

NASA
Plum Brook Station

Jan Temple
PB Sta Files
(Jan 74)

Sandusky, Ohio
July 9, 1962

MEMORANDUM to Charles S. Moore

Subject: Information for yearly experimental facilities operation report
for Plum Brook Station

1. The information contained herein is submitted as per your telephone request of 29 June 1962. The experimental facilities at Plum Brook Station do not lend themselves to the "running time" type of reporting usually associated with Wind Tunnels and similar rigs. This makes it necessary to present the information in a different format.

2. The Plum Brook Reactor went critical on a minimum size core June 14, 1961 and was first operated with the full size core on June 27, 1961. Since that time the Reactor has operated 318 hours at low power for calibration and training. Of this number 195 were spent approaching critical and 123 were spent at critical. A total integrated power for these very low power operations was 894 kilowatt hours. In addition to the Reactor operation at PBRF approximately 200 hours were spent in completing the hydraulic testing of the core. These are actually operating hours with the primary system pumps, etc being used. Test set up time of course has not been included.

3. Operations have continued in the Rocket Systems area for certain of the facilities and certain of the new facilities have gone operational during the past fiscal year. Many of the new facilities have been going through the shake-down runs and calibration tests associated with the initial operation. Some of the facilities have required rather extensive changes between scheduled test programs. Each of the facilities have been listed below with notes describing operations for the past year:

a. "A" Site - Pump Research Laboratory:

Between September of 1961 and May of 1962 ten Liquid Nitrogen and one Liquid Hydrogen run were made on the Liquid Hydrogen Pump Installation. No operation of the LOX pump portion of the facility took place during the year.

b. "B" Site - NERVA Test Stand:

This facility is still in the construction phase, no operation was scheduled during the past year.

c. "C" Site - Turbo Pump Facility:

The Boiling Fluids rig was in operation throughout the year using Liquid Hydrogen. Several preliminary runs were made in order to check out the newly installed equipment and the data handling capabilities of the equipment associated with the experiment operations of the Hydrogen Pump rig have been limited to five or six check-out runs on the thrust balance system of the pump and to cold shock tests

PLUM BROOK ROCKET SYSTEMS FACILITY

STATUS REPORT

AS OF 1-28-63

ITEM NO	LABORATORY	RESEARCH INSTALLATION (FOR)	DESCRIPTION
1	PUMP "A" Site	Hydrogen Pump F5A (Pinkel)	Liquid hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded

STATUS: Considerable difficulty has been encountered with the high speed drive components and little liquid hydrogen data has been obtained to date. Bearing failures were encountered in both the pump and gearbox during the last run in which the pump was operated for approximately one minute in a cavitating condition. At this time, anti-whirl bearings are being installed in the high speed gearbox and the pump is being rebuilt. The high speed drive is now being assembled and tentative plans call for a step wise checkout starting with the gearbox, then adding the torquemeter and finally the pump. Thermal expansions and contractions aggravate the alignment problems substantially in this rig. The elevation of the gearbox output shaft increases approximately 7 thousandths of an inch when the gearbox is warmed from room temperature to its operating temperature. In addition, some rather crude liquid nitrogen tests indicate that during cooldown, the pump output shaft undergoes some rather complex and torturous movements in the order of 5 to 10 thousandths of an inch. All experience to date has been at approximately 15,000 RPM which is one-half of the design speed. The probability of failures in this rig is high and therefore it should be supported with additional design study and back-up hardware.

All parts for the next buildup are due by February 1. Barring excessive alignment and checkout difficulties, the next liquid hydrogen run should occur soon after February 15.

PLUM BROOK STATUS REPORT (continued)

ITEM NO	LABORATORY	RESEARCH INSTALLATION (FOR)	DESCRIPTION
		LOX Pump F5A (Pinkel)	Liquid-oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressures. Four NASA inducer-impellers will be tested which may support the M-1 Engine Project

STATUS: During the last operation using liquid nitrogen, the pump bearings failed and some blades were cracked on the pump rotor. At this time, some minor facility improvements involving the purge system and a flow control valve are underway and the facility will be in operational status by February 4. Research pump components are scheduled for delivery by February 24. After assembly, a series of low speed liquid nitrogen tests will be started about March 1. It is understood that no testing with liquid oxygen will be attempted until an improved pump seal can be procured. Parts for fabricating the improved seals are on order but have been slow in delivery.

SECTION II

PLUM BROOK ROCKET SYSTEMS FACILITY

STATUS REPORT
AS OF 2-28-63

* GENERAL NOTE ON OPERATION SCHEDULES:

This report includes many changes from January reports. "Test Schedules" and "Days of Testing" have been changed due to an evaluation which was completed since the last report. All future changes will be explained in site status report.

Attention is called to the addition of "Number of Possible Test Days". These numbers are established after evaluating the following factors: interference from other research tests; common use of recording equipment, instruments, control equipment, liquid dewars, gas trailers, service air; and man power availability.

SITE	LABORATORY	RESEARCH INSTALLATION (FCR)	DESCRIPTION
A	PUMP	<u>HYDROGEN PUMP</u> F5A (Pinkel)	Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.
<p>STATUS: Several LH₂ transfers were made to checkout and evaluate the new Project Fab Dewars, controls, piping modifications, and instrumentation. The drive system gearbox was checked to evaluate the new bearing modifications. All systems are in operational status, however the drive system is questionable.</p>			
<p>The scheduled run of February 15, 1963 was not met due to minor problems encountered during dewar evaluation runs and minor delays caused by unforeseen research pump assembly problems.</p>			
<p>A 1000 RPM LH₂ run will be made during the first week of March. Data from this run should help to refine the automatic controls and to evaluate the modified drive system and air bearing torque meter. If the low speed run is successful a series of test runs at 15,000 RPM will be made during March and April.</p>			
		<u>LOX PUMP</u> F5A (Pinkel)	Liquid-Oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 Engine Project.
<p>STATUS: All test area systems are in operational status. Balancing of pump parts and pump assembly are scheduled to be completed the first week of March. The pump performance system controls and instrumentation will be evaluated in a series of runs with LN₂ which are scheduled between March 13 and May 15, 1963. The hardware for a new configuration is scheduled to be completed July 1, 1963. This pump will be tested in LO₂ at speeds up to 15,000 RPM.</p>			

SECTION 11

PLUM BROOK ROCKET SYSTEMS FACILITY

STATUS REPORT

FOR MONTH OF MARCH

SITE	LABORATORY	RESEARCH INSTALLATION (FOR)	DESCRIPTION
A	PUMP	<u>HYDROGEN PUMP</u> F5A (Pinkel)	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p> <p>STATUS: A 1000 RPM Liquid Hydrogen run was made on March 13, 1963 for the purpose of refining automatic NPSH control and evaluating the optical torque meter with a new air bearing supported shaft. All Facility systems functioned very satisfactory. The research hardware malfunctioned in that the air bearings rubbed and the pump bearing heaters failed. The air bearing concept has been apparently discarded in favor of a new shaft support system for the optical torque meter. To circumvent delays, a jack shaft has been installed for obtaining pump data (excluding torque) while the new torque meter shaft support system is being designed and procured. It is anticipated that a series of successful runs will be made with the "jack shaft" during the months of April and May.</p> <p>Note (A) - Availability of the new torque meter shaft and bearings has not been determined. Accordingly, schedules for the LH₂ centrifugal and three stage pump are no longer valid. When hardware availability date for new torque meter system is known, a new schedule will be established.</p> <p><u>LIQUID OXYGEN PUMP</u> F5A (Pinkel) Liquid-Oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 Engine Project.</p> <p>STATUS: All test support systems are in operational status. Pump performance, system controls and instrumentation will be evaluated during a series of LN₂ runs. Hardware for a new pump configuration is scheduled for delivery at Plum Brook on July 1, 1963. This configuration will be tested in LO₂ at speeds on 15,000 RPM.</p> <p>(Continued on next page)</p>

SITE	LABORATORY	RESEARCH INSTALLATION (FOR)	DESCRIPTION																																				
A	PUMP	LIQUID OXYGEN PUMP STATUS: (Continued) F5A (Pinkel)	<p>An attempt was made on March 27, 1963 to obtain preliminary performance data on a LOX pump impeller and to evaluate the pump mechanical design. LN₂ was used as a test fluid.</p> <p>All systems in the test facility operated satisfactorily. The research pump failed after 88 minutes of operation. Disassembly of pump revealed front ball bearing failure. The following is a time event record of the research run:</p>																																				
		<table border="1"> <thead> <tr> <th>RPM</th> <th>TIME IN MINUTES</th> <th>EVENT</th> </tr> </thead> <tbody> <tr> <td>(1) 600</td> <td>32</td> <td>Filling system loop with LN₂.</td> </tr> <tr> <td>(2) 600-1800</td> <td>13</td> <td>Pump speed increased in 500 RPM increments (approx.). Rear ball bearing temperature increasing 155°F to 160°F.</td> </tr> <tr> <td>(3) 1800-2500</td> <td>1</td> <td>Rear ball bearing temperature increased at rate of 10°/min. to 170°F.</td> </tr> <tr> <td>(4) 2500</td> <td>2</td> <td>Rear ball bearing temperature increased to 186° (interlock shut down 200°F).</td> </tr> <tr> <td>(5) 2500-850</td> <td>$\frac{1}{4}$ (aprox.)</td> <td></td> </tr> <tr> <td>(6) 850</td> <td>30</td> <td>Allowed bearings to cool (seal leak).</td> </tr> <tr> <td>(7) 850-1850</td> <td>1</td> <td>Research engineer requested 3000 RPM.</td> </tr> <tr> <td>(8) 1850</td> <td>6</td> <td>Front ball bearing temperature increasing.</td> </tr> <tr> <td>(9) 1850-3000</td> <td>1</td> <td>Front ball bearing temperature increasing from 50°F.</td> </tr> <tr> <td>(10) 3000</td> <td>2</td> <td>Front ball bearing temperature increasing at approximately 70°/min.</td> </tr> <tr> <td>(11) 3000-0</td> <td>Manual shut down TOTAL 88 Min.</td> <td>Front ball bearing temperature at 170°F before shut down (seal leak).</td> </tr> </tbody> </table>	RPM	TIME IN MINUTES	EVENT	(1) 600	32	Filling system loop with LN ₂ .	(2) 600-1800	13	Pump speed increased in 500 RPM increments (approx.). Rear ball bearing temperature increasing 155°F to 160°F.	(3) 1800-2500	1	Rear ball bearing temperature increased at rate of 10°/min. to 170°F.	(4) 2500	2	Rear ball bearing temperature increased to 186° (interlock shut down 200°F).	(5) 2500-850	$\frac{1}{4}$ (aprox.)		(6) 850	30	Allowed bearings to cool (seal leak).	(7) 850-1850	1	Research engineer requested 3000 RPM.	(8) 1850	6	Front ball bearing temperature increasing.	(9) 1850-3000	1	Front ball bearing temperature increasing from 50°F.	(10) 3000	2	Front ball bearing temperature increasing at approximately 70°/min.	(11) 3000-0	Manual shut down TOTAL 88 Min.	Front ball bearing temperature at 170°F before shut down (seal leak).	
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SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

for the month of

APRIL 1963

SITE	LABORATORY	RESEARCH INSTALLATION (FOR)	DESCRIPTION
A	PUMP	<u>PUMP - LH₂</u> F5A (Pinkel)	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p> <p>STATUS: Note (A) - A seven week delay in the research schedule resulted from the non-availability of LH₂ dewars.</p> <p>The new Project Fab LH₂ dewars which were used for previous run in March developed excessive losses of LH₂ and subsequent inspection revealed many leaks in the vacuum system. The dewars are undergoing major rework. The other two dewars at Plum Brook were in LN₂ service but have now been converted to LH₂ service. They will be used for a series of four hydrogen runs commencing May 3, 1963. These dewars could have been converted earlier to hydrogen service, however, by mutual agreement with research engineers it was decided to leave the dewars in LN₂ service to support the Turbo Pump Site check out runs.</p> <p>It is estimated that the new torque meter should be delivered in July. However, pump tests should not be delayed since present tests do not require torque meter data.</p> <u>PUMP - LO₂</u> F5A (Pinkel)
			<p>Liquid-Oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 Engine Project.</p> <p>STATUS: Note (A) - Due to the condition of the pump liquid seal which is worn, and damaged; and the fact that no spares are available; the exact number of run days cannot be estimated. A new seal is on order and should be delivered in July.</p> <p>On April 25, 1963 an 8000 RPM run was attempted. While the pump loop was being filled with LN₂ and with the pump idling at 500 RPM, the oil scavenge pressure decayed. Excessive leakage through the worn liquid seal, caused a pressure buildup between the liquid seal and the oil seal. The vent</p>

PLUM BROOK ROCKET SYSTEMS DIVISION STATUS REPORT

CONTINUED

SITE	LABORATORY	RESEARCH INSTALLATION (FOR)	DESCRIPTION
A	PUMP	<p>PUMP - LO₂ STATUS: (Continued) F5A (Pinkel)</p>	<p>noles between the two seals were not large enough to relieve the pressure causing the oil seal to unseat. The bearing cage was vented and a second run was attempted. The air pressure control valve in the turbine inlet line failed and the run had to be cancelled. The control system is presently being modified.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

for the month of

May 1963

SITE	LABORATORY	RESEARCH INSTALLATION (FOR)	DESCRIPTION
A	PUMP	<u>HYDROGEN PUMP</u> F5A (Pinkel)	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p> <p>NOTE (A) : The operations schedule is not firm due to the unknown delivery date of the new torque meter system. Additional runs of the present pump configuration (shrouded impeller) will be attempted to acquire pump efficiency data pending installation of the torque meter during July. If the torque meter parts do not arrive during July, the "follow-on" configuration (unshrouded impeller with balance piston system) will be installed. Since the installation lead time is two months, the unshrouded impeller should be ready for testing by Fall of 1963 rather than the originally scheduled run date of January 1964.</p> <p>STATUS: During the last three weeks in May a series of eighteen successful runs were completed for the shrouded impeller configuration. Fourteen were at 15,000 RPM and four were at 22,000 RPM. The research pump and new drive system (a two ball bearing supported drive shaft) worked very well. Eighteen good runs resulted from twenty-four attempts. The six unsuccessful runs resulted from control valve malfunctions and operational errors.</p> <hr/> <p><u>LIQUID OXYGEN PUMP</u> F5A (Pinkel)</p> <p>STATUS: During May an attempt was made to run the present pump configuration with LN₂. This run resulted in a pump failure similar to two previous failures. These malfunctions are attributed to inadequate seals which permit the liquid nitrogen to leak into the bearing cavities. Further testing has been cancelled by mutual agreement with the research engineers, until a new seal configuration is delivered in July.</p> <p>The existing LN₂/LO₂ heat exchanger in the piping system is not considered safe for LO₂ service due to improper design. This heat exchanger is scheduled for replacement by July.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION
STATUS REPORT

JUNE 1963

SITE	RESEARCH LABORATORY INSTALLATION (FOR)	DESCRIPTION
A	PUMP <u>PUMP - LH₂</u> (Pinkel) OF0553	<p>Liquid Hydrogen centrifugal pump design Study utilizing several impellers both shrouded and unshrouded.</p> <p><u>Note</u> (A) - The new torque meter system will not be available for installation during the month of July. The present pump configuration has been removed and the next configuration (unshrouded impeller) is being assembled. Interference problems have been encountered and the pump schedule has been changed for testing during late July or early August.</p> <p><u>STATUS:</u> Testing has continued using a solid drive shaft as a substitute for the bearing supported torque meter which still has not been delivered. Except for efficiency data which requires the torque meter, testing of the shrouded impeller was completed on June 29 when three successful runs were made.</p> <p>At this time, the unshrouded impeller configuration is being installed using the solid drive shaft. Pending unforeseen thrust balance system problems, four runs are planned during August and September. It is believed that this will allow ample time for delivery of the new torque meter. Efficiency runs on both the shrouded and unshrouded impeller are expected to commence in October.</p>
	PUMP - <u>LO₂</u> (Pinkel) OF0553	<p>Liquid-Oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA Inducer-impellers will be tested which may support the M-1 Engine Project.</p> <p><u>Note</u> (A) - A 30-day delay in the LO₂ pump test schedule has resulted from non-availability of new seals and parts. Pending delivery of the new pump seals and parts during July, testing will start the week of August 26.</p> <p><u>STATUS:</u> The LN₂-LO₂ heat exchanger is being reworked. This modified heat exchanger is scheduled for installation during early August for LO₂ runs. During August, two low speed LN₂ runs will be required with the new seal configuration for proof testing seals and the modified heat exchanger LO₂ runs are scheduled during September and early October. Lead time for modification of the heat exchanger may delay LO₂ runs scheduled for October.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

JULY 1963

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p><u>PUMP - LH₂</u> OF0553 (Pinkel)</p> <p>STATUS: The following tasks were accomplished in July in support of the open faced impellers tests scheduled for early August; (a) The pump was assembled, (b) The facility was modified to provide for the required thrust balance systems, (c) The existing lubrication and bearing heater systems were rebuilt and modified, and (d) A third dewar station (standby dewar) was installed. Testing of the open faced impeller will commence August 2, 1963 using the solid drive shaft as a substitute for the bearing supported torque meter shaft. Upon completion of these tests, both the shrouded and unshrouded impellers will be tested for pump efficiency data pending arrival of the new torque meter hardware.</p>	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p>
		<p><u>PUMP - LO₂</u> OF0553 (Pinkel)</p> <p>NOTE <u>Ⓐ</u> : Proof testing of the modified LO₂ pump with LN₂ has been delayed approximately 15 days due to rescheduled delivery date of pump hardware. It is anticipated that pump hardware will arrive on or about August 15. The schedule delay is also attributed to problems encountered during system heat exchanger modifications. The modified heat exchanger system will be completed and installed on or about August 30. LN₂ proof tests will commence during the first week of September. The number of required runs has been re-evaluated.</p> <p>STATUS: The following tasks are being accomplished in preparation for the first proof test run scheduled for early September: (a) Heat exchanger modification, (b) Re-calibration of instrumentation, and (c) Proof test and cleaning of system.</p>	<p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p>

SECTION 11

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

AUGUST 1963

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p>PUMP - LH₂ OF0553 (Pinkel)</p> <p><u>STATUS:</u> The liquid hydrogen pump was tested on Aug 13 and 23 with an open face impeller. Six successful data runs were made with various NPSH at 15000 RPM. The research pump functioned very well. Testing of the open face impeller at 22,500 RPM is scheduled for Sept. 4th. Upon completion of these tests, both the shrouded and open face impellers will be tested with the new torque meter configuration to obtain pump efficiency data. The new torque meter hardware is scheduled for delivery late Sept. or early Oct. Subsequent to successful runs for pump efficiency, the facility will be modified to accommodate the 3-stage axial flow LH₂ pump now undergoing a running gear checkout at "G" Site. Testing of the 3-stage axial flow pump is scheduled to commence during Jan. 1964. There are no anticipated delays in the research operations schedule.</p>	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p>
		<p>PUMP - LO₂ OF0553 (Pinkel)</p> <p><u>NOTE (A):</u> Research testing of the LO₂ centrifugal pump configuration has been delayed an additional two months due to non-availability of modified pump hardware. Accordingly, the pump test runs have been rescheduled for early November 1963. Modifications to this pump configuration have been underway since Nov. 1962. Speculation of an early November 1963 run represents a one-year delay in test operations due to non-availability of pump hardware.</p>	<p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p>

(Continued on Page 11-2)

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A		<p><u>PUMP - L₀₂</u> (Continued)</p> <p><u>STATUS:</u> The following L₀₂ pump parts are in the Lewis shops for work: (a) Bearing housings and spacers; (b) Seal spacers; (d) Schroll collector; (d) Impeller stationary shroud. The pump shaft has been splined and match fitting to the research impeller is being accomplished by contract. The modified L₀₂/LN₂ heat exchanger will be pressure tested by September 1 and installed by September 14. Refitting of the inlet line is dependant on arrival of research pump parts in November. The following tasks will be completed prior to test operations: (a) Recalibration of instrumentation; (b) Pressure checkout and cleaning of piping system; (c) Installation and checkout of L₀₂ dewar remote pressurization and venting system; (d) Installation and checkout of LN₂ line/dewar shutoff and pressure safety relief system. The facility will be in operational status during late October or early November 1963.</p>	

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

SEPTEMBER 1963

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;"><u>PUMP - LH₂</u> OF0-553 (Pinkel)</p>	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p> <p><u>STATUS:</u> The unshrouded impeller of the LH₂ Pump was tested several times during the month of September at various flow rates and net positive suction heads. A total of twelve data runs were completed, nine at 15,000 RPM and three at 22,500 RPM. On two of these runs NPSH - vapor pressure and inlet temperature did not correlate. Testing of the present pump configuration will continue during early October to acquire backup research data. It is anticipated that arrival of the new torque meter hardware will permit testing of the shrouded and unshrouded impellers for pump efficiency data during late October and early November. The new single bearing supported torque meter system represents a compromise between the existing double supported shaft which has been satisfactory and the original unsupported shaft. This solution to the problem should be carefully evaluated as severe damage to the gear box and pump is probable. A magneto restrictive torque measuring system is available and can be installed in the existing support system.</p> <hr/> <p style="text-align: center;"><u>PUMP - LO₂</u> OF0-553 (Pinkel)</p> <p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p> <p><u>STATUS:</u> The LO₂ Pump housing is being modified in the Lewis machine shop. The pump impellers are being splined by outside contractor. The LN₂/LO₂ heat exchanger has been cold shocked and leak tested. The heat exchanger is presently undergoing cleaning for LO₂ service and will be installed in the system during the second week in October. Valves and associated parts have been ordered for the LO₂ dewar remote pressurization and vent system. The LN₂ line/dewar shut off and pressure safety relief system valves are also on order. Modification of the inlet line to the research pump will be accomplished pending arrival of the modified pump schroll. The facility and support systems will be in operational status during late October or early November.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

OCTOBER 1963

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p><u>PUMP - LH₂</u> OF0-553 (Pinkel)</p>	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p> <p><u>STATUS:</u> Additional data runs were made on October 1 with the LH₂ pump unshrouded impeller at 22,500 RPM. Two good experimental runs resulted with the stationary shroud-to-blade clearance set at 0.025".</p> <p>Following these tests the following work items were accomplished:</p> <ol style="list-style-type: none"> 1. Eight Ball valves were installed to replace eight (8) leaking Superior valves. 2. The welding contract and installation of Flex Hoses in the He and N₂ filter systems were completed. 3. Hot water systems for the photocon pressure sensors were installed. 4. A heat exchanger was installed for the thrust balance hydraulic oil system. 5. A new wiring patch board for research parameters was placed in the instrumentation system. 6. All high pressure hoses were replaced. 7. Disassembled research pump to change spacers and shims, and moving forward the impeller to provide a 0.011" shroud-to-blade clearance. <p>With the research pump reassembled a series of runs were performed at a pump speed of 15000 RPM on October 30. A series of points were set, four of which provided useful data. Also of interest, is the fact that in a recent series of September re-run test points, the repeat data was displaced from the original by a factor of 10%. While the</p>

SITE	LABORATORY RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	<p>PUMP, LH₂ (Continued)</p> <p>discrepancy is believed due to a filed pitot-static pressure probe, a full investigation is being made and the proper preventative steps taken to prevent a recurrence. The pitot-static pressure probe was replaced for the October 30 run and preliminary data shows that test points did repeat previous data.</p> <p><u>NOTE (A)</u> : Balancing of the new torquemeter shaft has been completed and calibration of the system will be performed at Lewis Research Center in the near future. Following installation of the new torque system, pump efficiency and repeatability data runs will be programmed commencing approximately November 15, which represents a two week delay to the overall schedule.</p> <hr/> <p><u>PUMP - L_O₂</u> OF0553(Pinkel)</p> <p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p> <p><u>STATUS:</u> During October, research instrumentation was removed for calibration and cleaning and the rebuilt LH₂-L_O₂ heat exchanger was cleared and de-humidified. Also, the old pump lube oil (FS-5) system was disassembled.</p> <p>Although site hardware is available, the site manpower is limited and the following items are yet to be accomplished:</p> <ol style="list-style-type: none"> 1. Installation of the LN₂-L_O₂ heat exchanger. 2. Hookup of NPSH control system. 3. Hookup of the LN₂ line dewar shutoff and pressure safety relief system. 4. Modification of pump inlet line to accomodate the longer research pump. This work is awaiting receipt of the modified pump schroll. 5. Hookup of the L_O₂ dewar pressurization vent system. 6. Assembly of the new research pump lube system. <p>It is estimated that the above items will be completed by mid-December.</p> <p><u>NOTE (A)</u> : The operations schedule has been delayed due to lack of sufficient manpower and the late delivery of pump parts which are now scheduled for mid-December.</p>	

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

NOVEMBER 1963

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p><u>PUMP - LH₂</u> OF0-553 (Pinkel)</p>	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p> <p><u>STATUS:</u> The LH₂ pump, operating with unshrouded impeller, was operated on two days during the month of November. On November 8, a series of runs was attempted, but no data was forthcoming because of drive turbine speed control difficulties. Subsequently, the control problem was remedied, and a successful series was run off on November 19. At this time three good data runs at 15,000 RPM and three good data runs at 22,500 RPM were completed.</p> <p>In the report for October, 1963, it was observed that for a particular series of rerun data points, repeatability was off by a factor of 10%. The data was rechecked and it was found that the two series were off by 4.85%, rather than the 10% claimed. In addition, the data from a third series of runs on October 30 was compared favorably with the original data. It can be concluded, therefore, that the failed total-static pressure probe (replaced following the second series of data points) was the cause of the non-repeatability. Further investigations will be made as more data is made available by research engineering.</p> <p><u>NOTE (A):</u> At the close of the reporting period, the single support point optical torquemeter was in the process of installation. It is expected that pump efficiency tests with the open-faced impeller will begin during the second week of December. This represents an approximate three week delay in the overall program.</p> <p><u>NOTE (B):</u> A one month delay has resulted from delays of the running gear checkout of the three stage pump at "G" Site.</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FGR)	DESCRIPTION
A		<p><u>PUMP - LO₂</u> OFO 553 (Pinkel)</p> <p><u>STATUS:</u> Major work items accomplished during November include the following:</p> <ol style="list-style-type: none"> <li>1. Cleaned gear box and installed spring-loaded thermocouples. <li>2. Cleaned and reinstalled the rebuilt LN₂-LO₂ heat exchanger. <li>3. Hooked up NPSH control system. <li>4. Started work on the new fluorolube system and the LO₂ dewar pressurization-vent system. <li>5. Disassembled LO₂ loop for cleaning. <p><u>NOTE (A)</u> : While an additional man was assigned to the LO₂ rig in mid-November, there still remain many items to be completed prior to test operation. The pump parts delivery has not changed from last month's reported mid-December date. However, due to the amount of work yet remaining, the number of man hours available, and the forthcoming Holiday season, it is not expected that this rig will resume testing before January 1964.</p>	<p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

DECEMBER 1963

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p><u>PUMP - LH₂</u> OF0-553 (Pinkel)</p>	<p>Liquid Hydrogen centrifugal pump design study utilizing several impellers both shrouded and unshrouded.</p> <p><u>STATUS:</u> Considerable difficulty was experienced in aligning the research pump with the gearbox. Before completing the job, machine work was required, including milling the pump support stand, "trueing" the periphery of the pump thrust piston, the manufacture of a new pump shaft, etc. The following tasks must be accomplished before the run date; assembly of the pump, installation of auxiliary equipment, installation of the torquemeter bearing support stand and assembly of the torquemeter and gearbox.</p> <p>It should be noted that machined parts from Lewis Research Center for the torquemeter were of excellent quality. Items were received as per drawings, and with no mating problems.</p> <p><u>NOTE (A)</u> : Because of the difficulties mentioned above, plus an unanticipated large number of personnel taking accumulated annual leave, an additional four weeks of delay to the LH₂ pump was experienced. Therefore, testing of the open-faced impeller, making use of the single bearing supported torquemeter for efficiency data will commence the second week of January, 1964.</p> <hr/> <p><u>PUMP - LO₂</u> OF0-553 (Pinkel)</p> <p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p> <p><u>STATUS:</u> Considerable progress was made on the revamping of the LOX rig this month. As a result, the site is virtually ready to run, except for those items associated with the actual pump installation. The most recent report indicates (Continued on Page 13)</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A		<p>that LOX pump hardware (except for the impeller) is complete, and it will arrive in Plum Brook by January 7, 1964.</p> <p>Some of the major accomplishments for this reporting period were the following:</p> <ol style="list-style-type: none"> 1. Completed installation of LO₂ pressure-vent system. 2. Completed LN₂ fill line system. 3. Completed work on the seal system. 4. Completed installation of fluorolube lubrication system, except for the yet-to-be-received storage tank. 5. Completed calibration, LOX cleaning, and reinstallation of instrumentation. <p>Barring unforeseen difficulties or slippage of delivery dates, the first LO₂ pump scheduled run should take place on or about January 24, 1964.</p>	

SECTION 11

PLUM BROOK ROCKET SYSTEMS DIVISION

STATUS REPORT

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p>PUMP - LH₂</p> <p>OF0553 (Pinkel)</p> <p>STATUS: The optical torquemeter installation was completed. Only minor installation difficulties were encountered, such as required modifications to the torquemeter case cover to permit proper adjustment of the light source to the torque shaft. On January 21, a series of four runs were made at 15,000 R.P.M. and on January 29 a series of seven runs were made at 9,000 R.P.M. The pump speeds were reduced on the second series of runs because it was found that the torque in the first series was higher than anticipated and the torqueshaft was subject to overloads. Future tests will be run at 15,000 R.P.M. using the high range shafts.</p> <p>NOTE (A): It is estimated that the additional torque data requested by the Research Engineer will extend the pump test schedule to mid-March.</p> <p>NOTE (B): It is anticipated that system modifications for the 3-stage pump will be completed by mid-June.</p>	<p>Liquid Hydrogen centrifugal and axial pump design studies.</p>
		<p>PUMP - LO₂</p> <p>OF0553 (Pinkel)</p> <p>STATUS:</p> <p>1. The fluorolube (FS-5) system for the LOX pump bearings was completely installed, LOX cleaned, tested and necessary adjustments made.</p> <p>2. Pump inlet and exit piping was fitted to the new pump position.</p>	<p>Liquid Oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A		<p>3. As pump parts were received, dimensions were measured, recorded, and the following corrections were made in the Plum Brook Machine Shop:</p> <ul style="list-style-type: none"> (a) The bearing housing was machined to accept the seal housing. (b) Twenty-four scroll bolts were cut and re-threaded and the bolt holes were counter-bored and cleaned. (c) A groove was machined in the seal housing to match the lip on the scroll. (d) The pump shaft was machined to permit seating of seals and assembly of the ball bearings. <p>NOTE (C): The first test run has been rescheduled to the first of March. This change was necessary because the research hardware had to be reworked before assembly. Also the hardware delivery was later than originally scheduled. Part II, the pump shroud, has not been received at Plum Brook.</p>	

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 FEBRUARY 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;"><u>PUMP-LH₂</u> OF0553 (Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>The liquid hydrogen centrifugal pump was operated on February 5, 20 and 25. On February 5, the unshrouded impeller was tested at 9000 RPM for a total of 6 successful passes. The run of February 20 was marred by a faulty speed signal, plus several other minor difficulties, so that the test was aborted after only one successful pass using the shrouded impeller. An additional five passes were successfully completed on February 25, again making use of the shrouded impeller.</p> <p>Additional testing with the shrouded impeller is scheduled for March 6 and 9, and other runs, both shrouded and unshrouded, may be scheduled as backup. One run will be made with no impeller, to determine torque resulting from carbon seals, balance piston drag, etc.</p> <p>NOTE (A): Schedule was extended to obtain additional data points and backup runs requested by research engineers.</p> <p>The 3-stage axial pump parts are being machined in the Lewis Machine Shop and are scheduled to be completed the week of March 9.</p> <p>Due to insufficient manpower, only a limited amount of 3-stage pump facility modification work has been done since the area manpower is concentrating on the centrifugal pump operations.</p> <p>A possible delay in the 3-stage schedule may be caused by the shortage in Statham pressure transducers. Present estimates for Statham deliveries are July or August.</p> <p style="text-align: center;">Continued on Page 14</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A		<p><u>PUMP-LO₂</u> OF0553 (Pinke1)</p>	<p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p> <p>All pump hardware is now on hand. During this reporting period, work continued on measurement of pump parts in order to obtain proper clearances and stackup. Considerable re-machining time was outlined in last month's report, and this month saw a continuation of that trend. Time delays continue due to poor fit and the manufacture of numerous seal shims to obtain proper stackup. Final machining of the impeller was accomplished after stackup was completed. Both inlet and pressure sides of the liquid oxygen loop and liquid nitrogen troughs were fitted to the pump. All the welds on the pressure side and the modified inlet section were X-rayed. The liquid oxygen loop is now completely installed, cleaned and pressure and vacuum checked. The helium pressurization system to the liquid oxygen loop and the helium seal system have been completely installed.</p> <p>Barring additional and unforeseen difficulties with research pump seal checks and final assembly, it is planned to operate the liquid oxygen pump on liquid nitrogen during the week of March 15.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 MARCH 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;">PUMP - LH₂ OF0553(I.I.Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>On March 9 and March 23, the liquid hydrogen centrifugal pump was operated with the shrouded impeller. A total of 9 successful passes was obtained at pump speeds of 9000 RPM. Additional run days were scheduled, but had to be cancelled due to facility problems or lack of manpower.</p> <p>NOTE (A) : Since all data points requested by research engineers have not yet been obtained, a schedule extension is again necessary. Both 9000 and 15,000 RPM data points are required. It is expected that a maximum of six additional run days will provide data sufficient to report on the present impeller designs.</p> <p>Internal parts of the 3-stage axial pump have been assembled, redesigned, remachined, altered, and reassembled. Considerable changes to the lengths, clearances, and diameters resulted from the following:</p> <ol style="list-style-type: none"> (1) Excessive interference when installing torquemeter bearing support; (2) Excessive clearance at rear ball bearing; (3) Front roller bearing races misaligned by 0.179"; (4) Front spinner (roller bearing) clearance completely closed; (5) Rotating stackup (new pump shaft and blade supports) was 0.145" greater than original dummy stackup used at "G" Site. <p>Final stackup of the 3-stage pump is expected early in April. Installation of the pump into the liquid hydrogen loop is now planned for sometime in May, following installation of angle actuators and other tasks which can be accomplished with the centrifugal pump in operation.</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;">PUMP - L02 OF0553 (I.I. Pinkel)</p>	<p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested which may support the M-1 engine project.</p> <p>Problems continued to plague the liquid oxygen pump during the month of March. On February 17, the impeller was sent to Lewis for final machining and balancing. Because of balancing difficulties, the impeller was not returned until March 11. With all pump parts then on hand, an assembly was made which indicated that there were seal and "O" ring leakage problems within the pump. A considerable amount of effort was expended in locating and repairing these sources of trouble.</p> <p>The pump has now had all the necessary shims made and installed, and is fully balanced. It is expected that the initial run on liquid nitrogen will be April 17, which is the first available test date.</p> <p>Facility items completed during this period include the following:</p> <ol style="list-style-type: none"> (1) Liquid oxygen-liquid nitrogen heat exchanger insulation installed; (2) Control valve 145 actuator repaired and checked; (3) Miscellaneous ROV's wired, pressure regulators installed, etc. <p>NOTE (B) : Because of difficulties experienced with pump buildup, the first run was delayed until April 17. Number of runs was reduced because of possible program cancellation at the end of Fiscal Year 64.</p>

SECTION 11

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

APRIL 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p><u>PUMP - LH₂</u> OF0553(I.I. Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>On April 3, the liquid hydrogen centrifugal pump was tested with the shrouded impeller. A total of six successful passes were completed at a pump speed of 15,000 RPM.</p> <p>On April 6 and 8, the pump was tested with the unshrouded impeller at 15,000 RPM. Although five data passes were completed during these two days, approximately 40% of the data obtained was unusable because of a leak in the vacuum jacket around the venturi. This leak became especially critical at low flow rates. Inspection of the venturi flanges revealed that the leak was caused by cold flowing of the teflon gaskets. Both of the venturi flange gaskets were replaced.</p> <p>On April 15, the pump was tested again with the unshrouded impeller. A total of eleven successful passes were completed; eight at 9000 RPM and three at 15,000 RPM. This run completed the centrifugal pump test program.</p> <p>Thirty facility run days were utilized during the last 15 months to test the centrifugal pump. A total of 138 data passes were made and 111 were successful. The pump and auxiliary equipment should be completely removed and placed in storage by May 6.</p> <p>The three-stage pump modifications were completed and the proper clearances were achieved on the new internal parts. The pump vent line and angle actuator housing modifications have been started. It is expected that the pump installation will be completed by June 12.</p> <p>Due to the fact that the pump test program has not been defined, the research instrumentation installation and procurement are in doubt. This could cause a delay in the test schedule. Likewise, due to the lack of a comprehensive test program, planning for facility changes has been slowed.</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p><u>PUMP - LO₂</u> OF0553(I.I. Pinkel)</p>	<p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested.</p> <p>On April 17, the liquid oxygen pump was operated for the first time. Liquid nitrogen was used as the working fluid and four successful data runs were completed with various constant N.P.S.H. values, while the flow was varied. The data runs were all made at a constant pump speed of 7500 RPM. Two problems developed during the test:</p> <ol style="list-style-type: none"> (1) Nitrogen gas from the balance piston leaked into the fluorolube lubricating oil system. (2) The turbine speed control valves (#145) hydraulic cylinder piston rod failed at the clevis. <p>On April 27, a second series of data runs with liquid nitrogen was attempted. No useful data was obtained because of the following difficulties:</p> <ol style="list-style-type: none"> (1) The readings from the speed pickups did not agree with the flow and ΔP data. This problem is presently being investigated. It may have been caused by instrumentation cross talk. These readings were compatible during the April 17 run. (2) Several small liquid nitrogen leaks developed during the runs. (3) The pump forward bearing reached a maximum temperature of 242°F. Disassembly of the pump revealed that the impeller had rubbed on the shroud. Further pump disassembly will be done. <p>At this time, no lengthy delay to the testing program is foreseen.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

MAY 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p><u>PUMP - LH₂</u> OF0553(I.I.Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>The centrifugal pump has been disassembled, crated, and stored, and the 3-stage axial flow pump has been installed. Pump alignment has been completed and modifications to the inlet line are in progress.</p> <p>On May 8, research engineering requested a change in the pump discharge configuration in order to improve measurement of scroll losses. This new requirement will delay the first test runs. Necessary instrumentation is on order, with delivery scheduled for mid-June, and an estimated month's time will be required to install instrumentation. It is expected that previous problems with removable mirrored couplings of the optical torquemeter will be resolved by equipment modifications.</p> <p>Total work to be accomplished during the present pump change-over includes the following:</p> <ol style="list-style-type: none"> (1) Modification of pump inlet and discharge lines. (2) Construction of the liquid hydrogen bearing vent line. (3) Construction of railroad dewar connects and facility piping. (4) Construction of cabinet for the relocation of valve controllers from "A" Site to "H" Building. (5) Modification of "H" Building control panel to include switches and meters for angle actuators. <p>NOTE (A) : Because of necessary pump discharge line modifications, 3-stage pump operation will not commence prior to August 1.</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;"><u>PUMP - LO₂</u> 0F0553(I.I.Pinkel)</p>	<p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure. Four NASA inducer-impellers will be tested.</p> <p>On May 12, the pump was operated in liquid nitrogen for a total run time of 63 minutes. Bearing over-temperature problems were still present as the forward bearing reached 210° F. at 7660 RPM, at which time the run was aborted. Following this test, the pump was disassembled, with these results:</p> <ol style="list-style-type: none"> (1) There was no bearing damage. (2) All four seals were worn approximately 20%. (3) The impeller had scraped the shroud. <p>As a result, the following modifications in hardware and procedures will be accomplished for the next run:</p> <ol style="list-style-type: none"> (1) 50% of the pump bearing preload springs will be removed. (2) The impeller bolt torque will be increased from 350 to 500 in./lb. by installing a stainless steel insert for the aluminum impeller bolt. (3) The helium seal cavity pressure will be reduced from 50 to 20 PSIG. (4) Several minor facility changes will be made to improve the remote operation capabilities of the rig. <p>Additional test runs are scheduled for the month of June.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JUNE 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	PUMP - LH ₂ OF0553(I.I.Pinkel)	Liquid hydrogen centrifugal and axial pump design studies. During the month of June, site modifications were made for the three stage axial pump. At the close of the reporting period, status was as follows: (1) Pump alignment and gearbox reassembly was completed. (2) Tubing for new ROVs, inlet pipe modifications, and the LH ₂ bearing vent line were completed. (3) Fabrication of new torquemeter shafts was started. These shafts are necessary to eliminate the slippage problem which was encountered with the optical system on the centrifugal pump. (4) Control panel changes were started. (5) Angle actuator control panel purchase order was submitted and is awaiting FY65 funds. (6) Specifications and drawings on the liquid hydrogen pump discharge line were completed. The bids were opened and the contract award is imminent. The line should be constructed by the end of July. (7) Installation of tracks for the proposed railroad dewars will begin the first week in July, with completion expected by the end of July.

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p>PUMP - LO₂ OF0553(1.I.Pinkel)</p>	<p>Liquid oxygen centrifugal pump with an inducer-impeller designed to operate at low inlet pressure.</p> <p>On June 1, June 11, and June 18, the liquid oxygen pump was operated with liquid nitrogen as the working fluid.</p> <p>On the June 1st run, the pump speed was limited to 7500 RPM because high gear box bearing temperatures were recorded. After 33 minutes of operation, the bellows on a forward seal broke, which concluded activities for that date. The run of June 11 was essentially a repeat, except that pump speed reached 11,500 RPM and two seals failed. For the June 18th run, the gearbox bearing problem was corrected, and considerable data was collected at 11,800 RPM. However the pump failed while accelerating toward the design speed of 15,000 and at a speed of 13,600 RPM.</p> <p>Following a teardown and inspection, the following damage was observed:</p> <ol style="list-style-type: none"> (1) Severe damage to forward ball bearing - phenolic cage burned, inner race showed signs of high temperature. (Maximum temperature at shutdown was 175° F. on the outer race). (2) Impeller bolt melted off in the threaded area immediately beneath the forward bearing. (3) The entire rotor shifted approximately 1/8" which caused interference and damage to the balance piston within the housing. (4) Damage to the rear of the impeller. (5) Miscellaneous damage to pump shaft, seals, and spacers. <p>NOTE (A): After inspecting the pump following the June 18th run, a decision was made to terminate the program. The pump will be removed from the test loop for storage. No new pump program has been scheduled for this test loop.</p>

SECTION 11
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JULY 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	PUMP - LH2 PF0553(1.I.Pinkel)	Liquid hydrogen centrifugal and axial pump design studies. Continued progress was made during the month of July toward completing site modifications for the three-stage axial flow pump. The status as of July 31, and the estimated completion dates are as follows: (1) The installation and wiring for the new ROV's and Marotta valves have been completed. (2) The installation of new liquid hydrogen dewar stations and switches has been completed. (3) The angle actuator control panel was received and the installation should be complete by August 10. (4) Original probes received from Lewis Research Center for angle actuators were defective. A new set is being procured and should be received by August 7. Internal tubing of the probes, required thereafter, will be completed by August 26. (5) Except for a few items, instrumentation sensors are now on hand and they are scheduled to be installed by August 24. (6) Tracks for the railroad dewars were installed and a new concrete pad was poured at the rear of 'A' Site. Bumper stops for trailer dewars were relocated to match piping changes incurred by the railroad tracks and by the new pump discharge pipe. (7) The exit piping contract was awarded and piping fabrication is now taking place. The exit piping will be completed by August 18, but necessary sequential changes in the vacuum and hydraulic systems will require an additional week. (Continued on Page 16)

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	PUMP - LH ₂ (Continued)	<p>(8) A new optical torquemeter shaft is also being fabricated. Completion of this item is expected by August 20, and another week will be required to magnaflux, hardness test, balance, and calibrate the torqueshaft at Lewis Research Center.</p> <p>(9) All other miscellaneous changes at "A" Site will be complete by August 26.</p> <p>Because of the extension of completion dates for the torquemeter shaft and the discharge piping, the operation schedule for the three-stage pump was changed from the first of August to the first of September.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 AUGUST 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;"><u>PUMP - LH₂</u> PF0553(I.I.Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>The first 3-stage axial pump run scheduled for September 2 has been rescheduled to September 15 because of delays in completion of the new discharge piping. While pressure testing a section of new liquid hydrogen pump discharge piping, a flexible bellows failed, causing serious damage to the pipe section being tested. Details of the event may be learned from an Area 20 Safety Committee report. The contractor involved is making strenuous efforts to refabricate the damaged section in time for the scheduled September 15th run. Before operating the pump, the following work must be completed (Note: Some of these items are required because of the exit piping bellows failure, while others have to be delayed until the exit piping is installed):</p> <ol style="list-style-type: none"> (1) Assemble and calibrate angle actuator. (2) Calibrate and install the torquemeter shaft. (3) Complete instrument tubing and probe location. (4) Reassemble pump. (5) Complete re-design, fabrication and installation of the exit piping. (6) Install receiver dewar shutoff valve (ROV 119) and the discharge flex hose. (7) Receive, modify (weld flanges) and install a new 6" vent hose for the receiver dewar. (8) Install auxiliary piping to the pump exit pipe (hydraulic, vacuum, purge, and vent lines). <p>NOTE: The operations scheduled start date has been rescheduled from September 2 to September 15.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 SEPTEMBER 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;"><u>PUMP - LH₂</u> PF0553(I.I.Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>At the close of this reporting period, the LH₂ discharge piping was still in the process of installation. The required compound pipe angles have caused the contractor some difficulty in achieving desired locations for terminating flanges.</p> <p>Following completion of the discharge piping, certain sequential jobs on the facility must then be completed, including:</p> <ol style="list-style-type: none"> 1. The cleaning and reassembling of the pump. 2. Completing the vacuum system to the discharge pipe jacket. 3. Realigning of the pump (pump alignment was disturbed when the contractor mated discharge pipe to pump collector flange). 4. The reconnecting of the instrumentation to the pump. <p>NOTE: Because of additional delays in completing the discharge pipe contract, the first three stage run has been rescheduled from mid-September to mid-October.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

OCTOBER 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p><u>PUMP - LH₂</u> (I.I.Pinkel)</p>	<p>Liquid Hydrogen Centrifugal and Axial pump design studies.</p> <p>All work was completed during the month of October on system modifications to accommodate the three-stage axial pump. On October 15, representatives of the design, research and operations groups met to discuss the proposed method of testing and certain design features of the research hardware. An operating procedure was agreed upon, and the only design change was the reduction of the outside diameter of the thrust balance piston which increased the clearance between it and the labyrinth seal.</p> <p>After the front roller bearing was cleaned, the inner and outer races became severely oxidized. On further investigations it was found that both the bearing and cage materials should be replaced with materials that have better corrosion resistance and lubrication properties for liquid hydrogen operation. It was agreed by all parties concerned that the first two runs would be made with a new bearing of the present type with a change in cleaning procedures while research would procure another type of bearing. This new bearing would have 440 series stainless steel rollers and races, and Rulon or Armalon cage material.</p> <p>During pressure testing, prior to the first run on October 29, a large leak was discovered at the rear of the research pump. Analysis of the problem indicated that the main source of leakage was through the clearance between the seal holder and pump housing, with additional leaks through and around the carbon seal. Pump modifications are being made which will include the addition of "O" rings, gaskets, and repair of the carbon seal.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 NOVEMBER 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;">PUMP - LH₂ PF0553(I.I.Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>Repairs and alterations to the three-stage axial flow pump were completed during the first two weeks of November. These repairs were necessary to seal off the leakage that was outlined in last month's report.</p> <p>On November 17, five liquid hydrogen runs were made at maximum pump speeds of 15,000 RPM. Because of speed control problems, only a limited amount of useful transient data was obtained. All other systems appeared to function well; however the pump head pressure was lower than predicted.</p> <p>On November 20, two liquid hydrogen runs were attempted. On both occasions, the rig was shut down as the result of a 20% speed error signal which was attributed to a faulty valve controller. The next pump test is scheduled for December 2.</p> <p>The 204C bearings performed well during the November tests, although post-run inspections revealed some corrosion of the rollers and races. Due to the long procurement time for the replacement bearings, the present bearings with 52100 material will have to be used. Bearing inspections will be made after each run, and it is expected that replacements will be required after every two or three runs. The new bearings will have 440 series stainless steel rollers and races with an Armalon cage. At the present time, these bearings are scheduled to be delivered January 22, 1965.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 DECEMBER 1964

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	PUMP - LH ₂ PF0553 (I. I. Pinkel)	Liquid hydrogen centrifugal and axial pump design studies.
<p>On December 2, 8 and 18, Liquid Hydrogen runs were made with the three-stage axial flow pump. During all of the runs research data was recorded at pump speeds of 14 000 RPM.</p>			
<p>Some of the problems that were encountered during the December runs are listed below:</p>			
<ol style="list-style-type: none"> (1) Optical Torquemeter: On the December 2 run, the mirrors frosted from conductive chilling and/or from the balance piston chamber venting. To correct this condition an air line was installed to supply a stream of dry air across the mirror faces. Also pitted mirror faces were found on the 2000 in.-lb. shaft. The faces were repaired by lapping and gold plating. The 3000 in.-lb. shaft had previously been reworked in the same manner. (2) NPSH Control: On the December 18 run, the NPSH control was erratic and required that the pump be shut down before all of the research data could be obtained. The quality of the research data for this run will have to be checked. This control problem is still being investigated and at this time it is believed to be due to a faulty helium pressure regulator. (3) Angle Actuators: During all runs the operation of the Angle Actuators was generally erratic and sluggish. Prior to the December 18 run, two actuators were returned to the manufacturer for gear train changes to increase the angular velocity. Performance improvements were noted so the remaining six actuators were returned for similar work. (4) Carbon Seal: Leakage by the rear carbon seal was particularly noticeable during the high NPSH runs. Disassembly of the pump revealed a seal chatter problem. Studies are now underway to determine whether the seal is the proper type with respect to bonding, composition, crush, etc. 			
<p>Also during December the centrifugal pump, less its rotating parts, was assembled for stack-up purposes. Modifications will have to be made before final pump assembly.</p>			

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JANUARY 1965

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;">PUMP - LH₂ PF0553 (I.I. Pinkel)</p> <p>On January 19, seven liquid hydrogen runs were successfully completed and on January 21, three more tests were successfully completed. The majority of the three stage axial pump testing has now been completed. Only the high NPSH data has to be obtained and these runs are scheduled to be completed by March 25. During February several runs are scheduled to refine and obtain data on angle actuator operation. This data is considered essential for the forthcoming centrifugal and four stage pump programs and is being obtained before completing the three stage pump program.</p> <p>The following problems were encountered during the January runs:</p> <ol style="list-style-type: none"> (1) NPSH Control: Excessive NPSH pressure oscillations were recorded at low NPSH values. This appears to be a problem of control dynamics and a solution is expected in the near future. (2) Hydrogen Pressure Regulator: Failure of the gaseous hydrogen pressure regulator (seals diaphragm, etc.) was experienced. It is believed that the problem was also caused by control dynamics. (3) Angle Actuators: Inconsistent angle actuator performance was experienced. Changes have been made to the actuators to improve their operation and a new balancing and calibration procedure has been set-up. (4) Carbon Seal: As reported last month the carbon seals still are the prime source of leaks at high NPSH pressures. The bellows crush against the seal was checked and found to be less than what was recommended by the vendor so the crush has now been increased. However, no high NPSH runs have been made since the change was made. 	<p>Liquid hydrogen centrifugal and axial pump design studies.</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	(Continued)	<p>The centrifugal pump hardware is scheduled to be available the first of April. A check was made of the pump seals and it was found that several of the seals would be incompatible with the expected operating temperatures, therefore redesign will be necessary.</p> <p>NOTE: The test schedule of the three stage pump has been extended from the end of February to March 25 because of the addition of the angle actuator tests. As noted above the centrifugal pump will not be available for installation until April.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 FEBRUARY 1965

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p style="text-align: center;"><u>PUMP - LH2</u> PF0553(I.I.Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>On February 11 and 17, data runs were successfully completed with the three-stage hydrogen pump. Angle actuator data was obtained at NPSH values of 3.0 and 7.5 psid. Because of excessive oscillations during the low NPSH runs, it was impossible to secure a steady state value. The average values did reproduce the set points, but 3 to 4 cycles per second oscillations of up to 1/2 psi were experienced, particularly in the 0 to 5 psid range. The cause of the oscillations has not been determined. Continued efforts are being made to improve the quality of this data. Although the operations and the data from the angle actuators has improved, further improvement is expected during the March runs when new techniques will be used. An entirely new concept on angle actuator design is being studied which could prove useful for future pump runs.</p> <p>The pump runs scheduled for February 5 and February 25 had to be cancelled because of facility problems.</p> <p>The three-stage pump program is scheduled to be completed by March 12. The pump will then be removed and work will be started on preparing the test area to receive the centrifugal pump. The centrifugal pump hardware is scheduled to be delivered on April 1.</p> <p>Other work that is scheduled to be started in March includes:</p> <ol style="list-style-type: none"> (1) The moving of valve controllers to "H" Building. (2) The installation of a new hydraulic pump and associated equipment. (3) The extension of the hydraulic operation system to include Valves 112, 123, 131, and 131A. <p>The planning and the compiling of estimates are underway to modify the "A" Site loop to provide a suitable test area for the "G" Site single-stage axial flow liquid hydrogen pump.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

MARCH 1965

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p>PUMP - LH2 PF0553(I.I.Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>On March 2 and 17, successful runs were completed with the 3-stage axial flow pump. On March 2, seven passes were completed and on March 17, ten passes were completed. The March 17th run was especially significant because it was the first time that this pump has been run with ramped N.P.S.H.'s and also because this run completed the 3-stage pump test program.</p> <p>Between the two March runs, it was necessary to disassemble the pump for minor remachining and rebalancing. This repair work was required because an inlet total pressure probe had broken, and subsequently caused damage to some of the stator and rotating blades in each pump stage and, in addition, caused damage to the downstream instrumentation. During this downtime, the pump rear seal had to be replaced because the seal case bellows had been broken completely away from the seal case.</p> <p>Work currently in progress and work scheduled for the centrifugal pump tests includes the following items:</p> <ol style="list-style-type: none"> (1) The new liquid hydrogen transfer manifold is scheduled to be delivered by early April. The supports are ready so that the manifold can be installed immediately after delivery. (2) A contract for the moving of valve controllers from "A" Site to "H" Building is 60% complete. Cable terminations and equipment checkout remain. (3) The pressure probes for the new pump installation have been received. (4) A new pump support stand is scheduled to be delivered April 2. <p>(Continued on Page 20)</p>

SITE	LABORATORY	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP	<p>PUMP - LH₂ (Continued)</p> <p>(5) The hydraulic actuation system of the control valves is scheduled to be extended during this facility shutdown. However, delivery of the new hydraulic pump may cause some problems. The bids will be opened on April 5.</p> <p>(6) Pump test hardware is scheduled to be delivered April 14.</p> <p>The next series of research runs with the centrifugal pump is scheduled to start in May.</p>	

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 APRIL 1965

SITE	LOCATION	RESEARCH INSTALLATIONS (FOR)	DESCRIPTION
A	PUMP SITE	<p style="text-align: center;"><u>PUMP - LH₂</u> PF0553(I.I.Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>The month of April was primarily occupied by site and centrifugal pump preparations. In general, good progress was made, although receipt of the pump package was nearly four weeks later than expected. Site modifications, however, proceeded at better than expected rates and included the following:</p> <ol style="list-style-type: none"> (1) The new transfer manifold was installed. (2) All of the valve controllers were moved from the Site to 'H' Building. (3) Control valves 131, 131A, 112 and 123 were altered for hydraulic operation. (4) The new pump support and mounting stands were received and installed. <p>The installation of the new, larger capacity, hydraulic pump and several minor changes in the loop exit line still have to be completed before the centrifugal pump can be tested. Pump tests are scheduled for early June. The design is proceeding on the gaseous hydrogen manifold extension so that the new C.B. & I. railroad tuber which is under construction can be used.</p> <p>Planning is now in progress for the design and construction of a versatile pump loop, including quick change mounting and piping connection features. This modification will enable operation of the present pumps and several other pumps that are now in the design and fabrication stages. Assuming no unforeseen design problems, the site modifications should be ready for initial running of the four-stage axial flow pump by January 1966.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 MAY 1965

SITE	LOCATION	RESEARCH INSTALLATION	& DESCRIPTION
A	PUMP SITE	<p style="text-align: center;">PUMP - LH₂ PF0553(I.I.Pinkel)</p> <p>Build-up for the centrifugal pump continued throughout the month of May, and all of the pump hardware is now on hand. The pump stack-up, rebalancing, etc., has been completed. Site modifications were essentially completed; however, the new hydraulic pumping unit still has to be installed. This larger capacity unit is required to accomodate additional control valves and other valves that were converted from air to hydraulic operation. The first centrifugal pump tests are scheduled to start the week of June 14.</p> <p>The 4-stage axial flow pump has been delivered to Lewis Lab and is presently being inspected.</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JUNE 1965

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p style="text-align: center;"><u>PUMP - LH₂</u> PF0553(I.I.Pinkel)</p> <p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>During early June, the build-up of the liquid hydrogen centrifugal pump stands, instruments, etc., was completed and the pump was assembled and aligned. However, it was necessary to cancel two run days because of the delay in the delivery of the new hydraulic pump package which was not received until June 10. After extensive testing, rework, and replacement of the unloading valve and the pressure relief valve, the system was completed and ready for operation on June 28. The test run scheduled for June 28 had to be cancelled when a pre-run check showed that the pump was out of alignment. The pump was realigned to the gear box and a test run has been scheduled for the first week of July.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

JULY 1965

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p>PUMP - LH₂ (I. I. Pinkel) Liquid hydrogen centrifugal and axial pump design studies.</p> <p>On July 1 the re-designed centrifugal pump was operated with Liquid Hydrogen. The run was aborted after 21 seconds due to severe Liquid Hydrogen leakage in the inlet area of the pump. Post-run critiques showed that the bolting arrangement caused flange deflection which could have negated the action of an "O" ring seal. It was also found that the cross sectioned area of the "O" ring grooves was too great so that the crush on the Kel-F "O" rings was insufficient for proper seal. Re-design was initiated and stainless steel teflon coated "O" rings were ordered to replace the Kel-F "O" rings. The bolting arrangement was changed and new bolts were ordered. "O" ring seals were added to seal the rear bolts; also new grooves were machined where required. Liquid nitrogen leakage tests were made on July 26 and July 31. All of the planned changes were completed for the July 31 test and no pump leakage was experienced during a four hour LN₂ test at 50 psi.</p> <p>Planning and engineering for future "A" Site tasks are currently underway. Some of these items are:</p> <p>(1) Versatile Pump Loop - It is expected that new "quick change" loop components will be in place for initial testing of the four-stage pump early in 1966. The order for the pump stands is already in procurement, and the loop piping purchase request will follow shortly. Engineering is still required for the larger capacity vent and pressurization systems, but no delays to the research test schedule are anticipated at this time.</p>

SITE	SITE NAME	RESEARCH INSTALLATION	& DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>(2) Gas Manifold - In order to make use of the new dewar and gas tuber railcars which are required by the high flow LH₂ pumps and for extended research runs, an extension of the GH₂ manifold is now being designed in engineering.</p> <p>(3) Air Heater - Planning is also proceeding on the modification of the hot air system to provide sufficient energy to drive the four-stage pump.</p> <p>The four-stage pump is on hand and will be ready to install by the time the centrifugal test program is completed and after the necessary piping changes are made.</p>	

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 AUGUST 1965

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	PUMP - LH ₂ PF0553 (I.I.Pinkel)		<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>The centrifugal pump was tested four times during the past month. On the first three run days (August 6, 12 and 25) severe hydrogen leaks occurred in the vicinity of the pump inlet transition flange, during system chilldown. Subsequent to chilldown no leaks occurred. Hydrogen detectors indicated concentrations above lower explosive limits (LEL) for brief periods of time. All electrical systems not required for the chilldown pass were de-energized to minimize potential ignition sources. Between each run day seal modifications were made in an effort to eliminate the hydrogen leak on system chilldown.</p> <p>Prior to the August 27 run it was decided to change operating procedures for chilldown (low inlet pressure to the pump). The result was no detectable hydrogen leak. Previously some data has been obtained on system chilldown when vapor pressure and inlet temperature permitted. No</p>

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE			<p>further attempt will be made to obtain data on the chill-down pass. It is apparent that the hydrogen leak is peculiar to the pump design and occurs between -320°F and -423°F at an inlet pressure over 10 psig. It appears no further modifications excluding major redesign of the collector or adding helium pressure between double "0" Rings will eliminate the hydrogen leak. Accordingly, the remainder of the tests in the Centrifugal Pump Program will be accomplished with a low inlet pressure chilldown pass. Results of the tests during this month are as follows:</p> <p>August 6 run:</p> <ol style="list-style-type: none"> (1) This was the first hydrogen pump run following the pump modification which was reported in July. (2) A severe hydrogen leak was encountered during chill-down. (3) Minor data recording problems were experienced. (4) Six (6) good data ramps were obtained without any hydrogen leaks. <p>August 12 run:</p> <ol style="list-style-type: none"> (1) An Elastimer "0" Ring was added to existing groove which held the previously used Kel-F "0" Ring (location was between flange faces on the inlet and the flange bolt circle.

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p>(2) Severe hydrogen leaks were encountered during chill-down.</p> <p>(3) Speed control problems were experienced.</p> <p>(4) One (1) good data ramp was obtained without further hydrogen leaks.</p> <p>August 25 run:</p> <p>(1) Major seal modifications were made on the expected leak path between the inlet and flange bolt circle. (Addition of a double Elastimer "O" ring with a piston ring to obtain crush on rings on mating flanges.</p> <p>(2) A severe hydrogen leak was encountered during chill-down pass.</p> <p>(3) Seven (7) good data ramps were obtained.</p> <p>August 27 run:</p> <p>(1) A change was made in the operating procedures to chill down with very low pump inlet pressure.</p> <p>(2) No hydrogen leaks were observed.</p> <p>(3) Ten (10) good data ramps were obtained.</p> <p>The Centrifugal Pump Program will continue during the second quarter of this fiscal year.</p>

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 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 SEPTEMBER 1965

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p style="text-align: center;"><u>PUMP - LH₂</u> Liquid hydrogen centrifugal and PF0553 (I. I. Pinke!) axial pump design studies.</p> <p>During the month of September, the centrifugal pump was operated three times.</p> <p>On September 3, eight passes were completed, all passes were made at pump speeds of 9 000 rpm. A low inlet pressure was used during the chilldown pass, and no hydrogen leakage was detected. One Q/N pass was made to checkout the new equipment, all the equipment functioned perfectly.</p> <p>On September 8, eleven passes were completed. Two were required for chilldown. Although the same procedures were used for the chilldown passes as on September 3, the cell gas alarm actuated during the first chilldown pass. All runs were made at pump speeds of 9 000 rpm with various Q/N ratios. The Q/N system in conjunction with the new Boonshaft and Fuchs programming again functioned perfectly.</p> <p>On September 17, five passes were completed. The purpose of this run was to determine whether the temperature measurements in the pump discharge section were being affected by the helium seal leakage or were due to some other cause. Data playback indicated a generally higher than expected temperature level at low flow conditions with superimposed rapid fluctuations. By varying the helium seal pressure and oil temperature, it was determined that the source of the faulty temperature measurement was not due to the helium seal leakage. During the chilldown pass for this run a relatively heavy hydrogen leakage was observed.</p> <p>A decision was made to provide a vent system for the platinum resistor temperature probe to enable the liquid hydrogen to flow across the probe. This system was installed for</p>

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p>the T2 probes and it is felt that this alternate will solve the temperature measurement problem.</p> <p>On September 28 the scheduled run was cancelled because of excessive helium seal leakage. Tear down inspection revealed a broken bellows, probably resulting from pressure reversal during the September 17 run. While the pump was disassembled, a new type seal (Creavy) was installed in groove #105 which is between the discharge and the flange bolt circle.</p> <p>The next pump run is scheduled for October 1.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 OCTOBER 1965

SITE	SITE NAME	RESEARCH INSTALLATION	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE PUMP - LH ₂ PF0553 (I. I. Pinkel)		<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>During the month of October three centrifugal pump runs were completed. The run days were October 1, 5 and 27. These runs supplied a relatively productive amount of pump data. Two impeller configurations will have been completed if the computer results are satisfactory.</p> <p>On October 1, a total of eight passes were completed at pump speeds of 9 000 and 15 000 rpm. The pump discharge temperature probe vent system checked out very well. This system was installed to correct the faulty temperature readings encountered during low flow conditions.</p> <p>On October 5, eleven passes were completed at pump speeds which were equally divided between 9 000 and 15 000 rpm.</p> <p>Following this October 5 run, a new impeller and new seals were installed. Several scheduled runs had to be cancelled due to difficulty in obtaining the proper pump stack-up.</p> <p>On October 27, fourteen data passes were completed. Four of the passes were at 15 000 rpm with the balance at 9 000 rpm. The 13 000 gallon liquid hydrogen dewars were used for the first time and six passes with these dewars were equal to the duration of twelve passes with the former 6 000 gallon dewars. This meant that all of the second pump impeller configuration data was obtained in one run day.</p> <p>During the October runs no hydrogen leakage was observed, even during the chill-down passes. It is believed that the use of a Creavey seal in place of the former seal #105 between the discharge and the flange bolt circle prevented any leakage. Since there was no evidence of leakage, the pump inlet pressure was increased to 15 psig during chill-down passes.</p>

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>Status of the versatile loop is as follows:</p> <ol style="list-style-type: none"> <li>(1) Design of new loop piping is complete and the purchase request for the installation has been sent to procurement. <li>(2) The vent and pressurization piping modifications are in design and preliminary reviews have been held. <li>(3) The hot air heating system is currently being renovated and modernized. Very little data is available on this system, so that preliminary tests will be made in the near future to determine performance characteristics. <li>(4) New flow control valves, pump stands, etc., are on order. <p>Target date for completion of the versatile loop is February 1, 1966, although this schedule is somewhat contingent upon completion of the current centrifugal pump program.</p>		

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
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 NOVEMBER 1965

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<u>PUMP - LH₂</u> PF0553(I.I. Pinkel)		<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>No centrifugal pump runs have been made since October 27. This is because there are only two sets of rotating parts for the pump, each with a different impeller configuration. Programmed runs for these two impellers have been completed, but insufficient data has been reduced for analysis so that the existing impellers can be modified for the next configuration runs. The next test run is scheduled for the week of December 13.</p> <p>Status of the versatile loop modifications is as follows:</p> <ol style="list-style-type: none"> 1. Bids for modification of the loop piping will be opened the week of December 6. It is estimated that the contract will be completed by early April 1966. 2. Vent and pressurization piping changes are in drafting. 3. Pump stands, torque meter shafts, etc. have been engineered and are in various phases of procurement. 4. The contract for addition of tracks to accommodate gaseous hydrogen railcars is in procurement. <p>Considerable effort is being expended in rebuilding the turbine drive hot air system, which is necessary for supplying the torque requirements of the four-stage pump. All systems are being cleaned and inspected. Air flow will be controlled by means of two 12" butterfly valves. Cold and hot flow checks will take place in the near future, although fuel nozzle availability could cause delay in the hot flow tests.</p> <p style="text-align: center;">(Continued on Page</p>

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE (Continued)</p> <p>Four-stage axial flow pump trial assembly will continue through December. All material is on hand, with the exception of rotor blading, which is not expected before February 1966. It is not likely, however, that this pump will see operation before May or June because of delays encountered during planning and engineering of the versatile loop concept.</p> <p>During the past month, it was learned that the program for the single-stage axial flow pump has been temporarily shelved. Design of the pump will continue to completion, but no hardware will be built until additional research engineering manpower becomes available.</p> <p>NOTE: The schedule was extended from December 1965 to April 1966 for the reasons given above.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

DECEMBER 1965

SITE	SITE NAME	RESEARCH INSTALLATION	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>PUMP - LH₂ PF0553(I.I.Pinkel)</p> <p>On December 17, a research test run was made with the centrifugal pump. A number of passes were completed but only four of them could be regarded as successful. The next scheduled run date is January 7, 1966.</p> <p>Work is continuing on the preparation of the turbine hot air supply system. New butterfly valves were ordered for air control, both hot and cold, and the fuel nozzle spray pattern and flow checks are in process. A cold checkout of the system was made using temporary valving to check the control scheme.</p> <p>Bids for the first portion of the versatile loop piping are scheduled to be opened on January 6, 1966. Pressurization and vent piping is in engineering design, and the design is scheduled to be completed by the end of January. The new pump stand is already on hand, and the purchase request for the IV Stage pump optical torquemeter shafts was sent to Procurement.</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JANUARY 1966

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p style="text-align: center;">PUMP - LH2 Liquid hydrogen centrifugal and PF0553(I.I.Pinkel) axial pump design studies.</p> <p>The centrifugal pump operated twice during the month of January.</p> <p>On January 7, ten passes were made and usable data was obtained from five passes.</p> <p>On January 27, a second run was attempted, but a multitude of facility problems prevented any successful data passes.</p> <p>The bids for the versatile loop jacketed piping were opened January 6. Only two bids were received and they were rejected due to excessive pricing. A slight revision was made to the specifications and the piping was readvertised to a larger slate of potential bidders. The new bid opening date is February 24. Vent and pressurization piping design was completed the latter part of January and will be sent to Lewis-Cleveland for approval the first week of February.</p> <p>Four-stage pump assembly is still in progress at Lewis-Cleveland and minor modifications are being made when necessary. Mid-February is now the target completion date for this work. Main stage rotors are expected to be delivered about March 15, at which time they will be fitted into the pump. Rework for pump instrumentation is also being accomplished during the present trial assembly.</p> <p>Work is still in progress on the hot air system. Although cold flow checks have been made to try out the new air control valves, a hot gas test is temporarily delayed for lack of complete nozzle calibration and a detailed run procedure. It is expected that these issues can be corrected and a hot flow test made during the month of February.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

FEBRUARY 1966

SITE	SITE NAME	RESEARCH INSTALLATION	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>PUMP - LH₂ PF0553 (I.I. Pinkel)</p>	<p>Liquid hydrogen centrifugal and axial pump design studies.</p> <p>During the month of February, the A & C impeller configuration testing was completed. On February 4, eleven test runs were made on configuration 'A'. Of these, six resulted in good data.</p> <p>On February 9, impeller configuration 'C' was subjected to seven passes. One of these passes was for cooldown. Good data was obtained from 3 1/2 passes.</p> <p>Future centrifugal pump configuration testing plans were established this month. Impellers ED and EI are tentatively planned to run in March 1967 while a series of backswept impeller configurations tests are planned to be started by January 1968.</p> <p>Pressurization and vent piping portions of the versatile loop project had to be revised due to a relocation of the railroad tracks. These drawings are scheduled to be sent to Lewis-Cleveland the first week in March. The loop piping is out for bid. The bids are scheduled to be opened on March 17. It is planned to shutdown the site on approximately May 1, 1966 so that the versatile loop installation work can be started.</p> <p>The four stage axial pump trial assembly is nearly completed. The main stage rotors are scheduled to be delivered by mid-March, at which time they will be fitted into the pump.</p> <p>A review of the hot air heating system has indicated a need for an automatic start. Consequently, a timer will be added to the system, which will probably delay a "hot" checkout until late March. Since this system is required only for the IV stage axial pump, the delay in its checkout will not affect the sites testing schedule.</p>

SECTION 11
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 MARCH 1966

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p><u>PUMP - LH₂</u> PF0553(I.I.Pinkel) Liquid hydrogen centrifugal and axial pump design studies.</p> <p>The centrifugal pump was operated on three run days during March. All of the impeller configuration B testing and the 9000 rpm runs on impeller configuration C-1 were completed. The three run dates produced a total of 29 passes, three chilldown runs and 22 good data runs. By using the new, high capacity dewars, only half as many run days were required to obtain the test data.</p> <p>Since March 18, the last run day, work at the facility has been concentrated on maintenance and the checkout of the hot air system. However, a hot check has not yet been made, although plans and procedures for an automatic start are now ready for presentation to the Area 20 Safety Committee.</p> <p>Trial assembly of the IV-stage pump and the necessary machining for instrumentation has been completed. Delivery of the rotor and stator portions of the pump have been delayed. The complete pump assembly is now estimated to be completed by mid-June. This will not affect the initial test runs, however, since the versatile loop contract will not be completed until August.</p> <p>Bids for the readvertised portion of the versatile loop (jacketed piping) were opened on March 17. As before, the low bid was considerably (\$17,000) over the estimate. Because of the time limitations, notice to proceed was given to the contractor. Cost estimates for the pressurization and vent piping, plus associated electrical modifications, are being revised and this package should be ready for bidding by the first week of April.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

APRIL 1966

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p><u>PUMP - LH₂</u> PF0553 (I.I.Pinkel) Liquid hydrogen centrifugal and axial pump design studies.</p> <p>The centrifugal pump operated three times during the month of April. Test programs were completed on Impeller C-1, stackup "1" and Impeller D, stackup "2". Over 200 data points, plus additional ramped flow passes were recorded in the three run days.</p> <p>The April 29 run was planned to be the last of the centrifugal pump series, but the research division modified one additional impeller, therefore tests have been scheduled for this impeller on May 11 and May 12.</p> <p>The Area 20 Safety Committee is scheduled to review the hot air system May 19. By that time, wiring changes required for the automatic sequence system will be completed. It is expected that a check out of the system will be completed by May 30.</p> <p>Contract for the versatile loop jacketed piping was awarded to Gardner Cryogenics. NASA gave the notice to proceed on April 18. The contract completion date is August 26. The bid opening date for the pressurization and vent piping is June 1. Government furnished equipment for portions of this job is already on order. A contract for the rework of the "A" Site canopy to accommodate railroad dewars will be awarded the first week of May.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 MAY 1966

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p><u>PUMP - LH2</u> PF0553(I.I.Pinkel) Liquid hydrogen centrifugal and axial pump design studies.</p> <p>On May 11 and 12, nine successful data runs concluded the centrifugal pump program. Data parameters were as follows:</p> <p style="padding-left: 40px;">3 runs at 9000 rpm - NPSH constant with ten Q/N steps</p> <p style="padding-left: 40px;">3 runs at 15000 rpm - NPSH constant with ten Q/N steps</p> <p style="padding-left: 40px;">3 runs at 9000 rpm - Ramping flow with NPSH constant</p> <p>Status of work for preparation of the IV Stage LH₂ axial pump program is as follows:</p> <ol style="list-style-type: none"> (1) The IV-stage pump is expected to be completely assembled by late June. The main stage rotors have been received and accepted. The stators have also been received and are now awaiting inspection and acceptance. Modifications are proceeding for use of high pressure hydrogen in the labyrinth in order to reduce potential liquid hydrogen leakage. (2) The hot air drive system is ready for final checkout which will be accomplished early in June. (3) The Government-furnished equipment for the hydrogen manifold is now in the process of being purchased and the hydrogen regulator and filter delivery date is early June. (4) The contract for modification of the AEC railcar hydrogen tubers has been advertised for bid. <p style="text-align: center;">(Continued on Page 22)</p>

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE (Continued)</p> <ul style="list-style-type: none"> <li>(5) The contract for canopy modifications required for the liquid hydrogen railroad car dewars was awarded and the completion date is June 23. <li>(6) The railroad track modification for the railcar hydrogen tubers is proceeding and will be completed during the first week of June. <li>(7) Gardner Cryogenic, Inc., contractor for the versatile pump loop vacuum-jacketed piping, is three weeks behind schedule for submittal of piping shop drawings. <li>(8) Bid opening date for the pressurization, vent, gaseous hydrogen manifold and associated electrical modifications is June 8. <p>It is anticipated that the IV-Stage axial pump program will start late November 1966.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JUNE 1966

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p>PUMP - LH₂ <u>PF0553 (I.I.Pinkel)</u> Liquid hydrogen centrifugal and axial pump design studies.</p> <p>Status of preparation for the IV Stage pump program is as follows:</p> <ol style="list-style-type: none"> 1. Canopy modification for the railroad dewar is completed. 2. Railroad track changes for the GH₂ rail tubers are completed. 3. Shop drawings for the Versatile Loop jacketed piping were reviewed and, in most cases, approved. The drawings were returned to Gardner Cryogenics with recommendations to proceed with fabrication. The anticipated contract completion date is August 26. 4. Because there was no response to the first bid opening for the Versatile Loop pressurization and vent piping, the bid opening was delayed ten days. Two bids were received and Valley Electric was the low bidder. The contract was awarded on June 30. This contract has a 120 day completion date and it is the pacing item for IV Stage pump testing. 5. The hot air system was operated four times this month. During the first three tests ignitor burnouts and vent valve oscillation problems were encountered. These problems were corrected so that on June 28 stable burner discharge temperatures were maintained at various set points between 700 and 1200°F. <p style="text-align: center;">Continued on Page 22</p>

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE (Continued)			<p>6. IV Stage pump rotors are currently being fitted to the pump shaft, and the stators are being brazed and finish-machined. It is expected that the pump will be delivered to Plum Brook by July 15.</p> <p>7. Three contracts will be required to modify the AEC railroad tubers:</p> <p>Cleaning - Bids will be opened July 7.</p> <p>Testing - Bids were opened the end of June.</p> <p>Piping - The contract drawings are scheduled to be completed by July 15.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

JULY 1966

SITE	SITE NAME	RESEARCH INSTALLATION	& DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>PUMP - LH₂ PF0553 (I. I. Pinkel)</p> <p>Status of the IV-stage axial pump installation:</p> <p>(1) Vacuum-jacketed piping (Gardner Cryogenics) - Gardner's pre-fab drawings have been approved, and the shop work is underway. Gardner is having difficulty in obtaining material and has requested a 35-day contract extension. If the extension is granted, the contract completion date will be extended to September 30. This extension will not affect the overall project completion date.</p> <p>(2) Pressurization, vent piping and electrical (Valley Electric) - A preconstruction conference was held July 14, and the notice to proceed was given on July 18. The contractor has 80% of his material on hand and has started to work. Not all of the Government-furnished equipment is available. Some of the items are in the process of being purchased. Control wiring redesign was required and this redesign work is now in progress.</p> <p>(3) The late delivery of the new Rockwell vent valve prevented any further checkout of the hot air system. Latest promised delivery date is early August. Following acceptance and installation of the valve, refinement of hot air system operation will be continued.</p> <p>(4) Balancing of the IV-stage pump rotor has been completed. Delivery of the pump to Plum Brook is scheduled for the first week of August. The pump will then be instrumented, reassembled, pressure-checked and cold shocked.</p>	<p>Liquid hydrogen IV-stage axial pump design studies.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 AUGUST 1966

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>PUMP - LH₂ PF0553(I.I.Pinkel)</p> <p>Status of the versatile loop contracts is as follows:</p> <p>(1) Vacuum-jacketed piping (Gardner Cryogenics):</p> <p>This contract is approximately one month behind schedule, primarily because of the delay in the venturi delivery. The substitution of a temporary spool section for the venturi has been proposed so that installation and checkout of the piping can proceed. August 26 was the original contract completion date.</p> <p>(2) Pressurization, vent piping, electrical (Valley Electric):</p> <p>This contract is on schedule. Electrical work is 75% complete. Piping fabrication began the week of August 24. Some of the Government-furnished equipment and contractor-furnished material has not been received. Material will be supplied to the contractor on a replacement basis to accelerate job progress.</p> <p>The IV-stage pump was returned to Lewis-Cleveland for additional shop work. The addition of a total pressure probe required spacer changes. Because of these changes, Phase IV rotating assembly has to be rebalanced. Part #1 (front bearing housing) is being electrolyzed. Also, couplings and shafts are being drilled and tapped for set screws to achieve proper axial alignment.</p> <p>Testing of the hot air system will resume after the new vent valve has been installed, and following the rewiring of the control panel. Final testing of the hot air system is scheduled for September 9.</p>		<p>Liquid hydrogen IV-Stage Axial Pump design studies.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

SEPTEMBER 1966

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p><u>PUMP - LH₂</u> PF0553(I.I.Pinkel)</p> <p>The IV-stage pump has been rebalanced at Lewis-Cleveland and returned to Plum Brook. This rebalancing was done for Phase IV testing. Subsequent stackup changes will require the rotating parts to be rebalanced. Presently, the pump is being assembled and at the same time all necessary clearance fitting is being done. Final alignment will be made with the 2.2:1 gearbox shaft.</p> <p>The hot air system was operated four times during the month of September. Since the control panel had been rewired, a considerable amount of time was spent in debugging. Also, the 200 psi air supply compressor was out of service, so some delays were experienced due to insufficient air. Testing is scheduled to continue on a weekly basis as long as necessary.</p> <p>Operations Engineering is presently designing the thrust balance and bearing vent system. Included are an orifice design and the procurement of a mass flow measuring device. New hydraulic lines will have to be installed for the system.</p> <p>Contract status for the versatile loop is as follows:</p> <p>(1) Vacuum-jacketed piping (Gardner Cryogenics) -</p> <p>The contractor reports that the shop fabrication is 75 to 80% complete, and that he has started radiographing welds. He has scheduled the cold-shocking to begin the week of October 10, but the venturi has to be installed before the tests. A sub-contractor (B.I.F.) is now calibrating the venturi; then it has to be returned to Gardner for vacuum jacketing. and</p>		<p>Liquid hydrogen IV-stage axial pump design studies.</p>
		<p><u>PUMP - LH₂</u></p> <p>a sub-contractor (Zoellner) has to install the venturi. He is scheduled to begin his phase of the work on October 10 and complete it by October 31.</p>		
		<p>(2) Pressurization/Vent/Electrical, (Valley Electric) -</p> <p>The mechanical portions of this contract appear to be ahead of schedule, but some phases are being delayed by lack of Government-furnished equipment.</p>		

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

OCTOBER 1966

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	PUMP - LH ₂ PF0553 (I.I. Pinkel)		Liquid Hydrogen IV-stage axial pump design studies
<p>During the initial helium pressure check of the IV-stage pump a leak developed in the "O" ring seal No. 112 which is located behind the forward carbon seal mating ring. The thrust balance system torous tubing inserts leaked during the second helium test. These tubes will be bored out and replaced with machined inserts. The rework and hydrostatic pressure test are scheduled to be completed by November 2.</p>				
<p>During October a hot air system checkout was made. The pneumatically operated 12 inch vent valve (No. 1216) performed erratically. It was decided to change to a hydraulic operator. Conversion components are being procured and fabricated. Checkouts are scheduled to resume the week of November 14.</p>				
<p>Contract status for the versatile loop is as follows:</p>				
<p>(1) Vacuum-jacketed piping (Gardner Cryogenics) -</p> <p>The contractor has removed the existing exit line. Delivery of Gardner-fabricated piping is promised for the week of November 7. The contract completion has been extended to the end of November.</p>				
<p>NOTE: Due to the contract completion slippage, and the amount of NASA site work to be done following the contract work, the first run date has been extended to March 1967.</p>				
<p>(2) Pressurization/Vent/Electrical (Valley Electric) -</p> <p>All piping systems except the 4-inch gas manifold are complete. The contractor has cold shocked and pressure checked these systems and he is now cleaning them. The 4-inch manifold completion was delayed by unavailability of Government furnished equipment. Delivery is expected by November 9. The electrical work is 95% complete. If Government furnished equipment arrives as promised, the contractor will be done by November 18.</p>				

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 NOVEMBER 1966

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	PUMP - LH ₂ PF0553 (I.I.Pinkel)		Liquid hydrogen IV-stage axial pump studies. Checkout and installation of the pump was delayed due to the torus section repairs described in last month's report. Lewis-Cleveland returned the torus to Plum Brook on November 14. Following minor rework, site mechanics reassembled the pump. A helium leakage test was successfully completed with only minor leakage through the carbon seals. Following this a LN ₂ cold shock test was conducted. During this test a deflection versus time history was gathered for various points on the pump. A second helium leak check followed the cold shock. Pump instrumentation is the next project. Versatile loop contract status is as follows: (1) Vacuum-jacketed piping (Gardner Cryogenics) - All the vacuum-jacketed piping, venturi, flow control valves and flex sections have been received and installed. A LH ₂ railroad dewar was brought in on both the supply and receiver side to check for clearances, fits, etc. Everything on the supply side was acceptable, but when the dewar was moved to the receiver side, the six-inch vacuum-jacket return line was two inches shorter than the eight-inch vacuum-jacketed supply line. This condition is unacceptable and the six inch section of pipe has been returned to the factory for modification. The contractor is in the process of vacuum pumping the various sections of line, to meet specifications. Two more support stands are being fabricated in the contractor's shop. After reassembly of the six-inch vacuum-jacketed return line, the system will be given a bubble test. If no vacuum or pressure leaks are found, the contract should be completed by December 16. (2) Pressurization/Vent/Electrical (Valley Electric) - All piping systems, except the four-inch Gas Manifold, are complete. The delaying items are the high pressure flex hose. Partial delivery of the hoses was made on November 28. One of the items was rejected. Based on early delivery of acceptable

(Continued on Page 22)

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	PUMP - LH ₂ (Continued)		<p>hoses the contractor anticipates completion of the job by December 23. The electrical portion has been completed.</p> <p>(3) Status of Site Work by NASA personnel:</p> <p>In addition to the IV-Stage Pump build-up, the following major jobs were completed or started by NASA mechanics during the month of November:</p> <ul style="list-style-type: none"> (a) Installation of GN₂ system for dewar valves actuation was completed. (b) Installation of GHe system for dewar connection purge was completed. (c) Installation of sense lines for pressure read-outs at "H" Building was completed. (d) Installation of hydraulic systems to control valves in pressure/vent systems was completed. (e) Fabrication of control auxiliary control panel and installation of gages, regulators, and valves on panel for all support systems was started. (f) Installation of hydraulic system to twelve-inch vent valve in hot air system was completed.

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 DECEMBER 1966

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<u>PUMP - LH₂</u> PF0553(I.I.Pinkel)		Liquid hydrogen IV-stage axial pump studies. The versatile loop contract status is as follows: (1) Vacuum-jacketed piping (Gardner Cryogenics) - This contract is nearing completion. The only item remaining incomplete is the vacuum pressure level in Line 1. The contractor is in the process of "pumping down" Line 1 to meet the specified vacuum pressure level. (2) Pressurization/Vent/Electrical (Valley Electric) - Contract is complete with the exception of the installation of two 4" diameter high-pressure gaseous hydrogen manifold hoses. The supplier (Flexonics) did not deliver the hoses as promised. The new delivery date is early January. <u>Status of site work:</u> In addition to installing instrumentation on the IV-stage pump, the following major jobs were completed or initiated during the month of December. (1) The modification and installation of the old 1½" gaseous hydrogen high-pressure manifold was completed. (2) The fabrication of control auxiliary control panel for operation and read-out of all support systems was completed.
(Continued on Page 24)				

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE (Continued)	<u>PUMP - LH₂</u> (Continued)		<p>(3) Installation of purge valves for both the 1½" and 4" gaseous hydrogen manifold was completed.</p> <p>(4) Installation of hydraulic system to flow control valves in liquid loop was completed.</p> <p>(5) Installation of high pressure gaseous helium was completed.</p> <p>(6) The IV-stage axial flow pump instrumentation is approximately 95% completed.</p> <p>(7) The hot air drive system was successfully checked out on December 13. Additional control work will be required to correct air temperature fluctuations.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JANUARY 1967

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<u>PUMP - LH₂</u> YPF0553(I.I.Pinkel)		Liquid hydrogen IV-stage axial pump studies. The versatile loop contract status is as follows: (1) Vacuum jacketed piping (Gardner Cryogenics): A site inspection was made by representatives from the Construction Office, Operations Engineering, Mechanical Engineering and Gardner Cryogenics on January 13. The contract work was accepted as completed with one exception: The vacuum pressure level in the piping will be monitored weekly for a 30-day period. At the end of the 30-day period, a decision will be made, based on monitored data, to either accept, reject or repair the vacuum jacketed piping. (2) Pressurization/Vent/Electrical (Valley Electric): The Government-furnished 4-inch diameter, high pressure gaseous hydrogen flexible manifold hoses were received and installed. The gaseous helium purge line had to be removed and reinstalled according to contract drawing. All pressure testing has been completed. A site inspection is scheduled for the week of January 30 to determine the completion and acceptability of the contract work. <u>Status of Site Work:</u> The following major jobs were completed or initiated during the month of January: (Continued on Page 24)

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE (Continued)</p> <p><u>PUMP - LH₂</u> (Continued)</p> <ol style="list-style-type: none"> <li>(1) Completed the removal of 3.8:1 high speed shaft from the gearbox and installation of 2.2:1 shaft. <li>(2) Completed the alignment of IV-stage pump to gearbox shaft. <li>(3) Completed the fabrication and installation of instrumentation (pressure transducer) support stand. <li>(4) Completed the fabrication and installation of instrumentation tubing from pump probe to transducer mounted on stand. <li>(5) Completed the fabrication and installation of 2-inch vacuum manifold from test cell to dewar area. <li>(6) Completed the installation of new valve number identification tags on all facility valves. <li>(7) Fabrication and installation of IV-stage pump thrust balance system was initiated. <p>An intensive effort is being made for an initial pump checkout run by early March 1967.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

FEBRUARY 1967

SITE	SITE NAME	RESEARCH INSTALLATION	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p><u>PUMP - LH₂</u> YPF0553 (I.I.Pinkel)</p> <p>The versatile loop contract status is as follows:</p> <p>(1) Vacuum jacketed piping (Gardner Cryogenics):</p> <p>As of February 6, only one of the 13 sections of vacuum jacketed pipe had a pressure level within the specified limit of 10 microns. It took three days to pump down the system to a pressure below 10 microns, then vacuum pressures were read daily for a 16 day period. At the end of this time, only four sections were within limits. The contractor has been contacted, and will return to check out the system.</p> <p>(2) Pressurization/Vent/Electrical (Valley Electric):</p> <p>A final site inspection was made on February 3. Work done by this contractor was found to be satisfactory, and the job was accepted by NASA.</p> <p>(3) Insulation Contract:</p> <p>The insulation contract for the pump thrust balance and bearing vent system is expected to be complete by March 21.</p> <p><u>Status of Site Work:</u></p> <p>Major site work accomplished by NASA personnel during the month includes these items:</p>	<p>Liquid hydrogen IV-stage axial pump studies.</p>

(Continued on Page 22)

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE (Continued)	<p><u>PUMP - LH₂</u></p> <ol style="list-style-type: none"> <li>(1) Completed installation of hydraulic lines to all facility control valves. <li>(2) Tied in all new contract piping with existing facility piping for purging, evacuating and pressurizing of the pump loop and support systems. <li>(3) Completed installation of the auxiliary site control panel. <li>(4) Completed the fabrication and installation of the IV-Stage pump thrust balance and bearing vent system. <li>(5) Gearbox run-ins were conducted on February 9 and 23 using the 2.2:1 ratio shaft. Purpose of the test was to check bearing fit and alignment and to check speed control. All 12 bearings were instrumented and monitored. During the first test, two bearings indicated high temperature spikes. Upon inspection, it was revealed that the T/C leads had shorted out. A rerun of the test on February 23 produced no over-heating problems with input shaft periods up to 4000 rpm. From these tests, it was determined that the gearbox and speed control systems are ready for test. <p>It is expected that the IV-Stage pump, together with the loop piping, will be cold shocked with liquid hydrogen during the week of March 6. Assuming objectives of this test are accomplished, low speed pump testing will begin the following week.</p>		

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

MARCH 1967

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	PUMP - LH ₂ YPF0553 (I.I.Pinkel)		Liquid hydrogen IV-stage axial pump studies
		<p>On March 10, a liquid hydrogen cold shock test was run. The IV-stage pump and the new loop piping were successfully tested with no leaks being detected. The pump shaft could be manually rotated at low temperatures. Following the test all of the loop connection bolts were retorqued.</p>		
		<p>On March 17, three passes were run. On the first pass, a speed control valve malfunctioned and an overspeed shutdown occurred. The second pass, a pump and loop chilldown run, was made at a pump speed of 1200 rpm. The run duration was in excess of 10 minutes. On the third pass, thrust balance and pump flow were varied manually and a speed of 4500 rpm was attained. After several minutes, a 10g vibration level caused an automatic shutdown. Fine metallic particles were found in the pump inlet, forward (hydrogen cooled) bearing and throughout the entire pump. Some heat discoloration was found in the forward bearing. Disassembly of the piping revealed deposits of metallic particles in the inlet line up to the dewar connection. There was a 70 micron filter between the hydrogen dewar and the inlet line.</p>		
		<p>This 25' inlet line had recently been reworked and cleaned under contract. We are now recleaning the whole system and new pump bearings are being installed.</p>		
		<p>The insulation contractor is scheduled to complete the thrust balance vent pipe insulation by April 7. The next pump test is scheduled for April 13.</p>		

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

APRIL 1967

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>PUMP - LH₂ YPF0553 (I.I.Pinkel)</p> <p>On April 11, the test loop was flushed with liquid hydrogen. The IV-stage pump was installed with only the pump shaft and carbon seals in place. Two 8-inch 70 micron filters were installed in the test loop inlet line. After the flush was made, both filters were removed and inspected. No visible particle contamination could be found in the filters or in the inlet line.</p> <p>On April 14, a research test run was made with the IV-stage axial flow pump. The pump was assembled for Phase IV configuration (i. e., inducer and three main stage rotors). Two successful runs were made at 4500 rpm. The major reasons for not completing more runs were pump vibration and high dewar pressure. The pump head rise, for this configuration, was considerably lower than expected. The pump was disassembled on April 20 to verify the installation of the pump stators which were found to be correctly installed.</p> <p>On April 21, the IV-stage pump configuration with inducer only was sent to Lewis-Cleveland for balancing. The pump was returned to Plum Brook for assembly on April 24. The next series of test runs will be with the inducer only, at high speed, high flow and low head rise.</p> <p>The next pump test is scheduled for May 2.</p>		<p>Liquid hydrogen IV-stage axial pump studies</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

MAY 1967

SITE	SITE NAME	RESEARCH INSTALLATION	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p><u>PUMP - LH₂</u> YPF0553(I.I.Pinkel)</p> <p>On May 3, a research test run was made with the IV-stage axial flow pump. The pump was assembled in Phase I configuration (i.e., inducer only). Two attempts were made to operate the pump at 9000 r.p.m. After approximately 10 minutes of running time, the shaft carbon seal (liquid hydrogen side) failed. The next day, the seal was removed and submitted for lab failure analysis. Failure mode was the separation of the inconel bellows inside the seal. Metallurgical examination indicated possible manufacturing problems. Half of the failed seal was returned to the manufacturer for concurrent analysis. A duplicate seal was installed in the pump.</p> <p>On May 10, two run attempts were made. Again, with only eight minutes of running time, the seal failed. Post run inspection revealed an identical seal failure as experienced during the May 3 run.</p> <p>A report from the seal manufacturer indicated that there were, indeed, manufacturing faults present. Both heat treat and weld quality control problems were present in the bellows. Accordingly, all seals of this model were returned to the vendor for rework.</p> <p>The pump was reassembled with the original design carbon seal. This seal has a lower pressure rating and has stainless steel bellows.</p> <p>On May 25, five data runs were made at speeds up to 9000 r.p.m. Running time totaled approximately 23 minutes with no evidence of leakage.</p> <p>The next pump test is scheduled for June 1.</p>	<p>Liquid hydrogen IV-stage axial pump studies</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

JUNE 1967

SITE	SITE NAME	RESEARCH INSTALLATION	& DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p><u>PUMP - LH₂</u> YPF0553 (I. I. Pinkel)</p>	<p>Liquid hydrogen IV-stage axial pump studies.</p> <p>During the month of June, five liquid hydrogen runs were successfully completed. Run days were June 1, 7, 15, 21, and 28. These five run days provided a considerable amount of both pump performance and angle actuator (blade element) data for the inducer-only configuration. All test runs were essentially the same. Pump speed was either 7000 or 9000 r.p.m. NPSH ranged between 65 and 90 psid. The prime variable was the location and immersion depth of the five angle actuators. Performance of all systems was excellent.</p> <p>Disassembly of the pump is now in progress. It will be reassembled, making use of a dummy inducer and one mainstage rotor. It is expected that the new configuration will be balanced and ready for testing the week of July 17.</p> <p>NOTE: Because of testing delays caused by seal problems and the unplanned stage-by-stage testing program, the test program has been rescheduled to extend through December 1967.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

JULY 1967

SITE	SITE NAME	RESEARCH INSTALLATION	& DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p><u>PUMP - LH₂</u> YPF0553(I.I.Pinkel)</p> <p>Two successful run days were completed with the IV-Stage pump during the month of July. Also during this month, the pump configuration was changed from Phase I (inducer only) to an assembly made up from a dummy inducer, "straight through" guide vanes and one main stage rotor.</p> <p>On July 20, one chilldown pass and four data passes were run. Pump speed range was 7000 to 9000 RPM; Q/N ranged from 1.0 to 0; and the NPSH range was from 65 to 90 psid. As determined from extensive angle actuator instrumentation and the standard recorded parameters, performance of the IV-Stage pump fell far short of planned performance.</p> <p>Three additional data passes were conducted on July 28 to confirm July 20 data. It is now planned that instrumentation changes will be made, and a final main stage performance test will be conducted during the week of July 31.</p>	<p>Liquid hydrogen IV-Stage axial pump studies.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 AUGUST 1967

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p><u>PUMP - LH₂</u> YPF0553(I.I. Pinkel)</p> <p>Liquid hydrogen IV-stage axial pump studies.</p> <p>On August 4, a final test was made on the mainstage rotor. For this test, the five angle actuator probes behind the rotor were replaced by five fixed total probes. Data obtained from the fixed probes confirmed data values from the angle actuator probes on two previous run days. Evidence was conclusive enough to discontinue testing with mainstage rotors of the present design.</p> <p>During the August 4 test, the pump rear bearing failed. Exact cause of the failure has not yet been determined. Damage to the pump requires remanufacture of the rear and main labyrinths and a spacer (Parts #4, #14, and #61).</p> <p>Present plans call for testing of the inducer with a redesigned fixed stator section. The stator is now in procurement with an estimated delivery of mid-December. Based upon this schedule, the IV-stage pump program should resume in January 1968.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

SEPTEMBER 1967

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p><u>PUMP - LH₂</u> YPF0553 (I.I.Pinkel) Liquid hydrogen IV-Stage axial pump studies.</p> <p>Status of work for the resumption of IV-Stage pump testing is as follows:</p> <ol style="list-style-type: none"> (1) The eight inch vacuum jacketed pump inlet line was returned to Gardner Cryogenics for repairs. This line developed an internal leak during previous testing. Gardner has promised completion of repairs by late October. (2) The new venturi was calibrated in the Ohio State University hydraulics laboratory. It has been returned to Plum Brook for installation into the loop piping. (3) A fabrication contract for a new pump stator section has not yet been awarded. Current difficulties in processing PR's over \$2,500 may delay procurement of this hardware. (4) New pump parts being fabricated in Lewis-Cleveland are scheduled for completion in early November.

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

OCTOBER 1967

SITE	SITE NAME	RESEARCH INSTALLATION	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	PUMP - LH ₂ YPF0553(I.I.Pinkel)	<p>Liquid hydrogen IV-Stage Axial Pump studies.</p> <p>Lack of research hardware caused "A" Site to continue to be inoperative during October, and all service personnel have been assigned to other work. When all necessary parts are on-hand, a service crew will be reconstituted and operation will resume.</p> <p>Work status is as follows:</p> <ol style="list-style-type: none"> (1) Repair of the eight-inch vacuum-jacketed inlet line by Gardner Cryogenics has been delayed. The rescheduled delivery date is early November. (2) The contract for fabrication of the redesigned stator section was awarded to Ace Industries on October 24. The requested completion date was 45 days from award of contract, with a maximum of 60 days. (3) The new pump parts being fabricated at Lewis-Cleveland Machine Shop are being worked on intermittently. The estimated completion date is mid-November. (4) In order to obtain the requested cavitating data on the pump inducer, some blading in the existing pump collector ring must be removed to reduce the blockage. Presently, there are twenty-four blades in the collector ring and research has requested that sixteen blades be removed. However, the remaining eight blades may not be enough to maintain the structural integrity of the collector ring. By mid-November, the Cleveland Mechanical Engineering group will have completed an intensive analysis to verify the structural integrity of the collector, assuming that the blades are removed. Unfavorable results would postpone testing beyond the planned date of January 1968.

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 NOVEMBER 1967

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p>PUMP - LH₂ Liquid hydrogen IV-Stage YPF0553(I.I. Pinkel) Axial Pump studies. (FSCD - R.W. Frischmuth, Jr.; RSD - D. Cooksey)</p> <p>Preparations are being made to resume IV-stage pump testing in January.</p> <p>Status of work:</p> <ol style="list-style-type: none"> (1) The fabrication contract for the redesigned stator section is scheduled to be completed by December 26. The stator section is the last critical part required before the test proper can continue. (2) The pump has been disassembled, new parts have been made at Lewis-Cleveland Machine Shop, the shaft with inducer in place has been balanced. Some final pump machine work is being done at Plum Brook, then the pump will be reassembled. (3) The pump test loop lines are being cleaned for the pump tests <p>Mr. Ambrose Ginsburg made the decision that only data on the redesigned stator will be obtained during the next series of tests. If at a later date the inducer cavitation data is desired, the pump collector ring blades will be removed.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 DECEMBER 1967

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p><u>PUMP - LH₂</u> YPF0553 (FSCD - P.R.Meng; RSD - D.Cooksey)</p>		<p>Liquid hydrogen IV-stage axial pump studies.</p> <p>The lack of the research pump stator section will cause "A" Site to remain inoperative until March.</p> <p>The following preparations are being made for the IV-stage pump testing:</p> <ol style="list-style-type: none"> (1) The pump test loop lines, flow control valves, and venturi section are being cleaned. (2) The pump bearing housing has been re- turned to the Lewis-Cleveland Machine Shop for rework. (3) The new stator section is in Lewis-Cleveland for furnace brazing. After brazing, it will be returned to the contractor (Ace Industries) for final machining. The stator section is the last critical pump part required before testing can continue. It is estimated that it should be delivered by the middle of February.

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JANUARY 1968

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p>PUMP - LH₂ YPF0553 (FSCD - P. R. Meng; RSD - D. Cooksey)</p> <p>Liquid hydrogen IV-stage axial pump studies.</p> <p>The following preparations are being made for the IV-stage pump testing:</p> <ol style="list-style-type: none"> (1) The pump test loop lines and components are being cleaned. (2) The pump rear bearing housing is being machined by the Lewis-Cleveland Machine Shop. This re-work is scheduled to be completed by February 9. (3) The site main hydraulic supply unit has been disassembled, repaired, cleaned and reassembled. (4) The new stator section was returned to the contractor for final machining. During final machining a dimensional error was made in a critical section of the stator. The part is now being sent to Lewis-Cleveland for inspection and measurement. An analysis will be made to determine the strength of the modified stator. A decision will then be made to accept, reject, or remake the stator section.

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 FEBRUARY 1968

SITE	SITE NAME	RESEARCH INSTALLATION	& DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p><u>PUMP - LH₂</u> YPF0553 (FSCD - PR Meng; RSD - D Cooksey)</p> <p>The new pump stator section was delivered, inspected, and accepted at Lewis-Cleveland. Additional machining had to be done by the Lewis Cleveland Machine Shop before it could be fitted into the pump.</p> <p>The pump is being prepared for resumption of testing. It is being cleaned and assembled for the run configuration, and research instrumentation is being installed.</p> <p>Research testing is scheduled to resume during the week of March 18.</p>	<p>Liquid hydrogen IV-stage axial pump studies.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 MARCH 1968

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p style="margin-left: 40px;">PUMP - LH₂ YPF0553 (FSCD - PR Meng; RSD - D Cooksey)</p>		<p style="margin-left: 40px;">Liquid hydrogen IV-stage axial pump studies</p> <p>On March 20, a research test run was made with the IV-stage pump. The pump was assembled for Phase I testing to obtain stator exit flow conditions. Four survey runs were made from 0 to 15,000 RPM. These tests were made to determine the location, if any, of stator blade wakes. None were found to exist at the measured depths. Two more test runs will be required to cover all the various circumferential positions and depths behind the stator blades.</p> <p>On March 21 the pump was disassembled and inspected. The inducer blades showed some minor damage where they had rubbed the housing. This was caused by a lack of proper clearance between the blade tips and the housing. The blades have been cleaned up and the entire rotating assembly has been returned to Lewis-Cleveland for rebalance.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 APRIL 1968

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p><u>PUMP - LH2</u> YPF0553 (FSCD - PR Meng; RSD - D Cooksey)</p> <p>Liquid hydrogen IV-stage axial pump studies.</p> <p>Three test runs were made during April:</p> <p>On April 4, the pump was tested with only the inducer and stator installed. Data on the stator-exit flow conditions were obtained. At the higher flow coefficients, however, data could not be obtained due to an excessive pressure drop in the pump collector.</p> <p>On April 18, the pump was tested with the fourth-stage rotor and the same inducer and stator configuration as previously tested. The addition of this rotor was to compensate for the pressure drop in the collector. A 4-tube rake was used at various positions and depths behind the stator to obtain data on the stator-exit flow conditions. A review of the data failed to indicate the presence or influence of stator-blade wakes on total pressure at the stations measured. Also, the maximum flow coefficient obtainable was 0.80, while the design value was 0.90.</p> <p>On April 25, the pump was tested, assembled as on the previous run day. Angle actuators were used to obtain data on the stator-exit flow conditions in the hub, tip, and mainstream regions of flow at the lower flow coefficients. A liquid hydrogen leak at the railroad dewar (receiver) connection terminated the program before the higher flow coefficient survey could be made.</p> <p>The next run day is scheduled for May 8.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

MAY 1968

SITE	SITE NAME	RESEARCH INSTALLATION	&	DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p>	<p><u>PUMP - LH2</u> <u>YPF0553</u> (FSCD - PR Meng; RSD - D Cooksey)</p>		<p>Liquid hydrogen IV-stage axial pump studies.</p> <p>Two test runs were made during May:</p> <p>On May 7, five data passes were made with the inducer and fourth-stage rotor. Data were taken at five levels of Q/N, using angle actuators. All the requested data were obtained.</p> <p>On May 23, ten data passes were made with the pump in the same configuration as previously tested. Data were taken at six levels of Q/N at a reduced pump speed of 12,000 rpm. Angle actuators are continuing to obtain satisfactory stator performance results. All requested data were obtained.</p> <p>The next run is scheduled for June 4.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JUNE 1968

SITE	SITE NAME	RESEARCH INSTALLATION	& DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>PUMP - LH₂ YPF0553 (FSCD - PR Meng; RSD - D Cooksey)</p> <p>Four test runs were attempted during June:</p> <p>On June 4, the pump developed a leak through an "O" ring seal during the cool-down pass. The test was aborted.</p> <p>On June 12, four data passes were made. However, the Q/N control system was unstable during three of the passes. Usable data were obtained, using angle actuators, during one pass.</p> <p>On June 20, trouble developed in the NPSH control system during the first data pass. By the time the trouble was located and repaired it was too late to continue the test.</p> <p>On June 26, six data passes were made. Stator data were taken at six levels of Q/N with all five (5) angle actuators operating satisfactorily. All requested data were obtained. The test was completed and the facility was secured during the normal work day.</p> <p>The next run is scheduled for mid-July.</p>	<p>Liquid hydrogen IV-stage axial pump studies.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 JULY 1968

SITE	SITE NAME	RESEARCH INSTALLATION	& DESCRIPTION
A	LIQUID HYDROGEN PUMP SITE	<p>PUMP - LH₂ YON0553 (FSCD - PR Meng; RSD - D Cooksey)</p> <p>Two test runs were made during July:</p> <p>On July 10, six data passes were made. Stator data were taken at five levels of Q/N. Four of the five angle actuators operated satisfactorily. All requested data on the stator-exit flow conditions in the midstream region were obtained.</p> <p>On July 26, six data passes were made. Again stator data (exit flow conditions in the hub region) were taken at five levels of Q/H with all five angle actuators operating satisfactorily. All requested data were obtained.</p> <p>After an analysis of the data, it was determined that the remainder of the program could be completed in two run days. The next run is scheduled for the week of August 12.</p>	<p>Liquid hydrogen IV-stage axial pump studies.</p>

SECTION II

PLUM BROOK ROCKET SYSTEMS DIVISION

TEST OPERATIONS REPORT

FOR THE MONTH OF

AUGUST 1968

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p>PUMP - LH₂ YON0553 (FSCD - PR Meng; RSD - D Cooksey)</p> <p>Liquid hydrogen IV-stage axial pump studies.</p> <p>One test run was made during August:</p> <p>On August 15, three data passes were made. Stator data were taken at five levels of Q/N. However, a review of the playback data indicated only two of the five angle actuators were operating satisfactorily. One actuator was reading zero angle consistently even though the ΔP was changing. One actuator was not operational. One actuator was reading reverse because of wrong polarity. A severe lightning storm had damaged some components of the actuators and even though repairs had been made additional damage continues to reveal itself. The test was terminated due to insufficient quantity and quality of angle data. This test will have to be repeated.</p> <p>The next scheduled run is for the week of September 2.</p>

SECTION II
 PLUM BROOK ROCKET SYSTEMS DIVISION
 TEST OPERATIONS REPORT
 FOR THE MONTH OF
 SEPTEMBER 1968

SITE	SITE NAME RESEARCH INSTALLATION & DESCRIPTION
A	<p>LIQUID HYDROGEN PUMP SITE</p> <p> <u>PUMP - LH₂</u> YON0553 (FSCD - PR Meng; RSD - D Cooksey) </p> <p>Liquid hydrogen IV-stage axial pump studies.</p> <p> On September 12, eight data passes were made. Stator data were taken at five levels of Q/N. All five angle actuators were operating with a high degree of reliability and consistency. All requested data were obtained on the research pump. This test run was the last of the current research program. The data obtained from the completed test series should provide valuable information in the study of axial flow hydrogen pumps. </p> <p> At the present time no further tests are planned for this facility. The Cleveland Fluid System Components Division has requested that the facility and research hardware be kept in a "hold" condition whereby it could be readied for operation in a thirty-day period. </p>