SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

JANUARY 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC.	NERVA OT1016(L.V.Humble) — NERVA engine propellant feed system tests.

The second liquid hydrogen run which was scheduled for January 13, could not be made since the data from the first liquid hydrogen run (December 21, 1965) was not reduced until January 26. This data was needed before Run No. 2 could be made in order to check the program and data acquisition systems.

The long delay was reportedly caused by:

(1) A Lewis-Cleveland computer breakdown.

(2) "B-3" was the first facility to use 400 channels with variable multiplexing.

While the facility was in a standby condition, the following tasks were either accomplished or started:

(1) The re-heat system was cold flow tested with liquid nitrogen.

(2) Installation of new tank shutoff valve.

(3) Installation and checkout of mass flow meter.

(4) Installation and checkout of Fastex movie cameras.

(5) Installation of piping for turbopump test program.

(6) Checkout of turbine power control (scram) valve.

(7) Miscellaneous alterations to the instrumentation system.

(8) Installation of new ignition system for boilers.

(9) Checkout of steam pressure control system.

(10) Repair of mylar seal between nozzle and exhaust duct.

The above tasks are in addition to normal system checks and maintenance tasks.

NOTE: Liquid Hydrogen Runs 2 and 3 are currently scheduled for February 3 and 16.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

FEBRUARY 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROL FAC.	

NERVA
OT1016(L.V.Humble) — NERVA engine propellant feed system tests.

On February 3 and February 25, liquid hydrogen runs No. 2 and No. 3 were completed. Run No. 2 was a "wet" or pre-chilled pump test similar to Run No. 1, while Run No. 3 was a "dry" or unchilled pump test. Both tests were terminated in a normal manual mode when the system had reached the desired end conditions. The major parameters of the two tests were as follows:

		Run No. 2	Run No. 3
(a)	Liquid hydrogen tank pressure	10 psig	20 psig
(b)	Maximum liquid hydrogen flow	4 pps	12 pps
(c)	Turbopump rpm	0	0
(d)	Duration of flow	111 sec	95 sec

A summary of significant problem areas and comments concerning each test follows:

Run No. 2

(a) The liquid hydrogen mass flow meter did not function properly and no useful data was obtained from this device.

(b) The Fastax movie cameras were not used because they introduced noise on some of the instrumentation channels.

(c) Eight Rosemount temperature probes "opened" early in the test; therefore, no data was recorded from these probes.

Run No. 3

(a) Considerable effort had been expended to fix the liquid hydrogen mass flow meter since Run No. 2; however, several hours of work were required on the

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROL FAC.

NERVA (Continued)

run day to provide an acceptable signal. During the run, the device appeared to be working.

(b) The Fastax movie cameras were used for the first time in the belief that the problem of noise introduction had been solved. However, during the test, camera function generated sufficient noise to render unreadable pump speed and mass meter signals.

(c) The continuous liquid hydrogen level readout on the run tank malfunctioned during transfer to the facility. Point sensors and previous operating experience were used to approximate the liquid level in the run tank. No time or data were lost as a result of this problem.

The following problems were uncovered after the test, when research personnel started preliminary data evaluation.

(d) Thirty-two pressure transducers on the reactor were electrically calibrated (E.C.'d) 3% high. The problem has been traced to test conductor error in venting the system, thereby resulting in a "zero" when the actual system pressure in the exhaust duct was slightly negative rather than true atmospheric.

(e) FM recorder #401 failed to record and was traced to a loose wire on a relay. Fourteen channels of FM data were lost.

(f) The SEL subsystem did not sample each channel as programmed, but occasionally, in rather random fashion, sampled an incorrect channel. This problem, thought to be system noise at the time of the run, resulted in a scatter of random samples on several channels.

(g) The digital tape was found to have a lengthwise crease along one edge. The tape was played and checked at "H" Building after the run. Creasing may have occurred during rewind.

Most of the data on the digital tape is retrievable but would require a change in the computer program to

(Continued on Page 26)

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	(Continued)	accomplish. The 14 channgels of FM data and the mass meter signal were lost. As a result, consideration is being given to re-running Run No. 3 as a back-to-back run after Run No. 4, scheduled for March 10. To accomplish a re-run and Run No. 4 on this date, instrumentation is being selected to encompass the requirements of both tests. In order to perform a back-to-back test on March 10, a reheat system, consisting of a hot water to gaseous nitrogen heat exchanger, will be employed to bring the reactor components and turbopump essentially back to ambient temperatures with heated gas. This will constitute a first attempt at this mode of operation. The ability to run the second test will be contingent on the time the first test is made, as well as the performance of the reheat cycle. If the reheat system proves successful, it will be possible to complete two bootstrap runs on each run day. The frequency of the research runs could also be increased if it were possible to shorten the time required to reduce and analyze the test data.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

MARCH 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROL FAC.	

NERVA
OT1016(L.V.Humble) — NERVA engine propellant feed system tests.

Two test runs were completed during the month of March. The chilldown test run series was concluded with the completion of Test No. 4 on March 10. This test was a dry pump test similar to Test No. 3. The only exception was a variation in the run tank pressure. The test objective was to determine the system chilldown dynamics for a specific tank pressure. After the test objective had been accomplished, the new reheat system was tried. This system consists of a hot water to gaseous nitrogen heat exchanger where the heated nitrogen gas is used to warm-up the research hardware to ambient temperature; thereby making it possible to make at least two runs on the same run day, thus conserving manpower and money. The reheat system worked successfully on March 10, but a second run was not made because of an operational problem which now has been corrected.

On March 30, Test No. 5, the first of a series of three turbopump tests, was completed. These turbopump tests are intended to establish the lower end of the Aerojet Mark III pump performance map. This run was an unpowered (no turbine flow) test to obtain flow calibration data on the pump discharge valves and piping. Approximately 60 unique data conditions were established by automatic programming during the continuous 487-second run. The flow was ramped and stepped from 0 to 100% and back for run tank pressures of 10, 35, and 60 psig. The pump discharge was flashed to the burnoff at a maximum rate of 23.5 lb/sec. All of the test objectives were satisfied.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

APRIL 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROL FAC.	

NERVA
XD1016 (L.V.Humble) — NERVA engine propellant feed system tests.

On April 27, Test No. 6, the second of a series of three turbopump tests, was completed. The objective of these tests is to obtain low speed pump performance maps for the Aerojet Mark III turbopump. Turbopump speed lines of 1500, 3000 and 6000 rpm at propellant tank pressures of 35 and 50 psia were obtained during Test No. 6. Pump flow rate was ramped and held through seven steady state conditions at each turbopump speed and tank pressure. Forty-two steady state data conditions were obtained by automatic programming during the continuous 413 second run. The LH_2 being discharged from the pump was flashed to the burnoff at a maximum rate of 28 pps. The GH_2 railcar was used to supply turbine drive gas for this run. The car was charged to 2400 psig and the regulator was operated at pressures of 400 and 600 psig. The turbine drive gas was discharged through the exhaust duct and out the second stage steam ejector at a maximum flow rate of approximately 1 pps. This was the first time the GH_2 railcar had been used with GH_2 and it operated satisfactorily. All of the test objectives were satisfied.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

MAY 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC.	

NERVA
XD1016(L. V. Humble) — NERVA engine propellant feed system tests.

On May 19, Test No. 7, the third of a series of three turbopump tests was completed. The objective of this test was to obtain performance maps for the Aerojet Mark III Mod. 4 turbopump at speeds of 6000, 9000 and 11,000 rpm with propellant tank pressures of 35 and 50 psia. Pump flow rate was varied to obtain pump stall at each condition of speed and propellant tank pressure. Tank pressure, turbopump speed, and pump flow rate were varied through use of an automatic programmer. The test was programmed to run for 559 sec. However, 431 sec. into the run, automatic shutdown was manually initiated due to excessive turbopump vibration. The liquid hydrogen being discharged from the pump was flashed to the burn-off at a maximum rate of 35 pps. The gaseous hydrogen used to drive the turbine was discharged through the exhaust duct and out the second-stage steam ejector at a maximum rate of approximately 2 pps. The data indicates that turbopump speed, pressures and flow rates were oscillating at 12 cps and low amplitude during the run. The causes of these oscillations and the excessive turbopump vibration are still under investigation.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

JUNE 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC.	

NERVA
XD1016 (L.V. Humble) — NERVA engine propellant feed system tests.

On June 9, an attempt was made to run Test No. 8. This test was to be a re-run of Test No. 7, in which excessive turbopump vibrations and oscillations in speed, flow and pressure were experienced. Modifications were made to the turbine power control valve servoamp and the regulated pressure feeding the control valve was changed. No. 8 test had to be aborted because of malfunctions in the run tank vent servo valve and in a helium purge regulator.

On June 14 Test No. 8 was made. Pump flow rate was varied to obtain pump stall at speeds of 6 000, 9 000 and 11 000 rpm. The tank pressures were 35 and 50 psia. A full duration test was completed. Oscillations were still present but of a lesser degree. The current feeling is that the oscillations are due to an excessive amount of internal leakage in the TPCV actuator which causes deadband in its response. There are no plans to repeat this test in the immediate future but a re-run may be accomplished later in the program. After Test No. 8, the hardware was modified for No. 9 and No. 10 chilldown tests.

On June 30, Tests No. 9 and No. 10 were completed. The objective of Test No. 9 was to obtain the chilldown characteristics of the system starting from a "dry" or unchilled condition, while Test No. 10 was from a "wet" or chilled condition. It took three hours for the reheat system to bring the reactor and nozzle to ambient conditions. No significant problems were encountered.

Test No. 11, a bootstrap test, is scheduled for July 20. Depending on the results from Test 11, Test 12 may also be run the same day.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

JULY 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC.	

NERVA
XD1016 (L.V. Humble) — NERVA engine propellant feed system tests.

During the month of July, the research piping and instrumentation were altered for the bootstrap test series. On July 26, the first of nine scheduled bootstrap tests was performed. This was a wet, or chilled, pump test. On the first attempt to run the test, the controls programmer failed to start and the test was aborted. The cause of the malfunction was found and corrected and the steam accumulators were recharged. After re-chilling the AeroJet MARK III pump, the liquid hydrogen tank pressure was ramped to 35 psia and the pump main discharge and turbine power control valves were opened simultaneously. Flow was maintained through the Kiwi "B-1" reactor for 23 seconds and reached a maximum level of 34 pps. Turbopump speed reached a maximum of 9,500 rpm. All of the research objectives were satisfied.

The next two bootstrap tests are scheduled for August 24.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

AUGUST 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC.	

NERVA
PD1016(L.V.Humble) — NERVA engine propellant feed system tests.

The B-1 Boiler House was shut down for the first three weeks in August for the annual cleaning and State inspection of the boilers.

On August 25, the second in a series of nine System Bootstrap Start-Up tests was performed. This was a wet, or chilled, pump test in which the turbine power control valve was opened simultaneously with the pump main discharge valve. The primary test parameters were as follows:

Propellant tank pressure - 25 psia
Maximum turbopump r.p.m. - 8,600 r.p.m.
Maximum LH_2 flow rate - 30 pps (approx.)
Duration of LH_2 flow - 21 sec.

All test results seem to be satisfactory with the exception of a few transducers which were over-ranged during the test.

It had been planned to run a second test on August 25 on a back-to-back basis using the reactor re-heat system. However, the LH_2 mass flow meter was found to be inoperative during the first test. Since the second test was to be a dry pump test in which the data from the mass flow meter is essential, the second test was scrubbed.

The next test is presently scheduled to be run Sept. 14.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

SEPTEMBER 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC.	NERVA XD1016(L.V.Humble) — NERVA engine propellant feed system tests. No research tests were scheduled for September. The reasons were: (1) An evaporation rate test was made on the 200,000 gallon liquid hydrogen storage vessel. The vessel could not be used for approximately two weeks. (2) Two new steam accumulators for the "B-2" Facility were installed. While they were being installed, the steam injector system could not be operated. Tests were made on one of the new six-inch regulators for the 5000 psig gaseous hydrogen railcars. The regulator was found to be leak-tight and regulated satisfactorily over a wide range of flow rates. The next two research tests will be back-to-back runs and are scheduled for October 5.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

OCTOBER 1966

SITE	SITE NAME	RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC.	NERVA XD1016(L.V.Humble) — NERVA engine propellant feed system tests.

Four bootstrap tests were performed during October; Tests Nos. 10 and 11 on October 5 and Tests Nos. 12 and 13 on October 12. The primary test parameters are tabulated as follows:

	Test 10 Wet Pump	Test 11 Dry Pump	Test 12 Dry Pump	Test 13 Wet Pump
LH_2 Tank Press(PSIA)	25	25	35	35
Max Turbopump RPM	9000	14100	8880	8400
Max LH_2 flow (PPS)	28	16.7	35	31.5
Duration LH_2 flow (sec)	22.8	41.4	47	22

All controlled parameters followed the planned test profile for this series. During Test No. 11 the turbopump did not bootstrap successfully. The turbopump accelerated but little or no head rise was generated across the pump. During Test No. 12 a different method was used to predict the time delay prior to opening the Turbine Power Control Valve and the turbopump bootstrapped successfully. During Tests Nos 12 and 13 some instrument channels were unusually noisy.

On October 26, one of the new 6-inch 5000 PSIG gaseous hydrogen railcar regulators was tested. The regulator was found to be leak-tight and regulated satisfactorily over a wide range of flow rates. The addition of considerable accumulator capacity in the dome loading volume was found to have a very favorable effect in eliminating dome pressure variations. As a result, regulated pressure variations are also considerably reduced.

The next two research tests are scheduled for November 3.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

NOVEMBER 1966

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
B-3	NUCLEAR ROCKET DYNAMICS AND CONTROLS FACILITY NERVA / XD1016(L.V. Humble) — NERVA engine propellant feed system tests.

Four bootstrap tests were performed during November: Tests Nos. 14 and 15 on November 9, and Tests Nos. 16 and 17 on November 22. The primary test parameters are tabulated as follows:

	Test #14 Dry Pump	Test #15 Wet Pump	Test #16 Wet Pump	Test #17 Dry Pump
LH_2 Tank Pressure(psia)	35	35	35	35
Max Turbopump (RPM)	8,100	8,600	5,500	9,600
Max LH_2 Flow (PPS)	34	32.5	30	15
Duration LH_2 Flow (sec)	54	15.3	31.4	32.5

All controlled parameters followed the planned test profile for this series.

The turbopump bootstrapped successfully on all tests except #17. This test was an attempt to shorten the required time delay on pump speed for dry pump startup by throttling the pump discharge flow. Both pump speed and head rise were erratic during this test. The final two research tests in this program are scheduled for Dec 14.

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

DECEMBER 1966

B-3 NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC.

NERVA
XD1016(L.V.Humble) — NERVA engine propellant feed system tests.

On December 14, two wet bootstrap tests were performed. The primary test parameters are tabulated as follows:

	Test #18	Test #19
LH_2 Tank Press (psia)	25	25
Max Turbopump Speed (rpm)	5500	8650
Max LH_2 Flow (PPS)	22	29
Duration LH_2 Flow (sec)	37.9	28.3

All controlled parameters followed the planned test profiles. The turbopump bootstrapped successfully during both tests. These two tests complete the scheduled program.

With the completion of the test program, the worth of the reactor reheat system was evaluated. This reheat system shortened the program completion date by approximately three months and saved over $50,000 worth of propellants. The installed cost of the reheat system was about $3000. By using the reheat system, six tests

B-3 NUCLEAR ROCKET DYNAMICS AND CONTROLS FAC. (Continued)

NERVA (Continued)

were performed as back-to-back, or second, runs. Also, it was possible to complete another test run which would have normally required rescheduling to another test day.

A pump cavitation program has been approved for B-3 Stand. Detailed test requirements, task assignments, and schedules have not been published. The month of January will probably be spent removing the existing research hardware and overhauling the facility subsystems.