555318 14P

N90-18482

NASA S20-18 252710 14P

SPACE STATION TECHNOLOGY SUMMARY

R. Iacabucci, S. Evans, G. Briley
Rocketdyne
Canoga Park, California
R. Delventhal
NASA-JSC
Houston, Texas
E. Braunscheidel
NASA-LeRC
Cleveland, Ohio

RY 230510

ND 185000

ND 315753

ABSTRACT

The completion of the Space Station Propulsion Advanced Technology Programs established an in-depth data base for the baseline gaseous oxygen/gaseous hydrogen thruster, the waste gas resistojet, and the associated system operations. These efforts included testing of a full end-to-end system at National Aeronautics and Space Administration (NASA)-Marshall Space Flight Center (MSFC) in which oxygen and hydrogen were generated from water by electrolysis at 6.89 MPa (1,000 psia), stored and fired through the prototype thruster. Recent end-to-end system tests which generate the oxygen/hydrogen propellants by electrolysis of water at 20.67 MPa (3,000 psia) were completed on the Integrated Propulsion Test Article (IPTA) at NASA-Johnson Space Center (JSC). Resistojet testing has included 10,000 hours of life testing, plume characterization, and electromagnetic interference (EMI) testing. Extensive 25-lbf thruster testing has been performed defining operating performance characteristics across the required mixture ratio and thrust level ranges. Life testing has accumulated 27 hours of operation on the prototype thruster. A total of seven injectors and five thrust chambers have been fabricated to the same basic design. Five injectors and three thrust chambers have been extensively tested in various combinations. Two additional injectors and thrust chambers designed to incorporate improved life, performance, and producibility characteristics are ready for testing. Five resistojets have been fabricated and tested, with modifications made to improve producibility. The lessons learned in the area of producibility for both the O_2/H_2 thrusters and for the resistojet have resolved critical fabrication issues. The test results indicate that all major technology issues for long life and reliability for space station application have been resolved.

INTRODUCTION

New propulsion technologies are being developed by NASA and industry to enable the space station to be a permanent and efficient operating system. The 25-lbf O_2/H_2 propellant thruster is being developed to provide a reliable, safe, and economical propulsion system which will reboost the station to maintain its orbital altitudes and attitudes and keep the station stabilized during shuttle docking. The system is operationally efficient and very cost-effective using gaseous oxygen and hydrogen propellants generated by electrolysis of water collected from the shuttle, laboratories, and environmental control system. The water supply from these sources is adequate to keep the Space Station Freedom in orbit with minimal or no resupply from Earth.

Waste gases produced by normal station operations and laboratory experiments require a means of safe disposal. To bottle and return the waste gases to Earth via the shuttle would require significant effort and expense. The resistojet, incorporating an electrical heater coupled to an expansion nozzle, uses station electrical power to transform these waste gases into a useful propulsion fluid.

The objective of the efforts described herein was to demonstrate the producibility, durability, reliability, and performance of the 25-lbf O_2/H_2 thruster, the resistojet, the electrolysis units, and ultimately a complete end-to-end system, starting with water and producing propulsive thrust.

SPACE STATION PROPULSION TEST BED

In May 1989, Rocketdyne was awarded a contract by NASA-MSFC to design, fabricate, and deliver a test bed for oxygen/hydrogen (O_2/H_2) propulsion system testing for the space station. The space station propulsion test bed (SSPTB) and computer control system were delivered in December 1985, and testing was successfully completed in March 1988.

The test bed consists of propellant accumulators, valving, instrumentation, and controls configured in a 2.7-m (9-ft) cube structure as shown in Figure 1. The SSPTB was designed to fit into the MSFC altitude chamber at Test Stand 300 while simulating a basic building block structural element of the space station. With the

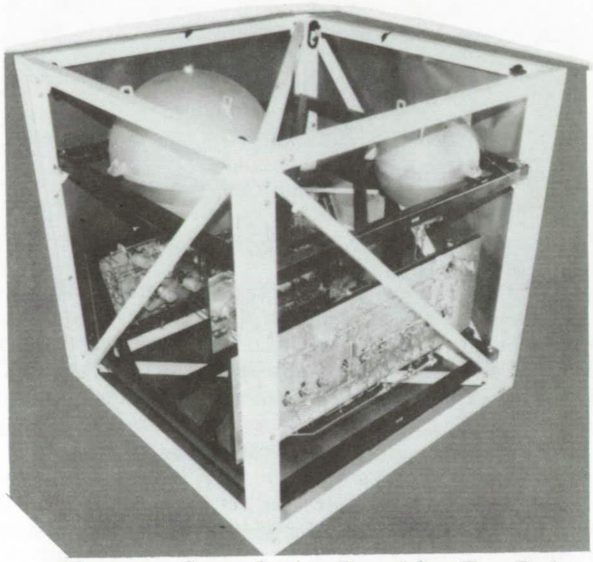

Figure 1. Space Station Propulsion Test Bed

addition of water electrolysis to the baseline system as the propellant supply in mid 1986, Rocketdyne designed and fabricated an electrolysis module to fit on top of the existing test bed cube. Components tested on the module included Arde Steel tanks, Structural Composites, Inc. (SCI) graphite-wrapped tanks, a Life Systems Inc. (LSI) electrolysis unit, and a Hamilton Standard (HSD) electrolysis unit. The module included pressurized canisters to contain each of the water electrolysis units not then operable in a vacuum. Figure 2 shows the LSI unit installed in such a canister. Molecular-sieve dryers designed by Boeing and fabricated at MSFC were also included on the module. A simplified schematic of the SSPTB is shown in Figure 3.

The control system was a microprocessor-based system which controlled the entire test sequence autonomously. The computer control system block diagram is shown in Figure 4, and Table I lists the microprocessor

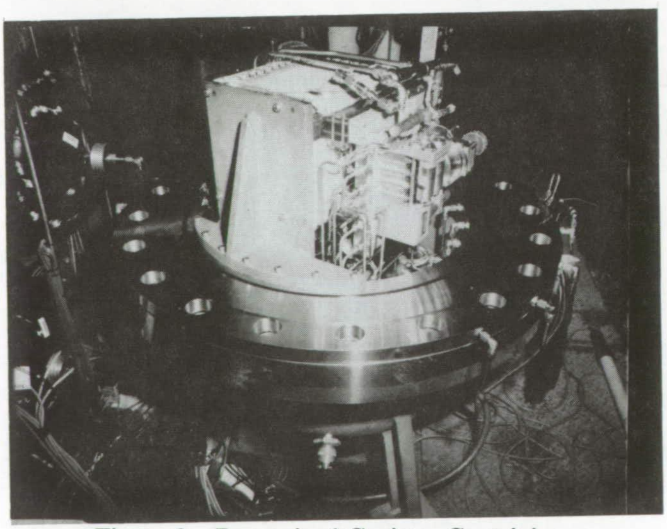

Figure 2. Pressurized Canister Containing
Water Electrolysis Unit

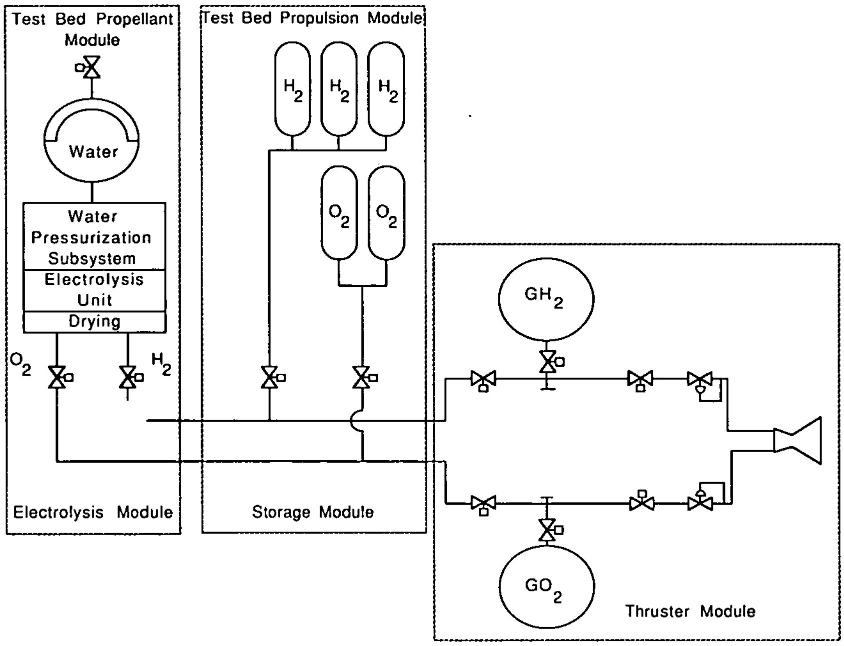

Figure 3. Simplified SSPTB Schematic

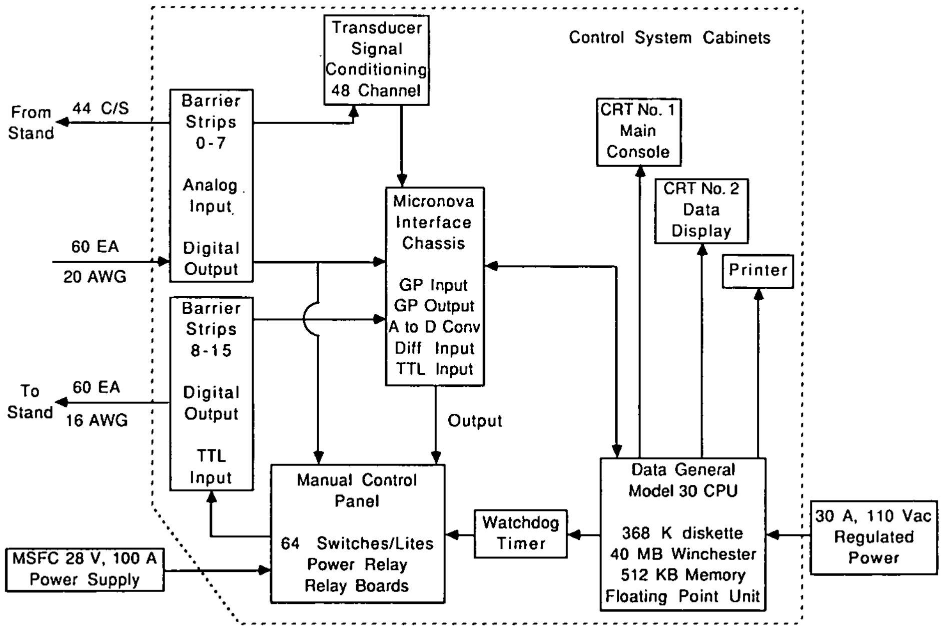

Figure 4. Computer Control System Block Diagram

hardware configuration. Sixty-four end devices were controlled and monitored, and 48 transducer data channels were monitored for use as redlines or "go-nogo" checks.

SPACE STATION PROPULSION TEST BED TEST PROGRAM

A series of preacceptance, acceptance, and system evaluation tests were conducted on the SSPTB. The initial acceptance test was conducted using gaseous nitrogen (GN_2) to simulate oxygen and gaseous helium (GHe)

Table I. Microprocessor Hardware Configuration

Microprocessor	Features
Data General Desktop	512 KB Semiconductor memory with byte parity
	Hardware floating point unit
Model 30	368 KB Diskette unit
	40 MB Winchester hard disk
	Two 123 W power supplies
	Digital-to-analog converter
	Differential multiplexer
	64 Digital 28 Vdc outputs (optoisolated)
	64 Digital inputs (optoisolated)
	Printer
	CRT display for 24 channels of engineering unit data
	CRT terminal for operating interface

to simulate hydrogen. A comparison between the measured and calculated (based on 70% isothermal condition) tank pressures produced a very close match between the theoretical and calculated data. Final acceptance tests were performed on the system utilizing GO_2 and GH_2. Transient plots were made to analyze accumulator pressure, accumulator skin temperature, and accumulator outlet temperature for both oxygen and hydrogen.

Following the acceptance tests, the Rocketdyne 25-lbf GO_2/GH_2 prototype No. 1 thruster was installed in the test bed. A series of system tests were conducted in December 1986, culminating with the thruster firing for 291 seconds, the oxygen tank maximum duration at these conditions (MR=8).

The electrolysis system testing began in early July 1988 with a complete LSI 2.4-MPa (350-psi) electrolysis system checkout test including operation of the dryers. A malfunction in the system caused leakage in the hydrogen lines and testing was terminated after three days. A test was considered a qualified success, however, in that gas was produced and delivered to the storage tanks up to 1.1 MPa (160 psia) under automatic control prior to the malfunction.

The HSD 6.89-MPa (1,000-psi) unit was installed on the test bed following the removal of the LSI unit. A checkout test was successfully conducted in late October 1987. The test series were started in November and completed successfully 10 days later with the firing of the 25-lbf prototype No. 1 thruster, using the gases generated at 6.89 MPa (1,000 psia) by the electrolysis unit.

Following completion of the electrolysis tests, 96 characterization tests were conducted on multiple configurations of the 25-lbf thruster. Up to 14 hot-fire tests per day were performed, routinely simulating multiple firings of the system. Following completion of the thruster tests, the test bed was removed from the vacuum chamber and stored while the chamber undergoes renovation and upgrade.

INTEGRATED PROPULSION TEST ARTICLE

Rocketdyne's involvement in the Phase I testing of the JSC IPTA commenced in December 1988 and is ongoing. IPTA, designed by JSC, is an end-to-end system which incorporates a 20.67-MPA (3,000-psi) electrolysis unit converting water to GO_2 and GH_2, propellant dew point control, 20.67-MPa (3,000-psi) GO_2/GH_2 storage, propellant distribution, and thruster operation. All Phase I testing was conducted under atmospheric conditions. Thruster testing was conducted on the first prototype thruster and included functional verification, steady-state and pulse mode operation, and tank depletion testing. Additional testing was conducted to use the engine as a "mass balancer" running at mixture ratios of 7:1 and 8.4:1 to balance the propellant stored in the tanks to a desired 8:1 mass ratio. An illustration of the IPTA test facility is shown in Figure 5.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

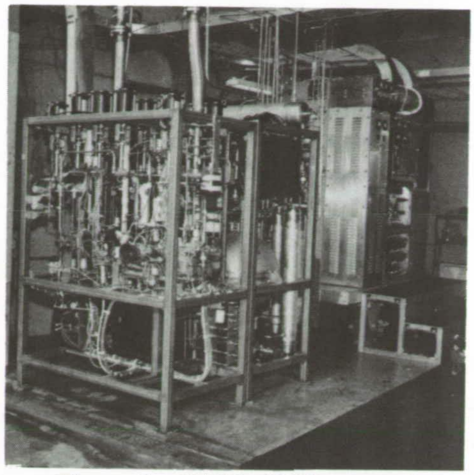

Figure 5. NASA-JSC Integrated Propulsion Test Article

This illustration shows both the Rocketdyne and Bell thrusters (the Rocketdyne prototype thruster is the smaller of the two shown), the propellant storage tanks, and the electrolysis unit.

25-lbf THRUSTER TECHNOLOGY

Rocketdyne initiated an independent reasearch and development (IR&D) program in 1984 to define an optimum concept for a GO_2/GH_2 thruster for the space station. Design requirements were established based on preliminary NASA-defined requirements and a system study of a propulsion system that incorporates pressure-fed thrusters and supercritical storage of O_2 and H_2. The study resulted in selection of a nominal thrust level of 25 lbf, a combustion chamber pressure of 6.89 KPa (100 psia), and a mixture ratio of 4. The mixture ratio requirement was later changed to 8, based on propellant supply by water electrolysis. The design parameters and demonstrated results are summarized in Table II.

Rocketdyne's 25-lbf O_2/H_2 thruster assemblies include a coaxial injector, a downpass thrust chamber, an ignition system, and two propellant valves. A schematic of the thruster assembly is shown in Figure 6. The

Table II. Rocketdyne Thruster Design Parameters and Demonstrated Results

Parameter	Design	Demonstrated
Thrust (N)	111.2	51.2 - 162.8
Chamber Pressure (kPa)	689.5	310 - 1014
Mixture Ratio (o/f)	8	3.0 - 9.0
Area Ratio	30:1	30:1
Specific Impulse, vacuum (sec)	400 (MR=4) 346 (MR=8)	406 350
Total Impulse (N-sec)	8.9 million	> 8.9 million
Minimum Impulse Bit (N-sec)	2.2	< 2.2

ORIGINAL PAGE IS OF POOR QUALITY

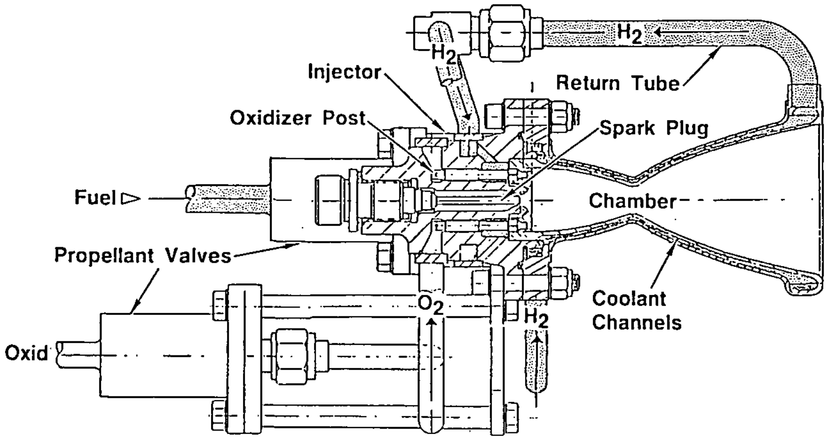

Figure 6. 25-lbf GO_2/GH_2 Thruster Schematic

thruster assemblies can be grouped in three categories: prototype, LeRC contract, and advanced prototypes. A summary of thruster assemblies is given in Table III.

Figure 7 illustrates the prototype injector and thrust chamber subassemblies. The injector body is made from 321 stainless steel (SS) and the faceplate is copper. The thrust chamber liner is NARloy-z, a high-strength copper alloy with machined coolant channels. The liner is closed off with an electroformed nickel structural jacket.

Figure 8 shows a LeRC thruster assembly. The advanced prototype assemblies are externally nearly identical to the LeRC assemblies. The LeRC and advanced prototype injectors have 316L SS bodies and NARloy-z faceplates. The advanced prototype injectors have a modified oxidizer post arrangement and boundary layer coolant configuration to provide cooler chamber wall temperatures, thus the name, low-heat flux (LHF). The LeRC thrust chambers and advanced prototype thrust chambers are made from the same materials as the first

Table III. Rocketdyne Thruster Assembly Log

Thruster Assembly	Injector		Thrust Chamber	
	Type/ Designation	% Boundary Layer Coolant	Type/ Designation	No. of Coolant Channels
Prototype No. 1	Prototype No. 1	40	Prototype No. 1	24
LeRC No. 1 Contract	LeRC No. 1	40	LeRC No. 1	30
LeRC No. 2 Contract	LeRC No. 2	40	LeRC No. 2	30
LeRC No. 3 Contract			Advanced LeRC No. 3	30
Advanced Prototype No. 2	LHF No. 1	15		
Advanced Prototype No. 3	LHF No. 2	40	Advanced Prototype No. 2	30
Advanced Prototype No. 4	LHF No. 3	7.5		
Advanced Prototype No. 5	LHF No. 4	7.5	Advanced Prototype No. 3	30

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

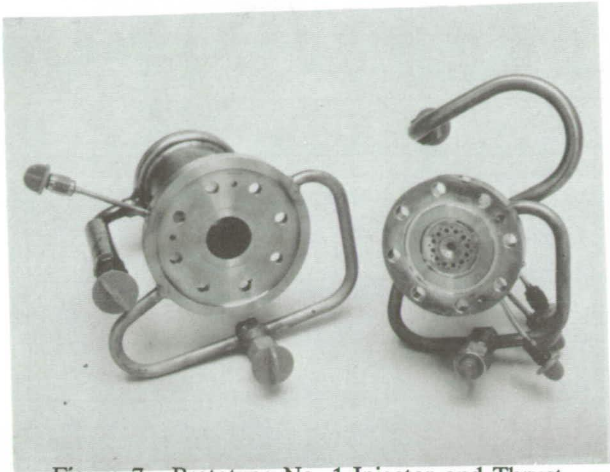

Figure 7. Prototype No. 1 Injector and Thrust Chamber Subassemblies

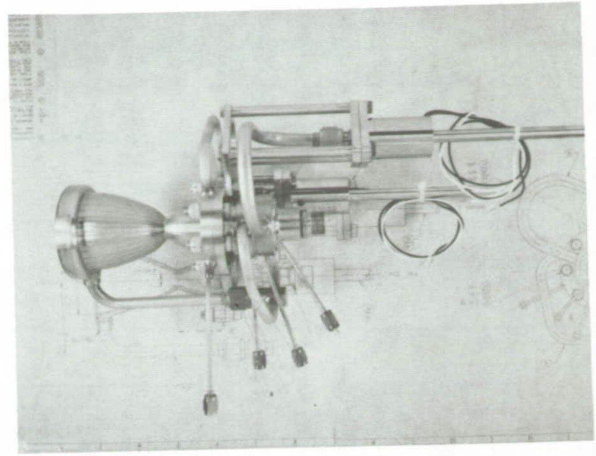

Figure 8. NASA-LeRC Thruster Assembly

prototype, with the number of cooling channels increased to 30 for improved cooling. The bellows installed in the return tube for thermal expansion was found to be unnecessary.

The thruster assemblies incorporate separate but identical EG&G Wright Components direct-operated, normally closed, spring return, coaxial solenoid valves and operate on nominal 28 Vdc.

Conventional electrical high-voltage spark ignition systems are used as the primary ignition device. The two electrical systems utilized were the Space Shuttle Main Engine (SSME) and the J-2. The SSME qualified igniter is expected to be used for flight applications with the tip modified to adapt to the 25-lbf igniter. The J-2 system was readily available and was used for the major portion of the thruster testing.

25-lbf THRUSTER FABRICATION

The component parts for the injector are all machined separately, then brazed together as an assembly with two braze cycles and one weld cycle. The primary component parts include the 316L SS body, a NARloy-z faceplate, 12 316L SS posts, two 316L SS manifold rings, and 321 SS tubing.

The thrust chamber inner liner, which includes the coolant channels, is machined from NARloy-z. Prior to the closeout of the coolant channels, the inlet flange and manifolds are brazed to the chamber. The coolant passages are filled with a wax, the assembly is copper plated, and the nickel closeout is electroformed. The wax is removed after electroforming to produce the hydrogen coolant passages. The layer of copper is deposited prior to the nickel to prevent hydrogen embrittlement of the nickel during thruster operation.

25-lbf THRUSTER TEST PROGRAM

Hot-fire testing of the thruster assemblies has been conducted at three NASA locations: JSC, LeRC, and MSFC. A test summary is given in Table IV, showing which thruster assemblies were tested at each location and pertinent results. Testing at MSFC was conducted in Test Stand 300, a 6.89-m (20-ft) diameter vacuum chamber, from November 1986 through March 1988. A photo of a thruster assembly mounted on the thrust measurement system of the test bed inside the vacuum chamber is shown in Figure 9. Extensive testing was conducted at MSFC utilizing Rocketdyne's SSPTB which provided propulsion system operating experience simultaneously. Thruster life, ignition, performance, pulsing, and repeatability tests were conducted on six different assemblies.

Hot-fire testing at LeRC began in March 1989 in a test cell shown in Figure 10. The thruster assembly is mounted horizontally on the thrust measurement system in a vacuum cell measuring 0.91m (3 ft) in diameter and 2.01 m (6 ft 7 in.) in cylindrical length. Checkout testing of the new facility and controller was conducted utilizing the LHF No. 1 injector and the LeRC No. 1 thrust chamber thruster assembly.

The variation of measured specific impulse with chamber pressure is shown in Figure 11, with the hot-fire data following closely to the predicted curve. Specific impulse versus mixture ratio is plotted in Figure 12 for the LeRC contract thruster assemblies and also for the LHF injector design. The LHF injector configuration has the potential to perform as well or better than that of the LeRC injectors. Thrust chamber external temperature

Table IV. Rocketdyne Thruster Hot-Fire Summary

NASA Location	Injector	Nozzle	No. of Tests	Duration (sec)	Pc (kPa)	MR	Results
MSFC	Prototype	Prototype	121 10,451 Pulses	87399	310.3 - 736.4	3.1 - 8.1	Life/performance/pulsing demonstration
MSFC	Prototype	LeRC 1	22	135	684.7 - 788.8	6.0 - 8.0	Performance verification with new nozzle
MSFC	Prototype	LeRC 2	4	155	715.0 - 766.7	6.0 - 8.1	Performance verification with new nozzle
MSFC	LeRC 1	LeRC 1	26	1866	358.5 - 1013.6	3.1 - 8.3	Performance/operation verified on new assembly
MSFC	LeRC 2	LeRC 2	20	1324	335.1 - 981.2	3.2 - 8.4	Performance/operation verified on new assembly
MSFC	LHF	LeRC 1	23	1376	322.7 - 937.7	3.2 - 8.5	Is vs % BLC established low skin temp/long life predicted
LeRC	LHF	LeRC1	110	6840	331.0 - 724.0	3.0 - 9.0	LeRC vacuum test cell checkout and verification of controller system
JSC	Prototype	Prototype	47 401 Pulses	1768	406.8 - 627.5	7.1 - 8.4	Integrated Propulsion Test Article checkout and tank balancing
3 Locations	4 Injectors	3 Nozzles	373 11,291 Pulses	100,863 (28.0 hr)	310.3 - 1013.6	3.0 - 9.0	Capability demonstrated

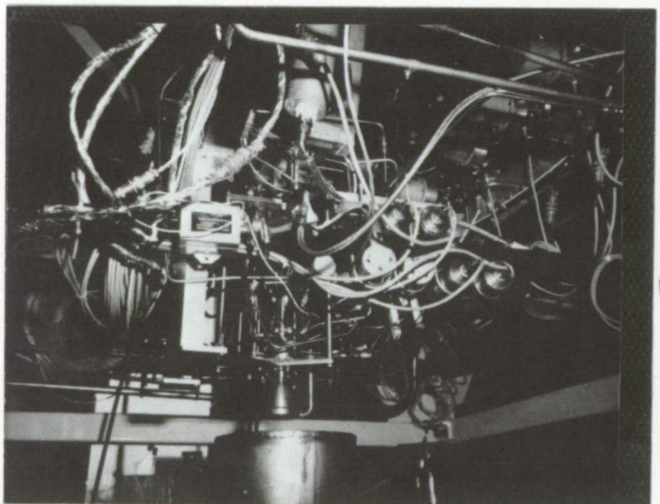

Figure 9. Prototype No. 1 Thruster Assembly Installed on Test Bed

is plotted for various thruster assemblies in Figure 13. Here, it can be seen that the LHF injector design provides a cooler thruster operating temperature, which significantly prolongs the life of the thruster assembly.

There were over 11,000 pulse tests accumulated during the testing. A typical pulse mode transient is shown in Figure 14.

RESISTOJET DESCRIPTION

An Engineering Model Multipropellant Resistojet (EMRJ) was developed by NASA-LeRC, Rocketdyne, and Technion to be used to expel station waste gas propellant with a high exhaust velocity by passing the propellant through an electric heat exchanger. The resistojet utilizes the electricity developed by the station as its power source. A summary of the design parameters and demonstrated results is given in Table V.

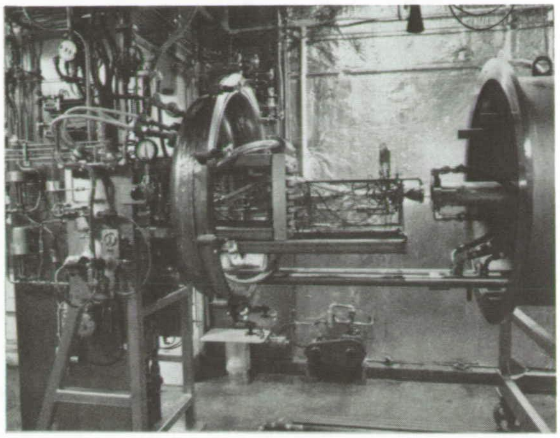

Figure 10. NASA-LeRC Test Facility

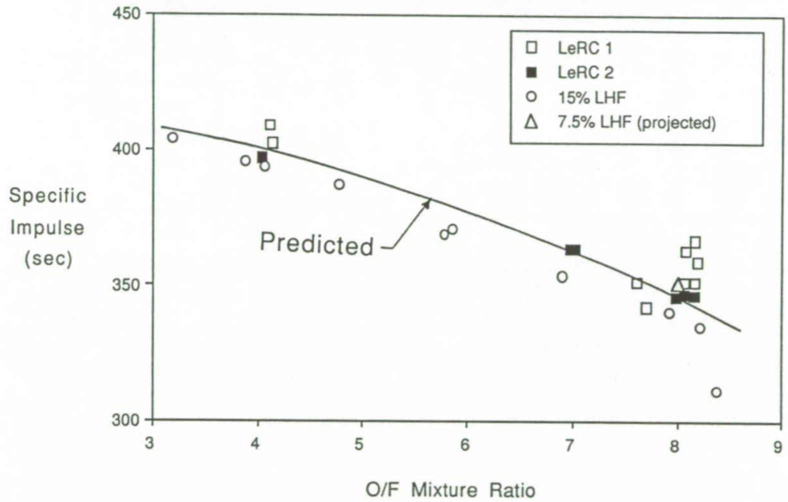

Figure 11. Thruster Performance Projection
Chamber Pressure Effects

A typical EMRJ is shown in Figure 15. The two primary subassemblies are the inconel outer case and the platinum sheathed heater and multichannel heat exchanger. A cone/trumpet nozzle is bonded to the heat exchanger assembly. The subassemblies are shown in Figure 16.

To provide the 10,000-hour life expectancy, all the EMRJ components in contact with waste gases are made of platinum. Platinum provides the best resistance to chemical oxidation or reduction at high EMRJ operating temperatures. The heater assembly is surrounded by multiple radiation shields encased in an inconel cylindrical shroud which serves as a mounting and support structure for the EMRJ. The radiation shields ensure that all heat energy is transferred to the gases and not radiated into space. A plume shield is bonded to the platinum nozzle to control the plume effects of the expelled contaminants on the space station environment.

A total of five EMRJs have been fabricated by Rocketdyne/Technion, Inc. and tested at LeRC. The first four EMRJs are of similar design, with the fifth EMRJ incorporating bonding improvements and improved radiation shield pack.

EMRJ TEST PROGRAM

The Rocketdyne/Technion EMRJ was fabricated to support the NASA-LeRC Space Station Advanced Development Program. All EMRJ performance testing has been conducted at the NASA-LeRC EPL complex. The

ORIGINAL PAGE IS OF POOR QUALITY

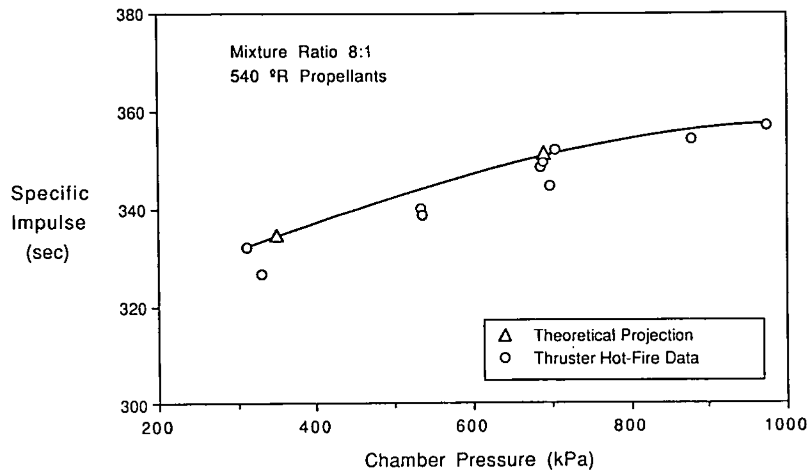

Figure 12. Specific Impulse versus Mixture Ratio

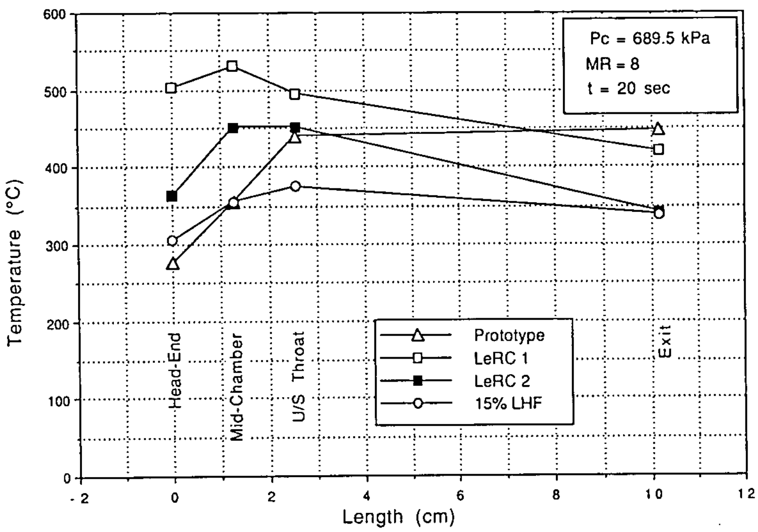

Figure 13. Thruster Comparison of Chamber Temperatures

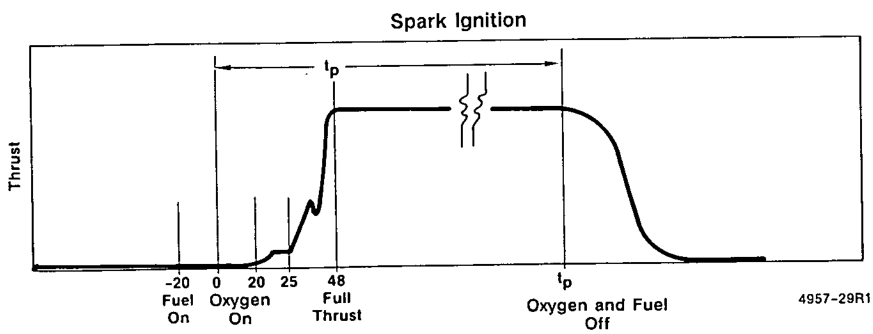

Figure 14. Thruster Pulse Profile

Table V. Engineering Model Resistojet Design Parameters and Demonstrated Results

Parameter	Design	Demonstrated
Life (hr)	10,000	9,600 (135 thermal cycles)
Propellants	CO_2, N_2, He, H_2, O_2, Ar, Krypton, Steam	CO_2, N_2, Argon, Ar/N_2 mixture
Specific Impulse (sec)	130 (CO_2 at 1300 °C) 500 (H_2 at 1300 °C)	138 (CO_2 at 1200 °C) 540 (H_2 at 1200 °C)
Thrust (N)	0.13 - 0.44	0.05 - 0.45
Thrust Chamber Pressure (kPa)	275.8	13.7 - 310.0
Maximum Operating Temperature (°C)	1400	1300

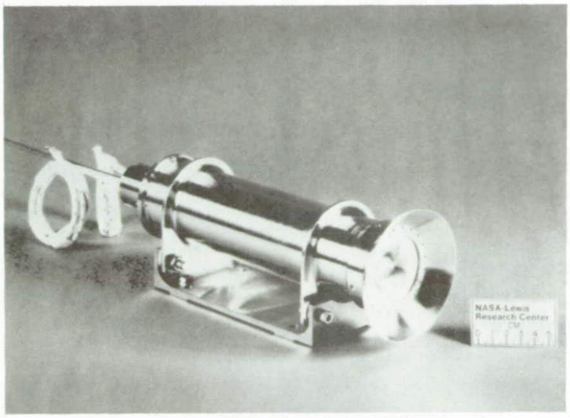

Figure 15. Engineering Model Resistojet

program objective is two-fold, to provide a means of safely repelling station waste gases and to provide impulse for the station. Of the five EMRJs tested, performance data was taken on EMRJ No. 3 and No. 5, and transient data was taken exclusively from EMRJ No. 5. EMRJ No. 5 utilized improved bonding techniques as well as 10 additional radiation shields.

Performance characterization testing was conducted on EMRJ No. 3 and No. 5 in tank No. 5, a 4.57-m (15-ft) diameter by 18.9-m (62-ft) long vacuum tank. Over 9,600 hours and 135 thermal cycles have accumulated without any noticeable degradation. Power efficiency and specific impulse have been mapped for N_2, CO_2, H_2, and Ar over a range of operating pressures and temperatures (which cover the operating envelope). Inlet pressures of 13.7, 68.9, 137.8, 206.8, and 310 kPa (2, 10, 20, 30, and 45 psia) were used for thrust level characterization and temperatures at ambient, 500, 900, and 1200°C (ambient, 930, 1650, and 2200°F) for specific impulse verification. Both units demonstrated good repeatability and steady-state values did not fluctuate with time. Both units performed similarly. EMRJ thrust efficiency versus thrust/power ratio is plotted in Figure 17, and specific impulse versus gas temperature is plotted in Figure 18. Typical heater temperature and specific impulse transient data are plotted for hydrogen in Figure 19.

Experimental data and a mathematical model were used to develope plume definition of the exhaust flow field in both the forward and back flux region. It has been surmised that the nozzle shapes do not significantly impact the flow field.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

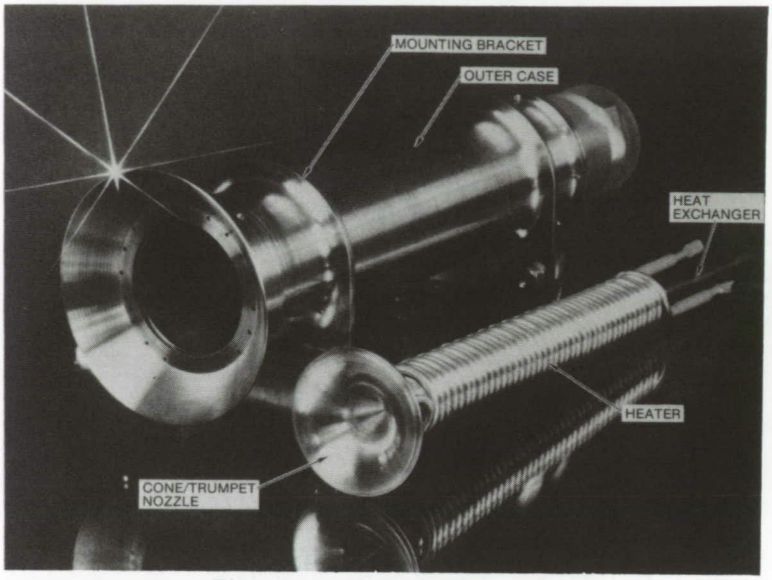

Figure 16. EMRJ Subassemblies

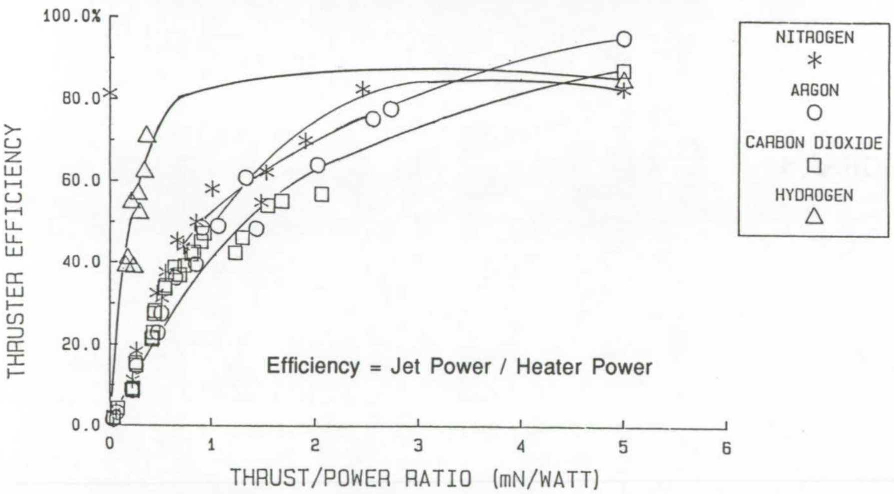

Figure 17. Thruster Efficiency versus Thrust/Power

The EMRJ was tested in the radio frequency interference facility at NASA–Goddard Space Flight Center (GSFC) to determine the electromagnetic radiation effects generated by the heater element. It was found that radiation from the EMRJ extrapolated to a distance of 7 cm (0.23 ft) is approximately 114 dBpt. The location of the resistojets on the station led to the conclusion that electromagnetic radiation is not of serious concern.

LESSONS LEARNED

25–lbf THRUSTER

Injector component tolerance variations may have contributed to circumferential variations in the thrust chamber external nozzle skin temperatures observed during early testing. Low–heat flux injectors No. 3 and No. 4 incorporate improvements to the original injector designs. Tighter tolerances were set for the flow passages and the concentricity of the injector elements. The post recess was controlled with improved tooling which held the posts stationary during the braze cycle.

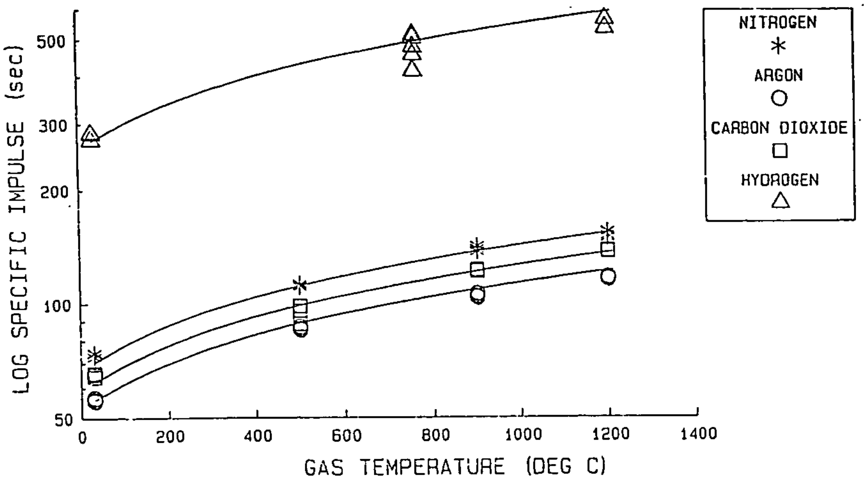

Figure 18. Specific Impulse versus Gas Temperature

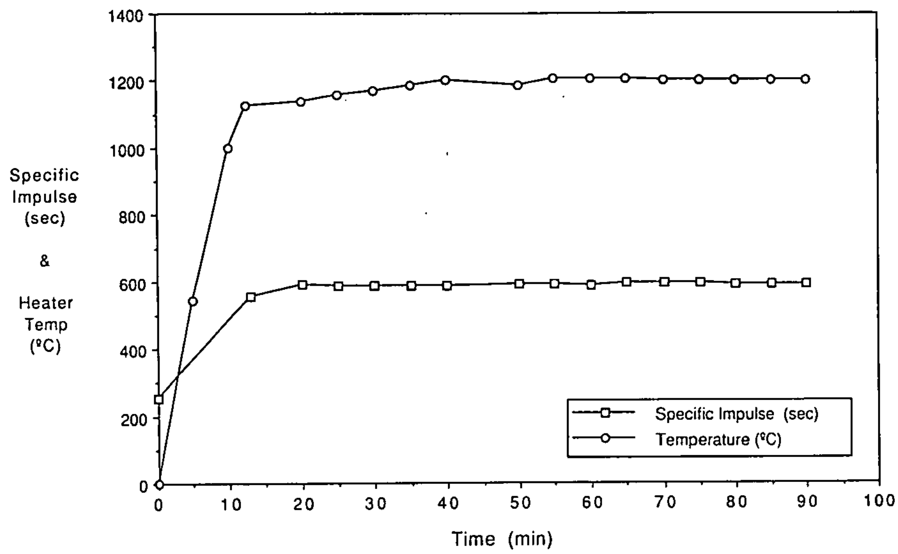

Figure 19. EMRJ Heater Temperature and Specific Impulse Transient Plots

Thrust chamber external skin temperature circumferential variations and a higher-than-predicted pressure drop observed during testing raised questions concerning the coolant passage dimensions. Various nondestructive inspections were performed which did not show any blocked coolant passages. A spare thrust chamber liner was available that had not had the electrodeposited nickel (EDNi) closeout completed. An in-depth detailed channel-by-channel dimensional inspection was performed on this liner which revealed that tighter control of the channel dimensions and wall thickness variations were required. Channel-to-channel depth variations and wall thickness control were improved by proper tooling. The advanced prototype nozzle No. 2, the LeRC nozzle No. 3, and the advanced nozzle No. 3 were machined, incorporating the modified tooling. Detail inspections were made during various stages of the machining process, indicating the desired results had been realized. An improved inlet flange design was also incorporated which allows hydrogen to enter the coolant passages closer to the injector, thus improving the injector and nozzle cooling.

RESISTOJET

A major challenge of the EMRJ fabrication process was to develop a bonding technique for the joints which would allow for structural integrity and gas-tightness which would withstand the severe EMRJ operating environment for long durations. Technion, Inc. came up with an innovative joint design bonded by diffusion and electron beam (EB) weld. Diffusion bonding was chosen as the principal technique for mating the EMRJ components because of its ability to produce a joint with identical properties with that of the parent material. This trait is inherently important for use with grain-stabilized platinum.

To ensure gas tight seals at the joint, EB welds were utilized located away from structural loading effects. In all joint configurations, the EB weld is a narrow and relatively deep penetration that provides a large ratio of joint interface area to weld zone volume. Pure platinum filler was added into the weld zone to fill voids and solidify into a fault-free seal.

SUMMARY AND CONCLUSION

The first simulation of the baseline propulsion system conducted with the SSPTB at NASA-MSFC provided assurance and data for the flight design system operation up to 6.89 MPa (1,000 psia). The NASA-JSC IPTA has demonstrated end-to-end system operation up to 20.67 MPa (3,000 psia), the anticipated operating level of the Space Station Freedom propulsion system.

The results of the component technology programs indicate that all major technology and producibility issues for long-life reliable thrusters and resistojets for space station application have been resolved. The various configurations of the 25-lbf thrusters have accumulated a total of over 28 hours of run time and over 11,250 pulses with no significant wear.

The resistojets test program at NASA-LeRC has reached the design goal of 10,000 hours of hot-fire with expected performance results with no life or durability issues discovered.

The technology, performance, life, durability, and component fabricability have all been demonstrated and a significant data base established for the Space Station Freedom propulsion system. The development and production of the system should proceed with minimum difficulty.