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MONOPROPELLANT HYDRAZINE RESISTOJET

MODEL SPECIFICATION TASK SUMMARY REPORT

TRW SYSTEMS GROUP
ONE SPACE PARK
REDONDO BEACH, CALIFORNIA 90278

FEBRUARY 1972

PREPARED FOR
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

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Approved by Charles K Murch

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TRW
SYSTEMS GROUP

FOREWORD

This is the third Task Summary Report submitted under Contract NAS5-11477, "Design, Development, and Testing of Engineering Model 20-Millipound Thrust Monopropellant Hydrazine Resistojet." The program originated in the Auxiliary Propulsion Branch of the NASA/Goddard Space Flight Center. Mr. Dennis Asato is the Technical Officer for the NASA/GSFC. Mr. Charles K. Murch is the Project Manager for TRW Systems Group. The primary contributor to this report was Mr. Rein Grabbi.

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1. SUMMARY

The model specification task for the Electrothermal Hydrazine Thruster (EHT) Program is intended to provide a model specification and preliminary engineering drawings for an engineering model thruster. The thruster specification includes and is predicated upon the results of earlier tasks of analysis and preliminary design. It defines all of the EHT operating parameters including:

a) Weight
b) Size
c) Performance requirements
d) Thermal design requirements
e) Mechanical design requirements
f) Interface design requirements and restraints
g) Electronic and electrical design requirements.

The environmental requirements of the EHT Statement of Work have been updated to comply with those of NASA/Goddard specification S-320-ATS-2, Rev. D, Environmental Test Specification for Components and Experiments ATS-F and G.

Included in this task summary report are also the Contamination Control Procedure and the Acceptance Test Plan for the EHT.

2. MODEL SPECIFICATION

The model specification for the Electrothermal Hydrazine Thruster has been divided into two parts. Part I specifies the performance, design and qualification requirements for the thruster, while Part II delineates the product configuration and acceptance test requirements. The scope of the specification has thus been extended to cover not only the engineering model EHT, but also any subsequent qualification or flight-type thrusters. Only minor modifications would be required to update the specification should the program be extended beyond the delivery of an engineering model.

The detail performance requirements of the EHT are described in Part I of the specification. These conform to the requirements specified in the Statement of Work. The propellant valve characteristics have been modified to meet those of the Parker-Hannifin propellant valve used on the ATS-F&G spacecraft. Part 1 of the specification also includes the design and construction requirements for the thruster. The weight of the thruster assembly, not specified in the Statement of Work, has been estimated at 0.4 pound maximum. The environmental requirements, also in Part 1, have been modified from the values specified in the EHT Statement of Work to conform to the requirements of NASA/Goddard specification S-320-ATS-2, Rev. D, Environmental Test Specification for Components and Experiments ATS-F&G. The last section of Part 1 of the specification deals with the quality assurance provisions. Flight qualification requirements are specified in terms of functional and environmental test requirements, test sequence, test conditions and test methods.

Part II of the model specification establishes the requirements for the acceptance test of the EHT. It specifies the requirements for performance and product configuration as well as those for quality assurance. The acceptance test requirements, test sequence, and test methods are described in detail. A baseline test schedule to verify proper thruster performance has also been included.

3. ACCEPTANCE TEST PLAN

The Acceptance Test Plan for the engineering model EHT has been prepared and included in Appendix III. The tests outlined in this plan are intended to verify the operating parameters of the thrusters. The planned tests include functional tests, thermal vacuum-temperature cycling, parameter variation, cycle life and steady-state life tests.

4. CONTAMINATION CONTROL PROCEDURE

The Contamination Control Procedure defines the cleanliness requirements for the thruster assembly and its components. The procedure also includes the proper contamination control of the hydrazine propellant for chemical and particulate impurities. Further paragraphs outline the proper methods of propellant and thruster handling and the general requirements for assembly and test areas. The procedure is presented in Appendix IV.

5. ENGINEERING DRAWINGS

Preliminary drawings have been prepared for the engineering model EHT. These are included in Appendix V. Two separate drawings have been provided to show the EHT final assembly configuration with Wright Components Model 15650 and Parker Model 5686070 solenoid valves. A new assembly drawing will be provided to show the configuration with the Parker hydrazine valve (P/N 5700060) built for use on ATS-F&G. The thruster assembly drawing (X409240) will also be updated to provide the proper mechanical interface with the ATS-F&G valve configuration.

APPENDIX I

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

CODE IDENT 11982

TITLE

Equipment Specification Part I
Performance/Design and Qualification Requirements
for
Hydrazine Resistojet

DATE 12 January 1972 NO.

SUPERSEDING: __________

PREPARED BY: Rein Grabbi
Rein Grabbi

APPROVAL SIGNATURES:

C. K. Murch DATE Principal Investigator	Ernest Cohen, Manager DATE Electric Propulsion Department
DATE	DATE
DATE	DATE

PART I

EQUIPMENT SPECIFICATION

HYDRAZINE RESISTOJET

PERFORMANCE, DESIGN AND QUALIFICATION REQUIREMENTS

1. SCOPE

This specification establishes the performance, design, fabrication, test and quality assurance requirements for an Electrothermal Hydrazine Thruster assembly, hereafter referred to as the thruster or unit.

2. APPLICABLE DOCUMENTS

The following documents of the exact issue shown, or the latest issue in effect, if not shown, form a part of this specification to the extent specified herein. Where differences occur between documents referenced herein and the detail content of Sections 3, 4 and 5, the requirements of this specification shall apply.

SPECIFICATIONS

Federal	
TT-I-735A	Isopropyl alcohol
Military	
MIL-P-26536C	Propellant, Hydrazine
MIL-P-27401B	Propellant, Pressurizing Agent, Nitrogen
MIL-P-27407	Propellant, Pressurizing Agent, Helium
MIL-S-38130	System Safety Engineering of Systems and Associated Subsystems and Equipment
TRW Systems Group	
PR2-2K	Cleaning of Fluid System Components
TBS	Equipment Specification for Hydrazine Propellant Valve

STANDARDS

Military	
MS 33586A	Metals, Definition of Dissimilar
MIL-STD-143A	Specifications and Standards, Order of Procedure for the Selection of
MIL-STD-130C	Identification Marking of US Military Property

Federal

Fed. Std. No. 209	Clean Room and Work Station Requirements, Controlled Environment

DRAWINGS

TRW Systems Group

409871	Electrothermal Hydrazine Thruster and Valve Assembly

OTHER DOCUMENTS

Air Force Eastern Test Range

AFETRM 127-1	Range Safety Manual

Military

MIL-HDBK-5A	Metallic Materials and Elements for Aerospace Vehicle Structures

TRW Systems

TBS	Contamination Control Procedure for the Monopropellant Hydrazine Resistojet

3. REQUIREMENTS

3.1 Performance. When supplied with liquid hydrazine propellant, the thruster shall provide pulse-mode and steady-state thrust as specified in this document. This shall be accomplished by thermal decomposition of the hydrazine and the expansion of the decomposition products through a converging-diverging nozzle.

3.1.1 Functional Characteristics

3.1.1.1 General Characteristics

3.1.1.1.1 Operating Propellant. The thruster shall be capable of operating with hydrazine conforming to MIL-P-26536C as modified per the Contamination Control Procedure for the Monopropellant Hydrazine Resistojet.

3.1.1.1.2 Operating Pressure. The thruster shall be capable of operating with propellant inlet pressures between 130 and 375 psia.

3.1.1.1.3 Operating Temperature. The thruster shall be capable of operating with propellant inlet temperatures between 40° and 120°F.

3.1.1.2 Steady-State Characteristics

3.1.1.2.1 Steady-State Specific Impulse. The vacuum specific impulse for steady-state operation shall be greater than 200 seconds.

3.1.1.2.2 Steady-State Thrust. The steady-state thrust shall be within the limits shown in Figure 1.

3.1.1.2.3 Steady-State Duty Cycle. The thruster shall be capable of continuous operation for a minimum of 30 hours.

3.1.1.3 Pulse-Mode Characteristics

3.1.1.3.1 Pulse Duration. The thruster shall be capable of operating with pulse on-times of 0.050 second to steady-state.

3.1.1.3.2 Pulse-Mode Specific Impulse. The average vacuum specific impulse for pulsed operation shall be greater than 175 seconds for duty cycles greater than 2 percent.

3.1.1.3.3 Pulse-Mode Impulse Bit Repeatability. For any given operating pressure, thruster temperature, and thruster on-time, the delivered vacuum impulse bit shall be repeatable within $\pm$ 10 percent.

3.1.1.3.4 Pulse Mode Duty Cycle. The thruster shall be capable of operation at any duty cycle from 0 to 100 percent. The minimum OFF-time between pulses shall be 0.025 seconds.

3.1.1.4 Leakage

3.1.1.4.1 Internal Leakage. Internal leakage of the unit with the valve closed shall not exceed 2.0 standard cubic centimeters per hour of helium gas, with inlet pressures between 130 and 400 psig.

3.1.1.4.2 External Leakage. External leakage of the unit with the valve opened and the nozzle throat plugged shall not exceed 1×10^{-6} scc/sec helium gas at 400 psig inlet pressure.

3.1.2 Operability

3.1.2.1 Reliability. The assessed probability of the unit functioning without failure shall be TBD. This probability is based upon the unit successfully surviving launch, ascent and initial deployment, and operating five years in orbit, under all operating and non-operating usage and environmental conditions specified herein. Failure is defined as any out-of-specification condition.

3.1.2.2 Useful Life. The thruster shall be capable of performing as specified for not less than five years under all natural combinations of operating conditions, after being stored in a non-operating condition for up to three years.

3.1.2.3 Duty Cycle Firing. The thruster shall meet the performance requirements throughout a cycle life of 1 million cycles.

3.2 Design and Construction

3.2.1 General Design Features

3.2.1.1 Configuration. The thruster assembly configuration shall be per TRW drawing 409871 and shall consist of a solenoid-actuated propellant valve, injector, thrust chamber, nozzle, insulation package, and electrical heater. These components shall be mounted on a support bracket. The unit shall include a thrust chamber temperature transducer.

3.2.1.2 Dimensions. The thruster shall be designed within the envelope specified in Figure 2.

3.2.1.3 Weight. The unit weight shall not exceed 0.4 pound.

3.2.1.4 Proof Pressure. The unit shall show no evidence of deformation or damage and shall meet the requirements of this specification after undergoing proof pressure of 600 psig.

3.2.1.5 Burst Pressure. The unit shall withstand a minimum burst pressure of 1000 psig without rupturing. Metal strength shall be based on MIL-HDBK-5.

3.2.1.6 Propellant Valve Coil Resistance. The coil resistance shall be greater than 260 ohms at 70 $\pm$ 5°F coil and ambient temperatures.

3.2.1.7 Heater Resistance. The heater resistance shall be greater than 146 ohms at 70 $\pm$ 5°F heater and ambient temperature.

3.2.1.8 Operating Voltage. The thruster shall operate within the requirements herein with 26 $\pm$ 5% Vdc supplied to the propellant valve and 27 $\pm$ 5% Vdc supplied to the heater.

3.2.1.9 Operating Power. The thruster shall require a maximum of 8 watts to operate at the nominal voltages of paragraph 3.2.18.

3.2.1.10 Holding Power. At the nominal supply voltage of 27 Vdc, the maximum holding power of the thruster shall be 5 watts.

3.2.1.11 Thrust Vector Alignment. The thruster shall have the capability of being aligned to ± 0.25° with respect to the nozzle exit plane.

3.2.1.12 Electrical Interface. TBS

3.2.1.13 Dielectric Strength. The unit shall be capable of withstanding 500 ± 5 Vac (60 cycle nominal) between shorted solenoid valve leads and the case for a period of 15 ± 1.0 seconds without insulation breakdown. Breakdown is defined as a current flow in excess of 2.0 milliamperes.

3.2.1.14 Insulation Resistance. The dc resistance between the shorted solenoid valve and heater leads and the case shall be greater than 1 megohm at 500 ± 50 Vdc.

3.2.1.15 Coil Protection. The propellant valve solenoid coil shall be protected by potting and hermetically sealing the coil cavity.

3.2.2 Materials

3.2.2.1 Materials Compatibility. All materials in contact with the working fluid shall be compatible with liquid and gaseous hydrazine (N_2H_4) and the fluids used to test, clean and dry the unit.

3.2.2.2 Corrosive Metals. Metals shall be corrosion resistant or suitably treated to resist the corrosive conditions likely to occur in storage and normal operation.

3.2.2.3 Fungus Resistance. Materials that are nutrients for fungi shall not be used.

3.2.2.4 Dissimilar Metals. Unless suitably protected against electrolytic corrosion, dissimilar metals, as defined in MS-33586, shall not be used in contact with each other.

3.2.2.5 Finish. When materials are used in the construction of the unit which are subject to deterioration when exposed to the specified environments, they shall be protected against such deterioration in a manner that will in no way prevent compliance with the performance requirements of this specification. The use of any protective finish that will crack, chip, sublimate, or scale with age or extreme environmental conditions shall be avoided. No cadmium or zinc plating shall be used on any component.

3.2.3 Construction. The unit shall be constructed in accordance with sound design principles. The number of parts and seals shall be minimized.

3.2.4 Workmanship. The thruster shall be constructed, finished and assembled in accordance with workmanship standards specified in the process specifications used for thruster manufacture.

3.2.5 Interchangeability. Each thruster shall be directly interchangeable in form, fit and function with other units of the same part number.

3.2.6 Selection of Specifications and Standards. Specifications and standards for necessary commodities and services not specified in this specification shall be selected in accordance with MIL-STD-143.

3.2.7 Cleanness. Thruster surfaces in contact with the operating propellant, with the exception of those in the thrust chamber, shall meet the cleanness requirements of Level 0 of PR2-2.

3.2.8 Identification of Product. The thruster shall be identified in accordance with MIL-STD-130 and TRW drawing 409871. Identification data shall include but not be limited to, the following:

a) Unit name
b) TRW part number
c) TRW serial number
d) Actual weight in pounds to an accuracy of 0.01 pound.

3.2.9 Maintainability. The unit shall be designed to permit its replacement with a minimum of disturbance to associated or adjacent equipment. Field maintenance shall be limited to checkout, removal, and replacement of the thruster as an integral unit containing factory-assembled parts.

3.2.10 Transportability. The thruster shall be designed to be transported by common carrier with a minimum of protection. Special packaging will be used as necessary to assure that transportation methods do not impose design penalties.

3.2.11 Safety. Safety hazards shall be identified and minimized in accordance with MIL-S-38130 and AFETRM 127-1.

3.2.12 Storage. The thruster shall be capable of being stored for a minimum of three years without requiring maintenance or repair at the end of storage.

3.3 Environmental Requirements. The thruster shall perform satisfactorily under the conditions expected to exist during the time of operation and be able to withstand, without damage or performance degradation, all environmental conditions expected to be encountered during test, storage, shipment, handling, standby and flight prior to the operational period. The unit status is defined under each environmental requirement.

3.3.1 Acceleration. With the inlet unpressurized, the unit shall be capable of withstanding linear acceleration of 9 ± 1 g's applied in a radial direction toward the spacecraft longitudinal axis for a period of 3 minutes.

3.3.2 Vibration. The thruster shall be capable of withstanding the following vibration levels with the inlet unpressurized. Attachment of the test unit to the shaker shall simulate the actual attachment to the spacecraft structure. Vibration shall be applied in each of the three orthogonal directions, one direction being parallel to the vehcile's thrust axis. The sinusoidal and random vibrations shall be applied independently. Vibration levels refer to measured and controlled amplitudes at the unit interface with the vibration test fixture.

3.3.2.1 Sinusoidal Vibration. Sinusoidal vibration shall be applied by sweeping the applied frequency once through each range specified in the schedule. The rate of change of frequency shall be two (2) octaves per minute.

SINUSOIDAL VIBRATION SCHEDULE DESIGN QUALIFICATION	
Frequency Range (Hz)	Longitudinal and Lateral Axes 0-to-Peak Acceleration, g's
5-22	0.5 in. d.a.
22-200	12.0
200-2000	5.0

3.3.2.2 Random Vibration. Gaussian random vibration shall be applied with the g-peaks clipped at three times the root-mean-square acceleration specified in the schedule. Vibration time shall be four (4) minutes per axis.

RANDOM VIBRATION SCHEDULE DESIGN QUALIFICATION	
Frequency Range (Hz)	Longitudinal and Lateral Power Spectral Density g^2/Hz
20-250	0.001 to 0.16 increasing at 6 db/octave
250-2000	0.16

3.3.3 Pressure. The unit shall be capable of meeting all performance requirements of paragraph 3.1 when operating at ambient pressures of one atmosphere to 10^{-10} mm Hg.

3.3.4 Thermal-Vacuum. The thruster shall be capable of meeting all the performance requirements of paragraph 3.1 when operating at vacuum conditions with the temperature of the mounting structure and all surrounding surfaces (except where exposed to space) in the range from 14°F to 122°F steady-state, or cycling between the extremes at a period greater than or equal to 6.2 hours.

3.3.5 Humidity. The thruster shall be capable of being subjected to simultaneous relative humidity of 90% at atmospheric pressure and temperature of 86°F for a time period of 24 hours.

3.3.6 Storage Temperature. The thruster shall be capable of meeting all the requirements of paragraph 3.3.4 after being exposed, while nonoperative, to storage temperatures of -22°F and 140°F for time periods of 6 hours.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection and Test. Unless otherwise specified in the contract or purchase order, the supplier shall be responsible for the performance of all test requirements specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the customer.

4.2 Classification of Inspection and Test. The inspection and test shall be classified as follows:

4.2.1	Engineering Test and Evaluation	Not applicable to this specification
4.2.2	Design Verification Test	Not applicable to this specification
4.2.3	Formal Qualification Test	See paragraph 4.3 of Part I
4.2.4	Acceptance Test	See paragraph 4.2 of Part II

4.3 Qualification Inspection and Test. The following subparagraphs specify the requirements for, and the methods of, formally verifying that the requirements of Section 3 have been satisfied.

4.3.1 Test Sample. The qualification test units shall be the first two thrusters, excluding all engineering models, if any, produced in accordance with this specification using production drawings, tooling and procedures. These two units shall differ from flight configuration by being equipped with a chamber pressure tap. The units shall have successfully completed the acceptance tests of Part II of this specification prior to initiating the qualification tests.

4.3.2 Inspection. The following requirements of Section 3 shall be verified by inspection of the test units and by review of design and fabrication data, as applicable.

3.2.1.1 Configuration
3.2.1.2 Dimensions
3.2.1.3 Weight
3.2.1.12 Electrical Interface
3.2.2.1 Materials Compatibility
3.2.2.2 Corrosive Metals

3.2.2.3 Fungus Resistance
3.2.2.4 Dissimilar Metals
3.2.2.5 Finish
3.2.3 Construction
3.2.4 Workmanship
3.2.5 Interchangeability
3.2.6 Selection of Specifications and Standards
3.2.7 Identification of Product
3.2.9 Maintainability
3.2.10 Transportability
3.2.11 Safety

4.3.3 Analyses. The following requirements of Section 3 shall be verified by analyses prepared in accordance with the initiated plans where noted.

3.1.2.1 Reliability
3.1.2.2 Useful Life
3.2.1.5 Burst Pressure
3.2.1.8 Operating Voltage
3.2.1.9 Operating Power
3.2.12 Storage

4.3.4 Functional Tests. The following requirements of Section 3 shall be verified during qualification tests:

3.1.1.1.2 Operating Pressure
3.1.1.1.3 Operating Temperature
3.1.1.2.1 Steady-State Specific Impulse
3.1.1.2.2 Steady-State Thrust
3.1.1.2.3 Steady-State Duty Cycle
3.1.1.3.1 Pulse Duration
3.1.1.3.2 Pulse-Mode Specific Impulse
3.1.1.3.3 Pulse-Mode Impulse-Bit Repeatability
3.1.1.3.4 and 3.1.2.3 Pulse-Mode Duty Cycle
3.1.1.4.1 Internal Leakage
3.1.1.4.2 External Leakage
3.2.1.4 Proof Pressure
3.2.1.6 Valve Coil Resistance

3.2.1.7 Heater Resistance
3.2.1.8 Operating Voltage
3.2.1.9 Operating Power
3.2.1.10 Holding Power
3.2.1.13 Dielectric Strength

4.3.5 Environmental Tests. The following requirements of Section 3 shall be verified during qualification tests.

3.3.2 Qualification Vibration
3.3.1 Acceleration
3.3.4 Temperature
3.3.3 Ambient Pressure

4.3.6 Qualification Test Sequence. Qualification tests for the thruster shall be conducted in the following sequence.

Sequence	Test	Paragraph No.
1	Acceptance test	Part II
2	Acceleration	4.3.10.1
3	External leakage	4.3.10.2
4	Internal leakage	4.3.10.3
5	Electrical characteristics	4.3.10.4
6	Vibration	4.3.10.5
7	External leakage	4.3.10.2
8	Internal leakage	4.3.10.3
9	Electrical characteristics	4.3.10.4
10	Baseline performance	4.3.10.6
11	Thermal Vacuum test	4.3.10.7
12	Baseline performance	4.3.10.6
13	Duty cycle firing	4.3.10.8
14	Baseline performance	4.3.10.6

4.3.7 Failure Criteria. The unit shall exhibit no failure, malfunction, or out-of-tolerance performance degradation as a result of the inspections and tests specified herein. Any such occurrence shall be cause for rejection.

4.3.8 Test Procedure. All qualification inspection and tests shall be performed in accordance with a detailed test procedure. This procedure shall specify least the following: All test equipment including recording, measuring, monitoring, and alignment equipment; equipment locations and relationships;

equipment settings and parameters, parameters to be measured; tolerances on measurable parameters; environmental test conditions; and acceptance criteria for all inspections and test.

4.3.9 Test Conditions. Unless otherwise specified in Section 4.3.10, qualification inspection and test shall be conducted in accordance with the conditions and tolerances specified herein.

4.3.9.1 Atmospheric and Environmental. Unless otherwise specified, all examinations and tests shall be conducted under the local prevailing pressure at the time of the test, at a temperature of 65 to 85^{o}F and at a relative humidity of less than 55 percent.

4.3.9.2 Measurement Accuracy. Measuring instruments used to determine functional parameter values (such as voltage, frequency, pressure, etc) shall indicate true values with an accuracy determined by the tolerance allowed for the parameter variation itself, such that the measuring instrument shall not introduce an uncertainty greater than ten percent of the allowable variation of the measured parameter. However, no such measurement accuracy shall be required to exceed 0.5 percent of the required value of the parameter unless otherwise specified.

4.3.9.3 Test Tolerance. Except as specifically noted in the Test Methods, test tolerances for all test condition measurements shall be as follows:

a)	Temperature	plus or minus 5^{o}F to 200^{o}F plus or minus 5% above 200^{o}F
b)	Pressure	plus or minus 2%
c)	Relative Humidity	plus 5%, minus 10%
d)	Vibration Amplitude (sinusoidal)	plus or minus 10%
e)	Vibration Frequency	plus or minus 2%
f)	Shock Amplitude	plus or minus 10%
g)	Time	plus or minus 5%, plus or minus 1.0 millisecond for pulse length
h)	Acceleration	plus or minus 10%
i)	Random Noise Vibration	plus or minus 3 db
j)	Thrust	plus or minus 5%
k)	Propellant Flow	plus or minus 5%

4.3.9.4 Test Fluids. Test fluids shall be as follows:

Hydrazine propellant per MIL-P-26536 and the Contamination Control Procedure for the Monopropellant Hydrazine Resistojet

Nitrogen gas per MIL-P-27401

Isopropyl alochol per TT-I-735

Distilled water

4.3.9.5 Temperature Stabilization. A stabilized temperature shall not vary in excess of 4.0°F about its mean value below 200°F, and not in excess of 2 percent above 200°F.

4.3.9.6 Temperature Changes. Changes from one specified temperature to another (with the exception of chamber temperature) shall be accomplished at a rate not to exceed 50°F per minute, unless otherwise specified.

4.3.9.7 Pressure Limits. At no time during testing of the unit shall the applied pressure exceed 400 psig except during proof and burst tests.

4.3.10 Test Methods

4.3.10.1 Acceleration. The thruster shall be subjected to acceleration while in a non-operational condition. The thruster shall be attached to the centrifuge in a manner that simulates its attachment to the spacecraft, and the acceleration shall be applied in the axis corresponding to the thrust axis of the spacecraft/launch vehicle. The acceleration level shall be per the requirements of paragraph 3.3.1. At the conclusion of the test, the unit shall be examined and measured, where necessary, to verify that no out-ot-tolerance deformation resulted from the test.

4.3.10.2 External Leakage. The external leakage of the thruster shall be measured with the propellant valve open, nozzle throat sealed with a removable plug, and the inlet pressurized to 400 psig with gaseous helium. The measured leakage shall not exceed the requirement of paragraph 3.1.1.4.2.

4.3.10.3 Internal Leakage. The internal leakage of the thruster shall be measured through the thruster nozzle with the propellant valve closed and the inlet pressurized to 130 psig and 400 psig with gaseous helium. The measured leakage shall not exceed the requirement of paragraph 3.1.1.4.1

4.3.10.4 Electrical Characteristics. The electrical resistances of the propellant valve coil and the heater element shall be measured when at room temperature. The measured valves shall meet the requirements of paragraphs 3.2.1.6 and 3.2.1.7.

4.3.10.5 Vibration Test. The vibration test shall be performed with the thruster nonoperative. The thruster shall be attached to the vibration fixture by simulating the actual attachment to the spacecraft structure. Vibration shall be applied in each of the three major orthogonal axes per the schedules defined in paragraph 3.3.2. The vibration levels shall be measured and controlled at the thruster-to-fixture interface. Two control monitor accelerometers shall be mounted, each perpendicular to the control accelerometer and aligned with the remaining two axes. The thruster shall be visually examined at the conclusion of the test for evidence of damage or other adverse effects.

4.3.10.6 Performance Verification. Baseline performance tests shall be performed at simulated altitude and room ambient temperature according the test parameters specified in Table II. Prior to each of these tests, the thruster chamber temperature shall be stabilized at 1100°F. The following data shall be recorded:

a) Temperatures - thrust chamber, propellant inlet
b) Pressures - thrust chamber, propellant inlet, environmental
c) Propellant valve solenoid coil voltage and current
d) Thrust chamber heater voltage and current
e) Thrust
f) Propellant flowrate

TABLE II

BASELINE TEST SCHEDULE

Test No.	Inlet Pressure (psia)	Pulse Width (Second)	Pulse Period (Second)	Number of Pulses
1	TBD	0.100	10	5
2	↓	0.100	5	5
3	↓	0.100	1	5
4	↓	60.0	1	5
5	↓	0.050	10	5
6	↓	0.050	5	5
7	↓	0.050	1	5
8	↓	60.0	Steady-State	2
9	↓	0.100	10	5
10	↓	0.100	5	5
11	↓	0.100	1	5
12	↓	60.0	Steady-State	2

4.3.10.7 Thermal-Vacuum Test. The thruster shall be installed in a high altitude test chamber with mounting configuration simulating thruster attachment to the spacecraft structure. Surrounding cold walls and heaters shall be provided to control the thruster temperature between 14°F and 122°F. The thruster shall be instrumented to measure the following parameters:

a) Chamber pressure
b) Propellant inlet pressure
c) Chamber temperature
d) Propellant inlet temperature
e) Propellant flowrate
f) Propellant valve coil voltage and current
g) Heater voltage and current
h) Thrust Level

4.3.10.7.1 Cold Temperature Performance. The altitude chamber pressure shall be reduced below 100 microns and the thruster temperature reduced to 14°F. Freezing of the propellant in the feed line shall be prevented by maintaining the propellant valve temperature above 40°F with an electrical heater. Baseline performance tests shall be performed according to the parameters defined in Table II. Prior to each test, the thruster chamber temperature shall be stabilized at 1100°F. The thruster functional characteristics shall meet the requirements of paragraph 3.1.

4.3.10.7.2 Hot Temperature Performance. The altitude chamber pressure shall be reduced below 100 microns, and the thruster temperature increased to 122°F. After stable temperature has been achieved, baseline performance tests shall be performed according to the parameters defined in Table II. Prior to each test, the thruster chamber temperature shall be stabilized at 1100°F. The thruster functional characteristics shall meet the requirements of paragraph 3.1.

4.3.10.8 Duty Cycle Firing. The thruster shall be operated for one million cycles. Total test time shall be minimized by performing most of the cycling at 0.050 second pulse widths and high (20 to 50 percent) duty cycles. Demonstration of longer pulse durations and low duty cycles shall be required. Thruster inlet pressure, heater voltage, valve voltage, pulse width and pulse gate shall be varied over the limits specified in Section 3 of this specification. Test parameters shall be assigned according to a test matrix such that thruster operation at extreme condition is verified. The size of the test matrix shall be kept within reasonable limits to avoid unreasonable test durations.

5. NOTES

5.1 Definitions

5.1.1 Duty Cycle. The duty cycle is the complete firing schedule to which the thruster is subjected.

5.1.2 Pulse On-Time. The pulse on-time is the duration of the electrical signal received by the propellant valve.

5.1.3 Impulse Bit. The impulse bit is the integrated thrust time curve over the pulse duration.

5.1.4 Internal Leakage. Internal leakage is the leakage that occurs across the seat of the propellant valve.

5.1.5 Propellant Inlet Pressure. The propellant inlet pressure is the pressure measured at the inlet to the propellant valve.

5.1.6 Steady State. Steady state operation is achieved after continuous firing with a delivered total impulse greater than 0.040 lb-sec.

6. APPENDIX

None.

TBD

Figure 1. Steady State Thrust

TBD

Figure 2. Thruster Envelope

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

CODE IDENT 11982

TITLE

Equipment Specification Part II
Product Configuration and Acceptance Test Requirements
for
Hydrazine Resistojet

DATE 12 January 1972 NO.

SUPERSEDING: ____________

____

PREPARED BY: Rein Grabbi
Rein Grabbi

APPROVAL SIGNATURES:

____________ DATE	____________ DATE
C. K. Murch Principal Investigator	Ernest Cohen, Manager Electric Propulsion Department
____________ DATE	____________ DATE
____________ DATE	____________ DATE

PART II

EQUIPMENT SPECIFICATION

HYDRAZINE RESISTOJET

PRODUCT CONFIGURATION AND ACCEPTANCE TEST REQUIREMENTS

1. SCOPE

This specification establishes the requirements for the acceptance inspection and test for an Electrothermal Hydrazine Thruster Assembly, hereafter referred to as the thruster or the unit.

2. APPLICABLE DOCUMENTS

The following documents of the exact issue shown, or the latest issue in effect, if not shown, form a part of this specification to the extent specified herein. Where differences occur between documents referenced herein and the detail content of Sections 3, 4 and 5, the requirements of this specification shall apply.

SPECIFICATIONS

Federal

TT-I-735A	Isopropyl alcohol

Military

MIL-P-26536C	Propellant, Hydrazine
MIL-P-27401B	Propellant, Pressurizing Agent, Nitrogen
MIL-P-27407	Propellant, Pressurizing Agent, Helium
MIL-S-38130	System Safety Engineering of Systems and Associated Subsystems and Equipment

TRW Systems Group

PR2-2K	Cleaning of Fluid System Components
TBS	Equipment Specification for Hydrazine Propellant Valve

STANDARDS

Military

MS 33586A	Metals, Definition of Dissimilar
MIL-STD-143A	Specifications and Standards, Order of Procedure for the Selection of
MIL-STD-130C	Identification Marking of US Military Property

Federal

FED. STD. No. 209	Clean Room and Work Station Requirements, Controlled Environment

DRAWINGS

TRW Systems Group

409871	Electrothermal Hydrazine Thruster and Valve Assembly

OTHER DOCUMENTS

Air Force Eastern Test Range

AFETRM 127-1	Range Safety Manual

Military

MIL-HDBK-5A	Metallic Materials and Elements for Aerospace Vehicle Structures

TRW Systems Group

TBS	Contamination Control Procedure for the Monopropellant Hydrazine Resistojet

3. REQUIREMENTS

3.1 Performance

3.1.1 Proof Pressure. The unit shall show no evidence of deformation or damage and shall meet the requirements of this specification after undergoing proof pressure of 600 psig.

3.1.2 Internal Leakage. Internal leakage of the thruster with inlet pressures from 130 to 400 psig shall not exceed 2.0 standard cubic centimeters per hour of helium gas.

3.1.3 External Leakage. External leakage of the thruster with an internal pressure of 400 psig shall not exceed 1×10^{-6} standard cubic centimeter per second of helium gas.

3.1.4 Dielectric Strength. The thruster shall withstand 500 ± 5 Vac (60 cycle nominal) between shorted solenoid valve leads and the case for a period of 15 ± 1.0 seconds without insulation breakdown. Breakdown is defined as a current flow in excess of 2.0 milliamperes.

3.1.5 Insulation Resistance. The dc resistance between the shorted solenoid valve and heater leads and the case shall be greater than 1 megohm at 500 ± 50 Vdc.

3.1.6 Solenoid Valve Coil Resistance. The coil resistance shall be greater than 260 ohms at 70 ± 5°F coil and ambient temperatures.

3.1.7 Heater Resistance. The heater resistance shall be greater than 146 ohms at 70 ± 5°F heater and ambient temperature.

3.1.8 Vibration. The thruster shall meet the requirements of this specification after being vibrated according to the following schedules. Attachment of the thruster to the shaker shall simulate the actual attachment to the spacecraft structure. Vibration shall be applied in each of the three orthogonal directions, one direction being parallel to the vehicle's thrust axis. Flight components shall be subjected to random vibration only. Flight spares shall be exposed to both sinusoidal and random vibration independently. Vibration levels refer to measured and controlled amplitudes at the unit interface with the vibration test fixture.

3.1.8.1 Sinusoidal Vibration. Sinusoidal vibration shall be applied by sweeping the applied frequency once through each range specified in the schedule. The rate of change of frequency shall be four (4) octaves per minute.

Sinusoidal Vibration Schedule Flight Acceptance	
Frequency Range (Hz)	Longitudinal and Laterial Axes Acceleration, g's 0-to-Peak
5-18	0.5 in D.A.
18-200	8.0
200-2000	3.3

3.1.8.2 Random Vibration. Gaussian random vibration shall be applied with the g-peaks clipped at three times the root-mean-square acceleration specified in the schedule. Vibration time shall be two (2) minutes per axis.

Random Vibration Schedule Flight Acceptance	
Frequency Range (Hz)	Longitudinal and Lateral Power Spectral Density g^2/Hz
20-250	0.00046 to 0.07 increasing at 6 db/octave
250-2000	0.07

3.1.9 Steady-State Thrust. The steady-state thrust shall be within the limits shown in Figure 1.

3.1.10 Specific Impulse. The vacuum specific impulse shall be greater than 200 seconds for steady-state operation, and greater than 175 seconds for pulse-mode operation for duty cycles greater than 2 percent.

3.1.11 Pulse-Mode Impulse Bit Repeatability. For any given operating pressure, thruster temperature, and thruster on-time, the delivered vacuum impulse bit shall be repeatable within $\pm$ 10 percent.

3.2 Product Configuration

3.2.1 Production Drawing. The configuration and dimensions of the thruster shall be in accordance with drawing No. 409871.

3.2.2 Weight. The thruster shall not weigh more than 0.4 pound.

3.2.3 Workmanship. The thruster shall be constructed, finished and assembled in accordance with workmanship standards specified in the process specifications used for thruster manufacture.

3.2.4 Identification of Product. The thruster shall be identified in accordance with drawing 409871. Identification data shall include but not be limited to, the following:

a) Unit Name
b) TRW Part Number
c) TRW Serial Number
d) Actual weight in pounds to an accuracy of 0.01 pound

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection and Test. Unless otherwise specified in the contract or purchase order, the supplier shall be responsible for the performance of all the test requirements specified herein. Except as otherwise specified, the supplier may utilize his own facility or any commercial laboratory.

4.2 Acceptance Inspection and Test. The following subparagraphs specify the requirements for, and the methods of, verifying that the requirements of Section 3 have been satisfied.

4.2.1 Acceptance Test Article. Unit acceptance test shall be conducted for every deliverable thruster.

4.2.2 Inspection. The following requirements of Section 3 shall be verified by inspection of the test unit.

3.2.1 Configuration and Dimensions
3.2.2 Weight
3.2.3 Workmanship
3.2.4 Identification of Product

4.2.3 Test. The following requirements of Section 3 shall be verified during acceptance test.

3.1.1 Proof Pressure
3.1.2 Internal Leakage
3.1.3 External Leakage
3.1.4 Dielectric Strength
3.1.5 Insulation Resistance
3.1.6 Propellant Valve Coil Resistance
3.1.7 Heater Resistance
3.1.8 Vibration
3.1.9 Steady-State Thrust
3.1.10 Specific Impulse
3.1.11 Pulse-Mode Impulse Bit Repeatability

4.2.4 Acceptance Test Sequence. Acceptance tests for the thruster shall be conducted in the following sequence.

Sequence	Test	Paragraph No.
1	Inspection	4.3.1
2	Proof pressure	4.3.2
3	External leakage	4.3.3
4	Internal leakage	4.3.4
5	Electrical characteristics	4.3.5
6	Vibration	4.3.6
7	Electrical characteristics (less dielectric)	4.3.5
8	Internal leakage	4.3.4
9	Performance verification	4.3.7
10	Internal leakage	4.3.4
11	External leakage	4.3.3

4.2.5 Failure Criteria. The unit shall exhibit no failure, malfunction, or out-of-tolerance performance degradation as a result of the inspection and tests specified herein. Any such occurrence shall be cause for rejection.

4.2.6 Test Procedure. All acceptance inspection and tests shall be performed in accordance with a detailed test procedure. This procedure shall specify at least the following: All test equipment including recording, measuring, monitoring, and alignment equipment, equipment locations and relationships; equipment settings and parameters, parameters to be measured; tolerances on measurable parameters; environmental test conditions; and acceptance criteria for all inspections and tests.

4.2.7 Test Conditions. Unless otherwise specified in Section 4.2.8, acceptance inspection and test shall be conducted in accordance with the conditions and tolerances specified herein.

4.2.7.1 Atmospheric and Environmental. Unless otherwise specified, all examinations and tests shall be conducted under the local prevailing pressure at the time of the test, at a temperature of 65 to 85°F and at a relative humidity of less than 55 percent.

4.2.7.2 Measurement Accuracy. Measuring instruments used to determine functional parameter values (such as voltage, frequency, pressure, etc.) shall indicate true values with an accuracy determined by the tolerance allowed for the parameter variation itself, such that the measuring instrument shall not introduce an uncertainty greater than ten percent of the allowable variation of the measured parameter. However, no such measurement accuracy shall be required to exceed 0.5 percent of the required value of the parameter unless otherwise specified.

4.2.7.3 Test Tolerance. Except as specifically noted in the Test Methods, test tolerances for all test condition measurements shall be as follows:

a)	Temperature	plus or minus 5°F to 200°F plus or minus 5% above 200°F
b)	Pressure	plus or minus 2%
c)	Relative Humidity	plus 5%, minus 10%
d)	Vibration Amplitude (sinusoidal)	plus or minus 10%

e)	Vibration	plus or minus 2%
f)	Time	plus or minus 5%, plus or minus 1.0 millisecond for pulse width
g)	Random Noise Vibration (for 50 cps bandwidth)	
h)	Thrust	plus or minus 5%
i)	Propellant Flow	plus or minus 5%

4.2.7.4 Test Fluids. Test fluids shall be as follows:

Hydrazine propellant per MIL-P-26536 and Contamination Control Procedure for the Monopropellant Hydrazine Resistojet

Nitrogen gas per MIL-P-27401

Isopropyl alcohol per TT-I-735

Distilled water

4.2.7.5 Pressure Limits. At no time during testing of the unit shall the applied pressure exceed 400 psig except during proof test.

4.3 Test Methods

4.3.1 Inspection. The thruster shall be visually examined to verify that the product configuration requirements of dimensions, weight, workmanship and identification of product are met according to the requirements of paragraphs 3.2.1, 3.2.2, 3.2.3, and 3.2.4.

4.3.2 Proof Pressure. The thruster shall be proof tested with nitrogen at 600 psig. The thruster shall be pressurized with the propellant valve closed (coil deenergized) for 5 minutes, and then with the valve open (coil energized) and the nozzle throat sealed with a removable plug for 5 minutes. There shall be no evidence of deformation or permanent damage.

4.3.3 External Leakage. The external leakage of the thruster shall be measured with the propellant valve open, nozzle throat sealed with a removable plug, and the inlet pressurized to 400 psig with gaseous helium. The measured leakage shall not exceed the requirement of paragraph 3.1.3.

4.3.4 Internal Leakage. The internal leakage of the thruster shall be measured through the thruster nozzle with the propellant valve closed and the inlet pressurized to 130 psig and 400 psig with gaseous helium. The measured leakage shall not exceed the requirement of paragraph 3.1.2

4.3.5 Electrical Characteristics

4.3.5.1 Dielectric Strength. The dielectric strength of the valve coil shall be measured by applying 500 Vac (60 cycle nominal) between the shorted coil leads and the thruster body for 15 seconds. The requirements of paragraph 3.1.4 shall be satisfied.

4.3.5.2 Insulation Resistance. The dc resistance between the shorted solenoid coil and heater leads and the thruster body shall be measured at 500 $\pm$ 50 Vdc. The requirement of paragraph 3.1.5 shall be satisfied.

4.3.5.2 Propellant Valve Coil Resistance. The electrical resistance of the solenoid coil shall be measured when at room ambient temperature. The measured value shall meet the requirement of paragraph 3.1.6.

4.3.5.3 Heater Resistance. The electrical resistance of the heater element shall be measured at room ambient temperature. The measured value shall meet the requirement of paragraph 3.1.7.

4.3.6 Vibration Test. The vibration test shall be performed with the thruster nonoperative. The thruster shall be attached to the vibration fixture by simulating the actual attachment to the spacecraft structure. Vibration shall be applied in each of the three major orthogonal axes per the schedule defined in paragraph 3.1.8. The vibration levels shall be measured and controlled at the thruster-to-fixture interface. Two control monitor accelerometers shall be required to measure cross axis motion. The thruster shall be visually examined at the conclusion of the test for evidence of damage or other adverse effects.

4.3.7 Performance Verification. A baseline performance test shall be performed at room ambient temperature according to Table I. Prior to each of the tests, the thruster chamber temperature shall be stabilized at 1100°F. Propellant valve excitation voltage shall be set at 26.0 Vdc. The following data shall be recorded during the baseline tests:

a) Temperatures - thrust chamber, propellant inlet
b) Pressures - thrust chamber, propellant inlet, environmental
c) Propellant valve solenoid coil voltage and current
d) Thrust chamber heater voltage and current
e) Thrust
f) Propellant flow rate

TABLE I

BASELINE TEST SCHEDULE				
Test No.	Inlet Pressure (psia)	Pulse Width (Second)	Pulse Period (Second)	Number of Pulses
1	TBD	0.100	10	5
2		0.100	5	5
3		0.100	1	5
4		60.0	1	5
5		0.050	10	5
6		0.050	5	5
7		0.050	1	5
8		60.0	Steady-State	2
9		0.100	10	5
10		0.100	5	5
11		0.100	1	5
12		60.0	Steady-State	2

The following data shall be reduced from the recorded parameters:

a) Specific impulse

b) Delivered impulse bit

c) Heater power

Thruster performance shall meet the requirements of paragraphs 3.1.9, 3.1.10 and 3.1.11. At the conclusion of the performance test, the thruster shall be decontaminated according to the requirements of the applicable Contamin-Control Procedure.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be in accordance with Section 5 of PR2-2.

6. NOTES

6.1 Definitions

6.1.1 Internal Leakage. Internal leakage is the leakage that occurs across the solenoid valve seat.

6.1.2 Propellant Inlet Pressure. The propellant inlet pressure is the pressure measured at the inlet to the solenoid valve.

6.1.3 Impulse Bit. The impulse bit is the integrated thrust time curve over the pulse duration.

7. APPENDIX

None

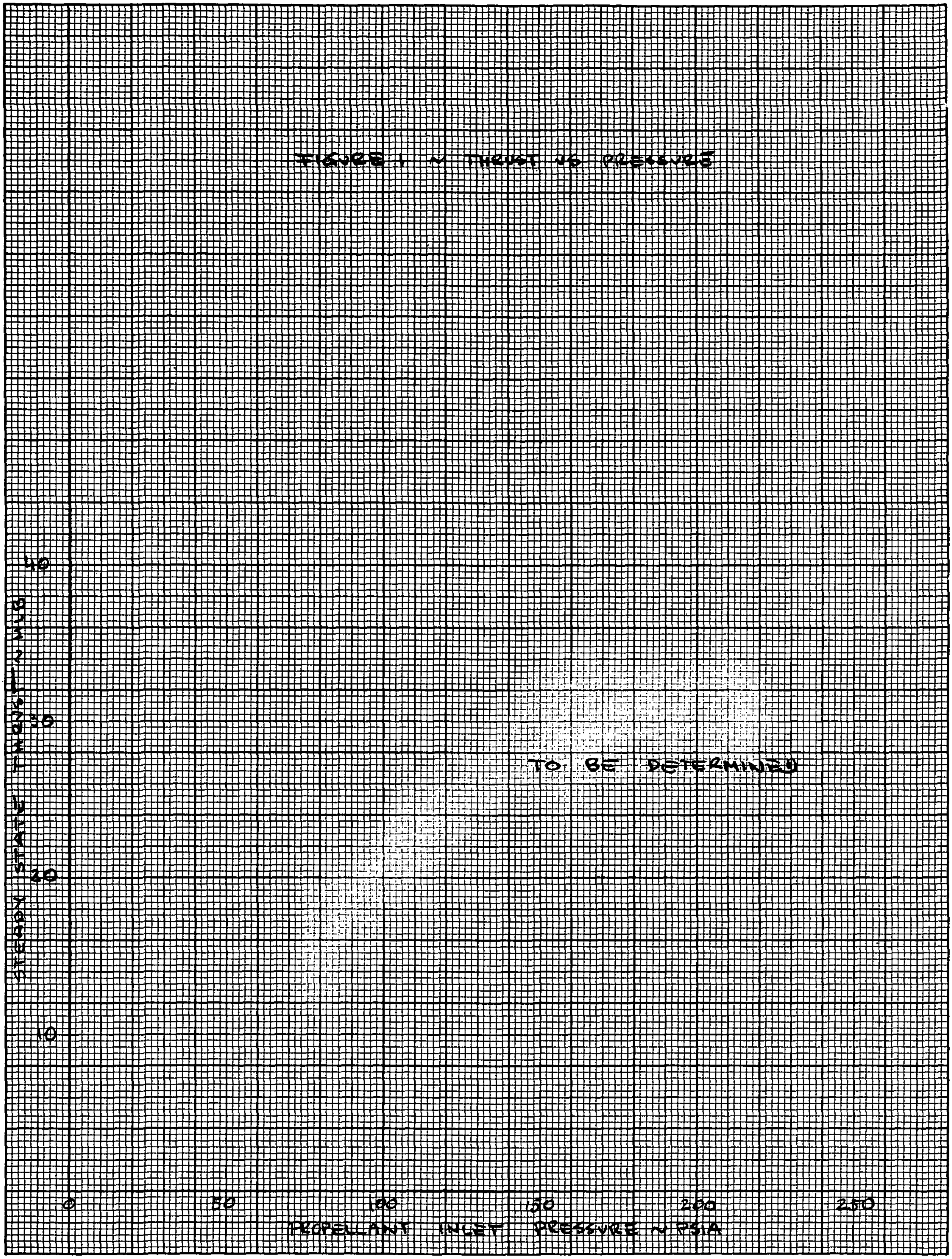

FIGURE 1 ~ THRUST VS PRESSURE

APPENDIX III

ACCEPTANCE TEST PLAN

FOR THE MONOPROPELLANT HYDRAZINE

RESISTOJET

27 December 1971

Prepared for:

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

Contract No. NAS5-11477

Prepared by:

Rein Grabbi

Approved by:

C. K. Murch
Principal Investigator

Ernest Cohen, Manager
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TRW Systems
One Space Park
Redondo Beach, California 90278

1. SCOPE

1.1 Equipment to be Tested. The equipment to be tested shall be the engineering model Electrothermal Hydrazine Thruster Assembly, hereafter referred to as the thruster unit.

1.2 Test Objective. The tests outlined in this plan are conducted to verify the operating parameters of the resistojet.

1.3 Test Description. The tests described in this Test Plan consist of those specified in paragraphs 3.1.1 through 3.1.13 and as outlined in Table I of this plan. Tests shall be conducted in the sequence shown in Table I.

Table I. Test Summary

Test		Test Plan Paragraph
1. Functional	3.1.1-3.1.9	(see Table II)
2. Thermal Vacuum/Temperature Cycling		3.1.10
3. Parameter Variation		3.1.11
4. Cycle Life		3.1.12
5. Steady-State Life		3.1.13

2. CONDITIONS

2.1 Facility. The tests outlined in this plan shall be conducted at the contractor's facility.

2.2 Referenced Documents. The following documents of the exact issue shown, or the latest issue in effect, form a part of this Test Plan to the extent specified herein. Where differences occur between documents referenced and the detail content of Section 3, of this specification, the requirements of this specification shall apply.

Table II. Functional Tests

Test		Test Plan Paragraph
1.	Inspection	3.1.1
2.	Proof Pressure	3.1.2
3.	External Leakage	3.1.3
4.	Internal Leakage	3.1.4
5.	Heater Resistance	3.1.5
6.	Valve Coil Resistance	3.1.6
7.	Dielectric Strength	3.1.7
8.	Insulation Resistance	3.1.8
9.	Valve Response	3.1.9
10.	Valve Pull-in and Drop-out Voltage	3.1.10

SPECIFICATIONS

Military

MIL-P-26536C	Propellant, Hydrazine

TRW Systems

TBA	Equipment Specification, 20-Millipound Hydrazine Resistojet, Parts I and II
PR2-2K	Cleaning of Fluid System Components
TBA	Equipment Specification, Hydrazine Propellant Valve

STANDARDS

Federal

Fed. Std. No. 209	Clean Room and Work Station Requirements Controlled Environment

DRAWINGS

TRW Systems

409871	Electrothermal Hydrazine Thruster and Valve Assembly

OTHER DOCUMENTS

TRW Systems

TBS	Contamination Control Procedure for the Monopropellant Hydrazine Resistojet

2.3 Test Fluids. Test fluids shall be as follows:

Hydrazine propellant per MIL-P-26536 as modified per the Contamination Control Procedure for the Monopropellant Hydrazine Resistojet.

Nitrogen gas per MIL-P-27401

Isopropyl alcohol per TT-I-735

Distilled water

2.4 Equipment Handling. Continuous precaution shall be taken to preserve and maintain the cleanliness level of the unit. Handling procedures shall comply with the requirements listed in the Contamination Control Procedure for the Monopropellant Hydrazine Resistojet.

2.5 Atmospheric and Environmental. Unless otherwise specified, all examinations and tests shall be conducted under the local prevailing pressure at the time of the test, at a temperature of 65 to 85^{o}F and at a relative humidity of less than 55 percent.

2.6 Measurement Accuracy. Measuring instruments used to determine functional parameters values (such as voltage, frequency, pressure, etc.) shall indicate true values with an accuracy determined by the tolerance allowed for the parameter variation itself, such that the measuring instrument shall not introduce an uncertainty greater than ten percent of the allowable variation of the measured parameter. However, no such measurement accuracy shall be required to exceed 0.5 percent of the required value of the parameter unless otherwise specified.

2.7 Test Tolerance. Except as specifically noted in the Test Methods, test tolerances for all test condition measurements shall be as follows:

a)	Temperature	plus or minus 5^{o}F to 200^{o}F plus or minus 5% above 200^{o}F
b)	Pressure	plus or minus 2%
c)	Relative Humidity	plus 5%, minus 10%
d)	Time	plus or minus 5%, plus or minus 1.0 ms for pulse length
e)	Thrust	plus or minus 5%
f)	Propellant Flow	plus or minus 5%

2.8 Temperature Stabilization. A stabilized temperature shall not vary in excess of 4.0°F about its mean value below 200°F, and not in excess of 2 percent above 200°F.

2.9 Temperature Changes. Changes from one specified temperature to another shall be accomplished at a rate not to exceed 50^{O}F per minute, unless otherwise specified.

2.10 Pressure Limits. At no time during testing of the unit shall the applied pressure exceed 400 psig except during proof test.

3. TEST METHODS

3.1 Functional Tests

3.1.1 Inspection. The thruster shall be visually examined to verify that the product configuration requirements of dimension, weight, workmanship and identification are satisfied according to the requirements of paragraphs 3.2.1.1., 3.2.1.2, 3.2.1.3, 3.2.4 and 3.2.8 of the thruster specification.

3.1.2 Proof Pressure. The thruster shall be proof tested with nitrogen at 600 psig. During the test, the unit shall be placed within an appropriate safety enclosure. The test shall be performed with the propellant valve closed (coil deenergized), and with the propellant valve open (coil energized) and the nozzle throat sealed with a removable plug.

3.1.3 External Leakage. The external leakage of the thruster shall be measured with the propellant valve open (coil energized), nozzle throat sealed with a removable plug, and the inlet pressurized to 400 psig with gaseous helium.

3.1.4 Internal Leakage. The internal leakage of the thruster shall be measured through the thruster nozzle with the propellant valve closed (coil deenergized) and the inlet pressurized to 130 psig and 400 psig with gaseous helium.

3.1.5 Heater Resistance. The electrical resistance of the thruster heater shall be measured when at room ambient temperature.

3.1.6 Valve Coil Resistance. The electrical resistance of the propellant vaLve coil shall be measured when at room ambient temperature.

3.1.7 Dielectric Strength. The dielectric strength of the valve coil shall be measured by applying 500 Vac (60 cycle nominal) between the shorted coil leads and the thruster body for 15 seconds.

3.1.8 Insulation Resistance. The dc resistance between the shorted valve coil and heater leads and the thruster body shall be measured at 500 $\pm$ 50 Vdc.

3.1.9 Propellant Valve Response. The propellant valve opening and closing transient times shall be measured from oscilloscope traces of the valve voltage and current. The thruster inlet shall be pressurized to 130 and 400 psig with gaseous nitrogen. The valve command voltage shall be 26.0 Vdc and the pulse length 100 milliseconds. The requirements of specification TBS shall be met.

3.1.10 Propellant Valve Pull-in and Drop-out Voltage. The propellant valve pull-in and drop-out voltages shall be measured with the inlet pressurized at 130 and 400 psig. The pull-in voltage shall be measured by slowly increasing the valve excitation voltage until the valve opens. The drop-out voltage shall be measured by slowly decreasing the valve excitation voltage from 27.5 Vdc until the valve closes. The requirements of specification TBS shall be met.

3.1.11 Thermal Vacuum/Temperature Cycling Test. The thruster shall be installed in a high altitude test chamber with mounting configuration simulating thruster attachment to the spacecraft structure. Surrounding cold walls and heaters shall be provided to control the thruster temperature between 14^{o}F and 122^{o}F. The thruster shall be instrumented to measure the following parameters:

a) chamber pressure
b) propellant inlet pressure
c) chamber temperature
d) fuel inlet temperature
e) injector temperature
f) valve body temperature
g) insulation exterior temperature
h) propellant flow rate
i) propellant valve coil voltage and current
j) heater power
k) thrust level

3.1.11.1 Ambient Performance. With the thruster at room ambient temperature the altitude chamber pressure shall be reduced below 100 microns. The thrust chamber heater voltage shall be set to 27.0 Vdc and the thrust chamber temperature allowed to stablize. The thruster shall then be fired continuously for one (1) minute with the propellant inlet pressure at 200 psia. After thruster temperature stablization at the holding level, the thruster shall be fired for 20 consecutive pulses of 50 millisecond duration at one (1) second intervals. Propellant valve excitation voltage shall be 26 Vdc.

3.1.11.2 Cold Temperature Performance. The altitude chamber pressure shall be reduced below 100 microns and the thruster temperature reduced to 14°F. Freezing of the hydrazine in the feed line shall be prevented by maintaing the propellant valve temperature above 40°F. After stable temperatures have been achieved, the thrust chamber heater voltage shall be set to 27.0 Vdc and the chamber temperature shall be allowed to stabilize at the holding level. The thruster shall then be fired continuously for one (1) minute with the propellant inlet pressure at 200 psia. The same sequence shall be followed for a thruster firing of 20 consecutive pulses of 50 millisecond duration at one (1) second intervals. Propellant valve excitation voltage shall be 26.0 Vdc.

3.1.11.3 Hot Temperature Performance. The altitude chamber pressure shall be reduced below 100 microns and the thruster temperature increased to 122°F. After stable temperatures have been achieved, the thrust chamber heater voltage shall be set to 27.0 Vdc and the chamber temperature shall be allowed to stabilize at the holding level. The thruster shall then be fired continuously for one (1) minute with the propellant inlet pressure at 200 psia. The same sequence shall be followed for a thruster firing of 20 consecutive pulses of 50 millisecond duration at one (1) second intervals. Propellant valve excitation voltage shall be 26.0 Vdc.

3.1.12. Parameter Variation. The thruster shall be installed in a high altitude test chamber with mounting configuration simulating thruster attachment to the spacecraft structure. With the thruster at room ambient temperature the altitude chamber pressure shall be reduced below 100 microns. The thruster shall be operated to map its performance over the parameter ranges specified in Table III.

Table III

Test Parameter	Test Valve
Inlet pressure (psia)	100, 150, 200, 250, 300, 350, 400
Heater voltage (VDC)	25, 27, 29
Pulse width (MS)	50, 75, 100, 150, 250, steady-state
Duty cycle (percent)	1, 2, 5, 10, 25, 100
Pulse number	1 through 20
Valve voltage (VDC)	24, 26, 28

The thruster and the test facility shall be instrumented to measure and/or record the following data:

a) temperatures - propellant inlet, thrust chamber, propellant valve, insulation package, nozzle exit, injector
b) pressures - propellant inlet, thrust chamber, environmental
c) propellant valve solenoid coil voltage and current
d) chamber heater voltage and current
e) thrust
f) propellant flow rate
g) command pulse width and pulse number

The following information shall be reduced from the recorded data:

a) Valve power
b) Valve response time
c) Heater power
d) Integrated thrust
e) Delivered impulse bit
f) Pulse centroid
g) Specific impulse
h) Impulse bit variation
i) Impulse bit reproducibility

3.1.13 <u>Cycle Life Test</u>. The thruster shall be operated for 10^6 cycles covering a range of duty cycles. The total test line shall be minimized by performing most of the cycling at 0.050 second pulse width and high (20 to 50 percent) duty cycles. Thruster inlet pressure and the heater and valve voltages shall be varied over the allowable specification limits during the test period. A baseline performance test accoring to the schedule in Table IV shall be performed at the beginning of the test, after 10,000, 20,000, 50,000 and 100,000 pulses and at 100,000 pulse intervals thereafter.

Table IV

BASELINE TEST SCHEDULE				
Test No.	Inlet Pressure (psia)	Pulse Width (Second)	Pulse Period (Second)	Number of Pulses
1	TBD	0.100	10	5
2		0.100	5	5
3		0.100	1	5
4		60.0	1	5
5		0.050	10	5
6		0.050	5	5
7		0.050	1	5
8		60.0	Steady-State	2
9		0.100	10	5
10		0.100	5	5
11		0.100	1	5
12		60.0	Steady-State	2

The thruster and the test facility shall be instrumented to measure and record data similar to paragraph 3.1.12. Data shall be recorded during all baseline tests and during cycle life test whenever deemed necessary. Data reduction shall be similar to paragraph 3.1.12.

3.1.14 Steady State Life Test. The thruster shall be operated for five 6-hour continuous firings. The thruster temperature may be allowed to reach room ambient between runs. The propellant inlet pressure shall be alternated between 150, 250 and 350 psia, while the propellant valve and heater excitation voltages shall remain at their nominal of 26.0 Vdc and 27.0 Vdc. The following parameters shall be monitored during the test:

a) chamber pressure
b) chamber temperature
c) inlet pressure
d) thrust
e) flow rate
f) propellant valve and heater voltage and current.

At the conclusion of the test a baseline test shall be conducted according to the schedule in Table IV. The following information shall be reduced from the recorded data:

a) valve power
b) heater power
c) specific impulse
d) impulse bit (baseline only).

CONTAMINATION CONTROL PROCEDURE
FOR THE MONOPROPELLANT HYDRAZINE
RESISTOJET

27 December 1971

Prepared for:

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

Contract No. NAS5-11477

Prepared by:

Rein Grabbi

Approved by:

C. K. Murch
Principal Investigator

Ernest Cohen, Manager
Electric Propulsion Department

TRW Systems
One Space Park
Redondo Beach, California 90278

1. SCOPE

This procedure establishes the contamination control procedures for the manufacture, test and handling of an Electrothermal Hydrazine Thruster, hereafter referred to as the thruster or unit.

2. OBJECTIVE

The objective of this procedure is to outline the contamination control requirements to assure proper operation of the thruster. This includes the proper contamination control of the hydrazine propellant for chemical and particulate impurities as well as the cleanliness requirements of the thruster assembly and its components. The procedure also outlines the proper methods of propellant and thruster handling to prevent possible contamination. General requirements for assembly and test areas are also delineated.

3. APPLICABLE DOCUMENTS

The following documents of the exact issue shown, or the latest issue in effect, if not shown, form a part of this procedure to the extent specified herein. Where differences occur between documents referenced herein and the detail content of this procedure, the requirements of this procedure shall apply.

SPECIFICATIONS

Federal

TT-I-735A	Isopropyl Alcohol

Military

MIL-P-26536C	Propellant, Hydrazine
MIL-P-27401B	Propellant, Pressurizing Agent, Nitrogen

TRW Systems Group

PR2-2K	Cleaning of Fluid System Components
TBS	Equipment Specification for Hydrazine Resistojet, parts I and II.

DRAWINGS

TRW Systems Group

409871	Electrothermal Hydrazine Thruster and Valve Assembly

STANDARDS

Military

MIL-STD-1246A	Product Cleanliness Levels and Contamination Control Program

Federal

Fed-Std No. 209A	Clean Room and Work Station Requirements, Controlled Environments

4. REQUIREMENTS

4.1 Hydrazine Propellant

4.1.1 Chemical and Physical Properties. The hydrazine propellant shall meet the requirements of MIL-P-26536. In addition, the propellant shall be analyzed for, and shall not exceed the limits of the following contaminants:

a)	Non-Volatile Residue (NVR)	20 mg/100cc max
b)	Aniline ($C_6H_5 \cdot NH_2$)	0.50% w/w max
c)	Carbon Dioxide (CO_2)	0.1 % w/w max
d)	Unsymmetrical Dimethylhydrazine ($N_2H_4(CH_3)_2$)	none

4.1.2 Storage. In the test set-up, the hydrazine propellant shall be stored in an approved container of Type 304 or 347 stainless steel. Prior to filling, the container shall be visually inspected for the presence of water, rust, scale, oil, or other foreign matter, and physical damage. The container shall then be cleaned to the requirements of PR2-2 Level II. The space above the liquid level shall be filled with nitrogen conforming to MIL-P-27401, Type I, at not less than atmospheric pressure.

4.1.3 Transfer. Stringent care must be taken to insure the propellant does not become contaminated during transfer procedures. The risk of propellant contamination shall be minimized by deleting unnecessary propellant transfer to intermediate containers between the shipping container and the run storage tank. Prior to filling the test set-up storage tank, the propellant shall be passed through a 10-micron absolute rating filter.

4.2 Thruster Assembly. The interior surfaces of the propellant valve and injector tubing which come in contact with the hydrazine propellant shall be cleaned to and shall meet the requirements of PR2-2, except that the particulate contamination count shall meet the standards of Level 100 of MIL-STD-1246 with no metallic particles over 50 microns. Freon shall not be used to flush the propellant valve or the assembled thruster, instead isopropyl alcohol per TT-I-735A shall be used. The thruster assembly shall be protected from particulate contamination by incorporating a 10-micron filter immediately upstream of the propellant valve.

4.3 Test Set-up. The components of the test set-up utilized to supply hydrazine to the thruster shall be cleaned to the requirements of PR2-2 Level II. Assembly of the test set-up shall be completed in an area meeting the clean room requirements of Fed. Std. No. 209A, Class 100,000. Continuous precaution shall be taken to preserve and maintain the cleanliness level of the test set-up. When not in use, all lines and fittings shall be capped. No fluid other than the specified test media shall be introduced into the test set-up.

4.4 Decontamination. At the completion of thruster hot firings, the unit shall be decontaminated to remove all traces of hydrazine. The decontaminant during flushing procedures shall be isopropyl alcohol. Freon cleaning agents shall not be used.

5. NOTES

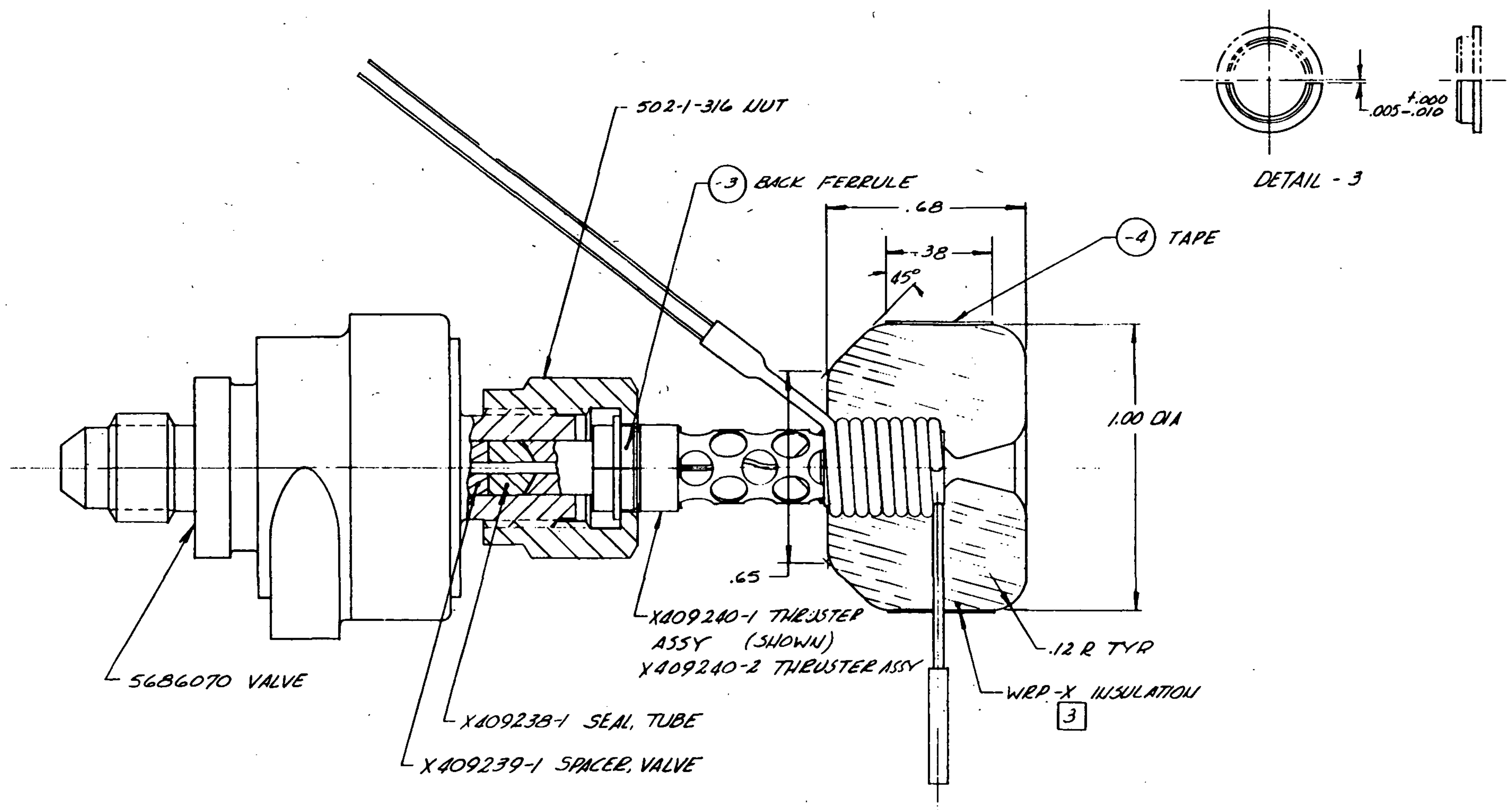
5.1 Definitions

5.1.1 Non-Volatile Residue: The dissolved hydrazine components which are non-volatile to vacuum distallation at 40°C and approximately 1 torr pressure.

5.1.2 Particulate: The undissolved solids retained on a 0.45-micron filter membrane.

Drawing List for the Engineering Model Electrothermal Hydrazine Thruster

Drawing No.	Title
X409289	Electrothermal Hydrazine Thruster and Valve Assembly
X409290	Electrothermal Hydrazine Thruster and Valve Assembly
X409240	Thruster Assembly, EHT
X409235	Body, Thruster-EHT
X409237	Nozzle, EHT
X409234	Retainer, Seal-EHT
X409236	Tube, Barrier-EHT
X409238	Spacer, Valve-EHT
X409239	Seal, Tube-EHT



-1 ASSY (SHOWN)
-2 ASSY

QTY REQD PER ASSY -2	QTY REQD PER ASSY -1	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.
1	1		-4	TAPE	AL FOIL - 4.00 LONG	TF101 5		
A/R	A/R	4	WRP-X	INSULATION				
1	1	92003	5686070	VALVE				
1	1	02570	502-1-316	NUT				
2	2	02570	-3	BACK FERRULE	M/F SWAGELOK #401-1-316			
1	1		X409239-1	SPACER, VALVE				
1	1		X409238-1	SEAL, TUBE				
1			X409240 -2	THRUSTER ASSY				
	1		X409240-1	THRUSTER ASSY				

(Rows for WRP-X, 5686070, 502-1-316 and -3 bracketed with note 2.)

PARTS LIST

NOTES: UNLESS OTHERWISE SPECIFIED

1. IDENTIFY PER PR 12-6-0900
2. SUGGESTED VENDOR
3. APPLY INSULATION PER (TBD)
4. REFRACTORY PRODUCTS CO., 220 SOUTH LINCOLN CARPENTERSVILLE, ILL.
5. TRW INVENTORY CONTROL NO.

UNLESS OTHERWISE SPECIFIED

1. DO NOT SCALE DRAWING.
2. INTERPRET PER MIL-STD-100.
3. DIMENSIONS ARE IN INCHES.
4. SURFACE TEXTURE SHALL BE 125 ✓
5. REMOVE BURRS AND SHARP EDGES.
6. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
7. PARENTHETICAL DATA IS FOR REFERENCE ONLY.

TOLERANCES

ON ALL HOLE DIAMETERS

UNDER .0140	+.0020 −.0005	.501 THRU .750	+.008 −.001
.014 THRU .125	+.004 −.001	.751 THRU 1.000	+.010 −.001
.126 THRU .250	+.005 −.001	1.000 THRU 2.000	+.012 −.001
.251 THRU .500	+.006 −.001	OVER 2.000	+.015 −.005

ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

ON ANGULAR DIMENSIONS: MACHINED ± 0°30′, LOCATING ± 0°30′, FORMED ± 2°, CHAMFERS ± 5°

FINISH

HEAT TREAT

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
EHT	–	

APPLICATION

PR 12-6

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

CONTRACT NO.

DRAWN J. WILKERSON 27 OCT 1971

CHECKED

STRUCTURES

MATERIAL/PROCESS

ENGINEER

SUPERVISOR

PROJECT

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

ELECTRO THERMAL HYDRAZINE THRUSTER AND VALVE ASSY

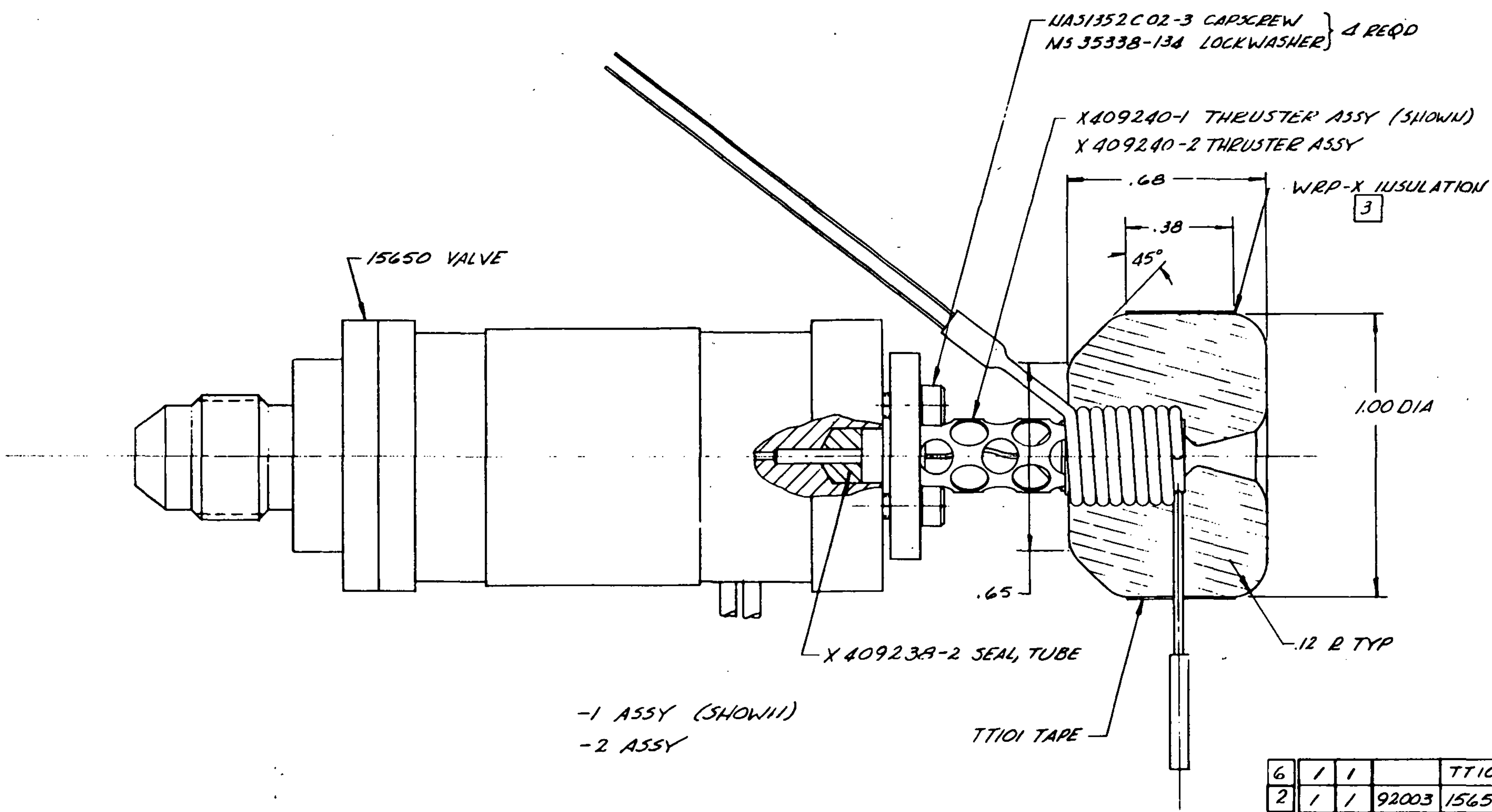
SIZE D | CODE IDENT NO. 11982 | X409289

SCALE 4/1 | SHEET

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

MJO 1483-23

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



NOTES: UNLESS OTHERWISE SPECIFIED

1. IDENTIFY PER PR 12-6-0900
2. SUGGESTED VENDOR
3. APPLY INSULATION PER (TBD)
5. REFRACTORY PRODUCTS CO., 220 SOUTH LINCOLN, CARPENTERSVILLE, ILL.
6. TRW INVENTORY CONTROL NO.

	-2	-1	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.
6	1	1		TT101	TAPE	AL FOIL TAPE- 4.00 LONG			
2	1	1	92003	15650	VALVE				
2	A/R	A/R	5	WRP-X	INSULATION				
	4	4		MS 35338-134	LOCKWASHER				
	4	4		NAS 1352C02-3	CAPSCREW				
	1	1		X 409238-2	SEAL, TUBE				
	1			X409240-2	THRUSTER ASSY				
		1		X409240-1	THRUSTER ASSY				

QTY REQD PER ASSY — PARTS LIST

UNLESS OTHERWISE SPECIFIED

1. DO NOT SCALE DRAWING.
2. INTERPRET PER MIL-STD-100.
3. DIMENSIONS ARE IN INCHES.
4. SURFACE TEXTURE SHALL BE 125
5. REMOVE BURRS AND SHARP EDGES.
6. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
7. PARENTHETICAL DATA IS FOR REFERENCE ONLY.

TOLERANCES

ON ALL HOLE DIAMETERS

UNDER .0140	+.0020 −.0005	.501 THRU .750	+.008 −.001
.014 THRU .125	+.004 −.001	.751 THRU 1.000	+.010 −.001
.126 THRU .250	+.005 −.001	1.000 THRU 2.000	+.012 −.001
.251 THRU .500	+.006 −.001	OVER 2.000	+.015 −.005

ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

ON ANGULAR DIMENSIONS: MACHINED ± 0°30′, LOCATING ± 0°30′, FORMED ± 2°, CHAMFERS ± 5°

FINISH

HEAT TREAT

NEXT ASSY	USED ON	NEXT ASSY QTY REQD
EHT	-	

APPLICATION

PR 12-6

APPLICABLE SPECIFICATIONS
THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

CONTRACT NO.

DRAWN	J. WILKERSON	27 DEC 1971
CHECKED		
STRUCTURES		
MATERIAL/PROCESS		
ENGINEER		
SUPERVISOR		
PROJECT		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

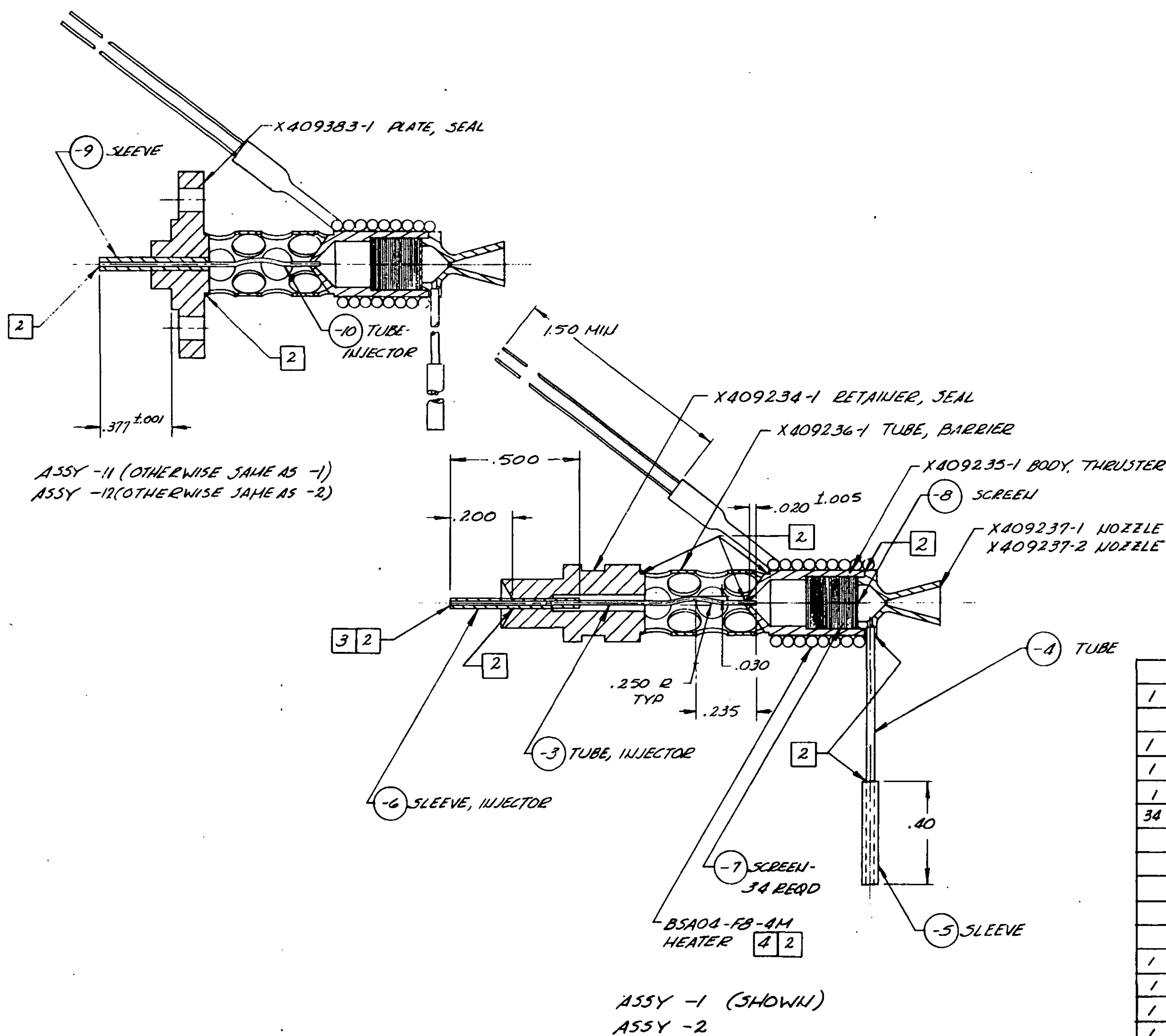
TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

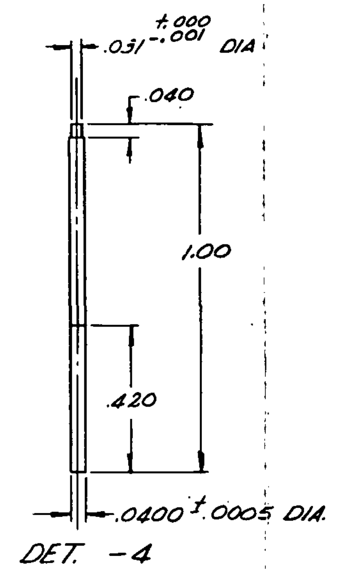
ELECTRO THERMAL HYDRAZINE THRUSTER AND VALVE ASSY

SIZE	CODE IDENT NO.	
D	11982	X409290

SCALE 4/1 SHEET

MJO 1483-23





NOTES: UNLESS OTHERWISE SPECIFIED

1. IDENTIFY PER PR 12-6-0900
2. BRAZE PER PR 3-16. USE NICROBRAZE 210 BRAZING ALLOY.
3. SWAGE -6 TO -3 BEFORE BRAZING
4. WRAP HEATER AROUND THRUSTER BODY & BRAZE IN PLACE
5. I.D. OF -3, -4, & -10 TUBES TO BE CLEAN & FREE FROM BRAZING MAT'L.

-12	-11	-2	-1	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.
1	1				-10	TUBE, INJECTOR	.014 OD x .005 I.D. TUBE L-605 (HAYNES 25)			
1	1	1	1	04849	BSA04-F8-4M	HEATER				
1	1				-9	SLEEVE, INJECTOR	.050 OD x .015 ID TUBE TYPE 304 CRES			
1	1	1	1		-8	SCREEN,	40 MESH, .011 L-605 (HAYNES 25) WIRE - .196 ±.001 DIA			
34	34	34	34		-7	SCREEN, PLATINUM	52 MESH, .004 PLATINUM WIRE - .201 ±.001 DIA			
		1	1		-6	SLEEVE, INJECTOR	.038 O.D. x .018 I.D. TUBE TYPE 304 CRES			
	1		1		-5	SLEEVE	.062 OD x .042 ID TUBE TYPE 304 CRES			
	1		1		-4	TUBE, PRESSURE TAP	.042 O.D. x .016 I.D. TUBE L-605 (HAYNES 25)			
		1	1		-3	TUBE, INJECTOR	.014 O.D. x .005 I.D. TUBE - L-605 (HAYNES 25)			
		1	1		X409234-1	RETAINER, SEAL				
1	1	1	1		X409235-1	BODY, THRUSTER				
1	1	1	1		X409236-1	TUBE, BARRIER				
1	1				X409383-1	PLATE, SEAL				
1		1			X409237-2	NOZZLE				
	1		1		X409237-1	NOZZLE				

QTY REQD PER ASSY

PARTS LIST

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
EHT	X409290	1(-12)
EHT	Y409290	1(-11)
EHT	X409289	1(-2)
EHT	X409289	1(-1)

APPLICATION

APPLICABLE SPECIFICATIONS: PR 12-6

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. DO NOT SCALE DRAWING.
2. INTERPRET PER MIL-STD-100.
3. DIMENSIONS ARE IN INCHES.
4. SURFACE TEXTURE SHALL BE 125
5. REMOVE BURRS AND SHARP EDGES.
6. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
7. PARENTHETICAL DATA IS FOR REFERENCE ONLY.

TOLERANCES

ON ALL HOLE DIAMETERS

UNDER .0140	+.0020 -.0005	.501 THRU .750	+.008 -.001
.014 THRU .125	+.004 -.001	.751 THRU 1.000	+.010 -.001
.126 THRU .250	+.005 -.001	1.000 THRU 2.000	+.012 -.001
.251 THRU .500	+.006 -.001	OVER 2.000	+.015 -.001

ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

ON ANGULAR DIMENSIONS:
MACHINED ± 0°30'
LOCATING ± 0°30'
FORMED ± 1°
CHAMFERS ± 5°

FINISH

HEAT TREAT

CONTRACT NO.

DRAWN J. WILKERSON 21 OCT 1971

CHECKED

STRUCTURES

MATERIAL/PROCESS ENGINEER

SUPERVISOR

PROJECT

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

THRUSTER ASSY, EHT

SIZE D | CODE IDENT NO. 11982 | X409240

SCALE 4/1 | SHEET

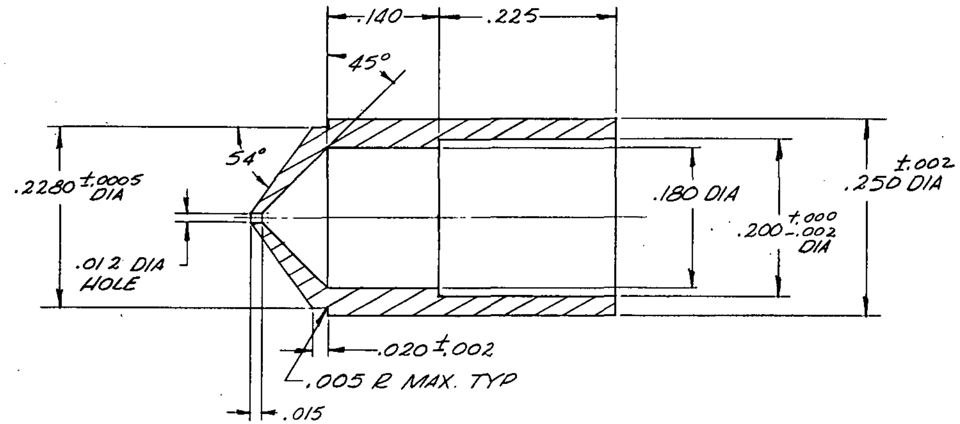
1483-23

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED

LTR	DESCRIPTION	DATE	APPROVED

REVISIONS



X409235

PARTS LIST

ITEM NO.	REF DES	SPEC.	MATERIAL	NOMENCLATURE OR DESCRIPTION	PART OR IDENTIFYING NO.	CODE IDENT NO.
		AMS 5759	L-605 (HAYNES 25) BAR	THRUSTER BODY	-1	

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

PR 12-6

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125√
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA

FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN J. WINGERSON 16 DEC 1971
CHECKED
STRUCTURES
MATL & PROCESS ENGR
SUPERVISOR

OTHER APPROVALS

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TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

BODY, THRUSTER-EHT

SIZE C | CODE IDENT NO. 11982 | X409235

SCALE 10/1 SHEET

SYSTEMS 3486 REV. 12-68

1. IDENTIFICATION MARKING PER PR 12-6-0900
TYPE_____ CLASS_____
PART NUMBER_____

NOTES: UNLESS OTHERWISE SPECIFIED

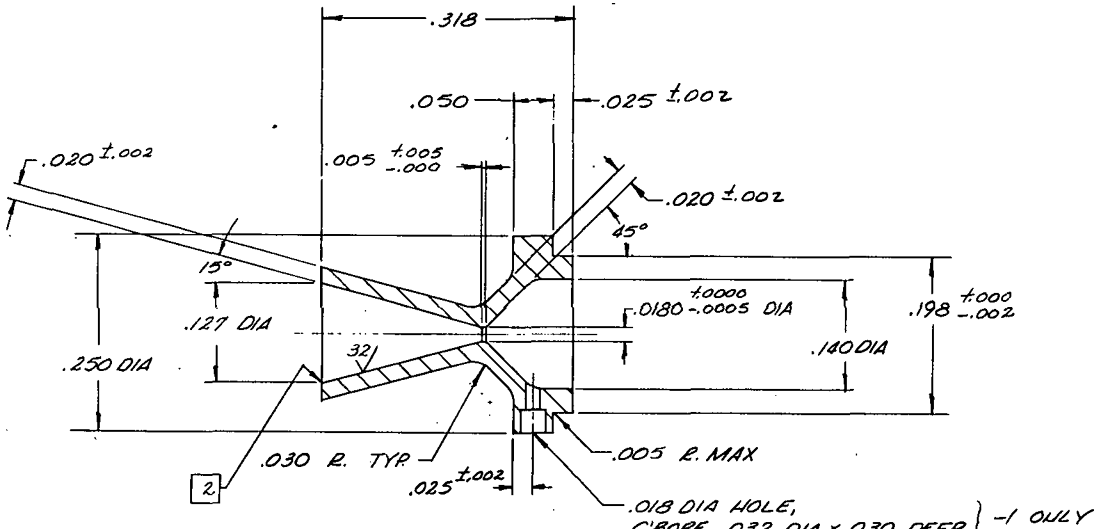
NEXT ASSY QTY REQD	NEXT ASSY	USED ON
1(-1)	X409240	EHT

APPLICATION

1/70 DIETERICH-POST CLEARPRINT 1020

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED



DET -1

-2 SAME EXCEPT ELIMINATE .018 DIA HOLE & .032 DIA x .030 DEEP CBORE

ITEM NO.	REF DES	SPEC	MATERIAL	NOMENCLATURE OR DESCRIPTION	PART OR IDENTIFYING NO.	CODE IDENT NO.
		AMS 5759	L605 (HAYNES 25) BAR	NOZZLE	-2	
		AMS 5759	L605 (HAYNES 25) BAR	NOZZLE	-1	

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 63
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES - ALL HOLE DIA

FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN J. WINGERSON 16 DEC 1971

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

NOZZLE - EHT

SIZE C | CODE IDENT NO. 11982 | X409237

SCALE 10/1 | SHEET

NEXT ASSY	USED ON	QTY REQD
X409240	EHT	1(-1)

APPLICATION

PR 12-6

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

2 REMOVE BURR BUT DO NOT BREAK SHARP CORNER.

1. IDENTIFICATION MARKNG PER PR 12-6-0900
TYPE ____ CLASS ____
PART NUMBER ____

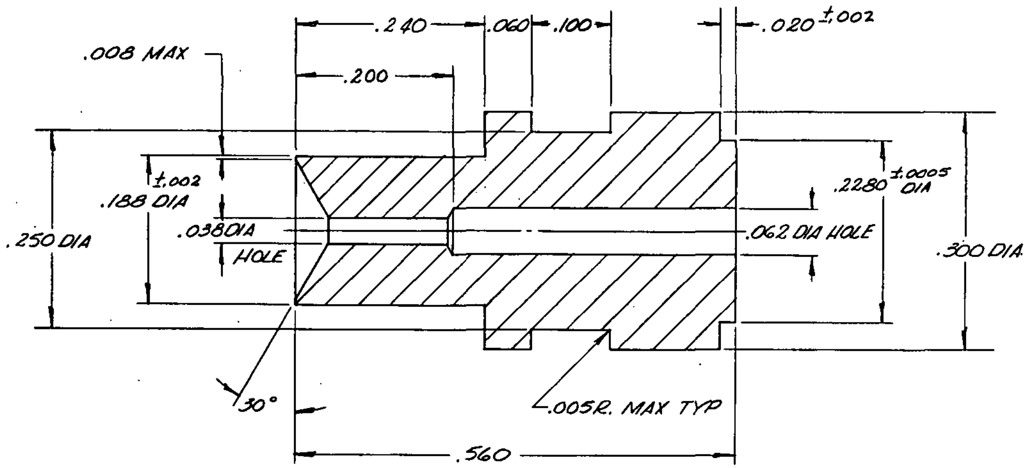
NOTES: UNLESS OTHERWISE SPECIFIED

X409237

6/68 DIETERICH-POST CLEARPRINT 1000 | SYSTEMS 1460C REV. 5-68

Q

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



X409234

	-1	RETAINER	TYPE 304 CRES BAR	AMS5759		
CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

PR 12-6

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

1. IDENTIFICATION MARKNG PER PR 12-6-0900
TYPE ______ CLASS ______
PART NUMBER ______

NOTES: UNLESS OTHERWISE SPECIFIED

EHT	X409240	(-1)
USED ON	NEXT ASSY	NEXT ASSY QTY REQD
APPLICATION		

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	J. WINGERSON	16 DEC 1971
CHECKED		
STRUCTURES		
MATL & PROCESS ENGR		
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

RETAINER, SEAL - EHT

SIZE	CODE IDENT NO.	
C	11982	X409234

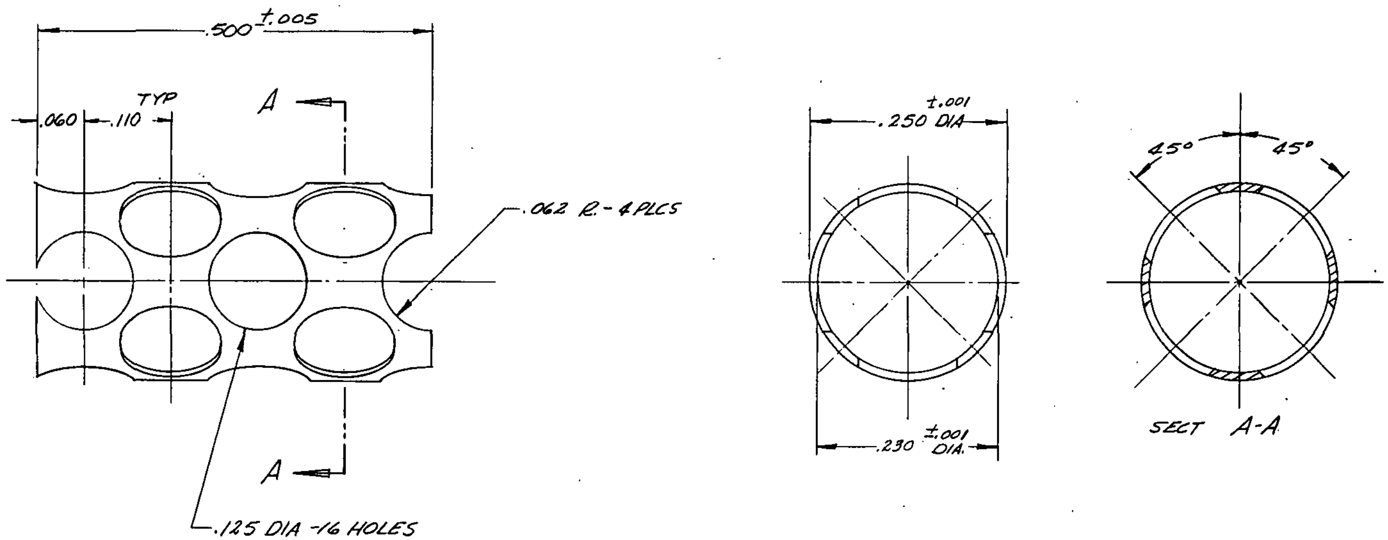
SCALE 10/1 SHEET

6/68 DIETERICH-POST CLEARPRINT 1000

SYSTEMS 1402C REV. 9-68

15

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



X409236

ITEM NO.	REF DES	SPEC.	MATERIAL	NOMENCLATURE OR DESCRIPTION	PART OR IDENTIFYING NO.	CODE IDENT NO.
		AMS 5759	L-605 (HAYNES 25) BAR	TUBE, BARRIER	-1	

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-6

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

NEXT ASSY	USED ON	QTY REQD
X409240	EHT	1(-1)

APPLICATION

1. IDENTIFICATION MARKING PER PR 12-6-0900
TYPE______CLASS______
PART NUMBER______

NOTES: UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN J. WINGERSON 16 DEC 1971

CHECKED

STRUCTURES

MATL & PROCESS ENGR

SUPERVISOR

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

TUBE, BARRIER - EHT

SIZE	CODE IDENT NO.	
C	11982	X409236

SCALE 10/1 SHEET

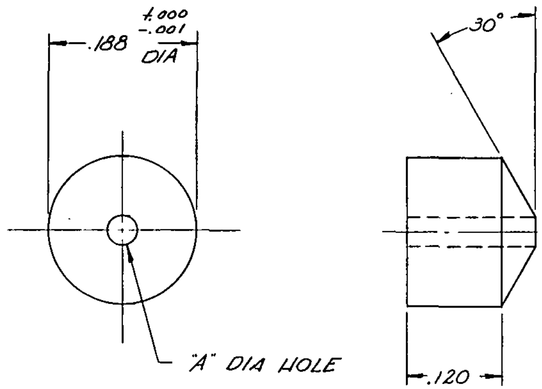
5/70 DIETERICH-POST CLEARPRINT 1020

SYSTEMS 3486 REV. 12-68

57

TABULATION		
PART NO.	DIMENSION	
	"A" DIA	
-1	.037	
-2	.0469	

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



X409238

ITEM NO.	REF DES	SPEC.	MATERIAL	NOMENCLATURE OR DESCRIPTION	PART OR IDENTIFYING NO.	CODE IDENT NO.
		MIL-P-19468	TEFLON ROD	SEAL	-2	
		MIL-P-19468	TEFLON ROD	SEAL	-1	

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

PR 12-6

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

NEXT ASSY	USED ON	QTY REQD
EHT	X409290	1(-2)
EHT	X409289	1(-1)

APPLICATION

1. IDENTIFICATION MARKING PER PR 12-6-0900 CLASS
PART NUMBER

NOTES: UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125√
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

DO NOT SCALE DRAWING
CONTRACT NO.
DRAWN J. WINGERSON 16 DEC. 1971
CHECKED
STRUCTURES
MATL & PROCESS ENGR
SUPERVISOR
OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

SEAL, TUBE-EHT

SIZE	CODE IDENT NO.	
C	11982	X409238

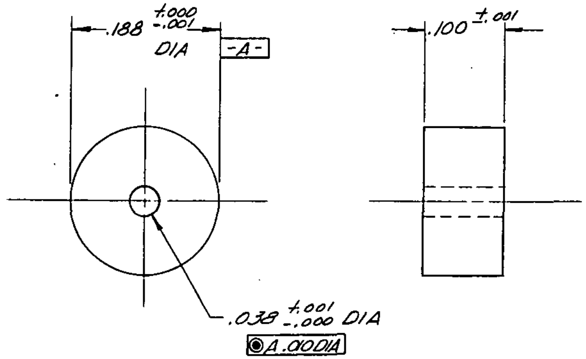
SCALE 10/1 SHEET

5/70 DIETZGEN-POST CLEARPRINT 1020

SYSTEMS 3486 REV. 12-68

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED



X409239

ITEM NO.	REF DES	SPEC.	MATERIAL	NOMENCLATURE OR DESCRIPTION	PART OR IDENTIFYING NO.	CODE IDENT NO.
		AMS 5759	L605 (HAYNES 25) BAR	SPACER	-1	

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

NEXT ASSY	USED ON	QTY REQD
X409289	EHT	(-1)

APPLICATION

1. IDENTIFICATION MARKING PER PR 12-6-0900

TYPE______ CLASS______

PART NUMBER______

NOTES: UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125 ✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA

FROM	THRU	TOL
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN J. WINGERSON 16 DEC 1971

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

SPACER, VALVE - EHT

SIZE	CODE IDENT NO.	
C	11982	X409239

SCALE 10/1 SHEET

5/70 DIETERICH-POST CLEARPRINT 1020

SYSTEMS 3455 REV. 12-69