of the pump suction and discharge lines.

d. "D" Site - Turbine Test Facility:

Operations have been limited to cold flow tests to investigate control problems and to a hot check of the gas generator. Results of these tests indicated that certain of the control valves and systems had to be modified and these changes are now being made.

e. "E" Site - Dynamics Laboratory:

Twenty-Nine research runs were completed between February and July of 1962 to support the MECA program, the SCOUT program and the Ranger payload systems as well as others.

f. "F" Site - Hydrogen Flow Facility:

This site was not operational during the Fiscal Year except for shake out testing that required several modifications to the existing equipment.

g. "G" Site - Pilot Plant:

Test operation of the Liquid Hydrogen Pump continued until the end of September 1961. After that time a new pump was installed and one run was made in June 1962. The turbine test facility at the same site had twelve runs between November 1961 and January 1962 using the NERVA three stage turbine. In addition one run was made in June of the Hy-Nut Turbine using Nitrogen gas.

h. Central Control:

This facility operates as a central control and data acquisition facility for most of the test stands. It has been in operation throughout the year as required to meet the various runs scheduled. In addition a considerable amount of time has been spent in de-bugging the data acquisition and read-out gear in order to eliminate deficiencies that showed up as part of various test operations as well as to improve the capabilities of the installed systems.

i. "I" Site - Liquid Fluorine Pump Laboratory:

During the past year this newly completed facility has been going through various check runs using gas helium and liquid nitrogen in order to "prove" the systems for use with liquid fluorine. Two liquid fluorine tests were conducted in March of 1962, one of which was considered successful. The second test resulted in partially destroying the test facility when a fluorine leak occurred in the equipment under test. The remainder of the fiscal year has been spent in rebuilding the facility for future fluorine tests.

PLUM BROOK STATUS REPORT (continued)

| | | | |
|---|---|---|---|
| 4 | TURBINE<br>"D" Site | F5B | Three stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application |
| | 8 STAGE TURBINE<br>"D" Site | 50601<br>(Pinkel) | Eight stage axial flow turbine for hydrogen propelled nuclear rocket application |

STATUS: To date, "D" facility has been incapable of supporting the research project. This has been because of the lack of a suitable driving fluid supply to turn the turbines. Extensive testing in the Spring of 1962 proved the pneumatic controls far too slow to handle the hydrogen-oxygen gas generators. At this time, two major facility modifications were begun: (a) high capacity cold gas manifold was designed and put on contract; (b) a fast response hydraulic control system was designed to replace the slow pneumatic equipment. Both of these modifications are now in their final stages. Since both turbine rigs share much common equipment, the problems of checking them out are identical. The three stage turbine rig will be put into operation first. A step-by-step checkout of the fluid drive system torquemeter, gearbox, and dynamometer will be carried out. Once the checkouts are complete, turbine research utilizing cold hydrogen as working fluid, can be commenced. Checkout of the eight stage turbine system will be similar and will lag the three stage by approximately 6 to 8 weeks.

It is planned to have the hydrogen-oxygen gas generators in operating condition by the time the cold gas turbine mapping work is completed.

PLUM BROOK ROCKET SYSTEMS FACILITIES STATUS REPORT CONTINUED

| SITE | LABORATORY | RESEARCH INSTALLATION (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3 STAGE TURBINE<br>F5B (Pinkel) | Three stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |
| | | 8 STAGE TURBINE<br>50601 (Pinkel) | Eight stage axial flow turbine for hydrogen propelled nuclear rocket application. |
| | STATUS: | Work at "D" Site is proceeding on schedule. The new hydrogen manifold pressure control system has been completely checked out. The three stage turbine is partially assembled and is being installed in its running position. This turbine should be completely installed and ready to run March 12, 1963. | |

PLUM BROOK STATION ROCKET SYSTEMS FACILITY STATUS REPORT CONTINUED

| SITE | LABORATORY | RESEARCH INSTALLATION (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3 STAGE TURBINE F5B (Pinkel) | Three stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

STATUS: Note (A)- Due to difficulties with the 3 stage thrust balance system and difficulties with alignment, the 3 stage turbine run has been delayed.

The 3 stage turbine is in place and is being aligned to the gear box. Inlet piping is being modified. The 3 stage turbine requires a thrust balance device. During this report period, 3 non-rotating runs were made to check out the thrust balance device. It has not performed satisfactorily and will require substantial work.

(Continued on next page)

Note (B)- The instrument systems revisions will be done by contract and work will be scheduled to coincide with major configuration changes so that required operation interferences will be held to a minimum.

| | | | |
|---|---|---|---|
| | | Liquid Hydrogen Turbo Pump F5A (Pinkel) | Liquid Hydrogen turbo-pump tests to study impeller matching with centrifugal pump at speeds to 60,000 RPM. |

STATUS: Rotating test with liquid nitrogen was attempted on March 22, 1963. The pump shaft would not rotate and presumably froze or seized due to the low temperature. No data was obtained. Research gear will be inspected and if no extensive damage is found; a rotating run will be scheduled for the first or second week of April.

| | | | |
|---|---|---|---|
| D | | 8 STAGE TURBINE 50601 (Pinkel) | 8 stage axial flow turbine for hydrogen propelled nuclear rocket application. |

STATUS: Some weld cracking occurred during fabrication of the 8 stage turbine casing. It has been returned to Cleveland for repairs

| SITE | LABORATORY | RESEARCH INSTALLATION (FOR) | DESCRIPTION |
|---|---|---|---|
| April 1963 D | TURBINE | 3 STAGE TURBINE F5B (Pinkel) | Three stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |
| | STATUS: | | Two nitrogen gas runs were made to check out the dynamometer. The turbine thrust balance could not be used for these runs because it was being modified. On the first run, the turbine was taken up to a speed of 5,800 RPM using pressure ratio to control the speed. After the turbine was running, unsuccessful attempts were made to control with the dynamometer.<br><br>After modifications were made to the dynamometer control circuit, another run was attempted. The results were the same. The run was then continued without dynamometer control and data was taken to determine the output of the dynamometer speed transducer with respect to speed.<br><br>On both of these runs, all attempts to control with the dynamometer resulted in almost complete stoppage of the turbine therefor the speed was limited to less than 6,000 RPM to prevent damage to the turbine.<br><br>On April 26 the Cleveland modified thrust balance system was returned to Plum Brook so additional runs are planned in May to check the non-rotating thrust balance device and the turbine will also be run to continue dynamometer control system check out. |
| | | 8 STAGE TURBINE 50601 (Pinkel) | Eight stage axial flow turbine for hydrogen propelled nuclear power applications. |
| | STATUS: | | Note (A) : Due to the late delivery of inlet housing from Cleveland and the rework required by our Machine Shop along with additional piping modifications the run schedule was changed from May to the end of June.<br><br>The gearbox is in the process of having bearing temperature thermocouples relocated for more accurate measurement. Modification of inlet piping to the turbine and assembly of the turbine is expected to be complete by the end of June |

PLUM BROOK ROCKET SYSTEMS DIVISION STATUS REPORT CONTINUED

| SITE | LABORATORY | RESEARCH INSTALLATION (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3 STAGE TURBINE F5B (Pinkel) | Three stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |
| | STATUS: | | Five nitrogen gas runs were made to check out the dynamometer. The turbine inlet pressure control valve malfunctioned in the first two runs. This malfunction was corrected and the valve functioned properly for the rest of the runs. Three more dynamometer control runs were made which resulted in substantial control progress. A limited degree of manual and automatic dynamometer control was obtained with turbine speeds up to 6600 RPM. A control circuit noise problem prevented accurate control. When this problem is solved, fine control of the dynamometer is expected.<br><br>Since the turbine thrust balance was being modified, these runs had to be made without a thrust balance. Several check out runs are planned during June to check the non-rotating thrust balance device and to continue dynamometer control system check out. |
| | | 8 STAGE TURBINE 50601 (Pinkel) | Eight stage axial flow turbine for hydrogen propelled nuclear power applications. |
| | STATUS: | | Installation of new gearbox bearing temperature thermocouples has been completed and the gearbox has been re-assembled. The turbine inlet housing was pressure checked and the turbine is being assembled. The first turbine check out run is expected by the end of June. The gas generator and fire valve controllers have arrived from Lewis and a check out of the fire valves and generator using gaseous nitrogen and liquid nitrogen is expected in June. |

June 1963

| SITE | LABORATORY | RESEARCH INSTALLATION (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3 STAGE TURBINE<br>0F0554(Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

STATUS: Two nitrogen gas runs were made to checkout the dynamometer. The noise in the control circuit was substantially reduced, and fine control of the dynamometer was obtained with turbine speeds up to 3000 RPM.
The non-rotating thrust balance device performed satisfactorily and plans are being made to modify the turbine so that it can operate with this type of thrust balance device.
A special adapter has been made to mate with the gas generator injector. This will permit the LOX and $H_2$ fire valves to be flow checked with nitrogen so that their control system can be checked out and adjusted under simulated operating conditions.

NOTE (A) : Due to the problems encountered in assembly, the first checkout run of the turbine has been re-scheduled for early August.

STATUS: During the initial buildup of the turbine, difficulty in centering the shaft was encountered. Machining of the pilot surface in the rear bearing housing and pinning of the power section appears to have corrected this problem. The turbine was completely assembled to determine whether there was any tip rub. No tip rub was found. The turbine is now being reassembled and all critical measurements are being taken.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | 3-STAGE TURBINE<br>OF0554 (Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |
| | | STATUS: Three gas generator checkout runs were made with nitrogen. Actual operation was simulated by the turbine back pressure valve. Liquid nitrogen was flowed on the first run, but the LOX fire valve could not be controlled. This was traced to a water hammer effect of the $LN_2$ in the lines. A surge tank was placed in the line and a second run was made similar to the first, but the water hammer was eliminated and the valve was controlled. On the third run, gaseous nitrogen and liquid nitrogen were flowed simultaneously and both the LOX fire valve and the $H_2$ fire valve were controlled. Additional runs are planned for August to perfect the control of the fire valve. | |
| | | 8-STAGE TURBINE<br>OF0554 (Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |
| | | STATUS: The turbine has been completely assembled and aligned and is awaiting installation of inlet piping and turbine by-pass valve system. Upon completion of the piping, the turbine will be ready for cold running and for further checking out of the dynamometer. | |

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | 3-STAGE TURBINE<br>0F0554 (Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |
| | | STATUS: Work on the 3-stage turbine has been stopped because all available manpower is being used on the 8-stage turbine. The work to be done on the 3-stage turbine involves the replacement of a bearing seal and a change in the thrust balance strain gage sensors. During the last run, the bearing seal leaked. Hence, the turbine will be taken apart when manpower is available and the research engineer will locate the trouble. At the same time, new thrust balance sensors that will allow longer running times than the ones presently used will be installed. | |
| | | NOTE (A) : Schedules had to be changed because of the reasons stated above in the Status report. | |
| | | 8-STAGE TURBINE<br>0F0554 (Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |
| | | STATUS: The installation of turbine inlet piping and by-pass valve system has been completed. The turbine oil system and thrust balance systems have been completed. The gear used on the speed pickup was re-designed upon request from instrumentation. Fitting the gear to the shaft caused a slight deformation of the shaft. The shaft could not be balanced; hence, a new gear is being fabricated with design changes. The turbine is scheduled for a cold run checkout on 9-12-63. Checkout runs are now being made to define the operation of the new hydraulic valve control system for the gas generator. Nitrogen checkout runs simulating actual operation will be continued until the response of the entire gas generator control system is defined. | |

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | 3-STAGE TURBINE<br>0F0554 (Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

STATUS: Due to use of available manpower on the 8-Stage turbine, no work was accomplished on the 3-stage turbine during this report period. During October, the turbine will be disassembled and the bearing seals and thrust balance strain gage sensor will be repaired.

| | | |
|---|---|---|
| | 8-STAGE TURBINE<br>0F0554 (Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |

STATUS: The turbine and dynometer were checked out at speeds up to 10,000 RPM and at pressure ratios up to 5:1. Checkout runs will be made in October to improve the operation of the hydraulic exit pressure control valves. Nitrogen checkout runs, simulating actual operation of the gas generator have been completed, and the LOX system is now being disassembled to permit cleaning. While the LOX system is being cleaned, the fluorine start system will be completed and modifications to the control panel and timer system will be made.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | 3-STAGE TURBINE<br>OF0554(Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

STATUS: The three-stage gas generator, which has been removed for testing of the eight-stage unit, has been reinstalled.

A flexible section for the turbine exit pipe has been received, and has to be installed.

The parts of the gas generator fluorine start system have been received, and the system is near completion.

Due to the demands on manpower of the gas generator and eight-stage turbine, no work was accomplished on the three-stage turbine thrust balance system this month.

See eight-stage turbine status for LOX system, instrumentation, and electrical status.

| | | |
|---|---|---|
| | 8-STAGE TURBINE<br>OF0554 (Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |

STATUS: The original facility hydrogen system is being used for the new Liquid Oxygen system. This necessitates thorough cleaning. In order to LOX clean the system, some pipes had to be cut and flanged, and some minor modifications are being made to the piping.

The flexible section for the turbine exit piping has been received, and is being installed.

The exit control valve checkout runs planned for October were cancelled because of mechanical problems with the link-

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | | 8-STAGE TURBINE (cont) | |

age and valve stem galling which caused considerable delay. These difficulties have been rectified and valve control simulation tests are nearing completion.

Because of the many changes in piping at "D" Site. the "H" Building graphic panel had to be altered. A new graphic panel has been completed and installed. The wiring for the graphic is being installed. Four Watson controllers for the gas generator fire valves areon order. The wiring for these controllers has to be installed. All necessary parts have been received for the gas generator timing system change to allow completely timed sequence start up, run, and shut down. Switches for auxiliary equipment, new relay meters, annunciator, and lights are being changed and relocated to conform with DPI 63-038, (Control Panel Layout and Hardware Standardization). Instrumentation work needed for hot gas runs, and a new scanning system have to be installed.

Contracts will be placed in November for a large portion of the electrical wiring and the instrument scanning system. The completion date of all the above-mentioned work is December 31, 1963. Gas generator runs and cold turbine runs are planned for January and February. A complete hot gas turbine data run is planned for March 1963.

NOTE Ⓐ: The October eight-stage exit valve checkout run was cancelled and no runs are scheduled for November or December due to reasons stated in Status Report.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FCR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 8-STAGE TURBINE<br>OFO-554(Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |

STATUS: During minor modifications of the Liquid Oxygen system the vacuum jacket was damaged. This damage has to be repaired before further Liquid Oxygen piping is installed.

The following work was done during the month of November:

1. The flexible turbine exit section was installed.
2. Work on the fluorine start system was started.
3. In preparation for the wiring changes outlined in October's status report, old wiring at "H" Building that will not be used was removed, and wiring to the Liquid Nitrogen and old LOX systems was removed.
4. It was decided to replace the exit pressure control valves with NASA designed valves. The original valves have been plagued with mechanical problems caused by linkage alignment and stem galling.
5. Contracts were placed for a portion of the electrical wiring.

The following work is planned for December:

1. Wiring for the graphic panel is to be installed.
2. Wiring for the new Watson controllers is to be installed.
3. The Gas Generator timing system is to be installed.
4. Switch and meter changes and relocations are to be made.
5. Instrumentation needed for the research runs will be installed.
6. Instrument scanning system will be installed.
7. Wiring for the relocation of the exit pressure and dynamometer controllers will be installed.
8. The control amplifiers for the turbine exit pressure control valves are to be relocated, which is required for the NASA designed valves.
9. Place the contracts for instrument scanning system and controller wiring.

The completion date of the above mentioned work is December 31, 1963. Gas Generator runs and cold turbine runs are planned for January and February. A complete hot gas turbine data run is planned for March 1963. The above dates may be delayed due to placement of contracts previously specified and new contracts for items held up because of the CENTAUR installation emphasis at 'F' Site.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3-STAGE TURBINE<br>OFO-554 (Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

STATUS: The following was done during the month of November:

1. The flexible turbine exit section was installed.
2. Work on the fluorine start system was continued.
3. In order that modification can be made to the thrust balance system, the 3-stage turbine was disassembled, packaged, and sent to Lewis, along with the thrust balance simulator.
4. New electrical and instrument wiring was installed in the 3-stage generator room to eliminate potential fire hazard conditions.

See the eight-stage turbine status for Liquid Oxygen System, Instrumentation, and electrical status.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |

3-STAGE TURBINE

OFO-554(Pinkel)

Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application.

STATUS: The three stage turbine is at Lewis for thrust balance modification, and is expected back during February.

The following work was done during December:

(1) The fluorine start system was finished.

(2) The gear box was disassembled and the bearings were instrumented.

The following is necessary to perform research runs with the 3-Stage turbine:

(1) Reinstall turbine after Lewis modification work is finished.
(2) Re-assemble and align the gear box.
(3) Check-out run (cold).
(4) Thrust balance system research and check-out.
(5) See 8-stage report for gas generator work.

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8-STAGE TURBINE

OFO-554(Pinkel)

Eight-stage axial flow turbine for hydrogen propelled nuclear power applications.

STATUS: The following work was done during the month of December:

(1) The gas generator installation was started and is 50% complete.

(2) The contracted portion of the electrical wiring at "H" Building was completed.

(3) The new NASA hydraulic valves, to replace the old exit pressure (2") control valves, were checked at the Combined Shop.

(4) The damage to the liquid oxygen system was repaired.

(5) Work was started on NASA-installed electrical wiring of valves and timers at "H" Building, and is scheduled to be done by the middle of January.

(6) Work was started on meter changes and relocation. This is scheduled to be finished by January 10, 1964.

(Continued on Page 17)

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | | 8-STAGE TURBINE (continued) | |

The following work is necessary before the gas generators can be checked out:

(1) The NASA-installed electrical wiring of valves and timers.

(2) Meter changes and relocation.

(3) Graphic panel wiring.

(4) Instrumentation of Venturis.

(5) Wire the new Watson controllers.

The following work is becessary before the turbines can be checked out:

(6) Complete all work necessary for gas generator checkout.

(7) Installation of research instrumentation.

(8) Relocation of the exist pressure and dynamometer controllers. (By contract)

(9) Relocation of the amplifiers for the turbine exit pressure control valves. (By contract)

(10) Instrument scanning system. (By contract)

Checkout of the gas generator system and cold gas turbine runs are scheduled for January and February. A shortage of Plum Brook manpower resulting from emphasis placed on CENTAUR work at "E" and "F" sites has resulted in a contract for completion of Items 8, 9, and 10 indicated above. Contract lead time may preclude meeting target date for hot gas turbine data runs currently scheduled for March 1964.

| | | | |
|---|---|---|---|
| E | DYNAMICS LABORATORY | CENTAUR (OVO-687) (D.S.Gabriel) | Static and dynamics test for Atlas Centaur vehicle. |

STATUS: As the reporting period opened final items in the flight type LOX duct installation were being completed, and on December 6, 1963, a rerun of Test #6 in the longitudinal dynamics series was completed. Test #6 was repeated to check the effects of both the LOX duct change and the removal of the XX Axis balance longerons.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | GAS GENERATORS (For 3 & 8-Stage Turbines) | Gaseous hydrogen and liquid oxygen gas generators with fluorine start systems. |

STATUS: The following work was done during January on the three and eight-stage gas generators:

1. The NASA-installed electrical wiring of valves and timers was completed.

2. Meter changes and relocations were completed.

3. Graphic panel was wired.

4. Three of the six required Watson Controllers were modified and installed.

5. The 3-stage gas generator was checked out using liquid and gaseous nitrogen.
valves.

5. Final pressure checking of hydrogen systems.

6. Final checkout of thrust balance system.

NOTE (B): A re-evaluation of the test schedule indicates that $1\frac{1}{2}$ runs per month will be maximum possible since there will be conflicts with the Boiling Fluids Rig which is in the same building. The next run is scheduled for February 24.

The following work is required before the gas generators can be used to power the turbine for research data:

1. Continue checkout runs on the three-stage gas generator until time sequence and the controllers operate in such a manner as to justify a hot hydrogen run.

2. Make hot hydrogen runs with the 3-stage gas generator.

3. Finish installation of the 8-stage gas generator and fluorine start system.

4. Make cold runs with 8-stage gas generator.

5. Install the research instrumentation for 8-stage turbine.

6. Finish the relocation of the exit pressure and dynamometer controllers.

7. Relocate the amplifiers for the turbine exit pressure control valves.

8. Install instrument scanning system.

9. Install new annunciator, fire alarm, and gas detection panels.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | (Continued) | 3-STAGE TURBINE OF0554 (Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

STATUS: The gearbox was reassembled during January and modifications to the thrust balance were proceeding at Lewis and are scheduled to be completed in February.

The following items must be completed before research runs can be started:

1. Complete thrust balance modifications and reinstall turbine.

2. Align the gearbox.

3. Make successful cold checkout run.

4. Complete thrust balance system research and checkout runs.

NOTE Ⓐ: The operation schedule includes runs for thrust balance investigation.

NOTE Ⓑ: Both the 3 and the 8 stage gas generators will be checked out and run hot during this period. (January, February, and March).

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8-STAGE TURBINE OF0554 (Pinkel) — Eight-stage axial flow turbine for hydrogen propelled nuclear power applications.

STATUS: The following work was done during the month of January:

1. The thrust balance system necessary for a hot gas research run was installed.

2. The pressure regulating equipment for nitrogen to the seals was replaced.

3. Work was started on the relocation of the exit pressure and dynamometer controllers, and the contracted portion of this work was completed.

A checkout run will precede the hot turbine run which is scheduled for mid-March.

NOTE Ⓑ: Both the 3 and 8-stage gas generators will be checked out and run hot during this period. (January, February and March.)

NOTE Ⓒ: The turbine is scheduled to be checked out with nitrogen gas before hot runs.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | GAS GENERATORS (For 3 & 8-Stage Turbines) | Gaseous hydrogen and liquid oxygen gas generators with fluorine start systems. |

During February, twelve checkout runs were made. These runs achieved the following results:

(1) Controller adjustments were made to the hydrogen fire valve loop.

(2) The hydrogen upstream pressure control valve loop would only work with a greatly reduced Cv. With this smaller than design Cv, the gas generator running time is reduced to 90 seconds. Additional investigation is proceeding to make the loop stable with a larger Cv.

(3) Checkout runs indicate that the oxygen fire valve is stable. Runs will be made in early March to calibrate the O/F ratio system.

The 3-stage hot gas generator runs are planned for the week of March 16. At the same time, work at the automatic controls lab will be continued in order to solve the problems connected with the instability of the upstream pressure control system when used with a large Cv.

The following work is required before the gas generators can be used to power the turbine for research data:

(1) Complete cold checkout runs on the 3-stage gas generator until the controllers operate properly.

(2) Make hot hydrogen runs with the 3-stage gas generator. (Scheduled for March 16).

(3) Finish installation of the 8-stage gas generator and fluorine start system which is 80% complete and is scheduled to be completed the week of March 23.

(4) Make cold runs with 8-stage gas generator. Should be ready for checkout the week of March 25.

(5) Install the research instrumentation for 8-stage turbine

(6) Finish the relocation of exit pressure and dynanometer controllers.

(7) Relocate the amplifiers for the turbine exit pressure control valves.

(8) Reinstall annunciator, fire alarm, and gas detection panels.

NOTE Ⓐ: The run schedule was delayed 30 days because of additional time required to correct controller problems.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | | 3-STAGE TURBINE<br>OF0554 (Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

Modifications to the thrust balance were proceeding at Lewis and are scheduled to be completed in March. This delay was due to the discovery of ruined bearing oil passages. The following items must be completed before research runs can be started:

(1) Complete thrust balance modifications and reinstall turbine.

(2) Align the gearbox.

(3) Make successful cold checkout run.

(4) Complete thrust balance system research and checkout runs.

NOTE Ⓑ: The 3-stage turbine test schedule has been delaye two months. Site manpower is concentrating maximum effort toward the operation of the 8-stage turbine.

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| | | | |
|---|---|---|---|
| | | 8-STAGE TURBINE<br>OF0554 (Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |

The following items must be completed before research runs can be started:

(1) Checkout the pressure regulating equipment for nitrogen seals.

(2) Complete the relocation work of the exit pressure and dynamometer controllers.

A cold checkout run will be made the first of May to be followed by a hot run in mid-May.

NOTE Ⓒ: The run schedule was delayed 30 days due to gas generator control problems.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | GAS GENERATORS (For 3 & 8-Stage Turbines) | Gaseous hydrogen and liquid oxygen gas generators with fluorine start systems. |

During March, seven hot gas checkout runs were made with the 3-stage turbine gas generator. Subsequent to the first run, the injector was removed, inspected, and replaced and six additional hot gas checkout runs were completed.

The checkout runs indicated:

(1) Startup with fluorine is smooth and reliable.

(2) The valve in the turbine bypass line is smaller than desired.

(3) The trim in the upstream pressure.control valve is too small.

The following work is planned for April:

(1) Remove the upstream pressure control valve and replace with a special pressure regulator.

(2) Using cold nitrogen gas, check out the special pressure regulator.

(3) Run the gas generator for the 8-stage turbine to check its operating characteristics.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | 3-STAGE TURBINE<br>OF0554(I.I.Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |
| | | | Modifications to the thrust balance are proceeding at Lewis and are scheduled to be completed in April. The following items must be completed before research runs can be started:<br>(1) Complete thrust balance modifications and reinstall the turbine.<br>(2) Align the gear box.<br>(3) Make successful cold checkout run.<br>(4) Complete thrust balance system research and checkout runs.<br>(5) Install research instrumentation. |
| | | 8-STAGE TURBINE<br>OF0554(I.I.Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |
| | | | The following items must be completed before research runs can be started:<br>(1) Check out the nitrogen pressure regulating equipment.<br>(2) Complete the relocation work for the exit pressure and dynamometer controllers.<br>(3) Install the research instrumentation.<br>(4) Finish the installation of the operations instrumentation.<br>A cold checkout run will be made the first of May to be followed by a series of hot runs. |

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | GAS GENERATORS (For 3 & 8-Stage Turbines) | Gaseous hydrogen and liquid oxygen gas – generators with fluorine start systems. |

During April, the gas generator for the 8-stage turbine was checked out.

The data from the eight runs showed the following:

(1) It will be possible to ignite the generator while ramping chamber pressure up from 0 psi to 400 psi.

(2) A duration run in excess of two minutes showed the sustained high temperature performance of the generator can be maintained.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | 3-STAGE TURBINE<br>OF0554(I.I.Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

The 3-stage turbine is expected to arrive from Lewis by mid-May. The following items must be completed before a hot turbine run can be made:

(1) Check out thrust balance system.

(2) Align turbine to gearbox.

(3) Install research instrumentation.

(4) Check out dynamometer at speeds in excess of 15,000 RPM.

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|---|---|---|
| | 8-STAGE TURBINE<br>OF0554(I.I.Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |

On April 28, 5 successful exploratory data runs were made at pressure ratios of 3:1 to 10:1, using gaseous nitrogen with a maximum speed of 7500 RPM.

The following items must be completed before a hot turbine run can be made:

(1) Dynamometer checkout at turbine speeds above 20,000 RPM.

(2) Check out turbine gaseous nitrogen seal pressure system.

(3) Check out turbine exit pressure system.

(4) Complete installation of research instrumentation.

Hydrogen exploratory data runs at turbine speed in excess of 20,000 RPM are scheduled for mid-May.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3-STAGE TURBINE<br>OF0554 (I.I.Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

The 3-stage turbine has arrived from Lewis. The following items must be completed before a hot turbine run can be made:

(1) Assemble and install turbine.

(2) Align turbine to gearbox.

(3) Check out thrust balance system.

(4) Install research instrumentation.

(5) Mechanically check out the system at speeds in excess of 15,000 RPM.

NOTE Ⓐ: The delay in the testing schedule is due to the late delivery of the turbine.

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|---|---|---|
| | 8-STAGE TURBINE<br>OF0554 (I.I.Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |

During May, one successful exploratory data run was made using gaseous nitrogen with a maximum speed of 7,500 RPM. Exploratory data runs were attempted on May 29, using gaseous hydrogen. On the first attempt, a problem with the dynamometer speed control allowed the turbine to run away and reach a speed in excess of 30,000 RPM; however, the turbine ran smoothly and no mechanical difficulties were encountered. The second attempt was successful except that the speed instrumentation on the turbine was defective. The turbine ran smoothly and no mechanical difficulties were encountered. On the third attempt, the torque shaft between the turbine and the gearbox broke, allowing the turbine to accelerate, causing damage to the shaft and ball bearings, and the 8th stage rotor blades were damaged. The other seven rotors rubbed due to unbalance caused by the broken shaft, and some of the stator vanes were nicked at the outside diameter by the rotor tips. At least six weeks will be needed to rebuild the turbine. A more detailed investigation is underway to determine the cause of the failure.

NOTE Ⓑ: The delay in the test schedule was caused by the shaft failure discussed in the report.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3-STAGE TURBINE<br>OF0554 (I. I. Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

The thrust balance system is being checked out. Two runs were made during the report period. The test resulted in a gaulled valve shaft which was traced to a defective Markite pot in the control system. Results of testing are inconclusive and further tests are required.

The following items must be completed before a hot turbine run can be made:

(1) Completion of the turbine stator and rotor assembly.

(2) Alignment gearbox to dynamometer.

(3) Alignment turbine to gearbox.

(4) Completion of thrust balance system checkout.

(5) Installation of research instrumentation.

(6) Installation of operations instrumentation.

(7) Checkout of hydrogen pressure regulating equipment.

A cold checkout run using gaseous nitrogen will be made in mid-July followed by a series of hot runs.

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|---|---|---|---|
| | | 8-STAGE TURBINE<br>OF0554 (I. I. Pinkel) | Eight-stage axial flow turbine for hydrogen propelled nuclear power applications. |

Detailed inspection of turbine stators and rotors following last month's failure indicated that it was not feasible to repair the turbine. Lewis research personnel decided to cancel the program. The turbine parts were shipped to Lewis for storage.

The facility has no additional program scheduled.

NOTE (A): Research program cancelled.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |

3-STAGE TURBINE
PF0554 (I.I.Pinkel)

Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application.

During July, the following were completed:

(1) The turbine stator and rotor assembly was completed.

(2) The gear box was aligned to the dynamometer.

(3) The turbine was aligned to gear box.

(4) The thrust balance was checked out.

(5) The research instruments were installed.

(6) The operations instruments were installed.

(7) One hydrogen regulator was checked out, and a partial check out was made of another hydrogen regulator.

On July 31, the turbine was power with nitrogen gas. The purpose of this run was to check vibration. The turbine was run at a maximum speed of 3,000 RPM and there were no vibration problems. Additional cold runs will be made in August followed by a series of hot gas turbine runs using the gas generator.

A four week delay in the operations schedule was required due to unforseen difficulties in the turbine alignment and because of the additional time required to make the thrust balance check outs.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | 3-STAGE TURBINE<br>PF0554(I.I.Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

During August, two turbine cold gas checkout runs and one gas generator checkout run were made. These runs were made to check out controls and instrumentation. It was determined from these runs that the output from the thrust measuring strain gages in the turbine was different than the output of identical strain gages used in the thrust balance simulator.

The reason for the difference between the output of the strain gages in the turbine and the output of identical strain gages in the thrust balance simulator will have to be determined before turbine runs can be made at high speeds. This is because the thrust balance control system used on the turbine was developed and checked out using the thrust balance simulator, and this thrust balance control system will not function properly if the output from the thrust measuring strain gages used in the turbine is not identical to the output of identical thrust measuring strain gages used in the thrust balance simulator.

The following is planned for September:

(1) An investigation into the lack of similarity between the output of the strain gages used in the turbine and the output of identical strain gages used in the turbine and the output of identical strain gages used in the thrust balance simulator.

(2) A hot gas generator and turbine run to determine the characteristics of the turbine when it gets hot. This run will be made without the thrust balance system, and without the turbine rotors.

NOTE: The test schedule start date has been rescheduled from August to November because of the reasons listed above.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3-STAGE TURBINE<br>PF0554(I.I.Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

During September, an investigation was made into the lack of similarity between the output of the strain gages used in the turbine and the output of identical strain gages used in the thrust balance simulator. The results of this investigation are reported in "A Study of the Three Stage Thrust Balance System" by R. E. Pampe and W. E.Kirchmeier dated September 22, 1964.

On September 8, 1964, hot gas at design temperature (1400°F) was passed through the three stage turbine (without stators or rotors). An inspection of the turbine after this test disclosed that the stator housing, the exist diffuser, and possibly the bearing housing warped from the heat. It was also determined that the seal between the stator housing and the inlet housing was faulty because an instrument passage interfered with the pressure on the "O" ring seal.

The present condition of the turbine requires that it be sent to Lewis for a complete re-evaluation of the original design and fabrication.

NOTE: The test schedule start date has been rescheduled from November to May to allow time to correct the problems discussed above.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |
| | | 3-STAGE TURBINE<br>PF0554 (I.I.Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

At a meeting held October 12, 1964, the machine design section agreed to do the following:

1. Redesign the stator housing and the bearing housing.
2. Check the design of the torque shaft.
3. Write the balancing specifications for the turbine shaft and the torque shaft.

Plum Brook personnel agreed to do the following:

1. Disassemble the turbine and send the parts to Lewis for redesign and modification.
2. Obtain the necessary hardware to assemble the turbine.
3. Evaluate the size of the gas generator needed to run the turbine at the latest operating conditions.
4. Adjust the pilots on the sixteen inch burnoff to facilitate ignition.
5. Modify the turbine inlet pipe supports.

The following work has been completed:

1. The turbine has been disassembled and certain parts have been sent to Lewis for re-evaluation of clearances and for balancing.
2. An investigation into the gas generator size revealed that the gas generator from the eight-stage turbine meets the latest operating requirements for the three-stage turbine.
3. The eight-stage gas generator has been installed in place of the three-stage gas generator.
4. The $H_2$ Venturi, the LOX Venturi, and the control valves needed for the new gas generator have been installed.
5. The turbine inlet pipe supports have been modified.
6. The stator housing has been redesigned from two half sections to a one piece housing.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3-STAGE TURBINE<br>PF0554(I. I. Pinkel) | Three-stage axial flow turbine designed for 100,000 pound thrust hydrogen-oxygen rocket application. |

The following work was accomplished during November:

(1) The turbine plenum was pressurized and checked for growth and leaks. (One leak was found.)

(2) The turbine was removed so that the leak could be fixed.

(3) The gas generator was pressure checked.

(4) The exit pressure valve was operated successfully on cold nitrogen gas.

(5) The input and output shafts of the gearbox were sent to Lewis for balancing.

(6) The 16-inch burnoff pilots were adjusted and checked.

The following work was completed at Lewis during November:

(1) Prints were completed for the torque meter adapter, the reworked torque shaft, the turbine case, and the bearing housing.

(2) Material was received for the turbine case.

(3) The turbine clearances were re-calculated and checked.

The following site work has to be completed before the turbine can be operated:

(1) The turbine plenum leak has to be fixed.

(2) The gas generator has to be run and a check made on the exit pressure valve.

(3) The gear box has to be reassembled and aligned to the dynamometer.

(4) The turbine has to be assembled, installed, and aligned to the gear box, then pressure checked.

The following has to be completed at Lewis:

(1) The gear box shafts, the turbine shaft and rotors, and the torque shafts have to be balanced.

(2) A new turbine case has to be fabricated.

(3) The exit diffuser and the torque shaft have to be reworked.

(4) New ends have to be fabricated for the torque shaft and the shaft has to be recalibrated.

(5) A new bearing support has to be fabricated.

NOTE: Due to the presently estimated shop completion dates, the run date has been extended three months.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |

3-STAGE TURBINE
PF0554 (I. I. Pinkel)

Three-stage axial flow turbine designed for 100 000 pound thrust hydrogen-oxygen rocket application.

The following work was accomplished during December:

(1) The gas generator was run under simulated conditions equal to those that would be encountered with the turbine.

(2) The exit pressure valves were checked out.

(3) The gear box was reassembled.

The following work was completed at Lewis Research Center:

(1) The gear box shafts, the turbine shaft and rotors were balanced.

(2) A new turbine case was fabricated.

(3) The exist diffuser was reworked.

(4) The torque shaft was reworked and new ends were fabricated.

(5) A new bearing support was fabricated.

The following work has to be completed before the turbine can be operated:

(1) The gear box has to be aligned to the Dynamometer.

(2) The turbine has to be assembled, installed, and aligned to the gear box, then pressure checked.

(3) The torque shafts have to be calibrated and balanced at Lewis.

NOTE: A cold gas turbine run is scheduled for the week of January 25. If this vibration test is successful, hot gas tests will be run in February.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |

3-STAGE TURBINE
PF0554 (I. I. Pinkel)

Three-stage axial flow turbine designed for 100 000 pound thrust hydrogen-oxygen rocket application.

The following work was accomplished during January:

(1) The gear box was aligned to the dynamometer.

(2) The torque shafts were calibrated and balanced at Lewis.

(3) The turbine was installed, assembled and pressure checked.

After the turbine was pressure checked, the first stage rotor rubbed against the first stage nozzle. An investigation revealed that this condition was caused by a broken weld on the turbine plenum. In order to repair the turbine and to insure against future failure, a slight design modification had to be made.

An inspection of the eight stage turbine dynamometer revealed that the bearings had started to fail after less than five hours of running time. The bearings were burnished in the area adjacent to an axial groove at the bottom of the bearing therefore replacement bearings were installed without grooves. The three stage turbine dynamometer will be replaced by this repaired unit.

The following work has to be completed before the turbine can be operated:

(1) Replace the present dynamometer with the newly rebuilt dynamometer.

(2) Rework and modify the turbine in the Lewis shops.

(3) Assemble, install, align and pressure check the turbine.

NOTE: The test program start date has been rescheduled from February to March to allow time to repair the broken weld on the turbine plenum.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | | |

3-STAGE TURBINE
PF0554 (I. I. Pinkel)

Three-stage axial flow turbine designed for 100 000 pound thrust hydrogen-oxygen rocket application.

The following work was accomplished during February:

(1) The dynamometer rotor journals were ground.

(2) Two dynamometers were sent to Lewis, and the newly rebuilt dynamometer was placed on the test stand.

(3) The gear box was disassembled, and the thrust bearing clearance was increased to allow operation at a higher temperature.

(4) A broken weld on the turbine plenum was repaired and the bearing support was modified at the Lewis shops.

(5) The turbine shaft was replaced.

The following items have to be completed before the turbine can be operated:

(1) Reassemble, install, align and pressure check the turbine.

(2) Reassemble, install, and align the gear box.

(3) Install the turbine instrumentation.

NOTE: The turbine is now scheduled to run in March and the test program is scheduled to be completed by July.

| SITE | LABORATORY | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE | 3-STAGE TURBINE<br>PF0554 (I.I. Pinkel) | Three-stage axial flow turbine designed for 100 000 pound thrust hydrogen-oxygen rocket application. |

The following work was accomplished during March:

(1) The gearbox was reassembled, installed, and aligned.

(2) The turbine was reassembled, installed, aligned, pressure checked and instrumented.

(3) The turbine was operated with cold nitrogen gas on March 18 and on March 19, to check its vibration characteristics. Its vibration was much higher than expected.

(4) The turbine was disassembled and an inspection disclosed a tip rub caused by an out-of-balance condition.

(5) The turbine shaft and wheels were rebalanced and the turbine was reassembled and pressure checked.

(6) The turbine was again operated on March 22, 23 and 26 to check the turbine vibration and the dynamometer control. The turbine was operated in cold gas to speeds of 26 000 rpm.

A hot gas run is scheduled for early April. The vibration runs of March 22, 23 and 26 will determine the test speeds.

| SITE | LOCATION | RESEARCH INSTALLATIONS (FOR) | DESCRIPTION |
|---|---|---|---|
| D | TURBINE SITE | 3-STAGE TURBINE<br>PF0554 (I.I.Pinkel) | Three-stage axial flow turbine designed for 100 000 pound thrust hydrogen-oxygen rocket application.<br><br>On April 9 the three stage turbine was tested with hot exhaust gas for the gas generator. After 57 seconds of operation an acceleration shut down device caused an emergency shut down. An examination of the turbine disclosed that the turbine ball (thrust) bearing failed, and that the turbine was damaged beyond reasonable repair.<br><br>At the present time, no new research program has been formulated. |

| SITE | LOCATION | RESEARCH INSTALLATION & DESCRIPTION |
|---|---|---|
| D | TURBINE SITE | 3-STAGE TURBINE PF0554(I.I. Pinkel) — Three-stage axial flow turbine designed for 100 000 pound thrust hydrogen-oxygen rocket application. |
| | | All research projects at this site have been terminated; therefore, "D" Site reports will be deleted from the monthly status report. |