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A SIMULATED ALTITUDE TEST OF A SATURN SIC RETRO DEVELOPMENT MOTOR (TEST UNIT NO. SD-20)

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ARO, Inc.

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ROCKET TEST FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
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NOTICES

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FOREWORD

The work reported herein was sponsored by the National Aeronautics and Space Administration (NASA) and The Boeing Company (TBC) for the Thiokol Chemical Corporation (TCC) under Program Area 921E, Project 9115.

The results of the test presented were obtained by ARO, Inc. (a subsidiary of Sverdrup and Parcel, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract AF 40(600)-1000. The test was conducted on February 24, 1965, under ARO Project No. RP1435, and the report was submitted by the authors on April 1, 1965.

This technical report has been reviewed and is approved.

Ralph W. Everett Major, USAF AF Representative, RTF DCS/Test	Jean A. Jack Colonel, USAF DCS/Test

ABSTRACT

Saturn SIC retro motor TE-M-424, Test Unit Number SD-20, was fired in Propulsion Engine Test Cell (J-5) as part of the user's, Thiokol Chemical Corporation, research and development program for this motor. The primary test objectives were to determine ignition characteristics, ballistic performance, and hardware integrity at altitude conditions. The motor was ignited, as planned, by the two ignition systems at a simulated altitude of 113,000 ft and burned at an average altitude of 113,000 ft for a total of 1.5 sec. The effective burn time was 0.626 sec, and the motor produced an effective vacuum impulse of 59,530 lb_f-sec, which is above the specification minimum of 57,300 lb_f-sec. The ignition time of 92 msec is within the specification requirements. Post-fire motor inspection revealed that the hardware integrity was satisfactory.

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SECTION I
INTRODUCTION

The Saturn V launch vehicle consists of three stages, SIC, S-II, and S-IVB, and the instrument unit. The first of the Saturn V stages, the SIC, has two TE-M-424 solid-propellant retro motors located in each of the four fairings, which are at the base of the stage (Fig. 1).

The nominal 800, 000-lb thrust produced by these retro rockets provides for a more rapid separation of the SIC and S-II stages, thus reducing the time in which there is no vector control of the vehicle. Ignition of these motors is programmed to occur during main engine tailoff. After ignition, the motors are to burn through the fairing and decelerate the stage.

The TE-M-424 Saturn SIC retro motor is built by Thiokol Chemical Corporation (TCC), Elkton Division. Test unit number SD-20 (Serial Number 5007) was test fired in Propulsion Engine Test Cell (J-5) at the Rocket Test Facility (RTF). This was the second and last firing of a TE-M-424 in an altitude facility as part of the research and development program for this motor. The results of the first firing are discussed in Ref. 1.

Objectives of the altitude test were to determine ignition characteristics when two ignition systems are used, ballistic performance, and hardware integrity at altitude conditions.

SECTION II
APPARATUS

2.1 TEST ARTICLE

Each retro motor has an approximate gross weight of 520 lb and is designed to produce 100, 000 lb_f for 0. 6 sec of its 1.5-sec burn time. The overall weight is less than the 537 lb specified in Ref. 2, and the motor fits within the physical envelope specified.

The motor chamber, 15. 2 in. in diameter and 79. 7 in. long, is constructed of 1/8-in. -thick Ladish DC-6 steel with a liquid polymer liner (TL-L-300) (Figs. 2a and b). A single fixed 15-deg, half-angle nozzle having a nominal throat diameter of 6. 70 in. is submerged 12. 9 in. into the chamber. The submerged portion of the nozzle is constructed of Ladish DC-6 steel, having a graphite throat insert backed by a cork and rubber composition gasket (Armstrong Type DK-149) and a cadmium plated steel retaining ring which is pinned to the nozzle body (Fig. 2c). The outside diameter of the throat portion of the submerged nozzle is insulated with a paper phenolic insulation material, whereas the remainder is insulated with TL-L-300. A tapered steel exit cone (AISI 4130 heat treated per MIL-H-6878) extends the nozzle from an area ratio of 3.7 to 8.7. A styrofoam nozzle closure is cemented into the nozzle at an area ratio of 1.6.

The chamber was loaded with approximately 278 lb of composite, case-bonded, polysulfide propellant (TP-E-8104) cast directly into the chamber in an internal burning twelve-point, double-web star grain configuration. Propellant composition is presented in Table I.

Propellant ignition is effected by a pyrogen-type igniter, which is ignited by two exploding bridgewire (EBW) initiators firing into a cavity containing Boron 2A pellets (Fig. 2c). The system is armed by providing 28 v to the EBW firing units that consist of a series of capacitors which accumulate a sufficient charge so that, upon applying the firing current to the system, a thyratron is triggered, supplying approximately 2300 v to the EBW initiators (Aerojet AGX-2008 Rev. K) (Fig. 3). This ignites 18 g of Boron 2A pellets which ignite the pyrogen grain. The pyrogen exhaust passes through five 3/8-in.-diam holes and impinges on the motor grain at a 45-deg angle. The 1.75-lb pyrogen grain, cast in a double-web star grain configuration, is the same composition as the motor grain.

To determine the condition of the EBW firing units after arming and before firing, an EBW Firing Unit Monitor (Fig. 3) was constructed. This monitor verifies that the system is armed prior to firing, indicates that the system has discharged, and relays the time of discharge to the end recording system.

2.2 TEST CELL AND INSTALLATION

The Propulsion Engine Test Cell (J-5) (Fig. 4) is a horizontal test cell designed for testing solid-propellant rocket engines with a thrust up to 100,000 lb_f (with a growth potential to 200,000 lb_f thrust) at altitudes in excess of 100,000 ft. The cell is a cylindrical section 16 ft in diameter and 50 ft long and is fabricated from a 1/2-in. hot rolled steel plate reinforced at 6-ft intervals with ring girders. It is insulated with 2 in. of cellular glass, coated with 1/8-in. vapor seal mastic, and protected by a 0.020-in. aluminum jacket.

The single component thrust stand used in this test is capable of measuring axial forces in excess of 100,000 lb_f. Axial thrust is reacted by two 33-in. I-Beams, which are anchored in the cell foundation containing approximately 600,000 lb_m of reinforced concrete. The stand is stabilized in the yaw plane by a forward and aft column extending through bellows seals in the wall of the test cell to a "seismic mass" consisting of approximately 600,000 lb_m of reinforced concrete. Calibration of the axial load cell is accomplished, in place, by a binary deadweight calibrator having a range from 0 to 127,000 lb_f. With the loaded Saturn motor and support hardware installed, the thrust stand had a natural frequency of approximately 55 cps in the axial direction.

Two tandem steam ejectors (Fig. 4c) are placed in each of four auxiliary ducts which are located circumferentially around the test cell at 90-deg intervals. The auxiliary pumping system is used for improvement of the test cell altitude or for removal of exhaust gases from thrust termination or other auxiliary control systems. Three of the ejector-duct systems were used during the Saturn tests.

The test cell is equipped with a temperature conditioning system designed to maintain the test cell and motor at the prescribed temperature from motor installation until just prior to pre-fire pumpdown.

The rocket exhaust discharged into a 53-in.-diam, water-cooled diffuser having a two-step entrance cone (Fig. 4d), which is inserted in a 102-in.-diam, water-cooled diffuser. A center-body steam ejector installed in the 102-in.-diam diffuser is used to facilitate pre-fire pumpdown, to maintain altitude, and to reduce recirculation of gases into the test cell at motor tailoff. The steam ejector has an 8.5-in.-diam throat and an area ratio of 10. It may be controlled automatically or manually over a driving-pressure range from 0 to 500 psig.

The exhaust-steam mixture then flows through a spray chamber 16 ft in diameter and 50 ft long which contains nine spray banks, each of which is capable of delivering approximately 9000 gpm at a maximum pressure of 47 psia. Water is supplied to the spray chamber from an elevated water tank with a usable capacity of approximately 250,000 gal. From the spray chamber, the exhaust gases flow through approximately 2000 ft of 13-ft-diam duct to the RTF exhauster machines and are pumped to atmosphere as shown schematically in Fig. 4e.

To provide additional light for the high-speed (2000 fps) optical data systems, the test cell was painted white, and a light hood was fabricated (Fig. 4f). The hood consists of 48 reflectors, each having two long duration (1.75 sec) flash bulbs. In order to provide the light required for three seconds, the reflectors were divided into three groups arranged to provide equal light intensity over the motor area. Ignition times are given as part of Table II.

2.3 INSTRUMENTATION

Axial thrust was measured using a nominal 100,000-lb_f, fourfold-output, bonded strain-gage-type load cell. Universal flexures were used to isolate the load cell from any force not directed through the load cell axis. Strain-gage-type transducers were used to measure pyrogen, chamber, steam, water, exhaust system, and auxiliary pumping system pressures. Motor case and nozzle temperatures were sensed with iron-constantan thermocouples bonded to the motor chamber and nozzle. Steam, water, exhaust system, and auxiliary pumping system temperatures were measured with iron-constantan thermocouples.

The output signal of each measuring device was recorded on redundant end recorders. 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 rate of 45 or 225 samples per second and recording on magnetic tape, single input analog continuous magnetic tape, FM systems recording on magnetic tape, photographically recording galvanometer-type oscillographs recording at paper speeds of 16 in./sec or 80 in./sec, and direct-inking null-balance potentiometer-type strip charts. Visual observation of the firing was provided by a closed-circuit television monitor. High-speed (2000 fps) optical data were obtained to provide a permanent visual record of the firing. Table III presents instrument ranges, recording methods, and system accuracies for all measured parameters.

2.4 CALIBRATION

The axial thrust instrumentation systems were calibrated at altitude conditions before and after the motor firing by using a remotely controlled, hydraulically activated deadweight binary calibrator. The axial thrust calibrator weights are secondary standard weights certified by the National Bureau of Standards (NBS) to be in error by less than 0.01 percent. By using a standard load cell system, accurate to 0.05 percent, the entire axial thrust calibrator was in-place calibrated from the 4000 to the 100,000 lb_f level.

All transducers used in this test were laboratory calibrated before installation. The strain-gage-type pressure transducers were in-place calibrated with an electrical calibration system. A voltage substitution-type of in-place calibration was used on the thermocouples. They had a 150°F reference junction, and the NBS (Ref. 3) iron-constantan tables were used to reduce the data to engineering units. All in-place calibrations were performed at altitude before and after the firing.

SECTION III
PROCEDURE

The motor arrived at AEDC January 29, 1965, and was transported to the AEDC Radiographic Inspection Laboratory and subjected to an inspection with the Betatron X-ray machine (Fig. 5). On February 17, 1965, it was transported to the Rocket Preparation Area where the pressure transducers and chamber thermocouples were installed. A pressure check was performed following TCC Procedure OCL-T-2198, Revision 2.

Prior to firing the first motor, an impulse test and linearity check were performed on the thrust stand with the mass simulated motor installed to determine basic thrust stand characteristics. In addition, an EBW initiator was fired by each ignition system, verifying the system's performance.

On February 19, 1965, the motor was transported to the test cell, installed in the thrust stand (Fig. 6), aligned, and prepared for firing. This included connecting, checking, and insulating the instrumentation cables with asbestos cloth, aluminum foil, glass tape, and RTV-88 silicone rubber as well as positioning the diffuser entrance cone and checking the ignition and camera systems.

The temperature conditioning system was started on February 19, and the test cell temperature was maintained between 62 and 75°F until 12 hr prior to air-on. During the 12-hr period, the motor case temperature was maintained between 66 and 69°F. This is within the limits of 70 ± 5°F specified by TCC.

On February 24, sea-level calibrations were performed followed by a sequence run, which verified that all transducers and end recording systems were operating properly and were acceptable for firing. Final test cell pre-fire operational procedures were completed; the test cell was sealed and evacuated by the RTF exhaust machinery to 0.34 psia (approximately 84,000 ft) (Ref. 4). Altitude calibrations were then performed.

Approximately 65 sec prior to ignition, the automatic sequencer was started, activating the steam, water, light, camera, instrumentation, and ignition systems at the times shown in Table II. Starting at T + 10 sec, the sequencer began the post-fire shutdown.

After post-fire altitude calibrations were performed, the cell was returned to sea-level pressure. The motor was removed from the test cell February 25, 1965, and returned to the Rocket Preparation Area for post-fire inspection. On March 2, 1965, the spent motor was returned to TCC by truck.

SECTION IV
RESULTS AND DISCUSSION

4.1 GENERAL

The results reported herein are those obtained from the firing of the Saturn SIC Retro Motor SD-20 in Propulsion Engine Test Cell (J-5) on February 24, 1965. In addition to ballistic performance, the objectives of this test were to verify hardware integrity and ignition characteristics at altitude conditions. The results, with the corresponding data from the test of motor SD-19, are summarized in Table IV.

4.2 MOTOR IGNITION

Propellant combustion was initiated by one of the two exploding bridgewire ignition systems at an altitude of 113,000 ft (Ref. 4). The second EBW initiator apparently fired 9 msec later. The nozzle closure, which sealed the chamber and igniter at atmospheric pressure, was ejected without damage to the nozzle or nozzle extension.

Ignition delay, defined as the time from receipt of ignition current by the EBW Firing Unit until chamber pressure reaches 100 psia, was 58 msec. The ignition rise time, which is the time required for chamber pressure to change from 100 psia to 75 percent of its maximum value, was 34 msec. Ignition time, the sum of ignition delay and ignition rise time, was 92 msec. This was less than the 130 msec required by Ref. 2. An analog trace of thrust, chamber pressure, and pyrogen pressure for the first 160 msec is presented in Fig. 7.

4.3 BALLISTIC PERFORMANCE

A measured thrust-time curve is presented in Fig. 8 along with chamber pressure and cell pressure. Motor-diffuser pumping was maintained throughout motor tailoff. The average altitude during the firing was 113,000 ft.

Motor operation time, defined as beginning at the first perceptible indication of thrust and ending when the thrust falls to zero, was approximately 1.5 sec. The effective burn time, defined as the elapsed time from the point where chamber pressure rises to 75 percent of its maximum value and ends when it returns to this value, was 0.626 sec.

The average effective measured impulse based on motor effective burn time as determined by five high accuracy magnetic tape systems was 59,510 lb_f-sec. One standard deviation was 0.105 percent. Effective impulse, corrected to vacuum conditions by adding the product of the cell pressure integral and pre-fire nozzle exit area, was 59,530 lb_f-sec. This is greater than the required 57,300 lb_f-sec stated in Ref. 2. This correction amounted to 0.033 percent of measured effective impulse. The average effective vacuum thrust was 95,100 lb_f, which is within the required limits of 81,500 and 100,140 lb specified in Ref. 2 for a 70°F motor.

Measured motor operation, or total impulse, was 66,000 lb_f-sec. The vacuum corrected total impulse including the correction to vacuum conditions was 66,050 lb_f-sec for a specific impulse of 234.6 sec based on the user's stated propellant weight.

The maximum chamber pressure was 1700 psia. Average chamber pressure based on motor effective burn time was 1679 psia. Figure 9 provides a comparison between the results predicted in Ref. 5, the results of the first test (SD-19), and those obtained in this test. The predicted data started at 100-psia chamber pressure. This time was correlated with the ignition delay experienced on both firings and the composite plot made. The SD-20 effective burn time was longer (0.626 versus 0.610 sec) and at a lower chamber pressure (1700 versus 1760 psia max) than SD-19. Both motors had substantially the same throat area.

4.4 MOTOR THERMAL DATA

Fourteen iron-constantan thermocouples were installed on the motor as shown in Fig. 10a. Figure 10b presents a series of plots of chamber, nozzle, and cell temperatures versus time from T - 0 to T + 320 sec. It is noted that the disagreement between two corresponding thermocouples located at different web sections 30 deg apart is less than 25°F.

Although cell temperature remained relatively constant during the peak period, all of the chamber temperatures continued to rise, indicating that they were insulated sufficiently to prevent the cell temperature from affecting the data significantly. The data indicate that there was no significant case temperature rise during the firing even though post-fire temperatures reached 280°F at T + 320 sec when data acquisition ended.

The nozzle exit cone thermocouples were bonded to the nozzle with epoxy cement in accordance with the user's request. Optical data systems indicated that thermocouples T-12 and T-14 came completely unbonded at T + 1.5 sec. Data analysis indicated that during post-fire heat soak these parameters approximated cell temperature.

Thermocouples T-11 and T-13 exhibited 6 and 16°F temperature rise, respectively, during the 1.5-sec motor burn time. It is believed that these data are invalid because the optical data recorders indicated that the nozzle paint blistered during this same time period. The post-fire heat soak resulted in maximum indicated exit cone temperatures of 190°F (Fig. 10b).

4.5 MOTOR STRUCTURAL INTEGRITY

Post-fire inspection (Fig. 11) revealed that all components of the motor were in satisfactory condition. The paint on the nozzle exit cone started to burn at approximately 0.7 sec, and a portion of it was blown off at the end of motor operation (T + 1.5 sec). There was a considerable amount of bluing on the exit cone with the hot spots corresponding to the valleys in the propellant grain configuration.

The nozzle throat remained in place and showed no sign of major erosion. Twelve propellant slivers, approximately 5/8 in. wide and 3/8 in. high, remained in the chamber. TCC estimated the remaining propellant at 3 to 4 lb. With the exception of the propellant slivers and the heating of the exit cone, the condition of the visible part of the motor was excellent.

SECTION V
SUMMARY OF RESULTS

The results of the firing of Saturn SIC Retro development motor SD-20 at a simulated altitude of 113,000 ft in Propulsion Engine Test Cell (J-5) are summarized as follows:

1. Structural integrity of the chamber, nozzle, nozzle extension, igniter, and throat was satisfactory.
2. With the pyrogen and chamber sealed at atmospheric pressure, the motor was successfully ignited by one ignition system as planned. The ignition time was 92 msec.
3. The motor produced an effective vacuum impulse of 59,530 lb_f-sec which is greater than the 57,300 lb_f-sec specified in Ref. 2.
4. Average effective vacuum thrust of 95,100 lb_f is within the specification limits of 81,500 to 100,140 lb_f for a 70°F motor.
5. Twelve slivers 5/8 in. wide and 3/8 in. high remained in the chamber after firing. TCC estimates that they contain 3 to 4 lb of propellant.

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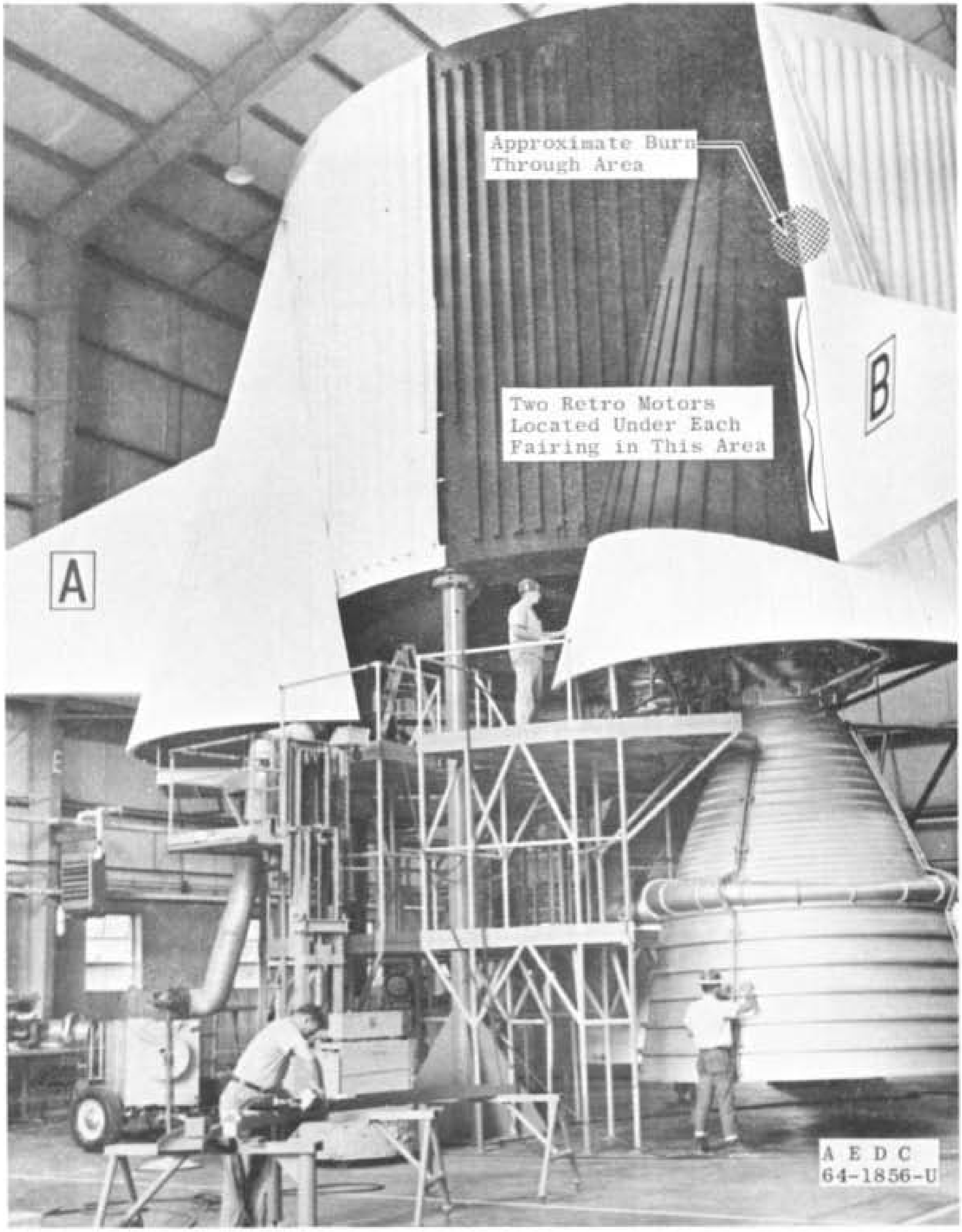
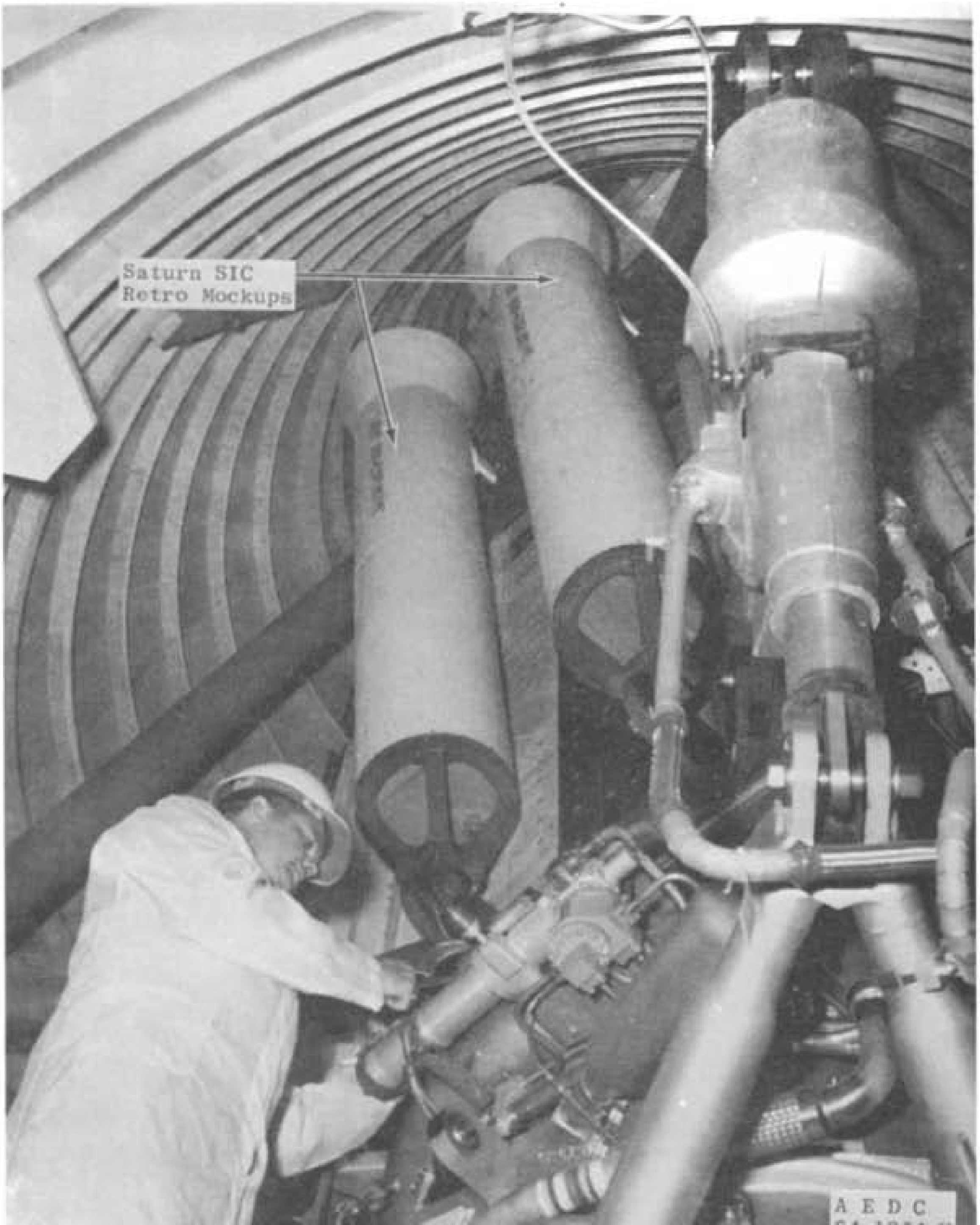


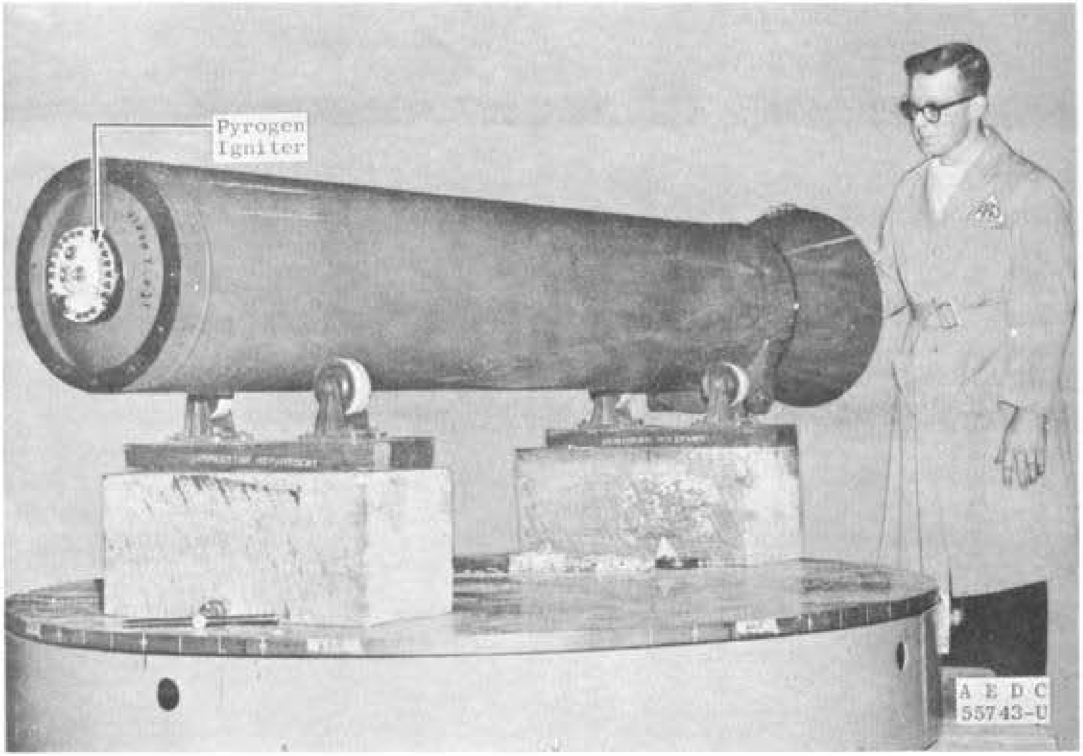
a. Retro Location

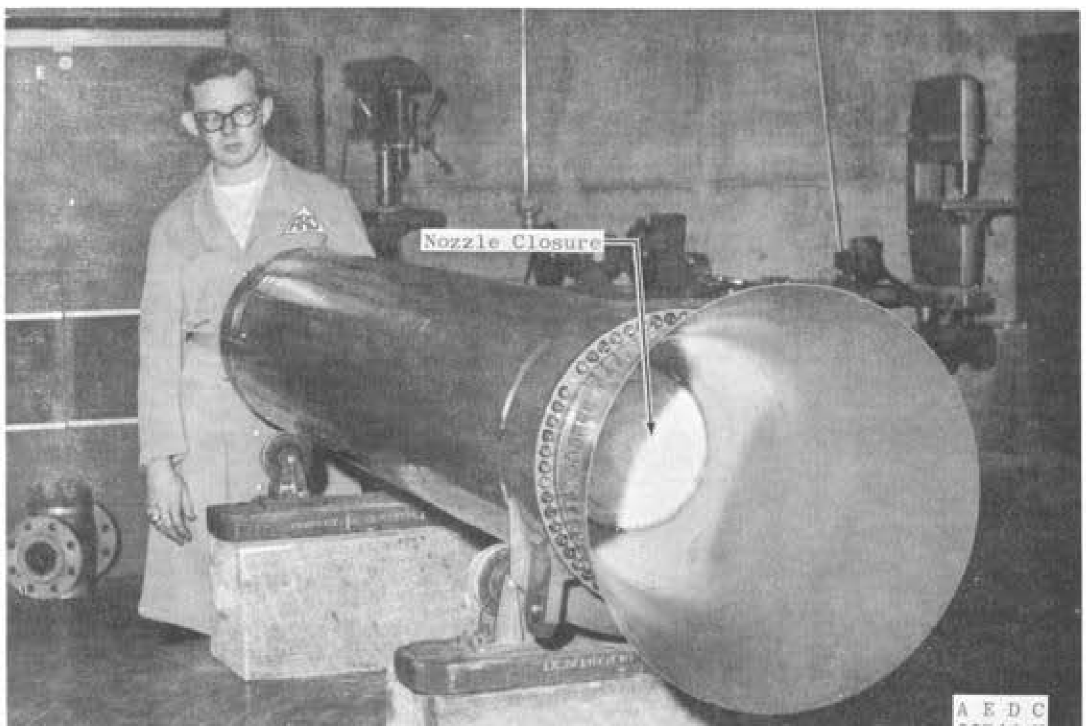
Fig. 1 Saturn SIC Mockup



b. Retros under Fairing

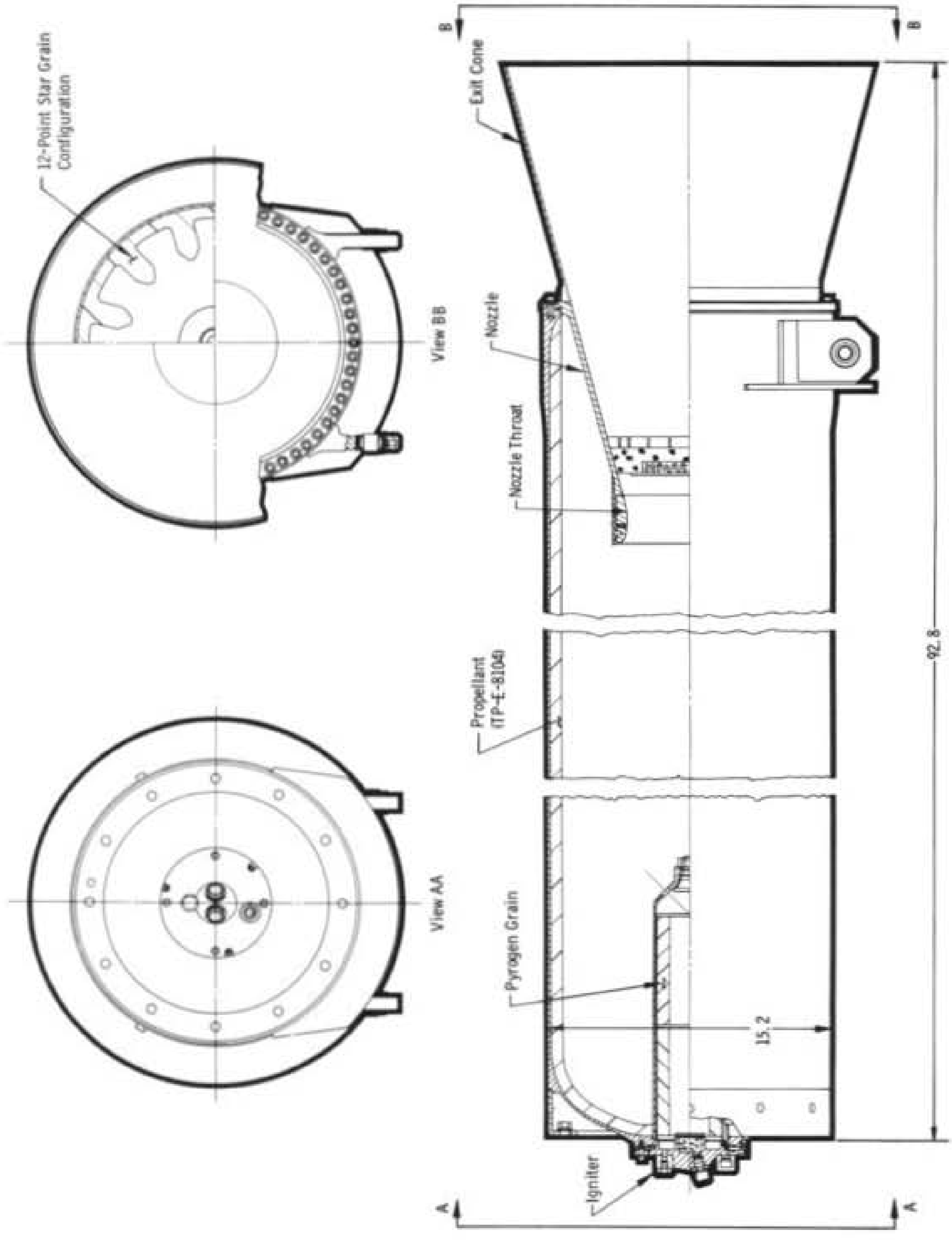
Fig. 1 Concluded





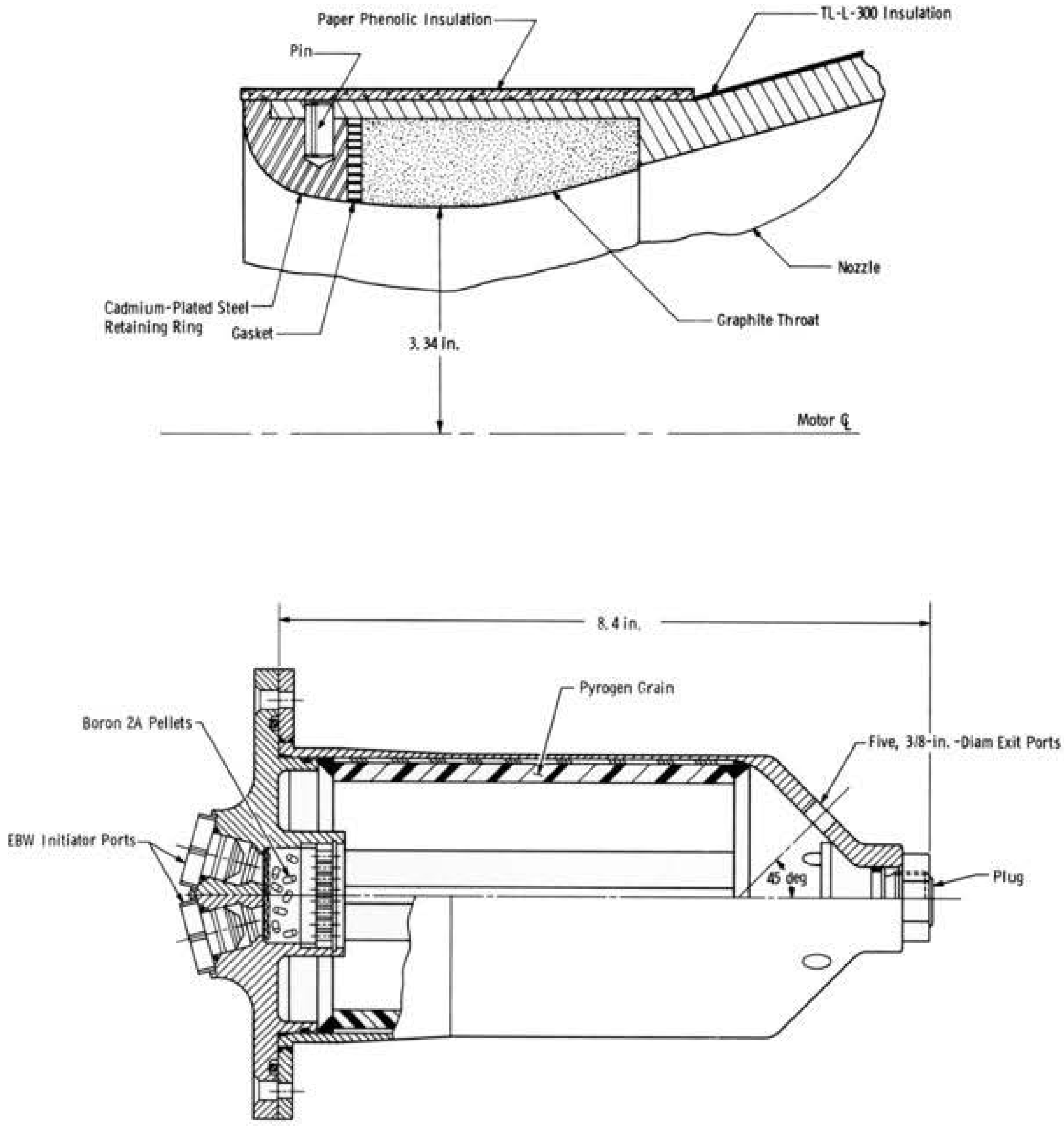
a. Overall View

Fig. 2 Saturn SIC Retro Motor



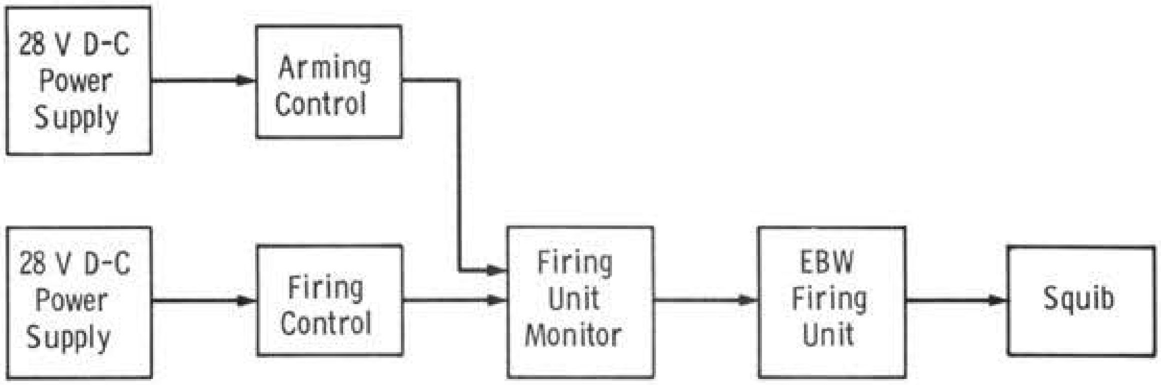
b. Sectioned View

Fig. 2 Continued

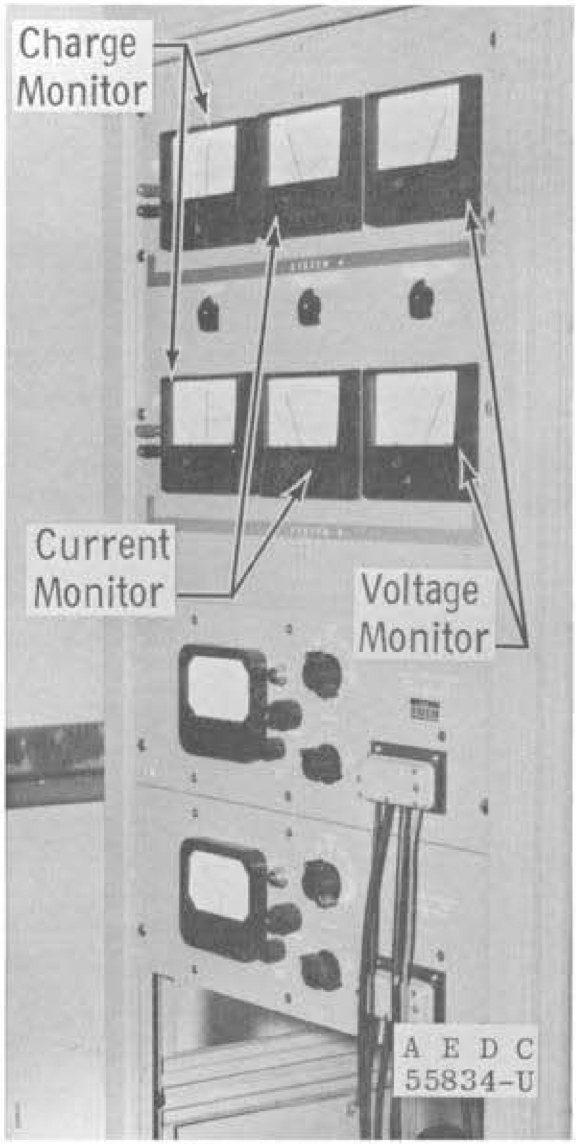


c. Throat and Pyrogen Detail

Fig. 2 Concluded

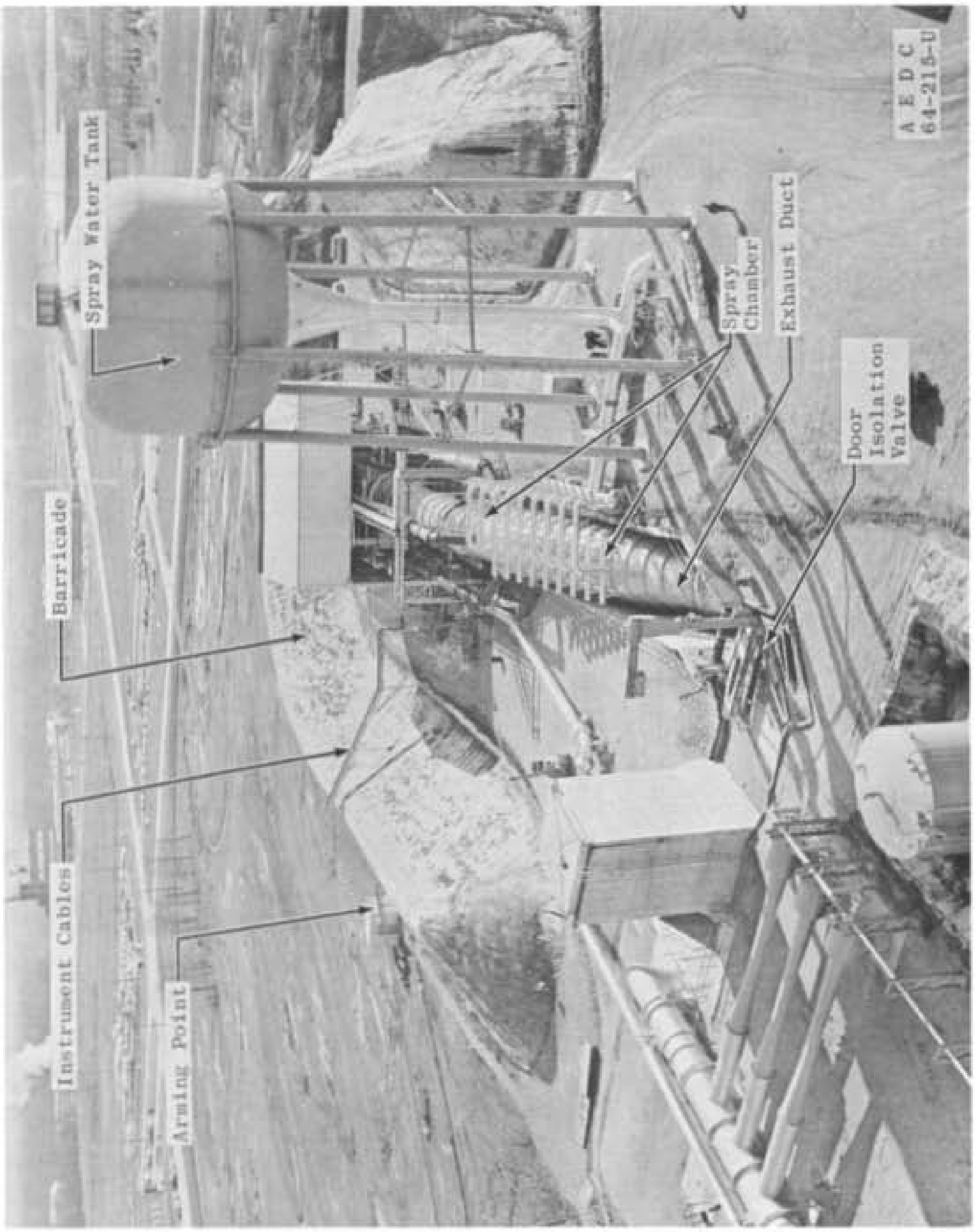


Block Diagram



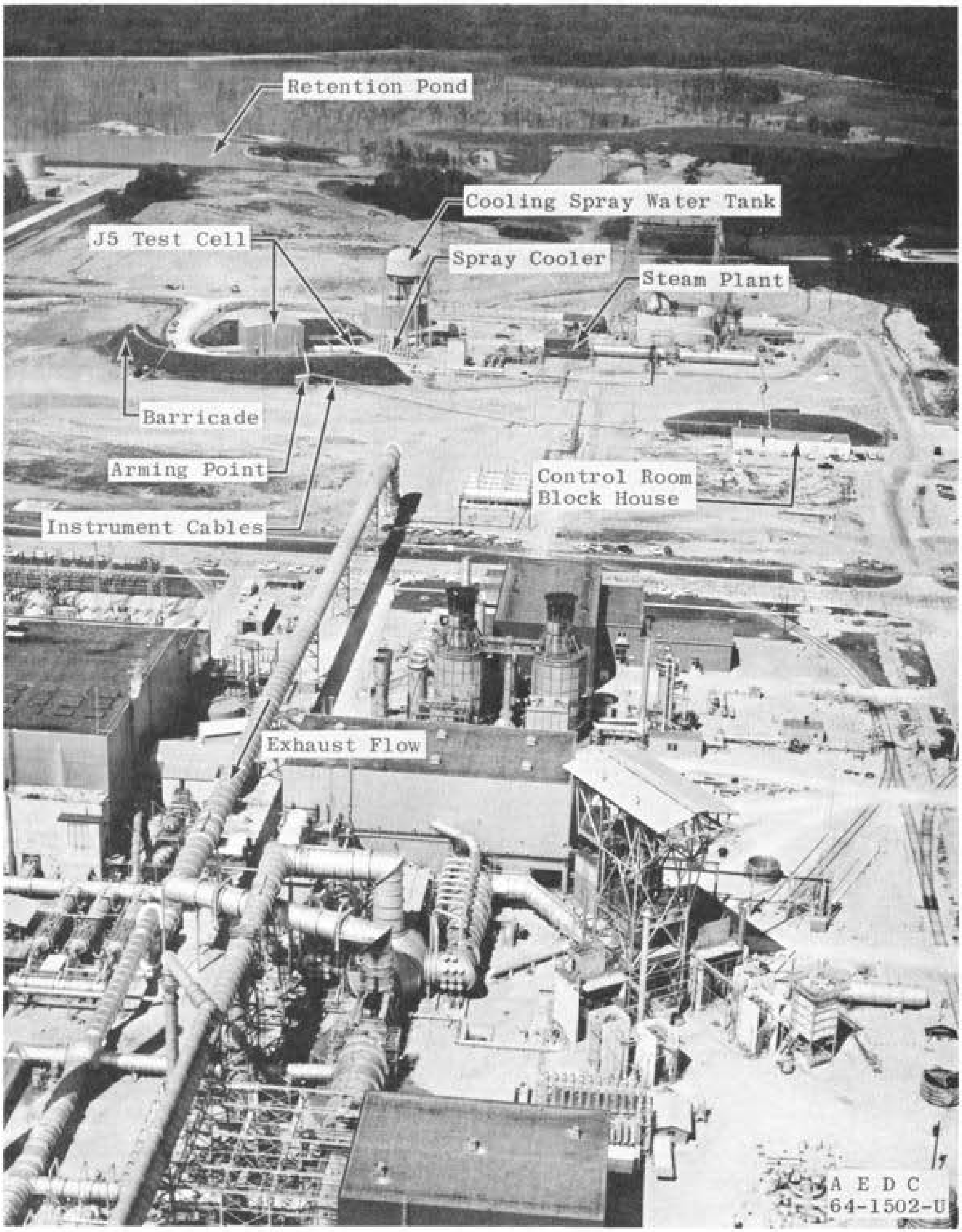
EBW Firing Unit Monitor

Fig. 3 Exploding Bridgewire Ignition System



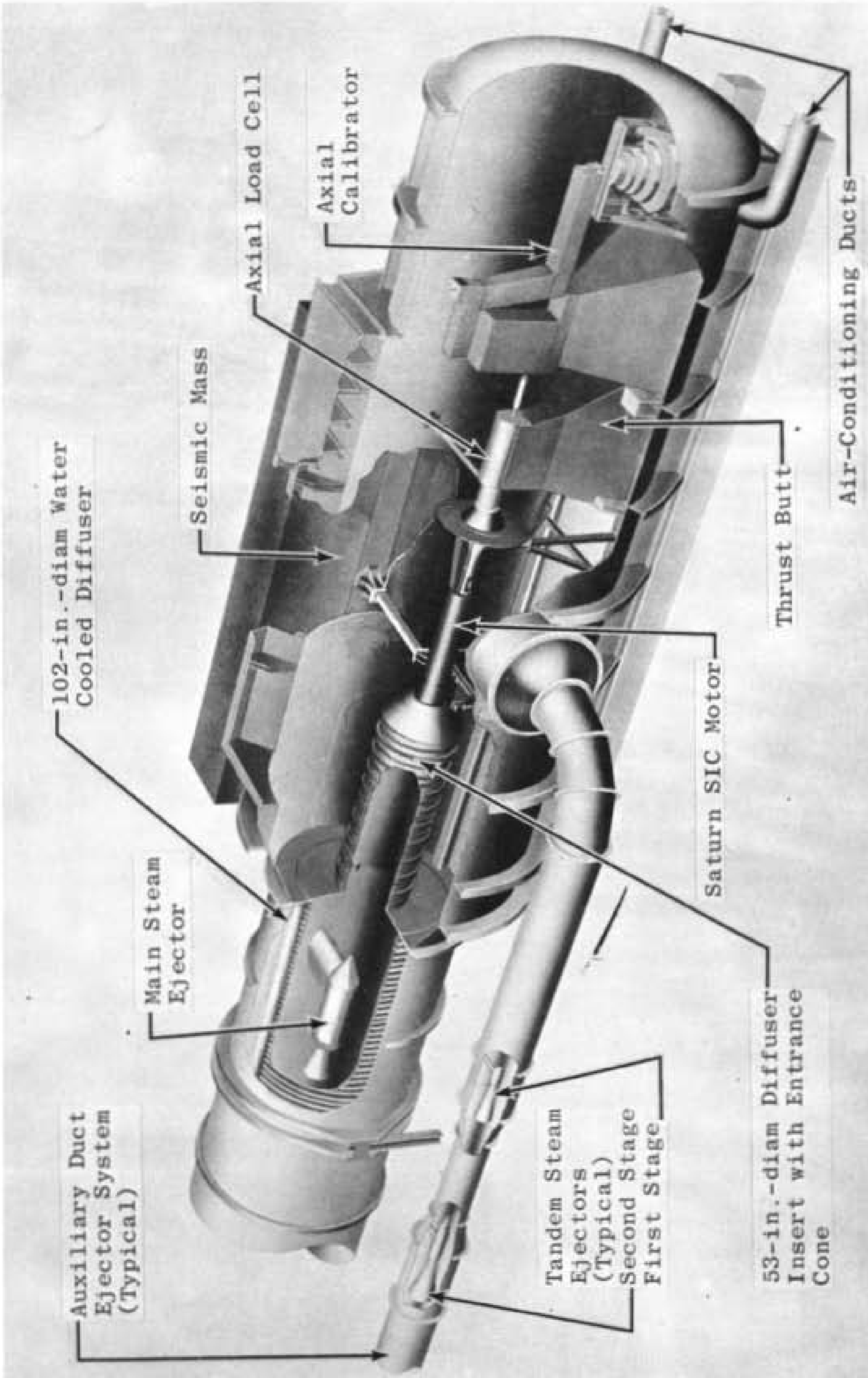
a. Spray Chamber and Elevated Tank

Fig. 4 Propulsion Engine Test Cell (J-5)



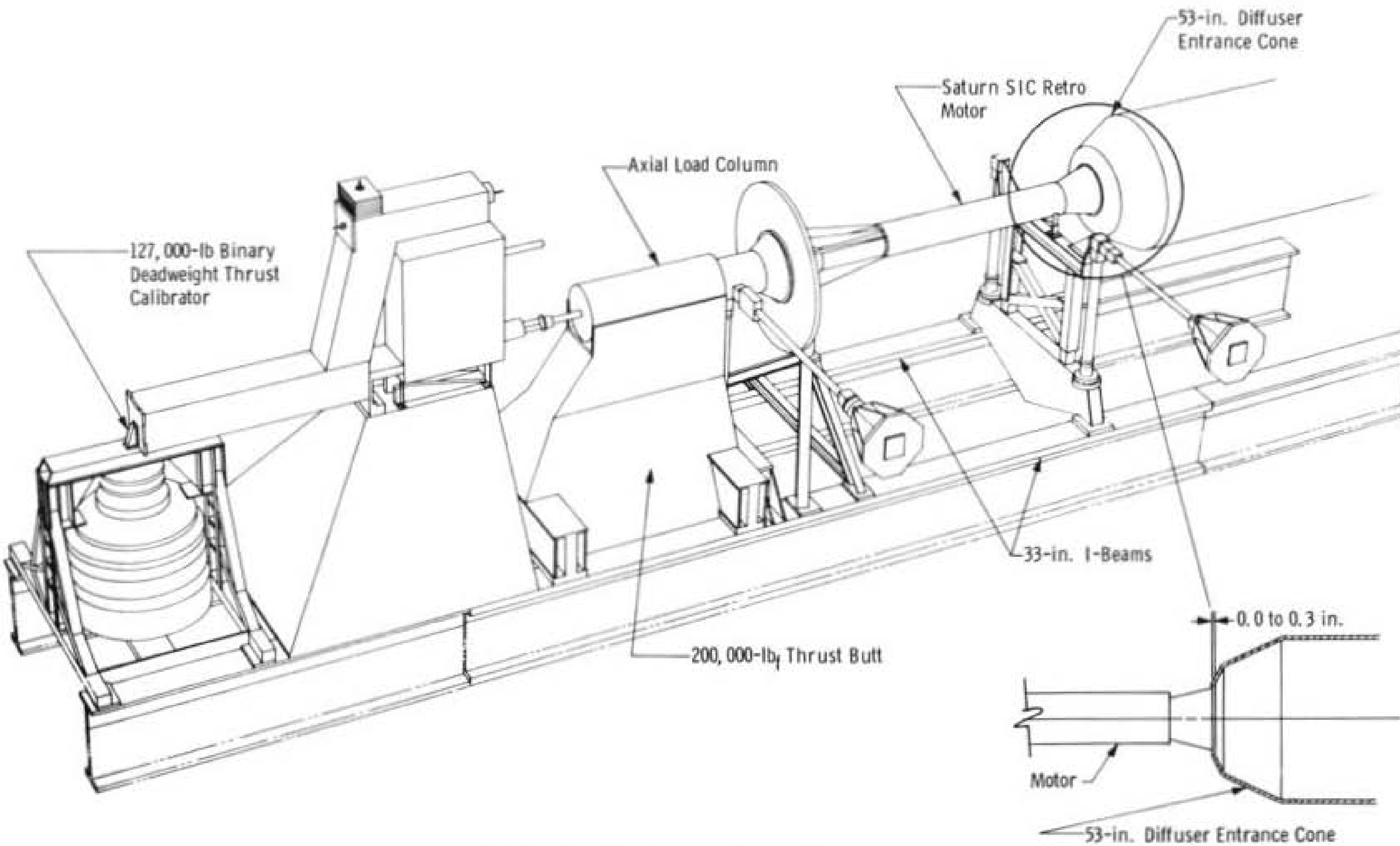
b. Overall Testing Complex

Fig. 4 Continued



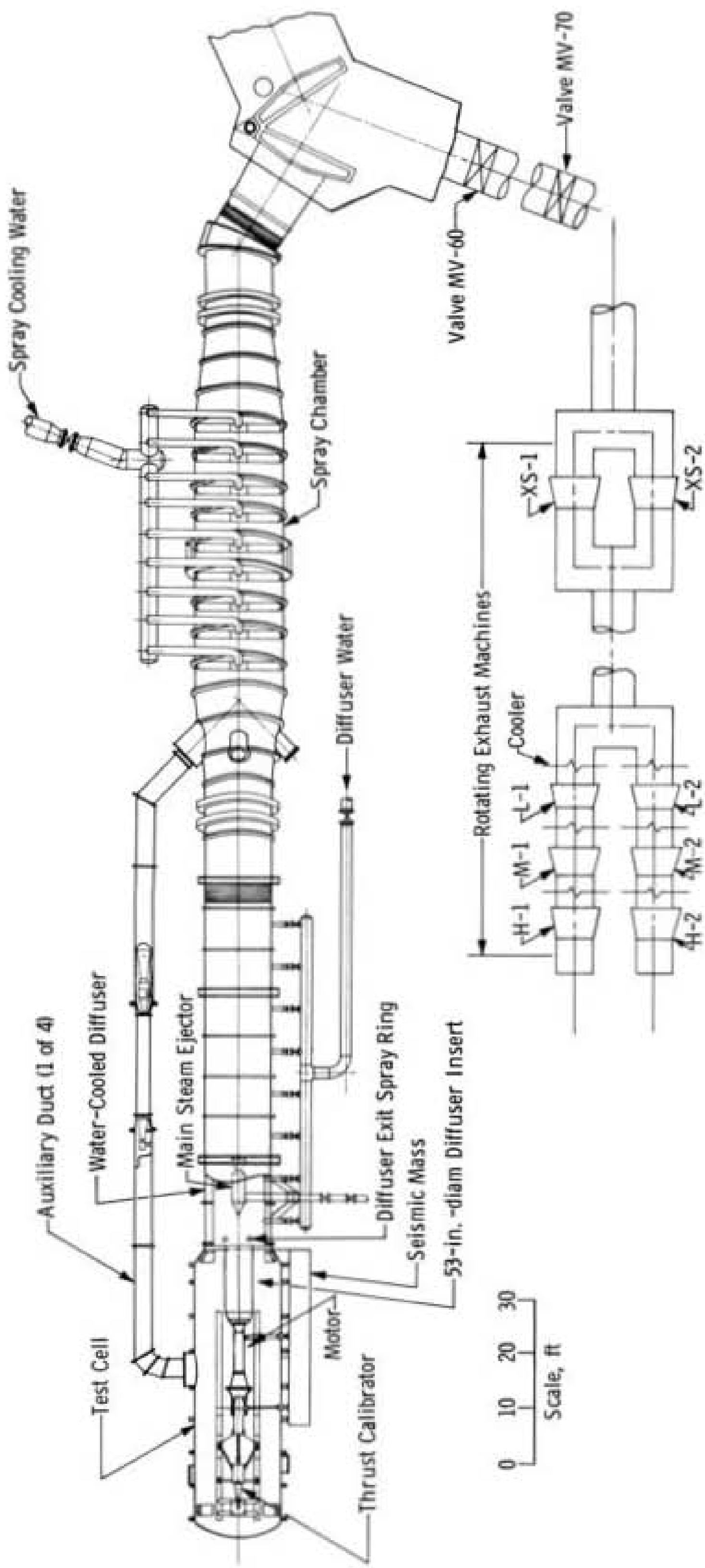
c. Artist's Cutaway View

Fig. 4 Continued



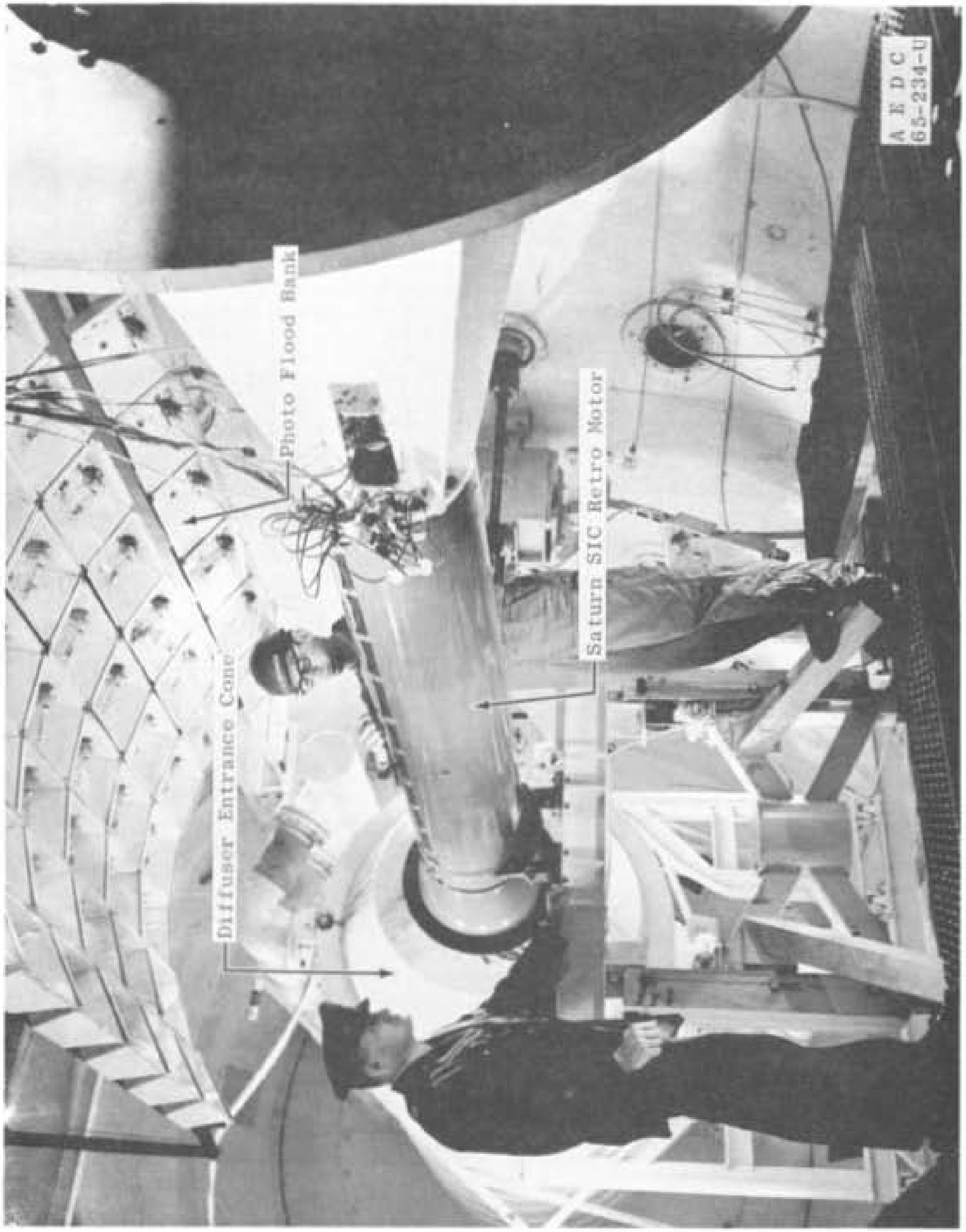
d. Schematic of Thrust Measuring System

Fig. 4 Continued



e. Plan View

Fig. 4 Continued



f. Interior View

Fig. 4 Concluded

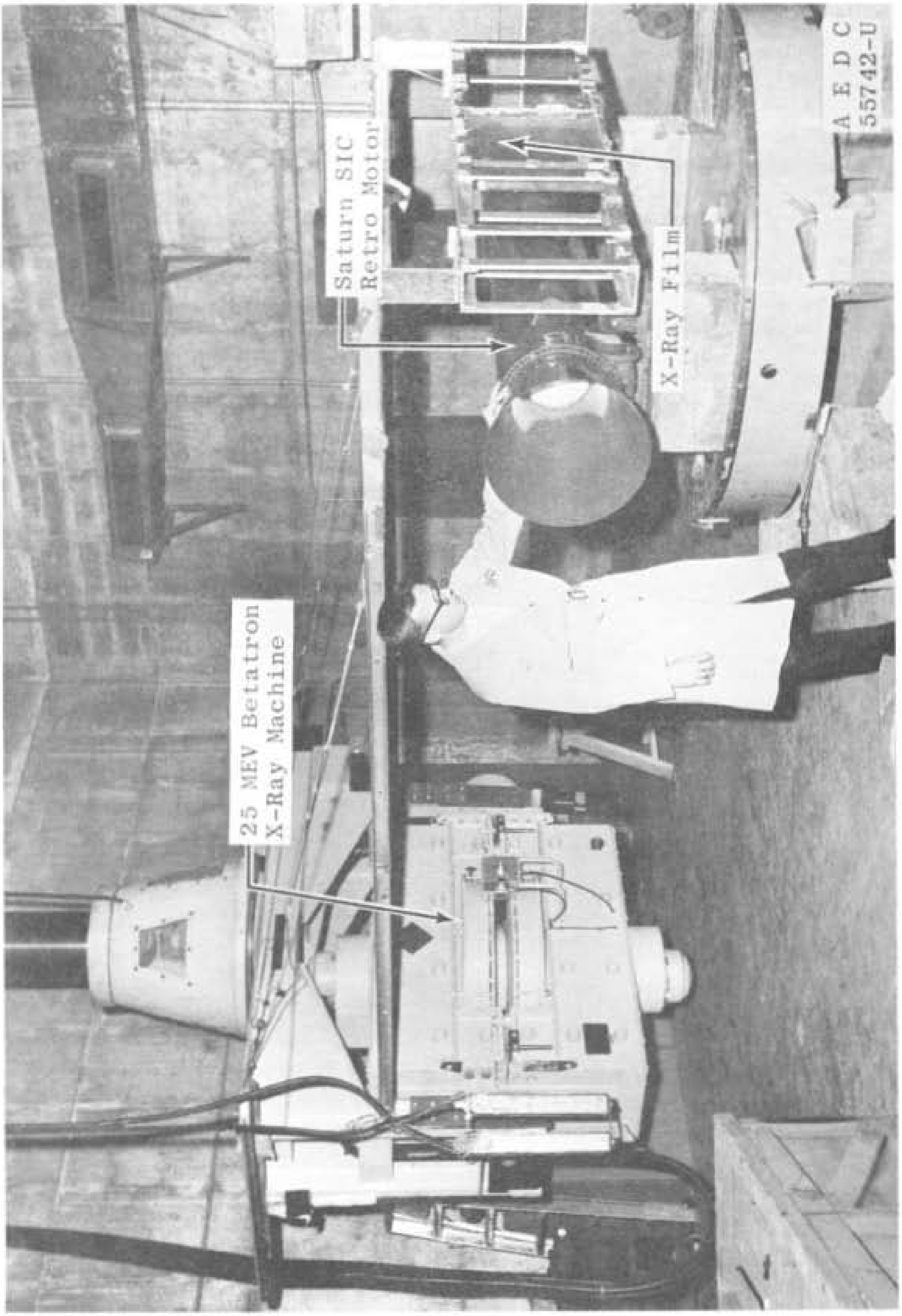


Fig. 5 Saturn SIC Retro in X-Ray Inspection

Fig. 6 Motor Installation

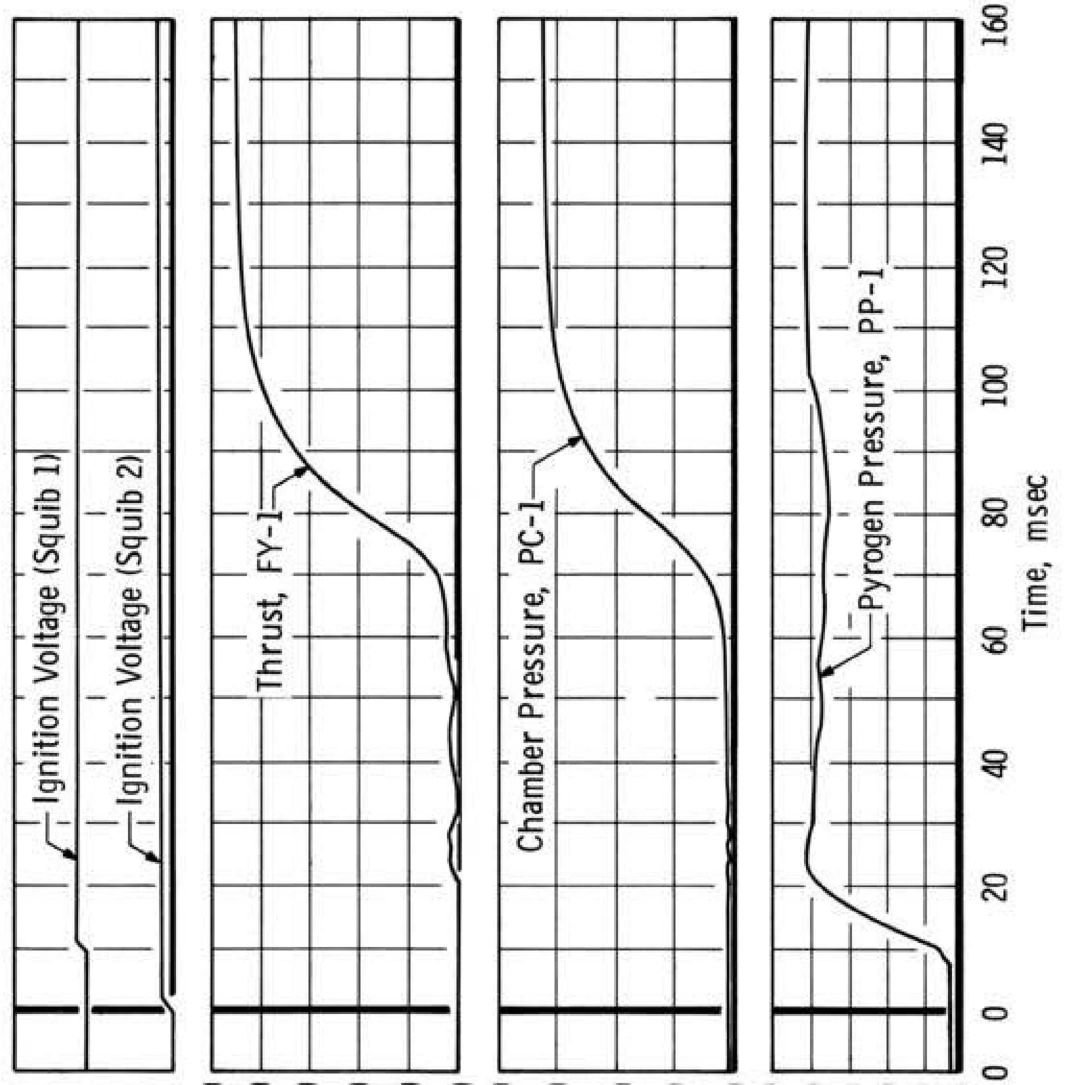


Fig. 7 Motor Ignition Detail

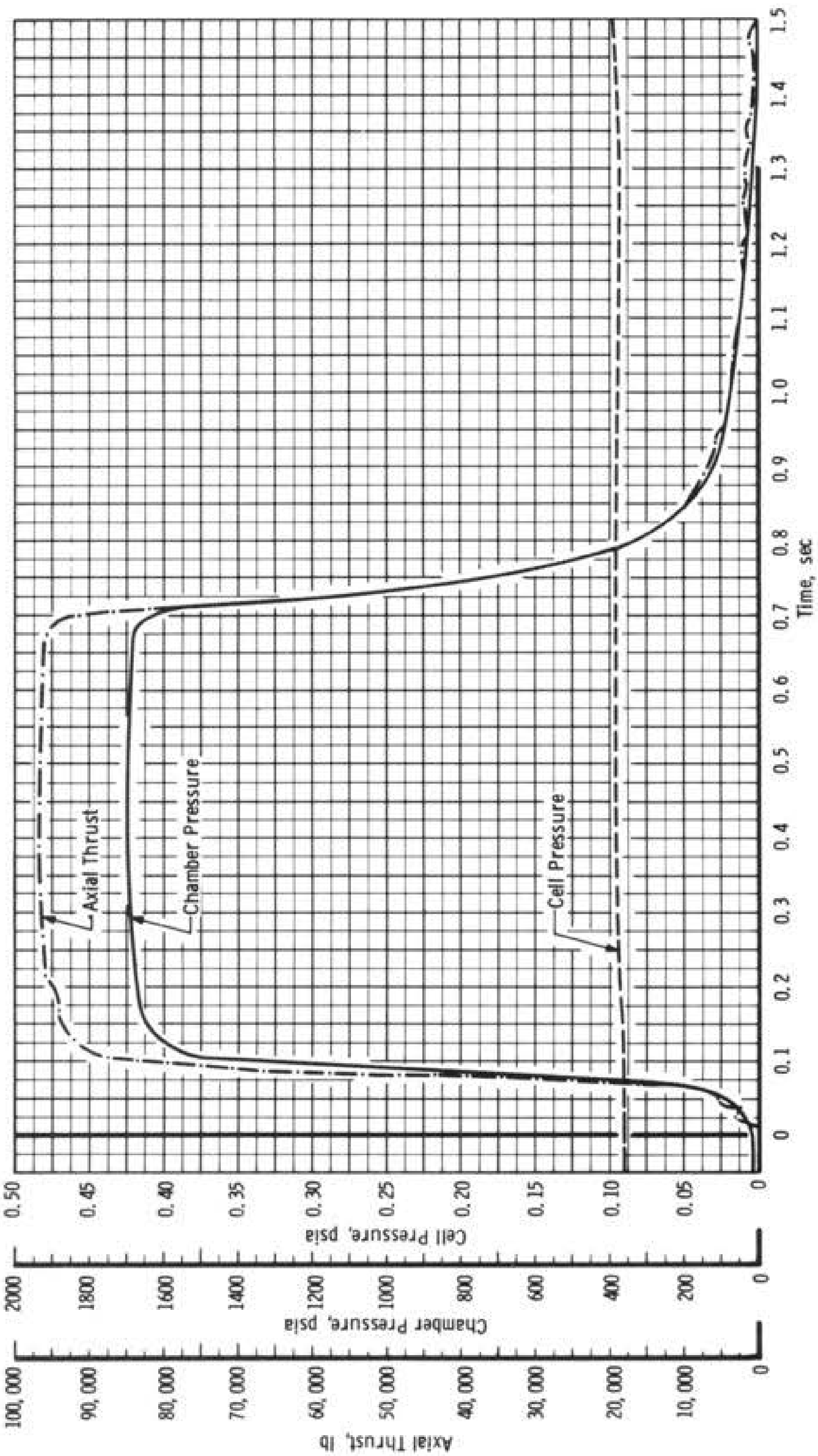
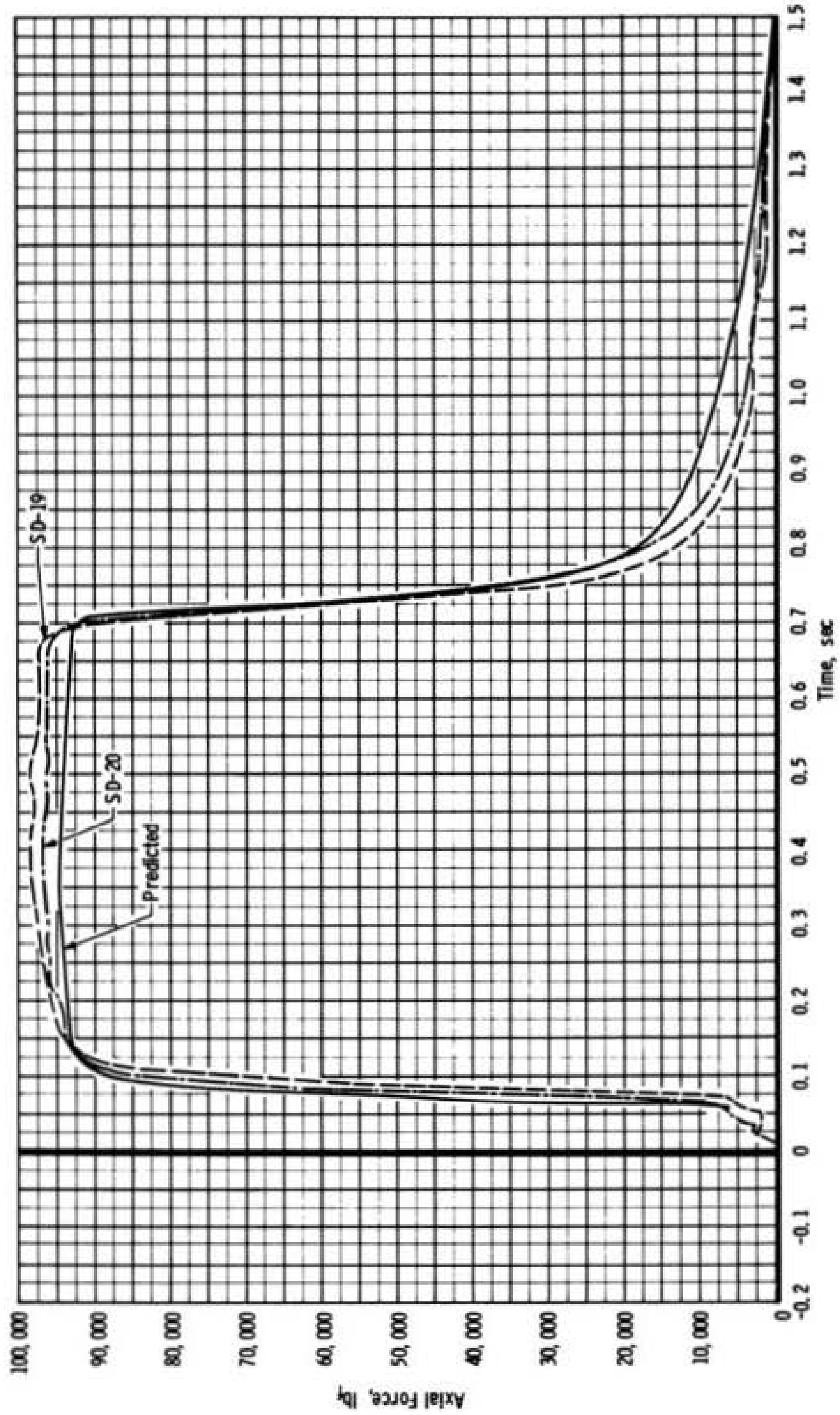
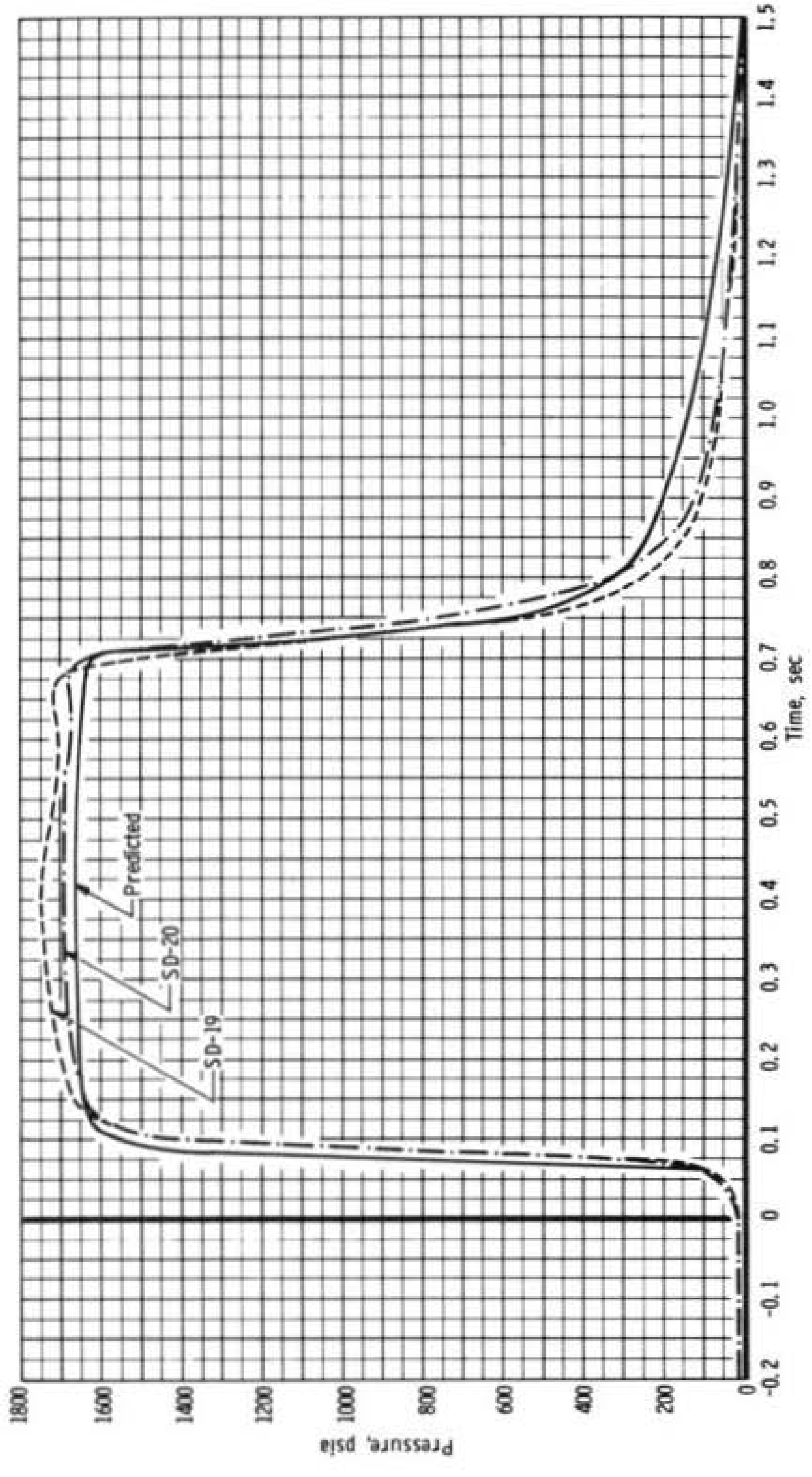


Fig. 8 Measured Motor Ballistic Performance



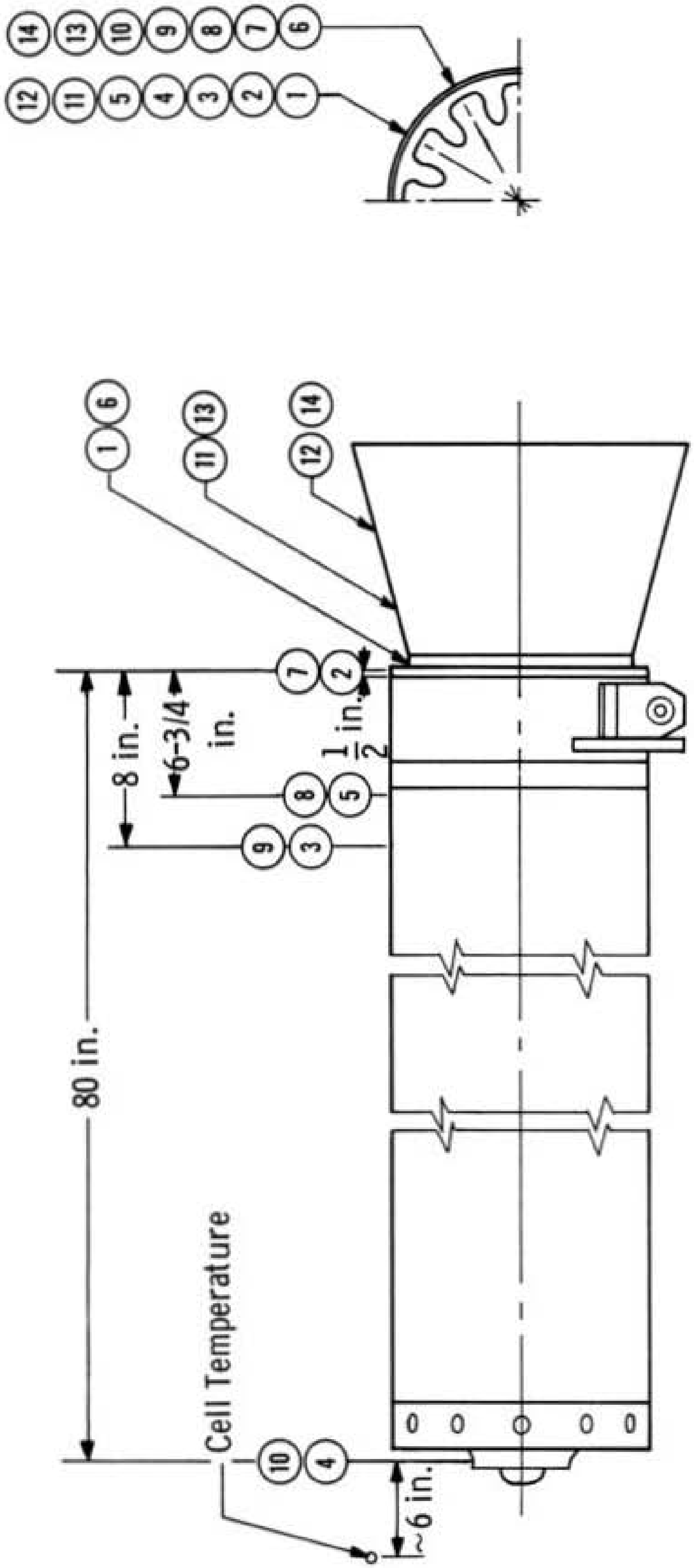
a. Axial Force

Fig. 9 Comparison of SD-19, SD-20, and Predicted Motor Vacuum Performance



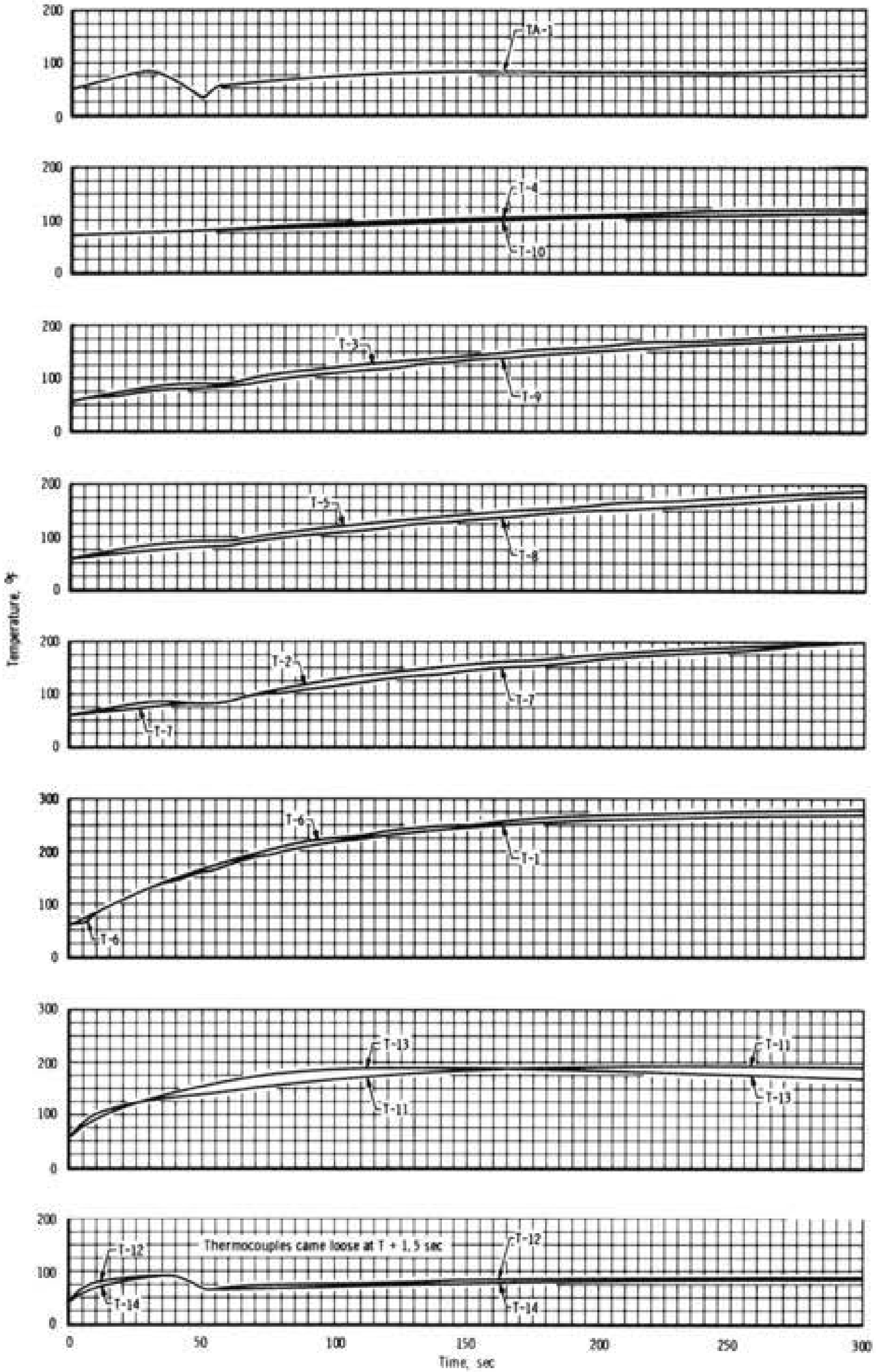
b. Chamber Pressure

Fig. 9 Continued



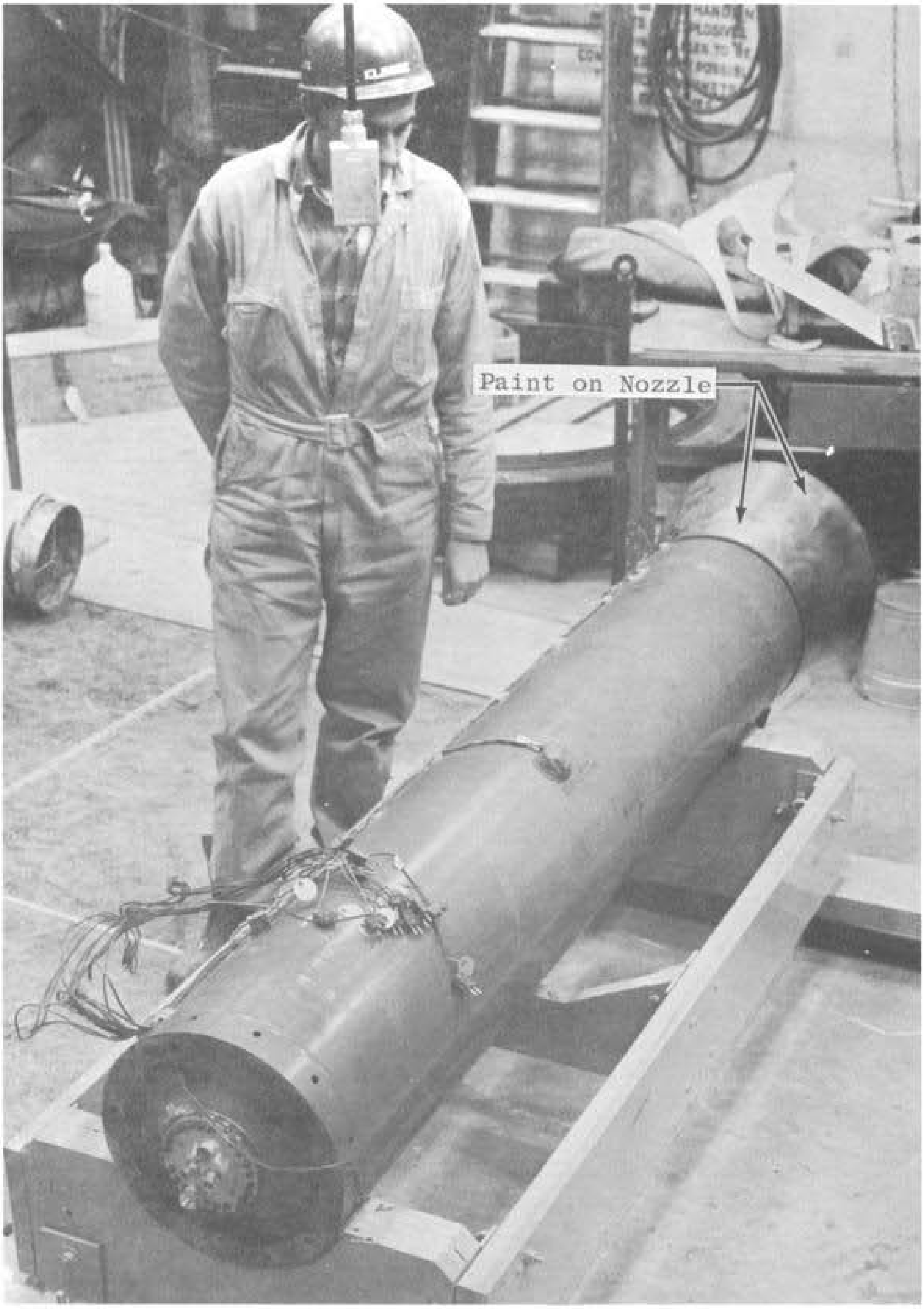
a. Thermocouple Location

Fig. 10 Chamber Temperatures



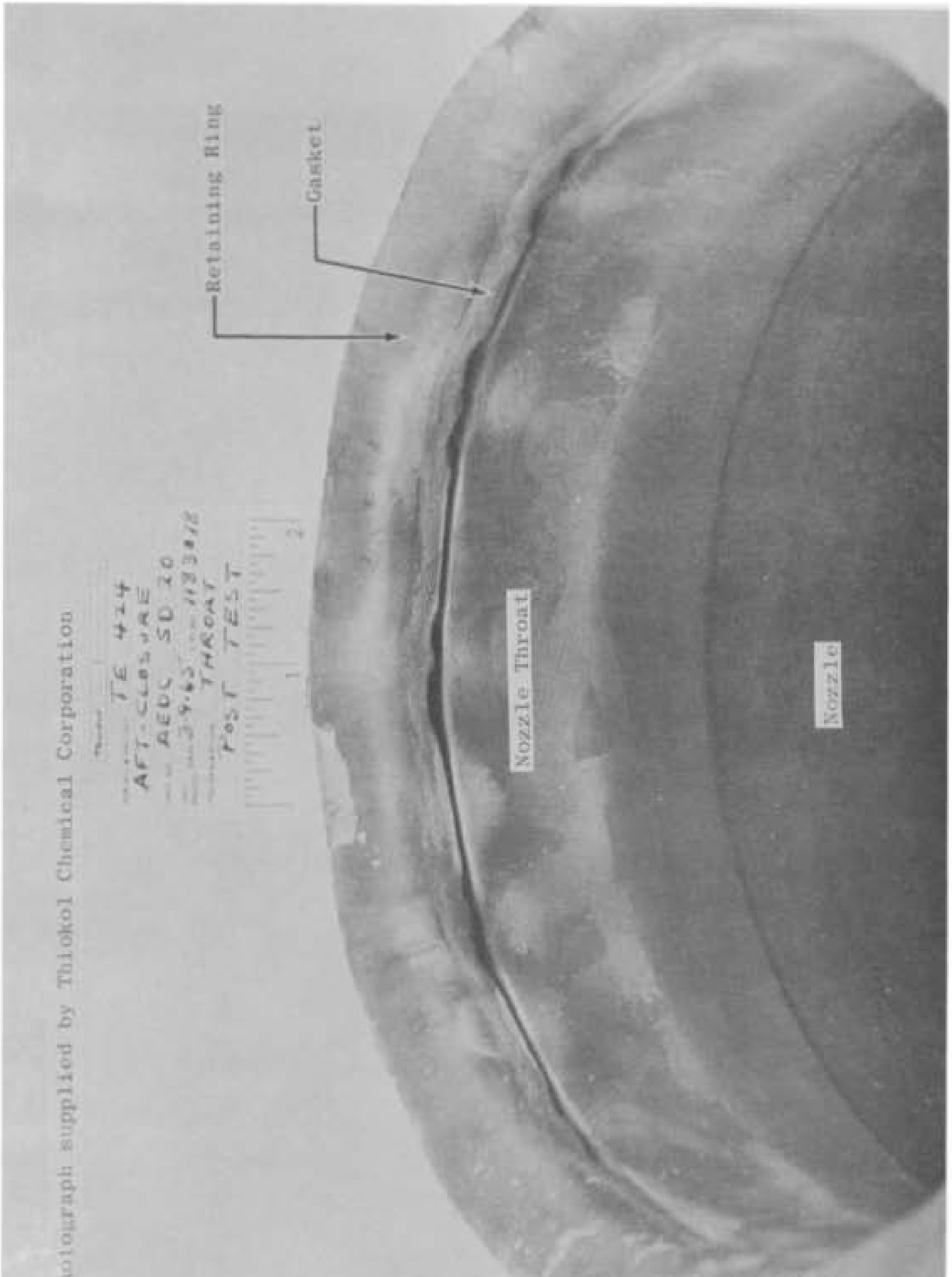
b. Data

Fig. 10 Concluded



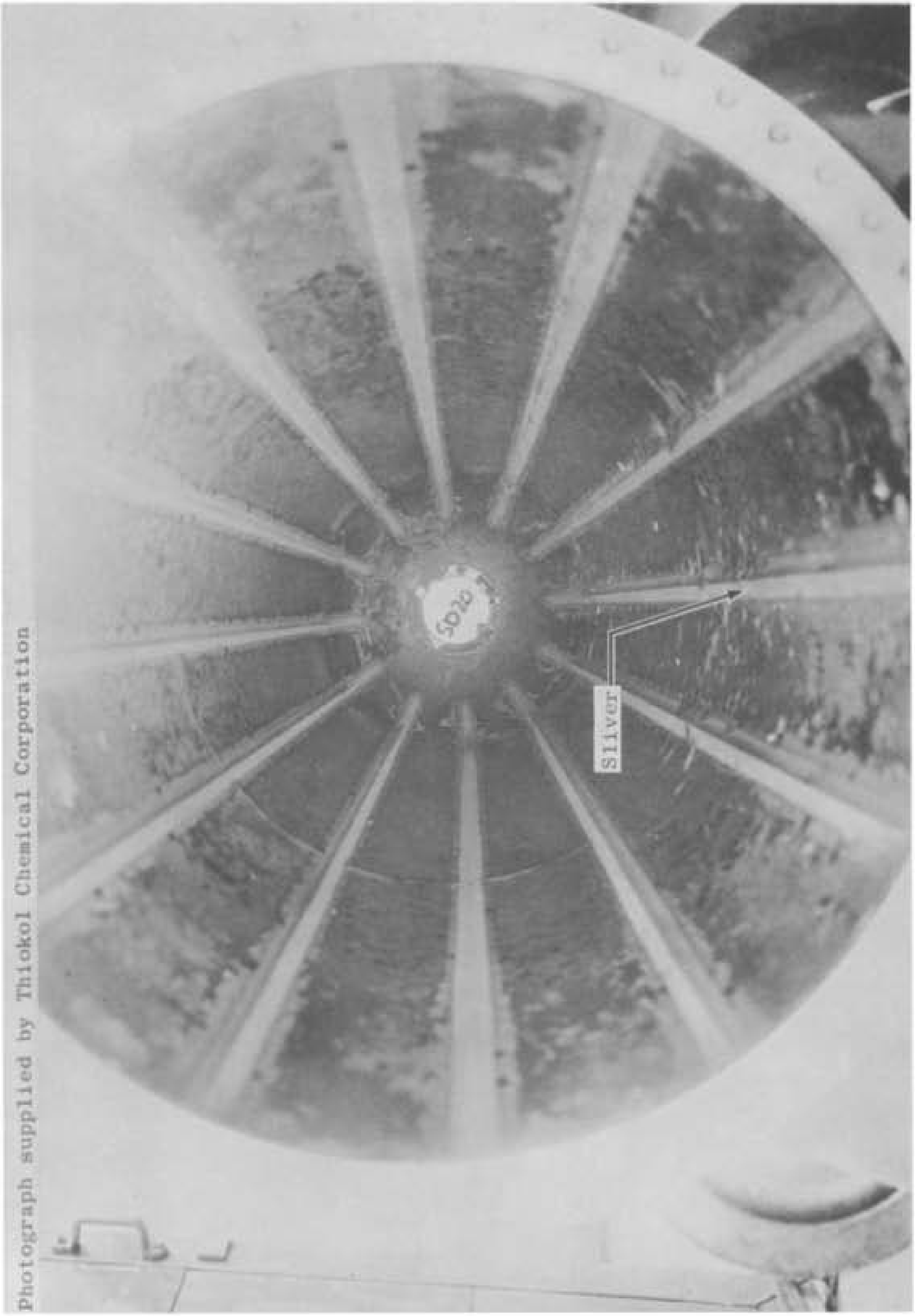
a. Overall View

Fig. 11 Post-Fire Motor Condition



b. Close-Up of Nozzle Throat

Fig. 11 Continued



c. Propellant Slivers

Fig. 11 Concluded

TABLE I
COMPOSITION OF TP-E-8104 PROPELLANT

Material	Purpose	Percent by Weight
Ammonium Perchlorate	Oxidizer	72.0
Ethyl Formal, Sulfide, Type LP-33	Fuel and Binder	18.8
Dibutyl Carbitol Formal	Plasticizer	2.1
Sulfur Diphenylquanidine p-quinonedioxime	Curing Agents	2.1
Aluminum Powder	Fuel	2.0
Ferric Oxide	Burning Rate Accelerator	2.0
Magnesium Oxide	Stabilizer	1.0

TABLE II
COUNTDOWN SEQUENCER PROGRAM

T - 65	Start steam system
T - 50	Start water systems
T - 40	Start digital data acquisition system
T - 38	Arm EBW ignition systems
T - 10	Start strip charts, oscillographs B and C, and magnetic tape recorders
T - 5	Start oscillographs A and D
T - 2	Start cameras
T - 1	Fire first series of photo flood bulbs
T - 0	Motor ignition Fire second series of photo flood bulbs
T + 1	Fire third series of photo flood bulbs
T + 10	Stop oscillographs A and D
T + 15	Initiate shutdown of water and steam systems
T + 30	Stop strip charts and magnetic tape recorders
T + 40	Stop cameras
T + 320	Stop oscillographs B and C and digital data acquisition system

Time in seconds

TABLE III
SUMMARY OF MOTOR INSTRUMENTATION

Parameter Symbol	Parameter	Range	Strip Chart	Oscillograph[1]	High Accuracy Analog System	FM	Digital Data System, Samples per Second
FY-1	Axial Force	0 to 150K lb_f	x	A, B			225
FY-2	Axial Force	0 to 150K lb_f		C, D	x		
FY-3	Axial Force	0 to 150K lb_f		A, B	x		225
FY-4	Axial Force	0 to 150K lb_f		C, D		x	
FY-5	Axial Force	0 to 150K lb_f				x	
PC-1	Chamber Pressure	0 to 2000 psia	x	A, B	x		225
PC-2	Chamber Pressure	0 to 2000 psia		C, D		x	
PP-1	Pyrogen Pressure	0 to 2500 psia	x	A, B			225
PP-2	Pyrogen Pressure	0 to 2500 psia		C, D	x		
PA-3	Cell Pressure	0 to 0.5 psia		C, D			225
PA-4	Cell Pressure	0 to 0.5 psia	x	A, B	x		
PA-5	Cell Pressure	0 to 15 psia		A, B			225
T-1	Nozzle Temperature	0 to 1000°F	x	B			45
T-2	Case Temperature	0 to 1000°F		B			45
T-3	Case Temperature	0 to 1000°F		B			45
T-4	Forward Dome Temperature	0 to 1000°F		B			45

TABLE III (Concluded)

Parameter Symbol	Parameter	Range	Strip Chart	Oscillo-graph[1]	High Accuracy Analog System	FM	Digital Data System, Samples per Second
T-5	Case Temperature	0 to 1000°F		B			45
T-6	Nozzle Temperature	0 to 1000°F		C			45
T-7	Case Temperature	0 to 1000°F		C			45
T-8	Case Temperature	0 to 1000°F		C			45
T-9	Case Temperature	0 to 1000°F		C			45
T-10	Forward Dome Temperature	0 to 1000°F		C			45
T-11	Nozzle Temperature	0 to 1000°F		C			45
T-12	Nozzle Temperature	0 to 1000°F		C			45
T-13	Nozzle Temperature	0 to 1000°F		D			45
T-14	Nozzle Temperature	0 to 1000°F		D			45
E-1, 2	EBW Charge Monitor	10 v		A, B, C, D			
I-1, 2	Ignition Current			A, B, C, D			45
V-1, 2	Ignition Voltage			A, B, C, D			45

[1]Oscillographs A and D were operated at 80 in./sec during the firing. Oscillographs B and C were operated at 16 in./sec during the firing.

TABLE IV
SUMMARY OF MOTOR PERFORMANCE DATA
(SATURN SIC RETRO MOTOR TEST)

Motor Number	SD-19	SD-20
AEDC Test Number	RP1435-01	RP1435-02
Test Date	2/18/65	2/24/65
Motor Environment during the 12 hours Prior to Cell Pump Down, °F	68 to 71	66 to 69
Ignition Altitude, ft	114,000	113,000
Average Altitude, ft	113,000	113,000
Propellant Mass, lb_m*	280.25	281.5
Pre-Fire Throat Area, in.^{2}*	35.10	35.08
Post-Fire Throat Area, in.^{2}	35.10	35.06
Pre-Fire Exit Area, in.^{2}	306.35	306.26
Post-Fire Exit Area, in.^{2}	307.16	306.85
Motor Weight, lb*	521.25	527.00
Mass Ratio*	0.54	0.53
Ignition Delay, msec	60	58
Ignition Time, msec	93	92
Effective Burn Time, msec	610	626
Total Burn Time, sec	1.5	1.5
Maximum Chamber Pressure, psia	1765	1700
Total Chamber Pressure Integral, psia-sec	1171	1171
Effective Chamber Pressure Integral, psia-sec	1047	1051
Average Effective Chamber Pressure, psia	1716	1679
Total Impulse, lb_f-sec		
Measured	66,090[1]	66,000[1]
Vacuum	66,140	66,050
Percent Vacuum Correction	0.076	0.076
Effective Impulse, lb_f-sec		
Measured	59,210[2]	59,510[1]
Vacuum	59,230	59,530
Percent Vacuum Correction	0.034	0.033
Average Effective Thrust, lb_f		
Measured	97,060	95,060
Vacuum	97,100	95,100
Specific Impulse, sec	236.0	234.6
Thrust Coefficient, vacuum	1.61	1.62

*Motor manufacturer's data

[1]Five data recording system readings were averaged to obtain this value.

[2]Three data recording system readings were averaged to obtain this value. Digital systems not used because of response characteristics.

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4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

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N/A	National Aeronautics and Space Administration Michoud Operations, New Orleans, La.

13. ABSTRACT

Saturn S1C retro motor TE-M-424, Test Unit Number SD-20, was fired as part of the Thiokol Chemical Corporation research and development program for this motor. Primary test objectives were to determine ignition characteristics, ballistic performance, and hardware integrity at altitude conditions. The motor was ignited by the two ignition systems at a simulated altitude of 113,000 ft and burned at an average altitude of 113,000 ft for a total of 1.5 sec. The effective burn time was 0.626 sec, and the motor produced an effective vacuum impulse of 59,530 lb_f-sec, which is above the specification minimum. The ignition time of 92 msec is within the specification requirements. Post-fire motor inspection revealed that the hardware integrity was satisfactory.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Rocket Engine						
Altitude Testing						
Retrograde Engine						

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