^2}$	$\frac{EN800}{FE014}$	PT866 psi	PT876 psi
62862.5	8.75	5.23	2500	0.148	286	13.3	9.1
62863.5	11.10	16.39	3140	0.133	283	14.2	8.9
62864.5	13.70	2.496	3880	0.134	283	18.3	8.9
62865.5	19.20	36.36	4590	0.099	238	24	8.7
62866.5	22.80	48.10	5110	0.093	225	29	8.5
62867.5	24.50	56.36	5450	0.094	223	32.3	8.1

*Density based on Average PT104, PT106 and Average TT103, TT105 due to loss of TT031.

FIGURE 1

4-5-68 TJS

FIGURE 2

FIGURE 3

4-5-68 TJS

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

REF. RN-S-0323, FIG 41

4-5-68
Tg8
T. Nishioka

FIGURE 8

WJ8 1-17-63
 4-5-68 TJS

FIGURE 9

FIGURE 10

4-5-68
TJF

SUBJECT: NOZZLE PERFORMANCE

SUMMARY

Nozzle parameters were approximately as expected except for the unintentional pre-chill of the nozzle plus minor instrumentation anomalies. The data used in this evaluation was from digital printout supplied by NRO.

DISCUSSION

1. Unintentional Nozzle Pre-Chill

Nozzle inlet temperatures were approximately 140°R at the time flow was initiated by opening PSV, and 40 seconds prior to opening PSV data showed the temperatures to be as cold as 36°R.

It was found that during the bleed in of the propellant line upstream of the PSV the pump discharge vent valve was open and since these two lines join before going into the flare stack it was speculated that LH₂ was aspirated through the nozzle by the low pressure created in the exhaust duct by the steam generator system. This problem is covered in more detail in Memo No. 3 by the engine group.

2. Nozzle Performance

Flow rate through the nozzle tubes was calculated by using the pressure drop and water Kw value as a check against the pump suction line flow measurement. Using the equation $W = Kw \sqrt{\Delta P \times S.G.}$ and 75% of hydro Kw of 29, the peak weight flow was determined to be 19.5 #/sec, which is 20% lower than determined by the pump suction line flowmeter.

Calculation of flow through the nozzle throat was made using equation $W = \frac{P_c A_e Z}{T_c}$ from XE Design Data Book RNS-0289A with values of $Z = .141$, and $A_e = 58.3 \text{ in}^2$. The maximum flow was 18.55 #/sec which agrees reasonably well with the calculated nozzle tube flow of 19.5 #/sec when subtracting 1.0 #/sec for hot bleed flow.

Pressures into and out of the nozzle and chamber pressure are shown in Figure 1. Temperatures into and out of the nozzle and chamber temperature are shown in Figure 2. These plots extend from the time the propellant supply valve was opened at 62802 seconds through shutdown by closing TPCV at 62868 sec. Data for these plots were taken from digital data printouts except for the portion from 62822 to 62850 sec. where data was lost on the digital printout. The gap was filled in

where possible from CRT plots. The pressure and temperature data as shown appear reasonable with the exception of abnormally low nozzle inlet temperatures prior to opening PSV.

ANOMALIES

- (a) Two of three chamber pressures (PT148 and PT149) were invalid on digital printouts. This also resulted in an invalid calculation of nozzle flow rate based on average chamber pressure on CRT plots.
- (b) The venturi delta P for determining diluent flow rate gave a negative reading and it appears that the transducer was plumbed in reverse.

CONCLUSIONS

The nozzle does not have any problems that require attention prior to EP-2.

It appears that the diluent venturi was plumbed in reverse and since the transducer is bidirectional the data can be made useable by reversing the sign.

The two chamber pressures (PT148, and PT149) which were invalid for this test should be checked and if they cannot be corrected prior to the next EP, all data plot and any control circuits based on chamber pressure should be taken from the one valid chamber pressure (PT151-A).

R B Wright *per*
RM

FIGURE 1

FIGURE 2

NOZZLE TEMPERATURES

NOTE: NOZ INLET TEMP AT 61900 = 525°R
MIN. NOZ. INLET TEMP AT 62750 = 35°R

SUBJECT: PUMP DISCHARGE SHUTOFF VALVE

SUMMARY

The valve failed to actuate closed during checkout on R-1 day and was inoperable during the test. On R+1 day the valve was successfully operated by energizing the closing pilot valve solenoid with 35 V (normal operating voltage is 28 V). The valve is now operable and can be used in future tests for chilled pump startup.

DISCUSSION

The pump discharge shutoff valve (PDSV) is a normally open valve which is actuated closed against a spring load by a pilot valve supplying 500 psi He. The valve actuation schematic is shown on Figure 1, while a cutaway of the pilot valve is shown on Figure 2. Helium actuation pressure is also used to assist the spring in returning the valve to its normally open position.

On R-1 day during the valve checkout portion of the dry run of the Test Operating Procedure, the valve failed to actuate closed. Approximately 50 actuations were attempted at this time; all were unsuccessful. Electrical continuity and resistance were checked for both of the valve potentiometers and for both pilot valve solenoid coils. A determination was made that actuating voltage was being supplied to the wire junction nearest the compartment and that the opening pilot valve was not being energized by the closing command.

An attempt to listen to the valve operation through the compartment shield yielded the information that some type of actuation was occurring. This was apparently just the operation of the opening pilot valve.

An attempt to pressurize the cavity between the PDSV, the PDVV and RSV-132 while actuating PDSV closed was attempted; it was unsuccessful.

On R+1 day the valve successfully actuated when 35V was applied to the closing pilot valve. Subsequent functional checkouts at 28 volts showed valve timings within 5% of those experienced during XECF-P16.

VALVE HISTORY

PDSV, P/N 1114342-9, S/N 880005, had a history of 49 actuation cycles. Of these 20 were checkout cycles at AGC, 17 were checkout cycles at NRDS and 12 were operating cycles at full LH₂ pressure at AGC. The last valve actuation was on 19 March 1968 and showed no problem.

Xf

The closing pilot valve, Marotta commercial P/N 806235, S/N 124, had seen the same number of cycles as the PDSV plus its unique acceptance test checkout cycles. During this acceptance test the solenoid coil pull in voltage under ambient conditions was measured as 15 volts; well less than the maximum acceptance limit of 22 volts. Under an LN₂ environment, the pull in voltage was 3 volts, again, less than the maximum acceptance limit of 22 volts. The other solenoid valve checkout characteristics, such as coil resistance, response time and leakage were all normal and well within acceptance limits.

CONCLUSION

The most likely cause for the pilot valve failure is contamination; small particles could have lodged between the slide and the housing during its last closing cycle creating a binding.

The helium system is protected by filters, however, contaminants could have been introduced either in original assembly or during timing orifice installation and replacement.

RECOMMENDATIONS

The PDSV closing pilot valve, S/N 124, should be removed from the UTSM and inspected and re-tested for acceptance after XECF. This inspection and test is necessary to attempt to isolate the cause of the malfunction and to ascertain that the valve is acceptable for future usage. Replacement of the unit should be considered for XE-1 but is not necessary for completion of XECF.

Attachments - Figures 1 and 2

KE Unmack
BM

ACTUATION SCHEMATIC PUMP DISCHARGE SHUTOFF VALVE

FIGURE 1

FIGURE 2

MAROTTA $\frac{3}{8}$ " SOLENOID
PILOT VALVE

p/m 806235
inst/m 906235

SUBJECT: PERFORMANCE OF MISCELLANEOUS ENGINE COMPONENTS

SUMMARY

Aside from the PDSV all miscellaneous engine components performed as expected and are ready for another test. The PDSV is discussed in SPEAR Memo No. 11.

DISCUSSION

VALVES

All valves performed as expected. Operating times during checkout and operation are listed on Table I along with those times previously recorded during engine checkout XECF-Pl6. No anomalies can be seen in the recorded times. Valve times were obtained from 10 sample/sec digital listings of selected time slices.

The flow of He actuator gas, shown in the digital listing of FE432, was studied to determine if leakage occurred in any pilot valves or valve actuators. No leakage can be detected. The He flow dropped back to zero approximately 6 seconds after opening of PSV and approximately 2 to 4 seconds after actuation of each 5 inch butterfly valve.

LINES

The pressure on all lines in the engine, both propellant and pneumatic were reviewed from CRT plots. Since each pressure is much less than that which each line was proof tested at there is no question that all lines are capable of further tests.

STRUCTURES AND PRESSURE VESSEL

Since the Upper Thrust Structure, Lower Thrust Structure, and Pressure Vessel were exposed to loads which were insignificant in comparison to those of proof test they are satisfactory and capable of further testing.

Maximum pressure recorded in the Pressure Vessel annulus was 91.4 psia at a temperature of 200°R. The allowable limit of this unit is 500 psig.

There are strain gages on the Upper Thrust Structure Longerons and Pump Inlet Line attachment strut; however, no data were available for these gages. This data would have been used in a detailed engineering evaluation and was not intended for SPEAR judgment of the acceptability of the structure for further cold testing.

Environmental temperatures contained in the CRT plots recorded in the UTSM ranged from 510°R to 550°R. Because of the short duration of LH₂ in the engine no environmental temperatures were as low as those recorded during the Cryo test at AGC. The lowest environmental temperature of 510°R was recorded at TE 901, near the Marotta pilot valves, the pump discharge line and the cooldown supply line. As a matter of interest these temperature measurements showed a + 10°R variation at approximately 2 cps during the period of time that PCV49 was open and the test compartment was being purged with Helium.

ENGINE SHIELD

This component performed as expected. The pressure in the shield was constant at 8 psi above compartment pressure; far less than the test parameter limit of 35 psi. Water level was constant since neither the high level switch nor the low level switch was actuated during the time period that data was recorded (40293 through 69251). The water temperatures indicated between 530°R and 560°R indicating no cooling due to LH₂ flow.

RECOMMENDATIONS (DATA)

The strain gages in the UTS MG 801, 802, 803, 804, 805, 806 and 115 should be recorded in the narrow band Digital Data System and reproduced on CRT plots.

ANOMALIES (DATA)

UTSM temperature TE858 dropped off and became erratic at time 63295. This temperature is on the turbopump support panel.

The strain gages in the UTSM were recorded in the wide band data system and not recorded in the narrow band digital data system and the CRT plots.

KE Ummaab
BM

TABLE I
Valve Operating Times (sec)

	SWITCH CONTACT TO START MOVEMENT		VALVE MOVEMENT	
	EP-I	P-16 C/O	EP-I	P-16 C/O
ACTUATOR PRESSURE 195 psig He				
PSV OPEN	0.1	NA	0.4	0.47
PSV CLOSE	1.0	NA	1.3	0.91
PDVV OPEN	0.3	--	2.1	----
PDVV CLOSE	0.1	--	2.2	----
CVV OPEN	0.3	--	2.6	----
CSV OPEN	NA	--	3.4	----
CSV CLOSE	NA	--	3.2	----
ACTUATOR PRESSURE (522 psig He)				
PSV OPEN	0.1	--	0.4	---
PSV CLOSE	NA	--	NA	---
PDVV OPEN	0.1	0.1	0.8	0.73
PDVV CLOSE	0.5	0.3	2.3	2.18
CVV OPEN	NA	0.1		0.81
CVV CLOSE	0.7	0.3	2.4	1.25
CSV OPEN	NA	0.2	2.6	2.62
CSV CLOSE	NA	0.1	NA	1.08

NOTE: TBV was actuated open and closed at 195 psig He but operating times were not available.

Subject: XECF AVERAGERS

SUMMARY

This memo evaluates the performance of the five averagers used on the XECF during the range time 62860 until 62870. It is concluded that the averagers performed satisfactorily with the possible exception of the TPCV averager. The conclusion reached is based on an analysis of NTO digital data plots and/or digital data printouts. Where possible, the reasonableness of the averagers was related to XECF performance as referenced to other SPEAR memoranda. The evaluation of the averagers uncovered a number of apparent data anomalies which are presented in this memo.

DISCUSSION

Chamber Temperature Averager

The chamber temperature averager is designed to accept and average five chamber thermocouple signals. This design is based on the requirements for XE-1. The XECF engine uses three RTT's, they are TT138, TT139 and TT144. Prior to XECF a temporary ECR was incorporated to use only TT139 and TT144 in the averager. However, each temperature signal was made to appear as two separate signals by parallel wiring from the rack Moduloks into the averager. The averager would then believe it was averaging four signals. The fifth channel of the chamber temperature was to be manually rejected at the setup panel. However, only TT139 was fed to the averager because reportedly TT144 was reading incorrectly. Figure 1, is a plot of the chamber temperature averager. The conclusion drawn from this plot is that the averager followed TT139 with reasonable accuracy. An error of approximately 20°R does exist at range time 62860. This is possibly due to the fact that the chamber temperature averager is linearized for the XE-1 thermocouples which would make the averager in error for the RTT's of the XECF. This figure also shows a large difference between TT139 and TT144. A check of the digital printout indicates that TT138 and TT144 are in close agreement. An investigation should be made as to why TT138 and TT144 were not fed to the averager and why they differ from TT139.

Reflector Inlet Temperature

The reflector inlet temperature averager is designed to accept and average three reflector inlet temperatures. For XECF the three RTT's used were TT207, TT210 and TT216. The plot of these individual signals is shown in Figure 2. The averager output signal T306 was not available as an NTO digital plot. The averaged T306, however, was obtained from a digital data listing for every second during this time plot. The plot during this time period shows that the reflector temperature inlet averager performed very

XE

satisfactorily. However, a check on this averager output was made at an earlier time while the reflector inlet temperatures were higher. This earlier data is shown in Table I. It indicates poor agreement between the average signal and the three individual channels. A possible reason for this is that the signal conditioner made use of mode cards ST03 which is very non-linear and would greatly accentuate the temperature differences.

Chamber Pressure Averager

The chamber pressure averager is designed to accept and average the three chamber pressure signals of the XE-1 engine. These three signals are to be ranged from 0 to 750 psia. In the XECF, chamber pressures PT148 and PT149 were ranged for 0 to 750 psia. The third chamber pressure PT151 was ranged for 0 to 100 psia. Pressure signal PT151, therefore, could not be used to compute an average and it was to be manually rejected from the average circuit at the setup panel. The chamber pressure average would then be averaging only PT148 and PT149. The performance of the chamber pressure averager is shown in Figure 3. Reviewing this plot, individual pressures PT148 and PT149 appear very suspect. It is noted that they read lower than possible. The average signal which is P158 agrees very well with the unaveraged PT151. The chamber pressure averager is of the same design as the chamber temperature averager and the reflector inlet temperature averager. For analytical reasons, which are discussed in SPEAR Memo No. 8, XECF EP-I, the pressure average P158 is believed to be correct. The trend and the magnitude appear reasonable from this analysis. This leads to the conclusion that the averager was receiving correct individual pressures PT148 and PT149 and was providing a correct average output. This leads to the further conclusion that the problem with the data for PT148 and PT149 probably lies between the data amplifier and the data acquisition system. The plot also shows all individual chamber pressures to be extremely noisy while the average is relatively smooth.

Pump Discharge Pressure

The pump discharge pressure averager for XECF was designed to average the two pump discharge pressures PT110 and PT112. The pressure input signal to the pressure averager are normally negative signals while the averaged output is positive. The pump discharge pressure averager is shown in Figure 4. It is noted that the plot of the individual signals PT110 and PT112 are obviously of the wrong sign. These two signals were replotted by simply reversing the sign and taking the data from the one second digital data list. These one second points were then connected by straight lines. It is noted that the individual pressures have the same trend as the average signal. However, the individual pressures are 20 to 30 psia lower than the average. Based on the analysis as reported in SPEAR Memo No. 9, XECF EP-I, the average value appears to be correct. Therefore, as in the case of the chamber pressure averager the input signals must be correct, while an error exists somewhere in the data acquisition system.

TPCV Averager

Table 2 shows the data on the two individual TPCV position signals as well as the average. It is seen that the individual positions are indicating approximately 30° at a time when the TPCV averager is indicating 90° . The thirty degree reading is suspect based on the low pressure differential obtained between the nozzle chamber pressure and the turbine inlet pressure. The 90° position appears reasonable based on anticipated control system performance with the large pressure error that the data indicated. This anomaly should be investigated further by actual operation of the TPCV controller prior to EP-II to ascertain where the error exists. The procedure specified in NTO-I-0446 for verifying the TPCV operation should be followed. A check must also be made at the same time to ascertain that the data acquisition system reads the correct individual TPCV position during the checks while performing Procedure NTO-I-0446.

ANOMALIES

1. TTL44.A not included in chamber temperature averager circuit.
2. Large temperature difference between TTL39.A and TTL44.A.
3. Poor agreement of the reflector inlet temperature averager as compared to the individual RTT's at high temperatures while there was excellent agreement at the lower temperatures which were plotted.
4. PTL48.A and PTL49.A do not compare with PTL41 and further they indicate negative pressures during certain times.
5. PTL10.A and PTL12.A apparently have the wrong sign and their magnitude is low.
6. Two TPCV position indications disagree with averaged value.

RECOMMENDATIONS

It is recommended that the data system be checked to verify and correct the observed anomalies.

The TPCV actuator should be put through operational test to ascertain the correct operation of the TPCV averager and to correct the cause of the data anomaly before XECF-EP2.

It is recommended that at least the signal from two RTT's be input to the chamber temperature averager.

D. Glover
agf

TABLE I
PERFORMANCE OF THE REFLECTOR INLET TEMPERATURE AT HIGH TEMPERATURES

<u>RANGE TIME</u>	<u>TT207.A</u>	<u>TT210.A</u>	<u>TT216.A</u>	<u>T.306..</u>
62800.3	284.8°R	288.9	305.9	341.3
62801.3	289.4°R	293.8	309.4	330.1
62802.3	289.0°R	293.8	310.4	337.5
62803.3	268.5°R	278.5	301.1	317.4
62804.3	237.0°R	257.5	273.9	281.8
62805.3	219.6°R	237.6	246.7	255.2
62806.3	207.6°R	224.2	230.9	237.8
62807.3	196.3	212.9	219.8	222.3
62808.3	187.7	201.8	210.6	212.7
62809.3	177.9	196.0	202.0	203.7
62810.3	172.3	187.6	194.0	191.8

TABLE II
TPCV AVERAGER

<u>RANGE TIME</u>	TPCV POSITION #1 <u>DP867.A</u>	TPCV POSITION #2 <u>DP868.A</u>	TPCV AVERAGER POSITION <u>DP870</u>
62860.5	31.3	32.09	91.81
62861.5	31.72	31.99	91.81
62862.5	31.55	32.08	91.81
62863.5	31.66	32.02	91.81
62864.5	31.73	32.06	91.81
62865.5	31.64	32.12	91.81
62866.5	31.70	32.16	91.81
62867.5	16.36	32.08	91.81
62868.5	3.12	3.30	8.19
62869.5	2.34	2.21	5.48
62870.5	1.86	1.52	3.92

D. GLOVER

D. GLOVER

UNIT 2 PLOT 1 AVG 1 PSIA

XECF EPI 4/02/68
AVG 1

1	PT148.A	PSIA
2	PT149.A	PSIA
3	PT151.A	PSIA
4	P.158.A	PSIA

D. GLOVER

AVG 4

1	PT110A	PSIA
2	PT112A	PSIA
3	P.120A	PSIA

UNIT 1 PLOT 2 AVG 4

PSIG

FIGURE 4

D GLOVER

Subject: V-5001 PRESSURE CONTROL SYSTEM

SUMMARY

For engine operation, it is required to pressurize the LH₂ run tank (V-5001) to a given pressure and to maintain this pressure throughout an engine run. The pressurization of V-5001 is controlled by two valves, PCV-165 to pressurize the tank and PCV-180 to vent the tank. Two modes of control of these valves are available to the operator. One mode of control is a manual valve position mode while the other mode available is an automatic V-5001 pressure control mode. In both the manual and pressure control mode, valves 180 and 165 are controlled with a common analog signal which ranges over both positive and negative voltages. This signal is the voltage on the arm of a pot when operating in the manual mode while it is the output voltage of the pressure controller when operating in the pressure control mode. One polarity of this signal causes the valve 165 to open, pressurizing the tank, while demanding 180 to close. The other polarity causes the valve 180 to open, venting the tank, while demanding the valve 165 closed.

The purpose of this memo is to discuss the automatic pressure control mode including the mode transfer from the manual to automatic mode.

The test data used here for evaluating the performance of the pressure control system during EP-I of XECF on April 2, 1968 are NTO digital data system plots.

The run tank pressurization was accomplished in the manual mode. Upon completion of this manual pressurization, the control mode for PCV-165 and PCV-180 was switched from manual to the automatic pressure control mode. This mode switch induced a transient in the PCV-165 valve before settling in control of V-5001 tank pressure.

The operation of the V-5001 pressurization system, operating in the automatic pressure control mode, performed satisfactorily during the bootstrap. The pressure control loop maintained V-5001 pressure between 35.5 and 35.3 psia through the engine bootstrap which is well within the required accuracy.

Several data labeling anomalies exist which should be corrected to avoid confusion in the future. These anomalies are listed in the Recommendations section of this memo.

The V-5001 automatic pressure control system and mode switching will satisfactorily meet the test objectives of XECF EP-II; however, this memorandum presents some suggestions which may improve the operating characteristics of this pressure control system.

XF

DISCUSSION

Figure 1, between range times 60800 and 61079, shows the manual pressurizing of the run tank V-5001. At range time 61079 the control of PCV-165 and PCV-180 was switched from the manual position to the automatic pressure control mode. At the time of the mode switch, it is observed the valve PCV-165 went full open for approximately one second then full closed for approximately three seconds, then assumed control, averaging approximately 40% open.

Figure 2 is a plot of the demanded versus measured PCV-165 position during the manual tank pressurization. This plot verifies the approximate 20% bias in the closed sense on the valve PCV-165.

The pressure demand shown in Figure 1 as Curve 3 is plotted negative and is in psig while the measured V-5001 pressure shown by Curve 5 is in psia. In the curve of Figure 3 these two curves are replotted with the pressure demand corrected to psia. As seen from this figure the operator apparently had the pressure error very nearly zeroed when the mode switch from manual to automatic control was made. Immediately following the mode switch, a V-5001 pressure transient started which settled out with an approximately constant bias error of 1.8 psia. This indicates that the mode switch was not performed with a zero pressure error (although it may have indicated zero error to the operator) but with a 1.8 psia pressure error. This effective 1.8 psia step demand in pressure upon making the mode switch is suspected to be the cause of driving the valve PCV-165 full open as indicated in Figure 1, Curve 1 at range time 61079. The possibility of a loading or bias effect in the V-5001 pressure controller should be investigated.

As seen from the pressure demand, Curve 3 of Figure 1, the operator reduced the pressure demand approximately 5 psi between range times 61079 to 61180 to obtain the desired 35 psia in the run tank V-5001. It is also seen from Curve 1 of Figure 1 that while the operator was reducing this pressure demand, the valve PCV-165 ranged in position between full closed and 51% open. This sensitivity in the valve PCV-165 position to changes in pressure demand is due to the high frequency gain of the pressure controller. The valve sensitivity to changes in pressure demand could possibly be reduced by reducing the high frequency gain of the controller or by filtering the pressure demand signal.

Figure 4 is a plot of the run tank pressure, PCV-165 and PCV-180 positions and PCV165 demand during the bootstrap run. As seen by the measured V-5001 pressure, Curve 5, the run tank pressures varied between approximately 35.5 psia and 35.3 psia during the bootstrap. This is within the required tolerance on the run tank pressure. The differences between the measured and demanded PCV-165 position, Curves 1 and 2, respectively, is again described by the curve of Figure 2. The indicated V-5001 pressure perturbation at range time, 62787.5, just prior to initiation of the bootstrap is not believed to be real since it cannot be varified with analog data (Control Room Sanborns recordings).

RECOMMENDATIONS

This section summarizes the recommendations made in this report and presents suggested changes in data channel labeling which will avoid confusion in the future.

1. An approximate 1.8 psi bias or loading effect in the V-5001 pressure controller circuitry should be investigated.
2. In order to reduce the sensitivity of the PCV-165 position to changes in pressure demand, the possibility of reducing the high frequency gain of the pressure controller or filtering the pressure demand signal should be investigated.
3. The data channel labeled CPL65.M is the position demand for the valve PCV-165 when operating this valve in the manual or the automatic control mode. The present data channel title implies that this channel is the demand only in the manual mode. The title of this channel should be changed to indicate that it is the demand for this valve regardless of the mode of operation.
4. The data channel labeled CPL65.S is not the valve PCV-165 position demand when operating in the automatic control mode but is the pressure demand to the V-5001 pressure controller. The data channel labeling should be changed accordingly.

L. C. Mackey
EP Bm

SPEAR MEMO 14
JECF EPT 4/2/68

FIGURE 2
PCV-165
MEASURED VS DEMAND

FIGURE 3 DEMANDED AND MEASURED V5001
PRESSURE VS TIME

SPARR MEMO 14
XREF EPI 4/2/68

OYDKOYDKOYDKOYDKOYDKOYDKOYDK

1	DR165	10PEN
2	CP165.M	1POT
3	CP165.S	1AUTE
4	DP180	10PEN
5	PT099	PSIG

FIGURE 4

STEAK MEMO 14
XECF EP1 4/2/68

Subject: PRESSURE CONTROL SYSTEM

SUMMARY

XECF EP-I bootstrap started when the TPCV started to open. A chamber pressure demand of 60 psia was initiated with the valve demand initially at 0 degree. The resultant pressure error causes the TPCV to open to its maximum position. The system seemed to operate satisfactorily.

At the conclusion of the run, control of TPCV was transferred from pressure control to position control, which had been locked at 0 degree demand. The result was a step demand to the TPCV to shut from 90 to 0 degrees. The valve then closed within 0.2 seconds.

The data used in the evaluation came from oscillograph traces (0307 and 0322), the digital data system, NRO digital plots and wide band tapes (F317).

Pressure Control System

The initial pressure error, seen by the pressure controller, would be in the order of 52 psi (60 psia demand minus an approximate 8 psi nozzle chamber pressure). After an initial transient this should have resulted in a TPCV demand velocity of 0.112 (the controller gain) $\times$ 52 (the pressure error, essentially constant over the TPCV opening time) or 5.8 deg/sec. The actual TPCV velocity during this time was 6.4 deg/sec (see Figure 1). This discrepancy between expected and actual velocity is well within the allowable tolerance in this pressure range. The measured and demanded pressure are scaled 0 to 750 psia for a 0 to 10 volt scale. The oscillograph trace of the torque motor current, 0322, initiated a total opening time of 12.6 seconds.

TPCV Actuator

Electrical and pneumatic power was applied to the TPCV actuator for almost 6 hours based on recorded times in "Test Operating Procedure for XECF Experimental Plan I" and data showing actuating pressure. Data samples were taken at 3 intervals during the time the TPCV actuator was powered show approximately 3 ma peak-to-peak 500 Hertz oscillation in torque motor current. This level is not expected to cause actuator problems.

When the TPCV position indicated full open, the TPCV began to oscillate over a very narrow range. This can be seen in Figure 2 which presents data from the oscillograph traces showing the oscillation of the TPCV position (DP867) and torque motor current (E.815). Because individual TPCV position measurements indicated only about one-third the actual

XE

position, the valve oscillation shown on Figure 2 has been increased by 3. (For a further discussion of this anomaly, see SPEAR Memo No. 13, XECF-EP-I.) The oscillation in position was 2.7 degrees and in torque motor current 25 ma peak-to-peak. The frequency of the oscillation was about 20 Hertz and lasted 0.6 seconds, and are probably due to the electronic limit on TPCV position.

Due to the lack of an expanded plot of TPCV closure, the slew velocity of the actuator and the maximum overshoot during closure could not be estimated.

ANOMALIES

Figure 3 is a graph presenting data on pressure error (P.615..E) and average nozzle chamber pressure (P.158..E). Just prior to the attempted bootstrap pressure error was reading 28 psi and average nozzle chamber pressure about 13 psia. The sum of these pressures should be the pressure demand (CC612..E) which is 58.5 psi (.78 volts at 75 psia/volt). The actual sum is 41 psi.

RECOMMENDATION

It is recommended, based on this analysis, that the apparent data anomaly be investigated and corrected.

Ad French
RM

SPERRY MEMO 15 XECF-EP

Figure 1

Curve 5 = DP 870 AE
Average TPCV position (deg)

Spear Memo 15

XECF-EP-1

Figure 2

E. J. Fenech 4/6/68

Speer Memo 15 XELF-ER1
Figure 3

Curve 1 - Pressure Error
P. 615.. E

Curve 2 - Pressure Demand
CC 612.. E
75 psi/volt

Curve 3 - Chamber Pres. Ave
P. 158.. E

E. J. Fenech 4/6/68

Subject: LOSS-OF-STEAM DETECTOR SYSTEM

SUMMARY

During XECF EP-I, the loss-of-steam pressure rate detector was activated five times. The first three trips were the result of large steam pressure oscillations without a loss-of-steam condition existing; the fourth and fifth trips resulted from the shutdown of the steam generator system. Helium flow was initiated through PCV-449 only on the third trip because the helium system was not armed in the other cases. Causes of the first two pressure oscillations were traced to the water supply system (see SPEAR Memo No. 18 (XECF-EP-I)). Cause of the third oscillation is unknown. The detector did operate as designed.

The helium valve control system appeared to work properly; however, there does seem to be a loading effect in the controller and several discrepancies in the data system.

The data used in this memo comes from the digital data system, NTO and NRO digital plots, and control room Sanborn readings.

DISCUSSION

Pressure Rate Detector

The pressure rate detector operates by tracking the steam pressure (PT425). The detector follows positive pressure transients at up to approximately 30 psi/sec and negative pressure transients at up to -5 psi/sec. The detector trips when actual pressure falls 10 psi below the tracked pressure.

Figures 1 and 2 are traces of PT425 as a function of time. The pressure oscillations have been traced to water valve operation and are of sufficient magnitude to easily trip the detector. Unfortunately, the data from PT425 were lost at the time of the third trip. Examination of Figures 3 and 4 (PT426 as a function of time) shows that the output from PT426 approximates PT425 closely enough to provide useful information. Figure 5 presents the data from the third trip during the bootstrap when the helium system was armed. Again, the oscillation is large enough to easily trip the detector.

A characteristic of all false loss-of-steam trips is illustrated by Figures 1 through 5; a sharp increase in pressure followed by a rapid decrease and then back to approximate pre-trip level. If the upward track rate were limited to a value in the order of 1 psi/sec, the probability of tripping on a false signal becomes much smaller. Under these conditions the second pressure oscillation would have provided a trip, the first pressure oscillation might have caused a trip and the third trip would not have occurred. Since the detector was qualified for a real loss-of-steam which did not have a positive portion no degradation in performance would be expected.

XF

Figure 6 shows PT425 and PT426 data over a long time period. The general noise level on the signal is about 4 psi peak-to-peak. The overall pressure drift is about 12 psi peak-to-peak, and a positive 1 psi/sec track limit is reasonable.

PCV-449 Control System

Upon receipt of the loss-of-steam signal, the helium valve, PCV-449, opened to 90% of the preset value within 200 msec. Within 10 sec the operator was able to determine that the steam generators had not failed and started corrective action. The operator ramped the manual demand to existing position and reset the circuit. The valve, now in manual control, was then closed. In this manner, if a true steam failure had occurred, the loss-of-steam detector would then have been able to open PCV-449 again. Figure 7 shows the PCV-449 manual and automatic demand and the valve position. Note that the 100% point on the graph represents the valve 20% open.

ANOMALIES

1. On Figure 7, the manual demand (DP449.M) is scaled 0 to 25% instead of 0 to 100%. The XECF data log lists the range as 0 to 25% and this agrees with the calibration. On the graph this trace should be raised by a factor of 4.
2. On Figure 7, the valve position (DP449) is listed in the data log as ranged from 0 to 100%, however, the calibration shows that the actual range was 0 to 200%. On the graph, this trace should be divided by a factor of 2.
3. On Figure 7, at an approximate range time of 62858 the command to the valve was switched from automatic to manual demand. The graph shows a resultant increase in auto demand and a reduction in manual demand suggesting the possibility of loading in the circuit.
4. On Figure 7, even with the correction in scaling apparently required, there exists a difference between the measured and commanded position of PCV-449. The position demand is approximately 10% greater than the measure position. This is believed to be a data anomaly only.

RECOMMENDATIONS

It is recommended on the basis of this study that:

1. The pressure rate detector be modified to incorporate a positive rate limit before XE-1 to lower the probability of an inadvertant helium flow if the cause of the pressure oscillation cannot be found and corrected.
2. That the scaling on the parameters CP449.M and DP449 be checked and corrected as required, and

3. That the apparent loading of the control and the difference between demanded and actual position be investigated and corrected as required.

E. J. French
B/11

Specr Memo 16 XECF-EP-1
Figure 5

62847.0 62851.0 62855.0
RANGE TIME-SECS. E. J. Fenech 4/6/68

Speed Memo 16 XECF - EP-1

Figure 6

PT 42.5 marked 2
PT 42.6 marked 3

Range Time

E.J. Fenech 4/6/68

Spear Memo 16 XECF-EP-1
Figure 7

Curve 1 CP449.M
Curve 2 DP449.
Curve 3 CP449.S

Subject: MEASUREMENT SYSTEM REVIEW

INTRODUCTION

All 1034 digital and analog measurement channels were reviewed for discrepancies which could affect data supplied to data users.

SUMMARY

Twenty-eight seconds of digital test data were lost during the bootstrap when non-standard width magnetic tape caught in a tape transport. Except for this major data system malfunction, only 4 percent of the measurements reviewed displayed anomalies requiring corrective action.

DISCUSSION

The ability of XECF-EP-I to meet the secondary goal of demonstrating bootstrap performance was jeopardized by the loss of 28 seconds of data from one entire digital data subsystem (S/S #1). This occurred when recording tape manufactured with too great a width could not be transported by the data system recorder. By the time the problem could be remedied, 28 seconds had elapsed. It is only because redundant and critical measurements had been spread between the two subsystems that a possible total loss was avoided. The tape was a high quality recognized name brand used successfully before with no problems of this nature. However, other tape switching problems have occurred on previous tests during critical run periods, and, indeed, an additional fourteen seconds of data were lost on Subsystem 2 later in the test during a less critical period.

This points to a serious problem which can best be solved with redundant recording of data. The "data link" currently being put into operation between ETS-1 and the A&E Building will provide this redundancy at the A&E Building. XE-1 tests should be run when this system has been proven to be operational and reliable. Until then, the steps being taken at ETS-1 to avoid costly loss of data for the remaining XECF EP's are as follows: 1) tapes to be used for a test are being run through the tape transports in an erasing mode to remove spurious signals and to demonstrate their ability to be properly transported. They are then further erased by bulk erasing equipment prior to storage for the test; 2) equipment and personnel are being positioned so as to cut tape transfer time down to a minimum for any emergency that might arise.

There are still some channels which tend to "fold over" the top of the digital system and come on scale at the low end with erroneous data. The data system personnel are fully aware of the problem and are taking corrective action as time permits. This results in no loss of data but is

very confusing to a data user not familiar with the intricacies of a modern data system. The problem most often arises in temperature data ranged for low values which see medium to high temperatures during part of the test.

After much concern over two absolute pressure measurements (PT110.AE and PT112.AE) indicating negative outputs, it was learned that at least one averaging circuit requires such a signal in order to function and produce a proper average output. Again, data can be salvaged for the data user, but it can be tedious. It is suggested that either the averaging circuits be designed to accept signals that can be recorded and reduced to engineering units with standard methods, or that on-line recording equipment and software be modified to produce true engineering unit output. It is inefficient and dangerous to rely on a data user to make corrections which he may not fully understand.

Much of the early analysis of the test was done using on-line strip charts and oscillograms. Loose headers were supplied with the strip charts but were not attached to them. Also, no units were placed on the 10% division markings so that it was necessary to consult the calibration steps to definitely determine the 0% and 100% ends, and, for non-linear functions, it was necessary to consult the "101-Point Listing" to determine the incremental values. It is understood that this resulted from a current serious lack of manpower within the data group. However, there are members of SPEAR standing by during and after a test who are qualified to give such assistance and should be utilized. It would avoid much inefficiency, duplication of effort, and error which resulted from each data user attempting to do the job himself with inadequate direction.

The cooperation and efficiency of all measurement system and data reduction personnel were excellent in support of SPEAR. Much was learned by both SPEAR and NRDS personnel during NEP-HE-2 in providing a better operation on XECF-EP-I. Data discrepancies were made known to NRDS in a much more timely manner and the resultant feedback was rapid.

Wide band channels were monitored on oscilloscopes and spectrum analyzers by TDC/SPEAR personnel in the Test Diagnostic Center (TDC) during the test. The oscilloscopes showed the presence of a 60K HZ sine wave on all five charge amplifier channels monitored throughout the test. The magnitude on each channel was constant and ranged from 3% to 20% of full scale. This was compounded by a signal or noise superimposed on this high frequency starting during pre-bootstrap facility preparation and disappearing during post-bootstrap shutdown. The 60K HZ is too high to be recorded and only poses a nuisance to visual observations. However, the other low-level signal or noise was recorded and as yet is unidentified. The 60K HZ signal was not present during NEP-HE-2 operations.

There has been no time to improve on the calibration diagnostic program discussed in detail in the NEP-HE-2 SPEAR memoranda, so the comments are, in general, still applicable. The existing diagnostics remain a great aid in analyzing data and become more useful as facility in their use is obtained.

The on-line oscillogram data were greatly improved in quality over NEP-HE-2. Some crystal transducer channels still experienced data spikes and undirectional noise which is characteristic of some units of this type. Most of the data reviewed visually was little impaired by this problem. However, analysis through power spectral density plots may be seriously bothered depending on the frequencies of interest.

Specific data anomalies and their resolution as of the time of this memorandum are listed in Table I. Continual reporting to NTO data groups of suspected anomalies in data will occur as source engineering groups review data at their respective locations.

The testing of XECF in the ETS-1 facility has provided invaluable aid in finding measurement system problems and in establishing more efficient procedures for providing, using, and analyzing data for future engine system tests.

RECOMMENDATIONS

1. Redundant data recording mandatory prior to XE-1.
2. Pre-testing of magnetic tape and improved tape transfer procedures must be accomplished prior to XECF EP-II.
3. Either modify averaging circuits to accept signals that can be recorded and reduced to engineering units with standard methods, or modify on-line recording equipment and software to produce true engineering unit data.
4. Make SPEAR personnel available to work with the NTO data group in properly identifying and attaching strip chart headers.

D. E. Luntz
4-5-65
mm

TABLE I
DATA ANOMALIES

SPEAR MEMO No. 17

ITEM	MEAS. NO.	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
1	PT148.AE	Nozzle Chamber	Data showed negative output during run.	Channel checked good electrically, transducer probably plumbed backward. Bidirectional transducer, data useable. Recommend the output signal for data system be reversed.
2	PT149.AE	Nozzle Chamber	Same as PT148	
3	PD209..A	Diluent Venturi	Data showed negative output during run.	
4	TE801..A	Drum Torque Transducer	No data recorded during run.	Channel checks good electrically.
5	TE858..A	Upper Thrust Structure	Dropped out halfway through run.	Zero suppression battery in signal conditioner failed. Replaced battery, channel checkout OK.
6	Recorder "A"	-	No Timing trace.	Bad recorder pen. Replaced pen.
7	PT864..A	Turbine Inlet (NAR RG)	Function reversed.	Transducer wired wrong. Output wiring reversed per ECR 139-000.
8	TT103..E	Pump Inlet	No post calibration on Beckman.	Digital Data System Post Calibration present, no drift between pre and post. Beckman checks OK.
9	TT318		Same as TT103.	Same as TT103.
10	EN800..E	Turbine Shaft Speed	Reading much too high.	Data reduction problem data being re-run.

TABLE I (Continued)

SPEAR MEMO No. 17

ITEM	MEAS. NO.	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
11	EN801..E	Turbine Shaft Speed	Same as EN800	Same as EN800
12	T.306..E	Reflector Inlet Plenum Average	Averaged data reads higher than inputs.	Data reduction problem, data being re-run.
13	TTO31..R	50FED14 Inlet Temp.	Function reads high, off scale during run.	Sensing element opened.
14	TT513..R	V-5001 Temp SNSR 10 PCT	Noisy.	Noisy DDS Channel. Channel being worked on.
15	PT290..F	ETC Top Chamber Pressure Indicator	Function reading slightly low.	Channel check OK per trans- ducer calib. No action taken.
16	TE160..A	Pump Inlet Line	Function inconsistent with similar channels.	Channel check good electric- ally.
17	TE161..A	Pump Inlet Line	Same as TE160.	Same as TE160.
18	PT226..A	Diluent Line Venturi	Non-linear at 25% and 50% cal. steps.	Bad amplifier, replaced amplifier.
19	TE729..A	Core Inlet Plenum	Non-linear at 25% and 50% cal. steps.	Bad amplifier, replaced amplifier.
20	TE310..A	Reflector Inlet Plenum	Non-linear at 25% and 50% cal. steps.	Bad amplifier bin. Replaced bin.
21	-	Oscillograph #3	Galvo ident. marker does not print legibly at high speeds.	
22	TE315..A	Outer Reflector Sector	Reading low by 100°R.	Check good at ambient cell temperature.
23	TE317..A	Outer Reflector Sector	Reading low by 100°R.	Check good at ambient cell temperature.

TABLE I (Continued)

SPEAR MEMO No. 17

ITEM	MEAS. NO.	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
24	TE320..E	Outer Reflector Sector	Reading low by 100°R.	Check good at ambient cell temperature.
25	TE321..E	Outer Reflector Sector	Reading low by 100°R.	Check good at ambient cell temperature.
26	PD114..A	Pump	Reading low.	Misranged, channel re-ranged.
27	CP165.S	V-5001 LH RTNK PG-PR Auto	Reading lower than DP165.	Required modifications to control circuit.
28	HT800R.A	TPA	Very high positive spikes during run.	
29	HT801R.A	TPA	Same as HT800R.	
30	HT802L.A	TPA	Same as HT800R.	
31	HT201R.A	Nozzle Fwd. Flg.	High level noise throughout run.	
32	HT203R.A	Pressure Vessel Fwd. Flg.	High level 120 Hz signal super imposed throughout run.	
33	TT262.. TT263..	Temp. Ref. Junction	Reads about 137°R on DDS. All on-line readouts indicate 610°R.	
34	TE707..E TE708..E TE710..E TE713..E TE714..E TE715..E TE728..A TE729..A TE730..A TE731..A	Core Element " " " " " Core Inlet Plenum " " " "	Data missing on Pass 9, Run 1.	Data to be re-run.

TABLE I (Continued)

SPEAR MEMO No. 17

ITEM	MEAS. NO.	MEASUREMENT DESCRIPTION	ANOMALY	COMMENTS
35	D.627..E	TPCV Position Error	Digital data read in micro amps. CRT plots erroneously labeled degrees.	
36	DP867.AE DP868..E	Turb. Pwr Cont Valve	Indicates 30 degrees open, all other data indicates 90 degrees open.	
37	FT434..F PT844..F PT278.F	Shld Total GN ₂ Flow Shld GN ₂ Sply ² Press S1 in H ₂ O Press.	Constant ambient output.	
38	FT434	Shld Total GN ₂ Flow	Eng. units listed as CPS on Sacramento CRT plots, should be PSID	
39	MG115L.A MG801L.A MG803L.A MG806L.A	Pump Inlet Line Upper Thrust Structure " "	Initial offset excessive.	
40	TE838..F	DCT VLT Door - West Edge	Does not follow predictions.	T/C not connected.
41	F4, F5	Wide Band Tape Recorder	Voice track modulated time trace.	
42	-	CRT Plots	A total of 35 sec. of CRT data (63295-63330) not plotted on time slices 62400-634400, 62800-63800.	Data is available on digital listings.
43	-	CRT Plots	Time slices 62400-63400 on CRT plots from Sacramento failed to print on 235 channels.	Channels of data available in digital listings. CRT data re-run.
44	PT894..R	TPA Purge	Negative readings.	
45	TT109..A	Pump Discharge	Negative readings.	

SUBJECT: STEAM GENERATOR SYSTEM (SGS) OPERATION

SUMMARY

The steam generator system experienced several major anomalies during XECF EP-I. The manual water injection valves moved and caused a pressure spike which was great enough to cause a trip of the ETC helium emergency repressurization system. Another anomaly was the plugging of the propane manifold filter by sand. The reduced propane manifold pressure, however, did not cause any apparent damage to the injector face due to the over-heating.

A chronology of steam generator events is shown in Table I. A data tabulation is shown in Tables II and III. The times in Table IV were taken from oscillograph traces; all other data was taken from digital data.

DISCUSSION

LIQUID OXYGEN SYSTEM

The flow rate to each module varied over the entire run from 16.3 lb/sec to 17.5 due to pressure oscillations in the tank (P49) and manifold (P421), see Figure 1. These oscillations are postulated to be caused by the pressurization regulator PRV-9. This regulator system should be serviced and checked out to ensure its proper operation.

A new method of LOX bleed-in was tried and worked satisfactorily. Essentially, it eliminated opening RSV-436 (2 inch bleed valve) when there was a large amount of liquid upstream of it.

Due to a LOX leak, the system had to be bled-in and pressurized twice.

The total usage for the two bleed-ins was approximately 3000 gallons. Previous bleed-ins consumed approximately 3200 gallons or more.

PROPANE SYSTEM

The propane system had large amounts of sand contamination which caused the manifold supply filter, GF436, to be plugged. The pressure drop from the tank (P-118) to the manifold (P-420) is shown in Figure 2. The manifold pressure, P-420, had dropped to approximately 230 psia just prior to idle and the resultant decrease in propane flow could have become very serious. This contamination was known to exist from a previous run on March 25, 1968, which was a checkout on the steam line after NEP-He-2. During this checkout test, the steam generator system module malfunctioned after 230 seconds as a direct result of the filter plugging when the manifold pressure

TABLE I
SGS CHRONOLOGY

<u>EVENT</u>	<u>RANGE TIME</u> (Seconds)
Idle Steam, SG #2	62450
Idle Steam, SG #3	62455
Full Steam, SG #2	62477
Full Steam, SG #3	62490
1st 449 trip (caused by shield water flow initiation)	62625
2nd 449 trip (caused by duct water flow initiation)	62649
3rd 449 trip (caused by SGS water valve adjustment)	62849
Idle Steam, SG #2	63445
Idle Steam, SG #3	63455
Stop SG #2	63592
Stop SG #3	63594

SGS Total Operation Times

	<u>SG #1</u>	<u>SG #2</u>
Idle	1142 sec.	1139 sec.
Full Steam	968 sec.	965 sec.

FIGURE 1
LOX System Oscillations

FIGURE 2
Propane Filter, Pressure Drop

reduced to 215 psia. During this test the plugging started after 620 seconds of flow, however, the SGS did not malfunction but was very close based on the previous test.

No anomalies were experienced as a result of the modification which shuts down the first stage propellant valves after combustion occurs in the second stage. This was the second satisfactory test of the modification.

The first stage propane valve on module 3 did not shut off when the unit was brought to idle steam and allowed propane to flow into the second stage while at full steam. An inspection revealed sand in the valve which probably caused it not to operate. As early as possible the entire propane system, including tank, line and module valves and lines, should be cleaned.

WATER SUPPLY SYSTEM

The water supply pressure to the generators spiked from 212 psia to 199 psia when the shield water valves (RSV303, 304, 305 and 306) were opened and from 212 psia to 189 psia when duct water flow was increased (FCV31) from 5000 GPM to 8000 GPM. Both of these occurred during generator operation and caused large spikes in the steam pressure. During both instances PCV-449 rate detector tripped and would have caused the PCV-449 to open if it had been armed.

During non-SGS operation the fire protection system deluged causing large pressure oscillations in the water supply P-168.

It is recommended that all water supply valves be operated before activation of PCV-449 and the fire protection valves, that would most likely operate, be opened for the time that opening of PCV-449 cannot be tolerated. If the above is not possible, a water accumulator on the SGS manifold should be installed to dampen-out the oscillations.

OPERATION

Module 1 was inoperable for this test because prior to the test, moisture was found in the conduit leading from the generator to the sequence unit.

The startups to idle steam and full steam are shown in Table IV. All startups and shutdowns were normal.

During about half of the test there was unequal water flow to the operating units. This was on the average of about 45 lbs/sec to Module 2 and 38 lbs/sec to Module 3, and could lead to overheating of the modules.

Three large steam pressure oscillations occurred during the test. The first two were discussed under the "Water System." The third is shown

Water Manifold
Pressure, PT427, Psia

220
200
180

PT426 Steam Plenum Pressure, psia
Module 2 and 3 Water Injection Control Valve Command, CF423-2, -3, % Open
Module 3 Water Injection Control Valve Position, DF423-3, % Open
PCV449 Valve Position, DP449, % Open

0 Time - 67843.0 Range Time

FIGURE 3

SGS Water System During PCV449 Trip

TABLE II

STEAM GENERATOR SYSTEM TEST DATA TABULATION

Test XECF - Run - EP-I - Range Time 62822.1

PARAMETERS	NOMINAL VALUE	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO ₂ Tank Press. (P-49) psig	315-320	324.2				
LO ₂ Manifold Press. (P-421) psia	305-310	317.6				
LO ₂ Manifold Temp. (T-479) ^{°R}	160-180	163.6				
Propane Tank Press. (P-118) psia	305-310	297.9				
Propane Tank Temp. (T-483) ^{°R}	490-520	498				
Propane Manifold Press. (P-420) psia	290-300	285.7				
Propane Manifold Temp. (T-418) ^{°R}	≤ 517	498.9				
Water Manifold Press. (P-427) psia	195-220	209.1				
Main Stage Propane Venturi (F-405) psia	285-295			282.8	283.5	
Main Stage Propane Flow (lb/sec)	7			303.7	302.8	
Main Stage LO ₂ Venturi (F-409) psia	290-295			17.12	17.10	
Main Stage LO ₂ Flow (lb/sec)	16.7			158.2	104.0	
Injection Water Venturi (F-406) psid	100-200			44.34	34.19	
Injection Water Flow (lb/sec)	30-50		3.56	3.38	3.4	
Water Film Cooling (lb/sec)	3-5			175.8	183.3	
First Stage Press. (P-416) psia	185-210			172.4	177.3	
Second Stage Press. (P-417) psia	170-180			132.8	132.0	
Main Stage Press. (P-438) psia	125-135			72.5	62.3	
One Module Flow Rate (lb/sec)	60-70					120.8
Plenum Press. (P-425) psia	120-125					117.4
Steam Line Press. (P-239) psia	115-120					130.1
Steam Line Temp. (T-159) ^{°R}	1200-1300					135.8
Total Steam Flow Rate (lb/sec)	135-140					

TABLE III

STEAM GENERATOR SYSTEM TEST DATA TABULATION

Test XECF - Run - EP-I - Range Time 63440.4

PARAMETERS	NOMINAL VALUE	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO ₂ Tank Press. (P-49) psig	315-320	320.4				
LO ₂ Manifold Press. (P-421) psia	305-310	315.9				
LO ₂ Manifold Temp. (T-479) ^{°R}	160-180	159.3				
Propane Tank Press. (P-118) psia	305-310	299.9				
Propane Tank Temp. (T-483) ^{°R}	490-520	496.9				
Propane Manifold Press. (P-420) psia	290-300	232.9				
Propane Manifold Temp. (T-418) ^{°R}	< 517	498.5				
Water Manifold Press. (P-427) psia	195-220	206.9				
Main Stage Propane Venturi (F-405) psia	285-295			230.8	230.2	
Main Stage Propane Flow (lb/sec)	7			6.1	6	
Main Stage LO ₂ Venturi (F-409) psia	290-295			300.5	298.7	
Main Stage LO ₂ Flow (lb/sec)	16.7			17.3	17.3	
Injection Water Venturi (F-406) psid	100-200			201.9	200.6	
Injection Water Flow (lb/sec)	30-50			50.1	49.9	
Water Film Cooling (lb/sec)	3-5		3.96	3.84	3.85	
First Stage Press. (P-416) psia	185-210			148.8	156.9	
Second Stage Press. (P-417) psia	170-180			144.9	152.6	
Main Stage Press. (P-438) psia	125-135			105.9	105.0	
One Module Flow Rate (lb/sec)	60-70			78.0	77.7	
Plenum Press. (P-425) psia	120-125					98.5
Steam Line Press. (P-239) psia	115-120					90.5
Steam Line Temp. (T-159) ^{°R}	1200-1300					77.1
Total Steam Flow Rate (lb/sec)	135-140					156.6

TABLE IV

STEAM GENERATOR START-UP EVENTS

EVENT	Time (Seconds)	
	Module 2	Module 3
<u>Idle Steam</u>		
1. Start	0. (62449.61)	0. (62454.6)
2. First Stage Pressure Switch	0.75	0.83
3. Shutdown First Stage	2.44	2.32
<u>Full Steam</u>		
1. Start	0. (62477.95)	0. (62490.0)
2. PDS406 Make	0.3	0.3
3. LOX Valve Start to Operate	0.74	0.64
4. LOX Valve Open	0.89	0.69
5. Fuel Valve Pilot	1.08	1.05
6. Fuel Valve Start to Open	1.47	1.32
7. Fuel Valve Open	1.5	1.4
8. PDS480 Make	1.76	1.8

in Figure 3. This spike caused PCV-449 to open signifying a loss of steam. The cause of spike was the movement of the manual water injecting valve to Module 3. It is recommended that during future tests the controls to these valves, FCV-423-1, -2 and -3, be adjusted prior to arming PCV-449 and left alone after PCV-449 arming.

To make the system less sensitive it is recommended that the valve trim of FCV-423-1, -2 and -3 be changed from 110 Cv to 75 Cv. This change will not affect the flow to the modules during the time that the valves are full open because the cavitating venturis, FE406-1, -2 and -3, are controlling the flow. It will, however, allow more valve displacement for the same equivalent flow rates.

It is recommended that a ten turn potentiometer replace the existing one turn potentiometer to assist in fine adjustment of the valves.

POST TEST INSPECTION

The post test inspection of the generators #1 and #2 revealed no major anomalies. Refer to Product Assurance Memo No. 27.

RECOMMENDATIONS

- 1) Liquid oxygen system pressurization system regulator PRV-9 should be serviced.
- 2) First stage propane valve on Module 3 should be removed and functionally checked because it malfunctioned.
- 3) Propane manifold supply filter should be cleaned and checked after future runs until the whole system can be cleaned. The pressure drop between the propane tank and manifold should be closely monitored and not allowed to exceed approximately 70 psid.
- 4) All shield water valves, duct water valves and fire protection system deluge valves that most likely will open should be opened prior to arming the ETC repressurization system (PCV-449) to avoid a false trip of PCV-449.
- 5) If recommendation No. 4 cannot be accomplished, a water accumulator should be installed on the SGS manifold.
- 6) Maintain equal water flow to each SGS module.

- 7) Set the module water injection valves and do not touch the controller after PCV-449 is armed.
- 8) Install a 75 Cv trim in all water injection valves.
- 9) Install ten turn potentiometers on the controllers of each water injection valve.

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Subject: NES DUCT COOLANT WATER FLOW AND DUCT FLARE REPORT

SUMMARY

Coolant Water Flow

The minimum water flowrate for this test was increased to approximately 2300 GPM through the elbow section in order to prevent the cold GH_2 from freezing the water in the duct coolant channels. The following sequence was followed to establish initial flow:

- (1) RSV-296, RSV-297, RSV-738, RSV-739, RSV-858, RSV-859 and FCV-30 were opened.
- (2) FCV-31 was opened approximately 25% and RSV-298 was opened establishing the following flowrates:

Section 1	1233 GPM
Section 2	1385 GPM
Section 3	<u>2394</u> GPM
Total	5012 GPM
Section 3-B	1103 GPM

- (3) FCV-31 was then opened 100% establishing the following flowrates:

<u>Section</u>	<u>Predicted GPM</u>	<u>Actual GPM</u>
1	2670	2354
2	2300	2299
3	<u>3170</u>	<u>3264</u>
TOTAL	8040	7917
3-B	1000	1079

While the duct was at the low water flow conditions the operation of the SGS was initiated resulting in an increase in the outlet water temperature at Section 3 of 30°R . When the water flow in Section 3 was increased to 3264 GPM the temperature dropped to the normal differential of $10^{\circ}\text{--}20^{\circ}\text{R}$. The steam temperature was approximately 1300°R .

The temperature in Section 1 was lowered approximately 5°R during the flow of cold GH_2 and the temperature in Section 2 was lowered approximately 8°R (Figure 1).²

The maximum strain recorded was between 465 and 470 microinches per inch at strain gage GG-017 located on top of the duct at Station 746. This reading is approximately 10% lower than during NEP-He-2 and approximately 7% lower than the allowable strain of 500 microinches. The maximum strains were obtained during SGS operation.

DISCUSSION

The object of the increased duct coolant water flow to 8000 GPM was to prevent the water in the coolant channels from freezing during cold GH_2 flow and this was satisfactorily demonstrated. The exhaust GH_2 temperature during this EP was approximately 200°R but in the next EP it is expected to be approximately 50°R . The original calculations to determine the flow required to prevent coolant water freezing covered a range from $40^\circ - 200^\circ\text{R}$ so no problems are anticipated with this temperature and the present flowrate.

SUMMARY

Duct Flares

The duct flare system operated satisfactorily before, during and after the test. During the initial phase of igniting the flares there was a problem with the two lower flares' propane supply. There was liquid propane collected downstream of the atmospheric propane vaporizer and, as a result, it froze in the regulator. The regulator had to be unfrozen and the system purged of the liquid propane. The system then worked satisfactorily.

DISCUSSION

As a consequence of EP-1, XECF, an ECR has been initiated to remove the existing regulator and install a back pressure regulator to prevent liquid from collecting downstream of the atmospheric propane vaporizer.

The above information was obtained from the strip charts and the one sample per second digital data.

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NES DUCT SECTION TWO OUTLET TEMPERATURE

FIGURE 1

Subject: ETC (1) SHIELD WATER FLOW RATES AND (2) GN₂ SEALING SYSTEM:
CONVOLUTE, BUFFER, BELLOW, AND BLADE SEALING PRESSURES

The data used for this report was taken from the thinned digital listing and also from the enclosed cal-comp plots.

INTRODUCTION

The ETC Shield Water Flow System had not been modified since NEP-He-2, therefore, the shield water flow rates still did not meet the required XE-1 flow rates.

The results of NEP-He-2 indicated the GN₂ usage to the various sealing systems of the ETC was excessive. NTO-I-320, the ETC Shield GN₂ Test Setup Procedure, was changed to establish a sequence of events in which the various buffer purges, gasket purges, blade sealing pressures, and convolute buffer purges were established one at a time. The Digital Data System was turned on for this sequence of events to determine how the flow through FT-434 changed as each purge or sealing system was activated. Thus the GN₂ flow requirement for each system could be determined. The instrumentation boxes, IB-1 and IB-2, behind the S-1 and S-2 side shields were previously purged. However, the revised NTO-I-320 Procedure requires the boxes to be sealed.

SUMMARY

The S-1 and S-2 side shields and S-4 bottom shield water flow rates were consistent with previous test data. They are still below XE-1 requirements.

NTO-I-320, the ETC GN₂ Shield Test Setup, was conducted on R-1 Day. The GN₂ flow rate through FT-434 indicated no flow. The differential pressure transducer across FT-434 indicated an erroneous constant negative 10.32 PSID. Therefore, it was not possible to evaluate the GN₂ flow required for each sealing system as planned. The pressures to the various sealing systems appeared to be normal except for PT-629 and PT-630 which were 0.70 PSI low.

During EP-1, the GN₂ flow (W FT-434) to the various sealing systems was essentially zero. The pressures to the various sealing systems were within 0.70 PSI of the operating pressures. PT-631, the bottom blade purge, and PT-632, the bottom seal blade purge, decreased and increased 0.90 PSI and 0.50 PSI, respectively, when the steam generators started up and were shut down.

TECHNICAL DISCUSSION

Figure I illustrates the S-1 and S-2 side shield and S-4 bottom shield water flow rates during the entire run. The flows are computed from PT-278 (S-1), PT-284 (S-2), and PT-262 (S-4), which are the inlet pressures to RSV-304, RSV-305, and RSV-306, respectively. The required water flow rate to the bottom shield is 604 gpm where the test flow rate was 550 gpm. The required flow rate to each side shield is 1474 gpm. During the test, the flow rate to the S-2 shield was 1150 gpm. In Figure I, the S-1 shield flow rate is indicated as 90 gpm which is erroneous. The flow is computed from PT-278 which indicated 12.8

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to 14.0 PSIA. PT-278 should be indicating approximately 236 PSIA which is the pressure head from the water reservoir V-3302. It appears as though the hand valve that isolates PT-278 from the water line was not opened prior to the test. The approximate flow to the S-1 shield is 1190 gpm based on the S-2 flow rate. The S-1 shield water temperatures were used to determine flow indication through the S-1 shield.

As mentioned previously, FT-434 indicated a constant negative ΔP during NTO-I-320. It appears as though a problem exists since the reading was locked on -10.32 PSID. Because of the above problem the GN_2 flow rates to the various sealing systems of the ETC were not available. It should be noted that the possibility of damaging FT-434 (50 PSID) exists whenever the original shield latches are actuated unless FT-434 is valved off during this time.

Since FT-434 (pressure transducer) was not checked out after NTO-I-320 was performed, the validity of the data from EP-1 with respect to FT-434 is questionable. During EP-1, W FT-434 indicated no appreciable GN_2 flow to the various sealing systems. The differential pressure transducer FT-434 indicated ± 0.13 PSID.

It should be noted that during the Mechanical Seal and Leak Test the total GN_2 flow to the various sealing systems was approximately 30 SCFM. This is

$$\left(30 \frac{FT^3}{MIN} \right) \times \left(\frac{1 MIN}{60 SEC} \right) \times \left(.0726 \frac{LBS}{FT^3} \right) = .0363 \frac{LB}{SEC} GN_2$$
 0.0363 lb/sec of GN_2 flow which would create a pressure drop across FT-434 of approximately 0.30 PSID. The pressure transducer across FT-434 is 50 PSID calibrated down to 12.5 PSID full scale. It is obvious the resolution of FT-434 is poor.

The instrument boxes IB-1 and IB-2 behind the S-1 and S-2 side shields were sealed during NTO-I-320 and left sealed for EP-1. It is possible the GN_2 flow was reduced since prior to EP-1 the instrument boxes were continuously purged.

Figures II and III illustrate the various sealing, buffer, and purge pressures versus time during the entire test. Figures II and III illustrate the decrease and increase in pressure at PT-632 and PT-631, respectively, during steam generator startup and shutdown. The 0.5 psi drop during SGS operation indicates a slight leak into the ETC. Pressure was still maintained greater than 1 PSIG so that no atmospheric inflow was possible. PT-636, the top bellows pressure, is not illustrated in Figures II or III. The pressure is 30 PSIA in the digital listing and is not effected by the steam generator operations.

RECOMMENDATIONS

The ETC shield water flow system will have to be modified if the requirements of Memo No. 7860:0710M, dated 3 January 1968, are to be met.

FT-434 should be isolated during operations of the side shield latching mechanism. FT-434 should be checked out and, if possible, determine why it indicated a constant negative pressure differential during NTO-I-320. It should also be checked out to determine if the readings during EP-1 were valid. This should be done prior to EP-2.

The possibility of installing turbine meters in the low pressure GN_2 lines (less than 500 PSIG) to determine GN_2 flow should be evaluated. Or the possibility of installing another orifice meter in parallel with FT-434 should also be investigated, such that flow can be diverted through either flow orifice.

It is recommended that meters for FT-434 and PT-844 be installed on the RIC Console so that the RIC Console Operator can monitor any sudden changes in GN_2 flow.

Jerry Endo

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XECF EP1 4/02/68
S1 AND S2

PARAMETER	DESCRIPTION	OPERATING PRESSURE PSIA
PT-627	O.B. CONVOLUTE BUFFER PURGE	14.8
PT-628	I.B. CONVOLUTE BUFFER PURGE	14.8
PT-629	O.B. S-1 CONVOLUTE SEAL PURGE	17.8
PT-630	I.B. S-1 CONVOLUTE SEAL PURGE	17.8
PT-632	S-1 BOTTOM SEAL BLADE PURGE	14.8
PT-633	S-2 BOTTOM SEAL BLADE PURGE	14.8

FIGURE II

48000.0

52000.0

56000.0
RANGE TIME-SECS.

60000.0

64000.0

68000.0

XECF EPI 4/02/68
RGE PRESS.

1	PT625..	PS1A
2	M.FT434	X20.0
3	PT625..	PS1A
4	PT631..	PS1A
5	PT634..	PS1A
6	FT434..	PS1D

SH TOP SHIELD PU

PARAMETER	DESCRIPTION	OPERATING PRESSURE
		PSIA
PT-625 W	GASKET CAVITY PURGE	14.8
PT-626 E	GASKET CAVITY PURGE	14.8
PT-631	S-4 BOTTOM BLADE PURGE	14.8
PT-634	TOP SEAL BLADE PURGE	14.8

STEAM GENERATORS
STARTUP

STEAM GENERATORS
SHUTDOWN

FIGURE III

48000.0

52000.0

56000.0
RANGE TIME-SECS.

60000.0

64000.0

68000.0

Subject: INERTING SYSTEMS

SUMMARY

TSER INERTING

The TSER inerting system performed satisfactorily. Approximately 15,300 lbs of GN_2 were used during the inerting operations. The TSER O_2 concentration was maintained between 4 and 5% after initial inerting. It is recommended that for future XECF testing the O_2 concentration be maintained at 4.8-5% to reduce GN_2 usage.

DUCT VAULT AND PIPE CHASE INERTING

The duct vault and pipe chase inerting system performed satisfactorily. About 47,500 lbs were used for all inerting operations. After initial inerting, the O_2 concentration was maintained between 4% and 5%. It is recommended that for future XECF testing the O_2 concentration be maintained at 4.8-5% to reduce GN_2 usage.

UTSM PURGE

The UTSM GN_2 heater purge system performed satisfactorily. The UTSM temperatures, TE-900, TE-904, and TE-905, were well above the required minimum of 500 R during testing. About 7100 lbs of GN_2 were used for the purge operation. It is recommended that the quantity of this purge and the time requirement be reassessed and reduced if possible.

ETC PURGE

At initiation of the ETC purge operation, PCV-621 failed to operate. Because of this the ETC purge gas was provided by an alternate system. During chilldown of the liquid propellant line to PSV the H_2 concentration in the ETC increased significantly. GN_2 flow was increased as required. The GN_2 usage during purge of the ETC was about 10,000 lbs.

The data used in these analyses were taken from "Thinned Digital Data".

DISCUSSION

TSER INERTING

Nitrogen vessels V-3201, V-3202 and V-3203 were used as a source of GN_2 for inerting of the TSER. The TSER was inerted to provide a non-combustible environment at an oxygen concentration of 5%, or less, at any time LH_2 is present in the V-5001 area. Figure 1 is a schematic of the TSER inerting system.

Initial inerting (from 20.9% to 4% O_2) of the TSER was performed prior to the V-5001 fill and chill operation. Approximately 1500 lbs of GN_2 were used, at 1.8 lbs/sec, in fourteen minutes to initially inert the TSER to 4% O_2 . The expected initial inerting usage was 1400 lbs of GN_2 .

The TSER inerting was maintained between 5% and 4% O_2 by opening or closing, as required, RSV-927. An average of about 5,000 lb/hr GN_2 was required for inerting maintenance. Previous test data indicated an inerting maintenance usage of 4750 lbs/hr.

Total usage during all TSER inerting operations was approximately 15,300 lbs GN_2 . So that the GN_2 usage may be reduced for future XECF testing, it is recommended that the O_2 concentration be maintained at 4.8-5%.

DUCT VAULT AND PIPE CHASE INERTING

The inerting gas was provided by nitrogen vessels V-3901, V-3902, V-3903 and V-3904. Figure 2 is a schematic of the duct vault and pipe chase inerting system.

Because rupture of V-5001 could permit H_2 to enter the duct vault (D.V.) and Pipe Chase (P.C.) the inerting was performed to reduce the oxygen content to 5% or less. Thus, the danger of a combustible mixture of gases is prevented.

Initially the D.V. and P.C. were simultaneously inerted. Inerting maintenance was performed individually to the duct vault and/or the pipe chase, as required, to keep the oxygen concentration below 5%.

The first attempt at initially inerting of the duct vault and pipe chase consumed 20,000 lbs of GN_2 . The inerting operation was terminated, before inerting was complete, after discovery of a LOX line leak in the Facility.

The normal requirement for inerting from 20.9% to 4% O_2 is 22,500 lbs as determined by a previous test (See NTO-M-21091).

The second, and final, initial inerting operation consumed 12,300 lbs of GN_2 .

The inerting maintenance usage for the D.V. and P.C. was 13,200 lbs in 2.2 hours. This is equivalent to 6,100 lb/hr for both compartments as compared to a rate of 10,700 lb/hr as determined from previous testing (See NTO-M-21091).

A post-test inspection of the duct vault indicated that there are approximately three of four locations where the metal screws securing metal sheeting to the frame were "popped" loose as a result of the sheathing vibration noted during the test run.

O_2 detector data was not taken during the test but, in general, the O_2 concentration was maintained between 4 and 5% O_2 .

The total usage during D.V. and P.C. inerting operations was 47,500 lbs of GN_2 .

UTSM PURGE

The UTSM purge gas was provided by nitrogen vessels V-3201, V-3202 and V-3203. The purge was initiated prior to the fill and chill of V-5001 and was terminated after the dry pump startup test with V-5001 at 35 psia. The UTSM purge system is shown in Figure 3.

The warm nitrogen environment was maintained for several reasons. The UTSM pressure transducer box was to be maintained between 500°R and 640°R because the pressure transducers are not temperature compensated below 500°R or above 640°R . The nitrogen purge is also required in order to keep the UTSM purged of GH_2 and O_2 .

UTSM pressure transducer box temperature, TE900, and UTSM environmental temperature, TE904 and TE905, and UTSM purge flowrate versus time are shown in Figure 4. It should be noted that the temperatures were well above the required minimum of 500°R .

The flowrate was maintained between .8 and 1.2 lb/sec as shown in Figure 4. The flowrate was not maintained at all times, at 1 lb/sec because header pressure decay, PTO02, required periodic adjustment of PCV-447.

Approximately 7100 lbs of GN_2 were used for UTSM inerting. The usage rate was about 3750 lbs/hr.

For future XE-1 testing it is recommended that the possibility of not initiating the UTSM purge until chilldown of the liquid propellant line be investigated so that the GN_2 usage may be reduced. The ETC O_2 and H_2 sensors might also be considered as criteria for purge initiating. Also, the 1.0 pps flowrate could possibly be reduced.

ETC PURGE

The ETC purge gas was provided by nitrogen vessels V-3201, V-3202 and V-3203. A 3 - 14 lb/sec purge was initiated prior to chilldown of the liquid propellant line. The ETC purge system is shown in Figure 3.

The primary purpose of the purge was to maintain the ETC O_2 concentration at less than 3%. The purge was initiated prior to the fill and chill of V-5001 to determine, in the event of leaks in the liquid propellant line, what nitrogen flow would be required to reduce the H_2 concentration to 2% or less.

PCV-621 would not open under pressure. An alternate flow path using FCV-50 was used to provide ETC purge flow. PCV-621 has been adjusted and subsequently flow checked. Its operation is now reported to be satisfactory. Figure 5 is a plot of P1192, PT474 and PT643 versus GN_2 ETC purge flowrate. It may be used in the future for setting flow through FCV-50.

During chilldown of the liquid propellant line to PSV the H_2 concentration in the ETC increased significantly and the ETC purge flow rate was increased until the H_2 concentration was reduced. The cycling of the H_2 and O_2 concentrations were, for the time span noted, as shown in Figure 6. Also shown on Figure 6 is the purging flowrate versus time. It should be noted that Figure 6 is presented for illustration only as accurate plots of these data were not available.

The GN_2 usage during purge of the ETC was about 10,100 lbs. The average usage rate was about 8300 lb/hr.

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FIGURE 1

SCHEMATIC, TSEr INERTING FLOW

FIGURE 2

SCHEMATIC, DUCT VAULT AND PIPE CHASE
INERTING SYSTEM

SCHEMATIC, ETC AND UTSM PURGE

FIGURE 3

PRESSURE VS GN₂ FLOWRATE
FOR ETC PURGE

FIGURE 5

SUBJECT: ENGINE VALVE ACTUATION SYSTEM

SUMMARY

The He header was pressurized to 2500 psig and the following sequence established actuation pressure at engine valves PSV, CSV, CVV, TBV, PDVV and PDSV:

- (1) The pressure was reduced to 1000 psia by PRV420.
- (2) The pressure was then further reduced to approximately 521 psia by PRV485 as read at PT017.
- (3) RSV702 was then opened, pressurizing the valve actuation system.

The flow to the above valve actuation system was measured by FE432. There was very little flow measured during operation of one or more of the valves (Table I). The total amount of He used for valve actuation during this EP was approximately 0.5 lbs. The pressure to TPCV actuation system was established in the following manner:

- (1) The pressure from the 2500 psig header was reduced to 1000 psia by PRV420.
- (2) RSV867 was then opened allowing pressure to flow through PRV402.
- (3) The pressure was reduced by PRV402 to 840 psia read at PT618.
- (4) The flow then passed through PRV200 and was further reduced to approximately 214 psia read at PT478 and PT897. This established pressure at TPCV actuation system.

The flow to TPCV actuation system was measured by FE431. There was no flow recorded to this valve even during operation, therefore, no He was used on this system.

DISCUSSION

This system worked very satisfactorily and there are no changes suggested.

The data was obtained from the L & N strip charts and the one sample per second digital data.

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TABLE 1

Engine Valve Actuation Gas Flow

<u>Valve</u>	<u>Position</u>	<u>Ave. Flow</u>
PDVV	Closing	.04 #/sec
PSV	Opening	.05 #/sec
PDVV	Opening	.05 #/sec
CSV	Closing	.05 #/sec

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run

SUBJECT: LH_2 PROPELLANT SUPPLY SYSTEM PERFORMANCE

INTRODUCTION

The propellant supply system consists of the 250,000 gal. storage dewar, V-3801; the transfer line, 3-LH-6; the 69,500 gal. run tank (V-5001; the propellant supply line (201-LH-8) and associated valves. This memo presents the results of an evaluation of the data related to: 1) the 3-LH-6 chilldown; 2) V-5001 initial fill and chill; 3) the LH_2 back-transfer from V-5001 to V-3801; 4) and PSL chilldown.

The source of data used for this evaluation was 1 sample/10 second and 1 sample/second digital data.

SUMMARY OF RESULTS

- 1) It took 5.2 minutes to fill and chill the 3-LH-6 transfer line. 500 to 750 lbs. were required to chill and fill the line.
- 2) PT-068 was not reading the correct dewar pressure because it was calibrated with pressure (4-5 psig) in V-3801.
- 3) It took 22.6 minutes to chill V-5001 and fill to the 90% level. The quantity of LH_2 required to chill and fill V-5001 to 88.5% volume (36,000 lbs) was about 40,000 lbs. This indicates approximately 4,000 lbs used for boiloff chill. These figures are preliminary and are subject to further analysis.
- 4) Backflow from V-5001 to V-3801 was accomplished with no problems.
- 5) The chilldown of the PSL through PCV-579 took 5.8 minutes.
- 6) Correlation of the FE-14 integral flow $\left(\frac{\text{FE-016}}{4.55}\right)$ was in fair agreement with V-5001 outflow based on LT453 changes.
- 7) TTO31 hung up at full scale during the 100% cal step of the pre-cals.
- 8) PSV stem pot showed an increase from 0.6 to approximately 5% at 62000 when PCV-579 was opened to start chill.

DISCUSSION

CHILLDOWN AND FILL OF 3-LH-6 (TRANSFER LINE FROM V-3801 TO V-5001)

Figures 1 and 2 illustrate chilldown and fill of the transfer line, chill

XI

and fill of V-5001, backflow from V-5001 to V-3801, PSL chill and fill, the bootstrap, and emptying of V-5001.

The transfer of LH_2 from V-3801 to V-5001 started at 58032 seconds by opening RSV-128. V-3801 pressure (Pt-68) was 48 psia during transfer. V-5001 pressure (Pt-99) was 13 psia. Approximately 310 seconds were required to chill the line down to 38°R . Between 500 and 750 lbs of LH_2 were used to chill down and fill the transfer line, of which 460 lbs are required to just fill the transfer line. This corresponds to a reported 500 lbs of LH_2 that was required during FEP-III to chill and fill the transfer line. V-5001 pressure (Pt-99) increased 2.50 psia initially when liquid flowed through RSV-128. This decreased back to 0 psig by the time 8% volume was reached (about 1000 seconds later).

CHILL AND FILL CHARACTERISTICS OF V-5001

V-5001 started to fill at 58250 seconds as indicated by LT-499. At 59150 LH_2 transfer was stopped, and a possible leak at the bottom of the run tank was investigated. V-5001 pressure (Pt-99) was increased from 13 to 31 psia by shutting the vents and allowing vapor pressure to build up. No increase in vapors was noticeable and, since the area was foam insulated instead of vacuum jacketed, it was concluded the vapors were from liquid air. V-5001 was then vented back to 12.8 psia at 59650 seconds and the fill of V-5001 continued. LT-499 indicated 90% height (88.5% volume) at 60400 seconds. Excluding the time when the transfer was stopped to check the possibility of a leak the total time required to chill and fill V-5001 to 90% height (88.5% volume) was approximately 23 minutes and required 40,000 lbs of LH_2 out of V-3801 based on LT-2. The capacity of V-5001 at 88.6% volume is 36,000 lbs of LH_2 . Thus, approximately 4000 lbs of LH_2 was boiled off to chill down V-5001. These figures are preliminary.

V-5001 DRAIN BACK TO V-3801

V-5001 was pressurized (Pt-99) to 35.5 psia and V-3801 was vented to 12.8 psia. Backflow to V-3801 was initiated by opening RSV-129 at approximately 60980 seconds. At 61640, RSV-129 was closed to stop LH_2 backflow to V-3801. LH_2 backflow was maintained for 660 seconds and V-3801 level Lt-2 increased from 62 to 73.3% (20,300 lbs of LH_2). However, V-5001 level (Lt-499) decreased from 88.5% volume to 25.2% volume which indicates 25,270 lbs of LH_2 flowed out of V-5001. Thus, a large discrepancy exists between the LH_2 used out of V-5001 versus the LH_2 put back into V-3801. This will have to be evaluated at a later date.

PSL CHILLDOWN

The chillover of the PSL was accomplished by opening PCV-579 and RSV-455. Chillover was initiated at 61900 seconds and terminated at 62778 seconds when PCV-579 was closed. Figures 3 and 4 are plots of data related to this chillover analysis. It took approximately 5.8 minutes to get sub-cooled

liquid ($T_{\text{sat}} = 42.7^{\circ}\text{R}$) at TT475. The temperature (TT475) decreased to 3.7°R to 4.2°R below the saturation temperature. This temperature condition was maintained for 5.5 minutes by flowing out of PCV-579. However, PCV-579 was closed 24 seconds prior to opening PSV and establishing bootstrap flow. This long non-flow period resulted in the propellant line fluid warming up to the **saturation temperature**. The warmup rate was $9.9^{\circ}\text{R}/\text{min}$ during the no-flow hold. Approximately 4800 lbs of LH_2 was used to chill the PSL down and maintain a chill. It is recommended that PCV-579 should be left open until PSV is opened. The valve should be regulated such that the minimum flowrate required to maintain sub-cooled LH_2 ($2-3^{\circ}\text{R}$ below T_{sat}) in the line until engine flow is initiated.

Full steam conditions were established during the PSL chilldown phase resulting LH_2 flowed back down the V-5001 flare stack line through PDVV and PDKV because of the increased differential across PDKV, and resulted in pre-chilling of the nozzle torus manifold. This pre-chilling would not have occurred if PDSV was operational and closed or if PDVV had not been open.

Correlation of FS-14 integral flow ($\frac{\text{FE-016}}{4.55}$) was in fair agreement with V-5001 outflow based on LT453 changes.

M W Brant
J. R. Endo Q

Q14

XECF EP1 4/02/68
V3801/V5001 LH2

1	PT068	PS1A
2	PT099	PS1A
3	TT401	RANKINE
4	TT044	RANKINE
5	LT002	IFULL
6	LT499	IFULL

XECF EP1 4/02/68
V5001 LH2 NO. 1

1	TT518..	—■—	RANKINE
2	TT517..	—■—	RANKINE
3	TT516..	—■—	RANKINE
4	TT515..	—■—	RANKINE
5	TT514..	—■—	RANKINE
6	TT513..	—■—	RANKINE

Backflow V-5001 to V-3801

Chiltdown and Fill of V-5001

FIGURE II

FIGURE 3

PCV-519 Position %

FE14 Flow PPS

PSL Pressure - Psls

100
50
0

44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3

Temp °R

$\theta = 62750.3$ seconds

Time, Seconds

FIGURE 4

Subject: V-5001 LEVEL INSTRUMENTATION

SUMMARY

The run tank level instrumentation performance was marginally adequate for operational use. Several easily implemented adjustments should be made to the continuous carbon resistor (LT-453) and the reflectometer (LT-499) channels to increase the confidence in their indications for operational use. These adjustments are discussed under the Discussion and Recommendation sections. The continuous capacitance probe (LT-009) was inoperative prior to the run. As previously experienced during the facility checkout test, the point capacitance probes did not function. The individual point resistance probes were not reliable. Figure 1 is a summary of all of the V-5001 level instrumentation

DISCUSSION

Continuous Capacitance Probe (LT-010)

This channel was not operative prior to the run. Problems exist with the electronics which are planned to be corrected by XE-1.

Capacitance Probes

There were 5 capacitance probes in the channel data log. None gave an indication at any time during the test. The cause for their malfunction is not known. These have not operated previously (See ETS-1 FDET Memo FEP-III-2 Memo No. 66 dated 31 March 1967). It is recommended that if the Instrumentation Group cannot correct this deficiency, that these channels be deleted so that the long lines can be used for the point carbon resistors which were deleted prior to EP-I.

Carbon Resistor Probes

There were 8 point indicating carbon resistor probes used. Up to about 6% level indication they seemed to give reasonable readings but the remainder of the level indications operated completely out of phase with the other instruments. At the 70% level, the probe never gave an indication. Until a better adjustment is made, these indicators should not be relied upon.

Resistance Thermometers

The resistance thermometers gave well defined indications of level which could be easily interpreted. An operator following change in level could have some trouble determining when the flat portion of the temperature curve is reached especially on the filling operation, but in post test analysis it is fairly well defined. The indicated levels agreed closely with the estimated actual level in all cases. The 10% RTT (LT-513) was excessively noisy.

XE

Continuous Carbon Resistor Channel (LT-453)

Adjustments were made to LT-453 in the TSER during the fill and at the 90% level hold. During the drain after these adjustments, this channel performed fairly well. The discrepancies are as follows:

1. The total voltage and the individual resistance values of the voltage divider network should be adjusted so the % volume step indications agree with the actual % volume. The indications are an average of 5.7% low. This will assure greater confidence in online indications.
2. The 60% point did not function properly and the 78, 80, and 90% points are questionable.

The problem noted on FEP-III-2 with the 30% point seems to have been corrected. The 60% point now seems to have this same problem.

During the outflow period, all of the points from 50% to 0% levels seemed to operate properly. It is therefore recommended that the average triggering voltage (or current) necessary to actuate these points be determined and this be used to set the 60 through 100% points. This criteria should be used for future pre-run setups as well.

Reflectometers

This was the first test at ETS-1 of this new channel. Similar devices have functioned satisfactorily at Test Cell "C". It gave a smooth continuous indication of level which followed all events during the fill and drain operations. It should be noted that this instrument operates on an elapsed time of a reflected signal and as such is inherently a height sensing device. Its output is thus percent of height. For online operational use, its meter face should also be calibrated in either percent volume or lbs LH₂. The percent range is the same as the carbon resistors according to the Instrumentation Group.

This channel appears to have provided the best indication of V-5001 level and should prove to be a very valuable addition to the continuous carbon resistor channel and the RTT's.

Recommendations

1. Substitute the Reflectometer for the defective LT-010 on the ASE console and make a new meter face which shows percent of volume, percent of height, and lbs of LH₂. It is understood that this recommendation is already in progress and will be done prior to EP-II.
2. Readjust LT-453, as outlined in the Discussion, prior to EP-II.
3. If possible determine the source of noise on TT-513 (the 10% RTT) and correct by EP-II.

4. Either make the point capacitance probes operative or delete prior to XE-1.
5. Repair LT-010 prior to XE-1.
6. Add the remainder of the point resistor channels to the ASE console and to data by XE-1.

J. H. Kanisthala / 1312
W F. Booty / 1312

Comparison Various Level Measurements V-5001

70
Level
100

FIGURE 1

J. H. R.

SUBJECT: PLUME HEATING OF DUCT EXIT AREA

SUMMARY

The thermocouples depicted in Figure 1 are to monitor the test stand and test stand area temperature during the periods when hydrogen is flowing to prevent equipment and facility damage. Test limits of 250°R and 300°F were placed on concrete and aluminum components, respectively. TE840 exceeded its 250°F limit for a short duration during bootstrap. As a result it was decided to use helium for the warmup instead of GH_2 .

The timing pen for the L & N recorders was not operating during the portion of the run when hydrogen was flowing from the duct exit. The lack of an absolute time base prevents correlating the temperature rise with hydrogen flow and wind data.

Figure 2 is the temperature rise rate of the thermocouples affected by the plume, TE839, 840, 842, 843 and 845. The remaining thermocouples remained at ambient except for TE838 which was not functioning properly.

E. J. Fuller

B

Bh

X3

FIGURE 1

FIGURE 2

— 283°F

Subject: FLUID USAGES

INTRODUCTION

The various fluids, which were used during XECF-EP-I, are: gaseous nitrogen (GN_2), gaseous helium (GHe), gaseous hydrogen (GH_2), liquid hydrogen (LH_2), liquid oxygen (LO_2), liquid propane (C_3H_8), and water. This memo does not consider the water utilization.

This evaluation is based on 1 sample per 10 second and 1 sample per second digital data.

TECHNICAL DISCUSSION

Gross Usages

The gross fluid usage is tabulated in Table I. The usage is based on initial conditions at 45021 seconds and final conditions at 67735 seconds.

SUMMARY OF RESULTS

1. The nitrogen utilization (on an individual operation basis) was not determined because seven tube trailers of unknown volume were used to implement the V-3201, O2 and O3 inventory; however, the relative usages based on rate of change of vessel pressure for concurrent operations were determined.
2. The nitrogen usage can be reduced by: 1) initially filling V-3401 and V-2801 to their maximum capacities; 2) initiating the constant 1 pps UTSM purge after RSV-132 or RSV-455 is opened. PCV-447 could be opened, as required, to maintain the UTSM purged prior to the aforementioned event; 3) operation of the nitrogen compressors during the test; 4) decreasing the V-5001 fill and chill time by (a) increasing the initial V-3801 pressure if GH_2 usage is not a problem, (b) opening PSV-129 sooner, (c) chilling the PSL simultaneously.
3. The high pressure nitrogen system, which is used to inert the duct vault and pipe chase, and the low pressure nitrogen system should be valved together when their pressures equalize to give more efficient use of the nitrogen.
4. The normal GHe storage system inventory is not sufficient to support a complete warmup of the engine and provide a minimum tank pressure of 1500 psig as required by the loss-of-steam flow safety system, therefore, GH_2 should be used intermittently for warmup.

XF

TABLE I
GROSS FLUID USAGE

Fluid	Vessel	Initial Level	Final Level	Initial Press. (psia)	Final Press. (psia)	Usage
LH ₂	V-3801	LT002=80.88% 85.7% volume 210,850 gal.	LT002=73.7 78.5% of vol. 193,223 gals.	_____	_____	11,000 lbs.
C ₃ H ₈	V-3401	LT-11=1.73 psid 63,000 lbs.	LT-11=1.15 51,300 lbs.	_____	_____	11,700 lbs
GN ₂	V-3201 V-3202 V-3203	_____	_____	2470 @ 545°R	654 @ (516 to 533°R)	Not ⁽¹⁾ Determined
GHe	V-3204 V-3205 V-3206	_____	_____	2608 (541 to 546°R)	1154 @ (524 to 536°R)	4522 lbs.
GH ₂	V-3207	_____	_____	2460 @ 507°R	995 496°R	1100 lbs.
LO ₂	V-2801	LT001=0 psid Not Determined	LT-001=1.45 50,300	_____	_____	Not Determined
GN ₂	V-3901 V-3902 V-3903 V-3904	_____	_____	3328 3281 3283 3397	1327 2042 2001 2048	16,200 lbs. 9500 lbs. 9700 lbs. 10,000 lbs.

- (1) The total inventory could not be determined because tube trailers were on-line. The volume of the tube trailers is unknown. Based on three vessels, the usage was 43,386 lbs.

5. The gaseous hydrogen usage was 1100 lbs. The total inventory is approximately 5980 lbs; therefore, the present inventory (at 2500 psi) is sufficient to support XECF-EP-II operations if conducted in a similar manner.

TECHNICAL DISCUSSION

GN₂ Usage

The 2500 psi gaseous nitrogen storage system, which consists of three 1760 cu. ft. storage vessels and seven tube trailers provided gaseous nitrogen for the following uses: 1) ETC inerting; 2) UTSM purge; 3) TSER inerting; 4) steam generator purge; 5) LOX tank (V-2801) pressurization; 6) propane tank (V-3401) pressurization; 7) ETC shield blades and buffer zone purges; and 8) facility valve operation. For the purposes of this memo the latter two uses will be neglected since the flow rates are relatively low.

The various individual usages for the various operations were not calculated because the volumes of the tube trailers, which were on-line during this test are not known and because several operations were conducted concurrently. The NTO Facilities Operations Group has been requested to provide volume information of all the tube trailers available for use at ETS-1 and to document for each run which tube trailers are used for each test. This data is required to make utilization predictions for XE-1.

Figure 1 is a plot of V-3201 pressure (PT-001) versus time. The V-3202 and V-3203 pressures (PT-004 and PT-007) were essentially equal to PT-001. The significant information extracted from Figure 1 is presented in Table II.

The respective pretest and post-test GN₂ supply system pressures were 2470 psi and 650 psi. The test usage was determined over a 5.7 hour interval. The minimum allowable GN₂ supply system pressure is 500 psi. It appears that the inventory was not sufficient to support another test based on the operational methods employed during this test; however, if the LOX leak had not occurred and the V-5001 was not filled to 90% and subsequently drained to 35% another run could have been made. The LOX leak resulted in a loss of 9.2% of the GN₂ inventory and filling V-5001 from 35% to 90% and subsequent draining to 35% took 31 minutes during which time 7.7% of the useable GN₂ inventory was utilized; therefore, the total of the LOX leak usage, post-test unused inventory (7.7%) and the V-5001 liquid level sensors checkout usage is 24.6% of GN₂ inventory as compared to the 21.2% used during the run phase.

In addition to the aforementioned considerations, the following action would decrease the overall nitrogen usage:

TABLE II

GN₂ USAGE

Operation ⁽¹⁾	Inventory Used % of Available (2470 → 500 psi)	Avg. $\frac{dp}{dt}$ psi/sec
1. Header Pressurization	3.1	_____
2. TSER Initial Inerting 1st LOX Tank Press. 1st Propane Tank Press.	9.2	.125
3. Second TSER Inerting 2nd LOX Pressurization Short Flare Purge Short ETC Purge UTSM Purge (1 pps)	9.7	.125
4. V-5001 Fill & Chill (1.08 hrs) a) UTSM Purge (1 pps) b) TSER (1.4 pps) c) ETC (intermittent) d) Steam Generators (short)	18.8	.082
5. Run Phase a) Steam Generators b) ETC Purge c) UTSM Purge d) LOX and Propane Tank Pressurization	21.1	.4 psi/sec
6. Post Run Phase	25.6	_____
7. Miscellaneous Holds	4.9	_____
8. Unused Inventory	7.7	_____

(1) Usages such as shield purge, valve actuation are included but not listed.

1. Fill V-3401 and V-2801 to the maximum fill level.
2. Initiate 1 pps UTSM purge and use only when necessary, for instance immediately before RSV-132/455 is opened.
3. Decrease the purge ring flow during the run and use the O_2/H_2 sensors for criteria for purging.
4. Operate the nitrogen compressors after the header pressurization. Vent if the header pressure reaches 2495 psi.
5. Install a filter in the cross-over line between the high pressure system (3500 psi) and the low pressure system (2500 psi) so that the two systems can be equalized after the high pressure vessels have decayed to a pressure which would result in a total system pressure lower than 2500 psi after equalization. There appears to be an imbalance in the two individual system usages; therefore, the most efficient use would result from the combination of the two systems.
6. Increase the V-3801 pressure to 50 psig to decrease the V-5001 fill and chill time if GH_2 usage is not a problem.
7. Evaluate the 1 pps UTSM purge requirement to determine if it can be reduced.
8. Operate the TSER, Duct Vault and Pipe Chase inerting valves only as necessary to hold the O_2 concentration below 5%.

In summary, the usage data indicates that two runs similar to the one conducted during XECF-EP-I can be supported with the present GN_2 inventory if no long holds are experienced and if the V-5001 fill and chill operations are limited to a 30% fill operation. The duct vault and pipe chase usages are discussed individually in SPEAR Memo No. 21.

GHe Usage

The sources for gaseous helium are three 1760 cu. ft. storage vessels. The helium was used during XECF-EP-I for the following uses: 1) engine valve actuation; 2) ETC repressurization system; 3) engine warmup; and 4) engine trickle purge and TPA bearing purge.

The GHe usage during XECF-EP-I is listed in Table III.

The normal useful pre-run to post-engine run inventory is 3090 lbs. based on an initial pressure of 2500 psia and a final pressure of 1500 psi. Estimates of the fluid requirements for warmup evidences that 4100 lbs of GHe would be required to warm the engine up to 500°R, therefore, a complete warmup between runs is not possible with helium only. The pre-run and post-run usages have not been broken down into individual usages. The

usages include the PSL purge through RSV-142, engine and TPA purge through RSV-446 and GH_2 header pressurization.

GH_2 Usage

The gaseous hydrogen sources are three 2400 cu. ft. vessels, where were initially pressurized to 2470 psia. The pertinent GH_2 usage data is presented in Table IV.

The total GH_2 inventory is 5980 lbs. The usage during the test was 1100 lbs. The estimated hydrogen usage for warmup is 1500; therefore, approximately 2400 lbs. is available for the LH_2 insertion tests if EP-II is conducted in a similar manner.

In summary, the GH_2 inventory is adequate to support the next test series as now planned.

H. B. Randt (Bm)

TABLE III

GHe USAGE

<u>Operation</u>	<u>Usage</u>	<u>Comments</u>
1. Pre-run Usage (45021-62800)	1613 lbs.	Vessel pressures decreased from 2608 to 2010 psia.
2. ETC Repressurization System	534 lbs.	Inadvertant trip of PCV-449.
3. Engine Warmup 148° R to 347° R	1000 lbs.	PCV-471 opened at 62997, closed at 63554 - engine warms up.
4. Post Run Usage	1387 lbs.	

TABLE IV
GH₂ USAGE SUMMARY

<u>Operation</u>	Initial Pressure (psia)	Final Pressure (psig)	Usage (lbs)
1. GH ₂ Header Pressurization	2470	2413	46
2. V-3801 Press. from 0 to 47 psia	2410	2307	76
3. Transfer of LH ₂ from V-3801 to V-5001	2273 2090	2118 1704	111 295
4. V-5001 Press. from 0 to 31 psia	2106 1685	2088 1661	25 25
5. Transfer LH ₂ back to V-3801	1685	1414	212
6. Run Phase	1349	1342	5
7. Post-test	134	994	278
8. Hold Losses	----	----	27
TOTAL USAGE			1100

Header Press.

1st LOX Tank Pressurization

TSER Initial Inerting

ETC Purge FCV-50 Opened
UTSM Purge PCV-447 Open

LOX Tank Depressurization

Closed PCV-50

LOX Tank Press.
C₂H₂ Tank Press.
C₂H₂ and LOX Tank Press. stopped
LOX Tank Press.
Cont'd.

FIGURE 1

Subject: NTO PRODUCT ASSURANCE STATUS REPORT

PRE-RUN ACTIVITIES

ETC Inspection

Prior to the closing of the shields on 3/21/68, a visual inspection of ETC was accomplished. The brackets on the shields, which were noted subsequent to NEP-HE-2, were removed and the inspection revealed that the bolts on the nozzle exit closure flange were not safety wired. The bolts were safety wired by E-MAD personnel.

UTS Water Leak

There were indications that there was water leakage in the UTS. The inspection made of the interior of the UTS could not establish the origin of the water. Photographs were made of the areas where the water was dripping from the UTS and are now in ETS-1 Product Assurance files.

Interior of Duct

The interior of the duct was inspected and the result revealed there has been no change in the interior. There were indications that the water which had been leaking from the UTS had drained into the interior of the duct system.

RUN DAY - DIR'S INITIATED

The following is an account of the run day discrepancies including the portion covering the run day checklist and run day operations.

During Status Board operations, Product Assurance was responsible for reviewing various checklists which must be accomplished prior to the run. In a number of cases the checklists were marked in certain areas with NA (not applicable). These checklists were returned to the initiator with a request to indicate the specific reasons why a particular operation was not applicable.

Prior to the actual Control Room operations, the following discrepancies were documented on run day:

1. The main hydraulic pump for the hydraulic actuated valve malfunctioned. Indications were oil starvation, probably caused by a leak in the accumulator. However, the pump was replaced and the system was determined to be operational for the test. QRDR #2656 was initiated and NTO Product Assurance is going to follow up with NTO Engineering to insure determination of the specific cause of the problem.

XF

2. Prior to the test the PDV was determined to be stuck in the open position. It was determined that the solenoids appeared to be operating, but the valve did not move. The exact cause of the problem will have to be investigated subsequent to XECF.

Run Operations - The Steam Generator Module #1 did not operate.

Indications were electrical problems - water in the control cable connector. ETS-1 Engineering is currently examining the problem and it is anticipated that a fix will be established which will eliminate the water and corrosion problem. DIR #756 was issued denoting all conditions which were considered abnormal.

The following is the remaining list of discrepancies which occurred during the run and which were discussed subsequent to the run:

- DIR #738 - Liquid oxygen leak developed where RSV-235 is located.
- DIR #739 - There was a considerable amount of unidentifiable noise on Net 10.
- DIR #740 - When pipe chase Fan #1 was activated a start indication on the TIE console was not present.
- DIR #741 - RSV-22 did not respond to the close command until the 4th attempt.
- DIR #742 - The position indication for RSV-853 was lost on the LFE console.
- DIR #743 - No response from PCV-621 when command was given from LFE console.
- DIR #744 - A searchlight was left in direct line of LOX bleed during bleed-in of LOX header.
- DIR #746 - The indication for FI-31 was lost on LFE console.
- DIR #747 - A trip indication for PCV-449 is present on TIE console for no apparent reason.
- DIR #751 - A helium leak developed at blind flange LB-34.
- DIR #752 - Pipe chase louvers wall vibration occurred during XECF EP-1 Test.
- DIR #753 - The PCV-164/180 error meter too sensitive causing control problems.
- DIR #754 - The heat from the V-5001 flare tripped the water deluge system causing severe facility water system oscillations.
- DIR #755 - The digital tape transport #1 did not pull tape at uniform rate.

NOTE: Range time of problem 62822 through 62850.

POST FIRE INSPECTION - Steam Generator Inspection - Steam Line Inspection -
Exterior of Duct Inspection

The steam line was inspected and found to have moved within the limitations anticipated and the apparent decision is to make only minor adjustments in the hanger prior to the next XECF EP. The exterior of the duct was visually inspected including the top bellows and no particular anomalies were noted. The inspection of the duct vault inerting system indicates there are approximately three or four locations where the metal screws securing metal sheeting to the frame were "popped" loose as a result of the sheathing vibration noted during the run. In addition, two of the cross members above the duct exit area appeared to be bowed. NTO Site Engineering indicated that they will provide an engineering change to remedy the problems. At the exit of the nozzle through the wall on the top side of the duct several of the bolts which retain a rubber gasket to the inerting wall were loosened or physically missing. It appears vibration of the wall caused the problem.

Post fire inspection of the steam generator revealed very little change in the igniters and injectors for Units #2 and #3. Unit #1 was not utilized for this test.

Injector S/N 01 has four small pinholes in the weld area of LOX Spud #1. These pinholes range in size from approximately .022 to .005 in diameter, with an unknown depth. There are two pinholes of approximately the same size in the weld areas on the weld on the outside periphery of the injector face. A fuel film coolant orifice in the areas immediately outside LOX spud weld have some indications of enlargement by erosion.

On LOX Spud Weld #1 there are four film coolant holes enlarged.
On LOX Spud Weld #2 there are two film coolant holes enlarged.
On LOX Spud Weld #4 there are four film coolant holes enlarged.
Injector S/N 0017, which was removed from Unit #2, LOX Spud Weld #1, had five film coolant holes enlarged.
On LOX Spud Weld #2 there are six film coolant holes enlarged.
On LOX Spud Weld #3 there is one film coolant hole enlarged.

A boroscopic inspection of the igniter removed from Unit #3, S/N 880003, revealed eroded areas approximately 1/8" in diameter in the first stage chamber area and approximately 1/2" upstream from the first stage throat area. This erosion does not appear to have a significant depth. A leak check was made of igniter S/N 880004 and S/N 880003 removed from Unit #2 and #3 at 70 psig pneumatic. This pressure was maintained for approximately 10 minutes with no pressure decay. Inspection of the combustion chamber S/N 0017 on Unit #3 and 0019 on Unit #3 revealed no changes since the last inspection was performed just prior to XECF EP-I. There was evidence of carbon deposits in the areas of the water injection pintles. These carbon deposits are normal in this area.

Removed the propane filter and the filter was found to contain almost as much contaminants as was experienced subsequent to NEP-He-2. A QRDR #2649

was initiated and the specific remedy to the problem has not been determined by ETS-1 Engineering personnel.

The inspection of the interior of the exhaust duct has not been made as of this date. However, inspection of the interior of the exhaust duct is to be made prior to XECF EP-II in accordance with NTO-I-0301.

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