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SPACE STATION PROPULSION TECHNOLOGY

SPACE STATION PROPULSION SYSTEM TEST BED TEST PLAN

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79

TABLE OF CONTENTS

SPACE STATION PROPULSION SYSTEM TEST BED TEST PLAN

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

FOREWORD

1.0 INTRODUCTION

2.0 REFERENCE DOCUMENTATION

3.0 GENERAL REQUIREMENTS

3.1 DESCRIPTION

3.2 RESPONSIBILITIES

3.2.1 ACCEPTANCE TESTS

3.2.1.1 ROCKETDYNE RESPONSIBILITIES

3.2.1.2 MSFC RESPONSIBILITIES

3.2.1.3 VERIFICATION ACCEPTANCE TESTS

3.2.1.4 VERIFICATION FUNCTIONS

3.3 LOSS OF DATA

3.4 SAFETY

3.5 CONFIGURATION CONTROLS

3.5.1 ENGINEERING WORK REQUEST

3.5.1.2 MODIFICATIONS, REPAIR, AND HARDWARE REPLACEMENT

3.5.3 TEST VARIATIONS

3.5.3.1 TEST DOCUMENT CHANGES

3.6 TEST DOCUMENTATION

3.6.1 TEST REQUEST

3.6.2 TEST PROCEDURES

3.6.3 LOG BOOK

3.7 REVIEWS

3.7.1 TEST READINESS REVIEWS

3.7.2 TEST DATA EVALUATION REVIEW (MSFC)

3.8 SECURITY

3.9 TEST CONDITIONS
3.10 FLUIDS AND GASES
3.11 CLEANLINESS AND CONTAMINATION CONTROL REQUIREMENTS
3.11.1 CLEANLINESS OF PROTECTIVE SERVICES
3.11.2 TEST BED CLEANLINESS
3.11.3 FACILITY CLEANLINESS
3.11.4 FLUID CLEANLINESS
3.12 CHECKOUT REQUIREMENTS
3.13 VISUAL INSPECTION
3.14 TEST WITNESSING
4.0 TEST
4.1 TEST CONFIGURATION
4.2 TEST CELL ACTIVATION
4.3 ACCEPTANCE TEST
4.3.1 CONTROLLER ACCEPTANCE CRITERIA
4.3.2 DATA ACQUISITION ACCEPTANCE CRITERIA
4.3.3 TEST BED SYSTEM ACCEPTANCE CRITERIA
4.4 SYSTEM EVALUATION/CHANGES
4.4.1 ENGINE TEST BED SYSTEM TEST
4.4.1.1 VENTURI EVALUATION/CHANGES
4.4.1.2 START TRANSIENT TESTS
4.4.1.3 DURATION TESTS
4.4.1.4 MASS FLOWRATE CONTROLS SYSTEM CHARACTERIZATION
4.4.1.5 MIXTURE RATIO/TANK PRESSURE EXCURSIONS
4.4.2 PLUMBING MODIFICATION
4.4.3 MODIFIED SYSTEM CHARACTERIZATION
4.4.4 MULTIPLE ENGINE SYSTEM OPERATION SIMULATION
4.4.5 ENGINE FIRING IN A MULTIPLE THRUSTER SYSTEM
4.4.6 AUTOMATIC PROPELLANT UTILIZATION (P/U) TESTS
4.4.7 ELECTROLYSIS SUPPLY SYSTEM
5.0 INSTRUMENTATION
6.0 TEST PROCEDURES

TABLE OF FIGURES

NO	TITLE
4-1	TEST POSITION 302 VACUUM CHAMBER VERTICAL INSTRUMENTATION
4-2	TEST POSITION 302 VACUUM CHAMBER PLAN VIEW INSTALLATION
4-3	ACCEPTANCE TEST SEQUENCE
4-4	SSPS TEST BED ACCEPTANCE SIGNOFF SHEET
4-5	REGULATOR RESPONSE CHARACTERIZATION
4-6	MODIFIED CONFIGURATION

FOREWORD

TEST PLAN FOR THE SPACE STATION PROPULSION TEST BED

This test plan contains the information required to support the testing of the Space Station Propulsion system hydrogen/oxygen test bed. This Test Plan contains a description of the Test Bed, Test Objective, Instrumentation Plan, and Controls plan. Each of these is discussed in detail below.

1.0 Introduction

Testing of the hydrogen/oxygen Space Station Propulsion System will demonstrate the technology readiness for the IOC Application. To facilitate early demonstration of this technology and to allow demonstration of maturing technology, this testing will be performed with the components installed on a test bed which simulates the Space Station Structure.

The basic objectives of this test program are to:

1) Acceptance test the test bed and its controller.
2) Evaluate hydrogen/oxygen propulsion technology readiness for the IOC station application, specifically gaseous hydrogen/oxygen and warm hydrogen gas thruster concepts with electrolysis supply systems.

2.0 Reference Documentation

The following documentation form a part of this plan to the extent specified herein. The effective issue of those documents not specifically identified by change letter or date shall be the latest issue in effect. In the event of conflict between the document referenced herein and the content of this plan, the content of this plan shall be the governing requirement.

Specifications

RJ 00097	Space Station Propulsion Test Bed
RL 00881	Test Bed/Facility In-Cell Leak check
RL 00082	Test Bed Post-Test safing, Inerting, and Backout Procedures
RL 00883	Test Bed System Inerting, Conditioning, and Propellant Loading

Interface Control Documents

ICD-101	SSPS TEST BED MECHANICAL/STRUCTURAL INTERFACES
ICD-301	SSPS TEST BED INSTRUMENTATION REQUIREMENTS
ICD-401	SSPS TEST BED CONTROLS AND ELECTRICAL REQUIREMENTS
ICD-601	SSPS TEST BED FLUID SERVICE REQUIREMENTS

Drawings

7R030300	Test Bed Assembly
7R030295	Test Bed Accumulator Thruster Module
7R032252	Instrumentation/Control Assembly

3.0 GENERAL REQUIREMENTS

3.1 Description

The SSPS test bed 7R030300** is based upon a possible flight propulsion system consisting of a centralized propellant supply (i.e. Electrolysis) with accumulators located at the four thruster array locations.

The test bed support structure in concept is representative of the space station structure with the exception of the overall dimensions. The space station module will be a 100 inch cube to be compatible with a fifteen foot test cell diameter.

The test bed together with its controller 7R032252 is designed to facilitate the evaluation of:

- Electrolysis of water supply system
- Supercritical hydrogen propulsion system.
- Supercritical oxygen hydrogen propulsion system.
- All of the above systems with hydrogen resisto-jet.

**7RXXXXXX Numbers refer to drawings

3.2 Responsibilities

3.2.1 Acceptance Tests

3.2.1.1 Rocketdyne Responsibilities

Rocketdyne has the primary responsibility for the Test Bed design, fabrication, test, and checkout activity, and for ensuring that the hardware turned over to the testing agencies is in a test-ready condition. Rocketdyne, in it's role as the Test Bed contractor, will maintain configuration status and will provide the necessary test requirements, test articles, and test support as required to satisfactorily support the Test Bed Testing at MSFC.

3.2.1.2 MSFC Responsibilities

MSFC is responsible for providing the necessary facilities, services, test planning, test conduct and technical and administrative support in the performance of all tests conducted at MSFC. MSFC has the responsibility for scheduling activities in all MSFC facilities. Any modification to the test article will be performed by MSFC personnel with support from Rocketdyne personnel.

3.2.1.3 <u>Verification - Acceptance Tests</u>

Rocketdyne will assign a Project Engineering representative to MSFC to verify test bed hardware configuration and integrity prior to, and during acceptance testing and interface with the test agency as required to coordinate overall acceptance test requirements. MSFC has primary overall responsibility and specific responsibility for facility items while Rocketdyne has primary responsibility for Test Bed equipment.

3.2.1.4 <u>Verification Functions</u>

The following verification functions will be performed by Rocketdyne personnel.

3.2.1.4.1 Prior to Acceptance Testing (from receipt at MSFC to start of test countdown):

A. Verify that applicable test documents are available and approved.

C. Ensure that any safety critical steps or sequences are in effect.

D. Verify that the test article is ready for test, and concur in the start of testing.

E. Maintain copies of facility and Rocketdyne "as used" procedures in the Log Book.

3.2.1.4.2 During Testing (from start of test countdown to opening of test cell for personnel access):

A. Document anomalies and their dispositions as well as coordinate any interface action should an anomaly and/or its disposition influence both Rocketdyne and MSFC.

B. Maintain copies of "as used" test procedures in the Log Book.

3.2.1.4.3 Subsequent to Testing (from test cell availability for personnel).

A. Document rework, repair, modification, or procedure changes during test operations.

B. Report any additional anomalies and their dispositions.

C. Ensure that remedial and preventive action has been accomplished relative to anomalies.

3.3 Loss of Data. Loss of data during a test shall not necessarily constitute cause for automatic termination or invalidation of the acceptance test. The validity of each test shall be determined on the basis of its merit.

3.4 Safety. MSFC System Safety will identify hazardous test conditions and with the support of Rocketdyne personnel shall establish precautionary procedures with test personnel. MSFC has primary safety responsibilities and Rocketdyne will act in a supporting role.

3.5 Configuration Controls.

3.5.1 Engineering Work Request (EWR). Authorization for any change to the test bed configuration, test plan, instrumentation, and Support Equipment prior to the completion of acceptance testing shall be an EWR issued by the on site Project Engineering Representative. Any changes to the configuration will be reflected by changes made to the drawings. The EWR will become a part of the test log.

3.5.1.2 <u>Modifications, Repair, and Hardware Replacement</u>.

A. Modifications:

1. <u>Electronic Support Equipment</u> - Any change to Rocketdyne electronic support equipment which affects the interface or function requires an EWR prior to implementation.

2. <u>Mechanical Support Equipment</u> - Any change to Rocketdyne supplied mechanical support equipment which affects the drawing configuration requires an EWR prior to implementation. Changes will then be reflected in the applicable drawings. The EWR will become a part of the Log Book.

3. <u>CFE</u> - Any repair or replacement to CFE Electronic support equipment, mechanical support equipment or special test equipment that is necessary to correct a discrepant condition and does not alter the part number, interface, fit, form or function of the item requires a EWR.

B. Post Acceptance Test:

Upon the satisfactory acceptance testing of the test bed and its controller the modification, repairs and hardware replacement will be performed by MSFC. With support from Rocketdyne these activities will be recorded in the log book. Rocketdyne will modify drawings and other documentation as required to maintain configuration control.

3.5.3 Test Variations. Any changes to the Test Request or Test Procedures/Specifications shall be documented on an EWR issued by the on site Project Engineering Representative. The affected document will be redlined to reflect the change and copies of the EWR and affected pages will become a part of the log book.

3.5.3.1 Test Document Changes. Immediate changes to approved and released test documents shall be permitted to avoid test delay. The documents shall be redlined to show the needed changes. Testing may then proceed while the affected document is subsequently being changed by Engineering Work Request (EWR). If the change is determined to be a permanent change, the provisions shall be entered in an Open Item Report by the Rocketdyne Representative. The status of Open Items shall be addressed at the appropriate TRR and the disposition approved prior to test.

3.6 Test Documentation.

3.6.1 Test Request. A test request for the acceptance test will be prepared defining thc test objectives, hardware to be tested, instrumentation, facility operating parameters and limits, and special requirements for each test or series of similar tests to be run in one setup.

Tests are to be conducted in accordance with the test plan; however, when approved by an EWR the test request will specify exceptions to the test plan. Accordingly, the test procedures or facilities may require modification in order to meet the requirements specified by the test request. Test requests will be signed by Rocketdyne Engineering and the testing agency representative.

3.6 Test Procedures

Any change to test bed related procedures prior to completion of acceptance testing must be concurred with and approved by Rocketdyne Engineering. Copies of completed procedures, signed by the test conductor, will be provided to Rocketdyne upon request. Post acceptance test any procedural change will be coordinated with Rocketdyne.

The entire set of integrated test procedures developed by the test agency must be submitted for approval to Rocketdyne 15 days prior to the first test. All integrated test procedures and subsequent changes/revisions must be approved prior to implementation.

The following Rocketdyne documents are provided for assistance in preparation of the test agency integrated test procedures:

RL 00881	Test Bed/Facility In-Cell Leak check
RL 00082	Test Bed Post-Test safing, Inerting, and Backout Procedures
RL 00883	Test Bed System Inerting, Conditioning, and Propellant Loading

3.6.3 Log Book.

A. Prior to acceptance test, test bed checkout and other appropriate data will be entered in the appropriate sections of the Test Bed Log Book by the designated Rocketdyne representative.

B. Post acceptance test, test bed checkout and other appropriate data will be entered in the appropriate sections of the Test Bed Log Book by Rocketdyne to maintain configuration control.

3.7 Reviews

3.7.1 Test Readiness Reviews (TRR). A Test Readiness Review will be conducted prior to start of each test and other occasions deemed appropriate by Rocketdyne and/or MSFC. The basic objective of these reviews is to verify that the test facility, test operating procedures, hardware, instrumentation system, data from previous tests, safety, and requirements for forthcoming tests have been adequately reviewed. These reviews will be chaired by MSFC. Representative(s) from the test agency and Rocketdyne shall be invited to attend the TRR.

3.7.2 Test Data Evaluation Review (MSFC). A quick look data evaluation review meeting will be held at MSFC with-in two working days of each test bed acceptance test. Rocketdyne will support this review with technical personnel to assist in the evaluation of the data at part of a joint data review team comprised of Rocketdyne and MSFC personnel. The purpose of the meeting will be twofold. First, a review of the data quality will be made to determine if any test or data anomalies exist which might require investigation prior to the next acceptance test.

Second, a preliminary evaluation of any anomalies will be conducted and the tasks necessary to complete the evaluation prior to the succeeding test will be outlined.

3.8 Security

This test program and its associated data is unclassified.

3.9 Test Conditions

All tests will be conducted under the following test conditions

A.	Temperature	32 to 160° F
B.	Altitude	100,000 Feet Min.
C.	Relative Humidity	Ambient

3.10 Fluids and Gases.

The fluids and gases required to service the test bed as specified in ICD 601.

3.11 <u>Cleanliness and Contamination Control Requirements</u>.

3.11.1 <u>Cleanliness of Protective Services</u>. Covers, caps, and other interim protective services used shall be cleaned to a level compatible with the system cleanliness requirements.

3.11.2 <u>Test Bed Cleanliness.</u> Any hardware that connects to the propulsion system and is installed after the test bed has departed from Rocketdyne shall be cleaned to the appropriate levels prior to installation.

3.11.3 <u>Facility Cleanliness</u>. Facility fluid/purge systems shall be cleaned and verified in accordance with standard facility practices.

3.11.4 <u>Fluid Cleanliness</u>. Fluid supplied to the test bed shall be verified prior to introduction into the test bed.

3.12 <u>Check out Requirements</u>

During the conduct of the Test Program, Test Bed Operations shall be verified before and after each test

The functional checkouts shall consist of the following:

A. Verify the control valve fidelity by reviewing the command/response of each individual valve.

B. Verify instrumentation operation by checking zero spans and R-cals or other calibration techniques.

3.13 Visual Inspection

The Test Bed will be visually inspected upon arrival at the testing agency and after the conduct of each test.

3.14 Test Witnessing.

All acceptance tests shall be witnessed by Rocketdyne personnel as detailed in the test procedure. Rocketdyne will be notified 48 hours in advance of acceptance tests. Following acceptance, Rocketdyne personnel will be available to witness and support all tests during the contractual period. For on site support, notification 48 hours in advance will be required.

4.0 Test

The test program for the test bed is divided into three elements. These are:

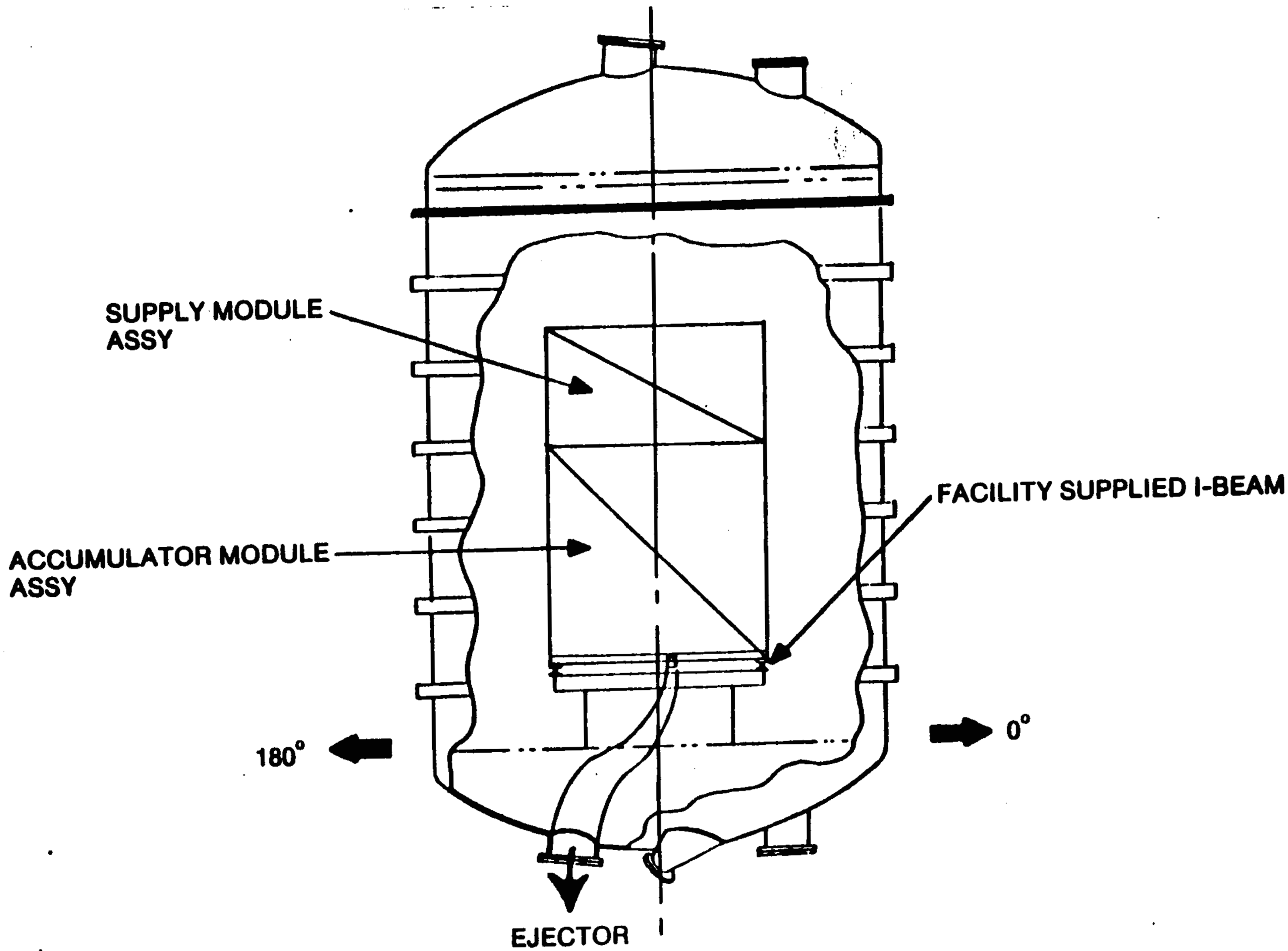
- Test cell activation.
- Test bed acceptance testing.
- System evaluation.

4.1 Test Configuration. The test bed shall be installed in the test cell with the axis vertical (See Figures 4-1 and 4-2).

The integration of the test bed with the test facility and controller will be in accordance with the interface control documents as follows:

ICD-101	SSPS TEST BE MECHANICAL/STRUCTURAL INTERFACES
ICD-301	SSPS TEST BED INSTRUMENTATION REQUIREMENTS
ICD-401	SSPS TEST BED CONTROLS AND ELECTRICAL REQUIREMENTS
ICD-601	SSPS TEST BED FLUID SERVICE REQUIREMENTS

TEST POSITIONN 302 VACUUM CHAMBER VERTICAL INSTALLATION



TEST POSITION 302 VACUUM CHAMBER PLAN VIEW INSTALLATION

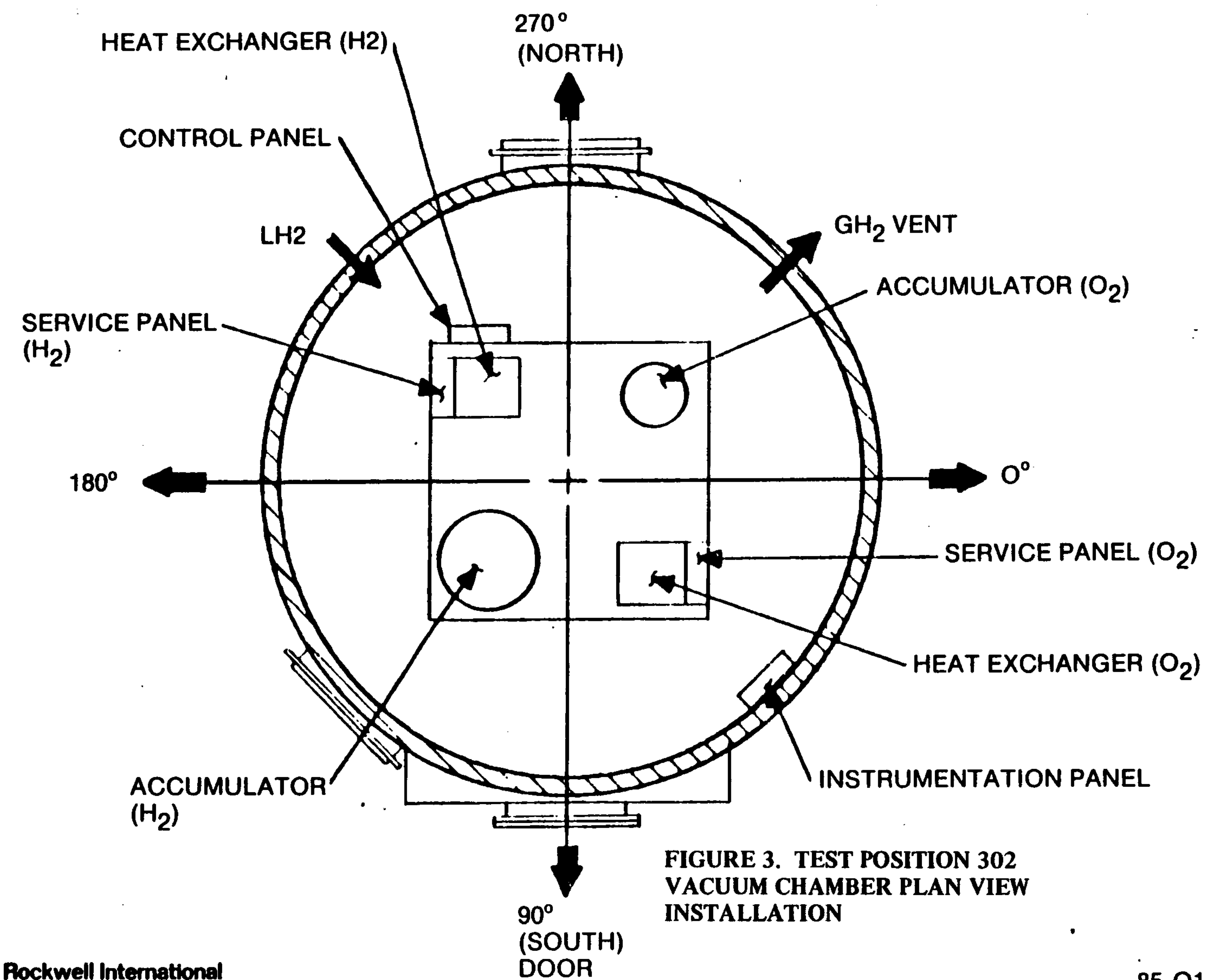


FIGURE 3. TEST POSITION 302 VACUUM CHAMBER PLAN VIEW INSTALLATION

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Figure 4- 2

4.2 Test Cell Activation

Before the initial test can be conducted it is necessary to demonstrate the satisfactory integration of the test bed with its controller and with the test facility. This will be accomplished by performing the following operations:

- Performing Test bed/controller receiving inspection.
- Installing the test bed in the test cell.
- Verifying all facility fluid interfaces.
- Connecting facility fluid interfaces to the test bed.
- Performing system leak check.
- Installing test bed controller in the control center.

- Verifying facility electrical/interfaces.
- Connecting facility electrical, instrumentation and control interfaces to the test bed and controller.
- Performing manual checkout of the facility and test bed valves and control elements.
- Perform manual check of test limit values.
- Verify instrumentation system.
- Conduct unpressurized combined system test (CST).

Upon satisfactory completion of the CST the integrated test bed/test facility are ready for the initial pressurized test.

4.3 Acceptance Test

Although the test bed and controller are fabricated at Rocketdyne, the functional acceptance test will be performed at Marshal Space Flight Center, (MSFC). The purpose of the acceptance test is to demonstrate the compliance of the test bed and controller with the requirements of C. E. Specification RJ00097.

The acceptance test will test the accumulator module and the test bed controller. All tests will utilize flow resistors in lieu of the Government furnished thrusters.

4.3.1 Controller Acceptance Criteria

Prior to the actual acceptance test of the complete system, preacceptance checks and tests will be performed to verify satisfactory operation of individual components.

The controller system will be accepted as operating satisfactorily when the checkout program used at SSFL to verify the system prior to shipment is successfully run on the installed system. The program is named "TEST 1" and is stored in the system memory. The separate sections of the program may be run during different setups. Output channels may be modified or disconnected if end items are cycled excessively.

Each valve system will be verified operational by remotely cycling it from the manual control panel. Micro switches will be adjusted and operation of indicator lights on the manual panel shall constitute acceptance of the manual control system.

4.3.2 Data Acquisition Acceptance Criteria

After control and instrumentation data systems installations are completed, the control system data acquisition will be verified operational by comparing data from the control system with data from Facility data acquisition system. If the Facility Data System is not available, a calibrated pressure gauge may be used. Each system will be calibrated for a standard test setup. The entire plumbing system will be pressurized to a medium pressure level (i.e. 500 psia) with GN_2 or He by opening all interconnecting and isolation valves until pressure is steady. Data recording will be made on both the Data acquisition and control systems. After the system has been vented, the data shall be sliced and reduced, and the results from the two systems shall be compared. Data from all transducers (pressures and temperatures) must agree within 2% of the transducer range for transducers located in the same area.

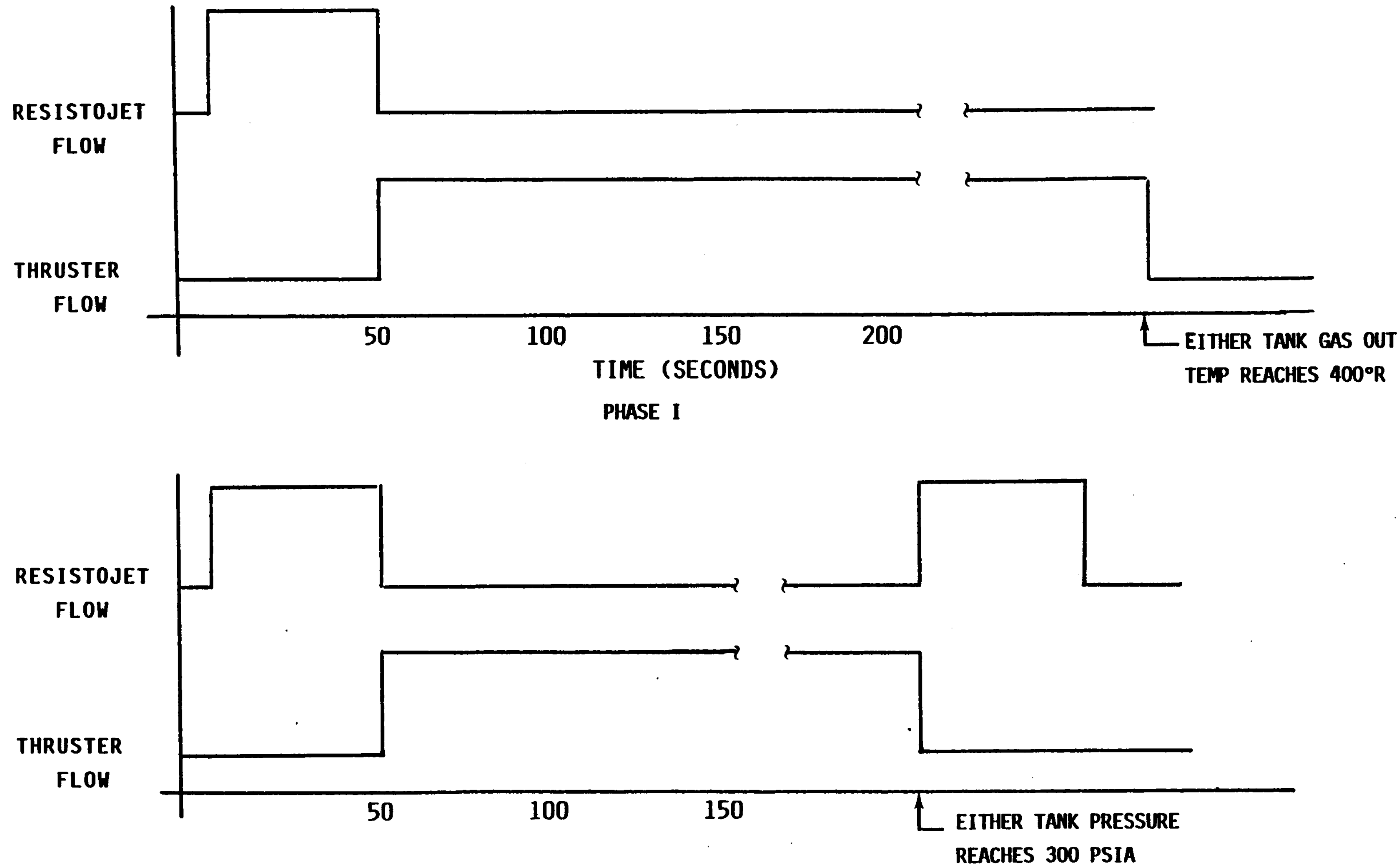
4.3.3 Test Bed System Acceptance Criteria

An acceptance test control sequence program will be prepared to cycle the test bed system in a manner described below and shown in Figure 4.3. The program will contain the normal prep complete and redline functions and will be throughly verified prior to system operation.

The acceptance test sequence will initially be performed utilizing GN_2 for GOX and GHe for GH_2.

ACCEPTANCE TEST SEQUENCE

FIG 4.3



One complete acceptance test cycle will be performed using the surrogate gasses, but will not constitute the official acceptance test. Additional surrogate gas cycle tests may be performed as deemed necessary by Rocketdyne or MSFC personnel to verify satisfactory operation prior to the official acceptance test.

For the official acceptance test, GO_2 and GH_2 will be loaded into their respective storage vessels from the facility systems to the pressures listed below:

GO_2	1000 psia $\pm$ 50 PSIA
GH_2	1000 psia $\pm$ 50 psia

The test cell shall be evacuated to a pressure of 8 TORR or lower prior to the loading operation, and this pressure shall be maintained throughout the acceptance test with the exception noted later. The engine feed lines shall have been previously capped and orifices simulating the engine back pressures shall have been installed in the respective engine bleed lines (items 38 on drawing 7R030294). The system bleed valves (item 37 and item 45) shall be used to simulate the engine and resistojet propellant valves and the venturi pressure will be set for a nominal mixture ratio of 4.

Target flowrates shall be 0.071 pounds/sec of GO_2 and 0.0179 pounds/sec of GH_2.

The sequence of operations will simulate a firing of a resistojet engine for 50 seconds followed by a long duration firing of the main thruster. The simulated steady state main thruster burn shall continue until either the GO_2 or GH_2 Tank outlet temperature decays to 400°R. This will conclude the first phase of the acceptance test.

The accumulator tanks will be allowed to return to 500°R minimum before beginning phase 2. Pressure in the chamber may be returned to ambient pressure at this point to facilitate warming of the gases.

Prior to beginning phase 2 of the acceptance test, the chamber shall be reconditioned to less than 8 TORR. The sequence of phase 2 shall be the same as phase 1 with the exception that the long duration burn will be terminated when either of the accumulator exit pressures (PH15 or PO15C) reaches 300 psia. At this point a resistojet burn of 50 seconds will be simulated and the test sequence will be terminated.

After the test has been secured, the data shall be reviewed to verify that stable venturi inlet pressures ($\pm$ 5% of nominal Value) were attained during the steady state burns and that the valve sequence matches the desired sequence as shown on the pretest sequence printout with the exception of the duration. This will constitute satisfactory completion of the Test Bed Acceptance test.

The SSPS TEST BED acceptance signoff sheet (Figure 4.4) shall be signed by the designated MSFC and Rocketdyne personnel. Completion of all signoffs will constitute acceptance of the Test Bed System. The complete acceptance criteria are shown in Table 4.1.

NOTE: In case either accumulator tank exit pressure decays to 300 psia in Phase 1 of the acceptance test prior to either of the tank temperatures decaying to 400°R, the final 50 second resistojet burn simulation will be immediately initiated and phase 2 will not be required.

SSPS TEST BED ACCEPTANCE SIGNOFF SHEET

CONTROLLER ACCEPTANCE

	ROCKETDYNE	MSFC
CHECKOUT PROGRAM "TEST #1" OPERATED SATISFACTORILY	__________	__________
MANUAL CONTROL OPERATED SATISFACTORILY	__________	__________
DATA ACQUISITION SYSTEM DATA AND CONTROL SYSTEM DATA AGREE WITHIN ± 2%	__________	__________
FLOWRATE STABLE WITHIN ± 5% DURING STEADY STATE TEST	__________	__________
ACCEPTANCE TEST SEQUENCE OF VALVES SATISFACTORY	__________	__________
SYSTEM ACCEPTANCE O.K.	__________	__________

Fig 4.4

TABLE 4.1 ACCEPTANCE TEST CRITERIA

TEST TYPE	ACCEPTANCE REQUIREMENT
COMPUTER CONTROLLER	A) RUN "TEST 1" CHECKOUT SEQUENCE PROGRAM SATISFACTORILY B) OPERATE ALL VALVES AND INDICATOR CIRCUITS FROM MANUAL PANEL SATISFACTORILY
DATA ACQUISITION SYSTEM	A) RECORD PRESSURE/TEMPERATURE DATA AT STEADY STATE PRESSURIZED CONDITION IN TEST BED B) ALL SIMILARLY LOCATED TRANSDUCER DATA FROM A) AGREE WITHIN ± 2% BETWEEN FACILITY DATA SYSTEM & CONTROL DATA SYSTEM
TEST BED SYSTEM OPERATION	SUCCESSFUL OPERATION OF SEQUENCE SHOWN ON FIGURE 1 AT FOLLOWING CONDITIONS A) INITIAL TANK PRESSURES - GO_2 1000 PSIA GH_2 1000 PSIA B) FINAL TANK PRESSURES (EITHER) GO_2 300 PSIA GH_2 0300 PSIA C) CELL PRESSURE 8 TORR D) VENTURI INLET PRESSURE - GO_2 200 ± 30 PSIA GH_2 200 ± 30 PSIA E) TANK GAS TEMPERATURES (MINIMUM) GO_2 400°R GH_2 400°R F) RESISTOJET VENTURI PRESSURE 200 ± 30 PSIA

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4.4 System Evaluation and operation

4.4.1 Engine Test Bed System Test

Following completion of the Test bed acceptance, it is recommended that a thruster be mounted on the system and a series of tests be run to characterize main thruster operation and identify any possible interactions with the test bed. A possible test matrix for these tests is shown in Table 4.2.

4.4.1.1 Venturi Evaluation/changes

The test bed was designed and configured for a nominal mixture ratio of 4.0. If the engine selected to be run has a nominal mixture ratio of 8.0, the venturies must be re-evaluated. It is probable in this case, that the GH_2 venturi will need to be changed. In addition, it is recommended that the venturies be moved and close coupled to the thruster propellant main valves to permit multiple start test.

TABLE 4.2 SYSTEM EVALUATION/OPERATION TEST MATRIX

OBJECTIVES	TEST SERIES 1	2	3	4	5	6	7	8	9	10	11	12	13	14
• CHARACTERIZE ENGINE/TEST BED INTERACTIONS	X	X	X		X	X								
• START TRANSIENT	X													
• STEADY START DURATION		X	X											
• MIXTURE RATIO VARIATIONS					X									
• TANK PRESSURE VARIATIONS						X								
• MASS FLOWRATE CONTROL SYSTEM CHARACTERIZATION				X										
• CHARACTERIZE MODIFIED SYSTEM							X	X	X					
• START/STOP							X		X					
• STEADY STATE								X	X					
• CHARACTERIZE MULTIPLE ENGINE SYSTEM OP										X				
• MULTIPLE ENGINE FIRING											X			
• AUTOMATIC PROPELLANT UTILIZATION												X		
• ELECTROLYSIS SUPPLY SYSTEM													X	

CONDITIONS	1	2	3	4	5	6	7	8	9	10	11	12	13
• TANK PRESSURES													
- NOMINAL 1000 PSIA	X	X					X						
- VARIABLE			X	X	X	X		X	X	X	X	X	X
• CELL PRESSURE													
- AMBIENT				X		X	X		X		X	X	X
- < 8 TORR START	X	X	X		X	X			X		X	X	X
• MIXTURE RATIO													
- 8	X	X	X										
- VARIABLE				X	X	X	X	X	X	X	X	X	X
• MASS FLOW CONTROL ACTIVE				X	X	X	X	X	X	X	X	X	X
• PROPELLANTS													
- GO_2/GH_2													
- GN_2/GHe													
• SIMULATED ENGINE							X	X	X	X			

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4.4.1.2 Start Transient Tests

The engine would be subjected to a series of tests beginning with ignition only and continuing through acquisition of steady state conditions. These tests would determine engine start and operating conditions on the test bed. The tanks would be loaded to nominal operating conditions prior to the first tests. The cell would be maintained at less than 8 TORR at the start of engine testing.

4.4.1.3 Duration Tests

The engine would be subjected to a series of tests of increasing duration culminating with a burn of maximum feed system duration. These would verify satisfactory system operation with the engine and test bed combination. The test cell would be conditioned to less than 8 TORR prior to the start of each series and maintained below the nozzle unstart pressure level at all times during a burn.

4.4.1.4 Mass Flowrate Control System Characterization

A blow down test series would be conducted to characterize the operation of the regulators under varying mixture ratio/mass flowrate changes during a continuous simulated thruster burn. The GO_2 and GH_2 systems would be operated in the same manner as for a real engine burn, but the system bleed valves would be actuated in place of the engine prop valves. The sequence of flowrate changes shown in figure 4.5 would be run during this test. The results of this test would be used to determine system operation for the next engine series.

4.4.1.5 Mixture Ratio/Tank Pressure Excursions

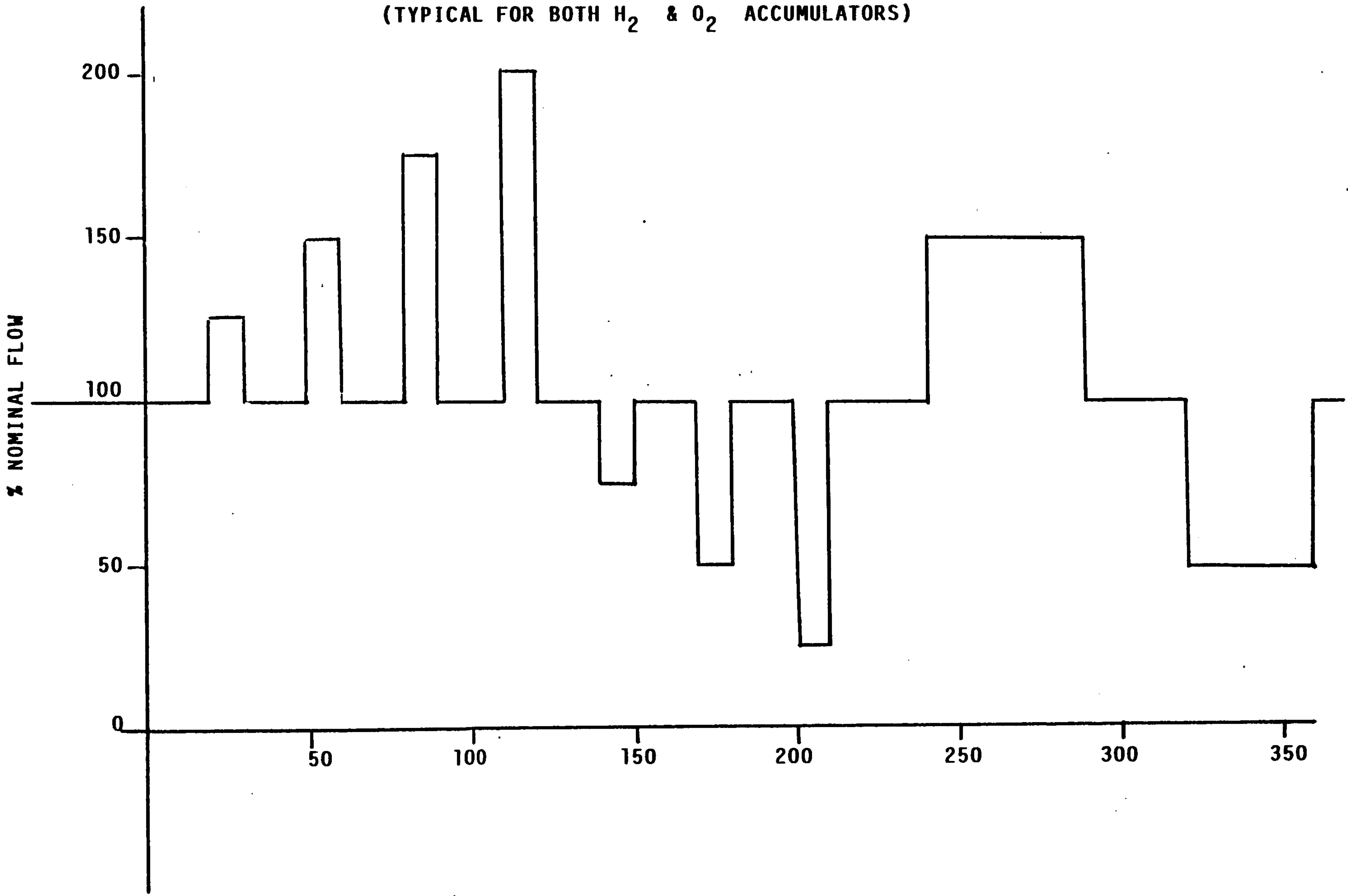
A series of test would be conducted at varying mixture ratio and tank conditions. These would further characterize the engine testbed operation.

The mass flowrate and mixture ratio of the engine would be varied as required during single engine burns based upon the results of the previous mass flowrate control system characterization series.

FIG. 4-5

REGULATOR RESPONSE CHARACTERIZATION

(TYPICAL FOR BOTH H_2 & O_2 ACCUMULATORS)



4.4.2 Plumbing Modification

A minor modification to the plumbing is recommended to facilitate multiple engine and pulse testing. The test bed system was originally designed for testing single engines for long steady state burns. In order to perform multiple burns of an engine during a single test or to verify operation of multiple engines from a single system, the following changes are recommended.

4.4.2.1 Move existing GO_2 and GH_2 venturies to a location immediately upstream of the prop valves and minimize the line volume between the venturies and valves.

The volume between the venturies and prop valves will be charged to the pressure upstream of the venturies after the engine has completed one start-stop cycle. During the remaining engine start transients, this precharged pressure will cause a higher than desired flowrate until the pressures decay to the run values. By reducing the volume between the valves and venturies, this effect can be minimized or eliminated.

4.4.2.2 Add a set of orifices immediately upstream of existing bleed valves (item 337 on drawing 7R030294) with A_e values the same as for the existing venturies and with the same line volumes as those of 4.4.2.1. Add new pressure and temperature transducers upstream of the venturies to measure flow rates.

4.4.2.3 Add manifold volume between the regulators and venturies. This is required to add some capacitance to the flow system to minimize flowrate perturbations during multiple engine firings. All lines from each manifold to the venturies should be of similar length and volume. A section of tubing might be used a shown in figure 4.6. New pressure and temperature measurements should be added to the manifold and lines as required for system characterization.

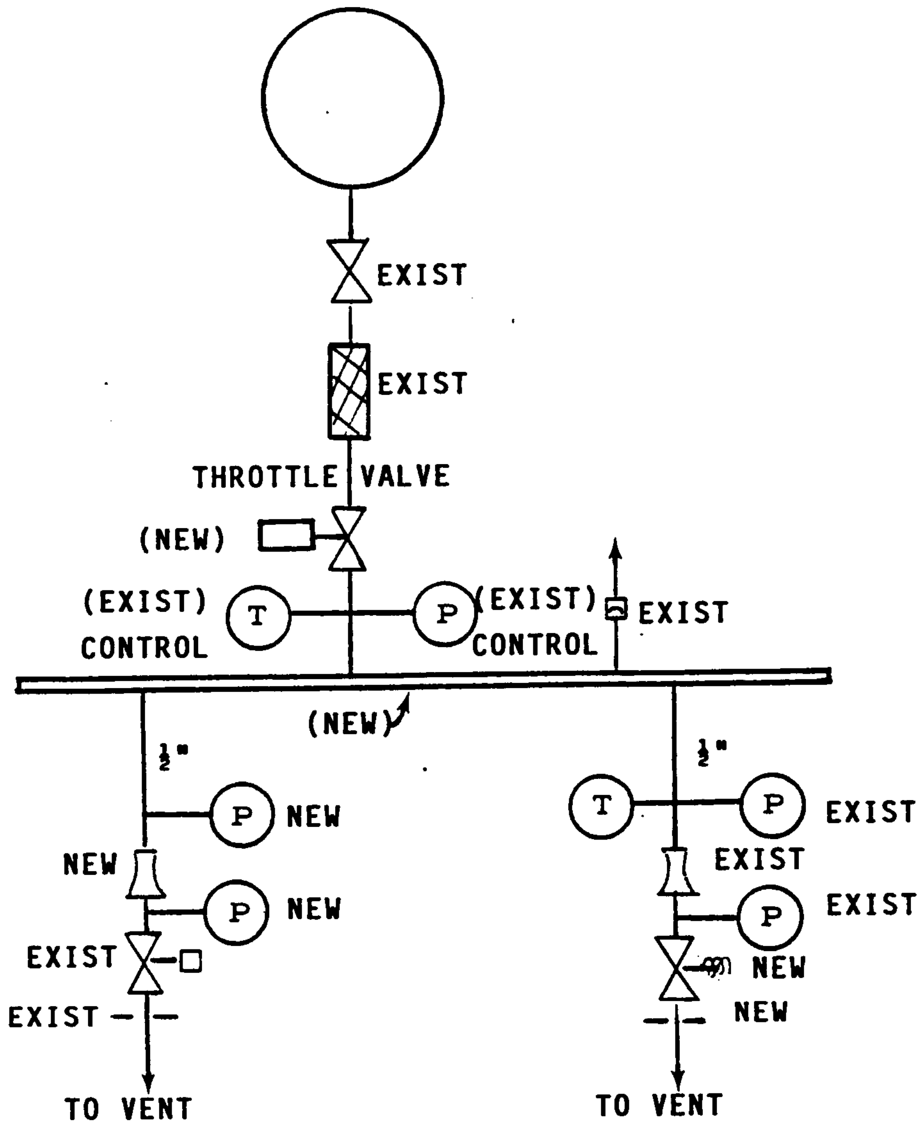


FIG. 4-6 MODIFIED CONFIGURATION

4.4.2.4 - Replace Main engine regulators with throttle valves controlled by the Computer Control System. Control system would maintain desired mass flow rate by changing position of throttle valve. Replacement of Resistojet regulator is not recommended at this time.

4.4.3 Modification System Characterization

A series of simulated engine runs would be required initially to calibrate and characterize the throttle valves, and verify stable system operation with the above changes. The engine would be replaced with the simulated prop valves plumbed to the bleed lines. The tanks would be loaded with GO_2 and GH_2 to nominal run conditions. The cell would be at ambient pressure. A series of tests to simulate various start-stop conditions and various flowrate conditions would be run to verify satisfactory operation at all conditions of supply pressure and flowrate.

4.4.4 Multiple Engine System Operation Simulation

A series of tests would be conducted using the bleed valves and simulated prop valves to determine the feed system characteristics for simultaneous operation of two thrusters on a common supply system. Tanks would be loaded to nominal conditions and the cell would be at ambient pressure. Various conditions of mixture ratios and tank pressures would be evaluated to assure stable feed system operation.

4.4.5 Engine Firing in a Multiple Thruster System

A series of tests would be conducted using the bleed valves to simulate a second thruster firing during firings of the actual thruster. These tests could verify satisfactory operation of two thruster system operation. Tank would be loaded to nominal conditions and the cell would be pressurized to less than 8 TORR at test starts. Various combinations of mixture ratios tank pressures, and engine firing sequences would be run to verify stable engine operations.

4.4.6 Automatic Propellant Utilization (P/U) tests

A Control System Program would be provided to perform automatic propellant utilization maximization during system operations. This would vary the engine mixture ratio and operating conditions to make maximum use of the propellants available in the accumulators. A series of tests would be run in which varying tank pressure conditions would simulate possible space station scenario caused by different load and use rates from the GO_2 and GH_2 systems.

4.4.7 Electrolysis Supply System

An electrolysis supply unit would be mounted on the test bed and connected to the accumulator tank system. A series of tests would be conducted in which the computer control system would automatically operate the electrolysis unit to load the accumulator and fire the engines. An integrated system scenario utilizing the engines, resistojet, P/U system and electrolysis systems would be devised to simulate the actual space station operation. The test cell would be maintained at less than 8 TORR except when the engine is firing.

5.0 Instrumentation

The test bed as delivered is equipped with instrumentation for monitoring performance and for control system interfacing.

The data instrumentation will monitor:

Thruster performance/operating conditions
Storage tank thermodynamics and outflow conditions
Stored fluid mass
Valve/regulator operations
Propellant leakage

In addition supplying operating data, this instrumentation will supply information for trouble shooting.

The instrumentation installation for the accumulator module is shown schematically in Figure 5-1. The pressure transducer master list is presented in Table 5-1. The temperature transducer master list is presented in Table 5-2.

These data will be updated to include the propellant storage module instrumentation when this information is available.

FIG URE 5–1

TESTBED INSTRUMENTATION SCHEMATIC

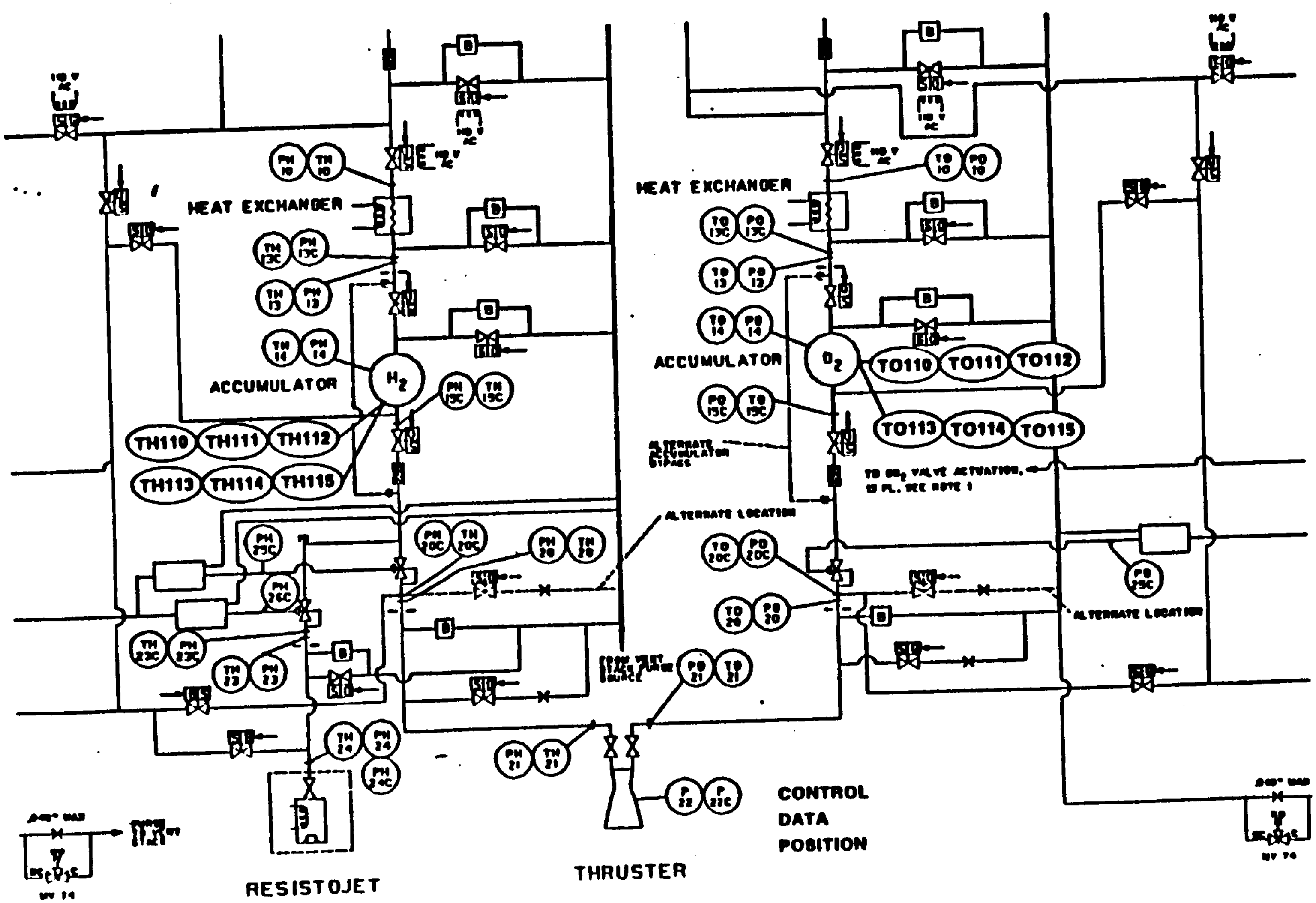


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TABLE 5–2

INSTRUMENTATION TEMPERATURE TRANSDUCER MASTER LIST

IDENTIFICATION NUMBER	LOCATION	TYPE	INSTRUMENTATION INTERFACE BOX CONNECTOR
TO10	OX HEATER INLET	CR-CON IMMERSION	T1
TH10	H2 HEATER INLET	CR-CON IMMERSION	T2
TO13	OX HEATER OUTLET	CR-CON IMMERSION	T3
TH13	H2 HEATER OUTLET	CR-CON IMMERSION	T4
TO14	OX ACCUMULATOR LIQUID	RTB 134FK-75 S/N 6070	P31
TH14	H2 ACCUMULATOR LIQUID	RTB 134FK-75 S/N 6592	P32
TO20	OX THRUSTER VENTURI INLET	RTB 150DL-12 S/N 004637	P33
TH20	H2 THRUSTER VENTURI INLET	RTB 150DL-12 S/N 004217	P34
TH23	RESISTOJET VENTURI INLET	RTB 150DL-12 S/N 005749	P35

24 TEMPERATURE MEASUREMENTS FOR DATA RECORDING
16 ADDITIONAL ARE SCHEDULED FOR STORAGE TANK

TABLE 5–2 (CONT.)

INSTRUMENTATION TEMPERATURE TRANSDUCER MASTER LIST

IDENTIFICATION NUMBER	LOCATION	TYPE	INSTRUMENTATION INTERFACE BOX CONNECTOR
TO21	OX THRUSTER INLET	CR-CON IMMERSION	T5
TH21	H2 THRUSTER INLET	CR-CON IMMERSION	T6
TH24	RESISTOJET INLET	CR-CON IMMERSION	T7
TO110	OX ACCUMULATOR SKIN	CR-CON SKIN TEMP	T8
TH110	H2 ACCUMULATOR SKIN	CR-CON SKIN TEMP	T9
TO111	OX ACCUMULATOR SKIN	CR-CON SKIN TEMP	T10
TH111	H2 ACCUMULATOR SKIN	CR-CON SKIN TEMP	T11
TO112	OX ACCUMULATOR SKIN	CR-CON SKIN TEMP	T12
TH112	H2 ACCUMULATOR SKIN	CR-CON SKIN TEMP	T13
TO113	OX ACCUMULATOR SKIN	CR-CON SKIN TEMP	T14
TH113	H2 ACCUMULATOR SKIN	CR-CON SKIN TEMP	T15
TO114	OX ACCUMULATOR SKIN	CR-CON SKIN TEMP	T16
TH114	H2 ACCUMULATOR SKIN	CR-CON SKIN TEMP	T17
TO115	OX ACCUMULATOR SKIN	CR-CON SKIN TEMP	T18
TH115	H2 ACCUMULATOR SKIN	CR-CON SKIN TEMP	T19

24 TEMPERATURE MEASUREMENTS FOR DATA RECORDING
16 ADDITIONAL ARE SCHEDULED FOR STORAGE TANK

The test bed controller interfaces with the test bed through dedicated control instrumentation. The dedicated control pressure transducer master list is presented in Table 5-3. The control temperature transducer master list is presented in Table 5-4. The design overview of the of the test bed and facility control and interface is presented in figure 5-2.

6.0 Test Procedure

The Pre-test, test, and post-test test operations are recommended in the following Rocketdyne supplied Procedures:

RL 00881	Test Bed/Facility In-Cell Leak check
RL 00082	Test Bed Post-Test safing, Inerting, and Backout Procedures
RL 00883	Test Bed System Inerting, Conditioning, and Propellant Loading

TABLE 5–3

CONTROL PRESSURE TRANSDUCER MASTER LIST

IDENTIFICATION NUMBER	LOCATION	RANGE	MSFC S/N	CONTROL INTERFACE BOX CONNECTOR
PO13C	OX HEAT EXCHANGER OUTLET	4,000	802964	P1
PH13C	H2 HEAT EXCHANGER OUTLET	4,000	802963	P2
PO15C	OX ACCUMULATOR OUTLET	3,000	802967	P3
PH15C	H2 ACCUMULATOR OUTLET	3,000	802966	P4
PO20C	THRUSTER OX FLOW VENTURI INLET	500	800835	P5
PH20C	THRUSTER H2 FLOW VENTURI INLET	500	810919	P6
P22C	CHAMBER PRESSURE	250	800838	P7
PH23C	RESISTOJET VENTURI INLET	250	800842	P8
PH24C	RESISTOJET INLET	3,000	24924	P9
PO25C	THRUSTER OX REGULATOR DOME REF.	3,000	24653	P10
PH25C	THRUSTER H2 REGULATOR DOME REF.	3,000	802968	P11
PH26C	RESISTOJET REGULATOR DOME REF.	3,000	802965	P12

12 PRESSURE MEASUREMENTS FOR CONTROL SYSTEM
2 ADDITIONAL ARE SCHEDULED WITH STORAGE TANK

36

TABLE 5–4

CONTROL TEMPERATURE TRANSDUCER MASTER LIST

IDENTIFICATION NUMBER	LOCATION	TYPE	CONTROL INTERFACE BOX CONNECTOR
TO13C	OX HEAT EXGR OUTLET	CR-CON IMMERSION	T1
TH13C	H2 HEAT EXGR OUTLET	CR-CON IMMERSION	T2
TO15C	OX ACCUMULATOR OUTLET	CR-CON IMMERSION	T3
TH15C	H2 ACCUMULATOR OUTLET	CR-CON IMMERSION	T4
TO20C	OX THRUSTER VENTURI INLET	CR-CON IMMERSION	T5
TH20C	H2 THRUSTER VENTURI INLET	CR-CON IMMERSION	T6
TH23C	RESISTOJET VENTURI INLET	CR-CON IMMERSION	T7

7 TEMPERATURES FOR CONTROL SYSTEM

2 ADDITIONAL ARE SCHEDULED FOR STORAGE TANK

FIGURE 5–2

DESIGN OVERVIEW INTERFACES