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PRODUCTION QUALITY ASSURANCE TESTING OF A THIOKOL MINUTEMAN LGM-30G STAGE III ROCKET MOTOR AT SIMULATED PRESSURE ALTITUDE, MOTOR PQA-102

D. E. Franklin and C. H. Kunz

ARO, Inc.

April 1973

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FOREWORD

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC) at the request of the Space and Missile Systems Organization (SAMSO), Air Force Systems Command (AFSC), for the Thiokol Chemical Corporation under Program Element 11213F, System 133B.

The results of the test were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the AEDC, AFSC, Arnold Air Force Station, Tennessee. The test was conducted on January 26, 1973, under ARO Project No. RA159, and the manuscript was submitted for publication on March 2, 1973. The ARO Project Engineer for this test was Mr. D. E. Franklin.

This technical report has been reviewed and is approved.

CHAUNCEY D. SMITH, JR. Lt Colonel, USAF Chief Air Force Test Director, ETF Directorate of Test A. L. COAPMAN Colonel, USAF Director of Test

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ABSTRACT

An LGM-30G Stage III solid-propellant rocket motor, PQA-102, was fired in Rocket Development Test Cell (J-5), Engine Test Facility (ETF), in support of the Minuteman Stage III Production Quality Assurance Test Program on January 26, 1973. The roll control subsystem was independently tested off-motor on January 27, 1973. Motor ballistic, roll control system, thrust vector control, and thrust termination system performance was within model specification requirements. The motor was ignited at a pressure altitude of 102,000 ft. Motor ignition delay time was 86 msec. Motor thrust termination occurred at 60.18 sec at a chamber pressure of 75.3 psia. Motor action time was 60.18 sec during which the motor produced an unaugmented vacuum total impulse of 2,083,534 lbf-sec. The unaugmented vacuum specific impulse was 284.94 lbf-sec/lbm. The roll control subsystem structural integrity was satisfactory.

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SECTION I

The objectives of the Thiokol Chemical Corporation (TCC) Minuteman Stage III Production Quality Assurance (PQA) Program (Ref. 1) are (1) to demonstrate that production motors meet the requirements outlined in the model specification (Ref. 2) and (2) to demonstrate reliability of the Stage III operational motor. The test of motor PQA-102 reported herein is the fourteenth in a series of Minuteman LGM-30G PQA Stage III motor tests to be conducted at AEDC in this program.

SECTION II APPARATUS

2.1 TEST ARTICLE DESCRIPTION

The TCC LGM-30G Stage III Minuteman motor (Fig. 1, Appendix I) is comprised of a glass filament-wound chamber loaded with ANB-3066 solid propellant; a solid-propellant igniter with a safe-and-arm device; a single, partially submerged nozzle with a nominal expansion ratio of 22; a liquid-injection thrust vector control (LITVC) system; a hot gas roll control (RC) system; and a motor thrust termination system. Test article configuration and component serialization are presented in Table I (Appendix II). Nominal motor length and diameter are 92 and 52 in., respectively. Maximum motor mass and minimum propellant weight limits are approximately 8070 and 7280 lbm, respectively. The motor nominally produces an average thrust of 34,000 lbf at an average motor chamber pressure of 500 psia for approximately 60 sec.

The LITVC system (Fig. 2) used for the static test consists of two operative and two electrically inactive electromechanical servoinjector valves, located at 90-deg intervals on the nozzle at an expansion ratio of 10.3; an injectant tank containing approximately 49.3 lbm of a 66-percent solution of strontium perchlorate injectant fluid; a squib-actuated isolation valve and pressure regulator assembly; a pressurant tank containing helium; and a launch limit pressure switch. The two electrically inactive valves, located at the 0- (target down) and 180-deg positions, are used to blank off those injection ports and provide flight configuration hydraulic simulation. Injection in the pitch plane is not required to establish system conformance to specification.

The hot gas RC system is mounted inside the forward skirt at an angular location of 22 deg. The system consists of a squib-actuated, solid-propellant gas generator and a shuttle valve with two opposed nozzles exhausting through the forward skirt. For this test, the roll control system was removed from the motor and tested independently as a subsystem (Fig. 1c).

The thrust termination system, located on the motor forward dome, consists of redundant squib initiators, redundant completely contained mild detonating fuses, linear-shaped charges, thrust termination stacks, stack bellows, and stack covers. The shaped charges, when activated, cut six circular holes in the forward dome, allowing the chamber to vent through the thrust termination stacks.

2.2 TEST CELL AND INSTALLATION

Rocket Development Test Cell (J-5)(Fig. 3 and Ref. 3) is a horizontal test complex for testing rocket motors with a maximum of 100,000-lbf thrust at pressure altitudes of approximately 100,000 ft. The cell is 16 ft in diameter and 50 ft long. The cell is equipped with a temperature-conditioning system designed to maintain the test cell and motor in a prescribed temperature range from motor installation until prefire pumpdown.

The multicomponent thrust stand utilized is capable of measuring axial forces of 100,000 lbf and yaw forces of 6000 lbf. The thrust stand natural frequency for a fully loaded LGM-30G Stage III motor is approximately 27 Hz in the axial direction and 22 Hz in the yaw direction. A steam ejector-diffuser system is used in conjunction with rotating exhauster machinery to provide altitude simulation.

2.3 INSTRUMENTATION

The types of data acquisition and recording systems used during this test were a multiple-input digital data acquisition system scanning each parameter at a basic rate of 100 samples/sec (with selected parameters supercommutated to 1000 samples/sec) and recording on magnetic tape; single-input continuous recording system recording in pulse form on magnetic tape; frequency modulation (FM) systems recording on magnetic tape; and photographically recording galvanometer-type oscillographs. Motion-picture cameras operating at 200 frames/sec provided a permanent visual record of the firing. Table II presents a summary of motor instrumentation. Instrumentation calibration techniques are described in Appendix III. Estimated uncertainties of the J-5 instrument systems are presented in Appendix IV. The digital data were reduced with an IBM 370/155 computer.

SECTION III PROCEDURE

The motor arrived at AEDC on January 16, 1973. Significant motor inspection and handling records are presented as follows:

Date	Activity or Item Performed	Remarks
January 16, 1973	Motor arrived at AEDC	
January 16, 1973	Motor off-loaded and visual inspection performed	No visible damge, 70 \pm 5°F temperature conditioning initiated
January 16, 1973	Prefire nozzle measurements taken	Results in Table III
January 16, 1973	Removal of RC subsystem from motor PQA-102	

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Date		Activity or Item Performed	Remarks
January 17,	1973	Injector valves installed	
January 18,	19 73	Interstage volume leak check	Leak check satisfactory
January 24,	1973	Motor transferred to test cell and installed	
January 24,	1973	Safe-and-arm, arm/disarm, and ignition systems check	Systems verified
January 24,	1973	Thrust vector control system leak check (STM-180)	Leak check satisfactory
January 24,	1973	Completed thrust vector control pintle calibrations	
January 26,	1973	Motor fired at 1437 hr	
January 26,	1973	Motor removed from test cell and visual inspection per- formed. Motor transferred to Rocket Preparation Area	Postfire motor condition satisfactory
January 26,	1973	RC subsystem transferred to test cell and installed for electrical checkout (STM-180) and instrumentation calibration	Checkouts satisfactory
January 27,	1973	RC subsystem fired at 0651 hr	
January 27,	1973	RC subsystem inspected and transferred to Rocket Preparation Area	Postfire condition of RC subsystem satisfactory
January 27,	1973	Postfire motor nozzle measure- ments taken	Results in Table III
January 27,	1973	RC subsystem reinstalled on motor	
January 31,	1973	Motor and RC subsystem shipped to TCC	

SECTION IV RESULTS AND DISCUSSION

4.1 GENERAL

The results reported herein were obtained from the firings of an LGM-30G Stage III motor, PQA-102, on January 26, 1973, and off-motor RC subsystem in Rocket Development Test Cell (J-5) on January 27, 1973. This was the fourteenth in a series of motors to be fired at AEDC as part of the Thiokol Minuteman LGM-30G Stage III Production Quality Assurance Program. The motor was temperature conditioned at 70 \pm 5°F for 60 hr prior to the test. The RC subsystem was temperature conditioned in excess of the required 24-hr minimum at 70 \pm 5°F. Motor propellant grain temperature at the time of ignition was 71°F; prefire RC subsystem temperature was 70°F. A summary of storage and conditioning temperatures is presented in Table IV.

Data from this test are compared with data from other AEDC tests of LGM-30G Stage III PQA motors in Table V.

4.2 BALLISTIC PERFORMANCE

Ballistic performance for this motor was within the requirements of the model specification. A summary of the performance data is presented in Table VI. Histories of axial force, chamber pressure, and test cell pressures are presented in Fig. 4.

4.2.1 Motor Ignition

The motor was successfully ignited at a pressure altitude of 102,000 ft (geometric pressure altitude, Z, Ref. 4). Motor ignition current was within the specification limits of 4.5 to 4.9 amp. Igniter performance was within specification limits (Ref. 5) and is summarized in Table VI. A history of igniter pressure during motor ignition is presented in Fig. 5.

Motor ignition delay (defined as the time from application of ignition voltage until 75 percent of the maximum chamber pressure attained during the first second of motor operation) was 86 msec. This was within the maximum specification limit of 200 msec.

4.2.2 Combustion Chamber Pressure

Average combustion chamber pressure during motor action time was 519 psia. The maximum operating chamber pressure achieved during the firing was 643 psia at T + 22.580 sec. Motor chamber pressure during motor operation is compared with the manufacturer's predicted chamber pressure (Ref. 6) in Fig. 6.

4,2,3 Axial Thrust

Vacuum-corrected thrust was within model specification limits for a motor temperature conditioned at 65 to 75°F and is presented with the specification envelope

in Fig. 7. Motor action time, defined as the time from the application of ignition voltage until 5000 lbf of vacuum thrust during motor tailoff, was 60.18 sec. This was within the specification limits of 57.53 to 62.53 sec for a motor with a propellant grain temperature of 71°F. Average unaugmented vacuum-corrected thrust during motor action time was 34,622 lbf.

The average thrust coefficient during motor action time, excluding thrust augmentation, was determined from vacuum-corrected total impulse, integral of motor chamber pressure, and a throat area input table supplied by TCC. The average thrust coefficient calculated for this motor was 1.75.

4.2.4 Impulse

Measured total impulse during motor action time was 2,071,285 lbf-sec. Total impulse corrected to vacuum conditions was obtained by adding the product of the cell pressure integral and nozzle exit area to the measured total impulse. The nozzle exit area was calculated using an interpolative procedure based on a prefire measured exit area and a calculated postfire exit area (Appendix V). This vacuum correction was approximately 0.6 percent of the measured total impulse. The vacuum total impulse during action time, including thrust augmentation, was 2,084,723 lbf-sec. The vacuum total impulse excluding augmentation was 2,083,534 lbf-sec. Unaugmented vacuum specific impulse for this motor, calculated using a total loaded propellant mass of 7312.3 lbm, was 284.94 lbf-sec/lbm and was within the specification limits of 283.1 to 286.1 lbf-sec/lbm. The unaugmented vacuum specific impulse, calculated using the total propellant mass minus a TCC-supplied sliver mass of 8.0 lbm, was 285.25 lbf-sec/lbm.

4.2.5 Motor Propellant Flow Rate

Average exhaust gas mass flow rate during action time was 121.5 lbm/sec. The flow rate calculation was performed utilizing Equation 16 presented in Appendix V.

4.3 MOTOR VIBRATION

A history of the vibrations recorded by the standard accelerometer on the igniter boss (AIGN30Y) and the nozzle aft flange (AN30Y) for the first 20 sec of motor operation is presented in Fig. 8. The maximum igniter boss amplitude during this period was 35-g peak at approximately 0.1 sec, and the maximum nozzle aft flange amplitude was 100g peak at 13.35 sec. The absolute acceleration values indicated by the standard accelerometers for this motor are comparable to those observed for previous PQA motors.

An accelerometer (AFS262) was added to the forward skirt for this test to study the transmissibility of vibrations through the skirt to upstage components. A comparison of data in Fig. 8 from the igniter boss and the forward skirt shows that the characteristic blossom of data subsequent to the ignition shock which is so evident at the igniter boss is not transmitted through the skirt. It should be recognized, however, that the mass and compliance of the J-5 thrust stand and test fixtures do not simulate the flight vehicle upstage components.

4.4 ROLL CONTROL AND LIQUID-INJECTION THRUST VECTOR CONTROL SYSTEMS PERFORMANCE

4.4.1 Roll Control System

The RC gas generator was ignited for the off-motor independent subsystem test at a simulated pressure altitude of 122,000 ft. Histories of gas generator pressure, roll moment, and roll moment null unbalance during gas generator operation are presented in Fig. 9 and are compared to the model specification limits. The RC system duty cycle is shown in Table VII. All valve response times were within the model specification limits. A summary of RC system performance is included in Table VIII.

4.4.2 Liquid-Injection Thrust Vector Control System

The LITVC isolation valve squib was ignited successfully at a simulated pressure altitude of 102,000 ft, 2.5 sec before motor ignition. Thrust vector control delay time, defined as the time from application of isolation valve squib current until attainment of 655-psia pressure in the injectant manifold, was 1.339 sec. This is within the specification limits of 1.0 to 1.6 sec.

Regulated helium pressure and injectant manifold pressure are presented in Fig. 10. During periods of no flow, following the establishment of steady pressure in the injectant manifold until thrust termination time, the injectant manifold pressure varied from 674 to 692 psia. This was within the specification limits of 655 to 735 psia. Manifold inlet pressure at time of slam suppressor pin shear was 585 psia.

The injector valves were operated per the duty cycle presented in Table IX. Plots of injector command voltage, injector feedback voltage, and injectant flow rate are presented in Fig. 11 for the two injectors which were operated during the firing. A compilation of thrust vector control performance parameters is presented in Table X.

A thrust vector angle of 2.12 was produced by an injectant flow rate of 10.4 lbm/sec during the time period from 3 to 4 sec. This is within the requirement to demonstrate a 2-deg capability. The indicated system performance during the nominal 1- and 2-lbm/sec flow rates was within the system gain specification as shown in Fig. 12.

4.5 THRUST TERMINATION

Thrust termination was initiated 60.18 sec after motor ignition at a chamber pressure of 75.3 psia. Breakwires indicated that the first thrust termination port had been opened by 403 μ sec after thrust termination signal application. The time from first port rupture to last port rupture was 87 μ sec. This met the specification requirements of 219 to 705 μ sec. (Table V1).

During the first 2 sec following thrust termination, the sealed forward dome interstage volume experienced a maximum pressure rise of 0.0764 psi. This is the highest pressure rise recorded for the PQA series.

4.6 STRUCTURAL INTEGRITY

Postfire photographs of the motor and RC subsystem are shown in Fig. 13. Postfire structural condition of the motor and RC subsystem was satisfactory. Gas leakage was noted at the bellows of thrust termination stacks 1 and 6. Leakage occurred from ruptures in the completely contained mild detonating fuses to thrust termination ports 1 and 6.

SECTION V SUMMARY OF RESULTS

The results of testing a TCC Production Quality Assurance LGM-30G Stage III motor, PQA-102, at an average simulated altitude of 91,000 ft and its RC subsystem off-motor at an average simulated altitude of approximately 122,000 ft are summarized as follows:

- 1. All motor ballistic and component performance data from this firing conformed to model specification requirements for the LGM-30G Stage III propulsion subsystem.
- 2. The motor was ignited at a pressure altitude of 102,000 ft and the ignition delay was 86 msec.
- 3. Vacuum-corrected unaugmented total impulse was 2,083,534 lbf-sec during a motor action time of 60.18 sec. Vacuum specific impulse was 284.94 lbf-sec/lbm.
- 4. Thrust termination was initiated 60.18 sec after motor ignition at a chamber pressure of 75.3 psia. All thrust termination ports were opened by 490 μ sec after signal application. Maximum thrust termination nonsimultaneity was 87 μ sec.
- 5. The thrust vector control system operated as programmed and met specification requirements.
- 6. Postfire structural condition of the motor was good.
- 7. The RC subsystem was ignited off-motor at a simulated altitude of 122,000 ft and operated as programmed throughout the gas generator operation time. RC gas generator pressure, roll moment, and roll moment null unbalance were within specification limits throughout the subsystem test. Postfire structural condition of the RC subsystem was good.

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1. Thiokol Chemical Corporation, "General Test Plan, Third Stage Minuteman III, Production Quality Assurance (PQA)." April 1971.

- 2. "Model Specification S-133-1003-0-4, Part II, Production Configuration and Acceptance Test Requirements." January 6, 1972.
- 3. <u>Test Facilities Handbook</u> (Ninth Edition). "Engine Test Facility, Vol. 2." Arnold Engineering Development Center, July 1971.
- 4. Dubin, M., Sissenwine, N., and Wexler, H. U.S. Standard Atmosphere, 1962. U.S. Government Printing Office, Washington, D.C., December 1962.
- 5. "Igniter, Propellant, Rocket Motor, Minuteman III Stage III." AGC Specification 32204, January 16, 1968.
- 6. "Rocket Motor Log Book, Motor PQA-102." Thiokol Chemical Corporation, October 1972.
- 7. "Forward Dome Accelerometer Maximum Response PQA-101." Thiokol Chemical Corporation Document No. TWR-6604, December 18, 1972.

APPENDIXES

- I. ILLUSTRATIONS
- II. TABLES
- **III. INSTRUMENTATION CALIBRATIONS**
- IV. UNCERTAINTIES OF THE J-5 INSTRUMENT SYSTEMS
- V. METHODS OF CALCULATION

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a. Cutaway Schematic of Motor Fig. 1 Minuteman LGM-30G Stage III Rocket Motor



b. Overall View, Typical Fig. 1 Continued

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Fig. 2 Liquid-Injection Thrust Vector Control System Schematic

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Fig. 3 Rocket Development Test Cell (J-5)

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Fig. 4 Measured Axial Force, Chamber Pressure, and Test Cell Pressure during Motor Operation

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Fig. 5 Igniter Pressure Transient during Ignition

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Fig. 6 Measured and Predicted Motor Chamber Pressure

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Fig. 7 Unaugmented Vacuum Thrust and Specification Envelope

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Fig. 8 Motor Accelerometer Vibrations



Fig. 9 Roll Control Gas Generator Pressure, Roll Moments, and Roll Moment Null Unbalance with Specification Envelopes

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Fig. 9 Concluded



Fig. 10 Regulated Helium and Injectant Manifold Pressures during Motor Operation



Fig. 11 Thrust Vector Control Data Summary



b. Valve 4 Fig. 11 Concluded

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Fig. 12 Thrust Vector Control System Gain and Specification

26



a. Overall



b. Forward Dome Fig. 13 Motor and Roll Control Subsystem Postfire Condition



c. Overall Nozzle Exit



d. Roll Control Subsystem Fig. 13 Concluded

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TABLE I TEST ARTICLE CONFIGURATION

NOMENCLATURE	PART NO.	SERIAL NO.
Motor Assy, Final	1147372-91 (1U43737-04)	TC 30195 PQA 102
Propellant	ANB-3066	7110021 7110022
Nozzle, Exhaust R. M.	1146002-39	1000202
Housing, Nozzle	1144447-19	318-3
Extension, Exit Cone	11 4 50 27– 1	8238-58
Exit Cone	1127578-1	311-4
Igniter and S&A Assy	1128361-511	1000192
Igniter Rocket Motor	1128360-505	1000192
Safe and Arm	KR80000-09	OB26674
Propellant	ANB-3066	7110015
Chamber	1127676-1	1000402
Thrust Termination System	1147368-19	N/A
Ring Assy, Retaining	1215685-17	1001772-777
Block Assy, Manifold	1214311-21	1000249
Ordnance Subsystem	1147373-19	1000180
A/D S&A Mechanism	1214110-9	1000274
Igniter Assy (Roll Control)	1128070-13	1000444
Squib Cartridge	1128115-41	1000323
Roll Control Assy	1128070-11	1000364
Valve Assy	010-58847	523
Gas Generator Assy	20840	P-0772
LITVC System	1145433-359	N/A
Injectant Tank Assy	1145560-79	1000230
Helium Tank Assy	1128811-479	1000213
Pressurization Package	1128115-129	1000179
Pressure Switch	1128084-13	1000183
Manifold Assy	1145522-29	1000214

TABLE | (Concluded)

NOMENCLATURE	PART NO.	SERIAL NO.
Servoinjector Valve	s*	
0 90 deg 180 deg 270 deg	401-09140-10(M) 401-09140-10 401-09140-03(M) 401-09140-10	HCC0004 HSD0131 HCC0006 HSD0099
Operational Pressur Transducers	e	
PC-1 PMI-4 PRCGG	1143914–1 1143914–3 1143914–5	1000367 1000625 1000685

*Valves cleaned and checked at AEDC for use on subsequent LGM30G Stage III motors.

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TABLE II

PARAMETER SYMBOL	PARAMETER DESCRIPTION	MEASUREMENT RANGE	SENSOR TYPE	SENSOR RANGE	OIGITAL [#] ANALOG SYSTEM TAPE	GRAPH CHART
	ACCEL ERATION	G PEAX		G PEAK		
AFS-262Y AIGN30Y AIGN330Y	FORWARO SKIRT 2 262 Igniter BDSS 2 30 Igniter BDSS 2 330 No21 6 AFT 61006 25	-100 TO 100 -100 TO 100 -100 TO 100 -200 TO 100	PIEZOELECTRIC PIEZOELECTRIC PIEZOELECTRIC PIEZOELECTRIC	1X TO 1X 1X TO 1K 1X TO 1K 1X TO 1X	X X X	
AN30Y	NOZZLE AFT FLANGE 30	-200 TO 200	PIEZOELECTRIC	IK TO IK	x	
	EVENT-VOL TAGE	V OC				
EFS-1	MAIN MOTOR IGNITION	0 TO 28			×** × ×**	X
EFS-2 FFS-3	LITYC IGNITION	0 TO 28			X	X
EFS-4	LITVE IGNITION	0 TO 28			X	X
EFS-5	ROLL CONTROL IGNIT.	0 TO 28			X X	X.
EFS-6	ROLL CONTROL IGNIT.	0 TO 28			ž ,	X
EFS-9	AOTT IGNITION	0 TO 4.4			÷ ^	x
542-10	AUTT IGNITION	0 10 28			-	
	EVENT	VOLTS				
EISA	IGNITER S/A ARMING	0 TO 40			X	X
EQA	AFT NOZZLE QUENCH	0 TO 10			X	ž.
EQF	FORWARD TT QUENCH	O TO 10			X	÷.
ERCV-1	RC COMMAND VOLTAGE	- 30 TO 30			***	~
EROS	RUPTURE DISC BREAKWR	0 TO 1000			×.	x
ES-Z	INJ VALVE #2 COMMAND	0 10 10			Î	X
ET CTT-1	TT DOPT 41				x x	
FT STT-2	TT PORT 42	0 TO 1000			X X	
ET STT-3	TT PORT #3	0 TO 1000			X X	
ETSTT-4	TT PORT #4	0 TO 1000			X X	
ETSTT-5	TT PORT #5	0 TO 1000			X X	
ETSTT-6	TT PORT #6	0 TO 1000			÷ ^	x
ETTPS	LAUNCH LIMIT SWITCH	0 TO 10			•	
	FORCE	LBF		LBF		
EV-1	AVIA TURIST	-10000 10 50000	STRAIN CACE	100K TO 100K	X	X X
EV-2	AYTAL THOUST	-10000 TO 50000	STRAIN CACE	100X TO 100K	X	
FY -3F	AXIAL THRUST (FILT)	5000 TO 5000	STRAIN GAGE	-100 TO 100	X X	

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TABLE II (Continued)

FORCE LBF LBF FY-3 F2A-1 F2A-1 AFT YAN ATIAL TWUST -1000 TO 50000 TO 50000 STRAIN GAGE 1000 TO 10 600 STRAIN GAGE X X F2A-2 F2A-3 F2A-3 F2A-3 F2A-3 F2A-1 F2A-3 F2A-1 F2A-3 F2A-1 F2A-3 F2A-1 F2A-3 F2A-1 F2A-3 F2A-1 F2A-3 F2A-3 F2A-1 F2A-3 F2A	PARAMETER SYMBOL	PARAMETER DESCRIPTION	NEASUREMENT RANGE	SENSOR TYPE	SENSOR RANGE	DIGITAL [#] ANALOG SYSTEM TAPE	OSCILLO- STRIP GRAPH CHART
FY-3 AXIAL YRUUST -10000 TO 50000 STAAIN GAGE 100K TO 100K X F2A-1 AFF YAN 1400 TO 1600 STAAIN GAGE 4K TO 4K X X F2A-2 AFF YAN 1600 TO 1600 STAAIN GAGE 4K TO 4K X X F2A-3 AFF YAN 1600 TO 1600 STAAIN GAGE 4K TO 4K X X F2A-3 AFF YAN -100 TO 5000 STAAIN GAGE 4K TO 4K X X F2A-3 AFF YAN -100 TO 5000 STAAIN GAGE 4K TO 4K X X F2A-3 FORMARD YAN -100 TO 5000 STAAIN GAGE 4K TO 4K X X F2A-3 ROLL CONTROL THRUST - 25 TO 25 STAAIN GAGE 00000 TO 0000 X X X FRC-3 ROLL CONTROL THRUST - 25 TO 25 STAAIN GAGE 00000 TO 0000 X X X FRC-1 ROLL CONTROL THRUST - 25 TO 25 STAAIN GAGE 00000 TO 0000 X X X FRC-1 ROLL CONTROL THRUST - 10 TO 5 X X X X X		FORCE	LBF		LØF		
FIA-1 AFT YAN 1600 TO 1600 STAIN GAGE 6K TO 6K X X X FIA-2 AFT YAN 1600 TO 1600 STAIN GAGE 6K TO 6K X X X FIA-3 AFT YAN 1600 TO 1600 STAIN GAGE 6K TO 6K X X X FIA-3 AFT YAN -300 TO 3000 STAIN GAGE 6K TO 6K X X X FIA-3 AFT YAN -300 TO 3000 STAIN GAGE 6K TO 6K X X X FIA-3 AFT YAN -300 TO 3000 STAIN GAGE 6K TO 6K X X X FIA-3 FCONMAD YAN -300 TO 300 STAIN GAGE 6K TO 6K X X	FY-5	AXIAL THRUST	-10000 TO 50000	STRAIN GAGE	100K TO 100K	x	
F2A-2 AFT YAM 1600 TO 1600 STRAIM GAGE 4K TO 4K X F2A-3 AFT YAM -300 TO 3600 STRAIM GAGE 4K TO 4K X X F2F-1 PORMARO TAM -300 TO 3600 STRAIM GAGE 4K TO 4K X X F2F-1 PORMARO TAM -300 TO 3600 STRAIM GAGE 4K TO 4K X X F2F-1 PORMARO TAM -300 TO 3600 STRAIM GAGE 4K TO 4K X X F3C-2 ROLL CONTROL TAMUST -25 TO 25 STRAIM GAGE 0000 TO 0000 X X X FRC-2 ROLL CONTROL TAMUST -25 TO 25 STRAIM GAGE 0000 TO 0000 X X X FRC-1 ROLL CONTROL TAMUST -25 TO 25 STRAIM GAGE 0000 TO 0000 X X X FRC-1 NOLL CONTROL TOWN O TO 5 X X X X X FRC-1 NOLL CONTROL IGNITION O TO 5 X X X X X FS-5 NOLL CONTROL IGNITION O TO 5 X X X X X	FZA-1	AFT YAW	1600 TO 1600	STRAIN GAGE	6K TO 6K	X	x
FAG-3 AFY TWN 1000 10 1000 STRAIN GAGE KK TO KK X X FAG-1 FORMARD YAN -300 TO 5000 STRAIN GAGE KK TO KK TA	FZA-2	AFT YAW	1600 TO 1600	STRAIN GAGE	6K TO 6K	X	
PdF-1 FURMARD VAN -3000 10 3000 STRAIN GAGE RK 10 RK X X FRC-1 FORMARD VAN -3000 10 3000 STRAIN GAGE RK 10	FZA-3	AFT YAN	1600 10 1600	STRAIN GAGE	SK TO SK	×	_
FAC-1 PORKAND VAN -200 10 3000 STAIN GAGE RX 10 EX X X FAC-1 NOLL CONTROL THRUST -25 TO 25 STAIN GAGE 0000 TO 0000 X X X FAC-2 NOLL CONTROL THRUST -25 TO 25 STAIN GAGE 0000 TO 0000 X X X FAC-2 NOLL CONTROL THRUST -25 TO 25 STAIN GAGE 0000 TO 0000 X X X FAC-3 MAIN MOTOR IGNITION 0 TO 5 X X X X X IFS-1 MAIN MOTOR IGNITION 0 TO 5 X	FZF~1	PURWARD YAW	-500 10 500	STRAIN GAGE		Č.	X
FRC-1 NOLL CONVERSE TWOLST -23 TO 2300 STRAIN GAGE 00000 TO 00000 X X X FRC-2 NOLL CONVERSENT -23 TO 23 STRAIN GAGE 00000 TO 00000 X X X FRC-2 NOLL CONVERSENT -23 TO 23 STRAIN GAGE 00000 TO 00000 X X X FRC-3 MAIN MOTOR IGNITION 0 TO 5 X	F2F-2	FORWARD YAW	-500 TO 500	STRAIN GAGE	AK TO AK		
FAC-2 NGLL CONTROL THRUST - 25 TO 25 STRAIN GAGE DOGO TO DOGO X <thx< th=""> <thx< th=""> X</thx<></thx<>	FRC-1	ROLL CONTROL THRUST	~ 25 TO 25	STRAIN GAGE	0000 TO 0000	x ^	* *
EVENT-CURRENT AMPS IF5-1 MAIN MOTOR IGNITION 0 TO 5 X X X IF5-2 MAIN MOTOR IGNITION 0 TO 5 X X X IF5-3 LITVC IGNITION 0 TO 5 X X X IF5-4 LITVC IGNITION 0 TO 5 X X X IF5-5 ROLL CONTROL IGNIT. 0 TO 5 X X X IF5-6 ROLL CONTROL IGNIT. 0 TO 25 X X X IF5-6 ROLT CONTROL IGNIT. 0 TO 25 X X X IF5-70 ACT IGNITION 0 TO 25 X X X IF5-70 ACT VALVE 61 GONAMO 0 TO 1.5 X X X IRCV-1 RC VALVE 62 - 10 TO 0 LVOT - 10 TO 0 X X IRCV-1 RC VALVE 62 - 10 TO 0 LVOT - 10 TO 0 X X IRCV-1 RC VALVE 62 - 10 TO 0 LVOT - 10 TO 0 X X	FRC-2	ROLL CONTROL THRUST	- 25 TO 25	STRAIN GAGE	0000 TO 0000	~ x	x î
IF5-1 MAIN MOTOR IGNITION 0 T0 5 X X X IF5-2 MAIN MOTOR IGNITION 0 T0 5 X X X IF5-3 LITVE IGNITION 0 T0 5 X X X IF5-4 LITVE IGNITION 0 T0 5 X X X IF5-5 ROLL CONTACL IGNITION 0 T0 5 X X X IF5-6 ROLL CONTACL IGNITION 0 T0 5 X X X IF5-6 ROLT IGNITION 0 T0 25 X X X IF5-10 RC VALVE #1 CONTAND 0 T0 25 X X X IF5-10 RC VALVE #1 CONTAND 0 T0 1.5 X X X POSITION V DC V DC V DC X X X LINU-4 PINTLE VALVE #2 -10 T0 0 LV0T -10 T0 0 X ** X IRCV-1 RC VALVE 0 T0 1 STRAIN GAGE 0 T0 1 X X IRCV-1 RC VALVE 0 T0 1 STRAIN GAGE 0 T0 1 X X IRCV-1		EVENT-CURRENT	AMPS				
IF5-2 NAIN WOTOR IGNITION 0 TO 5 1 <td< td=""><td>IES-1</td><td>HAIN MOTOR IGNITION</td><td>0 TO 5</td><td></td><td></td><td>x x</td><td>×</td></td<>	IES-1	HAIN MOTOR IGNITION	0 TO 5			x x	×
IFS-3 LITVC IGNITION 0 TO 5 X X X IFS-4 LITVC IGNITION 0 TO 5 X X X IFS-4 ROLL CONTROL IGNIT. 0 TO 5 X X X IFS-4 ROLL CONTROL IGNIT. 0 TO 5 X X X IFS-4 ROLL CONTROL IGNIT. 0 TO 25 X X X IFS-4 ROLT IGNITION 0 TO 25 X X X IRCV-1 R C VALVE #1 CONTAND 0 TO 25 X X X IRCV-1 R C VALVE #1 CONTAND 0 TO 0 LVOT -10 TO 0 X X IRCV-1 R C VALVE #2 -10 TO 0 LVOT -10 TO 0 X X IRCV-1 R C VALVE #2 -10 TO 0 LVOT -10 TO 0 X X IRCV-1 R C VALVE #2 -10 TO 0 LVOT -10 TO 0 X X IRCV-1 R C VALVE #2 -10 TO 0 LVOT -10 TO 0 X X IRCV-1 R C VALVE -10 TO 0 LVOT -10 TO 0 X <	IFS-2	MAIN MOTOR IGNITION	0 TO 5			x T	x
IF5-5 KOLL CONTROL IGNITION 0 T0 5 X X X IF5-5 ROLL CONTROL IGNIT. 0 T0 5 X X X IF5-6 ROLL CONTROL IGNIT. 0 T0 5 X X X IF5-7 ROLT IGNITION 0 T0 25 X X X IF5-10 ADTT IGNITION 0 T0 25 X X X IF5-10 ADTT IGNITION 0 T0 25 X X X IRCV-1 RC VALVE #1 CONRAND 0 T0 1.5 X X X POSITION V DC V DC V DC X X LINU-2 PINTLE VALVE #2 -10 T0 0 LVOT -10 T0 0 X X LINU-4 PINTLE VALVE #2 -4.5 T0 4.5 LVOT 0 T0 8 X** X PA-1 TEST CELL 0 T0 1 STRAIN GAGE 0 T0 1 X X X PA-2 TEST CELL 0 T0 15 STRAIN GAGE 0 T0 15 X X X PA-2 TEST CELL 0 T0 105 STRAIN GAGE 0 T0 1000 X <td>IFS-3</td> <td>LITVC IGNITION</td> <td>0 TO 5</td> <td></td> <td></td> <td>X</td> <td>X</td>	IFS-3	LITVC IGNITION	0 TO 5			X	X
IF5-5 ROLL CONTROL IGNIT 0 TO 5 X X X IF5-6 ROLL CONTROL IGNIT 0 TO 5 X X X IF5-9 AOTT IGNITION 0 TO 25 X X X IF5-10 AOTT IGNITION 0 TO 25 X X X IRCV-1 RC VALVE #1 CONTAND 0 TO 1.5 X X X POSITION V DC V CC X X X LINJ-2 PINTLE VALVE #2 - 10 TO 0 LVOT - 10 TO 0 X X LINJ-2 PINTLE VALVE #2 - 10 TO 0 LVOT - 10 TO 0 X X LINJ-4 PINTLE VALVE #2 - 4.5 TO 4.3 LYOT 0 TO 8 X** X IRCV-1 RC VALVE -4.5 TO 4.3 LYOT 0 TO 1 X X X IRCV-1 RC VALVE 0 TO 1 STRAIN GAGE 0 TO 1 X X X PRESSURE PSIA PSIA Y C Y Y Y Y Y PA-2 TEST CELL	IFS-4	LITVC IGNITION	0 TO 5			X	X
IF5-6 ROLL CONTROL IGNIT. 0 TD 5 X X X IF5-9 AOTT IGNITION 0 TO 25 X, X X IRCV-1 RC VALVE 61 CONMAND 0 TO 1.5 X X X POSITION V DC V DC X X X LINJ-2 PINTLE VALVE 62 -10 TO 0 LVOT -10 TO 0 X X LINJ-4 PINTLE VALVE 62 -10 TO 0 LVOT -10 TO 0 X X LINJ-4 PINTLE VALVE 64 -10 TO 0 LVOT -10 TO 0 X X PRESSURE PSIA -4.5 TO 4.5 LVOT 0 TO 8 X** X PA-1 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-2 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 15 X X PA-1 TEST CELL 0 TO 750 STRAIN GAGE 0 TO 750 X X PA-2 TEST CELL 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1 MOTOR CHAMBER (FILT) -25 TO 255	1FS-5	ROLL CONTROL IGNIT.	0 TO 5			×	x
IFS-10 AOTY IGNITION 0 TO 25 X </td <td>IFS-6</td> <td>ROLL CONTROL IGNIT.</td> <td>0 TO 5</td> <td></td> <td></td> <td>×</td> <td>X</td>	IFS-6	ROLL CONTROL IGNIT.	0 TO 5			×	X
IPS-10 IRCV-1 ACT I LEWITION RC VALVE \$1 COMMAND 0 TO 23 0 TO 1.5 X / X X POSITION V DC V DC V DC LINU-2 LINU-4 PINTLE VALVE \$2 - 10 TO 0 - 10 TO 0 LVOT - 10 TO 0 - 10 TO 0 X / X PRESSURE PSIA - 10 TO 0 - 4.5 TO 4.5 LVOT O TO 1 - 10 TO 0 X / X X PA-1 TEST CELL PA-2 0 TO 1 TEST CELL 0 TO 1 - 10 TO 1 STRAIN GAGE 0 TO 1 - 10 TO 1 X / X X PA-2 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 15 X / X X PC-1 MOTOR CHAMBER O TO 15 STRAIN GAGE 0 TO 15 X / X X PC-1 MOTOR CHAMBER O TO 750 STRAIN GAGE 0 TO 750 X / X X PC-1 MOTOR CHAMBER O TO 750 STRAIN GAGE 0 TO 150 X / X X PC-2 MOTOR CHAMBER O TO 750 STRAIN GAGE 0 TO 1000 X * X X PC-1 MOTOR CHAMBER O TO 100 STRAIN GAGE 0 TO 1000 X * X X PC-2 MOTOR CHAMBER O TO	IFS-9	AOTT IGNITION	0 TO 25			X X	X
IRCU-1 IRC VALVE #1 COMMAND D TO 1.5 X++ X POSITION V DC V DC V DC LINJ-2 PINTLE VALVE #2 - 10 TO 0 LVOT - 10 TO 0 X X LINJ-4 PINTLE VALVE #2 - 10 TO 0 LVOT - 10 TO 0 X X LINJ-4 PINTLE VALVE #2 - 4.5 TO 4.5 LVOT - 10 TO 0 X X PRESSURE PSIA PSIA PSIA PSIA PA-1 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-2 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 15 X X PA-3 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 750 X X PA-5 TEST CELL 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1F MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1F MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 1000 X X PC-1F MOTOR CHAMBER 0 TO 100 STRAIN	IF5-10	AUTT IGNITION	0 10 25			× + +	ž
POSITION V DC V DC LINJ-2 LINJ-4 LINJ-4 PINTLE VALVE #2 - 10 TO 0 LINJ -4 LINJ-4 PORT - 10 TO 0 PINTLE VALVE #2 PINTLE VALVE #4 PINTLE VALVE #4 PINTLE VALVE - 10 TO 0 - 10 TO 0 PINTLE VALVE #4 - 10 TO 0 - 10 TO 0 PINTLE VALVE - 10 TO 0 PINTLE VALVE - 10 TO 0 PINTLE VALVE X X PRESSURE PSIA PSIA PSIA PA-1 PA-1 PA-2 TEST CELL O TO 1 O TO 1 STRAIN GAGE O TO 1 O TO 1 STRAIN GAGE O TO 1 O TO 1 STRAIN GAGE X X PA-1 PC-1 PG-1 PG-1 PG-1 PG-1 PG-1 PGT 0 TO 15 STRAIN GAGE O TO 1 STRAIN GAGE O TO 1 STRAIN GAGE X X PA-2 PG-1 PG-1 PG-1 PGT 0 TO 15 STRAIN GAGE O TO 15 STRAIN GAGE X X X PC-1 PGT MOTOR CHAMBER PGT O TO 15 STRAIN GAGE O TO 15 STRAIN GAGE X X X PDF GN2 OIF GRIFICE -100 TO 100 STRAIN GAGE O TO 100 STRAIN GAGE TO 100 STRAIN GAGE TO 100 STRAIN GAGE TO 3000 STRAIN GAG	IKCA-I	KC VALVE #1 COMMAND	0 10 1.5			***	*
LINJ-2 PINTLE VALVE #2 -10 TO 0 LVOT -10 TO 0 X X LINJ-4 PINTLE VALVE #4 -10 TO 0 LVOT -10 TO 0 X X LRCV-1 RC VALVE -4.5 TO 4.5 LVOT -10 TO 0 X X PRESSURE PSIA PSIA PSIA PSIA PA-1 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-2 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-3 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 15 X X PA-4 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 750 X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 1000 X** X X PC-2 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 1000 X** X X PDF GN2 0 IF CR IFICE -100 TO 100 STRAIN GAGE -100 TO 1000 X ** X		POSITION	V DC		V DC		
LINJ-A PINTLE VALVE PA - 10 TO 0 LVOT - 10 TO 0 X X PRESSURE PSIA PSIA PSIA PA-1 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-2 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 15 X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1F MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-2 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1F MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 10000 X** X X PC-2 MOTOR CHAMBER 0 TO 100 STRAIN GAGE 0 TO 10000 X** X X PDF GN2 OIF OR IFICE -100 TO 100 STRAIN GAGE 0 TO 1000 <th< td=""><td>LINJ-2</td><td>PINTLE VALVE #2</td><td>- 10 TO 0</td><td>LVOT</td><td>- 10 TO O</td><td>X</td><td>x</td></th<>	LINJ-2	PINTLE VALVE #2	- 10 TO 0	LVOT	- 10 TO O	X	x
LRCV-1 RC VALVE -4.5 TO 4.5 LVOT 0 TO 8 X** X PRESSURE PSIA PSIA PSIA PSIA PSIA PA-1 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X X PA-2 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X X PA-4 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 15 X X X PA-5 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 15 X X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X X PC-1F NOTOR CHAMBER (FILT) - 25 TO 25 STRAIN GAGE 0 TO 10000 X X X PC-2 NOTOR CHAMBER (FILT) - 25 TO 25 STRAIN GAGE -100 TO 1000 X X X PG-4 GN2 OIF OR IFICE -100 TO 100 STRAIN GAGE -100 TO 100 X X X <t< td=""><td>LINJ-4</td><td>PINTLE VALVE #4</td><td>- 10 TO O</td><td>LVOT</td><td>~ 10 TO 0</td><td>X</td><td>X</td></t<>	LINJ-4	PINTLE VALVE #4	- 10 TO O	LVOT	~ 10 TO 0	X	X
PRESSURE PSIA PSIA PA-1 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-2 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-4 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-4 TEST CELL 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1F MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-2 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-2 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 10000 X** X X PDF GN2 01F OR IFICE -100 TO 100 STRAIN GAGE 0 TO 100 X X PfDA-1 FORWARD DOME AREA 0 TO 100 STRAIN GAGE 0 TO 200 X X PfDA-2 FORWARD DO	LRCV-1	RC VALVE	-4.5 TO 4.5	LVOT	0 TO 8	x * *	x
PA-1 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X X PA-2 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X X PA-5 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 15 X X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X X PC-1F MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X X PC-1F MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X X PC-2 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 10000 X** X X PDF GN2 01F ORIFICE -100 TO 100 STRAIN GAGE -100 TO 1000 X X X PFDA-1 FORWARD DOME AREA 0 TO 10 STRAIN GAGE 0 TO 255 X X X PFDA-2 FURMARD DOME AREA 0 TO 255 STRAIN GAGE 0 TO 25000 X X X PI-1 IGNITER 0 TO 3000 STRAIN GAGE		PRESSURE	PSIA		PSIA		
PA-2 TEST CELL 0 TO 1 STRAIN GAGE 0 TO 1 X X PA-5 TEST CELL 0 TO 15 STRAIN GAGE 0 TO 15 X X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X X PC-1F MOTOR CHAMBER (FILT) - 25 TO 25 STRAIN GAGE 0 TO 750 X X X PC-2 MOTOR CHAMBER (FILT) - 25 TO 25 STRAIN GAGE 0 TO 750 X X X PD-1 MOTOR CHAMBER (FILT) - 25 TO 25 STRAIN GAGE 0 TO 750 X X X PD-2 MOTOR CHAMBER (FILT) - 25 TO 25 STRAIN GAGE 0 TO 750 X X X PDF GN2 01F OR IFICE -100 TO 100 STRAIN GAGE -100 TO 100 X X X PFDA-1 FORWARD DOME AREA 0 TO 10 STRAIN GAGE 0 TO 255 X X X PFDA-2 FORWARD DOME AREA 0 TO 3000 STRAIN GAGE 0 TO 3000 X ** X X PI-1 IGNITER 0 TO 3000	PA-1	TEST CELL	0 TO 1	STRAIN GAGE	0 TO 1	x	x x
PA-R TEST CELL 0 TO 15 STRAIN GAGE 0 TO 15 X PC-1 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PC-1F MOTOR CHAMBER (FILT) -25 TO 25 STRAIN GAGE 0 TO 750 X X PC-2 MOTOR CHAMBER 0 TO 750 STRAIN GAGE 0 TO 750 X X PDF GN2 01F ORIFICE -100 TO 100 STRAIN GAGE 0 TO 100 X X X PDF GN2 01F ORIFICE -100 TO 100 STRAIN GAGE 0 TO 100 X X X PDF GN2 01F ORIFICE -100 TO 100 STRAIN GAGE 0 TO 100 X X X X X X X X X X X X X X X X	PA-2	TEST CELL	0 TO 1	STRAIN GAGE	0 TO 1	<u>i</u>	
PC-1 MOTOR CHAMBER 0 T0 750 STRAIN GAGE 0 T0 750 X X X PC-1F MOTOR CHAMBER (FILT) - 25 T0 25 STRAIN GAGE 0 T0 750 X X X PC-2 MOTOR CHAMBER 0 T0 750 STRAIN GAGE 0 T0 750 X X X PC-2 MOTOR CHAMBER 0 T0 750 STRAIN GAGE 0 T0 1000 X X X PDF GN2 01F CR IFICÉ -100 T0 100 STRAIN GAGE -100 T0 100 X X X PFDA-1 FORWARD DOME AREA 0 T0 10 STRAIN GAGE 0 T0 10 X X X PFDA-2 FORWARD DOME AREA 0 T0 25 STRAIN GAGE 0 T0 25 X X PfD-1 IGNITER 0 T0 3000 STRAIN GAGE 0 T0 3000 X X PhI-4 MANIFOLO INJECTANT 0 TO 1000 STRAIN GAGE 0 T0 3000 X X PNS GN2 SUPPLY 0 TO 500 STRAIN GAGE 0 T0 500 X X PQA AFT NOZZLE QUENCH 0 TO 200 STRAIN GAGE 0 T0 200 <td>PA-5</td> <td>TEST CELL</td> <td>0 TO 15</td> <td>STRAIN GAGE</td> <td>0 TO 15</td> <td>x</td> <td></td>	PA-5	TEST CELL	0 TO 15	STRAIN GAGE	0 TO 15	x	
PC-1F MOTOR CHAMBER (FILT) - 25 T0 25 STRAIN GAGE 0 T0 750 X PC-2 MOTOR CHAMBER 0 T0 750 STRAIN GAGE 0 T0 1000 X*X X PDF GN2 01F OR IFICE -100 T0 100 STRAIN GAGE -100 T0 100 X*X X PFDA-1 FORWARD DOME AREA 0 T0 10 STRAIN GAGE 0 T0 10 X X X PFDA-2 FORWARD DOME AREA 0 T0 10 STRAIN GAGE 0 T0 25 X X PI-1 IGNITER 0 T0 3000 STRAIN GAGE 0 T0 3000 X** X X PNI-4 MANIFOLO INJECTANT 0 T0 3000 STRAIN GAGE 0 T0 3000 X X PNS GN2 SUPPLY 0 T0 500 STRAIN GAGE 0 T0 500 X X PQA AFT NOZZLE QUENCH 0 T0 200 STRAIN GAGE 0 T0 500 X X PQA AFT NOZZLE QUENCH 0 T0 200 STRAIN GAGE 0 T0 200 X X PQA AFT NOZZLE QUENCH 0 T0 200 STRAIN GAGE 0 T0 200 X X PQA FOWAR	PC-1	NOTOR CHAMBER	O TO 750	STRAIN GAGE	0 TO 750	X X	X
PC-2 MOTOR CHAMBER 0 T0 750 STRAIN GAGE 0 T0 1000 X ** X X X PDF GN2 01F OR IFICE -100 T0 100 STRAIN GAGE -100 T0 100 X X X PFDA-1 FORWARD DOME AREA 0 T0 10 STRAIN GAGE 0 T0 10 X X X PFDA-2 FORWARD DOME AREA 0 T0 10 STRAIN GAGE 0 T0 25 X X PfDA-2 FORWARD DOME AREA 0 T0 25 STRAIN GAGE 0 T0 3000 X** X X PfDA-2 FORWARD DOME AREA 0 T0 3000 STRAIN GAGE 0 T0 3000 X** X X Pf1-1 IGNITER 0 T0 3000 STRAIN GAGE 0 T0 3000 X** X X PNI-4 MANIFOLO INJECTANT 0 T0 1000 STRAIN GAGE 0 T0 1000 X X PNS GN2 SUPPLY 0 T0 500 STRAIN GAGE 0 T0 200 X X PQA AFT NOZZLE QUENCH 0 T0 200 STRAIN GAGE 0 T0 200 X X PQ6 FOWARD TT QUENCH 0 T0 200 STRAIN GAGE 0 T0 200 X	PC-1F	MOTOR CHAMBER (FILT)	- 25 TO 25	STRAIN GAGE	O TO 750	X X	
PDF GN2 0 IF URIFICE -100 to 100 STRAIN GAGE -100 to 100 X PFDA-1 FORWARD DOME AREA 0 to 10 STRAIN GAGE 0 to 10 X X PFDA-2 FURWARD DOME AREA 0 to 10 STRAIN GAGE 0 to 25 X X PFDA-2 FURWARD DOME AREA 0 to 25 STRAIN GAGE 0 to 25 X X PI-1 IGNITER 0 to 3000 STRAIN GAGE 0 to 3000 X** X X PMI-4 MANIFOLO INJECTANT 0 to 1000 STRAIN GAGE 0 to 1000 X X PNS GN2 SUPPLY 0 to 500 STRAIN GAGE 0 to 500 X PQA AFT NOZZLE QUENCH 0 to 200 STRAIN GAGE 0 to 200 X PQA AFT NOZZLE QUENCH 0 to 200 STRAIN GAGE 0 to 200 X PQA FORWARD TT QUENCH 0 to 200 STRAIN GAGE 0 to 200 X	PC-2	MOTOR CHAMBER	0 TO 750	STRAIN GAGE	0 TO 1000	X** X	X X
PFDA-1 PURWARD DUME AREA 0 TO 10 STRAIN GAGE 0 TO 10 X X X PFDA-2 FURWARD DUME AREA 0 TO 25 STRAIN GAGE 0 TO 25 X X PFDA-2 FURWARD DUME AREA 0 TO 25 STRAIN GAGE 0 TO 25 X X PFD-1 IGNITER 0 TO 3000 STRAIN GAGE 0 TO 3000 X** X X PMI-4 MANIFOLO INJECTANT 0 TO 1000 STRAIN GAGE 0 TO 1000 X X PNS GN2 SUPPLY 0 TO 500 STRAIN GAGE 0 TO 500 X X PQA AFT NOZZLE QUENCH 0 TO 200 STRAIN GAGE 0 TO 200 X PQF FORWARD TT QUENCH 0 TO 200 STRAIN GAGE 0 TO 200 X	PDF	GNZ OIF ORIFICE	-100 TO 100	STRAIN GAGE	-100 TO 100	X	
PT-1 IGNITER 0 T0 20 STRAIN GAGE 0 T0 20 X X P1-1 IGNITER 0 T0 3000 STRAIN GAGE 0 T0 3000 X * X X PNI-4 MAINFOLO INJECTANT 0 T0 1000 STRAIN GAGE 0 T0 1000 X * X X PNS GN2 SUPPLY 0 T0 500 STRAIN GAGE 0 T0 500 X X PQA AFT NOZZLE QUENCH 0 T0 200 STRAIN GAGE 0 T0 200 X X PAF FORWARD TT QUENCH 0 T0 200 STRAIN GAGE 0 T0 200 X X	PP DA-1	FURWARD DURE AREA	0 10 10	STRAIN GAGE	0 10 10	<u>.</u>	X X
PHI-4 MANIFOLO INJECTANT 0 TO 3000 STRAIN GAGE 0 TO 3000 X X PNS GN2 SUPPLY 0 TO 500 STRAIN GAGE 0 TO 500 X PQA AFT NOZZLE QUENCH 0 TO 200 STRAIN GAGE 0 TO 200 X PGF FORWARD TT QUENCH 0 TO 200 STRAIN GAGE 0 TO 200 X	PFUA~Z	FURWARD DUME AREA	0 10 25	STRAIN GAGE	0 10 25		~
PNS GN2 SUPPLY O TO 500 STRAIN GAGE O TO 500 X PQA AFT NOZZLE QUENCH O TO 200 STRAIN GAGE O TO 200 X PQF FORWARD TT QUENCH O TO 200 STRAIN GAGE O TO 200 X	PI-L	IUNITER MANIEOLO INIECTANT	0 10 3000	STRAIN GAGE	0 10 3000	ደጥጥ ጀ	õ
PQA AFT NOZZLE QUENCH 0 TO 200 STRAIN GAGE 0 TO 200 X PAF FORWARD TT QUENCH 0 TO 200 STRAIN GAGE 0 TO 200 X	PHI-7	CN7 SUBOLY	0 10 1000	STRAIN GAGE	0 10 1000	X Y	*
POF FORWARD TT QUENCH Ó TO 200 STRAIN GAGE Ó TO 200 X	POA	AFT NOTTLE DUENCH	0 10 200	STRAIN CACE	0 10 200	÷.	
	POF	FORWARD TT QUENCH	0 TO 200	STRAIN GAGE	0 10 200	7	

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TABLE II (Concluded)

PARAMETER SYMBOL	PARAMETER DESCRIPTION	MEASUREMENT RANGE	SENSOR TYPE	SENSOR RANGE	DIGITAL [‡] ANALOG Systen tape	OSCILLO- STRIP GRAPH CHART
	PRESSURE	₽ SI A		PSIA		
PRCGG PRFG	ROLL CONTROL GAS GEN Regulated Helium	0 TO 1500 0 TO 1000	SÌRAIN GAGE Strain Gage	0 TO 1500 0 TO 1000	X X	x x
	TEMPERATURE	DEG. F		DEG. F		
TA-1 TA-2 TA-5	AMBIENT TEST CELL Ambient TEST Cell	0 TO 100 0 TO 500 0 TO 500	C/A, TYPE K C/A, TYPE K C/A, TYPE K	-300 TO 2500 -300 TO 2500 -300 TO 2500	×,	×
TF-1 TP-1	FORWARD GN2 FLOW LN PROPELLANT GRAIN	0 TO 200 0 TO 100	C/A, TYPE K C/A, TYPE K	-300 TO 2500 -300 TO 2500 -300 TO 2500	Â.	X
TRC-3	ROLL CONTROL GAS GEN	0 TO 200	C/A, TYPE K C/A, TYPE K	-300 TO 2500 -300 TO 2500	X	x

*BASIC SAMPLING RATE 100 SAMPLES/SEC **PARAMETER SUPERCOMMUTATED TO 1000 SAMPLES/SEC (1)SIGNALS FROM PC-1 AND FY-3 WERE FILTERED BEFORE RECORDING BY INSTALLING HIGH PASS FILTERS (3 db POINT OF 50 Hz WITH 6 db/OCTAVE ROLL OFF). NEITHER PARAMETER WAS SUCCESSFULLY RECORDED BECAUSE OF INSTRUMENTATION ANOMALIES.

TABLE III NOZZLE MEASUREMENTS

Prefire Nozzle Measurements

Degrees	Throat Diameter, in.	Exit Diameter, in.
		(0.25 in. upstream of exit)
0	6.878	33.311
30	6.877	33.309
60	6.877	33.315
90	6.876	33.327
120	6.378	33.334
150	6.877	33.330
Average, in.	6.877	33.321
Area, sq in.	37.146	872.021
TCC-supplied Areas,		
sq in.	37.100	-

Postfire Nozzle Measurements

Degrees	Throat Diameter, in.	Exit Diameter, in.		
		(0.25 in. upstream of exit)		
0	6.858	33.520		
30	6.861	33.625		
60	6.858	33.512		
90	6.839	33.626		
120	6.821	33.617		
150	6.853	33.505		
Average, in.	6.848	33.568		
Area, sq in.	36.835	884.971		
Percent Change in Area (AEDC				
Measurements)	-0.8	+1.5		

Temperature, *F		ture, *F	Location	Relative Hun	nidity, percent	Bemarke	
Date	High	Low	Motor	High	Low	NGUNALKA	
1/16/73	69	62	Rocket Preparation Area	31	29	Temperature below 65°F approxi- mately 15 min	
1/17/73	68	64		31	28	Temperature below 65°F'approxi- mately 10 min	
1/18/73	69	67		57	32		
1/19/73	70	62		57	29	Temperature below 65°F approxi- mately 5 min	
1/20/73	70	68		29	24		
1/21/73	69	68		49	25		
1/22/73	69	68		50	46		
1/23/73	70	67	¥	36	27		
1/24/73	72	69	Rocket Preparation Area and J-5 Test Cell (Motor)	31	26		
1/24/73	70	66	Rocket Preparation Area (Roll Control Subsystem)	26	22	Temperature below 65°F approxi- mately 10 min	
1/25/73	72	71	J-5 Test Cell (Motor)	34	26		
1/25/73	70	67	Rocket Preparation Area (Roll Control Subsystem)	30	22		
1/26/73	72	72	J-5 Test Cell (Motor)	42	28		
1/26/73	68	60	Rocket Preparation Area (Roll Control Subsystem)	52	26	Temperature below 65°F approxi- mately 15 min	
1/27/73	75	70	J-5 Test Cell (Roll Con- trol Subsystem)	50	34		

TABLE IV MOTOR TEMPERATURE-CONDITIONING HISTORY

TABLE V COMPARISON OF LGM-30G STAGE III POA MOTORS FIRED AT AEDC

Motor Number	PQA-1	PQA-2	PQA-3	PQA-4	PQA-5	PQA-63	PCA 7	PQA-8	PQA-9	1'QA-10	PQA-11	PQA-12	FQA-101	PQA-102
AEDC TR Number	71-240	71-248	71-251	71-233	71-269	71-275	12-49	72-77	72-105	72-152	72-177	73-7	73-43	73.76
Date Fired	6-14-71	8-19 71	6-28-71	9-8-71	9 30-71	11-3-71	1-25-72	3-21-72	5-15-72	6-29-72	6-23-72	10-17-72	11-17-72	1-26-73
Propellant Tempera- ture, "F	70	71	68	80	73	70	71	71	71	10	72	72	71	71
Ignition Delay, maec	88	82	64	85	86	87	68	89	86	65	84	69	64	86
Maximum ignitar Pres- sure, paia	2327	2 39 7	2246	2119	2121	2141	2245	2127	2327	2148	2407	2363	2246	2364
Action Tume, sec	59.43	39 01	60 23	59 82	59 26		82 70	60 74	58, 17	58, 14	56.05	58, 40	57.61	60, 10
Thruat 1 Maximum, lbf Average, lbf	43, 147 34, 979	43, 761 35, 267	42, 957 34, 482	43, 370 34, 783	43, 392 35, 006	43, 348 36, 603	41, 233 33, 103	42, 060 34, 205	43, 800 35, 723	44, 473 35, 644	44, 421 35, 813	44, 245 33, 542	44,562 36,084	42,025 34,622
Chamber Pressure Maximum, pris Avaraga, pais At Thrust Termina-	632 529	652 525	645 517	651 521	548 623	648 580	619 496	631 513	858 535	666 535	663 537	865 533	671 544	643 519
tion, psia	79 6	74 4	79.7	75 7	78 0	585.4	75 3	75.2	74 9	73 6	70.5	76_0	74,7	75.3
Total Impulse, ¹ lbf-ace	2, 076, 805	2, 081, 204	2, 077, 452	2, 079, 547	2, 075, 261	1, 368, 816	2, 1175, 555	2, 077, 586	2, 077, 980	2, 078, 457	2,078,955	2,075,882	2,078,776	2,013,534
Specific Imputse, 1, 2 lbf-aer/lbm	264, 53	284, 62	264 41	284. 33	284 18	264. 62	264 26	284.43	284,31	284, 41	284, 55	284, 41	284,24	264. 94
Thrust Termination Function- ing Time, (Farat Part), page	403	403	403	402	420	420	420	436	4204	437	455	480	460	403
Thrust Termination Interval, µsec	70	52	1243	18	35	157	18	17	18	18	17	20	30	67
Liquid Injection Thrust Vector Control Yaw Angle, 3 4 sec, dag	2 20	2, 13	2. 20	2. 18	2. 21	2 20	2 211	0. 32 ⁵	2.09	2 12	2, 12	2, 16	2,15	2.12

¹Thrust vector control system axial augmentation removad and vacuum correction added

²Calculated using total loaded propallant weight

³ SPQA-6 lhrust terminated at 35 40 sec, specific impulse calculated using a calculated expended propellant weight

⁴Functioning time of two libruat termination ports not recorded because of an instrumentation anomaly

⁵Thrust vector control yaw angle below specification bacause the slam suppressor pin failed to shear

TABLE VI							
SUMMARY	OF	MOTOR	PERFORMANCE				

GL NERAL INFORMATIONACTUALMINIMUMMAXIMUMNOTOR S/N *PQA102 30195NOTOR S/N *PQA102 30195NOTOR S/N *SR73AJ-1TYPE FIRINGALTITUDEDATE CAST *10-16-72DATE CAST *10-16-72TOTAL MOTOR WEIGHT IPREFIRE), LBM *8032.2CASE PROPELLANT MEIGHT INPERTIRE), LBM *8032.2TOTAL PROPELLANT MEIGHT INPT), LBM *7312.3TOTAL PROPELLANT MEIGHT INPT), LBM *8.0PROPELLANT MEIGHT INPT), LBM *8.0PROPELLANT MEIGHT INPT), LBM *8.0PROPELLANT MEIGHT INPT), LBM *7304.3PROPELLANT MEIGHT INPT), LBM *8.0PROPELLANT MEIGHT INPT), LBM *8.0PROPELLANT MEIGHT INPT, LBM *8.0PROPELLANT SQLIE THROAT AREA IAEDCI, SQ. IN.37.146POST FIRE NOZZLE THROAT AREA IAEDCI, SQ. IN.906.248PROPELLANT GAIN TENPERATURE, DEGREES F.71AMBIENT PRESSURE PRIOR TO FIRING, PSIA0.150RELATIVE HUNIDITY PRIDR TO TEST CELL EVACUATION, PERCENT37TEST CELL PERFORMANCE102000AT PRESSURANT SQUIB EGNITION, FT.102000AT NOTOR IGNITION, FT102000AT WOTOR IGNITION, FT91000AVERA
NOTOR S/N *PGA102 30195MODEL NUMBER *SR73AJ-1TYPE FIRINGALTITUDEDATE FIRED01-24-73DATE FIRED10-14-72TOTAL MOTOR WEIGHT IPREFIRE), LBN *6052.2TOTAL MOTOR WEIGHT, LBN *7312.3CASE PROPELLANT WEIGHT, LBN *7312.3TOTAL PROPELLANT WEIGHT, LBN *6.0PROPELLANT WEIGHT, LBN *7304.3PROPELLANT MELANT MELON, SQ. IN.37.100PREFIRE NOZZLE THROAT AREA IAEDCI, SQ. IN.38.106POST FIRE NOZZLE THROAT AREA IAEDCI, SQ. IN.906.246PREFIRE NOZZLE EXIT AREA IAEDCI, SQ. IN.906.246
MODEL NUMBER *SR 73AJ-1TYPE FIRINGALTITUDEDATE CAST *01-24-73DATE CAST *10-14-72TOTAL MOTOR WEIGHT IPREFIRE), LON *6052.2GASE PROPELLANT WEIGHT, LON *7312.3TOTAL PROPELLANT WEIGHT, LON *7312.3TOTAL PROPELLANT WEIGHT, LON *6.0EXPENDED PROPELLANT WEIGHT, LON *6.0PROPELLANT WEIGHT, LON *7304.3PROPELLANT WEIGHT, LON *7304.3PROPELLANT WEIGHT, LON *7304.3PROPELLANT MEIGHT, LON *80.10.PROPELLANT MEIGHT, LON *7304.3PROPELLANT MEIGHT, LON *80.10.PROPELLANT AREA IAEOCI, SQ. IN.37.100PREFIRE NOZZLE THROAT AREA IAEOCI, SQ. IN.38.106POST FIRE NOZZLE THROAT AREA IAEOCI, SQ. IN.36.106POST FIRE NOZZLE EXIT AREA IAEOCI, SQ. IN.36.106PREFIRE PROZEL EXIT AREA IAEOCI, SQ. IN.906.240PREFIRE PROZEL EXIT AREA IAEOCI, SQ. IN.91000PREFIRE PROZEL EXIT AREA
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PREFIRE PROPELLANT GRAIN TEMPERATURE, DEGREES F. 71 65 75 AMBIENT PRESSURE PRIOR TO FIRING, PSIA 0.150 0.150 RELATIVE HUMIDITY PRIOR TO TEST CELL EVACUATION, PERCENT 37 TEST CELL PERFORMANCE AT PRESSURANT SQUIB IGNITION, FT. 102000 AT PRESSURANT SQUIB IGNITION, FT. 102000 100000 AT INDOR IGNITION, FT 97000 60000 AVERAGE, FT 91000 60000
AMBIENT PRESSURE PRIOR TO FIRING, PSIA 0.150 RELATIVE NUMIDITY PRIOR TO TEST CELL EVACUATION, PERCENT 37 TEST CELL PERFORMANCE ALTITUDE AT PRESSURANT SQUIB EGNITION, FT. 102000 AT PRESSURANT SQUIB EGNITION, FT. 102000 AT THRUST TERMINATION, FT 9700 AVERAGE, FT 91000 60000
RELATIVE HUMIDITY PAIDR TO TEST CELL EVACUATION, PERCENT 37 TEST CELL PERFORMANCE ALTITUDE AT PRESSURANT SQUIB EGNITION, FT. 102000 AT HOTOR IGNITION, FT 100000 AT HRUST TERMINATION, FT 9700 AVERAGE, FT 91000 60000
TEST CELL PERFORMANCE ALTITUDE AT PRESSURANT SQUIB EGNITION, FT. AT PROTOR IGNITION, FT AT THRUST TERMINATION, FT AVERAGE, FT PRESSURE PROTOCOMPANY
TEST CELL PERFORMANCE ALTITUDE AT PRESSURANT SQUIB FGNITION, FT. AT NOTOR IGNITION, FT AT THRUST TERMINATION, FT AVERAGE, FT PRESSURE PRESSURE PRESSURE
ALTITUDE AT PRESSURANT SQUIB EGNITIDN, FT. 102000 AT PRESSURANT SQUIB EGNITIDN, FT. 102000 AT HRUST TERMINATION, FT 97000 AVERAGE, FT 91000 PRESSURE 91000
AT PRESSURANT SQUIB EGNITION, FT. 102000 AT MOTOR IGNITION, FT 102000 AT THRUST TERMINATION, FT 97000 AVERAGE, FT 91000 ADDOD 91000
AT NDTOR IGNITION, FT 102000 100000 AT THRUST TERMINATION, FT 97000 97000 AVERAGE, FT 91000 60000
AT THRUST TERMINATION, FT 9700 Average, FT 9100 60000
AVERAGE, FT 91000 60000
INTERNAL FOR A FOR
TARE TENTTON DELAY TRE 1000 BETAL MESC.
AT MAXIMUM VALUUM AXIAL IMKUSI, SEC.
ACTION 1/5 PSIA CHANGER PRESSURE 1, SEC. 60.100 97.33 62.33
THRUST TERMINATION ITT), SEC. 60.140
THRUST TERRINATION FUNCTIONING, MICROSEC.
STACK 1 403 219 705
STACK 2 420 219 705
STACK 3 420 219 705
STACK 4 455 219 705
STACK 5 430 219 705
STACK 6 4 <u>90</u> 219 705
THRUST TERMINATION INTERVAL, MICROSEC. 87

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TABLE VI (Concluded)

		SPECIF	ICATION
PRESSURF	ACTUAL	IN THE PART AND	MAXT MIN
MAYIMIM ICATTER, BELA	3354		34.83
	2334		2403
AVERAGE IGATIER, PSTA	1010	1 200	1420
INTEGRAL OF IGNITER, PSIA-SEC.	264.3	225	314
MAXINUM CHAMBER RISE RATE, PSIA/SEC.	6503		
NAXINUN NOTOR CHANGER + PSIA	643		
	610		
	214		
NUTUR CHANGER INTEGRAL, PSIA-SEC.	31260		
INTEGRAL OF MOTOR CHAMBER RAISED TO 0.30 POWER, PSIA-SEC.	390		
NOTOR CHANBER AT IT TIME. PSIA	75.3	70	80
NAXINUM FORWARD DORF CAVITY BETWEEN IT AND TT+2 SEC., PSID	0.744		
AVIAL TADIET			
ARIAL THRUST			
HAXINUN NEASURED FURCE, LBF	42723		
MAXIMUM AUGNENTEO YACUUM, LBF	42961		
NAXINUN UNAUGMENTEO VACUUN. LBF	42925		
AVERAGE MEASURED FORCE, LBF	34418		
	34.441		
AVERAGE AUGMENTED TACUMUL LOF	34041		
AVERAGE UNAUGHENTED VACUUM, LBP	34622		
IAPULSE			
NEASURED TOTAL, LBF-SEC.	2071285		
THE HOTHE ANGUENTATION, I BE SEE	2054 727		
	2004723		
EXCLUDING AUGMENTATION, LBF-SEC.	2083534		
AUGMENTED VACUUM SPECIFIC			
OPTION 1 IUSING WPC). LBF-SEC./LBM	283.45		
OPTION 2 LUSING MP3, LBE-SEC. / BM	285.41		
IMANCHENTER MACHINE ERECTOR	202071		
UPTION & IUSING WPCI, LBP-SEC./LBM	243.29		
OPTION 2 IUSING WP), LBF-SEC./LBM	285.25		
OPTIDN 3 IUSING WPT). LBF-SEC./LBM	284.94	263.1	286.1
PROPELLANT FLOW RATE			
	100 01		
	144.41		
INTEGRAL IUSING WOOTPC), LBM	7354.7		
AVERAGE IUSING WOOTPI, LBM/SEC.	121.50		
INTEGRAL (USING WOOTP). LBM	7311.6		
MISCELLANERUS			
AATTO AE ENECTETC HEAT TCANNAL +	1 30		
ANTID OF SPECIFIC NEAT IGAMMAS -	1.20		
GMARAGTERISTIC EXHAUST VELOCITY, FT./SEC.	5212.0		
LIGUID INJECTION THRUST VECTOR CONTROL PERFORMANCE			
TIME			
TWO DELAY- SEC	1 330	1.0	- 12 C
THE DELANT SEC.	1.337	4.0	T* 0
PRESSURE	623		
DURING INJECTION SURGE, PSIA	697		1875
AVERAGE INJECTION PRESSURE FOR 130 MILLISEC AFTER TVC DELAY. PSIA	679		1500
MAXIMUM IN FECTANT OURING ZERD SLOW, OSTA	497		736
	476	488	
HIMINDH INJECIANI DUKING ZERD FLUB, FSIA	0/4	822	
ROLL CONTROL PERFORMANCE			
ACTION TINE, SEC.	74-B10		
CAL CENEDATING ODESSIDE AT 13.4 SEC. DETA	1031		
AN CHURATOR FREJOURE AT 1340 JE449 FJIA	1031		
WAS GENERATUR PRESSURE AT OU. SEL., FSTA	102		
NAXIMUN GAS GENERATOR PRESSURE, PSIA	1291		
+ FROM MOTOR LOG BOOK	•		
**BASED ON TCC SUPPLIED TABLE			

.

TABLE VII ROLL CONTROL VALVE DUTY CYCLE

Time (sec)								
0 4.0 7.0 8.0 9.0	to to to to	4.0 7.0 8.0 9.0 10.0						
10.0 13.0 16.0 19.0 22.0	to to to to	13.0 16.0 19.0 22.0 25.0						
25.0 28.0 31.0 34.0 37.0	to to to to	28.0 31.0 34.0 37.0 40.0						
40.0 43.0 46.0 49.0 52.0	to to to to	43.0 46.0 49.0 52.0 55.0						
55.0 58.0 61.0 64.0 67.0 70.0	to to to to to	58.0 61.0 64.0 67.0 70.0 End						

Null Cw 10 Hz, null to Cw to null 10 Hz, null to Ccw to null 10 Hz, Cw to Ccw to Cw
Ccw Null 5 Hz, null to Cw to null 5 Hz, null to Ccw to null 5 Hz, Cw to Ccw to Cw
Cw Ccw Null 10 Hz, null to Cw to null 10 Hz, null to Ccw to null
10 Hz, Cw to Ccw to Cw Cw Ccw Null 20 Hz, null to Cw to null
20 Hz, null to Ccw to null 20 Hz, Cw to Ccw to Cw Cw Ccw Null Cw

Valve Position

TABLE VIII ROLL CONTROL SYSTEM PERFORMANCE SUMMARY

GENERAL

TEST ND. DATE FIRED MOTOR S/N ROLL CONTROL ASSEMBLY S/N TEST CONFIGURATION ALTITUDE AT GAS GENERATOR I SYSTEM TEMP. AT GAS GENERAT	GNITION, FT Or Ignition, deg f	04 01-26-73 PQA-102 (30195) 1000364 OFF Motor 122,000 70
TIMES	ACTUAL	MAXIMUM SPECIFICATION
MAXIMUM VALVE RESPONSE MSEC		
ROLL MOMENT BUILDUP		
5 HZ CW-NULL-CW	22	40
5 HZ CCW-NULL-CCW	22	40
10 HZ CW-NULL-CW	25	40
10 HZ CCW-NULL-CCW	22	40
ROLL MOMENT DECAY		
5 HZ CW-NULL-CW	20	29
5 HZ CCW-NULL-CCW	16	29
10 HZ CW-NULL-CW	22	29
10 HZ CCW-NULL-CCW	17	29
ROLL MOMENT HALF CYCLE		
5 HZ CW-NULL-CW	42	65
5 HZ CCW-NULL-CCW	38	65
10 HZ CW-NULL-CW	47	65
10 HZ CCW-NULL-CCW	39	65
ROLL MOMENT REVERSAL		
5 HZ CW-CCW-CW	29	47
10 HZ CW-CCW-CW	30	47
NULL DWELL		
5 HZ CW-NULL-CW	97	100
5 HZ CCW-NULL-CCW	97	100
10 HZ CW-NULL-CW	47	50
10 HZ CCW-NULL-CCW	47	50
COMMAND DWELL		
5 HZ, CW-NULL-CW	98	100
5 HZ CCW-NULL-CCW	98	100
10 HZ CW-NULL-CW	48	50
10 HZ CCW-NULL-CCW	48	50
5 HZ CW-CCW-CW	97	100
IO HZ CW-CCW-CW	48	50

.

Injector	Accumulated Firing Time, sec	Nominal Flow Rate, lbm/sec*
2	3 to 4	10.0
2	20 to 21	2.0
4	21 to 22	1.0
2	76 to 96	1.0
*Strontium Per	chlorate	

TABLE IX THRUST VECTOR CONTROL DUTY CYCLE

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TABLE X THRUST VECTOR CONTROL PERFORMANCE SUMMARY

NOMINAL TIME, SEC.	3-4	20-21	21-22
START TIME (CALC)	3.280	20.220	21.220
STOP TIME (CALC)	3.900	20.900	21.900
INJECTOR NUMBER	2	2	4
SPECIFIED FLOW RATE, L8M/SEC.	10.0	2.0	1.0
ACTUAL FLOW RATE, L8M/SEC.	10.4	2.01	0.99
PINTLE POSITION, MILLIINCHES	131.18	14.05	6.87
PINTLE PRESSURE, PSIA	543.	665.	679.
PROPELLANT FLOW RATE, LBM/SEC.	102	150	150
INJECTOR-TO-PROPELLANT FLOW Rate Ratio	0.102	0.013	0.007
RESULTANT YAW FORCE, LBF	1049.	415.7	236.8
UNAUGMENTED VACUUM AXIAL Thrust, LBF	28333	42756	42848
YAN-TD-AXIAL FORCE RATIO	0.0370	0.0097	0.0055
JET DEFLECTION ANGLE, DEG.	2.12	0.56	0.32
RESULTANT YAW FORCE INJECTANT Specific impulse, LBF-Sec./LBM	101	206	240
AXIAL-THRUST AUGMENTATION, LBF	759.	161.3	73.7
PERCENT AXIAL-THRUST AUGMENTATION	2.68	0.38	0.17
AXIAL-THRUST AUGMENTATION INJECTANT SPECIFIC IMPULSE, LBF-SEC./LBM	73.3	80.1	74.6

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APPENDIX III INSTRUMENTATION CALIBRATIONS

Axial-Force System

The axial-force load cell is physically calibrated in the AEDC calibration laboratory before installation in the force-measuring system. An in-place, binary-step, deadweight calibrator (permanently installed and independently grounded) is used to stimulate the force-measuring system with known physical forces. The calibrator is used before a motor firing to provide an end-to-end, in-place, multiple-step deadweight calibration of the sensing, signal conditioning, and recording systems for each of the redundant axial-force measurements. The calibrator is capable of producing forces in 1000-lbf increments from 0 to 127,000 lbf. Certification is periodically conducted to determine the magnitude of the force being produced by the calibrator at various levels within its operating range and to provide traceability to the National Bureau of Standards (NBS). The uncertainty of the certification is ± 0.030 percent of full scale. Estimated uncertainty of the axial-force measuring system at discrete thrust levels has been determined to be ± 0.13 percent for data obtained with the digital system.

Pressure Transducers and Yaw-Force Load Cells

These instruments were physically calibrated in the AEDC calibration laboratory before installation by direct load applications. The instrumentation recording systems were calibrated at ambient conditions and, subsequently, at pressure altitude conditions using a resistance shunting method to simulate the transducer output.

Operational Pressure Transducers (OPT)

These instruments were laboratory calibrated by TCC before installation on the motor. The calibrations were transmitted to AEDC with the motor. The operational pressure transducer incorporates a one-step internal calibration shunt which produces an electrical output signal simulating a known pressure level. This signal is used to calibrate the instrumentation recording systems both at ambient and pressure altitude conditions.

Temperatures

The thermocouples were fabricated from standard thermocouple wire, the electromotive force output of which is traceable to the NBS through the wire manufacturer. The thermocouples were connected directly to a 150°F reference temperature junction and the NBS standard temperature/voltage relationships were used for conversion to engineering units. The temperature instrumentation systems were calibrated at ambient conditions and, subsequently, at pressure altitude conditions by the voltage substitution method which simulated a known input signal.

Accelerations

The accelerometers were calibrated in the AEDC calibration laboratory using an eccentric mass vibrator before installation. The recording system was calibrated by the frequency/voltage substitution technique.

Liquid-Injection Thrust Vector Control System

Relationships between injector valve pintle position transducer feedback voltage and injectant flow rate at specific supply pressure and injectant specific gravity were provided by TCC for each valve. Calibrations at AEDC consisted of a determination of the relationship between injector valve pintle position (measured physically with a dial indicator), pintle position transducer feedback voltage, and command voltage for the particular test installation. Because the pintle position transducer feedback was measured after conditioning by the AEDC system, the magnitude obtained during the AEDC calibrations was different from those provided with the TCC-supplied injector valve calibrations which presented valve position transducer feedback voltage directly. Therefore, it was necessary to establish a relationship between AEDC feedback voltage at the fully closed and fully opened positions of the valve, and linearly interpolating to obtain intermediate points. In this manner the TCC-supplied flow rate calibration data, presented as a function of valve calibration feedback voltage, were converted to flow rate versus AEDC feedback voltage for each valve (Table III-1). The instrumentation system used to record valve feedback voltage during firing was calibrated by the voltage substitution method.

TABLE III-1 INJECTOR CALIBRATION

INJECTOR SERIAL ND. HS00131

MOTOR NO. PQA-102

INJECTOR LOCATION 90 DEGREES

PINTLE POSITION (MILLI-INCHES)	CALIBRATION VOLTAGE (MANUF)	FEEDBACK Voltage (Aedc)	FLOW RATE MIL-H-5606 (GPM)	FLÓW RATE Mil—H—5606 (LB/SEC)	FLOW RATE Strontium (LB/SEC)	CALIBRATION SUPPLY PRESSURE (PSIA)
0.0	G.0	-0.182	0.0	0.0	0.0	645.
2.1	0.100	-0.286	1.70	0.20	0.30	645.
4.2	0.200	-0.389	3.50	0.41	0.61	640.
6.4	0.300	-0.493	5.50	0.65	0.96	641.
6.8	0.320	-0.514	5.76	0.68	1.00	641.
8.5	0.400	-0.597	7.20	0.85	1.25	638.
10.6	0.500	-0.701	8.90	1.05	1.55	636.
12.7	0.600	-0.805	10.60	1.25	1-84	635.
13.7	0.648	-0.855	11.51	1.35	2.00	631.
14.8	0.700	-0.908	12.30	1.45	2.14	633.
16.9	0.800	-1.012	14.10	1.66	2.45	631.
19.1	0.900	-1-116	15.80	1.86	2.74	630
21.2	1.000	-1.220	17.30	2.03	3-01	622.
. 31.8	1.500	-1.739	23.60	2.77	4.10	608.
42.4	2.000	-2.258	30.20	3.55	5.25	598.
53.0	2.500	-2.777	35.80	4.21	6.22	590.
63.6	3.000	-3.296	40-80	4.79	7-09	578.
74.2	3.500	-3.815	45-00	5.29	7.82	567.
84.7	4.000	- 4. 334	48.60	5.71	8.44	555.
95.3	4.500	-4.853	51.80	6.09	9.00	546 -
105.9	5.000	-5.372	54.30	6.38	9.43	538.
116.5	5.500	-5.891	57.00	6.70	9.90	527.
120.8	5.700	-6.098	57.57	6.76	10.00	525.
127.1	6.000	-6-410	58.30	6.85	10.13	522.
148.3	7.000	-7.448	62.70	7.37	10.89	508.
169.5	8.000	-8-486	65.40	7.68	11-36	498.
190.7	9.000	-9.524	67.60	7.94	11.74	687.
211.9	10.000	-10-562	69-40	8.15	12.05	479.
233.1	11.000	-11.600	71-00	8.34	12.33	475
250.0	11.800	-12.430	71.30	8.38	12.38	472.

CALIBRATION TEMPERATURE 100 DEG F. Calibration Fluid Specific Gravity 0.8450 Test fluid Specific Gravity 1.850 TABLE III-1 (Concluded)

INJECTOR SERIAL NU. HSD0099

HOTOR NO. PQA-102

INJECTOR LOCATION 270 DEGREES

PINTLE POSITION (MILLI-INCHES)	CALIBRATION VOLTAGE (MANUF)	FEEDRACK VOLTAGE (AEDC)	FLOW RATE MIL-H-5606 (GPN)	FLOW RATE MIL-H-5606 (18/SEC)	FLOW RATE STRUNTIUM	CALIBRATION SUPPLY PRESSURE
	·					(*314)
0.0	0.0	-0.154	0.0	0.0	0.0	648.
2.1	0.100	-0.258	1.60	0.19	0.28	643.
4.2	0.200	-0.362	3.40	0.40	0.59	641.
6.3	0.100	-0.465	5.10	0.60	0.89	641.
7.1	0.340	-0.507	5.76	0.68	1.00	640.
8.4	0.400	-0.569	6.80	0.80	1.18	638.
10.5	0.500	-0.673	8.60	1.01	1.49	636.
12.6	0.600	-0.777	10.30	1.21	1.79	634.
14.4	0.685	-0.865	11.51	1.35	2.00	633.
14.7	0.700	-0.881	11.80	1.39	2.05	632.
16.8	0.800	-0.985	13.50	1.59	2.34	631.
18.9	0.900	-1.088	15.30	1.80	2.66	632.
21.0	1.000	-1.192	16.80	1.97	2.92	626.
31.5	1.500	-1.711	22.20	2.61	3.86	611.
42.0	2.000	-2.231	28.60	3.36	4.97	602
52.5	2.500	-2.750	34.30	4.03	5.96	596.
63.0	3.000	-3.269	39.50	4.64	6.86	581.
73.5	3.500	-3.788	43.20	5.08	7.50	571.
84.0	4.000	-4.307	46.80	5.50	8.13	560-
94.5	4.500	-4.826	50.40	5.92	8.75	549-
105.0	5.000	-5.346	53.40	6.27	9.28	535.
115.5	5.500	-5.865	56.20	6-60	9.76	528.
121.4	5.790	-6.155	57.57	6.76	10.00	523.
126-1	6.000	-6.384	58.30	6.85	10.13	520.
147.1	7.000	-7.422	62.00	7.28	10.77	506 -
168.1	8.000	-8.461	64.50	7.58	11.20	498.
189.1	9.000	-9.499	66.70	7.84	11.59	490.
210.1	10.000	-10.537	69.20	8-13	12.02	480.
231.1	11.000	-11.576	69.80	8.20	12.12	476
250.0	11.900	-12.510	71.60	8.41	12.44	473.

CALIBRATION TEMPERATURE 100 DEG F. Calibration fluid specific gravity 0.8450 test fluid specific gravity 1.850

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APPENDIX IV UNCERTAINTIES OF THE J-5 INSTRUMENT SYSTEMS

1.0 INTRODUCTION

The rationale for the estimated instrument system uncertainties contained in Table IV-1 is provided in this appendix. The general approach taken in the analysis, the definition of terms, and the specific evaluation of each system are presented.

2.0 METHODOLOGY

The approach taken in this analysis follows the methodology established by the ARO Standard Test Data Measurement Uncertainty (ARO-ENGR-STD-T-4, February 1972). A review of the basic concepts and terminology is given in the following paragraphs in order to provide a better understanding of individual evaluations of the J-5 instrument systems.

The uncertainty of a measurement is defined to be the maximum difference reasonably expected between a measured value and the true value. Measurement errors have two components: fixed errors and random errors. A random error results from variations between repeated measurements and is called the precision error. The statistic, s, is an estimate of the standard deviation of a population and is called the precision index. It is calculated to estimate the precision error. The precision index is

$$s = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \overline{x})^2}{(N-1)}}$$
(1)

where

- N is the number of measurements
- $\overline{\mathbf{x}}$ is the average value of the measurement
- x_i is the individual measurement

The second component of a measurement error is the constant or systematic error and is known as the bias. Each measurement of repeated measurements has the same bias. Large known biases are eliminated by calibrating the instrument, i.e., comparing the instrument to a standard and obtaining a correction. Small known biases may or may not be accounted for, depending upon the significance of the bias and the difficulty of correcting for the bias. Unknown biases are not correctable. Generally, the estimate of the limit for a bias is based upon judgment and experience. In order to establish a single number for expressing a reasonable limit for the error of a measurement, some combination of bias and precision is required. It is recognized that it is impossible to define a rigorous statistic because the bias is an upper limit based upon judgment. The uncertainty U is established as that single number for stating an error. The uncertainty is centered about the measurement and is defined as

$$U = \pm (B + t_{0.95} S)$$
 (2)

where

- **B** is the estimated bias limit
- S is the precision index
- t is the 95th-percentile point for the two-tailed students "t" distribution

The "t" value is a function of the number of degrees of freedom (d.f.). For 30 or more degrees of freedom, a t value of 2 is assumed.

The uncertainty is an arbitrary substitute for a statistical confidence interval and can best be interpreted as the largest error to be expected. The coverage of U is greater than 95 percent under reasonable assumptions of the distribution of the bias.

In general, the errors in a measurement process originate from a multitude of different sources. The uncertainty of a total measurement can be established by two approaches:

- (a) Determining the elemental error sources in the process and appropriately combining the errors and
- (b) Determining the error of the complete system by comparison with a standard.

Since the error of a measurement process is the result of elemental error sources, a methodology for combining elemental errors is required in order to arrive at the total uncertainty U.

The bias limit B in equation (2) is calculated as

$$B = \sqrt{b_1^2 + b_2^2 + b_3^2 - \dots - b_n^2}$$
(3)

where

b_n is the n elemental error source

- The above approach is taken because it is unreasonable to assume the unknown bias limits b_n are cumulative.

The precision error S in Equation (2) is

$$S = \sqrt{s_1^2 + S_2^2 + S_3^2 - \dots - s_n^2}$$
(4)

where

s_n is the precision error in the n elemental source

The degress of freedom for S may be found by use of the Welch-Satterthwaite formula as follows:

d.f. =
$$\frac{\left(s_{1}^{2} + s_{2}^{2} + s_{3}^{2} - \dots + s_{n}^{2}\right)^{2}}{\frac{s_{1}^{4}}{df_{1}} + \frac{s_{2}^{4}}{df_{2}} + \frac{s_{3}^{4}}{df_{3}} - \frac{s_{n}^{4}}{df_{n}}}$$
(5)

The establishment of the d.f. for S makes it possible to define the precision error of subsequent measurement processes or analyses.

The uncertainties of the J-5 instrument systems are tabulated in Table IV-1.

TABLE IV-1 ESTIMATED TOTAL UNCERTAINTY (±2 SIGMA LIMITS) OF INSTRUMENT SYSTEMS USED IN DETERMINING MOTOR PERFORMANCE

	Uncertainty, percent, full scale
Pressure Measurements ¹	± 0.44
Temperature Measurements (Thermocouples, C/A)	± 0.47
Accelerations	±14.2
Axial-Force Measurements	± 0.13
Side-Force Measurements	± 0.45

¹Uncertainty calculated for AEDC-supplied transducers only.

APPENDIX V METHODS OF CALCULATION

The following recorded parameters were used for the calculations:

FY-1, FY-2	Measured axial force, lbf
FZA-1, FZA-2	Measured aft yaw force, lbf
FZF-1, FZF-2	Measured forward yaw force, lbf
LINJ-2, LINJ-4	Measured injector position feedback, vdc
PA-1, PA-2	Measured test cell pressure, psia
PC-1, PC-2	Measured motor chamber pres- sure, psia
PMI-4	Measured injectant manifold pressure

The following input constants were used:

ATI	Prefire nozzle throat area, sq in. = 37.100
C*	Characteristic exhaust velocity, ft/sec = 5212
DI	Prefire nozzle exit diameter, in. (see Table III)
EAC	Nozzle exit area erosion factor based on measured prefire and postfire areas from the Qualification Program = 1.204
SPG CAL	Specific gravity of calibration fluid = 0.845
SPG TEST	Specific gravity of injectant fluid = 1.850
WPT	Manufacturer's stated total propellant mass, $1bm = 7312.3$

A table of nozzle static pressure at the injector exit (PNE) versus injectant flow rate was provided by TCC.

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Injectant	
Flow Rate,	PNE,
lbm/sec	psia
0	8.6
0.5	9.8
1.0	10.7
1.5	11.5
2.0	12.3
2.5	12.9
3.0	13.5
3.5	14.0
4.0	14.5
4.5	14.9
5.0	15.4
6.0	16.2
7.0	16.9
80	17.6
0.0	19.2
5.0	10.4
10.0	10.0
11.0	19.4
12.0	19.9
13.0	20.4
14.0	20.9

An input table was supplied by TCC to correct the nozzle throat area for the effects of erosion during motor operation. Nozzle throat areas versus time are as follows:

Time, sec	ATC, sq in.			
0.0	37.100			
0.2	37.170			
0.4	37.238			
0.6	37.308			
0.8	37.377			
1.0	37.443			
1.5	37.618			
2.0	37.704			
3.0	37.795			
4.0	37.861			
5.0	37.914			
6.0	37.956			
7.0	37.994			
8.0	38.024			
9.0	38.044			
10.0	38.065			

ATC, sq in.			
38.093			
38.107			
38.120			
38.129			
38.133			
38.134			
38.136			
38.144			
38.170			
38.195			
38.221			
38.246			
38.272			
38.272			

The following parameters were calculated from recorded data:

1.	FA =	Average measured axial thrust (parameters FY-1 and FY-2), lbf
2.	PO =	Average chamber pressure (parameters PC-1 and PC-2), psia
3.	PALT =	Average test cell pressure (parameters PA-1 and PA-2), psia
4.	FTSM =	Measured axial thrust smoothed by nine-point weighted average, lbf
	FTSM _i =	$(FA_{(i-4)} + 2FA_{(i-3)} + 3FA_{(i-2)} + 4FA_{(i-1)} + 5FA_i + 4FA_{(i+1)} + 3FA_{(i+2)} + 2FA_{(i+3)} + FA_{(i+4)})/25$
5.	AEC =	Calculated nozzle exit area, sq in.
	AEC =	AEI + (AEF - AEI) \cdot (t _i /TTT)
	where	
	AEI =	$((\sum_{i=1}^{6} DI_i/6) + 0.1247)^2 \cdot (0.7854)$
	where	
	AEF =	(EAC) (AEI)
	TTT =	Thrust termination

•

6.	FTSM VAC =	Vacuum-corrected smoothed measured thrust, lbf
	FTSM VAC =	FTSM + (PALT \cdot AEC)
7.	FZAA =	Average corrected aft yaw force (parameters FZA-1 and FZA-2), 1bf
8.	FZFA =	Average corrected forward yaw force (parameters FZF-1 and FZF-2), lbf
9.	FZR =	Resultant corrected yaw force, lbf
	FZR =	FZAA + FZFA
		FZR was then corrected for null level offsets to determine FZRC
1 0 .	FPR =	Thrust-to-pressure ratio, lbf/psia
	FPR =	FTSMVAC/PO
11.	FUPR =	Unaugmented thrust-to-pressure ratio, lbf/psia
	FUPR =	FPR corrected by straight line interpolation during periods of injection
12.	FTSMU VAC =	Unaugmented smoothed axial thrust, lbf
	FTSMU VÁC =	(FUPR) · (PO)
13.	DELTA FTSM =	Thrust augmentation attributable to liquid injection, lbf
	DELTA FTSM =	FTSM VAC - FTSMU VAC
14.	CFVU =	Unaugmented vacuum thrust coefficient
	CFVU =	(FTSMUVAC)/(PO · ATC)
15.	WDPTPC =	Propellant mass flow rate (Option 1), lbm/sec
	WDOTPC =	(g · ATC · PO)/C*

16. WDOTP = Propellant mass flow rate (Option 2), lbm/sec $(WP \cdot PO \cdot ATC)/\int_{t_0}^{t_A} (PO \cdot ATC)dt$ WDOTP =where WP =WPT - 8 (sliver weight, 1bm) t_A = Motor action time 17. WDOT-I = Injectant flow rate, lbm/sec WDOT CAL $\sqrt{\frac{(\Delta P \text{ TEST}) \cdot \text{SPG (TEST)}}{(\Delta P \text{ CAL}) \cdot \text{SPG (CAL)}}}$ WDOT-I =where WDOT CAL =Input table with injectant flow rate (WDOT CAL) as a function of injector feedback voltage (LINJ-I) and valve calibration differential pressure (ΔP CAL) (Table III-1) $\Delta P TEST =$ (PINJ-I) - PNE PINJ-4 =PMI-4 PINJ-2 =Surface fit with PINJ-2 as a function of PMI-4 and LINJ-2, supplied by TCC I = 2 or 4 18. ISPSP =Axial-thrust augmentation injectant specific impulse, 1bf-sec/lbm ISPSP =FZRC/(WDOT-I) 19. RZY = Yaw-to-axial force ratio RZY = FZRC/FTSMU VAC 20. WDOTR =Injectant-to-propellant flow rate ratio WDOTR =(WDOT-I)/WDOTP

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21. JDA = Thrust vector angle, deg

JDA = ARCTAN (RZY)

- 22. AAUGISP = Axial-thrust augmentation injectant specific impulse, lbf-sec/lbm
 - AAUGISP = (DELTA FTSM)/(WDOT-I)
- 23. RT = Roll control system torque, (or, moment), ft-lbf

RT = 2.06 (FRC-1)

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STAGE III ROCKET MOTOR AT SIMULATED	PRESSURE	ALTITUDE, MOTOR PQA-102		
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ABSTRACT An LGM-30G Stage III solid-r	propellant	rocket motor, PQA-102, was		
fired in Rocket Development Test Cel	(J-5), I	Engine Test Facility (ETF),		
in support of the Minuteman Stage II	I Product:	ion Quality Assurance Test		
Program on January 26, 1973. The rol	1 control	subsystem was independ-		
ently tested off-motor on January 27	, 1973. Me	otor ballistic, roll		
control system, thrust vector control	ol, and the	rust termination system		
performance was within model specifi	cation real	quirements. The motor was		
ignited at a pressure altitude of 10)2,000 ft.	Motor ignition delay time		
was 86 msec. Motor thrust terminatic	on occurre	d at 60,18 sec at a chamber		
pressure of 75.3 psia. Motor action	time was (60.18 sec during which the		
motor produced an unaugmented vacuum	total im	mulse of $2.083.534$ lbf-sec		
The uppugmented vacuum specific impu	$1 e \circ w e 2$	RA =		
and analgmented vacuum specific impo	the was ze	tafactory		
control subsystem structural integri	lly was sa	LISTACIOFY.		
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