ARCJET THRUSTER RESEARCH AND TECHNOLOGY

PHASE II FINAL REPORT
NAS 3-24631
91-R-1475

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The work described in this report was performed by Rocket Research Company (RRC) under Phase II of contract NAS3-24631 for the Lewis Research Center (LeRC) of the National Aeronautics and Space Administration. The reporting period covers the time between March 1987 and February 1990. Dr. F. M. Curran of NASA was the program technical Manager.

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Cathode Modeling:	Dr. G. W. Butler
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Manufacturing Engineering:	C. J. Henninger

Rocket Research Company would like to acknowledge the research work done at the NASA LeRC which contributed greatly to the success of this program. The open exchange of information and ideas which occurred throughout the program maximized the rate at which the arcjet technology was developed.

1.0 SUMMARY

This report documents the results of work performed by Rocket Research Company (RRC) during Phase II of contract NAS 3-24631, under the technical direction of the NASA Lewis Research Center. Phase II concludes the efforts under this contract. Phase I of this effort was described in NASA CR-182107. The principle objective of Phase II was to produce an engineering model N_2H_4 arcjet system which met typical performance, lifetime, environmental, and interface specifications required to support a 10-year N-S stationkeeping mission for a communications spacecraft. The system includes an N_2H_4 arcjet thruster, power conditioning unit (PCU), and the interconnecting power cable assembly. This objective was met with the successful conclusion of an extensive system test series. Figure 1-1 summarizes the key program accomplishments.

Following Phase I, the main technology issue remaining was the thruster lifetime. Experimental and analytical investigations of the critical cathode erosion mechanisms conducted at RRC and NASA produced an optimized configuration with acceptably low erosion rates. Additional technology development efforts were focused on characterizing the arc dynamic impedance and the arc EMI noise spectrum to support PCU design activities.

The engineering model system design work began with a survey of potential mission requirements and environments. This led to a system specification which covered performance, lifetime, environmental, and interface requirements for a system drawing 1400 W from a 2,000-kg spacecraft with a 10-year lifetime. The mission analyses assumed two such systems would be operated simultaneously.

The design activities for the arcjet and PCU were conducted in parallel. The arcjet design had to maintain the critical electrode geometries determined from prior technology work while meeting the imposed flight structural, thermal, and material constraints. Detailed structural and thermal finite element models were created to ensure design compliance. Process development was required for refractory metal weld and braze joints, and for a high emissivity coating applied to the arcjet barrel. Power cable and connectors were developed to transmit the power from the PCU to the arcjet. Two complete assemblies were produced. Performance data taken before and after successful qualification vibration tests showed no change.

A development PCU was built and tested. The design was based on previous work done at NASA and on Phase I results. This unit was used to verify stability margins, refine the start circuit, and support initial engineering model thruster tests. Over 1000 starts were accumulated on a single thruster with this PCU. The engineering model design was then created which addressed packaging, construction, and environmental issues typical of flight electronics. Two units were assembled and subjected to extensive standalone functional, thermal, and vibration testing. All design requirements were met with the exception of EMI. As a result, additional work was conducted to more fully diagnose the cause of the problem.

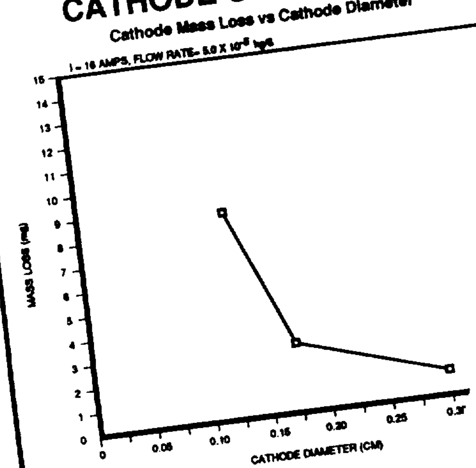
FOLDOUT FRAME 1.

FOLDOUT FRAME 2

TECHNOLOGY DEVE... ...OPMENT

CATHODE OPTIMIZATION

Cathode Mass Loss vs Cathode Diameter



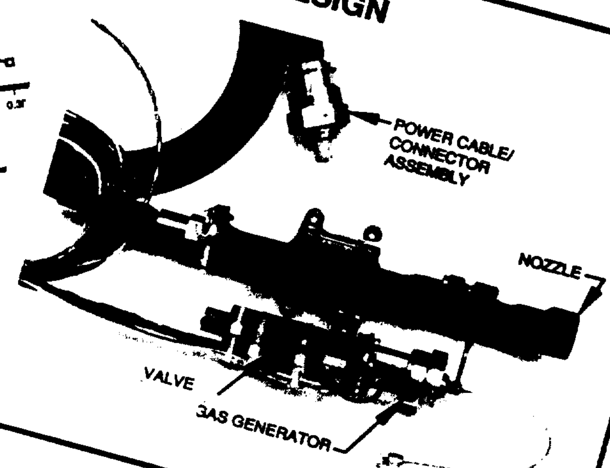
...ODEL UNIT

EMI IMPROVEMENT

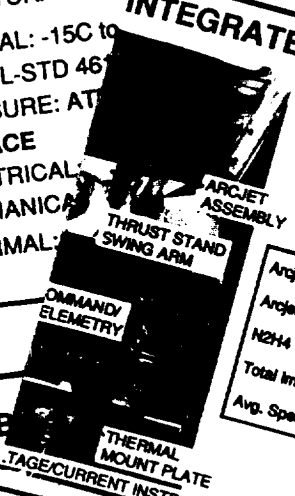
REQUIREMENTS DEF...

- PEFORMANCE
  - SYSTEM POWER = 1400...
  - Isp AVG. 450 SECON...
  - LIFETIME = 800 HOUR...
- ENVIRONMENT
  - STRUCTURAL: 20 g...
  - THERMAL: -15C to...
  - EMI: MIL-STD 46...
  - PRESSURE: AT...
- INTERFACE
  - ELECTRICAL...
  - MECHANICA...
  - THERMAL:...

...DEL ARCJET DESIGN



INTEGRATED SYSTEM LIFETEST



Arcjet System Life Test Summary

	Min. Goal	Demonstrated
Arcjet Firing Time (hr)	800	831
Arcjet Starts	632	845
N2H4 Throughput (kg)	96.1	118.6
Total Impulse (N-sec)	443,960	528,836
Avg. Specific Impulse (sec)	450	454.7

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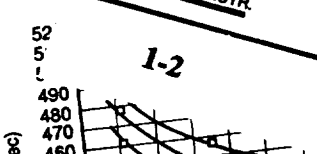

1-2

CU DEVEL

Substantial reductions in the noise levels were achieved through a redesign of several filtering circuits.

The arcjet, PCU, and power cable assemblies were integrated for system design verification testing. The entire system was mounted on a thrust stand inside a vacuum chamber. Performance and startup tests were completed. The data agreed with previous development results. Thermal data were acquired which were in agreement with analysis predictions. Conservative temperature margins were present throughout. System operation was verified over the full ranges of input feed pressures and battery voltages assumed. The final system test conducted was an 800-hour automated duty cycle life test. The feed pressure was incrementally decreased to simulate the spacecraft blowdown. Periodic performance mapping data were used to calculate a mission average specific impulse of 456 seconds.

The only difficulty encountered was at approximately 685 hours into the test when the gas generator began to degrade. The problem had been anticipated, and a parallel development effort started to build and test an alternate gas generator configuration. This second unit successfully completed over 900 hours of duty cycle operation in a separate test. Unfortunately, at the time the gas generator was selected for the system life test, it was not known which design was better. The degraded gas generator was replaced and the system life test completed without incidence.

The successful completion of this technology development effort demonstrated that the low power N_2H_4 arcjet system is mature enough to be used for flight applications.

2.0 INTRODUCTION

The low power hydrazine arcjet can provide significant propellant savings for space missions requiring large delta velocity changes. These benefits are achieved because of the high specific impulse levels produced. Electrical energy from the spacecraft is coupled into the gas by establishing an arc through the thruster throat. The arc heats the hydrazine decomposition products to very high temperatures, resulting in specific impulse levels 200 to 500 seconds higher than existing thruster control systems.

Near-term application of this technology will be for N-S stationkeeping on geosynchronous communications spacecraft. Propellant savings can be greater than 100 kg over existing bi-propellant systems.(1) To support such missions, arcjet lifetimes need to be from several hundred to over 1000 hours, depending on the power available and the spacecraft mass. Individual firing durations will typically be determined by the depth of discharge limit of the battery subsystem. The shorter the firing duration, the larger number of cycles necessary to provide the same total mission. Many spacecraft propellant tanks operate in a blowdown mode, so the mass flow of N_2H_4 to the arcjet would decrease with time. Typical batteries also have a range of output voltages that will be provided to the PCU. Table 2-1 summarizes the flight requirements placed on the arcjet system by these spacecraft considerations.

Table 2-1
ARCJET SYSTEM FLIGHT REQUIREMENTS

Spacecraft Input	Design Implications
Flow rate decrease due to tank blowdown	System must start and run stably over range of flow rates. Must operate over range of specific impulse levels to achieve mission average. Arc voltage will change as the flow rate decreases.
Battery voltage letdown over single firing/voltage change with life.	PCU must provide consistent start performance and stable constant output power for all input and output voltage combinations.
Power level	For a given blowdown, determines maximum mission average specific impulse. Thrust level follows. Affects thruster temperatures
Battery depth-of-discharge limit	Determines individual firing duration for given power.
Total required impulse	Given power level and specific impulse level desired, determines total lifetime. Total number of cycles determined by individual firing duration limit.

Phase I of this program focused on the fundamentals of arcjet operation. High specific impulse levels were demonstrated, N_2H_4 compatibility was shown, and the importance of the PCU to effective system operation was recognized. Phase II began by investigating fundamental issues effecting cathode lifetime. Promising results led to the initiation of engineering model system development. The added complexities of meeting real-mission requirements, as outlined above, were addressed during this work. Figure 2-1 provides an overview of the Phase II tasks.

The Phase II results are described in detail in Section 3.0.

PHASE II FLOW PLAN

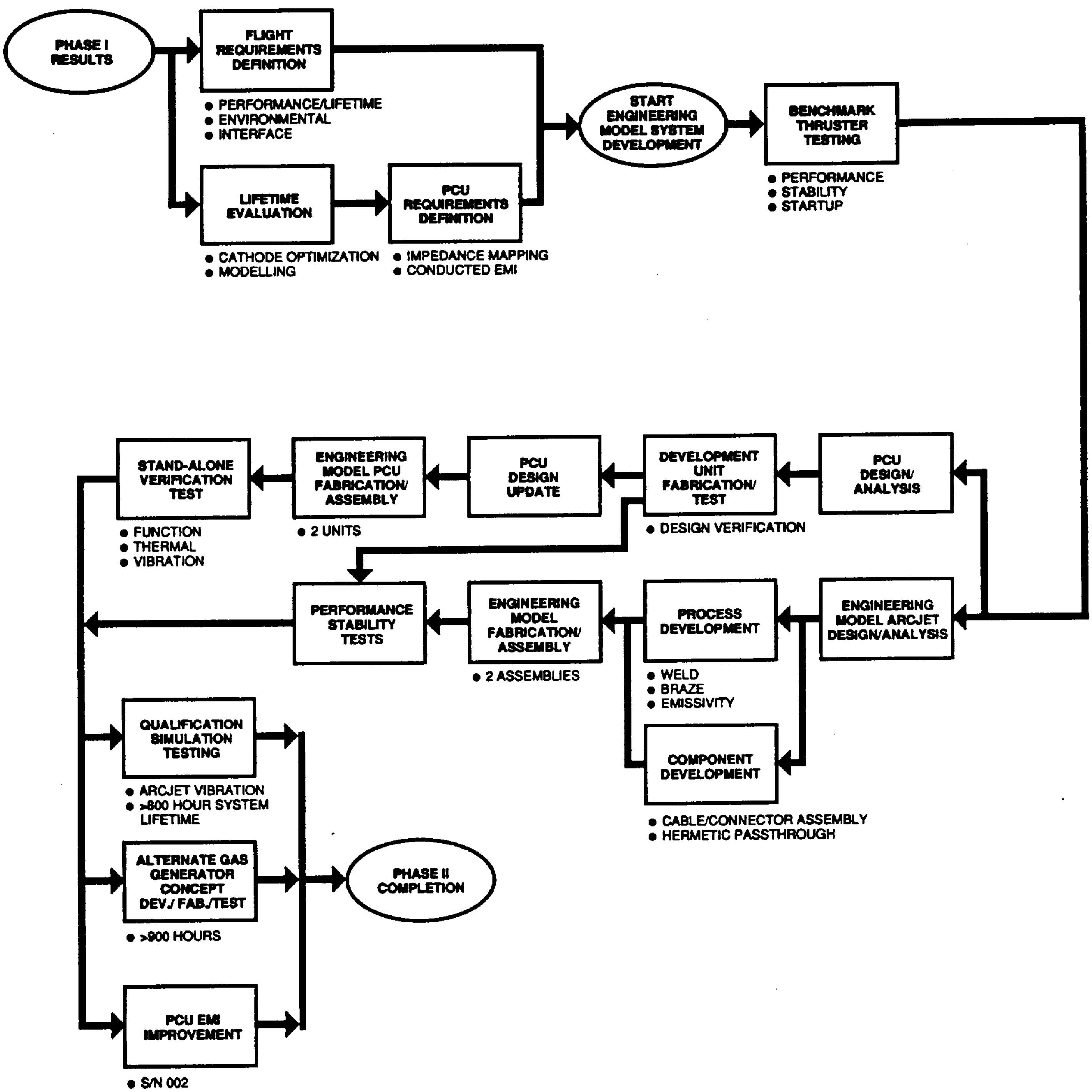

Figure 2-1

3.0 RESULTS AND DISCUSSION

3.1 ARCJET FLIGHT REQUIREMENTS STUDY

The purpose of this subtask was to investigate the relationships which exist between the spacecraft and arcjet system characteristics. These relationships are shown schematically in Figure 3-1. Several key data were required to provide definition to the development activities. These included predictions of mission lifetime and start up requirements, operating duty cycles, and expected voltage/current characteristics for PCU input power. Additionally, it was desired to assess the dependence of the overall mission benefits on different levels of arcjet and PCU performance.

Mission analyses were performed to compute comprehensive arcjet firing profiles based on accurate mission and spacecraft assumptions. A FORTRAN code entitled MISSION was used for this purpose. A flow chart for the code is shown in Figure 3-2. The program utilizes an iterative routine to determine the propellant mass consumption to achieve the required velocity change. Arcjet performance relationships between thrust, mass flow rate, and specific impulse were computed based on test data curve fits. The flow rate profile over lifetime was based on a typical spacecraft blowdown. The program also calculates the firing duration, duty cycle, and individual firing parameters, such as incremental impulse. A summary of the inputs required and the model outputs is given in Table 3-1.

Sensitivity analyses were performed to examine the range of performance and lifetime requirements which could be reasonably anticipated. Varying ranges of arcjet power (1000 to 2000 W), satellite mass (1000 to 2000 kg), battery depth-of-discharge (DOD), and pointing accuracy requirements were analyzed for ten year satellite lifetimes. It was assumed that two arcjets were fired simultaneously at the same power.

Lifetime requirements ranged between 300 to 700 hours depending on variations in mission requirements. Figure 3-3 shows the variation of I_{sp} for different power levels given initial assumptions of a 10-year mission, 1,500 kg spacecraft, 0.05 degree pointing accuracy, and 40% battery DOD. All cases were run assuming the same beginning-of-life (BOL) and end-of-life (EOL) flow rates. This caused the specific impulse levels to increase at the higher power levels.

The number of starts, firing duration, and frequency of burns can depend on the pointing accuracy required and the DOD limit of the batteries. In all cases run, only the latter limitation was a factor. A higher effective pointing accuracy results because of more frequent, short duration burns. For all cases analyzed, startup requirements numbered less than 1,000. Burn times are on the order of 1/2 to 1 hour.

ARCJET SYSTEM INTERRELATIONSHIPS

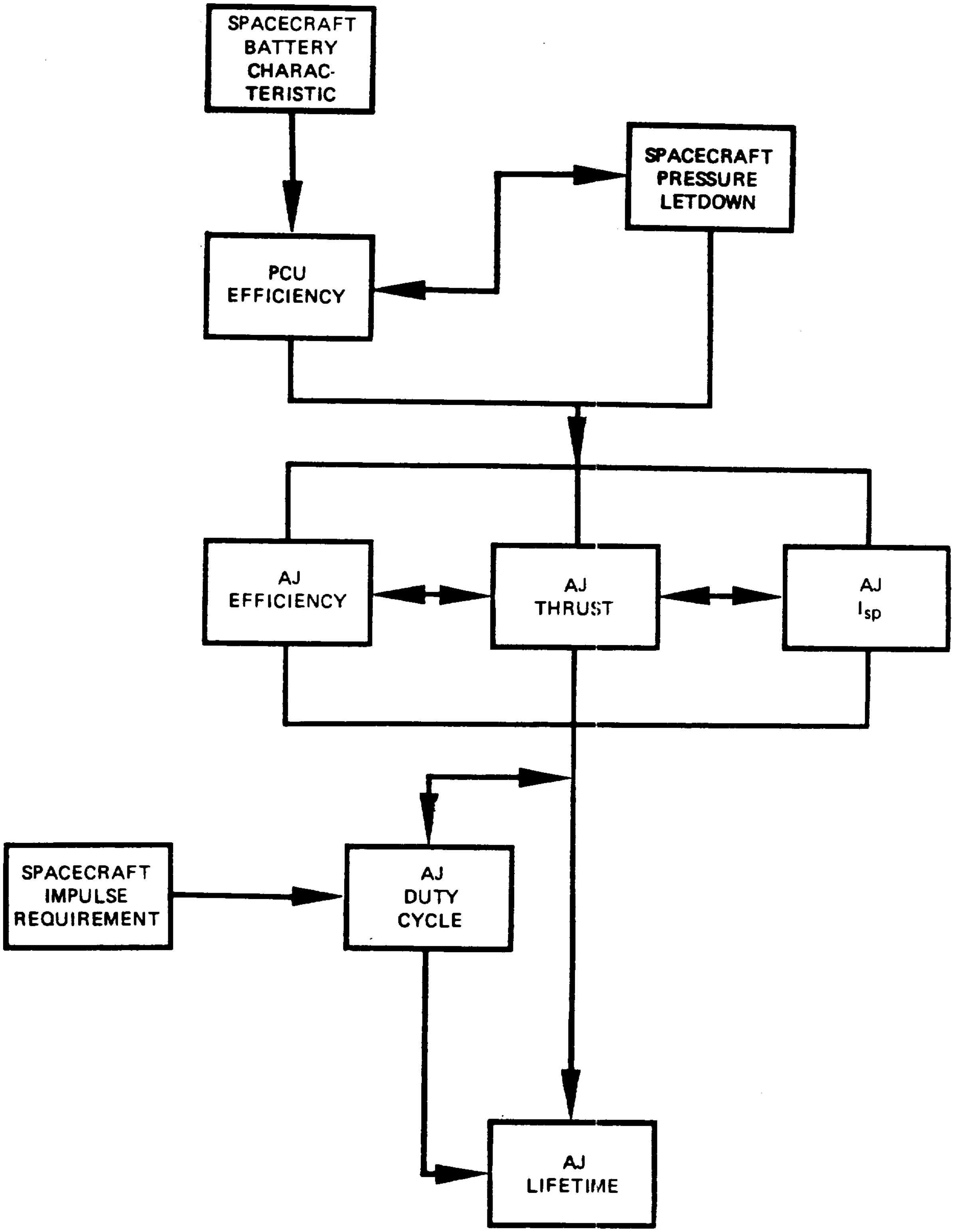

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Figure 3-1

MISSION CODE FLOW CHART

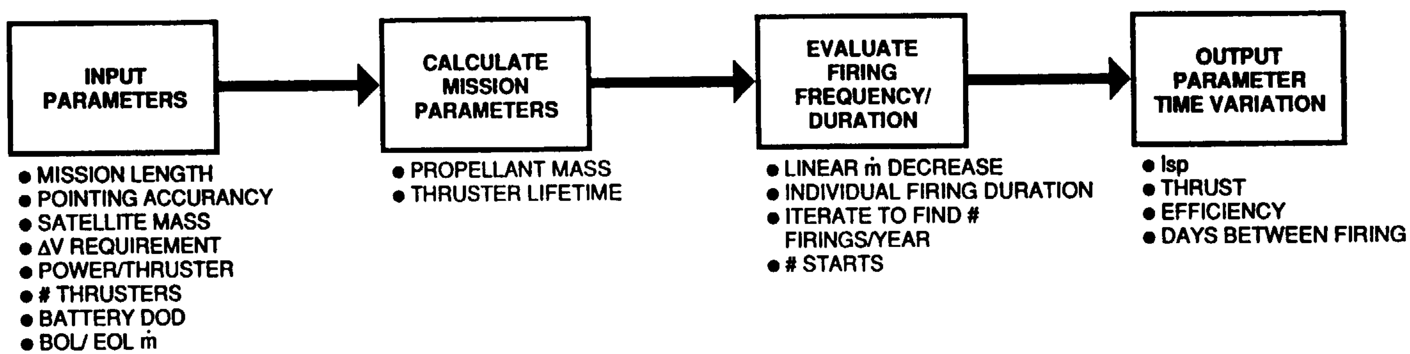
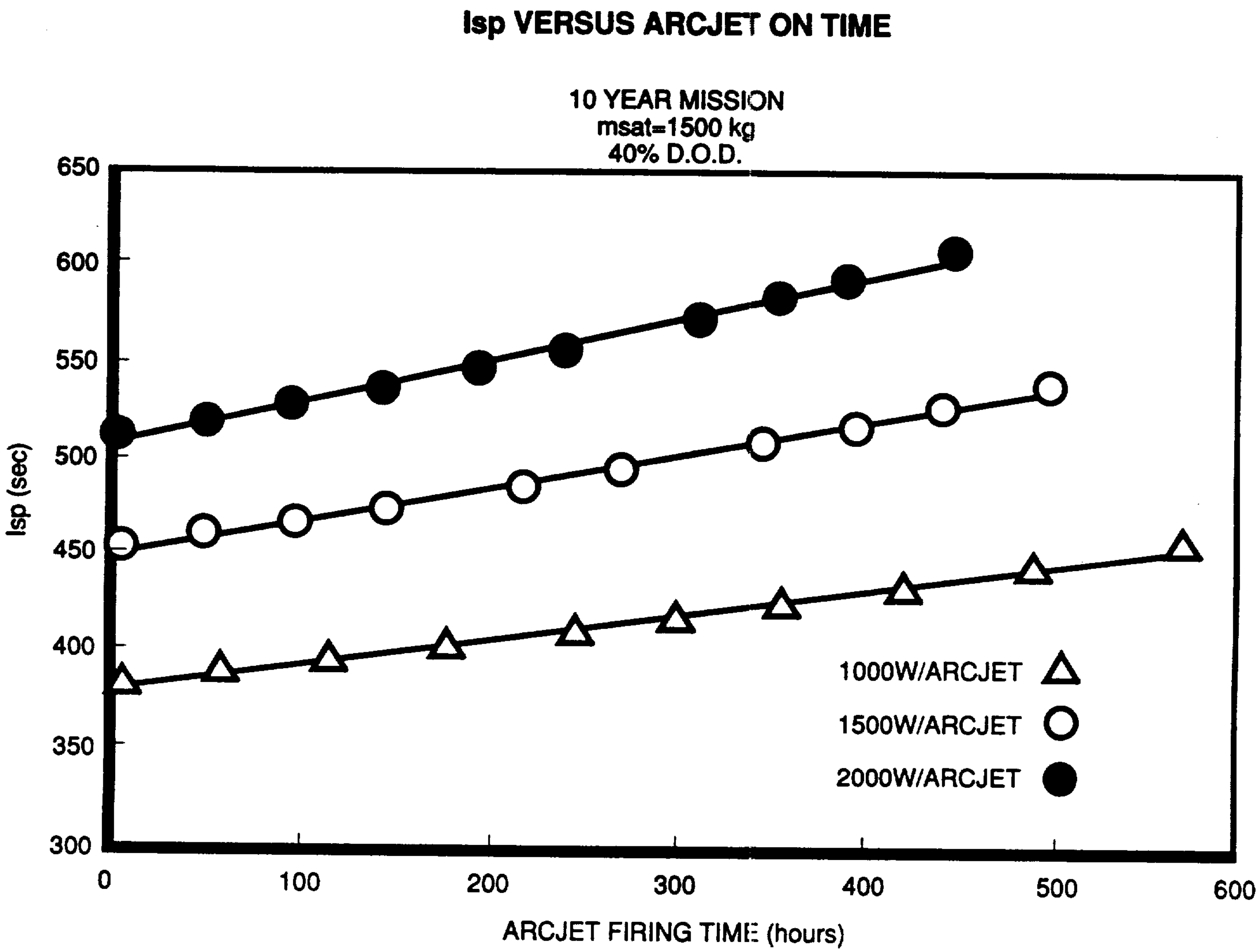


Figure 3-2



Isp VERSUS ARCJET ON TIME
10 YEAR MISSION
msat=1500 kg
40% D.O.D.
650
600
550
500
450
400
350
300
Isp (sec)
0
100
200
300
400
500
600
ARCJET FIRING TIME (hours)
1000W/ARCJET
1500W/ARCJET
2000W/ARCJET

Figure 3-3

Table 3-1
MISSION INPUT/OUTPUT PARAMETERS

Input	Description
Satellite pointing accuracy	Variable
Arcjet power	Variable (PCU efficiency not included)
Satellite mass	Variable
Battery type/depth of discharge	Variable DOD (Four Ni-H_2 cells assumed with constant 50 amp-hr rating)
Mission duration	Variable
Velocity increment	Fixed at 46 m/sec-yr
	Burn durations are short enough in length to accurately assume instantaneous correction occurs at the orbit nodes.
Arcjet flow rate vs firing life	Varies with life
	Initial/final flow rate achievable for a typical blowdown range.
	Linear decay a good approximation.
Number of arcjet systems	Fixed — two assumed

Output	Description
Arcjet specific impulse, thrust, efficiency	Derived from empirical curve fits for each burn.
Burn time	Per each burn and cumulative total
Velocity increment	Per each burn and cumulative total
Propellant consumed	Per each burn and cumulative total
Number of arcjet starts	Cumulative

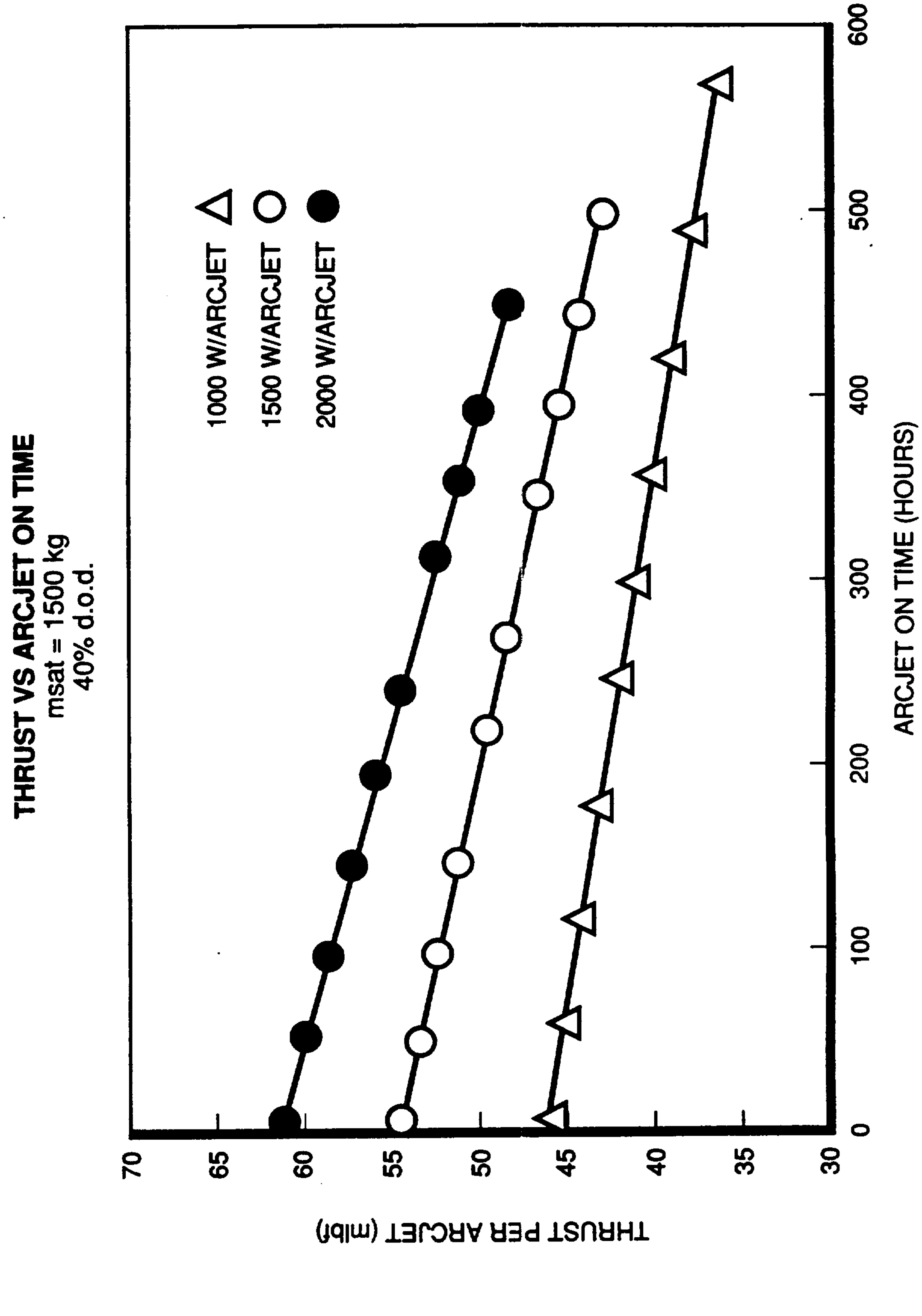
The variation in the thrust produced as a function of the on time is shown in Figure 3-4 for the same mission assumptions described above. Figure 3-5 gives the fuel required as a function of satellite mass. Figures 3-6 shows the dependence of the arcjet firing time on the power provided.

These results helped establish the arcjet system requirements discussed in section 3.3 for the engineering model system.

3.2 RESEARCH AND TECHNOLOGY DEVELOPMENT

3.2.1 Development Hardware Design and Fabrication

The basic components of the N_2H_4 arcjet developed during the Phase I program were again utilized in Phase II. This thruster configuration was used for all testing discussed in Sections 3.2.4 Cathode Lifetime Evaluation, 3.2.6 PCU Requirements Definition, and 3.3.2 Benchmark Thruster Evaluation.


THRUST VS ARCJET ON TIME
msat = 1500 kg
40% d.o.d.
1000 W/ARCJET
1500 W/ARCJET
2000 W/ARCJET
THRUST PER ARCJET (mlbf)
70
65
60
55
50
45
40
35
30
0
100
200
300
400
500
600
ARCJET ON TIME (HOURS)

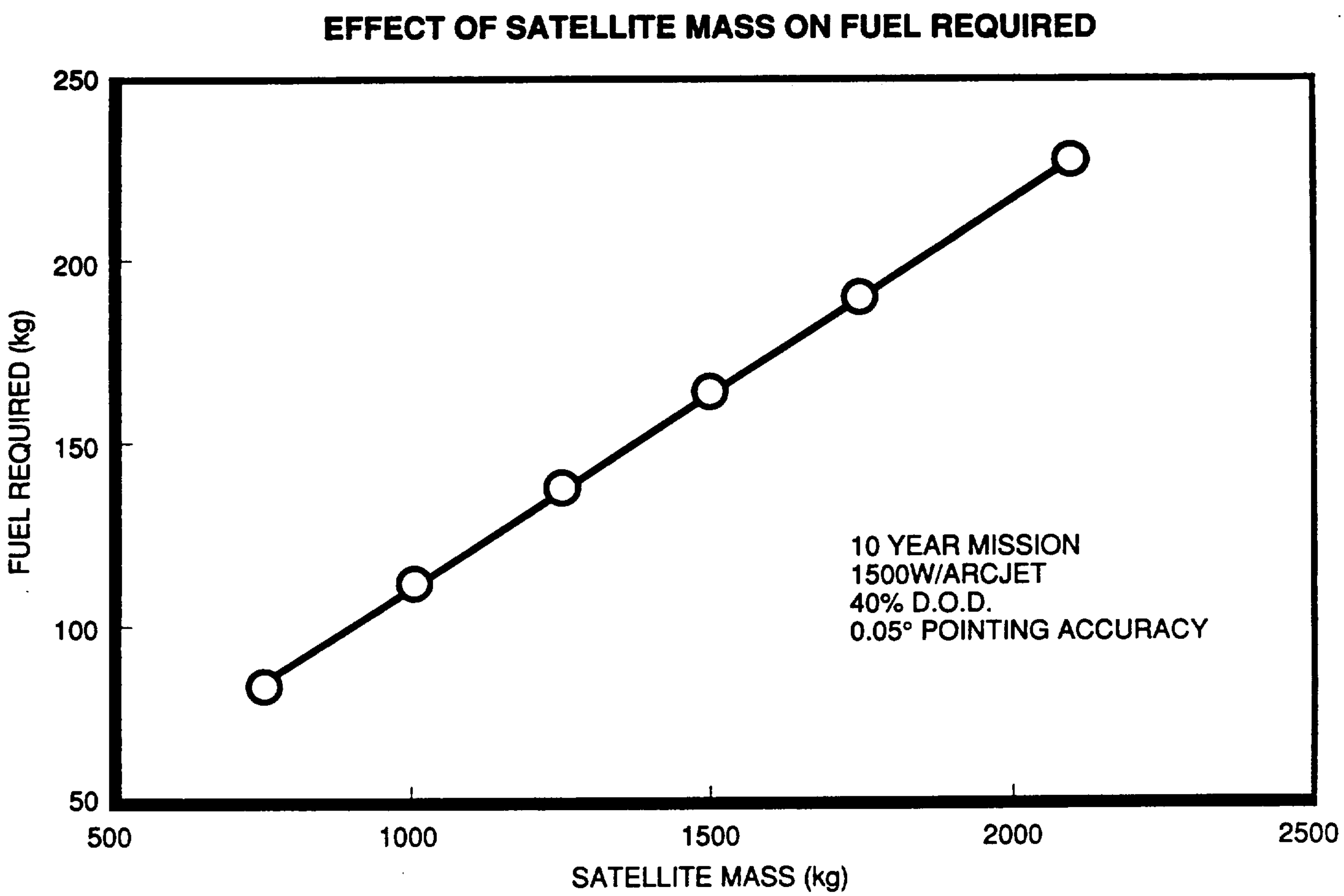


Figure 3-5

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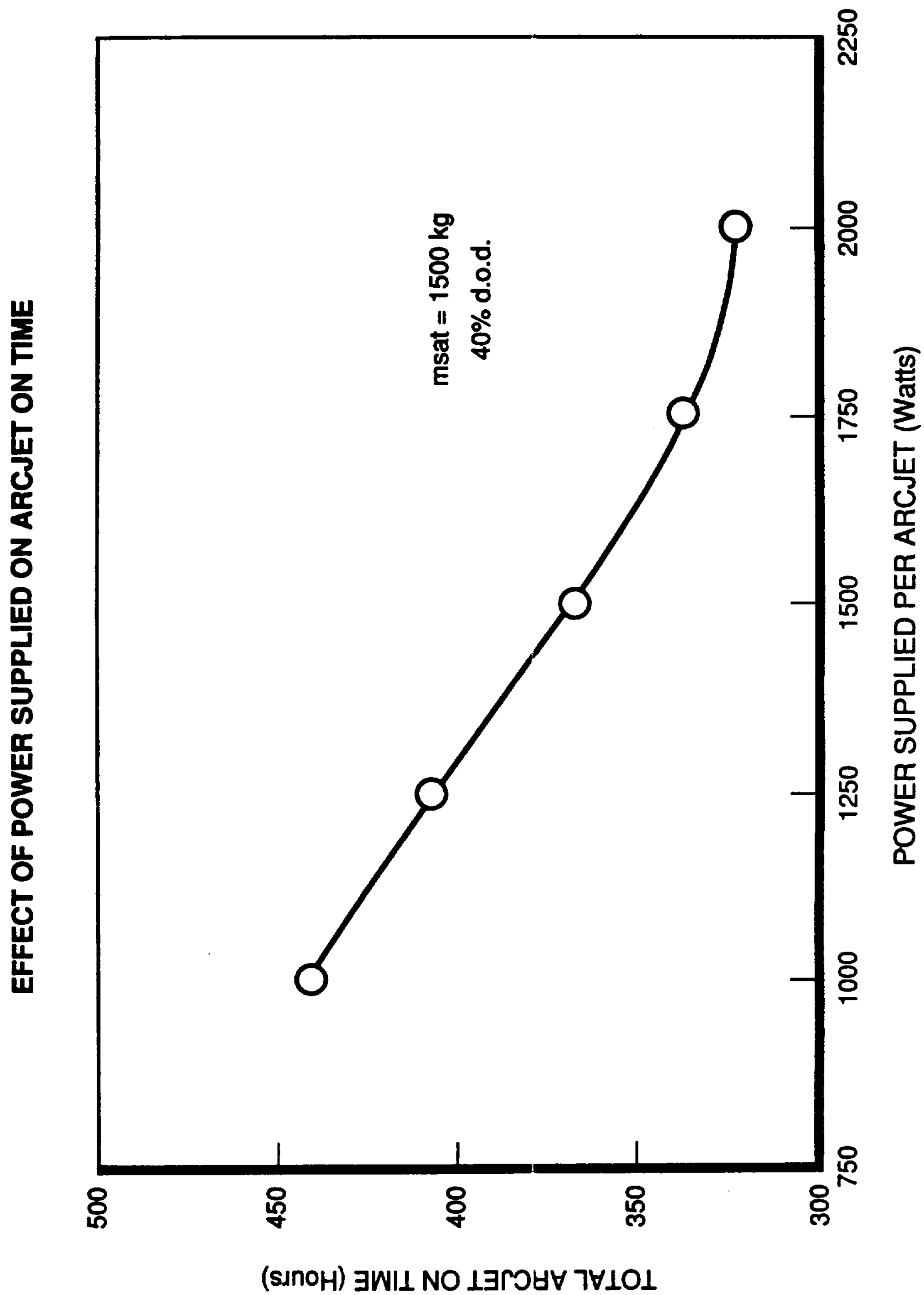

EFFECT OF POWER SUPPLIED ON ARCJET ON TIME
msat = 1500 kg
40% d.o.d.
TOTAL ARCJET ON TIME (Hours)
500
450
400
350
300
750
1000
1250
1500
1750
2000
2250
POWER SUPPLIED PER ARCJET (Watts)

The internal components of the arcjet and a list of materials used are shown in Figure 3-7. The overall length of the thruster is 24.4 cm and the diameter of the body is 3.1 cm. The seal design at the aft end of the arcjet was completely modified during Phase II to eliminate leakage problems which were previously experienced. A packing gland seal manufactured by Conax was incorporated. The seal is comprised of two alumina compression tubes and a crushable seal.

The complete test assembly, including arcjet, catalyst bed, propellant valve, fluid resistor, and mounting structure is shown in Figure 3-8. The catalyst bed, valve, and fluid resistor are flight qualified components used with the Electrothermal Hydrazine Thruster (EHT).

The fluid resistor is a device utilized in flight application to reduce the propellant inlet pressure from the levels typical of a spacecraft propulsion system to a range required for desired thruster performance. The fluid passes through a stack of discs which contain small spin chambers. This creates a tortuous flow path which results in dissipation of fluid energy and a reduction in pressure.

After passing through the valve, the propellant is fed into the catalyst bed. The N_2H_4 decomposes into an 800°C (1,470°F) gas mixture composed of NH_3, H_2, and N_2. The gases are vented through the gas delivery tube into the arcjet about 7.5 cm from the nozzle exit, as shown in Figure 3-7.

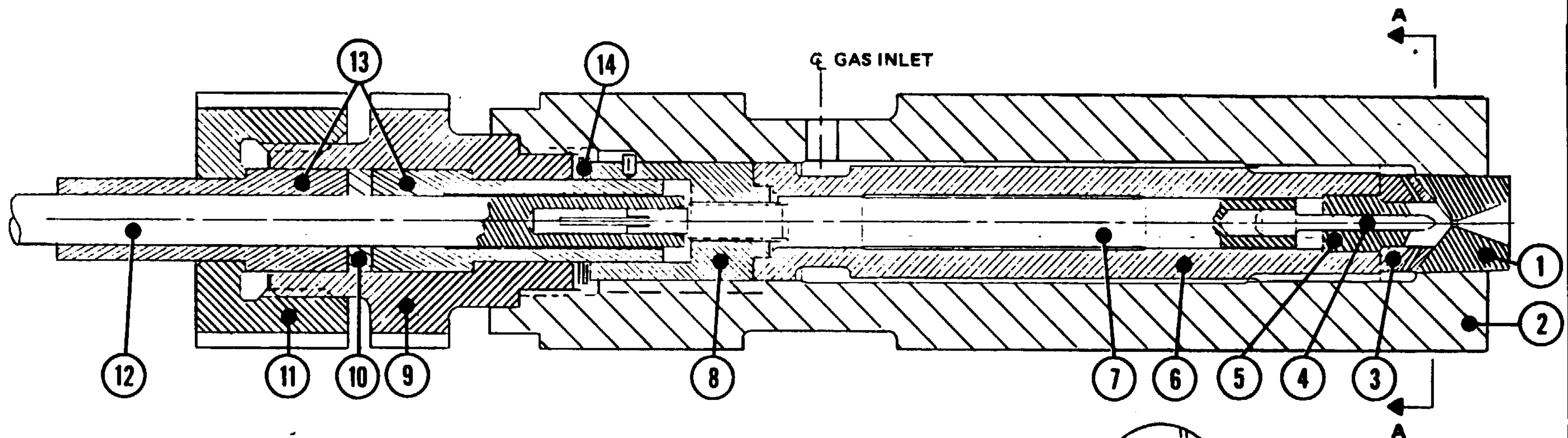
The anode is mated to the TZM body by a positive taper press-fit. This approach allows the same body to be used with more than one anode. The cathode is held by a TZM rod. This allows variation of the cathode material or geometry without requiring as much electrode material.

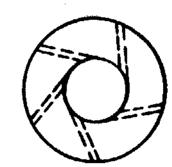
The injector support, feed block, and retaining plug are made from boron nitride, and provide electrical insulation of the cathode and its electrical connections to the aft end of the thruster. The retaining plug and cathode holder have mating threads which allow precise adjustment of the electrode gap to be made. There is an interference fit between the electrical contact and the end of the cathode holder. A graphite foil gasket is compressed between the fitting body and arcjet body to form a seal. The propellant inlet seal to the arcjet body is also made with a graphite gasket.

The modular design of the thruster proved valuable because many combinations of different critical components could be evaluated relatively quickly and inexpensively. The specific geometries of cathodes, anodes, and injectors which were tested will be discussed in subsequent sections.

A fabrication and assembly document controlled the assembly and disassembly of each thruster. The document lists part serial numbers, verifies that all assembly steps have been completed, and documents measurements for gap settings, leakage tests, and alignment runout of the cathode. All parts were thoroughly cleaned and assembled by personnel trained in clean room practices.

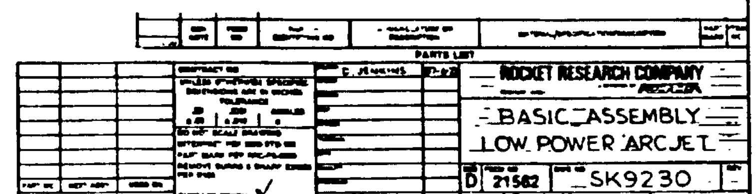
DEVELOPMENT ARCJET DESIGN





SECTION A-A

PART NAME	MATERIAL
1. ANODE	TUNGSTEN
2. ARCJET BODY	TZM
3. INJECTOR	TZM
4. CATHODE	2% THORIATED TUNGSTEN
5. INJECTOR SUPPORT	BORON NITRIDE
6. FEED BLOCK	BORON NITRIDE
7. CATHODE HOLDER	TZM
8. RETAINING PLUG	BORON NITRIDE
9. FITTING BODY	TZM
10. COMPRESSION SEAL	SOAP STONE
11. COMPRESSION NUT	STAINLESS STEEL
12. ELECTRICAL CONTACT	STAINLESS STEEL
13. COMPRESSION TUBES	ALUMINA
14. BELLEVILLE WASHERS	INCONEL



LOW POWER HYDRAZINE DEVELOPMENT ARCJET

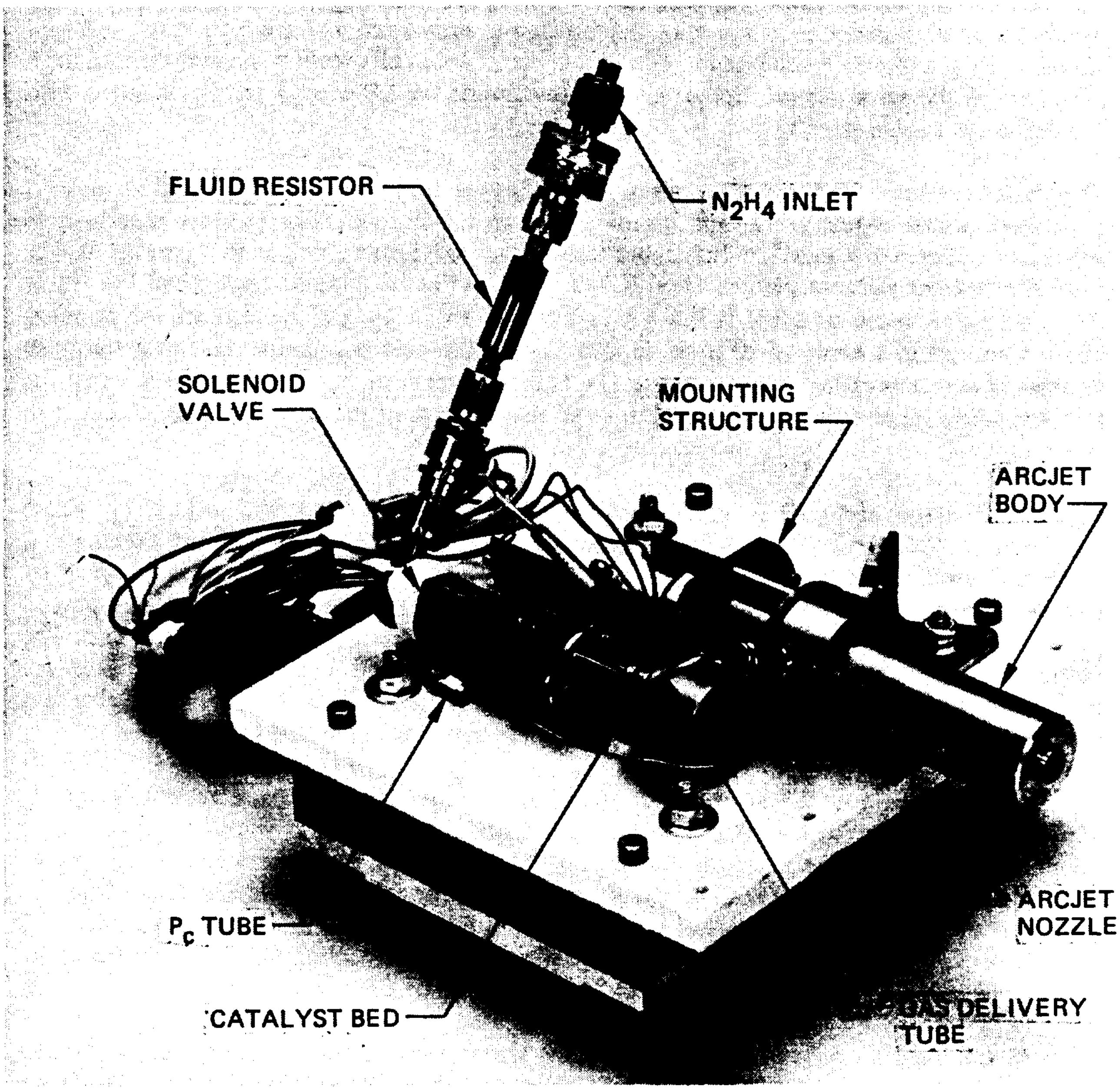


Figure 3-8

3.2.2 Test Facility

All test firings were conducted in RRC's Electric Propulsion Test Facility. Each of the three vacuum cells shown in Figure 3-9 were utilized during the course of the program. Cells 10 and 11 are 2.4 m in diameter by 2.4 m long, constructed of mild steel, and are fully water jacketed to enable long duration testing of high power devices. Both cells feature integral thrust stands which are of the same design. Cell 7 is a 1.5 m diameter by 1.8 m long steel tank fitted with interior water cooled panels.

The chambers have 30.5 cm diameter vacuum flanges to provide instrumentation, power, propellant, water conditioning, and visual access to the interior. The vacuum plumbing is arranged to allow each individual chamber to be either serviced by one or two parallel Stokes 1729 mechanical vacuum pumps, rated at 6.6 m^3/sec (13,950 ft^3/min) each. Over the N_2H_4 flow rate range tested of 2.3 x 10E-5 kg/sec to 6.0 x 10E-5 kg/sec, the background pressure was maintained in a range of 10 to 50 mTorr. This results in a maximum vacuum pressure to thruster chamber pressure ratio of about 1 x 10E-5. Studies of vacuum effects on thrust for low Reynold's number nozzles indicate that no degradation of the measured thrust occurs in this range.(2)

Figure 3-10 shows the Cell 10 thrust stand. An identical stand is located in Cell 11. These were built at RRC and are specifically designed for testing electric propulsion thrusters. A horizontal swing arm which supports the test hardware is fixed to a stationary pylon by torsional flexures at the axis of rotation of the arm. The flexures are used to carry power, propellant, cooling water, and instrumentation signals between the pylon and swing arm. The instrumentation capabilities on the thrust stand include 50 independent channels for measurement of temperature, pressure, voltages, and currents. Additionally, these channels are used for direct control of peripheral equipment attached to the test article.

Figure 3-11 shows how the thrust stand operates. A closed-loop feedback system is used in which an LVDT position sensor provides the feedback signal to a linear actuator which imposes an equal opposing force to the arm. The thrust arm is maintained in a null position, thereby minimizing error induced by hysteresis effects. The thrust level is calculated from the measured current driving the linear actuator, which has been calibrated independently in a separate fixture. Prior to start up of a test sequence, an in-situ calibration check on the entire thrust measurement system is made using hanging weights.

Each of the vacuum cells is permanently hard wired with an independent instrumentation system. The system is based on six-wire technology which incorporates remote excitation sensing, thereby eliminating line loss errors. Testing was monitored from a remote control bay adjacent to the test cells. All data acquisition equipment, including video monitoring of the arcjet, is located within the control bay, as shown in Figure 3-12.

All testing was controlled using an RRC personal computer based system which was programmed to remotely control external functions and record data on 16 available analog input channels. Automatic safety shutdowns were incorporated in the event a measured parameter exceeded a predetermined range. Table 3-2 summarizes the data acquisition specifications.

ELECTRIC PROPULSION VACUUM CHAMBER AND PUMPING TRAIN LAYOUT

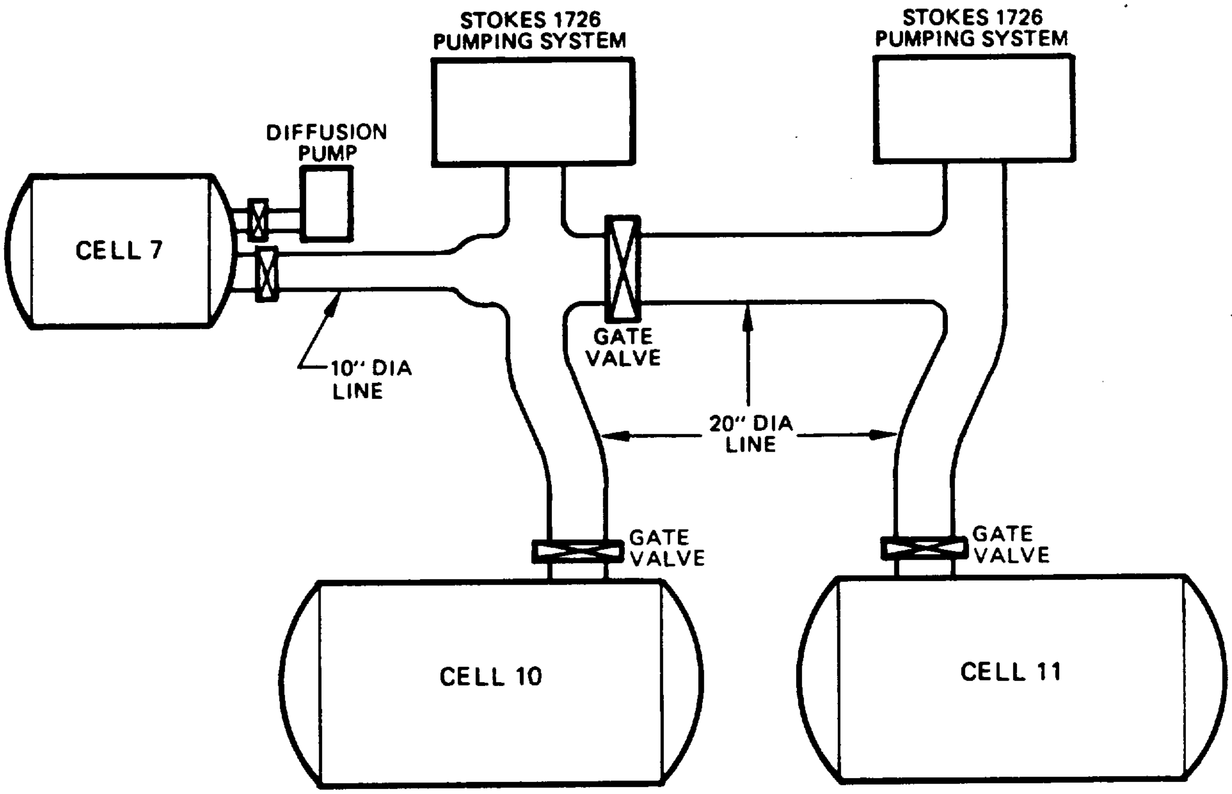
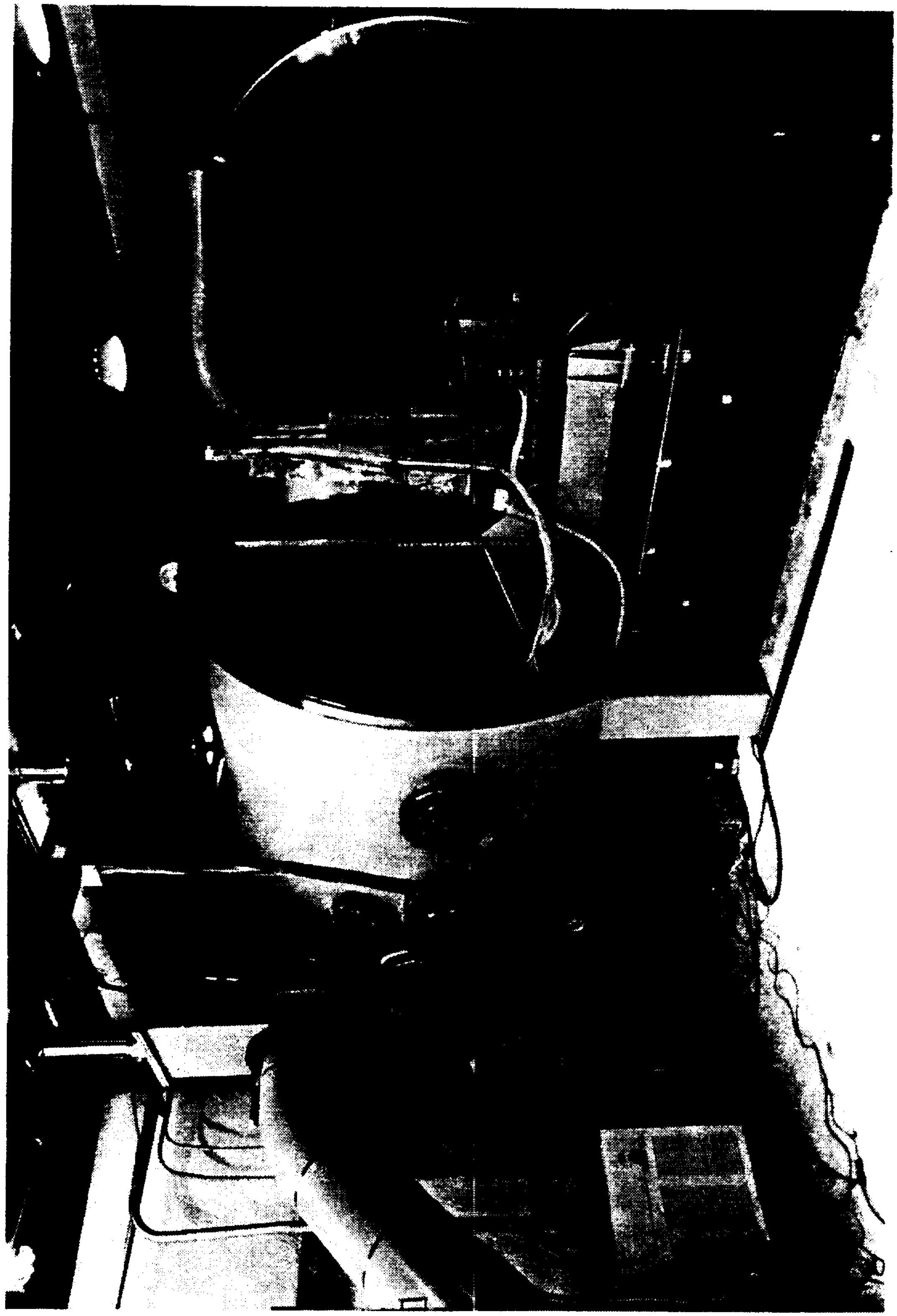


Figure 3-9



Thrust Stand

RRC NULL BALANCE THRUST STAND

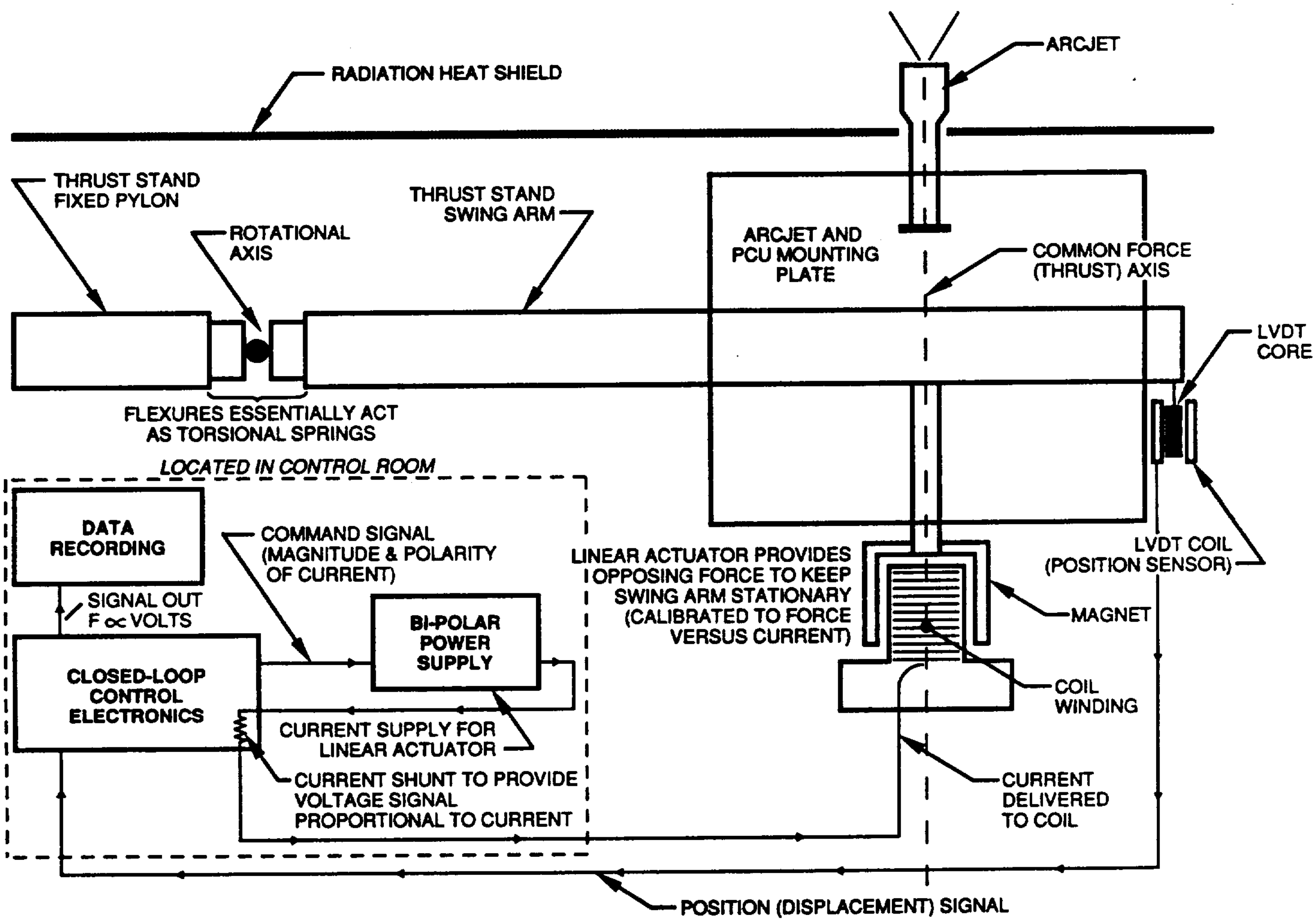


Figure 3-11

TEST CONTROL BAY

Table 3-2
DATA ACQUISITION CONFIGURATION

Input/Output:	16 analog input, 16 digital output channels.
Data Display:	Real time monitoring through CRT display and strip chart recorders.
Sampling:	230 Hz/channel rate.
Data Storage:	Hard/floppy disk and printed output in engineering units.

The propellant delivery system is shown in Figure 3-13. Pressurization of the N_2H_4 tank is remotely established and maintained. The propellant tank and feed lines up to the thrust stand flexure are temperature conditioned with water jackets. A short length of propellant line from the thrust stand flexure to the thruster inlet is wrapped with radiation shielding. These precautions were taken to prevent thermal flow transients which could cause flow measurement errors. A thermocouple measurement made at the inlet to the thruster assembly verified that ambient temperatures were maintained throughout the entire length of the propellant line.

Two methods of flow measurement were used. A mass flowmeter made by Micro Motion was used in all cases. This meter measures the mass flow by monitoring the Coreolis deflection of an oscillating U-tube through which the propellant flows. The meter is calibrated on a flow bench with water. The uncertainty of the measurement is ±0.9%. A remotely operated sightglass was also fitted to the propellant tank and used only for redundant checks of the flowmeter.

Fuel analyses were made of the fuel as received and when sampled through the propellant line. The latter analysis was made prior to testing any time the system had been broken for any reason and exposed to the environment. Conformance to MIL-P-26536C, Amendment 2, High Purity grade N_2H_4 was required. An example of a completed analysis report is shown in Figure 3-14.

An analysis of the measurement uncertainty was performed. The results are shown in Table 3-3.

3.2.3 Lifetime Evaluation Testing

The purpose of this task was to better understand cathode erosion mechanisms which occur in the hydrazine arcjet and to develop a configuration which would meet the lifetime requirements. A test plan was defined to parametrically examine the influence on erosion of the following variables:

1. Arc current
2. Cathode tip shape and size
3. Arc chamber pressure
4. Arc chamber flow field

Propellant System Schematic

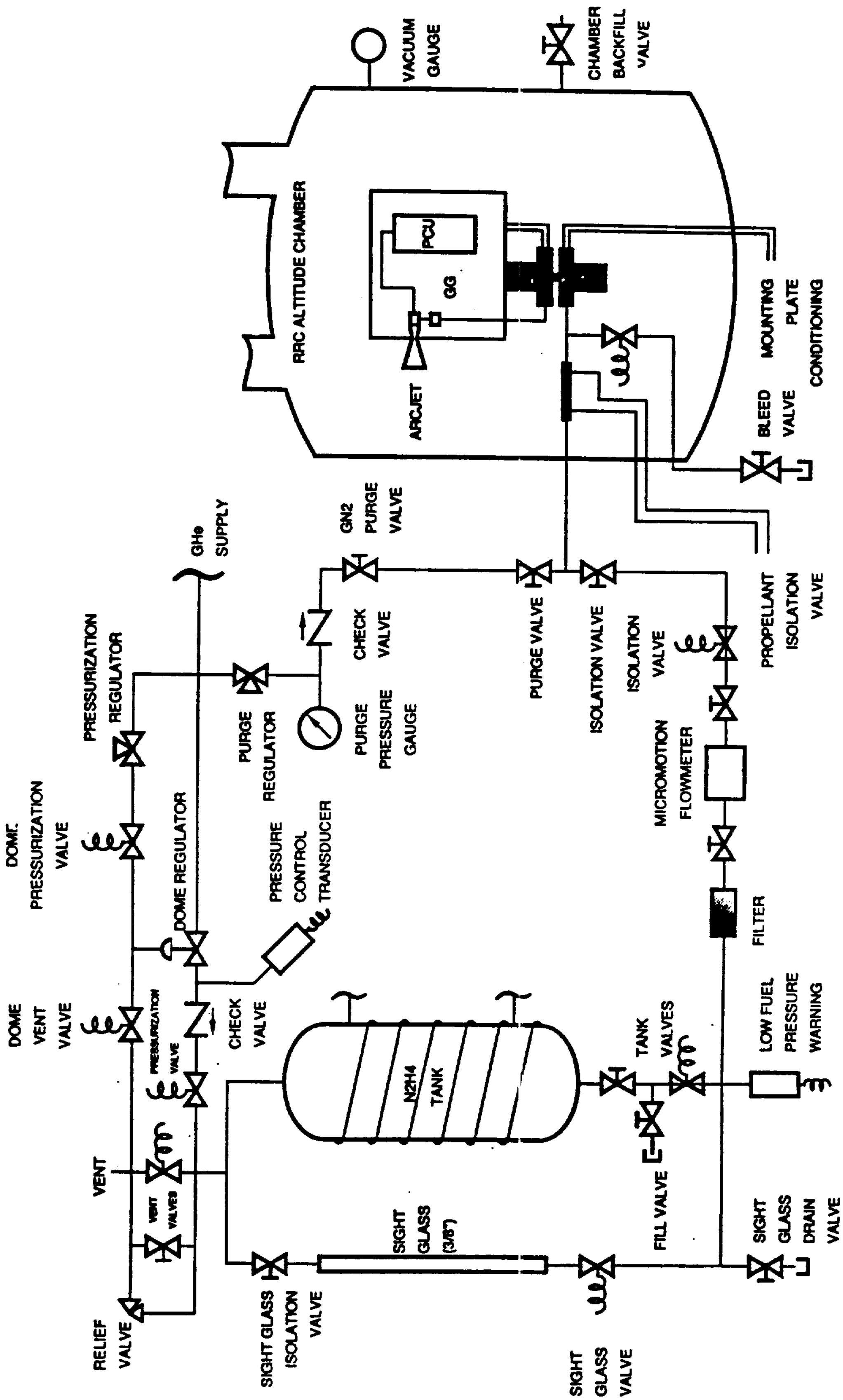


Figure 3-13

ROCKET RESEARCH COMPANY
HYDRAZINE ANALYTICAL FORM
FOR HYDRAZINE MEETING MIL – P – 26536, AMENDMENT 2

Date Sampled: 1-25-90 Orignator: G. Grout Approval: Randy Aadland

Date Due: ______ Sample ID: System Analysis for CH# 11

Date Recieved: 1-25-90 Charge No.: 121581-4840 Control No.: 06419

Disposition of Sample: Destroy

Check Upper Box For All → / ANALYSES REQUESTED	☐ CHK.	ACCEPTABLE VALUES MONOPROPELLANT GRADE % BY WEIGHT	ppm	RESULTS	☒	← Check Upper Box For All / ACCEPTABLE VALUES HIGH PURITY GRADE % BY WEIGHT	ppm	RESULTS
N_2H_4		98.50 min.	N/A	%		99.00 min.	N/A	99.29 %
H_2O		1.00 max.	N/A	%		1.00 max.	N/A	0.57 %
NH_3		0.40 max.	N/A	%		0.40 max.	N/A	0.14 %
Trace Organics Excluding Aniline		0.020 max.	200	ppm		0.005 max.	50	11 ppm
Aniline		0.50 max.	N/A	%		0.005 max.	50	3 ppm
Total Nonvolatiles (NVR)		0.0020 max.	20	ppm		0.0010 max.	10	8 ppm
Particulate		1 mg/L max.	N/A	mg/L		1 mg/L max.	N/A	~~0 mg/L~~
Corrosivity		0.00125 % Fe max.	12.5	ppm		0.00125 % Fe max.	12.5	2.5 ppm
Chloride		0.0005 max.	5	ppm		0.0005 max.	5	2.2 ppm
Iron		0.0002 max.	2	ppm		0.0002 max.	2	1.3 ppm
CO_2		0.0030 max.	30	ppm		0.0030 max.	30	13 ppm
Silicon (OPTIONAL)		0.000005 max.	0.05	ppm	Yes	0.000005 max.	0.05	0.02 ppm

Analysis Completed And Reviewed:

Signature J Maro Date 1-29-90

0636 A (3/85)

Figure 3-14

Table 3-3
DATA UNCERTAINTY

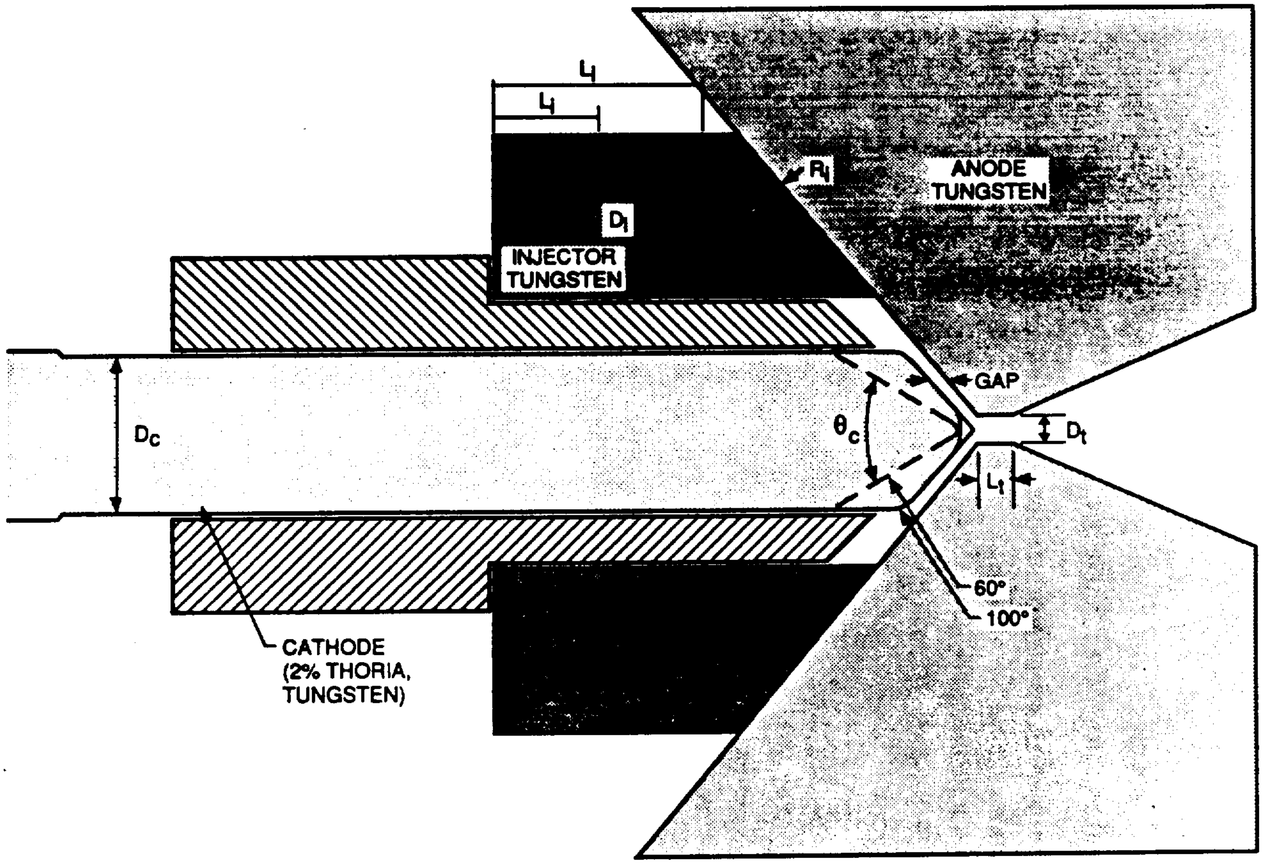
Parameter	Symbol	Measurement Technique	Accuracy In Measured Range (±%)
Flow Rate	$\dot{m}$	Micromotion Mass Flowmeter	0.9
Flow Rate	$\dot{m}$	Propellant Tank Sightglass	0.6
Propellant Feed Pressure GG Outlet Pressure	P_r P_c	Transducer	0.8
Temperatures	T	Chromel-Alumel Thermocouples	1.0
Thrust	F	Null Balance Thrust Stand	1.5
Arc Voltage	V_{DC}	Voltage Divider	0.5
Arc Current	I	Current Probe	1.0
Reduced Data			
Power (Arcjet)	P_N		1.1
Specific Impulse	I_{sp}		1.7
Efficiency (Arcjet)	η_{AJ}		3.3

Tests were run for durations of 20 hours. For concepts which proved attractive, additional 20- to 50-hour runs were made. Voltage, current, chamber pressure, and thruster temperatures were measured. Cathode inspections were made before and after the tests to assess tip geometry changes and mass loss. The mass loss measurements served as the primary basis of erosion comparison.

Figure 3-15 shows the thruster dimensions which were varied to produce the desired operational changes and the component materials used. Table 3-4 describes the actual geometric and operational variations which were tested. The test number designations in Table 3-4 are referred to throughout this section. Fifteen different configurations were evaluated with a total of 290 testing hours accumulated. A graphical summary of how each of the thruster configurations performed is shown in Figure 3-16 where cathode mass loss is graphed against the number of coulombs that passed through the electrodes.

A baseline configuration (Test 20) was selected which consisted of a 0.178 cm (0.070 in) diameter cathode with 100 degree tip angle, 0.076 cm (0.030 in) diameter by 0.076 cm (0.030 in) long anode throat, and vortex injection consisting of 5 hemispherical shaped ports with radius size of 0.051 cm (0.020 in). The baseline operating conditions were at constant 16 amps current and 5.0 x 10E-5 kg/sec flow rate. The baseline test results were compared to each of the subsequent parametric variations. In all the configurations, the gap setting established the same axial position of the extreme tip of the cathode with respect to the anode.

CATHODE TESTING THRUSTER GEOMETERY



D_c = CATHODE DIAMETER

θ_c = CATHODE TIP ANGLE

D_t = ANODE THROAT DIAMETER

L_t = ANODE THROAT LENGTH

L_i = AXIAL INJECTION LOCATION

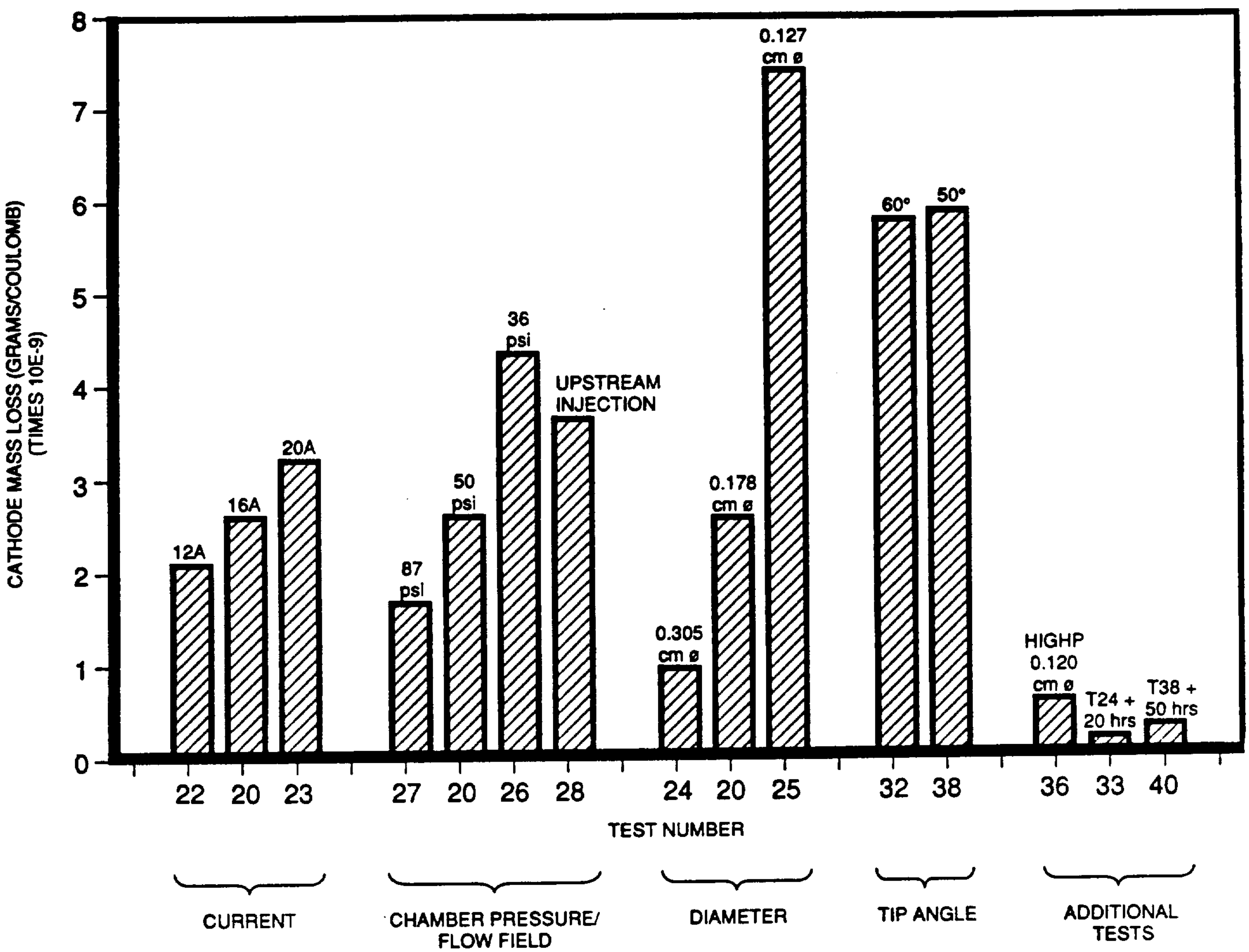
D_i = INJECTION PORT DIAMETER (SPHERICAL CROSS SECTION)

R_i = INJECTION PORT RADIUS (HEMISPHERICAL CROSS SECTION)

Table 3-4
CATHODE EROSION TESTING

Effect	Test No.	I (amps)	$\dot{m}$ (kg/s)	Cathode	Anode	Injector	Comments
Current	20	16	5.0×10^{-5}	0.178" φ, 100° tip angle	0.076 cm φ x 0.076 cm L	5 x 0.051 cm R ports	Baseline geometry
	22	12					Low current
	23	20					high current
Cathode diameter, cone angle	24	16		0.305 cm φ, 100° tip			Large diameter
	25			0.127 cm φ, 100° tip			Small diameter
	32			0.305 cm φ, 60° tip			Large diameter, sharp tip
	38			0.635 cm φ, 50° tip			Ultra-large dia., sharp tip
Arc chamber pressure/flow field	26			0.178 cm φ, 100° tip	0.084 cm φ x 0.084 cm L		Low pressure
	27				0.064 cm φ x 0.064 cm L		High pressure
	28				0.076 cmφ x 0.076 cm L	5 x 0.043 cm φ inlet ports	Alternate design
							Upstream injector
Additional tests	36			0.305 cm φ, 100°tip	0.064 cm φ x 0.064 cm L	5 x 0.051 cm R ports	Large diam./high pressure
	33			Test 24 cathode	Test 24 anode	Test 24 injector	20 additional hrs ss
	40			Test 38 cathode	Test 38 anode	Test 38 injector	50 additional hrs ss

NASA LeRC LPAJ CATHODE EROSION SUMMARY



C11205-67C

Figure 3-16

Arc Current Variation

Tests 20, 22, and 23 showed a strong dependence of the erosion rate on the current level. Quantitative comparisons could be made through mass loss and dimensional measurements. Table 3-5 provides a summary.

Table 3-5
TEST RESULTS: ARC CURRENT VARIATION

Test	(kg/s)	Current (A)	Voltage (V, Avg.)	Power (W, Avg.)	Cathode Length Change (cm)	Cathode Mass Loss (gm)
22	5.0×10^{-5}	12	104	1248	0.018	0.0017
20	5.0×10^{-5}	16	105	1680	0.023	0.0030
23	5.0×10^{-5}	20	102	2040	0.041	0.0046

The mass loss rate per unit time at 20 amps was more than double the rate at 12 amps. Measured dimensional changes supported this conclusion. Figure 3-17 shows the cathode before and after the 20 amp test. A general observation regarding all the cathodes was that the erosion was concentrated almost entirely within the crater-like region at the tip which becomes molten during operation. No evidence of chemical attack or sputtering of molten material could be identified. The dominant process affecting the erosion rate appeared to be evaporation from the molten region.

Figure 3-18 shows the dimensional change data measured for Test 23 using various inspection techniques. The primary difference between this and the other cathodes is the size of the crater at the tip. The overall reduction in length ranged from 0.018 cm to 0.041 cm for the 12 amp and 20 amp cathodes, respectively. No loss of arc stability was observed as a result of this cathode length change.

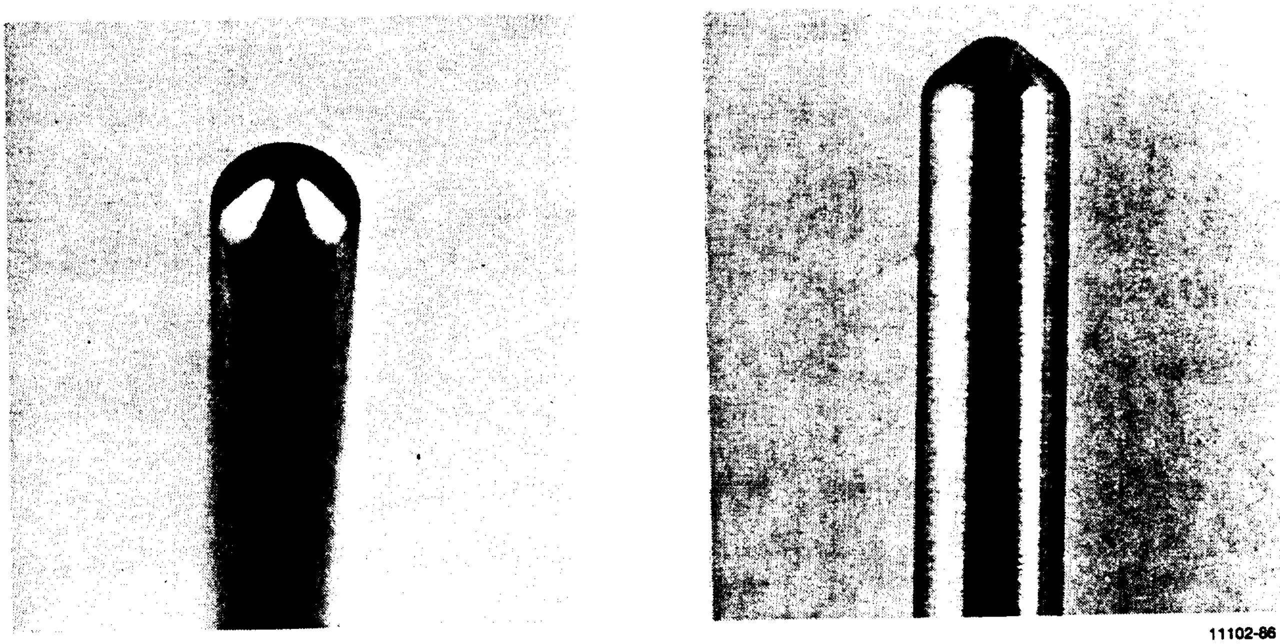
The results of this sequence strongly indicated that for cathode longevity, an advantage is gained by minimizing the current for a given power level. There are several ways to accomplish this. First, the gap setting and anode throat length have been shown to directly effect the arc voltage, with greater lengths in either dimension causing an increase in voltage. These can be adjusted within limits established by stability criteria to maximize voltage and minimize current. Second, the pressure in the arc chamber can be controlled by sizing the nozzle throat. Higher pressure increases the resistance of the arc, resulting in a voltage increase.

Cathode Geometry

Tests with cathodes of 0.127 cm (0.050 in) diameter and 0.318 cm (0.125 in) diameter were conducted during Tests 24 and 25 for comparison with the baseline case of 0.178 cm (0.070 in.). A clear correlation between lower erosion rates and increasing cathode diameter was established. Figure 3-19 shows mass loss versus diameter for each of the three tests. A total mass loss three times greater than the large diameter cathode was measured for the

TEST 23 CATHODE

BEFORE TEST 23
MAGNIFICATION = 11.2X



11102-86

AFTER TEST 23
MAGNIFICATION = 11.2X

11192-89

- 20 amps
- 5.0×10^{-5} kg/sec
- 0.178 cm ϕ
- 100° INCLUDED ANGLE TIP

TEST 23 DIMENSIONAL INSPECTION
(DIMENSIONS IN INCHES)

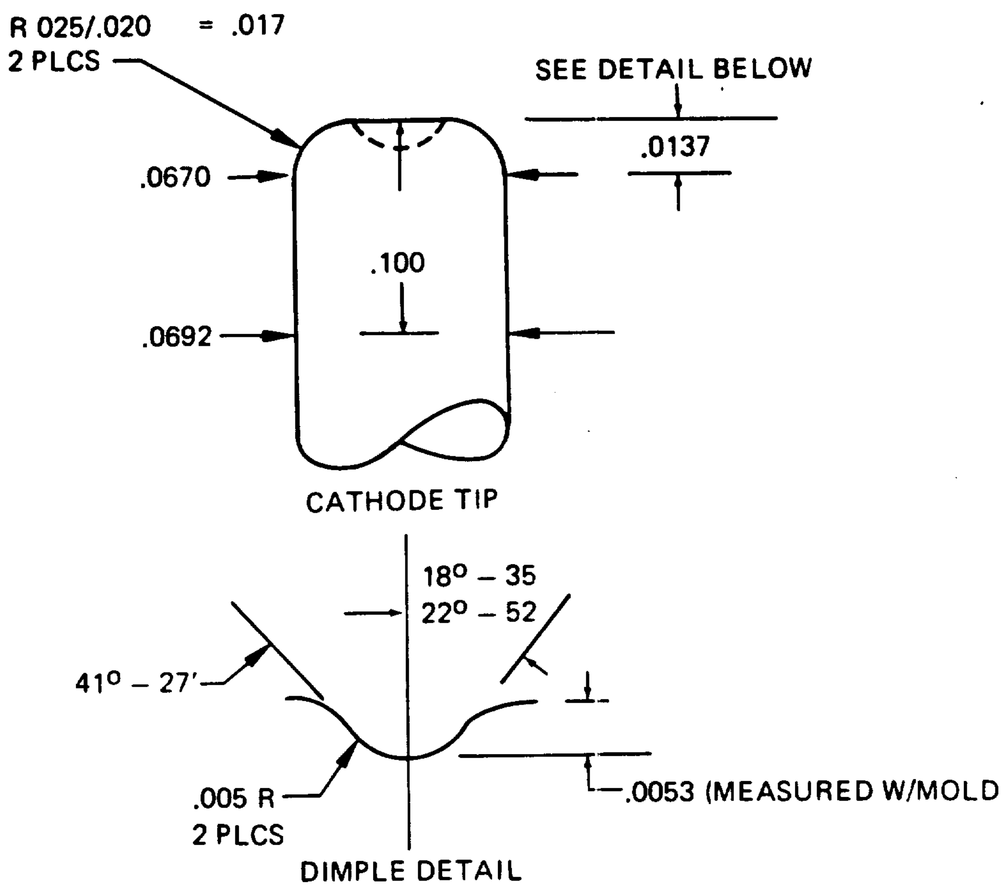


Figure 3-18

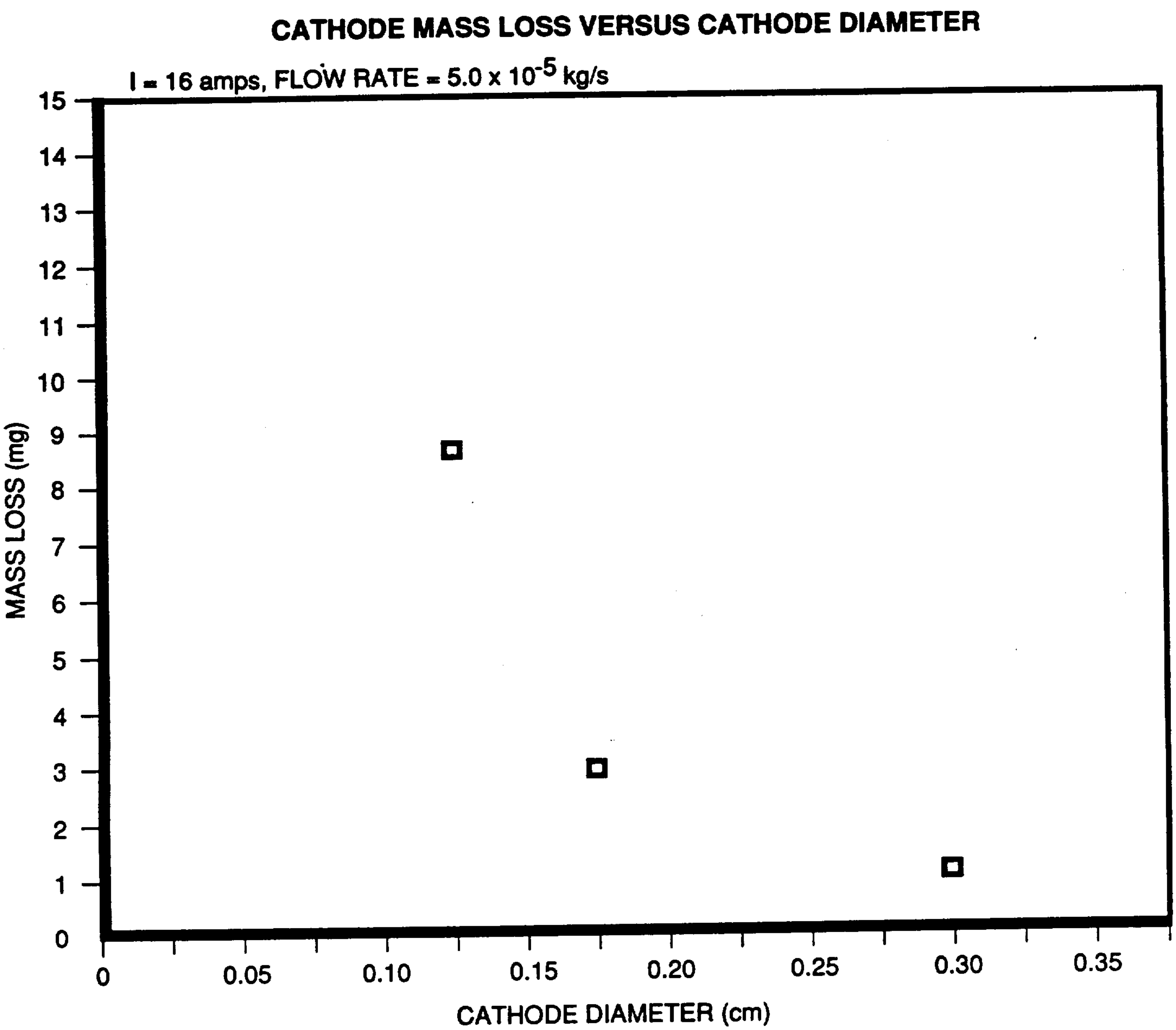

CATHODE MASS LOSS VERSUS CATHODE DIAMETER
I = 16 amps, FLOW RATE = 5.0 x 10-5 kg/s
MASS LOSS (mg)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
CATHODE DIAMETER (cm)

Figure 3-19

small diameter cathode. The length changes of the small and large cathodes were 0.064 cm and 0.015 cm, respectively.

Post-test photos of the small and large diameter cathodes are shown in Figure 3-20 for comparison. Each of the configurations was run at the same flow rate and current, and the resulting average chamber pressures varied by only ±4 psi. Since lower evaporation rates were experienced with larger diameters at nearly the same pressure, lower tip temperatures were likely experienced. With this evidence, it was clear that the 0.318 cm (0.125 in.) diameter should be established as a minimum dimension for any future point designs.

Tests 32 and 38 evaluated larger diameter cathodes with sharper tips, as defined in Table 3-4. These cathodes produced higher initial mass loss rates than the baseline case, as shown in Figure 3-16. However, later results of a retest of the 50 degree tip cathode showed that this rate of erosion is reduced considerably when the cathode was tested beyond the initial 20 hour period. This indicated that there was an important burn-in period that must be considered when evaluating cathode loss mechanisms.

Chamber Pressure/Flow Field

The effect of pressure on the cathode erosion rate was evaluated during Tests 26 and 27. Table 3-6 shows the resulting data. The power level varies because the voltage changes with the arc chamber pressure.

Table 3-6
TEST RESULTS: CHAMBER PRESSURE VARIATION

Test No.	Low Pressure 26	Nominal 20	High Pressure 27
$\dot{m}$ (kg/s)	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}
I (A)	16.0	16.0	16.0
V_{avg} (V)	96.9	105.0	128.7
P_{avg} (W)	1550	1480	2059
$P_{c\ avg}$ (psia)	36.3	50.0	86.6
Mass loss (mg)	5.0	3.0	1.9

Cathode mass loss measurements are shown in Figure 3-21 as a function of chamber pressure. Lower rates of erosion were seen at higher chamber pressures. It was also noted, however, that arc stability, as determined by the steadiness of the voltage and current strip chart traces and the exhaust plume, was poorer at higher pressures.

An alternate vortex configuration was used during Test 28 which featured injection of the gases in an alternate, upstream location compared to the baseline configuration shown in Figure 3-15. The resulting chamber pressure did not change from the baseline case. The measured cathode mass loss for this configuration was equivalent to the baseline case and therefore no notable erosion effects were directly attributed to this change. A useful result,

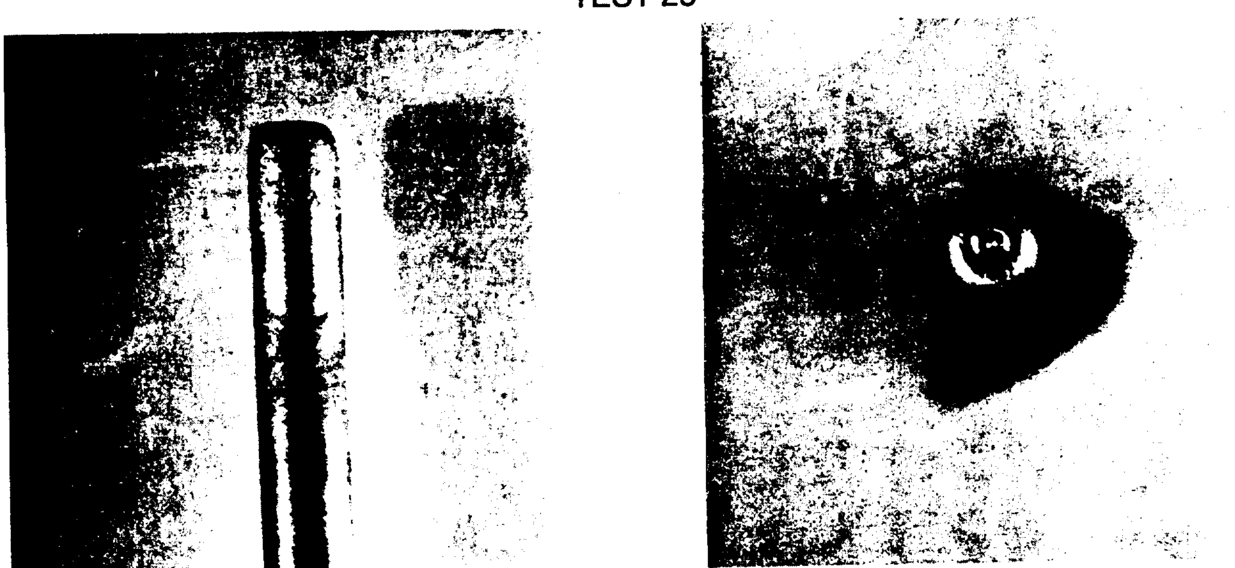
POST-TEST CATHODE GEOMETRIES

TEST 24

11192-90

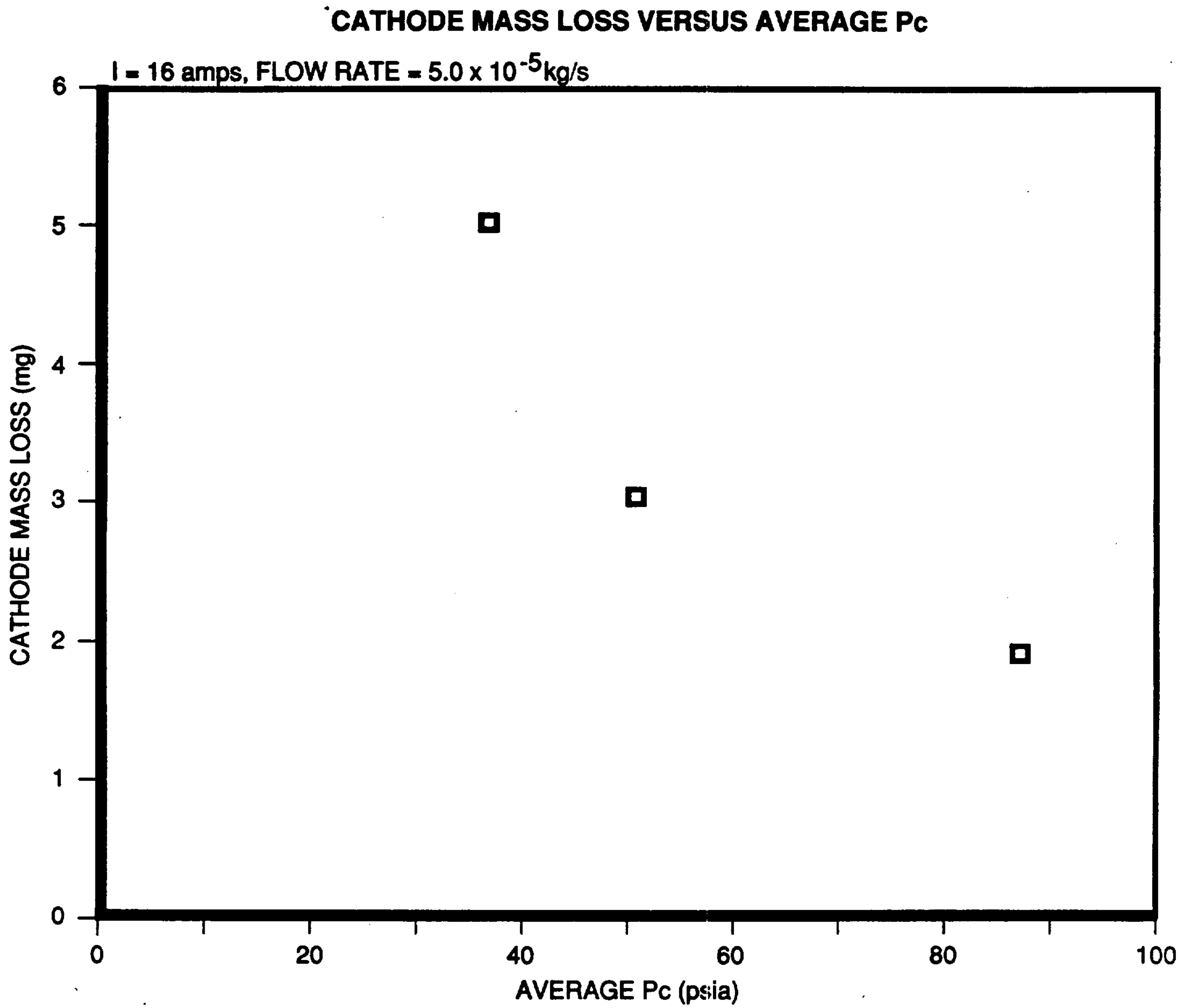
- 20 HOURS
- 16A
- 5.0 X 10^{-5} kg/sec
- 0.305 cm ϕ
- 100° INCLUDED ANGLE TIP

TEST 25



11193-73

- 20 HOURS
- 16A
- 5.0 X 10^{-5} kg/sec
- 0.127 cm ϕ
- 100° INCLUDED ANGLE TIP



CATHODE MASS LOSS VERSUS AVERAGE Pc
I = 16 amps, FLOW RATE = 5.0 x 10-5kg/s
CATHODE MASS LOSS (mg)
0
1
2
3
4
5
6
0
20
40
60
80
100
AVERAGE Pc (psia)

Figure 3-21

however, was that better stability characteristics of the arc were observed during this test. One hypothesis is that initiation of the vortex further upstream of the cathode may allow the flow to become more fully developed before it reaches the arc region. By doing so, recirculation or transient gas dynamic effects which may contribute to arc instability were minimized.

Additional Tests

Two additional investigations were conducted. First, a configuration combining the high pressure anode and larger diameter cathode was tested. These two effects, when tested separately, had produced the lowest erosion rates. Second, two of the large diameter cathode configurations were tested for extended periods to evaluate erosion rates past the original twenty hour time period.

Test 36 combined a 0.064 cm (0.025 in.) diameter anode with a new 0.318 cm (0.125 in.) diameter cathode with a 100-degree tip. This configuration yielded a very low cathode mass loss rate which was slightly less than the previous tests which evaluated these two effects separately. The results can be seen on Figure 3-16.

Two tests were conducted which extended the lifetime on the large diameter cathode configurations of Tests 24 and 38 to 40 and 70 hours respectively. As Figure 3-16 indicates, a much lower level of erosion was experienced on both tests after the initial twenty hours. The cathodes established a more stable geometry once this burn-in period was passed.

Cathode Investigation Conclusions

The important conclusions drawn from this testing are summarized below:

1. *Cathode Material*: Acceptable compatibility of the 2% Th/W cathode material and the hydrazine decomposition products was established. No evidence of chemical attack was detected and the overall resiliency of this material to erosion was judged to be acceptable. Therefore, no alternate materials were tested.
2. *Cathode Geometry*: Cathodes with larger diameters and larger tip angles have lower erosion rates. These geometries allow greater heat dissipation from the tip, resulting in reduced temperatures and evaporation rates. However, a sharper tip is more stable, and exhibits lower erosion rates after an initial burn-in period.
3. *Chamber Pressure*: Higher pressure in the arc chamber produces lower erosion rates. A higher pressure will reduce the net flux of evaporating particles leaving the cathode surface.
4. *Current*: Mass loss rates were found to vary linearly with current between 12 and 20 amps.
5. *Cathode "Burn-In"*: The mass loss rate diminishes with firing time. When burned in, a slightly flattened tip with a small depression is produced which varies little as firing continues. The burn-in period is also characterized by a 10 to 20 V increase. Pre-shaping the cathode should eliminate this high rate of initial change.

3.2.4 Cathode Processes Modelling

A modelling effort was conducted in parallel with the cathode life testing. The goal was to develop an analytical tool that would generate data for direct correlation to experimental results and aid in predicting erosion trends. A survey of existing literature on cathode erosion phenomena was made. Different erosion mechanisms, the environments to which they apply, and previous modelling approaches taken were examined. The modelling development was then carried out in a three steps:

1. A model describing the important processes which affect cathode erosion was constructed. The cathode and surrounding flow were examined in three discrete regions in which different energy transfer mechanisms and material phases are present.
2. A first-order modelling strategy was implemented which used simple but physically representative relationships and iterative numerical methods to compute quantitative results for a two-dimensional cathode. These included profiles of heat flux, surface temperature, current densities, and mass flux from the cathode surface.
3. Output from the model was generated and iterative refinements were made. The trends in erosion rates were compared to those observed in the parametric cathode testing. Areas of additional model refinement which could not be completed within the scope of this program were identified.

A description of the work completed under these three subtasks follows.

Physical Description of Arcjet Cathode Processes

Figure 3-22 illustrates the essential parameters of the erosion problem for a cathode operating in the diffuse or single spot mode with only one region of active attachment. There are three principal regions of interest, each separated by a boundary across which a phase change and/or chemical species change occurs:

I. The cathode interior — solid

II. The discharge region (a single spot or a cluster of spots) — solid, liquid, and vapor

III. The external flow region (neutrals, ions, and electrons) — gas.

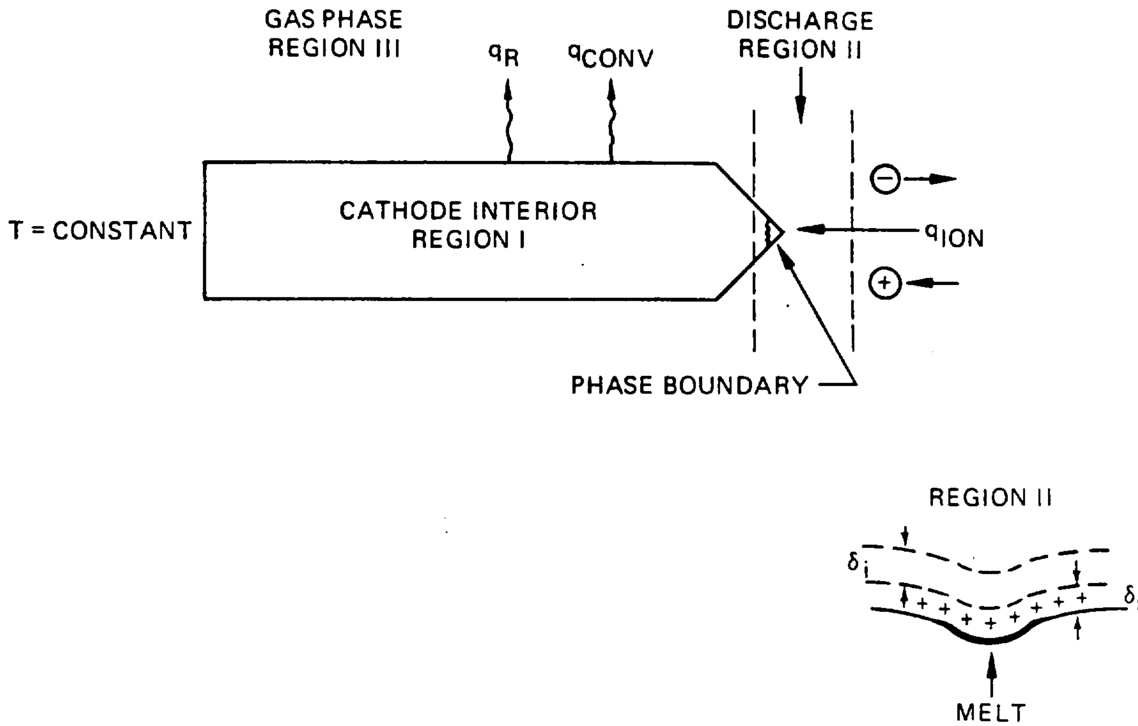
Region I

Physical processes of importance in this region are primarily heat transfer to the surroundings via conduction in the interior (Region I to II) and conduction, convection, and radiation from the cathode surfaces (Region I to III). The nonsteady heat conduction equation governing the energy transfer process is given by:

$$\rho\, C_c \frac{\partial T}{\partial t} = K \nabla^2 T + q \qquad \text{(K assumed constant)}$$

where K is the cathode thermal conductivity, ρ is the density, C_c is the heat capacity, q is the rate of energy addition due to surface fluxes and internal changes, and T is the instantaneous temperature. The boundary conditions for this equation reflect the nature of the heat transfer taking place at the cathode surface or phase boundary (convection, conduction, and/or radiation). It should be noted that phase changes represent a significant investment of energy.

CATHODE REGIONS



11194-43 (1) **Figure 3-22**

Region II

The discharge region is central to the cathode erosion problem and is coupled directly with processes in the solid cathode body (Region I) and the neutral gas (Region III). This region will encompass the solid-liquid, liquid, and liquid-vapor phases. Each phase may have a significantly different response to the flow of current and heat input. The transition between solid and liquid occurs in the vicinity of the $T = T_m$ contour, where T_m is the melting point of the cathode alloy. The shape and location of the liquid-vapor interface depends to first order on the saturated liquid temperature, pressure, surface tension, and current flux. The pressure of the vapor above the liquid is assumed to be due to pure cathode material. A space charge layer exists above both the solid and liquid surfaces. For a negative discharge ($V_c < O$), energetic electrons escape from the surface and essentially pass through the incoming positive ions with little interaction because the electron-ion collision cross-section is small. The slower moving ions drift under the influence of the local field to the cathode surface. Since the ion number density is much greater than the electron number density ($n_i >> n_e$) within this thin layer (δ_s), a net positive charge and an accompanying high intensity electric field are established. The thickness of this layer is determined by the positive ion concentration and is on the order of several mean free paths:

$$\delta_s \sim 1/(n_i\, d_i^2) = kT/(Pd_i^2),$$

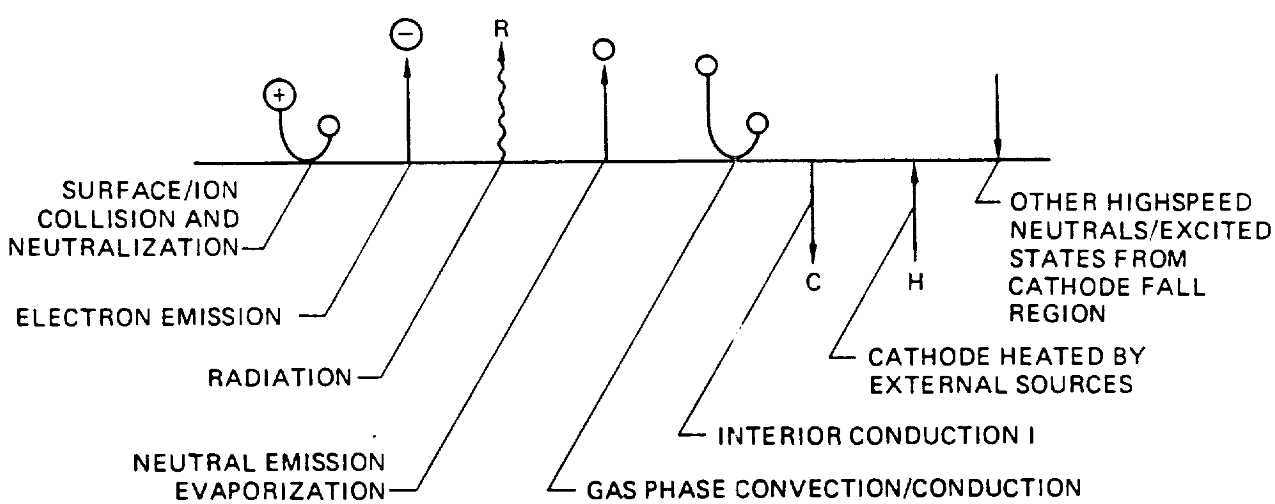
where k is the Boltzman's constant, T is the gas/vapor temperature, P is the gas/vapor pressure, and d_i is the effective diameter of the gas/vapor ions. The field strength scales roughly as $E_c \sim V_c/d_c$ where V_c is the cathode fall potential and d_c is the length scale associated with the potential drop. This implies that the local field strength varies as $E_c \sim V_i/(kT) \times Pd_i^2$ where V_i is the ionization potential of the cathode material ($\sim V_c$). Beyond the space charge layer, a somewhat larger ion production region (δ_i) and the fully developed plasma may be found.

Figure 3-23 illustrates the basic energy transfer mechanisms occurring at the cathode surface. The most important of these are ion-surface collisions and electron-surface emission. Considering only these two processes, the energy transfer to the surface is approximately:

$$H = j_i (\alpha V_c + \Phi_o) - j_e \Phi_{eff},$$

where j_i and j_e are the ion and electron current densities, respectively, α is the ion accommodation coefficient (~1), V_c is the cathode fall potential, Φ_o is the surface work potential, and Φ_{eff} is the effective surface work potential taking into account the distribution of electron energies actually leaving the surface. The energy exchange is sufficiently intense to allow electrons to escape from the emitting surface and accelerate under the influence of the high electric field.

SURFACE ENERGY EXCHANGE



11194-43 (2) **Figure 3-23**

Higher current densities are achieved as a result of the space charge enhanced field. The space charge layer thickness decreases above the liquid surface due to the high vapor pressure of the cathode material. The local field is therefore intensified, increasing the local current density and the heat flux to the surface. At sufficiently high current densities and surface temperatures, a significant number of cathode ions may be ejected from the liquid surface with enough energy to escape the space charge layer. This is a modified evaporation process and represents a principal material loss mechanism. It should be noted that the mechanism for field intensification and increased local temperature is appropriate for a single spot as well as a cluster of spots. Expressions which govern cathode mass loss are generally of the form

$$\dot{m}_V = C\,(M/T_s)^{1/2}\,I_s,$$

where $\dot{m}_V$ is the mass loss rate of cathode vapor, C is a constant, M is the molecular weight of the cathode materials, T_s is the spot temperature, and I_s is the current associated with the spot. For a given cathode material, the mass loss then varies inversely with the square root of temperature and directly with the spot current.

Region III

The solid-gas and vapor-gas interfaces shown in Figure 3-22 form the boundary between Regions I and II. Discharges along the I—III boundary most likely take the form of rapidly moving spots. At any given instant, these individual discharges present a microscale picture similar to the larger spot cluster sketched in Figure 3-22. For the operating conditions of present interest, the contributions of these microspots to the total mass loss rate will not be addressed.

The geometrical relationship between the cathode and anode not only affects the distribution of the electric field, but also the velocity field and resulting flow pressure. The gas flow provides convective cooling for the cathode surface and a source of neutral species for the ion production region of the arc just beyond the space charge layer. The flow field parameters and the cathode condition are coupled through the magnetic field which in turn results from locally high currents associated with the spot. The interaction between current density and magnetic field produces a pressure gradient given by $\Delta P = \bar{j} \times \bar{B}$, therefore, the flow field is coupled directly through the pressure to the local current density. For the same current density, a higher reservoir pressure should result in a higher vapor pressure, a smaller δ_s, and an increase in the local electric field intensity. If the total cathode current is held constant, the most probable outcome of the increase in pressure would be a reduction in spot area and an increase in spot temperature. Since the mass loss rate goes as $T^{-1/2}$, the mass loss from the cathode also decreases.

Modelling Approach

The approach taken was to model the cathode erosion using simple, physically consistent descriptions of processes coupling the three regions described in Figure 3-22. Much of the work completed focused on accurately coupling the discharge with the cathode interior (Regions I and II).

A two-dimensional, finite element heat transfer algorithm called TOPAZ 2D[3] was used with modifications made for the boundary conditions specific to the cathode problem. This program contains algorithms to model energy exchanges across phase boundaries. Table 3-7 lists the assumptions which were made to solve for the energy balance.

Table 3-7
MODEL ASSUMPTIONS

1. Energy Transfer Processes
   a. Ion collisions/neutralization at the cathode surface.
   b. Electron cooling by emission processes.
   c. Radiative and conductive heat transfer to or from the cathode surface.
   d. Energy loss due to sublimation/evaporation of the cathode surface.
2. Simplifying Assumptions
   a. The cathode surface discharge is thermionic.
   b. Cathode fall voltage is constant over the discharge surface.
   c. Total emitted current is constant.
   d. Ambient pressure is constant.
   e. The cathode mounting interface is assumed to remain at constant temperature.
   f. Reasonable magnitudes for the neutral gas and plasma parameters are assumed to establish radiative and convective boundary conditions for the cathode surfaces.

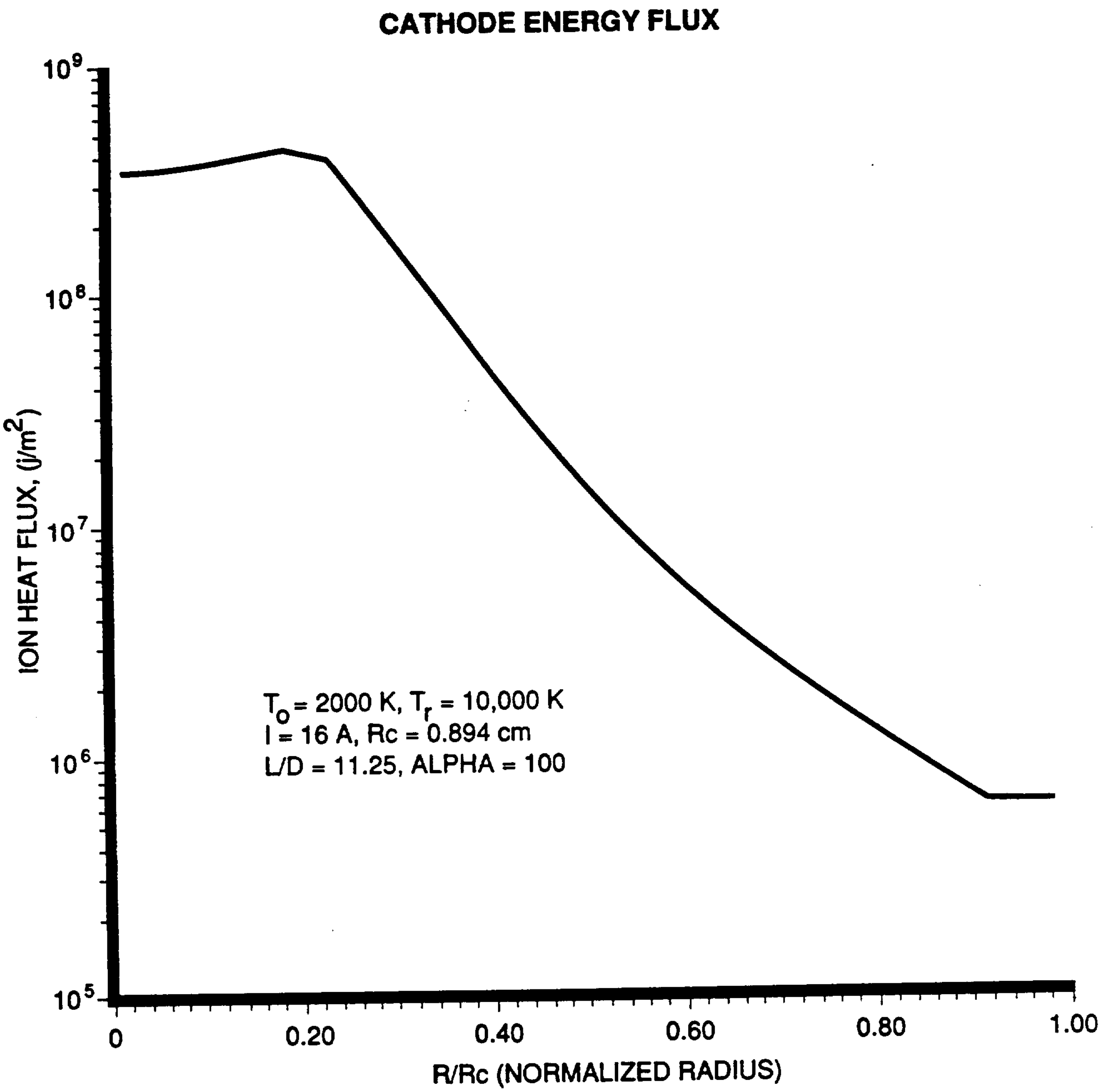
The heat flux to the surface elements due to ion-surface collisions was modelled as a function of surface temperature. Mass loss was also modelled as a function of local surface temperature. The resolution in the number of discrete elements used enabled cathode geometries identical to those tested to be modelled.

The numerical method is iterative and proceeds as follows:

1. A temperature distribution T (r, z) is assumed for the cathode.
2. The cathode fall and the ion current density are calculated as a function of the surface temperature subject to the constraint that the current remain constant.
3. The heat flux due to the discharge is determined and the heat conduction equation is solved with the appropriate boundary and initial conditions.
4. The solution to the problem posed in steps 1 through 3 is obtained, and the process is repeated if convergence is not satisfactory, i.e., the temperature distribution found in 3 replaces that in 1 and the procedure repeats.

Model Results/Conclusions

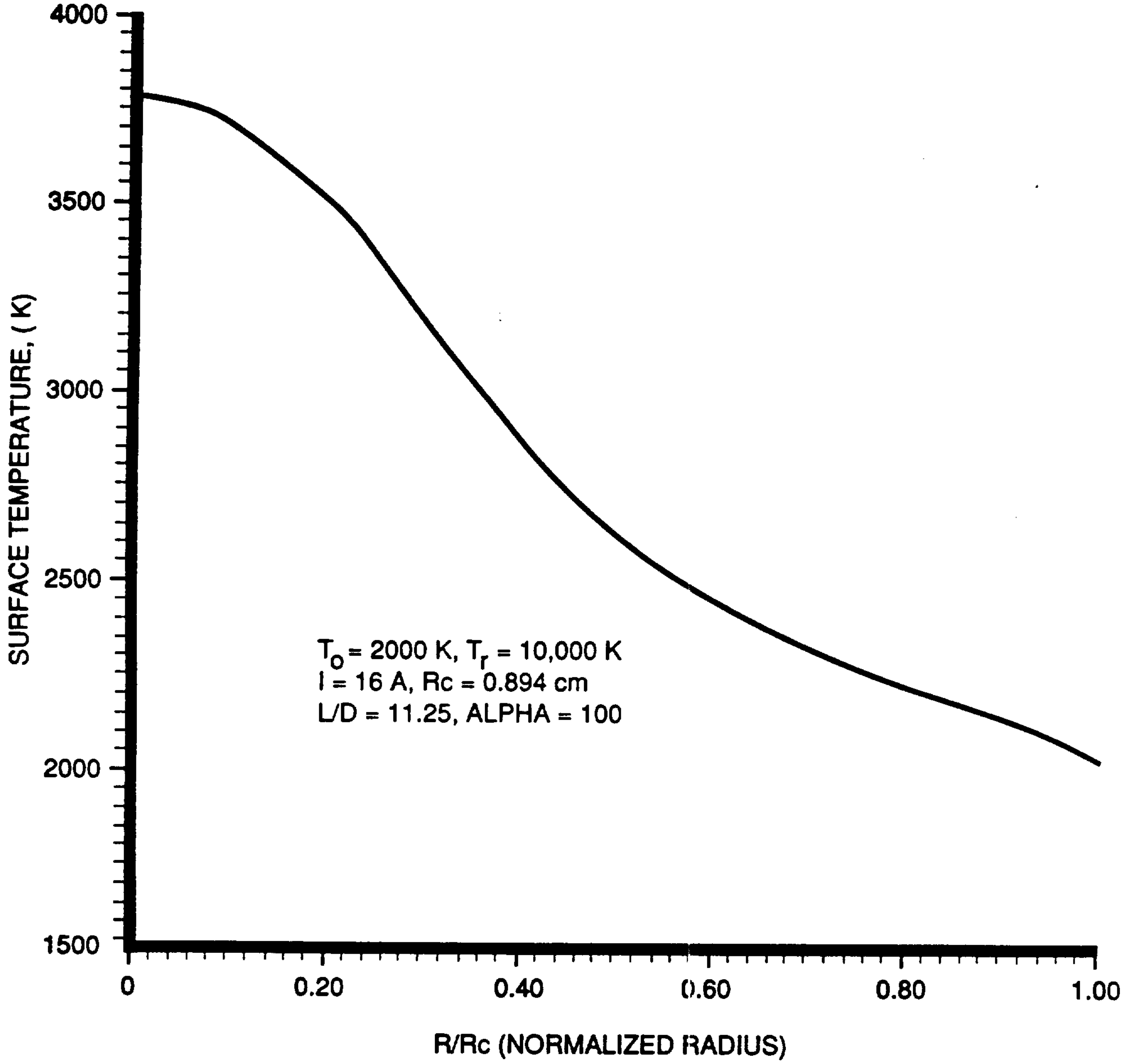
The model input for the same cathode geometry as the baseline design evaluated during life testing is shown in Table 3-8. Two dimensional solutions for this case are shown graphically in Figures 3-24 through 3-28.

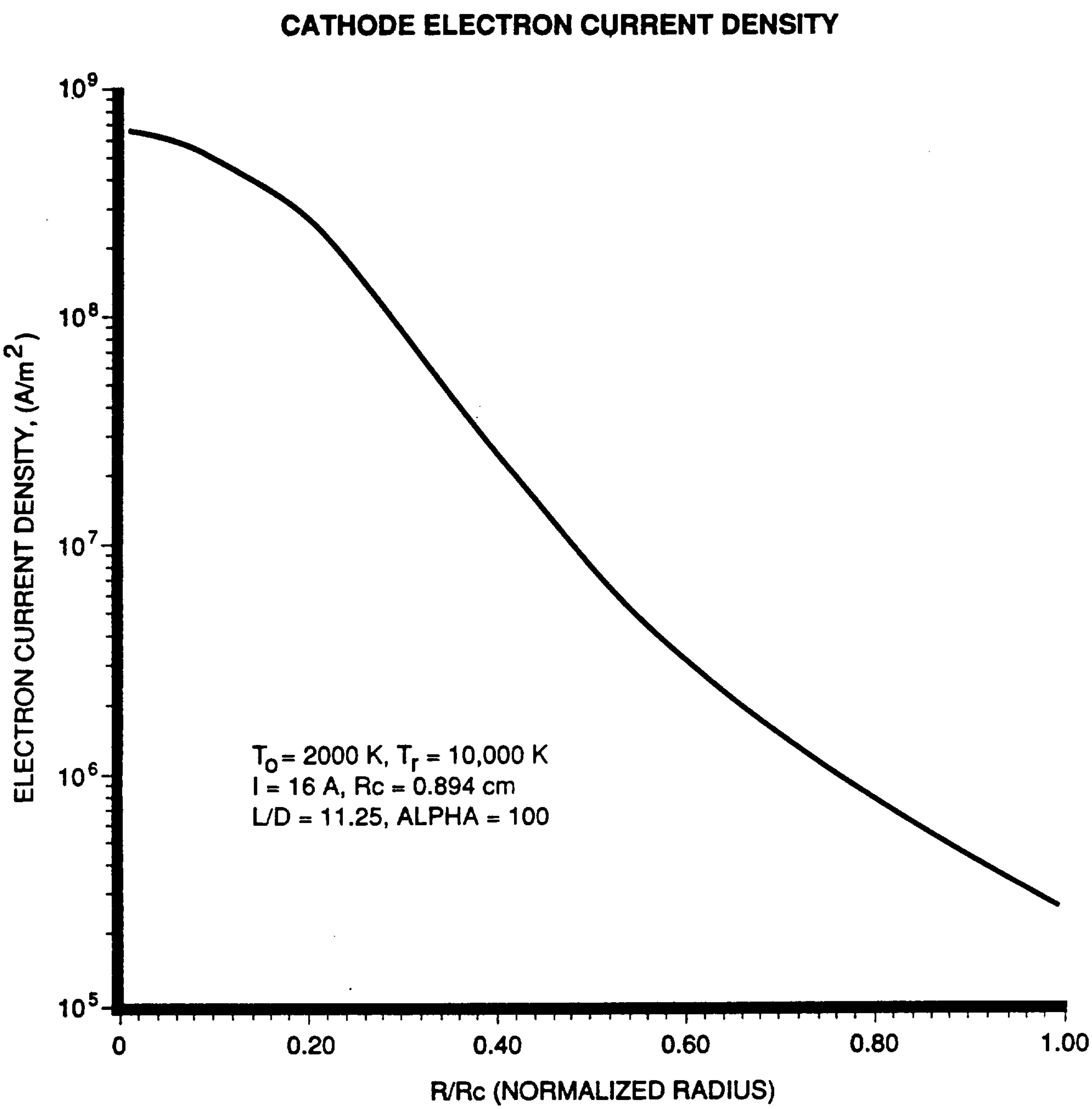


CATHODE ENERGY FLUX
ION HEAT FLUX, (j/m2)
10^9
10^8
10^7
10^6
10^5
T0 = 2000 K, Tr = 10,000 K
I = 16 A, Rc = 0.894 cm
L/D = 11.25, ALPHA = 100
0
0.20
0.40
0.60
0.80
1.00
R/Rc (NORMALIZED RADIUS)

Figure 3-24

CATHODE SURFACE TEMPERATURE





CATHODE ELECTRON CURRENT DENSITY
ELECTRON CURRENT DENSITY, (A/m2)
10^9
10^8
10^7
10^6
10^5
0
0.20
0.40
0.60
0.80
1.00
R/Rc (NORMALIZED RADIUS)
To = 2000 K, Tr = 10,000 K
I = 16 A, Rc = 0.894 cm
L/D = 11.25, ALPHA = 100

Figure 3-26

CATHODE ELECTRON CURRENT

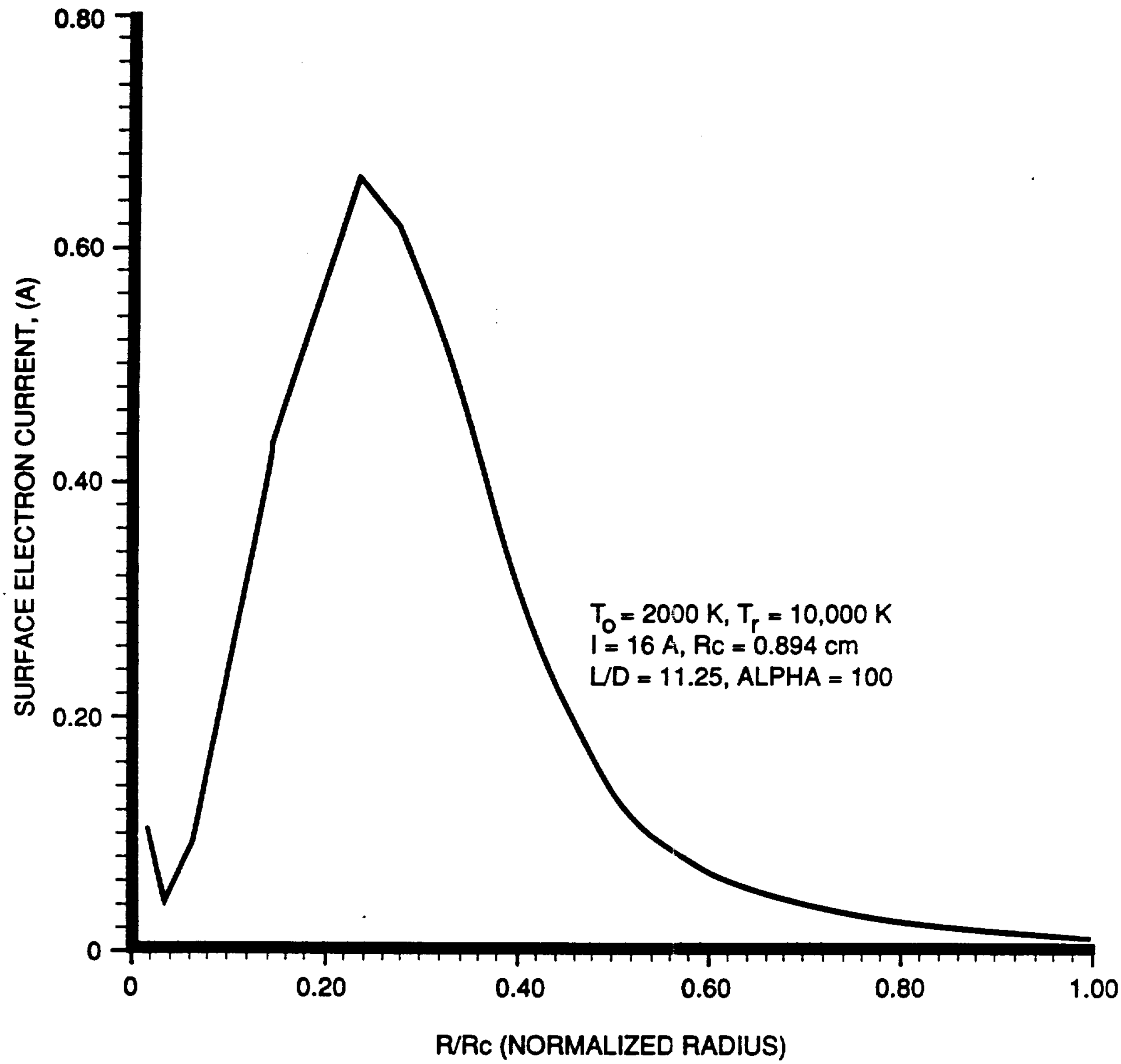
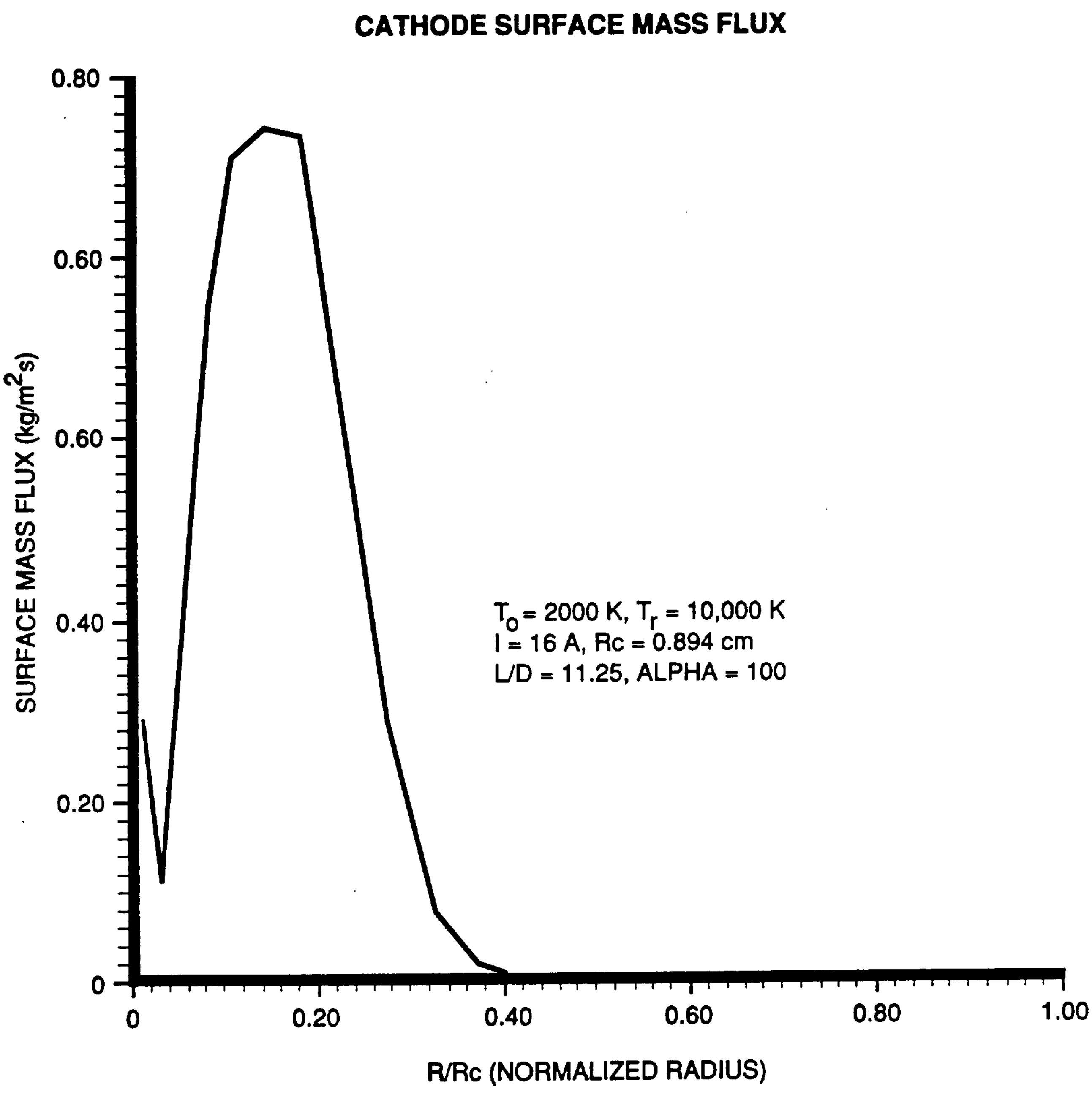


Figure 3-27



CATHODE SURFACE MASS FLUX
0.80
0.60
0.60
0.40
0.20
0
SURFACE MASS FLUX (kg/m2s)
T0 = 2000 K, Tr = 10,000 K
I = 16 A, Rc = 0.894 cm
L/D = 11.25, ALPHA = 100
0
0.20
0.40
0.60
0.80
1.00
R/Rc (NORMALIZED RADIUS)

 Figure 3-28

Table 3-8
CATHODE MODEL INPUT, BASELINE GEOMETRY

	Parameter	Input
1.	Cathode Material	2% Thoriated Tungsten
2.	Cathode Tip Angle	100 degrees
3.	Cathode Diameter	0.178 cm (0.070 in.)
4.	Current	16 amps
5.	Cathode Side/End Wall Temperature	2000 K
6.	Radiation Field Temperature	10,000 K

Figure 3-24 shows the surface energy flux due to ion neutralization, electron emission, and cathode mass loss. The flattening of the profile near the cathode center is a direct result of the cathode mass loss. The predicted cathode temperature and electron current density for thermionic emission only are shown in Figures 3-25 and 3-26. Peak temperatures of 3700°K and current densities on the order of 10^8 amp/m^2 are predicted.

Figures 3-27 and 3-28 show the current and mass loss rate as a function of normalized cathode radius. Although peak magnitudes and the integrated total current and erosion rate agree reasonably well with RRC experiments discussed previously, the trends shown near the cathode centerline still lack refinement. This is a numerical shortcoming which results from treating each surface element as a separate and independent source of current. Future efforts should focus on a better estimate of the integrated surface behavior.

Figure 3-29 shows a comparison between the model predictions and the cathode life test results for the cathode diameter variation. Good agreement in trend was achieved. The differences in absolute magnitudes shown by the model output are sensitive to assumptions made in establishing the boundary conditions, particularly the cathode interface temperature. Accurate measurement of this boundary condition would improve the model's accuracy.

Two additional areas of model development are recommended to improve the predictive capabilities of this model. First, a more accurate description of the cathode near field is required. For example, estimates of the cathode fall parameters (e.g., the electric field, space charge, and ion and electron current densities) and the physics governing the ion production zone are needed to correctly predict the heat flux to the cathode surface. The latter would require modelling the interaction of the local flow field with the discharge.

Second, a nonsteady solution could be obtained which incorporates the time dependence of the cathode boundary conditions and realistic operating constraints. In principle, this calculation could predict the location of the solid-liquid phase boundary and for sufficiently long times, would give a more accurate estimate of cathode mass loss.

CATHODE MODEL MASS LOSS COMPARISON

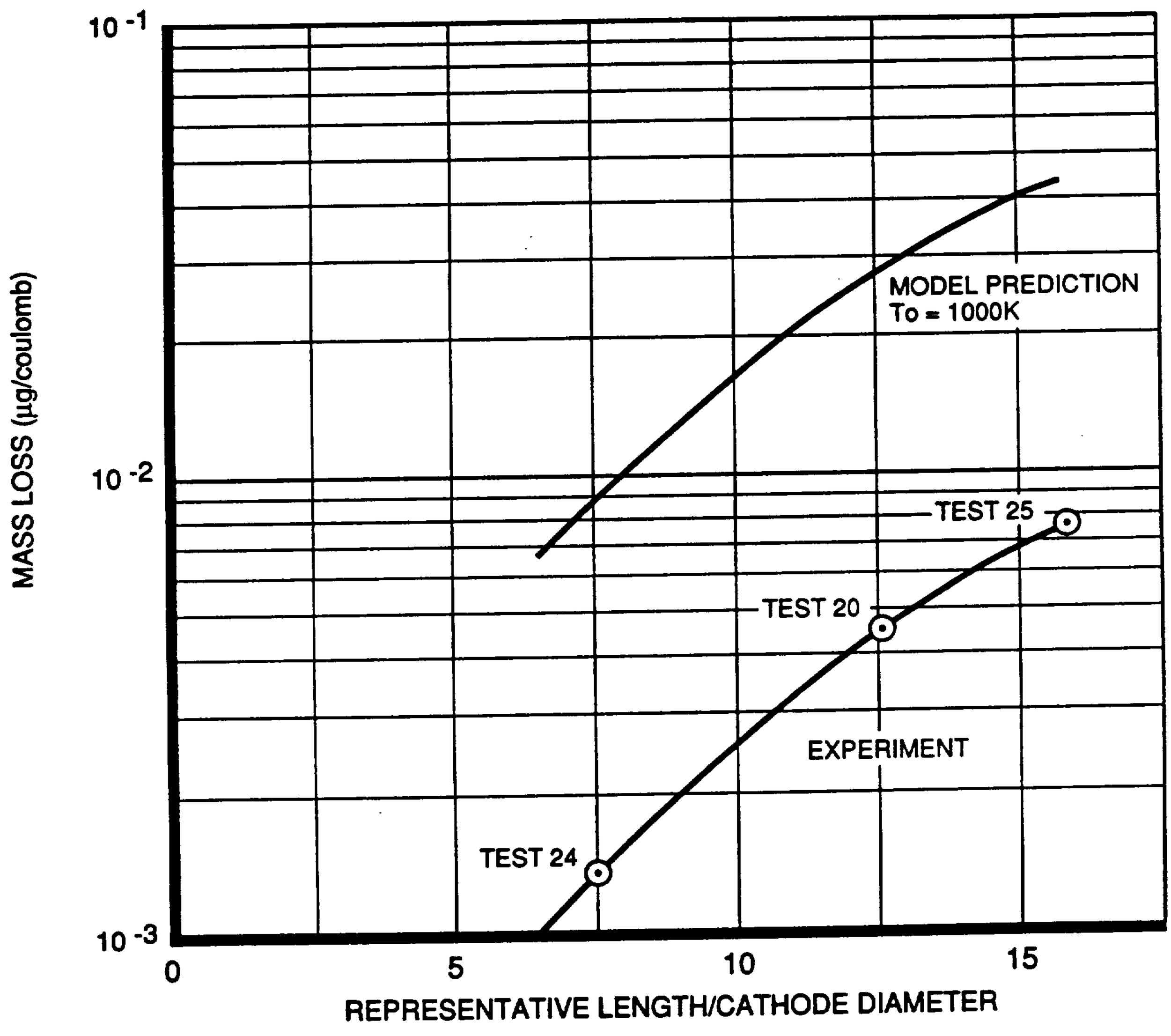


Figure 3-29

3.2.5 PCU Requirements Definition

Development of the power control unit (PCU) was continued during Phase II of this program. This work used as a basis the efforts conducted at NASA. (4) The PCU must start the arcjet, which requires 2000 to 4000 vdc, then transition to the steady state operating conditions of nominally 100 vdc and 15 A. A critical investigation conducted under this program in support of PCU design development was to characterize the arc as an electrical load. These data are important to ensuring that the control loop stability is adequate for the negative impedance arc. The following sections describe these characterization efforts.

3.2.5.1 Arc Stability Requirements

Figure 3-30 shows the DC voltage/current load characteristic of the arc which must be accommodated by the supply. The negative slope of the curve results from a lower arc resistance at higher DC currents due to increased levels of ionization. Superimposed on this load line, however, are two dynamic effects of interest whose characteristics are frequency dependent.

The first is the stochastic variation of arc voltage due to movement of the arc caused by gas dynamic and surface effects. This effect is of interest because of the potential EMI which can be generated on the arcjet power leads and conducted back into the PCU. Conducted EMI tests were performed per the requirements of tests CE01 and CE03 of MIL-STD 461B and 462. Measurements were made for two different thruster configurations operated over ranges of current and flow rate anticipated for flight.

The second dynamic feature of the arc is its response to a varying input current signal. To characterize this effect, complex impedance measurements were made over a frequency range of 50 Hz to 1 MHz. Again, two thruster geometries were evaluated and current and flow rate were varied.

The results from these tests are discussed in the following sections.

3.2.5.2 Arcjet Conducted EMI Test

The objective of this testing was to measure the conducted EMI generated by a low power arcjet operating on N_2H_4 propellant. The arcjet was mounted in a vacuum chamber and the test set up as shown in Figure 3-31. The current probes were clamped around the power line to the cathode of the arcjet since this line carries all the current, while the anode line, which in this system is the return line, is also grounded through the fuel line giving it more than one return path.

The arcjet was allowed to warm up and stabilize before scans were performed. After the operating parameters of the arcjet were changed, it was allowed to stabilize for about five minutes before the next data were taken.

DC/DYNAMIC ARCJET CHARACTERISTICS

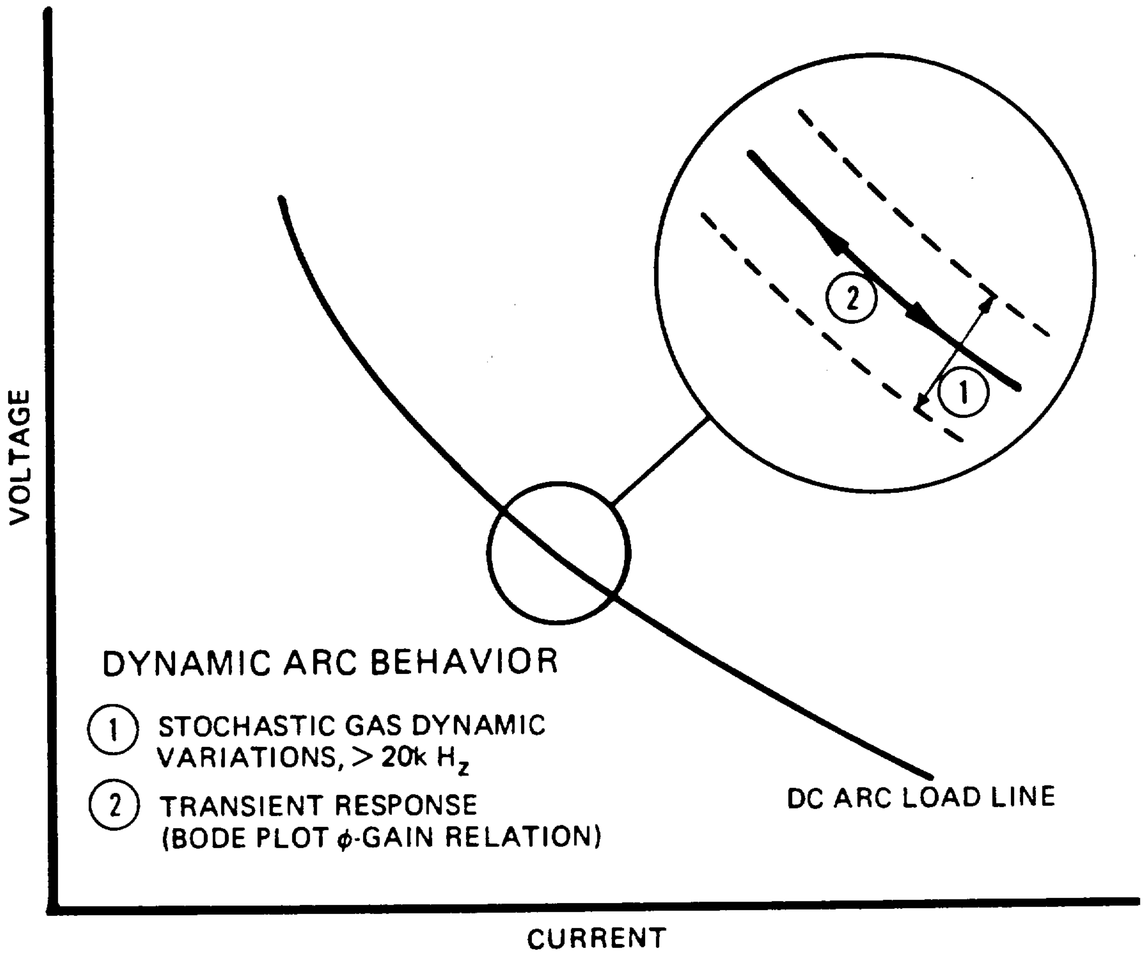
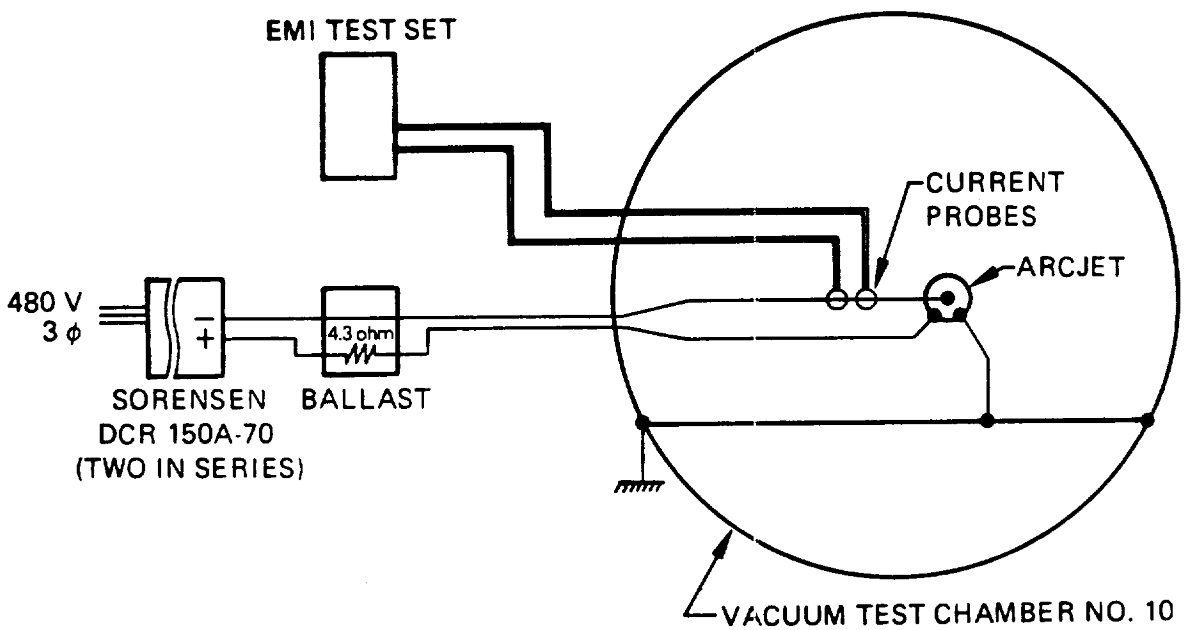


Figure 3-30

ARCJET EMI TEST SETUP



An Eaton Ailtech Series VII EMI Data Collection System was used to measure the emissions. The system is controlled by an HP 9836 computer. This system includes a CCI-7 controller Counter Interface Unit, and three receivers covering the range of frequencies from 20 Hz to 1 GHz.

The computer software controls all receiver functions, such as bandwidth, attenuation, frequency band, sweep speed, antenna port selection, and calibration. It also collects the data and corrects it for antenna factors or probe correction factors, broadband correction, and attenuation. The corrected data are displayed as a plot on the monitor, and are also directed to a graphics printer.

The CE01 test measures conducted emissions from 20 Hz to 15 kHz. The test is performed only with narrowband measurements since broadband measurements are eliminated by MIL-STD-461B. The Empire CP-315 current probe is clamped onto the cathode line, and a scan is taken with the smallest bandwidth that can reasonably be used.

The limit levels set are 130 dBuA from 30 Hz to 2 kHz and logarithmically decrease to 86 dBuA at 15 kHz.

The CE03 test measures emissions from 15 kHz to 50 MHz. Both broadband and narrowband emissions are measured with their own respective limit levels. The test setup specifications require the use of 10-microfarad feedthrough capacitors on the input power lines. These could not be used in this setup due to difficulties induced in starting and running the arcjet. A Singer 94106-1 current probe is clamped around the cathode line.

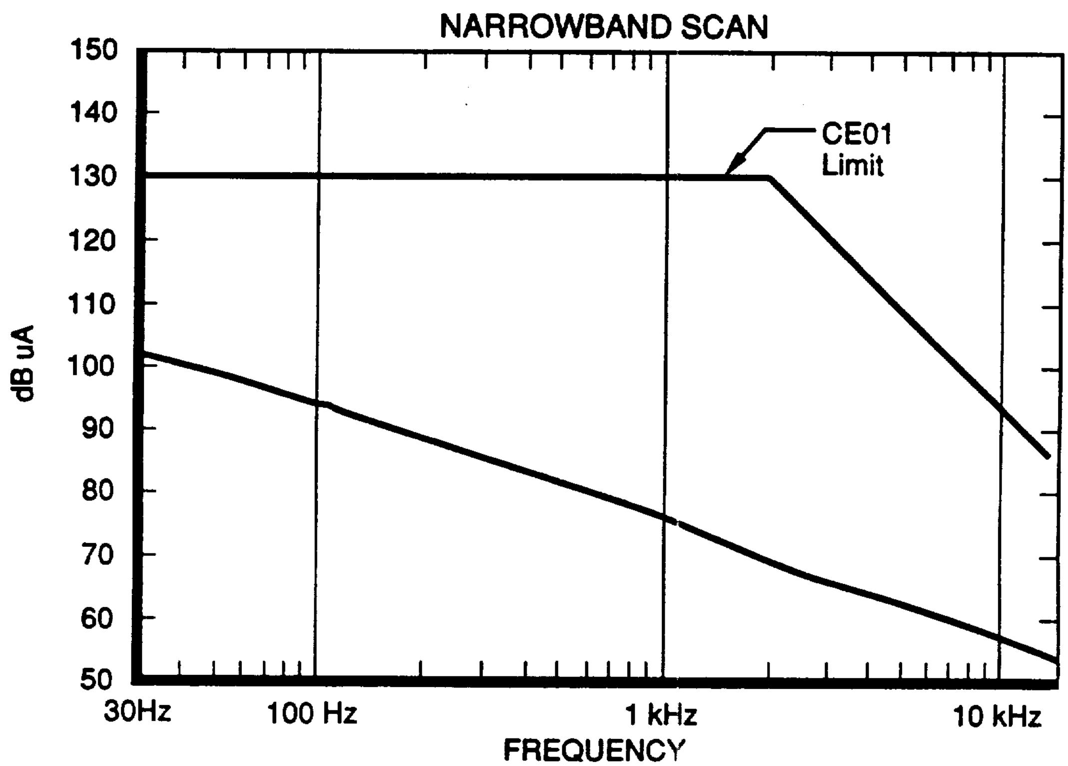
The limits for broadband emissions start at 15 kHz at 130 dBuA/MHz and logarithmically decrease to 50 dBuA/MHz at 2 MHz and remain at 50 dBuA/MHz up to 50 MHz. The narrowband limits start at 15 kHz at 86 dBuA and logarithmically decrease to a level of 20 dBuA at 2 MHz and remain at 20 dBuA up to 50 MHz.

Ambient conducted EMI scans were made with the power supply turned on and the arcjet not operating. Figures 3-32 and 3-33 show the results. A comparison of these figures with subsequent scans shows that the background noise is well below the conducted EMI measured with the arcjet operating.

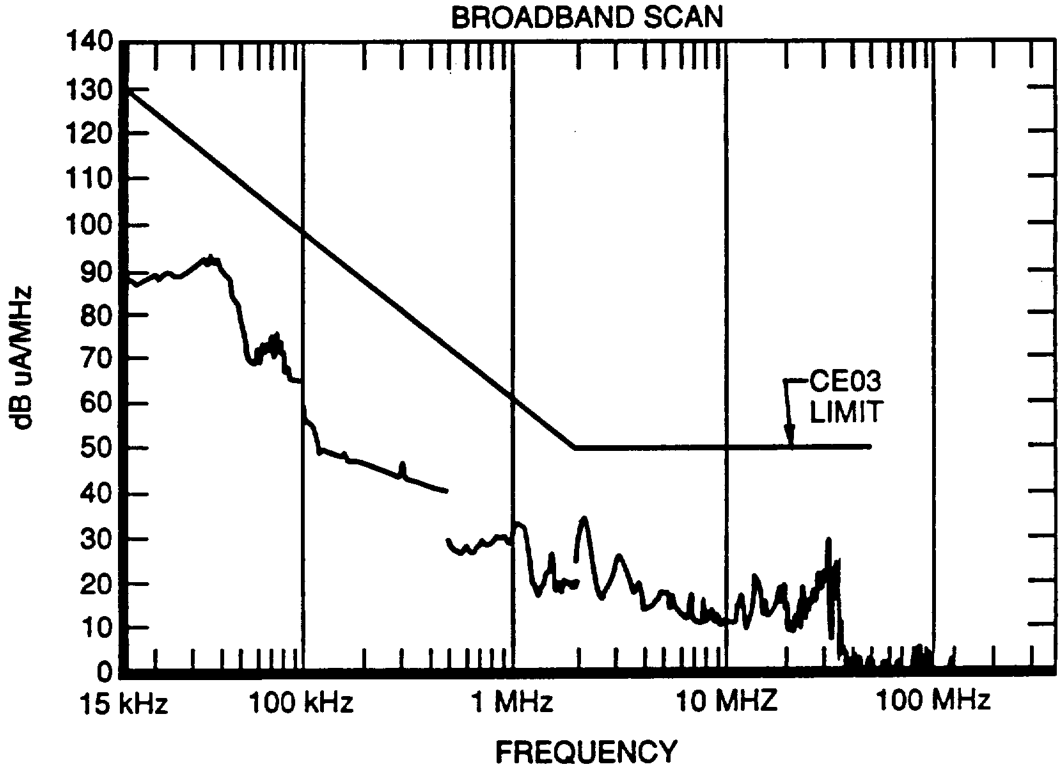
Two thrusters were tested at three fuel flow rates of 3.6×10^{-5}, 4.5×10^{-5}, and 5.5×10^{-5} kg/s, and at three DC current levels of 12.0, 16.0, and 20.0 amperes, for a total of nine operating points each.

S/N 30 had a 0.076 cm (0.030 in.) diameter, 0.076 cm (0.030 in.) long constrictor, and S/N 31 had a 0.076 cm (0.030 in.) diameter, "zero" length constrictor. The gap for each was set at 0.038 cm. All other features were identical.

CE01 AMBIENT TEST



CE03 AMBIENT TEST



Figures 3-34 to 3-36 show a typical data set. These figures are for thruster S/N 30 operating at 16.0 A and 4.5 x 10^{-5} kg/s fuel flow. Figure 3-34 is the narrowband graph to 15 kHz. Figure 3-35 is the broadband graph from 15 kHz to 400 MHz, and Figure 3-36 is the narrowband graph from 15 kHz to 400 MHz.

The dominating emission observed on all scans was in the 500 kHz to 10 MHz area. The noise is broadband in nature.

The emissions did not vary significantly from thruster to thruster or with the operating point. The levels start to drop off rapidly above 20 MHz. These measurements provided design guidelines in two areas. First, the data were used to help perform design trades on the arcjet power cable configuration to control radiated EMI. Second, the conducted emissions levels were considered as part of the PCU EMI design approach

3.2.5.3 Arcjet Impedance Mapping Tests

The objective of this testing was to characterize the small signal load impedance of a low power arcjet operating on N_2H_4 fuel. Chamber 10 was set up as shown in Figures 3-37 and 3-38. The HP 3577A network analyzer's output was amplified by the Krohn-Hite 7500 power amplifier, and used to modulate the arcjet's DC operating current. Voltage and current measurements were made at the test chamber passthroughs, and fed into the network analyzer's "A" and "R" inputs, respectively.

Prior to testing, a 1.0 ohm film resistor was installed in place of the arcjet. Measurements of current, voltage, and impedance were taken and the data stored in the network analyzer's memory. Subsequent impedance and admittance data were normalized with respect to this resistor to eliminate the effects of cable inductance, and voltage and current measurement errors. The reference resistor was installed again prior to testing the second arcjet, and also at the completion of this test series to verify measurement integrity.

The current probe was checked to verify that the DC current level did not effect the AC signal measurements. This was done with the power cables disconnected at the test chamber bulkhead, and terminated with the 1.0 ohm reference resistor. In addition to the power cable, 20 turns of wire were placed through the current probe window. A 4.0-ohm resistor and a 0 to 5 vdc power supply were placed in a series with the twenty turns. Voltage, current, and impedance measurements were made with 0, +20, and -20-amp turns. It was shown that there was no dependence of the AC signal on the DC current.

Two arcjets were tested. The configurations were identical except for the constrictor. Serial number 34 had a 0.076 cm (0.030-in.) diameter by 0.076 cm (0.030-in.) long throat, while serial number 35 had the same diameter throat but was a "zero" length design. The cathode, injector, and gap spacing were the same for each. The general procedure was to make the measurements listed below at each operating point for frequencies from 50 Hz to 1 MHz:

1. Voltage and current without a signal supplied. This provides a reference for the noise level in subsequent signal measurements. Both the voltage and current signal magnitudes are plotted directly, and are not normalized.

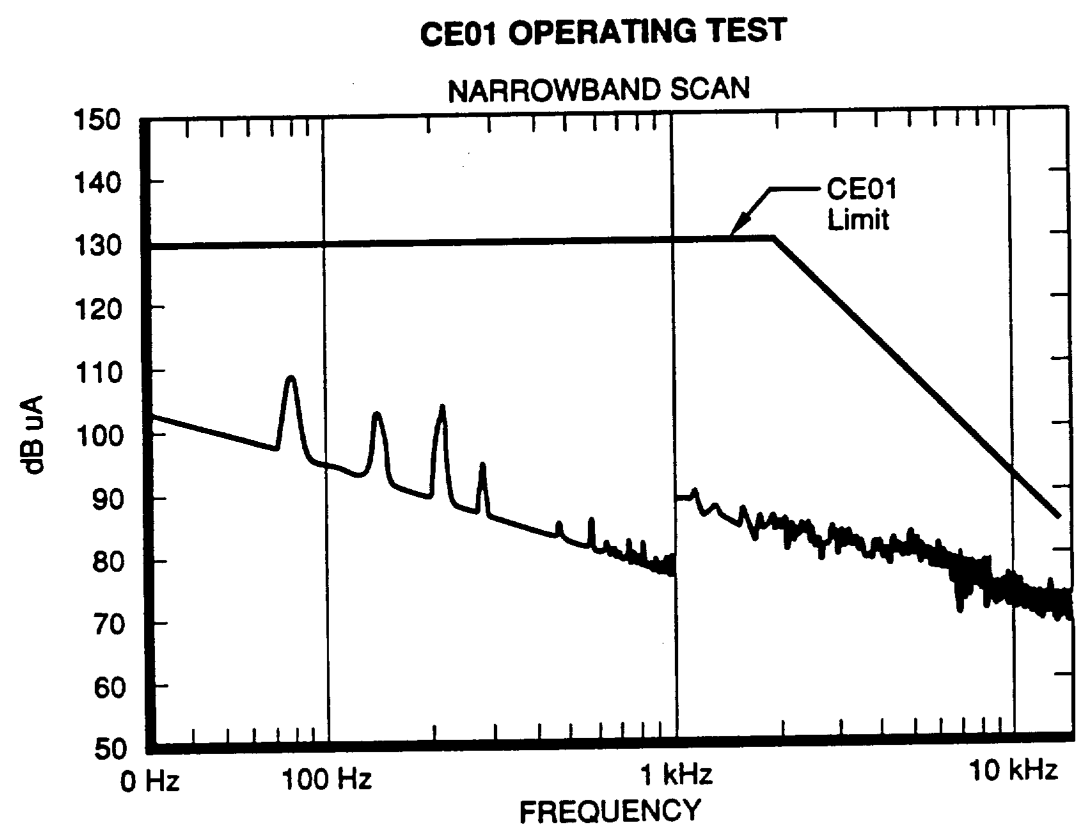
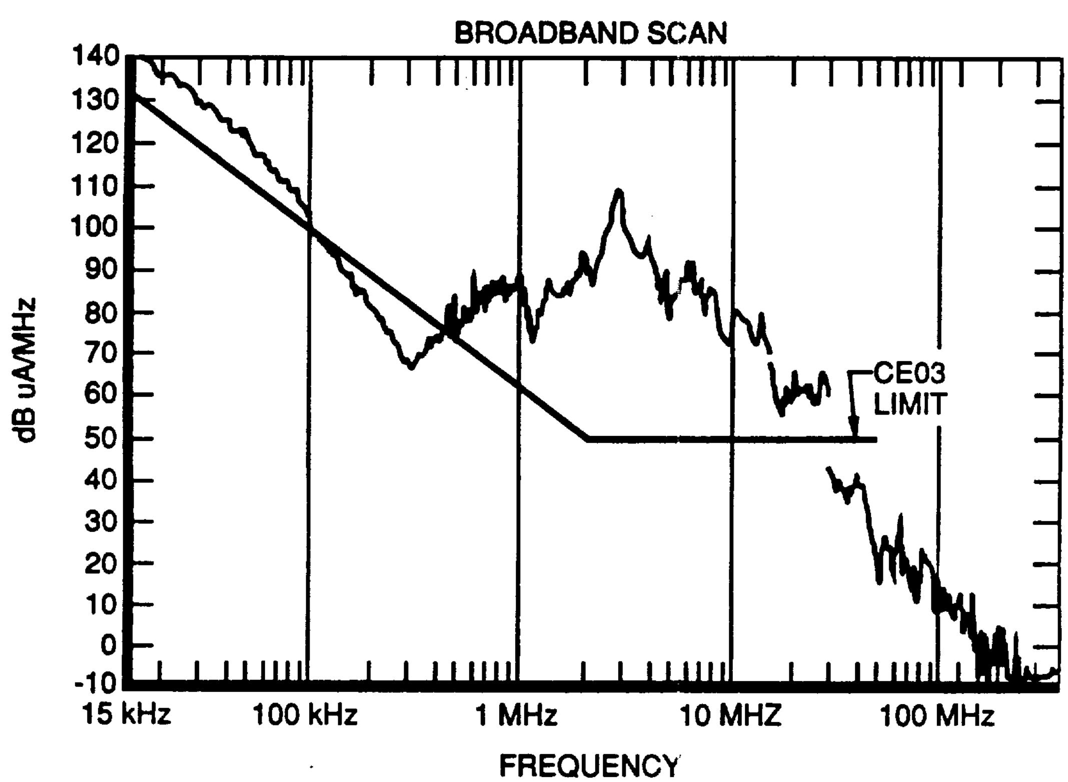
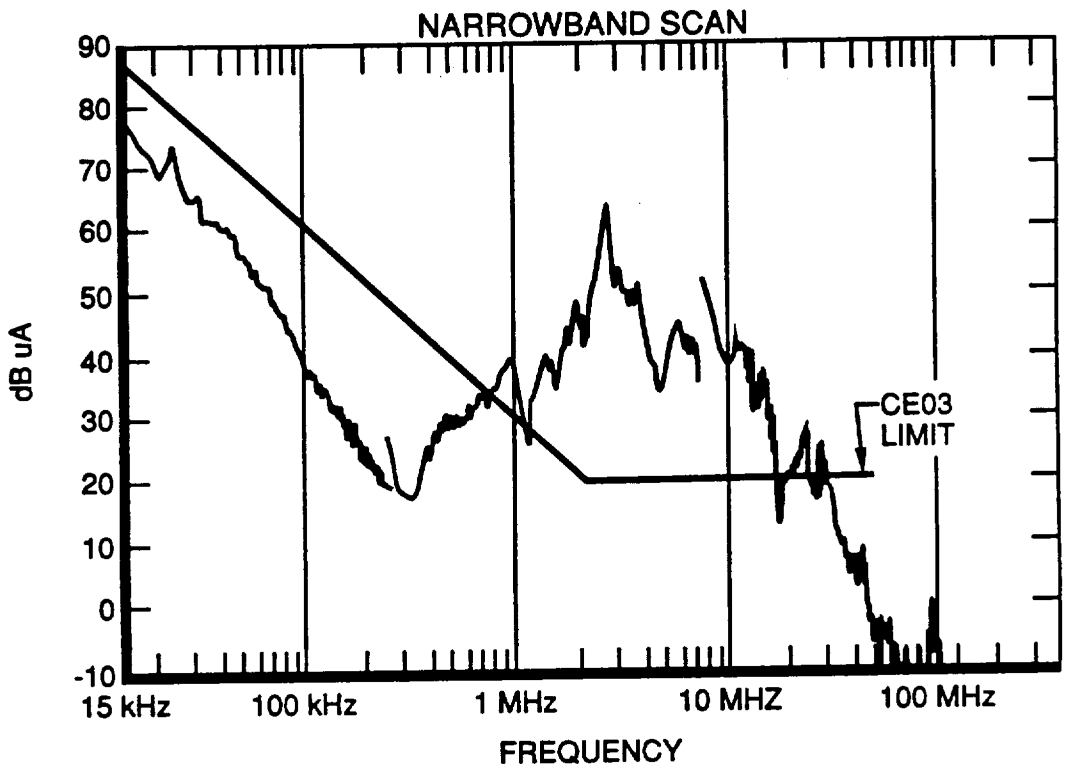

CE01 OPERATING TEST
NARROWBAND SCAN
150
140
130
120
110
100
90
80
70
60
50
dB uA
CE01
Limit
0 Hz
100 Hz
1 kHz
10 kHz
FREQUENCY

Figure 3-34

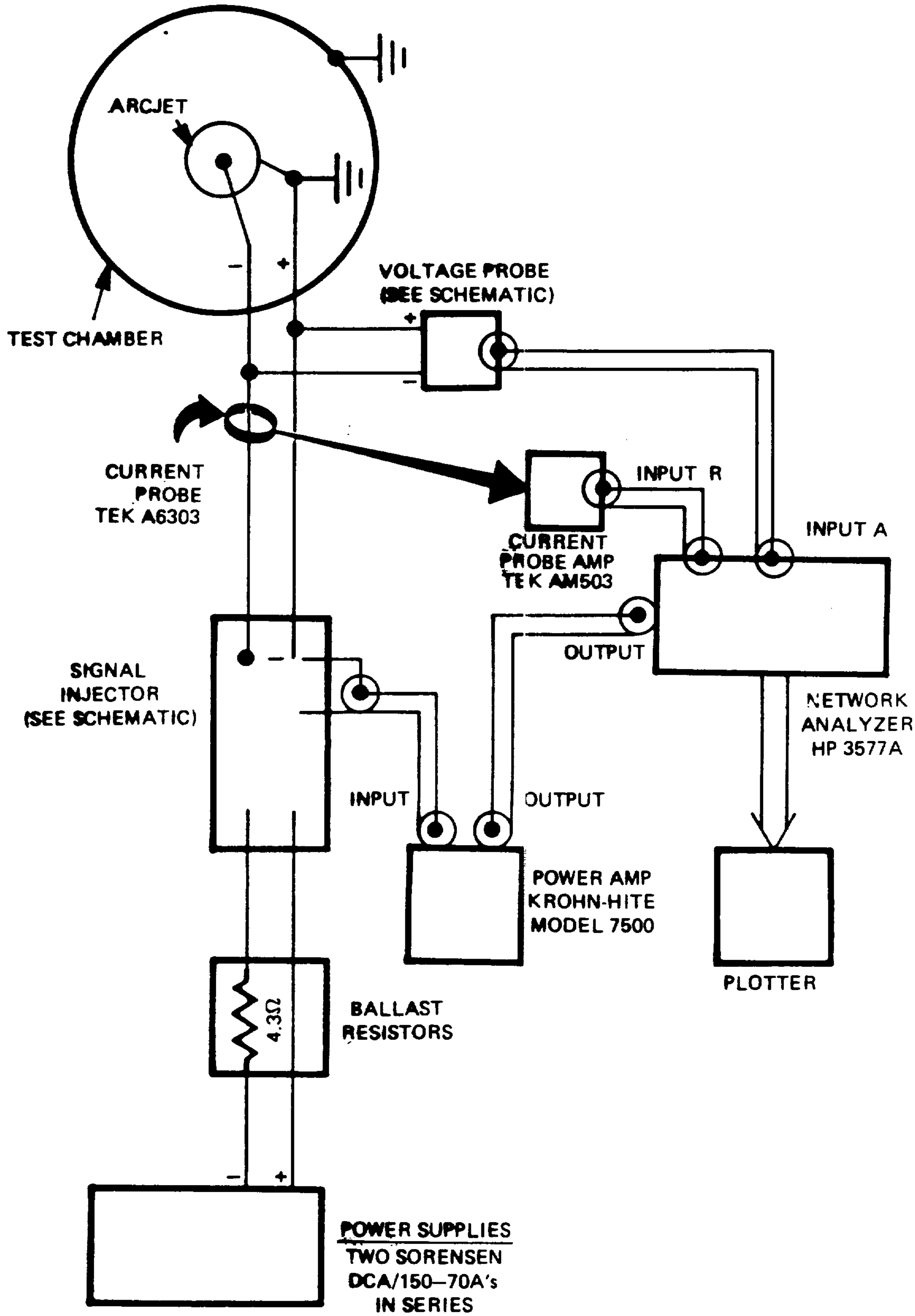
CE03 OPERATING TEST



CE03 OPERATING TEST

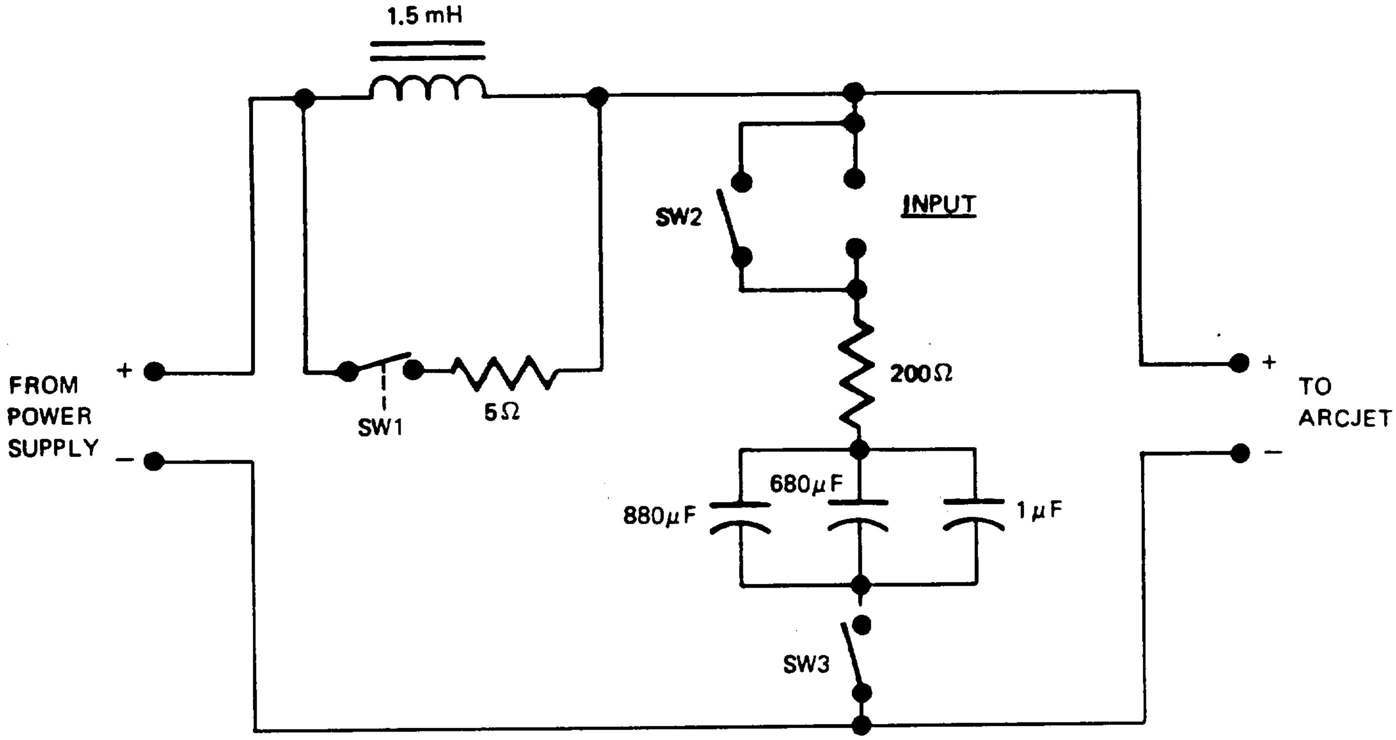


IMPEDANCE MAPPING
TEST EQUIPMENT CONFIGURATION

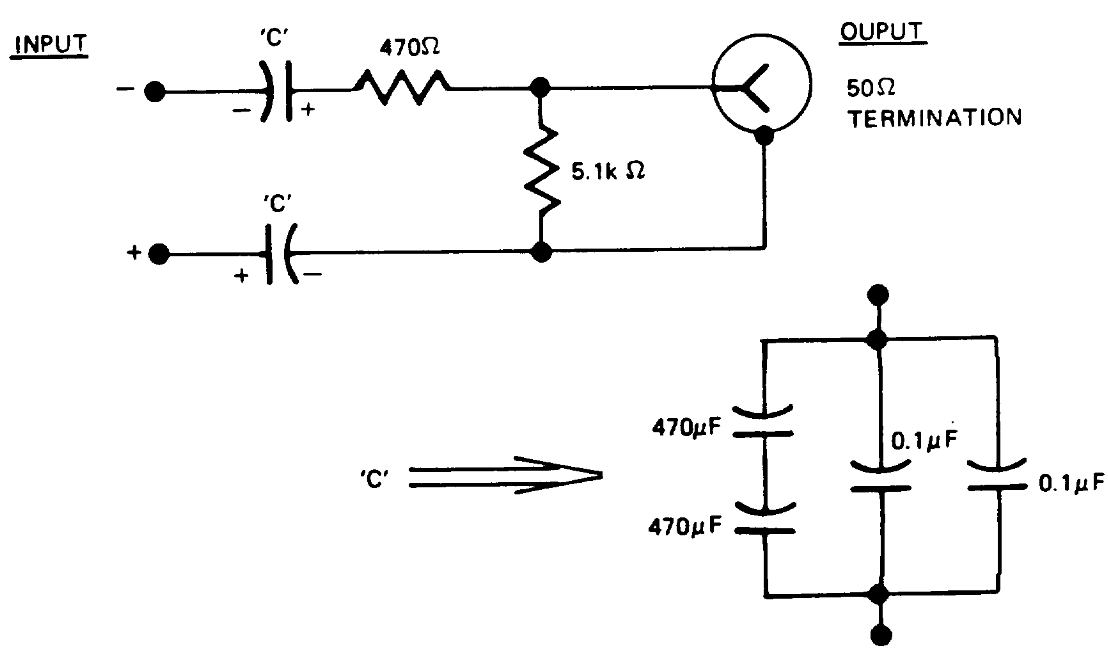


IMPEDANCE MAPPING TEST SETUP

SIGNAL INJECTOR SCHEMATIC



VOLTAGE PROBE SCHEMATIC



2. Same as 1, but the signal applied. This shows the raw data used to generate impedance and admittance plots.
3. Normalized impedance — magnitude and phase.
4. Normalized impedance — real and imaginary parts.
5. Normalized admittance — real and imaginary parts.

Each thruster was tested at three fuel flow rates of 3.6×10^{-5}, 4.5×10^{-5}, and 5.5×10^{-5} kg/s and at three DC current levels of 12.0, 16.0, and 20.0 amperes for a total of nine operating points each.

Figures 3-39 to 3-42 show a typical data set. The data are for thruster S/N 34 operating at 16.0 amperes and 4.5×10^{-5} kg/s.

Figure 3-39 is a plot of the magnitudes of the AC voltage and current signal without the small-signal input. This represents the background noise level.

Figure 3-40 is also a plot of the magnitudes of the voltage and current signals, but with a 100 mA rms AC signal injected on top of the DC arcjet current. A comparison of Figures 3-39 and 3-40 shows the small AC signal is significantly above the ambient noise level.

Figure 3-41 is a normalized magnitude and phase plot of the arcjet impedance. The HP 3577A network analyzer generates this plot by dividing the voltage signal input by the current signal input. Figure 3-42 is a real and imaginary plot of the normalized arcjet impedance.

Both of the impedance plots give the same information. The two different representations are included to aid in the interpretation of the data. Each of the plots of Figures 3-39 to 3-42 at the same operating point were generated with a fresh data scan which accounts for any minor discrepancies between the plots.

Figures 3-43 and 3-44 show impedance data for thruster S/N 34 at two different operating points. Figure 3-45 can be compared with Figure 3-42 to see the differences between the two configurations at the same operating point. In general, the main features of the impedances measured are relatively constant.

The variations in the apparent noise seen on some of the plots is due to differences in the way the network analyzer's controls were set. The voltage and current signal receiver bandwidths and the sinusoidal frequency scan rate were changed from 10 to 1 Hz, and from 30 to 60 seconds/plot, respectively, as the test progressed.

The matrices of Figures 3-46 to 3-49 summarize the key features and trends of the measured arcjet impedances.

Figures 3-46 and 3-47 show the impedance magnitudes for thrusters S/N 34 and 35, respectively. There are three features to note. First, the average normalized impedance for both thrusters is approximately 1.0 ohm, and it varies ±50%. Second, the impedance

BACKGROUND NOISE MEASUREMENTS

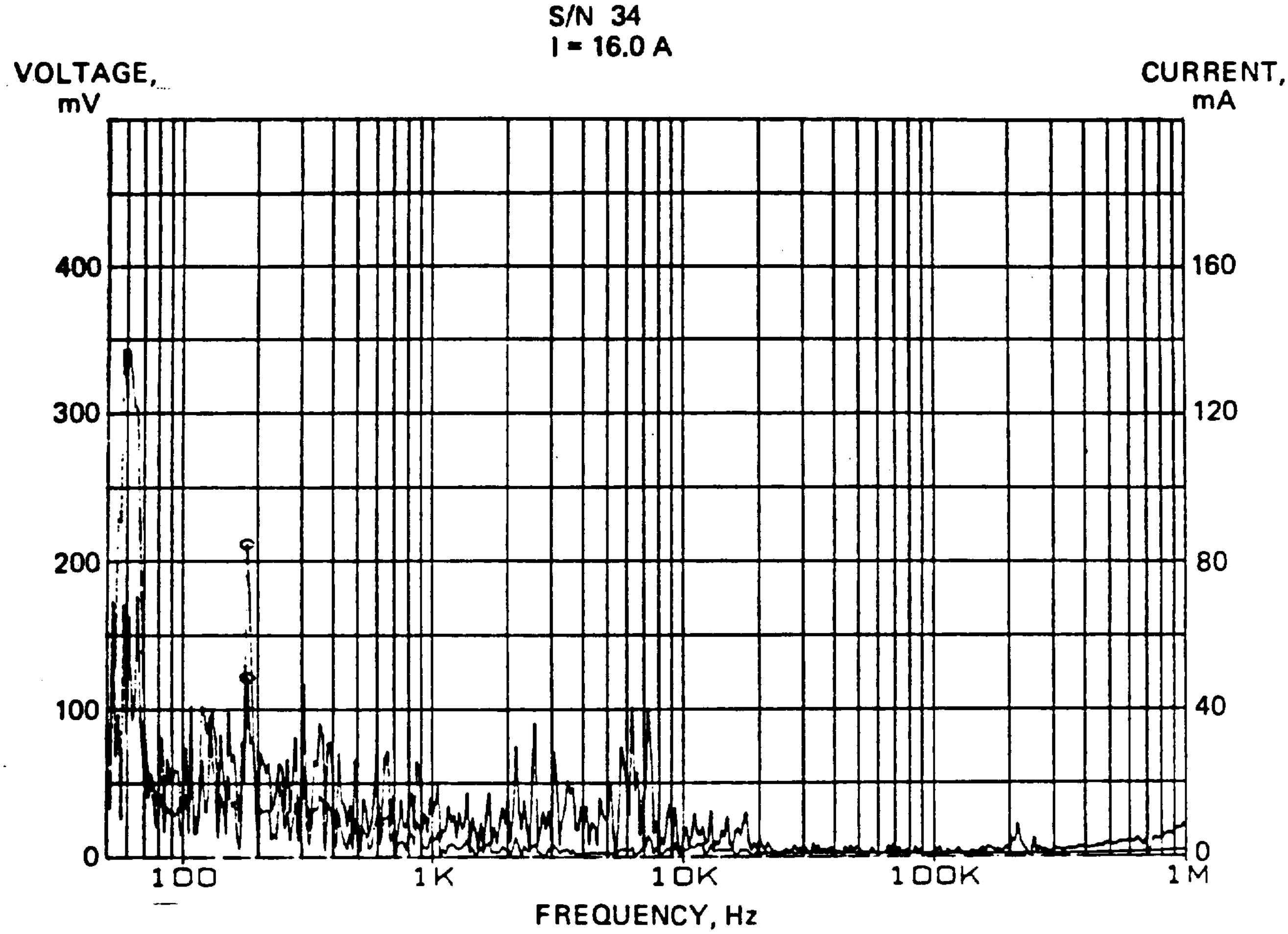
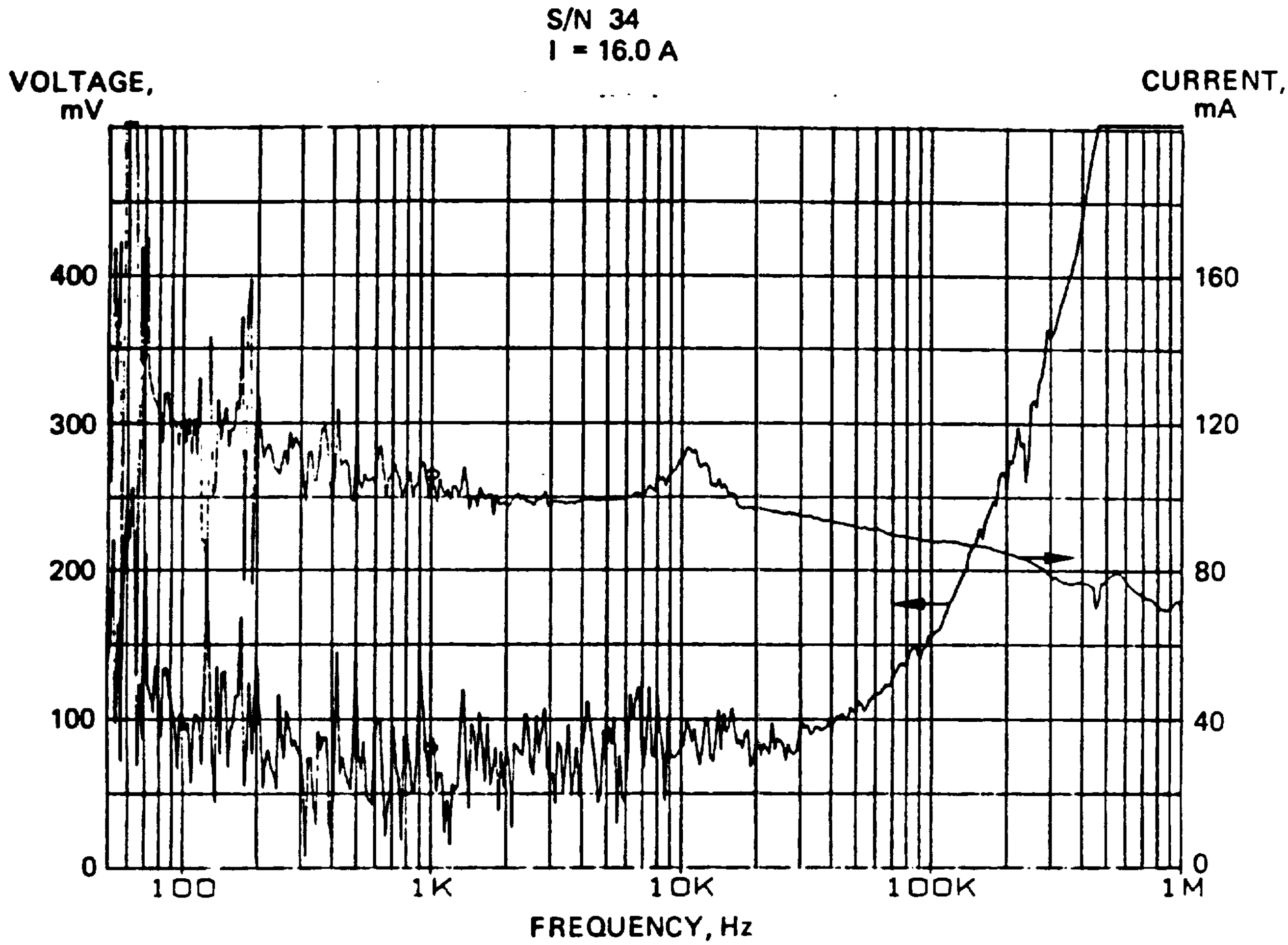


Figure 3-39


S/N 34
I = 16.0 A
VOLTAGE, mV
CURRENT, mA
0
100
200
300
400
0
40
80
120
160
100
1K
10K
100K
1M
FREQUENCY, Hz

NORMALIZED IMPEDANCE

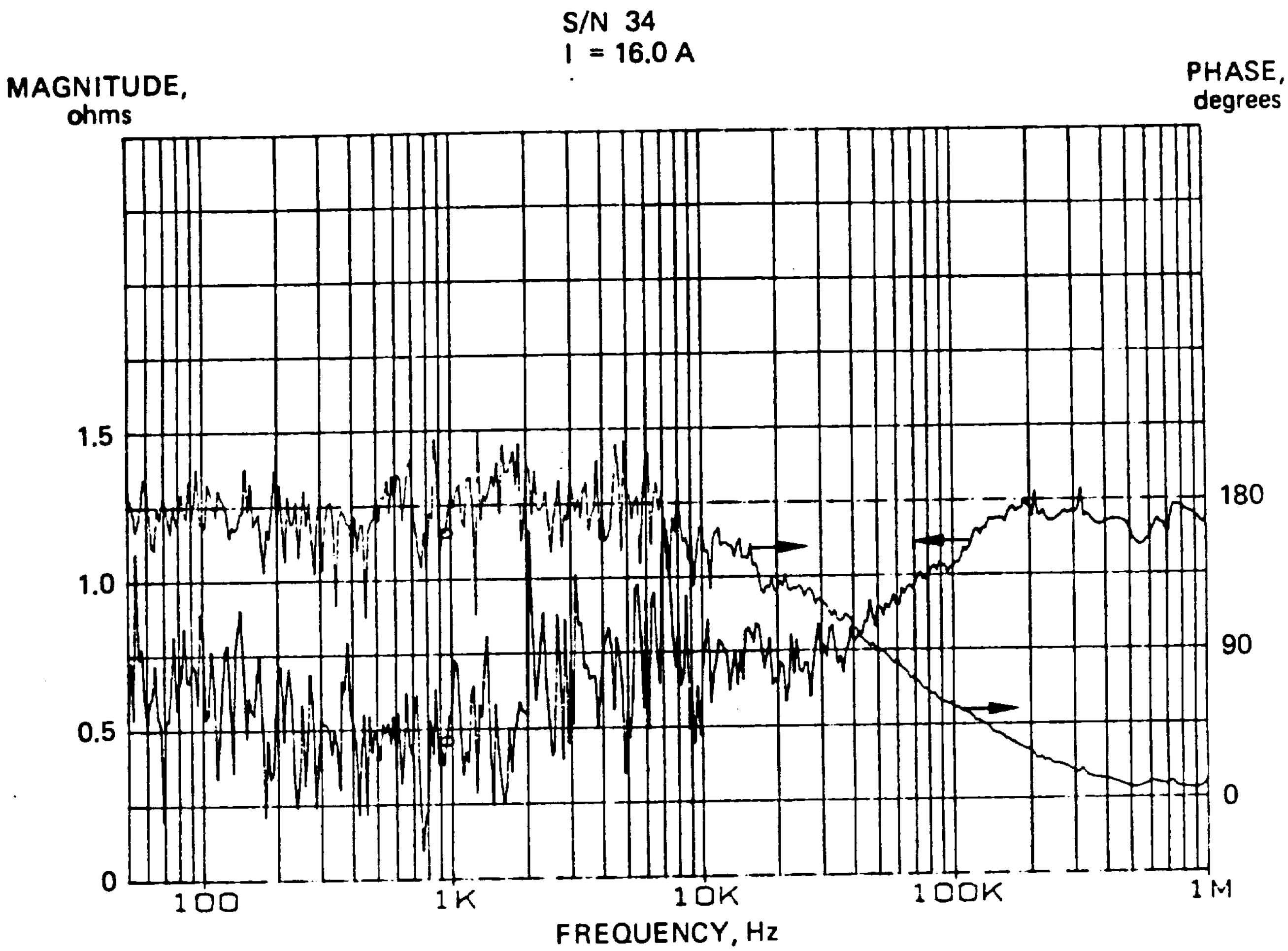
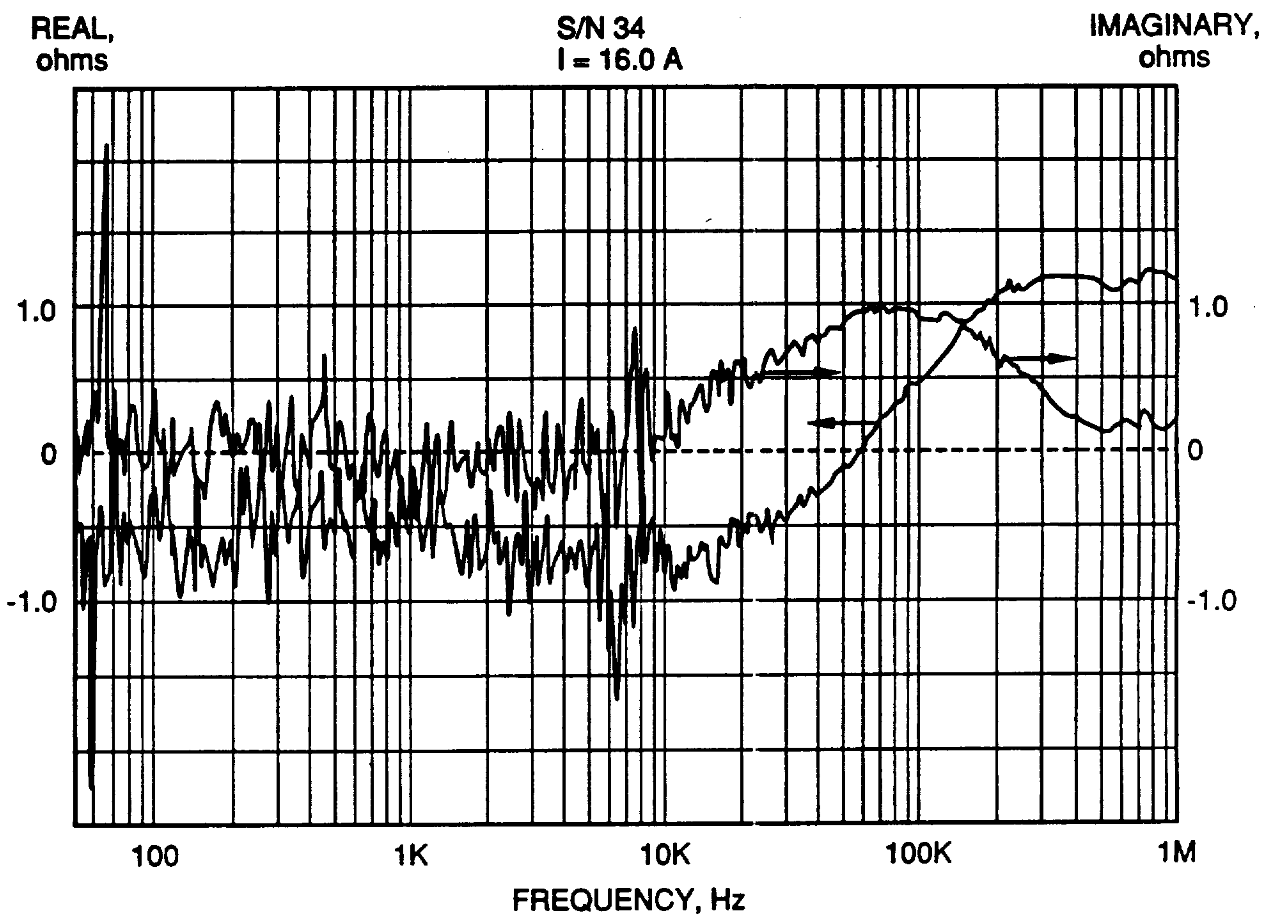
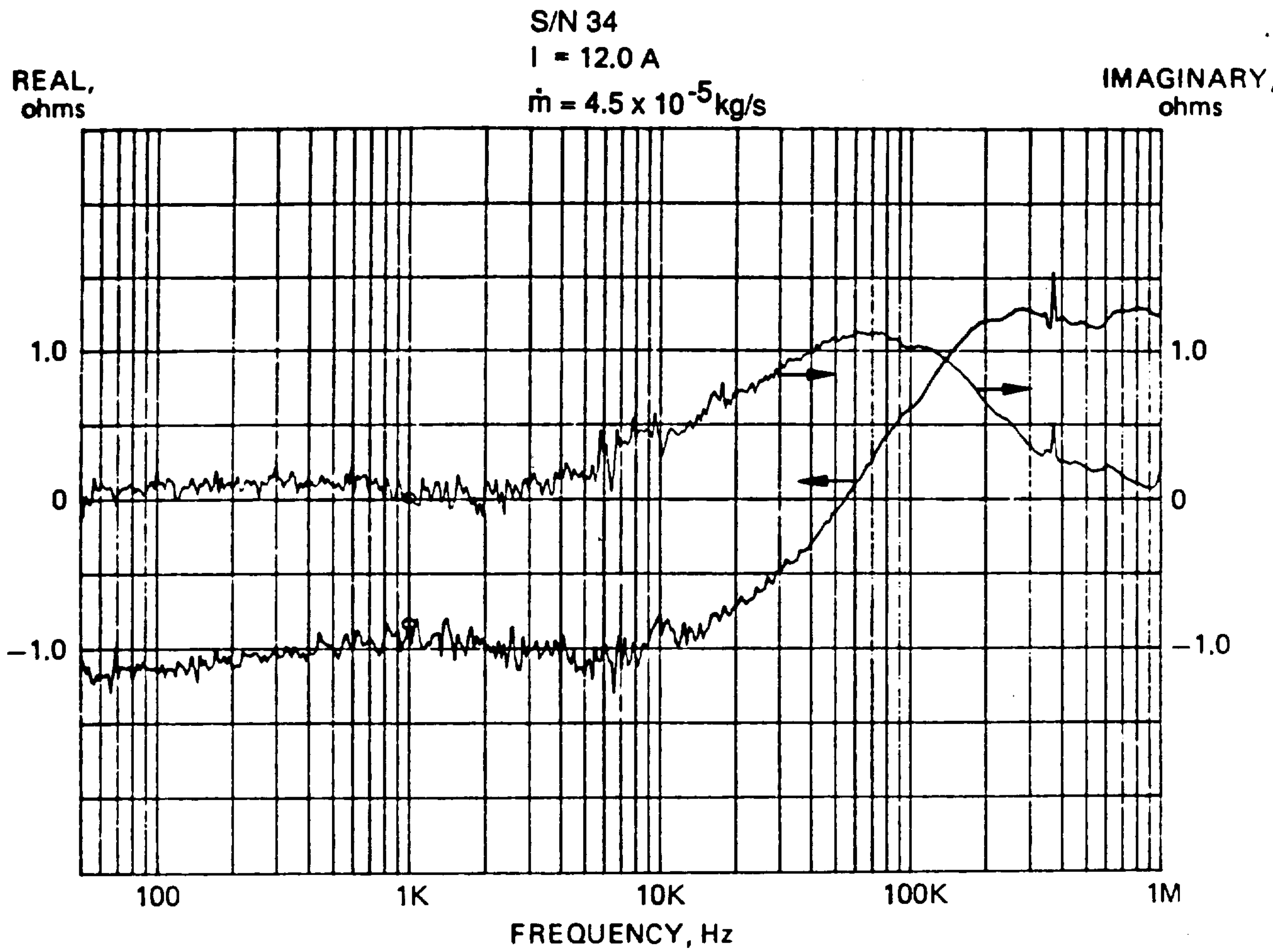


Figure 3-41

NORMALIZED IMPEDANCE



ARCJET STEADY-STATE COMPLEX IMPEDANCE



- TRANSITIONS FROM NEGATIVE TO POSITIVE IMPEDANCE AT ~ 60 kHz.

NORMALIZED IMPEDANCE

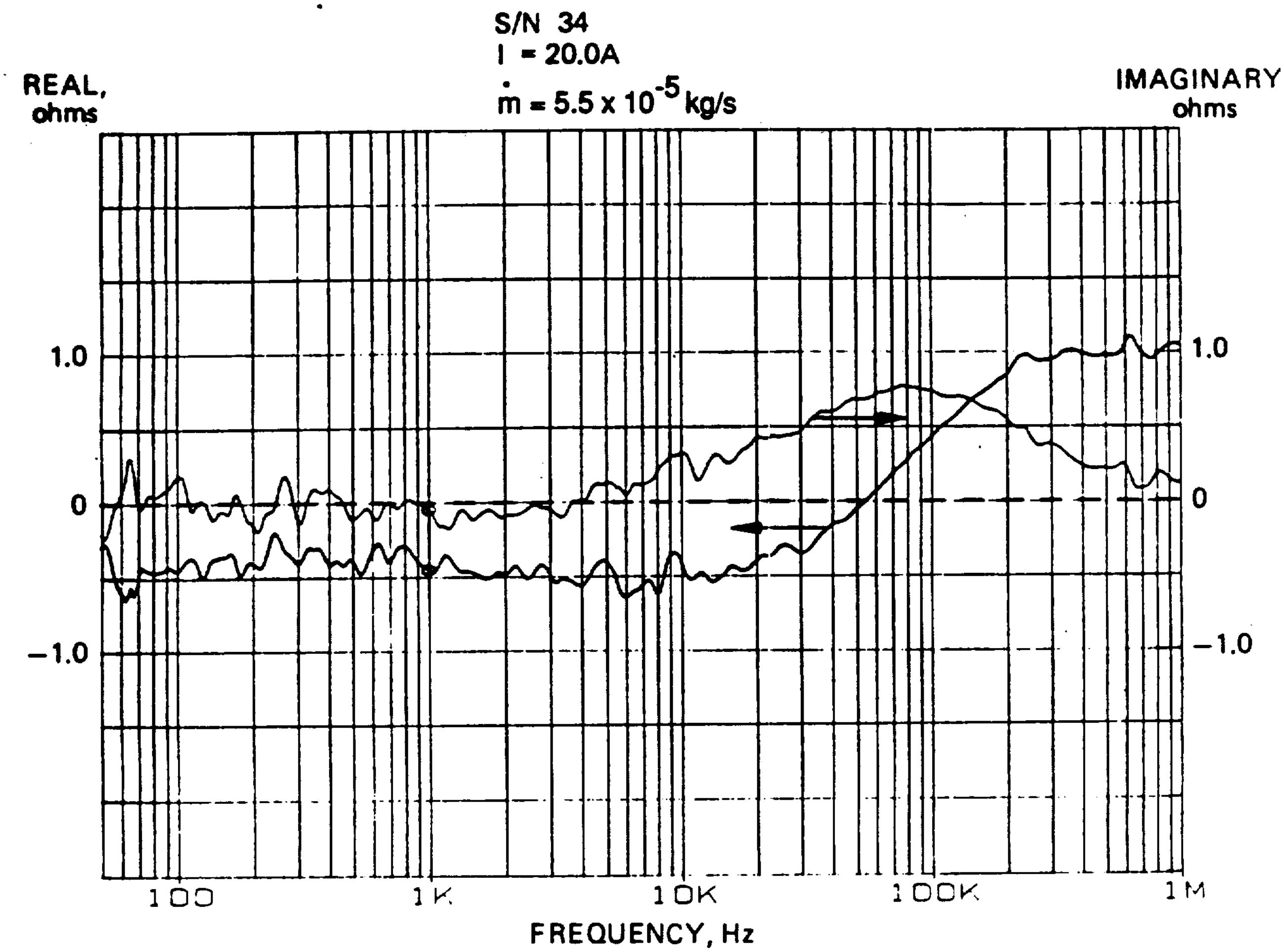


Figure 3-44

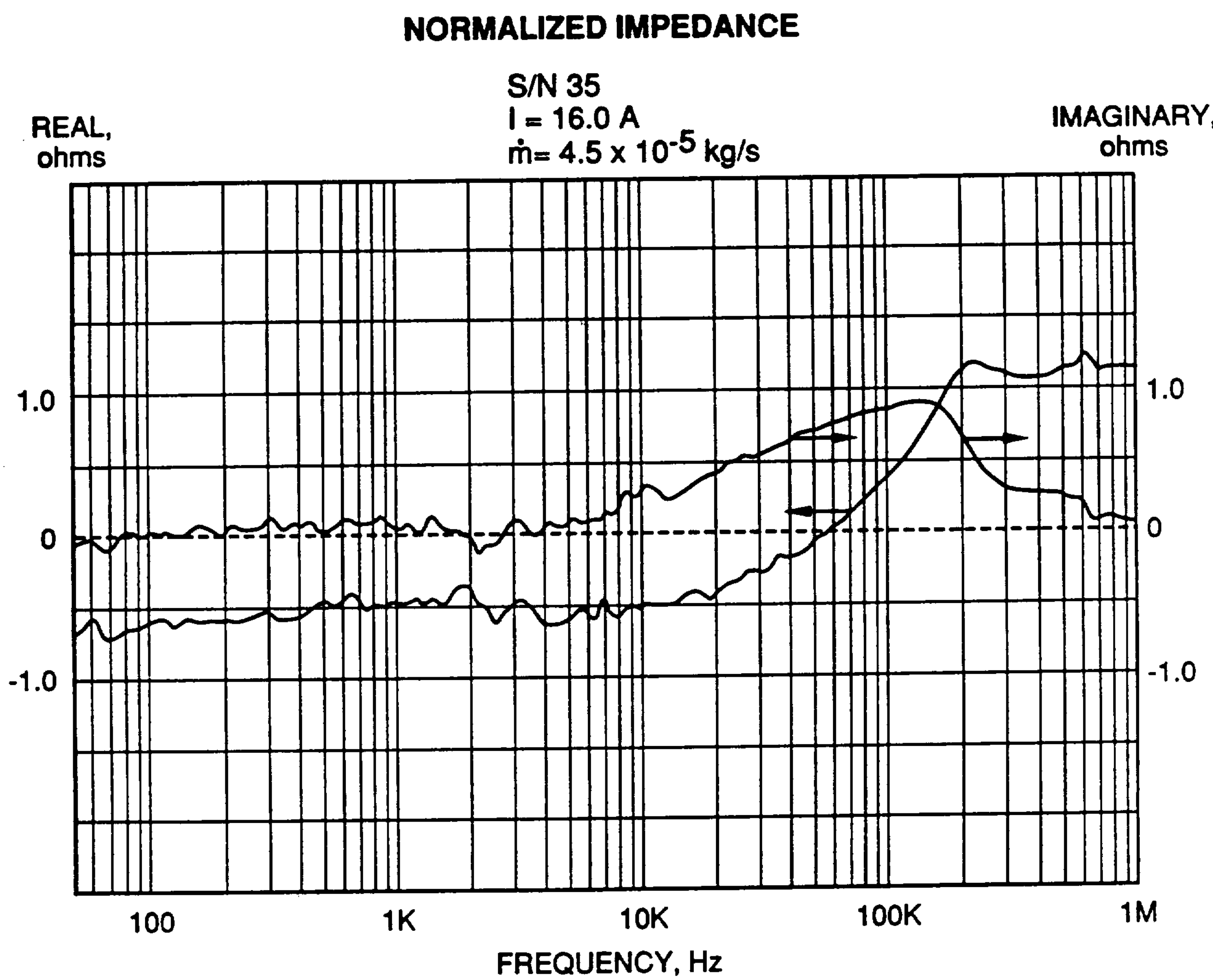

NORMALIZED IMPEDANCE
S/N 35
I = 16.0 A
ṁ= 4.5 x 10-5 kg/s
REAL, ohms
IMAGINARY, ohms
1.0
0
-1.0
1.0
0
-1.0
100
1K
10K
100K
1M
FREQUENCY, Hz

 Figure 3-45

IMPEDANCE MAGNITUDE AT 1 kHz, ohms
ARCJET S/N 34

FUEL FLOW RATE, x 10^{-5} kg/s \ CURRENT, amperes	12.0	16.0	20.0	AVG
5.5	1.0	0.85	0.43	0.76
4.5	0.91	0.46	0.55	0.64
3.6	--	1.4	1.2	1.3
AVG	0.96	0.90	0.73	0.85

11194-91A

Figure 3-46

IMPEDANCE MAGNITUDE AT 1 kHz, ohms
ARCJET S/N 35

FUEL FLOW RATE, x 10^{-5} kg/s \ CURRENT, amperes	12.0	16.0	20.0	AVG
5.5	1.6	0.8	0.3	0.9
4.5	1.2	0.5	0.4	0.7
3.6	1.5	0.75	0.5	0.9
AVG	1.4	0.7	0.4	0.84

11194-92A

Figure 3-47

FREQUENCY OF NEGATIVE REAL IMPEDANCE, kHz
ARCJET S/N 34

FUEL FLOW RATE, x 10^{-5} kg/s	CURRENT, amperes 12.0	16.0	20.0	AVG
5.5	75	68	58	67
4.5	59	50	49	53
3.6	—	50	50	50
AVG	67	56	52	57

11194-89A

Figure 3-48

FREQUENCY OF NEGATIVE REAL IMPEDANCE, kHz
ARCJET S/N 35

FUEL FLOW RATE, x 10^{-5} kg/s	CURRENT, amperes 12.0	16.0	20.0	AVG
5.5	80	62	50	64
4.5	75	52	78	68
3.6	75	58	55	63
AVG	77	57	61	65

11194-90A

Figure 3-49

magnitude decreases as the DC current level increases. This is consistent with the known DC load line slope characteristic. Third, there does not appear to be a direct correlation between fuel flow rate and impedance magnitude.

Figures 3-48 and 3-49 show the frequency at which the real part of the impedance becomes positive for S/N's 34 and 35. Three statements can be made about this data. First, the average frequency at which the real impedance becomes positive is approximately 62 kHz, and the variation is ±5 kHz. Second, the frequency tends to increase as the DC current level decreases. Third, there does not appear to be a direct correlation with the fuel flow rate.

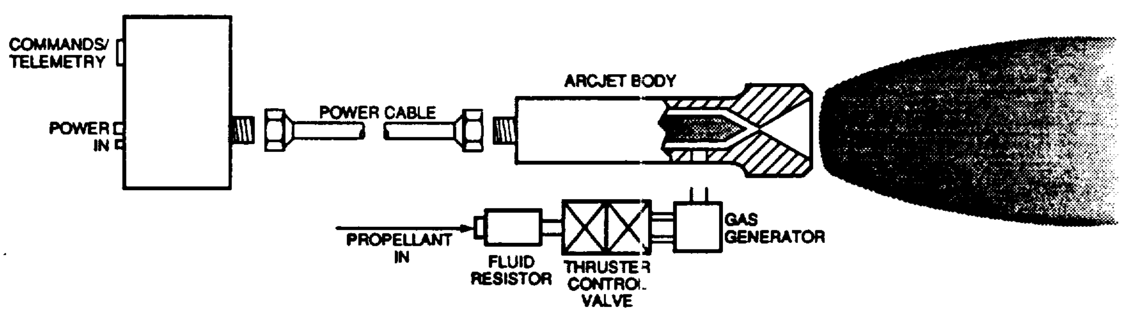
In addition to the variations with operating points, there were small thruster-to-thruster variations in the measured impedances. S/N 34 had an average negative normalized impedance magnitude of 0.85 ohms, and the real part turned positive at 57 kHz. S/N 35 averaged 0.84 ohms and 65 kHz, respectively.

These data were provided as inputs to the PCU design process to ensure that the control loop stability margins were adequate.

3.3 ENGINEERING MODEL ARCJET SYSTEM DEVELOPMENT

The overall objective of this task was to design and fabricate an engineering model (EM) arcjet system to demonstrate that flight requirements could be satisfied. The system, shown schematically in Figure 3-50, is comprised of the arcjet thruster assembly, power conditioning unit, and interconnecting power cable. Each of these components was designed to conform to typical flight performance, interface, and environmental requirements. A summary of the system specification requirements, design evolution, and manufacturing processes involved in the development of the arcjet system is presented in this section.

HYDRAZINE ARCJET SYSTEM SCHEMATIC



C11207-67C

Figure 3-50

3.3.1 System Performance and Interface Requirements

To determine the specification requirements, it was necessary to assess many spacecraft integration and operational issues. GE-ASD provided consulting support under a subcontract agreement with RRC during development of the specification. The requirements were derived assuming the use of two arcjet systems to perform North-South stationkeeping.

A 90% PCU efficiency was targeted after analyzing the trade between spacecraft thermal management considerations and design predictions for efficiency optimization in a flight weight unit. With 1400 W available to each system, the arcjet power consumption is reduced by 10% to 1260 W. The thruster performance predictions were based on this power level.

The EOL flow rate was determined from known stability limits of the arcjet. For a specific thruster operating at fixed power, this limitation establishes the maximum specific impulse which can be achieved. A flow rate 20% greater than an experimentally verified minimum value was used to guarantee that acceptable arc stability would be maintained. With the EOL minimum flow rate defined and the feed pressure blowdown, the flow rate at each point in the mission profile can be calculated.

Specifications for the arcjet system were established in three categories: performance, environmental, and interface. The mission assumptions shown in Table 3-9 were input into the MISSION model described in a previous section. The model output provides a complete mission profile showing performance, operational, and cumulative parameters for each sequential firing. These data are summarized in Table 3-10.

Table 3-9
ARCJET SYSTEM MISSION PARAMETERS

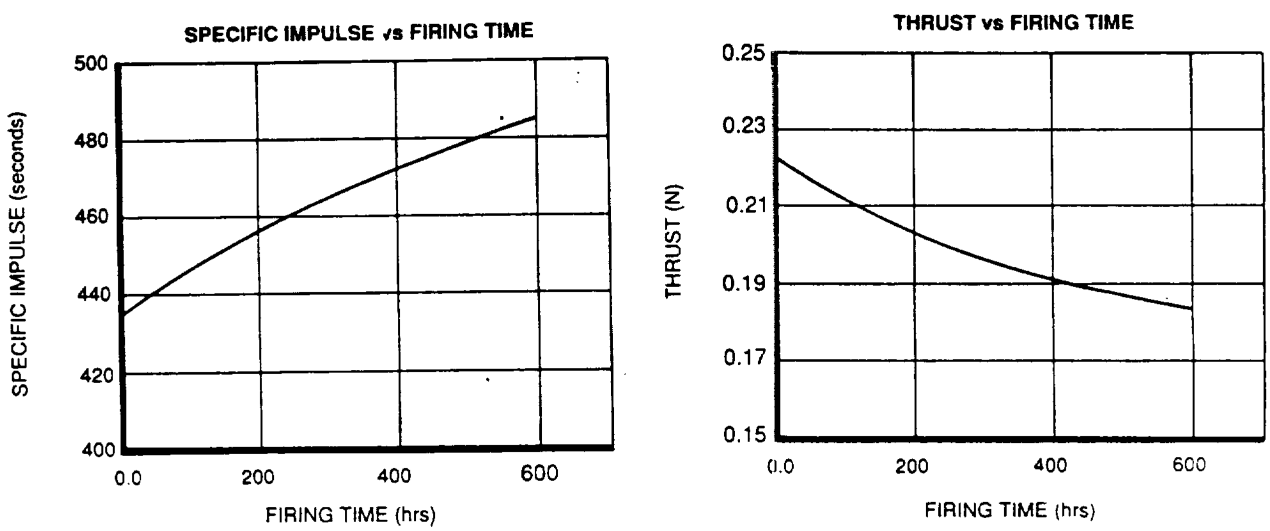
Mission Lifetime	10 years
Power Available	2 systems, 1400 W each
N_2H_4 Blowdown	2.07 to 1.17 MPa (300 to 170 psia)
Spacecraft Mass	2000 kg BOL at GEO, with propellant
Velocity Change	46 m/sec per year
PCU Input Voltage	32–25 vdc letdown
Battery Charge	4 at 1500 W-hour full charge
Depth of Discharge Limit	60% of full charge each
Pointing Accuracy, N-S	0.05 degrees
PCU Efficiency	90 %
End of Life Flow Rate	3.86E-4 kg/sec

The total predicted operating life for each thruster system was 607 hours with 472 starts. As shown in Table 3-10, a 25% margin was added as a qualification goal. The model predictions for thrust and specific impulse over the mission duration are shown in Figure 3-51. The corresponding mission average specific impulse, computed by dividing the total impulse by the propellant consumed over the mission duration, was 450 seconds.

Table 3-10
ARCJET SYSTEM PERFORMANCE REQUIREMENTS

Specific Impulse	450 seconds mission average (434 to 484 over blowdown)
Lifetime	607 hrs. mission; 800 qualification
Start ups	472 mission, 622 qual.
Firing Duration	77 minutes (battery limit)
Total Propellant	192 kg through 2 thrusters
Total Impulse	4.34E 05 N-sec
Thrust — BOL	0.223 N
— EOL	0.183 N

MISSION THRUST AND SPECIFIC IMPULSE VARIATION



11210-68 **Figure 3-51**

The environmental requirements were determined following a review of typical spacecraft specifications. A summary is shown in Table 3-11.

Table 3-11
ARCJET SYSTEM ENVIRONMENTAL REQUIREMENTS

Thermal	–15C to 65C
Structural	20 g rms for 2 minutes, 0.2 g^2/Hz over 20 to 2000 Hz in X, Y, and Z axes
Pressure	Atmospheric to 10^{-6} Torr
Outgassing	TWL: 1.0% max.; VCM: 0.1% max.
EMI	MIL-STD 461/462 requirements

The structural requirements shown correspond to qualification vibration test levels. The EMI requirements (MIL-STD 461/462) include conducted emissions and susceptibility tests, measured at the PCU input, as well as radiated emissions/susceptibility.

The interface requirements are summarized in Table 3-12.

Table 3-12
INTERFACE REQUIREMENTS

Thermal	— PCU	0.16 W/cm.^{2} °C nominal
	— ARCJET	Minimize conductive heat transfer (<10 W)
Mechanical		PCU Envelope: 24 x 20 x 10 cm Arcjet envelope: Similar to EHT resistojet
Electrical		PCU: 25 to 32 vdc/44 to 55 A input 100 vdc/12.6 A output steady state 4000 vdc pulse start up Command on/off: 10V for 40 msec Telemetry: output V and I

For components mounted to the spacecraft requiring conductive energy dissipation, mounting provisions to improve the thermal conductivity are allowed. This is the case with the PCU. A conductance range between 1.0 and 3.0 W/in.^{2} °C is typical and the former value was selected as a worst-case approach for PCU design temperatures. The amount of energy conducted to the spacecraft is then limited by the conversion efficiency requirement. For the arcjet thruster, conducted heat was to be kept below 10 W.

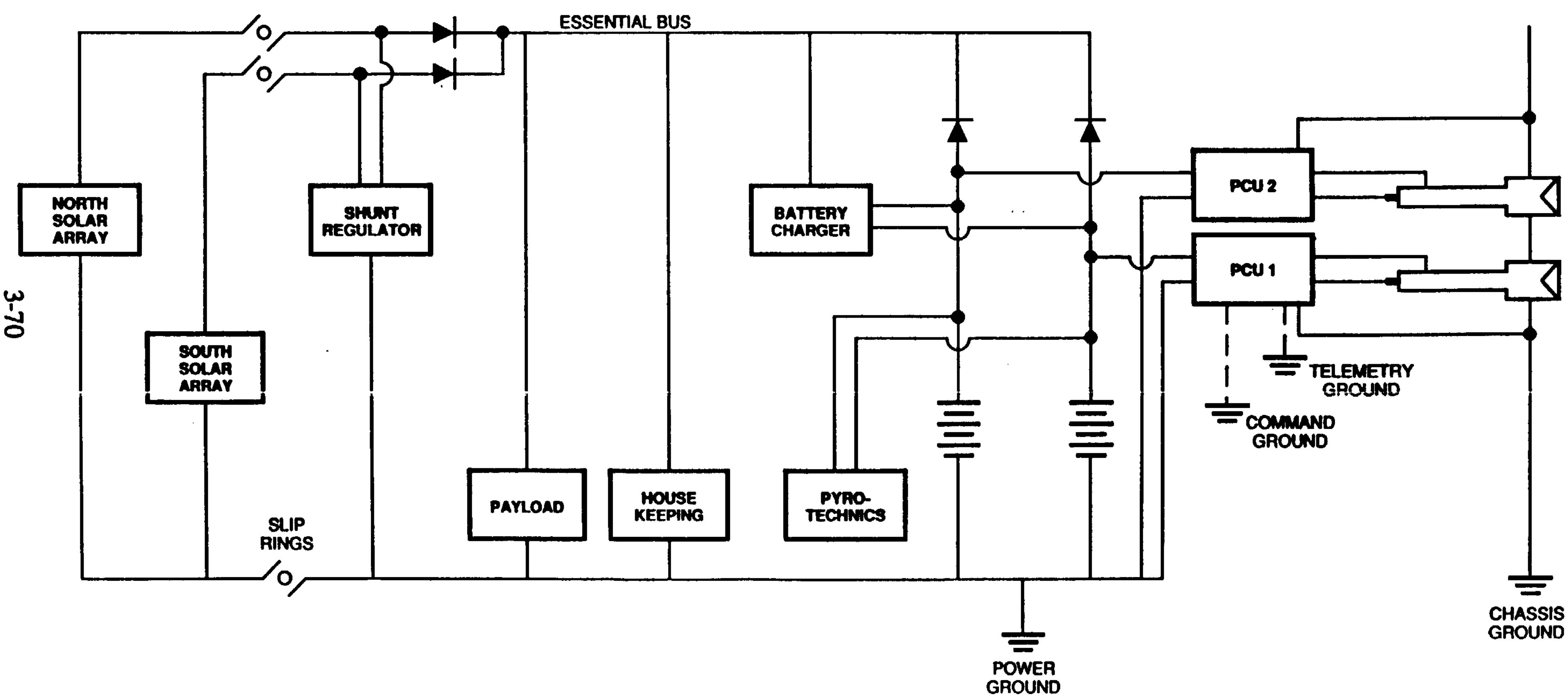
The envelope dimensions of the PCU resulted from a trade analysis between acceptable limits for integration to a spacecraft and the development risk involved with the PCU. For the arcjet, a goal of maintaining a similar envelope to the flight qualified EHT resistojet was targeted to simplify its integration.

The electrical interface is shown in Figure 3-52. Main power to the PCU's would be supplied from the spacecraft battery system through a power relay. The input voltage to the PCU was chosen to be 25 to 32 vdc. Although trends in the development of power systems have suggested that future spacecraft may run at higher bus voltages, it was felt that designing to the lower input voltage would be a worst-case approach. This is because at lower voltages, higher current handling capability of the PCU is required.

Three separate grounds were defined for the arcjet system and are shown in Figure 3-52 These are the power, command/telemetry, and chassis grounds. Isolation of these grounds is assumed to be maintained by the spacecraft.

The command and telemetry interface definition included "on/off" digital commands to the PCU and analog arcjet voltage and current telemetry.

TYPICAL ARCJET SYSTEM GROUNDING SCHEMATIC



3.3.2 Benchmark Arcjet Evaluation

A test program was established to evaluate several critical arcjet features and establish final definition of these components in the engineering model arcjet design. The benchmark arcjet was fabricated for this purpose, using the development hardware design described in paragraph 3.2.1.

The accomplishments were:

1. Final definition of cathode, anode, and injector geometries was made to deliver optimized stability characteristics
2. The effectiveness of cathode preshaping to enhance thruster lifetime and operational stability was demonstrated.
3. The use of high emissivity surfaces to reduce arcjet operating temperatures was developed and demonstrated.
4. High starting reliability and expected performance levels were verified.

This work is described below.

3.3.2.1 Stability and Performance Mapping

Tests were performed to establish the most stable configuration. Stability is measured by observing the variations in steady-state arc voltage and by noting the minimum operating flow rate at a given power. Several parameters were investigated.

Electrode Gap

A range of gaps between 0.051 cm (0.020 in.) and 0.076 cm (0.030 in.) were tested. Steady-state stability was reduced at the smaller gap settings and stable operation could not be maintained at as low a flow rate. During unstable periods, the traces showed voltage transients corresponding to fluctuations of the plume.

Figure 3-53 shows an example. At a 0.051 cm (0.020 in.) gap setting, perturbations in voltage occur at the low flow rate of 3.6 x 10^{-5} kg/s. The stability improves at higher flow rates. The low flow rate stability was improved at 0.063 cm (0.025 in.) and 0.076 cm (0.030 in.).

The 0.063 cm (0.025 in.) gap was selected for the engineering model thruster over the 0.076 cm (0.030 in.) gap because the start up voltages were less, and the latter configuration did not offer significantly better stability characteristics nor high enough voltages to impact the cathode erosion rates through lower current levels.

Nozzle Inlet Angle

Variations in operational stability for different anode inlet angles were investigated. Past RRC work had used a 100 degree included angle inlet. Intermediate angles of 90 and 60 degrees were tested with the benchmark thruster. Figure 3-54 shows these two configurations. Significantly greater steady state stability of the 60 degree anode was measured than with either the 90 degree anode or the 100 degree anode tested previously. Very smooth voltage traces with few or no arc perturbations were produced.

BENCHMARK ARCJET V/I SCR TRACES

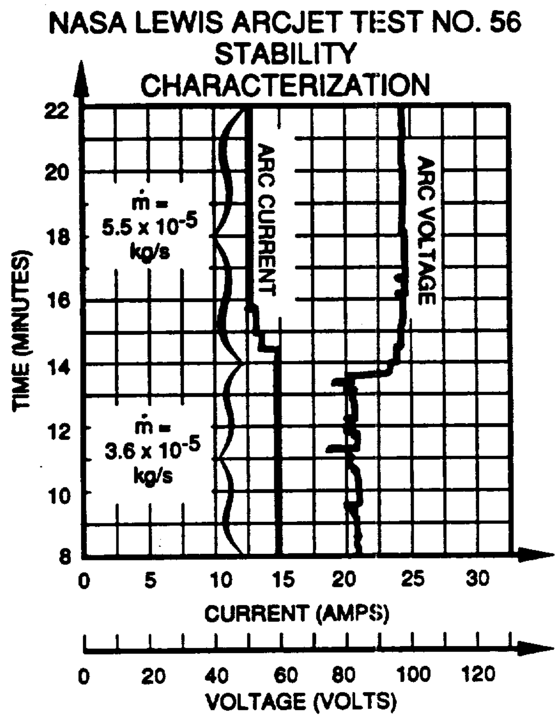
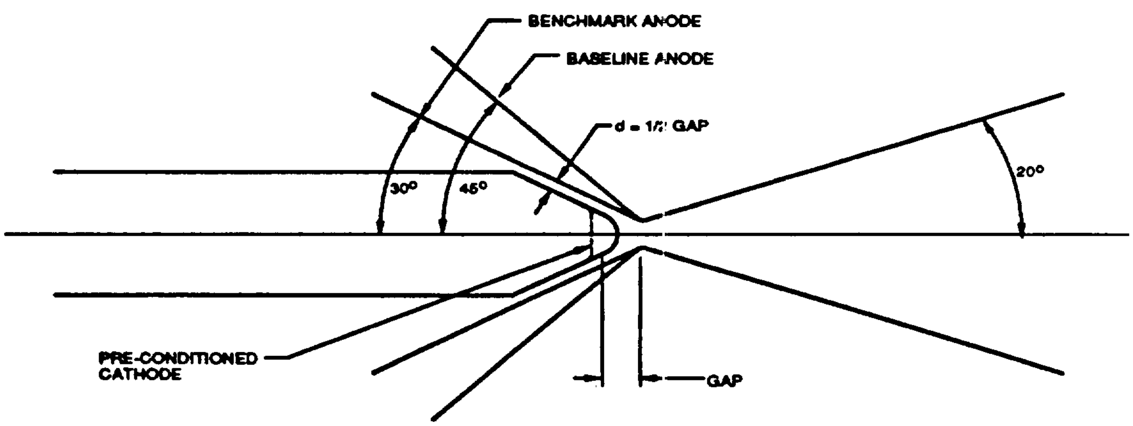


Figure 3-53

BENCHMARK ARCJET NOZZLE INLET ANGLE



C11202-54

Figure 3-54

Performance Verification

Testing was conducted to verify acceptable performance levels of the benchmark arcjet and to generate characteristic flow rate and pressure drop data used for sizing the fluid resistor in the EM system. The fluid resistor is a flight component with no moving parts which acts like an orifice upstream of the propellant valve. Its sizing determines the system flow rate for given inlet and back pressure conditions.

Two fluid resistors with different ratings were installed and tested in the benchmark arcjet test setup. Performance was mapped at power levels of 1200, 1300, and 1400 W. Graphs of flow rate, chamber pressure, thrust, and specific impulse for one of these tests are shown in Figure 3-55. For this case, the flow rate was slightly higher than the targeted values for the EM system. As a result, the average specific impulse was lower than the specification requirement of 450 seconds over the blowdown of 300 to 170 psia. The proper fluid resistor rating was calculated from these data to provide the required average specific impulse.

Specific impulse versus power/flow rate is shown in Figure 3-56. These data agree with previous empirical characterizations.

3.3.2.2 Cathode Preshaping

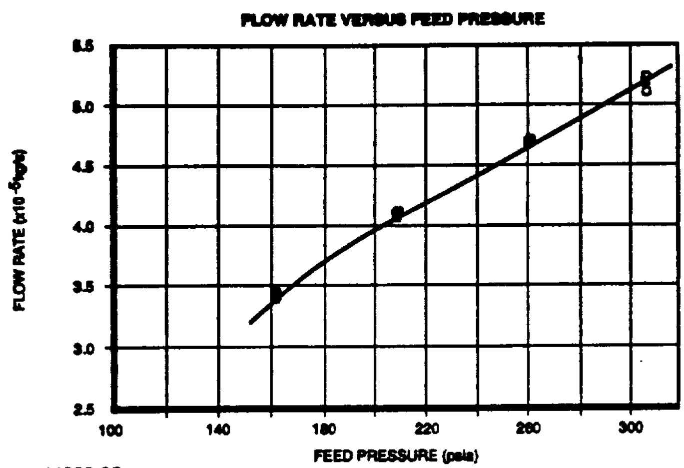
Previous life test results at RRC and NASA LeRC have shown that a high rate of erosion occurs on a sharp cathode tip during its initial stages of firing. After this burn-in period, the tip shape becomes more stable and the corresponding erosion is reduced for the remainder of the test.

Figure 3-57 shows cathode dimensional inspection data from a 200 hour RRC test. The length change occurring between 20 and 100 hours is less than for the first 20 hours of firing. The measured arc voltage, shown in Figure 3-58, shows further evidence of a more rapid cathode geometry change during the initial 20 to 30 hour period.

A reduction in this high rate of change during the burn-in period was desired to allow operation of the EM system over a narrower range of voltage and current from beginning to end-of-life. This would simplify the design of the PCU and make it easier to maintain thruster stability. Dimensional inspection data from lifetime testing were used to assess the burned-in cathode tip geometry and incorporate its major features into initial fabrication. Figure 3-59 shows the resulting preshaped cathode as compared to the original configuration. This cathode was tested in a benchmark thruster to evaluate any arc stability effects.

A 25 hour test was completed in a duty cycle mode of 1 hour on/0.5 hour off. The test was run at a constant flow rate of 4.1 x 10^{-5} kg/s and a current level of 12 amps. The nominal power level was 1250 W and the measured specific impulse ranged between 450 and 460 seconds. No changes in arc stability occurred. The voltage change over the 25 hour firing duration was minimal and is shown in Figure 3-60. A change of less than 3 volts from beginning-of-life was measured. Negative slopes in the curve occurred due to small variations in flow rate and current during the test. Post-test inspection showed minimal change in cathode geometry with a measured length change of only 0.0025 cm (0.001 in.). These results, when compared to the data shown in Figures 3-57 and 3-58, show the effectiveness of the premachined tip. A 10 volt change was reduced to less than 3 volts and the cathode length change went from 0.041 cm to 0.0025 cm for the same firing period.

BENCHMARK PERFORMANCE MAP RESULTS



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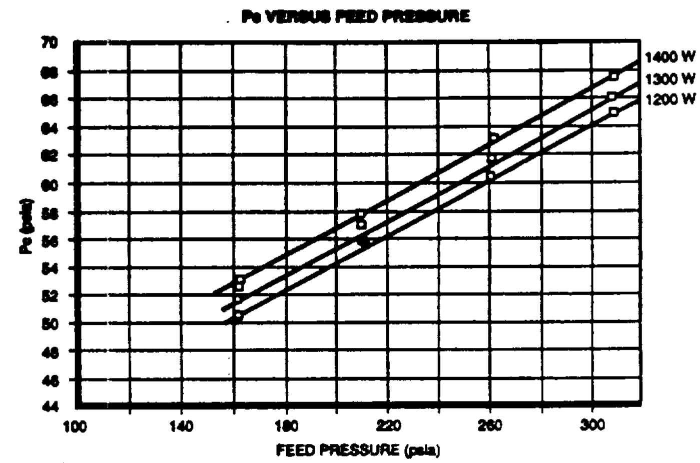

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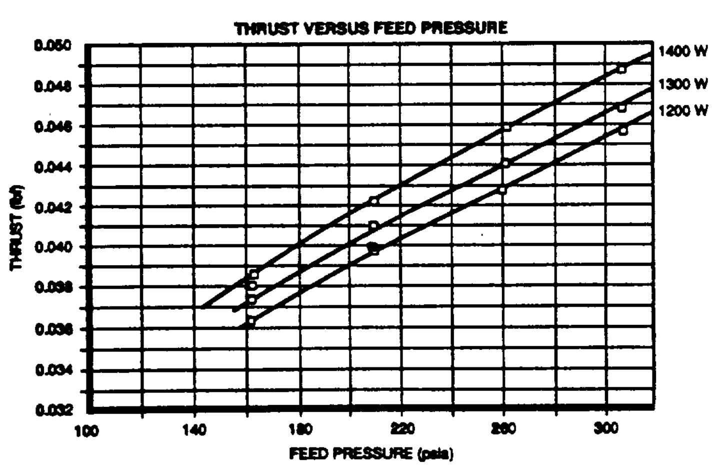

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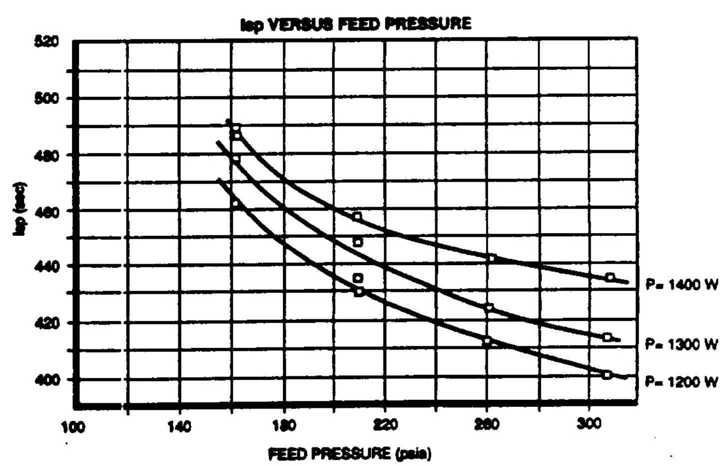
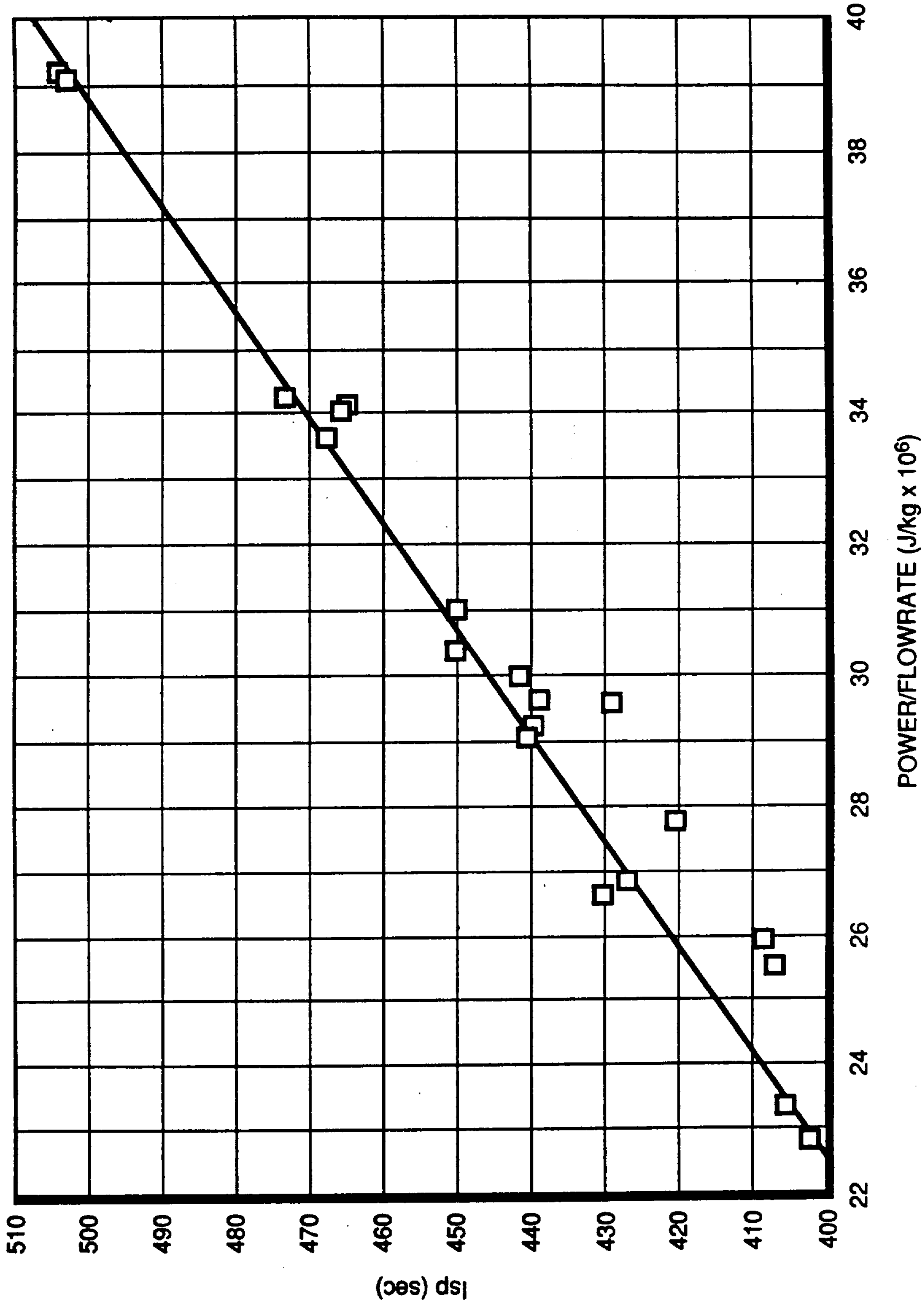


11222-97

Figure 3-55

Benchmark Performance Map



SS LIFE TEST DATA, 200 HOURS
CATHODE LENGTH REDUCTION VS. TEST TIME

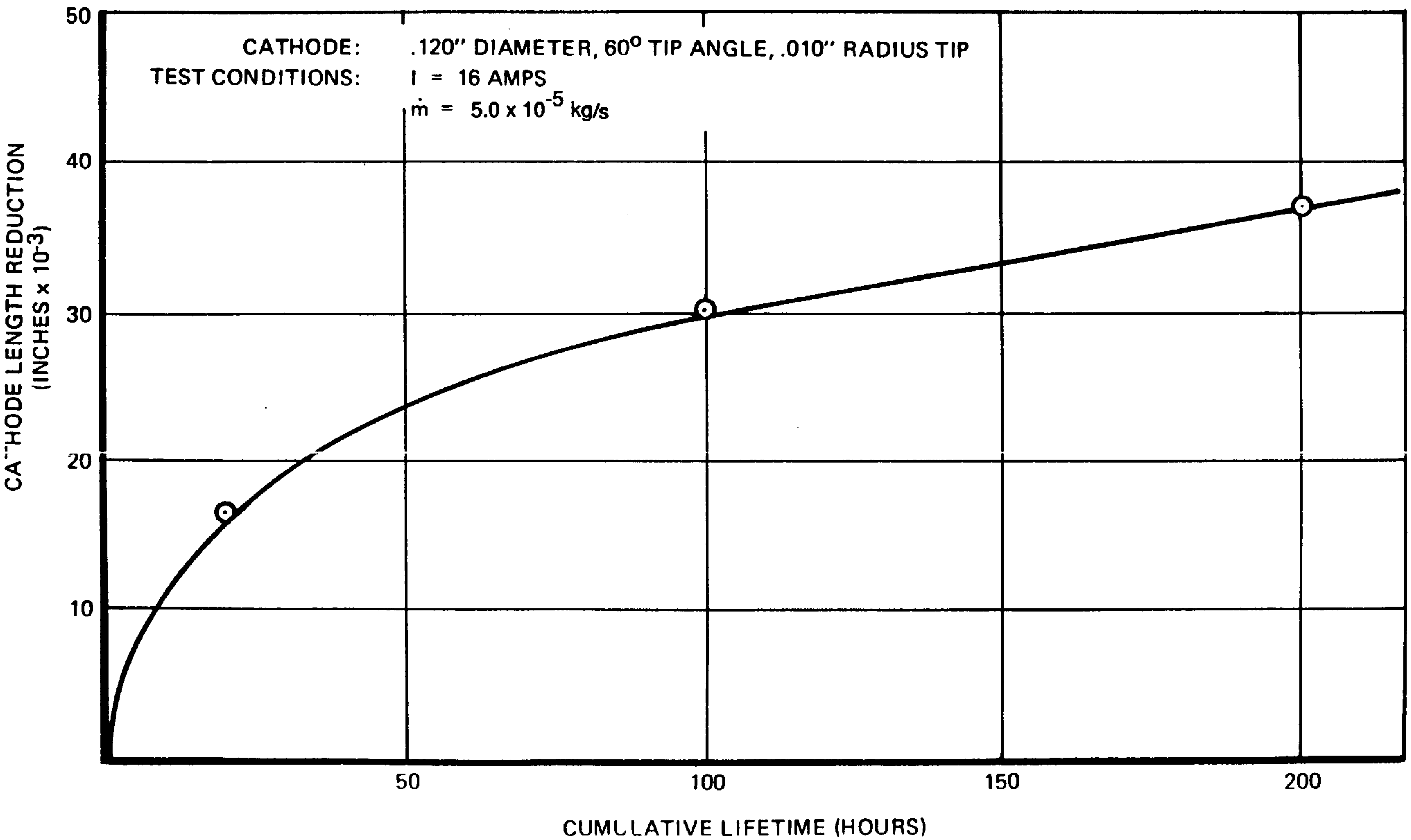
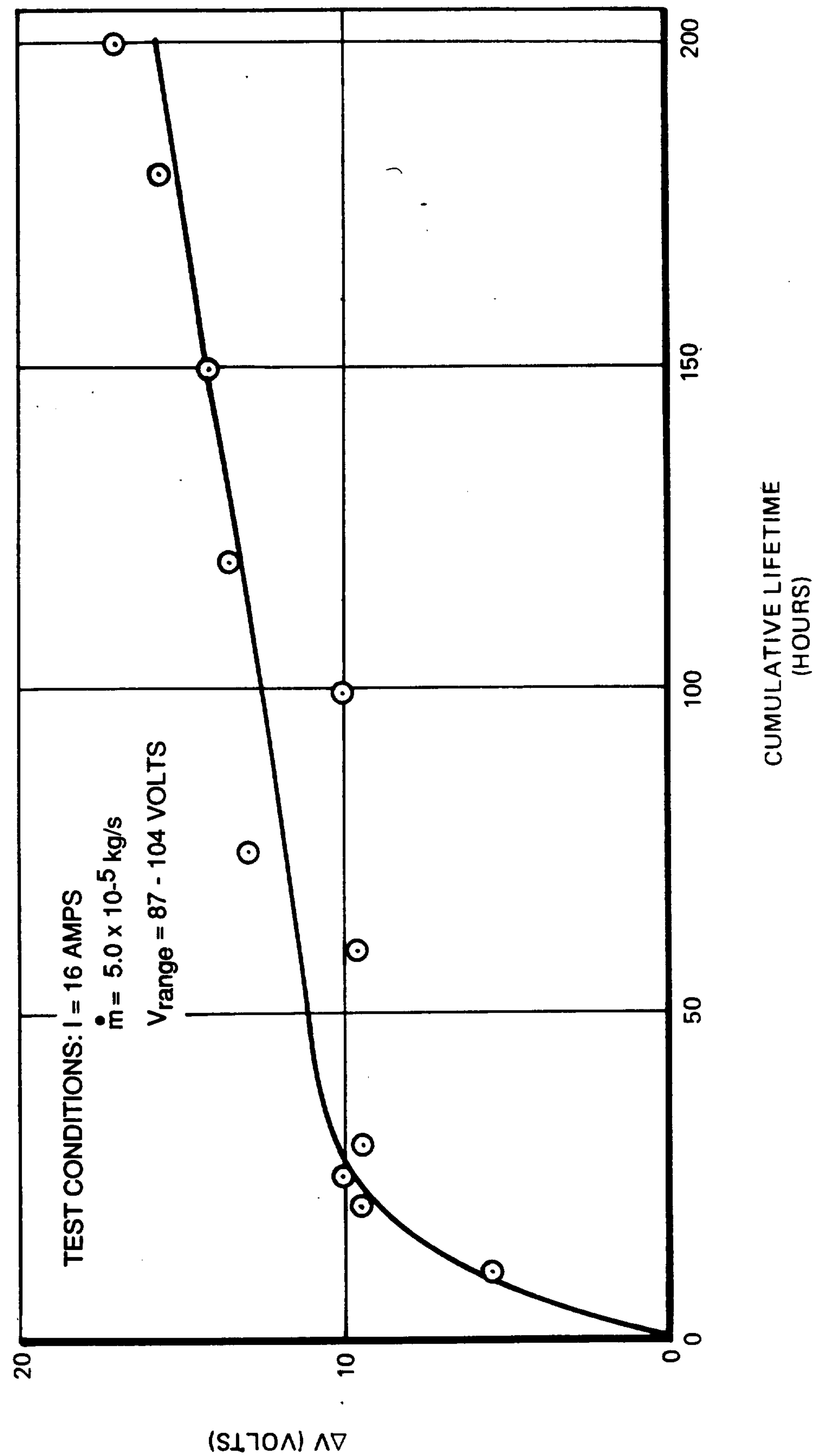


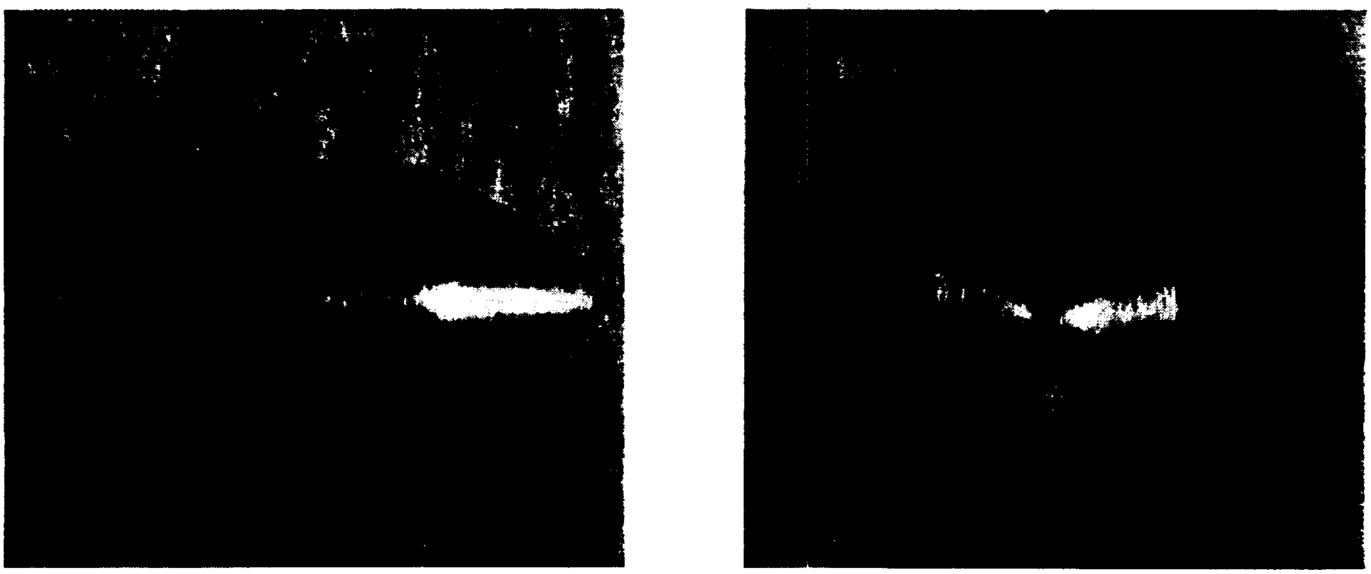
Figure 3-57

SS LIFE TEST DATA, 200 HOURS
VOLTAGE CHANGE VS. TEST TIME



PRESHAPED CATHODE GEOMETRY

STANDARD BENCHMARK CATHODE
MAGNIFICATION = 11.5X

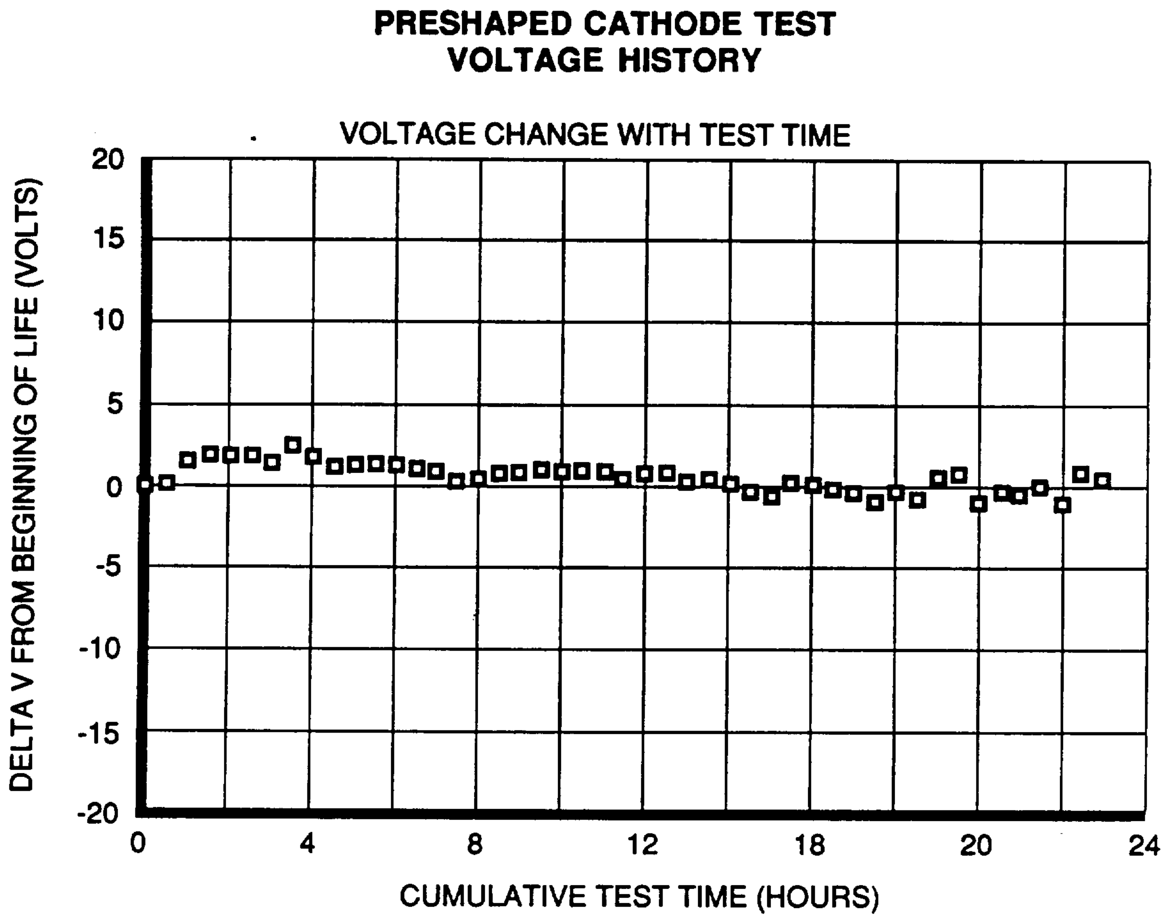


11202-55

PRE-SHAPED CATHODE
MAGNIFICATION = 11.5X

11202-56

Figure 3-59



C11222-64

Figure 3-60

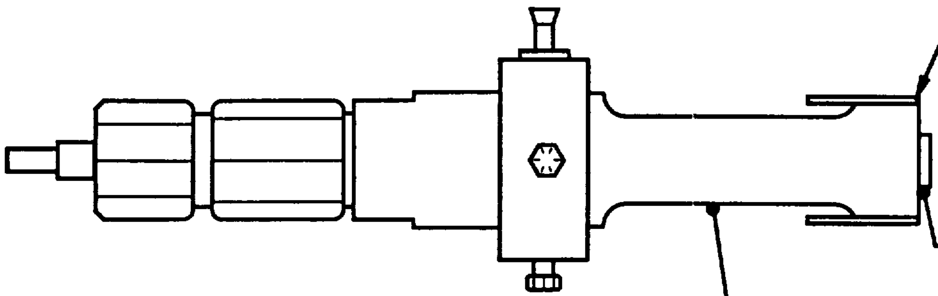
3.3.2.3 Benchmark Emissivity Testing

Development work was conducted to refine a method to improve the emissivity of the anode body. Maximum allowable temperatures were established at the weld and braze joints, and at the power cable interface. Analysis showed that a high emissivity surface, in the range of 0.6 to 0.8, would be required at the anode end of the thruster for sufficient radiative heat dissipation to maintain allowable structure temperatures. Emissivities of the refractory metals used in this high temperature environment are only on the order of 0.1 to 0.2. Two options were identified. The first involved coating the anode body with a high emissivity material. This work is discussed in paragraph 3.3.3.1. The second option was to mechanically attach a high emissivity sleeve to the anode. The sleeve was made from silicon carbide and had an emissivity of 0.9. The benchmark arcjet was used to evaluate the ability of the sleeve to lower the thruster temperatures.

The thruster body was first modified to reduce its cross-section to more closely simulate the projected configuration of the engineering model unit. The smaller cross section reduces the heat conducted back towards the temperature sensitive areas. The sleeve was made to provide an interference fit and was pressed onto the thruster.

A thermal mapping test was conducted. Figure 3-61 shows temperature data measured while firing the thruster both with and without the shield. Significant reductions of structure temperatures were achieved using the shield. Table 3-13 summarizes heat loss computations made for both cases based on the measured temperature data.

EMISSIVITY SLEEVE TEST-MEASURED TEMPERATURE



C11222-64 **Figure 3-61**

Although a significant enhancement was demonstrated in the thermal profile of the arcjet through use of the emissivity sleeve, several other factors were considered and a decision was made to suspend further development of this option. First, the silicon carbide is extremely stiff with a modulus of elasticity = 410 GPa, making it susceptible to fracture during handling or launch vibration. Second, the long-term effects of thermal cycling on reducing the thermal contact between the sleeve and arcjet surfaces were unknown. Third, results from environmental testing on the coated samples were highly successful and offered a more attractive solution.

3.3.2.4 Benchmark Start Up Testing

Start up testing of the benchmark arcjet was conducted during development of the EM PCU. A first-generation breadboard unit was used to achieve over 1000 start cycles on a single thruster, establishing a high degree of confidence in the starting capability of the thruster/PCU system design. Development of the PCU start circuit was completed prior to this test to help achieve an extremely high starting reliability. Post-test inspection of the benchmark electrodes showed no significant degradation.

Table 3-13
ARCJET HEAT LOSS SUMMARY

	Without Sleeve								With Sleeve							
$\dot{m}$ x 10^{-5} kg/s	P_{Elec} (W)	P_{Chem} (W)	$P_{In.Total}$ (W)	Q_{Rad} (W)	Q_{Cond} (W)	Q_{Total} Loss (W)	Q_{Exit} (W)	ηth	P_{Elec} (W)	P_{Chem} (W)	$P_{In.Total}$ (W)	Q_{Rad} (W)	Q_{Cond} (W)	Q_{Total} Loss (W)	Q_{Exit} (W)	ηth
4.16	1310	166.1	1476.1	114.1	250.5	364.6	1111.5	0.75	1310	166.1	1476.1	205.3	177.1	380.4	1094.7	0.74
5.05	1305	201.4	1506.4	101.2	243.2	344.4	1162.0	0.77	1340	201.4	1541.4	180.2	180.2	360.4	1100.0	0.77
5.68	1333	226.6	1559.6	78.3	214.0	292.3	1267.3	0.81	1325	226.6	1551.6	164.5	137.1	301.6	1251.5	0.81

C-2.

3.3.3 Engineering Model Arcjet System Design/Analyses/Fabrication

This section describes the design, analysis, and fabrication activities that produced the engineering model arcjet system. This system embodied the optimized features arrived at through development and benchmark testing while meeting the performance, interface, and environmental constraints established for typical spacecraft.

The design effort can be separated into three areas: the hydrazine arcjet thruster (AJT) assembly; the power conditioning unit (PCU); and the power cable and connectors. The AJT assembly consists of a fluid resistor, solenoid valve, catalytic gas generator, and the arcjet. The PCU and cable/connector assembly were developed and manufactured under subcontract by Watkins-Johnson Company and Reynolds Industries, respectively.

3.3.3.1 Arcjet Thruster Design/Analysis/Fabrication

3.3.3.1.1 Conceptual Design — Several key issues were addressed early in the design process. These were: overall layout of the hydrazine arcjet thruster (AJT) assembly (i.e., relative position of the arcjet and valve/GG); sealing requirements and design options; materials choices; cathode/anode relative positioning; high emissivity coatings; and materials joining techniques. Baseline design choices were made as a starting point for further analysis and evaluation.

Arcjet Thruster Layout — Two main approaches were considered for the thruster layout. One positioned the arcjet barrel next to the valve/gas generator assembly as was done for the EHT resistojet. The second approach positioned the valve, gas generator, and arcjet barrel on the same centerline.

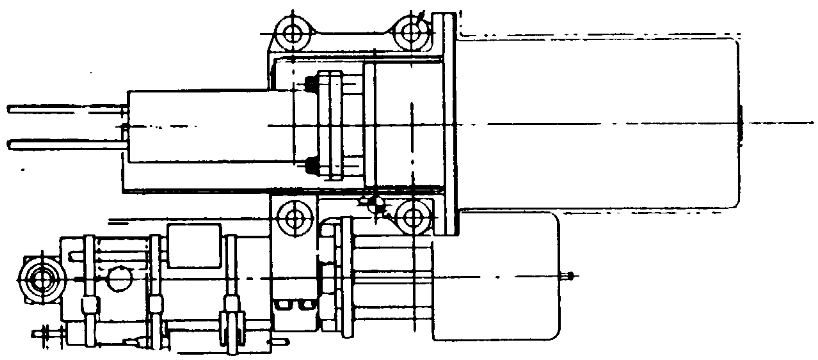
Several factors were evaluated that led to the selection of the side-by-side configuration. First, accommodating the thermal design requirements of the arcjet barrel were more easily met with this approach. The valve and gas generator are temperature limited, and separating the two assemblies substantially decoupled the two assemblies. Second, the side-by-side arrangement had been analyzed in great detail for the EHT resistojet, and was well understood thermally and dynamically. These models could be modified for the arcjet. Third, the power cable interface with the arcjet would be simplified by allowing open access to the end of the arcjet barrel. Finally, maintaining the same envelope and interface as the EHT ensured that adaptations to existing spacecraft structures to mount the arcjet would be minimal. A comparison of the EHT and arcjet layout approaches is given in Figure 3-62.

Seals and Material Selection — Figure 3-63 summarizes areas where gas tight interfaces were required and where key materials choices had to be made. Sealing areas included an anode-to-thruster body joint, gas delivery tube attachment point, power passthrough, and a mid-body braze joint. A key issue was to provide an interface between the tungsten or tungsten alloy anode and the rest of the arcjet barrel which serves as a thermal standoff and a structural support. Due to thermal, manufacturing, and cost constraints, it was not feasible to extend the anode material back to the power cable interface.

ARCJET DESIGN ENVELOPE COMPARISON

- OVERALL LAYOUT
  - DESIGN TRADE BETWEEN "SIDE-BY-SIDE" AND "IN-LINE" FAVORED FORMER BECAUSE OF DESIGN/ANALYSIS HERITAGE AND SPACE REQUIREMENTS FOR POWER CONNECTION

EHT LAYOUT



ARCJET LAYOUT

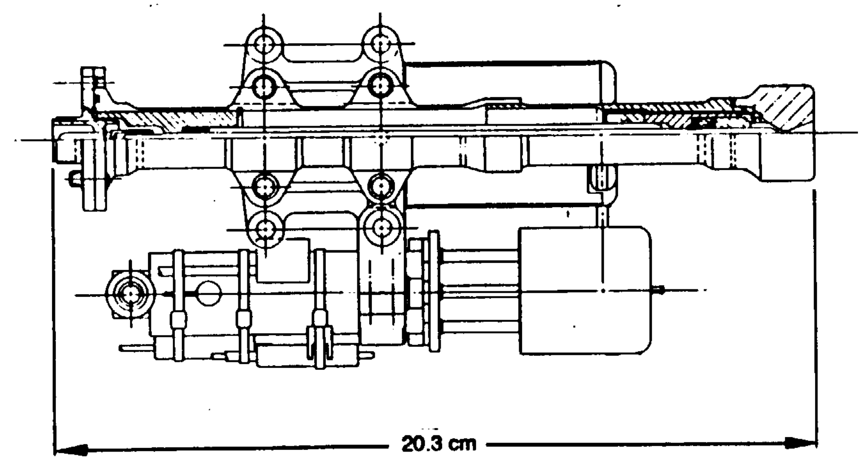


Figure 3-62

ARCJET CONCEPTUAL DESIGN CONSIDERATIONS

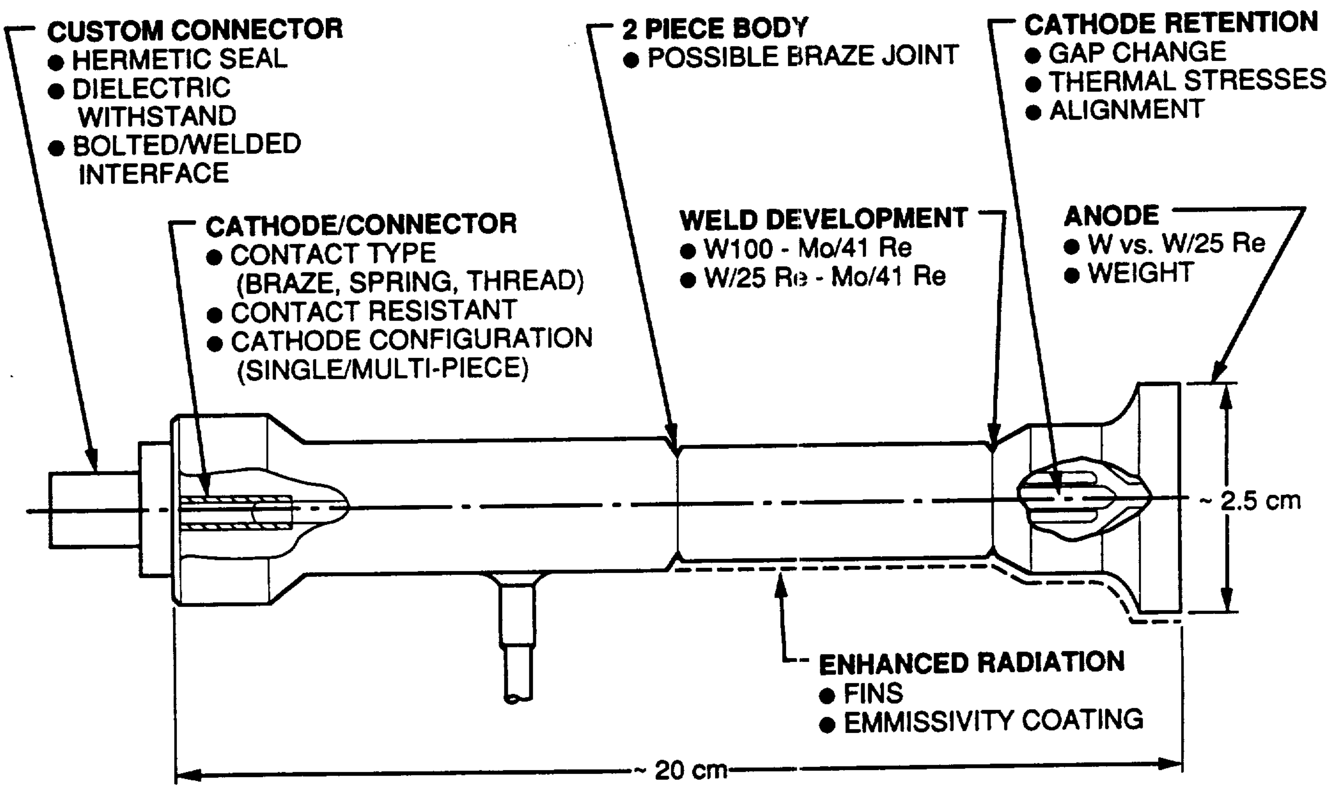


Figure 3-63

The approach taken was to make a two-step transition. First, the anode would be joined to a Moly/41 Re section which served to closely match thermal coefficients of expansion, provide a low thermal conducting material to prevent heat transfer back up the barrel, maintain high temperature capabilities, and provide good resistance to fracture formation and propagation under dynamic loading. The second transition was between the Moly/41 Re and an Inconel 625 section which allowed the gas delivery tube to be welded directly to the body.

Weld and braze development tasks to support this conceptual approach are described in later sections.

Materials choices were dependent upon many factors, including the results of thermal/structural modelling, test experience, compatibility with hydrazine, weldability, creep life, insulator dielectric strength, and thermal shock resistance. Baseline materials choices were tungsten or tungsten/25 Re for the anode, Moly/41 Re for the body, 2% thoriated tungsten for the cathode, and a combination of boron nitride and aluminum oxide for insulators.

Cathode Gap Retention — Maintaining a constant gap during operation is important to stable, repeatable operation. An approach was identified that minimized differential thermal expansion between the cathode and anode by appropriate materials choices and dimensions. Calculations showed that the total relative movement could be maintained below 0.0051 cm (0.002 ").

3.3.3.1.2 Thermal Analyses — Between 200 to 300 watts are input to the arcjet body at the electrodes. About 20 percent of this goes into the cathode, and the remainder into the anode. This heat must be dissipated primarily through radiation because of the limits placed on conductive losses through the mounting structure to the spacecraft. A finite difference model was constructed to guide thermal design choices. The important design constraints which were examined using the model are summarized below:

a. The mounting interface was assumed to have a conductance of only 0.05 W/°C. Consequently, almost all waste heat must be radiated from the thruster.

b. The arcjet was assumed to protrude partway through the spacecraft outer surface. Therefore, the valve and part of the arcjet barrel had view factors internal to the spacecraft. Internal temperatures ranged from -10° to 55°C, and deep space was assumed to be at -140°C.

c. The valve temperature must be kept below 150°C at worst case environmental temperatures to prevent damage to valve seat seals.

d. The arcjet barrel interface with the power connector must be maintained below 200°C due to temperature limits of the cable dielectric material.

e. The middle body braze joint must be kept below 590°C.

Of these requirements, the 200°C connector limit was the most difficult to meet. Initial predictions of temperatures at the cable connection were on the order of 480°C. This configuration assumed a continuous Moly/41 Re body welded to a tungsten anode. Several design features were evaluated in the thermal model to address this problem. Those eventually incorporated into the design are summarized in Table 3-14. Temperature predictions at the thruster connector were subsequently reduced to below the 200 C limit at all operating conditions.

Table 3-14
AJT THERMAL DESIGN FEATURES

Feature	Purpose
a. Two piece body structure (Moly/41 Re and Inco 625)	Inco 625 provides lower conductivity than Moly/41 Re
b. Al_2O_3 insulators	Low material thermal conductivity
c. Thin-walled sections (i.e., body and insulators)	Decrease conductance
d. Enlarged anode	Increase radiative surface area
e. Emissivity coating on anode/body	Increase radiation from high temperature surfaces

Predicted temperatures for the worse-case hot-bias thermal environment are shown in Figure 3-64. Several additional proven thermal features from RRC EHT designs were incorporated and are also shown. These include a controlled conductive resistance path between the valve and gas generator through the use of thermal standoffs, a titanium mounting structure for low conductivity, and a thermal spacer between the valve and GG mounting flanges.

The thermal design was shown to be fully compliant with the assumed interface requirements and the material temperature limits. As a result of these thermal analyses, several process development activities were initiated for the anode-to-body bi-metallic weld joint, body braze joint, and the high temperature emissivity coating.

3.3.3.1.3 Process Development

Arcjet Anode/Body Weldment — The weld joint between the tungsten anode and Moly/41 Re body was the subject of a development effort since it had not been demonstrated before. Tungsten/25 Re was also evaluated as a backup. Tungsten/25 Re was a less attractive option as an anode because of its lower melting temperature. It was pursued because it offers a coefficient of thermal expansion closer to Moly/41 Re than does tungsten, which in turn would make the weld joint less susceptible to fracturing under thermal loads.

Electron beam welding techniques were employed to produce several samples of each weld joint. The samples were then subjected to 400 thermal cycles between 157°C (250°F) and 1240°C (2200°F) in a hydrogen atmosphere. Heating was accomplished using an induction system and cooling was provided via a water cooled copper block used to support the samples. To simulate the operational axial thermal gradients, induction heating was confined to the anode until the weld joint reached the desired temperature.

HYDRAZINE ARCJET TEMPERATURE DISTRIBUTION

- TEMPERATURES IN °C
- LOCATIONS INDICATE THERMAL MODEL NODES

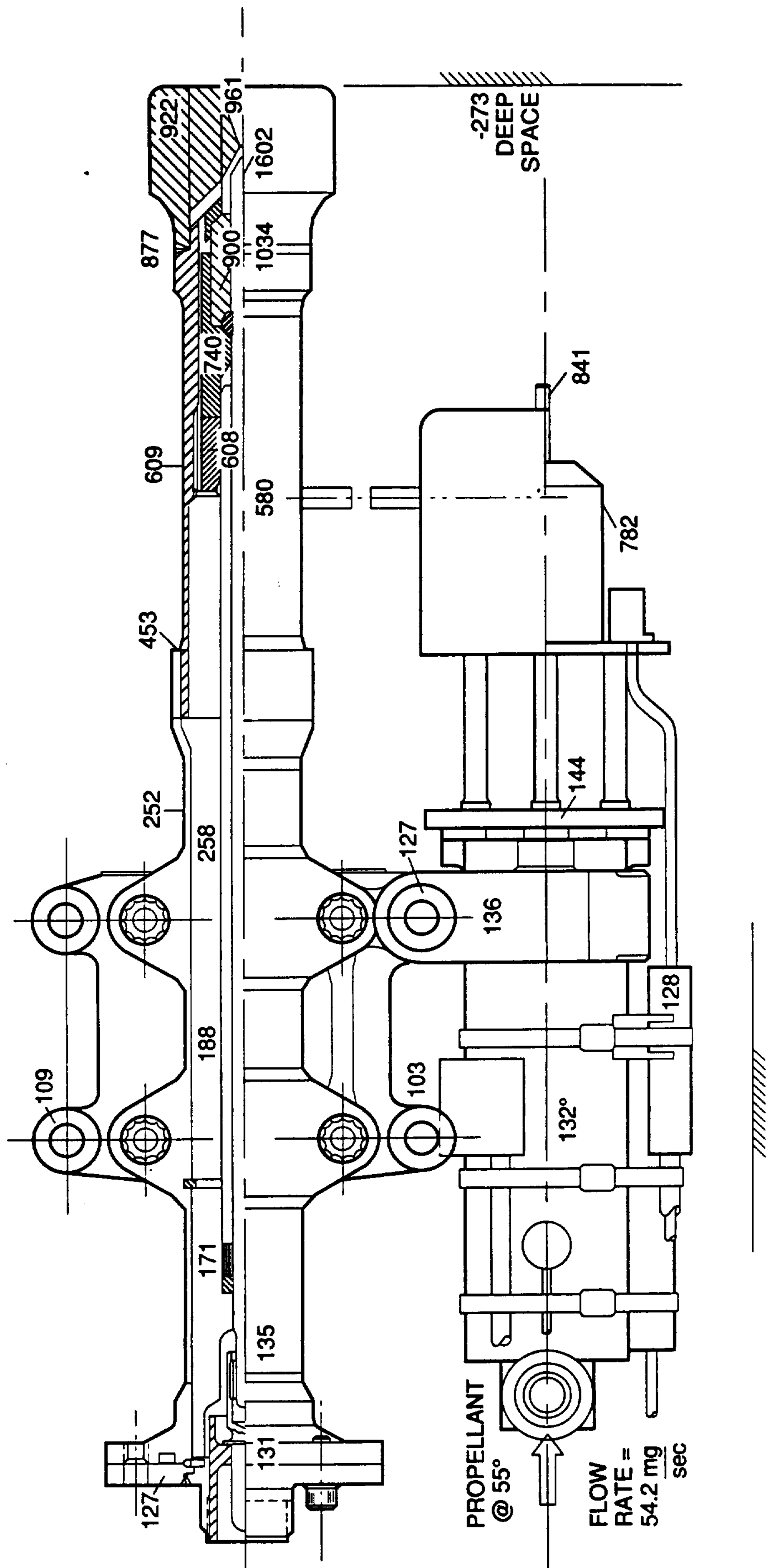


Figure 3-64

Post-thermal cycle testing visual and dye penetrant examinations showed no evidence of surface fractures on the weld joint face or heat-affected-zones for both material combinations. Additionally, the samples were metallographically prepared to expose a transverse weld cross-section. These were found to be free of fractures with a minimal amount of weld porosity detected. Photomicrographs of both metal combinations are shown in Figures 3-65 and 3-66.

It was concluded that both weld metal combinations possessed acceptable resistance to thermal fatigue cracking under the proposed application environment. Tungsten was retained for the anode because of its higher melting point. The weld schedule established was utilized during subsequent production of engineering model hardware.

Arcjet Body Bi-Metallic Braze Joint — The material transition at mid-body of the arcjet between Inconel 625 and Moly/41 Re required development of a braze procedure. The predicted steady state temperature was 457°C. A design requirement of 590°C for 800 hours in 1-hour cycles was established.

Vacuum furnace brazing and induction brazing techniques were evaluated with Au-100, Nicoro, and Nicoro-80 braze alloys using the following test series:

1. Thermal cycling: 38°C to 590°C, 800 cycles, GN_2 environment
2. Macroscopic visual inspection
3. Helium leak testing
4. Mechanical tensile strength test
5. Metallographic examination-joint sectioning/SEM examination.

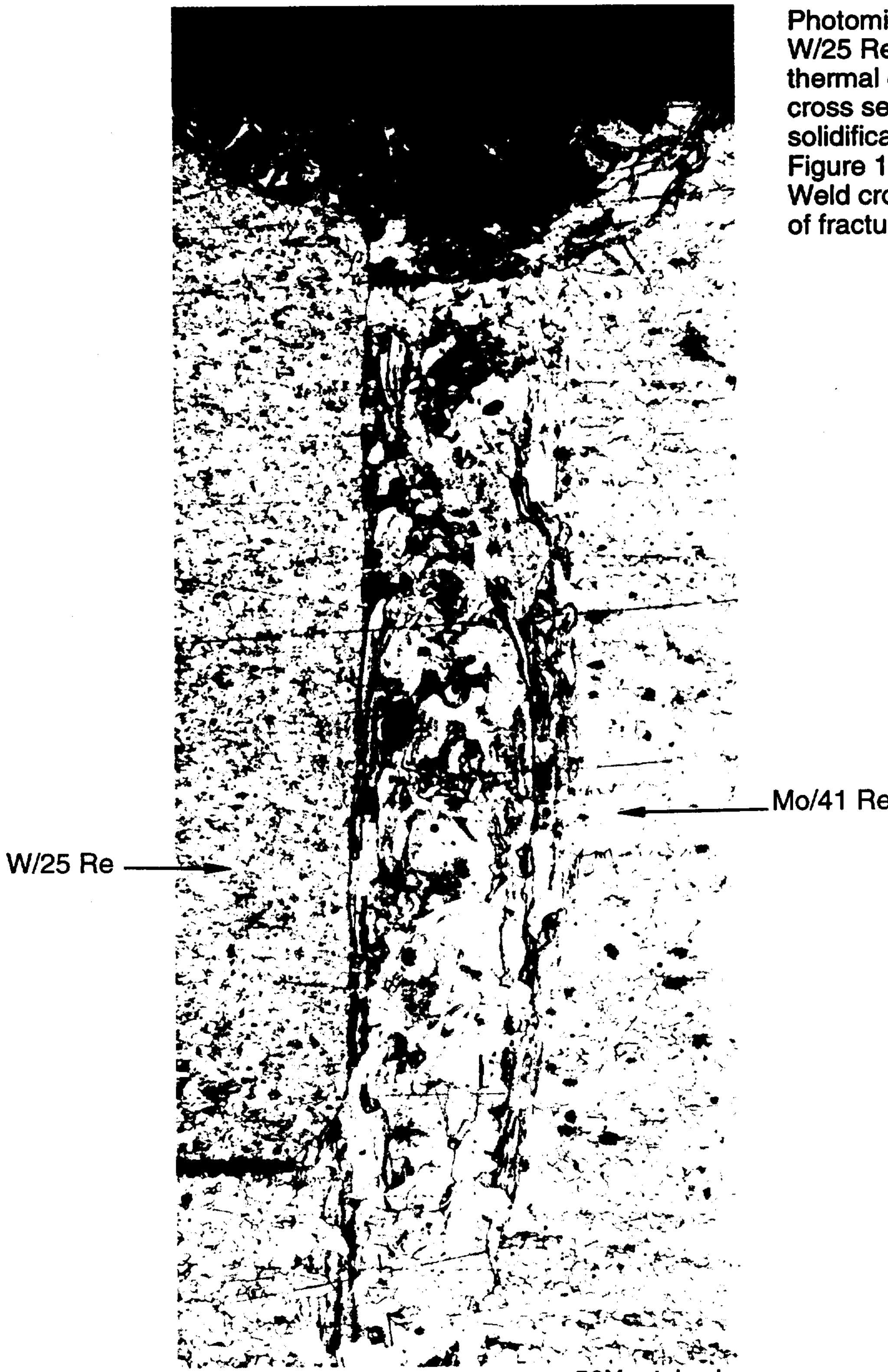
Furnace brazing was evaluated first. The samples showed excessive base metal penetration and accompanying erosion defects. Induction heating was subsequently tried. This method offered the advantage of achieving the required heating using a shorter braze cycle. This prevented base metal penetration from occurring.

The Nicoro alloy was eliminated when the sample failed to pass the helium leakage test. Post thermal cycling examination later indicated that excessive cracking in the joint was the cause. Nicoro 80 showed cracking to a lesser degree. The induction brazed Au sample passed all evaluation criteria and showed excellent metallographic characteristics. The Au-100 filler maintained excellent ductility throughout thermal cycling which ensured a long lasting leak tight joint. The induction braze schedule developed using Au-100 was therefore selected.

Emittance Coating Development — Identification of an emittance coating for the arcjet anode/body was one of the most critical development issues to be resolved for successful design of the EM arcjet. Thermal analyses indicated that this feature had a major influence on maintaining temperatures within design limits. The criteria established were as follows:

1. Adherence to Moly/41 Re and tungsten 100
2. Maximum temperature = 980°C
3. Minimum thermal cycle life of 800 hours
4. Minimum total emittance = 0.6

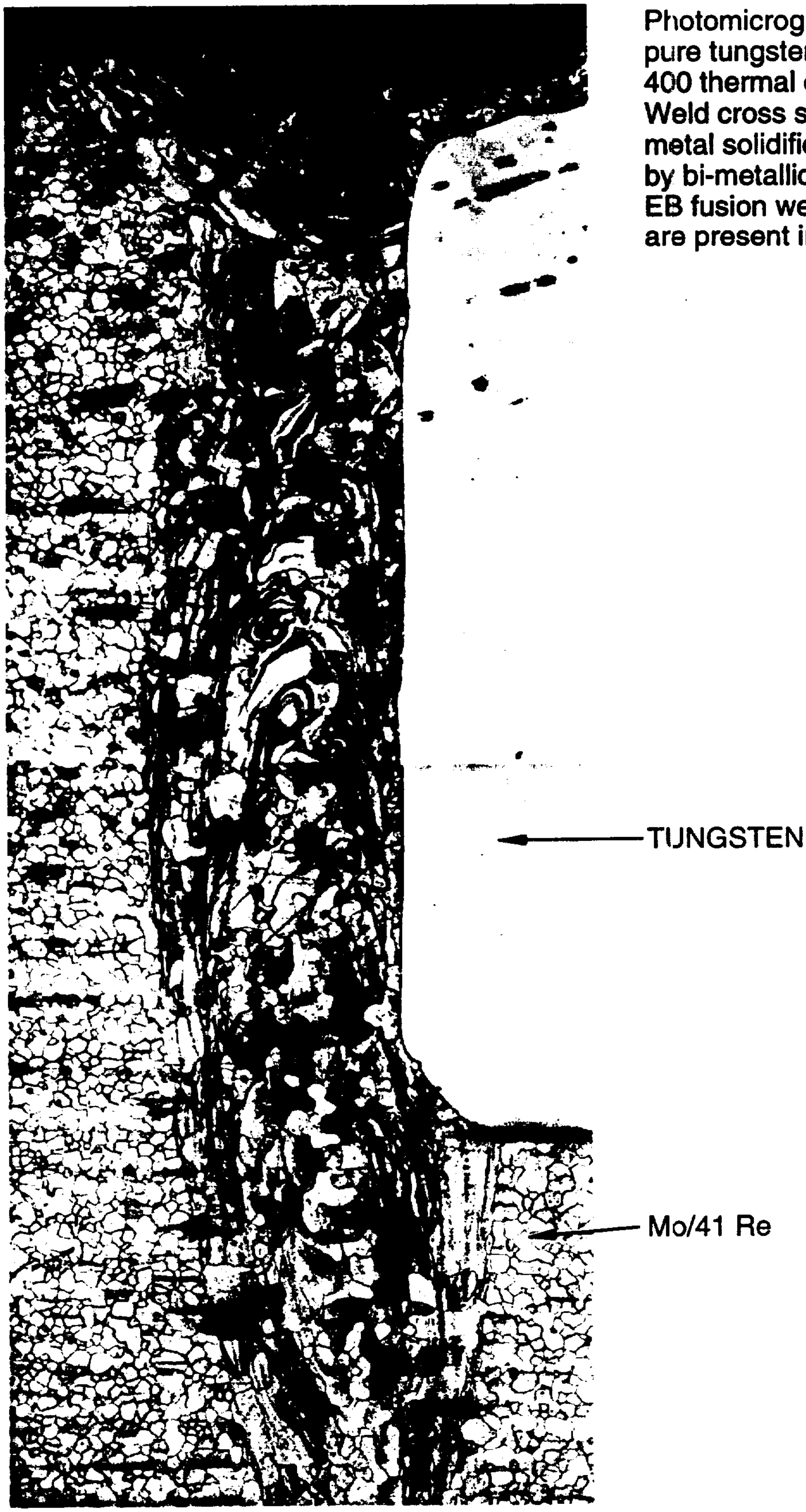
EB WELD JOINT: Mo/41 Re TO W/25 Re



50X, etched

Photomicrograph of a Mo/41 Re to W/25 Re EB weld following 400 thermal cycles to ~2200°F. Weld cross section reveals some solidification patterns similar to Figure 1, but to a lesser degree. Weld cross sections were found free of fractures.

EB WELD JOINT: Mo/41 Re TO W100



Photomicrograph of a Mo/41 Re to pure tungsten EB weld following 400 thermal cycles to ~2200°F. Weld cross section reveals weld metal solidification patterns caused by bi-metallic metal mixing during EB fusion welding. No fractures are present in either weld or HAZ.

5. Ease and repeatability of application
6. Low rate of evaporation

Many materials and application options were identified. Material choices included titanium carbide, silicon carbide, tantalum carbide, cupric oxide, zirconium di-boride, and several silicone based paints. The methods of application included chemical vapor deposition (CVD), physical vapor deposition (PVD), plasma spraying, and painting. After an initial screening process the following were selected for detailed evaluation: 1) CVD TiC; 2) PVD TiC; 3) plasma spray TiC; and 4) two high temperature paints.

Samples of each option were prepared using both Moly/41 Re and tungsten coupons. The sample surface characteristics were evaluated using SEM and the parts were then sent to an outside facility for emittance measurements. Emissivity measurements were made at ambient temperature per ASTM E-408 using a Gier-Dunkle DB 100 Infrared Reflectometer. Extrapolated estimates of the emissivity at 955 C were also made. This was achieved through measurement of the wavelength specific reflectances. These were then evaluated assuming discrete temperature levels using Planck's equation. A typical reflectance plot is shown in Figure 3-67.

Both paint options were eliminated due to poor adherence and the TiC PVD sample produced an unacceptable emissivity. The remaining options, TiC CVD and TiC plasma spray, were subjected to 100 thermal cycles from ambient to 980 C. SEM analysis and emittance measurements were repeated. The emissivity data measured before and after thermal cycling are summarized in Table 3-15. For TiC CVD and TiC plasma spray the measured emissivities were acceptable and remained stable through thermal cycling.

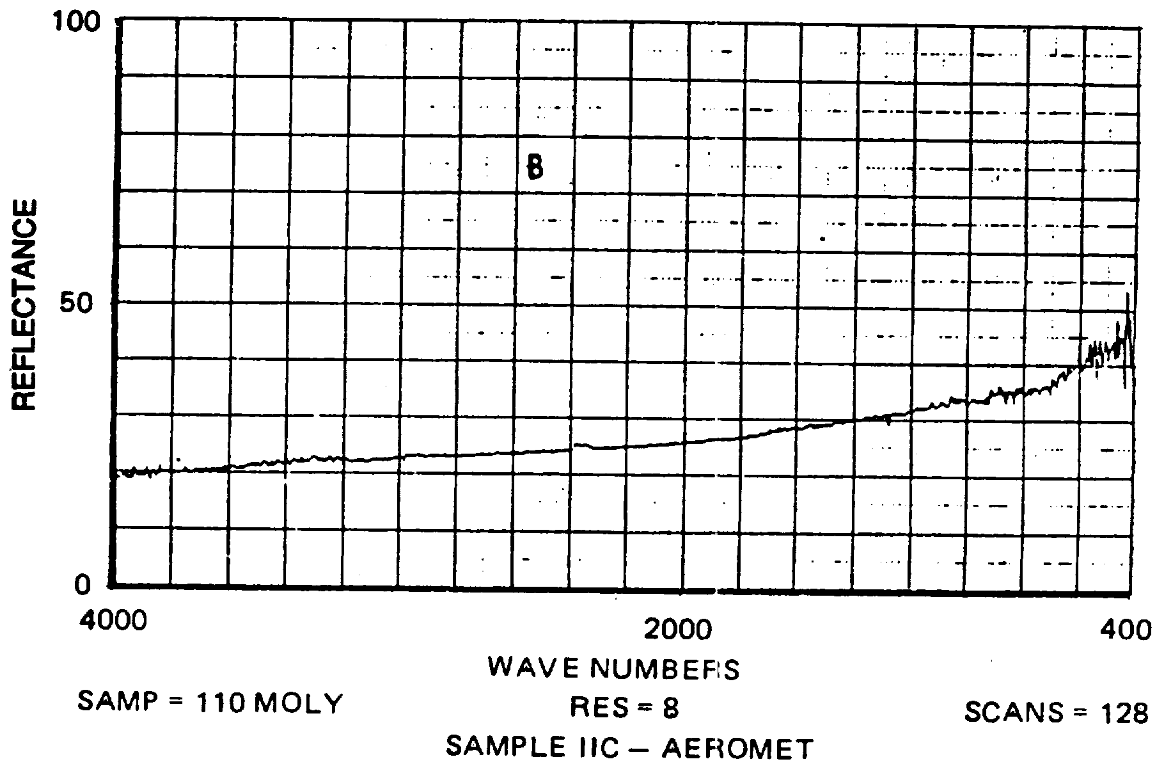
Table 3-15
HIGH EMISSIVITY COATING MEASUREMENTS

Coating	Substrate	ε @ 955°F (Extrapolated)		Notes
		Prethermal Cycling	Post-Thermal Cycling	
TiC CVD	W	0.705	0.657	
	Mo/41 Re	0.730	0.682	
TiC Plasma	W	0.766	0.810	
	Mo/41 Re	0.724	0.810	
TiC PVD	W	0.355	—	(1)
	Mo/41 Re	0.352	—	(1)
Paint #1	W	0.906	—	(1)
	Mo/41 Re	0.902	—	(1)
Paint #2	W	0.950	—	(1)
	Mo/41 Re	—	—	(2)

(1) These options eliminated due to poor ε or poor adherence before thermal cycling

(2) No Mo/41 Re sample prepared.

TYPICAL REFLECTANCE PLOT



• TiC PLASMA SPRAYING ON TUNGSTEN

Figures 3-68 and 3-69 show the surface characteristics of the CVD TiC and plasma spray TiC before and after thermal cycling at 500X. No signs of surface degradation or extensive evaporation were detected for either sample.

Although both options met the design criteria, plasma spray TiC was selected over CVD TiC because a significantly greater coating thickness could be achieved (100 microns vs. 10 microns), and because it would be easier to mask off surfaces that were not to be coated.

3.3.3.1.4 Arcjet Structural Analyses — Structural analyses were performed to show that the arcjet could satisfy typical launch vibration and thermal loading requirements. Finite element modelling techniques were used to predict natural frequencies and the response to random excitation. Adequate strength was demonstrated with positive safety margins calculated throughout the arcjet assembly. Additional analyses of the cathode positioning system, cathode insulator, and brazed barrel joint were also conducted assuming operational temperatures. Strength and displacement requirements were fulfilled in each of these cases.

The primary loads on the arcjet are in the form of random excitation transmitted through the support structure attachment points during launch. A random vibration specification representative of typical flight qualification levels was used for the analysis. The input spectrum is shown in Figure 3-70. The power spectral density (PSD) level of 0.2 G^2/Hz from 20 — 2000 Hz represents an integrated average acceleration of 19.9 g rms.

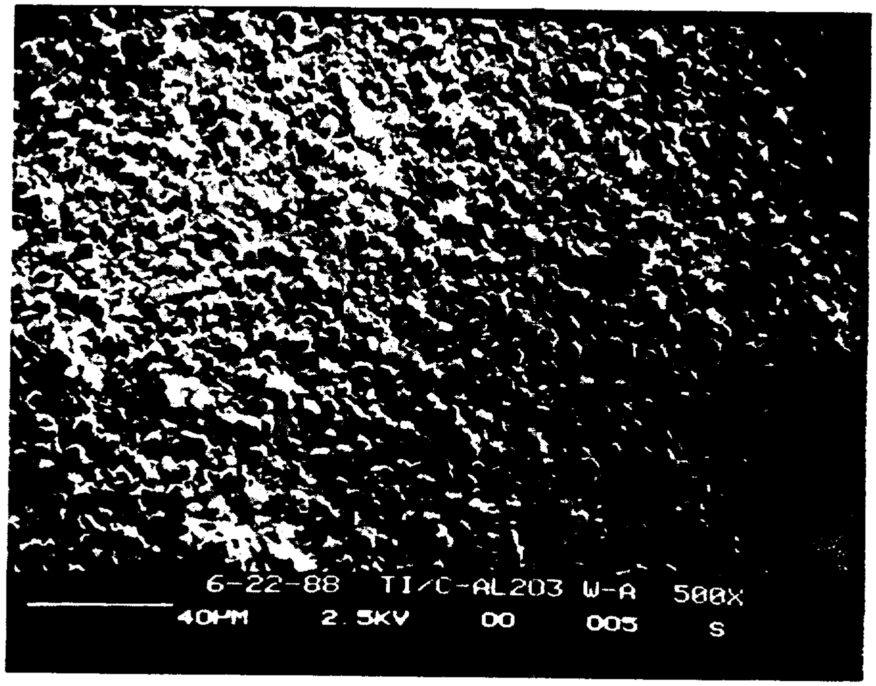
A NISA II finite element model was constructed and is shown in Figure 3-71. The model consisted of a total of 1460 elements. The five major substructures were the barrel, support structure, propellant valve, gas generator, and gas delivery tube. Most of the structure was modelled as thin shells. Tubing and thin bars were modelled using beam elements. The additional mass of the internal components was accounted for by the use of concentrated mass elements.

Structural responses to random excitation were determined. Resultant stresses in each of three orthogonal directions were computed. A typical stress contour is shown in Figure 3-72. Table 3-16 summarizes the predicted stresses and corresponding safety margins. The stresses presented are 3-sigma stresses, which represent a conservative measure of the expected stresses. The 3-sigma stresses were compared to the material yield strengths. With a factor of safety of 1.0 applied to the material strengths, positive margins of safety were still predicted at all locations. The lowest safety margin occurs at the base of the cantilevered barrel, where a value of 1.6 is predicted.

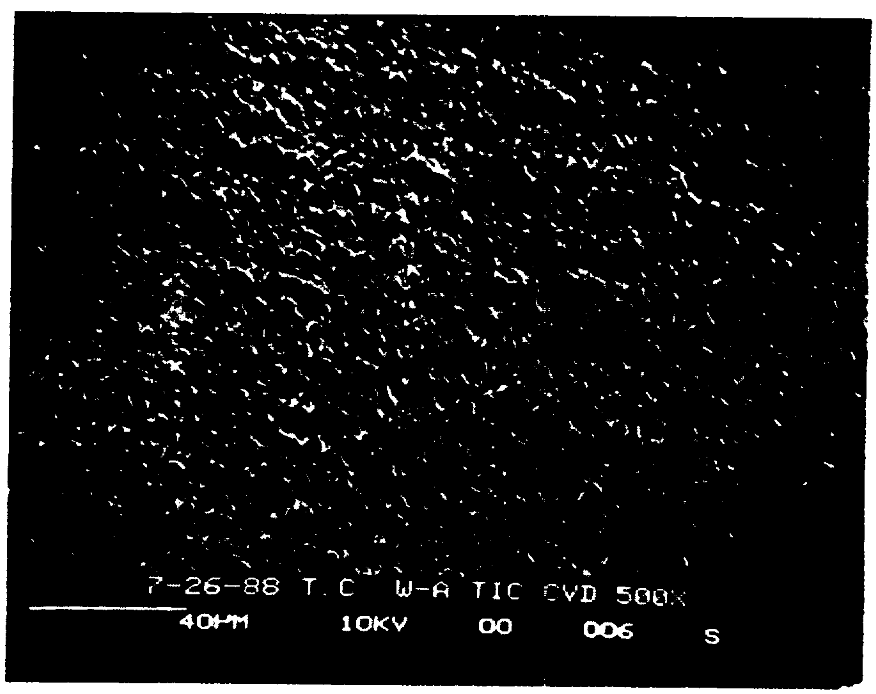
Natural frequencies and displacement mode shapes were also predicted in the frequency range of interest (0 – 2000 Hz). Fifteen modes, none of which induced excessive loading, were identified and are summarized in Table 3-17.

Three additional areas which resulted in stresses imposed during operation of the thruster were evaluated. The first was the proposed system of positioning the cathode. Calculations were performed to determine whether differential thermal growth of metallic and ceramic parts would permit excess travel of the cathode relative to the anode. The maximum predicted

CVD SAMPLE SURFACE CHARACTERISTICS

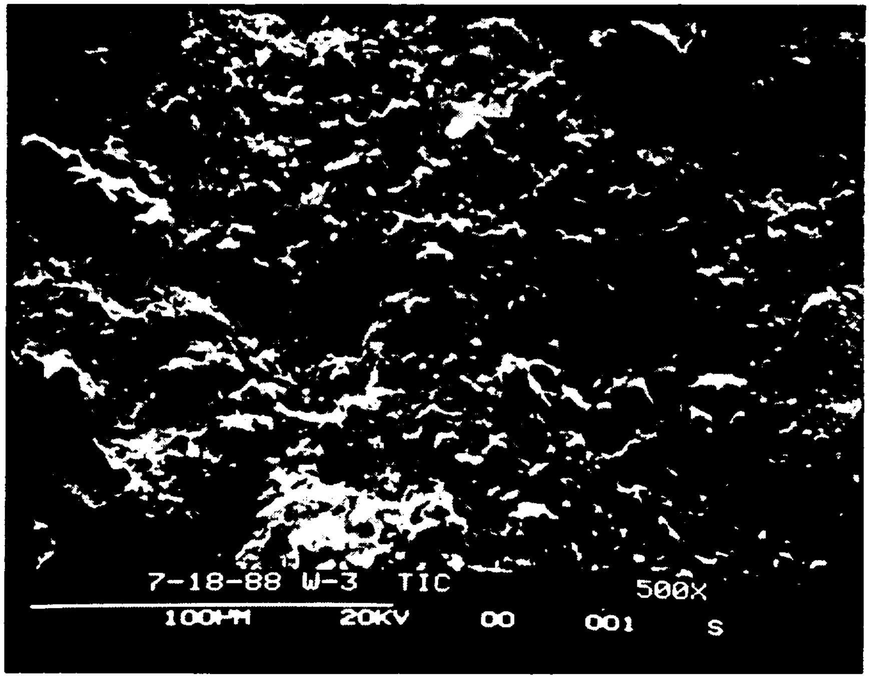


(a) TUNGSTEN SUBSTRATE, PRIOR TO THERMAL CYCLING

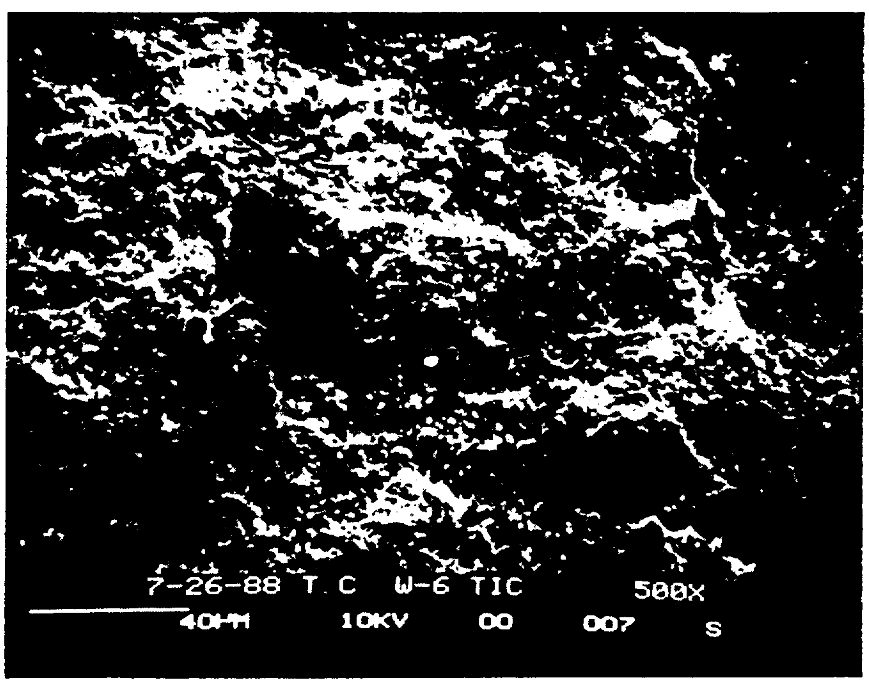


(b) TUNGSTEN SUBSTRATE, AFTER THERMAL CYCLING

TiC PLASMA SPRAY SAMPLE SURFACE CHARACTERISTICS

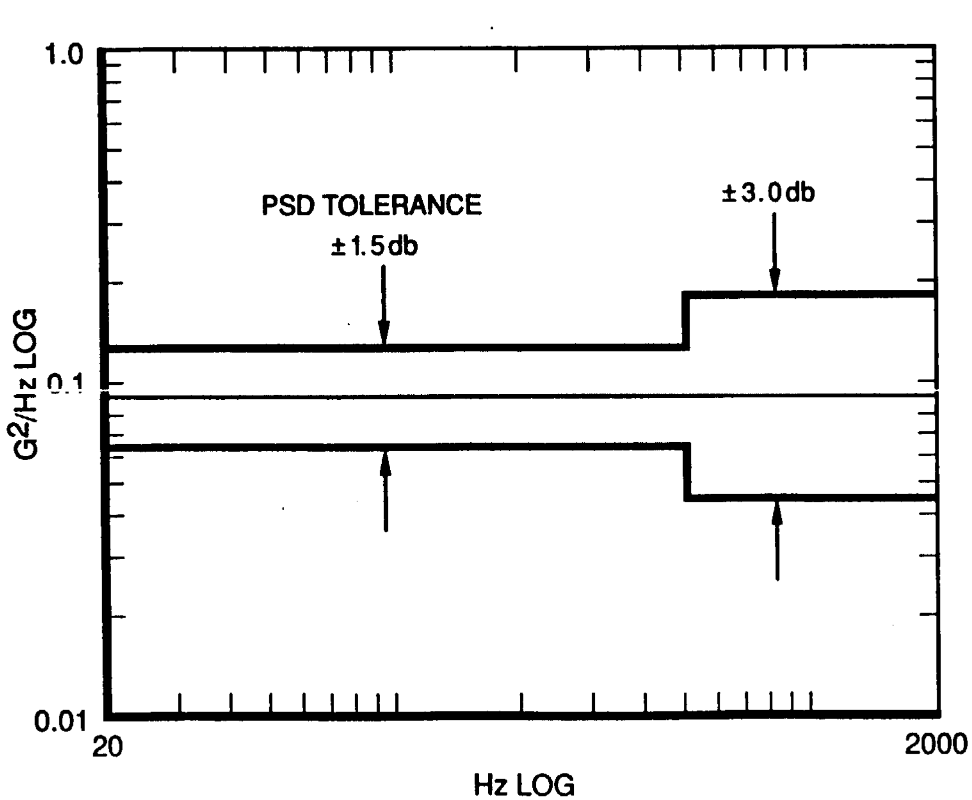


(a) TUNGSTEN SUBSTRATE, BEFORE THERMAL CYCLING



(b) TUNGSTEN SUBSTRATE, AFTER THERMAL CYCLING

ARCJET RANDOM VIBRATION SPECTRUM



Frequency Range	20-2000	
Duration Per Axis (sec)	120	
PSD (G^2/Hz)	20 – 500Hz	500–2000Hz
Level	0.2	0.2
Tolerance	± 1.5db	± 30db
Alarm Limit	± 1.5db	± 30db
Abort Limit	± 3.0db	± 6db
Overall (grms)		
Level	19.9	
Tolerance	±1.0 db	
Alarm Limit	21.8	
Abort Limit	22.3	
Roll Off (db/Octave)	12 (min.)	
Drive Clipping	3 Sigma	

Exploded View of Arcjet Finite Element Model

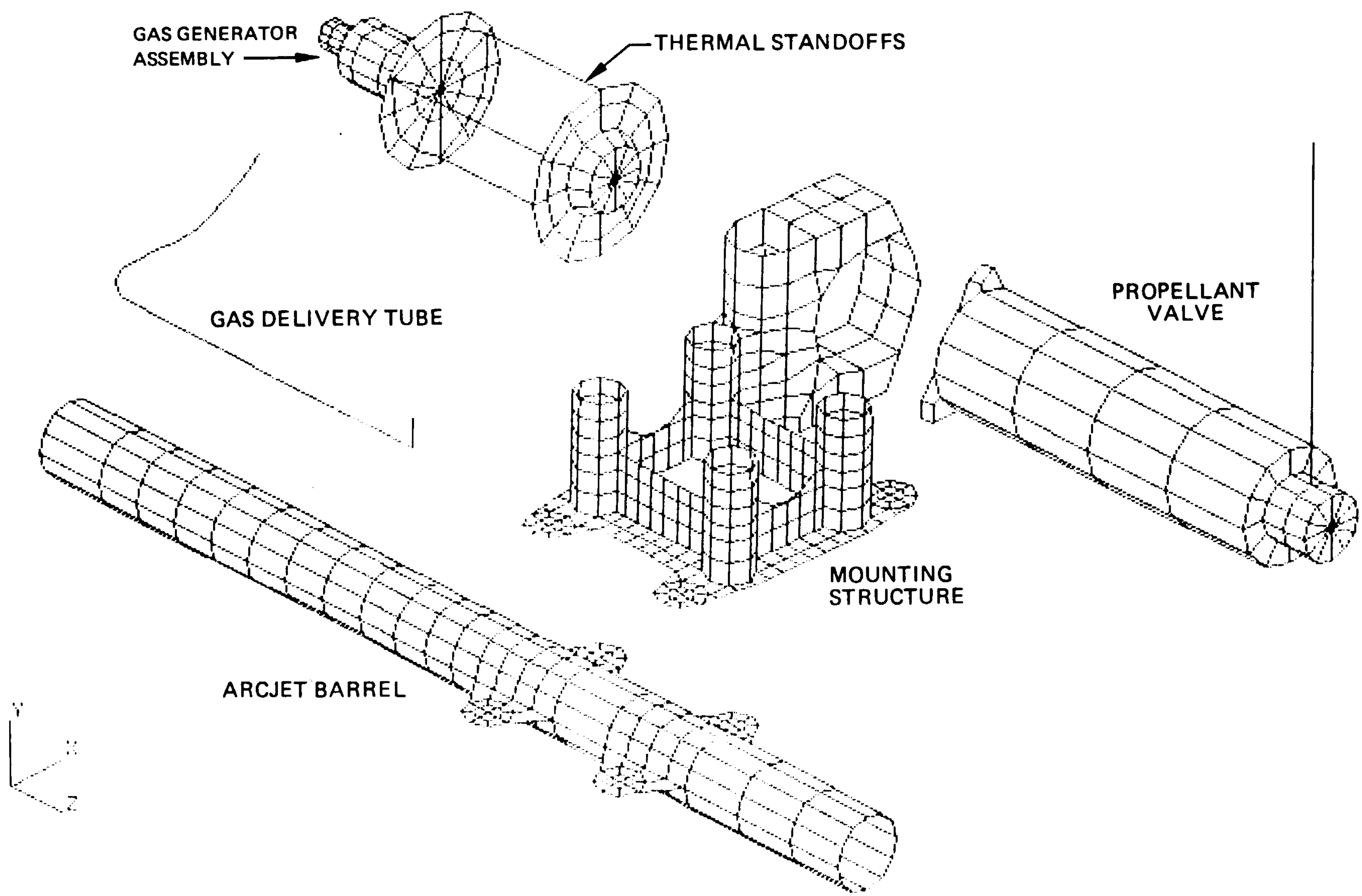


 Figure 3-71

ARCJET STRESSES DUE TO Y-AXIS RANDOM EXCITATION 3-SIGMA STRESS COMPONENT (BARREL BENDING STRESS)

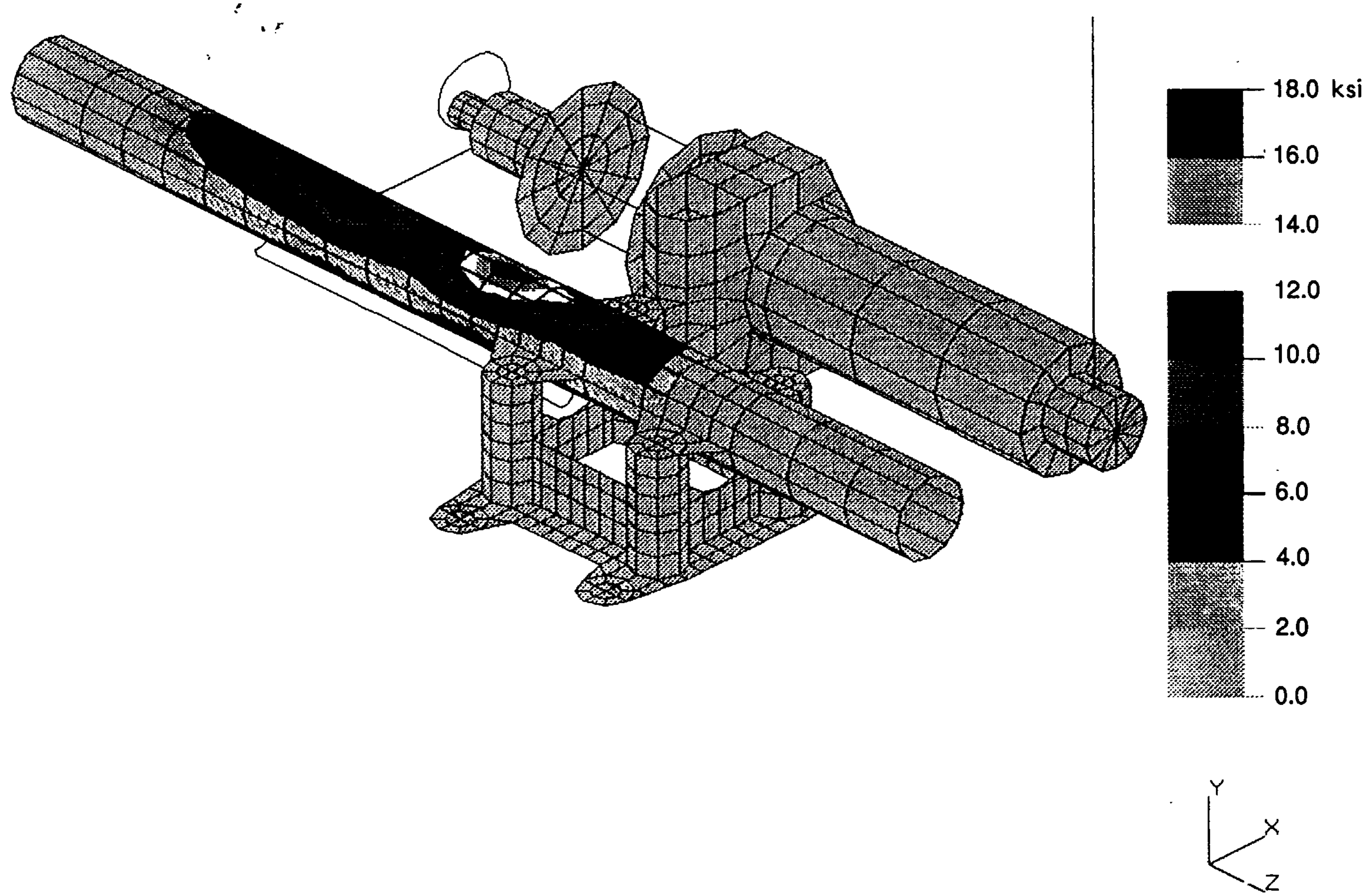


Figure 3-72

Table 3-16
THREE-SIGMA STRESSES AND MARGINS OF SAFETY BASED ON QUALIFICATION LEVEL RANDOM EXCITATION

Component	Location of Maximum Stress	Material	Material Yield Strength (ksi)	3-Sigma Stress (ksi)	Margin
Arcjet Barrel	Base of cantilevered section	Inconel 625	60	23.1	1.6
Support Structure	Mounting feet	Ti-6Al-4V	120	4.5	25.7
Propellant Valve	Inlet housing	CRES 430	45	1.9	22.7
Gas Generator Assembly	Chamber housing	Hastelloy B	48	4.0	11.0
Gas Delivery Tube	Curled section	Inconel 600	35	3.4	9.3
Thermal Standoffs	Base area	Inconel 625	60	9.3	5.5

FACTOR OF SAFETY = 1.0 ON YIELD

Table 3-17
FREQUENCIES AND MODES OF THE ARCJET ASSEMBLY

Frequency	Mode Description
261	Barrel Flexure (Y), Inlet Tube Flexure
269	Inlet Tube Flexure
270	Inlet Tube Flexure
293	Barrel Flexure (X), Inlet Tube Flexure
804	Gas Delivery Tube (Y)
933	Gas Generator (Y)
1001	Gas Generator (X), Gas Delivery Tube
1073	Gas Generator, Valve
1350	Gas Generator, Valve, Arcjet Barrel-Connector End Flexure (Y)
1476	Arcjet Barrel-Connector End Flexure (Y)
1608	Gas Delivery Tube (X)
1625	Gas Delivery Tube, Arcjet Barrel-Connector End Flexure (X)
1710	Gas Delivery Tube, Gas Generator
1883	Gas Delivery Tube, Gas Generator
1906	Gas Delivery Tube, Gas Generator

change was 0.0043 cm (0.0017 in.) which represents only a 7% change in the initial arc gap. Additionally, no high stresses resulting from restrained thermal growth were predicted.

The second area examined was bending of the alumina insulator sleeve which shields the cathode along a length of approximately 10 cm. It was found that the sleeve possessed sufficient flexibility and strength to withstand bending due to vibration. A margin of safety of 1.7 was predicted.

The third area of concern was the mid-section of the arcjet barrel, where the Inco 625 and Mo/41 Re are brazed together. Stresses due to unequal thermal growth of the two materials during thermal cycling were evaluated. At a maximum predicted temperature of 410°C a margin of safety on yield of 4.4 was calculated for the weaker Inco 625. The strength and cycle life of the actual braze joint was demonstrated in thermal cycle testing of the braze samples.

3.3.3.1.5 Arcjet Design Description — The engineering model arcjet thruster is shown in Figure 3-73. The fluid resistor acts as an orifice to reduce the spacecraft propulsion system supply pressure to levels required for desired thruster flow rates. The feed pressure blowdown and the arcjet performance versus flow rate relation are used to size the fluid resistor to obtain the required mission average specific impulse. The propellant valve is a dual seat, solenoid type. The dual seats are independently actuated which provides redundant capability to close the valve. Extensive RRC heritage has been established with this valve on numerous hydrazine thrusters. The gas generator used is a standard low flow unit used on a large number of RRC low thrust N_2H_4 engines.

The hermetic passthrough design resulted from a joint development effort conducted with the manufacturer, Reynolds Industries. The passthrough connector and mating cable assembly are discussed in detail in Section 3.3.3.1.6.

The mounting structure is constructed of Titanium 6Al-4V for a superior strength to weight ratio and good thermal isolation. A girth clamp retains the valve/GG assembly to the mounting structure. The clamp has elastomeric isolators located at the interface to the valve to provide additional thermal isolation and to dampen vibration loads.

As discussed previously, the electrode and vortex injector configurations were defined as a result of RRC and NASA development work.

A section view of the arcjet is shown in Figure 3-74. The assembly features a relatively simple overall geometry with a minimum number of parts. The thin walled sections have been optimized for thermal and structural design requirements. The overall length is 22.0 cm and the anode diameter is 2.54 cm.

The arcjet body assembly is comprised of three parts. The barrier tube and anode are joined by an EB weld. This subassembly is coated with the TiC emissivity coating. The barrier tube features an integral vortex injector. Prior to welding, a lapped face seal is made between the injector and anode surfaces to insure gas flow through the injector is maintained. Following the coating process, the manifold is joined to the barrier tube via an induction braze.

Alignment of the cathode is achieved through very close runout tolerances on the cathode, anode, vortex injector and cathode insulator. The cathode/anode gap is maintained through retention of the cathode within an insulator stack which is further held in place by a retention nut. By retaining the cathode over as short a length as possible, thermal growth relative to the anode is minimized. Cathode support at the opposite end of the thruster is provided by the support block.

Arcjet Thruster Design Description

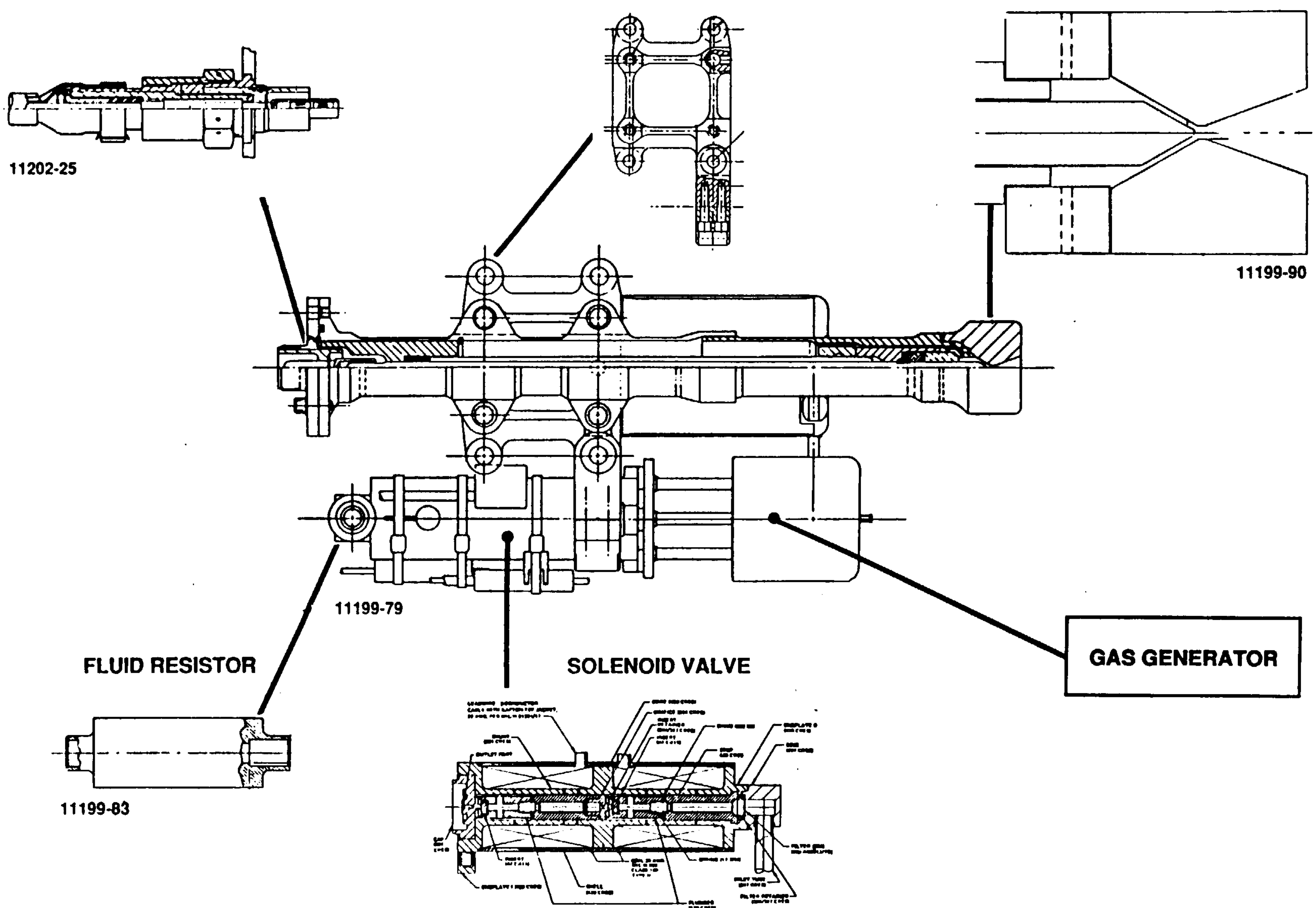


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Figure 3-73

ARCJET CROSS SECTION

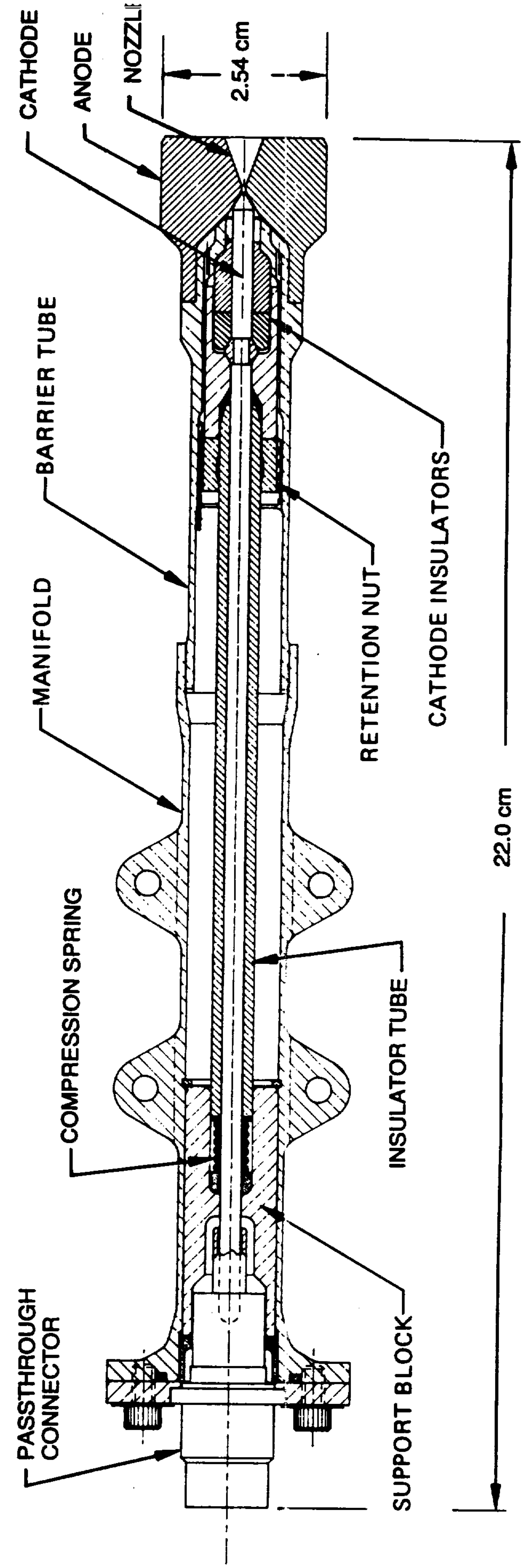


Figure 3-74

The electrical passthrough features a spring clip connection which slides over the cathode end. The passthrough is welded to a closure flange. The flange uses a bolted connection and O-ring seal which simplifies disassembly of the thruster. For a flight configuration, the flange would be welded to insure sealability.

A weight summary of the AJT is shown in Table 3-18. Two arcjet assemblies (S/N's 1 and 2) were completely assembled for testing. One is shown in Figure 3-75.

Table 3-18
ARCJET WEIGHT SUMMARY

Component/Subassembly	Weight (kg)
• Propellant valve, including heater, fluid resistor, and inlet adapter	0.26
• Gas generator — includes heater, thermocouple, and shielding	0.07
• Arcjet body — manifold, barrier tube/injector, anode, cathode, internal components and connector	0.37
• Mounting structure	0.10
• Assembly hardware	0.03
Total (kg)	0.83

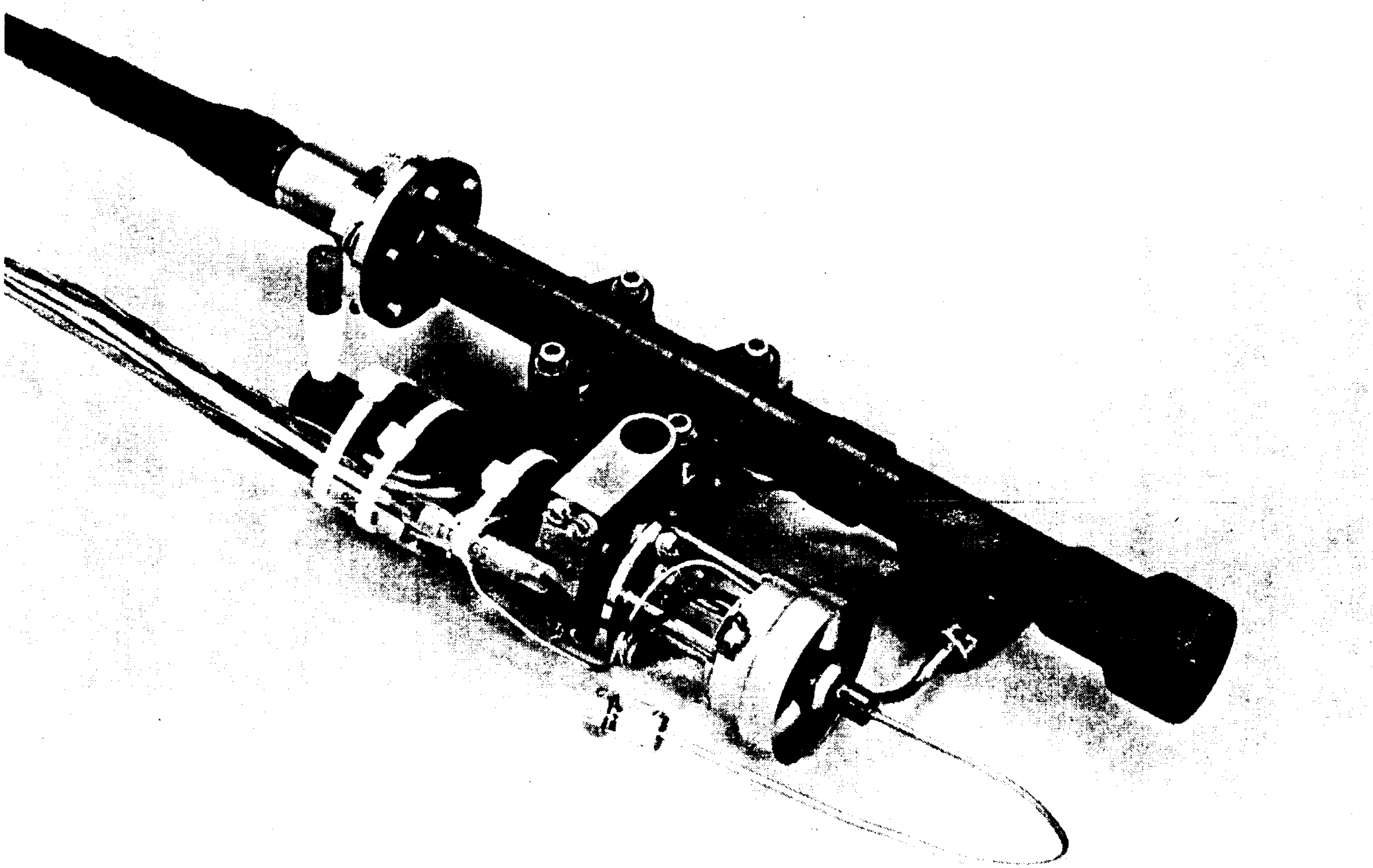
3.3.3.2 Power Cable Assembly/Hermetic Passthrough

The cable and connectors necessary for power transmission from the PCU to the arcjet must withstand the high voltage generated during the PCU start up pulse, conduct the steady state current level without overheating due to excessive resistance, operate at 200 C for extended periods, and meet typical spacecraft environment requirements. The primary functional requirements of the assembly are listed below:

Current:	Steady state current carrying capacity to 18 amps
Voltage:	Voltage withstand rating to 4000 V
Corona:	Breakdown resistance at both test and space vacuum conditions
Temperature:	Steady-state rating of 200°C maximum at the thruster connection
EMI:	Meet 461 requirements.

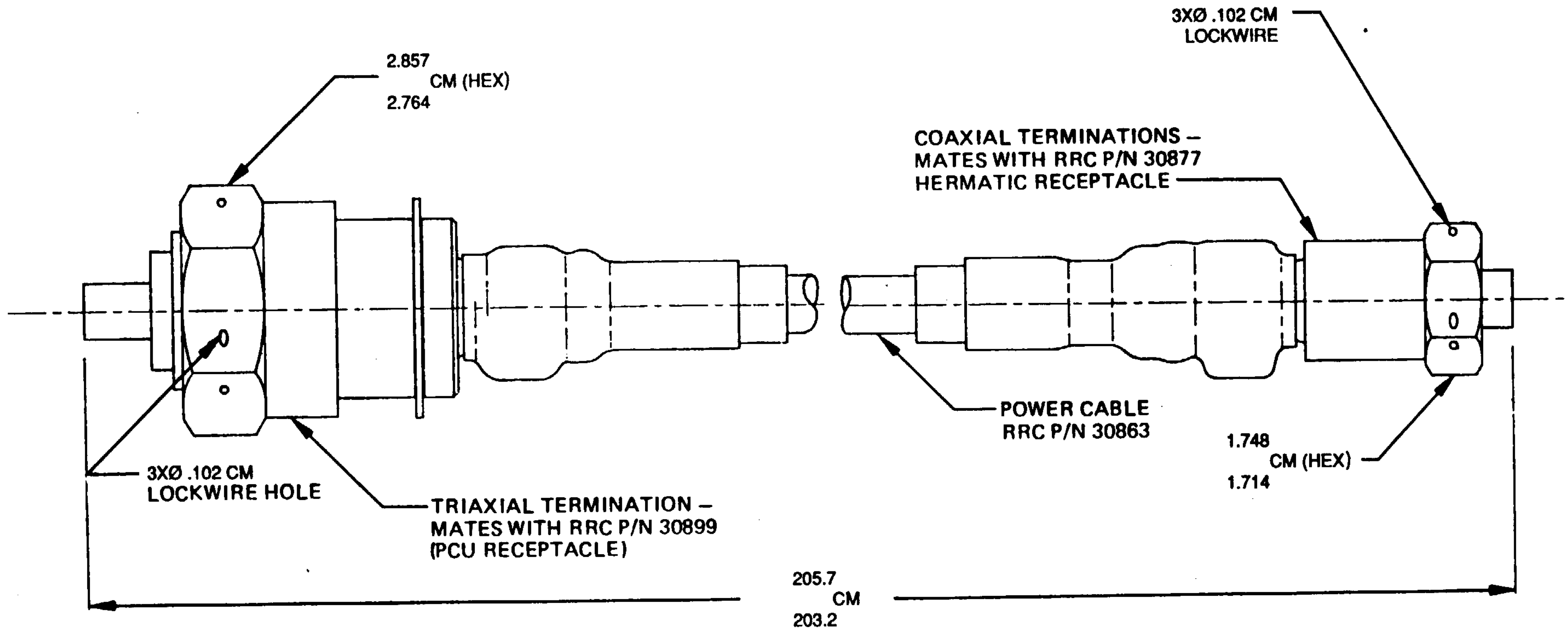
Development of a custom cable assembly was required. The design approach consisted of three separate components: a 2 m long triaxial cable with connector plugs attached at each end; a PCU receptacle which is attached to the PCU chassis and mates with the cable connector; and a hermetic connector/passthrough which is mounted to the arcjet and mates to one end of the cable connector assembly. These are shown in Figures 3-76, 3-77, and 3-78, respectively.

ENGINEERING MODEL
LOW POWER HYDRAZINE ARCJET



CABLE ASSEMBLY

RRC P/N 30898
RRC COMPONENT SPEC. CS-0224



PCU Receptacle

RRC P/N 30899-501
RRC COMPONENT SPEC. CS-0225

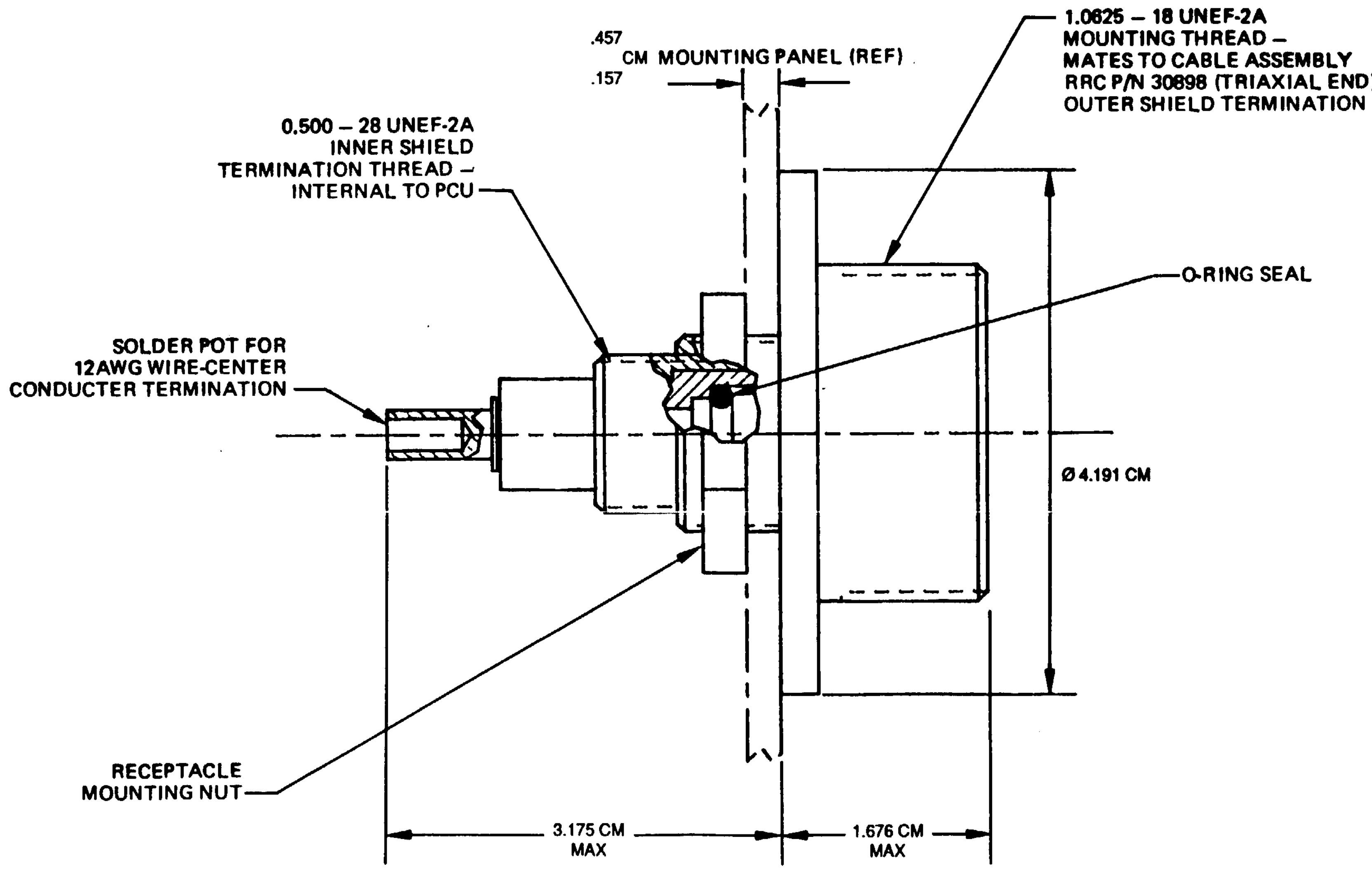


Figure 3-77

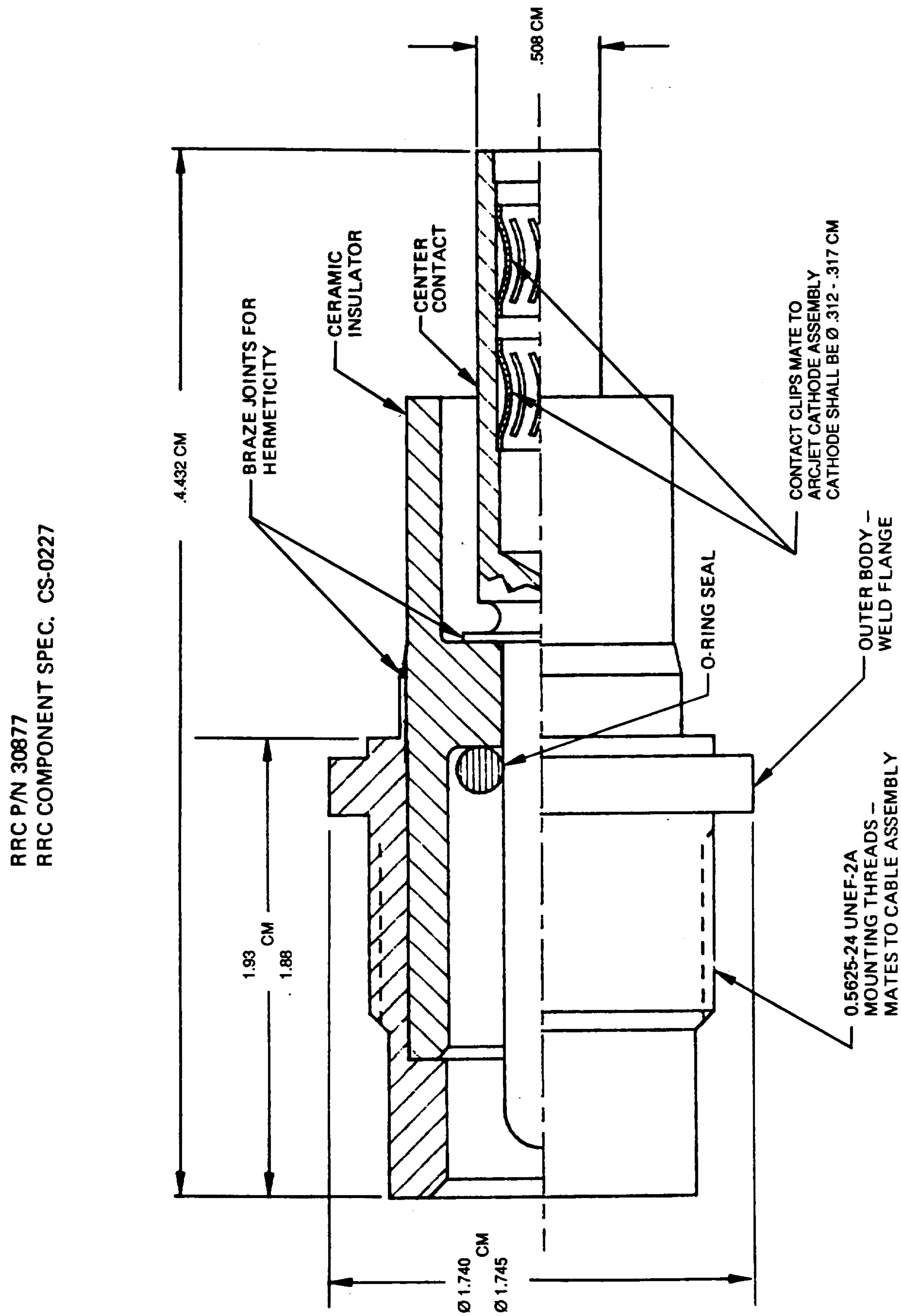

RRC P/N 30877
RRC COMPONENT SPEC. CS-0227
4.432 CM
.508 CM
BRAZE JOINTS FOR HERMETICITY
CERAMIC INSULATOR
CENTER CONTACT
CONTACT CLIPS MATE TO ARCJET CATHODE ASSEMBLY CATHODE SHALL BE Ø .312 - .317 CM
O-RING SEAL
OUTER BODY – WELD FLANGE
0.5625-24 UNEF-2A MOUNTING THREADS – MATES TO CABLE ASSEMBLY
1.93 CM 1.88
Ø 1.740 CM Ø 1.745

Figure 3-78

The cable materials of construction are shown in the section view of Figure 3-79. The center conductor is the negative output from the PCU and is connected to the cathode via the mating hermetic passthrough. The inner cable shield is used to conduct the current back from the anode to the PCU. A second outer braid was also included as an electrostatic EMI shield. This shield is connected to the anode return shield at the arcjet connector, and to the PCU chassis at the opposite end.

The hermetic passthrough is attached to the body of the arcjet thruster. A mounting flange, which is EB welded to the outer body of the passthrough, is bolted to the arcjet body and sealed with an O-ring. The threaded passthrough body mates with the cable plug and the cathode connection is made through the contact clips. The contact clips are gold plated to reduce contact resistance.

The brazed construction of the passthrough provides a hermetic seal. The ceramic insulator has sections which are metallized, and these areas are furnace brazed to the center contact and the outer body. The O-ring shown provides additional corona breakdown resistance.

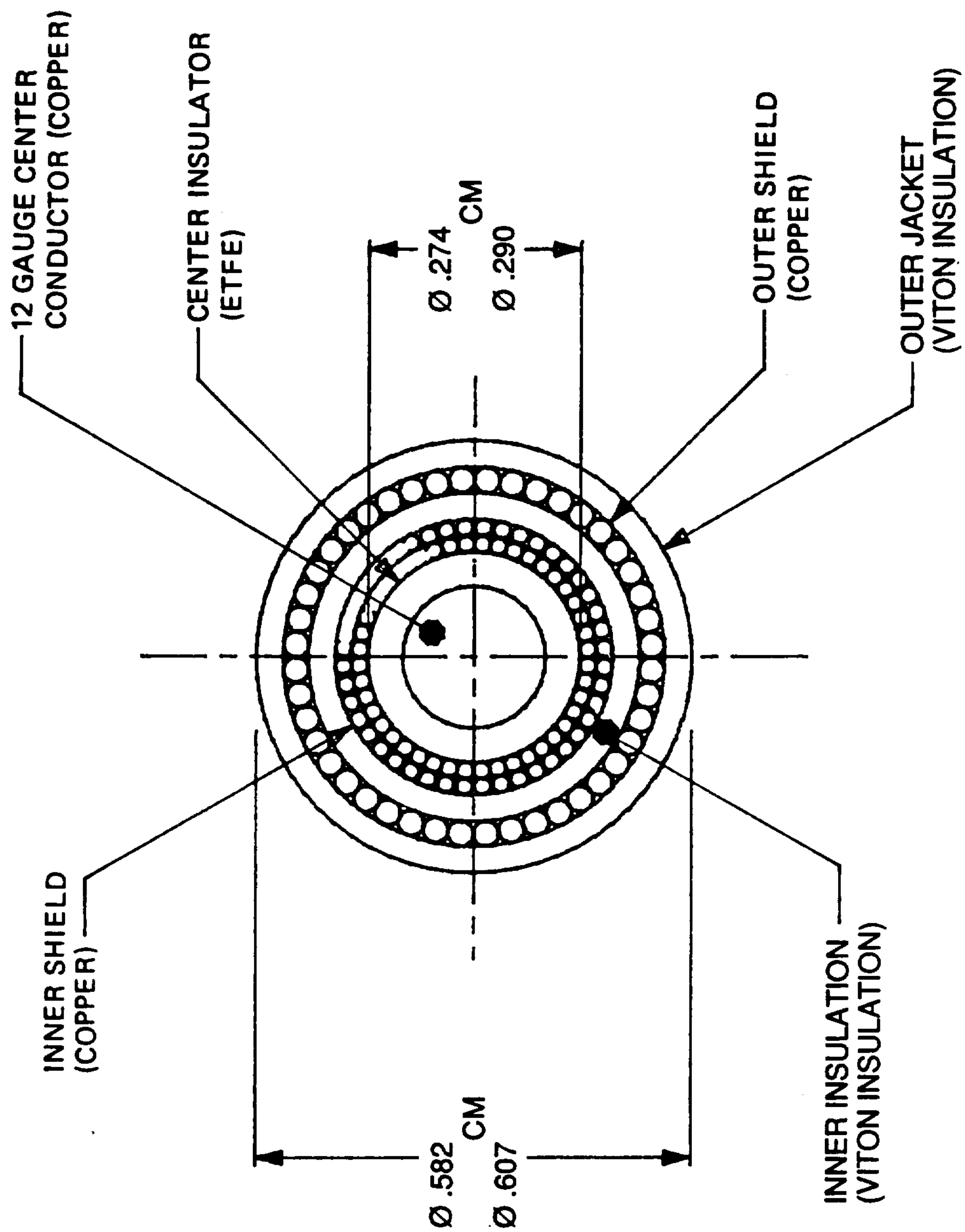
Development activities focused on the corona design and on reducing the connector contact resistance. Corona can occur in high voltage connectors due to ionization of localized gasses under high electric fields. This can lead to an arc breakdown between conductors. In geosynchronous orbit, the pressures are so low that corona events are very unlikely. However, outgassing from the cable materials or spacecraft surface ionization can create an environment in which corona can occur. In addition, the ground test environment is more severe due to the limitations on pumping capability.

As a result, the assembly was designed for all pressures between atmospheric and space vacuum. Silicone O-rings are installed in the passthrough and PCU receptacle to prevent breakdown from occurring. The separation distances required between conductors would have been 5 to 10 cm at the 50 mTorr vacuum level of the test cells if the O-rings were not used.

Extensive electrical contact resistance cycle testing was conducted at RRC on the spring contact design between the hermetic passthrough and the arcjet cathode. A development connector was fabricated and tested in a thermally controlled nitrogen environment. A steady state current of 15 A was delivered through the assembly and thermal cycle testing was conducted at temperatures ranging from ambient to 260°C. The connector design temperature, established through thermal modelling predictions of the arcjet thruster, was 204°C. Current and voltage were measured and the contact resistances calculated as a function of cycle life and temperature. Connector temperatures were also measured.

The initial configuration consisted of the 0.3175 cm diameter, 2% thoriated tungsten cathode rod inserted into the spring clip. Testing of this configuration showed that contact resistances increased substantially at the higher end of the tested temperature range. To improve contact resistance at the connection, the cathode end was gold plated. The resistance was reduced from 4 milliohms to less than 1 milliohm at the maximum temperature. The increase in connector temperature due to self heating at these levels of contact resistance were well

TRIAXIAL POWER CABLE
CROSS SECTION



within acceptable levels. The cathode plating process was refined and incorporated into fabrication of the EM arcjet cathodes.

After fabrication and assembly, the cable/connector assembly was subjected to acceptance testing conducted by the manufacturer per RRC specification requirements. The test requirements are listed below in Table 3-19. Four complete assemblies were fabricated and tested. No test failures were recorded.

Table 3-19
CABLE ACCEPTANCE TEST REQUIREMENTS

Item	Acceptance Criteria
1. Insulation Resistance	> 50 Megohms @ 500 vdc
2. Conductor Loop Resistance	< 50 milliohms
3. Dielectric Withstand	<10 microamps @ 6000 vdc, 1 minute, 50 mTorr (per MIL-STD-101F Method 301)
4. Mating Cycles	< 10% change in contact resistance following 10 cycles
5. Life Cycles	400 temperature cycles, 20° to 200°C (one assembly only)
6. Corona	< 15 picocoulombs average at 6000 vdc for 3 minutes (Biddle Test)
7. Hermetic Passthrough Leakage	< 1 x 10^{-7} scc/sec GHe @ 300 psid

3.3.4 Power Conditioning Unit Development

The PCU design which was fabricated and tested under this program is a lightweight, switching DC-DC converter supply which provides conditioned power for both start up and steady state operation of the arcjet. The functional and performance design requirements which were established for this unit are summarized in Table 3-20.

Of the main PCU elements, one of the most critical is the startup circuit. The start characteristics are important to electrode erosion. Up to 4000 volts are required to initially establish the arc at full mass flow rate. The PCU must then provide an initial sustaining current that is high enough to maintain an ionizing path, but not high enough to cause anode erosion. This initial current level is below the steady state level, so the PCU then ramps up the current. Current overshoot above the steady state level must be avoided, as this can also create excessive localized heating which causes erosion.

The steady state output must maintain control of the arc load which has a negative slope impedance. This is achieved through a cycle-by-cycle current regulating control loop.

Table 3-20
PCU Functional/Performance Requirements

Functional Requirements

a. Start the arcjet.
b. Provide a stepped up voltage from the spacecraft power source to the nominal 100 vdc required by the arcjet.
c. Maintain stability of the negative impedance arc.
d. Maintain constant power output over both the output voltage range of the arcjet (due to propellant blowdown) and supply voltage range (due to battery letdown).
e. Provide command/telemetry link to the spacecraft

Performance Requirements

a. Startup voltage	4000 V minimum
b. Start current overshoot	< 20% of steady state level
c. Input power	1400 W
d. Input voltage	25 to 32 vdc
e. Power regulation	3%
f. Output voltage	85 to 120 V
g. Output current	10.5 to 14.8 A, 18 A max.
h. Output current ripple	20% peak-to-peak

Power conversion efficiency is important for two primary reasons. The first is that power availability on a communications spacecraft is at a premium. Thrust output from the arcjet is maximized by optimizing the amount of power available. The second is that spacecraft thermal design constraints dictate that minimal heat be rejected by the PCU. For this design, an allowable conductance at the PCU interface of 0.16 W/cm2-C was assumed. The minimum efficiency goal was 90%.

These are several of the important design issues which were addressed during development of the PCU. Design and manufacturing were carried out by Watkins-Johnson Company in San Jose, CA. The basic design approach was based largely on the NASA Lewis Research Center 1 kW PCU design. The effort consisted of fabrication and test of a development unit followed by fabrication of two engineering model (EM) flight weight PCU's.

3.3.4.1 PCU Design

A block diagram of the PCU is shown in Figure 3-80. A functional description of these major elements follows.

ARCJET PCU BLOCK DIAGRAM

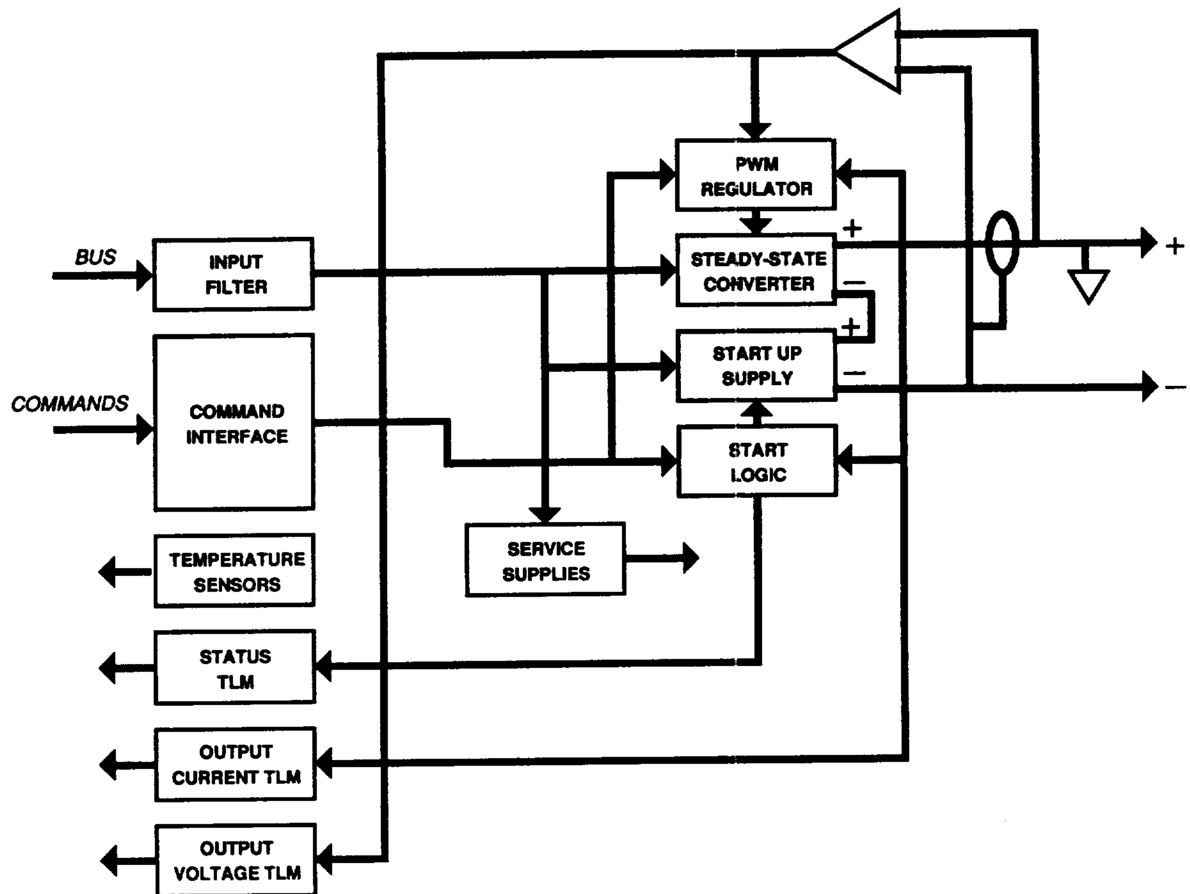


Figure 3-80

The main functional components of the power processing circuitry are the input filter, steady state converter, and pulse width modulated regulator. A damped, two-stage LC input filter is used for two purposes. The first is to attenuate current ripple that is generated by the main converter and the second is to reduce ripple that may be conducted to the PCU via the power source connection.

The steady state converter is a buck-derived push-pull regulator with the inductor on the output. The critical elements of the converter are the center-tapped transformer, which provides input/output isolation, and the main switching devices. These elements see the highest peak currents in the unit and are the source of the largest proportion of power losses.

The PWM regulator controls the switching frequency (32 kHz) and duty cycle to maintain constant output power, and it controls the current level transition to steady-state following arc breakdown. The main buck inductor current is fed back to the controller, which eliminates the effects of the output inductor from the small signal response and regulates the current limit. There is a slower secondary loop which compares the output current with a signal that is inversely porportional to the output voltage and establishes the cycle-by-cycle current limit needed to maintain constant power.

The start circuit consists of an additional winding coupled with the output inductor. To start the arcjet, a switch in series with the input power supply is closed which allows current to charge the winding to a pre-set energy level. The switch is then opened which causes the inductor magnetic field to collapse and produces a voltage pulse. A voltage is generated across the mutually coupled output inductor and the arcjet high enough to cause breakdown. Once breakdown occurs, the initial arc is sustained by the energy that was built up in the start winding. The main converter then increases the current level to the steady state value as determined by the constant power loop.

The command/telemetry interface consists of on/off commands, an input undervoltage shut-off, and analog telemetry signals for arcjet voltage and current. When the bus voltage is applied, the low-voltage converter becomes active and the command logic is reset. Once an "on" command is received, the main converter is activated which provides an open circuit voltage across the arcjet of about 200 vdc. After a 100 millisecond delay the start circuit is energized and the arcjet is started.

The "off" command shuts down the main converter output power. If the input voltage falls below 24 vdc, the undervoltage shut-off switches out the input power to the unit. Once the voltage is increased, the PCU will automatically reset and be ready for another "on" command.

One of the two engineering model PCU's fabricated is shown in Figure 3-81. The unit is 23.5 x 18.4 x 8.3 cm and weighs 4.52 kg. The chassis was made of magnesium to save weight. Input power is delivered through a pair of studs. Output power is passed through the specially designed triaxial connector described in an earlier section. The command and telemetry interface is through a multi-pin connector. The unit is vented to prevent outgassing induced corona and the high voltage circuits are potted to provide sufficient dielectric withstand capability. The heat generating components are conductively sunk to the base plate to dissipate waste heat.

3.3.4.2 Development Unit

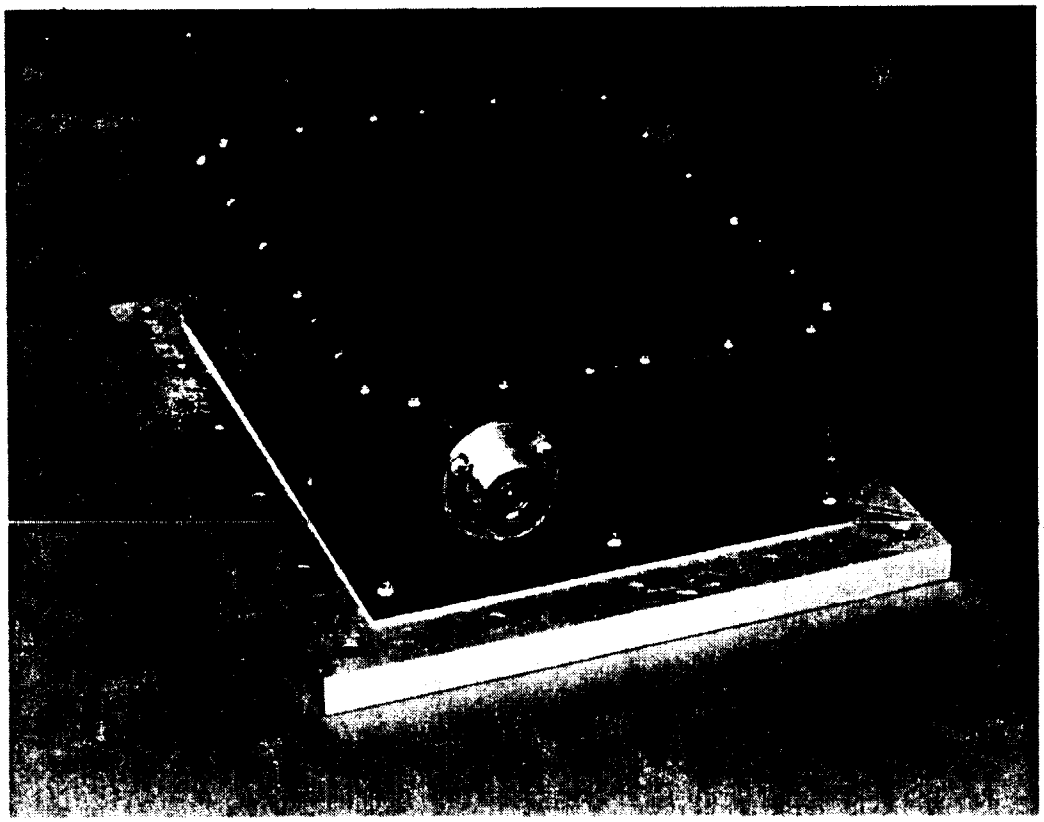
Fabrication and assembly of a development unit was conducted to establish preliminary performance characteristics of the PCU design. The development unit was different from the EM design in several ways. It had a less compact layout of circuit components to enable easy access to make modifications, it utilized a standard connector for the output power instead of the custom triaxial connector, and the thermal design was not optimized which prevented testing the unit under vacuum. The development PCU is shown in Figure 3-82. The unit dimensions are 12.7 cm x 20.3 cm at the base and 17.8 cm high.

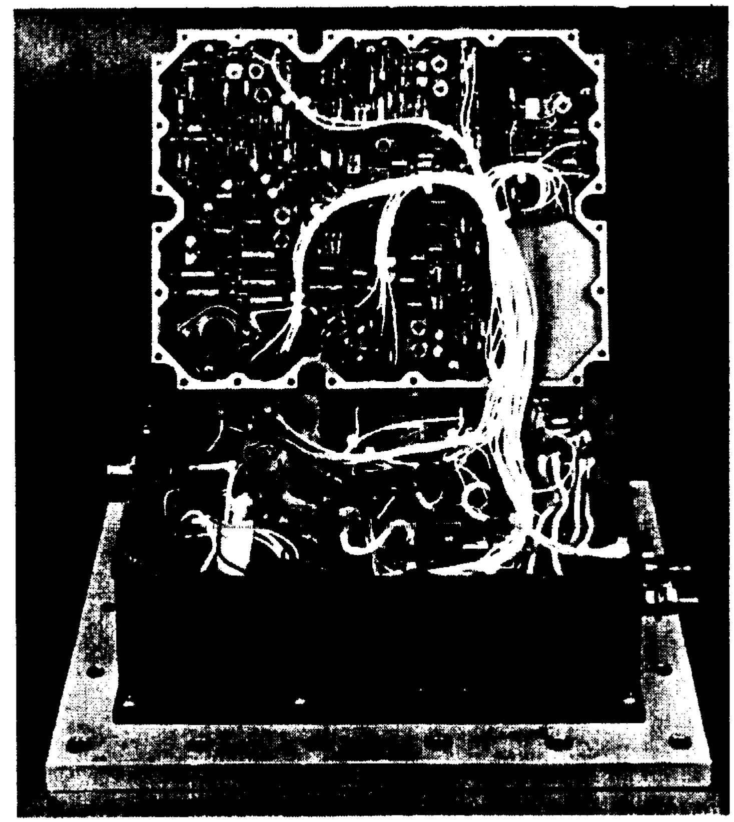
Extensive testing of the development PCU was conducted at RRC while running an arcjet. A summary of initial testing is shown in Table 3-21

Startup and stable steady state operation of the PCU were achieved with little difficulty. Performance characteristics observed are discussed below.

SYSTEM DEVELOPMENT

- POWER CONTROL UNIT





- DC-DC STEP UP CONVERTER, 30 VDC ⟶ 120 VDC
- 9.25" x 7.25" x 3.25"
- MASS - 9.95 lbm
- POWER DENSITY - 8 W/in^3

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Figure 3-81

DEVELOPMENT PCU

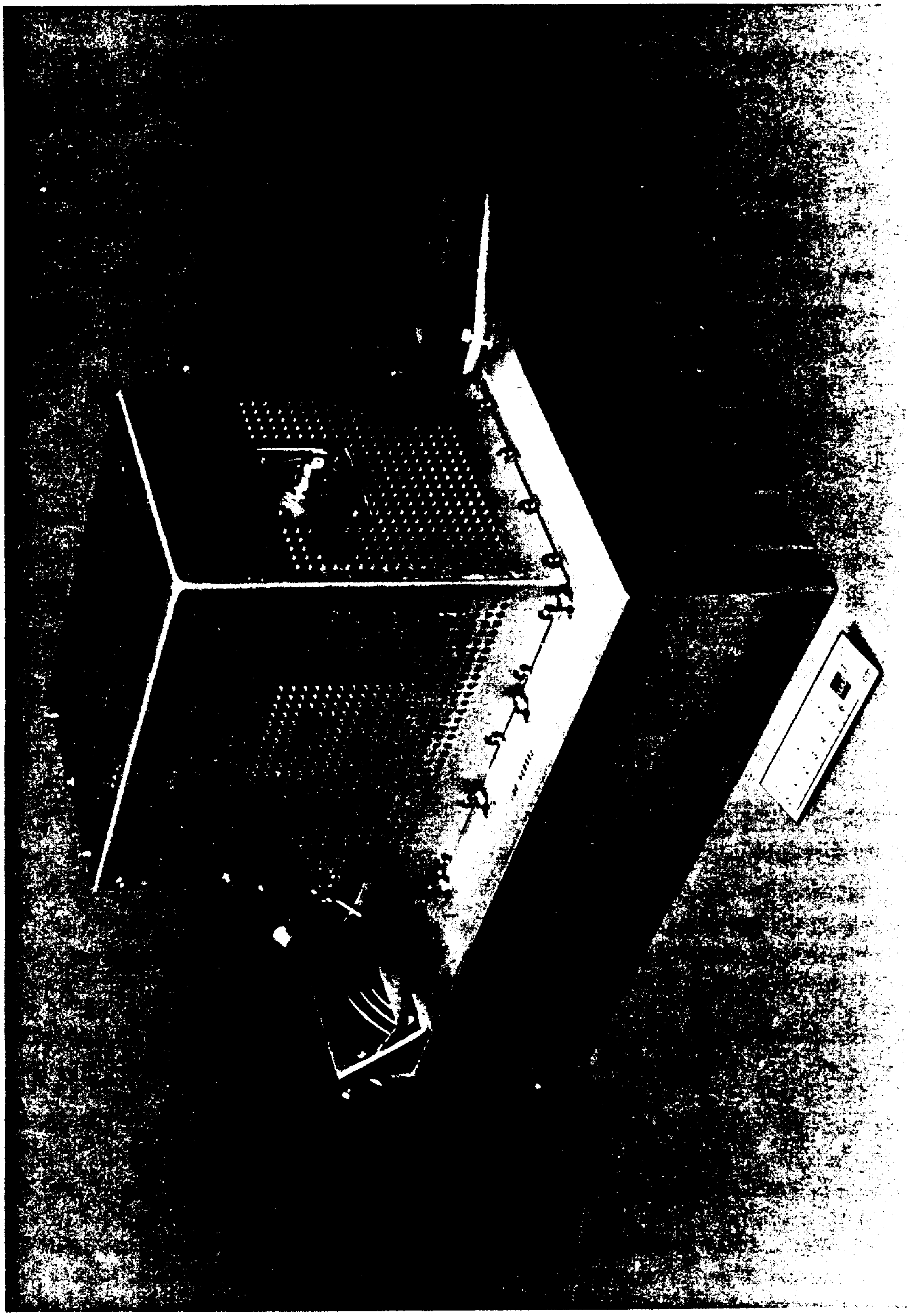


Figure 3-82

Table 3-21
DEVELOPMENT PCU TEST SUMMARY

Specification	RRC Requirement	Measured
Startup	4000	3000
1. Start Voltage Peak (Volts)		
2. Start Voltage Rise Time (sec)	10 – 30	2
3. Start Current Ramp Time (msec)	0.1 – 1.0	0.2
4. Current Overshoot (% of steady state)	20%	94% 32 amps peak, 16.5 amps SS, 20 msec.
5. Current Undershoot (amps)	1 A SS value	small, <1 A
Steady State	0.08 A ±10%	0.125 A 8% total, 1.2 pk. to pk.
6. Conducted Current Ripple (amps) Input Ripple (amps) Output Ripple (% of SS)		
7. Efficiency	90%	85.8 to 92.8 (90 to 104 output V)
8. Constant Power Regulation	3% variation	2.6% 1,258 W to 1,292 W, measured over flow range 4.0 – 5.4 x 10^{-5} kg/s and input voltage 25 to 32 V.

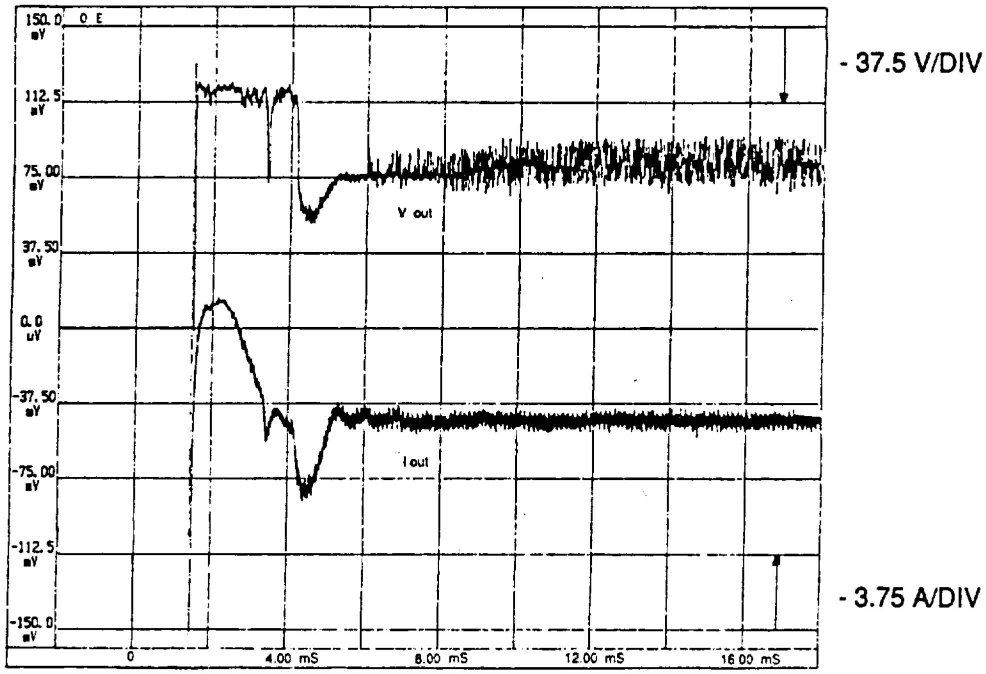
Start Circuit

Initial measurements showed that the current overshoot on startup was excessive. The approach to controlling the ramp-up was modified significantly to utilize a "bi-stable" method of current regulation. Additionally, the initial steady state set point for current was fixed for approximately one second at 12 amps instead of being established by the constant power requirement. This prevented high initial current levels at low flow rate operating conditions of the arcjet. A comparison of the output current waveform during startup before and after these changes is shown in Figure 3-83.

The voltage and current levels achieved during the starting pulse are critical to achieving reliable start up. Initially, the drive circuitry for the FET switches controlling the start pulse was inefficient. The result was that too low an energy level was developed in the start winding and an unacceptable number of failed start ups occurred. These were due either to insufficient voltage generated for arc breakdown or low current levels after breakdown which failed to sustain the discharge. An example of the latter case is shown in Figure 3-84. Further changes were incorporated to eliminate these problems.

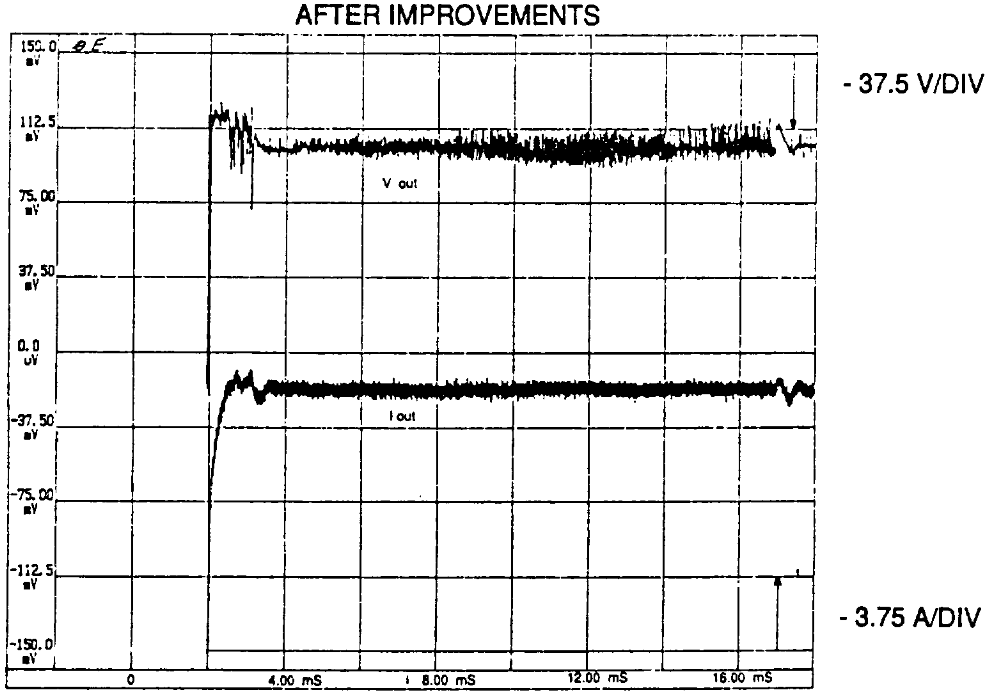
DEVELOPMENT PCU STARTUP WAVEFORMS

BEFORE IMPROVEMENTS

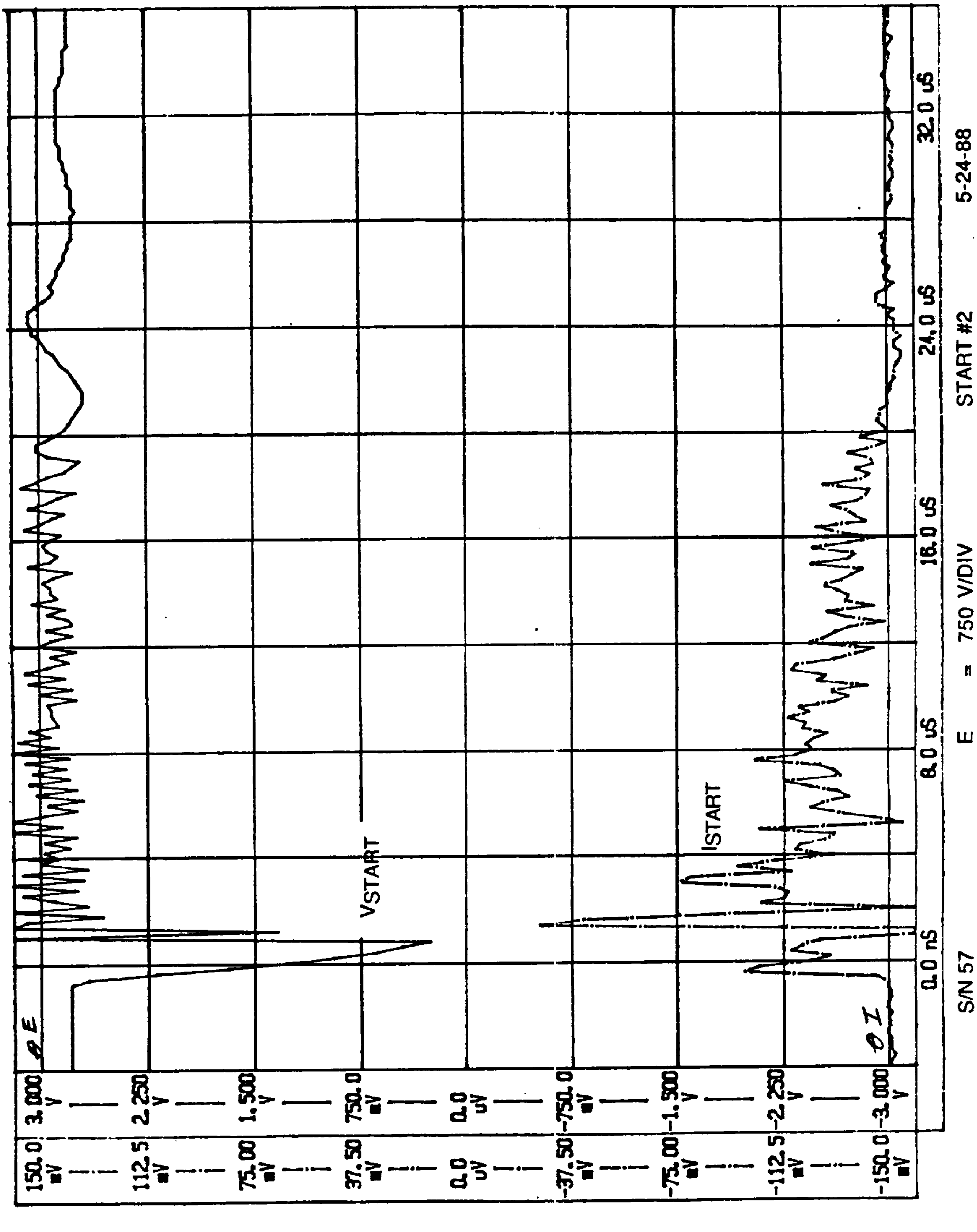


V out = 37.5 V/div
I out = 3.75 A/div

AFTER IMPROVEMENTS



PCU STARTUP FAILURE - LOW INITIAL I



Throughout the process of modifying the start circuit a total of 1500 starts were accumulated on a single arcjet. No performance or stability changes to the thruster occurred as a result of the multiple starts. Additionally, no sparks or other forms of erosion were observed while testing.

Once an optimized start circuit configuration was obtained, a start up test was conducted on the benchmark arcjet. This thruster had an identical electrode and vortex injector configuration to that selected for the EM arcjet.

During this test, the arcjet was started, allowed to run until the arc stabilized (a duration of 1 to 10 seconds), and stopped for a 4 minute cooling period prior to repeating the process. The operating flow rates and starting rate of reliability are shown in Table 3-22. Start up occurred on the first pulse attempt in 94% of the 300 total starts. The remaining 6% required 1 or 2 additional pulses.

Table 3-22
DEVELOPMENT PCU START UP TEST DATA

Flow Rate (kg/s)	1st Pulse Starts	Repeated Attempt Starts
3.2×10^{-5}	73	2
3.6×10^{-5}	74	1
4.5×10^{-5}	71	4
5.4×10^{-5}	64	11
Total	282	18

Efficiency

Efficiency data from the final development unit design over the full arcjet operating range are shown in Table 3-23. Measurements were slightly below 90% at most operating points. The efficiency scaled with output voltage, as is shown in Figure 3-85. Hence, greater losses were experienced at higher output current. This is caused by higher $I^2 \times R$ losses when the power converter FET switches are on and higher losses in the magnetics during FET turn-on and turn-off.

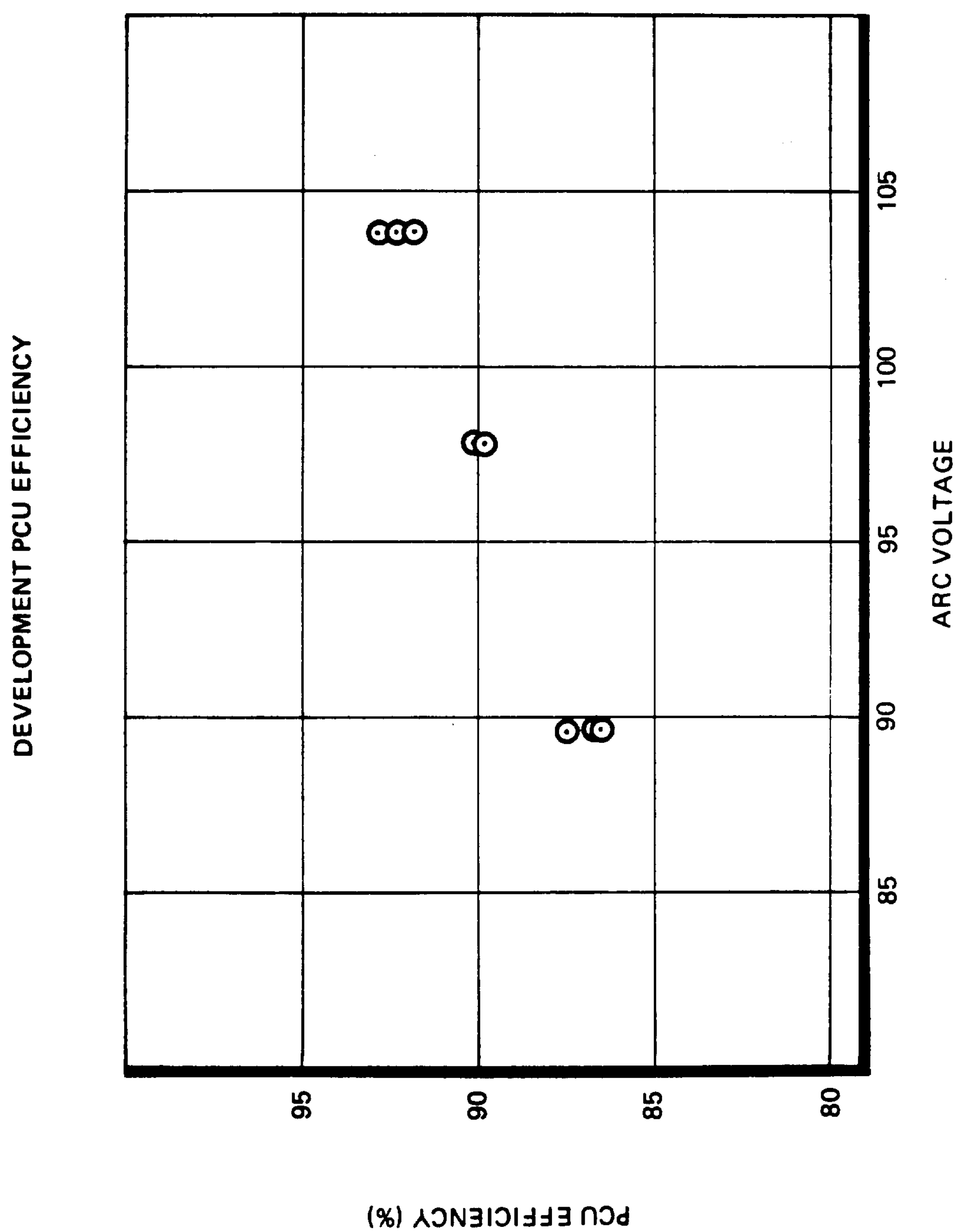
The initial efficiency measurements, however, were not this high. Efforts to improve the efficiency started with characterizing the losses. Switching losses in the Gentron power FET's caused more than half of the total losses. Figure 3-86 shows that during each cycle, the largest proportion of losses (81%) occurred during the turn-off of the power FET's.

Several improvements were made to the PCU design to improve the efficiency, as summarized in Table 3-24. Final efficiency measurements of the EM units are shown in the ATP test data. The changes incorporated are discussed below.

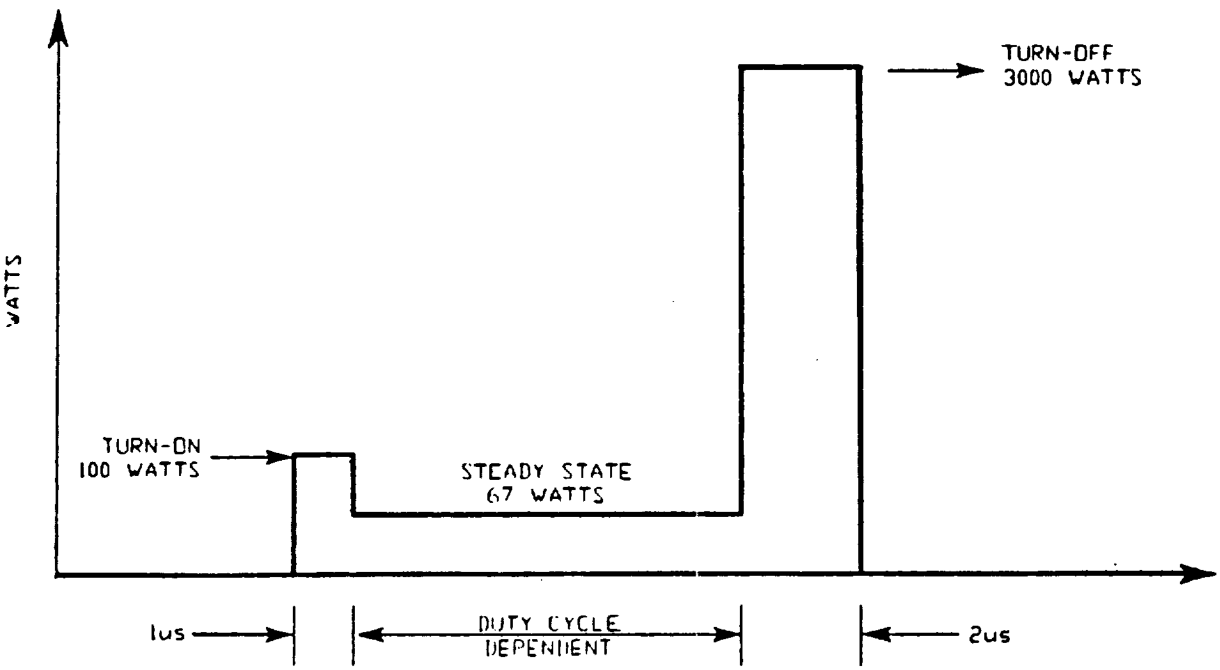
Modification A — The FET switching speed was increased substantially. The turn-off time was reduced from 2 microseconds to 300 nanoseconds. This dropped losses in the FET's by

Table 3-23
ARCJET DEVELOPMENT PCU EFFICIENCY MEASUREMENTS

Data Point #	1	2	3	4	5	6	7	8	9
Mass Flow Rate (kg/s)	4.0×10^{-5}	4.0×10^{-5}	4.0×10^{-5}	5.5×10^{-5}	5.5×10^{-5}	5.5×10^{-5}	4.7×10^{-5}	4.7×10^{-5}	4.7×10^{-5}
Input V (V)	32.3	28.1	25.3	32.1	28.1	25.3	32.3	28.1	25.3
Input I (A)	45.0	51.5	57.8	43.8	49.8	55.0	43.8	50.5	56.0
Input P (W)	1454	1447	1462	1406	1399	1392	1415	1419	1417
Output V (V)	89.9	89.7	89.5	104.0	104.2	104.2	98.0	98.0	97.9
Output I (A)	14.0	14.1	14.1	12.4	12.4	12.4	13.0	13.0	13.0
Output P (W)	1259	1265	1262	1290	1292	1292	1274	1274	1273
PCU Efficiency (%)	86.6	87.4	86.3	91.7	92.3	92.8	90.0	89.8	89.8


DEVELOPMENT PCU EFFICIENCY
PCU EFFICIENCY (%)
ARC VOLTAGE
80
85
90
95
85
90
95
100
105

PCU SWITCHING LOSSES



	LOSSES/CYCLE
TURN-ON	1.0×10^{-4}J
STEADY STATE	1.3×10^{-3}
TURN-OFF	6.0×10^{-3}
TOTAL	7.4×10^{-3}J

ASSUMING A 0.416 DUTY RATIO (30 VOLT INPUT— 70 VOLT OUTPUT AND 20kHz)

TOTAL SWITCH LOSS = 148 WATTS

81% IS LOST DURING TURN-OFF

Table 3-24
ARCJET PCU EFFICIENCY IMPROVEMENT ACTIVITIES

Power Sink	Dissipation (Watts)	Modifications and Results			
		Mod	Resulting Dissipation	Mod	Resulting Dissipation
Gentron MOSFETs	160	A1	40	B1	40
Snubber	50		140		15
Power Transformer	50	No Change		B2	80
Windings	20				10
Core	15				55
Stray	15				15
Output Components	25	A2	21	No Change	
Diodes & Inductor	15		15		
Snubber	10		6		
Input Filter	17	No Change		No Change	
Capacitors (ESR)	6				
Inductors	11				
Large: 1 ea x 3 W					
Small: 2 ea x 4 W					
Miscellaneous	6	No Change		No Change	
PCU TOTAL	308		274		179
Efficiency (%) (worst-case)	78.0%		80.4%		87.2%
HARDWARE STATUS	**DEVELOPMENT PCU (ACCEPTANCE TEST)**	**BREADBOARD (EXPERIMENTAL)**			

about 120 watts. Unfortunately, another result was that higher losses occurred in the snubbers placed across the FET drain and source to control voltage spikes. The net decrease in losses was only about 30 W.

Modification B — Methods to allow energy recovery in the snubbers were then incorporated. A cut C-core was also used in place of a torroidal core in the power transformer to reduce the leakage inductance. The net improvement achieved with these changes is also shown in Table 3-24. These changes reduced the losses by almost 130 W from the original configuration.

EMI

EMI testing was not planned until the EM units were completed. Conducted and radiated emissions were to be measured per MIL-STD 461 and 462. Laboratory testing with the development unit did, however, provide preliminary information on the EMI performance of the PCU.

Current ripple on the input power leads was about 50% in excess of the specification limits. This indicated a possible problem with the input filter design. An additional limitation of the input filter which was noted was a tendency to draw excessive power during startup. This caused a problem at the low end of the required input voltage range, where the high current demand caused a voltage drop from the Sorensen DC power supply to occur. This caused a shutdown of the PCU from triggering the undervoltage trip.

Test experience indicated that the command and telemetry lines were not sufficiently isolated. The command lines were found to be susceptible to low levels of external noise. Unintentional startup of the unit would occur when control signals to energize valves in the propellant system were activated. Filtering was installed external to the unit to alleviate this problem.

The telemetry lines were found to be conducting significant levels of noise energy with a fundamental frequency at the PCU switching frequency. These emissions caused amplifier error in the test instrumentation and made accurate data acquisition difficult.

Concern over the overall EMI performance of the PCU design was raised as a result of this preliminary testing. Modifications to both the input filter and command/telemetry grounding were made during fabrication of the EM PCU's. Additionally, it was expected that with these units, the layout of components and packaging into the flight chassis would improve the EMI characteristics.

3.3.4.3 Engineering Model PCU

PCU Acceptance Testing

Table 3-25 shows the acceptance test matrix used by Watkins-Johnson to verify EM PCU performance prior to RRC receival. Qualification level vibration levels were equivalent to those specified for the arcjet. Thermal vacuum testing was conducted at both extremes of the required operating range (-15 to 65 C). Where operational testing of the units was conducted, a resistive load was used in place of an arcjet.

Table 3-25
ACCEPTANCE TEST MATRIX: ENGINEERING MODEL PCU

Mode	Test Function	Baseline Functional	Vibration Sine/Random	Post-Vibe Functional	Thermal Vacuum	EMI/EMC	Final Functional
Transient Operation	Voltage Current Peak	X		X$^{(2)}$	X		X
	Voltage Rise Time	X		X$^{(2)}$	X		X
	Current Ramp	X		X$^{(2)}$	X		X
	Current Overshoot	X			X		X
	Current Undershoot	X			X		X
	Transition to Constant Power	X		X$^{(2)}$	X		X
	Constant Current	X		X$^{(2)}$	X		X
Interface Operation	Command Verification	X		X$^{(2)}$	X		X
	Telemetry Verification	X		X$^{(2)}$	X		X
Steady-State Output	Power Regulation	X			X		X
	Efficiency	X		X$^{(2)}$	X		X
	Output Current Ripple	X			X		X
	Input Current Ripple	X			X		X
	EMI/EMC					X$^{(2)}$	
	Nonoperating		X$^{(2)}$				

(2) Conducted on PCU S/N 002 only.

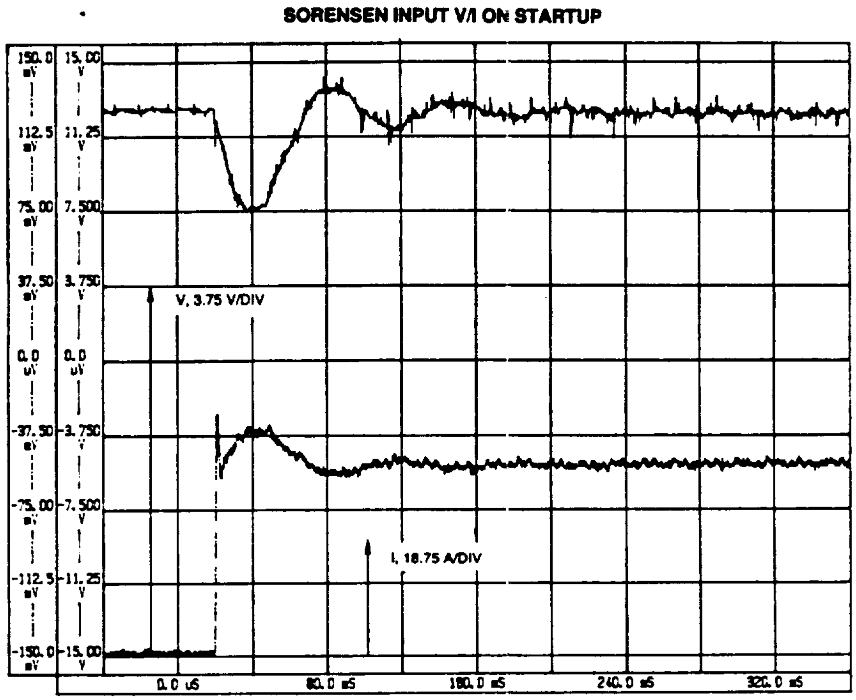
Notable deviations made to the initial test plan for the S/N 001 unit were to waive qualification vibration and EMI tests. Fabrication schedule delays made these exceptions necessary so that RRC system integration and testing could be conducted.

A summary of the S/N 001 results is shown in Table 3-26. Data were taken at temperatures of -15 C, 25 C, and 65 C. Performance during thermal vacuum testing showed no deviations from ambient test results. Efficiency was improved slightly from the development unit but was still slightly below the design goal. Final measurements on S/N 001 ranged from 87.7 to 91%.

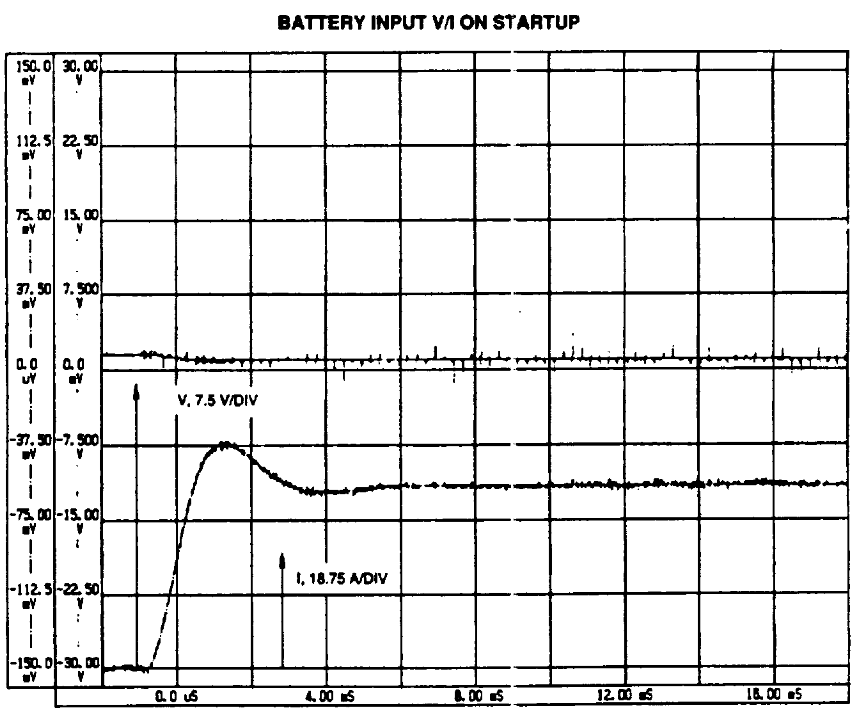
PCU System Integration Testing

Following acceptance testing, the S/N 001 PCU was tested at RRC on both a load resistor and a benchmark arcjet. During resistive load testing, comparitive measurements were made using a Sorensen DC power supply and lead-acid batteries as the power source. Figure 3-87 shows that the batteries are a far stiffer voltage source. Acceptable arcjet startup was achieved, however, with the power supply, so the batteries were not used during any subsequent testing.

POWER SUPPLY vs BATTERY INPUT SOURCE COMPARISON



11211-81



11211-82

Figure 3-87

Table 3-26
PCU S/N 001 ACCEPTANCE TEST DATA SUMMARY

	Input V	Efficiency (%) Goal: 90%, Min. 120 V Output	Efficiency (%) Goal: 90%, Min. 100 V Output	Peak(1) Start Voltage (kV) Goal: 4 kV, Min.	Current Overshoot (A) Goal: 2.5 A, Max.	Peak-to-Peak Output Current Ripple (A/% of DC) Goal: 20% of DC Current, Max.
Baseline 25°C	25	90.50	88.50	4.24	0.08	0.6 / 6%
	28	90.66	88.91	4.46	0.08	0.75 / 7%
	32	90.80	88.95	4.72	0.12	1.02 / 10%
Thermal −15°C	25	90.80	88.53	4.26	0.24	0.68 / 6%
	28	90.99	89.06	4.48	0.24	0.83 / 8%
	32	91.03	89.22	4.74	0.16	1.10 / 10%
Thermal 65°C	25	89.53	87.71	4.04	0.12	0.65 / 6%
	28	89.97	89.65	4.28	0.12	0.76 / 7%
	32	90.10	88.52	4.74	0.12	1.08 / 10%

NOTES: (1) 1,700 pF Load

The PCU started and operated the benchmark arcjet satisfactorily. Operation of the PCU in RRC's vacuum chamber (50 mTorr backpressure) was demonstrated without incidence. The only problem encountered was that the PCU generated EMI which affected the facility instrumentation, as was experienced with the development unit. Extensive filtering and ground isolation improvements were implemented to allow accurate data acquisition to be made. These facility changes allowed the complete EM system testing to continue with the S/N 001 PCU, but additional work was deemed necessary on S/N 002 to lower the EMI levels.

3.3.4.4 PCU Efficiency/EMI Improvement

A follow-on development effort was conducted to evaluate and improve the EM PCU S/N 002 efficiency and EMI performance. The following subtasks were established:

1. *PCU Characterization* — Characterize EMI performance and efficiency.
2. *Circuit Modification – Identification* — Identify potential PCU circuit modifications which could improve EMI and/or efficiency performance.

3. *Circuit Modification – Implementation* — Incorporate circuit modifications identified under Task 2 most likely to improve PCU performance with the least risk to the PCU.
4. *Final Assembly/Characterization* — Incorporate optimum selection of circuit changes into PCU using construction, assembly and fabrication techniques which are consistent with the existing PCU.
5. *Documentation* — Document circuit design changes to the PCU in the form of an addendum to the existing schematic diagram.

Pacific Electro Dynamics (PED), located in Redmond, Washington was selected to conduct the improvement program.

PCU Characterization

The PCU was configured in a standard test setup for all EMI and efficiency measurements as shown in Figure 3-88 This test configuration was maintained throughout the moficiation and retest process. Initial conducted emission data were taken during open bench testing performed in the PED Engineering Laboratory. Four conducted emissions plots were generated for the following PCU cables:

1. 28 vdc input (POS)
2. 28 vdc return (NEG)
3. Command/Telemetry Cable Set (COMMAND)
4. Output Triaxial Cable (OUT)

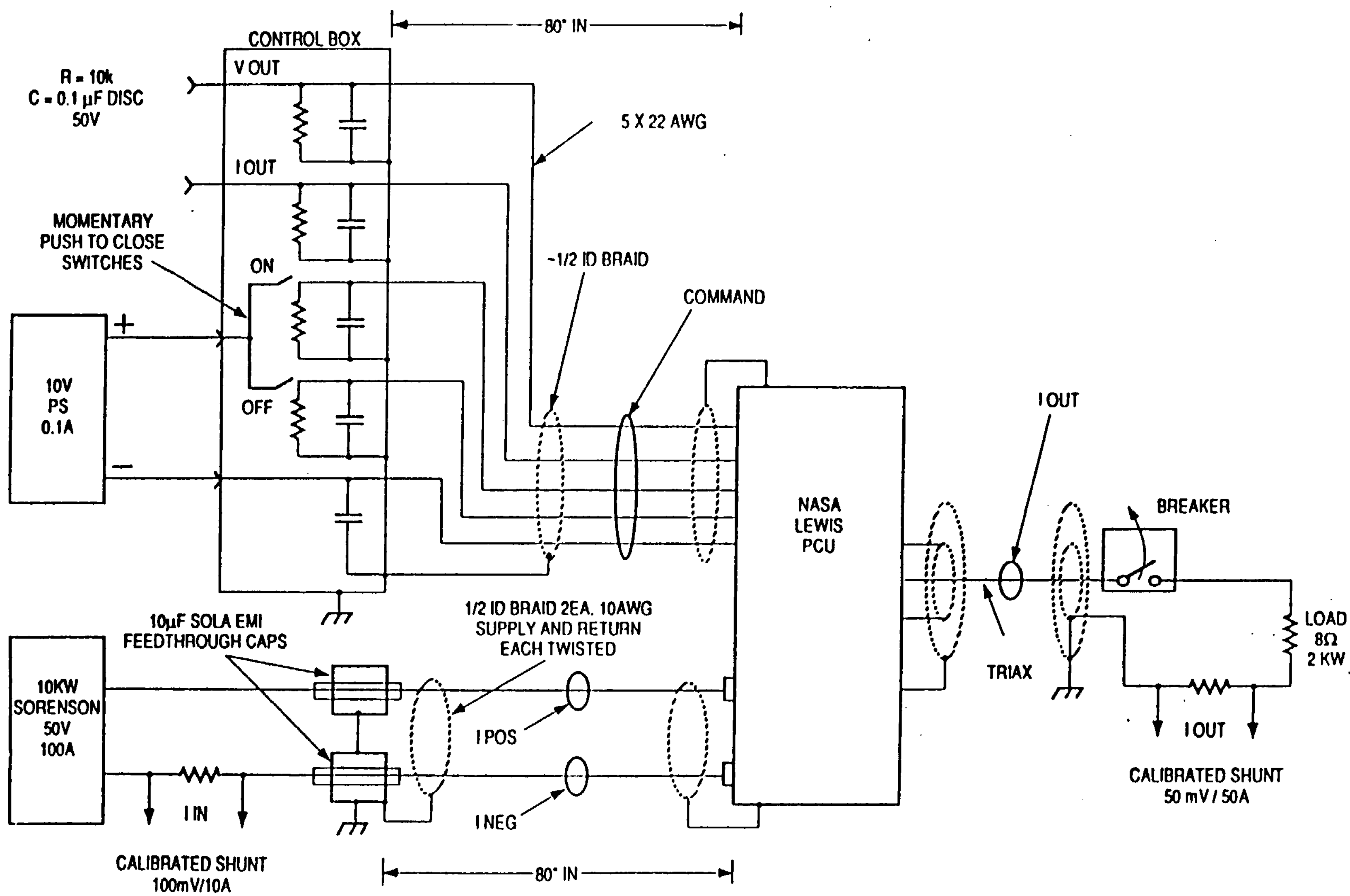
Each of the emission current measurements were made with the RF current probe placed around the entire cable set, including the shield braid. The currents measured are therefore the net unbalanced current in the cable set. The data are shown in Figure 3-89.

Efficiency measurements made in this initial configuration are as follows:

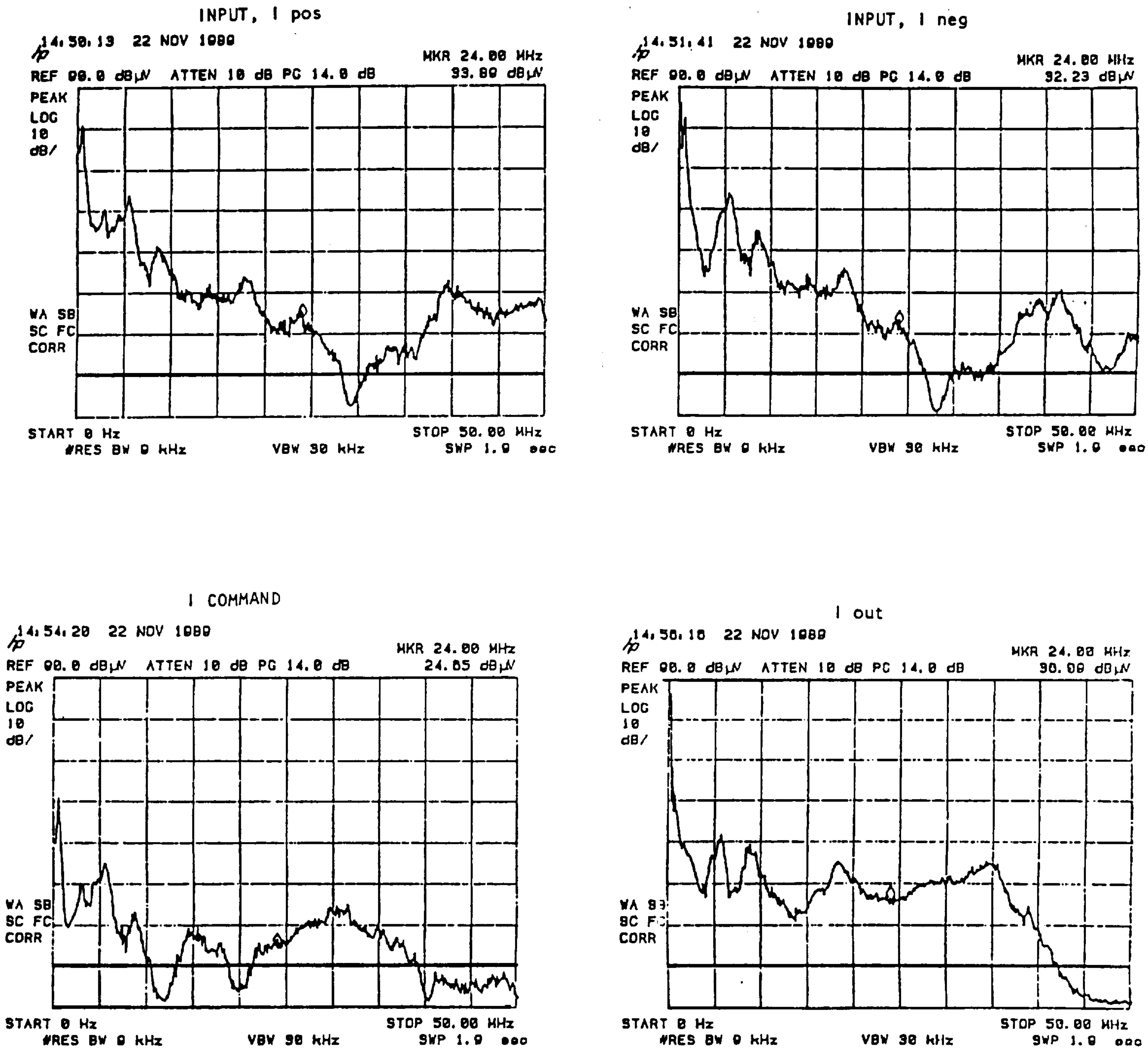
V_{in} (V)	I_{in} (A)	P_{in} (W)	V_{out} (V)	I_{out} (A)	P_{out} (W)	Efficiency (%)
27.0	54.32	1466.4	103.58	12.49	1293.7	88.22%
28.0	52.25	1463.0	103.68	12.50	1296.0	88.58%
32.0	45.70	1462.5	103.50	12.49	1292.7	88.40%

Additional data were taken on the input filter. The PCU cover was removed and the internal components evaluated with a Hewlett-Packard 4194A Impedance Analyzer. The original input filter is shown in Figure 3-90. Most of the components were as expected, but the two input inductors were off value by a ratio of 35 to 1. Impedance plots of the original configuration of L1 were made. The measured inductance was approximately 0.15 microhenries compared to the WJ schematic value of 5.5 microhenries. These inductors were fabricated with dual termination wires connecting to a single foil winding. They were miswired so that the inductor was effectively shorted out.

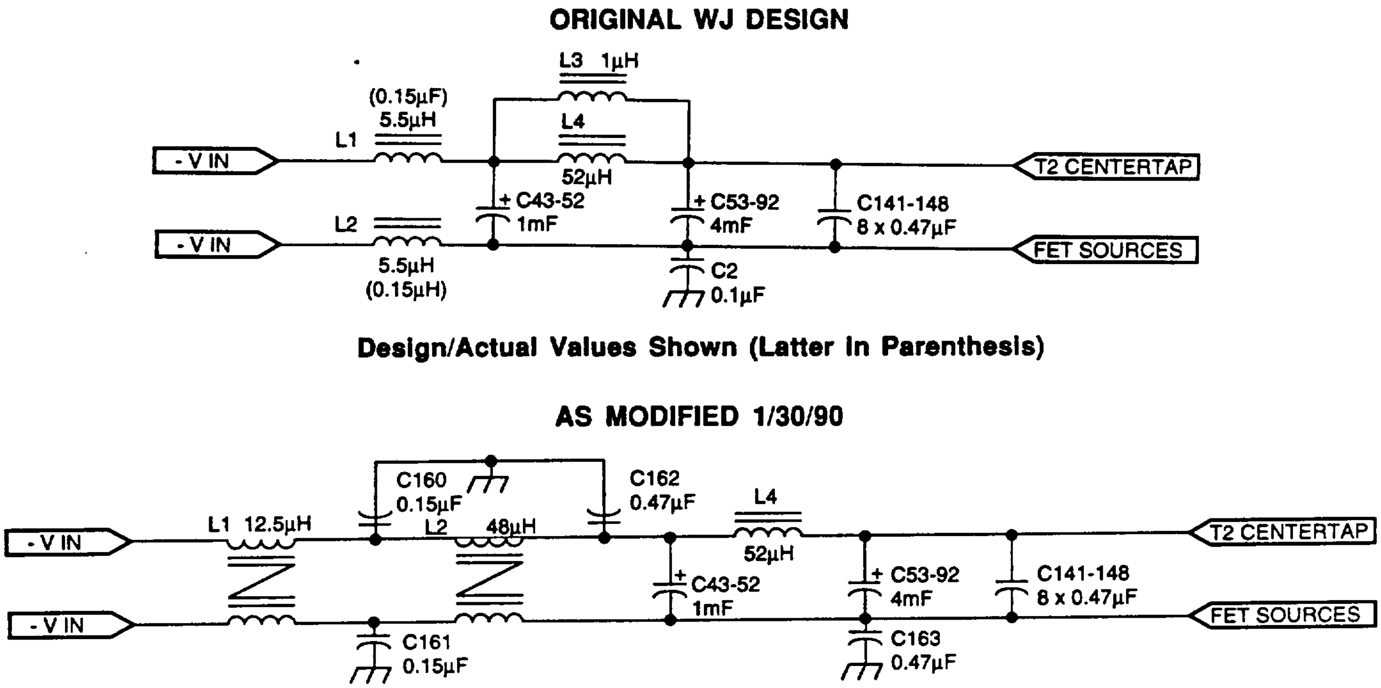
PCU EMI/EFFICIENCY TEST SETUP



PCU BASELINE EMI PERFORMANCE
CE03 NARROWBAND



INPUT FILTER DESIGNS



C11225-55 Figure 3-90

The remaining components were closer to the expected values. The relatively low ratio of damping inductor L3 to L4 used in the original configuration dramatically reduced the input filter's performance. The power handling filter components showed a substantial attenuation performance improvement when damping inductor L3 was removed. Greater than 60 dB attenuation was achieved at the ripple current fundamental of 32 kHz. These measurements indicated that a significant redesign of the input filter was required.

Circuit Modifications — Identification

Several methods to improve the EMI characteristics and efficiency of the PCU were identified. These are in Table 3-27. The risk of damaging the PCU was also assessed.

Table 3-27
CIRCUIT MODIFICATION EVALUATION MATRIX

Circuit Modification	Improve EMI	Improve Efficiency	Risk of Damage to PCU
1. Redesign Power MOSFET Snubbers	X	X	High
2. Modify Power MOSFET Gate Drive Circuit	X	X	High
3. Filter Pin Connector for Command/Telemetry Lines	X		Low
4. Add Filter Components (Ferrite Beads, Capacitors, etc.)	X		Low
5. Add EMI Gasket to Cover	X		Low
6. Eliminate Parasitic Oscillations	X		Low
7. Redesign Output Rectifier Snubbers	X		Medium
8. Add External Filtering to PCU Power and Signal Lines	X		Low
9. Redesign Power Converter Input Filter	X		Low

After an evaluation of the identified circuit modifications, it was determined that Items 3, 4, 5 and 9 represented the best tradeoff between performance improvement and risk of damage to the unit. Evlauation of the PCU revealed no parasitic oscillation (Item 6). Although Item 9 could be accomplished with low risk, it was judged that a filter external to the PCU would require an unacceptably large increase to the dimensions of the PCU.

Modifications to directly improve efficiency (Items 1 and 2) were judged to be too high of a risk to implement in the existing S/N 002 PCU.

Circuit Modifications — Implementation

The conducted emissions from the power input lines were primarily common mode. The source of the common-mode emissions is the switching voltage applied through parasitic capacitance to the case (i.e., FET drains to case). The emission appears as a high impedance current source that can be effectively filtered by a combination of low impedance bypass paths to case together with series impedance to the external leads. The modified input filter shown in Figure 3-90 was incorporated into the PCU. Adding high frequency common-mode inductors together with bypass capacitors to case allows a larger percentage of common-mode current to be returned to the case via bypass capacitors (C160-C163) rather than through the power leads external to the case. The filter is a fourth order Gaussian type scaled to achieve adequate attenuation of the dominant 100 kHz component. The parts list for the modified filter is as follows:

C160, C161	0.1 5uF, Ceramic CKR06, 100V
C162, C163	0.47uF, Metallized Polycarbonate, 50V, CRH02 Style
L1	See Figure 3-91
L2	See Figure 3-92

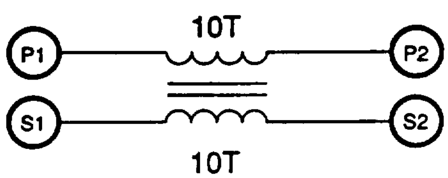
The high frequency common-mode inductor (L1) design is shown in Figure 3-91. The lower frequency common mode inductor L2, is shown in Figure 3-92.

Additional filtering was provided with a filtered pin connector for the command and telemetry signals. Additionally, ferrite filter beads were added to each of the five command/telemetry wires adjacent to the connector. The beads provided additional series impedance to further reduce emitted currents from these lines.

Conducted EMI bench testing was performed to evaluate the effectiveness of the modifications. A review of Figures 3-89 and 3-93 shows a comparison of data from MIL-STD-461 CEO3 measurements made on the positive and negative input power leads, output power lead, and command/telemetry leads before and after the circuit changes. The limits for MIL-STD-461 and TRW FLTSATCOM SR1-12C specifications are also shown. Significant improvement is evident in all cases. For conducted emissions, the MIL-STD-461 limits were still exceeded at some frequencies.

INDUCTOR L_1 DESIGN

SCHEMATIC & PERFORMANCE REQUIREMENTS



$L_M > 12.5$ uH (EACH WINDING)
$R_S < 3$ mΩ (EACH WINDING)
$I_{max} < 60$ Adc (EACH WINDING)

SUGGESTED BUILD:

EVENLY WIND 24 IN HAND.
10 TURNS OVER LENGTH OF TOROID. SECURE WITH TAPE.
DIVIDE NTO EQUAL 12 IN HAND WINDINGS

MATERIALS:

CORE: ARNOLD ENGINEERING
FERRITE TOROID
A-324117-2
1.45 O.D. 0.85 I.D.
0.45 HIGH

WIRE: 20 IN HAND 20 AWG HML WIRE. 10 TURNS

TEST REQUIREMENTS:

WINDING RESISTANCE
EACH WINDING
3 mOHM (10A)

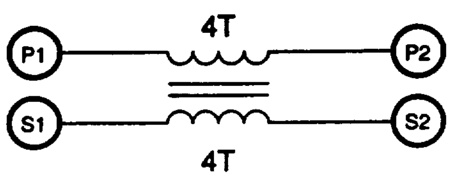
INDUCTANCE:

12uH MINIMUM (3 Ω @ 40kHz)

L1 12.5uH 60A. BALANCED
NASA/LEWIS PCU INPUT
FILTER MODIFICATION

INDUCTOR L_2 DESIGN

SCHEMATIC & PERFORMANCE REQUIREMENTS



$L_M > 45uH$ (EACH 4 TURN WINDING)
$R_S < 3\ m\Omega$ (EACH WINDING)
$I_{max} < 60$ Adc (EACH WINDING)

SUGGESTED BUILD:

EVENLY WIND 28 IN HAND.
4 TURNS UNIFORMLY OVER TOROID.
SECURE WITH TAPE.

MATERIALS:

CORE: FERRITE TOROID
FERROXCUBE P/N
846T250-3E2A
0.85 O.D. 0.55 I.D.
0.25 HIGH

WIRE: 28 IN HAND 20AWG HML
WIRE 4 TURNS

TEST REQUIREMENTS:

WINDING RESISTANCE
EACH WINDING
3 mOHM (10A)

INDUCTANCE:

45uH MINIMUM (11Ω 40kHz)

L2 45uH 60A. BALANCED
NASA LEWIS PCU INPUT
FILTER MODIFICATION

PCU EMI PERFORMANCE AFTER MODIFICATIONS

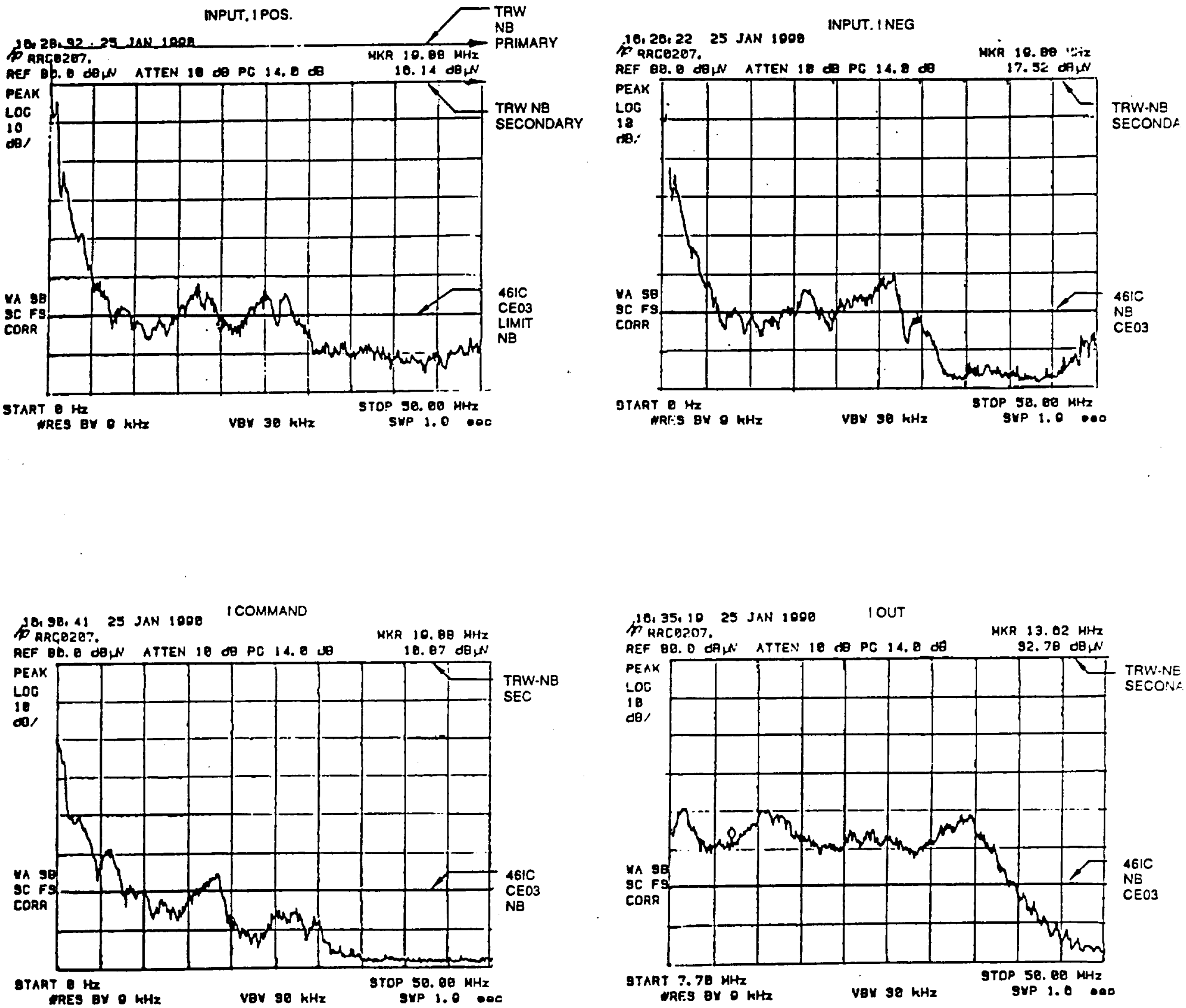


Figure 3-93

Final Assembly and Emission Characterization

As a final check on EMI performance, emission test data were taken in a certified EMI test facility at the ELDEC Corporation. The test was performed in January 1990 using the test configuration shown previously in Figure 3-88. Only the arcjet PCU and an 80-inch length of cable were inside the shield room. The Sorensen power source, load bank and the command/telemetry interface box along with instrumentation were located outside the screen room.

During this testing all shields were bonded to the screen room ground plane at both ends. This configuration is representative of a flight configuration on a low impedance vehicle frame. Some concern was raised regarding bonding of shields at both ends, so additional testing was undertaken to evaluate the effect of bonding shields at only one end. The radiated emission portion of the EMI testing was repeated on March 16, 1990, with shield grounds in several configurations.

Alternate Shield Ground Emission Testing

A repeat set of EMI tests were performed in March 1990 at ELDEC Corporation test facilities. The testing consisted of radiated emission testing (MIL-STD-461C, RE02) in several different shield ground conditions and audio frequency conducted susceptibility (CS01). The only significant change in the PCU since similar tests were conducted on January 27, 1990 was the addition of an EMI gasket between the cover and case. RE02 sweeps were made in the following four shield ground configurations:

- Configuration 1 — Power input, thruster output, and command/telemetry shields grounded at both ends, thruster anode grounded.
- Configuration 2 — All shield grounds removed at far end from the PCU with anode still grounded.
- Configuration 3 — Power input and command/telemetry shields grounded only at the outboard end. Output triax shield still grounded at PCU connector. Anode grounded.
- Configuration 4 — Same configuration as 2 but with anode floating.

A summary of the test results for the four configurations is as follows:

- Configuration 1 — Configuration 1 results were similar to the January 27 tests. Over specification emissions were slightly improved in the 200 to 500 MHz range but were still above specification.
- Configuration 2 — Emissions were somewhat higher in several frequency bands by up to 15 dB.
- Configuration 3 — Emissions appeared to be slightly higher still at some frequencies.
- Configuration 4 — Slightly higher emissions than Configuration 2.

Bonding the shields to the ground plane at both ends produced the best results.

Conducted Susceptibility (CS01 Test)

During the EMI testing at the ELDEC facilities, conducted susceptibility testing was also performed on the input power lines of the PCU. The test was conducted according to requirements that were nearly identical to MIL-STD-461C, CS01. The specification requires an injected voltage of 0.56 Volts peak from 20 Hz to 15 kHz (2% of line voltage at 28 vdc), decreasing to 0.28 V peak at 150 KHz (1% of line voltage or 1 Volt, whichever is greater). An injection signal of 1.2 Volt peak-to-peak minimum from 20 Hz to 150 kHz was considered more than adequate per the specification. The PCU output voltage was monitored continuously as the indication of a PCU malfunction.

Problems occurred running the test because the Sorensen input power source tended to oscillate before any injection was applied. The problem observed was basic instability of the Sorensen internal control loops when connected to the negative input impedance of the PCU. The Sorensen tended to oscillate at approximately 12 to 13 Hz (the control loop unity gain of the 6-phase 60 Hz SCR controller). The oscillation amplitudes varied up to 3 V peak-to-peak. The problem had been observed at low PCU input voltages previously (where negative input resistance is minimum) but was made worse when the injection transformer (Sola 6220-1A) was installed. A large capacitor bank was used at the Sorensen output to minimize the problem and an additional 2600 microfarad capacitor was placed across the power bus between the 10 microfarad feedthrough capacitors and the isolation transformer. The tendency to oscillate was reduced but could still be excited by the injected susceptibility signal.

The instability of the Sorensen power source made measurements difficult over some frequency ranges. Measurements from 20 Hz to approximately 100 Hz were difficult because the injected ripple tended to make the Sorensen oscillate. The large magnitude of input voltage variation (Sorensen oscillation plus injected signal) caused the PCU output to evidence ripple (up to 10 Volts peak-to-peak). Injection from 100 Hz to approximately 15 kHz caused no change in the PCU output. From approximately 15.5 kHz to 16.5 kHz, the Sorensen again experienced high amplitude oscillations, making susceptibility measurements difficult. From 17 kHz to 150 kHz no effect was observed on the PCU output.

In the frequency ranges where the Sorensen was affected, the true susceptibility performance of the PCU was difficult to determine, but it is believed that the PCU is not susceptible. The 16 kHz susceptibility is believed to be caused by the difference frequency between the 16 kHz ripple current from the PCU mixing with the injected signal to cause an apparent ripple current in the 100 Hz range where the Sorensen is unstable.

The following summarizes the results of the conducted susceptibility testing:

Frequency	Susceptibility
200 – 100 Hz	Sorensen oscillates
100 Hz to 15 kHz	No effect
15 kHz to 17 kHz (approximately)	Sorensen oscillates
17 kHz to 150 kHz	No effect

Summary

Conducted emissions were reduced significantly in the frequency range above 1 MHz. Radiated emissions were also reduced by the filter changes. Radiated emissions were probably most affected by good shielding of the external cabling. Low frequency conducted emission performance was still above MIL-STD-461C levels but did meet for the most part TRW FLTSATCOM requirements. Exceptions are approximately 10 dB above specifications in the 200 MHz to 300 MHz communication band where the specification has a 15 dB higher requirement. Significant magnetic emissions were measured (RE01) at frequencies less than 50 kHz.

Table 3-28 summarizes the EMI performance of the modified PCU relative to the limits of MIL-STD-461C and the TRW FLTSATCOM EMI specification. The conducted emissions results are peak values which generally occurred somewhere in the 1 MHz to 10 MHz range.

Table 3-28
EMI RESULTS SUMMARY

	Results	
Test	**MIL-STD-461C Test Limits**	**TRW FLTSATCOM Test Limits (DOC No. SR1-12C)**
Conducted Emissions (Broadband)		
Return	+47 dB	+10 dB
+28 V	+47 dB	+10 dB
Command	+12 dB	Meet
Output	+22 dB	+ 5 dB
Conducted Emissions (Narrowband)		
Return	+40 dB	Meet
+28 V	+40 dB	Meet
Command	+10 dB	Meet
Output	+22 dB	Meet
Radiated Emissions (Broadband)		
0.015 – 30 MHz	Meet	+ 6 dB
30 – 200 MHz (Horiz)	Meet	+ 2 dB
30 – 200 MHz (Vert)	Meet	+ 2 dB
200 – 100 MHz	Meet	+15 dB
1 – 10 GHz	Meet	+ 2 dB
Radiated Emissions (Narrowband)		
0.015 – 30 MHz	+5 dB	Meet
30 – 200 MHz (Horiz)	Meet	Meet
30 – 200 MHz (Vert)	Meet	Meet
200 – 100 MHz	Meet	Meet
1 – 10 GHz	Meet	Meet

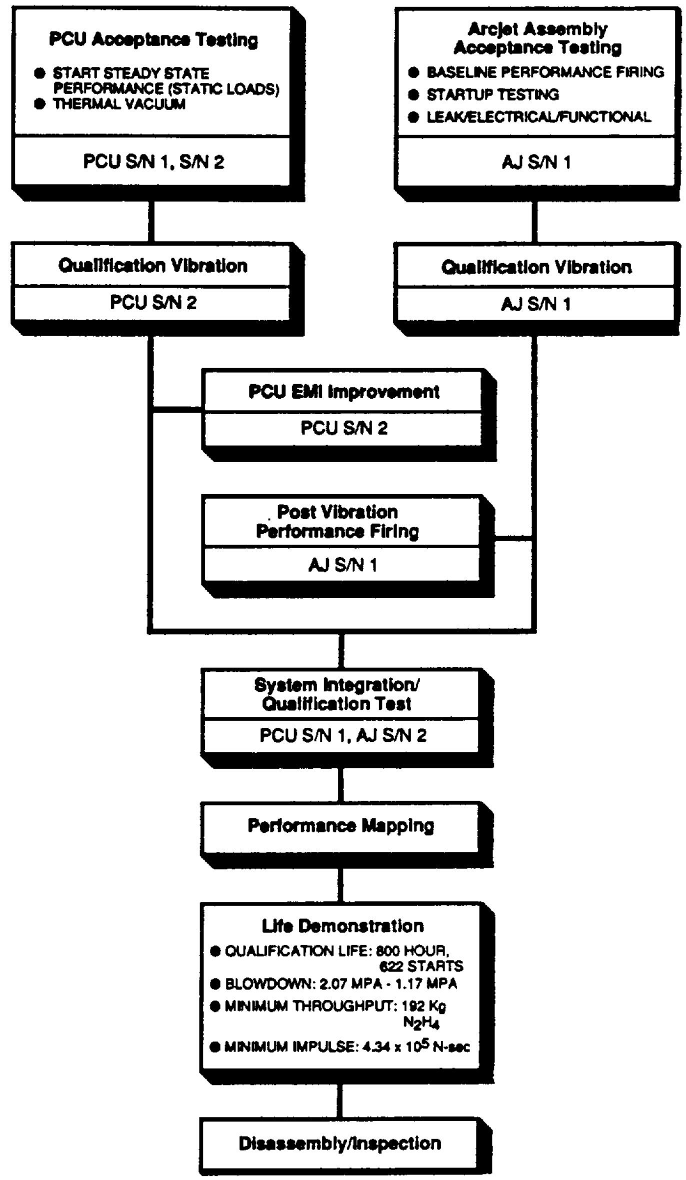
3.4 ARCJET SYSTEM TESTING

Final evaluation of the EM arcjet system was completed by conducting a comprehensive test program. To verify that the system could meet standard flight requirements, testing was structured to follow a format similar to typical RRC flight qualification programs. Procedures documenting setups and operator instructions were created to ensure test fidelity.

The important successes of this test program included qualification vibration testing of all system components, demonstration of performance, stability, and thermal design capability, and completion of an 800 hour system duty cycle life test.

The test flow plan is shown in Figure 3-94 Testing was conducted on two EM PCU's and arcjets as noted in the figure.

QUALIFICATION LIFE TESTING OF ARCJET SYSTEM



C11221-54 **Figure 3-94**

The S/N 001 arcjet was used during initial testing which evaulated performance, stability, and thermal/ mechanical design integrity. Included were performance, thermal map, start up, and qualification vibration tests. Test firings of S/N 001 were conducted with both the development PCU described in an earlier section and PCU S/N 001. This thruster was then made available to a s eparate NASA LeRC program (Arcjet Spacecraft Integration Program). AJT S/N 002 was integrated with PCU S/N 001 for performance mapping and the system life test.

Both PCU's underwent component level acceptance testing which included full functional characterization and thermal vacuum tests. These are discussed in Section 3.3. PCU S/N 001 was then used for the system level testing. PCU S/N 002 received qualification level vibration, post-vibration operational testing to verify full functional capability, and was then used for a follow-on EMI improvement program. The results from this effort are also located in Section 3.3.

3.4.1 Test Facility

Test firings of the arcjet system were conducted in Chambers 10 and 11 of the RRC Electric Propulsion Test Facility. Each chamber is 2.44 m in diameter by 2.44 m long, constructed of steel, and is water cooled through passages located between its interior and exterior walls. It is serviced by a Stokes 1726 mechanical pump with a capacity of 13,400 cfm. Over the propellant flow rates tested (30 to 55 mg/sec), the vacuum chamber pressure ranged between 25 to 50 mTorr. Thrust was measured on a swinging arm, null balance, thrust stand. The thrust stand is operated in a null displacement mode using a combination LVDT/linear actuator measurement system. Error due to hysteresis effects is minimized by maintaining nearly zero displacement of the thrust arm.

The system components were mounted on a heat exchanger plate which was fixed to the thrust arm. This allows the interface temperature of the PCU and arcjet to be controlled. Lines for electrical power, hydrazine, conditioning fluid, and instrumentation were integrated into torsional flexures which are aligned with the thrust arm axis of rotation. Arcjet voltage and current measurements were made from instrumentation designed to interface with a power cable which was modified for testing. These modifications allowed the cable to be assembled with a cabinet housing two current transformers, each with different frequency response characteristics, and a broadband voltage divider circuit to allow steady-state and transien measurements to be made. Steady-state voltage and current were also recorded from the PCU telemetry output.

The propellant delivery system was the same as for prior tests. To simulate spacecraft requirements, the propellant tank was pressurized with igh purity helium, the propellant feed line size was duplicated, and conditioning was installed to maintain uniform propellant temperatures. Flow rate was measured with a Micromotion mass flowmeter and a remotely controlled sightglass system was used less frequently for redundant measurements during performance mapping. A Sorensen DC power supply rated at 150 V and 70 amps was used to supply the PCU input power. The unit was operated in a voltage regulated mode at input levels to the PCU between 25 and 32 V.

Additional instrumentation included strain gauge pressure transducers, chromel-alumel thermocouples, and a digital storage oscilloscope for recording high frequency voltage and current measurements. Test control and data acquisition were performed by a micro-computer based system integrated with a 16-channel digitizing data logger. Software was developed to allow complete control of the arcjet system functions via the computer. Measurement uncertainty estimates were calculated from a standard equation which considers uncertainties specified for each parameter in a particular measurement or coputation. The uncertainty calculations are summarized in Table 3-29.

Flight level dynamic tsting was performed in the RRC vibration laboratory. The facility is comprised of a vibration control system and shaker table which can be oriented for displacement along three axes. The input frequency spectrum and amplitude levels are programmed into the control system and a response accelerometer on the shaker provides feedback to insure actual test vibration levels are maintained within tolerance limits. Twelve data acquisition channels were available for response accelerometer and strain gauge instrumentation of the arcjet hardware.

Table 3-29
CALCULATED DATA UNCERTAINTY

Parameter	Symbol	How Measured	Accuracy in Measured Range (±%)
Flow Rate	$\dot{m}$	Micromotion Mass Flowmeter	0.9%
Flow Rate	$\dot{m}$	Propellant Tank Sightglass	0.6%
Propellant Feed Pressure	P_f	Transducer	0.8%
GG Outlet Pressure	P_e		
Temperatures	T	Chromel-Alumel Thermocouples	1.0%
Thrust	F	Null Balance Thrust Stand	1.5%
Arc Voltage (DC)	V_{DC}	Voltage Divider	0.5%
		PCU Telemetry	1.5%
Arc Current (DC)	I_{DC}	Hall Effect DC Current Sensor	1.0%
		PCU Telemetry	1.5%
Arc Voltage (AC)	V_{AC}	Compensated Broadband Voltage Divider	1.0%
Arc Current (AC)	I_{AC}	Current Transformer	1.0%
PCU Voltage	V_{IN}	Voltage Divider	0.5%
PCU Current	I_{IN}	Current Shunt	0.3%
Reduced Data			
Power (Arcjet)	P_{AJ}		1.1%
Power (PCU)	P_{IN}		0.6%
Specific Impulse	I_{sp}		1.7%
Efficiency (Arcjet)	η_{AJ}		3.3%
Efficiency (PCU)	η_{PCU}		1.3%

3.4.2 AJT S/N 001 Performance, Stability, Environmental Testing

Performance/Stability

These test firings characterized the arcjet thermal design, startup parameters, and performance levels. The instrumentation used for these tests is shown in Figure 3-95. A full listing of the measured data can be found in Appendix A.

The mission analysis conducted during the system design phase yielded the propellant feed pressure blowdown curve representative of meeting the qualification lifetime requirement. During later life testing, this blowdown was simulated in a step-wise fashion with firings conducted at discrete feed pressure blocks, as is shown in Figure 3-96. The performance mapping measurements of S/N 001 were made at these same feed pressures so that mission average performance parameters could be estimated. The performance data were taken at the end of 30 minute duration firings for each feed pressure. Less than four minutes are required for thrust to reach equilibrium but the longer firing times were used to ensure thermal equilibrium had been achieved.

Any drift in thrust stand and flowmeter measurements between beginning and end of runs were measured at the test shutdown. The amount of measured drift was less than 4% of nominal thrust and 1% of nominal flow rate. The post-shutdown zero reference was then used to subtract out the measurement drift.

ARCJET FIRING INSTRUMENTATION

ROCKET RESEARCH INTEGRATED RECORD SYSTEM CONTINUATION SHEET

PAGE | REV: Orig | PART NO./DOCUMENT NO.: TP0699, Appendix B | LOT NO

ATP Reference Instrumentation List

Parameter	Symbol	Range	Measurement Device	Recording Device Micro-Dacs	Recording Device SCR
Gas Generator Chamber Body Temperature	T_{GG}	0 – 50 mV	Type K Thermocouple		x
Arcjet Cable Connector Temperature	T_{con}	0 – 50 mV	Type K Thermocouple		x
Propellant Inlet	T_f	0 – 5 mV	Type K Thermocouple	x	
Thermal Plate Temperature	T_{PL}	0 – 5 mV	Type K Thermocouple	x	x
Arcjet Temperatures	T_1	0 – 50 mV	Type K Thermocouple	x	x
	T_2	0 – 50 mV	Type K Thermocouple	x	x
	T_3	0 – 50 mV	Type K Thermocouple	x	x
	T_4	0 – 50 mV	Type K Thermocouple	x	x
	T_5	0 – 50 mV	Type K Thermocouple	x	x
	T_6	0 – 50 mV	Type K Thermocouple	x	x
Mount Structure Temperature	T_7	0 – 50 mV	Type K Thermocouple	x	
Valve Body Temp. OG End	T_{vt}	0 – 50 mV	Type K Thermocouple	x	
Valve Body Temp. Inlet End	T_{vi}	0 – 50 mV	Type K Thermocouple	x	
Ambient Temperature	T_9	0 – 10 mV	Type K Thermocouple	x	

ROCKET RESEARCH INTEGRATED RECORD SYSTEM CONTINUATION SHEET

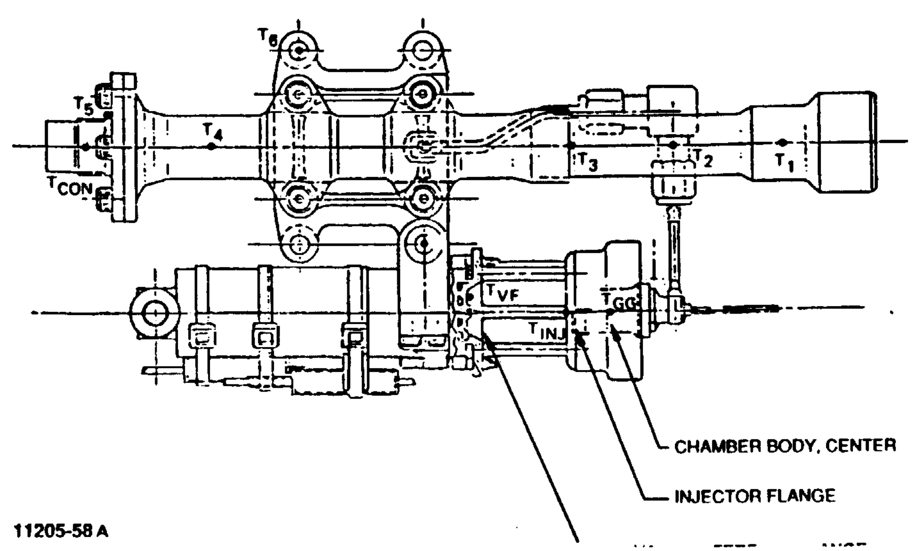
PAGE | REV: Orig | PART NO./DOCUMENT NO.: TP0699, Appendix B | LOT NO

ATP Instrumentation List

Parameter	Symbol	Range	Measurement Device	Recording Device Micro-Dacs	Recording Device SCR
Flowrate	w	0 – 2.0 x 10^{-4} lbm/s	Micromotion	x	x
Flowrate	w_{sg}	0 – 2.0 x 10^{-4} lbm/s	Sightglass	(manually record)	
Thrust	F	0 – 100 mlbf	Null Balance	x	x
Arc Voltage	V	0 – 150 V	1000:1 Voltage Divider	(manual, HP DVM)	
Arc Voltage	V_{VAC}	0 – 6 kV, 20 MHz	1000:1 Voltage Divider	(Nicolet Digital O-scope)	
Arc Voltage	V	0 –150 V	Fluke 80 K6	x	x
Arc Current	I	0 – 150 A	Hall Effect DC Current Sensor	(manual, HP DVM	
Arc Current	I_{AC}	0 – 50 A, 20 MHz	Pearson Current Transformer	(Nicolet Digital O-scope)	
Arc Current	I	0 – 100 A	Current Shunt	x	x
PCU Input Voltage	Vin	0 – 40 V	HP DVM	(manually record)	
Feed Pressure	P_f	0 – 500 psia	Transducer		x
Gas Generator Chamber Pressure	P_c	0 – 100 psia	Transducer	x	x
Vacuum Chamber	P_{vc}	0 – 1 Torr	MKS Baratron, Type 390 HA	(manually record	
Valve/GG Mount Flange Temperature	T_{vf}	0 – 50 mV	Type K Thermocouple	x	x

TP0699

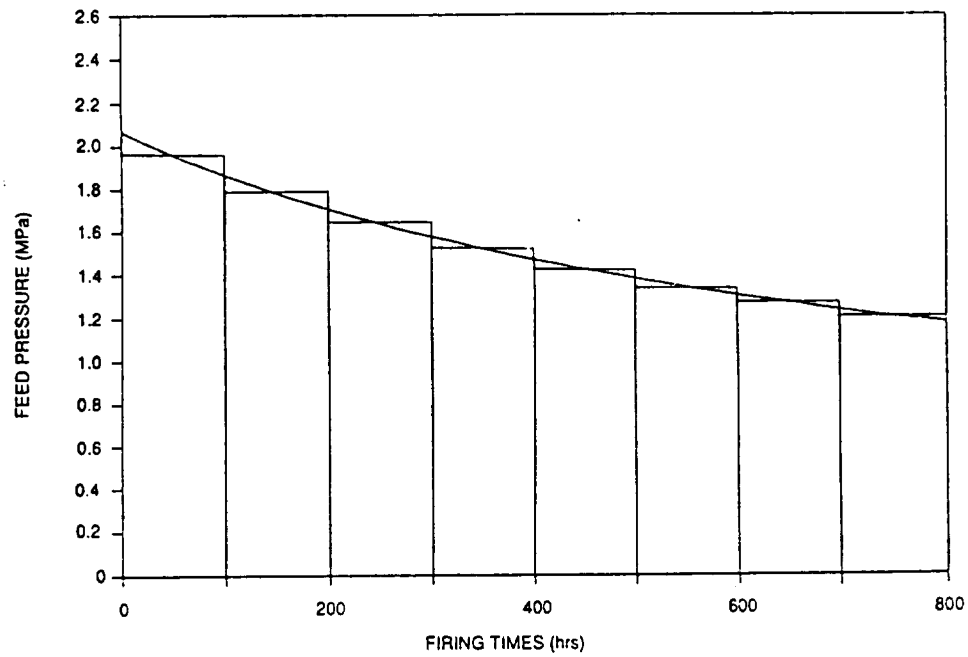
ATP Thermocouple Configuration



11205-58 A

Figure 3-95

LIFE TEST BLOWDOWN CURVE

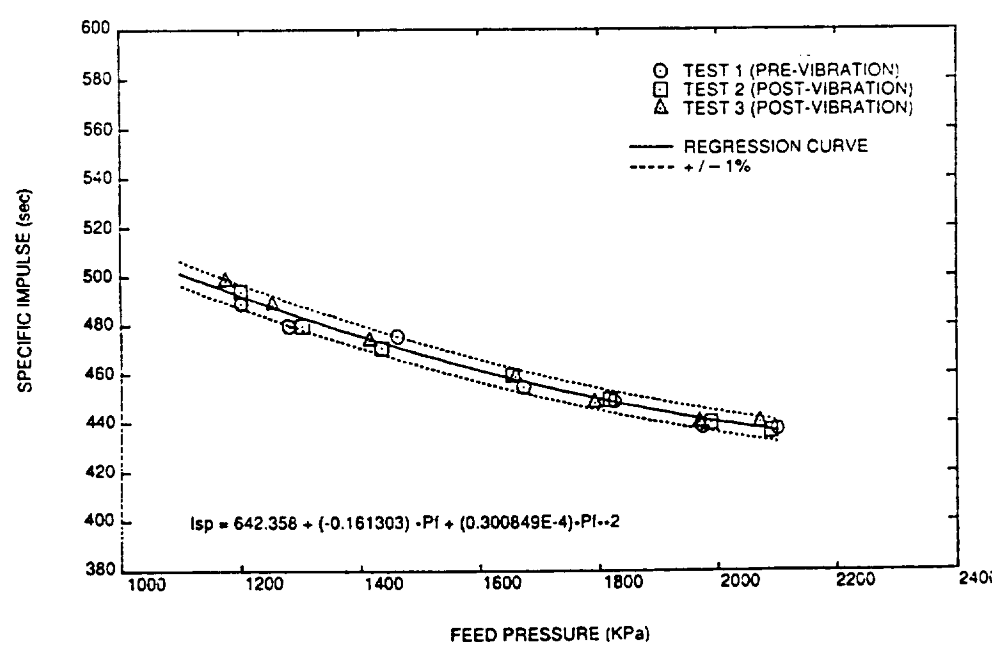


11210-87

Figure 3-96

Three performance tests were conducted with the PCU output power at the system design level of 1260 W. The first was conducted prior to qualification level vibration and the second and third following vibration to verify integrity of the hardware. Measured specific impulse vs. feed pressure and a regression curve fit of the data are shown in Figure 3-97. Excellent repeatability in performance was demonstrated with all data falling within ±1.0% of the nominal curve. No performance reduction resulted following vibration as indicated by the data.

I_{sp} VERSUS FEED PRESSURE



11211-24

Figure 3-97

Flow rate vs. feed pressure and thrust vs. flow rate curves are shown in Figures 3-98 and 3-99, respectively, for the three tests.

The range in specific impulse over the blowdown was 436 to 498 seconds. Based on the curve shown in Figure 3-96 of the feed pressure blowdown, the measured data were used to generate thrust and flow rate plots as a funtion of firing time. The best fit equations for these profiles were then integrated to compute a predicted mission average specific impulse of 465 seconds.

Performance of the S/N 001 thruster was also measured with firings conducted at higher power levels up to 1700 W. This was achieved by modifying the development PCU to deliver variable output power up to the 1700 W limit. A summary of the increase in specific impulse which was achieved is shown in Table 3-30. Figure 3-100 shows the steady state arc voltages and currents over the same flow rate range for each of the power levels tested. Stable thruster operation was achieved over the entire operating envelope shown of flow rate and power. Startups were observed to stabilize within several seconds and were very repeatable.

The thermal design of the arcjet assembly was also verified during thruster firings. The primary thermal design constraints were to control the conducted heat to the spacecraft mounting interface and maintain temperatures at critical thruster locations below allowable limits. The arcjet design incorporated the use of thin cross-section metals in the arcjet barrel and a high emissivity anode surface coating for enhanced radiation. These characteristics allow a steep temperature gradient to be achieved from the anode end of the barrel to the aft end. Table 3-31 shows a comparison of the design maximum, predicted and measured temperatures at critical locations of the arcjet assembly while operating at 1,260 watts power. Adequate safety margins exist at all locations. The predicted temperatures shown are from thermal analysis results at a nominal feed pressure value (1.67 MPa). The design temperatures of the weld joint, braze joint, and electrical connector were established through thermal cycling evaluations conducted during the design phase.

A startup characterization test was conducted on arcjet S/N 001 over the system flow rate range with cooldown periods used between starts to simulate cold conditions. In a total of 80 starts the demonstrated rate of reliability was 95% success on first pulse attempts with 5 requiring one additional pulse. Several characteristics that are important to reliable and low erosion startup were measured. Figure 3-101 shows the arc breakdown occurring at 3,179 volts and the initial current of approximately 6 amps which results from the discharge of start circuit inductively stored energy. Current flowing from the start circuit will sustain the ionized arc path at 30 to 40 V for approximately 40 usec. During this sustaining period, the power converter, which is already on prior to arc breakdown, begins to supply current to ramp up to a steady-state level. The initial start pulse current must be sufficient to prevent the arc from extinguishing. Subsequent to this transition, the arc moves from its initial location of low voltage attachment in the converging section of the nozzle to a nonerosive attachment mode in the lower pressure diverging section. This transition period is shown in Figure 3-102 where the arc voltage increases to a stable level in about 0.6 seconds. During start testing, the period for this transition varied between starts, but was less than 2 seconds in all cases.

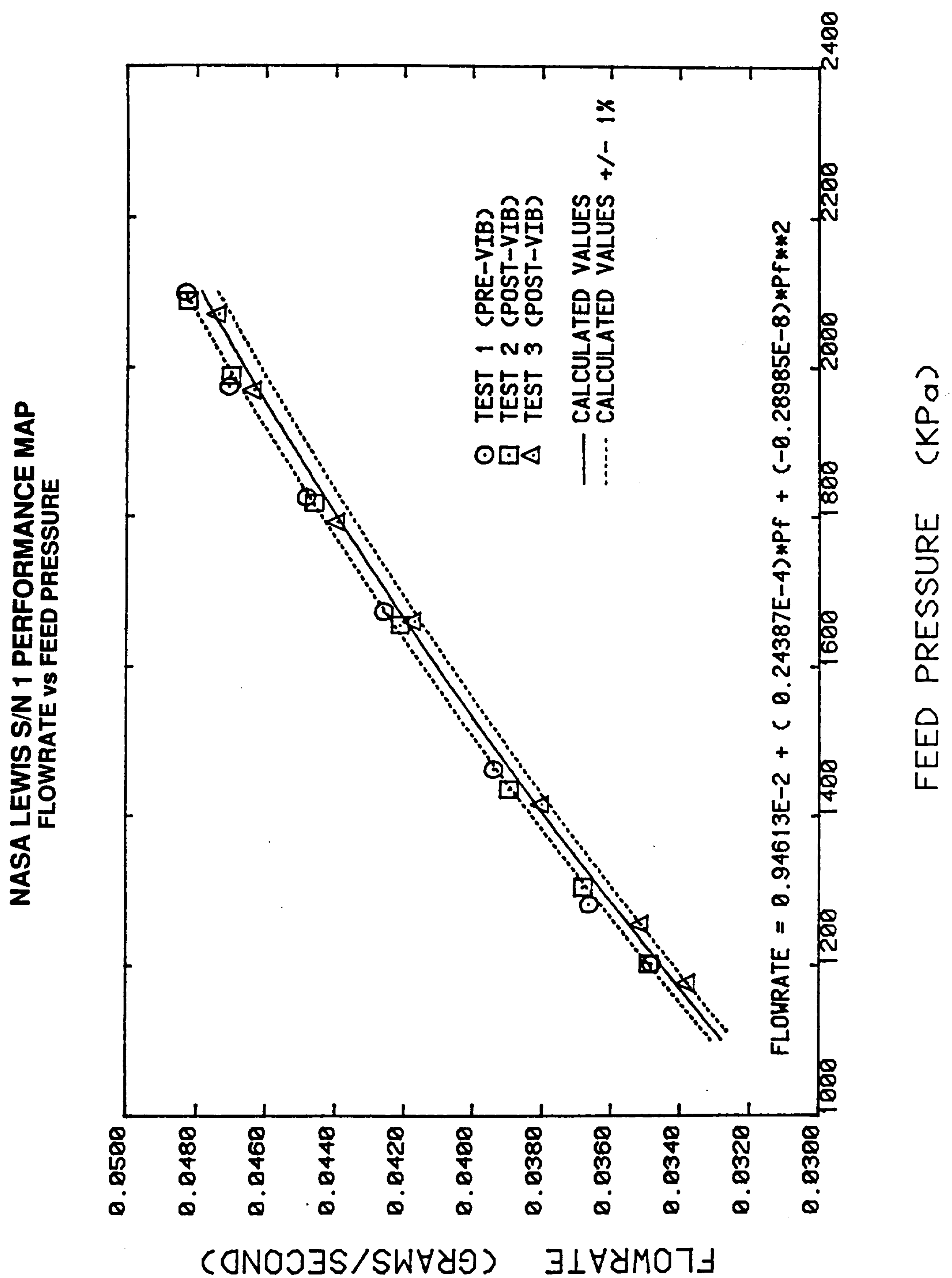

NASA LEWIS S/N 1 PERFORMANCE MAP
FLOWRATE vs FEED PRESSURE
TEST 1 (PRE-VIB)
TEST 2 (POST-VIB)
TEST 3 (POST-VIB)
CALCULATED VALUES
CALCULATED VALUES +/- 1%
FLOWRATE = 0.94613E-2 + (0.24387E-4)*Pf + (-0.28985E-8)*Pf**2
FLOWRATE (GRAMS/SECOND)
FEED PRESSURE (KPa)
0.0500
0.0480
0.0460
0.0440
0.0420
0.0400
0.0380
0.0360
0.0340
0.0320
0.0300
1000
1200
1400
1600
1800
2000
2200
2400

 Figure 3-98

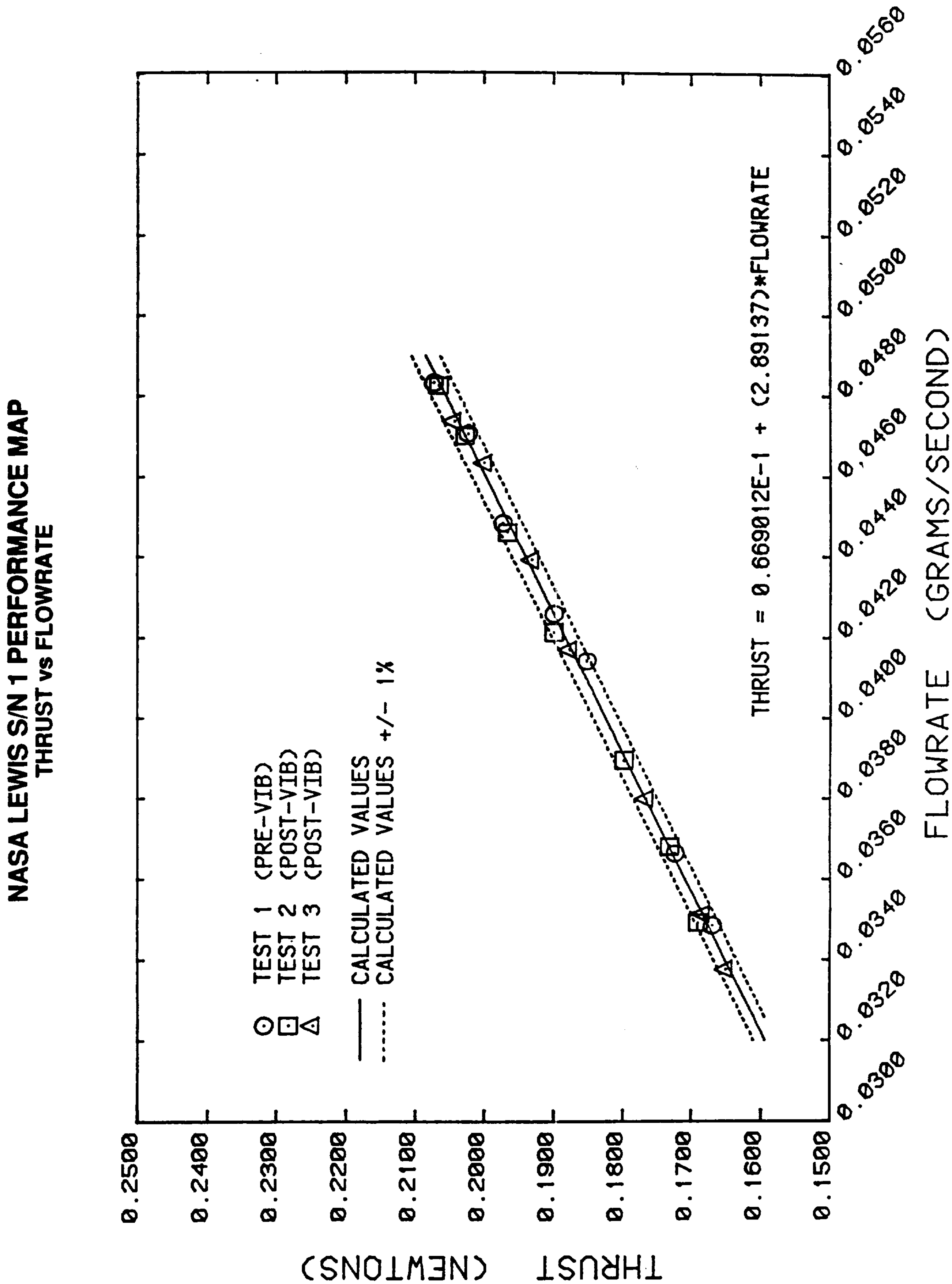
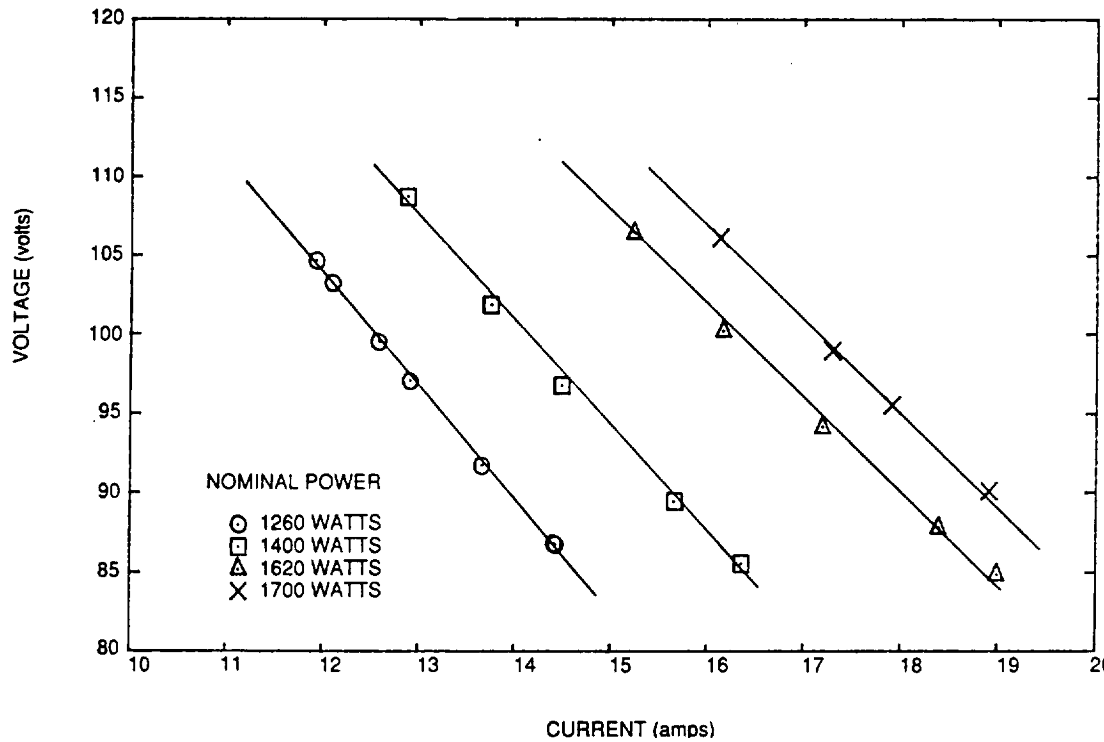

NASA LEWIS S/N 1 PERFORMANCE MAP
THRUST vs FLOWRATE
TEST 1 (PRE-VIB)
TEST 2 (POST-VIB)
TEST 3 (POST-VIB)
CALCULATED VALUES
CALCULATED VALUES +/- 1%
THRUST = 0.669012E-1 + (2.89137)*FLOWRATE
THRUST (NEWTONS)
FLOWRATE (GRAMS/SECOND)
0.1500
0.1600
0.1700
0.1800
0.1900
0.2000
0.2100
0.2200
0.2300
0.2400
0.2500
0.0300
0.0320
0.0340
0.0360
0.0380
0.0400
0.0420
0.0440
0.0460
0.0480
0.0500
0.0520
0.0540
0.0560

Figure 3-99

Table 3-30
SPECIFIC IMPULSE AT VARYING ARCJET POWER

	Arcjet Power			
	1260 (W)	1400 (W)	1620 (W)	1700 (W)
BOL Isp (Sec) Flow Rate (48.5 mg/s)	433	458	487	503
EOL Isp (Sec) Flow Rate (34.9 mg/s)	489	516	545	567
Mean Isp (Sec)	461	487	516	535
Mean Isp Increase Over Isp at 1,260 W		5.6%	11.9%	16.1%

ARCJET VOLTAGE VERSUS CURRENT



11211-25

Figure 3-100

Table 3-31
THERMAL MAPPING RESULTS

	Predicted	Design	Measured Range
Anode Weld Joint	877	1,204	787 – 880
Arcjet Body Braze Joint	457	593	383 – 414
Electrical Connector	138	200	99 – 126
Propellant Valve Flange	139	149	87 – 122

ARC BREAKDOWN

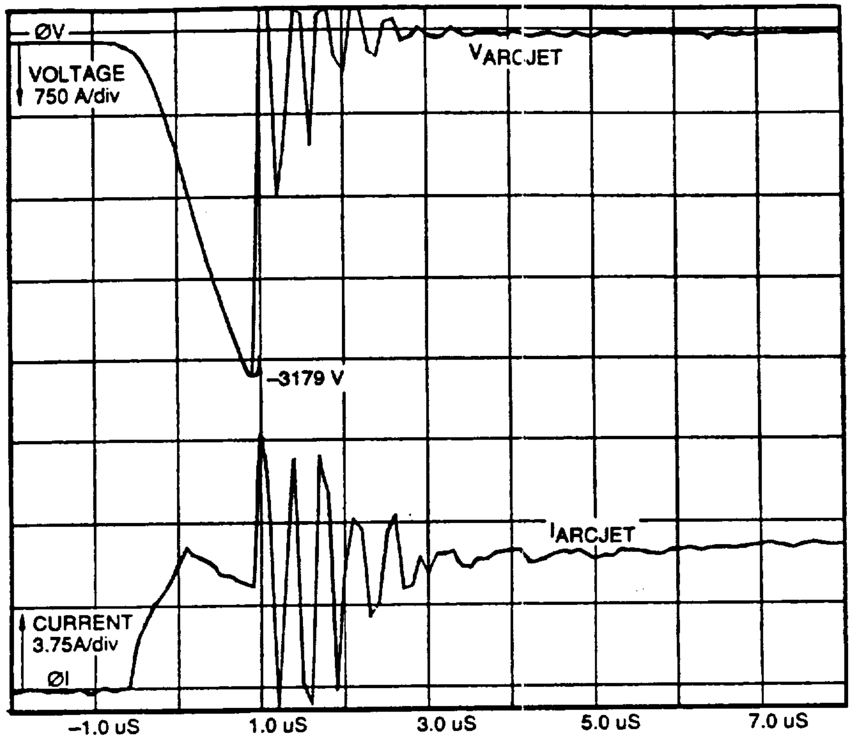


Figure 3-101

ARCJET STARTUP STABILIZATION

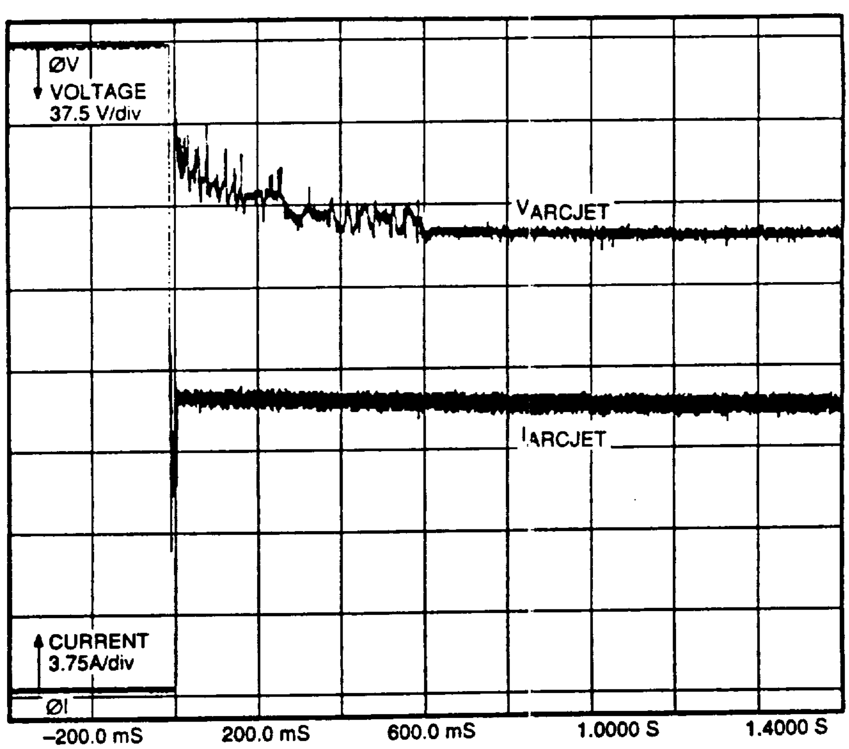
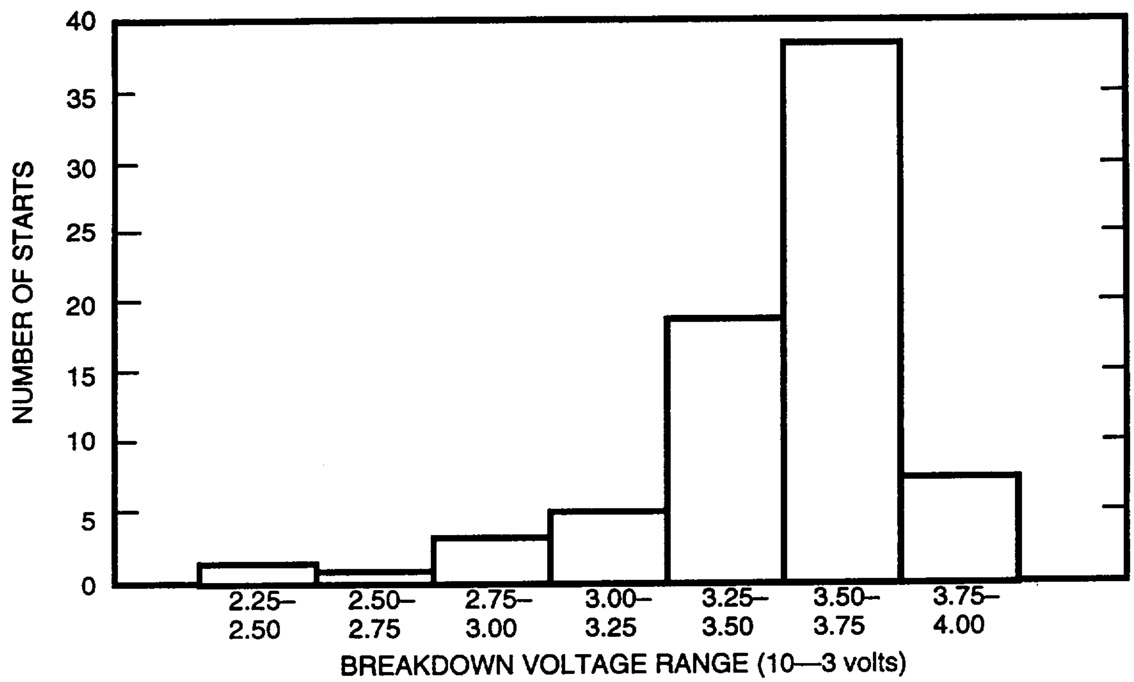


Figure 3-102

No spark discharge or other forms of erosion were observed. Finally, the magnitude of the voltage required to induce breakdown of the arc was measured. This characteristic of the engineering model arcjet is shown in Figure 3-103. The breakdown voltage did not vary significantly over the range of flow rates. The mean voltage range was 3,500 to 3,750 V.

STARTUP VOLTAGE VARIATION



11210-94

Figure 3-103

Vibration Testing

A test critical to the successful demonstration of the EM arcjet design was qualification vibration. The arcjet was tested with the power cable attached as shown in Figure 3-104. Strain gauge and accelerometers were attached to the test hardware.

Sine and random vibration tests were conducted in three axes. The vibration levels, frequency spectrums, and test durations shown in Table 3-32 are representative of current launch vehicle qualification requirements.

Strain gauge measurements indicated the highest stresses in the assembly were produced by the random excitation. In all cases, these were found to be well below the yield strength of the materials. Maximum stresses were in the gas generator thermal standoff and the arcjet barrel at its attachment location to the mount structure. These measurements are summarized in Table 3-33. A peak stress in the structure of 29.8 ksi (deduced from the elastic strain measurement) is shown for the arcjet barrel. Here, a positive margin of safety of 1.0 on yield is maintained. Safety margins at all other locations are significantly higher. Acceleration responses for the random vibration input were very near predicted levels at all locations.

Arcjet Vibration Test Setup

Table 3-32
QUALIFICATION VIBRATION LEVELS

Sine Vibration Levels		
Frequency Range (Hz)	Level	Sweep Rate (octaves/min)
10 – 24	1.27 cm displacement	2
24 – 36	15 G's	2
36 – 55	20 G's	2
55 – 200	7 G's	2
200 – 2,000	5 G's	2

Random Vibration Levels		
Frequency Range (Hz)	Level (G rms)	Duration (min)
200 – 2,000	20	2

Table 3-33
RANDOM VIBRATION PEAK STRESSES

	Peak Stress at Base of Arcjet Barrel (ksi)			Peak Stress at Base of Lower Gas Generator Thermal Standoff (ksi)	
Excitation	Outboard	Top	Inboard	Outboard	Bottom
Transverse Axis Random	14.0	—	14.0	15.9	14.9
Vertical Axis Random	—	29.8*	6.9	10.7	12.4
Longitudinal Axis Random	—	3.3	2.8	7.5	11.2
Transverse Axis Sine	11.9	—	6.6	10.5	7.7
Vertical Axis Sine	—	24.5	5.4	10.4	8.6
Longitudinal Axis Sine	—	3.6	3.0	5.7	11.9

* Peak stress, margin of safety $= \frac{60.0}{29.8} - 1 = 1.0$

The natural frequencies of the arcjet assembly were identified through analysis of the sine vibration data. A summary of measured and predicted frequencies for important modes is shown in Table 3-34. The lowest and most critical of these are the transverse (230 Hz) and vertical (260 Hz) flexural motions of the arjcet barrel, which is cantilevered from its attachment location at the mount structure. A peak acceleration of 182 g's was recorded when the vertical flexural mode was directly excited. This represents a worst-case condition for deflection of the arcjet barrel and its internal components. A differential displacement calculation between the end of the anode and the arcjet barrel at its attachment point to the support structure resulted in a maximum displacement of 0.066 cm corresponding to the peak acceleration. For this condition, flexural stresses in the internal ceramic components were calculated. Margins of safety of 4.5 or greater resulted. Additionally, no loss of cathode positioning was experienced to suggest possible failure of the ceramic components. This was verified through measurements made of the cathode/ anode gap throughout the test.

Table 3-34
MEASURED AND PREDICTED NATURAL FREQUENCIES

Mode Description	Predicted Frequency (Hz)	Measured Frequency (Hz)
Barrel flexure, Vertical	263	260
Barrel flexure, Transverse	294	230
Connector end flexure, Vertical	800	610
Connector end flexure, Transverse	879	620
Valve and gas generator motion	523 to 1,458	350 to 1,510
Support structure motion	1,887	1,210

Post-vibration leak and functional tests were performed. The assembly was successfully tested for the following: proof pressure; valve seat internal leakage; gas flow rate; electrical insulation resistance (valve, heaters, thermocouples, and cathode-to-anode); component circuit resistance (heaters, valve); and nitrogen leak detection. Leakage of less than 10^{-6} standard cubic centimeters of helium at 350 psig, a typical requirement for production hardware, was the only functional requirement not met due to leakage traced to a silicon rubber O-ring seal used at the thruster bolt-on connector flange. The measured leakage rate of 10^{-5} scc GHe has a negligible effect on thruster performance as it represents a rate of flow several orders of magnitude smaller than the propellant flow rate. A flight configuration assembly is projected to use welded construction of the flange, which will eliminate the potential for this leakage to occur.

Disassembly/Inspection

The cumulative test history of the S/N 001 arcjet is shown in Table 3-35. A total of 19.1 hours and 135 starts were completed in addition to the qualification level vibration test.

Table 3-35
S/N 001 THRUSTER TESTING HISTORY

Date	Run No.	Run Time (min.)	Starts	Description
12/13/88	80-5	112	3	Initial stability mapping.
12/14/89	80-6	30	8	Performance mapping
12/16/89	80-8	117	7	Performance mapping
1/4/89	—	—	—	Qual. vibration
1/17/89	81-2,3	198	7	Post-vibration performance mapping
1/18/89	81-4,5	10	90	Post-vibration startup
1/19/89	81-5,6	163	7	Repeat performance mapping
2/10/89	82-2	375	14	Higher power performance mapping at 1400, 1620, 1720 W arcjet power
5/16/89	84-3	141	6	S/N 001 system testing
	Totals	1,146 (19.1 hrs)	136	

Subsequent to these tests, the arcjet was disassembled and inspected. All parts were removed easily from the thruster body. The cathode and insulators are shown in Figure 3-105. All insulator parts were intact with no evidence of cracking. The measured mass lost from the cathode tip was 2.6 mg.

Since the thruster was to be used for additional testing no destructive examination was performed. Following photographic documentation, the thruster was reassembled without difficulty.

3.4.3 Arcjet System Demonstration

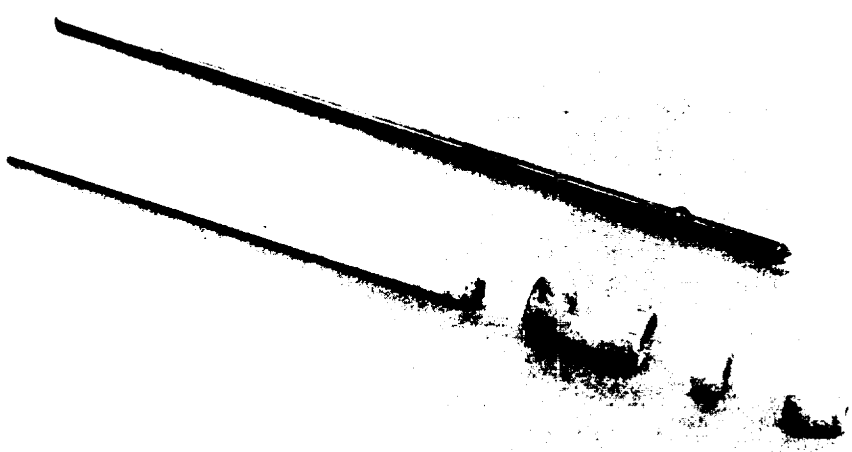
3.4.3.1 Baseline Performance Mapping

The final portion of the arcjet system demonstration included integrated performance and life test using EM arcjet S/N 002 and PCU S/N 001. The setup of system components in the Cell 11 facility is shown in Figure 3-106. A closeup view of arcjet S/N 002 is shown in Figure 3-107.

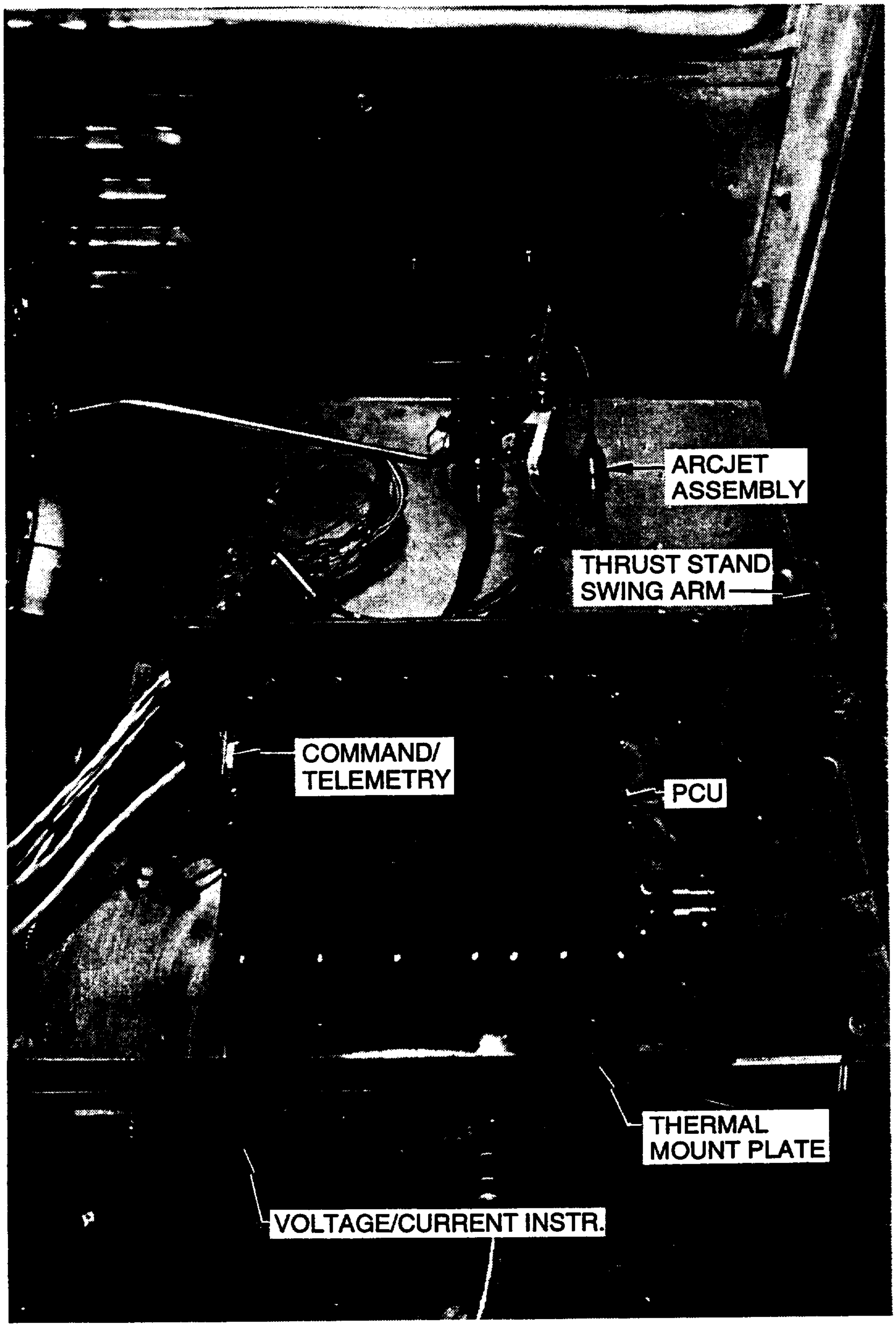
A long life gas generator concept being developed by RRC specifically for arcjet applications was integrated with the arcjet in place of the standard GG used for S/N 001 tests. This GG has improved thermal design features which maintain critical operating temperatures at lower levels.

S/N 001 CATHODE TIP AFTER FIRING

S/N 001 CATHODE INSULATORS AFTER FIRING



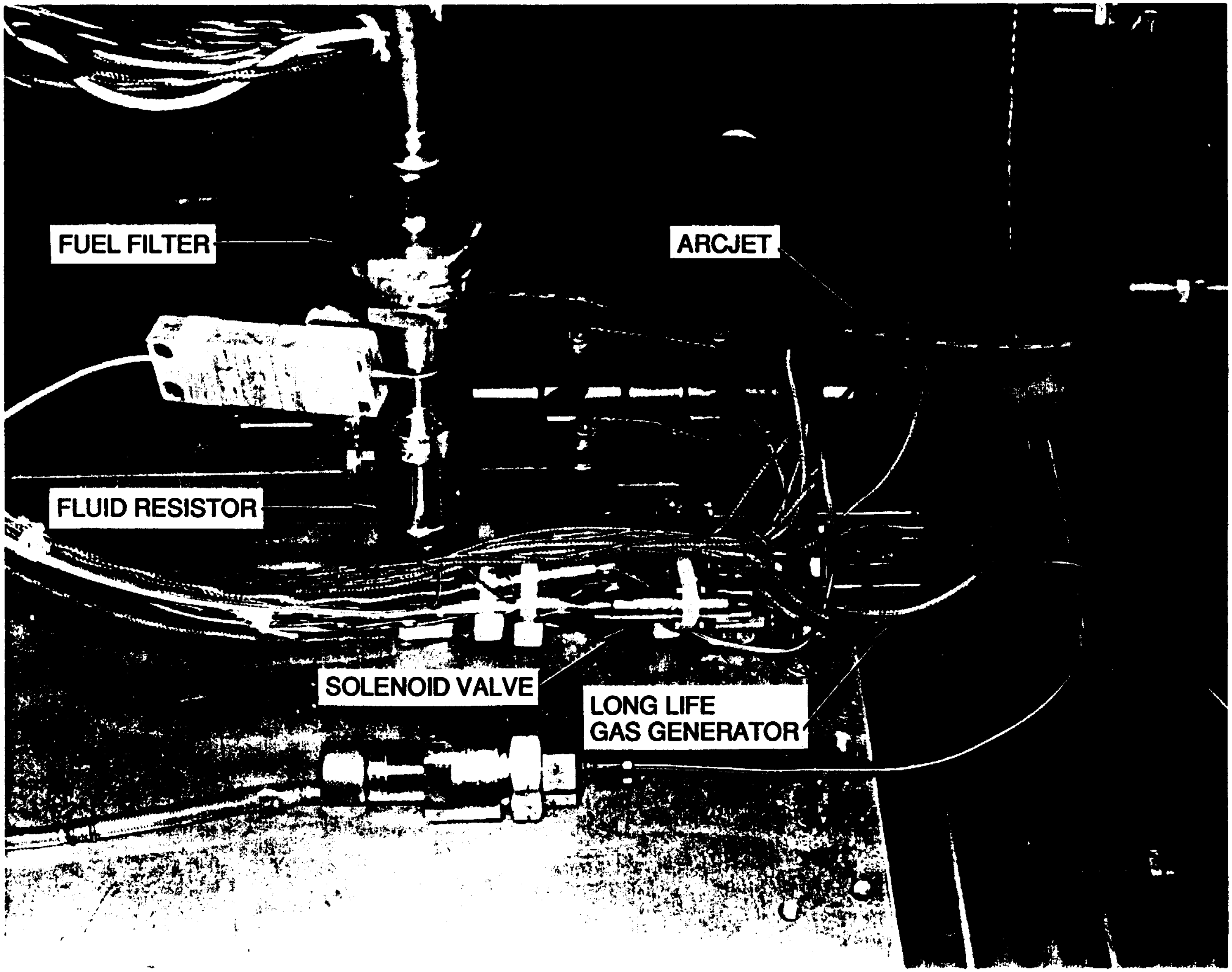
Arcjet System Test Setup



11216-29 3554-2

Figure 3-106

S/N 2 ARCJET ASSEMBLY



All testing was conducted with Olin purified hydrazine. Both prior to and after completion of testing, the fuel was sampled at the propellant line interface of the arcjet and verified to meet high purity grade requirements per MIL-P-26536, Amendment 2.

Performance map testing was conducted in a duplicate manner to the S/N 001 testing. Thirty minute runs were made at seven different feed pressures. A summary of the test data is given in Appendix B.

Measured performance levels compared very closely to arcjet S/N 001. Specific impulse vs. feed pressure for both units is shown in Figure 3-108. Based on the same assumed blowdown curve, the predicted mission average specific impulse for S/N 002 was 457 seconds. Compared to the 465 seconds for S/N 001, this is a difference of only 1.7%. A slightly higher flow rate for the S/N 002 assembly was expected due to variation in the fluid resistor characteristics. Component level testing had earlier indicated that the S/N 002 fluid resistor flowed about 0.5% higher. This difference accounted for most of the variation in specific impulse. Measured flow rate vs. feed pressure and thrust vs. flow rate for S/N 001 and S/N 002 are shown in Figures 3-109 and 3-110.

The stability of the arcjet was excellent. Stable startup was achieved on every initial attempt. Steady state arc voltage levels agreed within 3 volts for equivalent feed pressures compared to arcjet S/N 001. Temperatures of both the PCU and arcjet were well within design limits.

The PCU efficiency ranged between 87.7% and 90.0% as shown in Figure 3-111. These measurements do not include the small power losses in the input and output power cables. The triax output power cable resistance is approximately 60 milliohms which results in a loss of about 10 watts at the arcjet interface.

3.4.3.2 Gas Generator Development

As described previously, firing times on the order of 800 hours in a flow rate range of 30 to 50 mg/sec are required for near term qualification of the arcjet. Standard gas generator designs are generally not capable of meeting this requirement. One long-life design approach, a dual injector GG, was evaluated under the Arcjet Technology program. This effort was conducted in parallel to the system level testing. Design, fabrication, and stand-alone testing of one unit were completed. The effort was concluded with a successful life test in which 915 hours operation were demonstrated.

Design Description

The lifetime of the standard GG has been found to be limited by flow restriction in the fuel inlet tube at or near its injection to the catalytic chamber. Hydrazine liquid to gas phase transition occurs in this region, imposing a severe operating environment due to boiling and thermal decomposition.

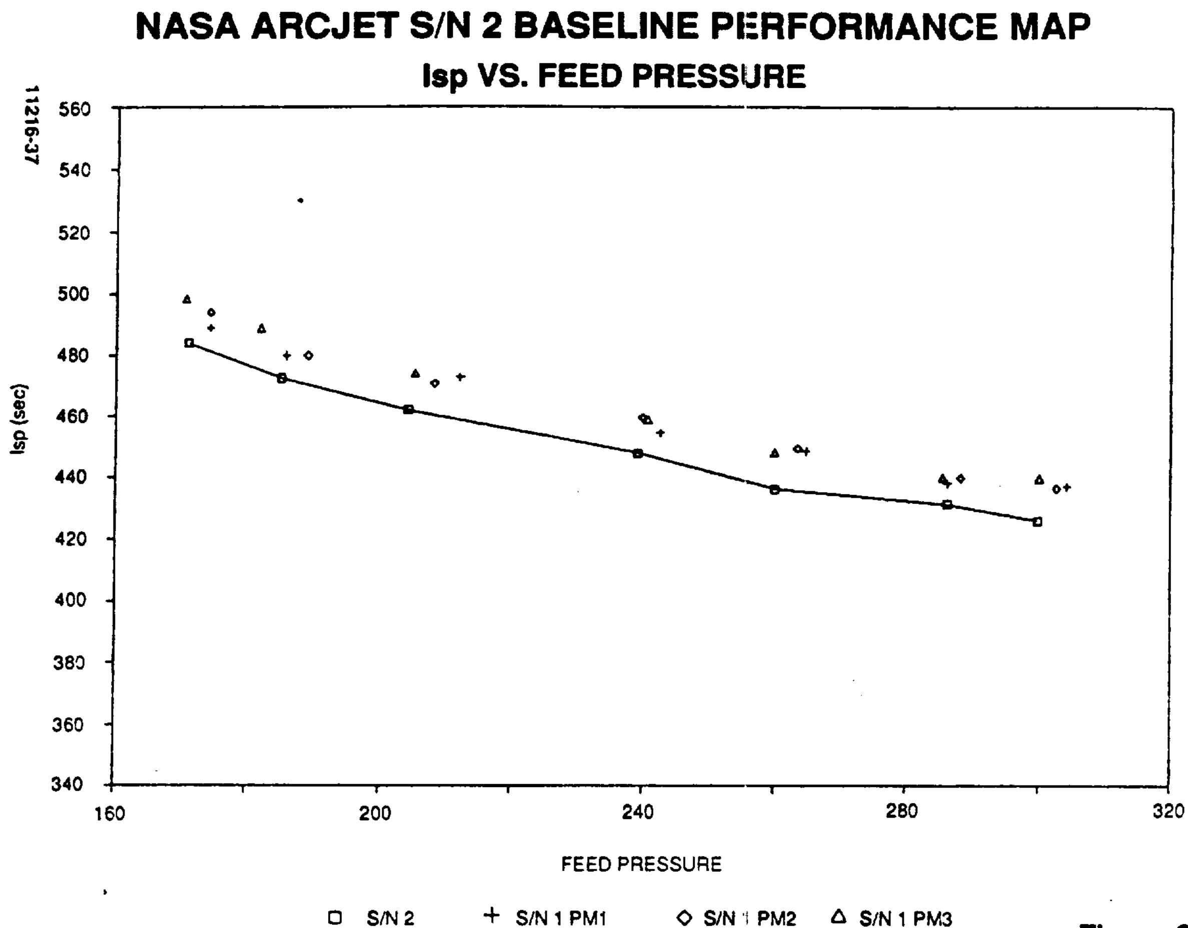


Figure 3-108

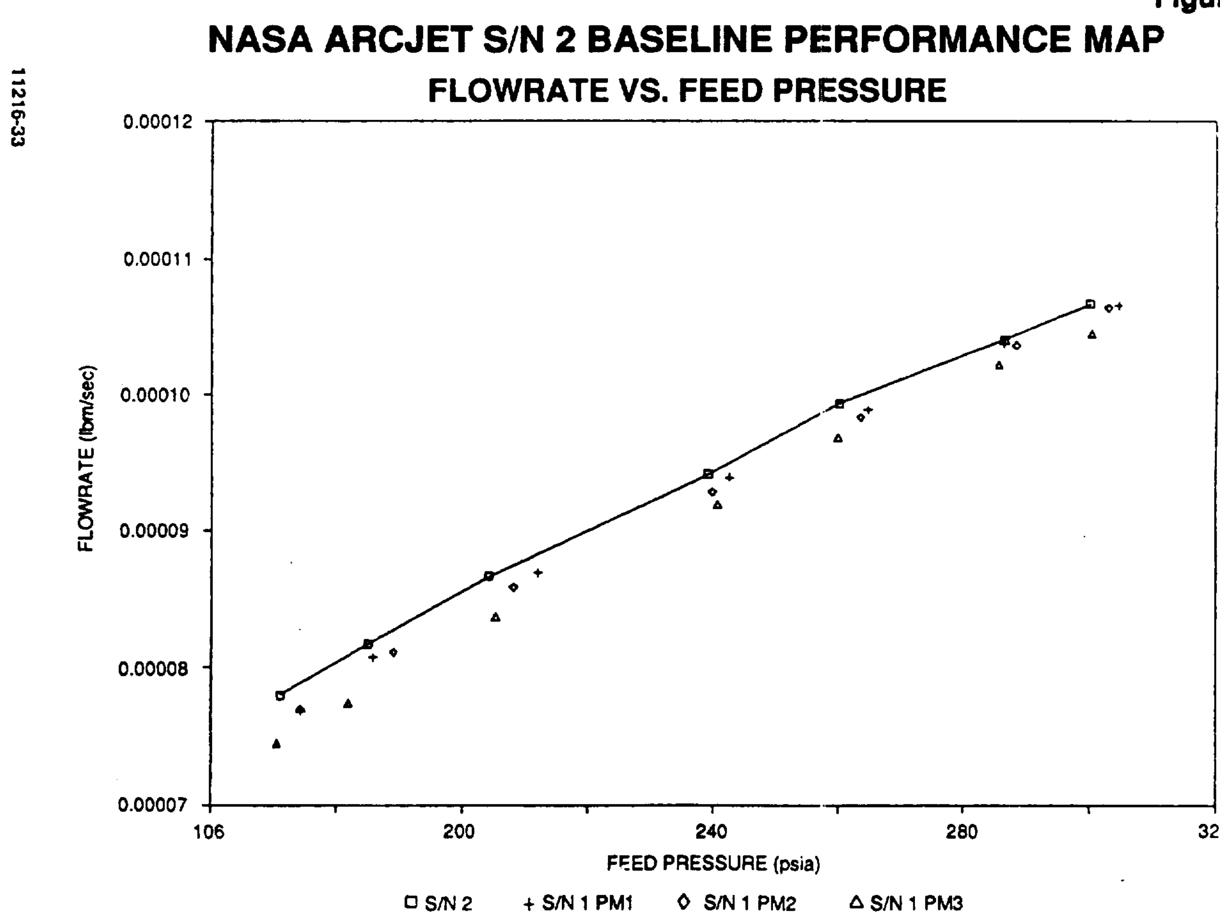


Figure 3-109

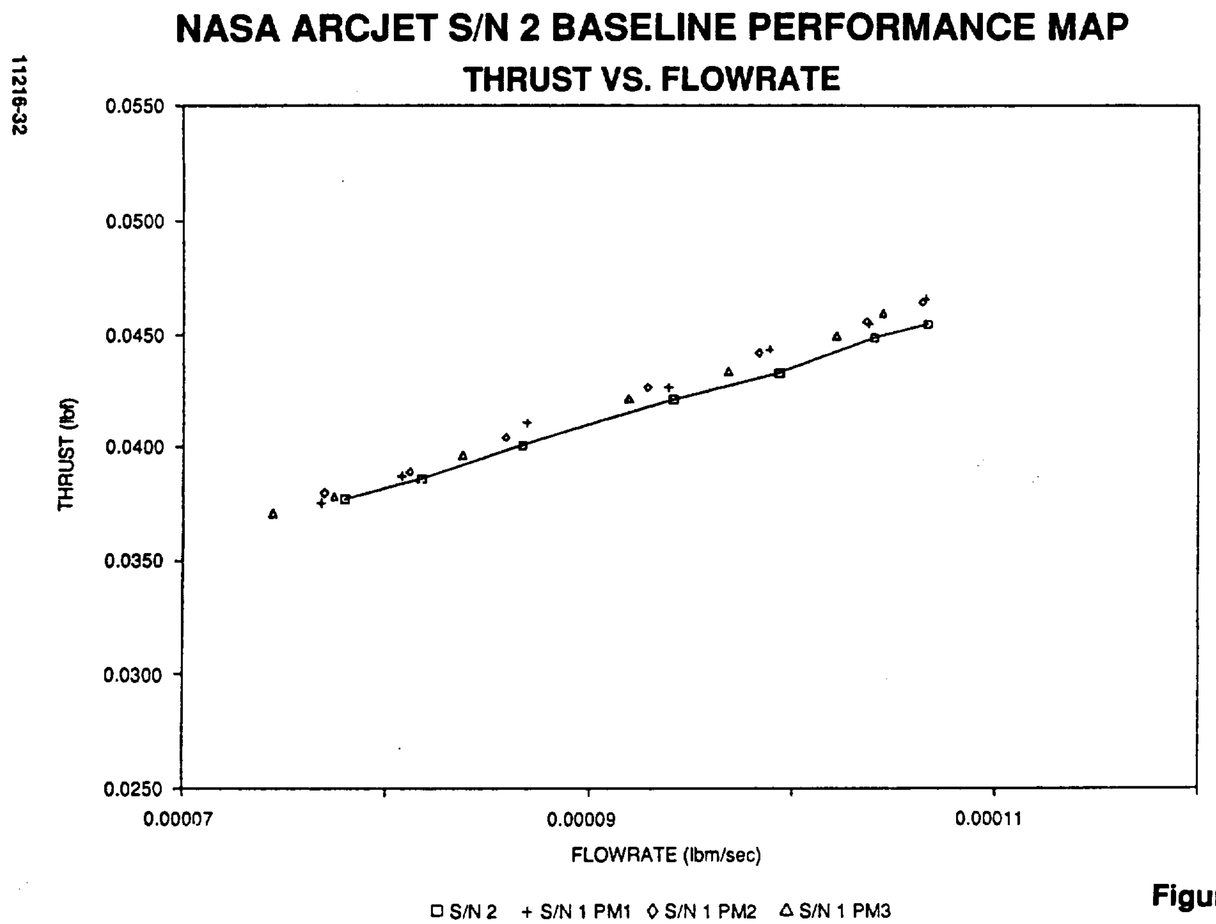


Figure 3-110

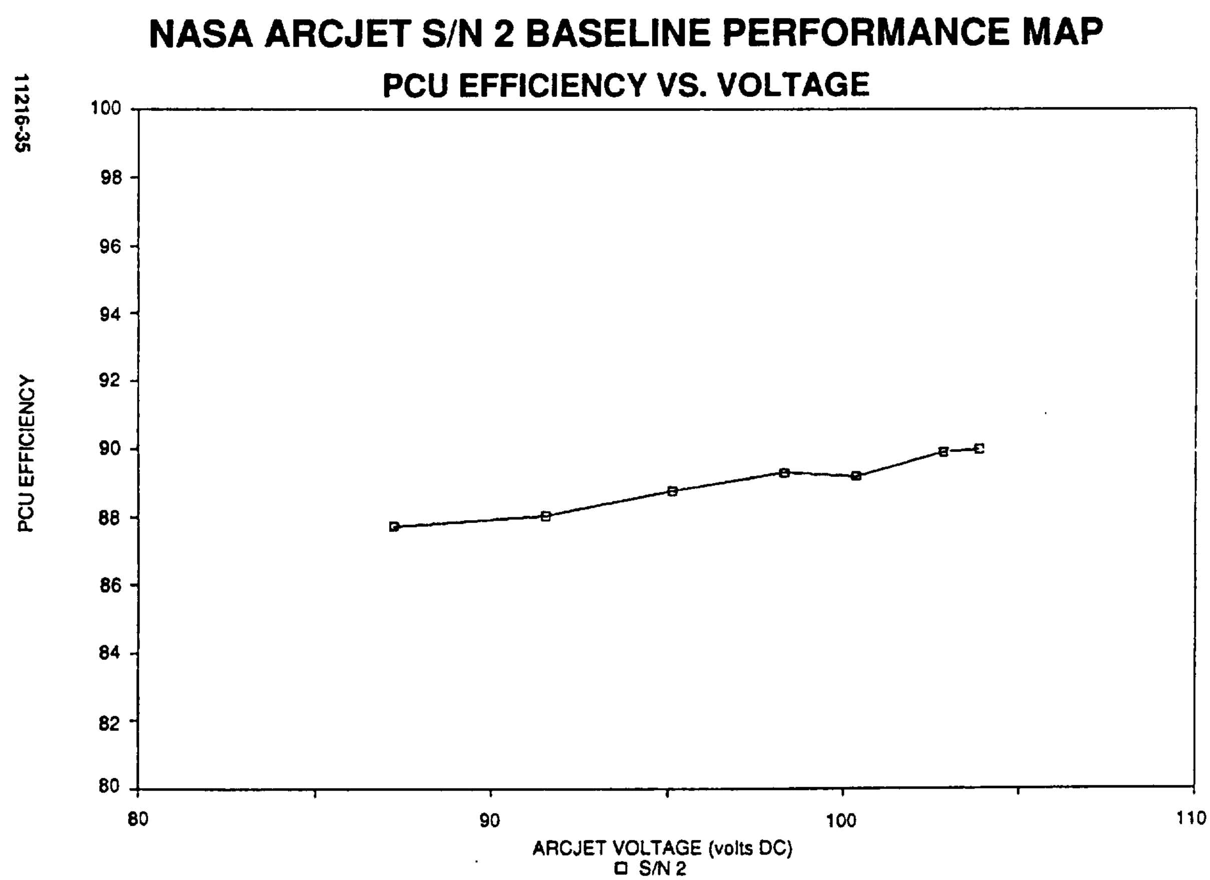


Figure 3-111

As a means to extend the useable lifetime, the dual injector design incorporated two standard injection subassemblies with a single catalyst bed. In application, the propellant is directed through one injector for one half of the required firing time or until its useful life is exhausted, and the second injector is utilized for the balance of the system lifetime. An identical dimensional envelope to the existing unit was maintained which greatly simplifies its integration. A propellant valve with two selectable outlets is required for on-orbit diversion of the flow. For these tests, a simple diverter was used.

Thermal analyses were performed to examine two areas. First, the effects of having the active injector off-center were evaluated. Results indicated the asymmetric heat source would not create any significant thermal imbalances in the GG structure. For example, predicted temperatures of the three thermal standoffs near the injector varied by only 6°C.

A second analysis examined the effects of having two capillary tube thermal shunts. There is a delicate balance between the temperature at the valve flange and the catalyst bed injector. The former temperature affects the temperature of the incoming hydrazine. If this temperature is too high, an increase in the rate of degradation to the injector can occur. At the same time, the injector temperature itself is a critical parameter for long lifetimes. The additional conducted heat back to the valve through the nonoperating tube shunt was estimated. A 30% increase was predicted with no other changes made to the hardware. A new thermal spacer design was incorporated between the valve and GG mounting flange. This helped to bring the predicted temperatures at the valve down to levels seen with single injector configurations.

No structural analyses were performed since the main structural members of the GG were not changed.

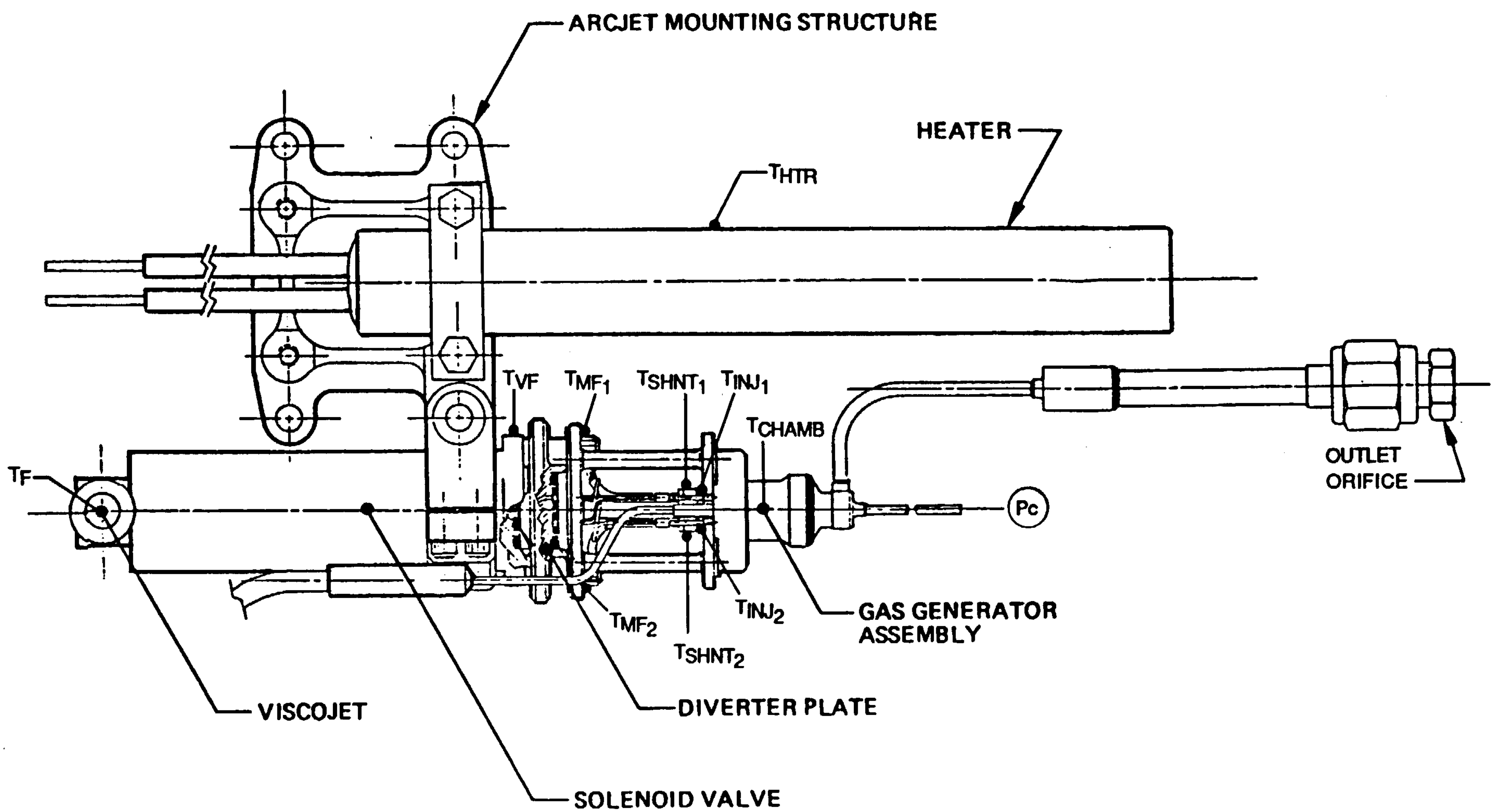
Test Results/Conclusions

Testing of the GG was conducted in a simulated arcjet firing environment. The setup is shown in Figure 3-112. The GG, valve, and a resistance heater were attached to a flight design mounting structure. The heater replaced the arcjet. By adjusting the heater power and its mounting surface conductance, the same mounting point temperatures and a similar radiation environment to that documented for the arcjet were achieved. An orifice was used on the GG outlet to achieve back pressures identical to those measured when exhausting into an arcjet. The control of flow through either injector was achieved by loosening the GG mounting fasteners and rotating the plate 180 degrees.

Initial performance tests were conducted which showed that stable and consistent flow and thermal characteristics could be achieved with either injector. Figure 3-113 shows flow rate and chamber pressure for each injector while operating with equivalent propellant feed pressures. These values agree between injectors to within 2%. Stable chamber pressure was demonstrated that was free of oscillations and dropouts. These characteristics are consistent with those of the standard, single injector GG.

The temperature profile of the unit was mapped in detail. Representative data are shown in Table 3-36 with thermocouple locations shown in Figure 3-112. Design goals for maintaining sufficiently low temperatures at the valve (83°C) were met through the use of the new thermal standoff design between the GG and valve mounting flanges.

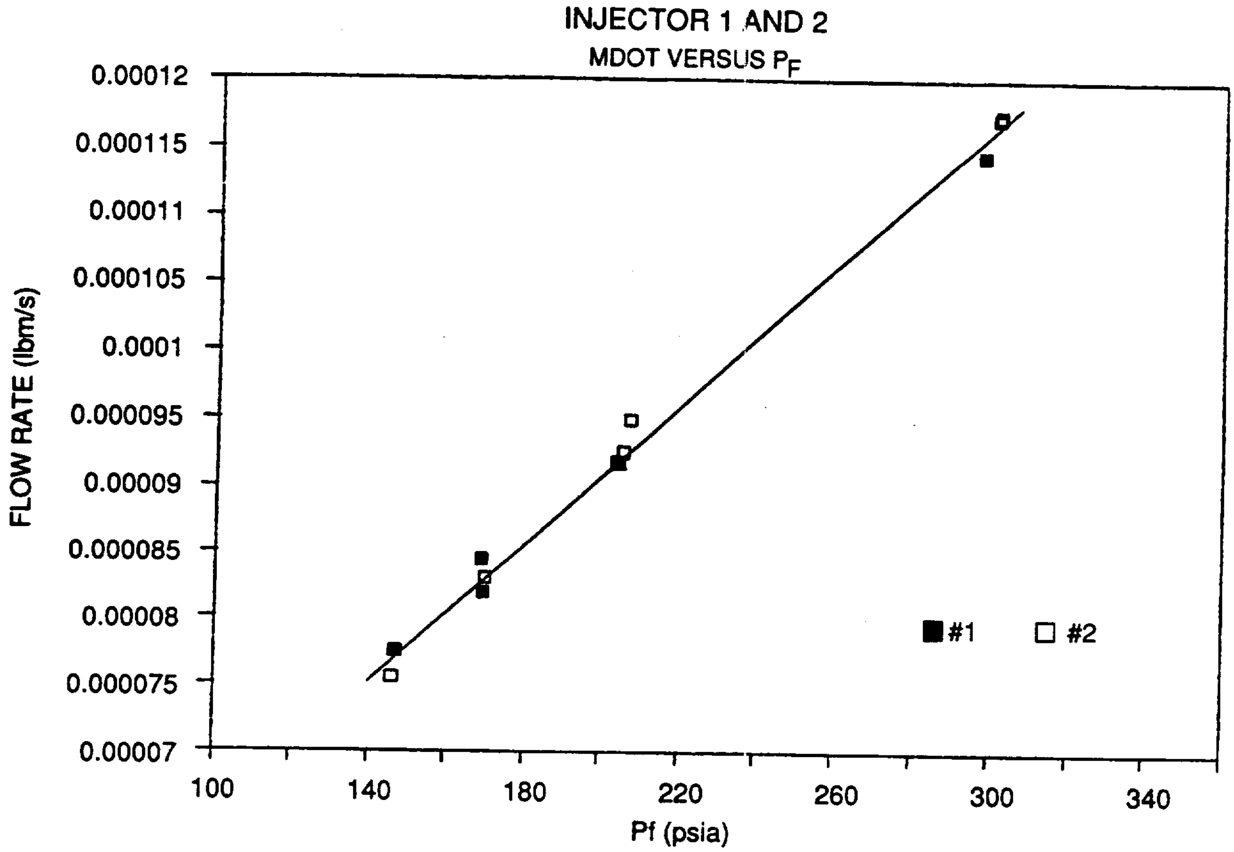
DUAL INJECTOR GAS GENERATOR TEST SETUP



11212-64A

Figure 3-112

GAS GENERATOR TEST DATA



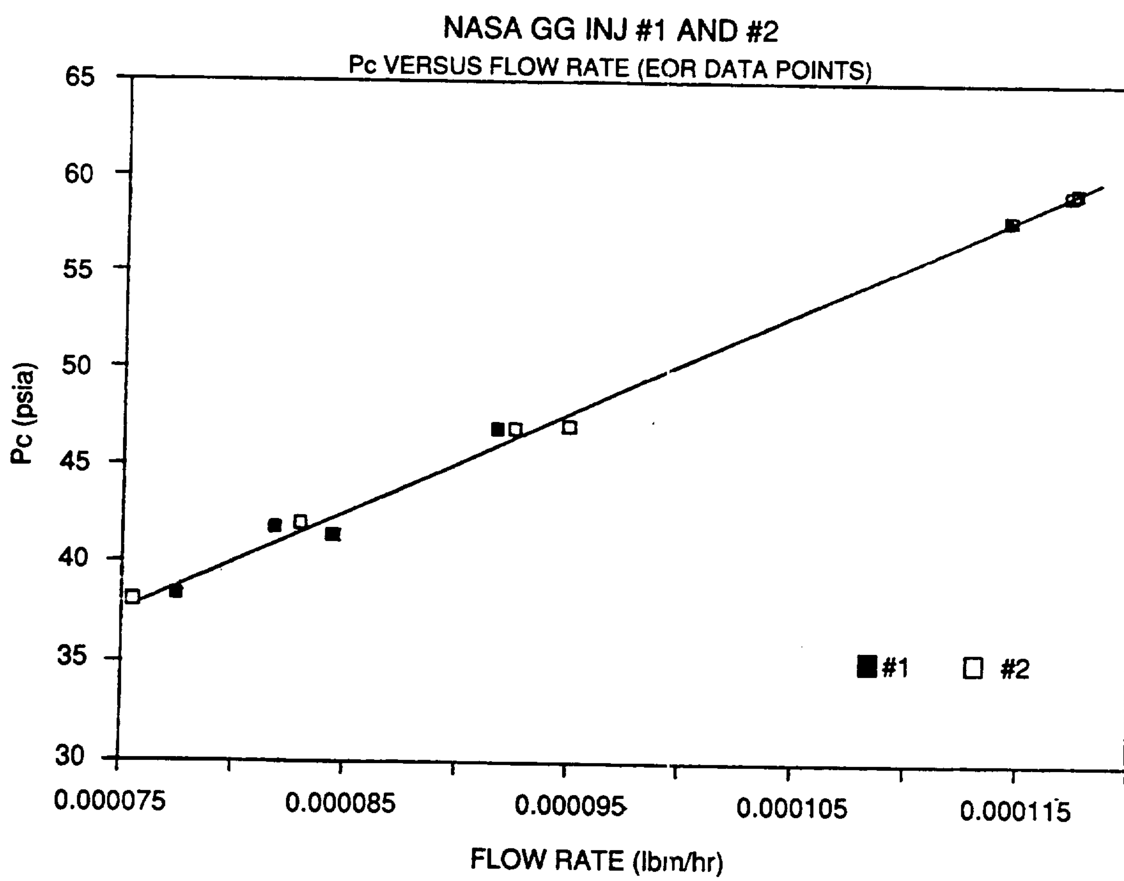


Figure 3-113

Table 3-36
DUAL INJECTOR GAS GENERATOR TEMPERATURE DATA

- Propellant flow through Injector No. 2
- $\dot{m} = 4.23 \times 10^{-5}$ kg/sec

Designation (See Fig. 3.4.3.2 B)	Location	Temperature (°C)
TF	Fuel Inlet	17
TVF	Valve Flange	83
T Chamb	Catalyst Chamber	561
T Inj1	Injector No. 1 Inlet	517
T Inj2	Injector No. 2 Inlet	565
T Shnt1	Thermal Shunt No. 1	249
T Shnt2	Thermal Shunt No. 2	137
Tmf 1	Mounting Flange No. 1 (Thermal Sink for Shunt No. 1)	139
Tmf 2	Mounting Flange No. 2 (Thermal Sink for Shunt No. 2)	116
Thtr	Cartridge Heater	316

The life test was conducted in a duty cycle of 1 hour on/0.5 hour off. A lifetime goal of 800 total hours was established. Each injector was operated over an equivalent flow rate range. Propellant feed pressure values were changed at 100 hour intervals to simulate a blowdown. Injector 2 was fired first for a total duration of 406 hours. Flow was then switched to injector 1 for an additional 509 hours. A summary of firing time, number of starts, and hydrazine throughput is shown in Table 3-37. At the conclusion of testing, both injectors were fully operational. No test shutdowns due to abnormal GG behavior were experienced.

Table 3-37
DUAL INJECTOR GAS GENERATOR — DEMONSTRATED LIFETIME

	Injector 1	Injector 2	Total
Hours fired	509	406	915
Number of Starts	514	410	929
Flow Rate Range (gm/s)	34.0 – 54.4	Same as 1	
N_2H_4 throughput (kg)	76.1	64.6	140.7

The encouraging results of these tests indicate that this GG concept is a viable means to achieving hydrazine arcjet lifetimes of over 1000 hours. Several suppliers were contacted regarding fabrication of a valve which could be integrated with the dual injector GG. A preliminary RRC specification drawing for this requirement is shown in Figure 3-114. The specified dimensional envelope is very similar to the existing valve used with the arcjet.

DUAL INJECTOR GG VALVE

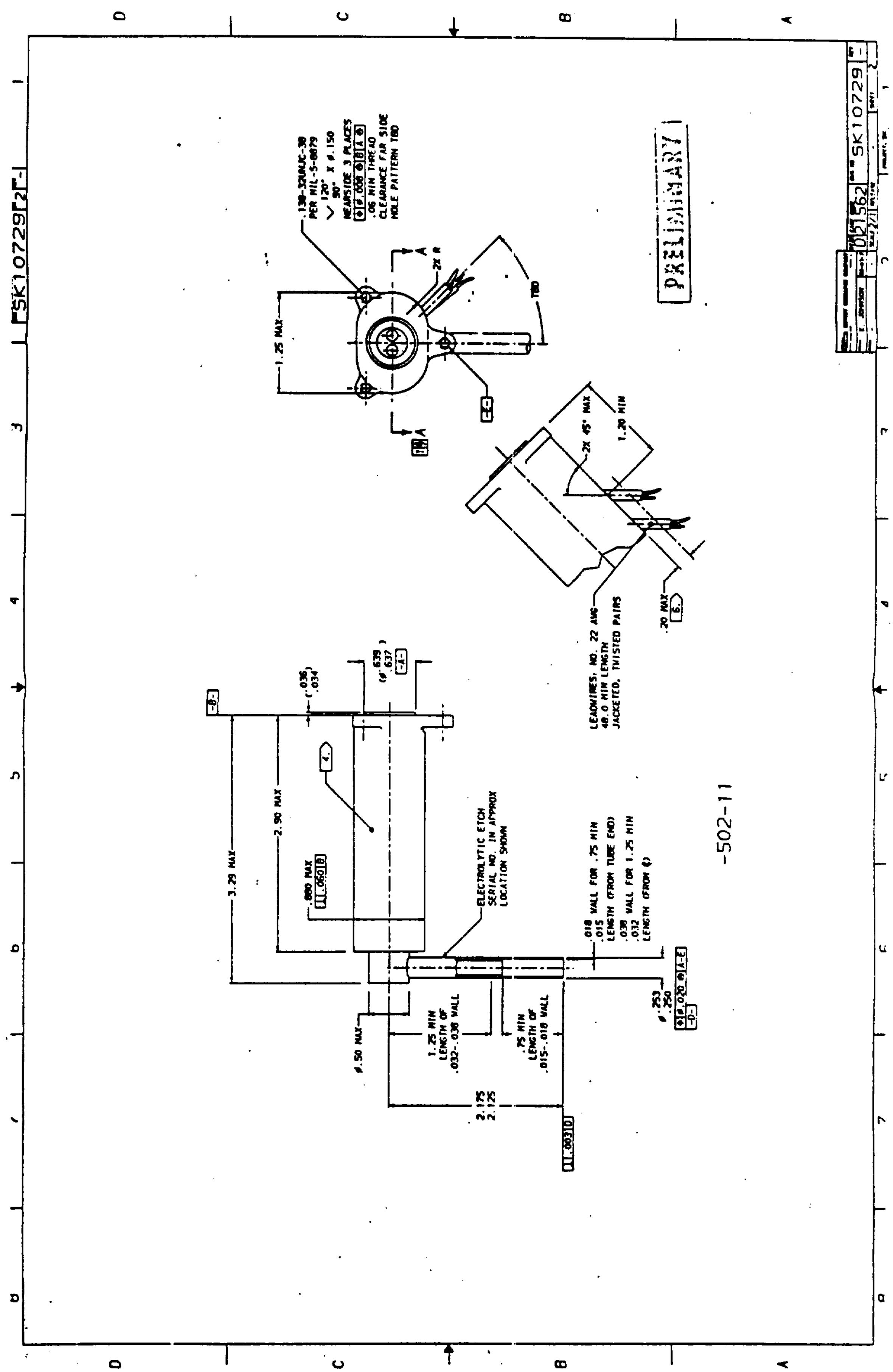


Figure 3-114

Several approaches were identified, of which two were the most attractive. The first is similar to the existing valve used except that an additional pair of solenoid actuated elements are located in parallel to the first which provides for both a dual path and series-redundant closing capability. The second incorporates a series-redundant element for turning the valve on and off with a latching section just downstream to control the dual path flow.

It was apparent from discussions that both of these concepts could be manufactured to meet RRC performance, weight, and dimensional requirements. The development of such a valve was not pursued on this program.

3.4.3.3 Life Test

The life test was initiated following the baseline performance map. The test was conducted on a 24 hour per day basis with a firing duty cycle of 1 hour on and 1/2 hour off. The 1/2 hour off time was sufficient for the refractory metal thruster parts (e.g., cathode, anode, body, and weld/braze joints) to transition through ductile-brittle phases, thus achieving a realistic thermal cycle environment. The command/telemetry interface of the PCU, flow control interface, and all steady state instrumentation were linked to a computer for automated monitoring and test control. The spacecraft propellant tank blowdown was simulated in a step-wise fashion. Eight feed pressure sequences were conducted in approximately equivalent 100 hour blocks.

The test was initiated on December 1, 1989 and completed February 3, 1990. A data summary package is given in Appendix B. The goal of 800 hours firing time was achieved with 811 hours completed during the life firing and 20 additional hours completed during intermittent health check firings. Both the arcjet thruster and PCU ran free of complications throughout the entire period. At the conclusion of testing, performance measurements and excellent demonstrated stability of the thruster indicated that additional life capability existed.

Some degradation in performance of the gas generator was observed, however, at 635 hours into the life test. A decline of 4% in flow rate occured over the 50 hour period between 635 and 685 hours. This was later found to be caused by propellant flow blockage in the GG injector. The blockage resulted from accumulation of non-volatile fuel deposits. The rate of flow reduction continually increased during this period and the GG degradation warranted interruption of the life test. The unit was removed from the test setup at 685 hours and replaced with a standard GG of the same configuration as used for S/N 001 testing. Following the changeout of GG's, the life test was resumed.

Performance of the system was extremely stable. The variation in system characteristics from the beginning to the end of life is shown in Table 3-38. Since the test was conducted entirely on the Cell 11 thrust stand, a comprehensive set of measurements was made for each of the 800 steady state runs. Figures 3-115 and 3-116 shows thrust and specific impulse data for these runs. Variation from run to run is due to small differences in feed pressure levels with the exception of the reduction observed at 685 hours. This corresponds to the change made in GG's where the restricted flow through the degrading GG resulted in higher specific impulse levels. The overall range as noted in Table 3-38 was 427 to 490 seconds. The corresponding mission average computed from the total impulse and propellant consumed was 454.7 seconds. This value exceeds the qualification goal of 450 seconds.

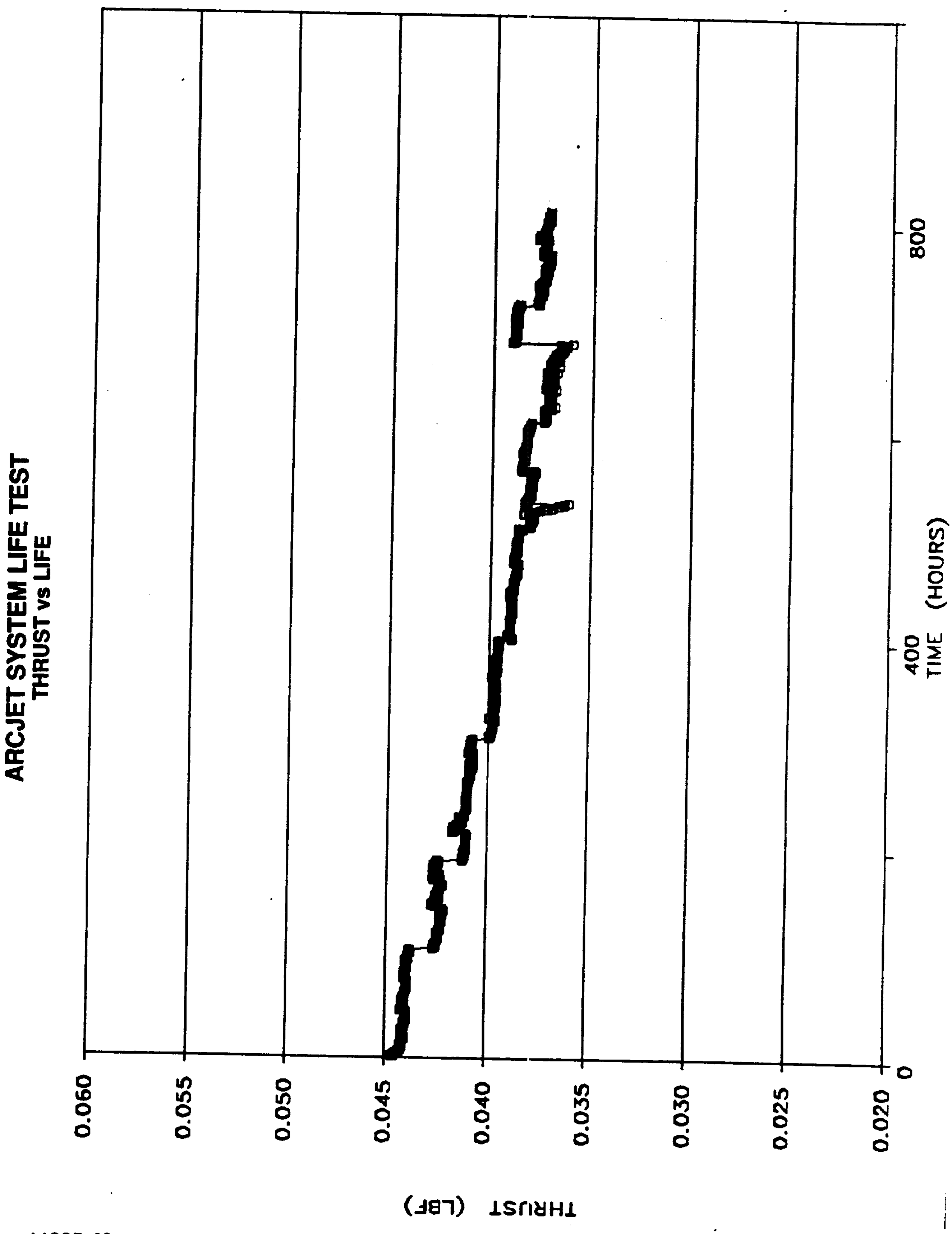
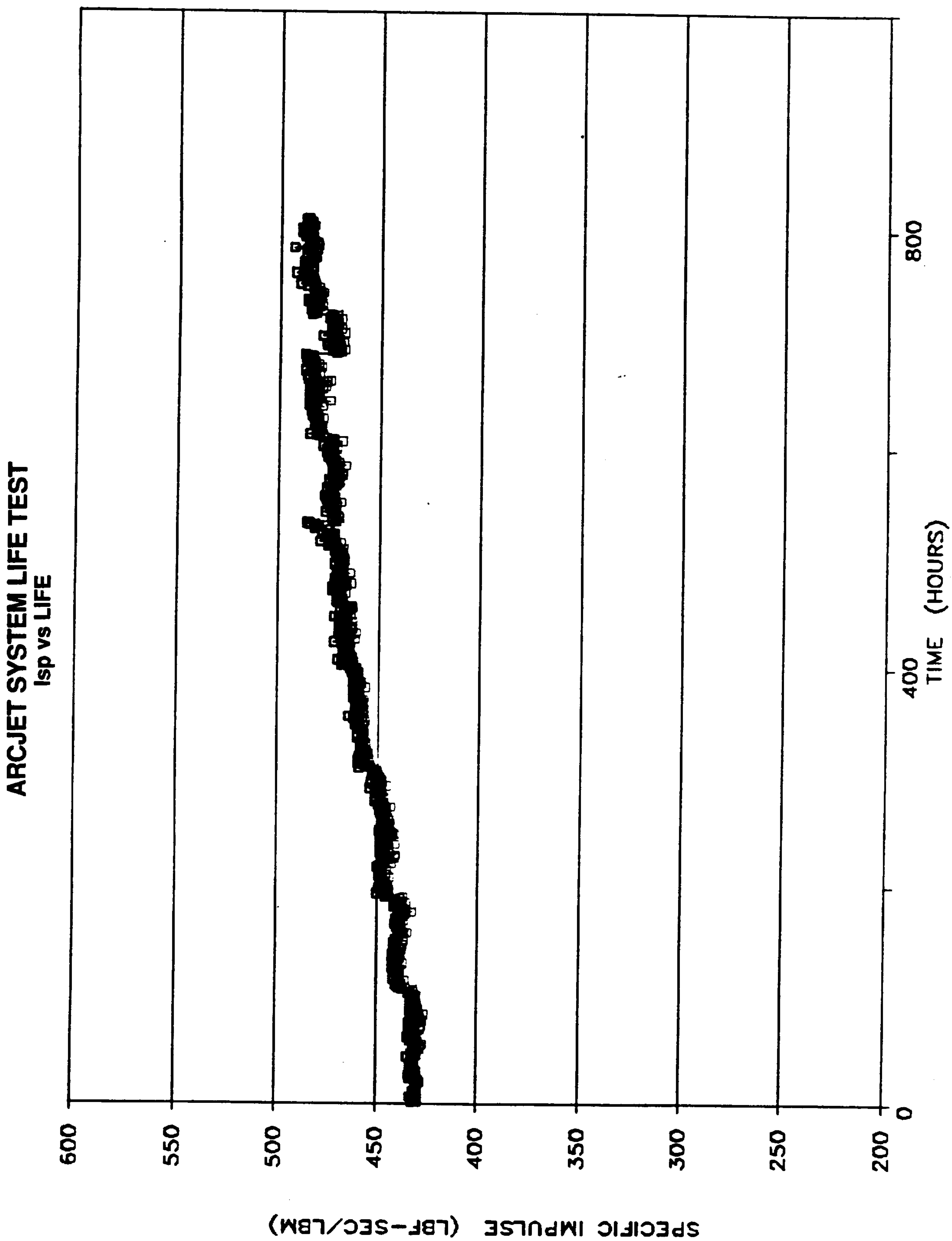

ARCJET SYSTEM LIFE TEST
THRUST vs LIFE
THRUST (LBF)
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0
400
800
TIME (HOURS)

Figure 3-115



ARCJET SYSTEM LIFE TEST
Isp vs LIFE
SPECIFIC IMPULSE (LBF-SEC/LBM)
600
550
500
450
400
350
300
250
200
0
400
800
TIME (HOURS)

Figure 3-116

Table 3-38
ARCJET SYSTEM LIFE TEST
MEASURED SYSTEM CHARACTERISTICS

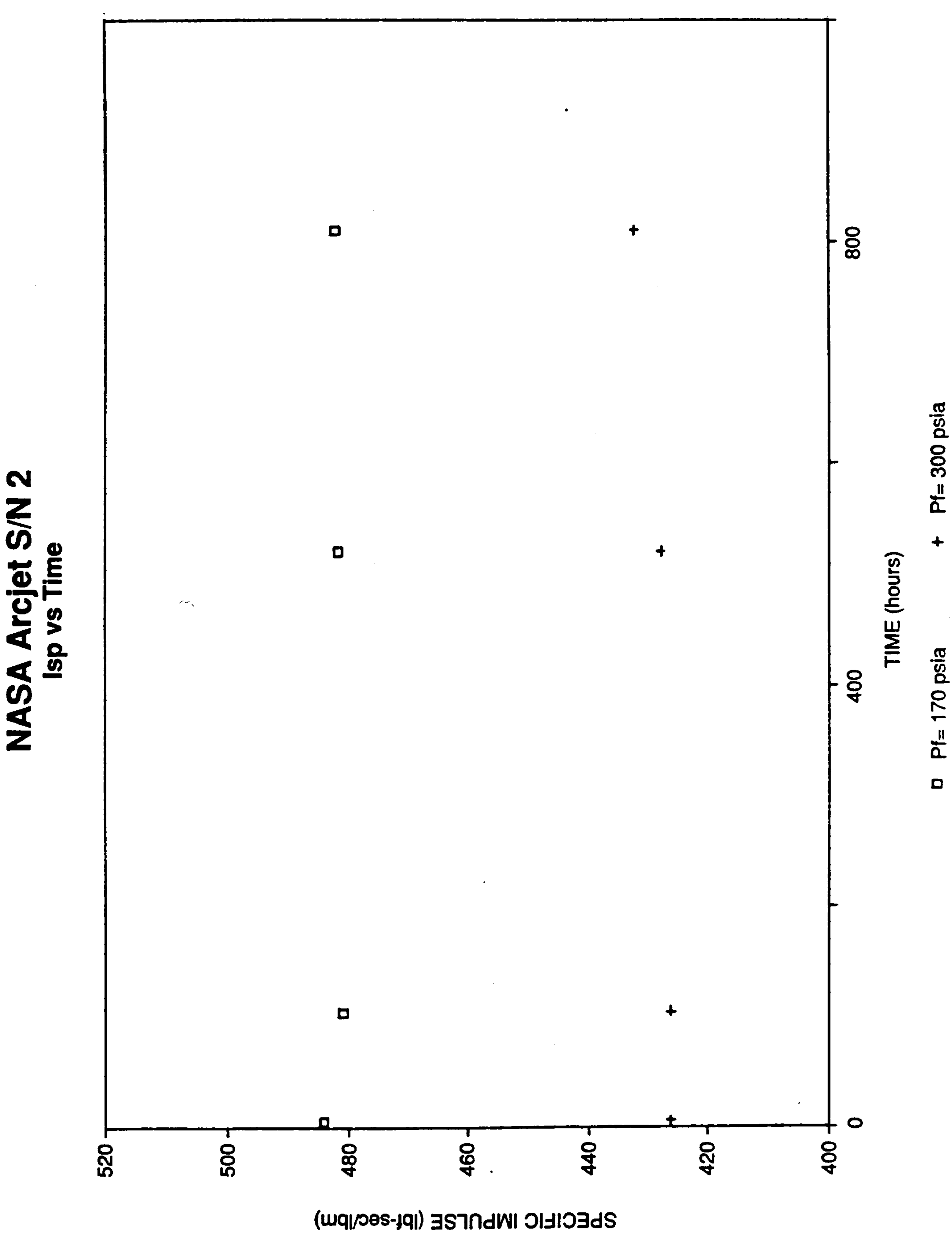
Parameter	Beginning-of-Life Measurement (0 Hours)	End-of-Life Measurement (811 HOURS)
Feed pressure (psia)	285	170
Flow rate (mg/sec)	46.7	34.7
Arcjet thrust (N)	0.198	0.165
Specific impulse (sec)	427	490
Arc voltage (V)	102.5	92.6
Arc current (A)	12.27	13.43
Arc power (W)	1254.6	1243.6
PCU efficiency (%)	89.8	87.7
PCU base temp. (°C)	26.7	26.7

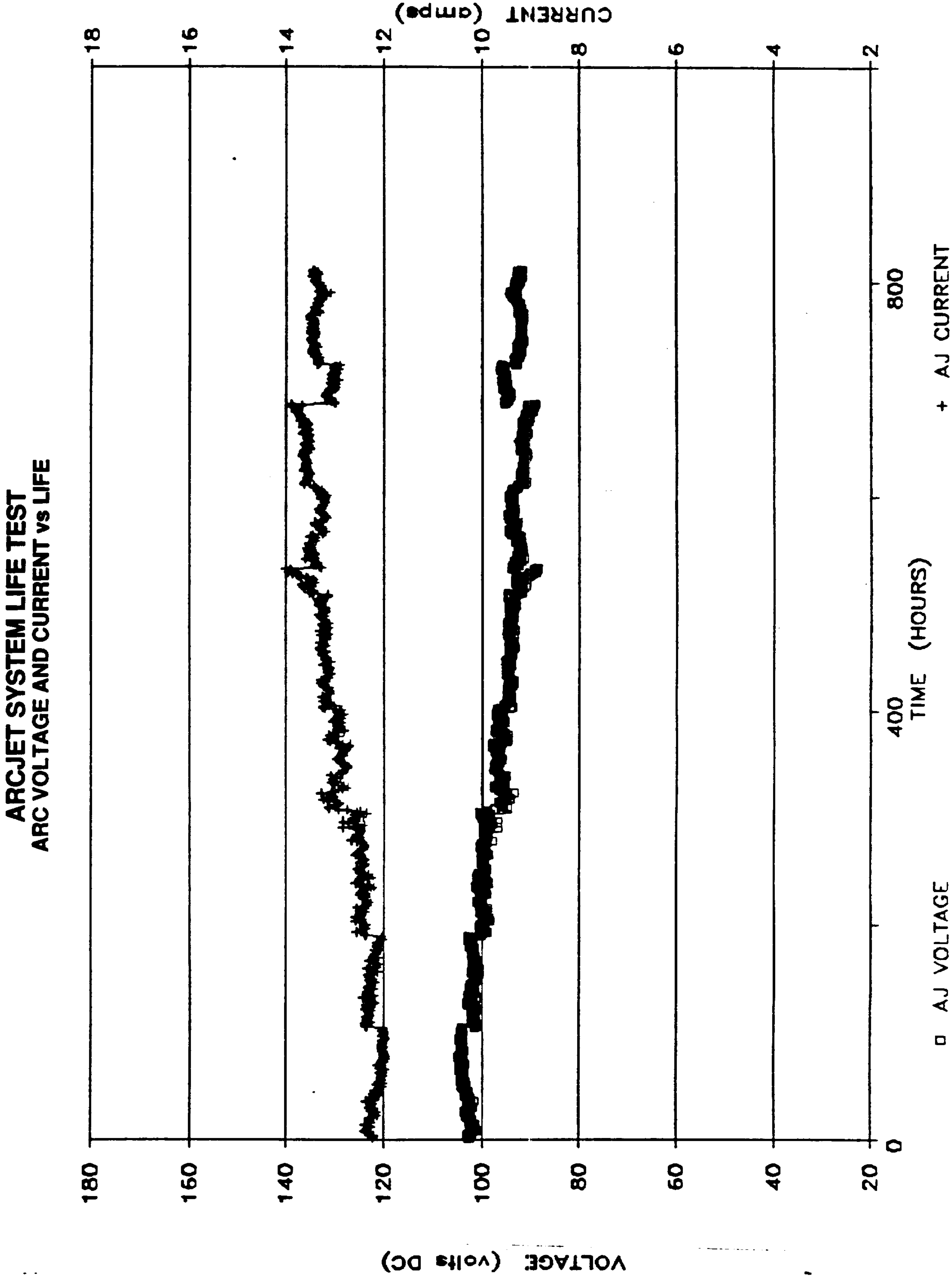
Further verification of the consistency in demonstrated performance was made through health check firings conducted at 0, 100, 500, and 800 hours cumulative lifetime. Figure 3-117 shows these measurements made at the upper and lower feed pressures in the blowdown range. For equivalent operating points, the maximum deviation between the four sets of specific impulse measurements is only 2.2% (9 seconds).

At constant power, the arc voltage tends to decrease with lower flow rate and increase as the cathode recesses due to erosion. These are therefore competing effects over the life of the system. The earlier development of cathode geometry was necessary to reduce these erosion rates to both maintain stable long term operation of the arcjet and minimize the voltage range required for PCU output. The demonstrated level of change shown in Figure 3-118, approximately 10 volts over 811 hours, easily met both of these criteria.

The PCU exhibited no changes in performance throughout the test. Constant input and output power regulation were maintained within 3% maximum deviation. Power conversion efficiency measurements were highly repeatable and ranged between 87.7% and 89.8%. The lower efficiency at end-of-life shown in Table 3-38 is due to operation at a lower output voltage. The PCU losses scale proportionately with the output current. The unit temperature measured at the hottest portion of its mounting interface, just beneath the power handling FET's, showed no variation over life.

The prior development of a reliable PCU start up circuit also proved succesful during the life test. A total of 845 starts were conducted throughout the entire set of qualification firings with start up occurring successfully on each first attempt. Additionally, the high number of start cycles induced no peformance inhibiting erosion to the anode nozzle, cathode, or any support hardware.


NASA Arcjet S/N 2
Isp vs Time
SPECIFIC IMPULSE (lbf-sec/lbm)
520
500
480
460
440
420
400
0
400
800
TIME (hours)
Pf= 170 psia
Pf= 300 psia



11225-50

Figure 3-118

In summary, the arcjet system demonstrated its capability to meet each of the reprentative qualification lifetime goals which are summarized in Table 3-39. The performance of the hydrazine gas generator which was used was not acceptable since it was replaced prior to completion of the life test. Other design options for this component are available however, which have demonstrated lifetimes exceeding the requirement of this test.

Table 3-39
ARCJET SYSTEM LIFE TEST SUMMARY

	Minimum Goal	Demonstrated	
Arcjet Firing Time (Hr)	800	811	Life
		20	Perf. map
		831	Total
Arcjet Starts	632	811	Life
		34	Perf. map
		845	Total
N_2H_4 Throughput (kg)	96.1	115.6	Life
		3.0	Perf. map
		118.6	Total
Total Impulse (N-sec)	443,960	515,323	Life
		13,313	Perf. map
		528,636	Total
Avg. Specific Impulse (sec)	450	454.7	Life

4.0 CONCLUSIONS

The low power hydrazine arcjet system designed and developed under the NASA LeRC Arcjet Research and Technology Program has successfully met almost all of the performance, environmental, and lifetime requirements established as representative of typical geosynchronous missions. A long duration, duty cycle life test was completed over a worst-case pressure blowdown. Performance, stability, and start-up characteristics were repeatable and consistent. Parallel gas generator development work has demonstrated lifetime capabilities in excess of those needed for near-term missions. The demonstrated system characteristics are summarized in Table 4-1. The knowledge developed under this program and at NASA LeRC has established the technology base needed to move into flight qualification of low power arcjet systems.

Table 4-1
DESIGN SUMMARY

Design Goal	Status
• Specific Impulse: 450 sec missions average	• Demonstrated 455 sec
• Life: 800 HR, 622 Starts	• 830 demonstrated on arcjet/PCU 680 on integrated GG 900 on stand-alone dual injector GG
• PCU Efficiency: 90%	• Demonstrated 87.7 to 91.0
• PCU EMI per MIL-STD-461/462	• Partial compliance
• PCU Start: 4 kV	• Demonstrated 4.72 kV
• Structural: Launch qualification level	• Demonstrated, arcjet assembly & PCU S/N 002
• Thermal: –15°C to 65°C Interface Temperature	• Demonstrated
• Weight/Volume: Arcjet/Cable – 1.5 kg	• Achieved, 1.32 kg
Arcjet Volume – Similar to ACT Resistojet	• Achieved, same mounting interface dimensions
PCU Mass – 4.54 kg	• Achieved, 4.52 kg
PCU Volume - 24 x 20 x 10 cm	• Achieved, 23.4 x 18.4 x 8.3 cm

5.0 REFERENCES

1. Knowles, S. C., Smith, W. W., Chun, S. I., and Feconda, R. T., "Low Power Hydrazine Arcjets: A System Description for Near-Term Applications," 1986 JANNAF Propulsion Meeting, August 1986.

2. Sovey, J. S., Penko, P. F., Grisnik, S. P., and Whalen, M. V., "Vacuum Chamber Pressure Effects on Thrust Measurements of Low Reynold's Number Nozzles,: NASA TM-86955, 1985.

3. Shapiro, A. B., TOPAZZD – A Two-Dimensional Finite Element Code for Heat Transfer Analysis, Electrostatic, and Magnetostatic Problems, UCID-20824, Lawrence Livermore National Laboratory, July 1986.

4. Gruber, R. P., "Power Electronics for a 1-Kilowatt Arcjet Thruster," AIAA Paper 86-1507, (NASA TM-87340) June 1986.

Appendix A

EM ARCJET S/N 001
PERFORMANCE MAPPING DATA

LPAJ NASA Lewis (V 1.09)   01-17 1989
NASA LPAJ ATP PERFORMANCE MAP S/N 001
STEADY-STATE END-OF-RUN REDUCED DATA

SEQ #	RUN #	Samp #	NOM Pf (psia)	NOM POW (watts)	Amps	XXXXX PCU Volts	XXXXXX PCU Power (watts)	ARCJET Volts	ARCJET Power (watts)	V/I	Thrust (lbf)	Thrust (N)
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1	80-8	CORRECT	300	1260	12.03	101.80	1224.65	101.36	1219.36	8.4256	0.046584	0.207217
2	80-8	CORRECT	285	1260	12.12	100.14	1213.70	99.69	1208.24	8.2252	0.045470	0.202258
3	80-8	CORRECT	260	1260	12.55	97.53	1224.00	97.07	1218.23	7.7347	0.044342	0.197243
4	80-8	CORRECT	240	1260	13.21	93.08	1229.59	92.59	1223.11	7.0091	0.042673	0.189819
5	80-8	CORRECT	205	1260	13.42	91.70	1230.61	91.21	1224.04	6.7966	0.041071	0.182691
6	80-8	CORRECT	185	1260	14.30	86.11	1231.37	85.58	1223.79	5.9846	0.038736	0.172304
7	80-8	CORRECT	170	1260	14.67	83.82	1229.64	83.28	1221.72	5.6769	0.037534	0.166961
== TEST 2	POST-VIBRATION PERFORMANCE ==											
1	81-2	20	300	1260	12.22	102.26	1249.62	102.03	1246.81	8.3494	0.046449	0.206614
2	81-2	34	285	1260	12.38	100.93	1249.51	100.70	1246.67	8.1341	0.045590	0.202793
3	81-2	51	260	1260	12.69	98.51	1250.09	98.27	1247.05	7.7439	0.044187	0.196553
4	81-2	65	240	1260	13.08	95.57	1250.06	95.33	1246.92	7.2882	0.042670	0.189805
5	81-2	79	205	1260	13.74	91.03	1250.75	90.77	1247.18	6.6063	0.040415	0.179774
6	81-2	93	185	1260	14.07	88.89	1250.68	88.63	1247.02	6.2992	0.038921	0.173128
7	81-3	15	170	1260	14.53	86.20	1252.49	85.93	1248.56	5.9140	0.037996	0.169014
== TEST 3	POST-VIBRATION PERFORMANCE ==											
1	81-5	45	300	1260	11.93	104.85	1250.86	104.63	1248.24	8.7703	0.045944	0.204370
2	81-6	13	285	1260	12.10	103.42	1251.38	103.19	1248.60	8.5281	0.044947	0.199933
3	81-6	28	260	1260	12.58	99.72	1254.48	99.49	1251.58	7.9086	0.043390	0.193007
4	81-6	42	240	1260	12.91	97.24	1255.37	97.00	1252.27	7.5136	0.042162	0.187543
5	81-6	55	205	1260	13.66	91.94	1255.90	91.69	1252.49	6.7123	0.039675	0.176483
6	81-6	69	185	1260	14.43	87.02	1255.70	86.76	1251.95	6.0125	0.037832	0.168285
7	81-6	84	170	1260	14.41	87.08	1254.82	86.82	1251.08	6.0250	0.037076	0.164923
== TEST 4	ALTERNATE POWER PERFORMANCE ==											
1	82-2	33		1400	12.88	108.94	1403.15	108.70	1400.06	8.4394	0.051623	0.229628
2	82-3	37		1400	13.75	102.08	1403.60	101.83	1400.16	7.4058	0.048720	0.216716
3	82-3	64		1400	14.49	96.98	1405.24	96.71	1401.33	6.6743	0.046292	0.205918
4	82-3	91		1400	15.66	89.71	1404.86	89.42	1400.32	5.7101	0.041549	0.184819
5	82-3	118		1400	16.36	85.84	1404.34	85.54	1399.43	5.2286	0.040197	0.178804
6	82-3	152		1620	15.23	106.70	1625.04	106.42	1620.78	6.9875	0.054944	0.244401
7	82-4	33		1620	16.16	100.49	1623.92	100.19	1619.07	6.1999	0.052295	0.232618
8	82-4	60		1620	17.19	94.42	1623.08	94.10	1617.58	5.4741	0.049031	0.218098
9	82-4	105		1620	18.39	88.13	1620.71	87.79	1614.46	4.7738	0.045237	0.201223
10	82-4	129		1620	18.99	85.21	1618.14	84.86	1611.49	4.4687	0.042809	0.190421
11	82-5	35		1700	16.13	106.43	1716.72	106.13	1711.88	6.5797	0.056862	0.252932
12	82-5	64		1700	17.29	99.28	1716.55	98.96	1711.02	5.7235	0.053566	0.238272
13	82-5	119		1700	17.91	95.82	1716.14	95.49	1710.23	5.3317	0.051237	0.227910
14	82-5	144		1700	18.91	90.46	1710.60	90.11	1703.98	4.7652	0.047752	0.212409

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OF POOR QUALITY

LPAJ NASA Lewis (V 1.09)   01-17-1989
NASA LPAJ ATP PERFORMANCE MAP S/N 001
STEADY-STATE END-OF-RUN REDUCED DATA

SEQ #	RUN #	Samp #	NOM Pf (psia)	NOM POW (watts)	FLOW (Lbm/Sec)	FLOW (g/SEC)	ISP (SEC)	Pf (PSIA)	Pf (KPa)	Pc (PSIA)	Pc (KPa)	P/MDOT
1	80-8	CORRECT	300	1260	0.00010654	0.048325	437.3	304.4	2098.8	63.6	438.5	25307400
2	80-8	CORRECT	285	1260	0.00010375	0.047060	438.3	286.2	1973.3	61.9	426.8	25974400
3	80-8	CORRECT	260	1260	0.00009883	0.044828	448.7	264.7	1825.0	60.1	414.4	27538800
4	80-8	CORRECT	240	1260	0.00009386	0.042577	454.6	242.6	1672.7	58.4	402.7	28767100
5	80-8	CORRECT	205	1260	0.00008690	0.039416	472.6	212.1	1462.4	55.2	380.6	31459100
6	80 8	CORRECT	185	1260	0.00008074	0.036623	479.8	185.8	1281.0	52.9	364.7	34044600
7	80-8	CORRECT	170	1260	0.00007678	0.034826	488.9	174.3	1201.8	51.9	357.8	35167100
== TEST 2	POST-VIBRATION PERFORMANCE ==											
1	81-2	20	300	1260	0.00010639	0.048256	436.6	302.8	2087.7	64.5	444.7	25846100
2	81-2	34	285	1260	0.00010363	0.047007	439.9	288.3	1987.8	63.2	435.7	26526400
3	81-2	51	260	1260	0.00009832	0.044598	449.4	263.5	1816.8	61.1	421.3	27965900
4	81-2	65	240	1260	0.00009284	0.042113	459.6	239.9	1654.1	59.0	406.8	29602700
5	81-2	79	205	1260	0.00008587	0.038948	470.7	208.2	1435.5	55.7	384.0	32017700
6	81-2	93	185	1260	0.00008113	0.036801	479.7	189.1	1303.8	53.7	370.2	33892500
7	81-3	15	170	1260	0.00007694	0.034898	493.9	174.3	1201.8	52.9	364.7	35777800
== TEST 3	POST-VIBRATION PERFORMANCE ==											
1	81-5	45	300	1260	0.00010444	0.047374	439.9	300.2	2069.8	65.7	453.0	26355900
2	81-6	13	285	1260	0.00010214	0.046332	440.0	285.5	1968.5	64.5	444.7	26953400
3	81-6	28	260	1260	0.00009680	0.043909	448.2	259.9	1791.9	62.6	431.6	28510900
4	81-6	42	240	1260	0.00009190	0.041687	458.8	240.7	1659.6	60.9	419.9	30042500
5	81-6	55	205	1260	0.00008374	0.037982	473.8	205.3	1415.5	57.2	394.4	32983300
6	81-6	69	185	1260	0.00007741	0.035112	488.7	181.9	1254.2	54.8	377.8	35666200
7	81-6	84	170	1260	0.00007441	0.033752	498.3	170.5	1175.6	53.1	366.1	37067500
== TEST 4	ALTERNATE POWER PERFORMANCE ==											
1	82-2	33		1400	0.00011783	0.053447	438.1	365.3	2518.7	74.2	511.6	26195000
2	82-3	37		1400	0.00010559	0.047895	461.4	307.7	2121.5	69.7	480.6	29244300
3	82-3	64		1400	0.00009764	0.044290	474.1	269.4	1857.4	66.5	458.5	31640500
4	82-3	91		1400	0.00008147	0.036954	510.0	198.9	1371.4	58.7	404.7	37900200
5	82 3	118		1400	0.00007858	0.035646	511.5	187.4	1292.1	57.9	399.2	39258700
6	82-3	152		1620	0.00011700	0.053070	469.6	387.9	2674.5	78.5	541.2	30545200
7	82-4	33		1620	0.00010764	0.048827	485.8	326.3	2249.8	73.7	508.1	33165000
8	82-4	60		1620	0.00009755	0.044250	502.6	275.3	1898.1	69.3	477.8	36562800
9	82-4	105		1620	0.00008541	0.038742	529.6	219.1	1510.6	64.0	441.3	41686100
10	82-4	129		1620	0.00007898	0.035825	542.0	194.3	1339.7	61.1	421.3	44995900
11	82-5	35		1700	0.00011912	0.054034	477.3	380.6	2624.1	79.8	550.2	31678400
12	82-5	64		1700	0.00010623	0.048187	504.2	313.9	2164.3	74.4	513.0	35521100
13	82-5	119		1700	0.00009887	0.044849	518.2	279.1	1924.3	71.3	491.6	38135800
14	82-5	144		1700	0.00008759	0.039730	545.2	228.4	1574.8	66.3	457.1	42892200

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LPAJ NASA Lewis (V 1.09)   01-17-1989
NASA LPAJ ATP PERFORMANCE MAP S/N 001
STEADY-STATE END-OF-RUN REDUCED DATA

SEQ #	RUN #	Samp #	NOM Pf (psia)	NOM POW (watts)	Tvf DEG F	Tvf DEG C	Tgg DEG F	Tgg DEG C	Tcon DEG F	Tcon DEG C	Tpl DEG F	Tpl DEG C	Tinj DEG F	Tinj DEG C
1	80-8	CORRECT	300	1260	189	87	855	457	210	99	76	24		
2	80-8	CORRECT	285	1260	181	83	852	456	211	99	83	28		
3	80-8	CORRECT	260	1260	201	94	854	456	211	99	80	27		
4	80-8	CORRECT	240	1260	233	112	855	457	215	102	79	26		
5	80-8	CORRECT	205	1260	241	116	855	457	225	107	86	30		
6	80-8	CORRECT	185	1260	269	131	853	456	220	104	85	29		
7	80-8	CORRECT	170	1260	31	1	853	456	215	102	91	33		
== TEST 2	POST-VIBRATION PERFORMANCE ==													
1	81-2	20	300	1260	201	94	1072	578	236	113			1161	627
2	81-2	34	285	1260	210	99	1071	577	246	119			1155	624
3	81-2	51	260	1260	218	103	1070	576	251	122			1164	629
4	81-2	65	240	1260	222	106	1063	573	252	122			1152	622
5	81-2	79	205	1260	228	109	1052	567	254	123			1146	619
6	81-2	93	185	1260	234	112	1049	565	251	122			1138	614
7	81-3	15	170	1260	234	112	1047	564	253	123			1129	609
== TEST 3	POST-VIBRATION PERFORMANCE ==													
1	81-5	45	300	1260	206	96	1068	575	235	113			1155	624
2	81-6	13	285	1260	209	99	1064	573	230	110			1148	620
3	81-6	28	260	1260	219	104	1066	574	247	119			1166	630
4	81-6	42	240	1260	226	108	1064	573	252	122			1157	625
5	81-6	55	205	1260	237	114	1060	571	253	123			1258	681
6	81-6	69	185	1260	239	115	1047	564	256	124			1143	617
7	81-6	84	170	1260	252	122	1049	565	259	126			1250	677
== TEST 4	ALTERNATE POWER PERFORMANCE ==													
1	82-2	33		1400	200	93	1073	578	236	113			1160	627
2	82-3	37		1400	210	99	1070	577	241	116			1162	628
3	82-3	64		1400	219	104	1067	575	252	122			1169	632
4	82-3	91		1400	234	112	1054	568	255	124			1259	682
5	82-3	118		1400	246	119	1054	568	258	126			1263	684
6	82-3	152		1620	230	110	1095	590	257	125			1299	704
[illegible]	82-4	33		1620	225	107	1074	579	245	118			1186	641
[illegible]	82-4	60		1620	235	113	1066	574	256	124			1170	632
9	82-4	105		1620	255	124	1068	576	275	135			1285	696
10	82-4	129		1620	257	125	1053	567	269	132			1163	628
11	82-5	35		1700	203	95	1081	583	234	112			1176	636
12	82-5	64		1700	218	103	1074	579	260	127			1171	633
13	82-5	119		1700	217	103	1066	574	239	115			1165	630
14	82-5	144		1700	241	116	1068	575	265	129			1286	697

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LPAJ NASA Lewis (V 1.09)   01-17-1989
NASA LPAJ ATP PERFORMANCE MAP S/N 001
STEADY STATE END-OF-RUN REDUCED DATA

SEQ #	RUN #	Samp #	NOM Pf (psia)	NOM POW (watts)	T1 DEG F	T1 DEG C	T2 DEG F	T2 DEG C	T3 DEG F	T3 DEG C	T4 DEG F	T4 DEG C	T5 DEG F	T5 DEG C	T6 DEG F	T6 DEG C
1	80-8	CORRECT	300	1260	1449	787	1004	540	721	383	289	143	248	120	96	36
2	80-8	CORRECT	285	1260	1450	788	1006	541	722	383	291	144	244	118	99	37
3	80-8	CORRECT	260	1260	1469	799	1014	546	726	385	291	144	247	119	101	38
4	80-8	CORRECT	240	1260	1514	823	1038	559	735	390	294	145	248	120	102	39
5	80-8	CORRECT	205	1260	1530	832	1057	569	743	395	296	147	263	128	105	40
6	80-8	CORRECT	185	1260	1584	862	1083	584	752	400	291	144	250	121	105	40
7	80-8	CORRECT	170	1260	1616	880	1103	595	759	404	277	136	240	116	105	41
== TEST 2	POST-VIBRATION PERFORMANCE ==															
1	81-2	20	300	1260	1471	799	1022	550	743	395	304	151	254	123	103	39
2	81-2	34	285	1260	1476	802	1026	552	744	396	310	154	263	128	110	43
3	81-2	51	260	1260	1502	817	1042	561	750	399	312	156	267	131	118	48
4	81-2	65	240	1260	1523	828	1057	569	756	402	312	156	268	131	122	50
5	81-2	79	205	1260	1544	840	1071	577	760	404	311	155	269	132	125	52
6	81-2	93	185	1260	1567	852	1085	585	765	407	308	153	266	130	129	54
7	81-3	15	170	1260	1598	870	1104	596	775	413	309	154	267	130	130	54
== TEST 3	POST-VIBRATION PERFORMANCE ==															
1	81-5	45	300	1260	1443	784	1009	543	737	392	303	150	252	122	108	42
2	81-6	13	285	1260	1461	794	1019	548	740	393	298	148	247	119	112	44
3	81-6	28	260	1260	1504	818	1044	562	751	399	309	154	263	128	119	48
4	81-6	42	240	1260	1525	830	1057	570	756	402	312	155	268	131	124	51
5	81-6	55	205	1260	1558	848	1079	582	763	406	309	154	268	131	127	53
6	81-6	69	185	1260	1592	867	1099	593	772	411	310	155	270	132	132	55
7	81-6	84	170	1260	1604	873	1109	598	777	414	311	155	272	133	136	57
== TEST 4	ALTERNATE POWER PERFORMANCE ==															
1	82-2	33		1400	1459	793	1012	544	743	395	305	152	254	123	100	38
2	82-3	37		1400	1520	827	1046	563	755	402	307	153	258	126	110	43
3	82-3	64		1400	1560	849	1070	576	764	406	313	156	268	131	117	47
4	82-3	91		1400	1624	884	1112	600	778	414	310	154	269	132	122	50
5	82-3	118		1400	1671	910	1132	614	790	421	312	155	272	133	128	53
6	82-3	152		1620	1529	832	1045	563	760	404	321	161	273	134	134	57
7	82-4	33		1620	1580	860	1072	578	766	408	310	155	261	127	131	55
8	82-4	60		1620	1631	888	1102	594	777	414	315	157	271	132	136	58
9	82-4	105		1620	1726	941	1159	626	805	429	327	164	288	142	143	61
10	82-4	129		1620	1771	966	1182	639	812	433	321	161	282	139	147	64
11	82-5	35		1700	1567	853	1062	572	769	410	307	153	252	122	105	41
12	82-5	64		1700	1632	889	1100	593	783	417	322	161	276	135	115	46
13	82-5	119		1700	1666	907	1117	603	787	419	306	152	254	123	117	47
14	82-5	144		1700	1747	953	1165	629	807	431	320	160	278	137	125	52

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C-3.

LPAJ NASA Lewis (V 1.09) 01-17-1989
NASA LPAJ ATP PERFORMANCE MAP S/N 001
STEADY-STATE END-OF-RUN REDUCED DATA

SEQ #	RUN #	Samp #	NOM Pf (psia)	NOM POW (watts)	GAS GENERATOR SEQ. ON TIME (MIN)	GAS GENERATOR CUM. ON TIME (MIN)	GAS GENERATOR SEQ. FUEL USED (LBM)	GAS GENERATOR CUM. FUEL USED (LBM)	GAS GENERATOR SEQ. IMPULSE (LBF-SEC)	GAS GENERATOR CUM. IMPULSE (LBF-SEC)	ARCJET SEQ. ON TIME (MIN)	ARCJET CUM. ON TIME (MIN)	ARCJET SEQ. FUEL USED (LBM)	ARCJET CUM. FUEL USED (LBM)	ARCJET SEQ. IMPULSE (LBF-SEC)	ARCJET CUM. IMPULSE (LBF-SEC)
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1	80-8	CORRECT	300	1260	28.7	28.7	0.18534	0.18534	84.7	84.7	28.7	28.7	0.18534	0.18534	84.7	84.7
2	80-8	CORRECT	285	1260	20.0	48.7	0.12537	0.31071	49.4	134.0	16.0	44.7	0.09940	0.28474	45.0	129.7
3	80-8	CORRECT	260	1260	14.0	62.8	0.08296	0.39367	37.9	171.9	14.0	58.8	0.08296	0.36770	37.9	167.6
4	80-8	CORRECT	240	1260	20.0	82.8	0.11403	0.50770	44.8	216.7	16.0	74.8	0.09038	0.45808	41.2	208.7
5	80-8	CORRECT	205	1260	18.0	100.8	0.09422	0.60192	44.3	261.0	18.0	92.8	0.09422	0.55230	44.3	253.0
6	80-8	CORRECT	185	1260	14.0	114.8	0.06717	0.66909	32.2	293.2	14.0	106.8	0.06717	0.61947	32.2	285.2
7	80-8	CORRECT	170	1260	10.0	124.8	0.04587	0.71496	22.5	315.7	10.0	116.8	0.04587	0.66534	22.5	307.7
== TEST 2	POST-VIBRATION PERFORMANCE ==															
1	81-2	20	300	1260	39.0	39.0	0.25285	0.25285	104.8	104.8	34.0	34.0	0.21878	0.21878	100.3	100.3
2	81-2	34	285	1260	24.0	63.0	0.14961	0.40246	65.5	170.3	24.0	58.0	0.14961	0.36838	65.5	165.8
3	81-2	51	260	1260	30.0	93.0	0.17747	0.57993	79.6	249.9	30.0	88.0	0.17747	0.54585	79.6	245.4
4	81-2	65	240	1260	24.0	117.0	0.13455	0.71448	61.3	311.2	24.0	112.0	0.13455	0.68041	61.3	306.7
5	81-2	79	205	1260	24.0	141.0	0.12413	0.83861	58.6	369.9	24.0	136.0	0.12413	0.80453	58.6	365.3
6	81-2	93	185	1260	24.0	165.0	0.11543	0.95404	56.7	426.6	24.0	160.0	0.11543	0.91997	56.7	422.0
7	81-3	15	170	1260	38.0	203.1	0.17576	1.12980	99.6	526.2	38.0	198.1	0.17576	1.09573	99.6	521.7
== TEST 3	POST-VIBRATION PERFORMANCE ==															
1	81-5	45	300	1260	33.0	33.0	0.20743	0.20743	98.2	98.2	33.0	33.0	0.20743	0.20743	98.2	98.2
2	81-6	13	285	1260	20.0	53.0	0.12373	0.33116	56.9	155.1	20.0	53.0	0.12373	0.33116	56.9	155.1
3	81-6	28	260	1260	22.0	75.0	0.12959	0.46076	58.5	213.6	22.0	75.0	0.12959	0.46076	58.5	213.6
4	81-6	42	240	1260	22.0	97.0	0.12181	0.58257	56.8	270.4	22.0	97.0	0.12181	0.58257	56.8	270.4
5	81-6	55	205	1260	20.0	117.0	0.10120	0.68377	48.6	319.0	20.0	117.0	0.10120	0.68377	48.6	319.0
6	81-6	69	185	1260	22.0	139.0	0.10304	0.78681	51.5	370.5	22.0	139.0	0.10304	0.78681	51.5	370.5
7	81-6	84	170	1260	24.0	163.0	0.10722	0.89403	55.1	425.6	24.0	163.0	0.10722	0.89403	55.1	425.6
== TEST 4	ALTERNATE POWER PERFORMANCE ==															
1	82-2	33		1400	43.0	43.0	0.30556	0.30556	132.6	132.6	38.0	38.0	0.26971	0.26971	127.7	127.7
2	82-3	37		1400	35.1	78.1	0.22393	0.52949	106.6	239.2	34.1	72.1	0.21650	0.48622	105.6	233.3
3	82-3	64		1400	25.0	103.1	0.14857	0.67806	67.1	306.3	23.0	95.1	0.13564	0.62186	64.9	298.2
4	82-3	91		1400	25.0	128.2	0.12318	0.80124	61.8	368.1	24.0	119.2	0.11798	0.73984	61.0	359.2
5	82-3	118		1400	25.0	153.2	0.11680	0.91804	59.8	427.9	24.0	143.2	0.11200	0.85184	59.1	418.3
6	82-3	152		1620	32.0	185.2	0.22132	1.13936	98.1	526.0	29.1	172.2	0.20475	1.05659	95.0	513.3
7	82-4	33		1620	31.0	216.3	0.19840	1.33776	104.6	630.6	29.0	201.3	0.18628	1.24287	102.8	616.1
8	82-4	60		1620	25.0	241.3	0.14387	1.48163	66.1	696.7	21.0	222.3	0.12000	1.36287	62.7	678.8
9	82-4	105		1620	44.4	285.7	0.21747	1.69910	104.8	801.6	37.0	259.3	0.19026	1.55313	101.9	780.8
10	82-4	129		1620	22.0	307.7	0.10426	1.80336	54.6	856.2	21.0	280.3	0.09913	1.65225	53.8	834.6
11	82-5	35		1700	33.0	340.7	0.23794	2.04130	97.4	953.6	25.0	305.4	0.18024	1.83250	89.8	924.4
12	82-5	64		1700	27.0	367.8	0.17491	2.21621	77.8	1031.4	23.0	328.4	0.14693	1.97943	74.1	998.5
13	82-5	119		1700	28.0	395.8	0.16695	2.38316	81.3	1112.8	25.0	353.5	0.14847	2.12790	79.4	1077.9
14	82-5	144		1700	23.0	418.9	0.12254	2.50570	62.6	1175.4	21.0	374.5	0.11053	2.23843	61.1	1139.0

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Appendix B

EM ARCJET SYSTEM LIFE TEST DATA

TEST DATA SUMMARY

NASA LEWIS ARCJET SYSTEM DEMONSTRATION TESTING
ARCJET S/N 2, PCU S/N 1

810 HOUR DUTY CYCLE LIFE TEST AND
PERFORMANCE MAP FIRINGS

CONDUCTED 11/15/89 THROUGH 2/3/90

MARCH 6, 1990

LIFE TEST DATA

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
329-17	5	12/01/89	60.0	60.0	1.0	283.2	0.0001038	0.38	0.38	61.9	0.04454	160.3	160	429.2	2.01	596512	2.055E+10
329-17	10	12/01/89	60.0	120.0	2.0	282.9	0.0001033	0.37	0.75	61.9	0.04460	160.6	321	431.8	2.11	599342	2.072E+10
329-17	15	12/01/89	60.0	180.0	3.0	282.6	0.0001038	0.37	1.13	62.0	0.04448	160.1	481	428.6	2.23	597475	2.049E+10
329-17	20	12/01/89	60.0	240.0	4.0	282.2	0.0001033	0.38	1.50	61.9	0.04444	160.0	641	430.0	2.01	599052	2.063E+10
329-17	25	12/01/89	60.0	300.0	5.0	281.8	0.0001024	0.38	1.88	62.1	0.04425	159.3	800	432.1	2.06	606386	2.095E+10
329-17	30	12/02/89	60.0	360.0	6.0	281.5	0.0001024	0.37	2.25	62.1	0.04430	159.5	960	432.6	2.24	606445	2.092E+10
329-17	35	12/02/89	60.0	420.0	7.0	281.3	0.0001029	0.37	2.62	62.2	0.04422	159.2	1119	429.9	2.13	604705	2.071E+10
329-17	40	12/02/89	60.0	480.0	8.0	281.1	0.0001029	0.37	3.00	62.3	0.04415	159.0	1278	429.3	2.19	605678	2.068E+10
329-17	45	12/02/89	60.0	540.0	9.0	280.9	0.0001024	0.37	3.37	62.3	0.04416	159.0	1437	431.3	2.02	608398	2.085E+10
329-17	50	12/02/89	60.0	600.0	10.0	280.9	0.0001028	0.37	3.74	62.4	0.04409	158.7	1596	428.8	2.02	606886	2.067E+10
329-17	55	12/02/89	60.0	660.0	11.0	281.1	0.0001024	0.37	4.11	62.5	0.04414	158.9	1755	431.2	2.09	610471	2.086E+10
329-17	60	12/02/89	60.0	720.0	12.0	282.7	0.0001029	0.37	4.48	62.7	0.04419	159.1	1914	429.3	2.12	609093	2.076E+10
329-17	65	12/02/89	60.0	780.0	13.0	282.1	0.0001027	0.37	4.86	62.6	0.04412	158.8	2073	429.7	2.19	609720	2.082E+10
329-17	70	12/02/89	60.0	840.1	14.0	282.5	0.0001027	0.37	5.23	62.7	0.04413	158.9	2231	429.6	2.10	610397	2.083E+10
329-17	75	12/02/89	60.0	900.1	15.0	282.4	0.0001028	0.37	5.60	62.8	0.04411	158.8	2390	429.3	2.12	611192	2.080E+10
329-17	80	12/02/89	60.0	960.1	16.0	282.5	0.0001027	0.37	5.98	62.8	0.04412	158.8	2549	429.8	2.34	611788	2.085E+10
329-17	85	12/02/89	60.0	1020.1	17.0	282.3	0.0001025	0.37	6.35	62.8	0.04409	158.8	2708	430.0	2.19	612563	2.088E+10
329-17	90	12/02/89	60.0	1080.1	18.0	281.9	0.0001026	0.37	6.72	62.7	0.04401	158.4	2866	429.1	2.20	611230	2.083E+10
329-17	95	12/02/89	60.0	1140.1	19.0	281.7	0.0001029	0.37	7.09	62.8	0.04399	158.4	3025	427.7	2.32	610539	2.069E+10
329-17	100	12/02/89	60.0	1200.1	20.0	281.7	0.0001029	0.37	7.47	62.8	0.04404	158.5	3183	427.9	2.21	610123	2.066E+10
329-17	105	12/02/89	60.0	1260.1	21.0	281.8	0.0001024	0.37	7.84	62.7	0.04403	158.5	3342	430.1	2.23	612424	2.090E+10
329-17	110	12/03/89	60.0	1320.1	22.0	281.8	0.0001029	0.37	8.21	62.8	0.04406	158.6	3500	428.3	2.19	610361	2.069E+10
329-17	115	12/03/89	60.0	1380.1	23.0	281.8	0.0001019	0.37	8.58	62.7	0.04411	158.8	3659	433.1	2.29	615611	2.112E+10
329-17	120	12/03/89	60.0	1440.1	24.0	281.9	0.0001023	0.37	8.95	62.8	0.04413	158.9	3818	431.2	2.23	613641	2.092E+10
329-17	125	12/03/89	60.0	1500.1	25.0	282.1	0.0001024	0.37	9.32	62.8	0.04415	158.9	3977	431.1	2.14	613281	2.091E+10
329-17	130	12/03/89	60.0	1560.1	26.0	282.1	0.0001018	0.37	9.69	62.9	0.04411	158.8	4136	433.2	2.16	617696	2.114E+10
329-17	135	12/03/89	60.0	1620.1	27.0	282.3	0.0001024	0.37	10.06	63.0	0.04412	158.9	4295	430.9	2.18	615355	2.092E+10
329-17	140	12/03/89	60.0	1680.1	28.0	282.4	0.0001025	0.37	10.43	62.9	0.04408	158.7	4453	430.2	2.27	613898	2.091E+10
329-17	145	12/03/89	60.0	1740.1	29.0	282.3	0.0001023	0.37	10.81	63.0	0.04403	158.5	4612	430.3	2.21	615595	2.094E+10
32[illegible]	150	12/03/89	60.0	1800.1	30.0	282.3	0.0001024	0.37	11.18	63.0	0.04399	158.4	4770	429.5	2.26	615174	2.091E+10
329-17	155	12/03/89	60.0	1860.1	31.0	282.3	0.0001018	0.37	11.55	63.0	0.04403	158.6	4929	432.4	2.08	618800	2.116E+10
329-17	160	12/03/89	60.0	1920.1	32.0	282.3	0.0001023	0.37	11.92	63.1	0.04398	158.3	5087	430.1	2.33	617115	2.097E+10
329-17	165	12/03/89	60.0	1980.1	33.0	282.2	0.0001019	0.37	12.29	63.1	0.04392	158.2	5245	431.2	2.10	619539	2.112E+10
329-17	170	12/03/89	60.0	2040.1	34.0	282.0	0.0001023	0.37	12.66	63.1	0.04404	158.5	5404	430.6	2.19	616934	2.092E+10
329-17	175	12/03/89	60.0	2100.2	35.0	281.8	0.0001014	0.37	13.03	63.3	0.04392	158.2	5562	433.1	2.62	624199	2.125E+10

LPAJ NASA LEWIS (
LIFE TEST NASA

RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-17	5	12/01/89	31.76	44.19	1403.55	102.48	12.24	1254.84	1260.24	89.79	33.25	26664300	192	955	251	1549	736	966	80		1
329-17	10	12/01/89	31.87	44.05	1404.00	102.65	12.22	1254.71	1260.09	89.75	33.51	26787100	192	954	251	1545	735	969	80		2
329-17	15	12/01/89	31.93	43.96	1403.34	102.85	12.22	1256.53	1261.90	89.92	33.12	26700200	193	953	251	1551	737	972	80		3
329-17	20	12/01/89	31.89	43.99	1402.83	102.73	12.20	1252.95	1258.31	89.70	33.29	26736300	195	963	251	1546	737	1008	80		4
329-17	25	12/01/89	31.88	44.08	1405.43	101.95	12.30	1253.91	1259.36	89.61	33.28	26998900	194	954	251	1562	739	978	80		5
329-17	30	12/02/89	31.91	44.05	1405.71	102.09	12.31	1256.23	1261.68	89.75	33.30	27051300	195	957	251	1561	739	1011	80		6
329-17	35	12/02/89	31.90	44.04	1404.94	101.79	12.35	1256.89	1262.37	89.85	33.02	26942400	195	955	251	1563	740	1006	80		7
329-17	40	12/02/89	31.87	44.15	1406.80	101.21	12.39	1254.35	1259.88	89.56	32.99	26889000	195	956	251	1569	741	1013	80		8
329-17	45	12/02/89	31.90	44.07	1405.73	101.91	12.34	1257.30	1262.78	89.83	33.07	27072600	195	958	251	1564	740	1008	80		9
329-17	50	12/02/89	31.88	44.11	1406.05	101.63	12.35	1254.68	1260.17	89.63	32.89	26908000	194	952	251	1568	741	978	80		10
329-17	55	12/02/89	31.90	44.08	1405.86	101.58	12.33	1252.38	1257.85	89.47	33.17	26974200	195	957	252	1570	742	1009	80		11
329-17	60	12/02/89	31.91	44.01	1404.29	102.11	12.26	1252.17	1257.58	89.55	33.07	26821200	194	954	251	1565	740	971	80		12
329-17	65	12/02/89	31.93	44.01	1405.34	101.91	12.29	1252.48	1257.92	89.51	33.04	26897700	194	959	252	1565	741	966	80		13
329-17	70	12/02/89	31.95	44.04	1407.07	101.38	12.38	1255.16	1260.68	89.60	32.97	26943200	196	963	252	1569	743	1012	81		14
329-17	75	12/02/89	31.96	43.97	1405.31	102.02	12.31	1255.64	1261.09	89.74	32.92	26945900	194	952	251	1565	741	979	80		15
329-17	80	12/02/89	31.97	43.90	1403.66	102.35	12.27	1256.06	1261.48	89.87	32.96	26982100	194	954	251	1558	739	972	80		16
329-17	85	12/02/89	31.97	43.94	1404.83	102.07	12.28	1253.12	1258.55	89.59	33.03	26951200	196	956	252	1562	741	1013	80		17
329-17	90	12/02/89	31.98	43.94	1405.03	102.02	12.30	1254.87	1260.31	89.70	32.85	26974900	194	953	252	1562	740	973	81		18
329-17	95	12/02/89	31.99	43.92	1404.87	102.25	12.28	1255.40	1260.82	89.75	32.72	26912700	194	954	252	1559	740	972	81		19
329-17	100	12/02/89	31.97	43.95	1404.88	102.25	12.30	1257.20	1262.65	89.88	32.72	26931600	196	960	252	1557	740	1019	81		20
329-17	105	12/02/89	31.98	43.85	1402.45	102.82	12.20	1253.92	1259.27	89.79	32.97	27007200	194	952	251	1548	738	972	80		21
329-17	110	12/03/89	32.00	43.81	1401.96	103.10	12.15	1252.83	1258.14	89.74	32.88	26849800	194	965	251	1548	739	966	80		22
329-17	115	12/03/89	31.98	43.85	1402.51	102.83	12.20	1254.53	1259.89	89.83	33.24	27160600	196	952	251	1548	738	1017	80		23
329-17	120	12/03/89	32.00	43.78	1400.87	103.07	12.19	1256.11	1261.46	90.05	33.07	27064300	194	951	251	1551	739	975	80		24
329-17	125	12/03/89	32.01	43.77	1400.75	103.19	12.15	1253.51	1258.82	89.87	33.15	26993000	195	957	251	1544	738	1003	80		25
329-17	130	12/03/89	32.00	43.79	1401.23	103.02	12.20	1256.63	1261.99	90.06	33.20	27209700	194	950	251	1550	738	972	80		26
329-17	135	12/03/89	32.01	43.85	1403.67	102.18	12.26	1252.88	1258.29	89.64	33.13	26983700	196	957	252	1557	741	1006	80		27
329-17	140	12/03/89	32.01	43.80	1402.17	102.91	12.20	1255.03	1260.38	89.89	32.99	27008000	195	951	252	1551	739	969	80		28
329-17	145	12/03/89	32.00	43.86	1403.48	102.21	12.25	1251.62	1257.02	89.56	33.04	26967700	195	962	253	1558	741	962	81		29
329-17	150	12/03/89	32.01	43.90	1404.87	101.93	12.31	1254.94	1260.40	89.72	32.86	27020800	197	955	252	1560	742	1017	81		30
329-17	155	12/03/89	31.99	43.86	1403.11	102.36	12.25	1253.71	1259.11	89.74	33.15	27151700	197	950	252	1557	741	1015	80		31
329-17	160	12/03/89	32.01	43.83	1403.16	102.33	12.25	1253.18	1258.58	89.70	32.95	27024000	197	956	252	1559	742	1004	81		32
329-17	165	12/03/89	32.01	43.85	1403.54	102.28	12.28	1256.15	1261.58	89.89	32.91	27195300	196	952	252	1560	741	964	81		33
329-17	170	12/03/89	32.00	43.80	1401.84	102.63	12.21	1253.29	1258.66	89.79	33.04	27020100	197	954	252	1556	741	1004	80		34
329-17	175	12/03/89	32.03	43.81	1402.98	102.25	12.27	1254.76	1260.18	89.82	33.10	27282200	197	956	252	1561	742	1006	80		35

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
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329-17	180	12/03/89	60.0	2160.2	36.0	281.8	0.0001015	0.37	13.40	63.2	0.04389	158.0	5720	432.4	2.31	622537	2.121E+10
329-17	185	12/03/89	60.0	2220.2	37.0	281.9	0.0001017	0.37	13.77	63.3	0.04395	158.2	5878	432.1	2.19	622119	2.114E+10
329-17	190	12/04/89	60.0	2280.2	38.0	281.9	0.0001019	0.37	14.14	63.2	0.04399	158.4	6037	431.9	2.33	620459	2.108E+10
329-17	195	12/04/89	60.0	2340.2	39.0	282.0	0.0001016	0.37	14.51	63.3	0.04391	158.1	6195	432.2	2.17	623031	2.119E+10
329-17	200	12/04/89	60.0	2400.2	40.0	281.8	0.0001021	0.37	14.88	63.3	0.04391	158.1	6353	430.2	2.32	620102	2.097E+10
329-17	205	12/04/89	60.0	2460.2	41.0	281.5	0.0001019	0.37	15.25	63.2	0.04395	158.2	6511	431.4	2.32	620338	2.103E+10
329-17	210	12/04/89	60.0	2520.2	42.0	281.4	0.0001019	0.37	15.62	63.2	0.04393	158.2	6669	431.2	2.11	620338	2.102E+10
329-17	215	12/04/89	60.0	2580.2	43.0	281.3	0.0001011	0.37	15.99	63.2	0.04389	158.0	6827	434.4	2.16	625433	2.136E+10
329-17	220	12/04/89	60.0	2640.2	44.0	281.3	0.0001023	0.37	16.36	63.2	0.04389	158.0	6985	429.1	2.30	617972	2.085E+10
329-17	225	12/04/89	60.0	2700.2	45.0	281.2	0.0001017	0.37	16.73	63.3	0.04386	157.9	7143	431.2	2.47	622235	2.106E+10
329-19	5	12/04/89	60.0	2760.2	46.0	285.8	0.0001022	0.38	17.10	63.8	0.04418	159.0	7302	432.4	2.36	624449	2.127E+10
329-19	10	12/04/89	60.0	2820.2	47.0	285.9	0.0001026	0.37	17.47	63.7	0.04414	158.9	7461	430.2	2.53	620858	2.111E+10
329-19	15	12/04/89	60.0	2880.2	48.0	285.9	0.0001022	0.37	17.84	63.9	0.04411	158.8	7620	431.5	2.38	625183	2.125E+10
329-19	20	12/04/89	60.0	2940.2	49.0	285.7	0.0001024	0.37	18.21	63.8	0.04410	158.8	7779	430.7	2.40	623108	2.117E+10
329-19	25	12/04/89	60.0	3000.2	50.0	285.6	0.0001031	0.37	18.58	63.5	0.04408	158.7	7937	427.7	2.23	616146	2.091E+10
329-19	30	12/04/89	60.0	3060.2	51.0	285.5	0.0001030	0.37	18.96	63.4	0.04403	158.5	8096	427.7	2.39	615833	2.096E+10
329-19	35	12/05/89	60.0	3120.2	52.0	285.4	0.0001029	0.37	19.33	63.4	0.04399	158.4	8254	427.7	2.39	616312	2.098E+10
329-19	40	12/05/89	60.0	3180.2	53.0	285.3	0.0001022	0.37	19.70	63.1	0.04401	158.4	8413	430.6	2.29	617417	2.127E+10
329-19	45	12/05/89	60.0	3240.2	54.0	285.4	0.0001032	0.37	20.07	63.2	0.04405	158.6	8571	426.9	2.48	612462	2.087E+10
329-19	50	12/05/89	60.0	3300.2	55.0	285.6	0.0001024	0.37	20.44	63.2	0.04416	159.0	8730	431.4	2.44	617489	2.123E+10
329-19	55	12/05/89	60.0	3360.2	56.0	285.6	0.0001024	0.37	20.81	63.2	0.04410	158.8	8889	430.6	2.34	617248	2.121E+10
329-19	60	12/05/89	60.0	3420.2	57.0	285.4	0.0001026	0.37	21.18	63.1	0.04410	158.8	9048	429.7	2.26	614770	2.110E+10
329-19	65	12/05/89	60.0	3480.2	58.0	285.6	0.0001016	0.37	21.55	63.0	0.04399	158.4	9206	432.9	2.41	619957	2.156E+10
329-19	70	12/05/89	60.0	3540.2	59.0	285.5	0.0001026	0.37	21.92	63.1	0.04402	158.5	9365	428.9	2.46	614770	2.111E+10
329-19	75	12/05/89	60.0	3600.2	60.0	285.3	0.0001023	0.37	22.29	63.0	0.04399	158.4	9523	430.2	2.39	616077	2.126E+10
329-19	80	12/05/89	60.0	3660.2	61.0	285.0	0.0001013	0.37	22.66	63.1	0.04398	158.3	9681	434.1	2.44	622841	2.162E+10
329-19	85	12/05/89	60.0	3720.2	62.0	285.1	0.0001018	0.37	23.03	62.8	0.04399	158.4	9840	432.0	2.36	616775	2.144E+10
329-19	90	12/05/89	60.0	3780.3	63.0	285.2	0.0001021	0.37	23.40	62.9	0.04396	158.3	9998	430.5	2.31	616063	2.132E+10
329-19	95	12/05/89	60.0	3840.3	64.0	284.9	0.0001019	0.37	23.77	62.6	0.04392	158.1	10156	430.8	2.33	614087	2.139E+10
329-19	100	12/05/89	60.0	3900.3	65.0	284.6	0.0001020	0.37	24.14	62.7	0.04391	158.1	10314	430.5	2.31	614706	2.133E+10
329-19	105	12/05/89	60.0	3960.3	66.0	284.5	0.0001016	0.37	24.51	62.7	0.04392	158.1	10472	432.1	2.26	616944	2.147E+10
329-19	110	12/05/89	60.0	4020.3	67.0	284.5	0.0001026	0.37	24.87	62.7	0.04389	158.0	10630	427.6	2.29	610873	2.105E+10
329-19	115	12/06/89	60.0	4080.3	68.0	284.4	0.0001014	0.37	25.25	62.6	0.04395	158.3	10789	433.2	2.47	617114	2.155E+10
329-19	120	12/06/89	60.0	4140.3	69.0	284.3	0.0001018	0.37	25.61	62.6	0.04390	158.0	10947	431.4	2.38	615173	2.141E+10
329-19	125	12/06/89	60.0	4200.3	70.0	284.2	0.0001025	0.37	25.98	62.7	0.04386	157.9	11104	427.9	2.42	611588	2.107E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-17	180	12/03/89	32.01	43.90	1405.33	101.65	12.36	1255.96	1261.45	89.76	32.98	27280200	197	955	252	1563	742	1004	81		36
329-17	185	12/03/89	32.01	43.78	1401.43	102.80	12.20	1254.43	1259.79	89.89	33.05	27197600	195	950	251	1555	740	974	80		37
329-17	190	12/04/89	32.01	43.79	1401.73	102.56	12.21	1251.96	1257.32	89.70	33.13	27102900	196	953	252	1556	741	992	80		38
329-17	195	12/04/89	32.04	43.77	1402.41	102.41	12.24	1254.00	1259.40	89.80	33.04	27216400	196	960	252	1559	742	959	80		39
329-17	200	12/04/89	32.03	43.78	1402.43	102.59	12.21	1253.03	1258.40	89.73	32.91	27067700	197	952	252	1555	741	1004	80		40
329-17	205	12/04/89	32.00	43.70	1398.41	103.34	12.10	1250.51	1255.78	89.80	33.09	27064100	195	957	251	1547	740	959	80		41
329-17	210	12/04/89	32.01	43.75	1400.45	102.70	12.18	1251.20	1256.54	89.72	33.04	27078600	197	958	251	1553	740	1011	80		42
329-17	215	12/04/89	32.00	43.79	1401.51	102.66	12.21	1253.13	1258.50	89.80	33.21	27344500	197	951	252	1555	741	995	80		43
329-17	220	12/04/89	32.01	43.72	1399.53	102.96	12.14	1249.82	1255.12	89.68	32.90	26945800	196	951	251	1552	740	976	80		44
329-17	225	12/04/89	32.01	43.74	1400.34	102.72	12.19	1252.01	1257.36	89.79	32.98	27136800	197	951	252	1549	740	1000	80		45
329-19	5	12/04/89	31.83	43.88	1396.42	103.02	12.15	1252.10	1257.42	90.05	33.30	27022000	197	955	250	1547	740	1012	79	1	46
329-19	10	12/04/89	31.87	43.84	1396.99	103.23	12.13	1252.01	1257.31	90.00	33.11	26908600	197	953	251	1547	740	1008	80	1	47
329-19	15	12/04/89	31.90	43.79	1397.07	103.57	12.08	1250.66	1255.91	89.90	33.22	26981100	198	952	251	1544	739	1010	80	1	48
329-19	20	12/04/89	31.89	43.76	1395.20	103.81	12.02	1247.95	1253.15	89.82	33.22	26874700	197	952	251	1542	738	975	80	1	49
329-19	25	12/04/89	31.91	43.74	1395.73	103.98	12.05	1252.66	1257.89	90.12	32.86	26800100	198	955	251	1542	739	993	80	1	50
329-19	30	12/04/89	31.91	43.79	1397.43	103.20	12.14	1252.76	1258.06	90.03	32.81	26830700	198	955	251	1543	739	1000	80	1	51
329-19	35	12/05/89	31.92	43.77	1397.14	103.42	12.05	1246.14	1251.37	89.57	32.96	26711600	198	953	251	1542	739	997	80	1	52
329-19	40	12/05/89	31.92	43.75	1396.36	103.78	12.03	1248.92	1254.14	89.82	33.12	26947000	197	950	251	1540	738	974	80	1	53
329-19	45	12/05/89	31.91	43.78	1397.17	103.44	12.10	1251.21	1256.47	89.93	32.80	26737000	198	956	251	1544	739	1005	80	1	54
329-19	50	12/05/89	31.92	43.72	1395.51	104.21	12.04	1254.27	1259.49	90.25	33.16	27020800	199	952	251	1536	738	1012	80	1	55
329-19	55	12/05/89	31.92	43.75	1396.54	103.88	12.07	1253.62	1258.86	90.14	33.07	26995900	199	955	252	1546	740	999	80	1	56
329-19	60	12/05/89	31.91	43.77	1396.75	103.60	12.07	1250.75	1255.99	89.92	33.07	26869500	200	955	252	1545	740	1003	80	1	57
329-19	65	12/05/89	31.91	43.75	1396.06	103.83	12.06	1252.41	1257.65	90.09	33.20	27175800	199	952	252	1542	739	998	80	1	58
329-19	70	12/05/89	31.91	43.73	1395.62	103.90	12.03	1250.03	1255.25	89.94	32.97	26855400	198	950	251	1542	739	966	80	1	59
329-19	75	12/05/89	31.92	43.72	1395.68	103.96	12.04	1252.05	1257.27	90.08	33.00	26997200	199	956	252	1538	739	1005	80	1	60
329-19	80	12/05/89	31.92	43.75	1396.48	103.64	12.06	1250.27	1255.50	89.91	33.33	27212800	198	954	252	1542	740	1009	80	1	61
329-19	85	12/05/89	31.94	43.72	1396.46	103.60	12.08	1251.01	1256.26	89.96	33.16	27091200	199	949	252	1542	739	1014	80	1	62
329-19	90	12/05/89	31.94	43.68	1395.25	103.98	12.03	1250.38	1255.59	89.99	33.04	27002900	198	954	251	1539	739	1017	80	1	63
329-19	95	12/05/89	31.94	43.68	1395.24	103.96	12.04	1251.18	1256.40	90.05	33.02	27062300	198	954	252	1535	738	1014	80	1	64
329-19	100	12/05/89	31.94	43.65	1394.21	104.26	11.97	1248.45	1253.61	89.92	33.05	26988500	199	958	252	1537	739	966	80	1	65
329-19	105	12/05/89	31.95	43.70	1396.33	103.74	12.08	1252.81	1258.06	90.10	33.07	27180500	198	951	252	1543	740	1007	80	1	66
329-19	110	12/05/89	31.96	43.69	1396.13	103.76	12.06	1251.39	1256.63	90.01	32.74	26884200	198	952	251	1543	739	1015	80	1	67
329-19	115	12/06/89	31.95	43.69	1395.78	103.78	12.04	1249.15	1254.37	89.87	33.27	27152900	198	951	251	1543	740	1018	80	1	68
329-19	120	12/06/89	31.96	43.66	1395.41	103.84	12.04	1249.78	1254.99	89.94	33.08	27081000	199	949	251	1543	739	975	80	1	69
329-19	125	12/06/89	31.97	43.70	1396.77	103.31	12.12	1252.14	1257.43	90.02	32.72	26931100	198	955	251	1549	741	1017	80	1	70

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
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329-19	130	12/06/89	60.0	4260.3	71.0	284.2	0.0001027	0.37	26.35	62.7	0.04389	158.0	11262	427.5	2.33	610694	2.101E+10
329-19	135	12/06/89	60.0	4320.3	72.0	284.3	0.0001022	0.37	26.72	62.4	0.04395	158.2	11421	430.1	2.28	610508	2.124E+10
329-19	140	12/06/89	60.0	4380.3	73.0	284.4	0.0001017	0.37	27.09	62.5	0.04389	158.0	11579	431.8	2.40	614855	2.148E+10
329-19	145	12/06/89	60.0	4440.3	74.0	283.1	0.0001012	0.37	27.46	62.4	0.04388	158.0	11737	433.4	2.49	616357	2.153E+10
329-20	5	12/06/89	60.0	4500.3	75.0	286.1	0.0001019	0.37	27.83	62.9	0.04395	158.2	11895	431.6	2.33	617575	2.152E+10
329-20	10	12/06/89	60.0	4560.3	76.0	286.8	0.0001030	0.37	28.20	62.6	0.04395	158.2	12053	426.7	2.53	607826	2.114E+10
329-20	15	12/06/89	60.0	4620.3	77.0	287.2	0.0001024	0.37	28.57	62.7	0.04405	158.6	12212	430.0	2.60	612066	2.139E+10
329-20	20	12/06/89	60.0	4680.3	78.0	287.5	0.0001029	0.37	28.94	62.7	0.04401	158.4	12370	427.8	2.46	609448	2.124E+10
329-20	25	12/06/89	60.0	4740.3	79.0	287.3	0.0001023	0.37	29.32	62.7	0.04399	158.4	12528	430.2	2.25	613143	2.148E+10
329-20	30	12/06/89	60.0	4800.3	80.0	287.0	0.0001021	0.37	29.69	62.7	0.04400	158.4	12687	431.0	2.51	614224	2.153E+10
329-20	35	12/06/89	60.0	4860.3	81.0	286.7	0.0001028	0.37	30.06	62.7	0.04401	158.4	12845	428.2	2.39	609982	2.120E+10
329-20	40	12/06/89	60.0	4920.3	82.0	286.4	0.0001034	0.37	30.43	62.6	0.04401	158.4	13004	425.8	2.33	605709	2.095E+10
329-20	45	12/06/89	60.0	4980.3	83.0	286.2	0.0001016	0.37	30.80	62.6	0.04393	158.1	13162	432.3	2.29	616142	2.166E+10
329-20	50	12/07/89	60.0	5040.3	84.0	286.1	0.0001016	0.37	31.17	62.7	0.04395	158.2	13320	432.6	2.25	617247	2.165E+10
329-20	55	12/07/89	60.0	5100.3	85.0	285.9	0.0001021	0.37	31.54	62.6	0.04393	158.1	13478	430.2	2.25	613064	2.142E+10
329-20	60	12/07/89	60.0	5160.3	86.0	285.7	0.0001020	0.37	31.91	62.5	0.04391	158.1	13636	430.5	2.23	612805	2.146E+10
329-20	65	12/07/89	60.0	5220.3	87.0	285.6	0.0001023	0.37	32.28	62.4	0.04387	157.9	13794	428.9	2.36	610030	2.133E+10
329-20	70	12/07/89	60.0	5280.3	88.0	285.5	0.0001018	0.37	32.65	62.5	0.04393	158.1	13952	431.4	2.43	613768	2.151E+10
329-20	75	12/07/89	60.0	5340.3	89.0	285.2	0.0001022	0.37	33.02	62.5	0.04392	158.1	14111	429.9	2.44	611785	2.134E+10
329-20	80	12/07/89	60.0	5400.3	90.0	285.4	0.0001023	0.37	33.39	62.3	0.04394	158.2	14269	429.4	2.30	608755	2.130E+10
329-20	85	12/07/89	60.0	5460.3	91.0	285.6	0.0001022	0.37	33.76	62.3	0.04395	158.2	14427	429.9	2.59	609410	2.137E+10
329-20	90	12/07/89	60.0	5520.3	92.0	285.9	0.0001016	0.37	34.12	62.2	0.04392	158.1	14585	432.3	2.48	612265	2.168E+10
329-20	95	12/07/89	60.0	5580.3	93.0	287.0	0.0001017	0.37	34.49	62.4	0.04400	158.4	14743	432.8	2.37	613750	2.173E+10
329-20	100	12/07/89	60.0	5640.3	94.0	285.4	0.0001017	0.38	34.87	62.1	0.04387	157.9	14901	431.2	2.32	610379	2.157E+10
329-20	105	12/07/89	60.0	5700.3	95.0	284.9	0.0001016	0.36	35.23	62.1	0.04384	157.8	15059	431.4	2.34	611100	2.158E+10
329-20	110	12/07/89	60.0	5760.3	96.0	285.1	0.0001014	0.37	35.60	62.2	0.04384	157.8	15217	432.3	2.44	613352	2.167E+10
329-20	115	12/07/89	60.0	5820.3	97.0	285.0	0.0001019	0.37	35.97	62.3	0.04382	157.8	15375	430.0	2.38	611324	2.144E+10
329-20	120	12/07/89	60.0	5880.3	98.0	284.9	0.0001019	0.37	36.34	62.2	0.04389	158.0	15533	430.9	2.24	610522	2.146E+10
329-20	125	12/07/89	60.0	5940.3	99.0	284.8	0.0001020	0.37	36.71	62.2	0.04384	157.8	15691	429.7	2.43	609625	2.138E+10
329-20	130	12/08/89	60.0	6000.3	100.0	284.7	0.0001016	0.37	37.08	62.2	0.04382	157.8	15848	431.1	2.17	611964	2.154E+10
329-20	135	12/08/89	60.0	6060.3	101.0	284.6	0.0001008	0.37	37.44	62.3	0.04374	157.5	16006	434.1	2.29	618240	2.189E+10
329-20	140	12/08/89	60.0	6120.3	102.0	284.5	0.0001011	0.37	37.81	61.7	0.04376	157.5	16163	432.9	2.29	610347	2.180E+10
329-20	145	12/08/89	60.0	6180.3	103.0	284.4	0.0001016	0.37	38.18	61.9	0.04382	157.8	16321	431.4	2.27	609312	2.156E+10
329-20	150	12/08/89	60.0	6240.3	104.0	284.3	0.0001015	0.37	38.54	61.8	0.04377	157.6	16479	431.3	2.26	608927	2.160E+10
329-22	5	12/08/89	60.0	6300.3	105.0	258.8	0.0000975	0.36	38.90	59.7	0.04261	153.4	16632	437.0	2.48	612207	2.094E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-19	130	12/06/89	31.96	43.68	1395.97	103.55	12.06	1248.56	1253.80	89.82	32.81	26815700	199	952	251	1544	740	1014	80	1	71
329-19	135	12/06/89	31.98	43.59	1393.96	104.32	11.99	1250.68	1255.86	90.09	33.00	26982300	198	964	251	1537	739	980	80	1	72
329-19	140	12/06/89	31.96	43.66	1395.27	103.79	12.04	1249.95	1255.17	89.96	33.10	27114000	198	950	251	1544	739	971	80	1	73
329-19	145	12/06/89	31.98	43.64	1395.58	103.87	12.02	1248.63	1253.83	89.84	33.25	27193700	200	952	251	1542	740	1014	80	1	74
329-20	5	12/06/89	31.96	43.60	1393.62	104.44	11.96	1249.38	1254.53	90.02	33.14	27048400	198	949	252	1537	739	1019	80	1	75
329-20	10	12/06/89	31.95	43.63	1394.09	104.18	12.01	1251.41	1256.60	90.14	32.72	26792100	200	951	252	1539	739	1009	80	1	76
329-20	15	12/06/89	31.96	43.59	1393.39	104.52	11.95	1248.94	1254.08	90.00	33.11	26882400	200	953	252	1537	739	1004	80	1	77
329-20	20	12/06/89	31.98	43.58	1393.87	104.29	11.97	1248.23	1253.39	89.92	32.93	26752900	200	953	252	1539	739	1015	80	1	78
329-20	25	12/06/89	31.98	43.57	1393.54	104.15	12.02	1251.41	1256.61	90.17	33.01	26984700	200	948	252	1541	740	1006	80	1	79
329-20	30	12/06/89	32.00	43.52	1392.72	101.15	11.98	1247.84	1253.01	89.97	33.17	26953300	198	952	252	1539	740	1000	80	1	80
329-20	35	12/06/89	31.98	43.58	1393.75	104.02	12.00	1248.08	1253.26	89.92	32.96	26772400	198	950	252	1539	740	1010	80	1	81
329-20	40	12/06/89	32.00	43.56	1393.96	104.23	12.00	1250.95	1256.13	90.11	32.70	26688800	199	948	252	1540	739	982	80	1	82
329-20	45	12/06/89	32.00	43.61	1395.44	103.68	12.04	1248.33	1253.55	89.83	33.21	27091300	200	950	252	1542	740	1004	80	1	83
329-20	50	12/07/89	31.97	43.60	1394.23	103.94	12.04	1251.35	1256.57	90.13	33.17	27162000	198	949	252	1540	740	1002	81	1	84
329-20	55	12/07/89	32.00	43.59	1394.78	104.00	12.03	1251.43	1256.64	90.10	32.97	27023500	198	948	252	1541	740	1009	81	1	85
329-20	60	12/07/89	31.97	43.61	1394.10	104.09	11.99	1248.09	1253.26	89.90	33.07	26983500	199	952	251	1538	739	1000	80	1	86
329-20	65	12/07/89	31.98	43.63	1395.30	103.77	12.04	1249.11	1254.33	89.90	32.88	26926100	199	951	251	1542	740	1007	81	1	87
329-20	70	12/07/89	31.99	43.61	1395.11	103.94	12.04	1251.20	1256.41	90.06	33.07	27094400	200	947	251	1542	740	1001	81	1	88
329-20	75	12/07/89	32.00	43.57	1394.26	103.94	12.01	1248.39	1253.59	89.91	33.02	26944100	199	952	251	1541	740	1009	80	1	89
329-20	80	12/07/89	31.98	43.61	1394.56	103.87	12.02	1248.71	1253.91	89.91	32.98	26905500	199	948	251	1541	740	1008	81	1	90
329-20	85	12/07/89	31.99	43.58	1394.27	103.90	12.02	1248.97	1254.17	89.95	33.02	26940200	199	951	251	1540	740	1008	81	1	91
329-20	90	12/07/89	31.99	43.55	1393.08	103.91	12.03	1249.77	1254.98	90.09	33.17	27124900	199	946	252	1540	740	1001	80	1	92
329-20	95	12/07/89	32.00	43.52	1392.50	104.28	11.97	1248.70	1253.86	90.04	33.29	27081700	199	948	251	1538	739	999	80	1	93
329-20	100	12/07/89	31.99	43.53	1392.68	104.20	11.98	1247.83	1252.99	89.97	33.10	27044800	199	948	251	1537	739	1005	80	1	94
329-20	105	12/07/89	32.01	43.52	1393.12	103.98	11.98	1245.18	1250.35	89.75	33.15	27019600	200	949	251	1540	740	1008	80	1	95
329-20	110	12/07/89	32.04	43.52	1394.38	103.75	12.03	1248.30	1253.51	89.90	33.15	27141500	199	945	251	1543	740	1006	80	1	96
329-20	115	12/07/89	32.03	43.52	1393.87	103.96	12.02	1249.53	1254.73	90.02	32.92	27036200	200	950	251	1540	740	1001	80	1	97
329-20	120	12/07/89	32.04	43.46	1392.21	104.03	12.00	1247.88	1253.06	90.01	33.09	27009200	199	948	251	1539	740	996	80	1	98
329-20	125	12/07/89	32.05	43.48	1393.37	104.03	12.00	1248.46	1253.65	89.97	32.94	26981400	200	946	251	1540	740	1002	80	1	99
329-20	130	12/08/89	32.05	43.48	1393.32	104.16	12.00	1249.78	1254.96	90.07	33.00	27112400	198	949	251	1540	740	998	80	1	100
329-20	135	12/08/89	32.04	43.50	1393.61	103.92	12.03	1249.90	1255.10	90.06	33.16	27350300	200	949	251	1541	740	998	80	1	101
329-20	140	12/08/89	32.05	43.49	1393.70	103.88	12.01	1248.11	1253.30	89.93	33.14	27225300	198	944	251	1540	740	1009	80	1	102
329-20	145	12/08/89	32.04	43.49	1393.53	103.97	12.01	1248.40	1253.59	89.96	33.06	27096200	200	946	251	1540	740	1007	80	1	103
329-20	150	12/08/89	32.04	43.50	1393.61	104.01	12.01	1248.64	1253.82	89.97	33.01	27128000	199	944	251	1541	740	998	80	1	104
329-22	5	12/08/89	32.02	43.73	1400.25	101.36	12.36	1252.77	1258.27	89.86	32.44	28327100	198	942	248	1564	745	999	80	1	105

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
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329-22	10	12/08/89	60.0	6360.3	106.0	259.3	0.0000970	0.35	39.26	59.8	0.04254	153.1	16785	438.6	2.58	616666	2.121E+10
329-22	15	12/08/89	60.0	6420.3	107.0	259.3	0.0000969	0.35	39.61	59.9	0.04252	153.1	16938	438.6	2.37	617870	2.122E+10
329-22	20	12/08/89	60.0	6480.3	108.0	259.1	0.0000965	0.35	39.96	60.0	0.04244	152.8	17091	439.8	2.47	621865	2.139E+10
329-22	25	12/08/89	60.0	6540.3	109.0	259.0	0.0000967	0.35	40.31	59.6	0.04256	153.3	17244	440.1	2.26	616339	2.132E+10
329-22	30	12/09/89	60.0	6600.3	110.0	259.0	0.0000971	0.35	40.66	59.5	0.04249	153.0	17397	437.4	2.40	612461	2.114E+10
329-22	35	12/09/89	60.0	6660.3	111.0	259.1	0.0000969	0.35	41.01	59.6	0.04246	152.9	17550	438.3	2.23	615175	2.125E+10
329-22	40	12/09/89	60.0	6720.3	112.0	258.9	0.0000967	0.35	41.36	59.7	0.04245	152.8	17703	438.9	2.47	617144	2.129E+10
329-22	45	12/09/89	60.0	6780.3	113.0	258.5	0.0000973	0.35	41.72	59.6	0.04239	152.6	17856	435.6	2.49	612369	2.100E+10
329-22	50	12/09/89	60.0	6840.3	114.0	258.3	0.0000960	0.35	42.07	59.7	0.04237	152.5	18008	441.3	2.24	621778	2.154E+10
329-22	55	12/09/89	60.0	6900.3	115.0	258.1	0.0000963	0.35	42.42	59.7	0.04234	152.4	18161	439.8	2.26	620124	2.141E+10
329-22	60	12/09/89	60.0	6960.3	116.0	258.1	0.0000964	0.35	42.77	59.7	0.04239	152.6	18313	439.7	2.29	619218	2.134E+10
329-22	65	12/09/89	60.0	7020.3	117.0	258.5	0.0000963	0.35	43.12	59.6	0.04233	152.4	18466	439.5	2.30	618777	2.144E+10
329-22	70	12/09/89	60.0	7080.3	118.0	259.1	0.0000967	0.35	43.47	59.6	0.04246	152.9	18618	438.9	2.37	616078	2.132E+10
329-22	75	12/09/89	60.0	7140.3	119.0	259.2	0.0000967	0.35	43.82	59.7	0.04238	152.6	18771	438.3	2.51	617527	2.135E+10
329-22	80	12/09/89	60.0	7200.3	120.0	259.0	0.0000965	0.35	44.17	59.6	0.04241	152.7	18924	439.4	2.31	617565	2.141E+10
329-22	85	12/09/89	60.0	7260.3	121.0	258.6	0.0000959	0.35	44.52	59.6	0.04233	152.4	19076	441.6	2.35	621734	2.166E+10
329-22	90	12/09/89	60.0	7320.3	122.0	258.0	0.0000965	0.35	44.86	59.6	0.04229	152.2	19228	438.4	2.52	617770	2.132E+10
329-22	95	12/09/89	60.0	7380.3	123.0	257.7	0.0000964	0.35	45.21	59.6	0.04225	152.1	19380	438.1	2.43	618033	2.130E+10
329-22	100	12/09/89	60.0	7440.3	124.0	257.6	0.0000956	0.35	45.56	59.6	0.04225	152.1	19533	441.7	2.26	623125	2.164E+10
329-22	105	12/09/89	60.0	7500.3	125.0	257.4	0.0000961	0.35	45.91	59.8	0.04225	152.1	19685	439.6	2.38	622223	2.139E+10
329-22	110	12/10/89	60.0	7560.3	126.0	257.3	0.0000962	0.35	46.26	59.7	0.04230	152.3	19837	439.8	2.29	620576	2.135E+10
329-22	115	12/10/89	60.0	7620.3	127.0	257.2	0.0000958	0.35	46.61	59.6	0.04229	152.2	19989	441.3	2.25	621857	2.151E+10
329-22	120	12/10/89	60.0	7680.3	128.0	257.0	0.0000967	0.35	46.96	59.5	0.04225	152.1	20141	437.0	2.32	615509	2.113E+10
329-22	125	12/10/89	60.0	7740.3	129.0	256.7	0.0000958	0.35	47.31	59.5	0.04224	152.1	20293	440.9	2.43	621021	2.148E+10
329-22	130	12/10/89	60.0	7800.3	130.0	256.5	0.0000955	0.35	47.66	59.2	0.04221	152.0	20445	442.2	2.29	620188	2.165E+10
329-22	135	12/10/89	60.0	7860.3	131.0	256.4	0.0000960	0.35	48.01	59.3	0.04222	152.0	20597	440.0	2.30	617914	2.140E+10
329-22	140	12/10/89	60.0	7920.3	132.0	256.4	0.0000959	0.35	48.36	59.4	0.04216	151.8	20749	439.5	2.34	619253	2.141E+10
329-22	145	12/10/89	60.0	7980.3	133.0	256.5	0.0000963	0.35	48.71	59.4	0.04225	152.1	20901	438.5	2.44	616515	2.123E+10
329-22	150	12/10/89	60.0	8040.3	134.0	257.1	0.0000962	0.35	49.06	59.5	0.04229	152.2	21053	439.4	2.39	618227	2.133E+10
329-22	155	12/10/89	60.0	8100.3	135.0	257.6	0.0000956	0.35	49.40	59.7	0.04225	152.1	21206	442.2	2.41	624758	2.167E+10
329-22	160	12/10/89	60.0	8160.3	136.0	257.3	0.0000965	0.35	49.75	59.5	0.04228	152.2	21358	438.3	2.34	616817	2.126E+10
329-22	165	12/10/89	60.0	8220.3	137.0	256.8	0.0000963	0.35	50.10	59.7	0.04215	151.7	21509	437.6	2.43	619783	2.124E+10
329-22	170	12/10/89	60.0	8280.3	138.0	256.2	0.0000954	0.35	50.45	59.5	0.04214	151.7	21661	441.6	2.38	623533	2.160E+10
329-22	175	12/10/89	60.0	8340.3	139.0	255.8	0.0000957	0.35	50.80	59.2	0.04216	151.8	21813	440.6	2.41	618664	2.147E+10
329-22	180	12/10/89	60.0	8400.3	140.0	255.5	0.0000956	0.35	51.15	59.1	0.04215	151.7	21965	441.0	2.38	618388	2.150E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-22	10	12/08/89	32.04	43.77	1402.20	101.01	12.39	1251.31	1256.83	89.63	32.55	28452700	199	942	250	1565	745	990	81	1	106
329-22	15	12/08/89	32.02	43.76	1401.24	101.38	12.35	1252.48	1257.98	89.78	32.50	28487100	198	942	249	1565	745	987	81	1	107
329-22	20	12/08/89	32.04	43.77	1402.40	101.12	12.39	1253.03	1258.55	89.74	32.52	28636000	198	938	249	1566	745	984	81	1	108
329-22	25	12/08/89	32.06	43.67	1399.83	102.08	12.25	1250.23	1255.63	89.70	32.70	28508400	198	941	249	1562	744	987	81	1	109
329-22	30	12/09/89	32.05	43.75	1401.98	101.47	12.35	1252.77	1258.25	89.75	32.39	28434100	198	940	249	1565	745	988	81	1	110
329-22	35	12/09/89	32.05	43.74	1401.65	101.38	12.35	1252.55	1258.04	89.76	32.43	28507300	199	940	250	1565	745	985	81	1	111
329-22	40	12/09/89	32.04	43.73	1401.30	101.57	12.34	1253.39	1258.87	89.84	32.45	28569800	199	939	250	1567	746	984	81	1	112
329-22	45	12/09/89	32.03	43.74	1401.19	101.58	12.31	1250.90	1256.36	89.66	32.23	28340000	200	941	250	1565	745	985	81	1	113
329-22	50	12/09/89	32.03	43.78	1402.24	101.35	12.37	1253.38	1258.89	89.78	32.56	28784000	200	937	250	1569	746	988	81	1	114
329-22	55	12/09/89	32.02	43.71	1399.47	102.01	12.28	1252.26	1257.69	89.87	32.46	28682100	200	940	250	1564	745	985	81	1	115
329-22	60	12/09/89	32.03	43.72	1400.41	101.83	12.31	1253.34	1258.80	89.89	32.46	28664600	200	937	250	1565	745	997	81	1	116
329-22	65	12/09/89	32.03	43.71	1400.20	101.83	12.30	1252.65	1258.10	89.85	32.42	28676600	200	940	250	1563	745	988	81	1	117
329-22	70	12/09/89	32.06	43.71	1401.06	101.64	12.30	1250.67	1256.12	89.66	32.52	28506200	198	940	250	1564	745	992	81	1	118
329-22	75	12/09/89	32.06	43.73	1401.88	101.53	12.33	1252.28	1257.75	89.72	32.38	28562200	199	939	250	1564	745	991	81	1	119
329-22	80	12/09/89	32.06	43.64	1398.75	101.87	12.25	1248.35	1253.76	89.64	32.59	28522100	198	939	250	1562	745	964	81	1	120
329-22	85	12/09/89	32.07	43.72	1402.29	101.21	12.39	1253.98	1259.51	89.82	32.54	28844200	200	939	251	1565	746	998	81	1	121
329-22	90	12/09/89	32.05	43.71	1400.69	101.57	12.33	1252.65	1258.13	89.82	32.31	28629800	199	938	251	1564	746	986	81	1	122
329-22	95	12/09/89	32.06	43.72	1401.48	101.31	12.34	1250.10	1255.58	89.59	32.33	28583600	199	939	250	1565	746	988	81	1	123
329-22	100	12/09/89	32.05	43.68	1399.86	101.74	12.30	1251.47	1256.92	89.79	32.55	28851000	198	937	250	1562	745	967	81	1	124
329-22	105	12/09/89	32.06	43.74	1402.50	101.27	12.36	1251.39	1256.88	89.62	32.40	28710800	200	934	249	1563	744	982	81	1	125
329-22	110	12/10/89	32.04	43.62	1397.60	102.54	12.21	1252.11	1257.48	89.98	32.44	28699400	199	937	249	1560	745	993	81	1	126
329-22	115	12/10/89	32.05	43.59	1396.93	102.95	12.17	1252.47	1257.80	90.04	32.53	28815100	199	945	249	1559	744	964	81	1	127
329-22	120	12/10/89	32.04	43.60	1397.03	102.46	12.23	1252.85	1258.24	90.07	32.17	28577500	198	938	249	1562	745	984	81	1	128
329-22	125	12/10/89	32.04	43.69	1399.56	101.87	12.31	1253.52	1258.97	89.96	32.44	28849000	198	936	249	1565	746	990	81	1	129
329-22	130	12/10/89	32.07	43.65	1399.92	101.81	12.28	1249.78	1255.20	89.66	32.60	28869600	200	936	249	1564	746	983	81	1	130
329-22	135	12/10/89	32.07	43.65	1400.07	101.95	12.27	1251.37	1256.80	89.77	32.41	28752100	200	937	249	1563	745	986	81	1	131
329-22	140	12/10/89	32.05	43.79	1403.52	101.19	12.43	1257.64	1263.21	90.00	32.17	28910100	200	936	249	1564	746	982	81	1	132
329-22	145	12/10/89	32.07	43.62	1398.77	102.37	12.24	1252.76	1258.15	89.95	32.29	28670300	198	935	249	1563	745	991	81	1	133
329-22	150	12/10/89	32.05	43.58	1396.82	102.58	12.20	1251.91	1257.27	90.01	32.40	28682200	200	937	249	1562	745	982	81	1	134
329-22	155	12/10/89	32.09	43.59	1398.93	102.11	12.28	1253.61	1259.04	90.00	32.54	28927500	198	934	250	1563	745	991	81	1	135
329-22	160	12/10/89	32.08	43.63	1399.57	101.86	12.30	1252.98	1258.43	89.92	32.28	28641300	198	935	249	1563	745	989	81	1	136
329-22	165	12/10/89	32.05	43.74	1401.74	101.31	12.35	1251.62	1257.11	89.68	32.17	28651200	198	936	250	1564	746	984	81	1	137
329-22	170	12/10/89	32.06	43.67	1399.75	101.96	12.29	1253.06	1258.49	89.91	32.42	28954900	199	934	249	1562	745	953	81	1	138
329-22	175	12/10/89	32.04	43.66	1398.75	101.94	12.30	1253.83	1259.28	90.03	32.35	28892100	200	936	249	1565	746	993	81	1	139
329-22	180	12/10/89	32.05	43.59	1397.08	102.42	12.20	1250.02	1255.38	89.86	32.47	28840200	199	943	249	1562	745	959	81	1	140

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
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329-22	185	12/10/89	60.0	8460.3	141.0	255.1	0.0000963	0.35	51.50	59.2	0.04211	151.6	22116	437.5	2.37	615046	2.114E+10
329-22	190	12/11/89	60.0	8520.4	142.0	254.9	0.0000961	0.35	51.85	59.0	0.04212	151.7	22268	438.2	2.26	613861	2.121E+10
329-22	195	12/11/89	60.0	8580.4	143.0	254.7	0.0000957	0.35	52.20	59.0	0.04212	151.6	22420	440.0	2.39	616388	2.136E+10
329-23	32	12/12/89	91.9	8672.3	144.5	261.0	0.0000971	0.54	52.74	58.8	0.05387	297.2	22717	554.7	2.37	605399	2.143E+10
329-24	5	12/12/89	60.0	8732.3	145.5	259.5	0.0000974	0.36	53.09	58.6	0.04252	153.1	22870	436.7	2.42	601908	2.120E+10
329-24	10	12/12/89	60.0	8792.3	146.5	260.2	0.0000970	0.35	53.44	58.8	0.04272	153.8	23024	440.3	2.46	606023	2.139E+10
329-24	15	12/12/89	60.0	8852.3	147.5	260.3	0.0000966	0.35	53.79	59.0	0.04268	153.6	23177	441.6	2.51	610539	2.156E+10
329-24	20	12/12/89	60.0	8912.3	148.5	260.2	0.0000973	0.35	54.14	58.9	0.04245	152.8	23330	436.2	2.51	605288	2.126E+10
329-24	25	12/13/89	60.0	8972.3	149.5	260.1	0.0000975	0.35	54.49	58.9	0.04253	153.1	23483	436.1	2.74	603911	2.115E+10
329-24	30	12/13/89	60.0	9032.3	150.5	259.8	0.0000966	0.35	54.85	58.7	0.04256	153.2	23636	440.4	2.54	607472	2.154E+10
329-24	35	12/13/89	60.0	9092.3	151.5	259.4	0.0000966	0.35	55.20	58.7	0.04240	152.6	23789	438.7	2.59	607390	2.149E+10
329-24	40	12/13/89	60.0	9152.3	152.5	259.0	0.0000970	0.35	55.55	58.8	0.04229	152.3	23941	436.1	2.52	606398	2.129E+10
329-24	45	12/13/89	60.0	9212.3	153.5	259.1	0.0000967	0.35	55.90	58.8	0.04242	152.7	24094	438.7	2.60	608173	2.143E+10
329-24	50	12/13/89	60.0	9272.3	154.5	259.1	0.0000964	0.35	56.25	58.7	0.04230	152.3	24246	438.8	2.60	608839	2.156E+10
329-24	55	12/13/89	60.0	9332.3	155.5	259.2	0.0000974	0.35	56.60	58.7	0.04247	152.9	24399	436.1	2.45	602744	2.114E+10
329-24	60	12/13/89	60.0	9392.3	156.5	259.8	0.0000976	0.35	56.95	58.9	0.04243	152.7	24552	434.8	2.47	603651	2.110E+10
329-24	65	12/13/89	60.0	9452.3	157.5	260.0	0.0000967	0.35	57.30	58.9	0.04237	152.5	24705	438.2	2.59	609258	2.152E+10
329-24	70	12/13/89	60.0	9512.3	158.5	259.8	0.0000967	0.35	57.65	58.9	0.04232	152.4	24857	437.5	2.55	608811	2.146E+10
329-24	75	12/13/89	60.0	9572.3	159.5	259.6	0.0000968	0.35	58.00	58.9	0.04237	152.5	25009	437.7	2.53	608396	2.141E+10
329-24	80	12/13/89	60.0	9632.3	160.5	259.5	0.0000964	0.35	58.35	58.6	0.04235	152.5	25162	439.3	2.53	607903	2.162E+10
329-24	85	12/13/89	60.0	9692.3	161.5	259.1	0.0000963	0.35	58.70	58.6	0.04235	152.5	25314	439.7	2.43	608446	2.162E+10
329-24	90	12/13/89	60.0	9752.3	162.5	258.8	0.0000964	0.35	59.05	58.7	0.04231	152.3	25467	438.8	2.70	608725	2.152E+10
329-24	95	12/13/89	60.0	9812.3	163.5	258.5	0.0000961	0.35	59.40	58.8	0.04225	152.1	25619	439.7	2.60	611971	2.163E+10
329-24	100	12/13/89	60.0	9872.3	164.5	258.2	0.0000960	0.35	59.75	58.8	0.04232	152.4	25771	441.0	2.45	612647	2.165E+10
329-24	105	12/14/89	60.0	9932.3	165.5	258.0	0.0000962	0.35	60.09	59.0	0.04214	151.7	25923	438.0	2.47	613127	2.149E+10
329-24	110	12/14/89	60.0	9992.3	166.5	257.9	0.0000963	0.35	60.44	58.9	0.04228	152.2	26075	438.9	2.58	611395	2.144E+10
329-24	115	12/14/89	60.0	10052.3	167.5	257.6	0.0000967	0.35	60.79	58.9	0.04222	152.0	26227	436.4	2.45	608817	2.123E+10
329-24	120	12/14/89	60.0	10112.3	168.5	257.5	0.0000964	0.35	61.14	58.6	0.04229	152.2	26379	438.5	2.56	607651	2.139E+10
329-24	125	12/14/89	60.0	10172.3	169.5	257.4	0.0000962	0.35	61.48	58.5	0.04234	152.5	26532	440.1	2.52	608032	2.149E+10
329-24	130	12/14/89	60.0	10232.3	170.5	257.3	0.0000965	0.35	61.83	58.6	0.04226	152.1	26684	437.9	2.74	607216	2.133E+10
329-25	5	12/14/89	60.0	10292.3	171.5	260.5	0.0000976	0.35	62.19	59.1	0.04258	153.3	26837	436.5	2.23	605825	2.116E+10
329-25	10	12/14/89	60.0	10352.3	172.5	261.1	0.0000972	0.35	62.54	58.8	0.04264	153.5	26991	438.9	2.40	605200	2.143E+10
329-25	15	12/14/89	60.0	10412.3	173.5	261.3	0.0000978	0.35	62.89	58.9	0.04256	153.2	27144	435.3	2.29	602539	2.118E+10
329-25	20	12/14/89	60.0	10472.3	174.5	260.9	0.0000971	0.35	63.24	58.9	0.04264	153.5	27297	439.0	2.22	606479	2.142E+10
329-25	25	12/14/89	60.0	10532.3	175.5	260.3	0.0000978	0.35	63.59	58.8	0.04228	152.2	27450	432.2	2.29	601086	2.106E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-22	185	12/10/89	32.05	43.69	1400.45	101.70	12.32	1253.18	1258.65	89.88	32.09	28708500	200	934	249	1565	746	995	81	1	141
329-22	190	12/11/89	32.07	43.66	1400.13	101.65	12.33	1253.27	1258.75	89.90	32.15	28752300	198	936	248	1563	745	949	81	1	142
329-22	195	12/11/89	32.05	43.63	1398.20	102.24	12.24	1251.72	1257.12	89.91	32.32	28834700	199	935	248	1564	746	981	81	1	143
329-23	32	12/12/89	31.73	43.90	1392.65	101.43	12.19	1236.03	1241.38	89.14	52.77	28061100	195	936	249	1563	743	978	79	1	144
329-24	5	12/12/89	31.73	43.89	1392.57	101.84	12.17	1239.06	1244.39	89.36	32.71	28062800	196	934	249	1558	742	981	79	1	145
329-24	10	12/12/89	31.75	43.94	1395.07	101.33	12.24	1240.19	1245.58	89.28	33.10	28184300	198	934	252	1562	744	974	80	1	146
329-24	15	12/12/89	31.76	43.91	1394.64	101.49	12.22	1240.33	1245.70	89.32	33.18	28301300	198	934	252	1566	745	984	80	1	147
329-24	20	12/12/89	31.75	43.98	1396.32	100.97	12.29	1240.76	1246.20	89.25	32.58	28115300	199	936	252	1569	745	976	80	1	148
329-24	25	12/13/89	31.75	43.94	1395.11	101.20	12.23	1237.88	1243.27	89.12	32.71	27986200	197	937	251	1565	744	940	80	1	149
329-24	30	12/13/89	31.75	43.93	1394.77	101.20	12.26	1241.15	1246.57	89.37	32.97	28321900	199	936	251	1567	745	975	80	1	150
329-24	35	12/13/89	31.71	44.02	1395.80	100.75	12.29	1237.78	1243.22	89.07	32.81	28241200	199	934	252	1569	746	975	80	1	151
329-24	40	12/13/89	31.72	43.97	1395.02	101.07	12.28	1241.33	1246.76	89.37	32.44	28227900	197	935	251	1565	744	942	80	1	152
329-24	45	12/13/89	31.71	44.03	1396.24	100.49	12.32	1237.84	1243.30	89.05	32.82	28230800	198	935	251	1568	745	974	80	1	153
329-24	50	12/13/89	31.73	43.92	1393.58	101.34	12.21	1237.25	1242.61	89.17	32.75	28296200	198	935	250	1564	744	981	79	1	154
329-24	55	12/13/89	31.73	43.88	1392.20	102.04	12.14	1238.94	1244.25	89.37	32.64	28051300	195	936	250	1560	743	942	79	1	155
329-24	60	12/13/89	31.75	43.88	1393.04	100.96	12.26	1237.35	1242.76	89.21	32.55	27962100	196	935	250	1566	744	960	80	1	156
329-24	65	12/13/89	31.73	43.88	1392.22	101.41	12.22	1239.39	1244.77	89.41	32.70	28268400	199	935	251	1565	744	985	80	1	157
329-24	70	12/13/89	31.72	43.99	1395.29	100.38	12.34	1238.65	1244.13	89.17	32.63	28231000	199	934	251	1568	746	976	80	1	158
329-24	75	12/13/89	31.74	43.85	1391.83	101.59	12.19	1237.98	1243.32	89.33	32.70	28196200	199	933	251	1566	745	983	80	1	159
329-24	80	12/13/89	31.72	43.85	1391.04	101.84	12.15	1237.58	1242.89	89.35	32.82	28308400	199	933	251	1562	744	978	80	1	160
329-24	85	12/13/89	31.73	43.84	1390.88	101.73	12.15	1236.14	1241.45	89.26	32.88	28300900	199	933	251	1561	744	978	80	1	161
329-24	90	12/13/89	31.75	43.80	1390.41	101.80	12.14	1235.97	1241.27	89.27	32.79	28261700	199	933	250	1566	745	977	79	1	162
329-24	95	12/13/89	31.75	43.80	1390.41	101.82	12.13	1235.26	1240.55	89.22	32.83	28347600	199	934	250	1567	745	977	79	1	163
329-24	100	12/13/89	31.76	43.81	1391.16	101.68	12.18	1238.80	1244.14	89.43	32.89	28460400	198	934	250	1568	745	974	79	1	164
329-24	105	12/14/89	31.74	43.93	1394.32	100.67	12.30	1238.62	1244.07	89.22	32.53	28382200	197	936	251	1568	745	937	80	1	165
329-24	110	12/14/89	31.75	43.89	1393.61	101.10	12.23	1236.64	1242.03	89.12	32.76	28304600	198	934	250	1567	746	974	80	1	166
329-24	115	12/14/89	31.76	43.80	1391.28	101.68	12.18	1238.54	1243.89	89.41	32.48	28228700	197	933	249	1562	744	973	79	1	167
329-24	120	12/14/89	31.76	43.79	1390.66	101.66	12.15	1235.04	1240.35	89.19	32.78	28238700	196	937	249	1562	744	934	79	1	168
329-24	125	12/14/89	31.74	43.81	1390.49	101.49	12.14	1232.57	1237.88	89.03	33.01	28248100	197	933	249	1564	745	973	79	1	169
329-24	130	12/14/89	31.75	43.82	1391.08	101.39	12.22	1238.71	1244.08	89.43	32.61	28302300	197	933	249	1568	745	971	79	1	170
329-25	5	12/14/89	31.76	43.76	1389.84	101.59	12.18	1237.46	1242.80	89.42	32.79	27970400	196	934	248	1565	745	975	78	1	171
329-25	10	12/14/89	31.75	43.78	1390.12	101.90	12.15	1237.78	1243.09	89.42	33.01	28091300	197	935	249	1563	745	974	79	1	172
329-25	15	12/14/89	31.74	43.80	1390.28	101.92	12.15	1238.14	1243.45	89.44	32.66	27928500	198	935	250	1565	745	974	79	1	173
329-25	20	12/14/89	31.77	43.76	1390.38	101.87	12.15	1237.77	1243.09	89.41	33.02	28102800	198	935	250	1565	745	973	79	1	174
329-25	25	12/14/89	31.77	43.77	1390.74	101.52	12.18	1236.28	1241.62	89.28	32.27	27866700	199	934	250	1566	745	972	79	1	175

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
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329-25	30	12/14/89	60.0	10592.3	176.5	259.8	0.0000971	0.35	63.95	58.6	0.04259	153.3	27603	438.9	2.20	603812	2.136E+10
329-25	35	12/14/89	60.0	10652.3	177.5	259.6	0.0000970	0.35	64.30	58.6	0.04252	153.1	27756	438.2	2.20	603937	2.135E+10
329-25	40	12/14/89	60.0	10712.3	178.5	259.6	0.0000971	0.35	64.65	58.7	0.04237	152.5	27908	436.1	2.32	604258	2.129E+10
329-25	45	12/15/89	60.0	10772.3	179.5	259.6	0.0000971	0.35	65.00	58.7	0.04241	152.7	28061	436.7	2.18	604419	2.130E+10
329-25	50	12/15/89	60.0	10832.3	180.5	259.7	0.0000966	0.35	65.35	58.8	0.04262	153.4	28215	441.4	2.29	608992	2.155E+10
329-25	55	12/15/89	60.0	10892.3	181.5	259.6	0.0000964	0.35	65.70	58.9	0.04249	153.0	28368	440.5	2.33	610730	2.158E+10
329-25	60	12/15/89	60.0	10952.3	182.5	259.6	0.0000972	0.35	66.05	58.9	0.04253	153.1	28521	437.8	2.31	606217	2.126E+10
329-25	65	12/15/89	60.0	11012.3	183.5	259.9	0.0000975	0.35	66.40	58.9	0.04245	152.8	28674	435.3	2.25	604028	2.111E+10
329-25	70	12/15/89	60.0	11072.3	184.5	259.9	0.0000967	0.35	66.75	58.8	0.04260	153.4	28827	440.5	2.32	608047	2.150E+10
329-25	75	12/15/89	60.0	11132.3	185.5	259.9	0.0000971	0.35	67.10	58.7	0.04252	153.1	28980	437.9	2.33	604494	2.134E+10
329-25	80	12/15/89	60.0	11192.3	186.5	259.6	0.0000964	0.35	67.45	58.6	0.04252	153.1	29133	441.2	2.38	608079	2.164E+10
329-25	85	12/15/89	60.0	11252.3	187.5	260.2	0.0000966	0.35	67.79	58.8	0.04236	152.5	29286	438.5	2.33	608607	2.158E+10
329-25	90	12/15/89	60.0	11312.3	188.5	260.5	0.0000971	0.35	68.14	58.8	0.04243	152.7	29438	436.8	2.16	605268	2.137E+10
329-26	5	12/15/89	60.0	11372.3	189.5	240.0	0.0000925	0.33	68.47	57.0	0.04120	148.3	29587	445.6	2.28	616529	2.141E+10
329-26	10	12/15/89	60.0	11432.4	190.5	240.0	0.0000928	0.33	68.81	57.1	0.04121	148.4	29735	444.2	2.32	615527	2.125E+10
329-26	15	12/15/89	60.0	11492.4	191.5	239.7	0.0000926	0.34	69.14	57.2	0.04110	148.0	29883	443.9	2.30	617764	2.129E+10
329-26	20	12/15/89	60.0	11552.4	192.5	239.6	0.0000915	0.33	69.48	57.4	0.04113	148.1	30031	449.8	2.29	627665	2.179E+10
329-26	25	12/15/89	60.0	11612.4	193.5	239.5	0.0000924	0.33	69.81	57.3	0.04107	147.9	30179	444.7	2.27	620351	2.136E+10
329-26	30	12/15/89	60.0	11672.4	194.5	239.5	0.0000923	0.33	70.14	57.3	0.04115	148.1	30327	446.1	2.34	621098	2.141E+10
329-26	35	12/16/89	60.0	11732.4	195.5	239.4	0.0000927	0.33	70.48	57.3	0.04113	148.1	30475	443.8	2.31	618376	2.121E+10
329-26	40	12/16/89	60.0	11792.4	196.5	239.2	0.0000922	0.34	70.81	57.1	0.04111	148.0	30623	445.7	2.50	618997	2.140E+10
329-26	45	12/16/89	60.0	11852.4	197.5	239.3	0.0000917	0.33	71.15	57.1	0.04115	148.1	30771	448.6	2.26	622432	2.165E+10
329-26	50	12/16/89	60.0	11912.4	198.5	239.2	0.0000925	0.33	71.48	57.2	0.04110	148.0	30919	444.5	2.47	618653	2.129E+10
329-26	55	12/16/89	60.0	11972.4	199.5	239.1	0.0000921	0.33	71.81	56.9	0.04101	147.6	31067	445.1	2.33	617592	2.146E+10
329-26	60	12/16/89	60.0	12032.4	200.5	239.1	0.0000921	0.33	72.15	56.9	0.04107	147.9	31215	445.9	2.31	617793	2.148E+10
329-26	65	12/16/89	60.0	12092.4	201.5	239.1	0.0000921	0.33	72.48	57.0	0.04103	147.7	31362	445.6	2.32	619141	2.149E+10
329-26	70	12/16/89	60.0	12152.4	202.5	239.2	0.0000920	0.33	72.81	56.9	0.04101	147.6	31510	445.9	2.28	618532	2.154E+10
329-26	75	12/16/89	60.0	12212.4	203.5	239.3	0.0000920	0.33	73.15	57.1	0.04106	147.8	31658	446.1	2.44	620389	2.151E+10
329-26	80	12/16/89	60.0	12272.4	204.5	239.3	0.0000917	0.33	73.48	57.0	0.04105	147.8	31806	447.7	2.34	621728	2.169E+10
329-26	85	12/16/89	60.0	12332.4	205.5	239.4	0.0000918	0.33	73.81	57.2	0.04106	147.8	31954	447.5	2.36	623379	2.164E+10
329-26	90	12/16/89	60.0	12392.4	206.5	239.2	0.0000926	0.33	74.14	57.3	0.04106	147.8	32101	443.5	2.43	618958	2.122E+10
329-26	95	12/16/89	60.0	12452.4	207.5	239.0	0.0000922	0.33	74.48	57.1	0.04102	147.7	32249	445.1	2.30	619575	2.142E+10
329-26	100	12/16/89	60.0	12512.4	208.5	238.7	0.0000915	0.33	74.81	57.2	0.04107	147.9	32397	448.9	2.43	625150	2.168E+10
329-26	105	12/16/89	60.0	12572.4	209.5	238.6	0.0000921	0.33	75.14	57.2	0.04102	147.7	32545	445.3	2.32	621051	2.138E+10
329-26	110	12/16/89	60.0	12632.4	210.5	238.4	0.0000914	0.33	75.48	57.2	0.04105	147.8	32692	448.9	2.29	625499	2.167E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-25	30	12/14/89	31.77	43.74	1389.42	102.03	12.12	1236.22	1241.50	89.35	33.01	28087300	199	933	249	1561	744	971	79	1	176
329-25	35	12/14/89	31.75	43.74	1388.91	102.10	12.08	1233.44	1238.70	89.19	32.97	28029900	199	934	249	1563	745	974	79	1	177
329-25	40	12/14/89	31.75	43.79	1390.38	101.68	12.15	1235.04	1240.36	89.21	32.66	28033300	199	934	249	1567	745	965	79	1	178
329-25	45	12/15/89	31.75	43.74	1388.66	102.38	12.09	1237.23	1242.49	89.47	32.68	28090500	198	934	249	1564	745	945	79	1	179
329-25	50	12/15/89	31.75	43.77	1389.62	101.97	12.14	1237.68	1242.99	89.45	33.18	28265200	199	934	249	1564	745	938	79	1	180
329-25	55	12/15/89	31.78	43.74	1390.03	101.82	12.13	1235.49	1240.79	89.26	33.07	28247600	198	933	249	1568	746	625	79	1	181
329-25	60	12/15/89	31.78	43.74	1389.99	101.86	12.15	1237.50	1242.82	89.41	32.84	28084600	198	933	249	1567	745	727	78	1	182
329-25	65	12/15/89	31.78	43.69	1388.55	102.34	12.09	1237.61	1242.88	89.51	32.59	27985600	198	932	249	1562	744	744	78	1	183
329-25	70	12/15/89	31.75	43.72	1388.39	102.34	12.08	1236.03	1241.28	89.40	33.14	28183700	198	933	249	1561	744	743	78	1	184
329-25	75	12/15/89	31.74	43.72	1387.39	102.71	12.03	1235.75	1240.97	89.45	32.89	28060400	198	933	249	1563	745	747	78	1	185
329-25	80	12/15/89	31.75	43.70	1387.50	102.74	12.02	1235.40	1240.60	89.41	33.15	28266900	199	933	249	1559	744	751	78	1	186
329-25	85	12/15/89	31.76	43.70	1388.10	102.51	12.06	1236.71	1241.95	89.47	32.79	28225100	199	932	249	1562	744	753	78	1	187
329-25	90	12/15/89	31.77	43.68	1387.37	102.74	12.04	1236.99	1242.21	89.54	32.71	28076600	199	933	249	1564	745	753	78	1	188
329-26	5	12/15/89	31.78	43.93	1395.99	99.96	12.38	1237.05	1242.57	89.01	32.39	29503800	199	927	249	1581	749	754	79	1	189
329-26	10	12/15/89	31.77	43.92	1395.14	100.50	12.36	1242.14	1247.64	89.43	32.17	29525000	199	926	249	1580	749	755	79	1	190
329-26	15	12/15/89	31.76	43.98	1396.90	99.82	12.41	1239.31	1244.86	89.12	32.13	29513200	199	927	249	1582	749	756	79	1	191
329-26	20	12/15/89	31.76	44.06	1399.63	98.90	12.56	1241.75	1247.42	89.13	32.53	29940300	199	926	249	1583	750	756	79	1	192
329-26	25	12/15/89	31.78	43.99	1398.03	99.44	12.46	1239.38	1244.97	89.05	32.17	29586600	199	925	249	1582	749	756	79	1	193
329-26	30	12/15/89	31.78	43.95	1396.74	99.85	12.43	1240.98	1246.54	89.25	32.29	29660600	199	925	249	1583	750	757	79	1	194
329-26	35	12/16/89	31.77	43.95	1396.21	99.70	12.42	1238.21	1243.77	89.08	32.18	29464800	199	925	249	1582	749	757	79	1	195
329-26	40	12/16/89	31.79	43.88	1395.05	99.95	12.37	1236.49	1242.00	89.03	32.35	29556300	199	925	249	1581	749	739	79	1	196
329-26	45	12/16/89	31.77	43.89	1394.61	100.44	12.37	1242.43	1247.94	89.48	32.43	29863100	199	924	249	1582	749	744	79	1	197
329-26	50	12/16/89	31.78	43.91	1395.18	99.99	12.38	1237.55	1243.06	89.10	32.22	29513500	199	925	249	1582	749	750	79	1	198
329-26	55	12/16/89	31.78	43.90	1395.18	100.14	12.36	1237.31	1242.81	89.08	32.20	29612600	199	926	249	1583	750	753	79	1	199
329-26	60	12/16/89	31.77	43.93	1395.91	99.78	12.40	1236.82	1242.35	89.00	32.32	29610700	199	926	249	1584	750	755	79	1	200
329-26	65	12/16/89	31.78	43.98	1397.74	99.33	12.48	1240.04	1245.65	89.12	32.19	29700100	200	924	249	1584	750	754	79	1	201
329-26	70	12/16/89	31.79	43.96	1397.75	99.48	12.47	1240.49	1246.09	89.15	32.18	29733900	199	925	249	1585	750	756	79	1	202
329-26	75	12/16/89	31.77	44.09	1400.64	98.40	12.58	1238.36	1244.06	88.82	32.29	29667500	200	924	250	1585	750	756	79	1	203
329-26	80	12/16/89	31.79	43.95	1397.16	99.71	12.43	1239.61	1245.18	89.12	32.36	29814100	200	925	249	1585	750	759	80	1	204
329-26	85	12/16/89	31.79	44.04	1399.92	98.78	12.54	1238.51	1244.16	88.87	32.39	29762000	200	924	250	1583	750	759	80	1	205
329-26	90	12/16/89	31.79	44.08	1401.57	98.51	12.58	1239.70	1245.40	88.86	32.07	29527900	200	924	250	1584	750	759	80	1	206
329-26	95	12/16/89	31.80	43.98	1398.46	99.41	12.47	1239.91	1245.51	89.06	32.14	29665900	201	925	249	1584	750	760	80	1	207
329-26	100	12/16/89	31.81	43.98	1398.69	99.17	12.49	1238.17	1243.78	88.93	32.50	29838600	200	926	249	1584	750	761	79	1	208
329-26	105	12/16/89	31.79	43.96	1397.38	99.68	12.43	1238.73	1244.29	89.05	32.19	29656200	200	923	249	1583	750	759	79	1	209
329-26	110	12/16/89	31.79	43.93	1396.51	99.72	12.43	1239.19	1244.75	89.13	32.47	29879900	200	925	248	1584	750	762	79	1	210

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
329-26	115	12/17/89	60.0	12692.4	211.5	238.3	0.0000915	0.33	75.81	57.2	0.04102	147.7	32840	448.3	2.26	625055	2.163E+10
329-26	120	12/17/89	60.0	12752.4	212.5	238.2	0.0000916	0.33	76.14	57.3	0.04104	147.7	32988	448.2	1.93	625730	2.157E+10
329-26	125	12/17/89	60.0	12812.4	213.5	238.1	0.0000920	0.33	76.47	57.4	0.04095	147.4	33135	444.9	1.95	623581	2.133E+10
329-26	130	12/17/89	60.0	12872.4	214.5	238.0	0.0000916	0.33	76.81	56.8	0.04102	147.7	33283	447.7	1.95	620026	2.159E+10
329-26	135	12/17/89	60.0	12932.4	215.5	238.0	0.0000917	0.33	77.14	57.1	0.04108	147.9	33431	448.1	2.03	622880	2.153E+10
329-27	7	12/17/89	60.0	13022.4	217.0	243.1	0.0000926	0.34	77.65	57.5	0.04169	150.1	33651	450.0	1.96	620676	2.163E+10
329-27	12	12/17/89	60.0	13082.4	218.0	243.2	0.0000927	0.33	77.98	57.3	0.04162	149.8	33801	449.0	1.93	618176	2.164E+10
329-27	17	12/17/89	60.0	13142.4	219.0	243.2	0.0000931	0.34	78.32	57.1	0.04163	149.9	33951	447.0	1.92	612996	2.145E+10
329-27	22	12/17/89	60.0	13202.4	220.0	243.1	0.0000933	0.34	78.65	57.0	0.04131	148.7	34099	442.6	1.84	610703	2.136E+10
329-27	27	12/17/89	60.0	13262.4	221.0	243.0	0.0000935	0.34	78.99	57.0	0.04166	150.0	34249	445.6	1.94	609691	2.128E+10
329-27	32	12/17/89	60.0	13322.4	222.0	242.9	0.0000925	0.34	79.32	57.2	0.04134	148.8	34398	447.1	2.04	618539	2.171E+10
329-27	37	12/17/89	60.0	13382.4	223.0	242.7	0.0000930	0.34	79.66	57.2	0.04147	149.3	34547	445.8	1.92	614770	2.143E+10
329-27	42	12/18/89	60.0	13442.4	224.0	242.6	0.0000932	0.33	80.00	57.4	0.04135	148.9	34696	443.7	2.03	615986	2.133E+10
329-27	47	12/18/89	60.0	13502.4	225.0	242.6	0.0000936	0.34	80.33	57.2	0.04129	148.6	34845	441.1	1.89	611033	2.116E+10
329-27	52	12/18/89	60.0	13562.4	226.0	242.5	0.0000923	0.34	80.67	57.1	0.04118	148.2	34993	446.0	2.00	618434	2.175E+10
329-27	57	12/18/89	60.0	13622.4	227.0	242.4	0.0000934	0.34	81.01	57.2	0.04121	148.4	35141	441.1	1.96	612210	2.122E+10
329-27	62	12/18/89	60.0	13682.4	228.0	242.5	0.0000936	0.34	81.34	57.5	0.04123	148.4	35290	440.6	2.30	614402	2.112E+10
329-27	67	12/18/89	60.0	13742.4	229.0	242.7	0.0000926	0.34	81.68	57.4	0.04117	148.2	35438	444.5	2.30	619737	2.160E+10
329-27	72	12/18/89	60.0	13802.4	230.0	243.0	0.0000922	0.33	82.02	57.6	0.04132	148.8	35587	448.2	2.26	624695	2.181E+10
329-27	77	12/18/89	60.0	13862.4	231.0	242.5	0.0000925	0.33	82.35	57.4	0.04135	148.9	35736	447.0	2.12	620500	2.163E+10
329-28	5	12/18/89	60.0	13922.4	232.0	239.8	0.0000919	0.33	82.68	56.9	0.04107	147.9	35884	446.8	2.40	618916	2.164E+10
329-28	10	12/18/89	60.0	13982.4	233.0	240.5	0.0000922	0.33	83.02	57.1	0.04110	148.0	36032	446.0	2.44	619554	2.159E+10
329-28	15	12/18/89	60.0	14042.4	234.0	240.7	0.0000925	0.33	83.35	57.1	0.04106	147.8	36179	443.9	2.23	617357	2.146E+10
329-28	20	12/18/89	60.0	14102.4	235.0	240.7	0.0000919	0.34	83.68	56.8	0.04108	147.9	36327	447.1	2.37	618278	2.179E+10
329-28	25	12/18/89	60.0	14162.5	236.0	240.4	0.0000917	0.33	84.02	56.9	0.04108	147.9	36475	448.2	2.28	620806	2.184E+10
329-28	30	12/18/89	60.0	14222.5	237.0	240.2	0.0000922	0.33	84.35	56.8	0.04108	147.9	36623	445.4	2.36	615825	2.156E+10
329-28	35	12/18/89	60.0	14282.5	238.0	240.1	0.0000930	0.33	84.68	56.7	0.04099	147.6	36771	441.0	2.37	609973	2.123E+10
329-28	40	12/18/89	60.0	14342.5	239.0	240.0	0.0000924	0.34	85.02	56.7	0.04102	147.7	36918	444.0	2.12	613743	2.148E+10
329-28	45	12/19/89	60.0	14402.5	240.0	240.0	0.0000918	0.33	85.35	56.5	0.04095	147.4	37066	446.1	1.92	615522	2.178E+10
329-28	50	12/19/89	60.0	14462.5	241.0	240.0	0.0000915	0.33	85.68	56.5	0.04098	147.5	37213	448.1	1.92	617824	2.194E+10
329-28	55	12/19/89	60.0	14522.5	242.0	239.9	0.0000923	0.33	86.01	56.5	0.04097	147.5	37361	444.1	1.96	612360	2.154E+10
329-28	60	12/19/89	60.0	14582.5	243.0	239.9	0.0000916	0.33	86.35	56.6	0.04099	147.6	37508	447.8	2.33	618214	2.187E+10
329-28	65	12/19/89	60.0	14642.5	244.0	240.0	0.0000918	0.33	86.68	56.5	0.04102	147.7	37656	447.0	2.26	615777	2.180E+10
329-28	70	12/19/89	60.0	14702.5	245.0	240.1	0.0000922	0.33	87.01	56.3	0.04099	147.6	37804	444.5	2.61	610543	2.162E+10
329-29	5	12/19/89	60.0	14762.5	246.0	239.9	0.0000928	0.34	87.35	56.0	0.04109	147.9	37952	442.9	2.11	603617	2.137E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-26	115	12/17/89	31.80	43.88	1395.22	100.19	12.37	1239.37	1244.88	89.22	32.39	29862700	200	924	248	1583	750	759	79	1	211
329-26	120	12/17/89	31.80	43.93	1396.85	99.56	12.44	1238.75	1244.32	89.08	32.42	29828200	199	925	248	1583	16	760	79	1	212
329-26	125	12/17/89	31.77	44.02	1398.66	99.20	12.50	1239.72	1245.34	89.04	32.08	29697000	199	924	248	1584	6	760	79	1	213
329-26	130	12/17/89	31.80	43.90	1396.03	99.88	12.40	1238.60	1244.14	89.12	32.37	29812700	199	924	248	1583	17	759	79	1	214
329-26	135	12/17/89	31.77	44.07	1400.07	98.76	12.55	1239.36	1245.03	88.93	32.42	29810900	199	923	249	1584	-8	760	79	1	215
329-27	7	12/17/89	31.76	43.94	1395.86	99.90	12.38	1236.64	1242.16	88.99	33.11	29434100	200	925	248	1576	23	761	79	1	218
329-27	12	12/17/89	31.77	43.88	1394.08	100.28	12.33	1235.98	1241.45	89.05	33.00	29402100	199	926	249	1580	20	760	79	1	219
329-27	17	12/17/89	31.80	43.85	1394.60	100.16	12.36	1237.96	1243.46	89.16	32.82	29304700	198	924	249	1581	19	763	79	1	220
329-27	22	12/17/89	31.83	43.80	1394.32	100.42	12.34	1239.40	1244.89	89.28	32.21	29280300	199	926	248	1580	22	762	79	1	221
329-27	27	12/17/89	31.78	43.81	1391.99	100.85	12.28	1238.16	1243.59	89.34	32.74	29202500	199	924	248	1579	27	763	79	1	222
329-27	32	12/17/89	31.77	43.88	1394.41	100.17	12.36	1237.97	1243.47	89.18	32.59	29518000	200	926	248	1581	17	762	79	1	223
329-27	37	12/17/89	31.79	43.87	1394.50	100.15	12.35	1236.54	1242.03	89.07	32.64	29304400	200	927	248	1581	19	763	79	1	224
329-27	42	12/18/89	31.78	43.94	1396.49	99.79	12.42	1239.80	1245.36	89.18	32.31	29337300	200	926	248	1581	15	763	79	1	225
329-27	47	12/18/89	31.81	43.89	1396.28	99.79	12.43	1240.65	1246.21	89.25	32.05	29222900	200	925	248	1582	17	763	79	1	226
329-27	52	12/18/89	31.79	43.91	1395.80	100.15	12.37	1238.98	1244.49	89.16	32.36	29589200	200	924	249	1583	12	763	79	1	227
329-27	57	12/18/89	31.80	43.87	1394.85	100.23	12.36	1239.09	1244.59	89.23	32.03	29242500	200	925	249	1583	750	765	79	1	228
329-27	62	12/18/89	31.76	43.97	1396.47	98.85	12.51	1236.45	1242.08	88.94	32.07	29131700	200	928	249	1583	750	764	79	1	229
329-27	67	12/18/89	31.80	43.84	1394.20	100.18	12.35	1237.50	1242.99	89.15	32.28	29461100	200	924	248	1583	750	764	79	1	230
329-27	72	12/18/89	31.78	43.98	1397.75	99.11	12.48	1236.60	1242.20	88.87	32.69	29572300	200	925	248	1581	749	765	79	1	231
329-27	77	12/18/89	31.80	43.91	1396.18	100.00	12.42	1241.60	1247.15	89.33	32.50	29595100	199	927	248	1582	749	767	79	1	232
329-28	5	12/18/89	31.80	43.94	1397.08	99.68	12.41	1237.45	1243.00	88.97	32.37	29679500	200	924	248	1584	750	764	79	1	233
329-28	10	12/18/89	31.80	43.86	1394.51	100.48	12.34	1240.05	1245.54	89.32	32.27	29668200	200	924	248	1584	750	764	79	1	234
329-28	15	12/18/89	31.79	43.78	1391.72	100.67	12.27	1234.76	1240.17	89.11	32.23	29436800	200	926	248	1583	750	764	79	1	235
329-28	20	12/18/89	31.80	43.71	1390.01	101.19	12.21	1235.54	1240.91	89.27	32.45	29655200	201	923	248	1582	750	766	78	1	236
329-28	25	12/18/89	31.79	43.96	1397.55	99.22	12.49	1239.38	1245.00	89.09	32.43	29816700	201	926	249	1583	750	765	79	1	237
329-28	30	12/18/89	31.81	43.79	1392.90	100.66	12.30	1238.03	1243.48	89.27	32.26	29597200	202	923	249	1585	750	767	79	1	238
329-28	35	12/18/89	31.81	43.88	1395.49	99.62	12.43	1238.26	1243.82	89.13	31.87	29373000	201	922	248	1584	750	767	79	1	239
329-28	40	12/18/89	31.81	44.00	1399.62	98.60	12.58	1240.44	1246.14	89.03	32.05	29606500	201	926	248	1584	-15	766	79	1	240
329-28	45	12/19/89	31.81	43.98	1398.80	99.04	12.52	1240.05	1245.69	89.05	32.16	29788100	202	921	249	1586	-6	765	79	1	241
329-28	50	12/19/89	31.81	43.96	1398.25	99.15	12.50	1239.01	1244.63	89.01	32.35	29874500	202	925	249	1586	3	768	79	1	242
329-28	55	12/19/89	31.81	43.95	1398.24	99.27	12.47	1238.18	1243.78	88.95	32.08	29590600	201	924	249	1587	2	769	79	1	243
329-28	60	12/19/89	31.82	43.82	1394.30	100.24	12.34	1237.33	1242.81	89.14	32.38	29800100	202	922	248	1586	751	766	79	1	244
329-28	65	12/19/89	31.81	43.73	1391.10	100.98	12.24	1236.09	1241.48	89.25	32.38	29705200	202	923	248	1585	750	767	78	1	245
329-28	70	12/19/89	31.79	43.84	1393.72	100.18	12.33	1235.46	1240.94	89.04	32.20	29542400	201	925	248	1586	751	767	79	1	246
329-29	5	12/19/89	31.78	43.97	1397.48	99.68	12.42	1237.95	1243.50	88.98	32.09	29422700	202	921	247	1588	752	963	78	1	247

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
329-29	10	12/19/89	60.0	14822.5	247.0	239.9	0.0000932	0.33	87.68	55.9	0.04106	147.9	38099	440.7	2.11	599914	2.119E+10
329-29	15	12/19/89	60.0	14882.5	248.0	240.0	0.0000929	0.34	88.02	56.0	0.04106	147.8	38247	442.1	2.09	602980	2.133E+10
329-29	20	12/19/89	60.0	14942.5	249.0	239.8	0.0000926	0.33	88.36	56.0	0.04103	147.7	38395	443.2	2.25	604921	2.145E+10
329-29	25	12/19/89	60.0	15002.5	250.0	239.5	0.0000914	0.33	88.69	56.0	0.04102	147.7	38543	448.8	2.31	612718	2.197E+10
329-29	30	12/19/89	60.0	15062.5	251.0	239.2	0.0000922	0.33	89.02	55.9	0.04095	147.4	38690	444.2	2.16	606278	2.156E+10
329-29	35	12/19/89	60.0	15122.5	252.0	239.1	0.0000917	0.33	89.35	55.9	0.04095	147.4	38837	446.7	2.21	609816	2.180E+10
329-29	40	12/19/89	60.0	15182.5	253.0	239.0	0.0000921	0.33	89.68	55.9	0.04099	147.6	38985	444.9	1.87	606699	2.157E+10
329-29	45	12/20/89	60.0	15242.5	254.0	238.9	0.0000922	0.33	90.02	55.9	0.04099	147.6	39133	444.8	1.92	606567	2.155E+10
329-29	50	12/20/89	60.0	15302.5	255.0	238.9	0.0000915	0.33	90.35	56.0	0.04097	147.5	39280	447.9	1.84	612209	2.186E+10
329-29	55	12/20/89	60.0	15362.5	256.0	239.0	0.0000923	0.33	90.68	56.0	0.04100	147.6	39428	444.2	1.81	606763	2.148E+10
329-29	60	12/20/89	60.0	15422.5	257.0	239.0	0.0000924	0.33	91.02	55.9	0.04097	147.5	39575	443.2	1.90	604671	2.142E+10
329-29	65	12/20/89	60.0	15482.5	258.0	239.2	0.0000916	0.33	91.35	56.1	0.04099	147.6	39723	447.6	2.27	612506	2.183E+10
329-29	70	12/20/89	60.0	15542.5	259.0	239.2	0.0000919	0.33	91.68	56.0	0.04098	147.5	39870	445.9	1.88	609325	2.169E+10
329-29	75	12/20/89	60.0	15602.5	260.0	239.2	0.0000923	0.33	92.01	56.1	0.04095	147.4	40018	443.9	2.21	608071	2.151E+10
329-29	80	12/20/89	60.0	15662.5	261.0	239.4	0.0000918	0.33	92.35	56.2	0.04098	147.5	40165	446.3	1.89	612127	2.173E+10
329-29	85	12/20/89	60.0	15722.5	262.0	239.7	0.0000922	0.33	92.68	56.3	0.04099	147.6	40313	444.5	1.91	610437	2.156E+10
329-29	90	12/20/89	60.0	15782.5	263.0	240.1	0.0000917	0.33	93.01	56.3	0.04098	147.5	40460	447.1	2.19	614159	2.187E+10
329-29	95	12/20/89	60.0	15842.5	264.0	239.8	0.0000919	0.33	93.35	56.4	0.04098	147.5	40608	445.8	2.07	613450	2.170E+10
329-29	100	12/20/89	60.0	15902.5	265.0	239.1	0.0000914	0.33	93.68	56.4	0.04090	147.2	40755	447.3	2.39	616818	2.185E+10
329-29	105	12/20/89	60.0	15962.5	266.0	238.9	0.0000913	0.33	94.01	56.4	0.04091	147.3	40902	448.2	1.98	617967	2.191E+10
329-29	110	12/20/89	60.0	16022.5	267.0	238.5	0.0000914	0.33	94.34	56.4	0.04089	147.2	41049	447.5	1.84	617189	2.181E+10
329-29	115	12/20/89	60.0	16082.5	268.0	238.3	0.0000914	0.33	94.67	56.2	0.04085	147.1	41197	447.1	1.96	615176	2.182E+10
329-29	120	12/20/89	60.0	16142.5	269.0	238.1	0.0000911	0.33	95.00	56.3	0.04086	147.1	41344	448.7	1.79	618342	2.193E+10
329-29	125	12/21/89	60.0	16202.5	270.0	237.9	0.0000917	0.33	95.33	56.0	0.04086	147.1	41491	445.8	1.76	611000	2.165E+10
329-29	130	12/21/89	60.0	16262.5	271.0	237.6	0.0000916	0.33	95.66	55.9	0.04083	147.0	41638	445.5	1.75	610049	2.164E+10
329-29	135	12/21/89	60.0	16322.5	272.0	237.7	0.0000922	0.33	95.99	56.0	0.04086	147.1	41785	443.1	1.79	607263	2.137E+10
329-29	140	12/21/89	60.0	16382.5	273.0	237.6	0.0000915	0.33	96.32	56.1	0.04088	147.2	41932	447.0	1.77	613437	2.170E+10
329-29	145	12/21/89	60.0	16442.5	274.0	237.9	0.0000909	0.33	96.66	56.0	0.04083	147.0	42079	449.2	1.92	616082	2.202E+10
329-29	150	12/21/89	60.0	16502.5	275.0	237.9	0.0000913	0.33	96.99	56.1	0.04090	147.2	42226	448.1	2.00	614599	2.182E+10
329-29	158	12/21/89	60.0	16592.5	276.5	237.6	0.0000914	0.33	97.48	56.2	0.04085	147.1	42447	447.1	1.95	615209	2.174E+10
329-29	163	12/21/89	60.0	16652.5	277.5	234.7	0.0000902	0.33	97.81	55.9	0.04069	146.5	42593	450.9	2.43	619507	2.196E+10
329-29	168	12/21/89	60.0	16712.5	278.5	235.7	0.0000909	0.33	98.14	56.2	0.04073	146.6	42740	448.1	2.05	618323	2.173E+10
329-29	173	12/21/89	60.0	16772.5	279.5	237.6	0.0000914	0.33	98.47	56.3	0.04079	146.8	42887	446.5	2.57	616284	2.172E+10
329-29	178	12/21/89	60.0	16832.5	280.5	238.1	0.0000916	0.33	98.80	56.4	0.04087	147.1	43034	446.3	1.88	615902	2.167E+10
329-29	183	12/21/89	60.0	16892.5	281.5	238.1	0.0000906	0.33	99.13	56.4	0.04089	147.2	43181	451.3	2.07	622386	2.213E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-29	10	12/19/89	31.81	43.87	1395.51	100.55	12.32	1239.01	1244.48	89.18	31.88	29319800	203	926	249	1588	752	967	79	1	248
329-29	15	12/19/89	31.80	44.02	1399.82	99.34	12.47	1238.62	1244.22	88.88	31.99	29407800	203	923	250	1589	752	967	79	1	249
329-29	20	12/19/89	31.80	44.03	1400.05	99.19	12.49	1238.93	1244.55	88.89	32.05	29510000	204	923	250	1590	752	967	79	1	250
329-29	25	12/19/89	31.79	44.03	1399.74	99.51	12.46	1240.31	1245.90	89.01	32.41	29923300	204	922	250	1591	752	973	79	1	251
329-29	30	12/19/89	31.79	44.06	1400.53	99.05	12.50	1237.64	1243.26	88.77	32.09	29598200	205	921	250	1591	752	969	79	1	252
329-29	35	12/19/89	31.80	44.09	1401.81	98.87	12.55	1240.38	1246.05	88.89	32.20	29836700	205	922	250	1591	498	967	79	1	253
329-29	40	12/19/89	31.79	44.02	1399.31	99.39	12.46	1238.36	1243.95	88.90	32.15	29635900	205	921	250	1591	6	973	79	1	254
329-29	45	12/20/89	31.79	43.98	1398.27	99.49	12.44	1238.07	1243.64	88.94	32.15	29622300	205	924	250	1591	-1	969	79	1	255
329-29	50	12/20/89	31.80	43.93	1397.04	99.87	12.40	1238.86	1244.40	89.07	32.34	29863600	205	919	250	1591	-1	969	79	1	256
329-29	55	12/20/89	31.81	43.93	1397.44	99.86	12.40	1238.59	1244.13	89.03	32.10	29591600	206	921	249	1590	3	967	79	1	257
329-29	60	12/20/89	31.81	43.90	1396.22	100.08	12.38	1239.04	1244.56	89.14	31.99	29553000	206	922	249	1590	752	969	79	1	258
329-29	65	12/20/89	31.81	43.99	1399.03	99.34	12.50	1241.69	1247.32	89.16	32.26	29893200	204	922	249	1590	752	975	79	1	259
329-29	70	12/20/89	31.80	43.95	1397.42	99.67	12.44	1240.09	1245.66	89.14	32.16	29752300	206	921	250	1589	122	967	79	1	260
329-29	75	12/20/89	31.80	43.93	1397.01	99.83	12.42	1239.62	1245.17	89.13	32.01	29626900	205	920	249	1590	246	971	79	1	261
329-29	80	12/20/89	31.81	43.90	1396.45	100.11	12.38	1239.41	1244.93	89.15	32.21	29766500	206	921	250	1590	752	967	79	1	262
329-29	85	12/20/89	31.79	43.94	1396.85	99.95	12.41	1240.06	1245.60	89.17	32.07	29647200	207	920	250	1589	698	968	79	1	263
329-29	90	12/20/89	31.79	43.98	1398.28	99.50	12.46	1239.59	1245.18	89.05	32.27	29816600	207	920	250	1590	349	969	79	1	264
329-29	95	12/20/89	31.78	44.04	1399.29	99.22	12.49	1239.58	1245.20	88.99	32.17	29729100	207	923	251	1590	753	977	79	1	265
329-29	100	12/20/89	31.78	44.12	1402.18	98.49	12.59	1239.67	1245.38	88.82	32.21	29894600	209	919	251	1592	753	969	79	1	266
329-29	105	12/20/89	31.79	44.06	1400.90	98.96	12.53	1240.46	1246.12	88.95	32.27	29969400	210	919	251	1592	-26	971	80	1	267
329-29	110	12/20/89	31.81	44.04	1401.09	99.10	12.53	1241.67	1247.32	89.03	32.17	29960600	210	918	251	1591	-22	972	80	1	268
329-29	115	12/20/89	31.80	44.03	1400.23	99.09	12.50	1238.50	1244.13	88.85	32.19	29893100	211	918	251	1591	-7	969	80	1	269
329-29	120	12/20/89	31.81	43.99	1399.24	99.32	12.49	1240.07	1245.68	89.03	32.27	30031100	209	921	251	1591	-15	972	80	1	270
329-29	125	12/21/89	31.81	43.92	1397.28	99.86	12.42	1240.60	1246.16	89.19	32.05	29846400	210	918	250	1590	-9	970	79	1	271
329-29	130	12/21/89	31.80	43.93	1397.03	99.91	12.42	1240.41	1245.96	89.19	32.01	29848800	210	918	250	1590	-10	969	79	1	272
329-29	135	12/21/89	31.82	43.92	1397.66	99.75	12.41	1238.36	1243.91	89.00	31.91	29610400	210	918	250	1589	-12	970	79	1	273
329-29	140	12/21/89	31.80	43.88	1395.17	100.23	12.39	1241.85	1247.38	89.41	32.13	29942300	208	920	250	1588	752	970	79	1	274
329-29	145	12/21/89	31.82	43.87	1396.21	99.99	12.40	1239.95	1245.48	89.21	32.29	30078800	210	918	250	1589	26	971	79	1	275
329-29	150	12/21/89	31.78	43.94	1396.47	99.94	12.39	1238.22	1243.75	89.06	32.31	29911300	207	921	249	1589	20	977	79	1	276
329-29	158	12/21/89	31.79	43.98	1397.78	99.56	12.42	1236.93	1242.49	88.89	32.23	29856600	208	921	249	1589	35	981	79	1	278
329-29	163	12/21/89	31.78	44.09	1401.36	98.87	12.55	1241.20	1246.87	88.98	32.27	30330700	210	916	250	1592	-19	971	79	1	279
329-29	168	12/21/89	31.80	44.17	1404.57	97.92	12.67	1240.95	1246.73	88.76	32.11	30105000	209	919	250	1591	-37	973	80	1	280
329-29	173	12/21/89	31.81	44.01	1400.19	99.00	12.51	1238.44	1244.08	88.85	32.11	29892000	211	917	251	1591	753	974	80	1	281
329-29	178	12/21/89	31.80	44.04	1400.51	98.99	12.53	1240.47	1246.12	88.98	32.11	29869600	209	919	251	1590	753	973	80	1	282
329-29	183	12/21/89	31.80	43.98	1398.68	99.44	12.47	1239.54	1245.13	89.02	32.50	30161300	209	920	251	1590	659	973	80	1	283

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
329-29	188	12/21/89	60.0	16952.5	282.5	238.0	0.0000912	0.33	99.46	56.2	0.04084	147.0	43328	447.8	1.90	616161	2.185E+10
329-29	193	12/21/89	60.0	17012.5	283.5	237.5	0.0000911	0.33	99.79	56.3	0.04079	146.8	43475	448.0	1.95	618314	2.186E+10
329-29	198	12/21/89	60.0	17072.5	284.5	237.1	0.0000904	0.33	100.12	56.2	0.04074	146.7	43622	450.5	1.94	621393	2.212E+10
329-29	203	12/21/89	60.0	17132.5	285.5	236.8	0.0000908	0.33	100.45	56.4	0.04077	146.8	43768	449.0	1.90	621214	2.189E+10
329-29	208	12/22/89	60.0	17192.5	286.5	236.6	0.0000910	0.33	100.78	56.4	0.04072	146.6	43915	447.4	1.92	619739	2.176E+10
329-29	213	12/22/89	60.0	17252.5	287.5	236.6	0.0000903	0.33	101.11	56.4	0.04073	146.6	44062	451.1	1.89	624640	2.210E+10
329-29	218	12/22/89	60.0	17312.5	288.5	236.5	0.0000909	0.33	101.43	56.4	0.04071	146.6	44208	447.8	1.86	620387	2.179E+10
329-29	223	12/22/89	60.0	17372.5	289.5	236.6	0.0000897	0.33	101.76	56.6	0.04072	146.6	44355	453.9	1.97	631041	2.237E+10
329-29	228	12/22/89	60.0	17432.5	290.5	236.8	0.0000909	0.33	102.09	56.8	0.04077	146.8	44502	448.4	2.29	624766	2.178E+10
329-29	233	12/22/89	60.0	17492.5	291.5	236.8	0.0000914	0.33	102.42	56.8	0.04069	146.5	44648	445.2	1.91	621478	2.155E+10
329-30	6	12/22/89	60.5	17553.0	292.6	240.3	0.0000913	0.33	102.75	57.2	0.04094	148.7	44797	448.2	1.94	626280	2.195E+10
329-30	13	12/22/89	65.6	17618.6	293.6	240.1	0.0000908	0.36	103.11	57.2	0.04088	160.9	44958	450.5	1.95	630303	2.221E+10
329-31	13	12/22/89	60.5	17679.1	294.7	239.6	0.0000912	0.33	103.45	57.3	0.04086	148.4	45106	448.2	2.26	628551	2.194E+10
329-31	26	12/22/89	60.5	17739.7	295.7	239.4	0.0000903	0.33	103.78	57.3	0.04090	148.6	45255	453.0	2.23	634537	2.233E+10
329-31	39	12/22/89	60.5	17800.2	296.7	239.0	0.0000913	0.33	104.11	57.2	0.04087	148.5	45403	447.6	2.28	626527	2.181E+10
329-31	52	12/22/89	60.5	17860.8	297.7	238.7	0.0000911	0.33	104.44	57.2	0.04081	148.3	45551	447.9	1.87	627723	2.186E+10
329-31	65	12/22/89	60.5	17921.3	298.7	238.4	0.0000907	0.33	104.77	57.0	0.04083	148.3	45700	450.1	2.02	628383	2.205E+10
329-31	78	12/22/89	60.5	17981.9	299.7	238.5	0.0000910	0.33	105.10	57.1	0.04081	148.2	45848	448.6	1.87	627555	2.191E+10
329-31	91	12/23/89	60.5	18042.4	300.7	238.5	0.0000900	0.33	105.43	56.9	0.04074	148.0	45996	452.6	2.01	632173	2.242E+10
329-31	104	12/23/89	60.5	18103.0	301.7	238.4	0.0000907	0.33	105.76	56.8	0.04084	148.4	46144	450.2	1.84	626144	2.207E+10
329-31	117	12/23/89	60.5	18163.5	302.7	238.4	0.0000904	0.33	106.09	56.8	0.04082	148.3	46293	451.4	1.84	628228	2.222E+10
329-31	130	12/23/89	60.5	18224.1	303.7	238.4	0.0000908	0.33	106.42	56.8	0.04082	148.3	46441	449.6	1.86	625509	2.202E+10
329-31	143	12/23/89	60.5	18284.6	304.7	238.4	0.0000902	0.33	106.75	56.6	0.04082	148.3	46589	452.8	2.01	627780	2.237E+10
329-31	156	12/23/89	60.5	18345.2	305.8	238.3	0.0000906	0.33	107.08	56.5	0.04076	148.1	46737	450.1	1.86	623903	2.217E+10
329-32	13	12/23/89	60.5	18405.7	306.8	222.5	0.0000882	0.32	107.40	55.1	0.03992	145.0	46882	452.4	1.93	624561	2.151E+10
329-32	26	12/23/89	60.5	18466.2	307.8	222.1	0.0000870	0.32	107.72	55.0	0.03992	145.0	47027	459.0	1.97	632395	2.209E+10
329-32	39	12/23/89	60.5	18526.8	308.8	222.1	0.0000878	0.32	108.03	55.1	0.03986	144.8	47172	454.1	1.97	627763	2.168E+10
329-32	52	12/23/89	60.5	18587.3	309.8	222.1	0.0000878	0.32	108.35	55.2	0.03983	144.7	47317	453.6	1.94	628609	2.164E+10
329-32	65	12/23/89	60.5	18647.9	310.8	222.1	0.0000877	0.32	108.67	55.1	0.03983	144.7	47461	454.3	1.83	628379	2.172E+10
329-32	78	12/23/89	60.5	18708.4	311.8	222.1	0.0000866	0.32	108.99	55.1	0.03980	144.6	47606	459.8	2.01	636509	2.229E+10
329-32	91	12/23/89	60.5	18769.0	312.8	222.0	0.0000872	0.32	109.30	55.1	0.03982	144.7	47751	456.5	1.88	631707	2.194E+10
329-32	104	12/23/89	60.5	18829.5	313.8	221.9	0.0000866	0.32	109.62	55.0	0.03981	144.6	47895	459.6	1.92	635001	2.225E+10
329-32	117	12/23/89	60.5	18890.1	314.8	221.8	0.0000871	0.32	109.94	54.9	0.03980	144.6	48040	457.1	2.02	630440	2.201E+10
329-32	130	12/23/89	60.5	18950.6	315.8	221.7	0.0000866	0.32	110.25	54.7	0.03976	144.4	48184	459.4	1.81	631924	2.229E+10
329-32	143	12/24/89	60.5	19011.2	316.9	221.6	0.0000877	0.32	110.57	54.8	0.03977	144.5	48329	453.7	1.80	625185	2.171E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf (°F)	Tgg (°F)	Tcon (°F)	T1 (°F)	T3 (°F)	Tinj (°F)	Tpcu (°F)	NUMBER STARTS	START NUMBER
329-29	188	12/21/89	31.80	44.03	1400.33	98.83	12.53	1238.23	1243.88	88.83	32.25	29934100	212	916	251	1591	-30	977	80	1	284
329-29	193	12/21/89	31.81	44.02	1400.12	98.97	12.56	1242.71	1248.38	89.16	32.10	30093800	210	918	250	1590	-36	973	80	1	285
329-29	198	12/21/89	31.81	43.98	1399.03	99.31	12.48	1239.31	1244.92	88.99	32.33	30214700	210	916	250	1591	-28	983	80	1	286
329-29	203	12/21/89	31.82	43.98	1399.34	99.38	12.50	1241.81	1247.43	89.14	32.18	30159500	210	916	250	1590	-23	982	80	1	287
329-29	208	12/22/89	31.81	43.94	1397.93	99.59	12.45	1239.72	1245.30	89.08	32.08	30037500	210	916	250	1591	-23	983	79	1	288
329-29	213	12/22/89	31.82	43.94	1398.47	99.38	12.46	1237.83	1243.42	88.91	32.40	30228800	211	916	250	1591	-24	985	79	1	289
329-29	218	12/22/89	31.83	43.98	1399.85	98.93	12.55	1241.54	1247.21	89.10	32.05	30113200	211	916	250	1592	753	981	79	1	290
329-29	223	12/22/89	31.82	44.05	1401.70	98.45	12.58	1238.65	1244.35	88.78	32.58	30450900	210	917	250	1591	753	976	79	1	291
329-29	228	12/22/89	31.82	44.22	1407.18	96.80	12.85	1243.88	1249.83	88.82	32.08	30168700	211	916	250	1591	-40	981	80	1	292
329-29	233	12/22/89	31.80	44.03	1400.23	98.89	12.57	1242.70	1248.38	89.16	31.82	29981300	210	916	250	1591	74	981	80	1	293
329-30	6	12/22/89	31.81	43.87	1395.64	99.64	12.41	1236.53	1242.07	89.00	32.40	29852700	210	921	248	1589	753	974	79	1	294
329-30	13	12/22/89	31.81	43.98	1398.90	98.90	12.52	1238.64	1244.29	88.95	32.46	30095900	211	917	250	1590	753	984	79	1	295
329-31	13	12/22/89	31.80	44.12	1402.90	97.76	12.72	1243.07	1248.89	89.02	32.16	30067100	211	917	249	1591	753	983	79	1	296
329-31	26	12/22/89	31.78	44.26	1406.52	96.76	12.83	1241.61	1247.54	88.70	32.57	30317800	212	917	251	1590	753	982	80	1	297
329-31	39	12/22/89	31.79	44.06	1400.58	98.41	12.58	1238.17	1243.87	88.81	32.26	29904400	210	919	250	1591	753	981	80	1	298
329-31	52	12/22/89	31.80	44.08	1401.83	98.34	12.61	1240.27	1246.00	88.88	32.18	30012200	210	919	250	1590	-44	976	80	1	299
329-31	65	12/22/89	31.78	44.05	1400.16	98.65	12.57	1239.51	1245.20	88.93	32.37	30130800	211	915	250	1590	-40	984	80	1	300
329-31	78	12/22/89	31.79	44.06	1400.91	98.35	12.60	1239.35	1245.06	88.88	32.25	30034200	211	918	250	1590	-52	984	80	1	301
329-31	91	12/23/89	31.81	43.93	1397.61	99.68	12.43	1239.31	1244.88	89.07	32.48	30360700	212	916	249	1589	-27	981	80	1	302
329-31	104	12/23/89	31.80	43.95	1397.58	99.13	12.51	1240.31	1245.95	89.15	32.36	30148400	211	916	249	1589	-36	987	79	1	303
329-31	117	12/23/89	31.80	44.03	1400.09	98.21	12.61	1238.85	1244.58	88.89	32.47	30213300	212	916	250	1590	-57	982	80	1	304
329-31	130	12/23/89	31.81	43.79	1393.22	100.12	12.35	1236.79	1242.28	89.17	32.39	30032600	211	915	249	1589	-23	984	79	1	305
329-31	143	12/23/89	31.81	43.91	1397.02	98.85	12.56	1241.28	1246.95	89.26	32.50	30357800	212	914	250	1588	-44	981	79	1	306
329-31	156	12/23/89	31.81	43.90	1396.51	99.22	12.49	1239.68	1245.30	89.17	32.31	30184700	212	915	250	1588	-34	979	79	1	307
329-32	13	12/23/89	31.82	44.23	1407.15	96.09	12.92	1241.71	1247.72	88.67	31.75	31035000	212	912	251	1601	-105	975	80	1	308
329-32	26	12/23/89	31.80	44.12	1403.09	97.36	12.75	1241.35	1247.20	88.89	32.22	31472300	214	908	250	1599	-72	978	80	1	309
329-32	39	12/23/89	31.80	44.41	1412.38	94.75	13.12	1242.80	1248.99	88.43	31.80	31221500	215	909	251	1603	-140	975	81	1	310
329-32	52	12/23/89	31.80	44.45	1413.27	94.74	13.14	1244.42	1250.63	88.49	31.70	31247600	215	909	251	1602	-141	977	81	1	311
329-32	65	12/23/89	31.79	44.35	1410.13	95.80	12.98	1243.64	1249.71	88.62	31.76	31273400	214	912	251	1603	-114	976	81	1	312
329-32	78	12/23/89	31.80	44.36	1410.83	95.72	12.99	1243.67	1249.74	88.58	32.12	31678700	216	909	252	1603	-124	974	81	1	313
329-32	91	12/23/89	31.81	44.32	1409.79	96.13	12.93	1242.88	1248.90	88.59	31.92	31419600	216	908	252	1602	-109	975	81	1	314
329-32	104	12/23/89	31.80	44.28	1408.33	96.39	12.89	1242.57	1248.55	88.66	32.14	31633000	214	912	251	1603	-95	981	81	1	315
329-32	117	12/23/89	31.81	44.33	1410.20	95.81	12.96	1241.74	1247.78	88.48	31.99	31441900	216	909	252	1605	-111	981	81	1	316
329-32	130	12/23/89	31.82	44.36	1411.40	95.55	12.99	1241.63	1247.71	88.40	32.11	31628700	217	908	252	1604	-122	974	81	1	317
329-32	143	12/24/89	31.80	44.50	1415.25	94.05	13.23	1243.81	1250.11	88.33	31.67	31289000	217	907	252	1605	-151	977	81	1	318

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
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329-32	156	12/24/89	60.5	19071.7	317.9	221.5	0.0000866	0.32	110.88	54.6	0.03973	144.3	48473	459.0	1.61	630842	2.228E+10
329-32	169	12/24/89	60.5	19132.3	318.9	221.4	0.0000869	0.32	111.20	54.5	0.03978	144.5	48618	457.7	1.52	627114	2.210E+10
329-32	182	12/24/89	60.5	19192.8	319.9	221.3	0.0000875	0.32	111.52	54.4	0.03978	144.5	48762	454.5	1.45	621452	2.178E+10
329-32	195	12/24/89	60.5	19253.4	320.9	221.2	0.0000874	0.32	111.83	54.3	0.03979	144.6	48907	455.2	1.83	621303	2.185E+10
329-32	208	12/24/89	60.5	19313.9	321.9	221.1	0.0000875	0.32	112.15	54.6	0.03974	144.4	49051	454.4	1.89	624264	2.177E+10
329-32	221	12/24/89	60.5	19374.4	322.9	220.8	0.0000871	0.32	112.47	54.9	0.03964	144.0	49195	455.3	1.93	630534	2.188E+10
329-32	234	12/24/89	60.5	19435.0	323.9	220.2	0.0000868	0.32	112.78	54.4	0.03965	144.0	49339	456.6	1.93	626396	2.198E+10
329-33	13	12/25/89	60.5	19495.5	324.9	220.5	0.0000872	0.32	113.10	54.8	0.03975	144.4	49484	455.7	1.88	628267	2.178E+10
329-33	26	12/25/89	60.5	19556.1	325.9	220.7	0.0000871	0.31	113.42	54.7	0.03994	145.1	49629	458.5	1.93	627841	2.187E+10
329-33	39	12/25/89	60.5	19616.6	326.9	220.8	0.0000873	0.32	113.73	54.8	0.03974	144.4	49773	455.5	1.96	628066	2.181E+10
329-33	52	12/25/89	60.5	19677.2	328.0	220.9	0.0000870	0.32	114.05	54.7	0.03976	144.4	49917	457.1	2.59	628859	2.197E+10
329-33	65	12/25/89	60.5	19737.7	329.0	221.0	0.0000869	0.32	114.37	54.8	0.03971	144.3	50062	456.9	2.11	630537	2.200E+10
329-33	78	12/25/89	60.5	19798.3	330.0	220.9	0.0000873	0.32	114.68	54.9	0.03973	144.3	50206	455.2	1.90	628931	2.179E+10
329-33	91	12/25/89	60.5	19858.8	331.0	220.7	0.0000868	0.31	115.00	55.2	0.03970	144.2	50350	457.5	2.17	636135	2.198E+10
329-33	104	12/25/89	60.5	19919.4	332.0	220.6	0.0000868	0.32	115.32	54.6	0.03979	144.5	50495	458.2	2.11	628728	2.201E+10
329-33	117	12/25/89	60.5	19979.9	333.0	220.4	0.0000868	0.31	115.63	54.6	0.03975	144.4	50639	457.8	1.92	628721	2.198E+10
329-33	130	12/25/89	60.5	20040.5	334.0	220.3	0.0000869	0.32	115.95	54.6	0.03973	144.3	50784	457.0	1.86	628027	2.192E+10
329-33	143	12/26/89	60.5	20101.0	335.0	220.2	0.0000869	0.32	116.26	54.7	0.03974	144.4	50928	457.3	1.91	629408	2.191E+10
329-33	156	12/26/89	60.5	20161.6	336.0	220.0	0.0000862	0.32	116.58	54.7	0.03963	144.0	51072	460.0	1.90	634895	2.227E+10
329-33	169	12/26/89	60.5	20222.1	337.0	219.9	0.0000868	0.31	116.89	54.8	0.03965	144.0	51216	456.7	2.00	631235	2.191E+10
329-33	182	12/26/89	60.5	20282.7	338.0	219.7	0.0000862	0.31	117.21	54.9	0.03963	144.0	51360	459.9	2.00	637054	2.219E+10
329-33	195	12/26/89	60.5	20343.2	339.1	219.6	0.0000862	0.32	117.52	55.0	0.03964	144.0	51504	459.9	2.65	638051	2.215E+10
329-33	208	12/26/89	60.5	20403.8	340.1	219.5	0.0000869	0.31	117.84	54.8	0.03969	144.2	51648	456.6	2.59	630421	2.180E+10
329-33	221	12/26/89	60.5	20464.3	341.1	219.4	0.0000865	0.32	118.15	54.9	0.03963	144.0	51792	458.0	2.62	634528	2.197E+10
329-33	234	12/26/89	60.5	20524.9	342.1	219.3	0.0000867	0.31	118.47	54.9	0.03960	143.9	51936	456.6	2.66	633028	2.186E+10
329-33	247	12/26/89	60.5	20585.4	343.1	219.4	0.0000864	0.31	118.78	55.0	0.03965	144.0	52080	459.1	2.69	636795	2.204E+10
329-33	260	12/26/89	60.5	20646.0	344.1	219.5	0.0000863	0.31	119.10	54.8	0.03960	143.9	52224	458.7	2.69	634847	2.210E+10
329-33	273	12/26/89	60.5	20706.5	345.1	219.5	0.0000864	0.31	119.41	54.8	0.03967	144.1	52368	459.0	2.51	634171	2.206E+10
329-33	286	12/26/89	60.5	20767.0	346.1	219.4	0.0000869	0.31	119.72	54.7	0.03965	144.0	52512	456.4	2.85	629669	2.182E+10
3[illegible]	299	12/26/89	60.5	20827.6	347.1	219.3	0.0000868	0.32	120.04	54.9	0.03966	144.1	52656	456.8	2.88	632416	2.182E+10
329-33	312	12/26/89	60.5	20888.1	348.1	219.1	0.0000860	0.32	120.36	54.8	0.03968	144.2	52800	461.3	2.60	637157	2.221E+10
329-33	325	12/26/89	60.5	20948.7	349.1	219.0	0.0000863	0.31	120.67	54.8	0.03964	144.0	52944	459.4	2.45	635149	2.206E+10
329-33	338	12/26/89	60.5	21009.2	350.2	218.9	0.0000870	0.32	120.98	54.8	0.03966	144.0	53088	455.8	2.47	629748	2.167E+10
329-33	351	12/27/89	60.5	21069.8	351.2	218.8	0.0000864	0.31	121.30	54.9	0.03968	144.2	53232	459.2	2.36	635299	2.195E+10
329-33	364	12/27/89	60.5	21130.3	352.2	218.6	0.0000859	0.31	121.61	54.9	0.03962	143.9	53376	461.2	2.71	639033	2.218E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
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329-32	156	12/24/89	31.81	44.46	1414.55	94.41	13.16	1242.16	1248.39	88.25	32.04	31645800	216	908	252	1607	-144	978	82	1	319
329-32	169	12/24/89	31.81	44.44	1413.43	94.91	13.10	1243.47	1249.65	88.41	31.97	31549900	216	910	252	1606	-132	971	82	1	320
329-32	182	12/24/89	31.82	44.39	1412.28	95.51	13.02	1243.14	1249.24	88.46	31.75	31313800	216	907	252	1605	-116	980	82	1	321
329-32	195	12/24/89	31.80	44.40	1412.00	95.17	13.06	1243.11	1249.25	88.47	31.81	31363300	215	909	252	1605	-124	978	82	1	322
329-32	208	12/24/89	31.82	44.38	1412.37	94.86	13.08	1241.05	1247.21	88.31	31.77	31287500	215	909	252	1606	-134	983	82	1	323
329-32	221	12/24/89	31.80	44.55	1416.51	93.51	13.29	1242.66	1249.02	88.18	31.70	31469900	215	907	252	1610	-174	980	82	1	324
329-32	234	12/24/89	31.81	44.34	1410.31	95.20	13.06	1243.62	1249.76	88.62	31.78	31575300	215	908	251	1606	-110	979	81	1	325
329-33	13	12/25/89	31.79	44.27	1407.42	96.01	12.92	1240.30	1246.31	88.55	31.88	31354300	209	907	247	1606	-101	979	79	1	326
329-33	26	12/25/89	31.81	44.25	1407.76	96.44	12.85	1238.75	1244.69	88.42	32.27	31351200	211	909	249	1604	-74	974	80	1	327
329-33	39	12/25/89	31.82	44.25	1408.20	96.40	12.86	1239.91	1245.87	88.47	31.87	31334800	211	908	249	1603	-8	981	80	1	328
329-33	52	12/25/89	31.82	44.12	1403.88	97.32	12.74	1239.88	1245.72	88.73	32.00	31430600	212	908	248	1601	757	980	80	1	329
329-33	65	12/25/89	31.80	44.24	1406.98	96.87	12.84	1243.91	1249.85	88.83	31.84	31559300	212	907	249	1602	-9	981	80	1	330
329-33	78	12/25/89	31.81	44.21	1406.42	96.76	12.82	1240.73	1246.65	88.64	31.82	31341500	212	909	249	1602	5	969	80	1	331
329-33	91	12/25/89	31.80	44.35	1410.52	95.47	13.01	1242.03	1248.13	88.49	31.92	31560900	212	907	249	1603	757	974	80	1	332
329-33	104	12/25/89	31.80	44.30	1408.90	95.78	13.01	1245.64	1251.73	88.84	31.96	31628000	213	908	249	1603	-77	977	80	1	333
329-33	117	12/25/89	31.82	44.34	1410.81	95.28	13.06	1244.59	1250.73	88.65	31.92	31600900	213	907	249	1603	-107	976	81	1	334
329-33	130	12/25/89	31.81	44.32	1409.87	95.75	13.00	1244.86	1250.95	88.73	31.84	31572900	213	907	249	1603	-104	983	81	1	335
329-33	143	12/26/89	31.83	44.31	1410.56	95.24	13.04	1242.24	1248.36	88.50	31.94	31518000	212	908	249	1604	-121	979	81	1	336
329-33	156	12/26/89	31.83	44.23	1407.54	96.34	12.89	1242.21	1248.19	88.68	32.04	31791900	213	908	249	1601	-89	980	80	1	337
329-33	169	12/26/89	31.84	44.26	1409.26	95.82	12.97	1242.82	1248.88	88.62	31.80	31566700	212	907	249	1601	-103	976	81	1	338
329-33	182	12/26/89	31.79	44.33	1409.47	95.58	12.98	1240.75	1246.81	88.46	32.07	31746400	212	908	249	1602	-102	975	81	1	339
329-33	195	12/26/89	31.81	44.38	1411.53	94.96	13.09	1242.85	1249.02	88.49	32.03	31792100	212	906	249	1603	757	979	81	1	340
329-33	208	12/26/89	31.80	44.21	1406.09	96.45	12.85	1239.33	1245.28	88.56	31.92	31437400	211	909	248	1599	747	965	80	1	341
329-33	221	12/26/89	31.81	44.21	1406.50	96.60	12.86	1242.74	1248.70	88.78	31.88	31671400	211	905	248	1599	757	971	80	1	342
329-33	234	12/26/89	31.83	44.16	1405.57	96.54	12.84	1240.04	1245.98	88.65	31.84	31527800	211	906	248	1599	757	971	80	1	343
329-33	247	12/26/89	31.81	44.18	1405.71	96.77	12.84	1242.95	1248.89	88.84	31.97	31731900	211	904	248	1600	757	975	80	1	344
329-33	260	12/26/89	31.82	44.15	1404.81	96.97	12.81	1241.80	1247.70	88.82	31.93	31721200	212	908	248	1599	757	981	80	1	345
329-33	273	12/26/89	31.82	44.10	1403.04	97.41	12.75	1242.28	1248.13	88.96	32.00	31699700	211	908	248	1598	757	975	80	1	346
329-33	286	12/26/89	31.83	44.10	1403.77	97.21	12.74	1238.45	1244.29	88.64	31.90	31434800	211	909	248	1598	757	974	80	1	347
329-33	299	12/26/89	31.82	44.08	1402.66	97.38	12.73	1239.46	1245.29	88.78	31.91	31482600	211	908	248	1598	757	973	80	1	348
329-33	312	12/26/89	31.82	44.10	1403.12	97.49	12.75	1242.62	1248.47	88.98	32.16	31857700	212	906	248	1597	757	975	80	1	349
329-33	325	12/26/89	31.83	44.16	1405.28	96.78	12.81	1240.15	1246.06	88.67	32.06	31694200	212	906	248	1596	-7	974	80	1	350
329-33	338	12/26/89	31.82	44.14	1404.46	97.10	12.79	1241.47	1247.35	88.81	31.79	31457800	211	908	248	1597	-44	973	80	1	351
329-33	351	12/27/89	31.81	44.24	1407.12	96.35	12.88	1241.49	1247.47	88.65	32.04	31678100	211	908	248	1597	-56	971	80	1	352
329-33	364	12/27/89	31.85	44.18	1406.84	96.31	12.89	1241.51	1247.49	88.67	32.13	31864700	211	908	248	1597	-73	971	80	1	353

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
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329-33	377	12/27/89	60.5	21190.9	353.2	218.4	0.0000859	0.31	121.92	54.9	0.03971	144.3	53521	462.2	2.62	638981	2.215E+10
329-33	390	12/27/89	60.5	21251.4	354.2	218.2	0.0000867	0.31	122.24	55.3	0.03970	144.2	53665	457.8	2.55	637714	2.166E+10
329-33	403	12/27/89	60.5	21312.0	355.2	218.0	0.0000855	0.31	122.55	55.3	0.03967	144.1	53809	464.1	2.69	646980	2.227E+10
329-33	416	12/27/89	60.5	21372.5	356.2	218.0	0.0000862	0.31	122.86	55.4	0.03959	143.8	53953	459.4	3.12	642945	2.190E+10
329-33	429	12/27/89	60.5	21433.1	357.2	218.1	0.0000868	0.32	123.18	55.0	0.03961	143.9	54097	456.5	3.01	633911	2.167E+10
329-33	442	12/27/89	60.5	21493.6	358.2	218.2	0.0000860	0.31	123.49	55.1	0.03961	143.9	54241	460.8	3.06	640988	2.207E+10
329-33	455	12/27/89	60.5	21554.1	359.2	218.3	0.0000870	0.31	123.80	55.0	0.03977	144.4	54385	457.2	3.21	632307	2.158E+10
329-33	468	12/27/89	60.5	21614.7	360.2	218.4	0.0000871	0.32	124.12	54.9	0.03974	144.4	54529	456.2	3.02	630274	2.155E+10
329-33	481	12/27/89	60.5	21675.2	361.3	218.4	0.0000863	0.31	124.43	54.8	0.03964	144.0	54673	459.5	2.92	635318	2.199E+10
329-33	494	12/27/89	60.5	21735.8	362.3	218.4	0.0000861	0.31	124.75	54.9	0.03968	144.2	54818	461.0	3.17	637786	2.207E+10
329-33	507	12/27/89	60.5	21796.3	363.3	218.3	0.0000865	0.31	125.06	54.8	0.03967	144.1	54962	458.3	3.11	633182	2.183E+10
329-33	520	12/27/89	60.5	21856.9	364.3	218.3	0.0000859	0.31	125.37	54.8	0.03964	144.0	55106	461.3	2.84	637758	2.214E+10
329-34	31	12/28/89	60.6	21917.4	365.3	221.7	0.0000869	0.32	125.69	54.5	0.03984	144.7	55250	458.7	3.06	627483	2.216E+10
329-34	62	12/28/89	60.6	21978.0	366.3	219.0	0.0000869	0.32	126.01	54.1	0.03965	144.0	55394	456.3	2.93	622612	2.184E+10
329-34	93	12/28/89	60.6	22038.5	367.3	219.0	0.0000866	0.31	126.32	54.1	0.03964	144.0	55538	457.6	3.04	624618	2.198E+10
329-34	124	12/28/89	60.6	22099.1	368.3	218.7	0.0000868	0.31	126.64	54.0	0.03961	143.9	55682	456.4	2.94	622213	2.187E+10
329-34	155	12/28/89	60.5	22159.6	369.3	218.5	0.0000864	0.31	126.95	54.1	0.03961	143.9	55826	458.4	2.92	626063	2.202E+10
329-34	186	12/28/89	60.6	22220.1	370.3	218.1	0.0000867	0.31	127.27	54.0	0.03959	143.8	55970	456.7	2.85	622880	2.183E+10
329-34	217	12/28/89	60.6	22280.7	371.3	217.6	0.0000858	0.32	127.58	54.1	0.03957	143.8	56114	461.0	2.46	630206	2.219E+10
329-34	248	12/28/89	60.6	22341.2	372.4	217.4	0.0000855	0.31	127.89	54.3	0.03955	143.7	56258	462.5	2.75	635095	2.231E+10
329-34	279	12/28/89	60.6	22401.8	373.4	217.3	0.0000864	0.31	128.21	54.2	0.03961	143.9	56401	458.4	2.62	627242	2.184E+10
329-34	310	12/29/89	60.6	22462.3	374.4	217.2	0.0000856	0.31	128.52	54.2	0.03953	143.6	56545	461.7	2.67	632963	2.223E+10
329-34	341	12/29/89	60.6	22522.9	375.4	217.1	0.0000859	0.31	128.83	54.2	0.03963	144.0	56689	461.6	2.54	631253	2.210E+10
329-34	372	12/29/89	60.5	22583.4	376.4	217.0	0.0000855	0.31	129.14	54.4	0.03953	143.6	56833	462.1	2.52	635900	2.222E+10
329-34	403	12/29/89	60.6	22644.0	377.4	217.0	0.0000863	0.31	129.45	54.2	0.03959	143.8	56976	458.7	2.66	627860	2.185E+10
329-34	434	12/29/89	60.6	22704.5	378.4	216.9	0.0000859	0.31	129.77	54.2	0.03951	143.5	57120	459.8	2.80	630827	2.204E+10
329-34	465	12/29/89	60.6	22765.1	379.4	217.0	0.0000864	0.31	130.08	54.2	0.03961	143.9	57264	458.4	2.27	627264	2.181E+10
329-34	496	12/29/89	60.6	22825.6	380.4	217.2	0.0000861	0.31	130.39	54.2	0.03961	143.9	57408	460.0	2.67	629391	2.198E+10
329-34	527	12/29/89	60.6	22886.2	381.4	217.5	0.0000868	0.31	130.70	54.3	0.03958	143.8	57552	455.8	2.67	625281	2.164E+10
329-34	558	12/29/89	60.5	22946.7	382.4	217.5	0.0000860	0.32	131.02	54.5	0.03963	143.9	57695	460.8	2.48	633780	2.204E+10
329-34	589	12/29/89	60.5	23007.2	383.5	217.5	0.0000863	0.31	131.33	54.3	0.03957	143.7	57839	458.5	2.54	629303	2.192E+10
329-34	620	12/29/89	60.6	23067.8	384.5	217.4	0.0000857	0.31	131.65	54.4	0.03959	143.8	57983	462.1	2.36	634928	2.220E+10
329-34	651	12/29/89	60.6	23128.3	385.5	217.2	0.0000862	0.31	131.96	54.5	0.03960	143.9	58127	459.5	2.57	632368	2.190E+10
329-34	682	12/29/89	60.6	23188.9	386.5	217.1	0.0000863	0.31	132.27	54.5	0.03953	143.6	58271	458.0	2.32	631430	2.183E+10
329-34	713	12/29/89	60.6	23249.4	387.5	217.0	0.0000856	0.31	132.58	54.8	0.03957	143.8	58414	462.1	2.38	639933	2.212E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-33	377	12/27/89	31.83	44.23	1407.61	96.31	12.91	1243.15	1249.14	88.74	32.23	31904200	211	908	248	1597	-74	971	80	1	354
329-33	390	12/27/89	31.82	44.25	1408.00	95.92	12.95	1242.26	1248.30	88.66	31.94	31588100	211	907	248	1597	-87	970	80	1	355
329-33	403	12/27/89	31.81	44.23	1407.09	96.00	12.91	1239.64	1245.65	88.53	32.42	31979600	211	906	248	1597	757	977	80	1	356
329-33	416	12/27/89	31.81	44.23	1406.69	96.36	12.90	1243.51	1249.50	88.83	31.93	31821500	211	905	248	1596	757	970	80	1	357
329-33	429	12/27/89	31.81	44.17	1405.04	96.70	12.82	1239.46	1245.38	88.64	31.85	31499900	210	906	247	1595	756	972	80	1	358
329-33	442	12/27/89	31.82	44.18	1405.70	96.59	12.87	1242.98	1248.94	88.85	32.06	31883900	210	906	247	1595	756	972	80	1	359
329-33	455	12/27/89	31.82	44.16	1405.04	97.01	12.82	1243.21	1249.12	88.90	31.93	31515200	210	906	248	1594	756	968	80	1	360
329-33	468	12/27/89	31.82	44.16	1405.17	96.55	12.85	1240.86	1246.80	88.73	31.89	31411400	210	906	248	1594	756	967	80	1	361
329-33	481	12/27/89	31.81	44.14	1403.99	97.09	12.78	1240.45	1246.32	88.77	32.06	31710200	211	906	248	1594	756	971	80	1	362
329-33	494	12/27/89	31.82	44.14	1404.67	97.00	12.78	1239.32	1245.20	88.65	32.22	31746400	211	906	248	1595	756	973	80	1	363
329-33	507	12/27/89	31.81	44.14	1404.32	97.03	12.78	1239.95	1245.82	88.71	32.01	31590700	211	906	248	1595	757	972	80	1	364
329-33	520	12/27/89	31.82	44.23	1407.41	96.11	12.91	1241.06	1247.06	88.61	32.17	31847500	212	905	249	1595	104	967	80	1	365
329-34	31	12/28/89	31.82	44.08	1402.56	97.49	12.72	1239.98	1245.81	88.82	32.17	31479800	209	907	245	1598	757	968	79	1	366
329-34	62	12/28/89	31.83	44.02	1401.26	97.72	12.69	1239.82	1245.62	88.89	31.86	31462200	210	907	246	1599	757	968	79	1	367
329-34	93	12/28/89	31.82	44.08	1402.76	97.63	12.69	1239.27	1245.08	88.76	31.95	31549600	211	907	247	1598	757	968	79	1	368
329-34	124	12/28/89	31.84	44.15	1405.97	96.55	12.84	1240.03	1245.97	88.62	31.83	31505600	212	906	247	1599	757	967	80	1	369
329-34	155	12/28/89	31.81	44.28	1408.25	95.74	12.96	1240.67	1246.72	88.53	31.95	31658100	212	906	247	1601	758	970	80	1	370
329-34	186	12/28/89	31.79	44.27	1407.62	95.99	12.92	1240.61	1246.62	88.56	31.82	31553900	212	906	247	1600	138	968	80	1	371
329-34	217	12/28/89	31.81	44.39	1411.85	94.78	13.10	1241.53	1247.71	88.37	32.08	31889600	212	905	248	1601	-108	971	80	1	372
329-34	248	12/28/89	31.82	44.40	1412.81	94.47	13.15	1242.38	1248.60	88.38	32.14	32040600	213	907	248	1603	-126	971	81	1	373
329-34	279	12/28/89	31.81	44.38	1411.73	94.78	13.08	1240.12	1246.29	88.28	31.97	31645400	213	906	247	1602	-116	971	81	1	374
329-34	310	12/29/89	31.81	44.32	1409.87	95.43	13.01	1241.82	1247.92	88.51	32.08	31977900	213	905	247	1601	-109	970	81	1	375
329-34	341	12/29/89	31.82	44.26	1408.06	95.91	12.93	1239.67	1245.68	88.47	32.21	31835900	212	905	247	1600	-96	971	80	1	376
329-34	372	12/29/89	31.82	44.36	1411.74	94.69	13.12	1241.95	1248.14	88.41	32.11	32011700	212	905	247	1601	758	972	80	1	377
329-34	403	12/29/89	31.80	44.34	1409.76	95.16	13.02	1239.46	1245.57	88.35	31.98	31659500	212	907	247	1601	758	970	80	1	378
329-34	434	12/29/89	31.81	44.32	1409.76	95.22	13.04	1241.90	1248.03	88.53	31.93	31872000	212	907	247	1600	758	968	81	1	379
329-34	465	12/29/89	31.81	44.26	1407.71	96.04	12.93	1241.66	1247.68	88.63	31.92	31685500	212	908	246	1600	373	969	80	1	380
329-34	496	12/29/89	31.82	44.15	1404.87	96.82	12.82	1240.83	1246.74	88.74	32.05	31771900	212	907	246	1598	757	968	80	1	381
329-34	527	12/29/89	31.83	44.12	1404.32	97.02	12.79	1241.11	1247.00	88.80	31.73	31513500	212	908	246	1598	757	968	80	1	382
329-34	558	12/29/89	31.82	44.23	1407.39	96.13	12.92	1242.26	1248.27	88.69	32.09	31853800	212	907	246	1598	-87	967	80	1	383
329-34	589	12/29/89	31.83	44.19	1406.42	96.25	12.87	1238.75	1244.71	88.50	31.97	31655800	213	903	247	1598	-41	981	80	1	384
329-34	620	12/29/89	31.83	44.23	1407.78	95.99	12.94	1241.93	1247.96	88.65	32.16	31961700	212	907	247	1598	-84	969	80	1	385
329-34	651	12/29/89	31.83	44.23	1407.48	96.04	12.93	1242.02	1248.04	88.67	31.98	31776900	213	903	247	1599	-77	976	80	1	386
329-34	682	12/29/89	31.82	44.24	1407.72	95.97	12.94	1241.63	1247.66	88.63	31.83	31719900	213	909	247	1598	-79	967	80	1	387
329-34	713	12/29/89	31.84	44.23	1408.24	95.92	12.94	1241.25	1247.28	88.57	32.16	31961100	213	903	247	1598	-91	972	80	1	388

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow^2 (PSI-SEC^2/LBM^2)
329-34	744	12/29/89	60.6	23310.0	388.5	216.9	0.0000860	0.31	132.90	54.7	0.03957	143.8	58558	460.0	2.22	635832	2.192E+10
329-34	775	12/30/89	60.5	23370.5	389.5	216.9	0.0000856	0.31	133.21	54.7	0.03955	143.6	58702	461.8	2.15	638675	2.211E+10
329-34	806	12/30/89	60.5	23431.1	390.5	216.9	0.0000860	0.31	133.52	54.6	0.03952	143.5	58845	459.4	2.40	634618	2.193E+10
329-34	837	12/30/89	60.6	23491.6	391.5	216.9	0.0000859	0.31	133.83	54.6	0.03956	143.7	58989	460.7	2.20	635860	2.201E+10
329-34	868	12/30/89	60.6	23552.2	392.5	216.9	0.0000859	0.31	134.14	54.3	0.03952	143.6	59133	459.9	2.10	631924	2.202E+10
329-34	899	12/30/89	60.6	23612.7	393.5	216.9	0.0000856	0.31	134.46	54.3	0.03949	143.5	59276	461.2	2.13	634235	2.218E+10
329-34	930	12/30/89	60.6	23673.3	394.6	216.9	0.0000855	0.31	134.77	54.4	0.03956	143.7	59420	462.7	2.39	636362	2.224E+10
329-34	961	12/30/89	60.6	23733.8	395.6	216.9	0.0000861	0.31	135.08	54.3	0.03952	143.6	59563	459.1	2.16	630882	2.195E+10
329-34	992	12/30/89	60.6	23794.4	396.6	217.0	0.0000859	0.31	135.39	54.4	0.03953	143.6	59707	460.3	2.08	633545	2.205E+10
329-34	1023	12/30/89	60.5	23854.9	397.6	217.1	0.0000857	0.31	135.70	54.5	0.03956	143.7	59851	461.4	1.98	635695	2.212E+10
329-34	1054	12/30/89	60.5	23915.4	398.6	217.3	0.0000853	0.31	136.02	54.5	0.03955	143.6	59994	463.5	2.11	638772	2.236E+10
329-34	1085	12/30/89	60.6	23976.0	399.6	217.3	0.0000859	0.31	136.33	54.4	0.03952	143.6	60138	460.1	1.98	633309	2.208E+10
329-34	1116	12/30/89	60.6	24036.5	400.6	217.1	0.0000856	0.31	136.64	54.4	0.03950	143.5	60281	461.7	2.15	635796	2.222E+10
329-35	31	12/30/89	60.6	24097.1	401.6	205.9	0.0000830	0.30	136.94	53.4	0.03888	141.3	60423	468.2	2.16	643110	2.212E+10
329-35	62	12/30/89	60.6	24157.6	402.6	205.6	0.0000830	0.30	137.24	53.3	0.03885	141.1	60564	468.0	1.62	642192	2.211E+10
329-35	93	12/30/89	60.6	24218.2	403.6	205.4	0.0000834	0.30	137.54	53.3	0.03882	141.0	60705	465.5	1.89	639043	2.186E+10
329-35	95	12/31/89	3.9	24222.1	403.7	208.3	0.0000844	0.02	137.56	53.8	0.03917	9.1	60714	463.9	0.00	637131	2.167E+10
329-35	126	12/31/89	60.6	24282.6	404.7	207.4	0.0000846	0.30	137.87	53.9	0.03906	141.9	60856	461.7	2.23	637101	2.145E+10
329-35	157	12/31/89	60.6	24343.2	405.7	207.2	0.0000837	0.31	138.17	53.8	0.03908	142.0	60998	466.9	2.04	642756	2.190E+10
329-35	188	12/31/89	60.6	24403.7	406.7	206.9	0.0000830	0.30	138.48	54.0	0.03902	141.8	61139	470.2	2.22	650696	2.220E+10
329-35	219	12/31/89	60.6	24464.3	407.7	206.6	0.0000833	0.31	138.78	53.9	0.03900	141.7	61281	468.0	2.05	646756	2.199E+10
329-35	250	12/31/89	60.5	24524.8	408.7	206.5	0.0000841	0.30	139.09	53.9	0.03898	141.6	61423	463.6	2.23	640927	2.158E+10
329-35	281	01/01/90	60.6	24585.3	409.8	206.5	0.0000842	0.31	139.39	53.8	0.03896	141.5	61564	462.4	2.12	638583	2.151E+10
329-35	312	01/01/90	60.6	24645.9	410.8	206.4	0.0000836	0.31	139.70	53.8	0.03896	141.5	61706	466.2	2.22	643733	2.185E+10
329-35	343	01/01/90	60.6	24706.4	411.8	206.4	0.0000841	0.30	140.00	53.4	0.03899	141.7	61847	463.7	2.20	635011	2.164E+10
329-35	374	01/01/90	60.6	24767.0	412.8	206.3	0.0000841	0.31	140.31	53.3	0.03899	141.7	61989	463.6	2.11	633852	2.164E+10
329-35	405	01/01/90	60.6	24827.5	413.8	206.3	0.0000838	0.30	140.61	53.4	0.03898	141.6	62131	465.3	2.19	637498	2.179E+10
329-35	436	01/01/90	60.6	24888.1	414.8	206.3	0.0000841	0.30	140.92	53.3	0.03896	141.5	62272	463.2	2.40	633784	2.163E+10
329-35	467	01/01/90	60.6	24948.6	415.8	206.3	0.0000834	0.30	141.22	53.5	0.03897	141.6	62414	467.3	2.12	641456	2.197E+10
329-35	498	01/01/90	60.6	25009.2	416.8	206.2	0.0000839	0.30	141.52	53.5	0.03895	141.5	62555	464.4	2.14	637862	2.171E+10
329-35	529	01/01/90	60.6	25069.7	417.8	206.1	0.0000842	0.30	141.83	53.5	0.03899	141.7	62697	463.2	2.38	635686	2.154E+10
329-35	560	01/01/90	60.6	25130.3	418.8	206.0	0.0000838	0.30	142.13	53.4	0.03897	141.6	62839	465.0	2.20	637095	2.172E+10
329-35	591	01/01/90	60.6	25190.8	419.8	205.9	0.0000837	0.30	142.44	53.4	0.03895	141.5	62980	465.1	2.38	637620	2.174E+10
329-35	622	01/01/90	60.5	25251.4	420.9	205.7	0.0000834	0.30	142.74	53.4	0.03892	141.4	63121	466.9	2.63	640672	2.192E+10
329-35	653	01/01/90	60.6	25311.9	421.9	205.4	0.0000836	0.30	143.04	53.3	0.03890	141.3	63263	465.1	2.52	637285	2.174E+10

LPAJ NASA LEWIS (
LIFE TEST NASA

RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	APC EFF	P/FLOW (J/Kg)	Tvt ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-34	744	12/29/89	31.83	44.19	1406.36	96.62	12.85	1241.19	1247.13	88.68	32.02	31812700	212	909	246	1598	-79	964	80	1	389
329-34	775	12/30/89	31.84	44.29	1410.17	95.13	13.04	1240.99	1247.11	88.44	32.13	31950000	213	908	247	1601	-118	964	80	1	390
329-34	806	12/30/89	31.82	44.31	1409.63	95.38	13.01	1240.86	1246.96	88.46	31.94	31802000	213	908	247	1600	-115	964	81	1	391
329-34	837	12/30/89	31.81	44.29	1408.92	95.61	12.99	1241.73	1247.80	88.56	32.04	31886000	213	908	247	1599	-110	964	80	1	392
329-34	868	12/30/89	31.81	44.20	1406.11	96.55	12.86	1241.76	1247.71	88.74	31.95	31864900	213	905	247	1599	-91	969	80	1	393
329-34	899	12/30/89	31.82	44.19	1406.46	96.44	12.89	1242.60	1248.58	88.78	31.99	32002800	213	908	247	1598	-96	963	80	1	394
329-34	930	12/30/89	31.81	44.24	1407.34	96.17	12.92	1242.40	1248.41	88.71	32.16	32046100	213	907	247	1598	-107	963	80	1	395
329-34	961	12/30/89	31.82	44.20	1406.37	96.54	12.85	1240.25	1246.19	88.61	31.93	31773600	213	905	247	1598	-96	965	80	1	396
329-34	992	12/30/89	31.82	44.16	1405.03	96.93	12.81	1241.59	1247.49	88.79	31.99	31883400	214	907	247	1598	-90	964	80	1	397
329-34	1023	12/30/89	31.82	44.23	1407.32	96.16	12.91	1241.35	1247.35	88.63	32.10	31926600	214	908	247	1598	-108	963	80	1	398
329-34	1054	12/30/89	31.82	44.28	1408.78	95.76	12.96	1240.85	1246.89	88.51	32.25	32068400	214	905	248	1598	-117	965	81	1	399
329-34	1085	12/30/89	31.87	44.17	1407.85	96.17	12.90	1240.52	1246.51	88.54	32.00	31843900	215	908	247	1598	-109	963	81	1	400
329-34	1116	12/30/89	31.84	44.18	1406.83	96.63	12.86	1242.82	1248.78	88.77	32.03	32028600	215	908	247	1597	-95	964	81	1	401
329-35	31	12/30/89	31.84	44.41	1413.91	94.16	13.21	1243.64	1249.92	88.40	31.95	33025300	215	903	248	1605	-139	957	81	1	402
329-35	62	12/30/89	31.84	44.45	1415.15	93.93	13.25	1244.49	1250.81	88.39	31.89	33062500	216	903	248	1605	-145	952	81	1	403
329-35	93	12/30/89	31.82	44.49	1415.68	93.60	13.25	1240.60	1246.93	88.08	31.80	32797800	216	902	248	1608	-149	957	82	1	404
329-35	95	12/31/89	31.67	44.20	1399.75	96.96	12.82	1242.54	1248.45	89.19	31.92	32446200	101	858	60	1522	-207	836	51	1	405
329-35	126	12/31/89	31.82	44.26	1408.48	95.19	13.02	1239.46	1245.56	88.43	31.76	32304300	209	903	244	1603	-107	955	80	1	406
329-35	157	12/31/89	31.83	44.29	1409.96	95.10	13.07	1243.12	1249.27	88.60	32.05	32748200	210	902	245	1603	-117	960	80	1	407
329-35	188	12/31/89	31.81	44.36	1410.90	94.72	13.09	1239.70	1245.87	88.30	32.31	32939100	211	903	245	1602	-125	959	80	1	408
329-35	219	12/31/89	31.83	44.37	1412.30	94.34	13.16	1241.97	1248.21	88.38	32.08	32860500	211	902	245	1605	-127	960	80	1	409
329-35	250	12/31/89	31.82	44.41	1413.46	93.99	13.23	1243.57	1249.87	88.43	31.72	32605900	211	902	245	1604	-135	956	81	1	410
329-35	281	01/01/90	31.82	44.40	1412.94	94.15	13.16	1238.84	1245.07	88.12	31.74	32423400	211	901	245	1605	-130	957	81	1	411
329-35	312	01/01/90	31.86	44.37	1413.45	94.11	13.21	1243.52	1249.81	88.42	31.89	32808500	211	902	245	1607	-135	952	81	1	412
329-35	343	01/01/90	31.83	44.38	1412.80	94.28	13.17	1241.59	1247.83	88.32	31.79	32555700	211	902	245	1606	-132	951	81	1	413
329-35	374	01/01/90	31.83	44.42	1413.72	93.83	13.26	1244.66	1250.99	88.49	31.70	32637700	211	902	245	1607	-127	950	81	1	414
329-35	405	01/01/90	31.84	44.38	1413.03	94.18	13.17	1240.52	1246.77	88.23	31.92	32654900	211	902	245	1606	-82	951	81	1	415
329-35	436	01/01/90	31.83	44.33	1410.98	94.82	13.10	1242.31	1248.49	88.48	31.71	32572600	211	900	245	1604	-92	951	80	1	416
329-35	467	01/01/90	31.81	44.39	1412.16	94.39	13.15	1240.89	1247.11	88.31	32.04	32806000	211	902	245	1604	-116	951	80	1	417
329-35	498	01/01/90	31.85	44.35	1412.31	94.73	13.10	1240.94	1247.12	88.30	31.82	32623500	211	902	245	1603	-42	948	81	1	418
329-35	529	01/01/90	31.84	44.35	1411.97	94.66	13.12	1241.83	1248.03	88.39	31.75	32535600	211	901	245	1602	120	951	81	1	419
329-35	560	01/01/90	31.85	44.36	1412.76	94.42	13.15	1242.08	1248.31	88.36	31.85	32675500	212	902	246	1604	-41	950	81	1	420
329-35	591	01/01/90	31.83	44.35	1411.72	94.58	13.12	1241.31	1247.51	88.37	31.86	32682000	212	902	246	1604	93	949	81	1	421
329-35	622	01/01/90	31.83	44.34	1411.62	94.74	13.12	1242.99	1249.19	88.49	31.92	32882900	212	902	246	1603	760	950	81	1	422
329-35	653	01/01/90	31.82	44.41	1413.16	94.01	13.21	1241.98	1248.26	88.33	31.80	32743800	212	902	246	1605	179	948	81	1	423

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
329-35	684	01/01/90	60.6	25372.5	422.9	205.3	0.0000825	0.30	143.35	53.2	0.03893	141.4	63404	471.8	2.00	644763	2.234E+10
329-35	715	01/01/90	60.6	25433.0	423.9	205.2	0.0000838	0.30	143.65	53.3	0.03890	141.3	63546	464.4	2.03	636327	2.165E+10
329-35	746	01/01/90	60.6	25493.6	424.9	205.1	0.0000839	0.30	143.95	53.3	0.03890	141.3	63687	463.7	2.08	635371	2.157E+10
329-35	777	01/02/90	60.6	25554.1	425.9	205.0	0.0000843	0.30	144.25	53.3	0.03889	141.3	63828	461.3	2.17	632131	2.134E+10
329-35	808	01/02/90	60.5	25614.7	426.9	204.8	0.0000833	0.31	144.56	53.2	0.03886	141.1	63969	466.2	2.08	638334	2.183E+10
329-35	839	01/02/90	60.6	25675.2	427.9	204.7	0.0000838	0.30	144.86	53.4	0.03887	141.2	64111	464.1	2.03	637551	2.157E+10
329-35	870	01/02/90	60.6	25735.8	428.9	204.7	0.0000830	0.30	145.17	53.3	0.03885	141.1	64252	467.8	1.97	641906	2.196E+10
329-35	901	01/02/90	60.6	25796.3	429.9	204.7	0.0000828	0.30	145.47	53.4	0.03886	141.2	64393	469.1	2.39	644624	2.205E+10
329-35	932	01/02/90	60.6	25856.9	430.9	204.9	0.0000844	0.30	145.77	53.3	0.03887	141.2	64534	460.4	2.33	631255	2.126E+10
329-35	963	01/02/90	60.6	25917.4	432.0	205.0	0.0000828	0.30	146.08	53.3	0.03887	141.2	64675	469.7	2.44	644008	2.215E+10
329-35	974	01/02/90	21.8	25939.2	432.3	205.5	0.0000831	0.11	146.19	53.3	0.03878	50.8	64726	466.8	2.31	641713	2.206E+10
329-35	1005	01/02/90	60.6	25999.8	433.3	205.1	0.0000827	0.30	146.49	53.3	0.03887	141.2	64867	469.8	1.71	644233	2.218E+10
329-35	1036	01/02/90	60.6	26060.3	434.3	205.5	0.0000831	0.30	146.79	53.3	0.03892	141.4	65009	468.3	2.47	641234	2.203E+10
329-35	1067	01/02/90	60.6	26120.9	435.3	206.1	0.0000842	0.30	147.09	53.4	0.03893	141.4	65150	462.5	2.42	634438	2.155E+10
329-35	1098	01/02/90	60.6	26181.4	436.4	206.0	0.0000839	0.30	147.40	53.4	0.03890	141.3	65291	463.5	2.48	636366	2.167E+10
329-35	1129	01/02/90	60.6	26242.0	437.4	205.7	0.0000833	0.30	147.70	53.3	0.03888	141.3	65433	466.7	2.53	639787	2.196E+10
329-35	1191	01/02/90	60.6	26302.5	438.4	205.2	0.0000830	0.30	148.00	53.2	0.03887	141.2	65574	468.5	2.11	641227	2.208E+10
329-35	1222	01/02/90	60.6	26363.1	439.4	205.0	0.0000830	0.30	148.30	53.2	0.03885	141.1	65715	467.8	1.96	640601	2.201E+10
329-35	1253	01/02/90	60.5	26423.6	440.4	204.9	0.0000828	0.30	148.60	53.0	0.03887	141.2	65856	469.5	2.15	640274	2.217E+10
329-35	1284	01/03/90	60.6	26484.2	441.4	204.9	0.0000840	0.30	148.90	53.0	0.03884	141.1	65997	462.5	2.04	631148	2.154E+10
329-35	1315	01/03/90	60.6	26544.7	442.4	204.9	0.0000831	0.30	149.21	53.1	0.03883	141.1	66138	467.1	1.91	638805	2.197E+10
329-36	13	01/03/90	57.6	26602.3	443.4	206.8	0.0000835	0.29	149.50	53.2	0.03894	134.5	66273	466.2	2.19	636905	2.201E+10
329-36	26	01/03/90	57.6	26659.8	444.3	206.6	0.0000839	0.29	149.79	53.3	0.03900	134.7	66408	464.7	2.65	635136	2.177E+10
329-36	39	01/03/90	57.6	26717.4	445.3	206.5	0.0000831	0.29	150.08	53.2	0.03899	134.6	66542	469.4	2.04	640509	2.222E+10
329-37	13	01/03/90	60.5	26777.9	446.3	205.8	0.0000825	0.31	150.39	53.1	0.03892	141.4	66684	471.6	2.38	643356	2.242E+10
329-37	26	01/03/90	60.5	26838.5	447.3	205.4	0.0000839	0.30	150.68	53.0	0.03886	141.2	66825	463.2	2.07	631772	2.165E+10
329-37	39	01/03/90	60.5	26899.0	448.3	205.2	0.0000832	0.30	150.99	53.0	0.03886	141.2	66966	466.8	2.55	636644	2.196E+10
329-37	52	01/03/90	60.5	26959.6	449.3	205.0	0.0000834	0.30	151.29	52.8	0.03881	141.0	67107	465.1	2.29	632805	2.186E+10
329-37	65	01/03/90	60.5	27020.1	450.3	204.8	0.0000833	0.30	151.59	52.8	0.03882	141.0	67248	465.9	2.28	633648	2.189E+10
3[illegible]	78	01/03/90	60.5	27080.7	451.3	204.7	0.0000827	0.30	151.90	52.8	0.03880	141.0	67389	469.1	2.14	638306	2.220E+10
329-37	91	01/04/90	60.5	27141.2	452.4	204.7	0.0000836	0.30	152.20	52.9	0.03877	140.9	67530	463.8	2.04	632828	2.172E+10
329-37	104	01/04/90	60.5	27201.8	453.4	204.5	0.0000831	0.30	152.50	52.9	0.03884	141.1	67671	467.1	2.11	636207	2.193E+10
329-37	117	01/04/90	60.5	27262.3	454.4	204.4	0.0000840	0.30	152.80	52.8	0.03883	141.1	67812	462.2	2.16	628482	2.148E+10
329-37	130	01/04/90	60.5	27322.9	455.4	204.4	0.0000833	0.31	153.11	52.8	0.03880	141.0	67953	465.8	2.30	633793	2.184E+10
329-37	143	01/04/90	60.5	27383.4	456.4	204.4	0.0000838	0.30	153.41	52.9	0.03880	141.0	68094	462.9	2.07	631047	2.156E+10

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LIFE TEST NASA

RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-35	684	01/01/90	31.84	44.41	1414.09	93.79	13.23	1241.14	1247.44	88.22	32.30	33167800	212	902	246	1606	-119	948	81	1	424
329-35	715	01/01/90	31.84	44.43	1414.35	93.75	13.23	1240.38	1246.68	88.15	31.80	32652300	212	902	246	1607	-120	953	81	1	425
329-35	746	01/01/90	31.83	44.46	1415.25	93.38	13.29	1240.55	1246.90	88.11	31.74	32607800	212	903	246	1609	-131	947	81	1	426
329-35	777	01/02/90	31.86	44.38	1413.94	94.06	13.23	1244.16	1250.46	88.44	31.48	32536100	213	902	246	1606	-135	954	81	1	427
329-35	808	01/02/90	31.84	44.44	1414.97	93.59	13.23	1238.25	1244.55	87.96	31.94	32760600	212	901	246	1607	-138	957	81	1	428
329-35	839	01/02/90	31.84	44.46	1415.66	93.45	13.29	1241.99	1248.35	88.18	31.71	32696500	212	902	246	1609	-146	953	81	1	429
329-35	870	01/02/90	31.84	44.38	1413.01	94.17	13.19	1241.71	1247.97	88.32	31.95	32974300	212	901	246	1605	-78	956	81	1	430
329-35	901	01/02/90	31.80	44.40	1412.18	94.44	13.11	1238.32	1244.51	88.13	32.13	32961400	211	902	245	1603	297	949	81	1	431
329-35	932	01/02/90	31.84	44.36	1412.42	94.37	13.15	1240.88	1247.10	88.30	31.48	32405300	211	902	245	1603	760	953	81	1	432
329-35	963	01/02/90	31.86	44.32	1411.98	94.51	13.13	1240.56	1246.77	88.30	32.13	33051700	212	902	245	1603	760	954	81	1	433
329-35	974	01/02/90	31.83	44.13	1404.94	94.64	13.11	1240.87	1247.06	88.76	31.85	32941900	204	899	214	1599	757	948	74	1	434
329-35	1005	01/02/90	31.84	44.31	1411.06	94.84	13.09	1241.61	1247.78	88.43	32.11	33091200	212	902	246	1601	760	952	81	1	435
329-35	1036	01/02/90	31.87	44.27	1410.62	94.87	13.07	1240.25	1246.40	88.36	32.08	32900900	212	901	245	1601	760	955	81	1	436
329-35	1067	01/02/90	31.85	44.34	1412.45	94.44	13.16	1242.58	1248.81	88.41	31.63	32552200	212	903	246	1603	760	951	81	1	437
329-35	1098	01/02/90	31.84	44.36	1412.63	94.29	13.14	1238.65	1244.86	88.12	31.78	32547800	213	903	246	1603	760	951	81	1	438
329-35	1129	01/02/90	31.86	44.33	1412.23	94.77	13.12	1243.67	1249.87	88.50	31.85	32917200	212	902	246	1601	760	949	81	1	439
329-35	1191	01/02/90	31.84	44.38	1413.06	94.65	13.13	1243.02	1249.23	88.41	31.98	33035900	213	903	245	1602	-107	952	81	1	440
329-35	1222	01/02/90	31.82	44.37	1412.07	94.97	13.10	1244.25	1250.43	88.55	31.88	33036500	213	903	245	1601	-115	953	81	1	441
329-35	1253	01/02/90	31.84	44.36	1412.22	94.73	13.11	1242.05	1248.24	88.39	32.08	33085600	213	903	245	1602	-122	951	81	1	442
329-35	1284	01/03/90	31.85	44.34	1412.47	94.34	13.16	1241.67	1247.90	88.35	31.58	32603700	213	902	245	1604	-131	959	81	1	443
329-35	1315	01/03/90	31.85	44.40	1414.10	93.95	13.23	1242.53	1248.83	88.31	31.86	32960300	214	904	246	1605	-136	962	81	1	444
329-36	13	01/03/90	31.85	44.30	1411.11	94.14	13.21	1244.04	1250.33	88.61	31.85	32840100	212	900	239	1607	760	967	79	1	445
329-36	26	01/03/90	31.85	44.33	1412.14	94.22	13.16	1240.22	1246.46	88.27	31.90	32587300	211	904	241	1604	-45	953	79	1	446
329-36	39	01/03/90	31.86	44.28	1410.83	94.87	13.07	1239.99	1246.14	88.33	32.22	32918500	211	904	241	1601	760	955	80	1	447
329-37	13	01/03/90	31.84	44.30	1410.71	94.44	13.16	1243.20	1249.44	88.57	32.23	33212600	210	904	240	1603	760	953	79	1	448
329-37	26	01/03/90	31.83	44.41	1413.66	94.00	13.21	1241.82	1248.10	88.29	31.64	32640100	212	901	241	1604	-27	968	80	1	449
329-37	39	01/03/90	31.84	44.38	1412.93	94.31	13.18	1243.46	1249.72	88.45	31.84	32935100	212	901	241	1603	420	968	80	1	450
329-37	52	01/03/90	31.83	44.40	1413.06	94.16	13.19	1241.90	1248.16	88.33	31.73	32819600	212	902	241	1604	-140	966	80	1	451
329-37	65	01/03/90	31.83	44.43	1414.03	94.12	13.21	1242.86	1249.14	88.34	31.77	32888500	213	901	241	1605	-140	966	80	1	452
329-37	78	01/03/90	31.83	44.44	1414.48	93.88	13.23	1242.25	1248.55	88.27	31.98	33114100	213	901	241	1605	-142	968	80	1	453
329-37	91	01/04/90	31.87	44.43	1415.88	93.60	13.27	1241.88	1248.22	88.16	31.61	32758100	213	901	241	1608	-148	967	80	1	454
329-37	104	01/04/90	31.84	44.43	1414.68	94.08	13.23	1244.89	1251.20	88.44	31.81	33012700	212	904	241	1606	-144	954	80	1	455
329-37	117	01/04/90	31.84	44.43	1414.75	94.15	13.19	1241.60	1247.86	88.20	31.55	32587200	213	903	241	1604	-152	955	80	1	456
329-37	130	01/04/90	31.83	44.41	1413.82	94.37	13.18	1243.97	1250.23	88.43	31.72	32925500	212	903	241	1605	-152	956	80	1	457
329-37	143	01/04/90	31.85	44.45	1415.62	93.85	13.28	1245.99	1252.34	88.47	31.47	32773900	213	902	241	1607	-41	961	80	1	458

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
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329-37	156	01/04/90	60.5	27444.0	457.4	204.4	0.0000830	0.30	153.71	52.9	0.03877	140.9	68235	467.0	2.00	637219	2.198E+10
329-38	13	01/04/90	60.5	27504.5	458.4	204.0	0.0000829	0.30	154.01	52.9	0.03872	140.7	68375	467.1	2.03	638041	2.198E+10
329-38	26	01/04/90	60.5	27565.1	459.4	203.5	0.0000825	0.30	154.32	52.8	0.03877	140.9	68516	470.0	2.10	640070	2.215E+10
329-38	39	01/04/90	60.5	27625.6	460.4	203.3	0.0000824	0.30	154.62	52.7	0.03877	140.9	68657	470.6	2.17	639617	2.218E+10
329-38	52	01/04/90	60.5	27686.2	461.4	203.2	0.0000824	0.30	154.92	52.7	0.03870	140.6	68798	469.7	1.88	639610	2.217E+10
329-38	65	01/04/90	60.5	27746.7	462.4	203.1	0.0000827	0.30	155.22	52.8	0.03870	140.6	68938	467.9	2.49	638275	2.196E+10
329-38	78	01/04/90	60.5	27807.3	463.5	203.0	0.0000824	0.30	155.53	52.8	0.03867	140.5	69079	469.2	2.46	640567	2.211E+10
329-38	91	01/04/90	60.5	27867.8	464.5	202.9	0.0000825	0.30	155.83	52.7	0.03865	140.4	69219	468.5	1.96	638842	2.207E+10
329-38	104	01/04/90	60.5	27928.4	465.5	202.8	0.0000824	0.30	156.13	52.6	0.03864	140.4	69360	469.1	2.34	638598	2.214E+10
329-38	117	01/04/90	60.5	27988.9	466.5	202.7	0.0000825	0.30	156.43	52.7	0.03868	140.5	69500	469.0	2.30	639051	2.206E+10
329-38	130	01/04/90	60.5	28049.5	467.5	202.6	0.0000829	0.30	156.73	52.7	0.03863	140.3	69640	466.3	2.38	636089	2.184E+10
329-38	143	01/04/90	60.5	28110.0	468.5	202.5	0.0000825	0.30	157.04	52.6	0.03864	140.4	69781	468.3	2.38	637390	2.201E+10
329-38	156	01/04/90	60.5	28170.6	469.5	202.4	0.0000825	0.30	157.34	52.8	0.03861	140.3	69921	468.3	2.16	640310	2.200E+10
329-38	169	01/04/90	60.5	28231.1	470.5	202.4	0.0000816	0.30	157.64	52.6	0.03861	140.3	70061	473.0	2.14	644324	2.248E+10
329-38	182	01/04/90	60.5	28291.7	471.5	202.3	0.0000821	0.30	157.94	52.6	0.03864	140.4	70202	470.7	2.09	640807	2.222E+10
329-38	195	01/04/90	60.5	28352.2	472.5	202.3	0.0000816	0.30	158.25	52.6	0.03861	140.3	70342	472.9	2.10	644253	2.246E+10
329-38	208	01/04/90	60.5	28412.8	473.5	202.4	0.0000825	0.30	158.55	52.6	0.03858	140.2	70482	467.8	2.05	637815	2.203E+10
329-38	221	01/04/90	60.5	28473.3	474.6	202.3	0.0000828	0.30	158.85	52.7	0.03856	140.1	70622	465.6	1.97	636350	2.181E+10
329-39	31	01/05/90	60.5	28533.9	475.6	206.4	0.0000833	0.30	159.15	53.4	0.03883	141.0	70763	465.8	2.40	640710	2.203E+10
329-39	62	01/05/90	60.6	28594.4	476.6	205.7	0.0000838	0.30	159.46	53.1	0.03881	141.0	70904	463.4	2.55	633931	2.175E+10
329-39	93	01/05/90	60.6	28655.0	477.6	205.5	0.0000831	0.30	159.76	53.1	0.03880	141.0	71045	467.1	2.40	639212	2.208E+10
329-39	124	01/05/90	60.6	28715.5	478.6	205.3	0.0000828	0.30	160.06	53.2	0.03874	140.7	71186	468.2	2.35	642900	2.221E+10
329-39	155	01/05/90	60.6	28776.1	479.6	205.0	0.0000823	0.30	160.36	53.1	0.03872	140.7	71327	470.7	2.43	645561	2.245E+10
329-39	186	01/05/90	60.6	28836.6	480.6	204.7	0.0000821	0.30	160.66	53.0	0.03871	140.6	71467	471.6	2.37	645696	2.252E+10
329-39	217	01/05/90	60.6	28897.2	481.6	204.7	0.0000830	0.30	160.96	53.0	0.03878	140.9	71608	467.3	2.33	638685	2.203E+10
329-39	248	01/05/90	60.6	28957.7	482.6	204.7	0.0000829	0.30	161.27	52.9	0.03870	140.6	71749	467.0	2.41	638326	2.210E+10
329-39	279	01/06/90	60.6	29018.3	483.6	204.6	0.0000825	0.30	161.57	53.1	0.03872	140.7	71889	469.4	2.49	643792	2.227E+10
329-39	310	01/06/90	60.6	29078.8	484.6	204.6	0.0000825	0.30	161.87	53.1	0.03867	140.5	72030	468.5	2.21	643293	2.224E+10
329-39	341	01/06/90	60.6	29139.4	485.7	204.5	0.0000834	0.30	162.17	53.2	0.03870	140.6	72170	464.2	2.31	638027	2.176E+10
329-39	372	01/06/90	60.6	29199.9	486.7	204.5	0.0000826	0.30	162.47	53.1	0.03864	140.4	72311	467.9	2.32	642958	2.220E+10
329-39	403	01/06/90	60.6	29260.5	487.7	204.5	0.0000822	0.30	162.77	53.1	0.03872	140.7	72452	471.0	2.19	645860	2.240E+10
329-39	434	01/06/90	60.6	29321.0	488.7	204.5	0.0000826	0.30	163.07	53.1	0.03863	140.3	72592	467.6	2.41	642748	2.218E+10
329-39	465	01/06/90	60.5	29381.5	489.7	204.5	0.0000823	0.30	163.37	52.9	0.03865	140.4	72732	469.4	2.21	642482	2.236E+10
329-39	496	01/06/90	60.6	29442.1	490.7	204.5	0.0000828	0.30	163.67	53.0	0.03871	140.6	72873	467.3	2.21	639865	2.208E+10
329-39	527	01/06/90	60.6	29502.6	491.7	204.5	0.0000827	0.30	163.97	52.9	0.03865	140.4	73013	467.2	2.51	639445	2.215E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-37	156	01/04/90	31.84	44.50	1416.79	93.40	13.31	1243.34	1249.72	88.21	31.79	33024300	212	903	241	1610	181	958	80	1	459
329-38	13	01/04/90	31.86	44.49	1417.24	93.31	13.30	1241.44	1247.81	88.05	31.81	33016200	213	901	241	1609	-90	971	80	1	460
329-38	26	01/04/90	31.83	44.50	1416.30	93.95	13.23	1242.46	1248.76	88.17	32.01	33211200	213	903	241	1606	35	956	81	1	461
329-38	39	01/04/90	31.84	44.44	1414.85	94.29	13.18	1243.20	1249.45	88.31	32.04	33270400	214	903	242	1604	762	956	81	1	462
329-38	52	01/04/90	31.85	44.44	1415.36	94.06	13.22	1243.87	1250.16	88.33	31.91	33287700	215	902	242	1606	97	966	81	1	463
329-38	65	01/04/90	31.84	44.41	1413.74	93.94	13.22	1241.46	1247.75	88.26	31.84	33091400	214	902	242	1606	-113	960	81	1	464
329-38	78	01/04/90	31.83	44.48	1415.77	93.52	13.30	1243.87	1250.24	88.31	31.85	33274800	215	902	242	1610	-165	961	81	1	465
329-38	91	01/04/90	31.83	44.45	1414.82	93.99	13.22	1242.82	1249.11	88.29	31.81	33220200	216	902	242	1604	-159	963	81	1	466
329-38	104	01/04/90	31.85	44.37	1413.33	94.13	13.21	1243.35	1249.63	88.42	31.83	33284500	216	901	242	1603	-159	970	81	1	467
329-38	117	01/04/90	31.82	44.42	1413.59	94.37	13.17	1242.86	1249.10	88.36	31.86	33231800	216	901	242	1601	-157	961	81	1	468
329-38	130	01/04/90	31.81	44.43	1413.44	94.15	13.18	1240.68	1246.93	88.22	31.70	33019900	215	901	241	1604	-164	962	81	1	469
329-38	143	01/04/90	31.84	44.38	1412.91	94.27	13.16	1240.53	1246.77	88.24	31.84	33146500	215	901	241	1602	-159	965	81	1	470
329-38	156	01/04/90	31.85	44.46	1416.15	93.45	13.29	1242.18	1248.54	88.16	31.77	33216200	216	899	242	1610	-164	968	81	1	471
329-38	169	01/04/90	31.84	44.38	1412.89	94.47	13.15	1242.24	1248.46	88.36	32.09	33553100	216	898	241	1602	-109	972	81	1	472
329-38	182	01/04/90	31.85	44.36	1412.73	94.76	13.12	1242.81	1249.00	88.41	31.95	33385000	215	899	241	1600	-146	965	81	1	473
329-38	195	01/04/90	31.85	44.36	1413.08	94.25	13.23	1246.65	1252.95	88.67	31.98	33668400	216	898	241	1602	761	973	81	1	474
329-38	208	01/04/90	31.86	44.37	1413.44	94.28	13.18	1242.86	1249.12	88.37	31.70	33230900	216	899	242	1603	-69	973	81	1	475
329-38	221	01/04/90	31.84	44.46	1415.58	93.23	13.30	1240.42	1246.80	88.08	31.60	33026600	216	901	242	1608	-155	972	81	1	476
329-39	31	01/05/90	31.87	44.24	1409.78	94.54	13.15	1242.84	1249.06	88.60	31.77	32881000	215	901	240	1603	761	968	80	1	477
329-39	62	01/05/90	31.85	44.29	1410.60	94.67	13.11	1241.36	1247.55	88.44	31.63	32678100	215	901	241	1601	761	972	80	1	478
329-39	93	01/05/90	31.84	44.34	1411.89	94.24	13.19	1242.69	1248.95	88.46	31.83	32985300	215	901	241	1602	761	973	81	1	479
329-39	124	01/05/90	31.82	44.41	1413.32	93.85	13.24	1242.25	1248.55	88.34	31.88	33101700	216	901	242	1606	762	973	81	1	480
329-39	155	01/05/90	31.84	44.38	1413.19	93.75	13.27	1243.79	1250.12	88.46	31.99	33342600	216	901	242	1606	762	974	81	1	481
329-39	186	01/05/90	31.83	44.38	1412.96	94.19	13.19	1242.56	1248.83	88.38	32.07	33379700	216	899	241	1604	762	979	81	1	482
329-39	217	01/05/90	31.83	44.37	1411.94	94.63	13.12	1241.89	1248.09	88.40	31.85	32999100	215	900	240	1600	761	970	81	1	483
329-39	248	01/05/90	31.83	44.37	1412.32	94.24	13.19	1243.07	1249.34	88.46	31.74	33074600	215	900	240	1602	761	977	81	1	484
329-39	279	01/06/90	31.83	44.40	1413.07	93.99	13.22	1242.66	1248.95	88.39	31.93	33220900	215	900	241	1604	762	971	81	1	485
329-39	310	01/06/90	31.84	44.40	1413.66	93.83	13.24	1242.21	1248.52	88.32	31.84	33183400	215	899	241	1608	763	977	81	1	486
329-39	341	01/06/90	31.85	44.39	1413.99	93.88	13.27	1245.82	1252.16	88.56	31.48	32945200	215	900	240	1605	762	970	81	1	487
329-39	372	01/06/90	31.84	44.42	1414.57	93.59	13.29	1243.65	1250.01	88.37	31.73	33204600	215	898	241	1607	762	980	81	1	488
329-39	403	01/06/90	31.83	44.41	1413.40	94.02	13.20	1241.33	1247.60	88.27	32.07	33292100	216	900	241	1604	762	970	81	1	489
329-39	434	01/06/90	31.86	44.44	1415.77	93.38	13.32	1243.90	1250.29	88.31	31.70	33200300	216	898	242	1609	763	981	81	1	490
329-39	465	01/06/90	31.87	44.37	1413.99	93.73	13.25	1241.67	1247.99	88.26	31.89	33252300	216	900	241	1606	762	977	81	1	491
329-39	496	01/06/90	31.85	44.40	1414.12	94.03	13.20	1241.61	1247.89	88.25	31.80	33052600	217	899	241	1605	762	974	81	1	492
329-39	527	01/06/90	31.88	44.33	1413.30	94.24	13.18	1242.39	1248.65	88.35	31.73	33114200	217	898	241	1604	762	982	81	1	493

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
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329-39	558	01/06/90	60.6	29563.2	492.7	204.5	0.0000826	0.30	164.27	53.1	0.03871	140.6	73154	468.5	2.36	642725	2.218E+10
329-39	589	01/06/90	60.5	29623.7	493.7	204.5	0.0000820	0.30	164.57	53.0	0.03866	140.4	73294	471.7	2.45	646728	2.256E+10
329-39	620	01/06/90	60.6	29684.3	494.7	204.4	0.0000819	0.30	164.86	53.1	0.03863	140.3	73435	471.6	2.18	648201	2.255E+10
329-39	651	01/06/90	60.6	29744.8	495.7	204.4	0.0000825	0.30	165.17	53.2	0.03865	140.4	73575	468.4	2.25	644794	2.221E+10
329-39	682	01/06/90	60.6	29805.4	496.8	204.3	0.0000828	0.30	165.46	53.2	0.03862	140.3	73715	466.4	2.11	642481	2.204E+10
329-39	713	01/06/90	60.6	29865.9	497.8	204.2	0.0000826	0.30	165.77	53.2	0.03860	140.2	73856	467.4	2.39	644216	2.214E+10
329-39	744	01/06/90	60.5	29926.5	498.8	204.1	0.0000828	0.30	166.07	53.3	0.03861	140.2	73996	466.4	2.28	643906	2.201E+10
329-39	775	01/07/90	60.6	29987.0	499.8	204.1	0.0000820	0.30	166.37	53.3	0.03859	140.2	74136	470.5	2.26	649842	2.242E+10
329-39	806	01/07/90	60.6	30047.6	500.8	204.1	0.0000822	0.30	166.67	53.3	0.03860	140.2	74276	469.5	2.26	648213	2.230E+10
329-39	837	01/07/90	60.6	30108.1	501.8	204.1	0.0000819	0.30	166.97	53.3	0.03861	140.3	74417	471.2	2.26	650539	2.246E+10
329-39	868	01/07/90	60.6	30168.7	502.8	204.0	0.0000826	0.30	167.27	53.3	0.03856	140.1	74557	466.8	2.19	645278	2.209E+10
329-39	899	01/07/90	60.6	30229.2	503.8	204.0	0.0000825	0.30	167.57	53.3	0.03856	140.1	74697	467.2	2.23	645779	2.212E+10
329-39	930	01/07/90	60.6	30289.8	504.8	204.1	0.0000826	0.30	167.87	53.1	0.03862	140.3	74837	467.8	2.16	643239	2.216E+10
329-39	961	01/07/90	60.6	30350.3	505.8	204.0	0.0000818	0.30	168.16	53.0	0.03858	140.2	74977	471.5	2.19	647629	2.255E+10
329-39	992	01/07/90	60.6	30410.9	506.8	204.1	0.0000821	0.30	168.46	53.1	0.03863	140.3	75118	470.6	2.24	647009	2.242E+10
329-39	1018	01/07/90	51.2	30462.0	507.7	204.1	0.0000822	0.25	168.71	53.0	0.03842	117.9	75236	467.1	2.22	644479	2.234E+10
329-40	31	01/07/90	60.6	30522.6	508.7	196.8	0.0000808	0.29	169.01	52.2	0.03807	138.3	75374	470.9	2.17	645696	2.213E+10
329-40	62	01/07/90	60.6	30583.1	509.7	196.4	0.0000806	0.29	169.30	52.3	0.03800	138.1	75512	471.7	2.16	649222	2.22[illegible]E+10
329-40	93	01/07/90	60.5	30643.7	510.7	196.2	0.0000800	0.30	169.59	52.1	0.03801	138.1	75650	475.0	2.36	651128	2.251E+10
329-40	124	01/07/90	60.6	30704.2	511.7	196.1	0.0000807	0.29	169.89	52.2	0.03799	138.0	75788	470.7	2.08	646808	2.209E+10
329-40	155	01/07/90	60.6	30764.8	512.7	196.0	0.0000802	0.29	170.18	52.3	0.03801	138.1	75926	474.1	2.22	652445	2.236E+10
329-40	186	01/07/90	60.6	30825.3	513.8	195.9	0.0000811	0.29	170.47	52.2	0.03798	138.0	76064	468.6	2.13	644039	2.187E+10
329-40	217	01/07/90	60.6	30885.9	514.8	195.8	0.0000792	0.29	170.76	52.3	0.03792	137.8	76202	479.0	2.22	660679	2.290E+10
329-40	248	01/08/90	60.5	30946.4	515.8	195.6	0.0000805	0.29	171.05	52.2	0.03798	137.9	76340	472.1	2.13	648721	2.215E+10
329-40	279	01/08/90	60.6	31006.9	516.8	195.5	0.0000800	0.29	171.35	52.3	0.03782	137.4	76477	472.8	2.27	653734	2.237E+10
329-40	310	01/08/90	60.6	31067.5	517.8	195.3	0.0000804	0.29	171.64	52.3	0.03793	137.8	76615	471.4	2.14	650126	2.210E+10
329-40	341	01/08/90	60.6	31128.0	518.8	195.4	0.0000802	0.29	171.93	52.4	0.03802	138.1	76753	473.9	2.00	653082	2.221E+10
329-40	372	01/08/90	60.6	31188.6	519.8	195.5	0.0000803	0.29	172.22	52.4	0.03799	138.0	76891	473.2	2.03	652732	2.220E+10
329-40	403	01/08/90	60.6	31249.1	520.8	195.4	0.0000797	0.29	172.52	52.4	0.03796	137.9	77029	476.2	2.63	657416	2.251E+10
329-43	13	01/08/90	60.5	31309.7	521.8	195.6	0.0000811	0.30	172.82	52.4	0.03834	139.3	77168	472.6	1.84	645893	2.176E+10
329-43	26	01/08/90	60.5	31370.2	522.8	192.1	0.0000808	0.29	173.11	52.0	0.03806	138.3	77307	471.2	2.00	643811	2.148E+10
329-43	39	01/08/90	60.5	31430.8	523.8	188.9	0.0000791	0.29	173.40	51.5	0.03783	137.4	77444	478.3	1.96	651124	2.196E+10
329-43	52	01/08/90	60.5	31491.3	524.9	185.7	0.0000792	0.29	173.69	51.1	0.03755	136.4	77580	474.3	2.18	645471	2.148E+10
329-43	65	01/08/90	60.5	31551.9	525.9	182.7	0.0000785	0.29	173.97	50.8	0.03733	135.6	77716	475.6	2.32	647150	2.141E+10
329-43	78	01/08/90	60.5	31612.4	526.9	179.8	0.0000772	0.28	174.26	50.5	0.03718	135.1	77851	481.7	2.19	654255	2.170E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-39	558	01/06/90	31.86	44.36	1413.34	94.07	13.19	1240.73	1246.99	88.23	31.91	33114400	217	899	242	1602	762	975	81	1	494
329-39	589	01/06/90	31.85	44.38	1413.55	93.99	13.23	1243.64	1249.94	88.43	32.01	33461700	218	899	242	1603	762	979	81	1	495
329-39	620	01/06/90	31.86	44.35	1412.82	94.22	13.19	1243.09	1249.36	88.43	31.99	33460200	218	898	242	1604	762	978	81	1	496
329-39	651	01/06/90	31.85	44.36	1413.08	94.07	13.21	1243.00	1249.29	88.41	31.80	33219500	218	899	242	1603	762	976	81	1	497
329-39	682	01/06/90	31.86	44.40	1414.51	93.42	13.29	1241.26	1247.61	88.20	31.68	33053600	218	899	242	1607	763	978	81	1	498
329-39	713	01/06/90	31.84	44.44	1414.95	93.07	13.33	1240.64	1247.04	88.13	31.74	33126300	217	898	242	1610	764	981	81	1	499
329-39	744	01/06/90	31.84	44.45	1415.26	93.45	13.31	1243.64	1250.01	88.32	31.61	33128000	218	898	242	1610	764	976	81	1	500
329-39	775	01/07/90	31.86	44.41	1414.57	93.40	13.31	1243.24	1249.61	88.34	31.89	33422900	218	899	242	1610	764	979	81	1	501
329-39	806	01/07/90	31.83	44.44	1414.86	93.27	13.33	1243.35	1249.75	88.33	31.82	33342200	218	897	241	1609	764	981	81	1	502
329-39	837	01/07/90	31.87	44.41	1414.98	93.40	13.26	1238.95	1245.29	88.01	32.05	33343600	217	897	241	1609	763	980	81	1	503
329-39	868	01/07/90	31.85	44.44	1415.23	93.17	13.34	1242.78	1249.19	88.27	31.61	33175800	217	896	241	1612	764	980	81	1	504
329-39	899	01/07/90	31.84	44.44	1415.19	93.32	13.30	1241.08	1247.45	88.15	31.69	33156400	217	898	241	1610	764	981	81	1	505
329-39	930	01/07/90	31.83	44.37	1412.34	94.34	13.16	1241.48	1247.71	88.34	31.77	33160700	218	898	241	1603	762	982	81	1	506
329-39	961	01/07/90	31.83	44.33	1411.32	94.56	13.14	1242.40	1248.61	88.47	31.96	33475000	218	897	240	1602	762	981	81	1	507
329-39	992	01/07/90	31.87	44.29	1411.38	94.55	13.14	1242.14	1248.36	88.45	31.95	33373300	218	897	240	1603	762	981	81	1	508
329-39	1018	01/07/90	31.86	44.26	1410.09	94.62	13.14	1243.09	1249.30	88.60	31.52	33330700	217	898	239	1601	762	986	80	1	509
329-40	31	01/07/90	31.85	44.46	1415.91	92.40	13.46	1244.11	1250.64	88.33	31.45	33933400	219	893	241	1618	767	983	81	1	510
329-40	62	01/07/90	31.85	44.51	1417.44	91.78	13.52	1240.64	1247.22	87.99	31.54	33958200	219	894	242	1626	768	979	82	1	511
329-40	93	01/07/90	31.87	44.45	1416.63	92.49	13.42	1241.62	1248.11	88.10	31.74	34215600	219	894	242	1621	767	980	82	1	512
329-40	124	01/07/90	31.86	44.49	1417.45	92.30	13.44	1240.36	1246.86	87.97	31.47	33889300	219	893	242	1625	768	978	82	1	513
329-40	155	01/07/90	31.86	44.50	1417.77	91.93	13.51	1241.63	1248.19	88.04	31.69	34153900	220	895	242	1625	768	983	82	1	514
329-40	186	01/07/90	31.88	44.48	1418.04	91.82	13.52	1241.42	1248.00	88.01	31.29	33773100	220	894	242	1625	768	975	82	1	515
329-40	217	01/07/90	31.86	44.56	1419.67	91.06	13.63	1241.06	1247.74	87.89	31.95	34568900	220	895	243	1631	769	984	82	1	516
329-40	248	01/08/90	31.87	44.43	1416.21	91.76	13.55	1242.96	1249.57	88.23	31.49	34060800	220	898	242	1625	768	975	82	1	517
329-40	279	01/08/90	31.85	44.60	1420.32	90.78	13.68	1242.16	1248.90	87.93	31.43	34236000	220	898	243	1634	770	981	82	1	518
329-40	310	01/08/90	31.85	44.50	1417.21	91.92	13.51	1241.43	1248.00	88.06	31.44	34027400	219	899	242	1625	768	978	82	1	519
329-40	341	01/08/90	31.83	44.47	1415.26	92.96	13.39	1245.08	1251.54	88.43	31.59	34217100	219	894	241	1620	767	974	82	1	520
329-40	372	01/08/90	31.85	44.48	1416.95	92.17	13.49	1243.09	1249.64	88.19	31.57	34144200	219	894	242	1625	768	976	82	1	521
329-40	403	01/08/90	31.83	44.52	1417.09	92.17	13.48	1242.60	1249.14	88.15	31.76	34375300	220	893	242	1623	768	977	82	1	522
329-43	13	01/08/90	31.85	44.43	1415.29	92.72	13.43	1245.17	1251.67	88.44	31.76	33843000	219	894	242	1615	766	975	82	1	523
329-43	26	01/08/90	31.85	44.52	1418.01	91.57	13.55	1241.04	1247.66	87.99	31.55	33880500	220	893	242	1623	768	973	82	1	524
329-43	39	01/08/90	31.82	44.56	1418.24	91.44	13.58	1241.82	1248.46	88.03	31.80	34619700	221	892	242	1626	769	971	82	1	525
329-43	52	01/08/90	31.85	44.58	1419.74	90.47	13.70	1239.67	1246.42	87.79	31.37	34527800	222	891	243	1636	771	970	82	1	526
329-43	65	01/08/90	31.85	44.61	1420.81	90.28	13.74	1240.45	1247.25	87.79	31.25	34844000	223	889	243	1638	772	973	83	1	527
329-43	78	01/08/90	31.85	44.61	1420.79	90.07	13.77	1240.12	1246.94	87.76	31.53	35426600	224	889	243	1642	774	972	83	1	528

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
329-43	91	01/09/90	60.5	31673.0	527.9	177.1	0.0000766	0.28	174.54	50.2	0.03693	134.2	77985	481.9	2.30	655104	2.161E+10
329-43	104	01/09/90	60.5	31733.5	528.9	174.4	0.0000764	0.28	174.81	50.1	0.03663	133.1	78118	479.7	2.43	656146	2.132E+10
329-43	117	01/09/90	60.5	31794.1	529.9	171.9	0.0000760	0.28	175.09	49.7	0.03657	132.9	78251	481.5	2.33	654369	2.118E+10
329-43	130	01/09/90	60.5	31854.6	530.9	169.4	0.0000750	0.27	175.36	49.3	0.03635	132.1	78383	484.5	2.61	657027	2.133E+10
329-43	143	01/09/90	60.5	31915.2	531.9	167.4	0.0000744	0.27	175.63	49.2	0.03613	131.3	78515	485.8	2.43	661513	2.137E+10
329-44	13	01/09/90	60.5	31975.7	532.9	194.0	0.0000813	0.29	175.93	51.5	0.03830	139.1	78654	471.0	2.39	633363	2.155E+10
329-44	26	01/09/90	60.5	32036.3	533.9	193.7	0.0000811	0.30	176.22	51.5	0.03823	138.9	78793	471.4	2.33	635120	2.163E+10
329-44	39	01/09/90	60.5	32096.8	534.9	193.4	0.0000807	0.29	176.52	51.5	0.03821	138.8	78931	473.5	2.06	638150	2.179E+10
329-44	52	01/09/90	60.5	32157.4	536.0	192.8	0.0000813	0.29	176.81	51.3	0.03814	138.6	79070	469.1	2.01	630919	2.140E+10
329-44	65	01/09/90	60.5	32217.9	537.0	192.3	0.0000809	0.30	177.11	51.2	0.03814	138.6	79209	471.5	2.36	632997	2.157E+10
329-44	78	01/09/90	60.5	32278.5	538.0	192.0	0.0000812	0.29	177.40	51.3	0.03815	138.6	79347	470.0	2.46	632061	2.136E+10
329-44	91	01/09/90	60.5	32339.0	539.0	192.1	0.0000808	0.29	177.69	51.2	0.03808	138.3	79485	471.2	2.32	633569	2.158E+10
329-44	104	01/09/90	60.5	32399.6	540.0	192.1	0.0000806	0.29	177.99	51.3	0.03801	138.1	79623	471.5	2.36	636366	2.167E+10
329-44	117	01/10/90	60.5	32460.1	541.0	192.0	0.0000804	0.29	178.28	51.4	0.03797	137.9	79761	472.4	2.33	639439	2.176E+10
329-44	130	01/10/90	60.5	32520.7	542.0	191.9	0.0000799	0.29	178.57	51.2	0.03808	138.3	79900	476.8	2.37	641066	2.206E+10
329-44	143	01/10/90	60.5	32581.2	543.0	191.8	0.0000808	0.29	178.87	51.3	0.03808	138.3	80038	471.1	2.33	634650	2.150E+10
329-44	156	01/10/90	60.5	32641.8	544.0	191.8	0.0000802	0.29	179.16	51.3	0.03800	138.0	80176	474.0	2.24	639890	2.186E+10
329-44	169	01/10/90	60.5	32702.3	545.0	191.7	0.0000803	0.29	179.45	51.3	0.03806	138.3	80314	474.1	2.15	639085	2.179E+10
329-44	182	01/10/90	60.5	32762.9	546.0	191.7	0.0000804	0.29	179.74	51.3	0.03807	138.3	80453	473.4	2.37	637925	2.171E+10
329-44	195	01/10/90	60.5	32823.4	547.1	191.7	0.0000808	0.29	180.03	51.3	0.03802	138.1	80591	470.8	2.44	635239	2.153E+10
329-44	208	01/10/90	60.5	32883.9	548.1	191.8	0.0000798	0.29	180.33	51.6	0.03794	137.8	80729	475.3	2.22	646455	2.201E+10
329-44	221	01/10/90	60.5	32944.5	549.1	192.1	0.0000802	0.29	180.62	51.7	0.03799	138.0	80867	473.8	2.07	644711	2.183E+10
329-44	234	01/10/90	60.5	33005.0	550.1	192.1	0.0000810	0.29	180.91	51.6	0.03795	137.9	81005	468.6	2.03	637131	2.142E+10
329-44	247	01/10/90	60.5	33065.6	551.1	191.8	0.0000799	0.30	181.20	51.6	0.03796	137.9	81142	474.8	2.09	645508	2.194E+10
329-44	260	01/10/90	60.5	33126.1	552.1	191.9	0.0000800	0.29	181.50	51.5	0.03801	138.1	81281	475.0	2.14	643597	2.193E+10
329-44	273	01/10/90	60.5	33186.7	553.1	191.7	0.0000797	0.29	181.79	51.5	0.03795	137.9	81418	476.1	1.94	646068	2.206E+10
329-44	286	01/10/90	60.5	33247.2	554.1	191.5	0.0000806	0.29	182.08	51.7	0.03804	138.2	81557	472.2	2.13	641702	2.154E+10
329-44	299	01/10/90	60.5	33307.8	555.1	191.4	0.0000806	0.29	182.37	51.7	0.03799	138.0	81695	471.1	2.38	641240	2.149E+10
329-44	312	01/10/90	60.5	33368.3	556.1	191.2	0.0000795	0.29	182.66	51.5	0.03793	137.8	81832	477.1	2.44	647872	2.211E+10
329-44	325	01/11/90	60.5	33428.9	557.1	191.1	0.0000801	0.29	182.95	51.4	0.03793	137.8	81970	473.6	2.28	641890	2.179E+10
329-44	338	01/11/90	60.5	33489.4	558.2	191.0	0.0000799	0.29	183.24	51.3	0.03791	137.7	82108	474.4	2.22	641900	2.187E+10
329-44	351	01/11/90	60.5	33550.0	559.2	190.9	0.0000802	0.29	183.53	51.3	0.03786	137.5	82245	472.2	2.45	639826	2.172E+10
329-44	364	01/11/90	60.5	33610.5	560.2	190.8	0.0000802	0.29	183.82	51.4	0.03803	138.2	82384	474.4	2.50	641146	2.169E+10
329-44	377	01/11/90	60.5	33671.1	561.2	190.7	0.0000801	0.29	184.11	51.4	0.03791	137.7	82521	473.4	2.44	641866	2.172E+10
329-44	390	01/11/90	60.5	33731.6	562.2	190.8	0.0000795	0.29	184.40	51.3	0.03780	137.3	82659	475.8	2.61	645681	2.210E+10

LPAJ NASA LEWIS (
LIFE TEST NASA

RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-43	91	01/09/90	31.85	44.66	1422.39	89.53	13.86	1240.86	1247.77	87.72	31.31	35705400	225	888	244	1651	776	971	83	1	529
329-43	104	01/09/90	31.85	44.69	1423.34	88.76	13.95	1238.31	1245.32	87.49	30.97	35760700	226	887	244	1658	778	969	84	1	530
329-43	117	01/09/90	31.86	44.65	1422.49	89.30	13.90	1241.68	1248.64	87.78	30.96	36047900	225	886	244	1652	777	967	84	1	531
329-43	130	01/09/90	31.84	44.71	1423.60	89.11	13.91	1239.51	1246.48	87.56	31.02	36424500	225	884	244	1655	778	967	84	1	532
329-43	143	01/09/90	31.85	44.69	1423.71	88.54	14.01	1240.45	1247.52	87.63	32.71	36775744	227	883	244	1663	780	967	84	1	533
329-44	13	01/09/90	31.84	44.44	1415.00	93.71	13.27	1243.76	1250.10	88.35	31.67	33727700	218	893	240	1613	765	973	81	1	534
329-44	26	01/09/90	31.85	44.46	1416.00	93.18	13.32	1241.11	1247.50	88.10	31.70	33749400	219	894	242	1614	765	974	82	1	535
329-44	39	01/09/90	31.85	44.49	1416.89	92.64	13.42	1242.93	1249.41	88.18	31.78	33960400	219	893	242	1616	765	974	82	1	536
329-44	52	01/09/90	31.84	44.51	1417.16	92.91	13.39	1243.73	1250.18	88.22	31.41	33728100	220	893	242	1614	766	973	82	1	537
329-44	65	01/09/90	31.85	44.48	1416.85	93.17	13.35	1243.73	1250.15	88.23	31.56	33905200	220	892	242	1613	766	973	82	1	538
329-44	78	01/09/90	31.85	44.45	1415.87	93.15	13.35	1243.61	1250.03	88.29	31.47	33786000	221	893	241	1614	766	973	82	1	539
329-44	91	01/09/90	31.84	44.51	1417.12	92.61	13.42	1242.48	1248.96	88.13	31.52	33901700	219	892	241	1617	767	973	82	1	540
329-44	104	01/09/90	31.82	44.58	1418.60	92.02	13.48	1240.59	1247.13	87.91	31.54	33933200	220	892	242	1623	768	974	82	1	541
329-44	117	01/10/90	31.85	44.60	1420.56	91.24	13.60	1241.15	1247.82	87.84	31.55	34046200	220	892	242	1629	769	974	82	1	542
329-44	130	01/10/90	31.85	44.52	1418.11	92.81	13.40	1244.09	1250.55	88.19	31.86	34347300	220	892	241	1617	767	974	82	1	543
329-44	143	01/10/90	31.86	44.53	1418.64	92.38	13.45	1242.06	1248.57	88.01	31.53	33882100	221	893	241	1616	767	974	82	1	544
329-44	156	01/10/90	31.84	44.59	1419.77	91.99	13.50	1242.04	1248.60	87.94	31.66	34161100	220	892	242	1622	768	976	82	1	545
329-44	169	01/10/90	31.83	44.54	1417.69	92.51	13.41	1240.73	1247.20	87.97	31.74	34082200	220	892	242	1616	767	974	82	1	546
329-44	182	01/10/90	31.82	44.55	1417.71	92.44	13.39	1237.90	1244.36	87.77	31.79	33942700	221	892	241	1616	767	975	82	1	547
329-44	195	01/10/90	31.85	44.49	1417.00	92.42	13.43	1241.52	1248.02	88.08	31.48	33898700	223	900	242	1617	768	972	82	1	548
329-44	208	01/10/90	31.84	44.57	1418.84	91.58	13.55	1240.93	1247.54	87.93	31.73	34280500	220	891	242	1625	769	973	82	1	549
329-44	221	01/10/90	31.86	44.56	1419.55	91.59	13.53	1239.29	1245.88	87.77	31.71	34076500	220	892	242	1626	769	973	83	1	550
329-44	234	01/10/90	31.86	44.56	1419.76	91.69	13.56	1242.98	1249.59	88.02	31.24	33841800	221	891	243	1622	769	973	83	1	551
329-44	247	01/10/90	31.84	44.61	1420.17	91.69	13.57	1244.39	1251.02	88.09	31.62	34325600	223	893	243	1624	769	972	83	1	552
329-44	260	01/10/90	31.83	44.59	1419.30	92.35	13.47	1244.34	1250.88	88.13	31.67	34288900	221	892	243	1621	769	973	83	1	553
329-44	273	01/10/90	31.83	44.58	1419.06	91.89	13.50	1240.82	1247.38	87.90	31.79	34323400	221	891	242	1623	769	974	83	1	554
329-44	286	01/10/90	31.83	44.58	1418.69	92.23	13.51	1245.93	1252.50	88.29	31.47	34099200	246	893	242	1620	768	956	83	1	555
329-44	299	01/10/90	31.82	44.58	1418.63	91.88	13.53	1243.14	1249.73	88.09	31.43	33998600	248	894	242	1624	769	957	83	1	556
329-44	312	01/10/90	31.83	44.59	1419.47	91.86	13.53	1242.62	1249.21	88.01	31.79	34468900	248	892	242	1621	769	976	83	1	557
329-44	325	01/11/90	31.82	44.54	1417.26	92.89	13.39	1244.13	1250.59	88.24	31.52	34258900	246	891	241	1615	768	980	82	1	558
329-44	338	01/11/90	31.83	44.54	1417.52	92.93	13.39	1244.41	1250.87	88.24	31.55	34334000	246	890	241	1613	767	985	82	1	559
329-44	351	01/11/90	31.84	44.56	1419.05	92.35	13.45	1242.15	1248.66	87.99	31.42	34160600	247	889	241	1616	768	988	83	1	560
329-44	364	01/11/90	31.85	44.53	1418.08	92.85	13.39	1243.42	1249.88	88.14	31.68	34199500	247	892	241	1613	767	963	83	1	561
329-44	377	01/11/90	31.83	44.55	1418.35	92.56	13.41	1240.81	1247.28	87.94	31.58	34166200	249	889	241	1615	768	985	82	1	562
329-44	390	01/11/90	31.85	44.58	1419.79	92.07	13.50	1242.68	1249.24	87.99	31.59	34488300	221	893	241	1620	769	979	82	1	563

LPAJ NASA LEWIS (121581-4840)
LIFE TEST   NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
329-44	403	01/11/90	60.5	33792.2	563.2	191.0	0.0000795	0.29	184.69	51.4	0.03785	137.5	82796	476.2	2.44	646622	2.209E+10
329-44	412	01/11/90	40.7	33832.8	563.9	199.4	0.0000815	0.20	184.89	52.3	0.03847	93.9	82890	472.2	1.90	642025	2.217E+10
329-45	5	01/11/90	60.5	33893.4	564.9	199.7	0.0000818	0.30	185.19	52.2	0.03852	139.9	83030	470.9	2.33	638072	2.204E+10
329-45	10	01/11/90	60.6	33953.9	565.9	199.4	0.0000815	0.30	185.49	52.2	0.03846	139.7	83170	472.0	2.49	640750	2.218E+10
329-45	15	01/11/90	60.6	34014.5	566.9	199.2	0.0000818	0.30	185.79	52.1	0.03848	139.8	83309	470.6	2.31	637215	2.200E+10
329-45	20	01/11/90	60.6	34075.0	567.9	199.1	0.0000819	0.30	186.08	52.2	0.03844	139.7	83449	469.2	2.37	637168	2.189E+10
329-45	25	01/11/90	60.6	34135.6	568.9	199.1	0.0000809	0.30	186.38	52.2	0.03843	139.6	83589	475.2	2.38	645440	2.246E+10
329-45	30	01/11/90	60.6	34196.1	569.9	199.1	0.0000812	0.30	186.67	52.2	0.03844	139.7	83728	473.3	2.22	642628	2.226E+10
329-45	35	01/11/90	60.5	34256.7	570.9	199.0	0.0000808	0.30	186.97	52.2	0.03839	139.4	83868	474.8	2.44	645720	2.246E+10
329-45	40	01/12/90	60.6	34317.2	572.0	198.9	0.0000818	0.30	187.27	52.2	0.03839	139.5	84007	469.3	2.37	638142	2.192E+10
329-45	45	01/12/90	60.6	34377.8	573.0	198.8	0.0000815	0.30	187.56	52.2	0.03834	139.3	84147	470.3	2.39	640247	2.205E+10
329-45	50	01/12/90	60.5	34438.3	574.0	198.6	0.0000816	0.30	187.86	52.2	0.03834	139.3	84286	469.6	2.39	639369	2.196E+10
329-45	55	01/12/90	60.6	34498.8	575.0	198.5	0.0000819	0.30	188.16	52.3	0.03831	139.2	84425	467.6	2.48	638389	2.178E+10
329-45	60	01/12/90	60.6	34559.4	576.0	198.3	0.0000818	0.30	188.46	52.1	0.03832	139.2	84564	468.4	2.23	636779	2.184E+10
329-45	73	01/12/90	60.5	34619.9	577.0	198.3	0.0000817	0.30	188.75	52.1	0.03837	139.4	84704	469.5	2.28	637457	2.189E+10
329-45	86	01/12/90	60.5	34680.5	578.0	198.5	0.0000815	0.30	189.05	52.2	0.03833	139.3	84843	470.3	2.48	640530	2.203E+10
329-45	99	01/12/90	60.5	34741.0	579.0	198.8	0.0000813	0.30	189.35	52.2	0.03834	139.3	84982	471.7	2.60	642169	2.219E+10
329-45	112	01/12/90	60.5	34801.6	580.0	199.4	0.0000812	0.29	189.64	52.2	0.03844	139.7	85122	473.2	2.71	642541	2.230E+10
329-45	125	01/12/90	60.5	34862.1	581.0	199.3	0.0000816	0.30	189.94	52.2	0.03837	139.4	85261	470.5	2.41	640075	2.212E+10
329-45	138	01/12/90	60.5	34922.7	582.0	199.2	0.0000817	0.30	190.23	52.1	0.03839	139.5	85401	469.9	2.19	637715	2.204E+10
329-45	151	01/12/90	60.5	34983.2	583.1	198.7	0.0000815	0.30	190.53	52.1	0.03834	139.3	85540	470.5	2.15	639374	2.208E+10
329-45	164	01/12/90	60.5	35043.8	584.1	198.4	0.0000821	0.30	190.83	52.2	0.03829	139.1	85679	466.6	1.71	636135	2.171E+10
329-45	177	01/12/90	60.5	35104.3	585.1	197.9	0.0000812	0.30	191.12	52.2	0.03827	139.0	85818	471.5	2.46	643079	2.211E+10
329-45	190	01/12/90	60.5	35164.9	586.1	197.6	0.0000812	0.30	191.42	52.2	0.03826	139.0	85957	471.2	2.28	642897	2.205E+10
329-45	203	01/12/90	60.5	35225.4	587.1	197.5	0.0000815	0.29	191.71	52.1	0.03828	139.1	86096	469.6	2.30	639162	2.188E+10
329-45	216	01/13/90	60.5	35286.0	588.1	197.3	0.0000812	0.30	192.01	52.2	0.03825	139.0	86235	471.1	2.44	642928	2.201E+10
329-45	229	01/13/90	60.5	35346.5	589.1	197.1	0.0000808	0.30	192.31	52.1	0.03826	139.0	86374	473.7	2.50	645113	2.223E+10
329-45	242	01/13/90	60.5	35407.1	590.1	197.0	0.0000810	0.29	192.60	52.1	0.03825	139.0	86513	472.3	2.33	643258	2.209E+10
329-45	255	01/13/90	60.5	35467.6	591.1	197.0	0.0000806	0.29	192.89	52.1	0.03821	138.8	86652	474.3	2.57	646739	2.233E+10
329-45	268	01/13/90	60.5	35528.2	592.1	196.9	0.0000804	0.30	193.19	52.0	0.03823	138.9	86791	475.6	2.29	646839	2.242E+10
329-45	281	01/13/90	60.5	35588.7	593.1	197.0	0.0000808	0.29	193.48	52.0	0.03823	138.9	86930	473.4	2.34	643795	2.223E+10
329-45	294	01/13/90	60.5	35649.3	594.2	197.3	0.0000808	0.29	193.77	52.1	0.03826	139.0	87069	473.6	2.54	644938	2.225E+10
329-45	307	01/13/90	60.5	35709.8	595.2	196.9	0.0000804	0.29	194.07	52.0	0.03820	138.8	87207	475.1	2.35	646702	2.241E+10
329-45	320	01/13/90	60.5	35770.4	596.2	196.9	0.0000804	0.29	194.36	52.0	0.03826	139.0	87346	476.1	2.40	647048	2.244E+10
329-45	333	01/13/90	60.5	35830.9	597.2	197.1	0.0000809	0.29	194.65	52.0	0.03824	138.9	87485	472.6	2.32	642737	2.217E+10

LPAJ NASA LEWIS (
LIFE TEST NASA

RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-44	403	01/11/90	31.86	44.57	1419.96	92.29	13.46	1242.52	1249.05	87.96	31.66	34466700	221	892	241	1621	769	979	83	1	564
329-44	412	01/11/90	31.84	44.44	1414.92	93.77	13.26	1243.39	1249.72	88.32	31.89	33656300	219	895	236	1603	764	981	80	1	565
329-45	5	01/11/90	31.87	44.43	1415.81	93.77	13.26	1243.01	1249.33	88.24	31.86	33502800	219	894	239	1602	763	975	81	1	566
329-45	10	01/11/90	31.86	44.47	1416.78	93.82	13.24	1241.77	1248.08	88.09	31.91	33610100	219	893	240	1603	764	981	82	1	567
329-45	15	01/11/90	31.88	44.36	1414.15	94.19	13.19	1242.66	1248.93	88.32	31.81	33512800	219	892	240	1599	763	980	82	1	568
329-45	20	01/11/90	31.87	44.46	1416.96	93.77	13.27	1244.53	1250.87	88.28	31.64	33496400	220	892	241	1604	764	981	82	1	569
329-45	25	01/11/90	31.87	44.49	1417.88	93.48	13.30	1243.44	1249.81	88.15	32.06	33901600	221	892	241	1604	764	981	82	1	570
329-45	30	01/11/90	31.88	44.38	1415.12	93.81	13.25	1242.70	1249.02	88.26	31.96	33733700	221	892	241	1600	764	981	82	1	571
329-45	35	01/11/90	31.87	44.42	1415.80	93.01	13.33	1239.92	1246.32	88.03	32.09	33820000	222	892	242	1608	766	982	82	1	572
329-45	40	01/12/90	31.87	44.42	1415.49	93.43	13.31	1243.21	1249.58	88.28	31.63	33511900	222	893	242	1607	765	981	82	1	573
329-45	45	01/12/90	31.85	44.47	1416.60	92.85	13.39	1243.34	1249.79	88.23	31.66	33626200	222	892	242	1611	766	980	82	1	574
329-45	50	01/12/90	31.86	44.45	1416.14	93.21	13.36	1245.08	1251.50	88.37	31.57	33626700	222	892	242	1609	766	980	82	1	575
329-45	55	01/12/90	31.85	44.49	1417.07	92.64	13.41	1242.16	1248.63	88.11	31.49	33432500	222	892	242	1614	767	980	82	1	576
329-45	60	01/12/90	31.86	44.42	1414.91	93.46	13.29	1242.32	1248.68	88.25	31.54	33480600	222	891	242	1606	765	978	82	1	577
329-45	73	01/12/90	31.86	44.41	1414.80	93.71	13.25	1241.78	1248.10	88.22	31.67	33501600	222	892	241	1605	765	979	82	1	578
329-45	86	01/12/90	31.84	44.43	1414.64	93.57	13.23	1238.28	1244.58	87.98	31.78	33504000	222	892	241	1603	765	979	82	1	579
329-45	99	01/12/90	31.86	44.38	1413.98	93.96	13.22	1242.35	1248.64	88.31	31.78	33700000	223	892	241	1600	764	979	82	1	580
329-45	112	01/12/90	31.87	44.30	1411.89	94.34	13.16	1241.48	1247.72	88.37	31.99	33696000	223	892	242	1597	763	979	82	1	581
329-45	125	01/12/90	31.84	44.41	1413.90	93.89	13.20	1238.98	1245.25	88.07	31.81	33499100	223	892	242	1601	764	979	82	1	582
329-45	138	01/12/90	31.88	44.32	1412.62	94.50	13.18	1245.63	1251.88	88.62	31.61	33619200	224	892	242	1599	764	980	82	1	583
329-45	151	01/12/90	31.87	44.36	1413.54	93.78	13.25	1242.72	1249.04	88.36	31.68	33627700	224	892	242	1606	766	979	82	1	584
329-45	164	01/12/90	31.86	44.36	1413.58	93.87	13.23	1241.93	1248.23	88.30	31.41	33372200	224	892	242	1602	765	979	82	1	585
329-45	177	01/12/90	31.86	44.42	1415.50	93.31	13.30	1240.94	1247.31	88.12	31.74	33709600	224	892	242	1606	766	978	81	1	586
329-45	190	01/12/90	31.85	44.45	1415.63	93.31	13.31	1242.29	1248.67	88.21	31.68	33736800	224	892	242	1604	765	978	82	1	587
329-45	203	01/12/90	31.87	44.42	1415.62	93.58	13.29	1244.06	1250.42	88.33	31.54	33653100	224	892	242	1603	765	979	82	1	588
329-45	216	01/13/90	31.86	44.45	1416.26	93.35	13.32	1243.60	1249.99	88.26	31.63	33773800	224	893	242	1606	766	978	82	1	589
329-45	229	01/13/90	31.87	44.43	1415.84	93.71	13.28	1244.78	1251.13	88.37	31.78	33986100	224	893	242	1605	766	978	82	1	590
329-45	242	01/13/90	31.88	44.41	1415.89	93.76	13.24	1241.21	1247.52	88.11	31.78	33791100	224	892	242	1603	765	978	82	1	591
329-45	255	01/13/90	31.85	44.42	1414.71	93.69	13.27	1243.18	1249.52	88.32	31.83	34027700	224	892	242	1606	766	979	82	1	592
329-45	268	01/13/90	31.87	44.34	1412.92	93.96	13.22	1242.41	1248.70	88.38	31.94	34077400	223	892	242	1602	765	979	82	1	593
329-45	281	01/13/90	31.88	44.33	1412.99	94.03	13.21	1242.35	1248.64	88.37	31.80	33915600	224	892	242	1602	765	978	82	1	594
329-45	294	01/13/90	31.88	44.33	1413.02	93.95	13.22	1241.64	1247.92	88.32	31.86	33890700	224	893	242	1601	765	979	82	1	595
329-45	307	01/13/90	31.89	44.31	1413.22	93.98	13.20	1240.75	1247.03	88.24	31.93	34024900	224	893	242	1600	765	979	82	1	596
329-45	320	01/13/90	31.89	44.33	1413.46	94.10	13.20	1242.48	1248.75	88.35	32.01	34090300	224	891	242	1600	765	979	82	1	597
329-45	333	01/13/90	31.89	44.34	1413.97	93.52	13.28	1241.63	1247.97	88.26	31.78	33840200	224	892	242	1602	765	979	82	1	598

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
329-45	346	01/13/90	60.5	35891.4	598.2	197.2	0.0000805	0.29	194.95	52.1	0.03822	138.8	87624	474.8	2.36	647253	2.239E+10
329-45	359	01/13/90	60.5	35952.0	599.2	197.1	0.0000812	0.29	195.24	52.0	0.03821	138.8	87763	470.8	2.41	640702	2.203E+10
329-45	372	01/13/90	60.5	36012.5	600.2	196.9	0.0000809	0.29	195.53	52.0	0.03822	138.9	87902	472.6	2.44	643015	2.216E+10
329-45	385	01/13/90	60.5	36073.1	601.2	196.8	0.0000810	0.29	195.83	52.1	0.03815	138.6	88040	470.8	2.59	642916	2.203E+10
329-45	398	01/13/90	60.5	36133.6	602.2	196.7	0.0000799	0.29	196.12	52.2	0.03820	138.8	88179	478.2	2.34	653497	2.265E+10
329-45	411	01/13/90	60.5	36194.2	603.2	196.6	0.0000803	0.29	196.41	52.2	0.03817	138.7	88318	475.3	2.43	650103	2.240E+10
329-45	424	01/14/90	60.5	36254.7	604.2	196.5	0.0000803	0.29	196.70	52.2	0.03811	138.5	88456	474.8	2.30	650354	2.240E+10
329-45	437	01/14/90	60.5	36315.3	605.3	196.4	0.0000806	0.29	197.00	52.2	0.03809	138.4	88595	472.7	2.41	647828	2.221E+10
329-45	450	01/14/90	60.5	36375.8	606.3	196.4	0.0000813	0.29	197.29	52.3	0.03809	138.4	88733	468.4	2.37	643249	2.180E+10
329-45	463	01/14/90	60.5	36436.4	607.3	196.3	0.0000804	0.29	197.58	52.3	0.03806	138.3	88871	473.3	2.27	650376	2.227E+10
329-45	476	01/14/90	60.5	36496.9	608.3	196.3	0.0000806	0.29	197.88	52.3	0.03805	138.2	89010	472.2	2.51	649061	2.218E+10
329-45	489	01/14/90	60.5	36557.5	609.3	196.3	0.0000799	0.29	198.17	52.4	0.03802	138.1	89148	475.9	2.49	655959	2.255E+10
329-45	495	01/14/90	27.2	36584.7	609.7	196.6	0.0000806	0.13	198.30	52.3	0.03810	62.3	89210	472.9	2.47	649262	2.224E+10
329-45	498	01/14/90	10.1	36594.9	609.9	189.9	0.0000789	0.05	198.35	51.4	0.03773	23.0	89233	478.4	0.00	651747	2.227E+10
329-45	511	01/14/90	60.5	36655.4	610.9	187.5	0.0000783	0.28	198.63	51.2	0.03741	135.9	89369	477.6	2.04	653678	2.222E+10
329-45	524	01/14/90	60.5	36716.0	611.9	187.0	0.0000778	0.28	198.92	51.2	0.03735	135.7	89505	480.0	2.05	658022	2.243E+10
329-45	537	01/14/90	60.5	36776.5	612.9	186.6	0.0000770	0.28	199.20	51.2	0.03732	135.6	89640	484.6	2.05	664762	2.283E+10
329-45	550	01/14/90	60.5	36837.1	614.0	186.4	0.0000775	0.28	199.48	51.1	0.03733	135.6	89776	481.6	2.00	659210	2.252E+10
329-45	563	01/14/90	60.5	36897.6	615.0	186.3	0.0000778	0.28	199.76	51.0	0.03736	135.7	89912	480.1	1.99	655519	2.235E+10
329-45	576	01/14/90	60.5	36958.2	616.0	186.3	0.0000779	0.28	200.04	51.0	0.03737	135.8	90047	479.9	2.07	655030	2.232E+10
329-45	589	01/14/90	60.5	37018.7	617.0	186.3	0.0000780	0.28	200.33	51.1	0.03733	135.6	90183	478.4	2.00	654960	2.221E+10
329-45	602	01/14/90	60.5	37079.3	618.0	186.3	0.0000776	0.28	200.61	51.0	0.03732	135.6	90319	481.1	2.23	657437	2.248E+10
329-45	615	01/14/90	60.5	37139.8	619.0	186.2	0.0000776	0.28	200.89	50.9	0.03734	135.7	90454	481.1	2.19	655810	2.246E+10
329-45	628	01/15/90	60.5	37200.4	620.0	186.2	0.0000780	0.28	201.17	50.8	0.03739	135.8	90590	479.1	2.16	650932	2.223E+10
329-45	641	01/15/90	60.5	37260.9	621.0	186.2	0.0000775	0.28	201.46	51.0	0.03738	135.8	90726	482.1	2.22	657708	2.249E+10
329-45	654	01/15/90	60.5	37321.5	622.0	186.1	0.0000774	0.28	201.74	50.8	0.03729	135.4	90861	481.7	2.27	656314	2.258E+10
329-45	667	01/15/90	60.5	37382.0	623.0	186.0	0.0000771	0.28	202.02	50.7	0.03708	134.7	90996	480.6	2.01	657178	2.273E+10
329-45	680	01/15/90	60.5	37442.6	624.0	185.9	0.0000770	0.28	202.30	50.6	0.03705	134.6	91131	481.1	2.01	656947	2.281E+10
329-46	13	01/15/90	60.5	37503.1	625.1	185.3	0.0000768	0.28	202.58	50.4	0.03685	133.9	91264	479.7	2.27	656036	2.286E+10
329-46	26	01/15/90	60.5	37563.7	626.1	185.1	0.0000769	0.28	202.86	50.6	0.03701	134.5	91399	480.9	2.41	657604	2.272E+10
329-46	39	01/15/90	60.5	37624.2	627.1	184.9	0.0000778	0.28	203.15	50.8	0.03718	135.0	91534	477.8	1.95	652797	2.214E+10
329-46	52	01/15/90	60.5	37684.8	628.1	184.8	0.0000772	0.28	203.43	50.8	0.03717	135.0	91669	481.3	1.94	657716	2.246E+10
329-46	65	01/15/90	60.5	37745.3	629.1	184.7	0.0000769	0.28	203.71	50.8	0.03715	135.0	91804	483.4	2.18	660994	2.267E+10
329-46	78	01/15/90	60.5	37805.9	630.1	184.7	0.0000774	0.28	203.99	50.7	0.03719	135.1	91939	480.2	2.07	654717	2.235E+10
329-46	91	01/15/90	60.5	37866.4	631.1	184.8	0.0000773	0.28	204.27	50.7	0.03718	135.1	92074	481.0	2.08	655912	2.244E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-45	346	01/13/90	31.88	44.36	1414.30	93.68	13.29	1244.54	1250.90	88.45	31.83	34092100	225	892	242	1605	766	979	82	1	599
329-45	359	01/13/90	31.87	44.33	1412.55	94.16	13.19	1242.02	1248.29	88.37	31.62	33743600	224	891	242	1601	765	979	82	1	600
329-45	372	01/13/90	31.85	44.36	1412.85	94.24	13.17	1240.98	1247.22	88.28	31.78	33836900	225	892	242	1601	765	980	82	1	601
329-45	385	01/13/90	31.88	44.37	1414.56	93.41	13.31	1243.34	1249.72	88.35	31.53	33831000	225	892	243	1605	766	980	82	1	602
329-45	398	01/13/90	31.86	44.36	1413.59	93.88	13.22	1241.01	1247.30	88.24	32.13	34257500	225	893	242	1602	766	981	82	1	603
329-45	411	01/13/90	31.87	44.36	1413.75	93.98	13.23	1243.68	1249.98	88.42	31.84	34153100	225	892	242	1604	766	980	82	1	604
329-45	424	01/14/90	31.88	44.36	1414.31	93.77	13.27	1244.37	1250.71	88.43	31.75	34185300	225	892	242	1604	766	979	82	1	605
329-45	437	01/14/90	31.87	44.37	1414.17	93.54	13.29	1243.27	1249.63	88.37	31.62	34022000	225	892	242	1608	767	980	82	1	606
329-45	450	01/14/90	31.87	44.40	1415.29	93.27	13.35	1244.80	1251.21	88.41	31.29	33758700	225	893	243	1610	767	983	82	1	607
329-45	463	01/14/90	31.87	44.44	1416.37	92.82	13.39	1243.06	1249.52	88.22	31.64	34085000	225	891	243	1611	768	984	82	1	608
329-45	476	01/14/90	31.86	44.46	1416.55	92.69	13.43	1244.57	1251.06	88.32	31.52	34057100	225	891	243	1614	768	982	82	1	609
329-45	489	01/14/90	31.86	44.46	1416.59	92.55	13.42	1242.01	1248.49	88.13	31.80	34282700	226	891	243	1618	769	982	82	1	610
329-45	495	01/14/90	31.86	44.25	1409.89	93.17	13.30	1239.27	1245.64	88.35	31.74	33922800	221	890	223	1611	766	980	77	1	611
329-45	498	01/14/90	31.81	44.35	1410.80	92.25	13.44	1239.59	1246.09	88.33	31.79	34657900	226	881	216	1615	764	969	73	1	612
329-45	511	01/14/90	31.86	44.57	1420.14	91.13	13.62	1241.32	1248.00	87.88	31.43	34945300	226	889	244	1632	773	982	83	1	613
329-45	524	01/14/90	31.85	44.60	1420.56	91.08	13.64	1242.33	1249.02	87.93	31.51	35205900	227	888	244	1632	774	982	83	1	614
329-45	537	01/14/90	31.85	44.61	1420.79	90.93	13.62	1238.93	1245.61	87.67	31.87	35469300	227	888	244	1634	774	982	83	1	615
329-45	550	01/14/90	31.88	44.58	1420.90	91.22	13.60	1240.74	1247.40	87.79	31.63	35293400	227	887	244	1630	773	980	83	1	616
329-45	563	01/14/90	31.86	44.58	1420.17	91.72	13.53	1241.00	1247.59	87.85	31.55	35172000	227	887	243	1627	772	979	83	1	617
329-45	576	01/14/90	31.87	44.55	1419.62	91.76	13.56	1243.87	1250.48	88.09	31.47	35226600	227	888	243	1628	773	980	83	1	618
329-45	589	01/14/90	31.87	44.49	1417.90	91.43	13.58	1241.88	1248.52	88.05	31.40	35097900	227	887	243	1629	773	980	83	1	619
329-45	602	01/14/90	31.88	44.47	1417.74	91.53	13.55	1240.21	1246.82	87.94	31.60	35252400	227	887	243	1627	772	979	83	1	620
329-45	615	01/14/90	31.86	44.51	1418.43	91.66	13.55	1241.83	1248.44	88.02	31.58	35280200	227	887	243	1626	772	977	83	1	621
329-45	628	01/15/90	31.85	44.54	1418.30	92.14	13.49	1243.38	1249.93	88.13	31.45	35130500	227	887	243	1620	771	978	83	1	622
329-45	641	01/15/90	31.84	44.52	1417.84	91.93	13.48	1239.35	1245.89	87.87	31.75	35242100	258	885	243	1624	772	987	83	1	623
329-45	654	01/15/90	31.86	44.51	1417.94	91.88	13.51	1241.36	1247.93	88.01	31.59	35363100	260	882	243	1625	773	1000	83	1	624
329-45	667	01/15/90	31.86	44.55	1419.21	91.70	13.59	1239.74	1246.40	87.82	31.38	35433800	262	885	244	1632	774	1007	83	1	625
329-45	680	01/15/90	31.87	44.55	1419.78	91.29	13.63	1244.05	1250.73	88.09	31.28	35614500	262	885	243	1633	775	1008	83	1	626
329-46	13	01/15/90	31.87	44.49	1418.17	91.12	13.64	1242.39	1249.08	88.08	31.06	35658600	260	881	242	1636	776	1012	82	1	627
329-46	26	01/15/90	31.86	44.53	1418.79	91.75	13.58	1246.00	1252.64	88.29	31.18	35706200	261	884	243	1631	775	1008	83	1	628
329-46	39	01/15/90	31.88	44.52	1419.00	91.49	13.60	1243.96	1250.61	88.13	31.18	35247300	226	888	243	1631	774	982	83	1	629
329-46	52	01/15/90	31.86	44.54	1418.90	91.57	13.57	1242.61	1249.24	88.04	31.43	35474800	226	888	243	1630	774	981	83	1	630
329-46	65	01/15/90	31.86	44.54	1419.03	91.44	13.60	1244.01	1250.67	88.14	31.51	35691400	226	887	243	1631	774	981	83	1	631
329-46	78	01/15/90	31.85	44.57	1419.51	91.48	13.56	1240.34	1246.96	87.84	31.43	35317700	226	888	243	1629	774	980	83	1	632
329-46	91	01/15/90	31.86	44.53	1418.76	91.50	13.57	1241.32	1247.94	87.96	31.44	35410100	226	888	243	1629	773	980	83	1	633

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
329-46	104	01/15/90	60.5	37927.0	632.1	184.7	0.0000770	0.28	204.55	50.7	0.03716	135.0	92209	482.6	2.00	658536	2.261E+10
329-46	117	01/15/90	60.5	37987.5	633.1	184.6	0.0000768	0.28	204.83	50.8	0.03713	134.9	92344	483.8	1.96	661872	2.271E+10
329-46	130	01/15/90	60.5	38048.1	634.1	184.5	0.0000768	0.28	205.11	50.8	0.03713	134.9	92479	483.5	2.03	661605	2.268E+10
329-46	143	01/16/90	60.5	38108.6	635.1	184.1	0.0000766	0.28	205.39	50.7	0.03708	134.7	92614	484.1	1.99	661906	2.274E+10
329-46	156	01/16/90	60.5	38169.2	636.2	184.1	0.0000769	0.28	205.67	50.8	0.03705	134.6	92748	481.8	1.90	660658	2.255E+10
329-46	169	01/16/90	60.5	38229.7	637.2	184.0	0.0000768	0.28	205.95	50.7	0.03702	134.5	92883	482.2	2.22	660380	2.262E+10
329-46	182	01/16/90	60.5	38290.3	638.2	184.0	0.0000774	0.28	206.23	50.7	0.03701	134.5	93017	478.0	2.18	654717	2.223E+10
329-46	195	01/16/90	60.5	38350.8	639.2	183.9	0.0000763	0.28	206.51	50.7	0.03702	134.5	93152	485.2	2.08	664517	2.288E+10
329-46	208	01/16/90	60.5	38411.4	640.2	183.9	0.0000765	0.28	206.79	50.6	0.03700	134.4	93286	483.9	2.05	661723	2.280E+10
329-46	221	01/16/90	60.5	38471.9	641.2	183.9	0.0000763	0.28	207.07	50.5	0.03682	133.8	93420	482.8	2.10	662156	2.293E+10
329-46	234	01/16/90	60.5	38532.5	642.2	183.9	0.0000764	0.28	207.35	50.4	0.03680	133.7	93554	481.5	2.08	659323	2.285E+10
329-49	13	01/16/90	60.5	38593.0	643.2	186.6	0.0000787	0.28	207.63	50.9	0.03735	135.7	93689	474.8	2.21	647006	2.193E+10
329-49	26	01/16/90	60.5	38653.6	644.2	186.1	0.0000770	0.28	207.91	50.6	0.03719	135.1	93824	483.1	2.13	657314	2.287E+10
329-49	39	01/16/90	60.5	38714.1	645.2	185.8	0.0000774	0.28	208.19	50.6	0.03714	134.9	93959	479.8	2.35	653696	2.256E+10
329-49	52	01/16/90	60.5	38774.6	646.2	185.6	0.0000764	0.28	208.47	50.4	0.03697	134.3	94094	484.0	2.61	659738	2.317E+10
329-49	65	01/16/90	60.5	38835.2	647.3	185.4	0.0000764	0.28	208.75	50.4	0.03703	134.5	94228	485.0	2.51	660118	2.316E+10
329-49	78	01/16/90	60.5	38895.7	648.3	185.2	0.0000764	0.28	209.03	50.4	0.03690	134.1	94362	483.3	2.83	660109	2.312E+10
329-49	91	01/17/90	60.5	38956.3	649.3	185.0	0.0000772	0.28	209.31	50.6	0.03702	134.5	94497	479.6	2.92	655466	2.255E+10
329-49	104	01/17/90	60.5	39016.8	650.3	185.0	0.0000776	0.28	209.59	50.8	0.03730	135.5	94632	480.4	2.81	654285	2.226E+10
329-49	117	01/17/90	60.5	39077.4	651.3	184.8	0.0000771	0.28	209.87	50.9	0.03717	135.0	94767	482.2	2.84	660259	2.253E+10
329-49	130	01/17/90	60.5	39137.9	652.3	184.8	0.0000767	0.28	210.15	50.8	0.03714	134.9	94902	484.0	2.79	662036	2.276E+10
329-49	143	01/17/90	60.5	39198.5	653.3	184.8	0.0000767	0.28	210.43	50.6	0.03720	135.1	95037	484.8	2.38	659490	2.280E+10
329-49	156	01/17/90	60.5	39259.0	654.3	184.7	0.0000776	0.28	210.71	50.7	0.03711	134.8	95172	478.5	2.34	653679	2.228E+10
329-49	169	01/17/90	60.5	39319.6	655.3	184.7	0.0000771	0.28	210.99	50.7	0.03720	135.1	95307	482.7	2.28	657869	2.256E+10
329-50	13	01/17/90	60.5	39380.1	656.3	187.3	0.0000780	0.28	211.27	50.8	0.03716	135.0	95442	476.6	2.90	651491	2.245E+10
329-50	26	01/17/90	60.5	39440.7	657.3	187.0	0.0000772	0.28	211.56	50.8	0.03730	135.5	95578	483.4	2.36	658355	2.288E+10
329-50	39	01/17/90	60.5	39501.2	658.4	186.8	0.0000766	0.28	211.83	50.2	0.03676	133.5	95711	479.7	2.23	655130	2.326E+10
329-50	52	01/17/90	60.5	39561.7	659.4	186.7	0.0000767	0.28	212.11	50.4	0.03690	134.0	95845	481.4	2.40	657431	2.319E+10
329-50	65	01/17/90	60.5	39622.3	660.4	186.6	0.0000779	0.28	212.39	50.9	0.03711	134.8	95980	476.1	2.26	653008	2.233E+10
329-50	78	01/17/90	60.5	39682.8	661.4	186.1	0.0000783	0.28	212.68	50.7	0.03713	134.9	96115	474.3	2.18	647692	2.210E+10
329-50	91	01/17/90	60.5	39743.4	662.4	185.6	0.0000765	0.28	212.96	50.5	0.03700	134.4	96249	483.6	2.49	660019	2.308E+10
329-50	104	01/17/90	60.5	39803.9	663.4	185.3	0.0000762	0.28	213.24	50.3	0.03697	134.3	96384	485.4	2.69	660400	2.327E+10
329-50	117	01/17/90	60.5	39864.5	664.4	185.1	0.0000760	0.27	213.51	49.8	0.03666	133.2	96517	482.6	2.73	655617	2.345E+10
329-50	130	01/18/90	60.5	39925.0	665.4	185.0	0.0000767	0.28	213.79	50.5	0.03710	134.7	96652	483.6	2.66	658315	2.286E+10
329-50	143	01/18/90	60.5	39985.6	666.4	184.9	0.0000763	0.28	214.07	50.5	0.03708	134.7	96786	486.0	2.74	661930	2.309E+10

IPAJ NASA LEWIS (
LIFE TEST NASA

RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-46	104	01/15/90	31.86	44.53	1418.55	91.38	13.57	1240.33	1246.96	87.90	31.56	35523700	227	888	243	1629	774	980	83	1	634
329-46	117	01/15/90	31.87	44.54	1419.17	91.48	13.58	1242.64	1249.28	88.03	31.55	35699700	228	887	243	1630	774	979	83	1	635
329-46	130	01/15/90	31.87	44.48	1417.94	91.30	13.60	1241.76	1248.42	88.05	31.56	35660000	228	886	243	1630	774	980	83	1	636
329-46	143	01/16/90	31.87	44.51	1418.78	91.15	13.60	1239.60	1246.26	87.84	31.61	35684400	229	886	243	1630	774	979	83	1	637
329-46	156	01/16/90	31.88	44.50	1418.77	91.22	13.60	1240.23	1246.89	87.89	31.42	35565100	229	886	243	1632	774	979	83	1	638
329-46	169	01/16/90	31.87	44.57	1420.37	90.87	13.66	1240.82	1247.53	87.83	31.40	35637200	230	883	243	1633	775	979	83	1	639
329-46	182	01/16/90	31.87	44.53	1419.24	90.62	13.67	1239.23	1245.96	87.79	31.16	35286300	230	882	243	1637	775	977	83	1	640
329-46	195	01/16/90	31.86	44.54	1418.71	90.93	13.64	1240.10	1246.79	87.88	31.62	35839300	230	882	242	1633	774	976	83	1	641
329-46	208	01/16/90	31.86	44.52	1418.30	91.39	13.56	1239.57	1246.19	87.87	31.54	35744100	230	882	242	1633	774	975	83	1	642
329-46	221	01/16/90	31.85	44.52	1418.22	91.01	13.63	1240.67	1247.36	87.95	31.28	35870200	261	883	242	1634	776	1007	83	1	643
329-46	234	01/16/90	31.86	44.53	1418.81	91.17	13.62	1241.80	1248.47	88.00	31.15	35819900	262	881	242	1633	775	1012	83	1	644
329-49	13	01/16/90	31.86	44.45	1416.19	92.03	13.52	1244.05	1250.62	88.31	31.12	34868600	230	884	242	1626	772	985	82	1	645
329-49	26	01/16/90	31.86	44.49	1417.51	91.98	13.49	1240.43	1246.98	87.97	31.62	35531000	261	883	242	1624	773	1013	82	1	646
329-49	39	01/16/90	31.87	44.46	1416.90	91.88	13.52	1242.58	1249.16	88.16	31.30	35396400	261	882	242	1625	773	1013	82	1	647
329-49	52	01/16/90	31.86	44.49	1417.48	91.51	13.58	1242.82	1249.47	88.15	31.43	35872400	262	881	242	1628	774	1013	82	1	648
329-49	65	01/16/90	31.87	44.47	1416.95	91.79	13.54	1242.64	1249.24	88.16	31.56	35887800	262	881	242	1628	774	1013	82	1	649
329-49	78	01/16/90	31.87	44.52	1418.72	91.12	13.61	1239.77	1246.44	87.86	31.40	35804300	262	881	242	1631	775	1014	82	1	650
329-49	91	01/17/90	31.87	44.49	1417.75	91.48	13.59	1243.66	1250.32	88.19	31.17	35523100	262	881	242	1629	774	1011	82	1	651
329-49	104	01/17/90	31.87	44.47	1417.02	92.09	13.50	1242.72	1249.28	88.16	31.47	35292600	223	887	242	1624	772	977	82	1	652
329-49	117	01/17/90	31.85	44.49	1417.05	91.84	13.51	1240.51	1247.08	88.01	31.54	35481600	225	888	243	1625	773	976	82	1	653
329-49	130	01/17/90	31.87	44.47	1417.15	91.84	13.55	1244.21	1250.82	88.26	31.54	35753800	225	887	242	1628	774	976	82	1	654
329-49	143	01/17/90	31.86	44.47	1416.89	91.64	13.55	1241.77	1248.38	88.11	31.70	35686900	224	887	242	1626	773	974	82	1	655
329-49	156	01/17/90	31.87	44.49	1417.90	91.52	13.57	1241.78	1248.41	88.05	31.22	35303100	226	888	243	1631	774	973	82	1	656
329-49	169	01/17/90	31.87	44.46	1416.78	91.87	13.54	1243.80	1250.40	88.26	31.52	35586900	225	888	242	1629	774	971	82	1	657
329-50	13	01/17/90	31.86	44.48	1417.16	91.62	13.54	1240.96	1247.56	88.03	31.15	35092000	261	885	242	1630	774	1008	82	1	658
329-50	26	01/17/90	31.86	44.46	1416.69	91.77	13.50	1238.63	1245.19	87.89	31.77	35395300	227	889	243	1631	774	970	83	1	659
329-50	39	01/17/90	31.86	44.52	1418.35	90.67	13.65	1237.95	1244.66	87.75	31.09	35623200	263	880	243	1637	777	1011	82	1	660
329-50	52	01/17/90	31.86	44.53	1418.55	91.18	13.62	1241.67	1248.35	88.00	31.23	35713900	263	882	243	1635	776	1009	83	1	661
329-50	65	01/17/90	31.85	44.54	1418.84	91.23	13.61	1241.17	1247.84	87.95	31.07	35111100	227	890	243	1637	776	972	83	1	662
329-50	78	01/17/90	31.85	44.47	1416.51	91.69	13.53	1240.95	1247.55	88.07	30.97	34956100	227	889	243	1634	775	971	82	1	663
329-50	91	01/17/90	31.86	44.48	1417.04	91.61	13.54	1240.38	1246.98	88.00	31.49	35746100	263	886	242	1633	776	1003	82	1	664
329-50	104	01/17/90	31.84	44.52	1417.57	91.60	13.58	1243.59	1250.22	88.20	31.50	36001800	264	886	242	1628	775	1005	82	1	665
329-50	117	01/17/90	31.84	44.54	1418.48	90.83	13.66	1240.61	1247.32	87.93	31.13	36013500	265	880	242	1635	777	1012	82	1	666
329-50	130	01/18/90	31.82	44.55	1417.81	91.63	13.57	1243.25	1249.87	88.16	31.50	35736000	224	888	242	1629	774	968	83	1	667
329-50	143	01/18/90	31.87	44.46	1416.72	91.62	13.53	1239.36	1245.95	87.95	31.74	35820000	223	887	241	1629	774	969	82	1	668

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
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329-50	156	01/18/90	60.5	40046.1	667.4	184.9	0.0000768	0.28	214.35	50.3	0.03708	134.7	96921	482.7	2.59	654897	2.282E+10
329-50	169	01/18/90	60.5	40106.7	668.4	184.7	0.0000771	0.28	214.63	50.4	0.03703	134.5	97056	480.0	2.79	653366	2.257E+10
329-50	182	01/18/90	60.5	40167.2	669.5	184.7	0.0000763	0.28	214.91	50.0	0.03676	133.5	97189	481.9	2.78	655360	2.314E+10
329-50	195	01/18/90	60.5	40227.8	670.5	184.7	0.0000757	0.28	215.18	49.9	0.03664	133.1	97322	484.0	2.94	659207	2.353E+10
329-51	13	01/18/90	60.5	40288.3	671.5	188.1	0.0000759	0.28	215.46	50.6	0.03698	134.3	97457	486.9	3.04	666237	2.384E+10
329-51	26	01/18/90	60.5	40348.9	672.5	188.1	0.0000765	0.27	215.74	50.5	0.03683	133.8	97590	481.7	2.84	660390	2.353E+10
329-51	39	01/18/90	60.5	40409.4	673.5	188.0	0.0000769	0.27	216.01	50.3	0.03683	133.8	97724	478.8	2.32	653994	2.328E+10
329-51	52	01/18/90	60.5	40470.0	674.5	187.9	0.0000764	0.28	216.29	50.4	0.03681	133.7	97858	482.0	2.35	659962	2.358E+10
329-51	65	01/18/90	60.5	40530.5	675.5	186.8	0.0000761	0.27	216.56	50.3	0.03682	133.8	97992	483.8	1.02	660920	2.357E+10
329-51	78	01/18/90	60.5	40591.1	676.5	185.7	0.0000765	0.28	216.84	50.3	0.03672	133.4	98125	480.1	2.48	657602	2.314E+10
329-51	91	01/18/90	60.5	40651.6	677.5	184.9	0.0000754	0.28	217.11	49.8	0.03653	132.7	98258	484.5	2.39	660486	2.376E+10
329-51	104	01/18/90	60.5	40712.2	678.5	184.4	0.0000753	0.28	217.39	50.0	0.03650	132.6	98390	484.8	2.84	664231	2.372E+10
329-51	117	01/18/90	60.5	40772.7	679.5	184.2	0.0000755	0.27	217.67	49.9	0.03644	132.4	98523	482.5	2.61	660796	2.355E+10
329-51	130	01/18/90	60.5	40833.3	680.6	184.0	0.0000753	0.27	217.94	49.8	0.03647	132.5	98655	484.5	2.74	661601	2.369E+10
329-51	143	01/19/90	60.5	40893.8	681.6	183.8	0.0000750	0.27	218.21	49.5	0.03646	132.5	98788	486.4	2.72	660308	2.390E+10
329-51	156	01/19/90	60.5	40954.4	682.6	183.8	0.0000747	0.27	218.49	49.5	0.03628	131.8	98920	485.5	2.59	662456	2.405E+10
329-51	169	01/19/90	60.5	41014.9	683.6	183.7	0.0000749	0.27	218.76	49.7	0.03628	131.8	99051	484.6	2.63	663817	2.391E+10
329-51	182	01/19/90	60.5	41075.4	684.6	183.6	0.0000756	0.27	219.03	49.8	0.03657	132.9	99184	483.6	2.70	658591	2.340E+10
329-51	195	01/19/90	60.5	41136.0	685.6	183.6	0.0000740	0.27	219.30	49.1	0.03602	130.9	99315	487.1	2.63	663881	2.459E+10
329-55	5	01/26/90	60.5	41196.5	686.6	186.5	0.0000827	0.31	219.60	52.8	0.03901	141.7	99457	471.4	2.87	638144	1.953E+10
329-55	10	01/26/90	60.5	41257.1	687.6	185.9	0.0000829	0.30	219.91	52.6	0.03890	141.3	99598	469.2	3.15	634476	1.939E+10
329-55	15	01/26/90	60.5	41317.6	688.6	185.6	0.0000822	0.30	220.21	52.6	0.03893	141.4	99740	473.6	2.98	639973	1.969E+10
329-55	20	01/26/90	60.6	41378.2	689.6	185.5	0.0000831	0.30	220.51	52.5	0.03890	141.3	99881	467.9	3.01	631473	1.924E+10
329-55	25	01/26/90	60.6	41438.7	690.6	185.4	0.0000823	0.30	220.81	52.6	0.03890	141.3	100022	472.6	3.07	638908	1.959E+10
329-55	30	01/27/90	60.6	41499.3	691.7	185.3	0.0000829	0.30	221.11	52.4	0.03892	141.4	100164	469.7	3.06	632438	1.936E+10
329-55	35	01/27/90	60.6	41559.8	692.7	185.2	0.0000823	0.30	221.41	52.5	0.03891	141.4	100305	472.8	3.00	637972	1.960E+10
329-55	40	01/27/90	60.6	41620.4	693.7	185.0	0.0000816	0.30	221.71	52.5	0.03885	141.1	100446	476.1	2.85	643445	1.990E+10
329-55	45	01/27/90	60.6	41680.9	694.7	184.9	0.0000816	0.30	222.01	52.5	0.03888	141.3	100587	476.5	3.03	643414	1.989E+10
329-55	50	01/27/90	60.5	41741.5	695.7	184.8	0.0000817	0.30	222.31	52.4	0.03886	141.2	100728	475.7	2.96	641465	1.984E+10
329-55	55	01/27/90	60.5	41802.0	696.7	184.7	0.0000830	0.30	222.61	52.4	0.03886	141.2	100870	468.1	2.94	631150	1.919E+10
329-55	60	01/27/90	60.5	41862.6	697.7	184.7	0.0000824	0.30	222.91	52.3	0.03887	141.2	101011	471.7	3.07	634647	1.950E+10
329-55	65	01/27/90	60.6	41923.1	698.7	184.7	0.0000826	0.30	223.21	52.4	0.03889	141.3	101152	470.7	2.94	634198	1.938E+10
329-55	70	01/27/90	60.6	41983.7	699.7	184.7	0.0000826	0.30	223.51	52.3	0.03884	141.1	101293	470.1	2.96	633057	1.940E+10
329-55	75	01/27/90	60.6	42044.2	700.7	184.9	0.0000824	0.30	223.81	52.3	0.03890	141.3	101435	472.2	2.85	634824	1.954E+10
329-55	80	01/27/90	60.6	42104.8	701.7	185.0	0.0000821	0.30	224.11	52.3	0.03891	141.4	101576	473.7	2.93	636811	1.967E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-50	156	01/18/90	31.85	44.50	1417.50	91.63	13.55	1241.82	1248.43	88.07	31.46	35651200	224	887	241	1631	775	967	82	1	669
329-50	169	01/18/90	31.83	44.55	1418.20	91.56	13.55	1240.33	1246.94	87.92	31.28	35454700	262	885	241	1630	775	1001	82	1	670
329-50	182	01/18/90	31.85	44.52	1418.13	91.18	13.62	1241.67	1248.35	88.03	31.15	35885700	263	885	241	1637	777	1006	82	1	671
329-50	195	01/18/90	31.85	44.57	1419.54	90.42	13.71	1239.98	1246.75	87.83	31.22	36119900	262	884	241	1640	778	1007	82	1	672
329-51	13	01/18/90	31.86	44.54	1419.21	90.50	13.67	1237.31	1244.04	87.66	31.77	35922100	262	887	241	1641	777	1008	82	1	673
329-51	26	01/18/90	31.89	44.52	1419.68	90.73	13.66	1239.47	1246.19	87.78	31.25	35739900	263	886	242	1639	777	1008	83	1	674
329-51	39	01/18/90	31.87	44.57	1420.42	90.31	13.71	1237.89	1244.66	87.63	31.10	35489200	264	884	243	1642	778	1012	83	1	675
329-51	52	01/18/90	31.87	44.55	1419.90	90.46	13.71	1240.28	1247.04	87.83	31.23	35810800	265	887	243	1639	777	1009	83	1	676
329-51	65	01/18/90	31.86	44.60	1421.11	90.95	13.69	1244.81	1251.55	88.07	31.24	36065500	265	887	244	1637	777	1007	83	1	677
329-51	78	01/18/90	31.87	44.58	1420.85	90.35	13.72	1240.06	1246.84	87.75	31.03	35747400	265	887	243	1640	778	1005	83	1	678
329-51	91	01/18/90	31.87	44.58	1420.96	90.21	13.73	1238.58	1245.37	87.64	31.20	36221600	265	883	242	1640	778	1009	83	1	679
329-51	104	01/18/90	31.84	44.64	1421.43	89.79	13.80	1239.24	1246.10	87.67	31.17	36300700	265	883	243	1648	780	1006	83	1	680
329-51	117	01/18/90	31.84	44.61	1420.41	89.52	13.82	1237.51	1244.39	87.61	31.02	36134400	265	883	242	1648	780	1007	83	1	681
329-51	130	01/18/90	31.85	44.58	1420.07	89.95	13.76	1237.88	1244.70	87.65	31.17	36262100	265	882	242	1646	780	1006	83	1	682
329-51	143	01/19/90	31.85	44.62	1421.16	90.27	13.73	1239.79	1246.58	87.72	31.23	36466800	265	881	242	1642	779	1008	83	1	683
329-51	156	01/19/90	31.85	44.64	1421.98	89.70	13.82	1239.75	1246.62	87.67	31.02	36584200	265	880	242	1649	781	1008	83	1	684
329-51	169	01/19/90	31.85	44.65	1421.92	89.44	13.86	1239.69	1246.60	87.67	30.96	36510300	264	881	242	1653	782	1007	83	1	685
329-51	182	01/19/90	31.86	44.59	1420.74	90.57	13.68	1239.42	1246.17	87.71	31.15	36142000	264	885	242	1642	779	1001	83	1	686
329-51	195	01/19/90	31.85	44.68	1422.88	89.13	13.90	1238.92	1245.88	87.56	30.92	36937100	265	879	242	1657	783	1008	83	1	687
329-55	5	01/26/90	31.81	44.29	1408.90	95.12	13.00	1236.22	1242.30	88.18	32.47	32944700	197	945	254	1623	616	1010	78	1	688
329-55	10	01/26/90	31.84	44.29	1409.88	95.14	13.02	1239.05	1245.15	88.32	32.15	32955300	201	951	254	1622	615	1219	79	1	689
329-55	15	01/26/90	31.84	44.33	1411.59	94.75	13.08	1239.58	1245.74	88.25	32.47	33255100	199	949	255	1623	615	1048	79	1	690
329-55	20	01/26/90	31.83	44.36	1412.30	94.56	13.13	1241.09	1247.30	88.32	32.02	32916100	199	947	254	1619	614	1037	79	1	691
329-55	25	01/26/90	31.87	44.30	1411.84	94.59	13.12	1240.57	1246.77	88.31	32.35	33226600	199	947	254	1620	615	1036	79	1	692
329-55	30	01/27/90	31.85	44.29	1410.56	94.69	13.10	1240.06	1246.24	88.35	32.18	33002100	198	946	254	1613	614	1034	79	1	693
329-55	35	01/27/90	31.84	44.34	1411.91	94.27	13.15	1239.72	1245.95	88.25	32.39	33218300	198	947	254	1612	614	1031	79	1	694
329-55	40	01/27/90	31.86	44.37	1413.69	94.03	13.19	1240.20	1246.46	88.17	32.56	33516200	200	951	254	1616	616	1219	79	1	695
329-55	45	01/27/90	31.85	44.37	1413.25	94.19	13.18	1240.98	1247.23	88.25	32.58	33535400	199	956	254	1614	616	1083	80	1	696
329-55	50	01/27/90	31.86	44.33	1412.28	94.35	13.17	1242.65	1248.89	88.43	32.48	33542600	198	946	253	1613	616	1046	79	1	697
329-55	55	01/27/90	31.82	44.37	1412.16	94.35	13.14	1239.78	1246.00	88.23	32.03	32927100	198	944	254	1613	616	1043	80	1	698
329-55	60	01/27/90	31.87	44.23	1409.61	94.70	13.10	1240.61	1246.79	88.45	32.27	33195100	197	947	253	1606	615	1042	79	1	699
329-55	65	01/27/90	31.86	44.29	1410.98	94.72	13.13	1243.56	1249.77	88.57	32.13	33187200	197	948	253	1607	615	1043	79	1	700
329-55	70	01/27/90	31.84	44.20	1407.37	95.23	13.01	1239.43	1245.53	88.50	32.15	33080400	199	951	253	1602	615	1219	79	1	701
329-55	75	01/27/90	31.86	44.21	1408.32	95.52	12.98	1239.96	1246.03	88.48	32.34	33187000	199	951	253	1598	615	1219	79	1	702
329-55	80	01/27/90	31.87	44.19	1408.24	94.99	13.05	1240.10	1246.24	88.50	32.45	33294700	199	944	253	1600	614	1062	79	1	703

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
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329-55	85	01/27/90	60.6	42165.3	702.8	185.1	0.0000812	0.30	224.40	52.3	0.03884	141.1	101717	478.4	2.95	644239	2.015E+10
329-55	90	01/27/90	60.6	42225.9	703.8	185.0	0.0000821	0.29	224.70	52.3	0.03884	141.1	101858	472.9	2.81	636881	1.968E+10
329-55	95	01/27/90	60.6	42286.4	704.8	185.1	0.0000830	0.30	225.00	52.3	0.03879	140.9	101999	467.5	3.01	630371	1.929E+10
329-55	100	01/27/90	60.6	42347.0	705.8	185.0	0.0000819	0.30	225.30	52.4	0.03881	141.0	102140	473.9	3.18	639922	1.978E+10
329-55	105	01/27/90	60.6	42407.5	706.8	185.0	0.0000821	0.30	225.60	52.3	0.03884	141.1	102281	473.3	3.00	637393	1.971E+10
329-55	110	01/28/90	60.6	42468.1	707.8	184.9	0.0000821	0.30	225.90	52.2	0.03877	140.9	102422	472.4	2.98	635988	1.970E+10
329-55	115	01/28/90	60.6	42528.6	708.8	184.8	0.0000827	0.30	226.20	52.2	0.03880	141.0	102563	469.3	3.01	631373	1.940E+10
329-55	128	01/28/90	60.5	42589.2	709.8	184.8	0.0000826	0.31	226.50	52.4	0.03892	141.4	102704	471.4	2.91	634705	1.943E+10
329-55	141	01/28/90	60.5	42649.7	710.8	184.7	0.0000821	0.30	226.80	52.3	0.03890	141.3	102846	474.0	3.03	637261	1.966E+10
329-55	154	01/28/90	60.5	42710.3	711.8	184.7	0.0000820	0.30	227.10	52.3	0.03890	141.3	102987	474.4	3.06	637859	1.969E+10
329-55	167	01/28/90	60.5	42770.8	712.8	184.8	0.0000825	0.30	227.40	52.3	0.03883	141.1	103128	470.9	2.99	634247	1.949E+10
329-55	180	01/28/90	60.5	42831.4	713.9	184.7	0.0000823	0.30	227.70	52.2	0.03886	141.1	103269	472.4	3.28	634650	1.959E+10
329-55	193	01/28/90	60.5	42891.9	714.9	184.7	0.0000822	0.30	227.99	52.3	0.03884	141.1	103410	472.3	3.01	635882	1.957E+10
329-55	206	01/28/90	60.5	42952.5	715.9	184.6	0.0000824	0.30	228.29	52.3	0.03885	141.1	103551	471.6	2.97	634871	1.950E+10
329-55	219	01/28/90	60.5	43013.0	716.9	184.7	0.0000820	0.30	228.59	52.2	0.03887	141.2	103693	474.1	3.08	636764	1.972E+10
329-55	232	01/29/90	60.5	43073.6	717.9	184.7	0.0000827	0.30	228.89	52.2	0.03880	141.0	103834	469.2	3.04	631174	1.937E+10
329-55	245	01/29/90	60.5	43134.1	718.9	184.6	0.0000817	0.30	229.19	52.2	0.03883	141.1	103975	475.3	3.00	638931	1.984E+10
329-55	258	01/29/90	60.5	43194.6	719.9	184.5	0.0000819	0.30	229.49	52.2	0.03878	140.8	104116	473.5	2.96	637332	1.972E+10
329-55	271	01/29/90	60.5	43255.2	720.9	184.3	0.0000822	0.30	229.79	52.2	0.03875	140.7	104256	471.2	3.01	634735	1.953E+10
329-55	284	01/29/90	60.5	43315.7	721.9	184.1	0.0000816	0.30	230.09	52.1	0.03869	140.6	104397	474.3	3.01	638606	1.983E+10
329-55	297	01/29/90	60.5	43376.3	722.9	171.7	0.0000780	0.28	230.37	50.8	0.03775	137.1	104534	484.1	2.92	651382	1.988E+10
329-55	310	01/29/90	60.5	43436.8	723.9	171.7	0.0000783	0.28	230.65	50.8	0.03774	137.1	104671	482.2	3.05	649044	1.974E+10
329-55	323	01/29/90	60.5	43497.4	725.0	171.6	0.0000784	0.28	230.94	50.8	0.03779	137.3	104808	481.9	3.05	647819	1.964E+10
329-55	336	01/29/90	60.5	43557.9	726.0	171.6	0.0000779	0.29	231.22	50.8	0.03775	137.1	104946	484.3	3.02	651775	1.989E+10
329-55	349	01/29/90	60.5	43618.5	727.0	171.6	0.0000781	0.28	231.50	50.8	0.03775	137.1	105083	483.4	3.15	650490	1.981E+10
329-55	362	01/29/90	60.5	43679.0	728.0	171.6	0.0000782	0.29	231.79	50.8	0.03778	137.3	105220	483.1	3.01	649533	1.975E+10
329-55	375	01/29/90	60.5	43739.6	729.0	171.5	0.0000786	0.28	232.07	50.7	0.03772	137.0	105357	480.3	3.09	645441	1.958E+10
329-55	388	01/29/90	60.5	43800.1	730.0	171.1	0.0000787	0.29	232.36	50.8	0.03769	136.9	105494	478.8	3.02	645374	1.942E+10
329-55	401	01/29/90	60.5	43860.6	731.0	170.9	0.0000780	0.29	232.65	50.8	0.03766	136.8	105631	483.1	2.98	651666	1.976E+10
329-55	414	01/29/90	60.5	43921.2	732.0	170.7	0.0000785	0.29	232.93	50.7	0.03758	136.5	105767	478.9	3.00	646156	1.949E+10
329-55	427	01/29/90	60.5	43981.7	733.0	170.6	0.0000778	0.29	233.22	50.7	0.03765	136.8	105904	484.0	3.00	651780	1.982E+10
329-55	440	01/30/90	60.5	44042.3	734.0	170.6	0.0000774	0.28	233.50	50.7	0.03764	136.7	106041	486.1	2.98	654726	2.000E+10
329-55	453	01/30/90	60.5	44102.8	735.0	170.6	0.0000778	0.28	233.78	50.8	0.03757	136.5	106177	483.2	2.97	653368	1.982E+10
329-55	466	01/30/90	60.5	44163.4	736.1	170.5	0.0000773	0.28	234.07	50.7	0.03759	136.6	106314	486.1	3.02	655564	2.003E+10
329-55	479	01/30/90	60.5	44223.9	737.1	170.5	0.0000779	0.28	234.35	50.8	0.03753	136.3	106450	482.0	2.85	652386	1.974E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-55	85	01/27/90	31.83	44.24	1408.22	95.07	13.02	1238.21	1244.32	88.36	32.76	33631800	199	947	254	1601	615	1048	79	1	704
329-55	90	01/27/90	31.85	44.23	1408.84	95.27	12.99	1237.24	1243.31	88.25	32.41	33221300	198	944	254	1600	614	1069	79	1	705
329-55	95	01/27/90	31.86	44.24	1409.43	94.73	13.10	1240.68	1246.85	88.47	31.91	32973100	199	946	254	1604	615	1084	79	1	706
329-55	100	01/27/90	31.85	44.26	1409.66	94.87	13.08	1240.93	1247.09	88.47	32.36	33415800	200	949	255	1603	615	1038	80	1	707
329-55	105	01/27/90	31.85	44.19	1407.28	95.30	13.01	1239.44	1245.53	88.51	32.37	33307300	198	944	254	1596	613	1062	79	1	708
329-55	110	01/28/90	31.86	44.15	1406.71	95.86	12.92	1238.58	1244.59	88.48	32.28	33274700	202	951	253	1595	613	1225	79	1	709
329-55	115	01/28/90	31.85	44.24	1409.05	95.20	13.06	1242.82	1248.96	88.64	31.99	33145900	200	943	253	1599	613	1057	79	1	710
329-55	128	01/28/90	31.84	44.23	1408.35	95.16	13.02	1238.67	1244.77	88.39	32.33	33083100	195	942	250	1594	612	1036	78	1	711
329-55	141	01/28/90	31.87	44.21	1409.00	95.21	13.02	1239.56	1245.66	88.41	32.48	33303700	196	946	252	1595	612	1044	79	1	712
329-55	154	01/28/90	31.86	44.23	1409.07	95.45	13.01	1241.99	1248.09	88.58	32.43	33400300	197	945	252	1594	612	1054	79	1	713
329-55	167	01/28/90	31.84	44.30	1410.46	95.03	13.07	1242.36	1248.51	88.52	32.13	33221000	197	945	252	1595	613	1030	79	1	714
329-55	180	01/28/90	31.86	44.22	1408.79	95.53	12.96	1238.35	1244.40	88.33	32.36	33198400	197	944	252	1591	612	1037	79	1	715
329-55	193	01/28/90	31.86	44.27	1410.48	95.47	12.99	1239.79	1245.86	88.33	32.30	33237900	198	944	252	1592	612	1037	79	1	716
329-55	206	01/28/90	31.86	44.28	1410.65	95.41	13.00	1240.30	1246.38	88.36	32.25	33198700	197	941	252	1593	612	1032	79	1	717
329-55	219	01/28/90	31.85	44.33	1412.06	95.40	13.02	1242.20	1248.30	88.40	32.39	33412600	198	944	253	1590	612	1035	79	1	718
329-55	232	01/29/90	31.85	44.29	1410.71	95.99	12.92	1240.27	1246.28	88.34	32.04	33067600	201	950	252	1589	613	1230	80	1	719
329-55	245	01/29/90	31.87	44.25	1410.23	95.43	13.02	1242.34	1248.44	88.53	32.44	33529800	199	944	253	1591	613	1042	79	1	720
329-55	258	01/29/90	31.83	44.26	1408.87	95.41	13.01	1241.40	1247.50	88.55	32.29	33420500	200	941	253	1591	613	1049	79	1	721
329-55	271	01/29/90	31.84	44.27	1409.51	95.68	12.97	1241.28	1247.34	88.50	32.11	33281200	200	943	253	1593	613	1045	79	1	722
329-55	284	01/29/90	31.84	44.23	1408.44	95.81	12.90	1235.54	1241.53	88.15	32.42	33393500	200	949	253	1589	613	1229	79	1	723
329-55	297	01/29/90	31.82	44.51	1416.55	92.88	13.36	1240.98	1247.40	88.06	32.15	35086900	200	934	254	1619	618	1052	79	1	724
329-55	310	01/29/90	31.84	44.51	1416.91	92.96	13.35	1241.17	1247.58	88.05	32.00	34966000	199	939	254	1617	618	1040	80	1	725
329-55	323	01/29/90	31.84	44.52	1417.24	93.25	13.33	1242.79	1249.19	88.14	31.99	34946200	199	940	253	1618	618	1044	80	1	726
329-55	336	01/29/90	31.85	44.55	1418.73	93.06	13.33	1240.40	1246.79	87.88	32.17	35091500	202	943	253	1616	618	1230	80	1	727
329-55	349	01/29/90	31.87	44.46	1416.92	92.91	13.35	1240.18	1246.59	87.98	32.12	35016400	198	935	253	1616	617	1043	80	1	728
329-55	362	01/29/90	31.85	44.46	1416.29	93.12	13.35	1243.28	1249.70	88.24	32.05	35052200	198	935	253	1615	617	1040	80	1	729
329-55	375	01/29/90	31.83	44.54	1417.41	93.04	13.32	1239.46	1245.85	87.90	31.91	34792900	198	934	253	1616	618	1038	80	1	730
329-55	388	01/29/90	31.86	44.57	1420.11	92.46	13.42	1241.15	1247.64	87.86	31.74	34768000	199	935	253	1618	618	1049	80	1	731
329-55	401	01/29/90	31.84	44.56	1418.66	92.41	13.41	1239.21	1245.68	87.81	32.05	35051900	199	935	253	1617	618	1052	80	1	732
329-55	414	01/29/90	31.84	44.61	1420.58	92.69	13.37	1239.17	1245.60	87.68	31.71	34823300	203	942	253	1616	619	1232	80	1	733
329-55	427	01/29/90	31.85	44.57	1419.66	92.17	13.46	1240.64	1247.16	87.85	32.06	35167800	199	935	253	1618	618	1054	81	1	734
329-55	440	01/30/90	31.87	44.47	1417.14	92.67	13.40	1241.96	1248.43	88.10	32.16	35364600	198	936	253	1617	618	1048	80	1	735
329-55	453	01/30/90	31.84	44.49	1416.71	91.86	13.47	1237.41	1243.94	87.81	32.02	35092300	199	938	253	1624	620	1040	80	1	736
329-55	466	01/30/90	31.87	44.54	1419.35	92.32	13.42	1238.74	1245.22	87.73	32.20	35318100	204	941	254	1620	620	1237	81	1	737
329-55	479	01/30/90	31.85	44.53	1418.38	91.92	13.47	1238.51	1245.04	87.78	31.89	35071000	199	939	254	1624	620	1047	81	1	738

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/ LBM)	(Pf-Pc)/Flow² (PSI-SEC²/ LBM²)
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329-55	492	01/30/90	60.5	44284.5	738.1	170.5	0.0000780	0.28	234.63	50.7	0.03759	136.6	106587	481.8	2.95	649933	1.969E+10
329-56	5	01/30/90	60.6	44345.0	739.1	173.6	0.0000786	0.28	234.91	51.0	0.03767	136.9	106724	479.3	3.02	648946	1.985E+10
329-56	10	01/30/90	60.6	44405.6	740.1	173.5	0.0000786	0.29	235.20	50.9	0.03774	137.1	106861	480.0	3.07	647484	1.984E+10
329-56	15	01/30/90	60.6	44466.1	741.1	173.5	0.0000785	0.29	235.49	50.9	0.03773	137.1	106998	480.5	2.99	648135	1.988E+10
329-56	20	01/30/90	60.5	44526.7	742.1	173.7	0.0000787	0.28	235.77	51.0	0.03766	136.8	107134	478.5	3.01	648080	1.981E+10
329-56	25	01/30/90	60.6	44587.2	743.1	173.8	0.0000784	0.28	236.06	51.1	0.03764	136.7	107271	480.0	3.01	651761	1.996E+10
329-56	30	01/30/90	60.6	44647.8	744.1	172.3	0.0000781	0.28	236.34	50.9	0.03754	136.4	107408	480.7	3.01	651729	1.990E+10
329-56	35	01/30/90	60.6	44708.3	745.1	171.9	0.0000776	0.28	236.62	50.8	0.03748	136.2	107544	483.1	3.10	654884	2.013E+10
329-56	40	01/30/90	60.6	44768.9	746.1	171.4	0.0000774	0.28	236.90	50.8	0.03743	136.0	107680	483.5	3.11	656085	2.012E+10
329-56	45	01/30/90	60.6	44829.4	747.2	171.2	0.0000779	0.28	237.19	50.7	0.03741	135.9	107816	480.1	2.83	650743	1.985E+10
329-56	50	01/30/90	60.6	44890.0	748.2	170.9	0.0000769	0.28	237.47	50.6	0.03744	136.0	107952	486.8	3.02	657895	2.034E+10
329-56	55	01/30/90	60.6	44950.5	749.2	170.7	0.0000774	0.28	237.74	50.6	0.03745	136.1	108088	483.7	3.12	653485	2.003E+10
329-56	60	01/31/90	60.6	45011.1	750.2	170.6	0.0000764	0.28	238.02	50.6	0.03745	136.1	108224	489.9	2.96	661888	2.053E+10
329-56	65	01/31/90	60.5	45071.6	751.2	170.4	0.0000775	0.28	238.30	50.6	0.03738	135.8	108360	482.3	2.96	652777	1.994E+10
329-56	70	01/31/90	60.5	45132.1	752.2	170.3	0.0000772	0.28	238.58	50.6	0.03745	136.0	108496	485.1	2.98	655339	2.008E+10
329-56	75	01/31/90	60.6	45192.7	753.2	170.1	0.0000775	0.28	238.86	50.5	0.03740	135.9	108631	482.8	2.98	651882	1.993E+10
329-56	80	01/31/90	60.6	45253.2	754.2	170.1	0.0000772	0.28	239.14	50.6	0.03732	135.6	108767	483.6	2.98	655619	2.006E+10
329-56	85	01/31/90	60.6	45313.8	755.2	170.2	0.0000770	0.28	239.42	50.6	0.03735	135.7	108903	485.3	2.91	657510	2.019E+10
329-56	90	01/31/90	60.6	45374.3	756.2	170.3	0.0000773	0.28	239.70	50.5	0.03739	135.8	109039	483.7	2.65	653290	2.005E+10
329-56	95	01/31/90	60.6	45434.9	757.2	170.3	0.0000766	0.28	239.98	50.6	0.03745	136.1	109175	488.9	2.72	660566	2.040E+10
329-56	100	01/31/90	60.6	45495.4	758.3	170.5	0.0000770	0.28	240.26	50.6	0.03739	135.8	109310	485.6	2.70	657254	2.023E+10
329-59	13	01/31/90	60.5	45556.0	759.3	169.1	0.0000772	0.28	240.54	50.5	0.03736	135.7	109446	483.8	2.69	654010	1.989E+10
329-59	26	01/31/90	60.5	45616.5	760.3	168.5	0.0000760	0.28	240.82	50.4	0.03735	135.7	109582	491.7	2.69	663568	2.047E+10
329-59	39	01/31/90	60.5	45677.1	761.3	168.1	0.0000769	0.28	241.10	50.3	0.03725	135.3	109717	484.7	2.66	654488	1.994E+10
329-59	52	01/31/90	60.5	45737.6	762.3	167.8	0.0000762	0.28	241.38	50.3	0.03720	135.1	109852	488.3	2.81	660192	2.024E+10
329-59	65	01/31/90	60.5	45798.2	763.3	167.6	0.0000764	0.28	241.66	50.3	0.03727	135.4	109988	487.7	2.58	658205	2.009E+10
329-59	78	02/01/90	60.5	45858.7	764.3	167.4	0.0000766	0.28	241.93	50.3	0.03723	135.3	110123	485.9	2.83	656495	1.995E+10
329-59	91	02/01/90	60.5	45919.3	765.3	167.4	0.0000769	0.28	242.21	50.3	0.03718	135.1	110258	483.4	2.63	653977	1.979E+10
329-59	104	02/01/90	60.5	45979.8	766.3	167.2	0.0000761	0.28	242.49	50.3	0.03714	134.9	110393	488.0	2.78	661007	2.019E+10
329-59	117	02/01/90	60.5	46040.4	767.3	167.3	0.0000763	0.28	242.77	50.3	0.03720	135.1	110528	487.8	2.82	659620	2.012E+10
329-59	130	02/01/90	60.5	46100.9	768.3	167.3	0.0000763	0.27	243.04	50.3	0.03717	135.0	110663	487.1	2.75	659153	2.009E+10
329-59	143	02/01/90	60.5	46161.5	769.4	167.4	0.0000764	0.28	243.32	50.3	0.03714	134.9	110798	486.0	2.69	658299	2.006E+10
329-59	156	02/01/90	60.5	46222.0	770.4	167.4	0.0000761	0.28	243.59	50.3	0.03715	135.0	110933	488.4	1.83	661250	2.024E+10
329-59	169	02/01/90	60.5	46282.6	771.4	171.8	0.0000777	0.28	243.88	50.8	0.03755	136.4	111070	483.5	1.71	654049	2.006E+10
329-59	182	02/01/90	60.5	46343.1	772.4	171.7	0.0000776	0.28	244.16	50.7	0.03755	136.4	111206	483.7	1.75	653064	2.008E+10

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RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-55	492	01/30/90	31.87	44.50	1418.05	92.02	13.44	1237.12	1243.63	87.70	31.96	34968900	200	935	254	1622	619	1039	81	1	739
329-56	5	01/30/90	31.83	44.51	1416.45	92.65	13.36	1237.51	1243.93	87.82	31.85	34721300	204	942	254	1616	619	1238	80	1	740
329-56	10	01/30/90	31.88	44.49	1418.01	92.34	13.45	1241.65	1248.16	88.02	31.85	34827100	199	936	254	1614	619	1043	80	1	741
329-56	15	01/30/90	31.85	44.50	1417.32	92.41	13.40	1237.97	1244.43	87.80	31.97	34759000	200	934	254	1616	619	1036	81	1	742
329-56	20	01/30/90	31.85	44.49	1416.98	92.21	13.39	1234.93	1241.39	87.61	31.85	34602700	204	941	254	1617	620	1242	81	1	743
329-56	25	01/30/90	31.85	44.53	1418.14	91.76	13.47	1236.15	1242.68	87.63	31.90	34765400	200	934	255	1626	621	1033	81	1	744
329-56	30	01/30/90	31.86	44.54	1419.14	91.65	13.47	1234.71	1241.24	87.46	31.91	34859700	201	934	255	1624	621	1048	80	1	745
329-56	35	01/30/90	31.84	44.54	1418.15	91.44	13.49	1233.73	1240.28	87.46	32.04	35069200	201	935	255	1623	621	1033	81	1	746
329-56	40	01/30/90	31.86	44.53	1418.68	91.70	13.48	1236.18	1242.72	87.60	31.96	35203400	201	934	255	1623	621	1033	81	1	747
329-56	45	01/30/90	31.85	44.54	1418.71	91.82	13.49	1238.20	1244.74	87.74	31.67	35042800	206	939	255	1620	622	1244	81	1	748
329-56	50	01/30/90	31.87	44.45	1416.68	91.95	13.43	1234.81	1241.30	87.62	32.22	35401100	201	934	254	1617	620	1038	81	1	749
329-56	55	01/30/90	31.86	44.51	1418.22	92.16	13.43	1238.08	1244.58	87.76	31.94	35256600	201	933	254	1617	620	1049	81	1	750
329-56	60	01/31/90	31.87	44.51	1418.40	92.22	13.44	1239.78	1246.28	87.87	32.30	35759200	201	934	254	1615	620	1041	81	1	751
329-56	65	01/31/90	31.87	44.42	1415.76	92.23	13.40	1235.56	1242.02	87.73	31.86	35147000	205	938	254	1615	621	1244	81	1	752
329-56	70	01/31/90	31.84	44.59	1419.38	91.88	13.48	1238.75	1245.30	87.74	32.01	35375900	201	935	254	1616	621	1047	81	1	753
329-56	75	01/31/90	31.84	44.49	1416.39	92.21	13.41	1236.92	1243.40	87.79	31.86	35206900	201	932	254	1615	620	1041	81	1	754
329-56	80	01/31/90	31.83	44.59	1419.19	91.63	13.48	1235.40	1241.95	87.51	31.89	35295200	201	934	254	1619	621	1037	81	1	755
329-56	85	01/31/90	31.85	44.75	1425.37	91.88	13.45	1235.99	1242.51	87.17	32.02	35414000	205	937	254	1617	622	1246	81	1	756
329-56	90	01/31/90	31.86	44.85	1429.02	91.96	13.43	1235.27	1241.76	86.90	31.96	35236000	200	931	254	1614	621	1036	82	1	757
329-56	95	01/31/90	31.82	44.85	1426.93	91.72	13.49	1237.47	1244.02	87.18	32.30	35620900	200	933	254	1618	621	1041	82	1	758
329-56	100	01/31/90	31.85	44.76	1425.66	92.01	13.45	1237.26	1243.77	87.24	32.04	35436500	202	936	254	1616	622	1205	82	1	759
329-59	13	01/31/90	31.86	44.50	1417.83	91.92	13.44	1235.37	1241.87	87.59	31.94	35277500	199	931	252	1615	621	1023	80	1	760
329-59	26	01/31/90	31.82	44.73	1423.51	91.91	13.42	1233.64	1240.13	87.12	32.50	35813800	200	933	254	1614	621	1015	81	1	761
329-59	39	01/31/90	31.86	44.70	1423.98	91.67	13.49	1237.13	1243.69	87.34	31.87	35494100	200	932	254	1617	622	1031	81	1	762
329-59	52	01/31/90	31.84	44.66	1421.79	91.94	13.43	1234.86	1241.36	87.31	32.11	35738000	204	936	253	1614	622	1245	81	1	763
329-59	65	01/31/90	31.85	44.54	1418.58	91.90	13.45	1236.39	1242.91	87.62	32.09	35674500	200	931	253	1613	622	1021	81	1	764
329-59	78	02/01/90	31.87	44.48	1417.70	92.13	13.42	1236.61	1243.10	87.68	31.93	35588100	199	929	252	1614	622	1025	80	1	765
329-59	91	02/01/90	31.86	44.56	1419.74	91.49	13.51	1235.92	1242.49	87.52	31.75	35431900	199	932	253	1616	622	1023	80	1	766
329-59	104	02/01/90	31.85	44.53	1418.03	91.83	13.45	1234.90	1241.41	87.55	32.04	35783100	203	935	252	1613	623	1245	80	1	767
329-59	117	02/01/90	31.87	44.52	1419.12	91.72	13.50	1238.43	1245.00	87.73	31.99	35810200	198	930	253	1616	622	1018	80	1	768
329-59	130	02/01/90	31.87	44.53	1418.91	91.44	13.50	1234.53	1241.09	87.47	32.02	35671900	199	931	253	1617	623	1033	80	1	769
329-59	143	02/01/90	31.85	44.49	1417.11	91.82	13.44	1234.41	1240.91	87.57	31.92	35622600	202	934	253	1614	623	1192	80	1	770
329-59	156	02/01/90	31.87	44.49	1418.11	91.57	13.47	1233.72	1240.26	87.46	32.11	35762100	198	929	253	1613	622	1037	80	1	771
329-59	169	02/01/90	31.87	44.38	1414.64	92.58	13.31	1232.22	1238.60	87.56	32.17	34981900	200	932	252	1603	620	1036	79	1	772
329-59	182	02/01/90	31.87	44.45	1416.64	92.29	13.37	1234.29	1240.73	87.58	32.12	35056900	200	932	252	1603	620	1026	80	1	773

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
329-60	5	02/01/90	60.6	46403.7	773.4	171.6	0.0000778	0.28	244.44	50.8	0.03752	136.3	111342	482.2	1.78	652981	1.996E+10
329-60	10	02/01/90	60.6	46464.2	774.4	170.4	0.0000767	0.28	244.72	50.6	0.03737	135.8	111478	487.0	1.92	659309	2.034E+10
329-60	15	02/01/90	60.6	46524.8	775.4	170.4	0.0000775	0.28	245.00	50.6	0.03743	136.0	111614	483.2	1.70	653139	1.996E+10
329-60	20	02/01/90	60.6	46585.3	776.4	170.2	0.0000773	0.28	245.28	50.6	0.03741	135.9	111750	484.1	1.86	654923	2.004E+10
329-60	25	02/01/90	60.5	46645.9	777.4	170.1	0.0000771	0.28	245.56	50.6	0.03735	135.7	111886	484.6	1.90	656427	2.011E+10
329-60	30	02/01/90	60.6	46706.4	778.4	170.1	0.0000767	0.28	245.84	50.6	0.03734	135.7	112021	486.9	1.89	659782	2.032E+10
329-60	35	02/01/90	60.6	46767.0	779.4	170.0	0.0000772	0.28	246.12	50.5	0.03742	135.9	112157	484.9	1.77	654365	2.006E+10
329-60	40	02/02/90	60.6	46827.5	780.5	170.0	0.0000776	0.28	246.41	50.6	0.03744	136.0	112293	482.4	1.74	652079	1.983E+10
329-60	45	02/02/90	60.6	46888.1	781.5	169.9	0.0000768	0.28	246.69	50.5	0.03739	135.9	112429	486.8	1.71	657432	2.024E+10
329-60	50	02/02/90	60.6	46948.6	782.5	170.0	0.0000778	0.28	246.97	50.5	0.03743	136.0	112565	481.3	1.69	649367	1.976E+10
329-60	55	02/02/90	60.6	47009.2	783.5	169.9	0.0000759	0.28	247.25	50.5	0.03742	135.9	112701	492.9	1.76	665191	2.072E+10
329-60	60	02/02/90	60.6	47069.7	784.5	169.9	0.0000773	0.28	247.53	50.5	0.03740	135.9	112837	483.8	1.73	653223	1.998E+10
329-60	73	02/02/90	60.5	47130.3	785.5	169.9	0.0000776	0.28	247.81	50.5	0.03731	135.5	112972	480.7	1.82	650513	1.981E+10
329-61	13	02/02/90	60.5	47190.8	786.5	173.6	0.0000779	0.28	248.10	51.0	0.03777	137.2	113110	484.8	1.75	654526	2.019E+10
329-61	26	02/02/90	60.5	47251.4	787.5	173.1	0.0000782	0.28	248.38	50.8	0.03772	137.0	113247	482.2	1.75	649392	1.999E+10
329-61	39	02/02/90	60.5	47311.9	788.5	173.1	0.0000782	0.29	248.66	50.8	0.03768	136.9	113384	481.6	1.69	649317	1.998E+10
329-61	52	02/02/90	60.5	47372.5	789.5	173.1	0.0000778	0.29	248.95	50.8	0.03763	136.7	113520	483.7	1.70	653023	2.021E+10
329-61	65	02/02/90	60.5	47433.0	790.6	170.9	0.0000773	0.28	249.23	50.6	0.03748	136.2	113656	484.8	1.81	654576	2.013E+10
329-61	78	02/02/90	60.5	47493.6	791.6	170.2	0.0000771	0.28	249.51	50.5	0.03744	136.0	113792	485.5	1.84	654841	2.013E+10
329-61	91	02/02/90	60.5	47554.1	792.6	170.1	0.0000774	0.28	249.79	50.4	0.03743	136.0	113928	483.5	1.71	651020	1.997E+10
329-61	104	02/02/90	60.5	47614.7	793.6	170.1	0.0000768	0.28	250.07	50.5	0.03743	136.0	114064	487.6	1.71	657886	2.030E+10
329-61	117	02/02/90	60.5	47675.2	794.6	170.1	0.0000769	0.28	250.35	50.5	0.03739	135.8	114200	485.9	1.82	656330	2.020E+10
329-61	130	02/02/90	60.5	47735.8	795.6	170.1	0.0000770	0.28	250.63	50.4	0.03736	135.7	114336	485.4	1.78	654869	2.021E+10
329-61	143	02/03/90	60.5	47796.3	796.6	170.0	0.0000773	0.28	250.91	50.4	0.03740	135.9	114472	483.8	1.79	651938	2.001E+10
329-61	156	02/03/90	60.5	47856.9	797.6	169.8	0.0000764	0.28	251.19	50.4	0.03735	135.7	114608	489.0	1.72	659902	2.047E+10
329-61	169	02/03/90	60.5	47917.4	798.6	169.9	0.0000767	0.28	251.47	50.4	0.03733	135.6	114743	486.8	1.78	657251	2.032E+10
329-61	182	02/03/90	60.5	47978.0	799.6	169.9	0.0000767	0.28	251.75	50.5	0.03733	135.6	114879	486.6	1.88	658298	2.029E+10
329-61	195	02/03/90	60.5	48038.5	800.6	169.9	0.0000764	0.28	252.03	50.5	0.03728	135.4	115014	488.2	1.82	661246	2.047E+10
329-61	208	02/03/90	60.5	48099.1	801.7	169.8	0.0000763	0.28	252.31	50.5	0.03732	135.6	115150	489.3	1.74	662156	2.051E+10
329-61	221	02/03/90	60.5	48159.6	802.7	169.8	0.0000769	0.28	252.58	50.5	0.03728	135.4	115285	484.8	1.78	656791	2.018E+10
329-61	234	02/03/90	60.5	48220.2	803.7	169.7	0.0000771	0.28	252.86	50.5	0.03720	135.1	115420	482.8	1.68	655410	2.008E+10
329-61	247	02/03/90	60.5	48280.7	804.7	169.7	0.0000768	0.28	253.14	50.6	0.03722	135.2	115556	484.3	1.75	658434	2.017E+10
329-61	260	02/03/90	60.5	48341.3	805.7	169.5	0.0000765	0.28	253.42	50.4	0.03725	135.3	115691	486.9	1.74	658677	2.034E+10
329-61	273	02/03/90	60.5	48401.8	806.7	169.5	0.0000764	0.28	253.70	50.5	0.03723	135.3	115826	487.1	1.74	660675	2.037E+10
329-61	286	02/03/90	60.5	48462.4	807.7	169.5	0.0000769	0.28	253.98	50.4	0.03723	135.3	115961	484.0	1.82	655269	2.013E+10

LPAJ NASA LEWIS (
LIFE TEST NASA

RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
329-60	5	02/01/90	31.87	44.45	1416.62	92.57	13.34	1234.45	1240.85	87.59	31.99	34987700	200	935	253	1601	620	1020	80	1	774
329-60	10	02/01/90	31.85	44.46	1416.17	92.07	13.39	1233.26	1239.72	87.54	32.22	35432700	198	934	253	1606	621	1018	80	1	775
329-60	15	02/01/90	31.86	44.44	1415.59	92.14	13.42	1236.20	1242.68	87.79	31.94	35184500	198	930	253	1606	621	1024	80	1	776
329-60	20	02/01/90	31.84	44.48	1416.48	92.26	13.41	1236.87	1243.34	87.78	31.96	35299700	199	929	253	1605	621	1023	80	1	777
329-60	25	02/01/90	31.84	44.47	1415.86	92.45	13.36	1235.14	1241.57	87.69	31.99	35331600	202	935	253	1604	622	1190	80	1	778
329-60	30	02/01/90	31.85	44.49	1416.69	92.46	13.34	1233.77	1240.18	87.54	32.17	35472500	204	935	253	1603	622	1243	80	1	779
329-60	35	02/01/90	31.85	44.50	1417.41	92.20	13.38	1234.03	1240.48	87.52	32.10	35258500	199	932	252	1601	621	1041	80	1	780
329-60	40	02/02/90	31.84	44.49	1416.54	92.50	13.37	1236.83	1243.27	87.77	31.88	35145300	199	929	252	1598	620	1032	80	1	781
329-60	45	02/02/90	31.83	44.45	1414.81	92.85	13.30	1234.64	1241.00	87.72	32.18	35441000	202	934	252	1595	621	1199	80	1	782
329-60	50	02/02/90	31.85	44.47	1416.19	92.73	13.32	1234.92	1241.31	87.65	31.85	35014700	198	925	252	1595	620	1025	80	1	783
329-60	55	02/02/90	31.87	44.37	1414.22	92.88	13.27	1232.81	1239.15	87.62	32.66	35806400	198	928	252	1595	620	1029	80	1	784
329-60	60	02/02/90	31.84	44.45	1415.53	92.94	13.36	1241.16	1247.58	88.14	31.83	35400300	198	927	252	1596	620	1029	80	1	785
329-60	73	02/02/90	31.86	44.39	1414.10	93.31	13.27	1238.06	1244.39	88.00	31.63	35165400	201	934	251	1592	620	1195	80	1	786
329-61	13	02/02/90	31.84	44.41	1413.88	93.73	13.20	1236.86	1243.13	87.92	32.32	35001600	199	929	251	1587	618	1030	80	1	787
329-61	26	02/02/90	31.84	44.38	1413.07	93.49	13.23	1236.37	1242.67	87.94	32.12	34849700	199	930	251	1588	618	1031	79	1	788
329-61	39	02/02/90	31.86	44.37	1413.65	93.55	13.19	1233.69	1239.95	87.71	32.11	34770400	199	929	251	1585	618	1018	79	1	789
329-61	52	02/02/90	31.85	44.31	1411.48	94.13	13.10	1233.47	1239.65	87.83	32.21	34962700	200	935	251	1585	619	1198	79	1	790
329-61	65	02/02/90	31.87	44.39	1414.68	92.92	13.27	1232.84	1239.18	87.59	32.17	35166300	200	928	252	1590	619	1027	79	1	791
329-61	78	02/02/90	31.84	44.46	1415.49	92.92	13.32	1237.29	1243.68	87.86	32.07	35377400	198	929	252	1592	620	1025	80	1	792
329-61	91	02/02/90	31.88	44.38	1414.78	92.89	13.28	1234.01	1240.36	87.67	32.01	35147400	199	929	252	1592	620	1020	80	1	793
329-61	104	02/02/90	31.87	44.40	1414.91	92.89	13.29	1234.38	1240.74	87.69	32.28	35458200	199	927	252	1593	620	1014	80	1	794
329-61	117	02/02/90	31.87	44.41	1415.04	92.88	13.30	1235.37	1241.74	87.75	32.11	35402900	199	928	252	1593	620	1011	80	1	795
329-61	130	02/02/90	31.87	44.40	1414.80	93.15	13.28	1236.69	1243.04	87.86	32.01	35431900	202	934	252	1592	621	1199	80	1	796
329-61	143	02/03/90	31.86	44.42	1415.36	92.79	13.34	1237.47	1243.87	87.88	31.92	35295200	199	928	252	1594	620	1031	80	1	797
329-61	156	02/03/90	31.88	44.42	1416.20	92.55	13.35	1235.59	1242.01	87.70	32.27	35672500	199	929	252	1595	621	1018	80	1	798
329-61	169	02/03/90	31.89	44.37	1414.84	92.89	13.32	1237.52	1243.91	87.92	32.05	35584300	202	933	252	1594	622	1200	80	1	799
329-61	182	02/03/90	31.86	44.46	1416.28	92.33	13.39	1236.05	1242.50	87.73	32.07	35528600	199	928	253	1597	621	1021	80	1	800
329-61	195	02/03/90	31.87	44.46	1416.90	92.21	13.41	1236.67	1243.14	87.74	32.13	35705200	200	928	253	1599	622	1010	80	1	801
329-61	208	02/03/90	31.86	44.44	1416.09	92.20	13.38	1234.00	1240.45	87.60	32.30	35677500	200	927	254	1597	622	1011	80	1	802
329-61	221	02/03/90	31.88	44.43	1416.10	92.15	13.40	1234.49	1240.95	87.63	31.96	35402100	200	929	254	1599	623	1016	80	1	803
329-61	234	02/03/90	31.86	44.44	1415.75	92.37	13.38	1236.14	1242.58	87.77	31.72	35375200	204	933	254	1598	623	1199	80	1	804
329-61	247	02/03/90	31.84	44.48	1416.35	91.83	13.46	1235.61	1242.13	87.70	31.85	35453100	201	928	254	1603	623	1007	80	1	805
329-61	260	02/03/90	31.87	44.46	1416.74	91.97	13.42	1234.69	1241.17	87.61	32.07	35580000	200	928	254	1596	622	1007	80	1	806
329-61	273	02/03/90	31.87	44.43	1415.96	92.61	13.34	1235.66	1242.07	87.72	32.03	35645500	204	932	253	1593	623	1198	81	1	807
329-61	286	02/03/90	31.89	44.42	1416.76	91.97	13.43	1234.86	1241.35	87.62	31.85	35400800	201	927	254	1597	622	1019	81	1	808

LPAJ NASA LEWIS (121581-4840)
LIFE TEST NASA S/N 002 IN CH. 11

RUN #	SAMP #	DATE	ON TIME (MIN)	CUM ON TIME (MIN)	CUM ON TIME (HR)	Pf (PSIA)	FLOW (LBM/SEC)	FUEL USED (LBM)	CUM FUEL USED (LBM)	Pc (PSIA)	THRUST (LBF)	IMPULSE (LBF-SEC)	CUM IMPULSE (LBF-SEC)	ISP (SEC)	REL. ROUGH (PSIA)	Pc/Flow (PSIA-SEC/LBM)	(Pf-Pc)/Flow² (PSI-SEC²/LBM²)
329-61	299	02/03/90	60.5	48522.9	808.7	169.3	0.0000765	0.28	254.26	50.4	0.03726	135.4	116097	487.0	1.72	658677	2.031E+10
329-61	312	02/03/90	60.5	48583.5	809.7	169.2	0.0000766	0.28	254.53	50.4	0.03719	135.1	116232	485.6	1.83	658187	2.026E+10
329-61	325	02/03/90	60.5	48644.0	810.7	169.2	0.0000765	0.28	254.81	50.4	0.03717	135.0	116367	485.9	1.68	658755	2.030E+10

IPAJ NASA LEWIS (
LIFE TEST NASA

RUN #	SAMP #	DATE	INPUT VOLTAGE (VOLTS)	INPUT CURRENT (AMPS)	INPUT POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC CURRENT (AMPS)	ARC POWER (WATTS)	PCU POWER (WATTS)	PCU EFF	ARC EFF	P/FLOW (J/Kg)	Tvf ('F)	Tgg ('F)	Tcon ('F)	T1 ('F)	T3 ('F)	Tinj ('F)	Tpcu ('F)	NUMBER STARTS	START NUMBER
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
329-61	299	02/03/90	31.88	44.43	1416.43	92.53	13.36	1236.35	1242.77	87.74	32.04	35628000	201	930	254	1595	622	1016	81	1	809
329-61	312	02/03/90	31.89	44.45	1417.22	91.82	13.46	1235.54	1242.06	87.64	31.91	35578500	201	927	254	1599	623	1010	81	1	810
329-61	325	02/03/90	31.89	44.44	1417.54	91.89	13.44	1235.44	1241.95	87.61	31.92	35606100	201	929	254	1600	624	1014	80	1	811

PERFORMANCE MAP DATA

PM REPORT

LPAJ NASA LEWIS (121581-4840) PERFORMANCE MAP

SEQ #	RUN #	SAMP NUM	DATE	NOM Pf	NOM POW	ARC CURRENT (AMPS)	PCU POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC POWER (WATTS)	ARC V/I	THRUST (LBF)	THRUST (N)	FLOW (LBM/SEC)	FLOW (Kg/SEC)	ISP (SEC)	Pf (PSIA)	Pf (KPa)	Pc (PSIA)	Pc (KPa)	P/FLOW (J/Kg)
1	329-07	23	11/15/89	300	1260	12.49	1252.2	99.78	1246.6	7.9888	0.045190	0.201014	0.00010564	0.047918	427.8	298.1	2055.3	60.5	417.1	26019900
2	329-07	41	11/15/89	285	1260	12.51	1256.8	100.04	1251.2	7.9968	0.044530	0.198078	0.00010300	0.046720	432.3	283.4	1954.0	59.1	407.5	26785100
3	329-07	59	11/15/89	260	1260	12.62	1255.7	99.07	1250.0	7.8502	0.043290	0.192563	0.00009727	0.044120	445.1	258.4	1781.6	57.1	393.7	28337000
4	329-07	76	11/15/89	240	1260	12.97	1256.1	96.41	1250.0	7.4333	0.042170	0.187581	0.00009428	0.042763	447.3	238.6	1645.1	55.7	384.0	29235800
5	329-07	94	11/15/89	205	1260	13.45	1257.7	93.06	1251.2	6.9190	0.040130	0.178506	0.00008674	0.039346	462.6	204.2	1407.9	52.4	361.3	31805700
6	329-07	111	11/15/89	185	1260	13.83	1252.6	90.07	1245.7	6.5127	0.038950	0.173257	0.00008119	0.036828	479.7	184.8	1274.2	50.6	348.9	33831300
7	329-07	129	11/15/89	170	1260	14.27	1251.0	87.16	1243.7	6.1079	0.037830	0.168275	0.00007723	0.035030	489.9	169.0	1165.2	49.0	337.8	35509200
7	329-08	10	11/15/89	170	1260	14.09	1245.8	87.93	1238.7	6.2406	0.037900	0.168587	0.00007721	0.035020	490.9	167.9	1157.6	49.3	339.9	35377000
7	329-08	31	11/15/89	170	1260	14.22	1244.6	86.99	1237.3	6.1174	0.037960	0.168854	0.00007705	0.034950	492.7	168.1	1159.0	49.3	339.9	35408300
1	329-09	25	11/16/89	300	1260	12.01	1246.0	103.32	1240.8	8.6028	0.045810	0.203772	0.00010587	0.048022	432.7	298.6	2058.8	61.5	424.0	25842200
PM TEST #2																				
14	329-12	20	11/29/89	260	1260	12.45	1254.8	100.35	1249.3	8.0602	0.043320	0.192696	0.00009931	0.045048	436.2	260.1	1793.3	59.1	407.5	27736700
16	329-13	21	11/29/89	240	1260	12.80	1264.2	98.30	1258.3	7.6797	0.042140	0.187447	0.00009412	0.042692	447.8	239.2	1649.2	57.4	395.8	29479400
17	329-13	39	11/29/89	205	1260	13.27	1269.0	95.12	1262.6	7.1680	0.040060	0.178195	0.00008666	0.039308	462.2	204.3	1408.6	54.0	372.3	32126400
18	329-13	58	11/29/89	185	1260	13.77	1267.1	91.53	1260.3	6.6471	0.038610	0.171745	0.00008173	0.037071	472.4	185.1	1276.2	52.0	358.5	34002600
19	329-14	17	11/30/89	300	0	0.00	0.0	-0.19	0.0	0.0000	0.015940	0.070904	0.00011253	0.051043	141.6	299.0	2061.5	33.3	229.6	0
20	329-14	34	11/30/89	170	0	0.00	0.0	-0.05	0.0	0.0000	0.011520	0.051243	0.00008631	0.039151	133.5	170.2	1173.5	24.1	166.2	0
22	329-14	63	11/30/89	170	1260	14.36	1260.3	87.23	1252.8	6.0745	0.037710	0.167742	0.00007792	0.035345	483.9	171.0	1179.0	50.8	350.3	35451900
23	329-14	81	11/30/89	300	1260	12.05	1256.5	103.85	1251.2	8.6183	0.045460	0.202215	0.00010666	0.048381	426.2	299.9	2067.7	62.9	433.7	25866900
24	329-14	99	11/30/89	285	1260	12.18	1257.9	102.83	1252.5	8.4425	0.044880	0.199635	0.00010402	0.047183	431.4	286.3	1974.0	61.9	426.8	26551400
PM TEST #3																				
1	329-21	17	12/08/89	300	0	0.00	0.0	-0.47	0.0	0.0000	0.015780	0.070193	0.00011280	0.051166	139.9	306.5	2113.2	33.6	231.7	0
2	329-21	34	12/08/89	170	0	0.00	0.0	-0.26	0.0	0.0000	0.011410	0.050754	0.00008565	0.038852	133.2	177.8	1225.9	24.3	167.5	0
3	329-21	51	12/08/89	300	1260	11.81	1250.5	105.50	1245.5	8.9331	0.044720	0.198924	0.00010492	0.047591	426.2	297.9	2053.9	63.2	435.7	26174600
4	329-21	68	12/08/89	260	1260	12.38	1254.0	100.84	1248.5	8.1454	0.042720	0.190027	0.00009684	0.043925	441.1	260.4	1795.4	59.4	409.5	28427600
5	329-21	85	12/08/89	205	1260	13.29	1262.2	94.51	1255.8	7.1114	0.039550	0.175926	0.00008607	0.039039	459.5	208.2	1435.5	54.5	375.8	32174700
6	329-21	102	12/08/89	170	1260	14.04	1261.3	89.35	1254.3	6.3640	0.037030	0.164717	0.00007702	0.034934	480.8	173.2	1194.2	50.8	350.3	35910000
PM TEST #4																				
1	329-41	17	01/08/90	300	0	0.00	0.0	-0.10	0.0	0.0000	0.015330	0.068191	0.00010999	0.049891	139.4	303.9	2095.3	32.3	222.7	0
2	329-41	35	01/08/90	170	0	0.00	0.0	-0.55	0.0	0.0000	0.011080	0.049286	0.00008377	0.037996	132.3	176.1	1214.2	23.2	160.0	0
3	329-41	53	01/08/90	300	1260	11.22	1241.3	110.27	1236.8	9.8280	0.044730	0.198968	0.00010452	0.047410	427.9	300.2	2069.8	62.3	429.5	26090200
4	329-41	70	01/08/90	260	1260	11.68	1237.3	105.48	1232.3	9.0308	0.042320	0.188248	0.00009606	0.043573	440.6	261.8	1805.0	58.8	405.4	28287500
5	329-42	9	01/08/90	205	1260	13.06	1247.1	95.00	1241.0	7.2741	0.039140	0.174103	0.00008464	0.038392	462.4	207.4	1430.0	53.9	371.6	32329500
6	329-42	26	01/08/90	170	1260	13.79	1247.9	90.02	1241.1	6.5279	0.036910	0.164183	0.00007665	0.034769	481.6	175.9	1212.8	50.2	346.1	35700700

PM REPORT

LPAJ NASA LEWIS (121581-4840) PERFOR

SEQ #	RUN #	SAMP NUM	DATE	NOM Pf	NOM POW	GG ON TIME (MIN)	GG CUM ON TIME (MIN)	ARC ON TIME (MIN)	ARC CUM ON TIME (MIN)	GG FUEL USED (LBM)	GG CUM FUEL USED (LBM)	ARC FUEL USED (LBM)	ARC CUM FUEL USED (LBM)	GG ONLY IMPULSE (LBF-SEC)	GG CUM IMPULSE (LBF-SEC)	ARC IMPULSE (LBF-SEC)	ARC CUM IMPULSE (LBF-SEC)
-----	-----	-----	-----	---	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1	329-07	23	11/15/89	300	1260	42.0	42.0	32.0	32.0	0.2726	0.27	0.2050	0.21	0.0	0.0	86.9	86.9
2	329-07	41	11/15/89	285	1260	32.0	74.1	30.0	62.1	0.1987	0.47	0.1857	0.39	0.0	0.0	80.2	167.1
3	329-07	59	11/15/89	260	1260	32.0	106.1	32.0	94.1	0.1860	0.66	0.1860	0.58	0.0	0.0	83.2	250.3
4	329-07	76	11/15/89	240	1260	30.0	136.1	30.0	124.1	0.1684	0.83	0.1684	0.75	0.0	0.0	75.9	326.2
5	329-07	94	11/15/89	205	1260	32.0	168.1	32.0	156.1	0.1660	0.99	0.1660	0.91	0.0	0.0	77.1	403.4
6	329-07	111	11/15/89	185	1260	30.0	198.2	30.0	186.2	0.1473	1.14	0.1473	1.06	0.0	0.0	70.2	473.6
7	329-07	129	11/15/89	170	1260	32.0	230.2	32.0	218.2	0.1478	1.29	0.1478	1.21	0.0	0.0	72.7	546.3
7	329-08	10	11/15/89	170	1260	8.2	238.4	8.2	226.4	0.0385	1.33	0.0385	1.24	0.0	0.0	18.6	564.9
7	329-08	31	11/15/89	170	1260	36.1	274.5	36.1	262.4	0.1671	1.49	0.1671	1.41	0.0	0.0	82.1	647.0
1	329-09	25	11/16/89	300	1260	37.0	311.5	30.0	292.5	0.2384	1.73	0.1906	1.60	0.0	0.0	82.5	729.5
PM TEST #2																	
14	329-12	20	11/29/89	260	1260	36.0	486.6	32.0	422.6	0.2162	2.85	0.1905	2.42	0.0	14.5	83.2	1075.6
16	329-13	21	11/29/89	240	1260	34.0	530.7	33.0	465.6	0.1950	3.10	0.1891	2.66	0.0	14.5	83.5	1184.7
17	329-13	39	11/29/89	205	1260	32.0	562.7	32.0	497.7	0.1663	3.27	0.1663	2.83	0.0	14.5	77.0	1261.7
18	329-13	58	11/29/89	185	1260	34.0	596.7	34.0	531.7	0.1681	3.44	0.1681	3.00	0.0	14.5	78.8	1340.5
19	329-14	17	11/30/89	300	0	30.0	626.8	0.0	531.7	0.2068	3.64	0.0000	3.00	28.7	43.2	0.0	1340.5
20	329-14	34	11/30/89	170	0	30.0	656.8	0.0	531.7	0.1574	3.80	0.0000	3.00	20.8	64.0	0.0	1340.5
22	329-14	63	11/30/89	170	1260	22.0	708.8	22.0	583.7	0.1026	4.05	0.1026	3.24	0.0	64.0	49.8	1456.3
23	329-14	81	11/30/89	300	1260	32.0	740.9	32.0	615.8	0.2020	4.25	0.2020	3.44	0.0	64.0	87.4	1543.7
24	329-14	99	11/30/89	285	1260	32.0	772.9	32.0	647.8	0.2001	4.45	0.2001	3.64	0.0	64.0	86.2	1629.9
PM TEST #3																	
1	329-21	17	12/08/89	300	0	30.0	802.9	0.0	647.8	0.2025	4.65	0.0000	3.64	28.4	92.4	0.0	1629.9
2	329-21	34	12/08/89	170	0	30.0	832.9	0.0	647.8	0.1553	4.81	0.0000	3.64	20.5	113.0	0.0	1629.9
3	329-21	51	12/08/89	300	1260	30.0	862.9	30.0	677.8	0.1876	4.99	0.1876	3.83	0.0	113.0	80.5	1710.4
4	329-21	68	12/08/89	260	1260	30.0	892.9	30.0	707.8	0.1876	5.18	0.1761	4.01	0.0	113.0	76.9	1787.4
5	329-21	85	12/08/89	205	1260	30.0	923.0	30.0	737.8	0.1876	5.37	0.1536	4.16	0.0	113.0	71.2	1858.6
6	329-21	102	12/08/89	170	1260	30.0	953.0	30.0	767.9	0.1876	5.56	0.1392	4.30	0.0	113.0	66.7	1925.3
PM TEST #4																	
1	329-41	17	01/08/90	300	0	30.0	983.0	0.0	767.9	0.1985	5.75	0.0000	4.30	27.6	140.6	0.0	1925.3
2	329-41	35	01/08/90	170	0	30.0	1013.0	0.0	767.9	0.1512	5.91	0.0000	4.30	19.9	160.5	0.0	1925.3
3	329-41	53	01/08/90	300	1260	32.0	1045.0	32.0	799.9	0.1988	6.10	0.1988	4.50	0.0	160.5	85.9	2011.2
4	329-41	70	01/08/90	260	1260	30.0	1075.0	30.0	829.9	0.1749	6.28	0.1749	4.68	0.0	160.5	76.2	2087.4
5	329-42	9	01/08/90	205	1260	25.0	1134.0	25.0	808.9	0.1275	6.58	0.1275	4.97	0.0	160.5	58.7	2222.5
6	329-42	26	01/08/90	170	1260	30.0	1164.1	30.0	918.9	0.1386	6.71	0.1386	5.11	0.0	160.5	66.5	2289.0

PM REPORT
LPAJ NASA LEWIS (121581-4840) PERFOR

SEQ #	RUN #	SAMP NUM	DATE	NOM Pf	NOM POW	T1 (DEG F)	T1 (DEG C)	T3 (DEG F)	T3 (DEG C)	Tvf (DEG F)	Tvf (DEG C)	Tgg (DEG F)	Tgg (DEG C)	Tcon (DEG F)	Tcon (DEG C)	Tinj (DEG F)	Tinj (DEG C)	Tpcu (DEG F)	Tpcu (DEG C)
1	329-07	23	11/15/89	300	1260	1528	831	724	384	187	86	961	516	231	111	937	503	76	25
2	329-07	41	11/15/89	285	1260	1527	831	726	385	192	89	954	512	242	117	977	525	80	27
3	329-07	59	11/15/89	260	1260	1548	842	730	388	194	90	952	511	243	117	950	510	81	27
4	329-07	76	11/15/89	240	1260	1579	859	737	391	195	91	944	507	242	117	950	510	82	28
5	329-07	94	11/15/89	205	1260	1604	874	743	395	198	92	929	498	243	117	937	503	84	29
6	329-07	111	11/15/89	185	1260	1619	881	748	398	198	92	919	493	242	117	930	499	86	30
7	329-07	129	11/15/89	170	1260	1639	893	755	401	201	94	911	488	244	118	922	495	87	31
7	329-08	10	11/15/89	170	1260	1643	895	730	388	137	58	895	480	120	49	890	477	65	18
7	329-08	31	11/15/89	170	1260	1649	898	756	402	191	88	914	490	235	113	912	489	84	29
1	329-09	25	11/16/89	300	1260	1517	825	725	385	187	86	959	515	227	108	979	526	77	25
PM TEST #2																			
14	329-12	20	11/29/89	260	1260	1561	850	733	390	187	86	942	505	227	108	968	520	76	24
16	329-13	21	11/29/89	240	1260	1589	865	741	394	197	91	938	503	243	117	967	519	79	26
17	329-13	39	11/29/89	205	1260	1626	886	751	399	200	93	924	496	247	120	960	516	83	28
18	329-13	58	11/29/89	185	1260	1640	893	755	402	203	95	917	492	250	121	954	512	85	30
19	329-14	17	11/30/89	300	0	402	206	459	237	153	67	930	499	178	81	907	486	51	10
20	329-14	34	11/30/89	170	0	346	175	395	202	155	68	881	471	180	82	867	464	51	10
22	329-14	63	11/30/89	170	1260	1657	903	759	404	199	93	909	487	241	116	959	515	82	28
23	329-14	81	11/30/89	300	1260	1523	828	728	387	190	88	957	514	242	117	979	526	79	26
24	329-14	99	11/30/89	285	1260	1540	838	732	389	191	89	952	511	245	118	971	522	80	26
PM TEST #3																			
1	329-21	17	12/08/89	300	0	404	206	461	238	161	72	920	493	189	87	918	492	51	11
2	329-21	34	12/08/89	170	0	349	176	399	204	162	72	874	468	181	83	929	498	50	10
3	329-21	51	12/08/89	300	1260	1521	827	734	390	190	88	952	511	235	113	967	520	74	23
4	329-21	68	12/08/89	260	1260	1566	852	744	395	195	91	943	506	228	109	990	532	76	24
5	329-21	85	12/08/89	205	1260	1608	875	756	402	201	94	923	495	245	118	986	530	81	27
6	329-21	102	12/08/89	170	1260	1647	897	767	408	207	97	909	487	246	119	971	521	84	29
PM TEST #4																			
1	329-41	17	01/08/90	300	0	400	204	457	236	178	81	900	482	187	86	968	520	49	9
2	329-41	35	01/08/90	170	0	344	173	393	200	175	79	853	456	173	78	931	499	48	9
3	329-41	53	01/08/90	300	1260	1515	824	739	392	203	95	926	497	217	103	995	535	70	21
4	329-41	70	01/08/90	260	1260	1543	840	746	396	208	98	917	492	223	106	990	532	72	22
5	329-42	9	01/08/90	205	1260	1595	868	759	404	214	101	898	481	230	110	977	525	77	25
6	329-42	26	01/08/90	170	1260	1641	894	773	412	220	104	886	474	238	114	969	521	80	27

PM REPORT
LPAJ NASA LEWIS (121581-4040) PERFOR

SEQ #	RUN #	SAMP NUM	DATE	NOM Pf	NOM POW	GG ON TIME (MIN)	GG CUM ON TIME (MIN)	ARC ON TIME (MIN)	ARC CUM ON TIME (MIN)	GG FUEL USED (LBM)	GG CUM FUEL USED (LBM)	ARC FUEL USED (LBM)	ARC CUM FUEL USED (LBM)	GG ONLY IMPULSE (LBF-SEC)	GG CUM IMPULSE (LBF-SEC)	ARC IMPULSE (LBF-SEC)	ARC CUM IMPULSE (LBF-SEC)
PM TEST #5																	
1	329-47	9	01/16/90	170	0	30.0	1194.1	0.0	918.9	0.1460	6.86	0.0000	5.11	18.8	179.3	0.0	2289.0
2	329-47	17	01/16/90	300	0	30.0	1224.1	0.0	918.9	0.1929	7.05	0.0000	5.11	27.2	206.5	0.0	2289.0
3	329-48	8	01/16/90	300	1260	30.0	1254.1	30.0	948.9	0.1851	7.24	0.1851	5.30	0.0	206.5	79.9	2368.9
6	329-48	16	01/16/90	170	1260	30.0	1284.1	30.0	978.9	0.1363	7.38	0.1363	5.43	0.0	206.5	65.3	2434.2
PM TEST #6																	
1	329-62	8	02/04/90	300	0	30.0	1314.1	0.0	978.9	0.2034	7.58	0.0000	5.43	28.9	235.4	0.0	2434.2
2	329-62	16	02/04/90	170	0	30.0	1344.1	0.0	978.9	0.1532	7.73	0.0000	5.43	20.9	256.3	0.0	2434.2
3	329-62	24	02/04/90	300	1260	30.0	1374.1	30.0	1008.9	0.1921	7.92	0.1921	5.62	0.0	256.3	82.7	2516.9
4	329-62	32	02/04/90	285	1260	30.0	1404.1	30.0	1038.9	0.1856	8.11	0.1856	5.81	0.0	256.3	80.9	2597.8
5	329-62	40	02/04/90	260	1260	30.0	1434.1	30.0	1068.9	0.1775	8.29	0.1775	5.99	0.0	256.3	78.0	2675.8
6	329-62	48	02/04/90	240	1260	30.0	1464.1	30.0	1098.9	0.1688	8.46	0.1688	6.16	0.0	256.3	75.6	2751.4
7	329-62	56	02/04/90	205	1260	30.0	1494.1	30.0	1128.9	0.1541	8.61	0.1541	6.31	0.0	256.3	71.9	2823.4
8	329-62	64	02/04/90	185	1260	30.0	1524.1	30.0	1158.9	0.1472	8.76	0.1472	6.46	0.0	256.3	69.7	2893.1
13	329-63	8	02/05/90	170	1260	30.0	1574.1	30.0	1208.9	0.1417	8.99	0.1417	6.69	0.0	256.3	67.7	3005.9

PM REPORT

LPAJ NASA LEWIS (121581-4840) PERFORMANCE MAP

SEQ #	RUN #	SAMP NUM	DATE	NOM Pf	NOM POW	ARC CURRENT (AMPS)	PCU POWER (WATTS)	ARC VOLTAGE (VOLTS)	ARC POWER (WATTS)	ARC V/I	THRUST (LBF)	THRUST (N)	FLOW (LBM/SEC)	FLOW (Kg/SEC)	ISP (SEC)	Pf (PSIA)	Pf (KPa)	Pc (PSIA)	Pc (KPa)	P/FLOW (J/Kg)
PM TEST #5																				
1	329-47	9	01/16/90	170	0	0.00	0.0	-0.15	0.0	0.0000	0.010420	0.046350	0.00008026	0.036404	129.9	177.0	1220.4	21.7	149.6	0
2	329-47	17	01/16/90	300	0	0.00	0.0	0.16	0.0	0.0000	0.015130	0.067301	0.00010877	0.049338	139.1	300.9	2074.6	31.6	217.9	0
3	329-48	8	01/16/90	300	1260	11.06	1238.9	111.61	1234.5	10.0913	0.044400	0.197500	0.00010205	0.046290	435.1	300.9	2074.6	61.8	426.1	26674200
6	329-48	16	01/16/90	170	1260	13.77	1242.2	89.71	1235.4	6.5149	0.036280	0.161381	0.00007376	0.033456	491.9	171.6	1183.1	49.3	339.9	36932900
PM TEST #6																				
1	329-62	8	02/04/90	300	0	0.00	0.0	0.38	0.0	0.0000	0.016070	0.071483	0.00011237	0.050971	143.0	299.6	2065.7	33.2	228.9	0
2	329-62	16	02/04/90	170	0	0.00	0.0	0.42	0.0	0.0000	0.011580	0.051510	0.00008513	0.038613	136.1	170.5	1175.6	23.8	164.1	0
3	329-62	24	02/04/90	300	1260	10.61	1241.3	116.62	1237.2	10.9915	0.045930	0.204306	0.00010625	0.048195	432.2	300.8	2073.9	63.5	437.8	25674500
4	329-62	32	02/04/90	285	1260	10.75	1239.0	114.91	1234.9	10.6893	0.044950	0.199947	0.00010355	0.046970	434.0	286.1	1972.6	62.4	430.2	26294200
5	329-62	40	02/04/90	260	1260	11.06	1233.4	111.13	1229.0	10.0479	0.043330	0.192741	0.00009819	0.044539	441.3	260.2	1794.0	60.1	414.4	27597900
6	329-62	48	02/04/90	240	1260	11.37	1229.1	107.66	1224.4	9.4688	0.042000	0.186824	0.00009379	0.042544	447.8	239.1	1648.5	58.0	399.9	28784900
7	329-62	56	02/04/90	205	1260	12.31	1232.9	99.71	1227.4	8.0999	0.039960	0.177750	0.00008508	0.038590	469.7	204.7	1411.4	54.6	376.5	31812600
8	329-62	64	02/04/90	185	1260	12.83	1241.7	96.29	1235.8	7.5051	0.038740	0.172323	0.00008091	0.036701	478.8	186.8	1287.9	52.7	363.4	33677000
13	329-63	8	02/05/90	170	1260	13.30	1241.1	92.84	1234.7	6.9805	0.037630	0.167386	0.00007805	0.035403	482.1	171.0	1179.0	50.9	350.9	34882400

PM REPORT

LPAJ NASA LEWIS (121581-4840) PERFOR

SEQ #	RUN #	SAMP NUM	DATE	NOM Pf	NOM POW	T1 (DEG F)	T1 (DEG C)	T3 (DEG F)	T3 (DEG C)	Tvf (DEG F)	Tvf (DEG C)	Tgg (DEG F)	Tgg (DEG C)	Tcon (DEG F)	Tcon (DEG C)	Tinj (DEG F)	Tinj (DEG C)	Tpcu (DEG F)	Tpcu (DEG C)
PM TEST #5																			
1	329-47	9	01/16/90	170	0	330	166	379	193	210	99	838	448	161	72	968	520	48	9
2	329-47	17	01/16/90	300	0	395	202	454	234	181	83	889	476	186	85	971	521	48	9
3	329-48	8	01/16/90	300	1260	1506	819	739	393	212	100	921	494	219	104	1016	547	69	21
6	329-48	16	01/16/90	170	1260	1647	897	778	415	225	107	877	470	234	112	975	524	79	26
PM TEST #6																			
1	329-62	8	02/04/90	300	0	398	203	373	189	151	66	939	504	178	81	976	524	46	7
2	329-62	16	02/04/90	170	0	345	174	326	163	155	68	901	483	182	83	956	513	46	8
3	329-62	24	02/04/90	300	1260	1454	790	596	313	180	82	971	522	232	111	1029	554	67	19
4	329-62	32	02/04/90	285	1260	1468	798	599	315	184	84	972	522	242	117	1025	552	70	21
5	329-62	40	02/04/90	260	1260	1485	807	602	317	190	88	969	520	241	116	1217	658	71	22
6	329-62	48	02/04/90	240	1260	1492	811	603	317	192	89	962	517	241	116	1209	654	72	22
7	329-62	56	02/04/90	205	1260	1524	829	608	320	193	89	943	506	242	117	1031	555	74	23
8	329-62	64	02/04/90	185	1260	1557	847	614	323	195	91	935	501	245	118	1019	548	76	24
13	329-63	8	02/05/90	170	1260	1585	863	619	326	191	88	925	496	223	106	1000	538	73	23

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