TEST REPORT

STEAM GENERATOR

DEVELOPMENT

TEST PROGRAM

EXPERIMENTAL PLAN VI

MASTER

NERVA TEST OPERATIONS

Jackass Flats, Nevada

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TEST REPORT
STEAM GENERATOR DEVELOPMENT TEST PROGRAM
EXPERIMENTAL PLAN VI
NTO-R-0083

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NES Test Group

September 1966

MASTER

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NERVA TEST OPERATIONS
ENGINE TEST STAND NO. 1

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I. OBJECTIVES

The objectives of the Experimental Plan VI of the Steam Generator System Development Test Program were to:

1. Evaluate performance of the integrated steam generator system when operated at full flow (two modules full steam, one module at idle).
2. Determine the best means for efficient operation of the steam generator when integrated and operated as a system.
3. Demonstrate the steam generator system will supply nominal 120 lb/sec steam at 1100^oF.
4. Evaluate harmonics or relevant vibration that may occur as a result of combustion or the discharging and mixing of hot gases in the plenum at generator system rated flow.
5. Determine the effect of system operation on propellant pressure, combustion pressure, cooling water pressure and pressure drops, and various system pressures.
6. Demonstrate that the idling unit, after a four second delay, will switch to full steam if one of two modules operating at full steam is shutdown.
7. Establish relationship between observed flow of water injected and stabilized steam temperature at the stack exit.
8. Evaluate heat transfer characteristics of the plenum at rated full flow operation.
- *9. Demonstrate the capability of each module main stage to startup from the ignitor second stage after a flame-out has been induced in the ignitor first stage.
- *10. Determine the effect on the SGS operation of shortened lead time of the main oxidizer valve opening ahead of the main fuel valve opening.
- *11. Continue the investigation of the system ability to deliver at rated performance under simulated duct conditions.

- *12. Investigate the depth of penetration on the generator exit flange thermocouples (50-TT-435, -436 and -437) to obtain an average temperature matching that of the steam exit thermocouples (50-TT-705, -706 and -707).

* These objectives were added after EP-VI-J-16.

II. SUMMARY

The ETS-1 Steam Generator System Development Test Program Experimental Plan VI was conducted between 28 April 1966 and 9 August 1966.

The type of tests conducted during EP-VI were with two of the three modules of the Steam Generator System at full steam for short and long durations.

Initial tests revealed that during multi-module operation the system would not maintain the steam temperature below the maximum allowable. The propellant flow rates to the modules were thus lowered by reducing the propellant tank pressure, and on subsequent tests the steam temperature could be controlled. However, operational problems were introduced as a result of the lower propellant tank pressures and were evident throughout the remaining test program.

Steam generator switching was attempted on several tests with limited success (generator switching is the shutting down of one module at full steam and the automatic full steam startup of the idling module). The first problem encountered during switching was an incomplete purge of combustible gases in second stage oxidizer line of the shutdown module which resulted in an explosion. The gaseous nitrogen purge was thus extended to all modules after shutdown. Another problem during switching was a second stage cutoff malfunction which was possibly caused by the reduced propellant tank pressures.

The last test run was two modules at full steam for approximately 1000 seconds duration. The Steam Generator System was very stable during the run with no evidence of pressure or temperature fluctuations.

The Steam Generator System was disassembled during and after the test program. The inspection during the test program revealed extensive deterioration of the welds in two injectors and warping of the combustion chamber inner liner in one module. For the balance of the test program, the damaged parts were reworked and/or replaced with spares. The inspection after the test revealed no major discrepancy to the reworked or spare parts.

III. CONCLUSIONS AND RECOMMENDATIONS

1. The Steam Generator System with two modules at full steam performed satisfactorily for a sustained duration of 1100 seconds delivering 124 lbs/sec steam at 1300°F and demonstrated safe operation through the facility steam line.
2. The propellant flow rates to each module should be reduced to 7 lbs/sec propane and 16.7 lbs/sec oxygen in order to achieve and control 1300°F steam temperature and a nominal 120 lb/sec total steam flow rate as demonstrated during this test series. Approximately 30 to 32 lb/sec of water injected into the combustion chamber of each module will produce 1300°F steam with the reduced propellant flow rates.
3. The performance of the steam generator switching operation was marginal due to a second stage cutoff malfunction. To eliminate this malfunction the following modification should be made:
 - a. The propellant tank pressures should be increased to approximately 300 psig.
 - b. The main stage propellant venturi throat diameter should be decreased to compensate for the higher inlet pressures and yet maintain the reduced flow rates.
 - c. The low pressure port of the second stage pressure switch should be connected to the lower portion of the combustion chamber rather than the upper.
4. When the Steam Generator System is supplying a nominal 124 lb/sec steam at 1300°F, the heat transferred to the plenum cooling water is approximately 1200 btu/sec with a cooling water temperature rise of 23°F.
5. The shortened leadtime of 0.75 second between the main oxidizer valve opening and the main fuel valve opening during full steam startup caused no detrimental effects or hard startup.
6. The penetration depth of the generator exit flange thermocouples (50-TT-435, -436 and -437) to obtain an average temperature that matches the steam exit temperature should be approximately $2\frac{1}{4}$ inches. This depth was derived from Module 3 and could change for Module 1 and 2.

7. The propane manifold line size which was changed three times during the development test program does not affect the propane pressure profile during the startup transient.
8. The generator injectors were in good condition following the 1100 seconds duration full steam run. However, the welds in the injectors which were made with N-61 weld rod should be rewelded using "hastelloy W" to alleviate the possibility of intergranular corrosion and porosity.
9. A soft aluminum gasket 1/8 inch thick should be used for the injector-to-combustion chamber joint, and the bolts should be torqued to 440 ft-lb.
10. A method to shorten the time required for the propane bleed in through the facility supply line should be investigated.
11. The facility main steam line during the 1100 seconds full steam run did not expand in the expected direction. An evaluation of the steam line supports should be made to determine the adequacy of the existing system.
12. This test series should complete the Steam Generator System Development Test Program, and a product improvement test program should be conducted prior to the NES Design Demonstration Test Program. The product improvement tests should include, but not be limited to, the following:
 - a. Evaluation of a shortened LOX lead time of 0.5 second to further reduce the possibility of an oxygen rich atmosphere.
 - b. Further generator switching operation in order to demonstrate that all problems have been eliminated.

IV. TECHNICAL DISCUSSION

1. General

The Steam Generator System (SGS) Development Test Program Experimental Plan VI (EP-VI) was initiated on 28 April 1966 and was completed on 9 August 1966. The test program was conducted in accordance with the following documents:

- a. REON Test Specification 006 with Supplements 1 through 10.
- b. Test Description for Experimental Plan VI, NTO-I-0085 (presented as Appendix I).
- c. Test Description for Experimental Plan VI, Supplement 1, NTO-I-0119 (presented as Appendix II).

The Field Action Request (FAR) procedure, established by the NES Project Department to define, specify, detail and approve all work on or affecting the Steam Generator System, was continued. An index of the FAR's received between 11 April 1966 and 9 August 1966 is presented as Appendix III.

Table I, Steam Generator System Test Summary, presents a brief description of the test planning data and results for EP-VI. The Steam Generator System Test Data Tabulation, which is shown in Table II, presents data from the test runs and calculated fluid flow rates and mixture ratios. The symbols used in the test report are defined in the Steam Generator System Test Nomenclature presented in Appendix IV.

Experimental Plan VI consisted of short and long duration dual generator operational tests and generator switching tests. The EP-VI tests were conducted from the ETS-1 Control Room utilizing the control consoles specifically provided for operation of the Steam Generator System and activities. The NERVA Test Operations Document No. NTO-I-0086, Revision C, titled "Operating Procedure for Experimental Plan VI Steam Generator Development Test Program," describes the SGS testing procedure.

2. Pretest Checkout and Modifications

Before the first EP-VI test, the following tasks relating to the facility and steam generator system were performed:

- a. The following parts were assembled to form the Steam Generator System:
 - 1) Steam Generator Module 1 included Ignitor S/N 0011, Injector S/N 0016 and Chamber S/N 0016.
 - 2) Steam Generator Module 2 included Ignitor S/N 0017, Injector S/N 0017 and Chamber S/N 0017.
 - 3) Steam Generator Module 3 included Ignitor S/N 0014, Injector S/N 0018, and Chamber S/N 0018.
 - 4) Plenum S/N 01.
- b. The plenum drain valve (50-RSV-439), which was found to have leaked during EP-V, was disassembled and a new seat and plug installed.
- c. A 12-inch diameter orifice was installed in the temporary exhaust duct to simulate the throat area of the NES duct secondary ejector.
- d. The propane overhead manifold size was increased from a 2-inch pipe to a 4-inch pipe. The welds were X-rayed and the manifold was hydrostatically proof tested to 675 psig.
- e. Leak tests were performed satisfactorily on the hot gas, oxidizer, fuel and water systems.
- f. For generator switching operation, a four second delay after one of the two modules operating at full steam is shutdown until the idling module is commanded to full steam was incorporated into the sequence units.
- g. The module check valves were removed, cleaned, pressure checked and reinstalled. Because of a leak across the seat, Module 2 first-stage-ignitor oxidizer check valve (50-CHV-1707-2) was replaced with a new valve.
- h. A 0.177 inch thick Flexitallic gasket was installed in the injector to combustion chamber joint on all modules. The gasket was compressed

between 0.040 and 0.045 inch by torquing the bolts in 75 ft-lb increments. The average torque required to compress the gaskets to these values was 245 ft-lbs.

- i. The sensing line to the low pressure port of the second stage differential pressure switches (50-PDS-407) on all modules was relocated from the lower flange of the combustion chamber to the upper flange of the combustion chamber. This was accomplished by utilizing the same line that connects the high pressure port of the differential pressure switches 50-PDS-480 to the combustion chamber.
- j. A flat aluminum gasket was installed in the ignitor-to-injector flange joint on all modules.
- k. The main fuel venturi (S/N 0016) on Module 1 was replaced with the main fuel venturi from S/N 0019 because a flow test was to be conducted on 0016 venturi.
- l. Pressure switches 50-PS-422, 50-PS-423 and 50-PS-403 on all modules were adjusted.
- m. The diaphragm in pressure switch 50-PS-422-2 was replaced because a leak occurred.
- n. The crack in Injector 0018, which was noted in EP-V, was repaired by grinding out and welding with Hastelloy "W".

3. Test EP-VI-A-1

The first test run of the series, EP-VI-A-1, was conducted on 28 April 1966. This test run was a scheduled 15 seconds full-steam duration run of Modules 1 and 2 with Module 3 at idle condition. Module 1, 2 and 3 were started, in that order, to steam idle in about three second intervals. Module 1 was brought to full steam after 67 seconds at steam idle condition. Nine seconds later Module 2 was commanded to full steam, but the module shutdown during the startup transient due to malfunction. The other units were then manually shutdown. The malfunction occurred because the differential pressure switch (50-PDS-406-2) deactuated. The pressure switch monitors the difference between the injection water pressure and the lower combustion chamber pressure and when actuated, indicates

that the prescribed minimum injection water flow rate is present. However, in this test run, the pressure surge from the combustion within the third stage of Module 2, combined with the pressure in the plenum created by Module 1 at full steam, deactuated the pressure switch and caused a "low injection water flow" cutoff. To correct the above abnormality, the pressure switch 50-PDS-406 was changed to sense the differential pressure between the inlet and throat of the water injection venturi on each module with the pressure actuation and deactuation setting changed accordingly. The injector-to-chamber bolt torque was checked, and the average torque on Module 1 had decreased from 240 ft-lb to 195 ft-lb. The average torque on Module 2 decreased from 247 ft-lb to 195 ft-lb. The average torque on Module 3 did not decrease an appreciable amount from its pretest value of 245 ft-lb.

The injector-to-chamber bolts in each module which had torque values below 200 ft-lb were tightened to 260 ft-lb in preparation for the next test.

The tasks below were also performed in preparation for the next test:

- a. A satisfactory leak test was performed on the propane system, liquid oxygen system and hot gas system.
- b. The high frequency response pressure transducer $P_{wCO(S)}$ was relocated to the outboard end of the 6" water supply header.
- c. The actuator on the injection water control valve for Generator 0016 was replaced because of unsatisfactory operation. The new actuator was taken from spare Generator 0019.
- d. During a routine inspection, the spark plug on Module 1 was broken on reinstallation; and consequently, a new plug was installed.

4. Test EP-VI-B-2

The next test, EP-VI-B-2, was conducted on 3 May 1966 and was scheduled to be a 180 second duration run with Modules 1 and 2 at full steam and Module 3 at idle condition. The injection water control valves, 50-FCV-423, on Modules 1 and 2 were adjusted to go to their fully open position upon a full steam command to their respective modules. The facility water

valves were set in their fully open position to obtain the maximum water pressure available to the Steam Generator System. Modules 1, 2 and 3 were brought to steam idle condition in that order. After 60 seconds at idle, Module 1 was commanded to full steam followed by Module 2 approximately ten seconds later. On startup of Module 1, the stack exit steam temperature T_{sEAV} increased to approximately 1000°F and continued to 1100°F during the next 60 seconds. Since 1100°F was the maximum allowable steam temperature for this test run, no attempt was made to decrease the quantity of water injected into the combustion chamber. After approximately 190 seconds at full steam, Module 1 was manually shutdown, followed by Modules 2 and 3 manual shutdown. The mass flow rate of the steam ($\dot{W}_t$), steam pressure in the plenum (P_{sPl}), and the average steam temperature in the exhaust stack (T_{sEAV}) are shown graphically versus time in Figure 1. A thermocouple in the exhaust stack T_{sE-1} failed after 102 seconds of full steam operation, and during the post test inspection it was found to be bent and have a broken junction. Consequently, three new thermocouple probes of an improved design were installed at T_{sE-1} , T_{sE-2} , and T_{sE-3} . The injector-to-chamber bolt torque was checked during the post test inspection, and the average torque on Module 1 had decreased from 255 ft-lbs to 163 ft-lbs. The average torque decreased on Module 2 from 261 ft-lb to 166 ft-lb and on Module 3 from 240 ft-lb to 146 ft-lb. The injector-to-chamber bolts in each module which had torque values below 200 ft-lb were tightened to 260 ft-lb in preparation for the next test.

5. Test EP-VI-C-3

The unexpectedly high steam temperature (1100°F) encountered in EP-VI-B-2 resulted in a change of the injection water control valve (50-FCV-423) porting. The valves on Module 1 and 3 were changed from 75 C_v trim to 110 C_v . In an effort to determine the cause of the loss of bolt torque in the injector-to-combustion chamber joint, special instrumentation was installed on Module 1. Six accelerometers were placed in various locations on Module 1 to measure vibration in the vertical axis. Also, a thermocouple was installed in the space between the injector-to-chamber flanges, touching the raised face of the flange in order to measure the temperature in the vicinity of the gasket. The peak values of the accelerometers and

EVENTS	TIME (sec)
FULL STEAM STARTUP	
Module 1	0
FULL STEAM STARTUP	
Module 2	16
FULL STEAM SHUTDOWN	
Module 1	197
FULL STEAM SHUTDOWN	
Module 2	200

NOTE:

Steam temperature was not obtained for the entire test because of instrumentation malfunction.

FIGURE 1
OUTPUT OF THE STEAM GENERATOR SYSTEM DURING EP-VI-B-2

temperature for two modules at full steam are presented in Table II. For Module 1 only at full steam, the accelerometers measured in excess of 40 g's.

Test EP-VI-C-3 was scheduled to be a 180 second duration run with Modules 1 and 2 at full steam and Module 3 at idle condition. The test was conducted on 5 May 1966. Modules 1, 2 and 3 were started to idle condition in that order. After 60 seconds at idle, Module 1 was brought to full steam and operated normally. Approximately 15 seconds later, Module 2 was commanded to full steam and a "second stage cutoff" malfunction shutdown occurred on this module during the startup transient. Module 1 was allowed to run at full steam for about 15 seconds and then manually shutdown, followed by the manual shutdown of Module 3 from idle. A "second stage cutoff" malfunction is initiated by the deactuation of the differential pressure switch 50-PDS-407. This pressure switch senses the difference in pressure between the second stage and the upper portion of the third or main stage. The pressure switch 50-PDS-407-2 was subjected to a post test check and the actuation and deactuation pressures were within their specified values. The second stage pressure P_{C2-2} and the upper third stage pressure P_{CU3-2} were then examined on the oscillograph records. It was discovered that during the startup phase of Module 2 a third stage pressure fluctuation occurred which was greater than the second stage pressure as shown in Figure 2. This condition caused the pressure switch to deactuate and shutdown the module.

A reexamination of the EP-VI-B-2 oscillograph records revealed the same condition existed during that test but did not cause a shutdown (see Figure 3). To eliminate this combustion chamber pressure fluctuation sensed by the pressure switch, a 0.040 inch diameter orifice was installed in the third stage pressure lines of the switch 50-PDS-407, on each module, and the 0.040 inch diameter orifice in the second stage pressure line to the switches was removed.

The injector-to-chamber bolt torque was checked during the post test inspection, and the average torque on Module 1 had decreased from 237 ft-lb to 162 ft-lb. The average torques on Modules 2 and 3 did not decrease an

FIGURE 2

SECOND STAGE AND UPPER MAIN STAGE PRESSURE DURING FULL STEAM STARTUP ON EP-VI-C-3

FIGURE 3

SECOND STAGE AND UPPER MAIN STAGE PRESSURE DURING FULL STEAM STARTUP ON EP-VI-B-2

appreciable amount from their pretest values of 264 ft-lb and 248 ft-lb, respectively.

6. Test EP-VI-D-4

The fourth test was scheduled to be a 180 second duration run with Modules 1 and 2 at full steam and Module 3 at idle condition. The injection water control valves 50-FCV-423 on Modules 1 and 2 were adjusted to go to their fully open position upon a full steam command to their respective modules. The facility water valves were set in their fully open position to obtain the maximum water pressure available to the Steam Generator System. The steam temperature at the exit stack T_{sEAV} was to be regulated during the run to 1200°F by closing the injection water control valves. Test EP-VI-D-4 was conducted on 9 May 1966. Modules 1, 2 and 3 were started to idle in that order. After 60 seconds at idle condition, Module 1 was brought to full steam, followed by Module 2 20 seconds later. The steam temperature at the exhaust stack T_{sEAV} increased to between 1100°F and 1200°F shortly after both modules reached full steam. The temperature continued to rise steadily to 1250°F at the end of the run; therefore, no attempt was made to adjust the injection water control valves as originally planned. Modules 1, 2 and 3 were shutdown in that order after approximately 190 seconds full steam on Module 1.

The injector-to-chamber bolt torque was checked during the post test inspection and the average torque decreased only slightly. The average torque decreased from 241 ft-lb to 226 ft-lb on Module 1, from 246 ft-lb to 226 ft-lb on Module 2, and from 244 ft-lb to 219 ft-lb on Module 3. Examination of the data revealed that the upper third stage pressure sensed by the pressure switch 50-PDS-407 was dampened enough to eliminate the problem encountered on EP-VI-C-3 and B-2.

An evaluation of the fuel pressure as it is related to the size of the fuel manifold was made after EP-VI-D-4. It had been conjectured that the momentary decrease in the fuel supply pressure during the startup transient which had caused a "first stage cutoff" during EP-V-A-1 was caused by the reduced line size of the manifold. The propane is supplied through a

four-inch line from the fuel tank to the manifold. The inlet pressure to the second stage propane venturi of Module 1 (P_{fV2-1}) was plotted as the generator progressed to full steam for the three fuel manifold configurations that have existed on the Steam Generator System. The graph is shown in Figure 4. As can be seen from the graph, the size of the fuel manifold had little effect on the SGS performance.

7. Test EP-VI-E-5

The steam pipe, which will eventually connect the Steam Generator System to the NES duct secondary ejector, was used in the next test. An illustration of the steam line is shown in Figure 5. The upstream end of the pipe was attached to the plenum exhaust tee and the downstream end was attached to a temporary duct. This temporary duct exhausted the steam through a 90 degree elbow and a horizontal line to atmosphere. A 12.0 inch diameter sharp edge orifice was installed upstream of the temporary duct elbow to simulate the throat area of the secondary ejector. Three thermocouples (T_{sD1} , T_{sD2} and T_{sD3}) were installed in the temporary duct upstream of the orifice, and one pressure measurement P_{sL} and one temperature measurement T_{sL} were installed upstream of the last elbow in the main steam pipe.

Test EP-VI-E-5 was scheduled to be a 30 second duration run with Modules 1 and 3 at full steam and Module 2 at idle condition. The injector water control valves 50-FCV-423 on Module 1 and 3 were adjusted to go to their fully open position upon a full steam command to their respective modules. The facility water valves were set in their fully open position to obtain the maximum water pressure available to the Steam Generator System.

Test EP-VI-E-5 was conducted on 12 May 1966. Modules 1, 2 and 3 were started to steam idle in that order. After 60 seconds at idle condition, Module 1 was brought to full steam followed by Module 3, 15 seconds later. The steam temperature upstream of the orifice rose to 900°F after 25 seconds full steam on Module 1 and then decreased to 773°F at shutdown. Modules 1, 2 and 3 were shutdown in that order after 30 seconds of full steam on Module 1. During the above test, a television camera was positioned to display "view A" (defined in Figure 5) of the steam line. It

LEGEND:

- 4 INCH DIAMETER OVERHEAD FUEL MANIFOLD DATA
FROM EP-VI-D-4
- 2 INCH DIAMETER OVERHEAD FUEL MANIFOLD DATA
FROM EP-V-F-6
- 2-1/2 INCH DIAMETER FUEL MANIFOLD DATA
FROM EP-IV-P-17

FIGURE 4
MODULE 1 SECOND STAGE PROPANE VENTURI INLET
PRESSURE (P_{FV2-1}) DURING FULL STEAM STARTUP

FIGURE 5

ILLUSTRATION OF MAIN STEAM LINE

was the impression of an observer that the steam line moved slightly during startup.

The injector-to-chamber bolt torque was checked during the post test inspection and the torque did not decrease a significant amount.

8. Test EP-VI-F-6

The main chamber differential pressure switch (50-PDS-480) on each generator was re-set to deactuate at 5 psid to minimize the possibility of opening during multiple unit operation. Three accelerometers (A_{XJ2-1} , A_{XUC2-1} and A_{XLC1-1}) were deleted from Module 1 and installed on the steam line at the location shown in Figure 5. Accelerometers ASL-X, ASL-Y and ASL-Z were to measure vibration in the X, Y and Z axis, respectively. Accelerometer A_{XLC2-1} was deleted and mounted in the Z axis on the upper combustion chamber flange.

Test EP-VI-F-6 was scheduled to be a 180 second duration run with Modules 1 and 3 at full steam and Module 2 at idle condition. The injection water control valves 50-FCV-423 on Modules 1 and 3 were adjusted to go to their fully open position to obtain the maximum water pressure available to the Steam Generator System. The steam temperature at the exit duct (T_{SDAV}) was to be regulated during the run to between 1150°F to 1200°F by closing the injection water control valve. If the steam temperature exceeded 1250°F without closing the injection water control valve, the test was to be terminated. Test EP-VI-F-6 was conducted on 16 May 1966. Modules 1, 2 and 3 were started to idle in that order. After 60 seconds at idle condition, Module 1 was brought to full steam, followed by Module 3, 15 seconds later. The steam temperature at the exit duct increased gradually such that after 95 seconds at full steam of Module 1 the temperature was approximately 1250°F . At this point the test was terminated as specified in the test plan. No attempt had been made to raise the steam temperature by closing the injection water control valve during the run. The mass flow rate of the steam ($\dot{W}_t$), steam pressure in the main steam line (P_{SL}), and the average steam temperature in the main steam line (T_{SDAV}) are shown graphically versus time in Figure 6. The injector-to-chamber bolt torque was checked after the test run and the torque did not decrease a significant amount.

FIGURE 6

OUTPUT OF THE STEAM GENERATOR SYSTEM DURING EP-VI-F-6

9. Test EP-VI-G-7 and 8

In preparation for the next test, new spark plugs were installed on Modules 2 and 3 as part of routine maintenance, and all accelerometers on Module 1 were deleted. Test EP-VI-G-7 was scheduled to be a 120 second duration run commencing after a full steam warmup period. Modules 2 and 3 would be run at full steam with Module 1 at idle condition. The main stage propellant flow rates to each module were to be reduced to 7.0 lb/sec propane and 16.7 lb/sec liquid oxygen in order to control the steam temperature. The facility water valves were set in the fully open position to obtain the maximum water pressure available to the Steam Generator System. The system was to be warmed-up by running Module 2 at full steam for a 60 second period and then running Modules 2 and 3 at full steam for a 120 second period. During the warmup period, the injection water control valve was to be in the fully open position. If the steam temperature at the exit duct T_{sDAV} was less than 1250°F initially, the injection water flow rate was to be reduced until the steam temperature was $1300 \pm 25^{\circ}\text{F}$. If at any time the steam temperature exceeded 1400°F , the test was to be terminated. Test EP-VI-G-7 was conducted on 18 May 1966. The reduced main stage propellant flow rates were achieved by pressurizing the liquid oxygen tank to 245 psig and the propane tank to 270 psig. Module 1 was commanded to idle condition followed shortly by Module 2 to idle. However, Module 1 did not reach idle condition but shutdown because of a "first stage cutoff" malfunction. Module 2 was then shutdown manually, and the bleed cycle was initiated on all modules. After a four-minute period, Test EP-VI-G-8 was initiated. The three modules were brought up to idle. After 60 seconds at idle condition, Module 2 was brought up to full steam and allowed to run for 60 seconds. Module 3 was then commanded to full steam and the two modules allowed to run for 120 seconds with the injection water control valves in the fully open position. The steam temperature at the exit duct during this warm up period gradually increased to 420°F . The injection water control valves on Module 2 and 3 were then throttled so as to maintain approximately equal water flow rates between the two modules. The steam temperature increased such that after 360 seconds of full steam of Module 2 (180 seconds after injection water control valves was throttled) the

temperature was 1150°F. The three modules were then shutdown. The injection water control valves had been modulated to approximately 25% of their opening at the end of the run. The mass flow rate of the steam ($\dot{W}_t$), steam pressure in the main steam line (P_{sL}), and the average steam temperature in the main steam line (T_{sDAV}) are shown graphically versus time in Figure 7.

The malfunction during EP-VI-G-7 occurred because the absolute pressure switch 50-PDS-413-1 did not actuate within the specified time span of the sequencing unit. This pressure switch monitors the pressure in the first stage and when actuated indicates first stage ignition. An examination of the data revealed that the first stage pressure P_{c1-1} increased slowly to just below the switch actuation pressure of 95 psig. The relative system was checked for leaks and obstructions but no abnormalities were found.

The injector-to-chamber bolt torque was checked after the test run and the torque did not decrease a significant amount.

10. Test EP-VI-H-9 Through 13

Test EP-VI-H-9 was conducted on 20 May 1966. The objective was to determine the pressure drop across the water strainer (50-ST-441), 80-mesh element, installed in the process water line upstream of supply valves 50-RSV-433 and 50-RSV-434. A differential pressure transducer ΔP_{ws} was installed across the strainer. The water supply valves 50-RSV-433 and 50-RSV-434 were opened along with the two water injection valves 50-FCV-423-1 and 50-FCV-423-2. This configuration which produced an estimated water flow rate of 255 lbs/sec caused a pressure drop across the strainer of 11.2 psid. With only 50-RSV-433 and 50-RSV-434 open, the estimated water flow rate was 155 lbs/sec and the resultant pressure drop across the strainer was 5.9 psid.

Test EP-VI-H-10 was scheduled to be two module full steam operation for 150 seconds followed by a switching operation of a module on standby. The test was to be conducted with the reduced propellant flow rates specified in EP-VI-G. Test EP-VI-H-10 was conducted on 20 May 1966. The

EVENTS	TIME (sec)
FULL STEAM STARTUP - Module 2	0
FULL STEAM STARTUP - Module 3	59
STARTED CLOSING INJECTION WATER CONTROL VALVES TO ACHIEVE STEAM TEMPERATURE OF 1300°F	185
FULL STEAM SHUTDOWN - Module 2	360
FULL STEAM SHUTDOWN - Module 3	363

FIGURE 7

OUTPUT OF THE STEAM GENERATOR SYSTEM DURING EP-VI-G-8

reduced main stage propellant flow rates were achieved by pressurizing the liquid oxygen tank to 233 psig and the propane tank to 261 psig. Module 1 was commanded to idle condition but a "first stage cutoff" malfunction occurred. The propellant bleeds were initiated and three minutes later Test EP-VI-H-11 was conducted. The same malfunction experienced in H-10 occurred again during this test. The propellant bleeds were started and three minutes later Test EP-VI-H-12 was initiated. Module 1 was brought to idle condition successfully; however, when Module 2 was commanded to idle a "first stage cutoff" malfunction occurred. Module 1 was then manually shutdown. The liquid oxygen tank pressure was then increased to 295 psig, and the propane tank pressure increased to 298 psig. This would increase the propellant flow rates per module to approximately 7.7 lb/sec propane and 18.5 lb/sec liquid oxygen. Twenty-six minutes after EP-VI-H-12, Test EP-VI-H-13 was initiated; Modules 1, 2 and 3 were brought to idle condition without incident and manually shutdown after about ten seconds run time. It was then concluded that the "first stage cutoff" malfunction that occurred in EP-VI-G-7, H-10, H-11 and H-12 was due to the low propellant tank pressures. Therefore, when the reduced flow rates are required, the first stage pressure switches 50-PDS-413 would have to be reset to actuate at a lower value.

11. Test EP-VI-I-14 and 15

During a hot gas leak test in preparation for the next test, the second stage fuel venturi on Module 2 was found to be cracked. There was no replacement for this part available, and an orifice with a diameter of 0.070 inch was substituted. Test EP-VI-I-14 was to be conducted as outlined below:

- a. The main stage propellant flow rates were to be 7.0 lb/sec propane and 16.7 lb/sec oxygen.
- b. The water pressure was to be the maximum available.
- c. Modules 1 and 2 were to be started to full steam with their injection water control valves fully open.
- d. The injection water control valves were to be adjusted so that the flow rate to each module would be about 37 lb/sec, and then allowed to run for 90 seconds.

- e. The water flow rates were to be decreased to achieve a steam temperature at the steam pipe exhaust ($T_{s\text{ DAV}}$) of 1100°F during the next 90 seconds.
- f. During the next 60 seconds, the water flow rate was to be decreased further until the steam temperature ($T_{s\text{ DAV}}$) increased to $1300 \pm 25^{\circ}\text{F}$.
- g. The Module 2 was to be manually shutdown and Module 3, which was placed on "standby," would automatically be brought to full steam. The injection water control valve on Module 3 was to go to the fully open position.
- h. Module 1 and 3 were to be allowed to run at full steam for 5 seconds before manual shutdown.

Test EP-VI-I-14 was conducted on 23 May 1966. The first stage pressure switch 50-PDS-413 was reset to actuate at 60 psig because of the reduced flow rates required for this run. The liquid oxygen tank was pressurized to 240 psig and the propane tank was pressurized to 260 psig to obtain the reduced flow rates. The facility water valves were set in the fully open position so that the maximum water pressure would be available. The three injection water control valves were set to go to their fully open position upon a full steam command to their respective modules. Modules 1, 2 and 3 were brought to idle condition. After 60 seconds at idle, Module 1 was brought up to full steam and approximately 15 seconds later Module 2 was brought up to full steam. At the time Module 2 was commanded to full steam, Module 1 shutdown due to a "second stage cutoff" malfunction. Module 2 was then manually shutdown. After a 5 minute period, Test EP-VI-I-15 was initiated. Modules 1, 2 and 3 were brought to idle condition in that order. Module 1 was brought to full steam followed by Module 2, 16 seconds later. After 54 seconds of full steam operation on Module 1, the water flow rate to Module 1 and 2 was adjusted to 37 lb/sec each by partially closing the injection water control valves. The injection water control valves were further closed, and the steam temperature $T_{s\text{ DAV}}$ reached about 1100°F after 157 seconds of full steam operation on Module 1. This steam temperature was held for 67 seconds and then the water flow rate was again decreased such that the steam temperature was

raised to approximately 1300°F. The steam temperature was held at this point for 37 seconds at which time Module 2 was manually shutdown. Module 3, which had been placed on "standby" 45 seconds before Module 2 shutdown, automatically progressed to full steam after the sequence-controlled four-second delay. Modules 1 and 3 were run at full steam for 9 seconds and then Module 3 was manually shutdown, followed shortly by Module 1.

The total mass flow rate of the steam ($\dot{w}_t$), steam pressure in the main steam line (P_{sL}) and average steam temperature in the main steam line (T_{sDAV}) are shown graphically versus time in Figure 8. The injector-to-chamber bolt torque was checked after the test run, and the average bolt torque on Module 1 had decreased from 211 ft-lb to 175 ft-lb. The bolt torque on Module 2 and 3 did not decrease significantly.

The main steam line was found to be warped after the test. The line had cocked at the bellows above the elbow as shown in Figure 9. The location of this area in the main steam line is denoted by "view B" in Figure 5. The line had bent slightly in several other locations, also. The steam line was blanked off and the exhaust stack was used for the next test. It was determined that these problems were partially a result of improper adjustment of the pipe hangers. The pipe hangers had been locked in one position for all tests up to this time.

The "second stage cutoff" malfunction which occurred in Test EP-VI-I-14 was initiated by the deactuation of the differential switch 50-PDS-407. The same malfunction had occurred previously in EP-VI-C-3 prior to the reduction in tank pressures, and an orifice had been installed in the pressure lines from the upper third stage combustion chamber to the pressure switch to dampen the pressure fluctuations to the switches. To minimize this false malfunction with the reduced tank pressures, the pressure switch (50-PDS-407) on each generator were set to deactuate at 5 psid, rather than the previous setting of 12 psid.

EVENTS	TIME (sec)
FULL STEAM STARTUP - Module 1	0
FULL STEAM STARTUP - Module 2	16
STARTED CLOSING INJECTION WATER CONTROL VALVES TO ACHIEVE 37 lb/sec WATER FLOW RATE TO EACH MODULE	36
ACHIEVED 37 lb/sec WATER FLOW RATE TO EACH MODULE	54
STARTED CLOSING INJECTION WATER CONTROL VALVES TO ACHIEVE 1000°F STEAM TEMPERATURE. .	136
STARTED CLOSING INJECTION WATER CONTROL VALVES TO ACHIEVE 1300°F STEAM TEMPERATURE. .	224
FULL STEAM SHUTDOWN - Module 2.	285
FULL STEAM STARTUP - Module 3	289
FULL STEAM SHUTDOWN - Module 3.	300
FULL STEAM SHUTDOWN - Module 1.	302

FIGURE 8

OUTPUT OF THE STEAM GENERATOR SYSTEM DURING EP-VI-I-15

FIGURE 9
MAIN STEAM LINE ELBOW AFTER EP-VI-I-15

12. Test EP-VI-J-16

The next test was to be conducted as outlined below:

- a. The main stage propellant flow rates to each module were to be 7.0 lb/sec propane and 16.7 lb/sec oxygen.
- b. The water pressure was to be the maximum available.
- c. Modules 1 and 2 were to be started to full steam with their injection water control valves 50% open.
- d. The injection water control valves were to be adjusted so that the flow rates to each module would be 37 lb/sec after 30 seconds full steam operation of Module 1.
- e. The water flow rates were to be decreased to achieve a steam temperature of $1100 \pm 25^{\circ}\text{F}$ after 90 seconds full steam operation of Module 1.
- f. After 190 seconds full steam operation, Module 1 was to be manually shutdown and Module 3, which was placed on standby, would automatically be brought to full steam. The injection water control valve on Module 3 was to go to a position slightly higher than Modules 1 and 2 valve positions used to achieve a steam temperature of 1100°F .
- g. The water flow rates were to be decreased to achieve a steam temperature of $1100 \pm 25^{\circ}\text{F}$, 20 seconds after Module 3 was brought to full steam.
- h. Modules 2 and 3 were to be allowed to run at full steam for 100 seconds before manual shutdown.

Test EP-VI-J-16 was conducted on 25 May 1966. The liquid oxygen tank was pressurized to 240 psig and the propane tank was pressurized to 270 psig to obtain the reduced flow rates. The facility water valves were set in the fully open position so that the maximum water pressure would be available. The injection water control valves on Modules 1 and 2 were set to go to 50 per cent open upon a full steam command. Modules 1, 2 and 3 were brought to idle condition. Module 1 was brought up to full steam followed by Module 2, 20 seconds later. After 35 seconds of full steam operation on Module 1, the water flow rates to Module 1 and 2 were adjusted to 37.1b/sec each by partially closing the injection water control

valves. The injection water control valves were further closed, and the steam temperature T_{sEAV} reached about 1100°F after 109 seconds of full steam operation on Module 1. The two modules were allowed to run at 1100°F steam exhaust temperature for about 80 seconds during which time Module 3 was placed on "standby" and its injection water control valve was set to a position slightly higher than Module 1 and 2 valve positions. Module 1 was manually shutdown and four seconds later Module 3 automatically came up to full steam. Approximately 4.5 seconds after full steam startup of Module 3, the second stage liquid oxygen valve 50-RSV-423B-1 on Module 1 exploded. Approximately 2.5 seconds later, a minor pressure surge was noted in the combustion chamber of Module 1. The malfunction was visually noted on the television monitor, and Module 2 and 3 were manually shutdown 14 seconds after the switching operation. A review of the test data indicated that the following events occurred:

- a. After Module 1 was shutdown from full steam the normal 1 second gaseous nitrogen purge occurred.
- b. On completion of the purge, it is conjectured that the LO_2 and propane which was trapped between their respective second stage propellant valves and check valves vaporized and diffused into the second stage combustion chamber and mixed.
- c. Four seconds after shutdown of Module 1, Module 3 automatically was sequenced to full steam, which doubled the plenum pressures. This caused the mixed gases to be compressed by the hot steam with the ensuing LO_2 valve detonation.
- d. The cause of the second non-destructive pressure surge is not known.

The second stage liquid oxygen valve which was destroyed by the explosion is shown in Figure 10. Also, the top works of Module 1 is shown in Figure 11. The mass flow rate of the steam ($\dot{W}_t$), steam pressure in the plenum (P_{sPl}), and the average steam temperature in the exhaust stack (T_{sEAV}) are shown graphically versus time in Figure 12. The injector-to-chamber bolt torque was checked and the average torque on Module 1 had decreased from 220 ft-lb to 168 ft-lb. The bolt torque on the other modules had changed only slightly.

FIGURE 10
SECOND STAGE LIQUID OXYGEN VALVE (50-RSV-423B-1)
WHICH WAS DESTROYED DURING EP-VI-J-16

FIGURE 11
MODULE 1 TOPWORKS AFTER EP-VI-J-16

FIGURE 12
OUTPUT OF THE STEAM GENERATOR SYSTEM DURING EP-VI-J-16

The Steam Generator System was then subjected to a detailed post test inspection. Each generator was disassembled and the following observations were made:

a. Module 1 Ignitor Assembly 0011

- 1) Second stage LO_2 propellant valve 50-RSV-423-B-1 was destroyed (see Figure 10). Carbon deposits were on the downstream side of valve.
- 2) Second stage LO_2 check valve 50-CHV-1708-1 was open and would not seal.
- 3) Second stage LO_2 supply manifold was bulged and distorted.
- 4) Second stage propane supply manifold and check valve 50-CHV-1703-1 were bulged.

b. Module 1 Combustion Chamber 0016 liner had a severe longitudinal bulge about 16 to 18 inches long, 3 inches wide, and $\frac{1}{4}$ inch high, beginning just below one group of film cooling holes as shown in Figure 13. There were several smaller longitudinal bulges in the lower surface.

c. Module 1 Injector 0016 was in generally good condition. There were "rolling" variations in the face between spud assemblies. A dye penetrant inspection revealed some minor porosity which had been observed before EP-VI (see Figure 14).

d. Module 2 Combustion Chamber 0017 was in generally good condition.

e. Module 2 Injector 0017 was subjected to a dye penetrant inspection as shown in Figure 15. The inspection revealed high porosity in all weld areas around the spud assemblies, and numerous parts of the injector. There was also evidence of slight erosion at the edges of the spud assembly and idle unit opening welds.

f. Module 3 Combustion Chamber 0018 was in generally good condition; however, several longitudinal ripples were beginning to appear.

g. Module 3 Injector 0018, shown in Figure 16, was in essentially the same condition as Injector 0017 except there was only slight

FIGURE 13
COMBUSTION CHAMBER 0016 AFTER EP-VI-3-16 SHOWING LONGITUDINAL BULGES

FIGURE 14
INJECTOR 0016 AFTER EP-VI-J-16 SHOWING RESULTS OF DYE PENETRANT INSPECTION

FIGURE 15
INJECTOR 0017 AFTER EP-VI-J-16 SHOWING RESULTS OF DYE PENETRANT INSPECTION

FIGURE 16
INJECTOR 0018 AFTER EP-VI-J-16 SHOWING RESULTS OF DYE PENETRANT INSPECTION

indications of cracks at the idle unit opening. The non-porous area in the weld on spud #3 which can be seen in Figure 16 is the repaired portion of the weld made by NRDS prior to EP-VI.

- h. The long bolt orifices in each module were measured and did not change in dimensions from the measurement made after EP-V.

13. Mid-Test Rework and Checkout

Extensive rework was required on the Steam Generator System before the remaining tests could be conducted. Injector 0016, Injector 0017 and Combustion Chamber 0016 were sent to REON-Sacramento for evaluation.

A metallographic examination disclosed intergranular attack and pitting present to a depth of .006" to .010" in Injectors 0017 and 0018 welds. Only intergranular pitting was evident in Injector 0016 welds to a depth of .004". Spectrographic analysis of weld samples from the spud welds of each injector disclosed that the weld joint material composition was N-61.

The N-61 weld material was removed on Injector 0018 and rewelded with Hastelloy "W" for the following reasons:

- a. The weld repair made with Hastelloy "W" on Injector 0018 before EP-VI exhibited no intergranular pitting.
- b. Hastelloy "W" possesses superior corrosion resistance at temperatures up to 1500⁰F and provides inherent protection to galvanic corrosive attack.

Injectors 001, 0018 and 0019 were inspected to assure that all the propellant injection holes were the correct diameter and depth and also free of obstructions. This was accomplished by passing the correct size drill into the holes. Injector 001 had approximately 10% of the fuel holes undersize, and Injector 0019 had approximately 50% of the fuel holes undersize. Injector 0018 had three fuel holes with broken drill bits in them and approximately 80% of the holes were undersize. The large number of undersized holes in Injector 0018 was attributed to the weld repair of the injector.

Injectors 001, 0018 and 0019 were then backflowed with water to force any foreign material out. The water flow rate was increased until there was a 60 psid differential pressure across the injectors. The fuel inlet to each injector was then connected to a water source, and the fuel injector flow pattern was observed to further ensure that all the fuel injection holes were unobstructed.

Ignitor 0011, which was previously assembled on Module 1, was shipped to REON-Sacramento. Ignitors 0014, 0017 and 0019 were entirely retubed using stainless steel tubing and fittings throughout.

The ignitors, injectors, and chambers were assembled in the following manner:

- a. Steam Generator Module 1 included Ignitor S/N 0019, Injector S/N 0019 and Combustion Chamber S/N 001.
- b. Steam Generator Module 2 included Ignitor S/N 0017, Injector S/N 001 and Combustion Chamber S/N 0017.
- c. Steam Generator Module 3 includes Ignitor S/N 0014, Injector S/N 0018 and Combustion Chamber S/N 0018.

A soft aluminum gasket, 0.0625 inch thick, was installed in the injector-to-combustion chamber joint on Modules 1 and 3; Module 2 injector-to-combustion chamber joint utilized a Flexitallic gasket 0.175 inch thick. The injector-to-combustion chamber joint bolts on all modules were torqued in steps to 440 ft-lbs.

To prevent a reoccurrence of the liquid oxygen valve detonation which took place during EP-VI-J-16, the Steam Generator System was modified as follows:

- a. During multiple unit operation, the gaseous nitrogen purge will automatically start immediately after the first module is shutdown and continue until one second after the last module is shutdown. However, a manual override switch was provided on the control console which will extend the purge after the last unit is shutdown. Previously there had been a one-second purge to each module after shutdown.

- b. The second stage fuel and oxidizer check valves (50-CHV-1703 and 50-CHV-1708) were modified to allow the gaseous nitrogen purge to enter upstream rather than downstream of the valve poppet.
- c. The gaseous nitrogen purge supply pilot valves (50-SV-432-1, -2, -3) were wired in parallel. This would open all three purge supply valves (50-RSV-432-1, -2, -3) when any module is shutdown. Also, the discharge of the purge supply valves were manifolded. These two modifications were made to increase the reliability of the purge system.

The low pressure side of the first stage pressure switch (50-PDS-413), which had previously sensed atmospheric pressure, was connected to the upper third (main) stage on all modules. The switches were set to actuate at 60 psid and deactuated at 15 psid. Also, both ports were orificed. This modification would prevent the plenum pressure resulting from modules at full steam from actuating the pressure switch of a non-operating module, and would make it possible to restart the non-operating module.

A turbine type flowmeter was installed in the liquid oxygen supply line of Module 1 as a redundant flow measuring device.

The combustion chamber exit thermocouples (T_{c1} , T_{c2} , T_{c3}) were installed at various depths into the gas flow stream in an attempt to obtain an average temperature which would match that obtained from the steam exit thermocouples (T_{sD1} , T_{sD2} , T_{sD3}). The thermocouples were inserted initially to the following depths:

- a. T_{c1-1} , T_{c2-1} , and T_{c3-1} were inserted in the gas stream 1.5 inches.
- b. T_{c1-2} , T_{c2-2} , and T_{c3-2} were inserted in the gas stream 2.0 inches.
- c. T_{c1-3} , T_{c2-3} , and T_{c3-3} were inserted in the gas stream 2.5 inches.

The injector-to-combustion chamber joint bolts on all modules were re-torqued twice before the next test to determine if change had occurred. The time intervals between the torquing were 10 and 21 days. There was no significant change in the torque values.

Extensive rework was done on the main steam line, pipe supports and hangers. The steam line was disconnected at the temporary exhaust duct and repositioned to remove the twist at the elbow noted after EP-VI-I-15. A shock suppressor was added at the elbow which had twisted to dampen the initial steam line surge. A 12.01 inch diameter orifice with a rounded entrance was installed in the main steam line.

A propane bleed valve 50-RSV-731 was installed in a one-inch take-off line just upstream of 50-RSV-482 which replaced 50-BV-2295. Downstream of 50-RSV-731 a thermocouple, 50-TT-509, was installed and a visual indication of the temperature was displayed in the control room. This modification would permit closer control of the propane bleed in operation.

New steam generator relay control racks (sequence units) were installed. These units would function the same as the replaced units and were used because they were of an improved design.

As a result of recent tests conducted by REON-Sacramento, an evaluation was made of the materials present in the Steam Generator Oxidizer (Liquid Oxygen) System Components to determine their compatibility for liquid or gaseous oxygen service. From the results of this evaluation, several materials that existed in the oxidizer system were not acceptable and were replaced with LOX compatible material. Appendix V shows the various components and their manufacturers' supplied materials along with the materials with which they were replaced, where required.

14. EP-VI-K-17

Before the modification of the LOX system components was completed, a satisfactory dry run, Test EP-VI-K-17, was conducted on 9 July 1966. This dry run utilized all checklists and checklist schedules associated with the Steam Generator System, up to and including propellant bleed in through the supply lines to the test stand.

15. EP-VI-L-18

The modified LOX system components were installed in the modules and checklist activities were begun for Test EP-VI-L-18 on 3 August 1966.

This test was to be a checkout test with each module run at full steam for 30 seconds as outlined in Appendix II, Paragraph 2.2.2. However, during the electromechanical test, the second stage propellant shutoff valves (50-RSV-423B and 50-RSV-423C) were found to leak past their seats from the downstream side to the upstream side when the purge was introduced. As noted earlier, the purge system had been modified after EP-VI-J-16 such that the gaseous nitrogen entered the second stage propellant lines between the check valves (50-CHV-1703 and 50-CLV-1708) and the propellant shutoff valves rather than downstream of the check valves. EP-VI-L-18 was terminated at this time and the purge lines were modified such that the gaseous nitrogen would enter downstream of the check valves.

16. EP-VI-M-19

The checklist activities were begun for Test EP-VI-M-19 on 4 August 1966. This test was to be the same type attempted in EP-VI-L-18. During the electromechanical tests, it was found that the first stage oxidizer valves (50-RSV-422A), which are three-way pilot operated valves, were inoperable and would not shutoff the purge. The second stage purge supply valves (50-RSV-423A) which are identical to the first stage oxidizer valves were also found to be inoperable. These valves had been modified by REON-Sacramento as part of the LOX compatibility refurbishment and were not subjected to an adequate acceptance test.

The valves were sent back to Sacramento for disassembly and repair.

17. EP-VI-N-20

The first stage oxidizer valves and second stage purge supply valves, which malfunctioned during EP-VI-M-19, were received from REON-Sacramento and installed in the Steam Generator System. The test was to be run as outlined in Appendix II, Paragraph 2.2.4, except as noted below:

- a. The TDR-4 module relay control box time was set at 0.75 seconds LO_2 lead control time. Previously it had been set at 1.0 seconds.
- b. The penetration depth of the module combustion chamber exit thermocouples were as outlined in Paragraph 13.

- c. Module 3 was to be brought to full steam first followed by Module 2, 30 seconds later.
- d. After 15 seconds of full steam operation of Modules 2 and 3, the injection water control valves were to be adjusted to provide 35 lb/sec water flow rate to each module.
- e. After 45 seconds of full steam operation of Module 2 and 3, the injection water control valves were to be adjusted to provide 1300°F steam temperature at T_{s_DAV} .
- f. After 190 seconds of full steam operation of Module 2 and 3, Module 2 was to be manually shutdown and Module 1 which was to have been placed on standby would automatically be brought to full steam.
- g. Module 1 injection water control valve was then to be adjusted to provide 1300°F steam temperature.
- h. After 120 seconds of full steam operation of Module 1 and 3, Module 3 was to be manually shutdown followed by Module 1, 5 seconds later.

The Test EP-VI-N-20 was conducted on 8 August 1966. The liquid oxygen tank was pressurized to 248 psig and the propane tank was pressurized to 271 psig to obtain the desired flow rates. The facility water valves were set in the fully open position so that the maximum water pressure would be available. The injection water control valves on Modules 2 and 3 were set to go to 40 per cent open upon a full steam command. Modules 1, 2 and 3 were brought to idle condition. After 67 seconds idle on Module 1, Module 3 was brought to full steam followed by Module 2, 35 seconds later. Shortly after Modules 2 and 3 were brought to full steam, a steam temperature at the combustion chamber exit of 1500°F was reported to the test conductor. Because of this unexpectedly high steam temperature no attempt was made to decrease the injection water. Switching, however, was achieved after 205 seconds of full steam operation of Modules 3 and 2. Modules 1 and 3 were then allowed to run for 105 seconds before Module 3 was manually shutdown followed by Module 1, 5 seconds later. The mass flow rate of the steam ($\dot{W}_t$), steam pressure in the main steam line (P_{sL}), and the average steam temperature in the main steam stream line (T_{s_DAV}) are shown graphically versus time in Figure 17.

EVENTS	TIME (sec)
FULL STEAM STARTUP - Module 3	0
FULL STEAM STARTUP - Module 2	35
FULL STEAM SHUTDOWN - Module 2	240
FULL STEAM STARTUP - Module 1	244
FULL STEAM SHUTDOWN - Module 3	349
FULL STEAM SHUTDOWN - Module 1	353

FIGURE 17

OUTPUT OF THE STEAM GENERATOR SYSTEM DURING EP-VI-N-20

The unexpectedly high steam temperatures at the combustion chamber exit were attributed to the new penetration depths of the thermocouple probes which were specified for this test. For the next test the thermocouples were inserted to the following depths:

- a. T_{c1-1} , T_{c2-1} , and T_{c3-1} were inserted in the gas stream 1.75 inches.
- b. T_{c1-2} , T_{c2-2} and T_{c3-2} were inserted in the gas stream 2.0 inches.
- c. T_{c1-3} , T_{c2-3} and T_{c3-3} were inserted in the gas stream 2.25 inches.

The injector-to-chamber flange bolt torque was checked after the test and the average torque on Module 1 had decreased from 435 ft-lbs to 225 ft-lbs. The average torque decreased on Module 2 from 414 ft-lbs to 144 ft-lbs and on Module 3 from 461 to 367 ft-lbs. Module 2 had one bolt with no torque. The injector-to-chamber flange bolts in each module which had torque values below 390 ft-lbs were tightened to 440 ft-lbs.

Several hangers on the main stream line were adjusted based upon observation made during the test.

18. EP-VI-0-21

Checklist activities in preparation for EP-VI-0-21 were begun on 9 August 1966. The water supply valve 50-RSV-433 was found to be leaking past the main seat but this discrepancy did not delay the test.

The test was to be as outlined in Appendix II, Paragraph 2.25 except as noted below:

- a. The LO_2 lead time remained at 0.75 seconds.
- b. The penetration depths of the module combustion chamber exit thermocouples were as outlined in Paragraph 17.
- c. Module 3 was to be brought to full steam first followed by Module 2, 15 seconds later.

The liquid oxygen tank was pressurized to 242 psig and the propane tank was pressurized to 260 psig to obtain the desired flow rates. The facility water valves were set in the fully open position so that the maximum water pressure would be available. The injection water control valves

on Module 2 and 3 were set to go to 40 per cent open upon a full steam command. The propane bleed-in operation took approximately $1\frac{1}{2}$ hours to chill the tank and facility supply line. Modules 1, 2 and 3 were brought to idle conditions. After 77 seconds idle on Module 1, Module 3 was brought to full steam followed by Module 2, 14 seconds later. By partially closing the injection water control valves, a water flow rate of 35 lb/sec to each module was achieved after 40 seconds of full steam operation of Modules 2 and 3. After 145 seconds of full steam operation of Modules 2 and 3, a steam exit temperature ($T_{s\text{ DAV}}$) of 1300°F was reached by further reducing the injection water flow rate. Modules 2 and 3 were then allowed to run at full steam for a total of 1089 seconds. During this period, the injection water control valves required minor adjustments to maintain 1300°F steam temperature and equal water flow rates to each module. At the end of this period Module 2 was manually shutdown. Module 1, which had been placed on standby earlier, attempted to go to full steam but shutdown due to a "second stage cutoff" malfunction. Module 3 was then manually shutdown 19 seconds later. The mass flow rate of the steam ($\dot{W}_t$), steam pressure in the main steam line ($P_{s\text{ L}}$), and the average steam temperature in the main steam line ($T_{s\text{ DAV}}$) are shown graphically versus time in Figure 18.

Erratic movement of the main steam line was noted during the test. The position of the constant spring support hangers prior to and after the test are tabulated below:

EVENTS	TIME (sec)
FULL STEAM STARTUP	
Module 3	0
FULL STEAM STARTUP	
Module 2	14
STARTED CLOSING INJECTION WATER	
CONTROL VALVES TO ACHIEVE	
35 lb/sec WATER FLOW RATE	
TO EACH MODULE	30
ACHIEVED 35 lb/sec WATER FLOW	
RATE TO EACH MODULE.	56
STARTED CLOSING INJECTION WATER	
CONTROL VALVES TO ACHIEVE	
1300°F STEAM TEMPERATURE . .	113
FULL STEAM SHUTDOWN	
Module 2	1105
FULL STEAM SHUTDOWN	
Module 3	1124

FIGURE 18
 OUTPUT OF THE STEAM GENERATOR SYSTEM DURING EP-V-0-21
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<u>Hanger*</u>	<u>Cold Position (Prior to Test)</u>	<u>Hot Position (Immediately After Test)</u>	<u>Post-Test Position (Ambient Temperature)</u>
2-1000 lb hangers on trapeze in horizontal run	Low Mark	$\frac{1}{4}$ of scale- travel toward high mark	Original low mark
5000 lb hanger at elbow in pipe chase	$\frac{1}{3}$ scale from high mark toward low	Bottomed out on low stop (hanger bottomed out when 900°F steam temp was reached)	High mark on scale
2750 lb hanger in duct vault	Low mark	Mid-scale	Original low mark

* Refer to Figure 5

As seen above, the 5000 lb hanger bottomed out shortly after full steam startup. This means that the steam line at this point moved in the opposite direction of the flow to such an extent that there was no load on the hanger. Also, the sliding shoe support on the steam line immediately downstream of the temporary exhaust tee had moved up and out of the guide approximately $1\frac{1}{2}$ inches and taken a permanent set. The actual motion of a portion of the steam line during the test was recorded using motion pictures of a pointer-scale arrangement in the area denoted by View A in Figure 5. Figure 19 shows this movement of steam line during full steam startup of Module 3, and the points which it expanded to during the test and returned to after the test.

The testing phase of Experimental Plan VI was terminated at this time in order to correct the cause of the "second stage malfunction" and to evaluate the erratic movement of the facility steam line. The test objective to demonstrate the capability of each module main stage to startup from the ignitor second stage after a flame-out has been induced in the ignitor first stage was not accomplished.

MOTION OF THE LOWER MAIN STEAM LINE DURING EP-VI-0-21

19. Post EP-VI Inspection

The injector-to-chamber bolt torque was checked and the average torque decreased from 435 ft-lbs to 385 ft-lbs on Module 1, from 442 ft-lbs to 93 ft-lbs on Module 2 and from 441 ft-lbs to 350 ft-lbs on Module 3. Three bolts on Module 2 did not have any torque on them.

A dye penetrant inspection was made on injectors 001, 0018 and 0019 and revealed only minor points of porosity. The injectors are shown in Figures 20, 21 and 22.

Combustion chambers 001 and 0017 were in generally good condition. The longitudinal bulges in chamber 0018, which were noted after EP-VI-J-16, had increased in size. The long bolt orifices in each module were measured and did not change significantly in dimensions from the measurements made after EP-VI-J-16.

The butterfly valve 50-RSV-433 which had been leaking past its main seat was removed from the water system and inspected. The leak was found to be caused by a torn seal which would not allow the butterfly to close.

FIGURE 20

INJECTOR 01 AFTER EP-VI-0-21 SHOWING RESULTS OF DYE PENETRANT INSPECTION

FIGURE 21
INJECTOR 0018 AFTER EP-VI-0-21 SHOWING RESULTS OF DYE PENETRANT INSPECTION

FIGURE 22

INJECTOR 0019 AFTER EP-VI-0-21 SHOWING RESULTS OF DYE PENETRANT INSPECTION

TABLE I
Steam Generator System Test Summary

Test Number	Date	Scheduled Type of Test	Full Steam Duration Sec.	Data Time (1) Sec.	Module Number	STEADY STATE OPERATIONAL DATA												Remarks
						1st.stg	2nd.stg	3rd Stage		Steam Plenum		Fluid Flow Rate(3)				Mixture Ratio		
						Press. psig	Press. psig	Press. psig	Temp. °F	Press. psig	Temp. (2) Avg. °F	Oxid lb/sec	Fuel lb/sec	Water lb/sec	Total lb/sec	MR _T (4)	MR _W (5)	
EP-VI-A-1	4/27/66	Full Steam Test for 15 Sec.on Module 1 and 2	19	8	1	183	159	70	336	56	243	19.2	8.1	53	80.3	2.37	1.94	Unsatisfactory Test.Module 1 brought to full steam successfully but Module 2 shutdown during its startup transient because of a false low injection water flow malfunction.
EP-VI-B-2	5/3/66	Full Steam Test for 180 Sec.on Module 1 and 2	200	100	1 2	203 202	183 181	130 131	361 341	123	660	18.9 18.9	8.6 8.6	37.7 43.2	65.2 70.7	2.2 2.2	1.37 1.57	Satisfactory test. The injection water control valves were not adjusted because the steam temperature reached the maximum value of 1100°F.
EP-VI-C-3	5/5/66	Full Steam Test for 180 Sec.on Module 1 and 2	38	38	1	190	158	74	300	57	250	19.6	8.2	53	80.8	2.39	1.91	Unsatisfactory test. Module 1 brought to full steam successfully but Module 2 shutdown during its startup transient because of a "Second stage cutoff" malfunction.
EP-VI-D-4	5/9/66	Full Steam Test for 180 Sec.on Module 1 and 2	192	190	1 2	208 188	184 182	137 136	348 342	128	794	19.6 19	7.9 7.9	40.5 40.5	68 67.4	2.48 2.4	1.47 1.51	Satisfactory Test. The injection water control valves were not adjusted because the steam temperature reached the maximum value of 1250°F.
EP-VI-E-5	5/12/66	Full Steam Test for 30 Sec. on Module 1 and 3	33	31	1 3	195 199	175 176	124 125	334 324	113	422	19.6 20.2	8.6 8.6	49.3 44.3	77.5 73.1	2.28 2.35	1.75 1.54	Satisfactory Test.
EP-VI-F-6	5/16/66	Full Steam Test for 180 Sec.on Module 1 and 3	100	98	1 3	187 194	179 181	132 134	336 333	124	643	19 19.9	8.2 8.2	42.1 44	69.3 72.1	2.32 2.43	1.55 1.57	Unsatisfactory Test. Test was terminated because steam temperature exceed 1250°F.
EP-VI-G-8	5/18/66	Full Steam Test for 120 Sec. after a 180 sec. warm-up on Modules 2 and 3	363	359	2 3	176 178	163 165	118 118	326 323	114	910	17.6 18.8	7.1 7.1	37.6 37.5	62.3 63.4	2.48 2.65	1.52 1.45	Satisfactory test.System operated with reduced flow rates. The injection water control valves were partially closed and the steam temperature increased to 1150°F.

TABLE I (CONT.)
Steam Generator System Test Summary

						STEADY STATE OPERATIONAL DATA													
Test Number	Date	Scheduled Type of Test	Full Steam Duration Sec.	Data Time (1) Sec.	Module Number	1st.stg	2nd.stg	3rd Stage		Steam Plenum		Fluid Flow Rate(3)				Mixture Ratio		Remarks	
						Press. psig	Press. psig	Press. psig	Temp. °F	Press. psig	Temp (2) Avg. °F	Oxid lb/sec	Fuel lb/sec	Water lb/sec	Total lb/sec	MR _T (4)	MR _W (5)		
EP-VI-I-15	5/23/66	Full Steam test for 255 sec. on Modules 1 and 2 and then switching to Modules 1 and 3 for 5 sec full steam	302	284	1	156	151	114	333	104	991	17.5	7.1	34.5	59.1	2.47	1.4	Satisfactory test. System operated with reduced flow rates. The injection water control valves were partially closed and the steam temperature increased to 1300°F. Switching was accomplished.	
					2	166	156	113	328			17.5	7.1	33.4	58	2.47	1.36		
					1	162	151	110	332			17.5	7	33.4	57.9	2.5	1.36		
					3	168	156	110	324	100	502	18.2	7	50.8	76	2.6	2.02		
EP-VI-J-16	5/25/66	Full Steam test for 190 sec. on Modules 1 and 2 and then switching to Modules 2 and 3 for 20 sec. full steam	215	191	1	166	155	111	330	103	944	16.6	7.3	33.7	57.6	2.27	1.41	Unsatisfactory test. Module 1 second stage LOX valve exploded after the module was shutdown during switching. Previously, the injection water control valves were partially closed to achieve a steam temperature of 1100°F.	
					2	166	155	112	323			16.6	7.3	33	56.9	2.27	1.38		
					2	165	153	108	325	99	701	16.5	7.3	32.5	56.3	2.26	1.37		
					3	164	153	107	317			17.5	7.3	42.2	67	2.4	1.7		
EP-VI-N-20	8/8/66	Full Steam test for 220 sec. on Modules 3 and 2 and then switching to Modules 3 and 1 for 120 sec. Full Steam.	353	220	2	169	153	102	330	90	476	17.2	7.8	52.4	77.4	2.21	2.1	Satisfactory test. The steam temperature of 1300°F was not achieved	
					3	167	153	99	798			18.2	7.8	51.8	77.8	2.33	1.99		
					1	156	146	102	319	93	661	17.9	7.8	39.1	64.8	2.3	1.52		
					3	159	154	101	691			18.5	7.8	51.8	78.1	2.37	1.97		
EP-VI-O-21	8/9/66	Full Steam test for 1080 sec. on Modules 3 and 2 and then switching to Modules 3 and 1 for 100 sec. Full Steam	1124	1060	2	165	156	112	883	100	1264	17.5	7.2	35.5	60.2	2.43	1.44	Satisfactory test. System ran very stable at 1300°F for about 1000 seconds. During switching Module 1 shutdown during startup transient because of a second stage cutoff malfunction	
					3	171	159	108	1298			18.4	7.2	35.8	61.4	2.57	1.4		

- (1) Time during full steam at which steady state operational data was taken.
 (2) Average temperature value of three plenum thermocouples.
 (3) Flow rates are total oxidizer, fuel and water for all module stages.

- (4) MR_T Mixture Ratio: Ratio of total oxidizer to total fuel flowing into all generator stages.
 (5) MR_W Mixture Ratio: Ratio of total water to total fuel plus total oxidizer flowing into all generator stages.

TABLE II
Steam Generator System Test Data Tabulation

RUN	DATE	TIME	Pft	TfT	PfM	TfM	PfJ1-1	PfV2-1	PfV3-1	PfJ-1	ΔPfJ3-1	TfJ3-1	TfJ4-1	Wf3-1	WfT-1	PfJ1-2	PfV2-2	PfV3-2	PfJ3-2	Wf3-2
Number		Sec.	psig	°F	psig	°F	psig	psig	psig	psig	psid	°F	°F	lb/sec	lb/sec	psig	psig	psig	psig	lb/sec
EP-VI-A-1	4/27/66	8	321	58	312	53	294	305	307	208	104	62	61	7.9	8.1					
EP-VI-B-2	5/3/66	100	297	56	282	46	265	276	278	201	55	50	52	8.4	8.6	264	278	262	201	8.4
EP-VI-C-3	5/5/66	38	302	56	294	49	274	289	291	189	84	60	60	8	8.2					
EP-VI-D-4	5/9/66	190	286	56	270	58	263	268	270	201	50	55	56	7.7	7.9	258	271	273	201	7.7
EP-VI-E-5	5/12/66	31	300	56	286	51	270	280	282	194	55	56	57	8.4	8.6					
EP-VI-F-6	5/16/66	98	300	55	262	48	250	257	259	195	50	47	47	8	8.2					
EP-VI-G-8	5/18/66	359	256	55	241	56									.15	230	239	237	176	6.9
EP-VI-I-15	5/23/66	284	241	55	228	55	215	224	220	168	45	57	57	6.9	7.1	220	226	226	167	6.9
EP-VI-I-15	5/23/66	299	240	54	229	56	216	223	220	166	42	55	59	6.8	7					
EP-VI-J-16	5/25/66	191	261	57	243	58	227	239	240	175	50	60	65	7.1	7.3	230	240	241	174	7.1
EP-VI-J-16	5/25/66	214	260	57	244	58										229	241	241	173	7.1
EP-VI-N-20	8/8/66	220	264	54	253	54									.15	236	247	246	179	7.6
EP-VI-N-20	8/8/66	345	268	54	257	54	236		247	167				7.6	7.8					
EP-VI-O-21	8/9/66	1060	257	56	243	55									.15	231	239	240	188	7

RUN	DATE	TIME	WfT-2	PfJ1-3	PfV2-3	PfV3-3	PfJ-3	ΔPfJ3-3	TfJ3-3	TfJ4-3	Wf3-3	WfT-3	Wf	PoT	PoM	ToM	WoT-1	PoV3-1	PoJ3-1	Wo3-1
Number		Sec.	lb/sec	psig	psig	psig	psig	psid	°F	°F	lb/sec	lb/sec	cps	psig	psig	°F	cps	psig	psig	lb/sec
EP-VI-A-1	4/27/66	8	.15									.15	210	302	283	-286		267	235	18.7
EP-VI-B-2	5/3/66	100	8.6									.15	426	296	281	-291		253	243	18.4
EP-VI-C-3	5/5/66	38	.15									.15	210	304	292	-289		274	226	19.1
EP-VI-D-4	5/9/66	190	7.9									.15	400	300	287	-290		272	247	19.1
EP-VI-E-5	5/12/66	31	.15	274	277	275	194	51			8.4	8.6	430	304	292	-288		275	248	19.1
EP-VI-F-6	5/16/66	98	.15	252	255	254	194	46			8	8.2	400	300	286	-284		268	244	18.5
EP-VI-G-8	5/18/66	359	7.1	232	234	235	174	41			6.9	7.1	360	244	235	-296				
EP-VI-I-15	5/23/66	284	7.1									.15	360	231	222	-295		212	195	17
EP-VI-I-15	5/23/66	299		221	223	224	166	41			6.8	7	350	231	222	-295		211	193	17
EP-VI-J-16	5/25/66	191	7.3									.15	370	230	220	-283		209	191	16.1
EP-VI-J-16	5/25/66	214	7.3	233	237	237	172	49			7.1	7.3	370	229	219	-288				
EP-VI-N-20	8/8/66	220	7.8	242	245	247	163		54	54	7.6	7.8	395	243	230	-293				
EP-VI-N-20	8/8/66	345		245	249	251	165		55	55	7.6	7.8	390	244	232	-298	483	218	195	17.4
EP-VI-O-21	8/9/66	1060	7.2	235	237	240	171		56	58	7	7.2	366	239	226	-299				

TABLE II (CONT.)
Steam Generator System Test Data Tabulation

RUN	DATE	TIME	WoT-1	PoV3-2	PoJ3-2	Wo3-2	WoT-2	PoV3-3	PoJ3-3	Wo3-3	WoT-3	PwH	PwM	TwFO	ΔPwV-1	PwVO-1	PwJ-1	PwCO3-1	TwCO3-1	LwCV-1
Number		Sec.	lb/sec	psig	psig	lb/sec	lb/sec	psig	psig	lb/sec	lb/sec	psig	psig	°F	psid	psig	psig	psig	°F	%
EP-VI-A-1	4/27/66	8	19.2				0.45				0.45	215	184	69	195	146	128	124	94	99.4
EP-VI-B-2	5/3/66	100	18.9	267	240	18.4	18.9				0.45	216	186	103	108	174	162	124	90	92.8
EP-VI-C-3	5/5/66	38	19.6								0.45	214	188	79	195	138	131	126	97	77.2
EP-VI-D-4	5/9/66	190	19.6	273	245	18.5	19.0				0.45	213	183	101	128	171	168	124	85	99.5
EP-VI-E-5	5/12/66	31	19.6				0.45	277	247	19.7	20.2	216	182	92	173	166	164	125	95	99.4
EP-VI-F-6	5/16/66	98	19				0.45	266	247	19.4	19.9	222	181	101	138	168	166	123	96	99
EP-VI-G-8	5/18/66	359	.45	224	203	17.1	17.6	225	207	18.3	18.8	216	182	98						0
EP-VI-I-15	5/23/66	284	17.5	212	192	17	17.5				0.45	214	182	109	87	176	135	126	98	16
EP-VI-I-15	5/23/66	299	17.5					214	197	17.7	18.2	209	176	100	81	170	131	122	97	15.6
EP-VI-J-16	5/25/66	191	16.6	210	191	16.1	16.6				0.45	218	182	110	83	176	133	125	100	15.5
EP-VI-J-16	5/25/66	214		209	189	16	16.5	209	192	17	17.5	216	179	102						0
EP-VI-N-20	8/8/66	220	.45	217	195	16.7	17.2	217	196	17.7	18.2	220	177	95						0
EP-VI-N-20	8/8/66	345	17.9					218	199	18	18.5	220	180	98	114	156	129	113	103	18.9
EP-VI-O-21	8/9/66	1060	.45	214	195	17	17.5	213	195	17.9	18.4	220	*	105						0

RUN	DATE	TIME	Ww3-1	WwF-1	WwT-1	ΔPwV-2	PwVO-2	PwJ-2	PwCO3-2	TwCO3-2	LwCV-2	Ww3-2	WwF-2	WwT-2	ΔPwV-3	PwVO-3	PwJ-3	PwCO3-3	TwCO3-3	LwCV-3
Number		Sec.	lb/sec	lb/sec	lb/sec	psid	psig	psig	psig	°F	%	lb/sec	lb/sec	lb/sec	psid	psig	psig	psig	°F	%
EP-VI-A-1	4/27/66	8	49	4	53						0		4.8	4.8						0
EP-VI-B-2	5/3/66	100	34.8	2.9	37.7	143	173	168	119	86	96.9	40	3.2	43.2						0
EP-VI-C-3	5/5/66	38	49	4	53						0		4.8	4.8						0
EP-VI-D-4	5/9/66	190	37.8	2.7	40.5	125	174	169	118	82	*	37.5	3	40.5						0
EP-VI-E-5	5/12/66	31	46.3	3	49.3						0		3.6	3.6	150	170	164	110	92	99.3
EP-VI-F-6	5/16/66	98	39.3	2.8	42.1						0		3.3	3.3	149	170	167	109	93	99.2
EP-VI-G-8	5/18/66	359		3.2	3.2	104	174	147	117	93	22.2	34.1	3.5	37.6	103	174	146	110	93	21.3
EP-VI-I-15	5/23/66	284	31.3	3.2	34.5	78	178	136	120	91	16.8	29.8	3.6	33.4						0
EP-VI-I-15	5/23/66	299	30.3	3.1	33.4						0		3.7	3.7	182	160	155	107	94	99.4
EP-VI-J-16	5/25/66	191	30.5	3.2	33.7	76	177	134	119	96	16.3	29.4	3.6	33						0
EP-VI-J-16	5/25/66	214		3.3	3.3	74	173	130	116	95	16.1	28.9	3.6	32.5	132	166	142	108	97	23.9
EP-VI-N-20	8/8/66	220		3.6	3.6	188	159	145	116	101	41	48.7	3.7	52.4	186	152	149	108	98	60
EP-VI-N-20	8/8/66	345	35.7	3.4	39.1						0		4.	4	188	152	153	107	97	97.7
EP-VI-O-21	8/9/66	1060		3.4	3.4	90	156	135	109	100	16.3	31.8	3.7	35.5	92	157	135	103	96	16.2

TABLE II (CONT.)
Steam Generator System Test Data Tabulation

RUN	DATE	TIME	Ww3-3	WwF-3	WwT-3	Pc1-1	Pc2-1	PcU3-1	PcL3-1	Tc1-1	Tc2-1	Tc3-1	TcAV-1	Pc1-2	Pc2-2	PcU3-2	PcL3-2	Tc1-2	Tc2-2	Tc3-2
Number		Sec.	lb/sec	lb/sec	lb/sec	psig	psig	psig	psig	°F	°F	°F	°F	psig	psig	psig	psig	°F	°F	°F
EP-VI-A-1	4/27/66	8		4.7	4.7	183	159	103	70	407	291	310	336	168	137	53	49	250	242	245
EP-VI-B-2	5/3/66	100		3.6	3.6	203	183	146	130	394	337	353	361	202	181	150	131	344	338	344
EP-VI-C-3	5/5/66	38		4.8	4.8	190	158	103	74	*	296	303	*	52	51	51	51	112	153	140
EP-VI-D-4	5/9/66	190		3.3	3.3	208	184	150	137	359	337	356	348	188	182	153	136	345	341	346
EP-VI-E-5	5/12/66	31	41	3.3	44.3	195	175	139	124	340	328	336	334	191	160	117	114	300	302	300
EP-VI-F-6	5/16/66	98	41	3	44	187	179	146	132	344	327	344	336	191	166	128	126	312	310	308
EP-VI-G-8	5/18/66	359	34	3.5	37.5	165	150	112	115	295	297	295	295	176	163	133	118	325	324	323
EP-VI-I-15	5/23/66	284		3.8	3.8	156	151	125	114	329	327	340	333	166	156	127	113	*	313	322
EP-VI-I-15	5/23/66	299	47.3	3.5	50.8	162	151	122	110	325	319	337	332	105	106	105	103	*	191	165
EP-VI-J-16	5/25/66	191		3.8	3.8	166	155	123	111	333	320	342	330	166	155	126	112	329	320	328
EP-VI-J-16	5/25/66	214	38.5	3.7	42.2	101	103	101	104	81	95	94	91	165	153	123	108	327	318	326
EP-VI-N-20	8/8/66	220	48	3.8	51.8	142	128	105	90	274	271	273	271	169	153	119	102	334	322	314
EP-VI-N-20	8/8/66	345	48	3.8	51.8	156	146	136	102	325	310	323	319	99	97	96	96	76	81	77
EP-VI-O-21	8/9/66	1060	32	3.8	35.8	142	133	102	104	286	285	284	289	165	156	126	112	1014	792	840

RUN	DATE	TIME	TcAV-2	Pc1-3	Pc2-3	PcU3-3	PcL3-3	Tc1-3	Tc2-3	Tc3-3	TcAV-3	PsP1	PsP2	TsP1	TsP2	TsP3	TsPAV	TsE1	TsE2	TsE3
Number		Sec.	°F	psig	psig	psig	psig	°F	°F	°F	°F	psig	psig	°F	°F	°F	°F	°F	°F	°F
EP-VI-A-1	4/27/66	8	249	175	143	59	57	279	290	269	280	56	55	265	275	268	243	278	285	287
EP-VI-B-2	5/3/66	100	341	178	164	127	116	298	301	313	303	123	121	223	961	826	660	1096	1097	1117
EP-VI-C-3	5/5/66	38	135	172	139	59	59	280	251	261	264	57	56	206	282	274	250	316	334	318
EP-VI-D-4	5/9/66	190	342	187	168	130	127	305	306	307	307	128	125	250	904	1078	794	1262	1259	1284
EP-VI-E-5	5/12/66	31	301	199	176	144	125	327	327	327	324	113	112	218	606	443	422			
EP-VI-F-6	5/16/66	98	311	194	181	152	134	337	326	338	333	124	122	211	991	720	643			
EP-VI-G-8	5/18/66	359	326	178	165	135	118	330	315	329	323	114	112	812	1105	814	910			
EP-VI-I-15	5/23/66	284	328	158	144	108	105	283	293	317	298	104	102	880	1085	1013	991			
EP-VI-I-15	5/23/66	299	165	168	156	127	110	320	313	339	324	100	98	526	470	508	502			
EP-VI-J-16	5/25/66	191	323	155	141	105	103	281	292	288	284	103	101	849	1036	958	944	1131	1128	1137
EP-VI-J-16	5/25/66	214	325	164	153	125	107	323	313	322	317	99	98	587	793	720	701	824	821	822
EP-VI-N-20	8/8/66	220	330	167	153	117	99	1517	566	325	798	90	90	312	340	311	315			
EP-VI-N-20	8/8/66	345	79	159	154	120	101	1371	396	321	691	90	91	438	507	514	482			
EP-VI-O-21	8/9/66	1060	883	171	159	124	108	2027	762	1123	1298	99	99	1007	1318	1071	1131			

TABLE II (CONT.)
Steam Generator System Test Data Tabulation

RUN	DATE	TIME	TsEAV	TsD1	TsD2	TsD3	TsDAV	PsL	TsL	WtT-1	WtT-2	WtT-3	Wt	MRT-1	MRT-2	MRT-3	MRW-1	MRW-2	MRW-3	AxJ1-1
Number		Sec.	°F	°F	°F	°F	°F	psig	°F	lb/sec	lb/sec	lb/sec	lb/sec							g peak
EP-VI-A-1	4/27/66	8	281							80.3	5.4	5.3	91	2.37			1.94			
EP-VI-B-2	5/3/66	100	1104							65.2	70.7	4.2	140.1	2.2	2.2		1.37	1.57		
EP-VI-C-3	5/5/66	38	324							80.8	4.9	5.4	91.1	2.39			1.91			*
EP-VI-D-4	5/9/66	190	1278							68	67.4	3.9	139.3	2.48	2.4		1.47	1.51		14
EP-VI-E-5	5/12/66	31		749	767	779	765	*	*	77.5	4.2	73.1	154.8	2.28		2.35	1.75		1.54	15
EP-VI-F-6	5/16/66	98		1248	1260	1270	1254	124	1246	69.3	3.9	72.1	145.3	2.32		2.43	1.55		1.57	65
EP-VI-G-8	5/18/66	359		1143	1157	1170	1155	108	1148	3.8	62.3	63.4	129.5		2.48	2.65		1.52	1.45	
EP-VI-I-15	5/23/66	284		1290	1295	1296	1293	104	1294	59.1	58	4.4	121.5	2.47	2.47		1.4	1.36		
EP-VI-I-15	5/23/66	299		836	827	819	827	102	835	57.9	3.7	76	137.6	2.5		2.6	1.36		2.02	
EP-VI-J-16	5/25/66	191	1132							57.6	56.9	4.4	118.9	2.27	2.27		1.41	1.38		
EP-VI-J-16	5/25/66	214	822							3.3	56.3	67	126.6		2.26	2.4		1.37	1.7	
EP-VI-N-20	8/8/66	220		475	476	476	476	90	476	4.2	77.4	77.8	159.4		2.21	2.33		2.1	1.99	
EP-VI-N-20	8/8/66	345		661	662	653	661	93	658	64.8	4	78.1	146.9	2.3		2.37	1.52		1.97	
EP-VI-O-21	8/9/66	1060		1262	1265	1268	1264	100	1260	4	60.2	61.4	125.6		2.43	2.57		1.44	1.4	

RUN	DATE	TIME	AxJ2-1	AxUC1-1	AxUC2-1	AxUC1-1	AxLC1-1	AxLC2-1	TjG-1	ASL-X	ASL-Y	ASL-Z
Number		Sec.	** g peak	** g peak	** g peak	** g peak	** g peak	** g peak	°F **	** g peak	** g peak	** g peak
EP-VI-A-1	4/27/66	8										
EP-VI-B-2	5/3/66	100										
EP-VI-C-3	5/5/66	38	*	*	*		*	*	164			
EP-VI-D-4	5/9/66	190	*	25	19		1	9	136			
EP-VI-E-5	5/12/66	31	17	34	30		12	29	131			
EP-VI-F-6	5/16/66	98		70		55			141	20	25	49
EP-VI-G-8	5/18/66	359							113	19	49	52
EP-VI-I-15	5/23/66	284										
EP-VI-I-15	5/23/66	299										
EP-VI-J-16	5/25/66	191										
EP-VI-J-16	5/25/66	214										
EP-VI-N-20	8/8/66	220										
EP-VI-N-20	8/8/66	345										
EP-VI-O-21	8/9/66	1060										

Note:

See Steam Generator System Test Nomenclature
Appendix IV for definition of symbols.

- * Data not obtained due to instrumentation malfunction.
- ** Data given is the maximum value during two module full steam operation.

A P P E N D I X I

TEST DESCRIPTION

for

EXPERIMENTAL PLAN VI

STEAM GENERATOR DEVELOPMENT

TEST PROGRAM

NTO-I-0085

Prepared by:

H. Henze
Test Conductor
Steam Generator Development Test Program

Approved by:

N. E. Erickson, Manager
NERVA Test Operations

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1.0 OBJECTIVES

- 1.1 Evaluate performance of the integrated steam generator system when operated at rated full flow (two modules full steam one module at idle).
- 1.2 Determine the best means for efficient operation of the steam generator when integrated and operated as a system.
- 1.3 Demonstrate that the steam generator system will supply nominal 120 lb/sec steam at 1100°F.
- 1.4 Evaluate harmonics or relevant vibrations that may occur as a result of combustion or the discharging and mixing of hot gases in the plenum at generator system rated flow.
- 1.5 Determine the effect of system operation on propellant pressure, combustion pressure, cooling water pressure and pressure drops, and various system pressures.
- 1.6 Demonstrate that the idling unit, after a 4 second delay, will switch to full steam if one of two modules operating at full steam is shutdown.
- 1.7 Establish relationship between observed flow of water injected and stabilized steam temperature at the stack exit.
- 1.8 Evaluate heat transfer characteristics of the plenum at rated full flow operation.

2.0 TEST DESCRIPTION

2.1 SET UP

Steam Generator module S/N 0016, 0017 and 0018 will be set up at steam plenum positions 1, 2 and 3, respectively.

2.2 TEST PROGRAM

2.2.1 General

During this program two steam generator modules will be operated at full steam conditions with the remaining unit at idle conditions. The three generator modules will be started and brought to idle operation following a standard start up operating procedure, after which two of the modules will be brought up to full steam.

- 2.2.1.1 The propane supply temperature shall not exceed a maximum of 60°F and the propane flow rate will be 7.7 lb/sec per module. The LO₂ supply temperature will be - 290 ± 5°F and the LO₂ flow rate will be 18.5 lb/sec per module.

2.2.1.2 Prior to each test, the combustion chamber to injector bolt torque will be checked and retorqued, if necessary, and the hot gas circuit will be tested to 120 psig with GH_2 .

2.2.2 Full Steam - Short Duration System Tests. The test requirements are defined in Table No. 1.

Table I

Test No.	Full Steam Duration (seconds)	Modules Operating at Full Steam	Facility Water Pressure	Operation of Injection Water Control Valves		Steam Temp. Regulation Goal ($^{\circ}\text{F}$)
				Module Water Flow Upon Full Steam Command	Module Water Flow During Run	
1	15	1,2	Max	Max	Constant	N.A.
2	180	1,2	Max	Max	Decrease	1100 Max
3	180	1,2	P_1^*	Preadjust	Decrease	1100 Max
4	30	1,3	P_2^*	Preadjust	Constant	1100 Max
5	180	1,3	P_3^*	Preadjust	Decrease	1100 Max
6	180	2,3	P_4^*	Preadjust	Decrease	1100 Max

* One of the runs to have the lowest expected water pressure, 175 psig (nearly empty tank, other water demands). For each of the remaining three runs set different intermediate values of facility water pressure between Maximum and Minimum by partially closing the facility water valve.

2.2.2.1 After the second test, preadjust control valves to admit less initial flow of injection water. The injection water flow into either chamber will be initially equalized and shall not fall below 30 lb/sec.

2.2.2.2 No regulation of injection water flow rates will be made until 60 seconds after two modules are operating at full steam, except as noted in 2.2.2.1.

2.2.2.3 The remaining module shall continue at idle flow conditions, but shall not be placed on standby status.

2.2.2.4 Whenever two generators are operating at full steam, keep both injection water flow rates equal (within 0.5 lb/sec) by monitoring the P across both water injection venturis and adjusting the water control valves as required for balance.

2.2.2.5 Monitor the steam temperature at the stack exit, if it is less than 1100°F regulate the injection water flow into both chambers equally until the steam temperature at the stack exit reaches 1100°F max. The injection water flow rate into either chamber shall not fall below 30 lb/sec at any time during main stage combustion.

2.2.3 Generator switching. The test requirements are defined in Table II.

Table II

Test Number	Full Steam Duration (seconds)	Initial Modules at Full Steam	Duration (seconds)	Shutdown Module Number	Final Modules at Full Steam	Duration (seconds)	Facility Water Pressure	Regulation of Injection Water During Test?	Steam Temp. Regulation Goal (°F)
7	300	1,2	160	2	1,3	140	P ₅ *	Yes	1100 Max
8	300	1,2	160	1	2,3	140	P ₆ *	Yes	1100 Max
9	300	2,3	160	2	3,1	140	P ₇ *	Yes	1100 Max

* Partially close facility water valve to simulate facility low water pressure. Set water pressure to fill in gaps of previous testing or to repeat values as required.

- 2.2.3.1 Two modules will be commanded to full steam operation with a preadjusted flow rate of injection water discharging into each combustion chamber. The injection water flow into either chamber will be initially equalized and shall not fall below 30 lb/sec.
- 2.2.3.2 No regulation of injection water flow rate to control steam temperature will be made until 60 seconds after two modules are operating at full steam, except as noted in paragraph 2.2.3.1.
- 2.2.3.3 After achieving correct operating conditions, the remaining module shall be placed on standby status.
- 2.2.3.4 Whenever two generators are operating at full steam, keep both injection water flow rates equal (within 0.5 lb/sec) by monitoring the P across both water injection venturis and adjusting the water control valves as required.

2.2.3.5 Monitor the steam temperature at the stack exit, if it is less than 1100°F regulate the injection water flow into both chambers equally until the steam temperature at the stack exit reaches 1100°F max. The injection water flow rate into either chamber shall not fall below 30 lb/sec at any time during main stage combustion.

2.2.3.6 After 160 seconds of dual generator operation, shutdown one of the modules operating at full steam. After 4 seconds, the idle module will go to full steam operation. Simultaneously a preadjusted flow rate of injection water will discharge into the chamber of the activated module.

2.2.4 Full Steam - System, 1220 Seconds Duration, Switching After 1060 Seconds. The test requirements are defined in Table III.

Table III.

Test No.	Full Steam Total Duration (seconds)	Initial Modules at Full Steam	Duration (seconds)	Shutdown Module No.	Final Modules at Full Steam	Duration (seconds)	Regulation of Injection Water During Test	Steam Temp. Regulation Goal (°F)
10	1220	1,2	1060	2	1,3	160	Yes	1100 Max

2.2.3.1 Modules 1 and 2 will be commanded to full steam operation with a preadjusted flow rate of injection water discharging into each combustion chamber. The injection water flow into either chamber will be initially equalized and shall not fall below 30 lb/sec.

2.2.4.2 No regulation of injection water flow rate to control steam temperature will be made until 60 seconds after two modules are operating at full steam, except as noted in paragraph 2.2.4.1.

2.2.4.3 After achieving correct operating conditions, Module 3 will be placed in standby status.

2.2.4.4 Whenever two generators are operating at full steam, keep both injection water flow rates equal (within 0.5 lb/sec) by monitoring the P across both water injection venturis and adjusting the water control valves as required.

2.2.4.5 Monitor the steam temperature at the stack exit, if it is less than 1100°F regulate the injection water flow into both chambers equally until the steam temperature at the stack exit reaches 1100°F max. The injection water flow rate into either chamber shall not fall below 30 lb/sec at any time during main stage combustion.

2.2.4.6 After 1060 seconds of dual generator operation, shutdown Module 2. Then after 4 seconds, Module 3 at idle will go to full steam operation. Simultaneously a preadjusted flow rate of injection water will discharge into the chamber of the activated module.

2.2.4.7 Before and after this run, Test No. 10, remove all five bolt orifices (P/N 940030-1) from the generator modules and record the following measurements:

- (1) Diameter at area of maximum erosion (minimum diameter).
- (2) Distance from end of bolt orifice to centerline of maximum erosion.
- (3) Obtain detailed photographs of eroded area, showing tip and side view.

Bolt orifice threads shall be cleaned and a suitable lubricant applied prior to reinstallation.

2.3 INSPECTION

On conclusion of the test program, the following inspections will be performed:

2.3.1 Injector

Dye penetrant inspection for cracks in injector faces on other damage. Document inspection by close-up photographs. LO₂ clean injectors prior to reassembly.

2.3.2 Combustion Chamber

2.3.2.1 Expansion Joints

Dye penetrant inspection

2.3.2.2 Chamber Liner

Visual inspection, check for damage and hot spots.

2.3.3 Plenum

Visually inspect interior for erosion and overheating.

2.4 REASSEMBLY OF MODULES

Upon completion of inspection, reassemble the steam generator modules.

3.0 SCHEDULE

One full steam test will be accomplished on each run day.

The tests will be conducted in accordance with the Operating Procedure (NTO-I-0086) which will be available on R-1 Day. The access list will be prepared on R-1 Day. Area control (ETS-1 Area Control and Safety Standards for Steam Generator Testing NTO-SOP-0068) will be initiated at 1700 hours on R-Day.

Operations will commence at 1500 hours on R-Day with the setup of instrumentation and the exercising of valves. After area control is imposed, the LO₂ system bleed-in will be initiated, followed by bleed-in of the propane system. The propellant tanks will be pressurized and the test will be performed.

After completion of the test, the system will be secured to allow re-entry for visual examination of the Steam Generator. Strip chart and oscillograph records will be examined and preliminary calculations will be performed.

The planned run schedule is as follows:

Test No.*	Scheduled Date
1	27 April
2	2 May
3	4 May
4	6 May
5	10 May
6	12 May
7	16 May
8	18 May
9	20 May
10	24 May

*See previous tables for test designation.

4.0 PREMATURE TEST TERMINATION CRITERIA

The following are specific conditions which warrant shutdown of the Steam Generator System. However, should any erratic operation occur, the test shall be terminated.

- 4.1 Should the propane flow rate show a decrease to 90% of nominal flow rate after steady state conditions have been achieved, execute an immediate shutdown.
- 4.2 Should the injector plate propane coolant passage temperature (50-TE-703) equal or exceed 75°F execute an immediate shutdown.
- 4.3 Should the steam temperature as measured by 50-TT-435, 436 and 437 exceed 1600°F immediate shutdown will be executed.
- 4.4 Should coolant water jacket outlet temperature (50-TT-434) and/or plenum coolant water outlet temperature (50-TT-431) approach 212 F, immediate shutdown will be executed.
- 4.5 Should the main stage chamber pressure exceed 160 psig, immediate shutdown will be executed.

5.0 SAFETY REQUIREMENTS

- 5.1 The safety requirements are specified in NTO-SOP-0068.
- 5.2 Following each test, gas samples shall be taken from the steam plenum with a combustible gas analyzer to verify that the propane valves are properly seated and not leaking.

6.0 QUALITY CONTROL REQUIREMENTS

- 6.1 Prior to start of full steam operation, it shall be verified that any repairs and modifications to the Steam Generator System have been properly documented.
- 6.2 Prior to start of full steam operation, it shall be verified that all test equipment has been properly calibrated and documented.

7.0 SUPPORT REQUIREMENTS

7.1 MAJOR TEST PARTICIPANTS

Facility Manager	B. A. Bernstein	V. R. Davis
Test Conductor	H. Henze	N. E. Erickson
		T. A. Keasling
		J. F. Christenson
Assistant Facility Engineer, Left	E. B. Graham	V. R. Hill
	J. A. Gaccione	E. M. Shultis
Health & Safety	F. M. Cox	R. E. Benshoof
		H. G. Simens
Security	A. B. Bagwell	J. S. Holt
Support	A. R. Marshall	W. J. Reibel
Advisor	NES Project Representative	
Quality Control	C. A. Thomas	D. J. McCroskey
Instrumentation	D. E. Bridenstine	R. J. Cooper
Facility Control	A. P. Vogt	D. S. Beesley
TV & Communications	R. C. Chavez	A. P. Vogt

7.2.1 GN₂ System

This system will be charged to a normal operating pressure with a maximum pressure of 2500 psig, and a minimum pressure of 1500 psig.

7.2.2 Process Water System

The level in the process water tank shall not be lower than 10 feet.

7.2.3 LO₂ System

The liquid level in the tank will be maintained consistent with economical scheduling; however, the tank level shall not be permitted to drop below 10,000 gallons. The tank pressure will be set in accordance with Appendix 1a to provide a nominal 18.5 lb/sec flow per module during steady state operation.

7.2.4 Propane System

The tank level shall not be permitted to drop below 7,000 gallons. The tank shall be pressurized to provide a nominal flow rate of 7.7 lb/sec per module during steady state operation.

7.3 INSTRUMENTATION AND DATA ACQUISITION REQUIREMENTS

7.3.1 Data requirements are as shown in Appendix 2. Refer to Appendix 3 for location and nomenclature of instrumentation.

7.3.2 The oscillograph chart speed shall be operated at approximately 10 in/sec during transient condition and reduced to approximately 1 in/sec during steady state operation for all tests in excess of 30 seconds at full steam. The test title and identification, including date, shall appear on each record. All parameters shall be identified on the record.

7.3.3 Photographic coverage for selected tests will be provided to show:

- (a) Exhaust Stack (infrared)
- (b) Steam Generator Enclosure (color)

The camera will run at 24 FPS and use 16mm film. Location of cameras to be mutually agreed upon between Test Conductor and Photographer. The exposed film will not be developed unless so directed by the Test Conductor.

7.3.4 Television coverage will be used for test observation and surveillance of the facility for safety consideration. The following cameras will be used, although all existing cameras (14) will be operational and capable of being substituted.

<u>Monitor No.</u>	<u>Camera Position No.</u>	<u>Location</u>	<u>Primary Observation</u>
1	1	North of Ditch	TS, Pad, Ditch
2	5	North End of Shadow Wall	S.G. Enclosure
3	20	Tripod North of LO ₂ Dewar	Pipe Chase Toward TS
4	6	Atop LH ₂ Dewar	Test Stand
5	7	Atop Fill Station	LO ₂ Dewar and TS
6	13	Northeast of Steam Generator	S.G. Enclosure
7	15	Tripod Southwest	Propane Tank
8	3	West of Ditch	Flare Stack

Auxiliary illumination will be provided by search lights trained on the test stand structure and steam generator enclosure.

7.4 AREA CONTROL

Area control will be in effect from 1700 hours on R-Day and remain in effect until removed by the Test Conductor.

7.5 PAN AMERICAN WORLD AIRWAYS

7.5.1 Operating Technicians

The crew normally assigned to the Steam Generator Operation shall be available. Overtime may be necessary in the event of unforeseen circumstances.

7.5.2 Photographic Services

Camera equipment and photographers are required to provide coverage from two locations. Overtime operation may be necessary.

7.6 EG&G

7.6.1 Operating Technicians

The crew normally assigned for the instrumentation and control activities shall be available. Overtime may be necessary in the event of unforeseen circumstances.

7.6.2 Support is required to process the oscillograph records produced during the test. These records will be processed by EG&G.

8.0 REPORTS

8.1 A "Quick Look" data report will be sent to project via TWX the day after a test. See Appendix 5 for format.

LO₂ VENTURI INLET PRESSURE vs
LO₂ FLOW RATE
GENERATOR S/N 16
(MODULE #1)

POV3-1, MAIN STAGE LO₂ VENTURI INLET PRESSURE, PSIG

- 275°F
- 280°F
- 285°F
- 290°F
- 295°F
- 300°F

400

350

300

250

200

16

17

18

19

20

21

22

23

24

LO₂ FLOW RATE - LB/SEC

LO₂ VENTURI INLET
PRESSURE vs LO₂ FLOW RATE
GENERATOR S/N 18
(MODULE #3)

P0V3-3 MAIN STAGE LO₂ VENTURI INLET PRESSURE, PSIG

400

350

300

250

200

16

17

18

19

20

21

22

23

24

LO₂ FLOW RATE LB/SEC

- 275°F
- 280°F
- 285°F
- 290°F
- 295°F
- 300°F

APPENDIX 2
EP VI
INSTRUMENTATION REQUEST

Page 1 of 3

		RECORDING METHOD													REMARKS		
FUNCTION	RANGE	OSC.			STRIP CHART						RFC	Meter on TC Console	Meter on ATC Console	Meter on AFEL Console	DDS	Oscilloscope	
		01	02	03	RA	RB	RC	RD	RE	RF							
PfJ1-1	0-500 psig	X							1						X		50-PT-407-1
PfV2-1	0-500 psig	X							2						X		50-PT-408-1
PfV3-1	0-500 psig	X												X	X		50-FT-405-1
PoV3-1	0-500 psig	X			3									X	X		50-FT-409-1
PoJ3-1	0-500 psig	X													X		50-PT-415-1
PwC03-1	0-200 psig	X													X		50-PT-410-1
PwJ-1	0-200 psig	X													X		50-PT-411-1
Δ PwV-1	0-250 psid	X			5									X	X		50-FT-406-1
PwV0-1	0-250 psig	X			4										X		50-PT-701-1
Pc1-1	0-250 psig	X												X	X		50-PT-416-1
Pc2-1	0-250 psig	X													X		50-PT-417-1
PcU3-1	0-200 psig	X			1										X		50-PT-709-1
PcL3-1	0-200 psig	X			2								X	X	X		50-PT-438-1
PsP1	0-250 psig	X							7						X		50-PT-425
PsP2	0-250 psig	X							8			X			X		50-PT-426
Tc1-1	32-2300°F	X													X		50-TT-435-1
Tc2-1	32-2300°F	X													X		30-TT-436-1
Tc3-1	32-2300°F	X													X		50-TT-437-1
TcAV-1	32-2300°F	X								1					X		
TwC03-1	0-150°F	X				6									X		50-TT-434-1
LwCV-1	0-100%	X													X		50-FCV-423-1
IwCV-1	0-100%	X													X		50-FCV-423-1
TfJ3-1	32-254°F	X													X		50-TE-703-1
TfJ4-1	32-254°F	X				7							X		X	X	50-TE-704-1
PfJ-1	0-300 psig	X			8								X		X		50-PT-703-1
Δ PfJ3-1	0-200 psid	X			6										X		50-PT-705-1
Pot	0-500 psig	X						1							X		28-PT-49
PoM	0-500 psig	X						2					X		X		50-PT-421
Tol1 - 390°F	to - 170°F	X						3					X		X		50-TT-479
PwC0 (3)	0-225 psig	X													X		50-PT-708-1
S.G. #1	Start																
1st Stage Signal	)																
2nd Stage Signal	)																
Main LO ₂ Valve Signal	)	X	X	X											X		
Main Fuel Valve Signal	)																
CCPD3-1		X															
PfJ1-2	0-500 psig		X						3						X		50-PDS-480-1
PfV2-2	0-500 psig		X						4						X		50-PT-407-2
PfJ3-2	0-500 psig		X							7					X		50-PT-408-2
PfV3-2	0-500 psig		X												X		50-PT-409-2
PoV3-2	0-500 psig		X											X	X		50-FT-405-2
PoJ3-2	0-500 psig		X			3								X	X		50-FT-409-2
PwC03-2	0-200 psig		X												X		50-PT-415-2
															X		50-PT-410-2

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APPENDIX 2
EP VI
INSTRUMENTATION REQUEST

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		RECORDING METHOD														REMARKS	
FUNCTION	RANGE	OSC.			STRIP CHART						RFC	Meter on TC Console	Meter on ATC Console	Meter on AFEL Console	DDS	Oscilloscope	
		01	02	03	RA	RB	RC	RD	RE	RF							
Tc1-3	32-2300°F			X											X		50-TT-435-3
Tc2-3	32-2300°F			X											X		50-TT-436-3
Tc3-3	32-2300°F			X											X		50-TT-437-3
TcAV-3	32-2300°F			X						3				X	X		
TWC03-3	0-150°F			X		8									X		50-TT-434-3
LWCV-3	0-100%			X										X	X		50-FCV-423-3
LWCV-3	0-100%			X											X		50-FCV-423-3
TfJ3-3	32-254°F			X											X		50-TE-703-3
TfJ4-3	32-254°F			X			7					X			X	X	50-TE-704-3
PEJ-3	0-300 psig			X			8					X			X	X	50-PT-703-3
ΔPEJ3-3	0-200 psid			X			6								X		50-PT-705-3
PET	0-500 psig			X				4						X	X		34-PT-118
PEM	0-500 psig			X				5				X		X	X		50-PT-420
TET	0-150°F			X						6				X	X		34-TT-483
TEM	0-150°F			X				6				X		X	X		50-TT-478
Wf (ac)	0-500 cps			X													50-FT-701
WF (dc)	0-500 cps							7							X		50-FT-701
S.G. #3	Start																
1st Stage Signal)																	
2nd Stage Signal)		X	X	X											X		
Main LO ₂ Valve Signal)																	
Main Fuel Valve Signal)																	
CCDPS-3				X											X		50-PDS-480-3
LoT	10 psid													X			28-LT-001
PeRL	500 psig													X			28-PT-440
LfT	25 psid													X			34-LT-011
PeRL	500 psig													X			34-PT-439
PgM2	500 psig													X			50-PT-428
ToT	-395÷194°F													X			50-TE-480
PgN1	250 psig													X			50-PT-574

ETS-1 STEAM GENERATOR SYSTEM SIMPLIFIED SCHEMATIC

STEAM GENERATOR QUICK LOOK DATA REPORT

TEST: _____

DATE: _____

DESCRIPTION: _____

TEST DATA

Run Duration (Full Steam):	_____	sec.	Data Time:	_____	sec.
PoT	LO ₂ Tank Pressure (50-PT-49)			_____	psig
PoM	LO ₂ Manifold Pressure (50-PT-421)			_____	psig
ToM	LO ₂ Manifold Temperature (55-TT-479)			_____	°F
PfT	Fuel Tank Pressure (34-PT-118)			_____	psig
TfT	Fuel Tank Temperature (34-TT-483)			_____	°F
PfM	Fuel Manifold Pressure (50-PT-420)			_____	psig
TfM	Fuel Manifold Temperature (50-TT-478)			_____	°F
PcL3-1	3rd Stage Chamber Pressure (50-PT-438)			_____	psig
PcU3-1	3rd Stage Chamber Pressure (50-PT-709)			_____	psig
PoV3-1	3rd Stage LO ₂ Venturi Inlet Pressure (50-FT-409)			_____	psig
PfV3-1	3rd Stage Fuel Venturi Inlet Pressure (50-FT-405)			_____	psig
△ PwV-1	Injection Water Venturi Differential Pressure (50-FT-406)			_____	psid
PwV0-1	Injection Water Venturi Outlet Pressure (50-PT-701)			_____	psig
TwCO3-1	Chamber Coolant Water Outlet Temperature (50-TT-434)			_____	°F
TcAV-1	Chamber Temperature (av. of 50-TT-435, 436, 437)			_____	°F
PcL3-2	3rd Stage Chamber Pressure (50-PT-438)			_____	psig
PcU3-2	3rd Stage Chamber Pressure (50-PT-709)			_____	psig
PoV3-2	3rd Stage LO ₂ Venturi Inlet Pressure (50-FT-409)			_____	psig
PfV3-2	3rd Stage Fuel Venturi Inlet Pressure (50-FT-405)			_____	psig
△ PwV-2	Injection Water Venturi Differential Pressure (50-FT-406)			_____	psid
PwV0-2	Injection Water Venturi Outlet Pressure (50-PT-701)			_____	psig
TwCO3-2	Chamber Coolant Water Outlet Temperature (50-TT-434)			_____	°F

TcAV-2	Chamber Temperature (av. of 50-TT-435, 436, 437)		°F
PcL3-3	3rd Stage Chamber Pressure (50-PT-438)		psig
PcU3-3	3rd Stage Chamber Pressure (50-PT-709)		psig
PoV3-3	3rd Stage LO ₂ Venturi Inlet Pressure (50-FT-409)		psig
PfV3-3	3rd Stage Fuel Venturi Inlet Pressure (50-FT-405)		psig
△PwV-3	Injection Water Venturi Differential Pressure (50-PT-406)		psid
PwVO-3	Injection Water Venturi Outlet Pressure (50-PT-701)		psig
TwCO3-3	Chamber Coolant Water Outlet Temperature (50-TT-434)		°F
TcAV-3	Chamber Temperature (av. of 50-TT-435, 436, 437)		°F
TsPAV	Plenum Steam Temperature (av. of 50-TE-504, 505, 506)		°F
TsDAV	Duct Vault Steam Temperature (av. of 50-TT-706, 707, 708)		°F
TsL	Steamline Temperature (50-TE-159)		°F
PsL	Steamline Pressure (50-PT-239)		psig
PsPl	Steam Plenum Pressure (50-PT-425)		psig
PwM	Water Inlet Manifold Pressure (50-PT-427)		psig
TwPO	Plenum Coolant Water Outlet Temperature (50-TT-431)		°F
PfJ3-2	3rd Stage Fuel Injector Inlet Pressure (50-PT-409)		psig
PsP2	Steam Plenum Pressure (50-PT-426)		psig
TsD1	Duct Vault Steam Temperature (50-TE-706)		°F
TsD2	Duct Vault Steam Temperature (50-TE-707)		°F
TsD3	Duct Vault Steam Temperature (50-TE-708)		°F
° Wo3-1	LO ₂ Flow Rate: Desired _____ lb/sec Actual		lb/sec
° Wo3-1	LO ₂ Flow Rate: (Potter)		lb/sec
° Wf3-1	Fuel Flow Rate: Desired _____ lb/sec Actual		lb/sec
° Wo3-2	LO ₂ Flow Rate: Desired _____ lb/sec Actual		lb/sec
° Wf3-2	Fuel Flow Rate: Desired _____ lb/sec Actual		lb/sec
° Wo3-3	LO ₂ Flow Rate: Desired _____ lb/sec Actual		lb/sec
° Wf3-3	Fuel Flow Rate: Desired _____ lb/sec Actual		lb/sec
° WfT	Total Fuel Flow Rate: Desired _____ lb/sec Actual		lb/sec

^o Ww3-1	Injection Water Flow Rate	_____	lb/sec
^o Ww3-2	Injection Water Flow Rate	_____	lb/sec
^o Ww3-3	Injection Water Flow Rate	_____	lb/sec

A P P E N D I X I I

TEST DESCRIPTION

for

EXPERIMENTAL PLAN VI

SUPPLEMENT NO. 1

STEAM GENERATOR DEVELOPMENT

TEST PROGRAM

NTO-I-0119

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	- LO ₂ Venturi Inlet Pressure vs LO ₂ Flow Rate, S.G. No. 18	
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1.0 EP SUPPLEMENT PURPOSE AND OBJECTIVES

1.1 EP SUPPLEMENT PURPOSE

The purpose of the Supplement is to define revised conditions and configuration of the steam generator modules for performance of EP-VI Tests No. 8, 9 and 10. The revised requirements here-in supercede and replace the previously specified testing requirements of EP-VI.

1.2 PRIMARY OBJECTIVE

The EP-VI primary objectives as originally stated are:

- 1.2.1 Evaluate performance of the integrated steam generator system when operated at rated full flow (two modules full steam one module at idle).
- 1.2.2 Determine the best means for efficient operation of the steam generator when integrated and operated as a system.
- 1.2.3 Demonstrate that the steam generator system will supply nominal 120 lb/sec steam at 1100°F.
- 1.2.4 Evaluate harmonics or relevant vibrations that may occur as a result of combustion or the discharging and mixing of hot gases in the plenum at generator system rated flow.
- 1.2.5 Determine the effect of system operation on propellant pressure, combustion pressure, cooling water pressure and pressure drops, and various system pressures.
- 1.2.6 Demonstrate that the idling unit, after a 4 second delay, will switch to full steam if one of two modules operating at full steam is shutdown.
- 1.2.7 Establish relationship between observed flow of water injected and stabilized steam temperature at the steam exit.
- 1.2.8 Evaluate heat transfer characteristics of the plenum at rated full flow operation.

1.3 SECONDARY OBJECTIVE

The EP-VI Supplement No. 1 addition objectives are:

- 1.3.1 Demonstrate the capability of each module main stage to startup from the ignitor second stage after a flame-out has been induced in the ignitor first stage.
- 1.3.2 Determine the effect on the SGS operation of shortened lead time of the main oxidizer valve opening ahead of the main fuel valve opening.

- 1.3.3 Continue the investigation of the system ability to deliver at rated performance under simulated duct conditions.
- 1.3.4 Investigate the depth of penetration required on the generator exit flange thermocouples (50-TT-435, -436 and -437) to obtain an average temperature matching that of the steam exit thermocouples (50-TT-705, -706 and -707).

2.0 TEST OPERATIONS DESCRIPTION

2.1 SET UP

- 2.1.1 The SGS will consist of Modules S/N 0016, 0017 and 0018, and the modules will be set-up at the Steam Plenum Positions 1, 2 and 3, respectively.
- 2.1.2 Steam Generator Module S/N 0016 assembly will include Injector P/N 901543 S/N 0019 Combustion Chamber P/N 901550 S/N 001, and Ignitor Assembly S/N 0019.
- 2.1.3 Steam Generator Module S/N 0017 assembly will include Injector P/N 901543 S/N 001, Combustion Chamber P/N 901550 S/N 001, and Ignitor Assembly S/N 0017.
- 2.1.4 Steam Generator Module S/N 0018 assembly will include Injector P/N 901543 S/N 0018, Combustion Chamber P/N 901550, S/N 0018, and Ignitor Assembly S/N 0014.
- 2.1.5 The SGS will be connected to the facility steam pipe which will utilize a load orifice located at the pipe discharge in the duct vault.
- 2.1.6 One set of three vibration transducers (one for each axis) shall be mounted on a module transducer box. These transducers shall be rotated from test to test between the different boxes so as to obtain data for each corresponding module when that module is at full steam.

2.2 TEST PROGRAM

2.2.1 General

During this program two steam generator modules will be operated at full steam conditions with the remaining unit at idle conditions. The three generator modules will be started and brought to idle operation following a standard start up operating procedure. The full steam operating conditions, which will be initiated after 60 seconds of idle operation are described for each particular test under specific headings to follow.

EP-VI SUPPLEMENT NO. 1
TEST PROGRAM SUMMARY

Test No.	EP-VI Supplement No. 1 Para. No.	Type of Test	Full Steam Total Duration, Seconds	Initial Modules at Full Steam	*Duration, Seconds	Shutdown Module No.	Final Modules at Full Steam	Duration, seconds	Regulate Injection Water During Test	Steam Exhaust Temp. Goal, °F
Check out	2.2.2	Checkout Test of SGS at Full Steam (Mod Run Singly)	90	1 2 3	30 30 30	- - -	NA NA NA	NA NA NA	NO NO NO	NA NA NA
8	2.2.3	SGS Full Steam with Gen. Switching	270	1,2	190	1	2,3	80	Yes	1300
9	2.2.4	SGS Full Steam with Gen. Switching	270	2,3	190	2	1,3	80	Yes	1300
10	2.2.5	SGS Long Duration Full Steam with Gen. Switching	1190	2,3	1090	2	1,3	100	Yes	1300
*Includes 90 second "warm-up period" for initial dual generator full steam operation.										

- 2.2.1.1 The propane supply temperature shall not exceed a maximum of 60°F and the propane flow rate will be 7.0 lb/sec per module. The IO_2 supply temperature will be $-290 \pm 5^\circ\text{F}$ and the IO_2 flow rate will be 16.7 lb/sec per module.
- 2.2.1.2 For the checkout test, the water injection control valves (50-FCV-423) console controls shall be placed in the "wide open" position. For all other tests the valves shall be pre-set to a position estimated to provide an injection water flow rate of 35 lb/sec.
- 2.2.1.3 For all tests, excepting the checkout test, sufficient warm up time at full steam (90 seconds) shall be allowed to obtain steam exhaust thermal equilibrium. At this point, the injection water shall be regulated as required to obtain $1300^\circ\text{F} \pm 25^\circ\text{F}$ steam.
- 2.2.1.4 Prior to each test, the combustion chamber to injection bolts torque will be checked and retorqued, if necessary, and the hot gas circuit will be leak tested to 120 psig with GN_2 .
- 2.2.1.5 Whenever two generators are operating at full steam, keep both injection water flow rates equal (within 1.0 lb/sec) by monitoring the ΔP across both water injection venturis and adjusting the water control valves as required for balance.
- 2.2.1.6 On all steam generator system tests, beginning with the shutdown of the last generator, a continuous 10 minute duration post test gaseous nitrogen purge will be made simultaneous through all modules. This will be accomplished by actuation of the SGS purge control switch on the SGS control console prior to the shutdown of the last operating module.
- 2.2.1.7 The installation of the thermocouples in the generator combustion chamber exit flange at various penetration depths will be specified within the description of each particular test.

2.2.2 Full Steam Checkout Test

In order to verify the readiness of the system after teardown and reassembly following the last test operations, a full steam checkout test will be performed on each module as described below:

2.2.2.1 Test Special Set-up Requirements

- 2.2.2.1.1 Install the module combustion chamber exit thermocouples for the following penetration depths:

- (a) 50-TT-435-1, 50-TT-436-1 and 50-TT-437-1 to penetrate the gas steam 1.5 inches.

(b) 50-TT-435-2, 50-TT-436-2 and 50-TT-437-2 to penetrate the gas stream 2.0 inches.

(c) 50-TT-435-3, 50-TT-436-3 and 50-TT-437-3 to penetrate the gas stream 2.5 inches.

2.2.2.1.2 All modules water injection control valves to be positioned full open for the checkout test.

2.2.2.2 Test Procedure

2.2.2.2.1 Conduct standard startup to idle operation of the three generators.

2.2.2.2.2 Command Generator No. 1 to full steam; verify satisfactory full steam operation has been achieved and shutdown after 30 seconds.

2.2.2.2.3 Command Generator No. 2 to full steam; verify satisfactory full steam operation has been achieved and shutdown after 30 seconds.

2.2.2.2.4 Command Generator No. 3 to full steam; verify satisfactory full steam operation has been achieved and shutdown after 30 seconds.

2.2.3 Full Steam SGS Test with Automatic Generator Switching to Full Steam (Modules 1 and 2 with switching to Modules 2 and 3).

2.2.3.1 Test Special Set-up Requirements

2.2.3.1.1 Set TDR-4 module relay control LO₂ time at 0.75 seconds. LO₂ lead control time for all three modules.

2.2.3.1.2 The combustion chamber exit thermocouples installation unchanged and the same as 2.2.2.1.1.

2.2.3.1.3 Provide temporary controls at the Steam Generator Control Console such that, for each module, the first state ignitor fuel and oxidizer propellant shutoff valves 50-RSV-422-A and 50-RSV-422-B can be manually closed or opened by the operation of a switch during the module idle and full steam operation. Simultaneous with the valves closure the ignitor spark plug operation will stop, and upon opening the valves the spark plug operation will resume.

2.2.3.1.4 Pre-set Modules 1 and 2 water injection control valves (50-FCV-423) to provide about 35 lb/sec flow rate when the modules are commanded to full steam.

2.2.3.2 Test Procedure

2.2.3.2.1 Conduct standard start up to idle operation of the three generators.

2.2.3.2.2 Shutoff the first stage ignitors of all three modules using the special control console switches provided.

- 2.2.3.2.3 Command Generator No. 1 to full steam. Verify that full steam operation has been achieved and after 10 seconds re-start the first stage ignitor. Without delay proceed to 2.2.3.2.4.
- 2.2.3.2.4 Command Generator No. 2 to full steam. Verify that full steam operation has been achieved and after 10 seconds re-start the first stage ignitor.
- 2.2.3.2.5 With Generators No. 1 and 2 at full steam make the initial water injection control valve (50-FCV-423) quick adjustment (within first 15 seconds of multiple full steam operation) to obtain injection water flow rate of 35 lb/sec each module. The generators warm-up period, beginning with multiple full steam operation, to obtain steam exhaust thermal equilibrium shall be 90 seconds duration.
- 2.2.3.2.6 At the completion of the warm-up period (2.2.3.2.5) monitor the steam temperature at the steam exhaust; if it is less or more than 1300°F regulate the injection water flow into both chambers equally until the steam temperature at the exhaust exit reaches 1300°F. Prepare for generator switching by adjusting Module 3 water injection valve control pot position to the same value as the operating units control pots PLUS 10% additional valve lift. Place Generator No. 3 into "standby" status.
- 2.2.3.2.7 After a total of 190 seconds of dual generator operation (including warm-up period), shut down Generator No. 1. After 4 seconds, the idle module (No. 3) will go to full steam operation. Simultaneously a preadjusted flow rate of injection water will be discharged into the chamber of the activated module. Verify that full steam operation has been achieved on Generator No. 3 and after 10 seconds re-start the first stage ignitor. Regulate the injection water flow into the chambers equally until the steam temperature at the exhaust exit reaches 1300°F. Continue dual full-steam operation after generator switching for 80 seconds, then shutdown Generators No. 2 and 3 in that order.
- 2.2.4 Full Steam SGS Test with automatic generator switching to full steam (Modules 2 and 3 with switching to Modules 1 and 3).
- 2.2.4.1 Test Special Set-up Requirements
- 2.2.4.1.1 Set TDR-4 module relay control box time at 0.50 seconds (LO₂ lead control time) for all modules (assuming no unacceptable main stage chamber pressure rise was noted during the preceding test).

2.2.4.1.2 Install the module combustion chamber exit thermocouples for the following penetration depths:

(a) 50-TT-435-1, 50-TT-436-1 and 50-TT-437-1 to penetrate the gas stream 3.0 inches.

(b) 50-TT-435-2, 50-TT-436-2 and 50-TT-437-2 to penetrate the gas stream 3.5 inches.

(c) 50-TT-435-3, 50-TT-436-3 and 50-TT-437-3 to penetrate the gas stream 2.5 inches.

2.2.4.1.3 Pre-set Modules 2 and 3 water injection control valves (50-FCV-423) to provide about 35 lb/sec flow rate when the modules are commanded to full steam.

2.2.4.2 Test Procedure

2.2.4.2.1 Conduct standard startup to idle operation of the three generators.

2.2.4.2.2 Command Generator No. 2 to full steam. After 15 seconds command Generator No. 3 to full steam and begin warm-up period to obtain steam exhaust thermal equilibrium. Make the initial water injection control valve (50-FCV-423) quick adjustment (within first 15 seconds of multiple full steam operation) to obtain injection water flow rate of 35 lb/sec each module. The generators warm-up period, beginning with the dual generator operation, shall be 90 seconds duration.

2.2.4.2.3 At the completion of the warm-up period (2.2.4.2.2), monitor the steam temperature at the steam exhaust; if it is less or more than 1300°F regulate the injection water flow rate into both chambers equally until the steam exhaust temperature reaches 1300°F. Prepare for generator switching by adjusting Module 1 water injection valve control pot position to the same value as the operating units control pots PLUS 10% additional valve lift. Place Generator No. 1 into "standby" status.

2.2.4.2.4 After a total of 190 seconds of dual generator operation (including the warm-up period), shutdown Generator No. 2. After 4 seconds, the idle module (no. 1) will go to full-steam operation. Simultaneously a pre-adjusted flow rate of injection water will be discharged into the chamber of the activated module; regulate the injection water flow into the chambers equally until the steam exhaust temperature reaches 1300°F. Continue dual full steam operation after generator switching for 80 seconds, then shutdown Generators No. 3 and 1 in that order.

2.2.5 Long Duration (1190 seconds) Full Steam SGS Test with automatic generator switching to full steam (Modules 2 and 3 with switching to Modules 1 and 3).

2.2.5.1 Test Special Set-up Requirements (Same as 2.2.4.1)

2.2.5.2 Test Procedure

2.2.5.2.1 Conduct standard start-up to idle operation of the three modules.

2.2.5.2.2 Command Generator No. 2 to full steam. After 15 seconds command Generator No. 3 to full steam and begin warm-up period to obtain steam exhaust thermal equilibrium. Make the initial water injection control valve (50-FCV-423) quick adjustment (within first 15 seconds of multiple full steam operation) to obtain injection water flow rate of 35 lb/sec each module. The generators warm-up period, beginning with the dual generator operation shall be 90 seconds.

2.2.5.2.3 At the completion of the warm-up period (2.2.5.2.2), monitor the steam temperature at the steam exhaust; if it is less or more than 1300°F regulate the injection water flow rate into both chambers equally until the steam exhaust temperature reaches 1300°F. Prepare for generator switching by adjusting Module No. 1 water injection valve control pot position to the same value as the operating units control pots PLUS 10% additional valve lift. Place Generator No. 1 into "standby" status.

2.2.5.2.4 After a total of 1090 seconds of dual generator operation (including the warm up period), shutdown Generator No. 2. After 4 seconds the idle module (No. 1) will go to full-steam operation. Simultaneously a pre-adjusted flow rate of injection water will be discharged into the chamber of the activated module; regulate the injection water flow into the chambers equally until the steam exhaust temperature reaches 1300°F. Continue dual full-steam operation after generator switching for 100 seconds, then shutdown Generators No. 3 and 1 in that order.

2.3 INSPECTION

On conclusion of the test program, the following inspections will be performed:

2.3.1 Injector

Dye penetrant inspection for cracks in injector faces or other damage. Document inspection by close-up photographs. LO₂ clean injectors prior to reassembly.

2.3.2 Combustion Chamber

2.3.2.1 Expansion Joints

Dye penetrant inspection

2.3.2.2 Chamber Liner

Visual inspection, check for damage and hot spots.

2.3.2.3 Water Injection Bolts

Measure and record critical bolt dimensions. Obtain detailed photographs of the eroded area, showing top and side views, of each bolt orifice. A water injection bolt orifice inspection shall not be required preceding the 1190 seconds duration test.

2.3.3 Plenum

Visually inspect interior for erosion and overheating.

2.4 REASSEMBLY OF MODULES

Upon completion of inspection, reassemble the steam generator modules.

3.0 PREMATURE TEST TERMINATION CRITERIA

The following are specific conditions which warrant immediate shutdown of the Steam Generator System. However, should any erratic operation occur, the test shall be immediately terminated.

- 3.1 Should the propane flow rate (50-FT-701) show a decrease to 90% of nominal flow rate after steady state conditions have been achieved, execute an immediate shutdown.
- 3.2 Should the propane manifold temperature (50-TT-478) exceed 65°F, execute an immediate shutdown. (Replaces requirement under Para. 4.2 of Basic EP-VI.)
- 3.3 Should the plenum exit pressure (50-PT-425, 50-PT-426) exceed 160 psig, execute an immediate shutdown.
- 3.4 Should the average steam exhaust temperature exceed 1400°F and the temperature cannot be brought lower by injection water control, execute an immediate shutdown. (Replaces requirements under Para. 4.3 of Basic EP-VI.)
- 3.5 Should the combustion chamber coolant water jacket outlet temperature (50-TT-434) and/or the plenum coolant water jacket outlet temperature (50-TT-431) approach 212°F, execute an immediate shutdown.

4.0 SAFETY REQUIREMENTS

- 4.1 The safety requirements are specified in NTO-SOP-0068.
- 4.2 Following each test, gas samples shall be taken from the steam plenum with a combustible gas analyzer to verify that the propane valves are properly seated and not leaking.

5.0 QUALITY CONTROL REQUIREMENTS

- 5.1 Prior to start of full steam operation, it shall be verified that any repairs and modifications to the Steam Generator System have been properly documented.
- 5.2 Prior to start of full steam operation, it shall be verified that all test equipment has been properly calibrated and documented.

6.0 SUPPORT REQUIREMENTS

6.1 MAJOR TEST PARTICIPANTS

		Alternate
Facility Manager	V. R. Davis	B. A. Bernstein
Test Conductor	T. A. Keasling	H. Henze J. F. Christenson
Deputy Test Conductor	H. Henze	C. K. Soppet S. N. Kemp W. L. McCarty
Assistant Facility Engineer, Left	V. R. Hill J. A. Gaccione	E. B. Graham G. W. Luther
Health & Safety	F. M. Cox R. E. Benshoof	H. G. Simens
Security	A. B. Bagwell	J. S. Holt
Support	A. R. Marshall	W. J. Reibel
Advisor	NES Project Representative	
Quality Control	C. A. Thomas	D. J. McCroskey
Data Observer	R. I. Lutz	V. R. Davis
Instrumentation	D. E. Bridenstine	R. J. Cooper
Facility Control	A. P. Vogt	D. S. Beesley
TV & Communications	R. C. Chavez	A. P. Vogt

6.2 FACILITY CONDITIONS

6.2.1 GN₂ System

This system will be charged to a normal operating pressure with a maximum pressure of 2500 psig, and a minimum pressure of 1500 psig.

6.2.2 Process Water System

The level in the process water tank shall not be lower than 10 feet.

6.2.3 IO₂ System

The liquid level in the tank will be maintained consistent with economical scheduling; however, the tank level shall not be permitted to drop below 10,000 gallons. The tank pressure will be set in accordance with Appendix 1 to provide a nominal 16.7 lb/sec flow per module during steady state operation.

6.2.4 Propane System

The tank level shall not be permitted to drop below 7,000 gallons. The tank shall be pressurized to provide a nominal flow rate of 7.0 lb/sec per module during steady state operation.

6.3 INSTRUMENTATION AND DATA ACQUISITION REQUIREMENTS

6.3.1 Data requirements are as shown in Appendix 2. Refer to Appendix 3 for location and nomenclature of instrumentation.

6.3.2 The oscillograph chart speed shall be operated at approximately 10 in/sec during transient condition and reduced to approximately 1 in/sec during steady state operation for all tests in excess of 30 seconds at full steam. The test title and identification, including date, shall appear on each record. All parameters shall be identified on the record.

6.3.3 Photographic coverage for selected tests will be provided to show the steam generator enclosure (color).

The camera will run at 24 FPS and use 16mm film. Location of cameras to be mutually agreed upon between Test Conductor and Photographer. The exposed film will not be developed unless so directed by the Test Conductor.

Photo coverage of the facility steam line, using 200 FPS film speed will be required on selected tests.

6.3.4 Television coverage will be used for test observation and surveillance of the facility for safety consideration. The following cameras will be used, although all existing cameras (14) will be operational and capable of being substituted.

<u>Monitor No.</u>	<u>Camera Position No.</u>	<u>Location</u>	<u>Primary Observation</u>
1	1	North of Ditch	TS, Pad, Ditch
2	5	North End of Shadow Wall	S.G. Enclosure
3	20	Tripod North of LO ₂ Dewar	Pipe Chase Towards TS
4	6	Atop LH ₂	Test Stand
5	7	Atop Fill Station	LO ₂ Dewar and TS
6	13	Northeast of Steam Generator	S.G. Enclosure
7	15	Tripod Southwest of Propane Tank	Propane Tank
8	3	West of Ditch	Flare Stack

Auxiliary illumination, as needed, will be provided by search lights trained on the test stand structure and steam generator enclosure.

6.4 AREA CONTROL

Area control will be in effect prior to propellant bleed-in on R-Day and remain in effect until removed by the acting Test Conductor.

6.5 PAN AMERICAN WORLD AIRWAYS

6.5.1 Operating Technicians

The crew normally assigned to the Steam Generator Operation shall be available. Overtime may be necessary in the event of unforeseen circumstances.

6.5.2 Photographic Services

Camera equipment and photographers are required to provide coverage from two locations. Overtime operation may be necessary.

6.6 EG&G

6.6.1 Operating Technicians

The crew normally assigned for the instrumentation and control activities shall be available. Overtime may be necessary in the event of unforeseen circumstances.

- 6.6.2 Support is required to process the oscillograph records produced during the test. These records will be processed by EG&G.

7.0 SCHEDULE

- 7.1 The tests will be conducted in accordance with the Operating Procedure (NTO-I-0086) which will be available on R-1 Day. The access list will be prepared on R-1 Day. Area control (ETS-1 Area Control and Safety Standards for Steam Generator Testing NTO-SOP-0068) will be initiated on R-Day prior to propellant bleed-in.

Operations will commence at 0800 hours on R-Day with the establishment of the Test Status Board which will control, monitor, observe, record and report the test preparation activities. The Status Board will inform the Test Conductor of changes in schedule, delays, problems, etc., such that timely action where appropriate, may be taken. A status board coordination meeting will be held on 14 July 1966.

After completion of the test, the system will be secured to allow re-entry for visual examination of the Steam Generator. Strip chart and oscillograph records will be examined and preliminary calculations will be performed.

EP-VI Supplement No. 1 testing is scheduled to begin on or shortly after 2 August 1966, and will continue on the basis of two test per week until the specified tests are completed.

8.0 REPORTS

- 8.1 A "Quick Look" data report will be sent to project via TWX the day after a test. See Appendix 4 for format.

LO₂ VENTURI INLET PRESSURE vs

LO₂ FLOW RATE
GENERATOR S/N 16
(MODULE #1)

POV3-1, MAIN STAGE LO₂ VENTURI INLET PRESSURE, PSIG

- 275°F
- 280°F
- 285°F
- 290°F
- 295°F
- 300°F

400

350

300

250

200

16

17

18

19

20

21

22

23

24

LO₂ FLOW RATE - LB/SEC

LO₂ VENTURI INLET
PRESSURE VS LO₂ FLOW RATE
GENERATOR S/N 18
(MODULE 43)

PoV3-3 MAIN STAGE NO₂ VENTURI INLET PRESSURE, PSIG

400

350

300

250

200

16

17

18

19

20

21

22

23

24

LO₂ FLOW RATE LB/SEC

- 275°F
- 280°F
- 285°F
- 290°F
- 295°F
- 300°F

APPENDIX 2
EP-VI
INSTRUMENTATION REQUEST

PAGE 1 OF 4

		RECORDING METHOD													REMARKS		
FUNCTION	RANGE	OSC.			STRIP CHART						RFC	Meter on TC Console	Meter on ATC Console	Meter on AFEL Console	DL3	Oscilloscope	
		01	02	03	RA	RB	RC	RD	RE	RF							
PoT	0-500 psig	X								1				X			28-PT-49
PoM	0-500 psig	X								2		X		X			50-PT-421
ToM - 390°F	to - 170°F	X								3		X		X			50-TT-479
Pc1-1	0-250 psig	X												X			50-PT-416-1
Pc2-1	0-250 psig	X															50-PT-417-1
PcU3-1	0-250 psig	X			2												50-PT-709-1
PcL3-1	0-250 psig	X			1								X	X			50-PT-438-1
PfJ1-1	0-500 psig	X							1								50-PT-407-1
PfV2-1	0-500 psig	X							2								50-PT-408-1
PfV3-1	0-500 psig	X			4									X			50-FT-405-1
PfJ3-1	0-500 psig	X															50-PT-409-1
PoV3-1	0-500 psig	X			3									X			50-FT-409-1
PoJ3-1	0-500 psig	X															50-PT-415-1
PwJ-1	0-200 psig	X															50-PT-411-1
ΔPwV-1	0-250 psid	X			5									X			50-FT-406-1
PwVO-1	0-250 psig	X			6												50-PT-701-1
IwCV-1	0-100%	X															50-FCV-423-1
LwCV-1	0-100%	X												X			50-FCV-423-1
PwCO3-1	0-200 psig	X															50-PT-410-1
TwCO3-1	0-150°F	X			7												50-TT-434-1
Tc1-1	32-2300°F	X															50-TT-435-1
Tc2-1	32-2300°F	X															50-TT-436-1
Tc3-1	32-2300°F	X															50-TT-437-1
TcAV-1	32-2300°F	X			8									X			
TsL	32-2300°F	X							3								50-TE-159
PsL	0-250 psig	X							4								50-PT-239
WfT (dc)	0-500 cps								8								50-FT-701
Start		X	X	X													S.G. #1
1st Stage Signal		)															
2nd Stage Signal																	
Main LO2 Valve Signal																	
Main Fuel Valve Signal																	
Main LO2 Valve Open		X												X			
Main Fuel Valve Open		X												X			

APPENDIX 2
EP-VI
INSTRUMENTATION REQUEST

PAGE 3 OF 4

		RECORDING METHOD													REMARKS		
FUNCTION	RANGE	OSC.			STRIP CHART						RFC	Meter on TC Console	Meter on ATC Console	Meter on AFEL Console	DDS	Oscilloscope	
		O1	O2	O3	RA	RB	RC	RD	RE	RF							
PsP1	0-250 psig		X					1							X		50-PT-425
PsP2	0-250 psig		X							8		X			X		50-PT-426
Start	)	X	X	X													S.G. #2
1st Stage Signal																	
2nd Stage Signal																	
Main L02 Valve Signal																	
Main Fuel Valve Signal)																	
Main L02 Valve Open			X											X			
Main Fuel Valve Open			X											X			
CCPDS-2			X														50-PDS-480-2
PwH	0-300 psig			X											X		50-PT-168
PwM	0-250 psig			X				6						X	X		50-PT-427
Pc1-3	0-250 psig			X										X	X		50-PT-416-3
Pc2-3	0-250 psig			X										X	X		50-PT-417-3
PcU3-3	0-250 psig			X			2								X		50-PT-709-3
PcL3-3	0-250 psig			X			1						X	X	X		50-PT-438-3
PfJ1-3	0-500 psig			X					5						X		50-PT-407-3
PfV2-3	0-500 psig			X					6						X		50-PT-408-3
PfV3-3	0-500 psig			X			4							X	X		50-PT-405-3
PfJ3-3	0-500 psig			X											X		50-PT-409-3
PoV3-3	0-500 psig			X			3							X	X		50-FT-409-3
PoJ3-3	0-500 psig			X											X		50-PT-415-3
PwJ-3	0-200 psig			X											X		50-PT-411-3
ΔPwV-3	0-250 psid			X			5							X	X		50-FT-406-3
PwV0-3	0-250 psig			X			6								X		50-PT-701-3
IwCV-3	0-100%			X													50-FCV-423-3
LwCV-3	0-100%			X										X	X		50-FCV-423-3
PwC03-3	0-200 psig			X											X		50-PT-410-3
TwC03-3	0-150°F			X			7								X		50-TT-434-3
TwP0	0-150°F			X				7						X	X		50-TT-431
Tc1-3	32-2300°F			X											X		50-TT-435-3
Tc2-3	32-2300°F			X											X		50-TT-436-3
Tc3-3	32-2300°F			X											X		50-TT-437-3

APPENDIX 2
EP-VI
INSTRUMENTATION REQUEST

PAGE 4 OF 4

		RECORDING METHOD														REMARKS	
FUNCTION	RANGE	OSC.			STRIP CHART						RFC	Meter on TC Console	Meter on ATC Console	Meter on AFEL Console	DDS	Oscilloscope	
		01	02	03	RA	RB	RC	RD	RE	RF							
TcAV-3	32-2300°F			X			8							X	X		
TsD1	32-2300°F			X							4			X			50-TE-706
TsD2	32-2300°F			X							5			X			50-TE-707
TsD3	32-2300°F			X							6			X			50-TE-708
TsDAV	32-2300°F			X				2									
WfT (ac)	0-500 cps			X													
Start	)	X	X	X													S. G. #3
1st Stage Signal	)																
2nd Stage Signal	)																
Main LO2 Valve Signal	)																
Main Fuel Valve Signal)																	
Main LO2 Valve Open				X													
Main Fuel Valve Open				X													
CCDPS-3				X										X	X		50-PDS-480-3
LoT	10 psid													X			28-LT-001
PoRL	500 psig													X			28-PT-440
LfT	25 psid													X			34-LT-011
PfRL	500 psig													X			34-PT-439
PgM2	500 psig													X			50-PT-428
Tot	-395+194°F													X			50-TE-480
PgM1	250 psig													X			50-PT-574
S.G. #1 1st	Stage Manual	Shutoff												X			
S.G. #2 1st	Stage Manual	Shutoff												X			
S.G. #3 1st	Stage Manual	Shutoff												X			
WoT-1 (AC)	0-500 cps	X													X		50-FT-428
WoT-1 (DC)	0-500 cps								8								50-FT-428
T _f J3-3	32-254°F			X											X		50-TE-703-3
T _f J4-3	32-254			X								X			X		50-TE-704-3

ETS-1 STEAM GENERATOR SYSTEM SIMPLIFIED SCHEMATIC

STEAM GENERATOR QUICK LOOK DATA REPORT

TEST: _____ DATE: _____

DESCRIPTION: _____

TEST DATA

Run Duration (Full Steam): _____ sec. Data Time: _____ sec.

PoT	LO ₂ Tank Pressure (50-PT-49)	_____	psig
PoM	LO ₂ Manifold Pressure (50-PT-421)	_____	psig
ToM	LO ₂ Manifold Temperature (55-TT-479)	_____	°F
PfT	Fuel Tank Pressure (34-PT-118)	_____	psig
TfT	Fuel Tank Temperature (34-TT-483)	_____	°F
PfM	Fuel Manifold Pressure (50-PT-420)	_____	psig
TfM	Fuel Manifold Temperature (50-TT-478)	_____	°F
PwM	Water Inlet Manifold Pressure (50-PT-427)	_____	psig
TwPO	Plenum Coolant Water Outlet Temperature (50-TT-431)	_____	°F
TwCO3-1	Chamber Coolant Water Outlet Temperature (50-TT-434)	_____	°F
PoV3-1	3rd Stage LO ₂ Venturi Inlet Pressure (50-FT-409)	_____	psig
PfV3-1	3rd Stage Fuel Venturi Inlet Pressure (50-FT-405)	_____	psig
PfJ-1	Injector Fuel Pressure (50-PT-703)	_____	psig
ΔPfJ3-1	Injector Fuel Pressure Drop (50-PT-705)	_____	psig
TfJ4-1	Injector Fuel Temperature (50-TE-704)	_____	°F
PcU3-1	Chamber Pressure (50-PT-709)	_____	psig
PcL3-1	Chamber Pressure (50-PT-438)	_____	psig
TcAV-1	Chamber Temperature (av. of 50-TT-435, 436, 437)	_____	°F
ΔPwV-1	Injection Water Venturi Differential Pressure (50-FT-406)	_____	psid
PwPO-1	Injection Water Venturi Outlet Pressure (50-PT-701)	_____	psig
TwCO3-2	Chamber Coolant Water Outlet Temperature (50-TT-431)	_____	°F

PoV3-2	3rd Stage LO ₂ Venturi Inlet Pressure (50-FT-409)	_____	psig
PfV3-2	3rd Stage Fuel Venturi Inlet Pressure (50-FT-405)	_____	psig
PfJ3-2	3rd Stage Fuel Injector Inlet Pressure (50-PT-409)	_____	psig
PcJ3-2	Chamber Pressure (50-PT-709)	_____	psig
PcL3-2	Chamber Pressure (50-PT-438)	_____	psig
TcAV-3	Chamber Temperature (av. of 50-TT-435, 436, 437)	_____	°F
ΔPwV-2	Injection Water Venturi Differential Pressure (50-FT-406)	_____	psid
PwV0-2	Injection Water Venturi Outlet Pressure (50-PT-701)	_____	psig
TwC03-3	Chamber Coolant Water Outlet Temperature (50-TT-431)	_____	°F
PoV3-3	3rd Stage LO ₂ Venturi Inlet Pressure (50-FT-409)	_____	psig
PfV3-3	3rd Stage Fuel Venturi Inlet Pressure (50-FT-405)	_____	psig
PfJ-3	Injector Fuel Pressure (50-PT-703)	_____	psig
ΔPfJ3-3	Injector Fuel Pressure Drop (50-PT-705)	_____	psig
TfJ4-3	Injector Fuel Temperature (50-TE-704)	_____	°F
PcU3-3	Chamber Pressure (50-PT-709)	_____	psig
PcL3-3	Chamber Pressure (50-PT-438)	_____	psig
TcAV-3	Chamber Temperature (av. of 50-TT-435, 436, 437)	_____	°F
ΔPwV-3	Injection Water Venturi Differential Pressure (50-PT-406)	_____	psid
PwV0-3	Injection Water Venturi Outlet Pressure (50-PT-701)	_____	psig
PsPl	Steam Plenum Pressure (50-PT-425)	_____	psig
TsPAV	Plenum Steam Temperature (av. of 50-TE-504, 505, 506)	_____	°F
TsE1	Exit Steam Temperature (50-TT-428)	_____	°F
TsE2	Exit Steam Temperature (50-TT-429)	_____	°F
TsE3	Exit Steam Temperature (50-TT-430)	_____	°F
TsEAV	Exit Steam Temperature (av. of 50-TT-428, 429, 430)	_____	°F
°Wo3-1	LO ₂ Flow Rate: Desired _____ lb/sec Actual _____		lb/sec
°Wf3-1	Fuel Flow Rate: Desired _____ lb/sec Actual _____		lb/sec
°Wo3-2	LO ₂ Flow Rate: Desired _____ lb/sec Actual _____		lb/sec
°Wf3-2	Fuel Flow Rate: Desired _____ lb/sec Actual _____		lb/sec

° Wo3-3	LO ₂ Flow Rate: Desired _____	lb/sec	Actual _____	lb/sec
° Wf3-3	Fuel Flow Rate: Desired _____	lb/sec	Actual _____	lb/sec
° WfT	Total Fuel Flow Rate (Potter)		_____	lb/sec
° Ww3-1	Injection Water Flow Rate		_____	lb/sec
° Ww3-2	Injection Water Flow Rate		_____	lb/sec
° Ww3-3	Injection Water Flow Rate		_____	lb/sec

Appendix III

STEAM GENERATOR DEVELOPMENT PROGRAM

FIELD ACTION REQUESTS INDEX

(FAR's received April 11 thru August 9, 1966)

<u>FAR NO.</u>	<u>TITLE</u>	<u>Date Received</u>	<u>Date Completed</u>
176	Weld Repair of Crack in S/N 0018 Injector	4-11-66	4-12-66
177	Installation of 4" Sch. 40 Propane Manifold	4-11-66	4-27-66
178	Thicker Flexitallic Gasket to be Used in the Cavity Form by the Groove of the Injector and the Tongue of the Combustion Chamber	4-12-66	4-16-66
179	Installation of Flexitallic Gasket in the Injector-Combustion Chamber Gland	4-13-66-	4-16-66
180	Four Second Delay, Generator Module Switching Command	4-15-66	4-21-66
181	Shipment of Blank Flange and Dis- charge Yoke to Sacramento	4-21-66	4-25-66
182	Torqueing Bolts on Injector- Combustion Chamber Flanges After Full Steam Operation of any Module	4-29-66	5 -6-66
183	Instrumentation on Permanent Steam Pipe and Temporary Extension Duct	4-26-66	5-12-66
184	Change of Plumbing to Differential Pressure Switches 50-PDS-406-1,-2,-3	5-3-66	5-5-66
185	Installation of C _v =110 Plugs and Seats in Injection Water Control Valve 50-FCV-423-1,-3 (Module 1 and 3)	5-4-66	5-5-66
186	Special Instrumentation on Module No. 1 to Determine the Vertical Vibration and the Temperature in the Vicinity of the Flexitallic Gasket	5-4-66	5-5-66
187	Orificing PDS-407, all Modules	5-6-66	5-9-66
188	Measurement of the Differential Pressure Across Pressure Switches PDS- 406, PDS-407, PDS-480	5-13-66	Open

Appendix III(continued)

<u>FAR NO.</u>	<u>TITLE</u>	<u>Date Received</u>	<u>Date Completed</u>
189	Measurement of the Differential Pressure Across the Strainer in the 8.0 Inch Water Line	5-19-66	5-19-66
190	Change Over From Facility Steam Pipe to Test Pipe for Steam Discharge	5-25-66	5-25-66
191	Change in Second Stage Differential Pressure Switch (50-PDS-407) Set Point	5-25-66	5-25-66
192	Change in First Stage Pressure Switch (50-PDS-413) Set Point	5-25-66	5-23-66
193	Shipment of Ignition System (S.G.S. Module 1) and Associated Components to Sacramento	5-27-66	5-27-66
194	Analysis of Spud to Injector Face Weld of S/N 0018 Injector	6-3-66	7-7-66
195	S.G.S. Purge Modifications	6-3-66	6-6-66
196	Shipment of the Following Items to Sacramento	6-6-66	6-6-66
197	Dye Penetrant Inspection of S/N001 and S/N 0019 Injectors	6-6-66	6-7-66
198	Ultrasonic Inspection of S.G.S. Plenum to Determine Internal Wall Thicknesses	6-6-66	6-7-66
199 (Rev A)	Weld Repair of S/N 0018 Injector	6-6-66	6-20-66
200 (Rev A)	Analysis of Injector Body to Injector Face Weld of S/N 0018 Injector	6-8-66	7-7-66
201	Modification of 2nd Stage LO ₂ and Propane Check Valves	6-9-66	6-30-66
202	Checkout and Updating of Top-works Components and Tubing of Modules 0017 and 0018	6-10-66	7-21-66
203	Inspection of 2nd Stage Chambers of Ignitors Used on Modules 2 and 3 During EPVI	6-14-66	6-16-66
204	Thermocouple Penetrations Into Lower Combustion Chambers	6-16-66	7-29-66

Appendix III(continued)

<u>FAR NO.</u>	<u>TITLE</u>	<u>Date Received</u>	<u>Date Completed</u>
205	Shipment of Injector Back Flushing Fixture and Four Solenoid Valves to Sacramento	6-20-66	6-20-66
206	Continuity Check and Resizing of Propellant Injection Holes	6-20-66	6-27-66
207 (Rev A)	Torquing Procedure for the Injector to Combustion Chamber Bolts and Studs When Installing a New Gasket (and Retorquing after a Test)	7-13-66	8-9-66
208	Deployment of Ignitors, Injectors, Combustion Chambers, and Combustion Chamber Gaskets	6-21-66	6-21-66
209	New Poppet Assys and Body "O" Rings for all 1st, 2nd and 3rd Stage Check Valves	6-23-66	Superceded
210	Temporary Replacement of 50-FE-404 of S/N 0017 Ignitor with a 0.070 Inch Orifice	6-27-66	6-27-66
211	Fabrication of 12.0 Inch Orifice for Exit of Facility Steam Pipe	6-28-66	7-7-66
212	Removal of Material on Top of Two S/N 0018 Combustion Chamber Studs to Provide Clearance with Injector LOX Manifold	6-28-66	6-28-66
213	Fabrication and Assembly of the Beckman 778 Sampling System	6-29-66	Open
214	Cleaning of Ignitor Assembly 0019	6-30-66	7-8-66
215	Incorporation of S.G.S. Modification Accomplished in FAR's 193 through 214 for the Remaining Tests of EPVI	7-5-66	7-5-66
216	Change of Plumbing and "Break" Pressure to Differential Pressure Switches PDS-413-1,-2,-3	7-13-66	7-18-66
217	Installation of New Relay Chassis (715J016 Preliminary I.D. Number)	7-14-66	7-25-66

Appendix III (continued)

<u>FAR NO.</u>	<u>TITLE</u>	<u>Date Received</u>	<u>Date Completed</u>
218	Removal of Check Valves and Differential Pressure Switches	7-21-66	7-26-66
219	Cleaning and Modification of Republic Check Valves for Compatibility With LO ₂	7-27-66	Superceded
220 (Rev A)	Shipment of LO ₂ System Components to Sacramento and Reinstall Items Below on S.G.S. Except Item 5	8-1-66	8-8-66
221	Temporary Change to S.G.S. Electrical Control System	7-28-66	8-2-66
222	Admission of GN ₂ Purge Downstream of CHV-1708-1, -2, -3 and CHV-1703-1, -2, -3 Check Valve Poppet Assys.	8-4-66	8-5-66
223	Change of Thermocouple Penetrations Into the Lower Combustion Chambers	8-9-66	8-9-66
224	Post Fire Torque Check off All Modules and Removal of S/N 0018 Injection After Test No. 10 NES Test Spec. 006	8-9-66	8-11-66

A P P E N D I X IV

STEAM GENERATOR SYSTEM TEST NOMENCLATURE

Nomenclature	Tag No.	Description
<u>PROPANE SYSTEM</u>		
PfT	34-PT-118	Propane Tank Pressure
TfT	34-TT-483	Propane Tank Temperature
PfM	50-PT-420	Propane Manifold Pressure
TfM	50-TT-478	Propane Manifold Temperature
PfJ1-1,-2,-3	50-PT-407	1st Stage Propane Injector Pressure
PfV2-1,-2,-3	50-PT-408	2nd Stage Propane Venturi Inlet Pressure
PfV3-1,-2,-3	50-FT-405	3rd Stage Propane Venturi Inlet Pressure
PfJ3-2	50-PT-409	3rd Stage Propane Injector Pressure
PfJ-1,-3	50-PT-703	Injector Propane Pressure
Δ PfJ3-1,-3	50-PT-705	Injector Propane Differential Pressure
$\dot{W}_f$	50-FT-701	Propane Potter Flow Rate
$\dot{W}_f3-1,-2,-3$		3rd Stage Fuel Flow
$\dot{W}_fT-1,-2,-3$		Total Fuel Flow ($\dot{W}_f3 + 0.15$)
<u>LIQUID OXYGEN SYSTEM</u>		
PoT	28-PT-49	LO ₂ Tank Pressure
PoM	50-PT-421	LO ₂ Manifold Pressure
ToM	50-TT-479	LO ₂ Manifold Temperature
PoV3-1,-2,-3	50-FT-409	3rd Stage LO ₂ Inlet Venturi Pressure
PoJ3-1,-2,-3	50-PT-415	3rd Stage LO ₂ Injector Pressure
$\dot{W}_o3-1,-2,-3$		3rd Stage Oxidizer Flow
$\dot{W}_oT-1,-2,-3$	Total Oxidizer Flow	Total Oxidizer Flow ($\dot{W}_o3 + 0.45^{**}$)
<u>WATER SYSTEM</u>		
PwH	50-PT-168	Process Water Header Pressure
PwM	50-PT-427	Process Water Manifold Pressure
Δ PwV-1,-2,-3	50-FT-406	Water Venturi Differential Pressure
PwVO-1-2,-3	50-PT-701	Water Venturi Outlet Pressure
PwJ-1,-2,-3	50-PT-411	Water Injector Pressure
PwCO3-1,-2,-3	50-PT-410	3rd Stage Coolant Water Outlet Pressure
TwPO	50-TT-431	Coolant Water Outlet Temperature
TwCO3-1,-2,-3	50-TT-434	3rd Stage Coolant Water Outlet Temperature
LwCV-1,-2,-3	50-FCV-423	Injector Water Valve Current Command
IwCV-1,-2,-3	50-FCV-423	Injection Water Valve Position

Nomenclature	Tag Number	Description
$\dot{W}w3-1,-2,-3$		Injection Water Flow
$\dot{W}wF-1,-2,-3$		3rd Stage Film Cooling Water Flow
$\dot{W}wT-1,-2,-3$		Total Water Flow ($\dot{W}w3 + \dot{W}wF$)
<u>STEAM SYSTEM</u>		
Pc1-1,-2,-3	50-PT-416	1st Stage Chamber Pressure
Pc2-1,-2,-3	50-PT-417	2nd Stage Chamber Pressure
PcU3-1,-2,-3	50-PT-709	3rd Stage Chamber Upper Pressure
PcL3-1,-2,-3	50-PT-438	3rd Stage Chamber Lower Pressure
Tc1-1,-2,-3	50-TT-435	Main Chamber Exit Temperature #1
Tc2-1,-2,-3	50-TT-436	Main Chamber Exit Temperature #2
Tc3-1,-2,-3	50-TT-437	Main Chamber Exit Temperature #3
TcAV-1,-2,-3		Main Chamber Average Exit Temperature
PsP1	50-PT-425	Plenum Steam Pressure #1
PsP2	50-PT-426	Plenum Steam Pressure #2
TsP1	50-TE-504	Plenum Steam Temperature #1
TsP2	50-TE-505	Plenum Steam Temperature #2
TsP3	50-TE-506	Plenum Steam Temperature #3
TsPAV		Plenum Average Steam Temperature
TsE1	50-TT-428	Exhaust Stack Steam Temperature #1
TsE2	50-TT-429	Exhaust Stack Steam Temperature #2
TsE3	50-TT-430	Exhaust Stack Steam Temperature #3
TsEAV		Exhaust Stack Average Steam Temperature
TsD1	50-TT-706	Duct Vault Steam Temperature #1
TsD2	50-TT-707	Duct Vault Steam Temperature #2
TsD3	50-TT-708	Duct Vault Steam Temperature #3
TsDAV		Duct Vault Average Steam Temperature
PsL	50-PT-239	Steam Line Pressure
TsL	50-TE-159	Steam Line Temperature
$\dot{W}tT-1,-2,-3$		Total Flow Each Module ($\dot{W}oT + \dot{W}fT + \dot{W}wT$)
$\dot{W}t$		Total Flow ($\dot{W}tT-1 + \dot{W}tT-2 + \dot{W}tT-3$)
<u>MISCELLANEOUS</u>		
MRT-1,-2,-3		Mixture Ratio - $\dot{W}oT/\dot{W}fT$
MRW-1,-2,-3		Mixture Ratio - $\dot{W}wT/\dot{W}oT + \dot{W}fT$
AxJ1-1		Accelerometer Mounted on Module 1 Injector Flange along X Axis
AxJ2-1		Accelerometer Mounted on Module 1 Injector Flange along X Axis

Nomenclature	Tag Number	Description
AxUC1-1		Accelerometer Mounted on Module 1 Upper Combustion Chamber Flange along X Axis
AxUC2-1		Accelerometer Mounted on Module 1 Upper Combustion Chamber Flange along X Axis
AzUC1-1		Accelerometer Mounted on Module 1 Upper Combustion Chamber Flange along Z Axis
AxLC1-1		Accelerometer Mounted on Module 1 Lower Combustion Chamber Flange along X Axis
AxLC2-1		Accelerometer Mounted on Module 1 Lower Combustion Chamber Flange along X Axis
TjG1		Injector-to-Chamber Gasket Temperature
ASL-X		Accelerometer Mounted on Steam Line along X Axis
ASL-Y		Accelerometer Mounted on Steam Line along Y Axis
ASL-Z		Accelerometer Mounted on Steam Line along Z Axis

APPENDIX V

MATERIAL MODIFICATION OF THE STEAM GENERATOR OXIDIZER SYSTEM COMPONENTS

Identification Tag Number	Nomenclature	NTO Part Number	Manufacturer and Part Number	Original Materials	Replacement Materials
50-RSV-422A 50-RSV-423A	Valve,1st Stage 3 way GOX Valve,2nd Stage Purge	901501 901501	Marotta - PV28B 219133 Rev. 2189A	1. Neoprene O-ring, 3 each 4200AR7 2. Neoprene O-ring, 3 each 4200AR12 3. Neoprene O-ring, 1 each 4200AR121 4. Kel-F Seat P/N 210932 5. Teflon Fitting O-ring	1. Viton A O-ring ARP568-007 2. Viton A O-ring ARP568-012 3. Viton A O-ring ARP568-121 4. Kel-F Seat (unchanged) 5. Teflon Fitting O-ring (unchanged)
50-CHV-1707 50-CHV-1785 50-CHV-1709	Check Valve,1st Stage GOX Check Valve,1st Stage Purge Check Valve,2nd Stage Purge	901504 901504 901504	Republic - 11-2263-3	1. Kel-F (soft)Poppet Seat Plasticized 2. Teflon O-ring SP-103-90	1. TFE Teflon Poppet Seal 2. Viton A O-ring ARP568-014
None None None	Shuttle Valve,1st Stage P _C 1 Shuttle Valve,2nd Stage P _C 2 Shuttle Valve,3rd Stage P _C 3	None None None	Clary - 524645	1. Teflon Poppet AMS3651 2. Silicone O-rings AMS3303	1. TFE Teflon Seat (unchanged) 2. Viton A O-rings ARP568-012, -112
50-PDS-413 50-PDS-407 50-PDS-480	Press. Switch 1st Stage ΔP Press. Switch 2nd Stage ΔP Press. Switch 3rd Stage ΔP	901512 901512 901512	Barksdale P/N 9653-IWA P/N 9653-2-IWA-AA	1. Buna-N O-ring,Gland & Piston, 2 ea. 2. Teflon Back-up Ring,Gland, 1 ea. 3. Buna-N O-ring,Shaft, 2 ea. 4. Teflon Back-up,Shaft, 2 ea. 5. Buna-N O-ring,Piston, 1 ea.	1. Viton A O-ring 2. Teflon Back-up Ring (unchanged) 3. Viton A O-ring 4. Teflon Back-up,Shaft (unchanged) 5. Viton A O-ring
50-RVS-423B 50-RSV-424	Valve,2nd Stage LOX Valve,1st & 2nd Stg LOX Bld.	901500 901500	Marotta - PV 200, P/N 203793, Rev. G 2190D P/N 203793-2190 Rev. C	1. Teflon O-ring, Piston 2. Teflon Seals 3. Kel-F (hard) Seat	Unchanged
50-CHV-1708 50-CHV-1728 50-CHV-1727	Check Valve,2nd Stage LOX Check Valve,3rd Stage Purge Check Valve,3rd Stage Purge	901525-2 901505 901505	Republic 11-2263-4	1. Kel-F (soft)Poppet Seal Plasticized 2. Rubber O-ring in Part No. 901505	1. TFE Teflon Poppet Seal 2. Teflon O-ring
50-RSV-426	Valve,3rd Stage LOX	901509	Annin 1621	1. Teflon Seat Seal 28265-81 2. Teflon Packing 85000-114 3. Teflon Cooling Fin Gasket 10882-81 4. Teflon Seat Ring Gasket 00522-81	Unchanged
50-SV-427	Valve,3rd Stage Purge	901527	Marotta 803664-10311	1. Teflon O-ring Back-up, 2 ea. 2. Neoprene O-rings, Stem 3. Neoprene O-rings, Seat Seal 4. Neoprene O-rings, Retainer Seal 5. Syn. Rubber O-rings Secondary Body Seals	Unchanged
50-PT-414 50-PT-416 50-PT-421 50-PT-415 50-PT-409	Press. Sensor P _O V2 Press. Sensor P _C 1 Press. Sensor P _O M Press. Sensor P _O J3 Press. Sensor P _O V3	None None None None None		1. Fitting O-ring, 1 each Teflon	Unchanged