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LRP INPUT
FOR THE
COLD FLOW DEVELOPMENT TEST SYSTEM
TEST PROGRAM PLAN
10 September 1963

E.L. Odgers

MASTER

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I. INTRODUCTION

The introduction to the Test Program Plan is to be provided by Department 737 of REON and will include the historical background leading up to the development work that is to be accomplished by this test program.

II. SCOPE

To be written by Department 737.

III. TEST OBJECTIVES

A. General Objectives

Five general objectives of the CFDTS have been established and are listed in the Equipment Specification AGC 10138B (See Appendix B).

They are repeated below:

The primary test objectives are:

1. To verify the control functions and startup sequence of operations previously determined by transient analysis of a mathematical model.
2. To evaluate flow characteristics of an unfueled nuclear engine system to determine chilldown time, temperatures, flow rates and pressure drop data throughout the system.

The secondary test objectives are:

3. To test functionally an unfueled nuclear engine assembly and its components as an integrated system to evaluate potential thermal shock problems, operational characteristics and other phenomena associated with the starting transient.
4. To develop a reliable startup procedure for the engine system.
5. To evaluate the effect of tank pressure, turbine power control valve setting and diluent valve setting on engine startup performance.
6. To demonstrate the bootstrapping capability of the system.

7. To aid in the development of assembly and fabrication techniques for the engine program.
8. To aid in the development of procedures for Engine Non-Nuclear Acceptance Testing (ENNAT).
9. To test the functioning of radiation hardened instrumentation in an engine system.
10. To develop techniques for instrumentation and test data accumulation.
11. To test the functioning of various components and determine the effect of any component modifications in an engine system.

B. Discussion of General Objectives

1. The control functions and startup sequence of operations have been analysed for the A J 30-5 Series, Block I Engine (See Appendix E). Since the CFDTS is a full scale version of this engine, but with nonfissionable fuel elements, the first primary objective is related to the extremely important task of determining the proper startup procedure for the engine system prior to the inclusion of active fuel elements. The mathematical model that has been set up to represent the various startup conditions and parameters will be verified and modified as required and to accurately predict engine operation. The development of a reliable computer code to simulate system performance is essential to the isolation, understanding and interpretation of non-nuclear start transient phenomena. Such a code can be used to predict the start characteristics of engines with active fuel elements. During the operation of a nuclear engine, the code may be used to determine which phenomena are the result of nuclear or non-nuclear operation. Knowing the sources

of phenomena, any necessary corrective action can be more easily accomplished.

2. The study of start transient and reactor chill-down flows, pressures and temperatures must be made in order to determine the heat transfer coefficients and pressures losses throughout the system for the prediction of start-up performance in a nuclear engine. The heat transfer coefficients thus determined for the reactor core, shield, reflectors and other system components will also be of use in the prediction and verification of the heat transfer coefficients in the hot firing of a nuclear core.

3. Individual components may be exhaustively tested and proved, but perform differently than expected once assembled in a system, possibly because of the influence of associated components or for some other unpredictable reason. Consequently, it is essential that the startup of a nuclear engine system be thoroughly investigated and understood and that the fuel supply system be perfected before operation of the engine with an active reactor assembly.

4. With the series of tests planned for the CFETS it will be possible to develop an optimum and reliable startup procedure for the engine system.

5. In determining the optimum mode of engine startup, it will be necessary to evaluate the effect of the propellant tank pressure, the turbine power control valve setting and the diluent valve setting.

6. With the variation of the parameters mentioned in objective (5), it should be possible to determine under what conditions bootstrapping is marginal and under what conditions it will occur with a satisfactory operational safety factor. Desirable component modifications, if any, will become obvious and their effects can be ascertained.

7. The building of the CFDTS will inevitably contribute greatly to the development of fabrication, assembly and handling techniques helpful for nuclear engine systems.
8. The CFDTS will serve as a basis for the development of procedures for the acceptance of non-nuclear components and the establishment and verification of reactor-pressure vessel interface requirements between WANL and LRP.
9. The functioning of radiation hardened instrumentation and controls can be correlated with the operation of standard units. This information could be used as a check or calibration method in comparing the performance of the radiation hardened instruments and controls on a nuclear engine.
10. Techniques developed with CFDTS instrumentation installation, ^{data} test data accumulation, reduction and code analysis will be helpful in the instrumenting of other NERVA engines.
11. The CFDTS can be used as a test bed for various system components as they become available such as advance models of TPA, different diluent injection systems, valves, controls, instruments, nozzles, skirts and pressure vessel closures, to determine their effect on the start-transient and their optimum modes of operation in the system.

C. Individual Test Objectives

The individual test objectives (See Figure 1) and number of tests have been determined by a consideration of the parameters of interest and the minimum number of variations therein which will provide enough data to be able to evaluate the effect of varying an individual parameter and various combinations thereof, in order to determine the optimum mode of controls sequencing and operation for start-up. Detailed information on the determination of these test objectives, the number of tests required and results that can be obtained from this tests program are discussed in Appendix A, "LRP Statistical Test Plan for NERVA CFDTS".

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IV.

SYSTEM DESCRIPTION

A. Applicable Documents and Drawings

The following documents establish in detail the system to be tested and form a part of this test plan.

1. Documents

Document No.Title

a. AGC Spec. 10138B

Equipment Specification Development Test System, Cold Flow, for NERVA Hot Bleed Engine AJ 30-5.

b. Project Directives

No. 25D NERVA Security Classification (Dated 12-11-62).

No. 91B S/Task 1.01 Engine System Development.

c. No number assigned

Assembly and Disassembly Procedures

d. AGC Technical Memorandum No. 125 Rev. D

Revised Estimate of Instrumentation Accuracy for Performance Calculations.

e. AGC Report No. 2320

Instrumentation Data Book

f. CG-RK1

Joint Classification Guide; Nuclear Rocket Program dated 18 Sept. 1961.

g. Report 2469 Vol. II Rev. A

Quality Assurance Program Plan for NERVA Propulsion System.

h. No number assigned

Operational Support Plan.

i. Safety

Aerojet General Liquid Rocket Plant Test Division Safety Manual.

j. AGC Specification 42136/5

Component Spec, Thermocouples, General Spec for

2. Drawings

a. 299500-9

CFDTS Assembly (Includes Mechanical Interface with Test Stand).

b. 294130

Layout CFDTS

c. 294129

Schematic CFDTS

d. 702160

Instrumentation Location, CFDTS.

e. 701940

Radiation Hardened Instrumentation Kit Drawing, CFDTS.

f. No number assigned

Interface, Electrical LRP - Test Area.

g. No number assigned

Engine System Controls Interface.

h. By REON

CFDTS Engine Sequencer Schematic

i. No number assigned

Facilities Installation Drawings

j. By WANL

Instrumentation Location Drawing,
Reactor

B. Engine System

1. Overall Engine System Description

The engine to be used for this program will be that described by AGC Specification # 10138B, Cold Flow Development Test System, Appendix B, CFDTS Final Assembly Print #299500, Figure 2, CFDTS Layout Print #294130, Figure 3 and the CFDTS Basic Parts List, Appendix C.

Basically, this engine is to consist of all non-nuclear components of the engine system and will be provided with the same depleted fuel reactor as used in the NRX-A1 test series. The major components of the engine system will consist of the pressure vessel, nozzle with skirt, turbine and pump assembly, propellant feed lines, upper and lower thrust structures, a pneumatic actuation controls system and an engine sequencer system. The differences between the E-Engine and the Cold Flow Development Test System and a brief description of the major components are given in the following paragraphs.

2. Comparison Between the CFDTS and the E-Engine.

The non-nuclear components of the CFDTS will be identical to the E-Engine in all major respects. The minor variation between the design of the CFDTS and the E-Engine as described below are of such a nature that they will not effect the results of the tests, and the objectives of the test as described previously may be obtained and will be directly applicable to the E-Engine system.

The primary modification to the CFDTS as presently contemplated will be the utilization of the Mark IV Mod II Turbopump Assembly rather than the Mark III Mod III. However, this change will not be sufficiently gross to invalidate the information learned from the CFDTS. In fact, the test series will give realistic results in determining the effect on engine operation for a change of TPA.

Other minor changes to the system will be that the CFDTS will not require the use of an emergency cool down line in the test set-up. The engine controls system is not required to be as elaborate, being only those components as required for the conduct of the test. The upper thrust structure will not contain all of the instrumentation and controls connectors as will be required by the E-engine system. The TSOV by-pass line will not be used, and in its place will be installed a warm nitrogen purge system. Only a portion of the instrumentation installed on the CFDTS system will be of the radiation hardened type mounted in the same manner as it would be on the E-Engine system. There will be only two control rod actuators installed rather than the twelve required for the E-Engine. The remaining control rods will be installed without actuators. The CFDTS will not be provided with vernier roll control nozzles. However, the nozzles will be simulated with two flow nozzles installed in the TPA exhaust lines to maintain the back pressure on the TPA that would exist with the roll control nozzles.

3. Pressure Vessel Assembly

The pressure vessel (P/N 294063-9) consists of a forward closure and a cylinder. The closure portion is a 2:1 elliptical dome made from an aluminum forged pressing. It contains twelve instrumentation bosses and twelve control rod ports. However, there will only be two control rod actuators installed in this system. Unused parts will be capped off. The closure has an integral warman flange for attachment of the pressure vessel to the thrust structure.

The cylinder is welded together from three aluminum rolled ring forgings. The forward end of the cylinder is joined to the closure with high strength steel bolts. Sealing between the forward closure and cylinder is accomplished by the use of lead plated aluminum omega shaped seal. The aft flange of the pressure vessel contains 96 holes into which are installed helical insert to accept the bolts. Both the forward and aft closures are located by means of indexing pins.

4. Nozzle Assy (P/N 294900-9.)

The nozzle assembly has both a convergent and a divergent contour. The half angle of the convergence is 45° and the divergent half angle is 17.5° . The nozzle is regeneratively cooled and made up of stainless steel tube assemblies brazed in a longitudinal direction. Each assembly has one entrance and two exit tubes. A structural jacket of aluminum is cast around the brazed tube bundle assembly to which has been added wire interlocks used to improve the bond between the stainless steel tubes and cast aluminum.

The liquid hydrogen propellant from the propellant inlet feed line enters the nozzle assembly through a torus inlet manifold at the exit end of the nozzle. It then flows through the tube bundle to ^a plenum formed by the nozzle core support structure and the pressure vessel.

5. Thrust Structure Assembly (P/N 29046-9)

The thrust structure extends from the test stand engine interface to the pressure vessel and is divided into an upper and lower assembly by the gimbal joint.

The upper thrust structure consists of a truncated cone from the gimbal to the engine test stand interface, a clamp to mate the engine and test stand, a disconnect flange for pneumatic and electrical interfaces; the upper section of the pump suction line and the upper gimbal support structure.

The lower thrust structure consists of a truncated cone and cylinder from the joint between the cone and lower gimbal support structure to the pressure vessel interface.

The lower section of the pump and suction line ^{consists of} the lower gimbal support structure and the turbopump assembly. A more complete description of the TPA is given below.

6. Turbine and Pump Assembly (P/N 278000-59)

The turbopump assembly (TPA) for this series of tests shall be the Mark III Mod III and will consist of a centrifugal pump impeller including an

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inducer section coupled to a two stage turbine drive by a common shaft supported by hydrogen lubricated bearings. Liquid hydrogen propellant is supplied to the pump inlet. The turbine drive gas is bled from the thrust chamber, mixed with a diluent flow to cool it to the proper conditions and supplied to the turbine. The turbine exhaust exits from two ports of the exhaust manifold to the ejector system of the test area. The turbine is accelerated during the start up by using gas generated from the heat capacity of the engine components.

The turbopump assembly is so designed that it is capable of being installed and removed from the engine and disassembled by remote methods.

7. Propellant Feedline Assemblies (P/N 299080-9, 298606-9 and 700511-9).

The propellant feed line assembly consists of the turbine inlet line, the pump discharge line and the diluent line.

The turbine inlet line assembly carries the hydrogen heated by the reactor from the nozzle to the turbine inlet. In order to cool the gases from to permissible turbine inlet temperature, the reactor/diluent is taken from the forward dome of the pressure vessel and then passed through a jacket around the inlet line and injected into the inlet line at the hot bleed port on the nozzle.

The pump discharge line delivers the liquid hydrogen from the pump to a torus around the nozzle at the junction of the nozzle to skirt and also to a torus around the nozzle skirt.

8. Pneumatic Controls System

The pneumatic system will supply gaseous hydrogen as a working fluid for the engine system actuators. Test area will provide a filtered regulated supply of hydrogen to the engine pneumatic system at 200 psia and 530°R. The pneumatic system actuates the tank shut off valve, turbine power control valve, and the two drum actuators. During the test there will be sufficient gas bled off the dome of the pressure vessel to simulate actuating all twelve of the control drum actuators. The gas will then be dumped into the turbine exhaust ejector.

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9. Engine Sequencer

The engine sequencer will be designed and fabricated by REON. They, REON Dept. 737, shall be responsible for describing this system.

C. Test Facilities

All of the Cold Flow System Development Tests are to be conducted at the Aerojet-General, Liquid Rocket Plant Test Facility, H-5. This test complex consists primarily of a propellant supply system, an engine test stand, and an ejector system. An integral part of the system is the controls and data acquisition equipment. An isometric view of the test/ facility is given in Figure 4, and a flow diagram of that portion of the H-Area test system which will be utilized by the CFDTs is included in Figure 5. A brief description of the major facility components is given below:

1. Propellant Supply System

a. Main Run Tank

The main run tank for use in these tests will be V-H11. This tank has the capability of storing 105,000 gallons of liquid hydrogen at a pressure of 100 psi and a temperature of -423°F. In order to help maintain this temperature the tank itself is insulated with a vacuum jacket. The inner tank is supported by means of two load cells so that the weight of the hydrogen in the tank and the flow rate from the tank may be recorded during the tests.

A 36" diameter vortex breaker is installed just above the supply line exit at the bottom center of the inner tank. The line is 10" in diameter where it emerges from the inner

tank. However, it is reduced to an 8" diameter line before it emerges from the outer tank. After emerging from the main supply tank there is a "T"-section to supply the other test stands. None of the line inside the tank before the T-section is included in loss calculations, since it is considered to be an integral part of V-H11.

b. Run Tank to Propellant Line Assembly

The engine feed line supplying the liquid hydrogen from the run tank to the engine is designed to meet all the requirements of the line which is to be used at the Nevada Test Site for the E-Engine Test Series. This will be an eight inch line capable of passing up to the maximum design flow of liquid hydrogen with a maximum of 6 psi pressure drop.

Since Vessel V-H11 supplies the ^{H-Area} test stands, the first segment of the line is a T-section which drops straight into H-5, and directs flow to H-4 and H-6 in a horizontal line. This is followed by a Y-pattern glove valve and then by a 19 tube pin type flow straightener prior to entry into the turbine type flowmeter. To provide repeatability at widely varying flows, a 6" flowmeter incorporated in a suitably reduced insertable spool will be available to supplement the 8" flowmeter integral to the line. Below the flowmeter a baffle section incorporating a minimum of 2" thickness of lead shielding is provided to simulate line shielding in the region of the required ETS-1/ the 30" water shield. Following this section which is enlarged to achieve a minimum pressure loss through the lead shields, the line remains large. This

simulates, the RIFT tank bottom, permitting angular impingement on the TSOV at a minimum cost. The line is either vacuum jacketed or foam covered (at replaceable sections) to minimize heat transfer. Suitable venting and chillover bleed-in provisions are made.

2. Ejector System

In order to simulate the altitude start conditions with the engine system will see in actual operation, an ejector system composed of 2 stage ejectors will be used for this series of tests. One of these ejectors will be attached to the engine nozzle and the other to the turbine exhaust system. These ejectors are capable of reaching a "pull-down" pressure of 1 psia. However, the back pressure of the system itself will vary depending upon the flow rate of the engine system.

The ejector system is supplied from (3) 1300 cu. ft. N_2 tanks, manifolded together to provide a 3900 cu. ft. source at 5000 psig pressure and ambient temperature. From this, 81,900 lb of N_2 are available. Flowing at a maximum anticipated rate of 416 lb/sec (119 lb for turbine exhaust, 397 lb for main nozzle) this permits a run of 197 seconds. Since turbine exhaust evacuation is not likely to be continued after 20 seconds, and main nozzle demand may be cut back, the ejector N_2 requirements are more than adequately provided for.

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3. Control System

The controls system for the H-5 facility is completely independent from that of the instrumentation system except for the electrical ground which both systems use.

The power supply system for the controls function consists of two solid state, Perkins Power supply systems which takes the standard AC power and converts it to 28 volts DC. These units are capable of supply 200 amps each and since they are arranged in a parallel circuit the entire system is capable of supplying a total of 400 amps. As a back-up to this main power supply in the event of a power failure there is a system of batteries capable of supplying the necessary voltage and amperage for the duration of the test.

The power from the control room is supplied to a vector board and to an amp patch network both located in the area terminal room. The vector board is used to control the facilities and the propellant feed line system while the amp patch is used to control the engine sequence and the test hardware.

In order to determine the proper functioning of the facility and engine control valves remotely from the control room, the position of these valves is measured by means of microprocision switches and this information is indicated on the control panel by means of panel lights.

The timing of events for this facility is controlled by means of transistorized, solid state timing relays. However, it should be noted that the start-up for the engine will be controlled by means of the engine controls sequencer as described in Paragraph IV.B.9. of this test plan.

4. Data Acquisition System

The data acquisition system for H-Area consists primarily of transducers, a balance and calibration system, amplification and readout equipment and a computer system. A pictorial representation of the system available is given in Figure 6. A brief description of the equipment to be used for this series of tests is given below.

a. Instrumentation Channels

The following data acquisition channels are available in the H-5 facility for CFDTS.

<u>Channel Description</u>	<u>Available For Tests</u>	<u>Available For Facilities</u>
Strain Gage	105	24
RTT	84	6
TC/CC	120	5
TC/CA	18	0
TC/CuCup	18	0
Valve Trace	12	0
Flow & Speed	12	0
High Frequency	12	0

b. Data Recording Channels

The following data recording channels are available for the conduct of the CFDTS tests.

<u>Recording System</u>	<u>Channels Available</u>
Data Conversion System	
Low Level	96
High Level	92
Digital	4

<u>Recording System</u>	<u>Channels Available</u>
Low Level Digital System	192
Analog Magnetic Tape System	64
Oscilloscope	36
Strip Chart	52
Electronic Visual Gage	24

c. Data Readout Equipment

(1) Millisadic

The millisadic is an accurate, high speed, digital data processing system. It is capable of accepting inputs in the form of analog voltages, pulse width information or pulse train information. The output of this system takes the form of digital magnetic tape. This tape can then be utilized in a variety of applications, such as direct entry into the computer system, or it can be played into the tape card converter to generate punched cards which can then be used in computer, tabulations, X-Y plotters, etc. The main advantage of the millisadic is primarily its high speed of delivery and its accuracy.

The millisadic unit is divided into two ^{primary} systems, a 96 channel low level unit and a 92 channel high level unit plus four digital channels. The input signal to the high level channels is amplified prior to being submitted to the analog to digital converter and each signal is sampled at the rate of 38.2 samples per second. The low level system receives the output signal directly from the transducer without amplification and this signal is sampled at the rate of only 2.4 samples per second.

As a part of the data conversion system in conjunction with the Millisadic system is a 192 channel low level Beckman digital system. This system is basically like the Millisadic system. The primary difference is that it receives the direct, unamplified signal and samples it at a rate of 38.2 samples per second.

(2) Magnetic Tape

There are available 64 channels of magnetic tape data. This basically consists of FM and AM recording amplifiers, playback amplifiers, voltage regulators, tape transport and power supply. Its main advantage is that it can record and reproduce data over a large frequency range. This data can then be stored for an indefinite time or can be played back at a slower speed, i.e., expanded time scale, and recorded by other systems.

(3) Oscillograph

There is one thirty-six channel oscillograph available for this test. This graph is capable of giving a continuous recording of parameters up to the range of approximately 2000 cps. The system itself is not as accurate as the millisadic or the magnetic tape and is used primarily as a back-up for these other two data instruments.

(4) Strip Charts

The strip charts available for the tests are also continuous recording devices. However, they are slow response systems. They are used primarily for a visual indication of events as they occur during the test.

V OPERATION FLOW PLAN

A. Flow Chart

The operational flow plan is shown diagrammatically in Figure 7. This gives a representation of the flow of the hardware from the time it is received at AGC Sacramento until the Cold Flow Development Tests have been completed.

B. Flow Plan Description

A discussion of the block by block progression outlining the objectives and procedures for accomplishing each objective is given in Appendix D.

VI TEST DESCRIPTION

A. Pre-Test Analysis, CFDTs System

A pre-test analysis of the system has been completed and is included as Appendix E (to be provided by REON, Dept. 737). There will be a pre-test analysis of the system for each individual test run. The results of this analysis will be the basis for the test specification for the test so analysed.

B. Test Specification

The test specification shall contain all the detailed information necessary for the conduct of the test. This shall include, but not be limited to, the following items:

1. Introduction

This shall consist of a brief statement of the accomplishments of the test program to date.

2. Test Objectives

This section shall state the objectives to be accomplished by this particular test.

3. Pre-Test Analysis, Individual Test

The pre-test analysis will consist of the prediction of the performance of the major parameters for that particular test run. It shall be based upon the computer program of the system and upon the results of previous tests. This pre-test analysis shall be the responsibility of LRP, Sacramento.

4. Test Description

a. Procedures

The test specification shall include as a reference the detailed test procedures for the conduct of the test. It shall be the responsibility of the LRP Test Division to prepare these detailed procedures, however, they shall be coordinated with the NERVA Operations Section.

b. Instrumentation

An instrumentation list and an instrumentation location drawing shall be included in each test specification.

c. Photographic Coverage

Each test specification shall contain the requirements for still and movie coverage for that test.

d. Post-Operative Examination

The requirements for any post-operative examination of the system after each test shall be specified in the individual test specification.

e. Test Schedule

The test specification for that run shall state the latest scheduled date on which the test shall be conducted.

C. Individual Test Description

1. System Checkout Tests

The first three tests of this series are checkout of the system only. These tests are to be run under the most favorable conditions for achieving bootstrapping of the TPA, i.e., maximum tank pressure, TPCV open and the diluent valve closed. After each of the tests are completed a review of the proper procedures for achieving the desired results will be made. The instrumentation will be ranged and procedures modified if required.

2. System Tests

These will consist of a series of sixteen tests broken down into two groups of eight tests each. Each of these eight tests will have one of the combinations of tank pressure, TPCV setting and diluent valve setting obtainable. (See LRP Statistical Test Plan for NERVA CFDES, Appendix A). They are to be the primary data gathering tests of the series.

3. Verification Tests

At the conclusion of the sixteen systems tests the optimum conditions for starting the E-Engine will be determined. These conditions will then be used in the last three tests. Also at the conclusion of the system tests, the computer program will be refined sufficiently to give accurate predictions of the system performance and the last three tests will be used to verify this computer program.

D. Test Conditions

1. Location

The tests will be conducted at the Aerojet-General Liquid Rocket Plant, H-5 facility.

2. Altitude

All tests will be conducted using an exhaust ejector system in order to create a simulated altitude start condition. This system is capable of achieving an absolute pressure of approximately .3 psi, however, for the conduct of these tests a back pressure of 1 psi will be required at the time of the start of the test. The inlet pressure of the ^{ejector} will not be maintained constant throughout the entire run but will vary with hydrogen flow rate through the system.

3. Temperature

All tests will be conducted at ambient temperature conditions. However, the temperature of the system at the time of initiation of the test shall be $75^{\circ} \pm 10^{\circ}\text{F}$. This is to be accomplished by means of a nitrogen purge system.

E. Test Procedures

1. Engine Test Stand Installation

The engine system will be received at the test area in the following major subassemblies:

- a. Thrust Structure and Pressure Vessel Assembly
- b. Nozzle Assembly
- c. Propellant Feed Line Assemblies
- d. Skirt to Ejector Adapters

These will be assembled into the test stand and leak checked in accordance with the test stand installation print and in accordance with the Operations Support Plan.

F. Instrumentation Requirements

1. Instrumentation Philosophy

In order to accomplish the test objectives of the program as stated earlier, it is necessary to know the flow rate and temperature and pressure of the hydrogen throughout the system. The flow is determined by means of flow measuring devices at the inlet to the pump, the nozzle exhaust, and the turbine inlet and exhaust. The state of the fluid is determined at the inlet and outlet of the pump, into the nozzle tubes, into the reactor reflector, into the shield, into the core, into the engine nozzle and the turbine inlet line, and into and out of the turbine.

In order to insure that the data desired is obtained from these tests there is a sufficient degree of redundancy in the manner of measurements taken. This assures a high reliability of obtaining valid data from the tests.

This also permits a degree of dual ranging of the transducers in order to insure the highest degree of accuracy possible.

In those locations where temperature measurements are being taken, there are three transducers utilized in the same location. One of these, an RTT, will be ranged in the LH_2 temperatures for high accuracy, another RTT will be ranged to cover the temperature drop from ambient conditions to the temperatures of LH_2 . A third temperature measurement will be taken by means of a thermocouple. The purpose of this measurement will be to give fast response time for the temperature changes.

places in
There will be used at various places in the system three RTT's, three pressures and one differential pressure transducers of the NRX radiation hardened type mounted in the identical manner and ranged to the same values as will be used on the NRX-A2. The purpose of these transducers is to obtain start transient data on the NRX transducers so that it may then be compared to the actual NRX test run. This will also give data on the transducers as to the effect of the environment on them.

2. Transducers - Description

a. Pressure Transducers

Pressure transducers provided by AGC-LRP to acquire the absolute and differential pressure measurements will be of the strain gage type. These transducers require a 10 volt excitation to a 350 ohm bridge network and have a 30 millivolt output at full scale. The transducers will be calibrated by means of shunt calibration. The WANL provided transducers will be a strain gage type requiring 5 volt excitation to a 350 ohm impedance and Kistler dynamic pressure transducer Model 601.

There will be four pressure transducers of the NRX radiation hardened type. These are to be of the NRX-A2 design, ranged for a full scale "hot" firing.

b. Temperature Transducers

The temperature measuring devices to be used on these tests will be resistance temperature transmitters, thermocouple probes, and surface mounted thermocouples. In the system redundant RTT's will be used. Some will be ranged in the lower temperature region, i.e., LH_2 , to obtain as accurate reading as possible, and some will be ranged

over the entire anticipated temperature spread, i.e., ambient down to the LH_2 region. In order to determine the rapid changes in temperature, open element, immersion type copper/constantan thermocouple probes, as described in AGC Specification 42136/5 will be used. The temperature of the hardware surface itself will be taken several places throughout the system by means of copper/constantan and chromel-alumel thermocouples.

For additional information concerning the transducer requirements and specifications, see the Instrumentation Data Book.

c. Flow Measuring Devices

The flow into the pump will be measured by means of a turbine type flow meter. This is a volumetric flow measuring transducer with a digital signal output whose frequency (cps) is directly proportional to flow rate. Each pulse represents a discrete volume of flow. The output signal has a linear response to volumetric flow over the entire anticipated flow range.

The flow into the turbine will be measured by means of an orifice plate. The design of this plate is in accordance with standard ASME procedures.

The flow out of the turbine is determined by means of two ISA type flow nozzles. The temperature and pressure of the fluid passing through these nozzles is determined by temperature and pressure probes.

d. Position Indicating Devices

The position of the valves throughout the entire system

will be determined by means of electrical potentiometers which are an integral part of the valve.

3. Instrumentation Measurement List

The parameters which are to be measured, their anticipated ranges, accuracy requirement, frequency response required, method of recording and priority are given in Figure 8.

4. Instrumentation Location

The location of each parameter in the entire system is given in Figure 9, Drawing 702160. The exact location for the WANL provided transducers will be as per Drawing No. (to be provided by WANL).

5. Transducer Requirements

The transducer requirements for the program are specified in the Instrumentation Data Book.

6. Transducer Mounting

a. The NRX Radiation Hardened Transducers will be mounted to the engine as per Drawing 701940.

b. All other pressure transducers, whenever practical will be mounted away from the engine on the test stand itself. However, there shall be no tube length of a pressure transducer longer than eight inches.

c. The Test Division will provide all tubing and seals required for the mounting of pressure transducers and RTT's. The type bosses provided at each location will be as specified on Drawing 702160, Figure 9.

7. Instrumentation Accuracy

The accuracy of the instrumentation as stated in the measurements requirements list is based upon the capability of the data

acquisition system available at the LRP H-Area facility. The method of determining this accuracy is described in AGC Technical Memorandum 125D, Revised Estimate of Instrumentation.

G. Photographic Requirements

1. Still Photos

Still photos of the test set-up will be taken showing installation of the engine in the stand, the installation of the instrumentation and any photos which the cognizant project personnel might direct at that time.

Additional still photos may be requested in the individual engine test specification.

2. Motion Pictures

Two documentary (up to ^{200 fps}/) cameras will be set-up covering the entire engine in the test stand. These cameras are to be run from FS-1 minus 3 seconds to FS-2 plus three seconds.

Additional motion picture coverage may be requested in the individual engine test specification.

H. Data Acquisition

1. Recording Method

All parameters shall be recorded by the system specified by the instrumentation measurements list.

2. Dimensional Units

All dimensions will be expressed in the English gravitational system of units.

3. Symbols and Definitions

All symbols and definitions shall be as specified in the Engine Equipment Specification, AGC 10138B, the Instrumentation Data Book and this test plan.

I. Data Reduction Requirements

1. Distribution of Data

a. Preliminary Data

Within one hour after the conduct of the test, project will receive two copies of the raw millisadic data. This data will be in a preliminary form with pressure expressed in psi, temperature in millivolts, flow in cycles per second.

b. Final Data

Within 48 hours after the completion of the test, the raw data will be processed through the 7090 Computer Program. This program will give the correct parametric measurements, expressing the temperature in °F, the pressure in psi, and flow rate in pounds per second of liquid hydrogen.

The computed performance parameters will be calculated and presented in tabulated form.

Distribution of the final data is to be made as follows: NERVA Project Operations will receive two copies, REON will receive one copy and NASA one copy.

c. Final Plots

(1) Within seventy-two hours after the completion of the test, final plots of the measured and calculated parameters are to be made. These are to have a distribution of: NERVA Project Operations, two copies; REON, one copy; and NASA one copy.

(2) The detailed requirements of the plots describing time scales and parameters to be plotted will be specified in the test specification.

J. Report Requirements

1. Quick Look Report

The quick look report will be submitted by TWX within ten days after the test and will contain the following information?

- a. Test Number, Engine Tested and Test Date
- b. A brief description of the test giving any changes to the system that might have been made since the last test.
- c. A preliminary estimate of the success or failure of the test.
- d. A statement of the known instrumentation anomalies for major parameters.
- e. A brief statement of the major performance parameters.
- f. Recommended changes for the next test performance

2. Individual Engine Test Report

Within thirty days after the completion of the tests an individual engine test report will be issued. This report will contain the following information:

- a. A brief description of the test and a detailed description of any changes from the other tests.
 - b. A description of the test set-up, test methods, the parameters measured and the location of the measuring devices.
 - c. A chronological record of all events leading up to the conduct of the test, i.e., anything which might have happened to the engine system during the test set-up which might have affected the results.
 - d. A detailed discussion of the test and the test results.
- This shall include, but not be limited to the following items:

- (1) Probable reasons for any failure,
- (2) Comparison of performance with the predicted test performance,
- (3) Analysis and general operations of the engine system.

VII PROCEDURES

A. Pre-Operative

1. Detailed Test Procedures

The engine system is to be purged with dry nitrogen prior to the initiation of the test in order to insure that there is no moisture in the system and to bring the system to the desired temperature.

The main supply line is to be bled in with liquid hydrogen until there is all liquid hydrogen at the TSOV. The purpose of this is to insure that there is liquid hydrogen into the pump as rapidly as possible.

The engine start-up is to be controlled by means of an engine sequencer. The circuitry is described in Print Number (to be provided by REON Dept. 737). The exact sequence of start-up depends upon the test objective and will be described in the individual test specification.

The test shall be considered concluded when the temperature of the hydrogen into the reactor core has reached a temperature of 150°R. This shall be considered as fire switch 2.

All instrumentation shall be run until FS-2 plus five seconds in order to insure valve closing information.

B. Post-Test Operations

1. After Individual Tests

The engine and instrumentation system will be inspected after each test as specified in the individual test request. This is to include a post calibration of all instrumentation, and a visual inspection of the engine and test hardware.

2. After a Block of Tests

After the completion of not more than eight tests or after the turbopump assembly has passed a maximum of 80,000 gallons of liquid hydrogen, whichever occurs first, all moving parts used in the system will be removed and replaced by new or reconditioned parts. Each of these new or rebuilt parts utilized in the system shall have passed all of the necessary component tests necessary to qualify it for use in the engine system.

Those parts which are removed from the system are to be disassembled and analyzed in accordance with the individual test Spec.

3. Conclusion of Test

At the conclusion of the test, the entire system is to be removed from the test stand, disassembled and analyzed. The procedures for this disassembly and analysis will be included in the final engine test specification. At the conclusion of the analysis, the hardware will be modified and shipped to NRDS.

VIII TEST ACTIVITY SCHEDULES

A. Program Schedule

The program schedule is presented in Figure 13 and gives a brief outline of when the major mileposts of the program will be accomplished.

B. Test Schedule

The expected test schedule is presented in Figure 14. This preliminary schedule may be revised by the individual test specification. It is based on the premise that eight tests may be conducted before replacement of the TPA is required.

IX ADMINISTRATIVE PROGRAM REQUIREMENTS

A. Program Approval

1. Test Plan

Before the initiation of the test program, approval of this test plan is required by the following people or their designated representatives: Manager, NERVA Project Engineer; Manager, Test and Facilities Coordination; Manager, NERVA Test Planning; Manager, NERVA Test Operations; as well as REON and NASA, SNPO-C Office.

2. Test Specification

The same requirements as specified above will apply to the test specification with the exception that it will be approved by the resident representative of SNPO-C.

3. Test Request

Before initiation of the test a Test Request will be issued. This request will require approval of Dept. 8700, but will not require the approval of any outside agencies.

4. Individual Engine Test Reports

Before submittal of the individual test report it must be approved by the Manager, Test and Facilities Coordination; Manager, NERVA Project Engineering; and Manager, NERVA Test Operations.

B. Cognizant Project Representative Responsibilities

1. If any part of these tests cannot be performed in full compliance with this test plan, the test specification, and its expedited supplements, the Test Division is to notify the cognizant project representative and obtain a Test Request Supplement or Expedited Test Request supplement to conduct the test under revised conditions.

2. The cognizant representative must be notified in sufficient time to be able to witness installation of the instrumentation, test equipment and the conduct of the test.

3. To expedite the test immediately prior to fire switch, the cognizant project representative may assume full responsibility for authorizing the test.

C. Number and Distribution of Reports

Four copies of the individual engine test report will be submitted to REON by LRP.

D. Disposition of Test Data

CFDTS test data will be retained by AGC-LRP for a minimum of three years and will be made available to REON or NASA upon request.

E. Quality Control

1. Program Requirements

For the conduct of the CFDTS the Test Division will be delegated the responsibility for all quality operations. This includes planning, inspection of all component installations and replacements, test performance, and ^{supplying} the results and records of tests to Engineering, Reliability, Quality Control and the other divisions. The requirements for performing this function will be as specified in Report No. 2469, Volume II, Revision A. "Quality Assurance Program Plan for NERVA Propulsion System".

2. Quality Engineering

The Quality Engineer will review the test plan, test request, and expedited test request supplements to insure that good quality engineering operations are maintained.

3. Instrumentation, Transducer Calibration

Each instrument or other measuring apparatus, upon which the accuracy and precision of the test results depend, will be calibrated frequently enough to ensure the steady state accuracy as specified in the instrumentation measurement list. Calibration

records will be maintained for a minimum of three years and will be made available to REON or NASA upon their request.

Each of the measuring devices used in this test will be calibrated back to the National Bureau of Standards references per the standard Aerojet LRP practices. See Figure 10, 11, and 12.

4. Data Analysis

The Quality Control Engineer will review the test data for validity and completeness in order to insure that the tests are being conducted in such a manner that will lead to the accomplishment of the test objectives as stated herein. He shall be responsible for the statistical evaluation of the test.

F. Safety Requirements

The safety procedures which shall be followed shall be as specified in the applicable sections of the Aerojet-General, Liquid Rocket Plant Test Division Safety Manual.

G. Security Requirements

The security requirements governing the handling of the hardware, the test set-up, and the data will be as specified in AGC Liquid Rocket Plant Project Directive 25D, NERVA Security Classification, dated 11 December 1962. If further information is required, see Document CG-RR1, Joint Classification Guide, Nuclear Rocket Engine Program, dated 18 September 1961.

Figure (1)

INDIVIDUAL TEST OBJECTIVES - CFDTIS

<u>Test No.</u>	<u>Test Type</u>	<u>Test Objectives</u>
1.	System Checkout and Instrumentation Ranging.	A. To verify the proper functioning of the mechanical and electrical test set-up. B. To verify the proper instrumentation ranging. C. To evaluate the altitude simulation ejector system. D. To review the proper procedures for obtaining specific results in subsequent tests. E. To verify system bootstrapping under maximum operating conditions.
2.	System Checkout and Instrumentation Ranging.	A. To determine the repeatability of component and instrumentation characteristics. B. To verify the proper functioning of the mechanical and electrical test set-up. C. To verify the proper instrumentation ranging. D. To evaluate the altitude simulation ejector system. E. To review the proper procedures for obtaining specific results in subsequent tests. F. To verify system bootstrapping under maximum operating conditions.
3.	System Checkout and Instrumentation Ranging.	A. To determine the minimum conditions under which system bootstrapping will occur. B. To verify the proper functioning of the mechanical and electrical test set-up. C. To verify the proper instrumentation ranging. D. To evaluate the altitude simulation ejector system. E. To review the proper procedures for obtaining specific results in subsequent tests.
4.	System Test	A. To evaluate the effect of reduced tank pressure on the start transients with the TPCV open and the diluent valve open.
5.	System Test	A. To determine the effect on the start transients of the TPCV being partially closed and the diluent valve closed in conjunction with reduced tank pressure.

INDIVIDUAL TEST OBJECTIVES - CFDTs (Cont'd)

Figure (1)

<u>Test No.</u>	<u>Test Type</u>	<u>Test Objectives</u>
6.	System Test	A. To evaluate the effect on the start transients of TPCV partially closed and the diluent valve open along with maximum tank pressure.
7.	System Test	A. To determine the engine start-up characteristics under optimum starting conditions. ie: TPCV open, diluent valve closed, tank pressure maximum. B. To evaluate the effect of re-start on the TPA and engine system.
8.	System Test	A. To determine the system to system variability by repeating test no. 7 with a new TPA.
9.	System Test	A. Determination of the start transients with the TPCV partially closed, the diluent valve open and maximum tank pressure.
10.	System Test	A. To evaluate the effect on system start transients of TPCV partially closed, diluent valve open and minimum tank pressure.
11.	System Test	A. To evaluate the effect of reduced tank pressure on start transients, with TPCV open and diluent valve open.
12.	System Test	A. To determine the effect of TPCV partially closed, diluent valve closed and maximum tank pressure.
13.	System Test	A. To evaluate the start transients under a condition of maximum tank pressure, the TPCV open and the diluent valve open.
14.	System Test	A. To determine the effect on start transients of the TPCV open, the diluent valve closed and the tank pressure minimum.
15.	System Test	A. To determine the engine start-up characteristics with the TPCV partially closed, the diluent valve open and minimum tank pressure.
16.	System Test	A. Determination of system start transients with the TPCV partially closed, the diluent valve open and minimum tank pressure. B. To determine the system to system variability by repeating test no. 15 with a new TPA.

INDIVIDUAL TEST OBJECTIVES - CFDTs (Cont'd)

Figure (1)

<u>Test No.</u>	<u>Test Type</u>	<u>Test Objectives</u>
17.	System Test	A. To evaluate the effect of the TPCV open, the diluent valve open and a minimum tank pressure on engine start-up.
18.	System Test	A. To determine the start transient characteristics with the TPCV open the diluent valve open and the tank pressure maximum.
19.	System Test	A. To evaluate the start transients under a condition of maximum tank pressure, the diluent valve closed and the TPCV partially closed.
20.	Verification Test	A. Verification of the optimum start-up conditions as determined by the previous tests. B. Verification of the accuracy of prediction of start transient conditions by use of the computer code developed throughout the testing.
21.	Verification Test	A. Verification of the optimum start-up conditions as determined by the previous tests. Verification of the accuracy of prediction of start transient conditions by use of the computer code developed throughout the testing.
22.	Verification Test	A. Verification of the optimum start-up conditions as determined by the previous tests. B. Verification of the accuracy of prediction of start transient conditions by use of the computer code developed throughout the testing. C. To establish a reliability and confidence level in the start-up program determined in previous tests.

FIGURE 2

Top Assy Print No. 299500 to be supplied at a later date by LRP.

FIGURE 3

CFDTS Layout Print No. 294130 to be supplied by REON, Dept. 737.

FIGURE 5

LRP Test Facility H-5 Isometric View to be supplied at a later date by LRP.

FIGURE 7

Operational Flow Plan to be supplied by REON, Dept. 737

FIGURE 13

Program Schedule to be supplied by REON, Dept. 737

APPENDIX B

Cold Flow Development Feed System Equipment Specification to be supplied by REON, Dept. 737.

APPENDIX D

Operational Flow Plan to be supplied by REON, Dept. 737.

APPENDIX E

Preliminary Pre-Test Analysis of the CFDTS TM 738:63-204 to be supplied by REON, Dept. 737

INSTRUMENTATION AND DATA PROCESSING SYSTEMS

FIGURE 6

CFDTS
MEASUREMENT REQUIREMENT LIST

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
B - Beckman
T - Tape
S - Strip Chart
O - Oscillograph

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MEAS. NO.	COMPONENT	MEASURAND				XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVE		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER	REQ'D BY	LOCATION		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		Ambient	Cold	Ambient	Cold	Ambient	Cold	
1	TSOV Inlet	PTSVI-1	Press	AGC	702160	AGC	10-45	+ .5	100	GD		Mf-O-T-S				P	
2		PTSVI-2	Press	AGC	702160	AGC	10-45	+ .5	20	GD		Mf				P	
3		PTSVI-3	Press	AGC	702160	AGC	10-45	+ .5	100	GD		Mf				S	
4		PTSVI-4	Press	AGC	702160	AGC	10-45	+ .5	20	GD		Mf				S	
6	TSOV Outlet	PTSVO-1	Press	AGC	702160	AGC	10-45	+ .297	100	GD		Mf-O				P	
7		PTSVO-2	Press	AGC	702160	AGC	10-45	+ .297	20	GD		Mf				P	
8	Pump Inlet Line	PPIL-1	Press	AGC	702160	AGC	10-45	+ .297	100	GD		Mf-O				P	
9		PPIL-2	Press	AGC	702160	AGC	10-45	+ .297	20	GD		Mf				P	
11	Pump Discharge Line	PPDL-1	Press	AGC	702160	AGC	0-50	+ .5	100	GD		Mf-O-S-T				P	
12		PPDL-2	Press	AGC	702160	AGC	0-218	+ .5	100	GD		Mf-T				P	
13		PPDL-3	Press	AGC	702160	AGC	0-218	+ 2.0	300	GD		T				S	
14	Nozzle Manifold Inlet	PNMI-1	Press	AGC &	702160	AGC	0-50	+ .5	20	GD		Mf				P	
15		PNMI-2	Press	WANL	702160	AGC	0-218	+ .5	100	GD		Mf				P	
17	Nozzle Manifold	PNM-1	Press	AGC	702160	AGC	0-218	+ .5	100	GD		Mf-T				P	
18		PNM-2	Press	&	702160	AGC	0-218	+ .5	20	GD		Ms				S	
19		PNM-3	Press	WANL	702160	AGC	0-218	+ .5	20	GD		Mf				P	
20		PNM-4	Press		701940	AGC*	0-1000	+ 2.0	20	GD		Ms				S	
22	Nozzle Manifold Differential	DPNM-1	Press	AGC &	702160	AGC	0-10	+ 1.0	20	GD		Ms				P	
23		DPNM-2	Press	WANL	702160	AGC	0-10	+ 1.0	20	GD		Ms				P	
24	Nozzle Tube Outlet	PNT0-1	Press	AGC	701940	AGC*	0-1000	+ 2.0	20	GD		Ms				S	
25		PNT0-2	Press	&	702160	AGC	0-200	+ .5	100	GD		Mf-T				P	
26		PNT0-3	Press	WANL	702160	AGC	0-200	+ .5	20	GD		Ms				S	
27		PNT0-4	Press		702160	AGC	0-200	+ .5	20	GD		Mf				P	
29		P-303	Press, Transient		702160	WANL	0-50	+ 2.0	100	GD		Mf-O				S	
30		P-304	Press, Transient		702160	WANL	0-50	+ 2.0	100	GD		Mf				S	
31	Nozzle Tube Differential	DPNT-1	Press	AGC	701940	AGC*	0-200	+ 2.0	20	GD		Ms				S	
32		DPNT-2	Press	&	702160	AGC	0-50	+ 1.0	20	GD		Ms				P	
33		DPNT-3	Press	WANL	702160	AGC	0-50	+ 1.0	20	GD		Ms				S	
35	Pressure Nozzle Skirt Manifold, Outlet	PNSMO-1	Press	AGC	702160	AGC	0-200	+ 1.0	20	GD		Ms				S	
36		PNSMO-2	Press	AGC	702160	AGC	0-200	+ 1.0	20	GD		Ms				S	
37		PNSMO-3	Press	AGC	702160	AGC	0-200	+ 1.0	20	GD		Ms				S	
38	Nozzle Skirt Differential	DPNS-1	Press	AGC	702160	AGC	0-20	+ 1.0	20	GD		Ms				P	
39		DPNS-2	Press	AGC	702160	AGC	0-20	+ 1.0	20	GD		Ms				S	

* To be NRX-Radiation Hardened Transducers.

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
B - Beckman
T - Tape
S - Strip Chart
O - Oscillograph

CFDTS
MEASUREMENT REQUIREMENT LIST

MEAS. NO.	COMPONENT	MEASUREMENT			XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVES		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER	REQ'D BY		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		AMBIENT	COLD	AMBIENT	COLD	AMBIENT	COLD	
41	Reflector Outlet	P-305	Press	AGC	WANL	0-175	+ .5	100	GD		M _f -T				P	
42		P-306	Press	& WANL	WANL	0-175	+ .5	20	GD		M _s				S	
43		P-307	Press	Transient	WANL	0-50	+ 2.0	100	GD		M _f -O				S	
44		P-308	Press	Transient	WANL	0-50	+ 2.0	100	GD		M _s -O				S	
46	Outer Reflector Differential	DP-303	Press	AGC & WANL	WANL	0-50	+ 1.0	20	GD		M _s				P	
47	Inner Reflector Differential	DP-401	Press	AGC	WANL	0-10	+ 1.0	20	GD		M _s				P	
48		DP-402	Press	&	WANL	0-10	+ 1.0	20	GD		M _s				S	
49		DP-403	Press	WANL	WANL	0-10	+ 1.0	20	GD		M _s				S	
41	Annulus P.V./Reflector	P-201	Press	WANL	702160	AGC	0-175	+ .5	GD		M _s				S	
52		P-202	Press	WANL	702160	AGC	0-175	+ .5	GD		M _s				P	
53	Shield Pressure, Dome End	P-501	Press	AGC	WANL	0-175	+ .5	100	GD		M _f -T				P	
54		P-502	Press	&	WANL	0-175	+ .5	20	GD		M _s				S	
55		P-503	Press	Transient	WANL	0-50	+ 2.0	100	GD		M _f -O				S	
56		P-504	Press	Transient	WANL	0-50	+ 2.0	100	GD		M _f -O				S	
58	Core Inlet	P-701	Press	AGC	WANL	0-150	+ .5	100	GD		M _f -T				P	
59		P-702	Press	&	WANL	0-150	+ .5	20	GD		M _s				S	
60		P-703	Press	WANL	WANL	0-150	+ .5	20	GD		M _f				P	
61		P-704	Press	Transient	WANL	0-50	+ 2.0	100	GD		M _f -O				P	
62		P-705	Press	Transient	WANL	0-50	+ 2.0	100	GD		M _s -O				S	
64	Shield Inlet to Core Inlet Differential	DP-701	Press	AGC	WANL	0-10	+ 1.0	20	GD		M _s				P	
65	Nozzle, Chamber	PNC-1	Press	AGC	702160	AGC	0-96	+ .297	GD		M _f -T				P	
66		PNC-2	Press	&	702160	AGC	96	+ .297	GD		M _f				P	
67		PNC-3	Press	WANL	702160	AGC	96	+ .297	GD		M _f				S	
68		PNC-4	Press		701940	AGC*	1000	+ 2.0	GD		M _s				S	
70	Core Differential Pressure	DP-702	Press	AGC &	WANL	0-50	+ 1.0	20	GD		M _s				P	
71		DP-703	Press	WANL	WANL	0-50	+ 1.0	20	GD		M _s				S	
73	Diluent Flow Line	PD-1	Press	AGC	702160	AGC	0-175	+ .5	GD		M _f -T				P	
74		PD-2	Press	AGC	702160	AGC	0-175	+ .5	GD		M _s				S	
75		PD-3	Press	AGC	702160	AGC	0-175	+ .5	GD		M _f				S	
76		PD-4	Press	AGC	702160	AGC	0-175	+ .5	GD		M _s				S	

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
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O - Oscillograph

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MEASUREMENT REQUIREMENT LIST

MEAS. NO.	COMPONENT	MEASURAND				XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVES		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER	REQ'D BY	LOCATION		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		AMBIENT	COLD	AMBIENT	COLD	AMBIENT	COLD	
	Turbine Inlet Line																
78		PTIL-1	Press	AGC	702160	AGC	0-96	+ .5	20	GD		M _f				P	
79		PTIL-2	Press	AGC	702160	AGC	0-96	+ .5	20	GD		M _s				S	
80		PTIL-3	Press	AGC	702160	AGC	0-96	+ .5	20	GD		M _f					
81		PTIL-4	Press	AGC	702160	AGC	0-96	+ .5	20	GD		M _f				S	
82		PTIL-5	Press	AGC	702160	AGC	0-96	+ .5	100	GD		M _f -T				P	
83		PTIL-6	Press	AGC	702160	AGC	0-96	+ .5	20	GD		M _s				S	
84		DPTIL-1	Press	AGC	702160	AGC	0-50	+ 1.0	20	GD		M _f				P	
85		DPTIL-2	Press	AGC	702160	AGC	0-20	+ 1.0	20	GD		M _f				S	
	Turbine Power Control Valve Differential																
87		DPTPV-1	Press	AGC	702160	AGC	0-20	+ 1.0	20	GD		M _s				P	
88		DPTPV-2	Press	AGC	702160	AGC	0-10	+ 1.0	20	GD		M _s				S	
	Turbine Inlet																
90		PTI-1	Press	AGC	702160	AGC	0-96	+ .5	100	GD		M _f -T				P	
91		PTI-2	Press	AGC	702160	AGC	0-96	+ .5	20	GD		M _f				S	
	Turbine Exhaust																
93		PTE-1	Press	AGC	702160	AGC	0-10	+ .5	100	GD		M _f -T				P	
94		PTE-2	Press	AGC	702160	AGC	0-10	+ .5	20	GD		M _s				S	
95		PTE-3	Press	AGC	702160	AGC	0-10	+ .5	20	GD		M _f -T				P	
96		PTE-4	Press	AGC	702160	AGC	0-10	+ .5	20	GD		M _s				S	
	Bolt Coolant Line																
98		DPBCL-1	Press	AGC	702160	AGC	0-20	+ 1.0	20	GD		M _s				S	
99		DPBCL-2	Press	AGC	702160	AGC	0-20	+ 1.0	20	GD		M _s				S	
100		DPBCL-3	Press	AGC	702160	AGC	0-20	+ 1.0	20	GD		M _s				S	
	Pneumatics System Filter																
101		DPPSF-1	Press	AGC	702160	AGC	0-2	+ 1.0	20	GD		M _s				S	
	Plenum Bleed																
102		PPBL-1	Press	AGC	702160	AGC	0-175	+ 1.0	20	GD		M _s				S	
	Plenum Bleed Filter																
103		DPPBF-1	Press	AGC	702160	AGC	0-2	+ 2.0	20	GD		M _s				S	
	Pneumatic Discharge Pressure																
104		PPDL-1	Press	AGC	702160	AGC	0-50	+ 1.0	20	GD		M _s				S	

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
B - Beckman
T - Tape
S - Strip Chart
O - Oscillograph

CFDTS
MEASUREMENT REQUIREMENT LIST

MEAS. NO.	COMPONENT	MEASURAND				XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVES		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER	REQ'D BY	LOCATION		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		AMBIENT	COLD	AMBIENT	COLD	AMBIENT	COLD	
105	TSOV Valve Actuator PTSVA-1	Press	AGC	702160	AGC	psig 0-250	3σ ± 1.0	100	GD		B -	O					P
106	TPCV Actuator PTPVA-1	Press	AGC	702160	AGC	0-250	± 2.0	100	GD		B -	O					P
107	Control Drum Actuator PCDA-1	Press	AGC	702160	AGC	0-250	± 1.0	100	GD		B -	O					P
108	TPA Casing PTPC-1	Press	AGC	702160	AGC	0-175	± 1.0	20	GD		B						S
Pressures - TOTAL - 86 Millisadic fast 41 Tape - 14																	

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
B - Beckman
T - Tape
S - Strip Chart
Q - Oscillograph

CFDTS
MEASUREMENT REQUIREMENT LIST

MEAS. NO.	COMPONENT	MEASURAND		REQ'D BY	LOCATION	XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVES		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER				RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		AMBIENT	COLD	AMBIENT	COLD	AMBIENT	COLD	
109	Tank Propellant Feed Line	THTFL-1	Temp	AGC	702160	AGC	35-45	+ .15° R	20	GD			M _f -S-T			P	(RTT)
110		THTFL-2	Temp	AGC	702160	AGC	35-45	+ .15° R	20	GD			M _f			S	(RTT)
111		THTFL-3	Temp	AGC	702160	AGC	35-45	+ .15°	20	GD			M _f -T			P	(RTT)
112		THTFL-4	Temp	AGC	702160	AGC	35-45	+ .15°	20	GD			M _f			S	(RTT)
114	TSOV Outlet	THTSVO-1	Temp	AGC	702160	AGC	35-535	+ .5° R	20	GD			M _s -T-O			P	(RTT)
115		THTSVO-2	Temp	AGC	702160	AGC	35-45	+ .25° R	20	GD			M _f			P	(RTT)
116		THTSVO-3	Temp	AGC	702160	AGC	35-45	+ .25° R	20	GD			M _f			S	(RTT)
117		THTSVO-4	Temp	AGC	702160	AGC	35-45	+3° R	20	GD			M _s -T			P	TC/CC PROBE
119	Pump Inlet Line	THPIL-1	Temp	AGC	702160	AGC	35-535	+ .5° R	20	GD			M _s -T-O			P	(RTT)
120		THPIL-2	Temp	AGC	702160	AGC	35-45	+ .25° R	20	GD			M _f			P	(RTT)
121		THPIL-3	Temp	AGC	702160	AGC	35-45	+ .25° R	20	GD			M _f			S	(RTT)
122		THPIL-4	Temp	AGC	702160	AGC	35-535	+ 3° R	20	GD			M _s -T			P	TC/CC Probe
124	Pump Discharge Line	THPDL-1	Temp	AGC	702160	AGC	35-535	+ .5° R	20	GD			M _f -T			P	(RTT)
125		THPDL-2	Temp	AGC	702160	AGC	35-45	+ .15° R	20	GD			M _f			P	(RTT)
126		THPDL-3	Temp	AGC	702160	AGC	35-535	+ 3° R	20	GD			M _s -T			P	TC/CC PROBE
128	Nozzle Manifold Inlet	THNMI-1	Temp	AGC	702160	AGC	35-535	+ .5° R	20	GD			M _f -T			P	(RTT)
129		THNMI-2	Temp	&	702160	AGC	35-45	+ .5° R	20	GD			M _f			P	(RTT)
130		THNMI-3	Temp	WANL	702160	AGC	35-535	+ 3° R	20	GD			M _s -T			P	TC/CC PROBE
132	Nozzle Manifold	THNM-1	Temp	AGC	701940	AGC*	35-45	+ 1° R	20	GD			M _f			P	(RTT)
133		THNM-2	Temp	&	702160	AGC	35-535	+ .5° R	20	GD			M _f -T			P	(RTT)
134		THNM-3	Temp	WANL	702160	AGC	35-45	+ .5° R	20	GD			M _f			S	(RTT)
135		THNM-4	Temp		702160	AGC	35-535	+ 3° R	20	GD			M _s -T			P	TC/CC PROBE
136		THNM-5	Temp		702160	AGC	35-535	+ 3° R	20	GD			M _s			S	TC/CC PROBE
137		THNM-6	Temp		702160	AGC	35-535	+ 3° R	20	GD			M _s			S	TC/CC PROBE
139	Nozzle Tubes Outlet	THNTO-1	Temp	AGC	701940	AGC*	35-535	+ 1° R	20	GD			M _s			S	(RTT)
140		THNTO-2	Temp	&	702160	AGC	35-535	+ .5° R	20	GD			M _f			P	(RTT)
141		THNTO-3	Temp	WANL	701940	AGC*	35-535	+ 1° R	20	GD			M _s			S	(RTT)
142		T-301	Temp		702160	AGC	35-535	+ .5°	20	GD			M _s -T-O			S	TC/CC
143		T-302	↓		↓	↓	↓	↓	↓	↓			M _s			S	TC/CC
144		T-303	↓		↓	↓	↓	↓	↓	↓						S	TC/CC
145		T-304	↓		↓	↓	↓	↓	↓	↓						S	TC/CC
146		T-305	↓		↓	↓	↓	↓	↓	↓						S	TC/CC
147		T-306	↓		↓	↓	↓	↓	↓	↓						S	TC/CC

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
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S - Strip Chart
O - Oscillograph

CFDTS
MEASUREMENT REQUIREMENT LIST

MEAS. NO.	COMPONENT	MEASUREMENT				XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVES		PRIORITY		INSTRUMENTATION DATA BOOK REF.														
		SYMBOL	PARAMETER	REQ'D BY	LOCATION		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		AMBIENT	COLD	AMBIENT	COLD	AMBIENT	COLD															
Core Module																															
186	187	T-710	Temp	WANL & AGC		WANL	150-535	± 3°R	10	GD		B					TC/CA														
		T-711	Temp																												
188		T-712	Temp																												
189		T-713	Temp																												
190		T-714	Temp																												
191		T-715	Temp														TC/CA														
Inner Reflector Graphite Cylinder																															
192		T-401	Temp	WANL & AGC		WANL	150-535	± 3°R	10	GD		B					TC/CA														
193		T-402	Temp																												
194		T-403	Temp																												
195		T-404	Temp																												
196		T-405	Temp																												
197		T-406	Temp																												
198		T-407	Temp																												
199		T-408	Temp																											TC/CA	
Control Drum																															
200		T-331	Temp	WANL		WANL	150-535	± 3°R	10	GD		B					TC/CC														
201		T-332	Temp																												
202		T-333	Temp																												
203		T-334	Temp																												
204		T-335	Temp																												
205		T-336	Temp																											TC/CC	
Outer Reflector Metal																															
206		T-313	Temp	WANL		WANL	150-535	± 3°R	10	GD		B					TC/CA														
207		T-314	Temp																												
208		T-315	Temp																												
209		T-316	Temp																												
210		T-317	Temp																												
211		T-318	Temp																												
212		T-319	Temp																												
213		T-320	Temp																												
214		T-321	Temp																												
215		T-322	Temp																												
216		T-323	Temp																												
217		T-324	Temp																												
218		T-325	Temp																												
219		T-326	Temp																												
220		T-327	Temp																												TC/CA
Nozzle Chamber Fluid																															
		THNC-1	Temp	AGC	702160	AGC	150-535	± .5°R	20	GD		M _F -T			P		(RTT)														
		THNC-2	Temp	&	702160	AGC	150-535	± .5°R	20	GD		M _F			P		(RTT)														
		THNC-3	Temp	WANL	702160	AGC	150-535	± .3°R	20	GD		M _F			S		TC/CC														

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
B - Beckman
T - Tape
S - Strip Chart
O - Oscillograph

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CFDTS
MEASUREMENT REQUIREMENT LIST

MEAS. NO.	COMPONENT	MEASUP AND		REQ'D BY	LOCATION	XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVE		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER				RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		AMBIENT	COLD	AMBIENT	COLD	AMBIENT	COLD	
	Nozzle End Support Ring																
225	T-337	Temp	WANL			WANL	100-535	+ 3°R	10	GD		B				S	TC/CC
226	T-338	Temp	WANL			WANL	100-535	+ 3°R	10	GD		B				S	TC/CC
	Dome End Support Ring																
227	T-339	Temp	WANL			WANL	100-535	+ 3°R	10	GD		B				S	TC/CC
228	T-340	Temp	WANL			WANL	100-535	+ 3°R	10	GD		B				S	TC/CC
	Bearings, Actuator Control Rod																
229	T-341	Temp	WANL			WANL	100-535	+ 3°R	10	GD		B				S	TC/CC
230	T-342	Temp	WANL			WANL	100-535	+ 3°R	10	GD		B				S	TC/CC
	Nozzle Skirt Inlet																
231	THNSI-1	Temp	AGC	702160	AGC	35-535	+ 3°	20	GD		M _s					S	TC/CC PROBES
232	THNSI-2	Temp	AGC	702160	AGC	35-535	+ 3°	20	GD		M _s					S	TC/CC PROBES
233	THNSI-3	Temp	AGC	702160	AGC	35-535	+ 3°	20	GD		M _s -T					S	TC/CC PROBES
	Nozzle Skirt Outlet																
234	THNSO-1	Temp	AGC	702160	AGC	35-535	+ 3°	20	GD		M _s					S	TC/CC
235	THNSO-2	Temp	AGC	702160	AGC	35-535	+ 3°R	20	GD		M _s					S	TC/CC
236	THNSO-3	Temp	AGC	702160	AGC	35-535	+ 3°R	20	GD		M _s -T					S	TC/CC
	Turbine Inlet Line																
237	THFIL-1	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _s					S	(RTT)
238	THFIL-2	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f					P	(RTT)
239	THFIL-3	Temp	AGC	702160	AGC	150-535	+ .3°R	20	GD		M _f					P	TC/CC PROBE
240	THFIL-4	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _s					S	(RTT)
241	THFIL-5	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f					P	(RTT)
242	THFIL-6	Temp	AGC	702160	AGC	150-535	+ .3°R	20	GD		M _f					P	TC/CC PROBE
243	THFIL-7	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f -T					P	(RTT)
244	THFIL-8	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _s					P	(RTT)
245	THFIL-9	Temp	AGC	702160	AGC	150-535	+ .3°R	20	GD		M _f					S	TC/CC PROBE
	Turbine Inlet																
246	THFI-1	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f -T					P	(RTT)
247	THFI-2	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f					S	(RTT)
248	THFI-3	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f					S	(RTT)
	Turbine Exhaust Line																
249	THFE-1	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f -T					P	TC/CC
250	THFE-2	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f					S	TC/CC
251	THFE-3	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f -T					P	TC/CC
252	THFE-4	Temp	AGC	702160	AGC	150-535	+ .5°R	20	GD		M _f					S	TC/CC

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
B - Beckman
T - Tape
S - Strip Chart
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DATE:
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CFDTS
MEASUREMENT REQUIREMENT LIST

MEAS. NO.	COMPONENT	MEASURAND		REQ'D BY	LOCATION	XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVE		PRIORITY		INSTRUMENTATION DATA BOOK REF.	
		SYMBOL	PARAMETER				RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		AMBIENT	COLD	AMBIENT	COLD	AMBIENT	COLD		
Circuit Module (Contd)																		
Diluent Line & Jacket																		
253		THD-1	Temp	AGC	702160	AGC	35-535	+ - 3°R	20	GD			M _f -T		P	TC/CC	PROBE	
254		THD-2	Temp	AGC	702160	AGC	35-535	+ - 3°R	20	GD			M _s		S	TC/CC	PROBE	
255		THD-3	Temp	AGC	702160	AGC	35-535	+ - 3°R	20	GD			M _f		S	TC/CC	PROBE	
256		THD-4	Temp	AGC	702160	AGC	35-535	+ - 3°R	20	GD			M _s		S	TC/CC	PROBE	
TPA Bearing Housing																		
257		TTPB-1	Temp	AGC	702160	AGC	35-535	+ - 3°R	10	GD			B		S	TC/CC		
		↕	↕	↕	↕	↕	↕	↕	↕	↕			↕		↕	↕		
264		TTPB-8	Temp	AGC	702160	AGC	35-535	+ - 3°R	10	GD			B		S	TC/CC		
Nozzle Wall Inner																		
265		TNWI-1	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
266		TNWI-2	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
267		TNWI-3	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
268		TNWI-4	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
Nozzle Wall Outer																		
269		TNWO-1	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
270		TNWO-2	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
271		TNWO-3	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
272		TNWO-4	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
Environmental Pressure Vessel																		
274		TPV-1	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
275		TPV-2	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
276		TPV-3	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
277		TPV-4	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
278		TPV-5	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
279		TPV-6	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
280		TPV-7	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
281		TPV-8	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
282		TPV-9	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
283		TPV-10	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
284		TPV-11	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
285		TPV-12	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
Environmental Pressure Dome																		
286		TPVD-1	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
287		TPVD-2	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
288		TPVD-3	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			B		S	TC/CC		
289		TPVD-4	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		
290		TPVD-5	Temp	AGC	702160	AGC	150-535	+ - 3°R	10	GD			↕		↕	↕		

CFDT'S

Temperature Total
RTT - 74
TC/CC - 111
TC/CA - 32
Millisadic fast -
Tape -

CFDTS
MEASUREMENT REQUIREMENT LIST

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
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MEAS. NO.	COMPONENT	MEASURAND				XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVE		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER	REQ'D BY	LOCATION		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		Ambient	Cold	Ambient	Cold	Ambient	Cold	
313	Nozzle, Wall	External GNWXE-1X	Acceler	AGC	702160	AGC	+ - 10G	5%	10-10,000			T				S	
314		GNWXE-1Y	Acceler	AGC	702160	AGC	+ - 10G	5%	10-10,000			T				S	
315		GNWXE-1Z	Acceler	AGC	702160	AGC	+ - 10G	5%	10-10,000			T				S	
316	TPA	GTP-1X	Acceler	AGC	702160	AGC	+ - 10G	5%	10-10,000			T				S	
317		GTP-1Y	Acceler	AGC	702160	AGC	+ - 10G	5%	10-10,000			T				S	
318		GTP-1Z	Acceler	AGC	702160	AGC	+ - 10G	5%	10-10,000			T				S	
319	Reactor Core	GRC-X1	Acceler	AGC		WANL	+ - 10G	5%	10-10,000			T				S	
320		GRC-Y1	Acceler	AGC & WANL		WANL	+ - 10G	5%	10-10,000			T				S	
321		GRC-Z1	Acceler			WANL	+ - 10G	5%	10-10,000			T				S	
322		GRC-X2	Acceler			WANL	+ - 10G	5%	10-10,000			T				S	
323		GRC-Y2	Acceler			WANL	+ - 10G	5%	10-10,000			T				S	
324		GRC-Z2	Acceler			WANL	+ - 10G	5%	10-10,000			T				S	
325	TSOV	LTSV-1	Position	AGC	702160	AGC		3%	100			O			P		
326		LTSV-2	Position	AGC	702160	AGC		3%	100			O			S		
327	TPCV	LTPCV-1	Position	AGC	702160	AGC		3%	100			O			P		
328		LTPCV-2	Position	AGC	702160	AGC		3%	100			O			S		
329	Diluent Valve	LDV-1	Position	AGC	702160	AGC		3%	100			O			P		
330		LDV-2	Position	AGC	702160	AGC		3%	100			O			S		
331	Control Drum	LCD-1	Position	AGC	702160	AGC		3%	100			O			P		
332		LCD-2	Position	AGC	702160	AGC		3%	100			O			S		
333		LCD-3	Position	AGC	702160	AGC		3%	100			O			P		
334		LCD-4	Position	AGC	702160	AGC		3%	100			O			S		
337	Tank Supply Line	QTSL	Flow	AGC	702160	AGC		+ - .807				M _f -O-T			P		

CFDTS
MEASUREMENT REQUIREMENT LIST

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
B - Beckman
T - Tape
S - Strip Chart
O - Oscillograph

REVISION: A
DATE:
Page No. 12

MEAS. NO.	COMPONENT	MEASURAND				XDCR SPID BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVE		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER	REQ'D BY	LOCATION		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		Ambient	Cold	Ambient	Cold	Ambient	Cold	
338	Pneumatics System	QTSVA-1	Flow	AGC	702160	AGC	.0014	+3%				M _s -O		S			
339		QTPCVA-1	Flow	AGC	702160	AGC	.009	+3%				M _s -O		S			
340		QCDA-1	Flow	AGC	702160	AGC	.008	+3%				M _s -O		S			
341		QCDA-2	Flow	AGC	702160	AGC	.008	+3%				M _s -O		S			
342		QPSD-1	Flow	AGC	702160	AGC	.75	+3%				M _s -O		S			
343	Pump Speed	NPT	RPM	AGC	702160	AGC	17.00	± .5	0-40,000			M _f -O-T		P			

CFDTS
MEASUREMENT REQUIREMENT LIST
(Facilities Requirements)

LEGEND: M_f - Millisadic-fast
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MEAS. NO.	COMPONENT	MEASURAND				XDCR SPLD BY	MEASUREMENT REQUIREMENTS ¹			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVE		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER	REQ'D BY	LOCATION		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		Ambient	Cold	Ambient	Cold	Ambient	Cold	
	Ejector Pressures (Cont'd)	Pt	Press	AGC		AGC		± 1.0	10								
		Pt	Press	AGC		AGC		± 1.0	10								
		Pt	Press	AGC		AGC		± 1.0	10								
		Pt	Press	AGC		AGC		± 1.0	10								
	Flow Meter Pressure	PTFM-1	Press	AGC		AGC		± 1.0	10			B				P	(RTT)
		PTFM-2	Press	AGC		AGC		± 1.0	10			B				S	
	<u>Temperature</u>																
	VH-11 Tank Temperature	TT-H103	Temp	AGC		AGC	35-45°R	± .5°R	10			Ms				P	(RTT)
	GH ₂ OVBO Vent	TT-H160	Temp	AGC		AGC						Ms				S	(TC/CC)
		TT-H161	Temp	AGC		AGC						Ms				S	(TC/CC)
	VH-11 Orifice Temperature	TT-H136	Temp O	AGC		AGC			10			Ms				S	(TC/CC)
	Ejector Temperature	TT	Temp	AGC		AGC			10								
		TT	Temp	AGC		AGC			10								
		TT	Temp	AGC		AGC			10								
		TT	Temp	AGC		AGC			10								
		TT	Temp	AGC		AGC			10								
		TT	Temp	AGC		AGC			10								
	Fluid Flow Meter	TTFM-1	Temp	AGC		AGC			10			B				P	
		TTFM-2	Temp	AGC		AGC			10			B				S	

CFDTS
MEASUREMENT REQUIREMENT LIST
(Facilities Requirements)

LEGEND: M_f - Millisadic-fast
M_s - Millisadic-slow
B - Beckman
T - Tape
S - Strip Chart
O - Oscillograph

REVISION: A
DATE:
Page No. 14

MEAS. NO.	COMPONENT	MEASURAND				XDCR SPLD BY	MEASUREMENT REQUIREMENTS			PURPOSE	DISPLAY REQUIREMENTS		MEASUREMENT OBJECTIVE		PRIORITY		INSTRUMENTATION DATA BOOK REF.
		SYMBOL	PARAMETER	REQ'D BY	LOCATION		RANGE MIN-MAX	SYSTEM ACCY	SYSTEM FREQ. RESP.		Ambient	Cold	Ambient	Cold	Ambient	Cold	
	<u>PRESSURE</u>																
	Main Supply Tank																
		P _t H106	Press	AGC		AGC	10-45	± .5	10	GD		B				P	
		P _t H156	Straw	AGC		AGC	10-45	± .5	10	GD		B				P	
		Pt H157	Straw	AGC		AGC	10-45	± .5	10	GD		B				P	
	Storage Vessel Pressure																
		Pt H3	Press	AGC		AGC	10-45	± .5	10	GD		B				P	
	Dome Loader Pressure																
		Pt H5	Press	AGC		AGC		± 1.0	10	GD		B				S	
	Receiver Manifold Pressure																
		Pt H8	Press	AGC		AGC		± 1.0	10	GD		B				S	
	VH 11 Orifice Pressure																
		Pt H136	Press	AGC		AGC		± 1.0	10	GD		B				S	
		Pt 137	Press	AGC		AGC		± 1.0	10	GD		B				S	
	Ejector Supply Pressure																
		Pt H108	Press	AGC		AGC		± 1.0	10	GD		B				S	
		Pt H110	Press	AGC		AGC		± 1.0	10	GD		B				S	
	Ejector Manifold Inlet Pressure																
		Pt H201	Press	AGC		AGC		± 1.0	10	GD		B				S	
		Pt H202	Press	AGC		AGC		± 1.0	10	GD		B				S	
	Servo Valves Hydraulic Actuation Pressures																
		Pt-1	Press	AGC		AGC		± 1.0	10								
		Pt-2	Press	AGC		AGC		± 1.0	10								
		Pt-3	Press	AGC		AGC		± 1.0	10								
		Pt-4	Press	AGC		AGC		± 1.0	10								
		Pt-5	Press	AGC		AGC		± 1.0	10								
		Pt-6	Press	AGC		AGC		± 1.0	10								
		Pt-7	Press	AGC		AGC		± 1.0	10								
		Pt-8	Press	AGC		AGC		± 1.0	10								
		Pt-9	Press	AGC		AGC		± 1.0	10								
	Ejector Pressures																
		Pt	Press	AGC		AGC		± 1.0	10								
		Pt	Press	AGC		AGC		± 1.0	10								

CALIBRATION REFERENCES FOR THE TEMPERATURE MEASURING SYSTEMS

9951 -62-941
6 JUN 1962

Figure 10

CALIBRATION REFERENCES FLOW MEASURING SYSTEM

9931-62-927

5 JUNE 1962

CALIBRATION REFERENCES FOR THE STRAIN GAGE SYSTEM

CFDTS TEST SCHEDULE														
		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
		1 8 15 22 29	5 12 19 26	3 10 17 24 31	7 14 21 28	4 11 18 25	2 9 16 23 30	6 13 20 27	4 11 18 25	1 8 15 22 29	5 12 19 26	6 13 20 27	3 10 17 24	1 8 15 22 29
Test No.	1	x												
	2		x											
	3			x										
	4				x									
	5					x								
	6						x							
	7							x						
	8								x					
	9									x				
	10								x					
	11									x				
	12										x			
	13											x		
	14												x	
	15													x
	16													
	17													
	18													
	19													
	20													
	21													
	22													
<div><div><div>1. Test Dates are shown as Friday; Tests are to be conducted during that week.</div><div>2. Quick look reports; due ten days after test firing.</div><div>3. Individual engine reports; due thirty days after firing.</div></div><div>Figure 14</div></div>														

Statistical Test Plan for NERVA CFDTS

The main objective of this investigation is to determine how the variation of start transient thermodynamic characteristics affect pressures, temperatures, and flow rates throughout the complete engine system and what effect this variation has on the pump speed in the turbopump assembly. The characteristics to be varied are:

- (a) Feed tank pressure (P)
- (b) Diluent valve opening mode (D)
- (c) TPCV setting (T)

In developing this test plan the above characteristics will be called the independent or influence variables while the measurable responses will be referred to as dependent or response variables.

Each of the above independent variables is to be investigated at two test levels. Since the latter are yet to be specified, these two levels will be referred to as low and high. Low test level of each variable will be denoted by the subscript 0, high by the subscript 1*. Variable combinations of the three influence factors, P, D, and T will be denoted by their respective lower-case letters. For example: $p_0 d_1 t_0$ is the combination of tank pressure at its low level, diluent valve at its high level, and TPCV at its low level, etc. Since there are three variables each at two levels, this will give rise to eight variable combinations:

<u>Combination</u>	<u>Tank Pressure</u>	<u>Diluent Valve</u>	<u>TPCV</u>
p ₀ d ₀ t ₀	low	low	low
p ₁ d ₀ t ₀	high	low	low
p ₀ d ₁ t ₀	low	high	low
p ₁ d ₁ t ₀	high	high	low
p ₀ d ₀ t ₁	low	low	high
p ₁ d ₀ t ₁	high	low	high
p ₀ d ₁ t ₁	low	high	high
p ₁ d ₁ t ₁	high	high	high

It is anticipated that the functional components in CFDTs, primarily the TPA, are subject to wear and a possible complete failure after a certain number of test runs. In view of this, a restriction has to be imposed on the number of tests to be conducted with a particular system. At the present time it is believed that 8 test runs can be performed before replacement of the functional components. In view of this, the following test plan is proposed, based on three systems, two with seven runs and one with eight runs. The recommended test sequence is outlined in Table 1.

* Present thoughts are that low and high levels will correspond to the following:

	<u>Low (o)</u>	<u>High (1)</u>
Tank pressure	Minimum	Maximum
Diluent valve	Closed	Open
TPCV Setting	Reduced Flow Area	Open

These levels may change at a later date.

TABLE 1

Test Sequence for NERVA CFDTS

System I		System II		System III	
<u>Test No.</u>	<u>Variable Comb.</u>	<u>Test No.</u>	<u>Variable Comb.</u>	<u>Test No.</u>	<u>Variable Comb.</u>
1*	System	8	$p_1 d_1 t_1$	16	$p_o d_o t_o$
2*	Checkout	9	$p_o d_o t_1$	17	$p_1 d_1 t_o$
3		10	$p_o d_1 p_1$	18	$p_1 d_o t_1$
4	$p_1 d_o t_o$	11	$p_1 d_o p_o$	19	$p_o d_1 t_1$
5	$p_o d_1 t_o$	12	$p_o d_1 t_1$	20	Computer Verification
6	$p_o d_o t_1$	13	$p_1 d_o t_1$	21	
7	$p_1 d_1 t_1$	14	$p_1 d_1 t_o$	22	
		15	$p_o d_o t_o$		

It should be noted from above table that three initial tests are needed to checkout the system and to determine its bootstrapping capability. The terminal three tests will be used to verify system performance with computer simulation. The intermediate 16 tests (two full repetitions of the variable combinations described earlier) are recognized to be adequate to accomplish the following:

- (a) Statistically estimate and test for significance effects of the influence variables
- (b) Determine whether the influence variables interact with each other
- (c) Statistically estimate system-to-system variability between the three systems caused by the use of three TPA's
- (d) Evaluate test-to-test variability to determine function component degradation effects with increase of number of tests in a system
- (e) Make a valid statistical interpretation of the test results

* Maximum system operating conditions

The effect of an influence variable is the change in response produced by a change in the test level of that variable, averaged over all levels of the other variables. In the case of two-level variables, the effect is estimated simply by taking the difference between the average response with all tests carried out at the first test level of the variable and that of all tests at the second level. For example, say, if it is wished to determine the increase in flow rate brought about by increasing the pressure of the feed tank from p_0 to p_1 . This increase in flow rate will be estimated by the average difference between all variable combinations containing p_1 and all containing p_0 .

An interaction between two influence variables is said to be present if the effect of one variable is different at the two test levels of the other variable. To illustrate, tank pressure and TPCV setting is considered and the question is asked: Is the increase in flow rate by increasing the tank pressure from minimum to maximum different at reduced flow area than at open TPCV setting? Symbolically, if the effect of tank pressure at both test levels of the TPCV setting is denoted by

$$p_1 - p_0 = a, \text{ at } t_0$$

and

$$p_1 - p_0 = b, \text{ at } t_1,$$

then the interaction PT will be

$$PT = a - b,$$

where a and b are flow rate values in pounds per second. It should be mentioned that in obtaining an estimate of this interaction the third influence variable, diluent valve opening mode, is averaged over both of its test levels.

Estimates of effects and interactions will be obtained from all of the 16 tests. To determine whether these estimates exert significant influences in this investigation, statistical hypotheses will be set up and tested by analysis of variance techniques. The latter will not be discussed here and the reader is referred to Enclosure (1) of this Appendix.

System-to-system variability will be determined by comparison of average responses of each of the three systems. If this variance is small, the assumption can be made that component change does not affect the test results significantly and test-to-test variability can be assessed. If the between-system variance is large, one can conclude that a significant difference does exist between the systems, and that this difference most likely is due to large inherent variability between like function components in the three systems or the manner in which they have been replaced or the combination of both. If this is the case, the between-test variability cannot be determined.

The enclosure develops source of the statistical theory on which this test plan is based and the reader is referred to it on the aspects not covered in this discussion.

Enclosure (1)
Appendix A

The experiment proposed is a 2^3 in three blocks of 8. Because 4 initial test runs are needed for system checkout and 4 terminal runs for computer simulation, blocks one and three will contain only a half of the total 8 treatment combinations. It is convenient to choose two - 1/2 replicates based on the 3-factor interaction PDT for these respective blocks. That is, block 1 will contain those combinations arising from $I = -PDT$, while block 3 will have those from $I = PDT$. Together with block 2, all 8 combinations, the experiment will be replicated twice, i.e., it will have 16 test runs. The model can be written as

$$y_{ij} = \mu + b_i + t_j + e_{ij}, \quad \begin{array}{l} i = 1, 2, 3 \\ j = 1, \dots, 7 \end{array}$$

where

μ is the overall mean
 b_i are parameters associated with block effects,
 t_j are parameters associated with treatment effects,
and e_{ij} are normally and independently distributed random errors with mean 0 and variance σ^2

The t_j here, of course, refer to the 7 effects and interactions P, D, PD, T, PT, DT, and PDT. The design matrix, X, can be expressed as follows:

	μ	B_1	B_2	B_3	P	D	PD	T	PT	DT	PDT
	p	1	1	0	0	1	-1	-1	-1	1	1
	d	1	1	0	0	-1	1	-1	1	-1	1
	t	1	1	0	0	-1	-1	1	1	-1	1
	pdt	1	1	0	0	1	1	1	1	1	1
	pdt	1	0	1	0	1	1	1	1	1	1
	p	1	0	1	0	1	-1	-1	-1	1	1
	d	1	0	1	0	-1	1	-1	1	-1	1
	t	1	0	1	0	-1	-1	1	1	-1	1
X =	pd	1	0	1	0	1	1	1	-1	-1	1
	pt	1	0	1	0	1	-1	-1	1	-1	-1
	dt	1	0	1	0	-1	1	-1	1	1	-1
	(1)	1	0	1	0	-1	-1	1	-1	1	-1
	(1)	1	0	0	1	-1	-1	1	-1	1	-1
	pd	1	0	0	1	1	1	1	-1	-1	-1
	pt	1	0	0	1	1	-1	-1	1	-1	-1
	dt	1	0	0	1	-1	1	-1	1	1	-1

The information matrix $X'X$ is given by:

	μ	B_1	B_2	B_3	PDT	P	D	PD	T	PT	DT
μ	16	4	8	4	0						
B_1	4	4	0	0	-4						
B_2	8	0	8	0	0						
B_3	4	0	0	4	4						
PDT	0	-4	0	4	16						

$X'X =$	P					16					
	D						16				
	PD							16			
	T								16		
	PT									16	
	DT										16

It is apparent from the above matrices that

- (a) Blocks one and three (B_1 and B_3) are not orthogonal with the 3-factor interaction PDT,
- (b) All three blocks (B_1 , B_2 , and B_3) are orthogonal with each other but not with overall mean μ ,
- (c) Effects and interactions P,D,PD,T,PT,DT are orthogonal with blocks, PDT, and with each other, and
- (d) Orthogonality holds between PDT and μ .

Matrix $X'X$ is singular and hence its inverse does not exist. To alleviate this we impose the condition $\sum n_i B_i = 0$, i.e., the sum of linear contrasts between observations of the three blocks is equated to zero. Uncorrelated estimates now may be obtained and can be presented in the following form:

$$16\hat{\mu} = T$$

$$16\hat{P} = (P)_1 + (P)_2 + (P)_3$$

$$16\hat{D} = (D)_1 + (D)_2 + (D)_3$$

$$16\hat{PD} = (PD)_1 + (PD)_2 + (PD)_3$$

$$16\hat{T} = (T)_1 + (T)_2 + (T)_3$$

$$16\hat{PT} = (PT)_1 + (PT)_2 + (PT)_3$$

$$16\hat{DT} = (DT)_1 + (DT)_2 + (DT)_3$$

$$8\hat{PDT} = (PDT)_2$$

$$8(\widehat{B_1 - B_3}) = B_1 - B_3$$

$$16(\widehat{B_1 + B_3 - B_2}) = B_1 + B_3 - B_2$$

where T denotes the sum of all treatment combinations, (P) denotes the sum of the treatment combinations containing p, minus those not containing p, (PD) denotes the sum of the combinations whose expectations contain PD positively, minus the sum of those containing PD negatively, and so on. Finally, B_1 , B_2 , and B_3 denote the sum total of combinations in each of the three blocks respectively.

The variances of these estimates are easily obtained and are as follows:

$$\text{VAR}(\hat{\mu}) = \text{Var}(\hat{P}) = \text{Var}(\hat{D}) = \text{Var}(\hat{T}) = \text{Var}(\hat{PD}) = \text{Var}(\hat{PT}) = \text{Var}(\hat{DT})$$

$$= \text{Var}(\widehat{B_1 + B_3 - B_2}) = \sigma^2/16$$

$$\text{Var}(\hat{PDT}) = \text{Var}(\widehat{B_1 - B_3}) = \sigma^2/8$$

In order to determine the importance of these estimated effects, the following analysis of variance is used to test the null hypothesis H_0 : effect = 0 versus some alternative, say, H_a : effect $\neq$ 0;

Analysis of Variance

<u>Source of Variation</u>	<u>Degrees of Freedom</u>
Blocks, ignoring PDT	2
Treatments	6
P	1
D	1
PD	1
T	1
PT	1
DT	1
PDT, eliminating blocks	1
Error	6
Total	15

The sum of squares are obtained the usual way with the exception that "Block SS" ignores the PDT interaction and "PDT SS" eliminates block variation. The individual mean squares ($M.S. = SS/D.of F.$) are then compared with the Error mean square, which is the estimate of the experimental variance σ^2 , to determine whether the null hypothesis, H_0 , should be accepted or rejected in favor of the alternative H_a .

BASIC PARTS LIST

DRAWING NO.
299500

SHEET

OF

9

LET.	DATE	REVISION	BY	CK-D	TITLE	DRAWN	DATE
					TOP ASSY CFDT5	W. BURNS	8-20-63
					SACRAMENTO, CALIFORNIA	CHECKED	
						APPROVED	

SIZE	DWG. NO.	REV.	1	2	3	4	5	6	PART NAME	NO. REQ'D.		
	299500		X						TOP ASSY, CFDT5	1		
	299046-9		X						THRUST STRUCTURE ASSY	1		
	283471			X					GASKET	1		
	263857			X					↓	3		
	263864			X					↓	1		
	263868			X					↓	1		
	283426			X					↓	1		
	263807			X					GASKET	2		
	268795-19			X					VALVE POPPET	1		
	283410			X					GASKET	3		
	283414			X					GASKET	1		
	283440			X					GASKET	2		
	284081			X					COUPLING	5		
	284620-1			X					SCREW, FOWARD	1		
	284621-1			X					SCREW, AFT	1		
	284622-9			X					FAIRING, UPPER	1		
	284625-9			X					FAIRING, LOWER	1		
	284843-9			X					GIMBAL UNIT	1		
	283422			X					GASKET	1		
	285104-9			X					VALVE	1		
	285902								BELLOWS	1		
	285903								BELLOWS	1		

BASIC PARTS LIST

DRAWING NO.
299500

SHEET 2 OF 9

LET.	DATE	REVISION	BY	CK-D	TITLE	DRAWN	DATE
					TOP ASSY CFDTs	W. BURNS	8-20-63
					AEROJET-GENERAL CORPORATION SACRAMENTO, CALIFORNIA	CHECKED	
						APPROVED	

SIZE	DWG. NO.	REV.	1	2	3	4	5	6	PART NAME	NO. REQ'D.		
	296923-9				X				DUMMY ACTUATOR	2		
	294070-9								PURGE LINE	1		
	296922-1				X				BOLT	2		
	296922-3				X				BOLT	2		
	296954-1				X				THRUST STRUCTURE, UPPER	1		
	297741-1				X				SPACER	4		
	298223-9				X				THRUST STRUCTURE, LOWER	1		
	298663-1				X				CAP, FEMALE	1		
	278000-49				X				TURBOPUMP ASSY MARK III MOD. 3	1		
	299031-1				X				FLANGE, ADAPTER	1		
	299069-9				X				FLANGE, CHAMBER, CAP	1		
	284840-9				X				VALUE, TURBINE	1		
	284040				X				COUPLING	3		
	284044				X				COUPLING	1		
	284105				X				COUPLING	2		
	284119				X				COUPLING	2		
	299521-1				X				CAP, MALE	3		
	299521-5				X				CAP.	1		
	299544-1				X				CAP, FEMALE	1		
	299509-9				X				CONNECTOR	1		
	701810-9				X				INTERFACE FLANGE	1		
	701812-9				X				INTERFACE FLANGE	1		

BASIC PARTS LIST

DRAWING NO.
299500

SHEET 3 OF 9

LET.	DATE	REVISION	BY	CK-D	TITLE	DRAWN	DATE
					TOP ASSY CFDTs	W. BURNS	8-20-63
					SACRAMENTO, CALIFORNIA	CHECKED	
						APPROVED	

SIZE	DWG. NO.	REV.	1	2	3	4	5	6	PART NAME	NO. REQ'D.		
	264187				X				GASKET	1		
	264192				X				GASKET	1		
	AMER STD. #607				X				WOODRUFF KEY	4		
	298606-9			X					MANIFOLD ASSY TURBINE EXHAUST	1		
	284702-7				X				FLANGE, FEMALE	1		
	284702-5				X				FLANGE, FEMALE	1		
	284703-1				X				FLANGE, MALE	2		
	284703-7				X				FLANGE, MALE	1		
	294143				X				BELLOWS	1		
	294144				X				BELLOWS	1		
	297768-5				X				REDUCER, TUBE	1		
	297999-1				X				TUBE SEGMENT	1		
	298605-1				X				TUBE SEGMENT	1		
	284699				X				COLLECTOR	1		
	298606-1				X				ELBOW	1		
	283418				X				SEAL	1		
	COML PROD 53252-650				X				COUPLING	1		
	283410				X				SEAL	1		
	283414				X				SEAL	1		
	57518-450				X				COUPLING	1		
	53252-550				X				COUPLING	1		

BASIC PARTS LIST

DRAWING NO.

299500

SHEET 4

OF 9

LET.	DATE	REVISION	BY	CK-D	TITLE	DRAWN	DATE
					TOP ASSY CFDT5	W. BURNS	8-20-63
					SACRAMENTO, CALIFORNIA	CHECKED	
						APPROVED	

SIZE	DWG. NO.	REV.	1	2	3	4	5	6	PART NAME	NO. REQ'D.		
	283414				X				SEAL	1		
	COML PROD 53252-550				X				COUPLING	1		
	299080-9			X					PUMP DISCHARGE ASSY	1		
	294057-9				X				COUPLING	1		
	283414				X				CONICAL SEAL	2		
	299082-9				X				FLANGE & BELLOWS	1		
	COML PROD 53252-550				X				COUPLING	2		
	299081-9			X					ELBOW & FLANGE SEC. PUMP DISCHARGE	1		
	299081-1				X				FORGING, MACH.	1		
	299081-3				X				VANE	1		
	299081-5				X				SEGMENT	1		
	269860-1				X				BOSS, TUBE	3		
	291662				X				BELLOWS	3		
	284702-3				X				FLANGE, FEMALE	1		
	284703-3				X				FLANGE, MALE	1		
	283414				X				SEAL	2		
	COML PROD 53252-550				X				COUPLING	2		
	COML PROD AS1128 B4-6				X				ADAPTER FLARED TUBE	2		
	WELD ROD				X				CRES 347	AR		
	WELD ROD				X				308 ELC.	AR		
	299081-19				X				ELBOW SUB ASSY	1		

SHEET	5	OF	9
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AGC 3-45

BASIC PARTS LIST

DRAWING NO.
299500

SHEET 6 OF 9

LET.	DATE	REVISION	BY	CK-D	TITLE	DRAWN	DATE
					TOP ASSY CFDTs
					SACRAMENTO, CALIFORNIA	CHECKED	
						APPROVED	

SIZE	DWG. NO.	REV.	1	2	3	4	5	6	PART NAME	NO. REQ'D.		
	299082-9			X					FLANGE & BELLOWS SEC. PUMP DISCHARGE	1		
	299082-5				X				TUBE, SEGMENT	1		
	-7				X				TUBE, SEGMENT	1		
	-11				X				TUBE, SEGMENT	1		
	-15				X				COLLAR	2		
	-17				X				PIN	1		
	-21				X				KEY	1		
	-23				X				LUG	1		
	291662				X				BELLOWS	3		
	269860-1				X				BOSS, TUBE	4		
	284702-3				X				FLANGE, FEMALE	2		
	284703-3				X				FLANGE, MALE	1		
	AS-1128 B 4-6				X				ADAPTER	2		
	CRES 347				X				WELD ROD	AR		
	308 ELC				X				WELD ROD	AR		
	283414				X				SEAL	2		
	COML PROD 53252-550				X				COUPLING	2		
	299082-19				X				ELBOW, SUB. ASSY.	1		
	-1				X				FORGING, MACH.	1		
	-3				X				VANE	1		
	-25				X				SEGMENT	1		

BASIC PARTS LIST

DRAWING NO.

299500

SHEET

7

OF

9

LET.	DATE	REVISION	BY	CK-D	TITLE	DRAWN	DATE
					TOP ASSY CFDTs	W. BURNS	8-20-63
					<i>Aerojet-General</i> CORPORATION	CHECKED	
					SACRAMENTO, CALIFORNIA	APPROVED	

SIZE	DWG. NO.	REV.	1	2	3	4	5	6	PART NAME	NO. REQ'D.		
	COML PROD 50888-175-S				X				FLANGE	1		
	294063-9			X					PRESSURE VESSEL ASSY. COLD FLOW DEVELOPMENT TEST SYSTEM	1		
	263857				X				SEAL	12		
	265144-1				X				PLUG	12		
	284081				X				COUPLING	12		
	294900-9				X				NOZZLE	1		
	286766				X				SEAL	1		
	286767				X				SEAL	1		
	294053-9				X				CYLINDER	1		
	298252-9				X				CLOSURE	1		
	298370-1				X				FLANGE, CAP	12		
	AN-960 C 1016				X				WASHER	120		
	EWB 22-10-30 298725				X				BOLT	120		
	EWB 22-10-22 298725				X				BOLT	96		
	COML PROD 1212 68 C				X				K SEAL	96		
	COML PROD 12195-DL-3000				X				K SEAL	12		

BASIC PARTS LIST

DRAWING NO.
299500

SHEET 8 OF 9

LET.	DATE	REVISION	BY	CK-D	TITLE	DRAWN	DATE
					TOP ASSY CFDTs	W. BURNS	8-20-63
					SACRAMENTO, CALIFORNIA	CHECKED	
						APPROVED	

SIZE	DWG. NO.	REV.	1	2	3	4	5	6	PART NAME	NO. REQ'D.		
	294066-9		X						COOLANT ASSY EMERGENCY	1		
	284703-3			X					FLANGE, MALE	4		
	284702-3			X					FLANGE, FEMALE	4		
	296856-9			X					FLANGE & BELLOWS	1		
	294057-9			X					COUPLING, TUBE	2		
	294065-9			X						1		
	294056			X					ELBOW & FLANGE	1		
	294057-9			X						1		
	284540-5			X					PUMP ASSY	1		
	294058-9			X					FLANGE & BELLOWS	1		
	263815			X					CONOSEAL	2		
	283414			X					SEAL	8		
	COML PROD 53252-550			X					COUPLING	8		
	CRES 347			X					WELD ROD	AR		
	282379-1			X					FLANGE	1		
	294053-9			X					CYLINDER PRESSURE VESSEL	1		
	298252			X					CLOSURE PRESSURE VESSEL	1		
	294195			X					SKIRT ASSY	1		
	284078			X					SEAL	1		

SHEET 9	OF 9
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[illegible]

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NOTES:

1. ALL SECTIONS ON SHEETS 4 & 5 ARE BOTTOM VIEW LOOKING UP (EXCEPT AS NOTED).
2. TRANSDUCERS TO BE MOUNTED ON TEST STAND, IF POSSIBLE.
3. PRESSURE TUBE LENGTHS TO BE KEPT AT A MAX. OF 8.00 INCHES.
4. NUMBERED BLANKS ARE PROVIDED IN INSTRUMENTATION LIST TO ACCOMMODATE REVISIONS WHICH MAY BE MADE AT A LATER DATE.
5. TEST DIVISION IS TO PROVIDE ALL ATTACHING & MOUNTING HARDWARE, INCLUDING SEALS.

133	THNM-2	TEMP.	NOZZLE MANIFOLD	134CT-186	269860	294900			5	1
132	THNM-1	TEMP.	NOZZLE MANIFOLD	134ET-186	269860	294900			5	0
131										
130	THNM-3	TEMP.	NOZZLE MANIFOLD	267114	AS1128346	299082			5	1
129	THNM-2	TEMP.	NOZZLE MANIFOLD	134CT-250	269860	299082			5	0
128	THNM-1	TEMP.	NOZZLE MANIFOLD	134CT-250	269860	299082			5	0
127										
126	THPD-3	TEMP.	PUMP DISCHARGE LINE	267114	AS1128346	299081			5	1
125	THPD-2	TEMP.	PUMP DISCHARGE LINE	134CT-250	269860	299081			5	0
124	THPD-1	TEMP.	PUMP DISCHARGE LINE	134CT-250	269860	299081			5	0
123										
122	THPL-4	TEMP.	PUMP INLET LINE	267111	AS1128346	294620			4	1
121	THPL-3			134CT-186	269860				4	0
120	THPL-2			134CT-186	269860				4	0
119	THPL-1	TEMP.	PUMP INLET LINE	134CT-186	269860	294620			4	0
118										
117	THSV-4	TEMP.	TSOV OUTLET	267112	AS1128346	294620			4	0
116	THSV-3	TEMP.		134CT-250	269860				4	0
115	THSV-2	TEMP.		134CT-250	269860				4	0
114	THSV-1	TEMP.	TSOV OUTLET	134CT-250	269860	294620			4	0
113										
112	THFL-4	TEMP.	TANK FEED LINE	134CT-900		FA-7996			4	0
111	THFL-3								4	0
110	THFL-2								4	0
109	THFL-1	TEMP.	TANK FEED LINE	134CT-900		FA-7996			4	0
108	PTPC-1	PRESS.	TPA CASTING	PAT32TC-200-350	AS1128346	278000			5	0
107	PCDA-1		CONTROL DRUM ACTUATOR			299500			6	0
106	PTCA-1		TPCV ACTUATOR						6	0
105	PTVA-1		TSOV ACTUATOR	PAT32TC-200-350					6	0
104	PPDL-1		PNEUMATIC DISCHARGE PRESS.	PAT32TC-50-350					6	0
103	DPPE-1		PNEUM BLEED FILTER	PM132TC-5-350					6	0
102	PPBL-1		PNEUM BLEED	PAT32TC-200-350					6	0
101	DPPE-1		PNEUMATIC DISCHARGE PRESS.	PM132TC-5-350		299500			6	0
100	DPBL-3		BOLT COOLANT LINE	PM132TC-20-350		294900			4	0
99	DPBL-2		BOLT COOLANT LINE	PM132TC-20-350		294900			4	0
98	DPBL-1	PRESS.	BOLT COOLANT LINE	PM132TC-20-350	AS1128346	294900			4	0
97										
96	PTE-4	PRESS.	TURBINE EXHAUST	PAT32TC-5-350	AS1128346	284699			5	1
95	PTE-3			PAT32TC-5-350		284699			5	0
94	PTE-2			PAT32TC-10-350		298606			5	0
93	PTE-1	PRESS.	TURBINE EXHAUST	PAT32TC-10-350	AS1128346	298606			5	0
92										

MEAS. NO.	SYMBOL	INSTRUMENT	COMPONENT	TRANSDUCER PART NO.	PART NO. MOUNTING PROVIDED	DETAIL LOCATION REF. PRINT	INST. DATA BOOK NO.	REMARKS	ZONE
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91	PTI-2	PRESS.	TURBINE INLET	PAT32TC-100-350	AS1128346	285251			5	1
90	PTI-1	PRESS.	TURBINE INLET	PAT32TC-100-350	AS1128346	285251			5	0
89										
88	DPTV-2	PRESS.	TPCV	PM132TC-10-350	AS1128346	2781009			5	1
87	DPTV-1	PRESS.	TPCV	PM132TC-20-350	AS1128346	2781009			5	0
86										
85	DPTIL-2	PRESS.	TURBINE INLET LINE	PM132TC-20-350	AS1128346	702391			4	3
84	DPTIL-1			PM132TC-50-350		702391			4	3
83	JPTIL-6			PAT32TC-100-350		702401			5	1
82	PTIL-5					702401			5	1
81	PTIL-4					702391			4	0
80	PTIL-3					702391			4	0
79	PTIL-2					702391			5	1
78	PTIL-1	PRESS.	TURBINE INLET LINE	PAT32TC-100-350	AS1128346	702391			5	1
77										
76	PD-4	PRESS.	DILUENT FLOW LINE	PAT32TC-200-350	AS1128346	702401			5	1
75	PD-3					702401			5	1
74	PD-2					702386			4	1
73	PD-1	PRESS.	DILUENT FLOW LINE	PAT32TC-200-350	AS1128346	702386			4	1
72										
71	DP-703	PRESS.	CORE DIFF. PRESS.							
70	DP-702	PRESS.	CORE DIFF. PRESS.							
69										
68	PNC-4	PRESS.	NOZZLE CHAMBER	PAT32TC-1M-350	2870269	294900			4	2
67	PNC-3			PAT32TC-100-350					4	2
66	PNC-2			PAT32TC-100-350					4	2
65	PNC-1		NOZZLE CHAMBER	PAT32TC-100-350	2870269	294900			4	2
64	DP-701	PRESS.	SHIELD INLET TO CORE DIFF.							
63										
62	P-705	PRESS.	CORE INLET							
61	P-704									
60	P-703									
59	P-702									
58	P-701	PRESS.	CORE INLET							
57										
56	P-504	PRESS.	SHIELD PRESS. DOME END							
55	P-503									
54	P-502									
53	P-501		SHIELD PRESS. DOME END							
52	P-202		ANNULUS PV/REFLECTOR	PAT32TC-200-350	AN815-4	294053			4	2
51	P-201	PRESS.	ANNULUS PV/REFLECTOR	PAT32TC-200-350	AN815-4	294053			4	2
50										
49	DP-403	PRESS.	INNER REFLECTOR DIFF.							
48	DP-402	PRESS.	INNER REFLECTOR DIFF.							
47	DP-401	PRESS.	INNER REFLECTOR DIFF.							

MEAS. NO.	SYMBOL	INSTRUMENT	COMPONENT	TRANSDUCER PART NO.	PART NO. MOUNTING PROVIDED	DETAIL LOCATION REF. PRINT	INST. DATA BOOK NO.	REMARKS	ZONE
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ON THRU
EFFECTIVE SERIAL NO.
USAGE DATA

PART NO.
NEXT FINAL
QTY REQ FOR ASSY

APPLICATOR
DRAWING LEVEL

WEIGHT
CALC. NO.

CUSTOMER

DESIGN ACTIVITY APPD

CODE IDENT. NO.
05824

DWG NO.
702160

SCALE NONE
RELEASE DATE
SHEET 1 OF 6

46	DP-303	PRESS.	REFLECTOR DIFF.							
45										
44	P-308	PRESS.	REFLECTOR OUTLET							
43	P-307									
42	P-306									
41	P-305	PRESS.	REFLECTOR OUTLET							
40										
39	DPNS-2	PRESS.	NOZZLE SKIRT DIFF.	PM132TC-20-350	AS1128346	294195			4	4
38	DPNS-1		NOZZLE SKIRT DIFF.	PM132TC-20-350	AS1128346				4	4
37	PNSMO-3		NOZZLE SKIRT MANIFOLD OUTLET	PAT32TC-300-350	AS1128346				4	4
36	PNSMO-2		NOZZLE SKIRT MANIFOLD OUTLET	PAT32TC-300-350	AS1128346				4	4
35	PNSMO-1	PRESS.	NOZZLE SKIRT MANIFOLD OUTLET	PAT32TC-300-350	AS1128346	294195			4	4
34										
33	DPNT-3	PRESS.	NOZZLE TUBE DIFF.	PM132TC-50-350	AS1128346	294900			4	1
32	DPNT-2		NOZZLE TUBE DIFF.	PM132TC-50-350	AS1128346	294000			4	1
31	DPNT-1		NOZZLE TUBE DIFF.	PL132TC-50-350	AS1128346	294900			4	1
30	P-304		NOZZLE TUBE OUTLET							
29	P-303	PRESS.	NOZZLE TUBE OUTLET							
28										
27	PNT-4	PRESS.	NOZZLE TUBE OUTLET	PAT32TC-300-350	AN815-4	294053			4	1
26	PNT-3			PAT32TC-300-350					4	1
25	PNT-2			PAT32TC-300-350					4	1
24	PNT-1		NOZZLE TUBE OUTLET	PAT32TC-1M-350	AS1128346	294053			4	1
23	DPNM-2		NOZZLE MANIFOLD	PM132TC-10-350	AS1128346	294900			5	1
22	DPNM-1	PRESS.	NOZZLE MANIFOLD	PM132TC-10-350	AS1128346	294900			5	1
21										
20	PNM-4	PRESS.	NOZZLE MANIFOLD	PAT32TC-1M-350	AS1128346	294900			5	2
19	PNM-3			PAT32TC-300-350					5	1
18	PNM-2								5	1
17	PNM-1	PRESS.	NOZZLE MANIFOLD	PAT32TC-300-350	AS1128346	294900			5	1
16										
15	PNM-2	PRESS.	NOZZLE MANIFOLD	PAT32TC-300-350	AS1128346	299082			5	1
14	PNM-1		NOZZLE MANIFOLD	PAT32TC-50-350	AS1128346	299082			5	1
13	PPDL-3		DISCHARGE LINE	PAT32TC-300-350	702158-1	299082			4	4
12	PPDL-2			PAT32TC-300-350	AS1128346	299081			5	3
11	PPDL-1	PRESS.	DISCHARGE LINE	PAT32TC-50-350	AS1128346	299081			5	3
10										
9	PPIL-2	PRESS.	PUMP INLET LINE	PAT32TC-50-350	AS1128346	294621			4	2
8	PPIL-1					294621			4	2
7	PTSV-2		TSOV OUTLET			294620			4	2
6	PTSV-1	PRESS.	TSOV OUTLET	PAT32TC-50-350	AS1128346	294620			4	2
5										
4	PTSVI-4	PRESS.	TSOV INLET	PAT32TC-50-350	AS1128346	FA-7996			4	2
3	PTSVI-3								4	2
2	PTSVI-2								4	2
1	PTSVI-1	PRESS.	TSOV INLET	PAT32TC-50-350	AS1128346	FA-7996			4	2

MEAS. NO.	SYMBOL	INSTRUMENT	COMPONENT	TRANSDUCER PART NO.	PART NO. MOUNTING PROVIDED	DETAIL LOCATION REF. PRINT	INST. DATA BOOK NO.	REMARKS	ZONE
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UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DECIMAL TOLERANCE
XXX = .010
DO NOT SCALE DRAWING

DRAWN BY
CHECKED
DESIGN
PROJECT
STRESS WEIGHT
NOMENCLATURE
FABRICATING ENGR
DESIGN ACTIVITY APPD

AEROFJET-GENERAL CORPORATION
LIQUID ROCKET PLANT, SACRAMENTO, CALIFORNIA
TITLE
INSTRUMENTATION LOCATION
C.F.D.T.S.
CODE IDENT. NO.
05824
SCALE NONE
RELEASE DATE
SHEET 1 OF 6

NOTES:

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED

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REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED

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NERVA
OPERATIONS

CODE IDENT. NO. 05824	DATE E	DWG NO. 702160
SCALE NONE	RELEASE DATE	SHEET 6 OF 6