NTO-R- 0161

SPEAR TEAM REPORT

**N E S STEAM LINE
DESIGN DEMONSTRATION
TESTS**

**PHASE I
SEPARATOR CHECKOUT**

OCTOBER 18, 1968

950 0447

NERVA TEST OPERATIONS
Jackass Flats, Nevada

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SPEAR TEAM REPORT

TO: TEST REVIEW BOARD
N. Leerskov, D. Reilly, P. W. Davison
DATE: 18 October 1968
NTO-M-25839
FBD:cjd

FROM: SPEAR Team

SUBJECT: SPEAR Reports, NES Steam Line Demonstration Tests, EP-I and EP-II

ENCLOSURES: (1) through (10) SPEAR Memoranda (see Table of Contents)

Enclosed are the final SPEAR Team memoranda for NES Steam Line Demonstration Tests, EP-I and EP-II. The SPEAR Team activity following EP-I stressed the evaluation of problem areas in order to proceed with EP-II and does not have individual memoranda except as related to EP-II.

The memoranda cover detailed analyses of the facility and data processing systems by individual SPEAR Team members of the Facility and the Instrumentation Groups.

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18 October 1968

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71362

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: SUMMARY OF SPEAR ANALYSES

INTRODUCTION

This memo summarizes the SPEAR Analyses for Phase I NES Steam Line Demonstration Tests conducted on October 3 and 9, 1968. These tests were performed at ETS-1 to checkout the Steam Separator installed to prevent water entering the steam line during emergency shutdown of the SGS. In addition, water interaction information was obtained to evaluate the water coverage provided by the test stand cooling system and the modifications to the duct discharge water piping.

All test objectives were successfully met. A description of the tests as run and the detailed chronology is in Memo No. 10.

SUMMARY

The following summarize the SPEAR findings.

SGS Performance

The Steam Generating System (SGS) was run for a total of 1436 seconds (two module operation) during Tests 1, 2, and 3. Several anomalies occurred during the test series, the majority of which were due to component failures.

The induced water interaction had a pronounced effect on the steam temperature causing it to rise to 1850°R, however, the PCV-449 circuit did not trip during the interaction or when the operator increased the water flow to reduce the Steam temperature.

Separator Performance

Hot core temperature pattern exists in the gas mixture at the inlet.

At the outlet, the temperature is uniform across the gas stream, and at times, this temperature is higher than the average inlet temperature.

The sump temperature is always below the steam inlet temperature but above the saturation point during the period of closed drain valve.

The pressure drop across the separator is 11 psi.

During emergency shutdown, fluid below the saturation temperature entered the outlet.

Water Flow Test

Water coverage to the duct vault door, the test stand weather door, the east duct vault wall, the stairway, and the concrete/gunite pads was adequate when the duct was at full flow; the water coverage to the test stand was adequate only when RSV-937 was open.

Flow through RSV-937 completely covered the front of the test stand. This indicates that flow to the test stand (TS-1 and TS-2) through FCV-31 is not required when RSV-937 is open.

NES Duct Coolant System

The modifications made to the duct water discharge piping did not adversely effect the duct water flow rates. The percent of total flow in each section and the system flow coefficient (kw) were the same as in previous runs. Opening of RSV-937, or activation of Zone 8 fire protection system results in a duct water flow dip. These temporary decreases in water flow do not adversely affect duct performance.

NES Performance

Temperature surges were observed during Test No. 3 which was conducted at a steam temperature of 1510°R. The temperature variations are a result of steam line pressure surges which directly affect the injection water flow. These pressure surges are not associated with any blockage in the steam line or intermittent operation of the separator drain valve.

The separator pressure drop of 11 ± 4 psid is well above the predicted value of 5 psid which adds an additional impedance that was not experienced during previous testing programs. This added impedance increases the module chamber pressure and decreases the differential water pressure available for flow control.

With the steam line installed resulting in an even higher back-pressure than experienced in Test No. 3, initial two unit full steam operation, at the same conditions as Test No. 3, will start at approximately 1100°R and temperature control will be even more sensitive to any pressure surges.

Data System

Of 44 line items reported on EP-II, 24 line items had useable data and 15 had correctable data. Only 5 measurement channels, listed in Enclosure (1), may have lost data. (Following EP-I, 25 channels were suspect). The list of anomalies reported to NTO Data Acquisition and Data Reduction groups immediately after EP-I were expeditiously handled by all concerned. No wide band FM tape information was reviewed during this SPEAR effort.

RECOMMENDATIONS

Following are the SPEAR recommendations from this series of tests:

1. Investigation of Hot Core Temperature profile should be conducted to explain fully the observed phenomena that the outlet steam temperature is higher than the inlet. (Reference Memo # 2)
2. The separator design should be reviewed to determine whether modifications can be incorporated to reduce the separator pressure drop to within design limits. (Reference Memo # 2)
3. Determine whether the thermal stresses induced in the inlet and outlet piping during the simultaneous shut-down, due to circumferential ΔT are acceptable. (Reference Memo # 2)
4. LCV-407 differential pressure setting should be checked prior to testing. (Reference Memo # 3)
5. The propane fill line filter should be checked after each truck unloading operation. (Reference Memo # 3)
6. The propane manifold filter (LF-436) should be checked after each EP. (Reference Memo # 3)
7. New type pressure switches that will exhibit more reliability than the existing switches should be procured and installed prior to Steam Line Separator Phase II testing. (Reference Memo # 3)
8. The low pressure side of PDS-413-1, -2, and -3 should be changed from the top of the combustion chamber to the bottom of the chamber. (Reference Memo # 3)
9. FCV-31 valve opening should be slowed down from 15 seconds to about 30 to 45 seconds. (Reference Memo # 3)
10. The water interaction of opening Zone 8 and its effect on steam generator operation and the PCV-449 trip circuit should be checked during Phase II testing. (Reference Memo # 3)
11. The water interaction of opening FCV-32 and RSV-937 should be checked during Phase II to determine its effect on steam generator operations. (Reference Memo # 3)
12. The water injection system should be evaluated and made insensitive to plenum pressure surges. (Reference Memo # 4)
13. The separator should be evaluated and modifications considered to reduce the pressure drop to the design limits. (Reference Memo # 4)

14. Efforts should be continued to determine the cause of the plenum pressure and temperature surges. (Reference Memo # 4)
15. The electrical connections within the SGS module control boxes are exposed to water because hydraulic systems are also contained within the boxes, and the wiring can be expected to become wetted from time to time. This condition should be reviewed and action taken to prevent moisture contact with any wiring, electrical equipment or terminals which could disrupt generator operations. (Reference Memo # 5)
16. The finding of welding rod pieces within the separator after EP-I, indicates careful examination of the steam system for contaminants, together with close control of system access, is especially important to prevent possible damage during future test operations. Reference Memo # 5)
17. Direct nozzles on the upper concrete apron coolant pipe downward toward concrete aprons and eliminate 33% of them. (Reference Memo # 6)
18. Reduce duct vault door and test stand weather door water flow by eliminating 10% of the nozzle area. (Reference Memo # 6)
19. Since flow from TS-3 and TS-4 completely covers the front of the test stand and the flow through FCV-31 covers the remaining areas, RSV-935 is not required. (Reference Memo # 6)
20. When the Test Stand Cooling System is required, RSV-937 should be opened and FCV-31 should be opened to achieve a minimum pressure of 35 psig at P-863. (Reference Memo # 6)
21. The Test Stand Cooling System should be checked during Phase II testing to verify the new duct vault inerting wall coverage as well as the test stand coverage at rated duct flow conditions. (Reference Memo # 6)
22. Although the activation of Zone 8 fire protection and RSV-937 have no adverse effect on the duct flow rates, it is recommended that the opening times of FCV-31 and RSV-937 be increased in order to prevent pressure oscillations in the SGS or other water systems. (Reference Memo # 7)
23. It was noted that the minimum required flow through section 2 was not obtained. This is a result of holding 14.0 psid at F-56 rather than 15.7. Although the flow rate was not critical for this test, in future tests it is required that the F-56 ΔP be set at a minimum of 15.7 psid and maintained. (Reference Memo # 7)
24. ETS-1 Data Acquisition personnel should indicate to Data Processing personnel what calibration sequence number should be used for each channel. (Reference Memo # 8)

25. Properly identify all traces found on oscillograms. (Reference Memo # 8)
26. Make duplicates of all strip charts and oscillograms as soon as possible, Z-fold the duplicates prior to delivery to SPEAR. (Reference Memo # 8)
27. Perform special calibrations such as zero-pressure and valve trace calibrations before each major experimental plan. (Reference Memo # 8)
28. Complete listing of channels subject to data foldover. Continue corrective modifications as time and budget permit. (Reference Memo # 8)
29. Re-emphasize completeness and accuracy of Datalog. (Reference Memo # 8)
30. Consider need for and method of improving FE channel calibration technique. (Reference Memo # 8)
31. The thermocouple probe installation fittings should be examined for possible changes in the installation procedure or change in materials, such that the loosening of these fittings will not occur during tests. (Reference Memo # 5)

PHASE I NES STEAM LINE DEMONSTRATIONS TESTS

SUBJECT: WATER SEPARATOR PERFORMANCE

INTRODUCTION

The primary objective of the water separator in the steam line is to prevent water from going to the steam line during emergency shutdown of the steam generator. The initial design criteria of the separator was as follows:

1. Operating pressure, 135 psia.
2. Operating temperature, 1400°F.
3. Flow rate 140 pps of steam mixture.
4. Service life, 100 hours at temperature.
Normal shutdown 5000 cycles, and emergency shutdown 25 cycles.
5. The pressure drop across the separator shall be about 5 psi.

The operating temperature was later lowered to 1100°F.

The thermal shock in the separator during steam generator shutdown was expected to be severe; therefore, a thermal shield was designed as part of the separator.

For demonstration test, the steam line and the ejector were simulated by the exhaust stack and the orifice nozzle. Three tests were conducted. Test No. 1 was a loc temperature run. Post-test inspection discovered that the thermal shield inside the separator was severely distorted. The shield was removed from the separator for the remaining tests.

Test No. 2 was to operate at a steam temperature of 1260°R followed by normal shutdown; and test No. 3 at 1510°R followed by emergency shutdown. Difficulties in control of steam temperature and pressure which fluctuated excessively were experienced during both tests.

The pressure drop across the separator was in the neighborhood of 11 psi. During emergency shutdown, fluid below the saturation temperature was present in the outlet of the separator. Detailed discussion of the test results is presented below.

TECHNICAL DISCUSSION

Data Acquisition

The following data were collected during the tests:

1. Steam temperature and pressure upstream of the separator inlet,
2. Steam temperature and pressure at the separator outlet,
3. Sump temperature of the separator,
4. Steam temperature at the nozzle, and
5. Skin temperature of the pipe upstream of the separator inlet.

The location and number of the thermocouples and pressure probes are shown in Figure 2-1. The accuracy of the thermocouples is $\pm 1^{\circ}\text{F}$; and the pressure transducer, $1/4\%$.

Inlet Temperature Distribution

The steam temperature at the separator inlet was measured by the following thermocouples with noted depths of penetration into the gas stream.

TE-582, 1"; TE-583, 3"; TE-584, 5"; and TE-583, 1/4".

Except that TE-585 went bad during the early part of Test No. 2, all the other three produced good data as shown in Figures 2-2 and 2-3. The data indicate that "hot core" phenomena exist throughout the full steam time range during both Tests No. 2 and No. 3. The radical temperature pattern for a few selected time points is plotted in Figure 2-17.

All the plots are consistent in shape. Since no data was available near the wall, the lowest pipe skin temperature was plotted instead. During full steam condition, no skin temperature is below the saturation temperature of the steam, it can be concluded that no water was present in the steam.

During shutdown, the temperature plot in Figure 2-17 is reversed in shape indicating reverse heat flow from the hot pipe to the coolant water.

Outlet Temperature Distribution

The outlet temperature was measured by TE-586, -587, -588, -589 and -590 with depths of penetration and at locations as shown in Figure 2-1. TE-588 and -590 malfunctioned during Test No. 2. The time-temperature chart of the other three was shown in Figures 2-4 and 2-5. The data indicated uniform temperature distribution over the cross-section of flow reflecting the mixing effect of the separator.

It is noted that during full steam periods, the outlet temperature is higher than the average recorded inlet temperature at times. This indicates that from the principle of balance of energy, the inlet temperature at the center is substantially higher than recorded at the 5" penetration.

During normal shutdown the outlet temperatures remained uniform above the saturation point indicating no water carry-over in the steam. During emergency shutdown, TE-589 located at 30° from the bottom showed an abrupt temperature drop from 1540°R to 647°R within 5 seconds, while TE-586 and -587 dropped only to 1141°R. At this time, the pressure is 13.4 psia and the saturation temperature (667°R) is higher than 647°R which was measured near the bottom of the elbow. After the abrupt drop, TE-589 recovers gradually and TE-586 and -587 continue to drop at a lower rate to approach a uniform temperature again.

This temperature pattern indicates the presence of fluid at a temperature slightly below the saturation temperature in the separator outlet. This is further substantiated by visual observation of the IR equipped TV picture which showed small black splotches in the elbow just after shutdown. The recovery of TE-589 after its abrupt dip indicates that residual heat in the metal is increasing the fluid temperature.

Exhaust Temperature

The exhaust temperature was measured by TE-850 at 18" upstream of the orifice as shown in Figure 2-1. The data as shown in Figure 2-6 and 2-7 indicates wild oscillation of temperature during the latter part of Test No. 2 and during a large part of the full steam period of Test No. 3. During emergency shutdown, the temperature profile and magnitude are similar to that of TE-589 at the separator outlet.

Sump Temperature

The sump temperature measured by TE-591 is shown in Figure 2-6 and 2-7. It is always above the saturation temperature during full steam condition indicating no water in the sump at full steam.

Drain Temperature

The drain temperature can be closely represented by the sump temperature. During Test No. 2 the drain valve RSV-439 closes at a superheated steam condition of 112 psia and 860°R during startup. It opens at shutdown also at a superheated state. It is assured that the drain valve was not closed when there was water in the sump. During Test No. 3, at startup, the valve also closes at superheated condition. During the emergency shutdown, the valve was commanded to open at the same instant the steam generator was commanded to idle. The signal was given at 71295 sec. Allowing 2 seconds for the valve opening time, the temperature in the sump is about 1250°R at the time of open as shown in Figure 2-8. The sump reaches saturation temperature at about 3-1/2 seconds after the commanding signal. There is a time delay in thermocouple response which may be compensated for by the response of the steam generator control and the time required for the water to flow from the steam generator to the sump. Taking all into consideration,

it is likely that no water enters the sump prior to the opening of the drain valve during emergency shutdown.

Pipe Skin Temperature

The pipe skin temperatures at the inlet at different circumferential locations exhibit a maximum spread of 150°F during the normal shutdown test as shown in Figure 2-9. The maximum spread during emergency shutdown as shown in Figure 2-10 is 500°F . At the outlet of the separator, the maximum spread during emergency shutdown is probably greater than 500°F because the steam mixture shows a larger temperature difference between top and bottom of the stream at the outlet than at the inlet. (See Figures 2-3 and 2-5)

The drain pipe temperature of the first carbon steel section about 15' downstream of the separator, TE-607, was 735°R maximum as shown in Figure 2-11 for Test No. 2, and 770°R maximum as shown in Figure 2-12 for Test No. 3. No abrupt changes were observed during either test. This temperature is well within the design temperature of 700°F .

Pressure Drop Across the Separator

The pressure drop across the separator as shown in Figures 2-13 and 2-14 oscillates frantically. The mean value is 11 psi during full steam condition, which is more than twice of the expected 5 psi in design. The separator inlet and outlet pressure, PT-864 and PT-865, shows also wide fluctuation but in phase as seen in Figures 2-15 and 2-16.

CONCLUSION

The above data analysis can be summarized as follows:

1. Hot core temperature pattern exists in the gas mixture at the inlet.
2. At the outlet, the temperature is uniform across the gas stream, and at times, this temperature is higher than the average inlet temperature.
3. The sump temperature is always below the steam inlet temperature but above the saturation point during the period of closed drain valve.
4. The pressure drop across the separator is 11 psi.
5. During emergency shutdown, fluid below the saturation temperature entered the outlet.
6. The steam temperature and pressure fluctuations were excessive.

7. The differential circumferential metal temperature is 500°F at the inlet during emergency shutdown. Higher ΔT could exist at the outlet piping.
8. The ΔP design objective (about 5 psid) has not been met.

RECOMMENDATIONS

The following actions are recommended:

1. Investigation of Hot Core Temperature profile should be conducted to explain fully the observed phenomena that the outlet steam temperature is higher than the inlet.
2. The separator design should be reviewed to determine whether modifications can be incorporated to reduce the separator pressure drop to within design limits.
3. Determine whether the thermal stresses induced in the inlet and outlet piping during the simultaneous shutdown, due to circumferential ΔT are acceptable.

Fig 2-1

FIGURE 2-1

ETS-I STEAM SEPARATOR
INSTRUMENTATION LOCATION

Fig 2-2a

Fig 2-26

Fig 2-3a

SEP C/O PHASE I EP2 10/9/6

GAS STEAM INLET TEMP

1	---	TE582..	---	RANKINE
2	---	TE583..	---	RANKINE
3	---	TE584..	---	RANKINE

Fig 2-4a

Fig 2-4 b

Fig 2-52

Fig 2-56

SEP C/O PHASE I EP2 10/9/6
GAS STEAM ALT TEMP

1	★	TE586..	★	RANKINE
2	★	TE587..	★	RANKINE
3	★	TE589..	★	RANKINE

Fig 2-60

UNIT 1 - PLOT 5 S00-1

DECREES RANKINE

SEP 070 PHASE I EP-2 10/09/6
S00-1

500-1

2:15, 16

2000
 2001
 2002
 2003
 2004
 2005
 2006
 2007
 2008
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 2012
 2013
 2014
 2015
 2016
 2017
 2018
 2019
 2020
 2021
 2022
 2023
 2024
 2025
 2026
 2027
 2028
 2029
 2030

RANKINE
RANKINE
RANKINE
RANKINE

~~1/2 oz of essential oil of orange 13.2 ml~~

NEED FIND AN EASY-TO-REACH
ADDRESS BET-1.50

SG-2 TO 1DLE

56-3 TO 1016

509-2 JAN 20 1965
509-3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
---	---	---	---	---	---	---	---	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----

EX-31 C-450

57860.0

57940.0

58020.0

50100.0

Fig 2-76

70970.0

71050.0

71130.0

71210.0

71290.0

71370.0

71450.0

Fig 86

SEP C/O PHASE I EP-2 10/09/6
SEP IN/OUT, SUMP TEMP

TES84
TES91
TES88
TES50
RANKINE
RANKINE
RANKINE
RANKINE

UNIT 2
PLBT
5 SEP IN/OUT, SUMP TEMP
TEMP DEG R

Fig 2-9a

UNIT 1 FLEET 8 500-4

SEP C/O PHASE I EP-2 10/09/6
800-4

Fig 2-10a

SEP C/O PHASE I EP-2 10/09/6
500-4

Fig 2-13a

Fig 2-13b

Fig 2-192

Fig 2-196

Fig 2-15

SEP C/O PHASE I EP-2 10-9-68
STEAM PRESSURE

PT42F..	PSJA
PT664..	PSJA
PT665..	PSJA

Fig 2-16

FIG 2-16

SEP C/O PHASE I EP-2 10-9-68
STEAM PRESSURE

1	PT425..	PSIA
2	PT864..	PSIA
3	PT865..	PSIA

SEPARATOR
C/O PHASE I
EP-2 10-9-68

FIG. 2-17 RADIAL TEMP. DISTRIBUTION OF STEAM AT INLET

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: SGS PERFORMANCE

SUMMARY

The Steam Generating System (SGS) was run for a total of 1436 seconds (two module operation) during Tests 1, 2, and 3. Several anomalies occurred during the test series, the majority of which were due to component failures.

The induced water interaction had a pronounced effect on the steam temperature causing it to rise to 1850°R, however, the PCV-449 circuit did not trip during the interaction or when the operator increased the water flow to reduce the Steam temperature.

Test data tabulations for the three tests are shown in Tables 1 through 5.

RECOMMENDATIONS

1. LCV-407 differential pressure setting should be checked prior to testing.
2. The propane fill line filter should be checked after each truck unloading operation.
3. The propane manifold filter (LF-436) should be checked after each EP.
4. New type pressure switches that will exhibit more reliability than the existing switches should be procured and installed prior to Steam Line Separator Phase II testing.
5. The low pressure side of PDS-413-1, -2, and -3 should be changed from the top of the combustion chamber to the bottom of the chamber.
6. FCV-31 valve opening should be slowed down from 15 seconds to about 30 to 45 seconds.
7. The water interaction of opening Zone 8 and its effect on steam generator operation and the PCV-449 trip circuit should be checked during Phase II testing.
8. The water interaction of opening FCV-32 and RSV-937 should be checked during Phase II to determine its effect on steam generator operations.

DISCUSSION

Liquid Oxygen System

During Test 1 the liquid oxygen bleed-in and pressurization were normal. The LO₂ tank pressure remained constant throughout the test, and the flow rate to each module was 16.6 lb/sec. (16.7 lb/sec required).

During the bleed-in for Test 2 LCV-407 opened during tank pressurization thus causing pressure fluctuations in the system. The system was depressurized and LCV-407 was purged to warm up the piping downstream of RSV-496. The system was bled-in and LCV-407 again opened during pressurization. The system was vented and purged and a re-entry team sent in to investigate the problem. It was found that the differential pressure required to close LCV-407 was too high. This was reset to 22 psid and the system was bled-in and pressurized with no anomalies. The flow rate increased from 16.0 lb/sec to 16.4 lb/sec during the test because the tank pressure was manually increased.

The bleed-in and tank pressurization for Test 3 was normal. The flow rate was 15.8 lb/sec at the beginning of the full steam test and increased to 16.2 lb/sec at the end.

Liquid Propane System

During all three tests the propane bleed-in and tank pressurization were normal. There was no evidence of filter plugging during the tests. The propane tank had been cleaned prior to this test series and a filter installed in the tank fill line. After the tank was filled from a truck, the fill line filter was found contaminated with about the same type of solids found in the manifold filter (LF-436) during the XECF test. See Memo No. 5 for a more detailed analysis. The propane flow rate to each module during Test 1 was 7.0 lb/sec and for Tests 2 and 3 was 6.8 lb/sec.

SGS Operation

Test # 1 - The operation at idle and full steam was satisfactory for modules 1 and 3 except for a first stage cutout on Module 1 when it was returned to idle steam from full steam. The pressure switch PDS-413-1 which caused the apparent malfunction was checked and found to be deactivating high. This problem has been intensified somewhat because of the recent modification which deactivated the SGS first stage after start-up. It is recommended that the low pressure side of the switch be connected to the bottom of the combustion chamber rather than the top. This will increase the pressure differential about 10 psi during the shutdown transient and reduce the probability of inadvertently de-activating PDS-413.

Test # 2 - Several apparent malfunctions occurred during this test. The first was when Module 2 was commanded to idle steam and there was a second stage cutoff. Data revealed that there was enough pressure to actuate the pressure switch. The second occurred when Module 1 was running at full steam and Module 3 at idle, Module 1 experienced a low water cutout. Data revealed that there was no loss of differential water pressure. Module 1 was again placed at full steam and the same malfunction happened again.

Module 2 was reset and started to idle steam without experiencing the false second stage cutoff. Modules 2 and 3 were then used for Test 2. A post test inspection revealed that the injection water pressure switch PDS-406-1 was breaking at a high pressure. Also moisture was found in electrical connectors. Memo No. 5 has detailed inspection results and recommendations.

The startups to idle and full steam for this test were normal. The actuation of the combustion chamber pressure (BS-480) switch was not evaluated because of a problem in the acquisition of digital events data.

The SGS controlled reasonably well at $1060 \pm 50^{\circ}\text{R}$ and $1260 \pm 50^{\circ}\text{R}$.

Test # 3 - Modules 2 and 3 were used for this test because of the apparent malfunction encountered during Test 2. Also, no perturbation of the water system was planned because of the high steam temperature that resulted when FCV-31 was opened during Test 2. The duct water flow was established at approximately 40,000 gpm and the modules were brought to full steam. The SGS was adjusted to 1500°R . Attempting to control to this temperature, the operator encountered large temperature and pressure fluctuations. This problem is discussed in detail in Memo 4.

The operating modules were returned to idle steam simultaneously from operating conditions to simulate a malfunction. During this shutdown, Module 3 had a high temperature cutout. Since there are no thermocouples at the same location at the temperature switch the validity of the cutout can not be substantiated. However, it is feasible that there could have been a localized "hot spot" on a shutdown of this nature. A post test inspection revealed no apparent damage to the combustion chamber or the temperature switch. It is recommended that a new temperature switch be installed in the unit.

Water Interaction

During Test 2 when the steam temperature was relatively stable at 1250°R , a water interaction test was initiated by opening FCV-31. FCV-31 caused the steam temperature to climb to such a level that the SGS water injection valves were opened and the opening of FCV-31 stopped. However, PCV-449 did not trip at any time during this interaction test. Figure 1 shows various parameters during this test. When the injection valves (FCV-423 X and Y) were opened, the steam temperature, which lags the water manifold pressure significantly, was peaking and probably would not have gone much higher than 1850°R .

Figure 2 shows the SGS water manifold pressure during various perturbations in the water system, namely FCV-32 opening, Zone 8 opening, and RSV-937 opening. All of these events occurred after FCV-31 had opened and for the last two after FCV-32 was open which means that a considerable amount of water was flowing through the duct. It can be seen from Figures 1 and 2 that the FCV-31 opening was the most severe of any of the events. FCV-31 opening caused the SGS manifold pressure to dip 33 psi while Zone 8 caused a dip of 20 psi. To minimize FCV-31

perturbations the valve opening should be slowed down from 15 seconds to about 30 or 45 seconds. It is further concluded that if FCV-31 is 100% open, FCV-32 can be opened without any PCV-449 trip and only cause a minor sustained temperature rise which can be compensated for by opening the injection water valves slightly.

In the case of Zone 8 deluge and RSV-937 opening, there would be no trip of PCV-449 and the steam temperature should peak out at about 200°R above operating temperatures and then recover.

TABLE 1
STEAM GENERATOR SYSTEM TEST DATA TABULATION
 STEAM SEPARATOR - PHASE I - TEST 1 - RANGE TIME 66900

PARAMETERS	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO ₂ Tank Press. (P-49) psia	321				
LO ₂ Manifold Press. (P-421) psia	314				
LO ₂ Manifold Temp. (T-479) °R	169				
Propane Tank Press. (P-118) psia	304				
Propane Tank Temp. (T-483) °R	502				
Propane Manifold Press. (P-420) psia	300				
Propane Manifold Temp. (T-478) °R	506				
Water Supply Press. (P-168) psia	234				
Water Manifold Press. (P-427) psia	211				
Main Stage Propane Venturi (F-405) psia		297.2			
Main Stage Propane Flow (lb/sec)		7.1			
Main Stage LO ₂ Venturi (F-409) psia		299			
Main Stage LO ₂ Flow (lb/sec)		16.6			
Injection Water Venturi (F-406) psid		205			
Injection Water Flow (lb/sec)		50.4			
Water Film Cooling (lb/sec)		4.6	4.7	4.7	
First Stage Press. (P-416) psia		152			
Second Stage Press. (P-417) psia		150			
Main Stage Press. (P-438) psia		70			
One Module Flow Rate (lb/sec)		79.4			
Plenum Press. (P-425) psia					66
Separator Outlet Press. (P-865) psia					64
Separator Outlet Temp. (T-850) °R					735
Total Steam Flow Rate (lb/sec)					90

TABLE 2

STEAM GENERATOR SYSTEM TEST DATA TABULATION

STEAM SEPARATOR - PHASE I - TEST 1 - RANGE TIME 66950

PARAMETERS	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO ₂ Tank Press. (P-49) psia	319				
LO ₂ Manifold Press. (P-421) psia	308				
LO ₂ Manifold Temp. (T-479) °R	167				
Propane Tank Press. (P-118) psia	299				
Propane Tank Temp. (T-483) °R	502				
Propane Manifold Press. (P-420) psia	290				
Propane Manifold Temp. (T-478) °R	506				
Water Supply Press. (P-168) psia	232				
Water Manifold Press. (P-427) psia	203				
Main Stage Propane Venturi (F-405) psia		287		286	
Main Stage Propane Flow (lb/sec)		7		7	
Main Stage LO ₂ Venturi (F-409) psia		295		295	
Main Stage LO ₂ Flow (lb/sec)		16.6		16.6	
Injection Water Venturi (F-406)		199		195	
Injection Water Flow (lb/sec)		49.7		49.3	
Water Film Cooling (lb/sec)		3.5	3.5	3.4	
First Stage Press. (P-416) psia		171		171	
Second Stage Press. (P-417) psia		170		168	
Main Stage Press. (P-438) psia		124		128	
One Module Flow Rate (lb/sec)		77.3		76.8	
Plenum Press. (P-425) psia					119
Separator Outlet Press. (P-865) psia					116
Separator Outlet Temp. (T-850) °R					780
Total Steam Flow Rate (lb/sec)					159

TABLE 3

STEAM GENERATOR SYSTEM TEST DATA TABULATION

STEAM SEPARATOR - PHASE I - TEST 2 - RANGE TIME 57800

PARAMETERS	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO ₂ Tank Press. (P-49) psia	312				
LO ₂ Manifold Press. (P-421) psia	304				
LO ₂ Manifold Temp. (T-479) °R	167				
Propane Tank Press. (P-118) psia	295				
Propane Tank Temp. (T-483) °R	504				
Propane Manifold Press. (P-420) psia	287				
Propane Manifold Temp. (T-478) °R	506				
Water Supply Press. (P-168) psia	228				
Water Manifold Press. (P-427) psia	204				
Main Stage Propane Venturi (F-405) psia			283	284	
Main Stage Propane Flow (lb/sec)			6.9	6.9	
Main Stage LO ₂ Venturi (F-409) psia			288	290	
Main Stage LO ₂ Flow (lb/sec)			16.4	16.5	
Injection Water Venturi (F-406) psid			137	131	
Water Valve Position (D-423) %			24.7	27.6	
Injection Water Flow (lb/sec)			39.2	38.2	
Water Film Cooling (lb/sec)		3.4	3.3	3.3	
First Stage Press. (P-416) psia			173	173	
Second Stage Press. (P-417) psia			171	171	
Main Stage Press. (P-438) psia			132	132	
One Module Flow Rate (lb/sec)			66.4	65.6	
Plenum Press. (P-425) psia					122
Separator Outlet Press. (P-865) psia					114
Separator Outlet Temp. (T-850) °R					1211
Total Steam Flow Rate (lb/sec)					136.4

TABLE 4

STEAM GENERATOR SYSTEM TEST DATA TABULATION

STEAM SEPARATOR - PHASE I - TEST 2 - RANGE TIME 57615

PARAMETERS	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO ₂ Tank Press. (P-49) psia	312				
LO ₂ Manifold Press. (P-421) psia	303				
LO ₂ Manifold Temp. (T-479) °R	170				
Propane Tank Press. (P-118) psia	294				
Propane Tank Temp. (T-483) °R	504				
Propane Manifold Press. (P-420) psia	286				
Propane Manifold Temp. (T-478) °R	507				
Water Supply Press. (P-168) psia	227				
Water Manifold Press. (P-427) psia	202				
Main Stage Propane Venturi (F-405) psia			282.	283.	
Main Stage Propane Flow (lb/sec)			6.8	6.8	
Main Stage LO ₂ Venturi (F-409) psia			288.	290.	
Main Stage LO ₂ Flow (lb/sec)			16.2	16.3	
Water Valve Position (D-423) %			26.4	28.	
Injection Water Venturi (F-406) psid			148.6	140.9	
Injection Water Flow (lb/sec)			40.9	39.8	
Water Film Cooling (lb/sec)		3.5	3.3	3.4	
First Stage Press (P-416) psia			170.	169.	
Second Stage Press. (P-417) psia			166.	166.	
Main Stage Press. (P-438) psia			127.	127.	
One Module Flow Rate (lb/sec)			67.9	66.9	
Plenum Press. (P-425) psia					117
Separator Outlet Press. (P-865) psia					109
Separator Outlet Temp. (T-850) °R					1092
Total Steam Flow Rate (lb/sec)					139.3

TABLE 5

STEAM GENERATOR SYSTEM TEST DATA TABULATION

STEAM SEPARATOR - PHASE I - TEST 3 - RANGE TIME 70982.7

PARAMETERS	FACILITY SUPPLY	MODULE 1	MODULE 2	MODULE 3	STEAM LINE
LO ₂ Tank Press. (P-49) psia	303				
LO ₂ Manifold Press. (P-421) psia	297				
LO ₂ Manifold Temp. (T-479) °R	170				
Propane Tank Press. (P-118) psia	289				
Propane Tank Temp. (T-483) °R	499				
Propane Manifold Press. (P-420) psia	280				
Propane Manifold Temp. (T-478) °R	502				
Water Supply Press. (P-168) psia	215				
Water Manifold Press. (P-427) psia	193				
Main Stage Propane Venturi (F-405) psia			277.	277.	
Main Stage Propane Flow (lb/sec)			6.9	6.9	
Main Stage LO ₂ Venturi (F-409) psia			283.	284.	
Main Stage LO ₂ Flow (lb/sec)			16.	16.	
Water Valve Position (D-423) %			25.7	30.2	
Injection Water Venturi (F-406) psid			110.4	96.4	
Injection Water Flow (lb/sec)			35.2	32.9	
Water Film Cooling (lb/sec)		2.9	2.9	3.8	
First Stage Press. (P-416) psia			177.	178.	
Second Stage Press. (P-417) psia			176.	173.	
Main Stage Press. (P-438) psia			138.	142.	
One Module Flow Rate (lb/sec)			63.2	61.7	
Plenum Press. (P-425) psia					128
Separator Outlet Press. (P-865) psia					121
Separator Outlet Temp. (T-850) °R					1506
Total Steam Flow Rate (lb/sec)					122.9

SPEAR MEMO NO 3
FLRP 1

SEP C/O PHASE I EP2 10/9/6
FCV 31 OPENING

WATER INJECTION
VALVES OPENED

1	DF423X.	PERCENT
2	DF423Y.	PERCENT
3	PT425..	PSIA
4	PT427..	PSIA
5	FE850.	RANKINE X 10 ⁻¹

SEP C/O PHASE I EP2 10/9/6
FCV 32 OPENING

1 -*- PT427.. -*- PSIA

SEP C/O PHASE I EP2 10/9/6
ZONE 8 OPENING

1 -*- PT427.. -*- PSIA

SEP C/O PHASE I EP2 10/9/6
RSV 937 OPENING

1 -*- PT427.. -*- PSIA

TIME-SECS.

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: NES OPERATING CHARACTERISTICS

INTRODUCTION

During EP-II, steam temperature surges of approximately 200°R were observed while attempting to maintain a nominal temperature of 1510°R. This memo presents the data observed and discusses its effect on SGS operation. Determination of the source of the oscillations and the corrective action required is continuing and will be documented by a separate report to be issued later by NRO.

SUMMARY

Steam separator Test No. 3 was conducted under the most severe water conditions, i.e., low process water tank level (~15 ft.) and maximum water utilization (duct flow ~38,000 gpm). Temperature surges were observed during this test which was conducted at a steam temperature of 1510°R. The temperature variations are a result of steam line pressure surges which directly affect the injection water flow. These pressure surges are not associated with any blockage in the steam line or intermittent operation of the separator drain valve.

The separator pressure drop of $11 + 4$ psid is well above the predicted value of 5 psid which adds an additional impedance that was not experienced during previous testing programs. This added impedance increases the module chamber pressure and decreases the differential water pressure available for flow control.

It is concluded that with the steam line installed which will give an even higher backpressure than experienced in Test No. 3, initial two unit full steam operation, at the same conditions as Test 3, will start at approximately 1100°R and temperature control will be even more sensitive to any pressure surges.

ANOMALIES

None that effect this analysis.

TECHNICAL DISCUSSION1. Comparison of Test Conditions with XECF Conditions

In order to validate the analysis of this technical discussion, a base point must be established. That point must be the determination of the equivalence between the separator test data and previous data with the steam line connected to the duct.

1. Comparison of Test Conditions with XECF Conditions (Cont'd)

Table 1 presents a tabulation of XECF and separator test data at equivalent steam temperature conditions, namely separator outlet temperature (T-586) for the separator tests and steam line temperature (T-159) for the XECF tests. Approximately 140 ft. of steam line separates these two points but for steady state conditions, they can be considered identical. Evaluation of the table indicates that the 8.5 inch diameter load orifice is too large to simulate duct impedance. Converting the XECF EP-II P-425 for kinetic energy recovery for the equivalent P-865 condition gives a value of $120.4 + 2.4$ or 122.8 psia. Assuming the pressure drop in the new steam line is the same as the old steam line, P-865 should have been 122.8 psia. The values for P-865 for Test No. 2 and Test No. 3 were 114.0 and 111.0 psia, well below the 122.8 psia requirement.

2. Separator Drain Valve, RSV-439, Flow Split

The flow split between RSV-439 and the separator outlet was predicted to be 11.1 lb/sec and 118 lb/sec respectively which should result in an approximate 11 psi pressure plenum pressure increase when RSV-439 closes. The results of separator Test No. 1 conducted on 3 October 1968 with RSV-439 open was evaluated to determine load orifice sizing. Based on the flow split predictions, the load orifices were increased from 8.0 inches diameter to 8.5 inches diameter. The actual test data during EP-II revealed only about a 2 psi pressure increase much less than the predicted 11 psi increase. It is known that RSV-439 closed since the drain line pipe temperature never exceeded 735°R.

A favorable result of this pressure distribution is that an unscheduled opening of RSV-439 should not cause a PCV-449 actuation.

3. Water System Pressure Variations

To determine any variations in the water supply system, Test No. 3 data was compared with a previous test. This comparison is tabulated in Table 2 at the same conditions of steam temperature and duct flow rate.

The data would indicate only a very small change in system flow coefficient and that the water system modifications incorporated prior to the initiation of the separator test program has no detrimental effect, over the previous system.

The pressure oscillations were evaluated at both the 1369°R steam temperature condition and also at a steam temperature condition of 1537°R Table 3 presents this data. The higher the temperature, the more the manifold pressure is affected by chamber pressure feedback oscillations.

4. Evaluation of Temperature and Pressure Fluctuations

A portion of Test No. 3 was evaluated between range time 71144 and 71200 seconds and especially the interval between 71172 and 71180 seconds.

At the start of the overall time span the water flow control valves (FCV-423) were being opened approximately 3% to 33% and 37% respectively for Module No. 2 and No. 3. The flow control valves were not adjusted during the shorter time interval and the valve position varied $33.2 \pm .4$ and $37.1 \pm .4\%$ for Module No. 2 and No. 3 respectively. The total movement on either is less than 1% and this movement should not cause the flow rate variations noted.

Figure No. 1 shows the water control valve position for the time period selected in addition to the Module No. 2 chamber pressure, plenum pressure and separator pressures. Comparison of Figure 1 with Figure 2 shows that the pressure fluctuations in Module No. 2 and No. 3 are in phase with themselves and with the plenum and separator pressures.

Comparing Figure 3, a plot of Separator ΔP (PD-866), with either Figure 1 or 2 shows the ΔP to be generally oscillating in phase with the line pressures.

The water injection flow rates are directly influenced by the system pressure oscillations as shown in Figure 4.

The influence of the plenum oscillations on the water supply manifold, is shown in Figure 5.

The two pressure spikes occurring during the time period 71172 and 71180 are not triggered by any operator action or external system perturbation, yet a temperature excursion to 1550°R from 1325°R was experienced.

The pressure variations are the cause of the temperature excursions.

5. Steam Generator Temperature Control with Steam Line Installed

This section attempts to predict whether steam generator operation can be established at the 1510°R condition with the steam line installed between the steam separator and duct.

Table 2 indicates that P438 is an average of 135 psia, and as discussed in Section 1, with the steam line installed the P425 and also P438 pressure should be between 8.8 and 11.8 psi or an average of 10.3 psi higher. P438 should then be 145.3 psia. Performing a simple steam balance:

NES Operating Characteristics (Cont'd)

$$P_{438} = 145.3 \text{ psia}$$

$$\Delta P = \left(\frac{W}{K_w} \right)^2$$

$$\Delta P_{inj} = \left(\frac{35}{6.6} \right)^2 = 28.0 \text{ psid}$$

$$\text{Injector } K_w = 6.6$$

$$\Delta P_{FCV423} = \left(\frac{35}{15.3} \right)^2 = 5. \text{ psid}$$

$$\text{FCV 423 } K_w = 15.3$$

Neglecting Venturi and other line losses

$$P_{427} = \underline{\hspace{1.5cm}} 178.3 \text{ psia}$$

The minimum pressure necessary for the required injection of 35 lb/sec water is 178.3 psia. Since 191 psia was available for Test No. 3, the system should operate at this 1510°R temperature condition.

The flow rate of water achievable neglecting venturi and other line losses is $\Delta P = 191 - 145 = 46 \text{ psi}$

$$W = K_w \sqrt{\Delta P}$$

K_w of Injector and Valve combined is 6.06

$$w = 6.06 \sqrt{46} = 41 \text{ lb/sec}$$

These flow conditions should result in an initial temperature of 1100°R.

RECOMMENDATIONS

1. The water injection system should be evaluated and made insensitive to plenum pressure surges.
2. The separator should be evaluated and modifications considered to reduce the pressure drop to the design limits.
3. Efforts should be continued to determine the cause of the plenum pressure and temperature surges.

TABLE 1

XECF EP-II RANGE TIME 47562	SEPARATOR TEST EP-II TEST 2 RANGE TIME 57715	SEPARATOR TEST EP-II TEST 3 RANGE TIME 70876.7
P-425 = 120.4 psia	P-425 = 120.6 psia	P-425 = 118.0 psia
P-239 = 115.2 psia	P-864 = 125.9 psia	P-864 = 120.4 psia
T-159 = 1302.6°R	P-865 = 114.0 psia	P-865 = 110.0 psia
$\dot{W}_s$ = 134.7 lb/sec	P-866 = 11.9 psid	P-866 = 9.4 psid
	T-586 = 1309°R	T-586 = 1303.5°R
	$\dot{W}_s$ = 134.2 lb/sec	$\dot{W}_s$ = 132.2 lb/sec

TABLE 2

	PHASE I DDT NEP-IV RT 71430	PHASE I SEPARATOR TEST TEST 3 RT 70952.7	PHASE I SEPARATOR TEST TEST 3 RT 71016.8
P-168 (psia)	213.0	215.4	213.6
P-427 (psia)	192.0	191.8	190.4
P-438x (psia)	130.0	132.4	136.2
P-438Y (psia)	129.0	131.4	133.8
P-425 (psia)	119.0	122.9	126.9
T-159 (°R)	1369.		
T-586 (°R)		1369.	1537.
Ws (lb/sec)	85.9 + Jacket Cooling	81.1 + Jacket Cooling	80 + Jacket Cooling

Jacket Cooling $\sim 40 \times 3 = 125$ lb/sec

$$Kw = \frac{Ww}{\sqrt{P-168 - P-423}} =$$

$$Kw_{NEP-IV} = \frac{206}{\sqrt{21}} = 45$$

$$Kw \text{ tests} = \frac{201}{\sqrt{23.6}} = 41.5$$

TABLE 3

PHASE I SEPARATOR TEST - TEST NO. 3

Time	P-168 (psia)	P-427 (psia)	T-586 (°R)
70938.7 → 70985.7	214.9 ± .7	191.7 ± 2.5	1369
70986.7 → 71040.8	214.9 ± 1.3	193.2 ± 4.1	1537

Specr Memo 4

Figure 1

Spec. Memo 4

Figure 2

SEP C/O PHASE I EP2 10/9/6
SACTO 2

1	PT418V.	PSIA
2	PT438V.	PSIA
3	PT425V.	PSIA
4	PT864V.	PSIA
5	PT865V.	PSIA

Specr Memo 4

Figure 3

SEP C/O PHASE I EP2 10/9/6
HENZE ONE

1 - PDB66 . . - PSID

Spear Memo 9

Figure 1

NH for T.A.K.

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: STEAM GENERATOR SYSTEM CHECKOUT TESTS INSPECTION OBSERVATIONS

ENCLOSURES: (1) Contamination of Steam Separator
(2) SGS Separator Measurements
(3) SGS Plenum Measurements

Following each of the three Phase I tests, inspections were made of the steam generators, steam plenum, water separator and steam piping. Observations made during these post-test inspection activities are described below.

I. EP-I Post-Test Inspection

After test EP-I, conducted on 3 October 1968, the exhaust stack together with the separator outlet 90° elbow, were disconnected from the separator and an internal inspection of the separator was performed from the outlet elbow location.

- A. The internal heat shield (P/N 1135263-8) around the lower cylindrical portion of the separator was found to be dislodged and bent; the shield was deformed such that the upper edge was three to six inches away from the separator wall (instead of the nominal 1-3/8 inch spacing as originally installed), and one lower corner had been bent back from a point near the steam inlet to within about six inches of the "back" of the shield; the entire shield had dropped about six inches into the lower basket (P/N 1135263-9).
- B. Loose pieces of welding rod (two) were found in the basket heat shield, and inspection of the separator drain valve (50-RSV-439) also revealed four pieces of weld rod had entered the valve. Actuation of the valve during the test with weld rod present had damaged the seat; the valve seat was replaced. Later removal of the basket heat shield disclosed three additional pieces of welding rod which were lying on the separator bottom. (See Enclosure (1) for additional information on weld rod pieces.)
- C. Comparison of the pre and post-test measurements of the position of the water separator indicated the change in the separator position was nil. (See Enclosure (2) for separator measurements tabulation.)
- D. Comparison of the pre and post-test measurements of the position of the SGS plenum indicated no significant change in the basic position, but that the plenum may have "stretched" slightly, about 1/16 inch over the distance between the front and rear sliding supports. (See Enclosure (3) for plenum measurements tabulation.)
- E. Examination of the plenum steam outlet flange disclosed that the maximum breakaway torque on the stud-bolts was 25 ft/lbs and some stud nuts were "finger tight". All stud-bolts had been torqued to 500 ft/lbs prior to the checkout test.

- F. The plenum steam outlet flange was disconnected and the following conditions were found:
1. The RTJ sealing ring (No. R-73) was galled in several areas of the sealing surfaces on both sides of the ring.
 2. There was a marked indentation at one location of what appeared to be a screw driver "tip", and this had caused deformation of the ring sealing surface. This indentation was located on the ring, as installed, on the pipe spool side and at about 1:00 o'clock when looking into the plenum flange opening.
 3. In the pipe-spool flange RTJ ring groove, a sliver of metal about ten inches long had been gouged from the inner radius sealing surface edge.
 4. The pipe-spool flange was discolored in the 6:00 o'clock area, indicating hot gas leakage had occurred at this location.
 5. A marked carbon deposit was noted in the plenum flange RTJ ring groove at about 11:00 o'clock (when looking into the flange opening). This was the same area of "soap-bubble" leakage observed prior to the checkout test.
 6. Some white powder-like material was noted as "dust" in the flange sealing grooves.
- G. The water separator inlet flange was disconnected and the RTJ ring sealing grooves were found to contain a considerable amount of a white powder-like material; in one area on the separator flange groove the material had been compressed into a hard layer.
- H. A check of the bolt tightness of the flange on 50-RSV-439 outlet revealed two bolts had loosened and were easily turned with a wrench.
- I. Generator Module No. 1 first stage ignitor pressure switch (50-PDS-413) actuation was checked and the operating pressure values were found to be slightly higher (104 psig/24 psia) than the specified actuation pressures of $95 \pm \frac{5}{0}$ psig make, $15 \pm \frac{5}{0}$ psig break. This out of tolerance condition explains the malfunction shutdown experienced during test no. 1.
- J. The steam generator propane supply line filter (50-LF-436) (100 Micron) was inspected and a brown rust-like granular material was found, some on the filter element but primarily in the filter housing.
- K. Actions taken as a result of the inspections noted above included:
1. The plenum outlet pipe-spool flange sealing groove edge was smoothed with an abrasive stone, and then the groove was "lapped" with grinding compound, using the "best" side of the

R-73 ring, to remove or minimize surface defects in the sealing groove. The plenum flange groove was also "lapped" as described above. The flanges were cleaned and then connected, using a new RTJ R-73 ring.

2. Following disconnection of the separator inlet flange, the separator was moved away about two feet in order to gain entry into the separator at this connection.
 3. The separator heat shields were flame-cut into small pieces within the separator so removal of the shields could be accomplished through the 18 inch inlet flange. After internal cleaning, the separator was returned to its normal position for reconnection to the piping.
 4. The separator inlet flanges were cleaned and reconnected.
 5. The exhaust stack and attached 90° pipe elbow were reattached to the separator outlet flange. Initially, the flange faces were not parallel for proper engagements, so the exhaust stack was heated and quenched to "draw" the piping, and the flanges were successfully brought into a parallel condition.
 6. The 90° elbow outlet (20 inch) flange stud-bolts were torqued to 1000 ft/lbs, while the other 18 inch and 20 inch flanges were tightened by measuring the stud-bolts elongation; proper tightness was achieved when the stud elongation was approximately 0.001 inch per inch of stud length between the nuts inside faces.
 7. The separator drain valve, 50-RSV-439, was serviced, a new steel (SS316) seat being installed, and the valve was reinstalled in the drain piping.
 8. The SGS pressure switch, 50-PDS-413-1, was readjusted to operate within the specified actuation range.
 9. A clean filter element was installed in the SGS propane line filter (50-LF-436).
 10. Leak tests of the hot gas system, liquid oxygen and propane headers were satisfactorily performed.
- L. Measurements taken of the separator and SGS plenum position after the piping re-assembly, indicate that:
1. The separator position is 1/4 inch closer to the shadow wall than the previous location.
 2. The plenum outlet flange is about 3/16 inch closer to the SGS enclosure wall than previously (in a direction toward the separator).
 3. The plenum has "stretched" an additional 1/4 inch between the front and rear sliding supports, since the "first" post-test measurements.

II. EP-II Post-Test Inspection

Test EP-II was conducted about 1600 on 9 October 1968, and an inspection of the steam generators, plenum, water separator and steam piping was made within the succeeding three-hours period.

- A. The steam generators and plenum were visually examined and no abnormalities were observed.
 - 1. The injector bolts of all three modules were checked for tightness and retorqued where appropriate. All stud nuts were then re-safety wired.
 - 2. The "top works" of each generator module was checked for tightness of tubing "B-nuts" and no loosening was noted.
 - 3. Generator Module No. 1 injection water pressure switch (50-PDS-406-1) was checked, found to be operating out of the specified range at 19 psig make 15 psig break, and then was reset to correct values of $12 \pm \frac{0}{2}$ psig make and 8 ± 2 psig break. The pressure switch sensing line orifices were checked and found free of obstructions. The line connections were also found to be tight.
- B. Plenum position measurements were made. (See Enclosure (3)).
- C. The plenum-to-separator pipe spool inspection disclosed the eight gusset guides, which restrain the pipe spool movement from the wall-anchor plate, had not been installed during the EP-II test. No significant movement of the spool piece was noted from the pre and post-test measurements. The gusset guides were installed on the anchor plate, preparatory for the succeeding test.
- D. The separator, 90° elbow and exhaust stack were visually examined together with the associated flange connections, and no abnormalities were observed.
- E. Separator position measurements were made (See Enclosure (2)).

III. EP-III Post-Test Inspection

Test EP-III was conducted on 9 October 1968, approximately four hours after test EP-II. The post-test inspection has continued since Run Day, and is still in progress at this writing (16 October 1968).

- A. The steam generator pressure switches were checked for actuation within the specified pressure ranges.
 - 1. Records indicate all switches in Modules 1 and 2 operated within specification on first actuation.
 - 2. In Module 3, 50-PDS-413 would not operate on first pressurization, but functioned within required pressures on second actuation; 50-PDS-480 operated at 8.5 psig make, and 5.5 psig break, and was then readjusted to operate within the specified 7 ± 1 psig make 5 ± 1 psig break. Other Module 3 pressure switches operated within specifications.

- B. Inspection of the individual generator module control (explosion proof) box electrical connectors J-203-1, -2 and -3 revealed that Module 1 and 3 connectors each contained a considerable amount of water, while the Module 2 connector was moist. It is planned to remove the Clearseal compound used to "pot" the connectors; dry the connectors, and then "re-pot" the connector wiring with RTV-11 potting compound in order to get an improved water-tight connector installation.
- C. Water flow checks were made on Module 1 water injection control valve (50-FCV-423-1) to observe the valve operation at different stem positions; the valve was found to be "stable", that is no "hunting" was observed in the position of the valve stem during this flow check.
- D. Torque checks were made on each module injector bolts and average "breakaway" torque was about 300 ft/lbs.
- E. The "top works" and ignitors were removed from each module injector; ignitor S/N 0017 used on Module 1 has two bulges in the second stage lines. The first bulge is approximately 1 inch long, $\frac{3}{8}$ inch wide and $\frac{1}{6}$ inch high and is located about 1-1/2 inch above the second stage nozzle. The second smaller bulge is approximately $\frac{1}{4}$ inch in diameter and $\frac{3}{32}$ inch high and located about 2 inches above the second stage nozzle. No abnormalities were noted on the other ignitors.
- F. The generator module injectors were removed from the combustion chambers and the following conditions observed:
 - 1. Module No. 1, Injector S/N 88001
 - a. The spud assembly no. 1 circular weld contained a $\frac{1}{4}$ inch long crack.
 - b. The spud assembly no. 2 circular weld contained a one inch long crack.
 - c. Two cracks were found in spud assembly no. 3 circular weld, one crack being 2-1/2 inches long and the other crack about $\frac{5}{8}$ inch long.
 - d. A 1-1/2 inch long crack was found in the face plate peripheral weld.
 - 2. Module No. 2, Injector S/N 01
 - a. A one inch long crack was observed in the face plate peripheral weld.
 - b. The face plate appeared to be in good condition.
 - 3. Module No. 3, Injection S/N 0017
 - a. The injector appeared to be in good condition.

- G. Inspection of the SGS combustion chambers (while installed on the plenum) indicated all were in good condition. No carbon build-up was observed in Module No. 1, Chamber S/N 880051; Module No. 2, Chamber S/N 0017 and Module No. 3, Chamber S/N 0019, had several large carbon deposits at the water injection pintles.
- H. The Module No. 1 fuel line strainer (at injector inlet) contained rust-like particles of less than a one-half teaspoon quantity. All other propellant lines strainers (both fuel and oxidizer) were clean.
- I. The combustion chambers were removed from each plenum "station", and an inspection of the combustion chambers and the plenum internal surfaces was performed.
 - 1. A 3/4 inch longitudinal crack was found in the inner liner approximately 4 inches below the top combustion chamber flange adjacent to a cluster of film coolant holes on Module 2 (S/N 0017).
 - 2. Dye penetrant inspection of the plenum at Module 1 "station" revealed three cracks in circumferential weld about 8 inches below the flange. The cracks were about one inch, 5/8 inch and 3/8 inch in length. No other abnormalities were noted in the plenum.
- J. The propane supply line filter 50-LF-436 was inspected and found to be in a clean condition.
- K. The exhaust stack and attached 90° elbow were disconnected from the separator outlet flange. An internal inspection of the separator was performed from the outlet elbow location. The bottom of the separator contained "about two handfuls of black, flaky material", presumed to be carbon from the steam generators.
- L. The separator drain line had heat discoloration from the bottom of the separator to the inlet flange of the drain valve. The valve was removed for routine inspection and servicing; no abnormalities were reported.
- M. The exhaust stack discharge flange stud-bolts were checked for tightness.
 - 1. The flange directed toward the shadow wall had 13 loose bolts, one bolt missing, and the remaining six bolts were tight when "checked by hand".
 - 2. The flange directed away from the shadow wall had 19 loose bolts and one bolt which was tight when "checked by hand".
- N. Thermocouple installations were examined following EP-III, and the findings to 16 October 1968 reveal:
 - 1. 50-TE-588 (separator outlet 90° from top of pipe) was loose in the installation fitting and the probe tip did not penetrate past the internal wall surface.

2. 50-TE-590 (separator outlet at bottom of pipe) was hanging from lead wire, and apparently had come out of the installation fitting during SGS operation.
3. 50-TE-650 (exhaust stack outlet) was slightly bent sufficient to prevent easy removal from the pipe fitting.
4. The pipe external wall thermocouples 50-TE-592 through 50-TE-597 were in good condition.

IV. Conclusions and Recommendations

1. The separator returned after the test to approximately the same position as before the test. The steam plenum, although "stretched" (apparently by mechanical movement when separating the plenum outlet flange) is tending to return to about the original position as measured before EP-I.
2. The steam generator pressure switches continue to be a source of problem because actuation pressures change. 50-PDS-413-1 was readjusted after EP-I; 50-PDS-406-1 was readjusted after EP-II; 50-PDS-413-3 failed to actuate upon the first pressurization check after EP-III, and 50-PDS-480-3 was readjusted after EP-III. Switch 50-PDS-413-3 should be removed from Module No. 3 and replaced with a newly serviced item before the next test of the SGS.
3. The electrical connections within the SGS module control boxes are exposed to water because hydraulic systems are also contained within the boxes, and the wiring can be expected to become wetted from time to time. This condition should be reviewed and action taken to prevent moisture contact with any wiring, electrical equipment or terminals which could disrupt generator operations.
4. Significant deterioration of injector welds was found on Modules 1 and 2. Repair welding of the cracks must be performed before these injectors are returned to service.
5. Slight cracks found in the plenum internal liner should be repair-welded before reassembly of the steam generator. This repair work can be done in place.
6. The propane supply line contamination appears to have been corrected by addition of the fill line filter, since the filter 50-LF-436 was clean after EP-III.
7. The separator heat shields installation was inadequate to support the shields in the desired position.
8. The residue within the separator after EP-III should be removed before additional tests are made so that specific identification can be made.
9. The finding of welding rod pieces within the separator after EP-I, indicates careful examination of the steam system for contaminants, together with close control of system access, is especially important to prevent possible damage during future test operations.

10. The exhaust stack flanges stud nuts should be safety wired to prevent loosening during test operations.
11. The thermocouple probe installation fittings should be examined for possible changes in the installation procedure or change in materials, such that the loosening of these fittings will not occur during tests.
12. The steam plenum flange was improperly engaged prior to EP-I and resulted in a leaky flange connection during the subsequent test. The plenum flange as well as the separator inlet flange were dirty when the couplings were made. It should be noted that both of these flanges were assembled by the steam line installation contractor and "turned over" to NTO in the conditions described herein.

CONTAMINATION OF STEAM SEPARATOR

A test was made of the steam separator on October 3, 1968. During this test 50-RSV-439, in the drain line at the bottom of the separator, failed to function properly. Subsequent removal and disassembly of the valve after the test revealed the presence of pieces of weld rod in the valve. The weld rod had lodged in the valve and the operation of the valve had damaged the seat of the valve.

After the test, the temporary stack was removed to facilitate an internal examination of the separator. Among other discrepancies discovered during this examination, several pieces of weld rod were found lying on the bottom of the separator. These pieces, and those found in the valve were approximately 3 to 4 inches long, with diameters of 5/32 and 3/16 inches. They appeared to be the stub ends of weld rod used for Shielded Metal Arc Welding. There wasn't any coating present on the pieces, but the ends of the pieces were typical of rods used for the SMAW process. Some of the pieces of weld rod were sent to a laboratory for analysis. The analysis revealed the material to be 308L weld rod filler material.

STEAM GENERATOR SYSTEM SEPARATOR MEASUREMENTS

	A	B	C	D	E	F	G	H	J	K	L
Before EP-I	$35\frac{5}{16}$	$42\frac{3}{16}$	$66\frac{1}{16}$	66 -	$68\frac{5}{16}$	$68\frac{5}{8}$	$65\frac{13}{16}$	$65\frac{3}{4}$	$44\frac{1}{2}$	$45\frac{3}{16}$	$63\frac{3}{8}$
After EP-I	$35\frac{1}{4}$	$42\frac{1}{4}$	$66\frac{1}{16}$	66 -	$68\frac{5}{16}$	$68\frac{9}{16}$	$65\frac{7}{8}$	$65\frac{3}{4}$	$44\frac{9}{16}$	$45\frac{3}{16}$	$63\frac{3}{8}$
Before EP-II	35 -	$41\frac{7}{8}$	$65\frac{13}{16}$	$65\frac{3}{4}$	$68\frac{7}{16}$	$68\frac{5}{8}$	$65\frac{9}{16}$	$65\frac{7}{16}$	$44\frac{5}{16}$	$44\frac{15}{16}$	$63\frac{5}{16}$
After EP-II Before EP-III	$35\frac{1}{4}$	42 -	66 -	$65\frac{15}{16}$	$68\frac{15}{32}$	$68\frac{17}{32}$	$65\frac{7}{8}$	$65\frac{3}{4}$	$44\frac{1}{2}$	$45\frac{3}{32}$	$63\frac{5}{8}$
After EP-III	$35\frac{9}{32}$	$42\frac{3}{32}$	$66\frac{1}{16}$	$65\frac{31}{32}$	$68\frac{5}{16}$	$68\frac{19}{32}$	$65\frac{7}{8}$	$65\frac{3}{4}$	$44\frac{17}{32}$	$45\frac{5}{32}$	$63\frac{7}{32}$

- Measurements taken with steel tape. All measurements in inches

Separator Measurements
Near Bottom

Separator Measurements
Near Top

SEPARATOR PLAN VIEWS

STEAM GENERATOR SYSTEM PLENUM MEASUREMENTS

	A	B	C	D	E	F	G	
Before EP-I	$39\frac{1}{16}$	$39\frac{5}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	11	
After EP-I	$39\frac{1}{16}$	$39\frac{5}{16}$	$\frac{5}{8}$	$\frac{13}{32}$	$\frac{7}{16}$	$\frac{7}{16}$	—	
Before EP-II	39-	$39\frac{5}{16}$	$\frac{1}{64}$	$\frac{1}{64}$	$\frac{1}{4}$	$\frac{9}{32}$	$10\frac{13}{16}$	
After EP-II Before EP-III	39-	$39\frac{5}{16}$	$\frac{1}{64}$	$\frac{1}{64}$	$\frac{5}{16}$	$\frac{3}{8}$	$10\frac{13}{16}$	
After EP-III	$39\frac{1}{32}$	$39\frac{9}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{33}{64}$	$10\frac{15}{16}$

Plenum Measurements
on Sliding Supports ~

Measurement Details

PLENUM PLAN VIEW

- Measurements taken with
steel tape. All measurements
in inches.

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: TEST STAND COOLANT WATER SYSTEM

INTRODUCTION

A water flow test was conducted to determine the adequacy of coolant water coverage to the test stand, the duct vault door, the test stand weather door, the east duct vault wall, the stairway, and the concrete/gunite pads.

SUMMARY

The first attempt at checking out the test stand cooling system resulted in obtaining only 33 psig at PT-683 because of the 4-1/2 inch orifice located downstream of FCV-31. The orifice was subsequently removed prior to the next test.

Water coverage to the duct vault door, the test stand weather door, the east duct vault wall, the stairway, and the concrete/gunite pads was adequate when the duct was at full flow; the water coverage to the test stand was adequate only when RSV-937 was open.

Flow through RSV-937 completely covered the front of the test stand. This indicates that flow to the test stand (TS-1 and TS-2) through FCV-31 is not required when RSV-937 is open.

TECHNICAL DISCUSSION

The test stand has four coolant lines, the upper two controlled by RSV-937 and the lower two and the rest of the coolant system are controlled by RSV-935 and FCV-31. From bottom to top, the test stand coolant lines will be identified as TS-1, TS-2, TS-3, and TS-4.

Test Stand Cooling Test No. 1

During the first attempt at checking the test stand cooling system, the pressure in the supply line (PT-863) could only be raised to 33 psig with FCV-31 in the full open position. It was discovered that an orifice used to suppress cavitation in the duct discharge system in the previous configuration was still installed downstream of FCV-31. The test was terminated and the orifice removed.

The following observations were made during this test:

1. When FCV-31 was opened, there were no vibrations nor other signs of excessive pressure surges in the rubber supply hose to the duct vault or in any of the coolant pipes.

2. The coverage on the concrete aprons was satisfactory. However, better coverage could be obtained if all the nozzles on the upper coolant pipes, which face away from the ditch, would be directed more toward the concrete apron. In addition, several of the nozzles appeared to be plugged.
3. The duct vault door, the test stand weather door, the east duct vault wall and the stairway had excellent coverage at 33 psig (PT-863).
4. RSV-935 and RSV-937 were not opened during this test.

Test Stand Cooling Test No. 2 (Figure 2)

The first three observations made for Test No. 1 are applicable for this test.

With PT-863 at 32 psig, the lower test stand coolant line (TS-1) provided very little flow out of the top of the line and a low steady flow out of the bottom. There was no flow out of TS-2. TS-3 and TS-4 were not flowing because RSV-937 was closed.

With PT-863 at 42 psig, the lower line (TS-1) provided adequate coverage. The next line up (TS-2) provided very little flow out of the top of the line and a low steady flow out of the bottom. TS-3 and TS-4 were not flowing because RSV-937 was closed.

With PT-863 at 52 psig, TS-1 and TS-2 provided good coverage. Flow at the top of TS-2 reached about six feet up the duct vault door.

The flow rates established through the duct by the above pressure steps are the actual flow rates for the test stand coolant system. With RSV-738, RSV-739, RSV-858 and RSV-859 in the closed position, all flow going through the duct has to go to the test stand coolant system. Therefore the plot (Figure 1) of PT-863 pressure and water flow rate may be used for future estimation of flow to the test stand coolant system.

With 19,760 gpm established through the duct (FCV-32 open about 6%, F-57 at 4 psid, PT-863 at 47 psig, PT-896 at 200 psig, valves RSV-738, RSV-739, RSV-858 and RSV-859 open) there was a visible decrease in flow through TS-2. Examination of the data revealed a 4 to 5 psi drop at PT-863. (Figure 3)

No visible effect on the coolant flow was observed when the Zone 8 fire protection system was activated, however, examination of the data revealed a momentary pressure drop of 3 psi at PT-863. (Figure 3)

When the full flow of approximately 37,550 gpm was established through the duct by opening FCV-32 about 30%, with FCV-31 100% open, flow to TS-2 was lost and the flow in TS-1 was reduced to approximately 5 feet up the test stand door. Examination of the data revealed that pressure at PT-863 was approximately 35 psig (a drop of 18 psi), which appears to be the maximum pressure when the duct is at full flow and RSV-935 is closed. FCV-31 pressure drop at this time was 43 psid. (Figure 3)

RSV-935 could not be opened when the pressure drop, PT-596 to PT-863, was 67 psid. No other attempt was made to open this valve.

When RSV-937 was opened to establish flow through TS-3 and TS-4, the entire front of the test stand was flooded. The data did not reveal any change in supply pressure at PT-863. The water more than covered the areas covered by TS-1 and TS-2. (Figure 4)

Because one branch of the duct vault inerting wall coolant line was capped off and the other branch was orificed to simulate flow, the duct vault inerting wall coverage is not known.

RECOMMENDATIONS

1. Direct nozzles on the upper concrete apron coolant pipe downward toward concrete aprons and eliminate 33% of them.
2. Reduce duct vault door and test stand weather door water flow by eliminating 10% of the nozzle area.
3. Since flow from TS-3 and TS-4 completely covers the front of the test stand and the flow through FCV-31 covers the remaining areas, RSV-935 is not required.
4. When the Test Stand Cooling System is required, RSV-937 should be opened and FCV-31 should be opened to achieve a minimum pressure of 35 psig at P-863.
5. The Test Stand Cooling System should be checked during Phase II testing to verify the new duct vault inerting wall coverage as well as the test stand coverage at rated duct flow conditions.

ANOMALIES

1. DF-031 was not properly reporting FCV-031 valve position.
2. RSV-935 would not open under 67 psi pressure differential.

PT-863 Pressure - psia

Test Stand Cooling Flowrate, gpm H₂O

PT-683 PRESSURE VS TEST STAND COOLING WATER FLOWRATE

FIGURE 1

Spec Memo 6

Fig 2a

SEP C/O PHASE 1 EP2 10/9/6
 DUCT H2O PRESSURES

1	-*	PT596	-*	PSIA
2	-*	PT597	-*	PSIA
3	-*	PT663	-*	PSIA
4	-*	WWT	-*	GPM

RSV-738 }
 RSV-739 } OPEN
 RSV-858 }
 RSV-859 }

52495.7

52455.7

52475.7

52495.7

52515.7

52535.7

SEP C/O PHASE I EP2 10/9/6
DUCT H2O PRESSURES

Spec. Mem. 6

Fig. 4

RANI

SEP C/O PHOGE21 EP2 18/9/6
DUCE H2O PRESSURES

TIME-SECS.

SEP C/O PHASE I EP2 10/9/6
DUCT H₂O PRESSURES

1	---	PT895	---	PSIA
2	---	PT597	---	PSIA
3	---	PT863	---	PSIA
4	---	WWT-1	---	SPM-H ₂ O

Spec M-206
Fig 6a

SEP C/0 PHASE I EP2 10/9/6
DUCT H2O PRESSURES

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: NES DUCT WATER FLOW PERFORMANCE

INTRODUCTION

Prior to this test series the duct coolant water discharge system was modified, as shown in Figure 1, to supply water to the test stand coolant system. A line was run from the upstream side of the duct discharge valves (FCV-30, FCV-31 and FCV-32) through RSV-935 to the test stand coolant system and the duct discharge line downstream of FCV-31 was replumbed into the test stand water coolant line downstream of RSV-935. The planned mode of operation, to minimize system surging, was to open FCV-31, building up pressure in the test stand coolant line, open FCV-32, lowering the pressure upstream of RSV-935 and then open RSV-935.

SUMMARY

The modifications made to the duct water discharge piping did not adversely effect the duct water flow rates. The percent of total flow in each section and the system flow coefficient (kw) were the same as in previous runs. Opening of RSV-937, or activation of Zone 8 fire protection system results in a duct water flow dip. These temporary decreases in water flow rate do not adversely affect duct performance.

TECHNICAL DISCUSSION

The maximum flow rates now obtainable with FCV-31 in 100% open position is approximately 12,000 gpm (compared to 8,000 gpm with the previous configuration) which gives a larger range of operation for low flow conditions.

Although the impedance of the Test Stand cooling system was less than the impedance of the 4-1/2 inch orifice previously installed downstream of FCV-31 (as indicated by the higher flow rate) there was no cavitation or vibration in the duct discharge system during opening of FCV-31. These modifications therefore do not affect the duct performance in this area.

With FCV-31 set to establish approximately 10,000 gpm flow, FCV-32 was open approximately 30% to bring the total to approximately 38,000 gpm. The duct inlet and outlet pressures and the total flows were compared with previous runs and the tabulated results (Table I) show that the system operates the same as before at the full flow conditions.

The duct flow was established at 20,000 gpm and the Zone 8 fire protection system was activated. This caused a dip in the duct inlet pressure of 20 psi which lasted 5.5 seconds. When RSV-937 was actuated at a duct flow of 34,000 gpm

a dip of 15 psi occurred which lasted 4.5 seconds. Due to the short duration and the slight effect on the total flow rate (Table II) these actuations do not affect duct performance.

CONCLUSIONS

The NES duct coolant system is functioning satisfactorily in its present configuration.

RECOMMENDATIONS

Although the activation of Zone 8 fire protection and RSV-937 have no adverse effect on the duct flow rates, it is recommended that the opening times of FCV-31 and RSV-937 be increased in order to prevent pressure oscillations in the SGS or other water systems.

It was noted that the minimum required flow through section 2 was not obtained. This is a result of holding 14.0 psid at F-56 rather than 15.7. Although the flow rate was not critical for this test, in future tests it is required that the F-56 ΔP be set at a minimum of 15.7 psid and maintained.

FIGURE 1

TABLE I

DUCT WATER FLOW COMPARISON

TEST NUMBER	DATE	DUCT INLET PRESS PSIG	DUCT OUTLET PRESS PSIG	SECTION 1			SECTION 2			SECTION 3			TOTAL FLOW GPM	DUCT KW
				ACTUAL FLOW GPM	% TOTAL FLOW	MIN REQD FLOW GPM	ACTUAL FLOW GPM	% TOTAL FLOW	MIN REQD FLOW GPM	ACTUAL FLOW GPM	% TOTAL FLOW	MIN REQD FLOW GPM		
NEP-III	2/2/67	198	58	12420	31.4	11756	11470	28.9	11152	15770	39.7	15126	39660	3350
NEP-IV	2/7/67	199	61	12400	31.9	11756	10990	28.3	11152	15490	39.8	15126	38880	3310
Phase I EP-2	10/9/68	204	76	11836	31.6	11756	10903	29.1	11152	14700	39.3	15126	37439	3310

TABLE II

EFFECT OF VALVE OPENING ON DUCT FLOW & PRESSURE

	INITIAL DUCT FLOW GPM	INITIAL DUCT INLET PRESSURE-PSIA	PRESSURE DIP PSI	FLOW DIP GPM	TIME OF PRESS. TRANSIENT SEC.
FCV-31 Opening	1700	232	40	N/A	5.0
FCV-31 Opening	5500	232	38	N/A	6.0
Zone 8 Opening	20,000	237	20	1000	5.5
RSV-937 Opening	34,000	225	15	1500	4.5

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: DATA SYSTEM PERFORMANCE

SUMMARY

Of 44 line items reported on EP-II, 24 line items had useable data and 15 had correctable data. Only 5 measurement channels, listed in Enclosure (1), may have lost data. (Following EP-I, 25 channels were suspect). The list of anomalies reported to NTO Data Acquisition and Data Reduction groups immediately after EP-I were expeditiously handled by all concerned. No wide band FM tape information was reviewed during this SPEAR effort.

DISCUSSION

The major number of line items reported during EP-I and -II came from two sources, viz. a lack of formal transmittal of information between data acquisition personnel at ETS-1 and the data processing personnel at the A&E Building, and 60 Hz noise on several data channels at ETS-1. No data is known to be lost from either cause. The raw data could be reprocessed and become useful, while the 60 Hz problem caused a slight degradation of data in some instances.

Before each test, several data system calibrations are performed and one is later selected by data personnel to process the run data. These calibrations are taken over a period of days while the facility is in various states of operational readiness. There are times when the information presented by the raw data is inadequate to accurately make a decision regarding which calibration to use and errors result.

One of the above mentioned calibrations is normally a zero-pressure cal. This, by necessity, is accomplished two to three days prior to the test and is the calibration information which must be used to process some test data (such as tank pressures). In the case of EP-II, no zero-pressure calibration was performed, so numerous pressure channels had the option of being reduced based on calibration data over a week old, or on arbitrary decisions as to the measurement offset. If such a condition must exist, it would greatly increase the validity of the data if the actual pressure conditions of the transducer were transmitted with the raw data.

Another problem which reoccurs is the foldover of data. That is, a voltage is received by the data acquisition system which drives the digitizer higher than its operating limit of 9999 counts. When this occurs, unless special circuits are provided, the data reappears at some lower count value and is

reduced as valid data of inconsistent and lower magnitude. Some channels have been modified at ETS-1 such that when a voltage drives the digitizer to 9999 it is locked at that point until the voltage drops back into the operating range and is readily recognized as valid or invalid data. A list is being prepared by ETS-1 personnel indicating those channels which are subject to foldover to alert data users to the potential for this problem.

Some confusion resulted in trying to identify oscillogram traces, using trace identifier breaks, when additional unlisted traces were found on the oscillogram. At times there has been misnumbering of galvo traces on the attached header and unidentified reference traces. With a data user inexperienced with these problems, misinformation can be generated. Such problems would be greatly minimized if every trace on an oscillogram is identified by channel number, including static reference traces found in the center of the record.

Much time is lost by using oscillograms available only in rolls. There is a natural reluctance to Z-fold original records, but there should also be a greater reluctance to give original records to data users. It would facilitate the use of strip chart and oscillogram type information greatly if the originals would be immediately reproduced in their entirety with the reproduced records put in Z-fold format. Z-folding equipment is available at NRDS. The availability of several copies would also make the information available to more people during the SPEAR activity.

Much setup information required for special setups is contained in the datalog. However, there are many cases where the special instructions are not noted for all the channels affected, or no special instructions are given when it is assumed that the setup is known. No setup errors were found by SPEAR during this effort inspite of the lack of or misinformation in the datalog. However, when the full number of facility and engine channels are in operation, the chance for error will be greatly increased unless readily available and detailed information is present in the datalog.

The FE type of measurement channels (turbine flow) are calibrated by putting in a known frequency simulating the turbine output at a full scale condition. The other end of the calibration curve is anchored by a zero frequency input. Low level 60 Hz noise signals frequently found on channels in the system could be detected as a legitimate zero input signal and would not be differentiated from electronic drift, thus providing an improper zero point. An alternate solution for reducing this data would be to use the impressed frequency from another specified calibration step to anchor the bottom end of the calibration curve. Such a system would have to be coordinated between the data acquisition and data processing groups to evaluate whether the added accuracy would be worth the added effort.

RECOMMENDATIONS

1. ETS-1 Data Acquisition personnel should indicate to Data Processing personnel what calibration sequence number should be used for each channel.
2. Properly identify all traces found on oscillograms.
3. Make duplicates of all strip charts and oscillograms as soon as possible, Z-fold the duplicates prior to delivery to SPEAR.
4. Perform special calibrations such as zero-pressure and valve trace calibrations before each major experimental plan.
5. Complete listing of channels subject to data foldover. Continue corrective modifications as time and budget permit.
6. Re-emphasize completeness and accuracy of Datalog.
7. Consider need for and method of improving FE channel calibration technique.
8. Continue fight against 60 Hz noise.

DATA ANOMALIES

SEPARATOR CHECKOUT, EP-II

ITEM	MEASUREMENT NUMBER		COMMENTS
1	TE590..F		Thermocouple data invalid. Installation Faulty.
2	BS480..F		Digital events listing does not indicate switch closure.
3	BS480Y..F		Digital events listing does not indicate switch closure.
4	TE585..F		Data irregular, but no known measurement system problem.
5	TE588..F		Data irregular, but no known measurement system problem.

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: FLUID UTILIZATION

INTRODUCTION

The fluids considered in this report will be the liquid oxygen and propane used for the SGS and the water used for duct flow (includes test stand coolant through FCV-31), SGS operation, Zone 8 fire protection system, and test stand coolant (RSV-937).

SUMMARY

1. The total water used was 1,510,000 gallons.
2. The total liquid oxygen used was 8,200 gallons.
3. The total propane used was 5,000 gallons.

DISCUSSION

The water usage has been divided into five time intervals while the oxygen and propane usage was divided into two intervals. The time intervals are described below and Table I contains the amounts used for each interval.

Interval W1 is the first test stand coolant flow check. FCV-31 was opened 100% but due to an orifice downstream of the valve, the full flow to the system could not be reached.

Interval W2 is the attempt to run separator Test No. 2. LCV-407 malfunctioned and the test terminated.

Interval W3 is the second water flow test. FCV-31 was opened in steps to 100%, RSV-738, RSV-739, RSV-858 and RSV-859 were opened, FCV-32 was opened to approximately 30%, RSV-937, RSV-433 and RSV-434 were opened and Zone 8 fire protection system actuated.

Interval W4 is separator Test No. 2. The SGS malfunctioned three times before it finally ran. While the SGS was operating, FCV-31 position was increased to observe its interaction on the water system.

Interval W5 is separator test no. 3. FCV-32 was open approximately 30% prior to full steam, FCV-31 was opened to test stand coolant and RSV-738, RSV-739, RSV-858 and RSV-859 were opened.

Interval L/P 1 is Separator Test No. 2 including all SGS malfunctions and the actual run.

Interval L/P 2 is Separator Test No. 3.

CONCLUSIONS

Due to the number of bleed-ins and false starts, no accurate measurements are available for steady state usage. The information is indicative of the fluid usage which may occur if false starts are encountered during engine testing.

TABLE IFLUID USAGE

INTERVAL	TIME (seconds)	WATER USAGE (gallons)	PROPANE USAGE (gallons)	LIQUID OXYGEN USAGE (gallons)
W-1	870	155,000		
W-2	7,345	45,000		
W-3	115	345,000		
W-4	2,504	300,000		
W-5	1,772	665,000		
L/P 1	10,857		3,000	5,600
L/P 2	2,688		2,000	2,600
TOTAL		1,510,000	5,000	8,200

11/12/68

PHASE I NES STEAM LINE DEMONSTRATION TESTS

SUBJECT: TEST DESCRIPTION AND CHRONOLOGY

- A. Phase I of the NES Steam Line Demonstration Test program consisted of two experimental plans with the prime objective being evaluation of the steam separator performance. A secondary objective was evaluation of the test stand cooling system.
- B. EP-I consisted of one test and was conducted on 3 October 1968. Steam Generator modules No. 1 and No. 3 were brought to full steam conditions with temperature control not attempted.

Post test inspection revealed the separator heat shield was deformed and it was subsequently removed.

- C. EP-II was conducted on 9 October 1968 to evaluate steam separator performance at operating temperatures and evaluate the test stand cooling system.

The first attempt at operating the test stand cooling system, between range time 36880 and 37550, was discontinued when it was determined that a 4-1/2 inch diameter orifice plate downstream of FCV-31 had not been removed and limited the flow capability.

The LO₂ and propane systems were then bled in between range time 38785 and 46130 in preparation for the Steam Separator tests. The propane system was bled-in without problem but difficulty was experienced in bleeding in the LO₂ system because LCV-407, the LO₂ surge tank liquid level controller, would not close properly. The LCV-407 difficulty was corrected by resetting the liquid level differential pressure setting. The 4-1/4 inch orifice was removed during this re-entry.

The test stand cooling system evaluation was then conducted between range time 52028 and 53143. The planned sequence of operations were completed however RSV-935 would not open when the command was given. Bleed-in of the propane and liquid oxygen system was then re-initiated between range time 53710 and 55630.

Following Lox and propane tank pressurization steam separator test No. 2 was initiated. The first attempt was aborted at range time 55715 when module No. 2 during the start to idle steam malfunctioned because the 2nd stage pressure switch did not close even though sufficient chamber pressure existed.

The second attempt was aborted when Steam Generator No. 1 malfunctioned from full steam condition, at range time 55914, due to an apparent opening of the water injection pressure switch, PDS-406, even though sufficient pressure to maintain the switch was available.

The third attempt experienced a similar shutdown of Steam Generator No. 1 (range time 56480) with both Steam Generator No. 1 and Steam Generator No. 3 at full steam condition.

The fourth attempt between range time 57230 and 58134 was satisfactory with Steam Generator modules No. 2 and No. 3 being utilized. A severe steam temperature excursion was experienced at range time 57869 when FCV-31 was commanded open as part of the water interaction evaluation. As a result of this temperature excursion, the water interaction evaluation planned for test 3 was deleted.

Steam Separator test No. 3 was conducted between range time 70349 and 71461 with full duct flow initiated between the Idle and Full Steam conditions. Except for the inability to maintain a constant steam temperature, all test conditions were met.

Attached is the detailed test chronology.

PHASE I NES STEAM LINE DEMONSTRATION TESTS

EP-I Chronology 3 October 1968

I. PRE-OPERATIONAL PHASE

63085 - 63295	Performed data system calibration
63307 - 63627	Exercised valves.
63701 - 64953	LOX bled in.
64080 - 64189	GN ₂ Header pressurized.
64680 - 64820	Propane bled in.
65312 - 66525	LOX and propane tanks pressurized.

II. OPERATIONAL PHASE

A. SGS COOLANT FLOW SETUP

66596	RSV-439 placed in MANUAL-OPEN POSITION.
603	RSV-434 opened.
647	RSV-433 opened.
665	RSV-434 closed.
680	Steam Generator reset.
690	Ready switches depressed.
704	Injection water control valve port positioned to 1000.

B. STEAM SEPARATOR TEST NO. 1

66716	DDS to continuous.
742	Manual SGS purge ON.
748	Camera Group A ON.
754	SG-1 to IDLE STEAM.
763	SG-3 to IDLE STEAM.
829	Recorders to HIGH.
843	SG-1 to FULL STEAM.
914	SG-3 to FULL STEAM.
986	SG-1 to IDLE STEAM.
67001	SG-3 to IDLE STEAM.
010	Recorders to LOW.
020	SG-1 shutdown.
024	SG-3 shutdown.
063	DDS to PERIODIC.

III. SHUTDOWN PHASE

67097 - 67238	LOX systems vented.
67280 - 68195	Propane system vented.
67848	Coolant water shutoff.
67900 - 67949	GN ₂ system secured.
68218 - 68300	Data system calibration.

EP-II CHRONOLOGY

9 October 1968

34363 - 35465	Performed data system calibration
36300 - 36676	Exercised valves.

A. TEST STAND COOLING SYSTEM WATER FLOW TEST

36680	RSV-296 opened and duct bled in.
735	RSV-297 and RSV-298 opened.
895	RSV-331 opened.
900	Data to 10 samples per second.
941	RSV-434 opened.
966	RSV-433 opened.
37008	FCV-31 used to establish 30 psig at PT-863.
140	FCV-31 closed.

HOLD FOR SYSTEM EVALUATION.

400	FCV-31 used to establish 12 psig at PT-863.
450	FCV-32 to 15%.
480	FCV-32 closed.
550	FCV-31 closed.

HOLD FOR SYSTEM EVALUATION.

38785 - 39866	Bled in LOX.
39015 - 39310	Pressurized GN ₂ Header.
40054 - 40150	Bled in propane.

40430 - 41300 Pressurized propane and LOX tanks.

41300 LOX and propane tanks pressurized.
370 Secured LOX tank pressurization system.

HOLD FOR LCV-407 RE-ENTRY.

42680 RSV-436 opened.
690 RSV-496 opened.
710 RSV-92X and Y opened.
790 LOX tank pressurized to 80 psi and LOX bled in.
825 With LOX tank at 290 psig, LCV-407 oscillated.
43480 LOX and propane tanks depressurized.

HOLD FOR LCV-407 RE-ENTRY.

45890 Propane tank pressurized to 295 psig.

46130 LOX tank depressurized.

HOLD FOR LCV-407 RE-ENTRY.

A. TEST STAND COOLING SYSTEM WATER FLOW TEST

52028 RSV-296 opened and duct bled in.
086 RSV-297 opened.
130 RSV-434 open.
156 RSV-433 open.
192 RSV-298 open.
266 Data to 10 samples per second.
296 30 psig established at P-863 using FCV-31.
383 40 psig established at P-863 using FCV-31.
431 50 psig established at P-863 using FCV-31.
462 52 psig established at P-863 using FCV-31.
512 RSV-738, 739, 858, and 859 opened.
573 FCV-32 opened and FCV-31 closed to obtain 4 psid (20,000 GPM)
at F-56 and 50 psig (8500 GPM) at P-863.
588 Opened Zone 8.
625 Closed Zone 8.
655 Opened FCV-32 until P-596 was 108 psig.
715 Full flow in duct.
771 RSV-935 commanded open (did not open).
815 RSV-935 closed.
823 RSV-937 opened.
900 FCV-32 closed.
963 15.7 psid established at F-56 and F-57 (38,000 GPM) with
FCV-32.
975 RSV-937 closed.
53033 FCV-32 closed.
086 FCV-31 closed.
115 RSV-434 closed.
121 RSV-738 and RSV-739 closed.

53127 RSV-858 closed.
 128 RSV-859 closed.
 143 Data OFF.

53710 - 54007 Bled in LOX.

54126 - 54187 Bled in propane.

54228 - 55630 Pressurized LOX and propane tanks.

B. STEAM GENERATOR SET UP AND DUCT COOLANT FLOW ESTABLISHED

55087 Obtained less than 180°R at T-479.
 RSV-296, RSV-297 and RSV-298 verified open.
 100 Verified RSV-439 open.
 124 RSV-434 opened.
 147 RSV-433 opened.
 55166 Reset steam generators.
 184 Ready switches depressed.
 195 Injection water control valve pots positioned to 1000.
 435 RSV-738, RSV-739, RSV-858 and RSV-859 open.
 676 22 psig established at P-863 with FCV-31.

C. STEAM SEPARATOR TEST No. 2

55692 DDS to continuous.
 700 Manual SGS purge ON.
 710 Camera Group A started.
 715 SG-2 started to IDLE STEAM, 2nd stage malfunction and shutdown.
 740 Camera Group A OFF.
 746 DDS OFF.
 774 DDS to CONTINUOUS.
 785 Camera Group A started.
 790 SG-1 started to IDLE STEAM.
 799 SG-3 started to IDLE STEAM.
 867 Recorders to HIGH.
 872 SG-1 to FULL STEAM.
 914 SG-1 malfunction and shutdown.
 942 SG-3 shutdown.

B'. STEAM GENERATOR SET UP AND DUCT COOLANT FLOW ESTABLISHED

56220 Ready switches depressed.
 225 Injection water control valve pots positioned to 1000.
 326 22 psig established at P-863 with FCV-31.

C'. STEAM SEPARATOR TEST No. 2

56343 DDS to CONTINUOUS.
 350 SGS manual purge ON.
 354 Camera Group A started.
 360 SG-1 to IDLE STEAM.
 373 SG-3 to IDLE STEAM.
 444 Recorders to HIGH.
 450 SG-1 to FULL STEAM.
 471 SG-3 to FULL STEAM.
 480 SG-1 malfunction and shutdown.
 491 SG-3 to IDLE STEAM.
 513 SG-3 shutdown.

HOLD FOR SYSTEM EVALUATION.

C''. STEAM SEPARATOR TEST No. 2

57230 Camera Group A started.
 235 SG-2 to IDLE STEAM.
 243 SG-3 to IDLE STEAM.
 311 Recorders to HIGH.

 57320 SG-2 to FULL STEAM.
 344 SG-3 to FULL STEAM.
 519 RSV-439 closed.
 578 FCV-423-2 and -3 adjusted until T-850 indicated 1060°R.
 686 FCV-423-2 and -3 adjusted until T-850 indicated 1260°R.
 869 FCV-31 opened to 100% and then closed to 20%.
 958 RSV-439 opened.
 965 FCV-423-2 and -3 to FULL OPEN.

58030 SG-2 to IDLE STEAM.
 040 SG-3 to IDLE STEAM.
 049 SG-2 shutdown.
 053 SG-3 shutdown.
 060 DDS to PERIODIC.
 065 Camera Group A OFF.
 085 RSV-738, 739, 858 and 859 closed.
 134 FCV-31 closed.

58112 - 58600 LOX systems vented.

58241 - 58527 Propane system vented.

58298 - 58360 Coolant water shut off.

58400 - 68400 HOLD FOR DATA ANALYSIS AND FACILITY INSPECTION

68438 - 68464 GN₂ header pressurization.
 68478 - 68909 LOX bled in.
 68659 - 68917 Propane bled in.
 68929 - 69170 LOX and propane tanks pressurized.

B''. STEAM GENERATOR SET UP AND DUCT COOLANT FLOW ESTABLISHED

70024 Obtained less than 180°R at T-479.
 056 RSV-296 open.
 202 RSV-297 and RSV-298 open.
 136 RSV-434 open.
 154 RSV-433 open.
 260 Steam generators reset.
 295 Ready switches depressed.
 304 Injection water control valve pots positioned to 1000.
 341 RSV-738, 739, 858, 859 open.

D. STEAM SEPARATOR TEST No. 3

70349 DDS to CONTINUOUS.
 355 Manual SGS purge ON.
 362 Camera Group A started.
 369 SG-2 to IDLE STEAM.
 379 SG-3 to IDLE STEAM.

70419 35 psig established at P-863 with FCV-41.
 459 15.7 psig established at F-56 with FCV-32.
 527 Recorders to HIGH.
 603 SG-2 to FULL STEAM.
 626 SG-3 to FULL STEAM.
 816 RSV-439 closed when T-591 indicated 860°R.
 991 1510°R established at T-586 with FCV-423-2 and -3.
 Steam temperature control difficulties during this interval.

71285 Camera Group B ON.
 295 SG-2 and SG-3 to IDLE STEAM. (SG-3 malfunction shutdown - XTS)
 313 DDS to PERIODIC and recorders to LOW.
 370 FCV-32 closed.
 413 RSV-738 closed.
 416 RSV-739 closed.
 438 RSV-858 closed.
 439 RSV-859 closed.
 440 FCV-31 closed.
 470 RSV-297 closed.
 729 RSV-296 and RSV-298 closed.
 425 SG-2 shutdown.
 459 RSV-439 switch energized open.
 461 Camera Group A OFF.

71495 - 71597	LOX system vented.
71608 - 72083	Propane system vented.
71688 - 71828	Coolant water shutoff.
72062 - 72133	GN ₂ system secured.