~~CONFIDENTIAL~~

[redacted]

Accession No 10541

This reissue completely supersedes and replaces the 30 January 1962 issue of this report.

SID 62-148

APOLLO SPACECRAFT LAUNCH VEHICLE INTEGRATION REPORT (U)

NAS 9-150

30 January 1962 Reissued 15 May 1962

Approved by

J. W. Paup
Vice President and Apollo Program Manager

CLASSIFICATION CHANGE
To UNCLASSIFIED
By authority of GDS-EO 11652 Date 12/31/72
Changed by L. Shirley
Classified Document Master Control Station, NASA
Scientific and Technical Information Facility

~~This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18 U.S.C Section 793 and 794. Its transmission or revelation of its contents in any manner to an unauthorized person is prohibited by law.~~

~~DOWNGRADED AT 3 YEAR INTERVALS; DECLASSIFIED AFTER 12 YEARS. DOD DIR 5200.10~~

NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

~~CONFIDENTIAL~~

CON[redacted]

CONTENTS

[redacted]

[redacted]

~~CONFIDENTIAL~~

[redacted]

Section Page

~~CONFIDENTIAL~~

ILLUSTRATIONS

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

TABLES

[redacted]

[redacted]

INTRODUCTION

The material in this report has, for the most part, been adopted from NASA documents and working papers. In some cases, the information is an approximation and is meant to be used only as a guide.

As additional or more exact information becomes available, it will be incorporated in subsequent revisions.

[redacted]

I. LITTLE JOE II LAUNCH VEHICLE

OBJECTIVE

The primary purpose of the Little Joe II launch vehicle will be to provide trajectory to the Apollo prototype spacecraft for testing the abort systems at high altitude. Both the launch-escape and service module methods will be used.

DESCRIPTION

The design of Little Joe II is not yet firm; the descriptions and configurations given are only approximate.

The Little Joe II is twice as large and four times as heavy as the Little Joe I booster. It is a staged-fired, fin-stabilized, solid-fuel rocket booster designed to accommodate up to seven Algol rocket motors with provisions to eliminate motors to change performance characteristics. The booster consists of three major assemblies: the forward body, the after-body, and the fins. (See Figure 1.)

The various sequences of staging which may be utilized, depending upon the performance required, are given in Table 1.

PROPULSION

ROCKET MOTORS

Up to seven Algol (first-stage Scout) solid-fuel rocket motors may be used.

[redacted]

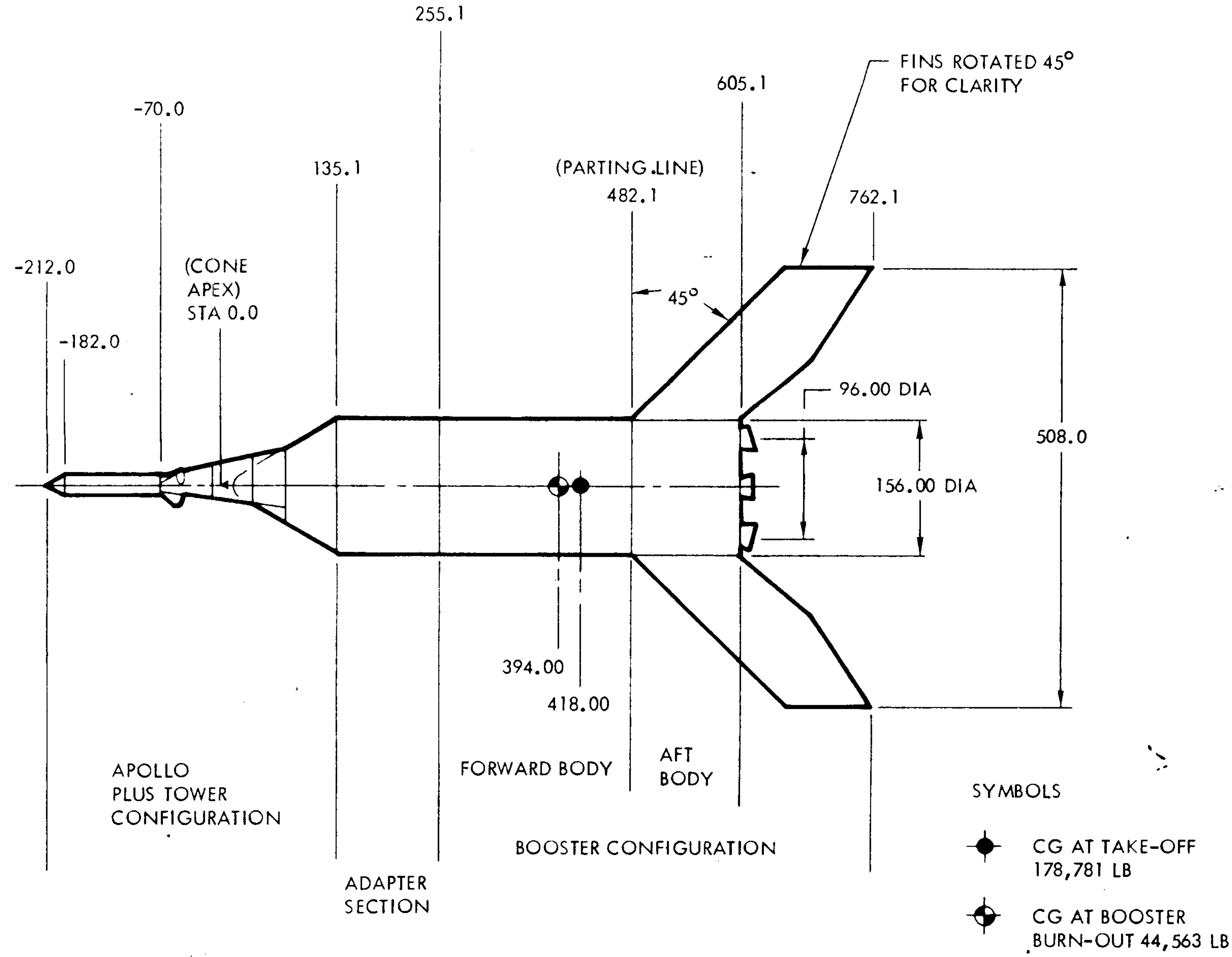


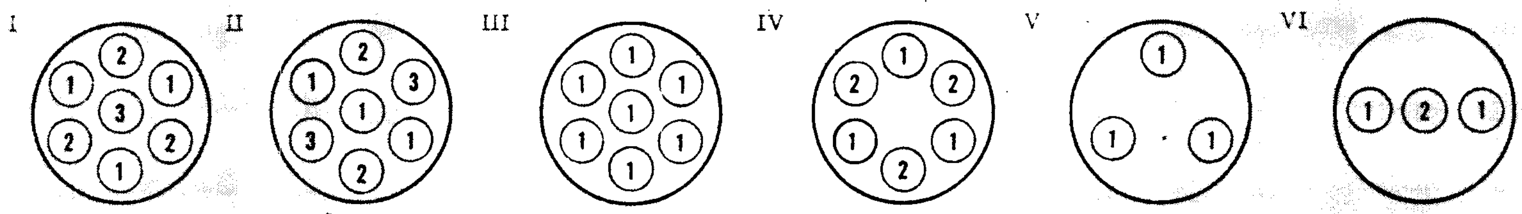
Figure 1. General Arrangement of Little Joe II Booster and Apollo Prototype

~~CONFIDENTIAL~~

[redacted]

Table 1. Little Joe II Weight, Center of Gravity, and Moments of Inertia for Six Booster Configurations

END VIEWS OF BOOSTER CONFIGURATIONS



NUMBERS ON ROCKET MOTORS DENOTE MOTORS IGNITED FOR FIRST, SECOND, AND THIRD STAGES

	At First-Stage Ignition		At Second-Stage Ignition		At Third-Stage Ignition		*Moments of Inertia at First-Stage Ignition	
	Weight (lb)	Center of Gravity Station	Weight (lb)	Center of Gravity Station	Weight (lb)	Center of Gravity Station	Roll	Pitch-Yaw
I	178,800	418	102,100	412	63,800	404	110,000	734,000
II	178,800	418	121,300	414	83,000	409	110,000	734,000
III	178,800	418					110,000	734,000
IV	156,200	415	98,700	409			109,000	687,000
V	88,400	398					71,000	541,500
V								525,000
VI	88,400	398	50,000	376			60,000	547,000

*Slug-ft²

Note

Weight, center of gravity, and inertia figures are for the total configuration escape system, capsule, retropack, adapter, booster, and other components.

[redacted]

[redacted]

PROPELLANT

To perform satisfactorily, the Algol rocket-motor propellant must be maintained at a temperature of 70 to 90 F before flight.

INSTRUMENT UNIT (NOT APPLICABLE)

GUIDANCE AND CONTROL

A control system will be required; however, these requirements have not been established.

INSTRUMENTATION

DESCRIPTION

MONITORING

MEASUREMENT LIST

Mandatory

Optional

TELEMETRY AND RADIO FREQUENCY SYSTEMS

ABORT SENSING AND DESTRUCT SYSTEMS

ABORT SYSTEMS

DESTRUCT SYSTEM

INTERFACES

MECHANICAL

ELECTRICAL

AERODYNAMIC

CONTROL DYNAMICS

MISSION-TRAJECTORY/PAYLOAD CAPABILITIES

ENVIRONMENTAL PROFILES

PHYSICAL CONFIGURATION

OVERALL DIMENSIONS

The overall dimensions given in Figure 1 include the Little Joe II booster, adapter section, prototype Apollo spacecraft, and launch escape tower.

WEIGHTS AND CENTER-OF-GRAVITY LOCATIONS

A list of weights and center-of-gravity stations are included in Table 1.

LIMITATIONS

SURFACE WIND VELOCITIES

WIND SHEAR

LAUNCH ANGLE

PAYLOAD

Weight

Center-of-Gravity Location

II. C-1 LAUNCH VEHICLE

OBJECTIVE

The purpose of the C-1 launch vehicle will be to provide the Apollo spacecraft with the necessary guidance and propulsion for unmanned reentry and unmanned and manned earth-orbital spacecraft missions.

DESCRIPTION

The typical two-stage Apollo Saturn C-1 launch vehicle, Figure 2, consists of four major components.

STAGE S-I

The first stage (S-1) is powered by eight Rocketdyne H-1 engines with a total thrust of 1.5 million pounds. Propellants for these engines consist of 850,000 pounds of LO_2 and RP-1. Tail fins are provided to improve the stability of the first-stage flight. The diameter of the propellant tanks is about 257 inches.

S-1/S-IV INTERSTAGE SECTION

This is a 220-inch-diameter cylindrical section which remains with the first stage (S-1) after in-flight separation of the second stage (S-IV).

STAGE S-IV

The second stage (S-IV), shown in Figure 3, will be powered by six Pratt & Whitney RL10-A-3 engines with a total thrust of 90,000 pounds. Propellants for these engines consist of 100,000 pounds of LO_2/LH_2. The rear and forward interfaces of the S-IV have nominal diameters of 220 inches and 154 inches respectively.

After second-stage boost into orbit, the S-IV booster and attached instrument unit are separated from the payload.

[redacted]

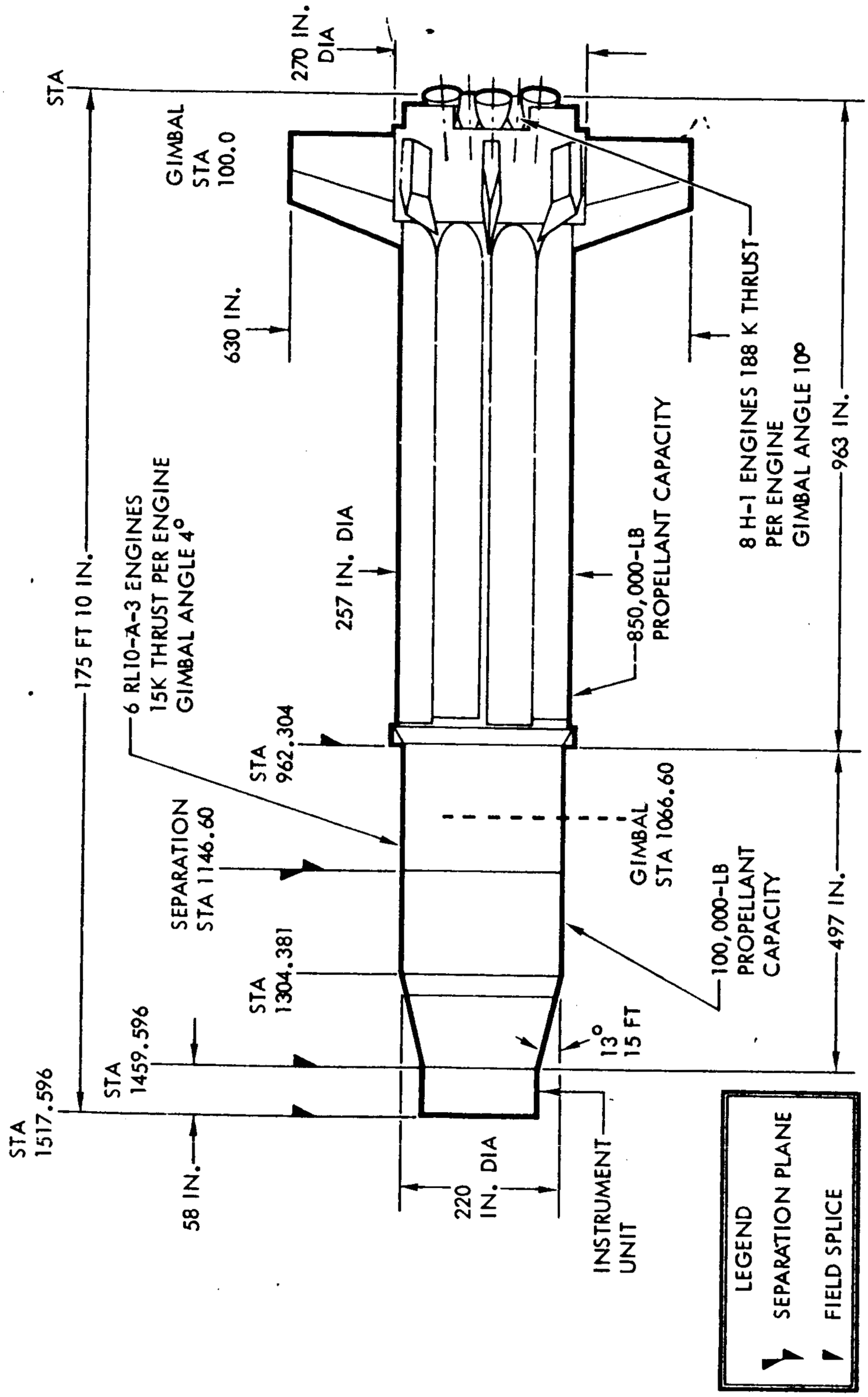


Figure 2. Saturn C-1 Launch Vehicle

~~CONFIDENTIAL~~

[redacted]

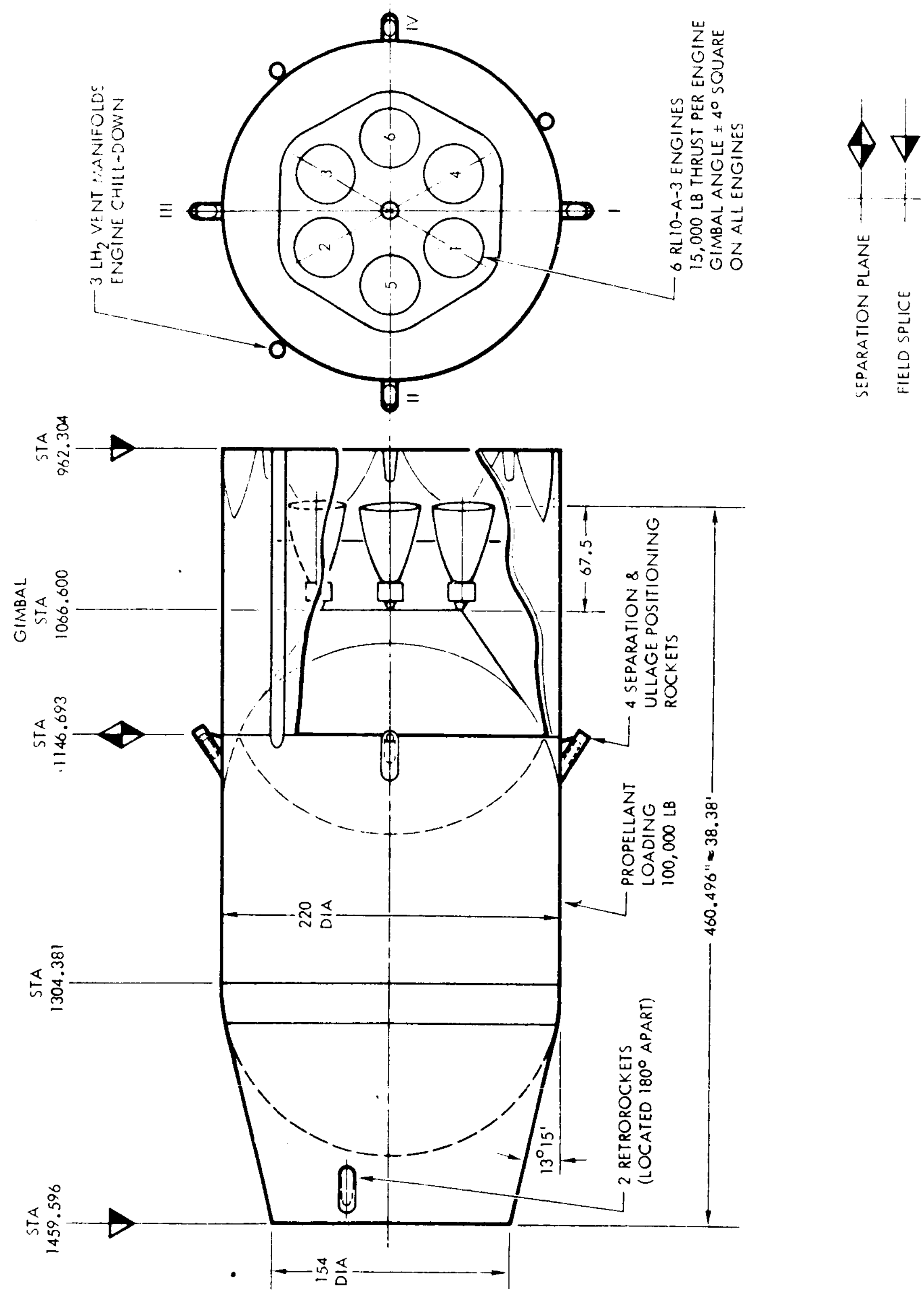


Figure 3. Saturn C-1 S-IV Stage Configuration

[redacted]

INSTRUMENT UNIT

The instrument unit contains the Saturn C-1 launch vehicle guidance and instrumentation. It has a nominal diameter of 154 inches. (See Figure 4.)

PROPULSION

FIRST STAGE (S-1)

Engines

The S-1 stage power plant consists of eight engines. Four, inboard engines, are mounted in a closed square pattern. The other four, outboard engines, are mounted on the points of a larger square rotated 45 degrees from the inner pattern. Each outboard engine is designed to permit a ±10 degree square gimbal pattern in any direction from the null position by means of two hydraulic actuators. This gimbaling establishes proper forces for pitch, yaw, and roll control of the launch vehicle.

The Rocketdyne H-1 engine is a greatly simplified and repackaged S-2D engine. The engine parameters are shown in Table 2.

Propellant

The propellants used in the S-1 stage are RP-1 and LO_2. The RP-1 containers are pressurized with GN_2 and the LO_2 containers are pressurized by GO_2.

Control System

Each outboard engine is equipped with an independent closed-loop hydraulic system which supplies hydraulic pressure for engine gimbaling. Two electrically controlled, hydraulically operated actuators; a main hydraulic pump; an auxiliary motor and pump; and an accumulator-reservoir assembly are the major components in the S-1 stage control system.

SECOND STAGE (S-IV)

Engines

Six 15,000-pound vacuum-thrust LO_2/LH_2 RL10-A-3 engines are used on the S-IV stage. Each engine is a regeneratively cooled, turbopump-fed rocket engine.

[redacted]

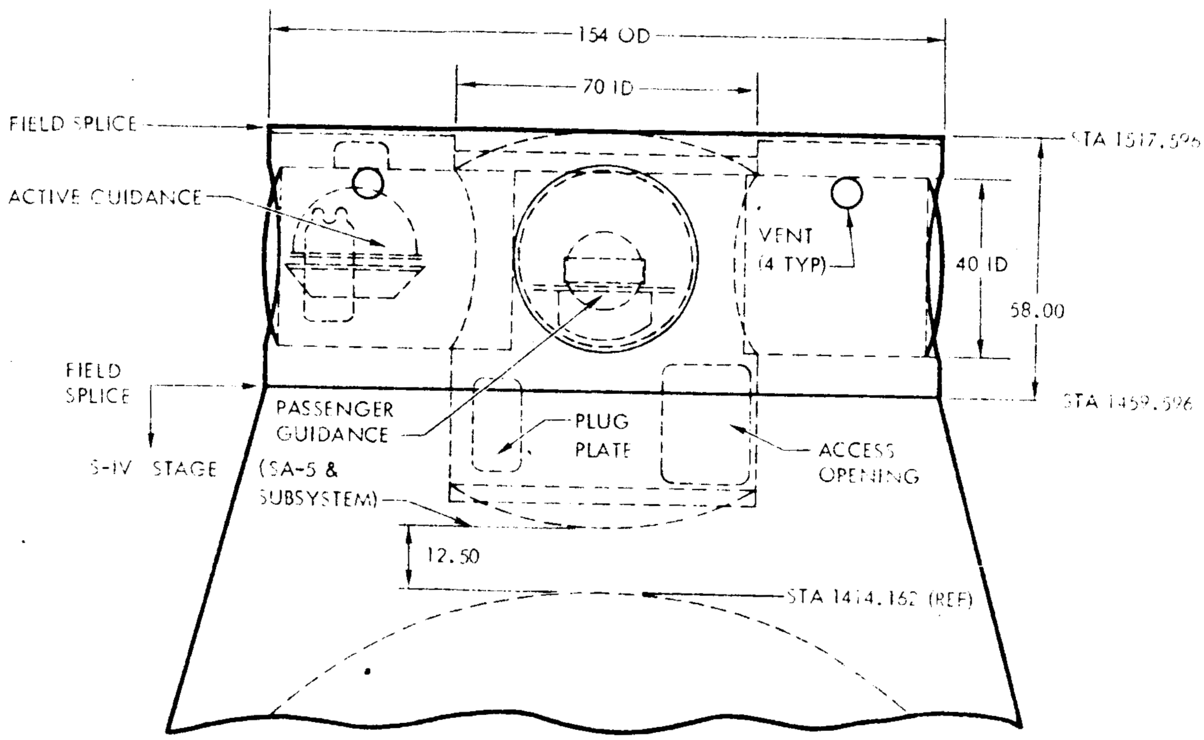


Figure 4. Saturn C-1 Instrument Unit Configuration

~~CONFIDENTIAL~~

~~[redacted]DENTIAL~~

Table 2. H-1 Engine Performance Parameters
(Based on Saturn SA-1 Flight Data)

Nominal engine thrust	188K lb (sea level)
Thrust variation	±3%
Thrust overshoot	5%
Time from ignition to 90% thrust (maximum)	1.3 sec
Nominal specific impulse	255.0 lb-sec/lb (sea level)
Engine mixture ratio	2.26
Cutoff impulse (sea level)	42,000 lb-sec
Cutoff impulse (altitude)	
Maximum	98,400 lb-sec
Minimum	73,640 lb-sec
Average	82,170 lb-sec
Cutoff impulse variation Maximum (sea level)	±7,500 lb-sec
LO_2 pump NPSH (required)	60 ft
Fuel pump NPSH (required)	35 ft
Thrust build-up rate (average)	71,300 lb/10 ms
Thrust build-up deviation (for 3σ confidence level)	27,200 lb/10 ms

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

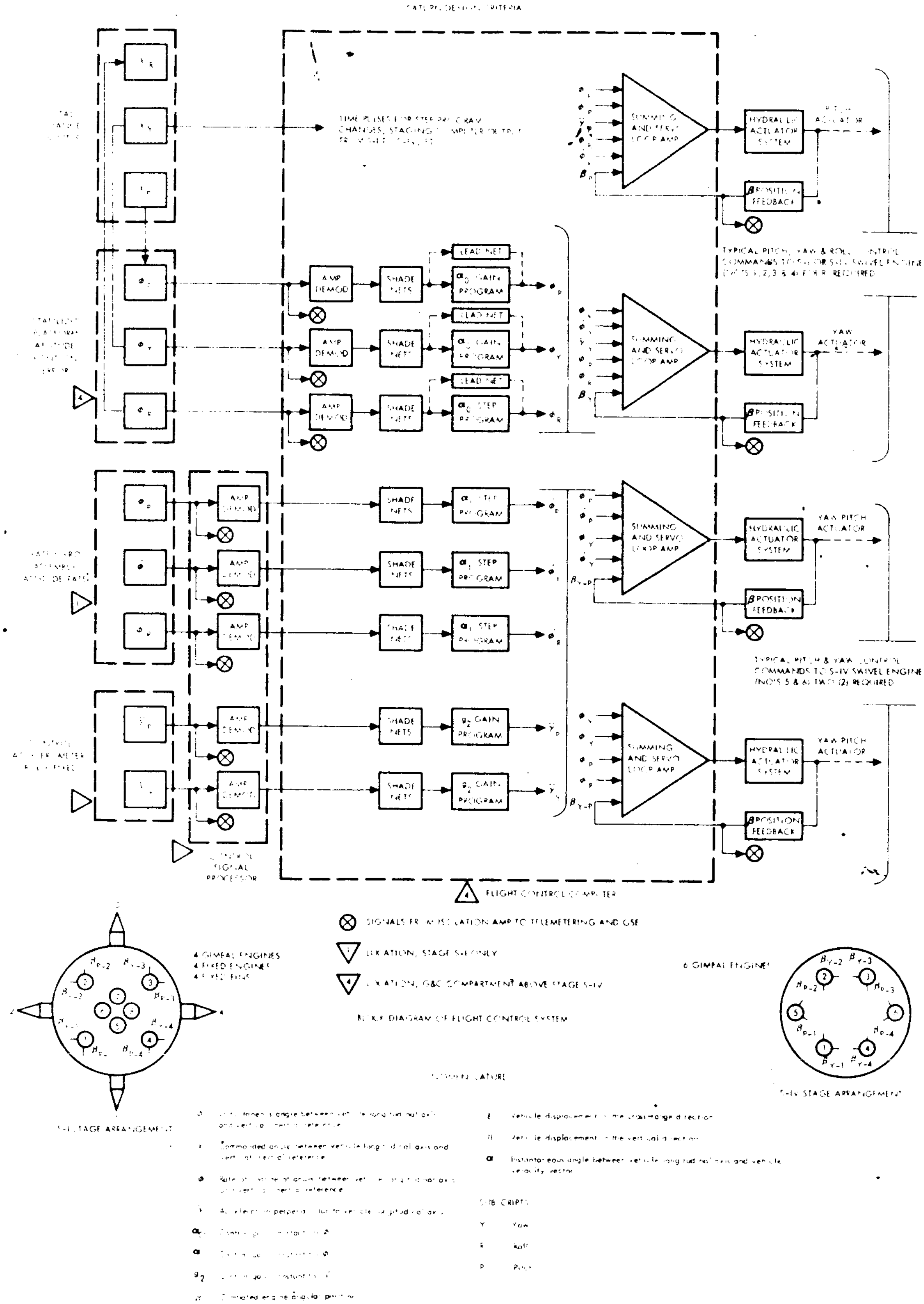
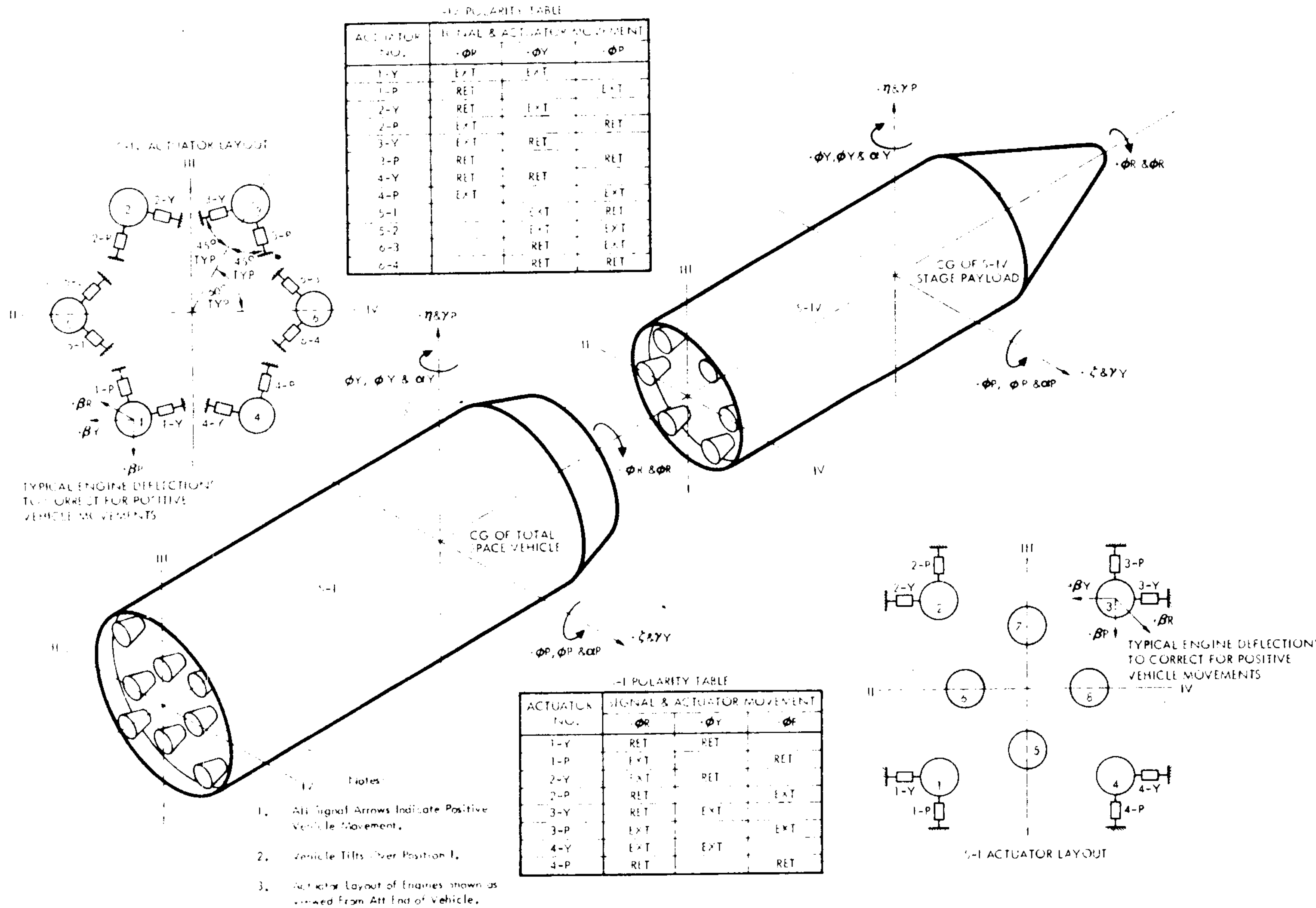


Figure 5. Saturn C-1 Flight Control System

~~CONFIDENTIAL~~

[redacted]



S-IV POLARITY TABLE

ACTUATOR NO.	SIGNAL & ACTUATOR MOVEMENT $+\phi P$	$+\phi Y$	$+\phi P$
1-Y	EXT	EXT	
1-P	RET		EXT
2-Y	RET	EXT	
2-P	EXT		RET
3-Y	EXT	RET	
3-P	RET		RET
4-Y	RET	RET	
4-P	EXT		EXT
5-1		EXT	RET
5-2		EXT	EXT
6-3		RET	EXT
6-4		RET	RET

S-I POLARITY TABLE

ACTUATOR NO.	SIGNAL & ACTUATOR MOVEMENT $+\phi R$	$+\phi Y$	$+\phi P$
1-Y	RET	RET	
1-P	EXT		RET
2-Y	EXT	RET	
2-P	RET		EXT
3-Y	RET	EXT	
3-P	EXT		EXT
4-Y	EXT	EXT	
4-P	RET		RET

Figure 6. Integrated Polarity Chart for S-I and S-IV Stages

~~CONFIDENTIAL~~

Thrust control is accomplished by sensing engine chamber pressure. Ignition is accomplished by means of an electric spark ignitor projecting into the combustion chamber. Starting and stopping are controlled by valving. A hydraulic pump is used to provide power for the gimbal actuator.

The RL10-A-3 engine performance parameters are shown in Table 3.

Propellants

The propellants used in the S-IV stage are LO_2 and LH_2. The LO_2 container is pressurized by ambient He during ground operation and by heated GHe during flight. The LH_2 container is pressurized by ambient He during ground operation and, in flight, pressurized as required prior to GH_2 flow from the engines to the pressurization system.

Control System

The S-IV stage contains six independent closed-loop, flight-control hydraulic systems. Two linear-type hydraulic actuator assemblies are connected to each engine to provide gimbal motion. Proper gimbal positioning of the engines during flight is provided by correction signals generated in the guidance and control system.

INSTRUMENT UNIT

The instrument unit is mounted to the forward end of the S-IV stage. The forward end of the unit's fuselage provides the interface mount for the Apollo spacecraft. In order to satisfy the requirements of noninterference with the spacecraft body, no portion of the units structure extends above the interface. The form of the unit is much like four spokes attached to the hub of a wheel forming a hollow cavity of five elements. The outside diameter and length of the fuselage rim are 154 inches and 58 inches respectively; the inside diameter of each spoke tube container is 40 inches. The inside diameter and length of the hub container are 70 inches and 103.434 inches respectively.

The seven major items contained in the instrument unit are as follows:

1. Vehicle guidance system
2. Control system
3. Time base selector
4. Networks
5. Instrumentation and measuring
6. Air-bearing system
7. Special equipment

[redacted]

Table 3. RL10-A-3 Engine Performance Parameters

Nominal thrust (vacuum)	15,000 lb
Thrust variation (vacuum)	±2% (±300 lb)
Maximum time from ignition to 90% thrust	2 sec
Minimum specific impulse (I_{sp}) (vacuum)	420 lb sec/lb
Engine mixture ratio	5:1 ± 1.67%
Cutoff impulse (vacuum)	2500 lb sec
Cutoff impulse variation (vacuum)	±140 lb sec
LO_2 pump inlet nominals	46.5 psia at 163 R
Fuel pump inlet nominals	31.5 psia at 37 R
Rate of thrust increase	250 lb/ms
Nozzle area ratio	40:1
Chamber pressure	300 psia
LO_2 NPSH (required)	15 psi
Fuel NPSH (required)	8 psi

GUIDANCE AND CONTROL

The guidance system for the Saturn C-1 vehicles will be integrated for all stages, and only switching networks will be necessary within each stage. The control system utilizes attitude information from the inertial platform, attitude rate derived from rate gyros or differentiated attitude signals, and lateral control derived from control accelerometers or "Q-Ball" transducer. These signals are summed and amplified in an analog control computer for transmittal of d-c signals to the actuators of the active stage. The flight control system of the vehicle is shown in Figure 5, and the integrated polarity chart for S-I and S-IV stages are shown in Figure 6. The excitation voltage for the engine position potentiometer, both for control and measuring instrumentation, shall be supplied from the instrument unit.

Vehicle control during S-I stage operation is maintained by gimbaling the four outboard engines to provide pitch, yaw, and roll control forces. The hydraulic actuators that provide the necessary engine gimbaling forces are capable of deflecting the engine plus or minus 8 degrees. Vehicle (attitude, attitude rate, angle-of-attack, or lateral acceleration) signal errors are sensed and transmitted to the control computer. The control computer distributes correction signals to the servo-valves on the outboard engine actuators.

S-IV stage in-flight control is accomplished by gimbaling the six engines. The hydraulic actuators that provide the necessary engine gimbaling forces are capable of deflecting the engine ±4 degrees. The amount of deflection is proportional to the command signals furnished by the control computer in the instrument unit.

The instrument unit will provide vehicle structure for stabilized platforms, guidance and instrumentation equipment. The design dictates that skin cutouts be made only where mandatory; therefore, all antennas or other exterior equipment shall be surface mounted.

[redacted]

Table 4. Condensed S-I Measurement List

Parameter	Range
Flight sequencer steps	On-off
First motion	On-off
Cut-off signal	On-off
Engine cut-off	On-off
LO_2 level cut-off	On-off
Fuel-level cut-off	On-off
Retrorocket ignition signal (EBW)	On-off
Breakwire, retrorocket ignition	On-off
Temperature, base, tail	0 to 1500 C
Actuator support temperature	-50 to +500 C
Temperature at various inboard and outboard locations	-50 to +900 C
Outrigger thrust assembly liquid-propellant temperature	-50 to +300 C
Lower thrust ring temperature	-50 to +300 C
Outrigger support temperature liquid-propellant assembly	-50 to +300 C
Engine shroud temperature	0 to 500 C
Thrust frame area temperature	-50 to +100 C
Radiation shield temperature	0 to 800 C
Tank shroud temperature	0 to 300 C
Shroud skin temperature	0 to 800 C
S-I/S-IV interstage temperatures	0 to 825 C
Base pressure tail	0 to 20 psia
Retrorocket pressure	0 to 2500 psia
Surface pressure, various stations	0 to 25 psia
Mounting stud strain	0.0008 to 0.008 in.
Radiation shield longitudinal vibration	±50 g
Strain, top skirt	0.0005 to 0.005 in./in.
Retrorocket longitudinal vibration	0 to 40 g
Spider beam longitudinal vibration	0 to 40 g
Sound intensity, fine	10 db
Sound intensity, coarse	110 to 190 db

~~CONFIDENTIAL~~

[redacted]

Table 4. Condensed S-I Measurement List (Cont)

Parameter	Range
Experimental EBW, voltage	0 to 5 v
Experimental EBW, trigger	On-off
Experimental EBW, breakwire	On-off
EBW voltage	0 to 5 v
Measuring voltage	0 to 5 v
Frequency of inverter	400 ± 0.25 cps
AGC voltage, UDOP	0 to 5 v
AGC voltage, command	0 to 5 v
Beta reference voltage	0 to 5 v
Command voltage	55 to 65 v
Power transformer bus voltage	0 to 28 v
Thrust commit voltage	0 to 28 v
Bus voltage	24 to 32 v
Power output, Azusa	0 to 2.4 v dc
AGC voltage, Azusa	0 to 2.4 v dc
Frequency, static inverter	400 to 0.25 cps
Fuel pump inlet temperature	-20 to +40 C psid
ΔP fuel sloshing, pitch	±0.3 psid
ΔP fuel sloshing, yaw	±0.3 psid
ΔP LO_2 sloshing, pitch	±0.5 psid
ΔP LO_2 sloshing, yaw	±0.5 psid
ΔP propellant utilization computer, LO_2	0 to 30 psid (1)
ΔP propellant utilization computer, fuel	0 to 20 psid (1)
Fuel pump inlet pressure	0 to 100 psi
LO_2 pump inlet pressure	0 to 150 psia
Fuel suction line vibration, longitudinal	±50 g
Fuel tank vibration, pitch	±0.5 g
Fuel tank vibration, yaw	±0.5 g
LO_2 emergency pressure switch	On-off
LO_2 relief control valve	On-off

[redacted]

[redacted]

Table 4. Condensed S-I Measurement List (Cont)

Parameter	Range
Fuel temperature	0 to 40 C
Main fuel valve position	On-off
Main fuel flow rate, dc	0 to 40 gal/sec
Main LO_2 flow rate, dc	0 to 50 gal/sec
Main LO_2 valve position	On-off
Main fuel flow rate, ac	0 to 40 gal/sec
Main LO_2 flow rate, ac	0 to 50 gal/sec
Propellant utilization computer output, coarse	
Propellant utilization computer output, fine	
LO_2 level, discrete	On-off
Fuel level, discrete	On-off
Gas top fuel tank temperature	-50 to +50 C
Gas top LO_2 tank temperature	-50 to +200 C
Skin LO_2 tank temperature	-185 to +150 C
Skin fuel tank temperature	0 to 300 C
LO_2 temperature	-190 to -40 C
LO_2 pump inlet temperature	-200 to -160 C
LO_2 flow rate to heat exchange, ac	33 gpm
Heat-exchange O_2 outlet temperature	0 to 300 C
High-pressure spheres temperature	-70 to +150 C
O_2 manifold temperature	-200 to +700 C
Pressurization Gas in fuel tank	0 to 30 psi
Pressurization Gas in LO_2 tank	0 to 100 psi
Pressurization Gas high-pressure spheres	0 to 3500 psi
Pressurization O_2 manifold	0 to 400 psi
Gas generator chamber temperature	0 to 1000 C
Pressurization gas in fuel tank	0 to 30 psi
Pressurization gas high-pressure spheres	0 to 3500 psi
Pressurization gas generator LO_2 injector	0 to 800 psia
Turbine rpm	0 to 7000 rpm

[redacted]

[redacted]

Table 4. Condensed S-I Measurement List (Cont)

Parameter	Range
LO_2 pump bearing temperature	-20 to +200 C
Intermediate shelf bearing temperature	0 to 150 C
High-speed bearings temperature	0 to 150 C
Turbine shaft bearings temperature	0 to 300 C
Turbine exhaust temperature	0 to 800 C
Gas generator chamber temperature	0 to 1000 C
Hydraulic oil temperature	-20 to +135 C
Engine compartment temperature	0 to 1000 C
Fire wall temperature	0 to 1500 C
Combustion chamber pressure	0 to 600 psia
Turbine inlet pressure	0 to 650 psia
Turbine exhaust pressure	0 to 40 psi
ΔP turbine outlet to aspirator inlet	0 to 20 psid
Gear case top pressure	0 to 30 psi
Gear case lubrication high pressure	0 to 800 psia
Pressure gear case lubrication low	0 to 200 psia
ΔP across aspirator	0 to 10 psid
Inside tail pressure	0 to 25 psia
Hydraulic source pressure	0 to 3500 psi
ΔP yaw actuator	±3000 psid
ΔP pitch actuator	±3000 psid
Hydraulic oil return pressure	0 to 100 psi
ΔP turbine outlet to exhaust nozzle	0 to 20 psid
Combustion chamber pressure	0 to 6 psia
Ignition monitor valve inlet pressure	0 to 1000 psia
Thrust chamber dome lateral vibration	±50 g
Turbine gear box vibration	±50 g
Thrust chamber dome, vibration Longitudinal	±50 g
Pitch actuator pitch vibration	±40 g
Yaw actuator yaw vibration	±40 g

[redacted]

[redacted]ENTIAL

Table 4. Condensed S-I Measurement List (Cont)

Parameter	Range
Gimbal point support vibration, longitudinal	+50 g
Propulsion unit distribution 9A1 vibration, longitudinal	±30 g
Thrust chamber dome lateral vibration	±50 g
Pitch actuator position	±10 deg
Actuator position	±10 deg
ΔI pitch actuator	±10 ma
ΔI yaw actuator	±10 ma
Level, hydraulic oil	0-3.75^2
LO_2 temperature, pump bearing No. 1	-20 to +200 C
Hydraulic oil temperature	-20 to +135 C
Gear case lubricant temperature	0-150 C
Turbine spinner case temperature	-50 to -100 C
Fire detection temperature	
Hydraulic source pressure	max 23 psi
Gas generator fuel injector pressure	0 to 800 psi
Combustion stability monitor vibration, longitudinal	±100 g

~~CONFIDENTIAL~~

[redacted]

Table 5. Condensed S-IV Measurements List

Parameter	Range
Prestart signal to sequencer	0 to 28 v dc
S-I separation signal	0 to 28 v dc
Engine start pressure switch pickup, Engine 1	0 to 28 v dc
Engine prestart pressure switch pickup, engine 1	0 to 28 v dc
Engine cut-off signal	0 to 28 v dc
S-IV engines start signal	0 to 28 v dc
Ullage rocket jettison current	
Ullage rocket pressure switch	0 to 28 v dc
Retrorocket pressure switch	0 to 28 v dc
Payload abort signal to sequencer	0 to 28 v dc
Engine russ enable signal	0 to 28 v dc
Control switching network start command	0 to 28 v dc
Ignite retrorockets signal	0 to 28 v dc
Blow S-I to S-IV explosive bolts command	0 to 28 v dc
Payload separation signal	0 to 28 v dc
Base calorimeter temperature, black	
Base calorimeter temperature, gold	
Base pressure	
Base temperature	
S-I to S-IV extensiometer	0 to 24 ft
Axial acceleration	-1 to +2 g
Detonation pressure switch	0 to 28 v dc
Vibration pickup, engine compartment pitch axis	0 to 1200 cps
Vibration pickup, engine compartment	0 to 660 cps
Vibration pickup, forward interstage, thrust axis	0 to 1200 cps
Vibration pickup, Forward Interstage, pitch axis	0 to 600 cps
Vibration (electronics package in engine compartment)	0 to 20 g rms
Vibration (oxidizer feed line)	0 to 20 g rms
Vibration (fuel feed line)	0 to 20 g rms
Vibration (turbopump)	0 to 20 g rms

~~CONFIDENTIAL~~

[redacted]

Table 5. Condensed S-IV Measurements List (Cont)

Parameter	Range
Vibration (aft skirt, radial direction)	0 to 20 g rms
Vibration (aft skirt, thrust axis)	0 to 20 g rms
Vibration (telemetry package)	0 to 20 g rms
Vibration (outer tank surface)	0 to 20 g rms
Static inverter inner temperature	0 to 160 F
Battery temperature	0 to 160 F
Reference voltage, high	+5 v dc
Reference voltage, low	0 v dc
Static inverter 115 v voltage	110 to 120 vac
Battery voltage	27 to 29 v dc
D-c converter negative 6-volt output	-5.5 to -6.5 v dc
D-c converter negative 12-volt output	-10 to -14 v dc
D-c converter positive 28-volt output	26 to 30 v dc
Range safety AGC voltage	
Telemetry antenna SWR	
EBW converter output voltage	
D-c power signal to interface	0 to 28 v dc
LH_2 Temperature, suction line inlet	
LO_2 Temperature, suction manifold	
Oxidizer tank ullage temperature, 85% level	-100 to -300 F
Fuel tank ullage temperature 85% level	-200 to -423 F
Temperature probe, LH_2 tank, 40% level	-323 to -423 F
Temperature probe, LH_2 tank, 5% level	-413 to 423 F
Temperature probe, LH_2 tank, 1% level	-413 to -423 F
Temperature probe, LO_2 tank, 40% level	-187 to -297 F
Temperature probe, LO_2 tank, 5% level	-287 to -297 F
Temperature probe, LO_2 tank, 1% level	-287 to -297 F
Fuel tank gas supply orifice differential pressure	0 to 500 psid
Fuel tank ullage pressure	0 to 40 psia
Oxidizer tank ullage pressure	0 to 50 psia
Fuel tank inner skin temperature	
Base thrust structure temperature	
Aft dome stress	
Side tunnel temperature (internal)	
Engine mount stress	

[redacted]

Table 5. Condensed S-IV Measurements List (Cont)

Parameter	Range
Thrust beam stress	
LH_2 tank mass, fine	0 to 5 v dc
LH_2 tank mass, coarse	0 to 5 v dc
LO_2 tank mass, fine	0 to 5 v dc
LO_2 tank mass, coarse	0 to 5 v dc
LH_2 tank vent valve closed	0 to 28 v dc
LO_2 tank vent valve closed	0 to 28 v dc
Fuel tank step pressure signal	0 to 28 v dc
LH_2 point level sensor	0 to 28 v dc
LO_2 point level sensor	0 to 28 v dc
Cold helium bottle gas temperature	-225 to -423 F
Cold helium outlet temperature	-200 to -400 F
Helium heater chamber pressure	0 to 20 psia
Cold helium bottle gas pressure	0 to 3500 psia
Cold helium orifice differential pressure	0 to 600 psid
Ambient helium bottle pressure	0 to 3500 psia
Ambient helium regulator outlet pressure	0 to 750 psia
Helium heater combustion temperature	0 to +1500 F
Outer surface temperature helium heater	
Ambient helium bottle gas temperature	-100 to +100 F
Helium heater oxidizer valve closed	0 to 28 v dc
Helium heater activate signal	0 to 28 v dc
Helium heater fuel valve open	0 to 28 v dc
Helium heater fuel valve closed	0 to 28 v dc
Helium heater oxidizer valve open	0 to 28 v dc
Helium heater ignition exciter command	0 to 28 v dc
Thrust chamber pressure	0 to 400 psia
Oxidizer pump speed	(0 to 60 cps)
Turbine inlet temperature	-100 to 250 F
Fuel pump inducer inlet temperature	-415 to -423 F
Oxidizer pump inlet temperature	-275 to -300 F
Fuel pump housing temperature	+110 to -423 F
Oxidizer pump housing temperature	+110 to -423 F
Thrust chamber pressure	325 to 375 psia
Thrust chamber pressure (low range)	0 to 50 psia

[redacted]

Table 5. Condensed S-IV Measurements List (Cont)

Parameter	Range
Fuel injector differential pressure	0 to 50 psid
Oxidizer injector differential pressure	0 to 80 psid
Venturi inlet pressure	-1200 psia
Turbine differential pressure	0 to 600 psid
Fuel pump outlet pressure	0 to 1500 psia
Oxidizer pump outlet pressure	0 to 600 psia
Oxidizer pump inlet pressure	0 to 50 psia
Fuel pump inducer inlet pressure	0 to 50 psia
Accumulator GN_2 pressure, engine yaw actuator	0 to 3400 psia
Accumulator GH_2 pressure, engine pitch actuator	0 to 3400 psia
Reservoir-oil pressure	0 to 300 psia
High-pressure oil, vehicle pump engine	0 to 3400 psia
Hydraulic pump inlet oil temperature-engine	-40 + 350 F
Yaw actuator reservoir surface temperature, engine	0 to 500 F
Pitch actuator reservoir surface temperature, engine	0 to 500 F
Engine pitch position	
Engine yaw position	
Engine position monitor reference voltage	+5 v dc
Engine position monitor reference voltage	-5 v dc
Propellant utilization ratio valve position	0 to 5 v dc
Propellant utilization error signal	
Propellant utilization start signal to sequencer	0 to 28 v dc
Propellant utilization depletion signal to sequencer	0 to 28 v dc
Hydraulic accumulators solenoid valve open command	0 to 28 v dc
Ignition exciter box output	0 to 6 v dc

[redacted]

[redacted]

Table 6. Condensed Instrument Unit Measurement List

Parameter	Range
Q Ball, Internal Temperature	0 to 150 C
Total temperature	0 to 800 C
Wall temperature, density gage	0 to 100 C
Air temperature, density gage	0 to 100 C
Gas nitrogen manifold temperature	-50 to +50 C
Azusa temperature, internal	10 to 65 C
Instrument compartment pressure	0 to 20 psia
Air bearing supply ST-90 pressure	0 to 60 psid
Control equipment pressure, supply	0 to 3500 psi
Control equipment pressure, regulator	0 to 800 psia
Dynamic pressure (Q)	5 to 750 PSF
Q ball, Differential pressure, pitch	±5 psi
Q ball, Differential pressure, yaw	±5 psi
Differential pressure, Q compensation	15 psi
Pressure instrument compartment	0 to 20 psia
ST-90, Y Axis Vibration	±3 g
Instrument Panel, Lateral Vibration	±5 g
Lower Support, Longitudinal Vibration	±20 g
Instrument Panel, Pitch Vibration	±3 g
Angular Velocity, Pitch	±10 deg/sec
Angular Velocity, Yaw	±10 deg/sec
Longitudinal acceleration	0 to 5 g
Longitudinal coarse acceleration	0 to 5 g
Longitudinal acceleration	±1 g
Pitch control acceleration	±5 m/sec sq
Yaw control acceleration	±5 m/sec sq
Pitch control angular velocity	±10 deg/sec
Yaw control angular velocity	±10 deg/sec
Roll control angular velocity	±10 deg/sec
Local angle-of-attack	±10 deg.

[redacted]

Table 6. Condensed Instrument Unit Measurement List (Cont)

Parameter	Range
Pitch angular velocity	±100 deg/sec
Yaw angular velocity	±100 deg/sec
Roll angular velocity	±100 deg/sec
Q ball, angle of attack, pitch	±15 deg
Q ball, angle of attack, yaw	±15 deg
Ram Air Density	10^{2} to 10^{-3} mb, in 5 range steps
Pitch position, ST-90 minus program	±15 deg
Yaw position, ST-90	±15 deg
Roll position, ST-90	±15 deg
Servo signal, cross range acceleration	±100 mv
Slant range acceleration, servo signal	±100 mv
Slant range, servo signal	±100 mv
Time base selector output	0 to 5 v
Time base selector zero indication	on-off
Instrument compartment temperature	0 to 60 C
Temperature Inlet Air For Air Bearing	20 to 30 C
Air-Bearing Supply Pressure	0 to 60 psid
Air-Bearing Supply Pressure ST-90	0 to 3500 psig
Control Equipment Pressure, Supply	0 to 3500 psig
Control equipment pressure regulator	0 to 800 psi

[redacted]

Second Stage (S-IV)

The telemetry of the S-IV stage uses three RF links. The links are three PDM/FM/FM sets. This telemetry system has 24 standard IRIG analog channels and 405 commutated channels. The only other RF link in the stage is the range safety command destruct link.

The frequencies are as follows:

Telemetry	251.5 mc 255.1 mc 258.5 mc
Command	(Classified Secret)

Instrument Unit

The telemetry in the instrument unit consists of three FM/FM sets and one PCM/FM/FM set. This telemetry system has 48 standard IRIG analog channels and a PCM bit rate of 36,000 per second. All of the RF links for tracking are carried in the instrument compartment.

The frequencies are as follows:

Telemetry	248.6 mc 252.4 mc 256.2 mc 1 unassigned
UDOP	900 mc and 450 mc
Azusa	500 mc
Radar altimeter	Unassigned
C-band radar	5555 mc
Development tracking	Unassigned

ABORT SENSING AND DESTRUCT SYSTEMS

ABORT SENSING SYSTEM

[redacted]

DESTRUCT SYSTEMS

INTERFACES

MECHANICAL

Propellant Systems

Hydraulic Systems

ELECTRICAL

Instrumentation System

Guidance and Control Systems

Electrical Power System

Abort Sensing and Destruct Systems

DESIGN CRITERIA

VEHICLE CONFIGURATION

The Saturn C-1 Apollo space vehicle consists of an S-I stage, and S-IV stage, an instrument unit, and a spacecraft (Figure 7).

The S-I stage has four LO_2 and four fuel containers mounted circumferentially around a center LO_2 container and is loaded with 850, 000 pounds of useable propellants. Fins are provided for flight stability and are located on the aft section of the stage (Figure 2).

The S-IV stage is a cylindrical configuration, 220 inches in diameter and is loaded with 100, 000 pounds of useable propellants. Exclusive of engines, the S-IV stage basically consists of four major units: the propellant containers, the forward interstage structure, the aft interstage structure, and the heat shield (Figure 3).

[redacted]

~~CONFIDENTIAL~~

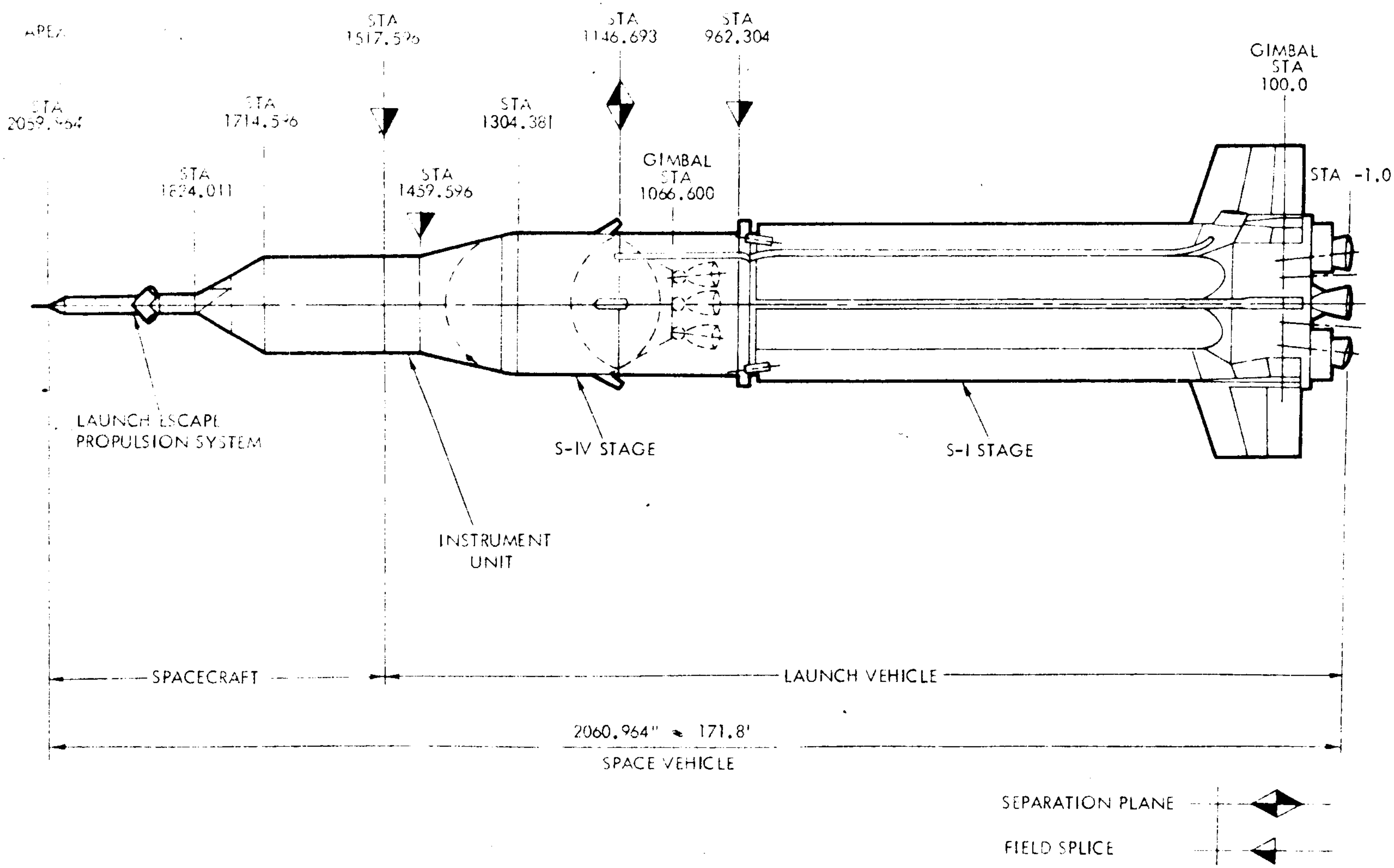


Figure 7. Saturn C-1 and Apollo Spacecraft Configuration (Orbital Payload Version)

~~CONFIDENTIAL~~

The instrument unit is located on top of the S-IV stage and houses the active and passenger guidance systems and instrumentation, power supplies, antennas, and an X-shaped pressurized cylindrical section (Figure 4).

The spacecraft consists of a command module, service module, adapter, and a launch escape system.

MASS CHARACTERISTICS

Preliminary mass characteristics and weight breakdown of the Saturn C-1 Apollo space vehicle for a 100-nautical-mile orbit are shown in Tables 7, 8, and 9. Mass moments of inertia, center of gravity shift, and decrease in weight versus burning time are shown in Figures 8 through 11.

DESIGN TRAJECTORIES

Design trajectories of the Saturn C-1 Apollo space vehicles for a 100-nautical-mile orbit are shown in Tables 10 through 13. Trajectories are for both 7-engine and 8-engine control of the S-I stage.

ENVIRONMENTAL CONDITIONS

The following natural and induced environments are those experienced by the Saturn C-1 vehicles during the manufacture, storage, test, transportation, launch, and flight phases.

Ground Wind Criteria

Vehicle Free Standing on Launcher

While free standing on the launcher at Cape Canaveral, Florida, the Saturn C-1 vehicle, empty or fueled, will be designed to be structurally capable of withstanding the conditions stated in Table 14.

Vehicle Secured on Launcher

During periods when ground wind speeds are expected to exceed the conditions stated in Table 14, the vehicle must be secured to prevent excess loading. The vehicle may be secured by placing it in a shelter or by tying it to the service structure with the propellant tanks pressurized.

Vehicle During Launch

The peak wind speeds to be considered for a Saturn C-1 vehicle 95-percent launch capability are stated in Table 15.

[redacted]

Table 7. Preliminary Mass Characteristics During First-Stage Burning (100-Nautical-Mile Orbit)

Item	Weight (lb)	Vehicle Center of Gravity (in.)	Moment of Inertia (Kg-M-Sec^2) Roll	Pitch
Total dry first stage	94, 000	375	30, 150	312, 700
First interstage	1, 879	1060		
First stage retro-rocket cases and mounts	1, 660	922		
Residuals	17, 423	286		
First stage after retrorocket burnout	114, 962	380	34, 677	379, 719
First-stage retro-rocket propellant	1, 340	922		
First stage at first separation command	116, 302	387	35, 320	391, 656
Apollo launch escape propulsion system	3, 700	1880		
Vehicle at second-stage ignition	135, 018	1242		
Vehicle at end of first-stage thrust decay	255, 020	861	39, 549	2, 018, 783
First-stage main propellants (including reserve and thrust decay)	854, 369	550		
Second-stage Chill-down and vented gases	376	1275		
Vehicle at first-stage lift-off	1, 109, 765	622	206, 770	3, 441, 964
First-stage transition propellants	18, 381	852		
Vehicle at first-stage ignition	1, 128, 146	625	210, 468	3, 474, 056

~~CONFIDENTIAL~~

[redacted]

Table 8. Preliminary Mass Characteristics During Second-Stage Burning (100-Nautical-Mile Orbit)

Item	Weight (lb)	Vehicle Center of Gravity (in.)	Moment of Inertia ($Kg-M-Sec^2$)	
			Roll	Pitch
Total dry second stage	11,700	219	2,268	6,554
Residuals	494	192		
Reserve propellants	500	157		
Second stage at second separation command	12,694	216	2,281	6,800
Vehicle instrument unit assembly	4,405	516		
Apollo orbital payload	17,300	697		
Vehicle at end of second stage thrust decay	34,399	496	3,955	61,837
Second-stage main propellants (including thrust decay and helium heater propellants)	100,090	199		
Second-stage vehicle at lift-off**	134,489	275	3,971	137,891
Second-stage weight loss between first-stage separation and second-stage start	529	216		
Vehicle at second-stage ignition	135,018	275	4,106	137,923

**Lift-off = The time at which main stage reaches 90-percent thrust.

[redacted]

Table 9. Instrument Unit Assembly Weight Breakdown
(100-Nautical-Mile Orbit)

Item	Weight (lb)		Vehicle Center of Gravity (in.)*
Structure		1700	1486
Instrument panels		119	1477
Guidance and control system		1049	1482
ST-90-S (including rack)	480		
ST-124 (including rack)	125		
Servo amplifiers	70		
Test adapter	13		
Flight control computer	50		
Program device	32		
Time base selector	5		
Guidance signal processors	80		
Platform distributor	20		
Guidance computers	174		
Electrical power supply system		220	1480
1000 VA inverters	60		
Control voltage supply	10		
Batteries	150		
Electrical network system		360	1483
Wiring (including clamps)	300		
Power distributor	38		
Flight sequencer	2		
Control distributor	20		
Measuring network system		80	1476
Measuring racks	60		
Measuring distributors	20		
Telemetry system		293	1486
PCM telemeters	59		
Telemeter subcarriers	58		
Telemeters (X 04)	58		
P-F amplifiers	28		
Telemeter power divider	1		
Telemeter multicoupler	3		

[redacted]

Table 9. Instrument Unit Assembly Weight Breakdown
(100-Nautical-Mile Orbit) (Cont)

Item	Weight (lb)		Vehicle Center of Gravity (in.)*
Telemetry system (Cont)			
Telemeter for PCM (X 07)	30		
Telemeter auxiliary equipment	16		
Telemeter antennas	40		
Range safety and tracking		230	1481
Azusa transponder	42		
Azusa antenna	2		
Horizon sensor	60		
Horizon sensor power supply	20		
C-band radar	11		
C-band radar antenna	2		
Radar altimeter	16		
Radar altimeter antenna	8		
UDOP transponder	24		
UDOP antennas	15		
Power dividers	1		
Mistram transponder	17		
Mistram antenna	2		
Command antenna	10		
In-flight cooling system		180	1483
LN_2 cooler (wet)	130		
Ducting and valve	50		
Air bearing system (2 spheres)		94	1453
Insulation		40	1488
Abort distributor		20	1449
Attaching hardware		20	1472
Total instrument unit		4405	1483

*During first-stage burning

~~CONFIDENTIAL~~

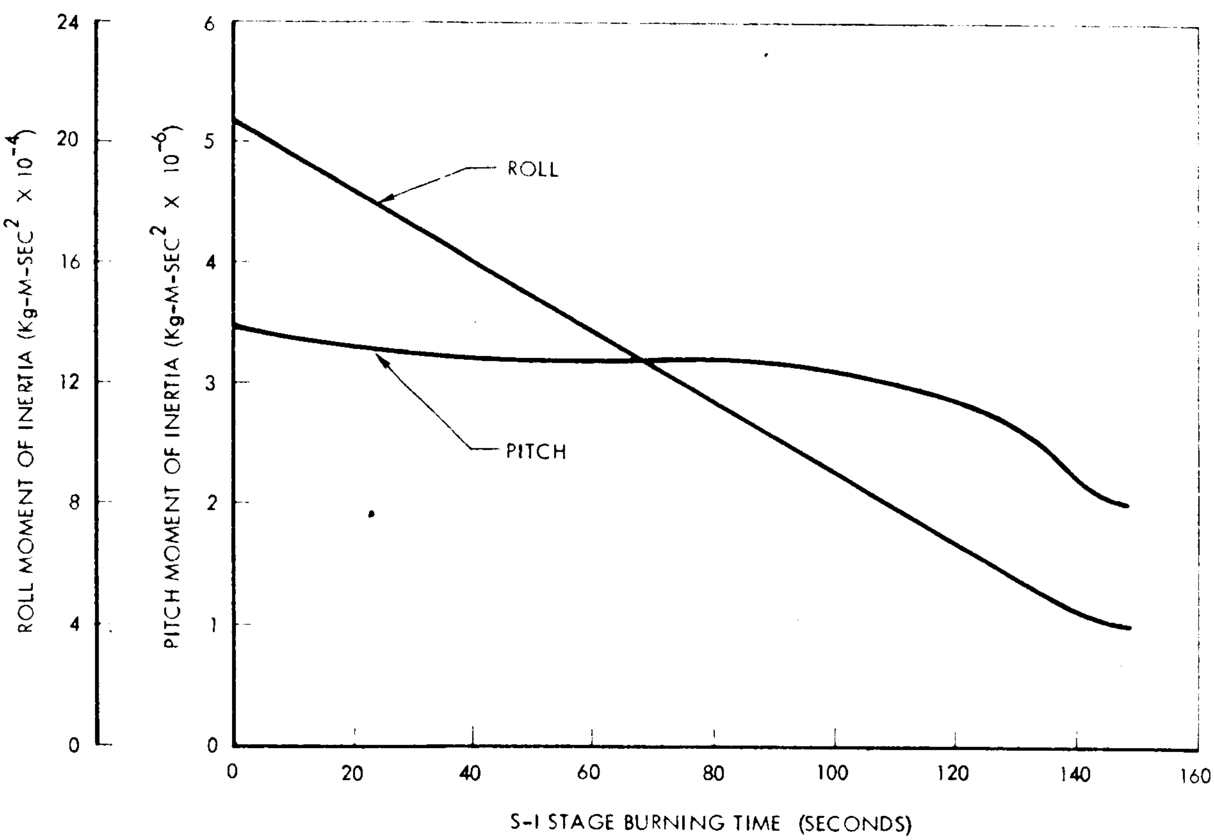


Figure 8. Mass Moment of Inertia During First-Stage Burning (100-Nautical-Mile Orbit)

[redacted]

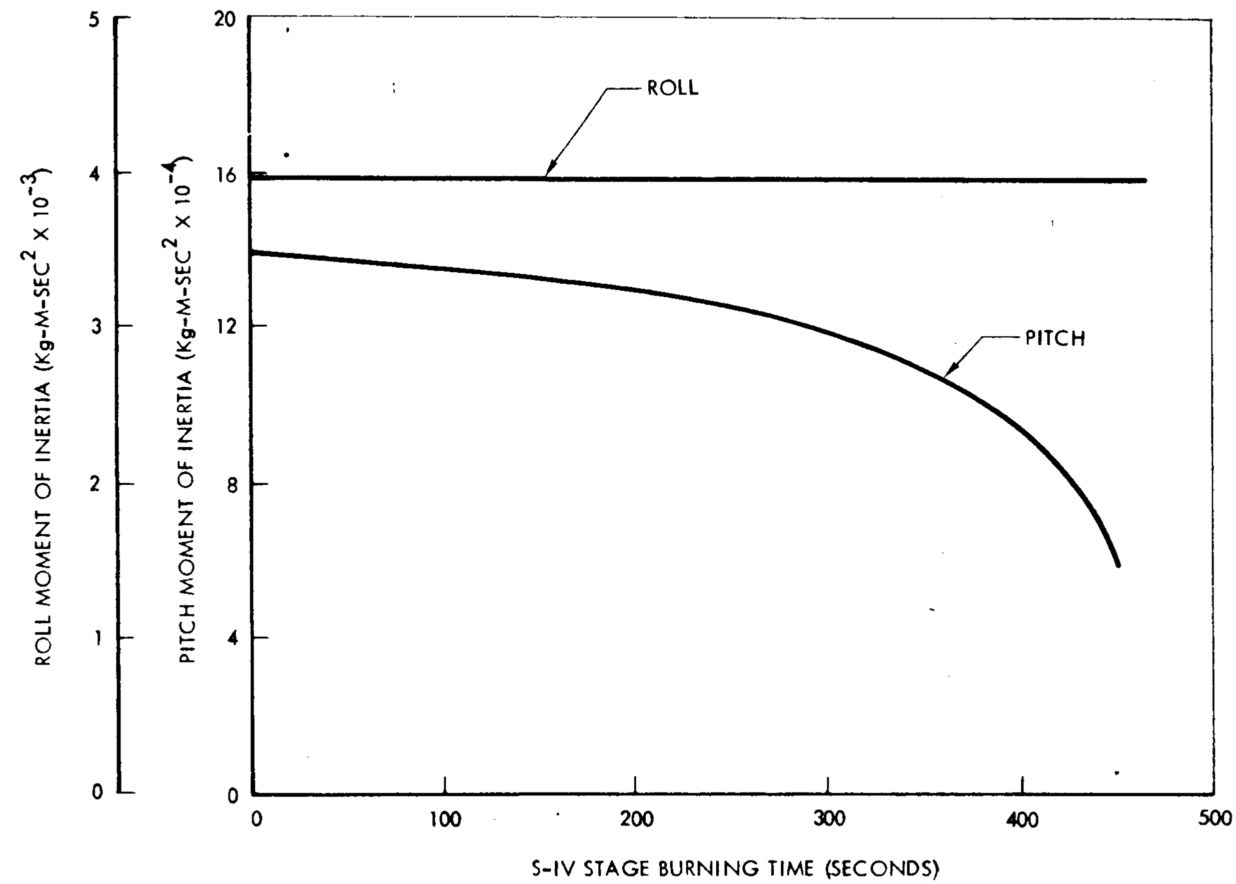


Figure 9. Mass Moment of Inertia During Second-Stage Burning (100-Nautical-Mile Orbit)

[redacted]

[redacted]

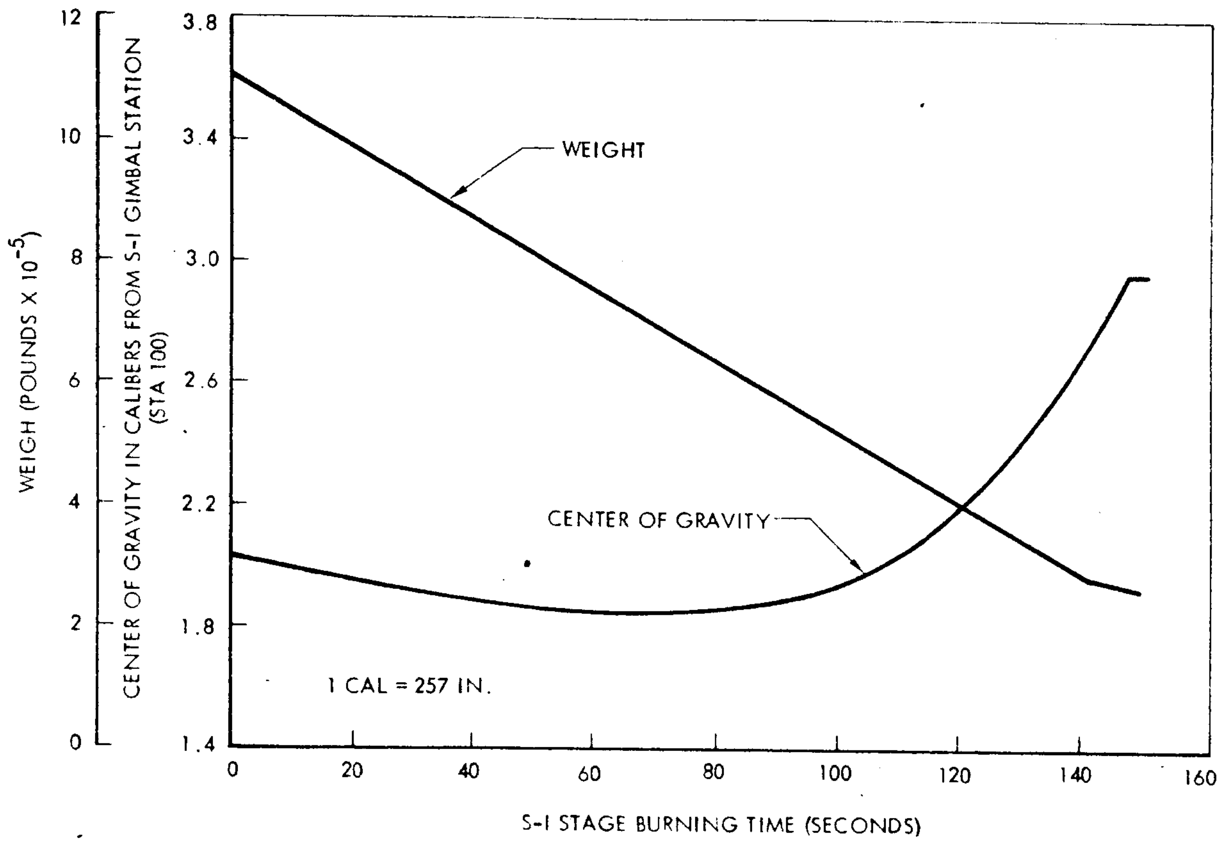


Figure 10. Vehicle Weight and Center of Gravity During First-Stage Burning (100-Nautical-Mile Orbit)

[redacted]

[redacted]

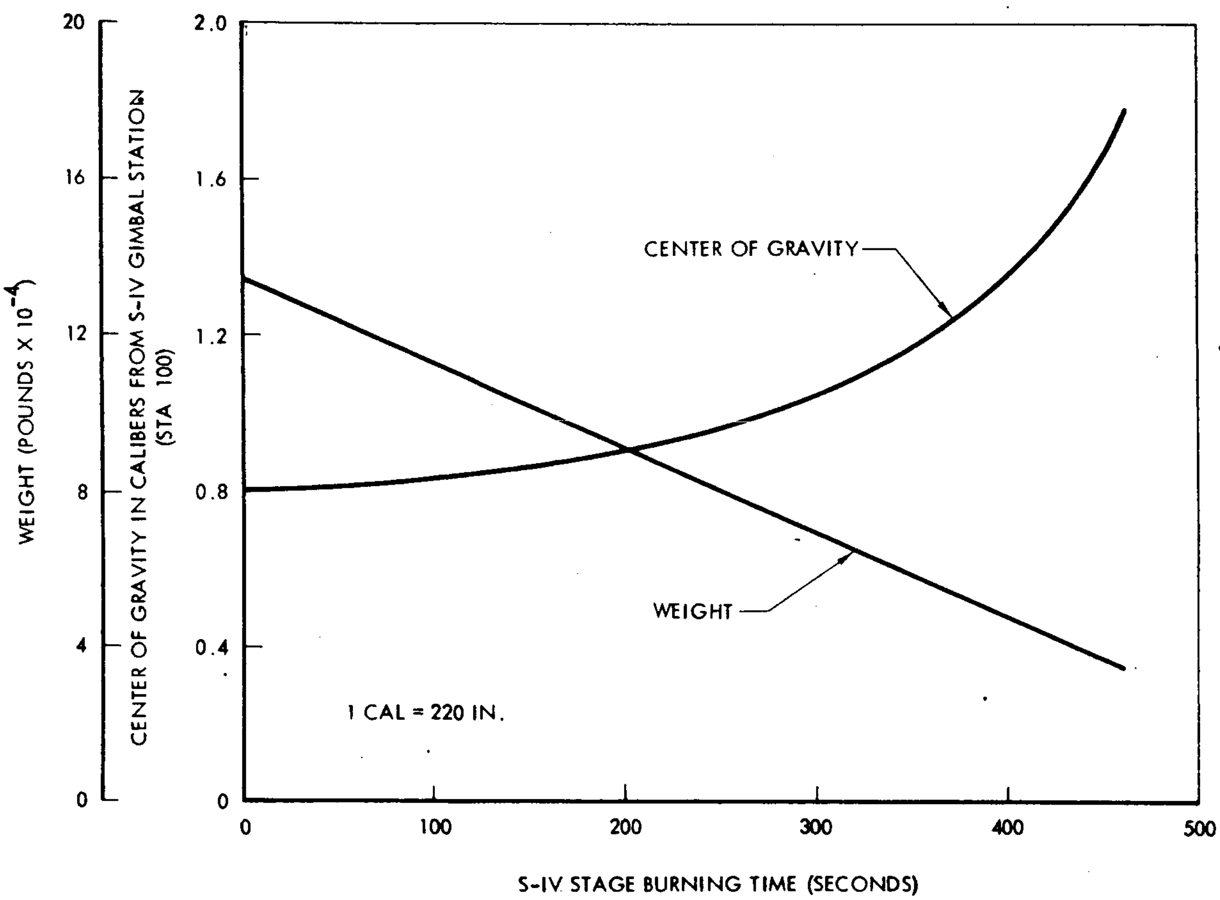


Figure 11. Vehicle Weight and Center of Gravity During Second-Stage Burning (100-Nautical-Mile Orbit)

[redacted]

Table 10. First-Stage Flight Design Trajectory, 8-Engine (100-Nautical-Mile Orbit)

Time (sec)	Path Angle (deg)	Altitude (ft)	Range (naut mi)	Velocity (ft/sec)	Longitudinal Inertial Acceleration (g)	Dynamic Pressure (lb/sq ft)	Tilt Angle (deg)	Weight (lb)	Thrust (lb)	Drag (lb)	Mach No.
0	0	0	0	0	1.36	0	0	1,105,425	1,498,850	0	0
10	0	656	0	131	1.43	19.7	0.1	1,045,090	1,503,244	6,808	0.1
20	3.0	2,625	0	279	1.52	85.6	3.6	987,690	1,516,207	15,333	0.3
30	8.7	6,234	0.1	466	1.63	213.2	9.4	928,830	1,538,363	22,765	0.4
40	16.2	11,811	0.3	696	1.75	400.2	16.9	869,970	1,567,861	43,133	0.7
50	23.8	19,685	0.8	971	1.82	605.4	23.8	811,100	1,600,864	126,422	0.9
60	31.4	29,527	1.6	1,283	1.92	742.0	31.4	752,230	1,631,993	193,932	1.3
*66	35.8	36,417	2.4	1,503	2.05	783.2	35.8	716,920	1,647,933	176,099	1.6
70	38.6	41,667	3.0	1,673	2.17	761.6	38.6	693,370	1,656,928	152,172	1.7
80	45.0	55,774	5.1	2,132	2.49	655.8	45.0	634,510	1,673,176	98,110	2.3
90	50.4	72,506	8.1	2,822	2.82	493.6	50.5	575,640	1,682,325	54,827	2.9
100	54.9	91,863	12.3	3,599	3.21	309.7	55.1	516,780	1,686,822	26,943	3.6
110	58.6	113,845	17.9	4,523	3.66	170.6	58.9	457,910	1,688,696	12,123	4.4
120	61.6	139,107	25.0	5,633	4.22	88.1	62.0	399,050	1,689,402	5,172	5.2
130	64.0	167,650	34.2	6,959	4.97	44.4	64.6	340,180	1,689,688	2,081	6.3
140.5	66.0	202,427	46.3	8,678	6.08	21.3	66.7	278,180	1,689,799	763	8.4
146.5	67.0	223,753	54.3	9,206	3.24	10.6	66.7	260,520	844,899	390	9.5

*Max q

S-I main-stage propellants, 850,000 lb
S-I thrust, 8 x 188 K lb
S-I F/dm/dt, 255.5 sec (S. L.)

S-IV main-stage propellants, 100,000 lb
S-IV thrust, 6 x 15 K lb
S-IV I_{sp}, 420 sec (vac)

[redacted]

[redacted]

Table 11. Second-Stage Flight Design Trajectory, 8-Engine S-I Flight (100-Nautical-Mile Orbit)

Time (sec)	Path Angle (deg)	Altitude (ft)	Range (naut mi)	Velocity (ft/sec)	Longitudinal Inertial Acceleration (g)	Dynamic Pressure (lb/sq ft)	Tilt Angle (deg)	Weight (lb)	Thrust (lb)	Drag (lb)	Mach No.
146.5	69.9	228,753	54.3	10,470	0.64	NA*	62.4	139,850	89,876	NA*	NA*
176.5	73.3	324,146	103.4	10,801	0.67		64.7	133,420	89,876		
206.5	76.5	409,776	154.9	11,211	0.70		67.0	126,990	89,876		
236.5	79.3	481,298	209.0	11,702	0.74		69.3	120,560	89,876		
266.5	81.9	539,697	265.9	12,270	0.78		71.7	114,140	89,876		
296.5	84.1	585,628	325.9	12,913	0.84		74.0	107,710	89,876		
326.5	86.0	620,077	389.3	13,635	0.89		76.4	101,280	89,876		
356.5	87.6	643,371	456.3	14,432	0.95		78.8	94,850	89,876		
386.5	88.8	657,150	527.4	15,315	1.02		81.3	88,420	89,876		
416.5	89.8	662,400	602.9	16,283	1.10		83.8	81,990	89,876		
447.1	90.6	660,103	684.8	17,365	1.19		86.4	75,450	89,876		
477.1	91.0	652,557	770.6	18,540	1.30		88.9	69,020	89,876		
507.1	91.2	640,746	862.4	19,836	1.44		91.6	62,590	89,876		
537.1	91.2	627,623	960.8	21,276	1.60		94.2	56,160	89,876		
567.1	90.9	615,484	1066.5	22,897	1.80		96.9	49,730	89,876		
597.1	90.3	607,938	1180.6	24,741	2.08		99.7	43,300	89,876		
609.2	90.0	607,282	1229.5	25,568	2.21		100.8	40,700	89,876		

*NA = Not applicable

S-IV main-stage propellant, 100,000 lb
S-IV thrust, 6 x 15 K lb
S-IV I_{sp}, 420 sec (vac)

S-I main-stage propellants, 850,000 lb
S-I thrust, 8 x 188 K lb
S-I F/dm/dt, 255.5 sec (S.L.)

~~CONFIDENTIAL~~

[redacted]

Table 12. · First-Stage Flight Design Trajectory, 7-Engine (100-Nautical-Mile Orbit)

Time (sec)	Path Angle (deg)	Altitude (ft)	Range (naut mi)	Velocity (ft/sec)	Longitudinal Inertial Acceleration (g)	Dynamic Pressure (lb/sq ft)	Tilt Angle (deg)	Weight (lb)	Thrust (lb)	Drag (lb)	Mach No.
0	0	0	0	0	1.19	0	0	1,102,625	1,311,882	0	0
10	0	328	0	72	1.25	6.1	0	1,049,830	1,313,999	2,317	0
20	0.4	1,312	0	161	1.32	29.3	0.5	921,750	1,320,569	9,180	0.1
30	2.1	3,609	0	272	1.39	79.7	2.2	948,100	1,332,584	13,964	0.2
40	5.6	6,890	0	413	1.49	165.3	5.6	896,600	1,350,111	19,312	0.4
50	10.8	11,811	0.2	591	1.59	287.5	10.8	845,090	1,372,509	29,714	0.6
60	17.1	18,701	0.4	807	1.69	430.9	17.1	793,580	1,397,863	56,866	0.8
70	24.0	27,231	1.0	1,056	1.72	546.0	24.0	742,080	1,423,084	145,902	1.0
*78	29.7	35,761	1.7	1,286	1.84	592.7	29.7	700,870	1,440,875	153,336	1.3
80	31.1	38,058	1.9	1,348	1.88	589.0	31.1	690,570	1,444,755	148,369	1.4
90	37.9	50,525	3.3	1,729	2.12	529.6	37.9	639,060	1,460,231	102,400	1.8
100	44.0	65,289	5.4	2,215	2.40	428.9	44.1	587,560	1,469,733	63,105	2.3
110	49.3	82,349	8.4	2,812	2.69	305.2	49.4	536,050	1,474,892	34,039	2.9
120	53.8	102,034	12.5	3,530	3.02	181.5	54.0	484,540	1,477,317	16,480	3.5
130	57.5	124,344	17.8	4,380	3.40	101.0	57.8	433,040	1,478,331	7,491	4.2
140	60.6	149,278	24.7	5,384	3.86	53.5	61.0	381,530	1,478,728	3,366	4.9
150	63.2	177,165	33.2	6,571	4.48	28.5	63.7	330,020	1,478,905	1,422	6.0
160.6	65.4	210,629	44.6	8,097	5.37	13.5	65.9	275,380	1,478,971	496	8.0
166.6	66.4	230,971	52.0	8,478	2.42	6.6	65.9	262,130	634,071	236	8.9

*Max (q)

S-I main-stage propellants, 850,000 lb
S-I thrust, 7 x 188 K lb
S-I F/dm/dt, 255.5 sec (S.L.)

S-IV main-stage propellants, 100,000 lb
S-IV thrust, 6 x 15 K lb
S-IV I_{sp}, 420 sec (vac)

[redacted]

[redacted]

Table 13. Second-Stage Flight Design Trajectory, 7-Engine S-I Flight (100-Nautical-Mile Orbit)

Time (sec)	Path Angle (deg)	Altitude (ft)	Range (naut mi)	Velocity (ft/sec)	Longitudinal Inertial Acceleration (g)	Dynamic Pressure (lb/sq ft)	Tilt Angle (deg)	Weight (lb)	Thrust (lb)	Drag (lb)	Mach No.
166.6	69.6	230,971	52.0	9,734	0.65	NA*	57.5	137,050	89,876	NA*	NA*
196.6	73.1	325,787	97.7	10,066	0.69		59.9	130,620	89,876		
226.6	76.3	406,823	145.6	10,476	0.72		62.4	124,190	89,876		
256.6	79.2	475,065	196.2	10,965	0.76		64.9	117,760	89,876		
286.6	81.7	530,839	249.6	11,532	0.81		67.4	111,340	89,876		
316.6	83.9	574,802	306.2	12,178	0.86		70.1	104,910	89,876		
346.6	85.8	608,266	366.1	12,904	0.92		72.8	98,480	89,876		
376.6	87.4	631,888	429.7	13,711	0.98		75.5	92,050	89,876		
406.6	88.7	646,324	497.4	14,606	1.05		78.3	85,620	89,876		
436.6	89.6	652,886	569.6	15,594	1.13		81.2	79,190	89,876		
465.1	90.3	652,886	642.8	16,627	1.23		84.1	73,090	89,876		
495.1	90.8	647,308	725.2	17,828	1.35		87.1	66,660	89,876		
525.1	91.1	638,122	813.6	19,167	1.49		90.3	60,230	89,876		
555.1	91.1	626,967	908.9	20,663	1.67		93.5	53,800	89,876		
585.1	90.8	616,140	1011.9	22,359	1.90		96.7	47,370	89,876		
615.1	90.4	608,595	1123.6	24,308	2.19		100.1	40,940	89,876		
632.3	90.0	606,954	1192.0	25,568	2.42		102.0	37,270	89,876		

*NA = Not applicable

S-IV main-stage propellants, 100,000 lb
S-IV thrust, 6 x 15 K lb
S-IV I_{sp}, 420 sec (vac)

S-I main-stage propellant, 850,000
S-I thrust, 7 x 188 K lb
S-I F/dm/dt, 255.5 sec (S.L.)

CONFIDENTIAL

Table 14. Ground Wind Gradient During Free Standing*

Height Above Ground Level		Steady-State Wind**		Peak Wind***	
(meters)	(ft)	(m/sec)	(knots)	(m/sec)	(knots)
3.0	10	11.8	23.0	16.6	32.2
9.1	30	14.8	28.8	20.7	40.3
18.3	60	17.3	33.6	24.2	47.0
30.5	100	19.3	37.5	27.0	52.5
61.0	200	21.9	42.6	30.7	59.6
91.4	300	23.7	46.0	33.2	64.4
121.9	400	24.9	48.3	34.8	67.6

*99.9-percent probability of occurrence during the strongest wind month at Cap Canaveral, Florida.

**Steady-State Wind: Average wind speed over a period of one (1) minute.

***Peak Wind: Based on a gust factor of 1.4 applied to a steady-state wind magnitude.

Winds at Altitude

Wind speed profile, wind shear, and wind speed change data for 95 percent probability of occurrence conditions are presented in Figures 12 through 16.

Induced Environments

The following induced environmental criteria are preliminary but represent the latest available information.

The vehicle has been assigned an arbitrary zone breakdown, and the detailed environmental data corresponding to these specific zones are listed in Figure 17.

Vibration, Shock, and Acoustic Criteria

The vibration criteria levels given in Figure 17 are the input levels specified for a 10-minute logarithmic sweep of the frequency range of

[redacted]

Table 15. Ground Wind Gradient During Launch*

Height Above Ground Level		Steady-State Wind**		Peak Wind***	
(meters)	(ft)	(m/sec)	(knots)	(m/sec)	(knots)
3.0	10	7.2	14.0	10.1	19.6
9.1	30	9.0	17.5	12.6	24.5
18.3	60	10.8	21.0	15.1	29.4
30.5	100	11.6	22.5	16.2	31.5
61.0	200	13.3	25.9	18.7	36.3
91.4	300	14.4	28.0	20.2	39.2
121.9	400	15.1	29.4	21.2	41.2

*95-percent probability of occurrence during the strongest wind month at Cape Canaveral, Florida.

**Steady-State Wind: Average wind speed over a period of one (1) minute.

***Peak Wind: Based on a gust factor of 1.4 applied to a steady-state wind magnitude.

interest (thereby simulating the transient conditions of launch and flight). These levels are to be divided by two to obtain the levels for a 5-minute dwell at the major resonances of the hardware under investigation (thereby simulating the steady-state or "mainstage" portion of flight).

The shock criteria levels given in Figure 17 are input levels of a half-sine shock pulse of 8 milliseconds duration.

The acoustic criteria given in Figures 18 through 21 represent the launch condition external sound pressure level spectrum for various stations throughout the complete Saturn C-1 vehicle. The maximum broad band (0.10 kc) overall sound pressure levels (SPL) are also shown in these illustrations.

Acoustic Environments

During the launch and flight phases of the Saturn vehicle, the following environments are induced for launch complex 37.

~~CONFIDENTIAL~~

[redacted]

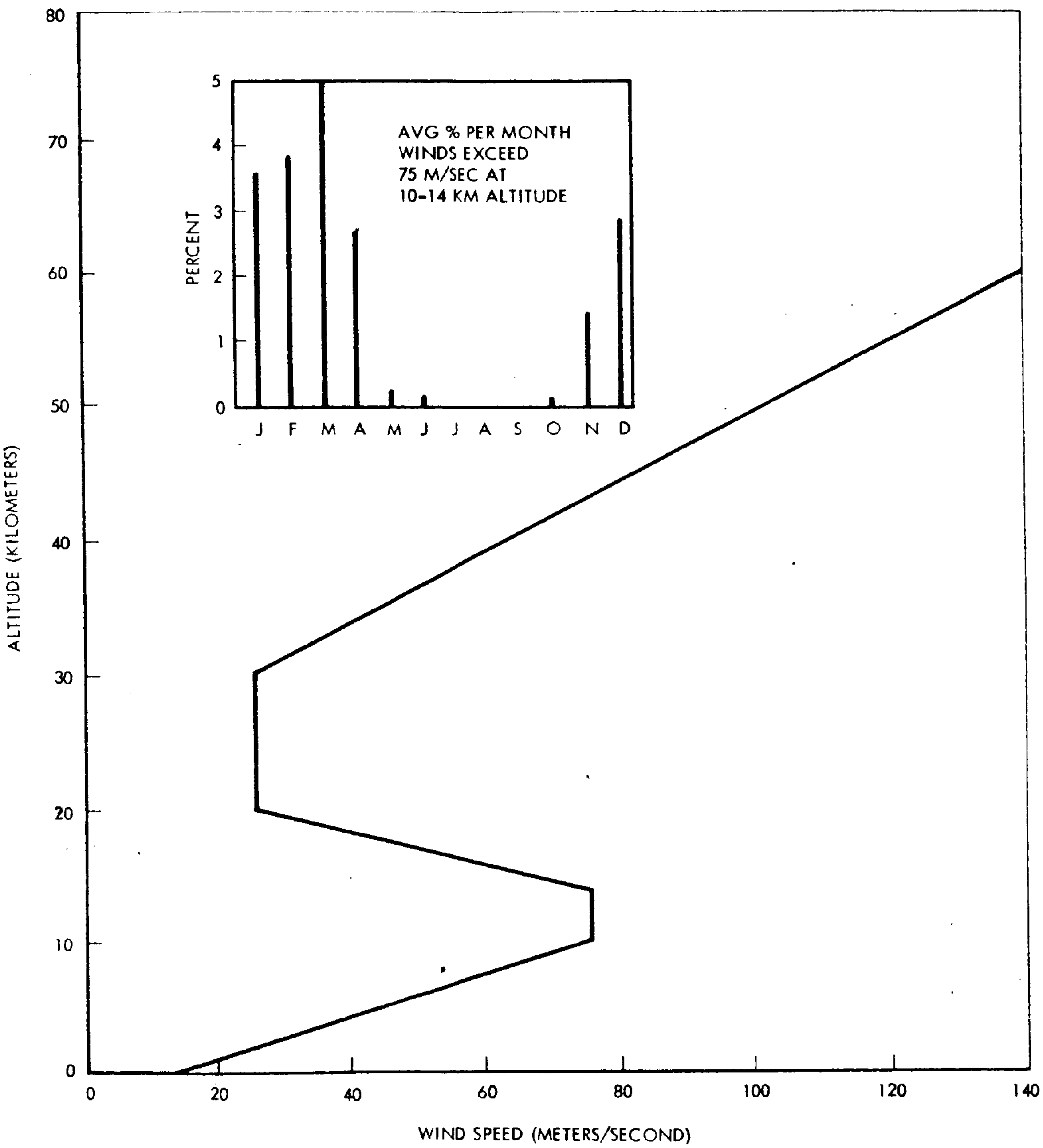


Figure 12. Two Sigma (95-Percent Probability Level) Wind Profile Envelope

~~CONFIDENTIAL~~

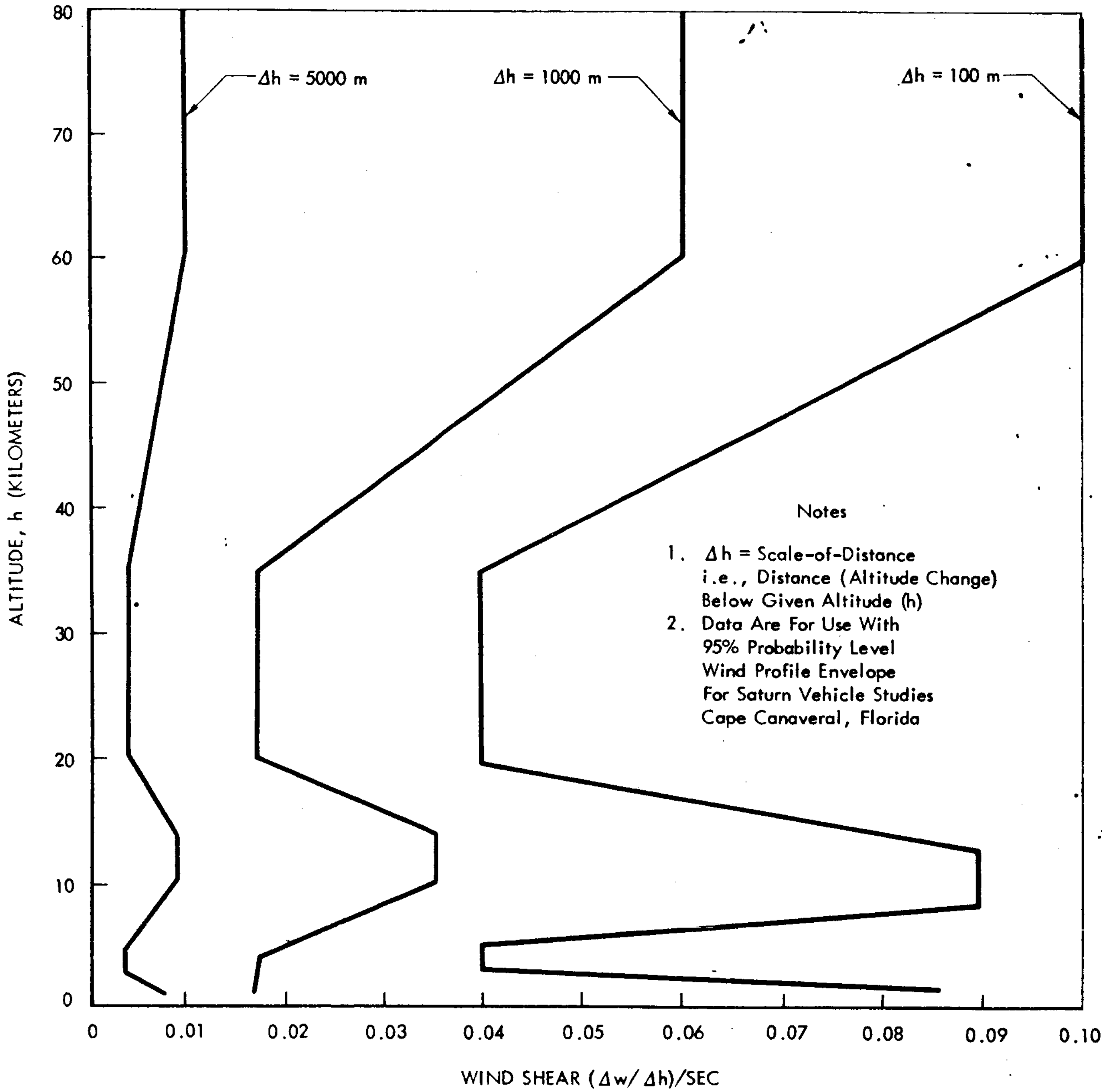


Figure 13. Vertical Wind Shear Spectrum as Function of Altitude

~~CONFIDENTIAL~~

[redacted]

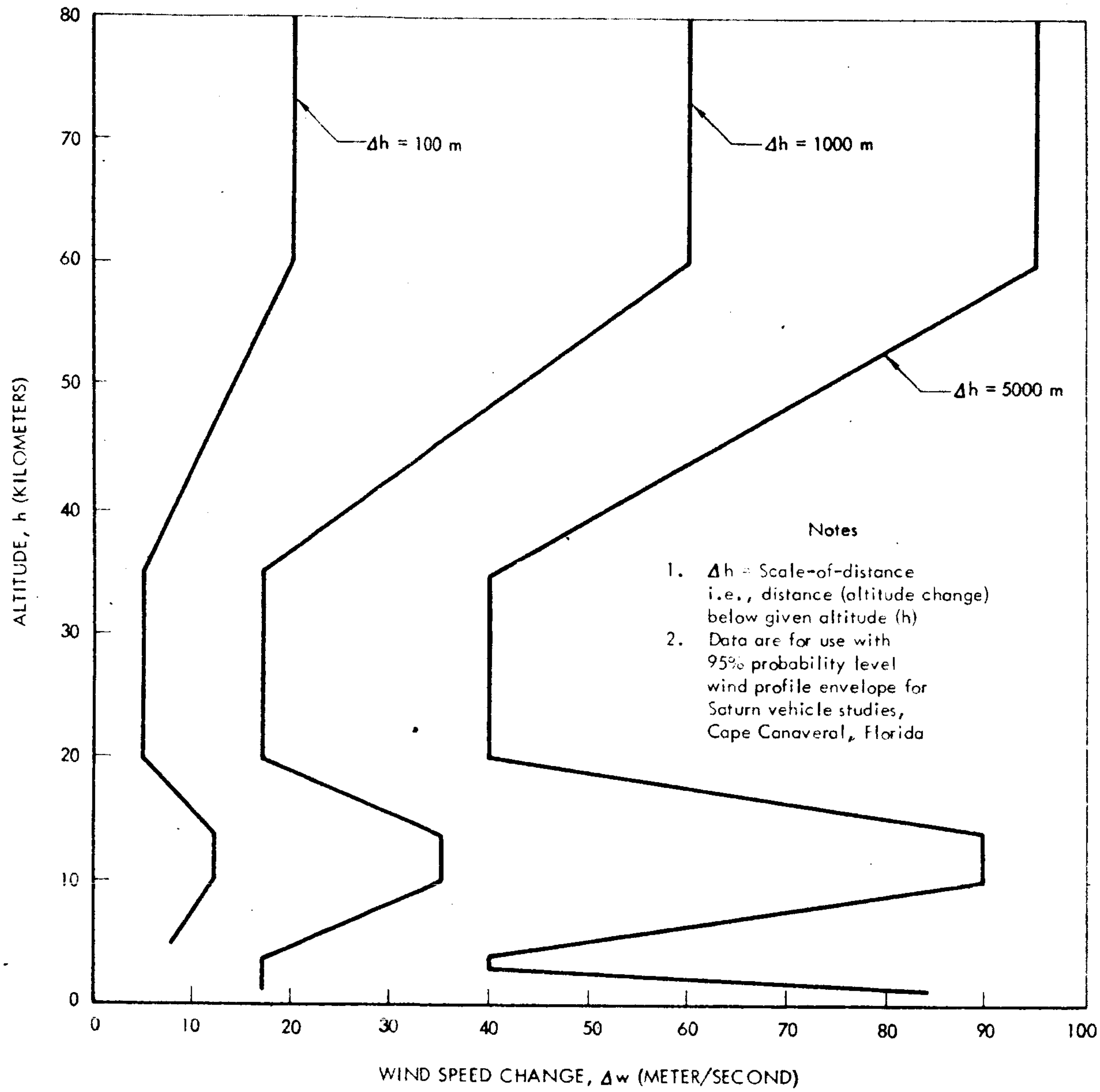


Figure 14. Vertical Wind Speed Change Spectrum as Function of Altitude

[redacted]

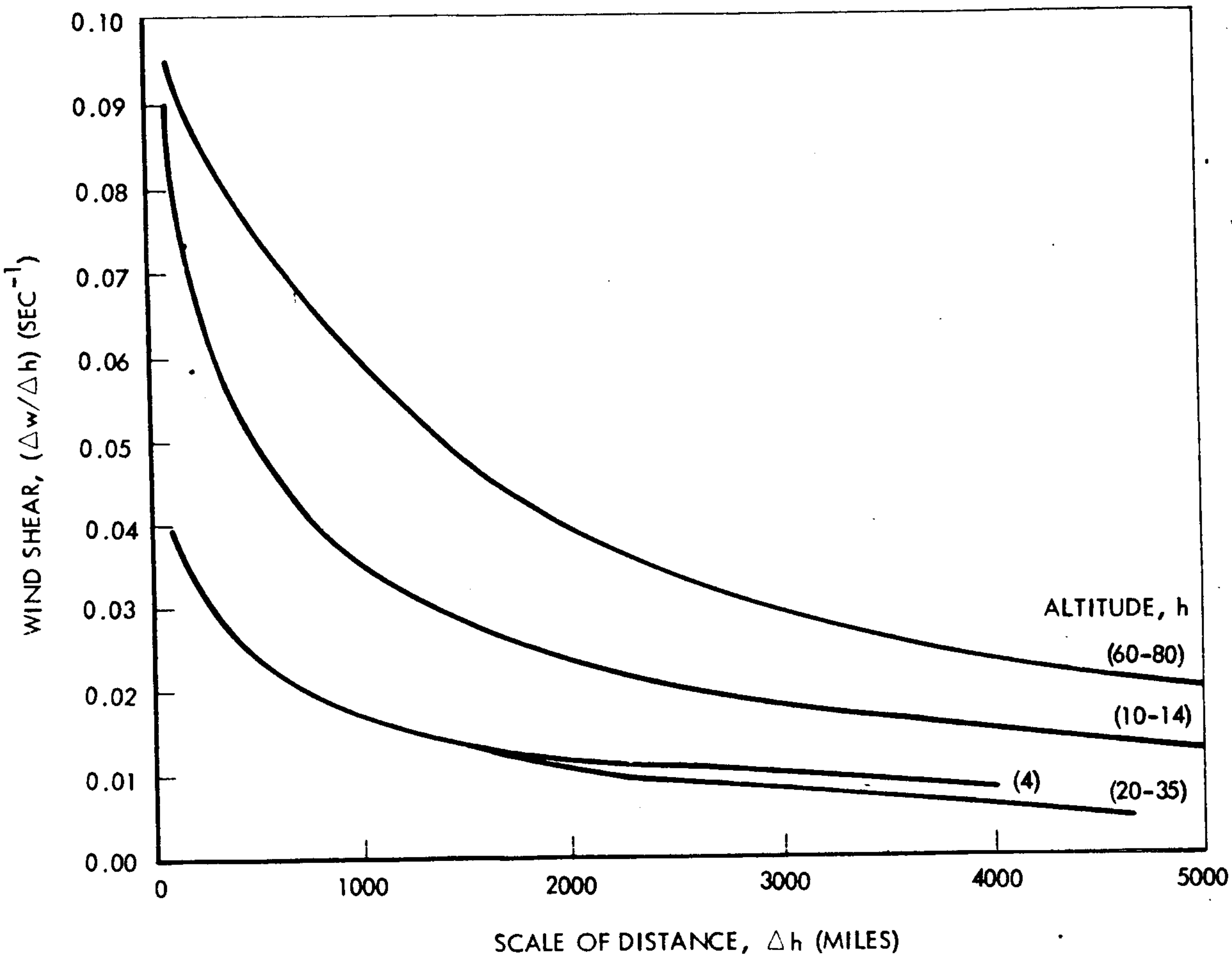


Figure 15. Selected Vertical Shear Spectrums (Cape Canaveral, Florida)

[redacted]

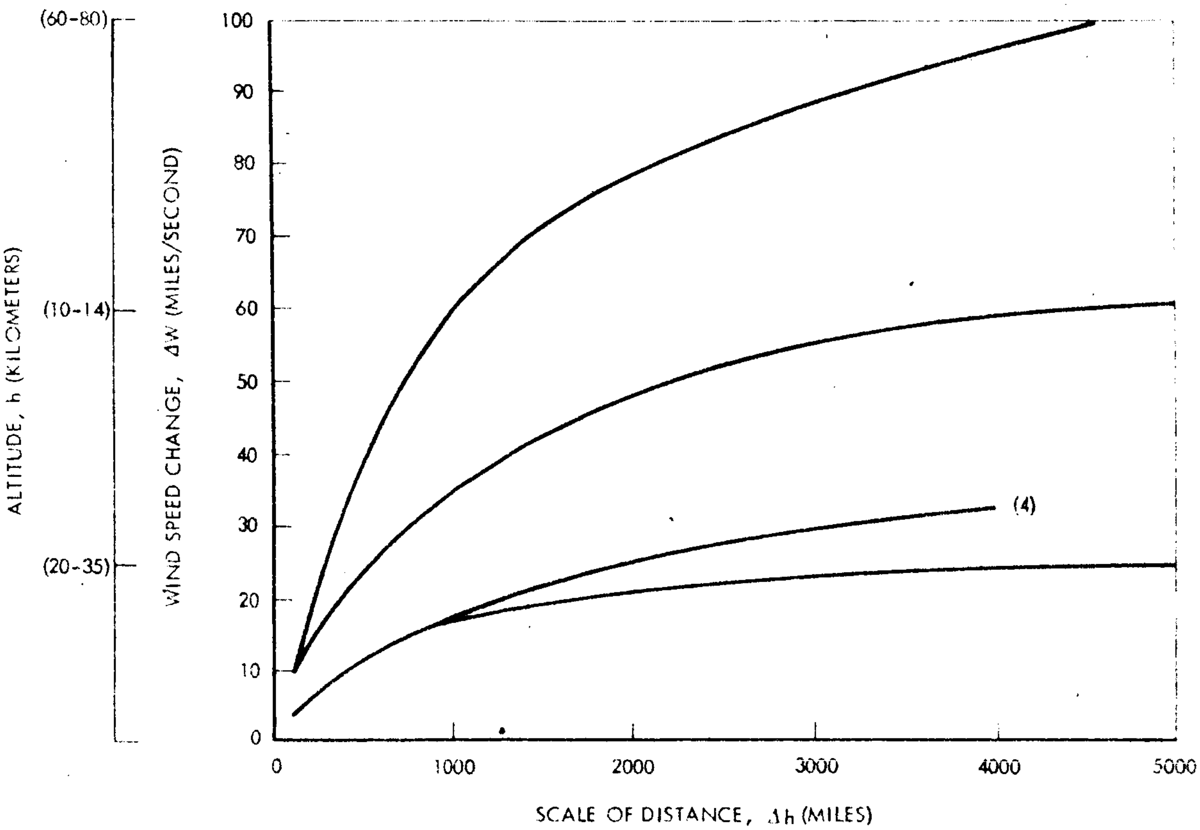
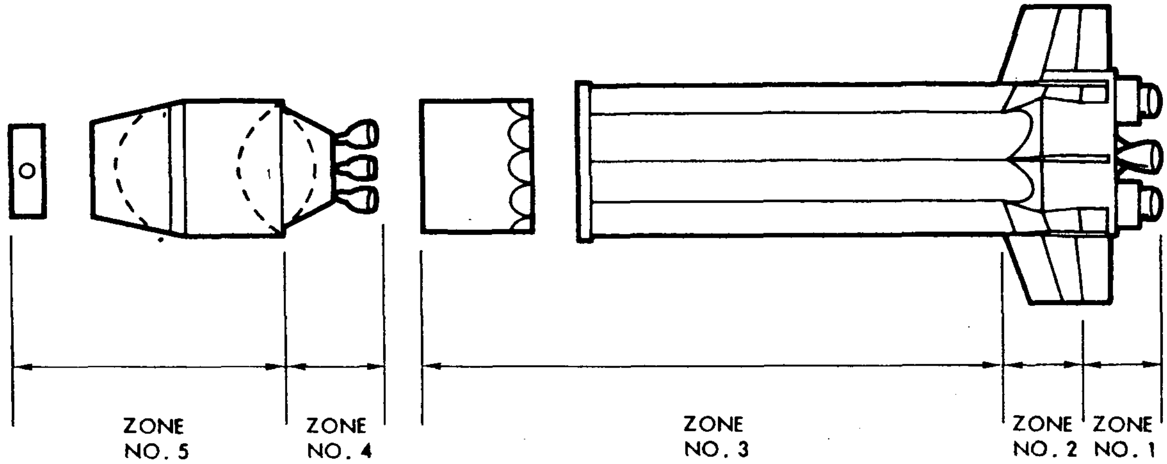


Figure 16. Selected Vertical Wind Speed Change Spectrums
(Cape Canaveral, Florida)

[redacted]



Zone Area	Vibration Level (Transient Condition)	Shock Leveling's Peak
1	16 to 37 cps at 0.45-in. double amplitude 37 to 84 cps at 32-g peak 84 to 119 cps at 0.09-in. double amplitude 119 to 2000 cps at 65-g peak	150
2	16 to 29 cps at 0.35-in. double amplitude 29 to 100 cps at 15-g peak 100 to 189 cps at 0.029-in. double amplitude 189 to 2000 cps at 52-g peak	100
3	16 to 35 cps at 0.35-in. double amplitude 35 to 2000 cps at 22-g peak	65
4	16 to 40 cps at 0.33-in. double amplitude 40 to 100 cps at 27-g peak 100 to 114 cps at 0.053-in. double amplitude 114 to 2000 cps at 35-g peak	80
5	16 to 42 cps at 2-g peak 42 to 95 cps at 0.022-in. double amplitude 95 to 2000 cps at 10-g peak	35

Figure 17. Saturn C-1 Launch Vehicle Vibration and Shock Environment

[redacted]

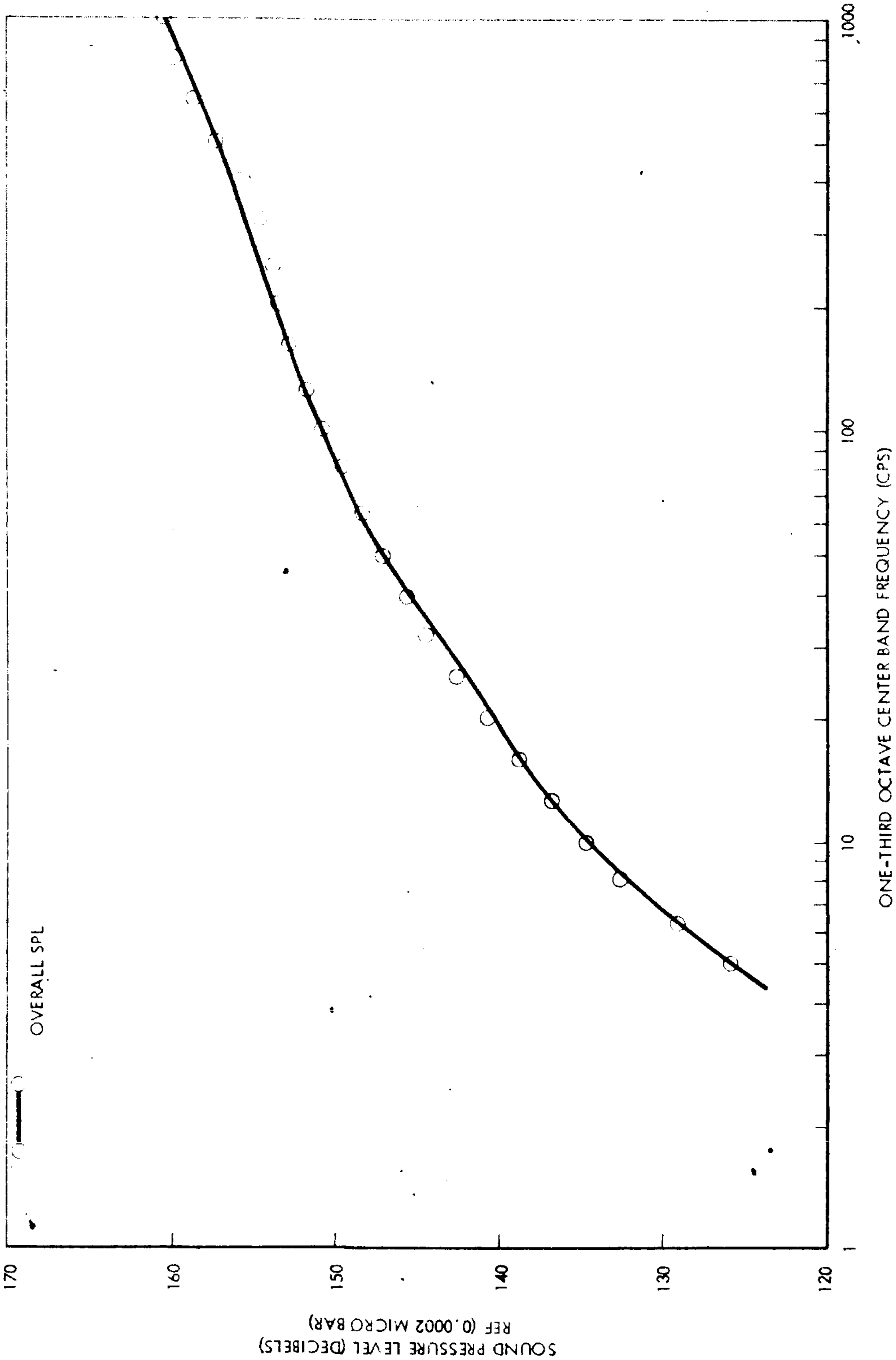


Figure 18. Frequency Spectrum at Station 0, C-1 Configuration (188 K)

[redacted]

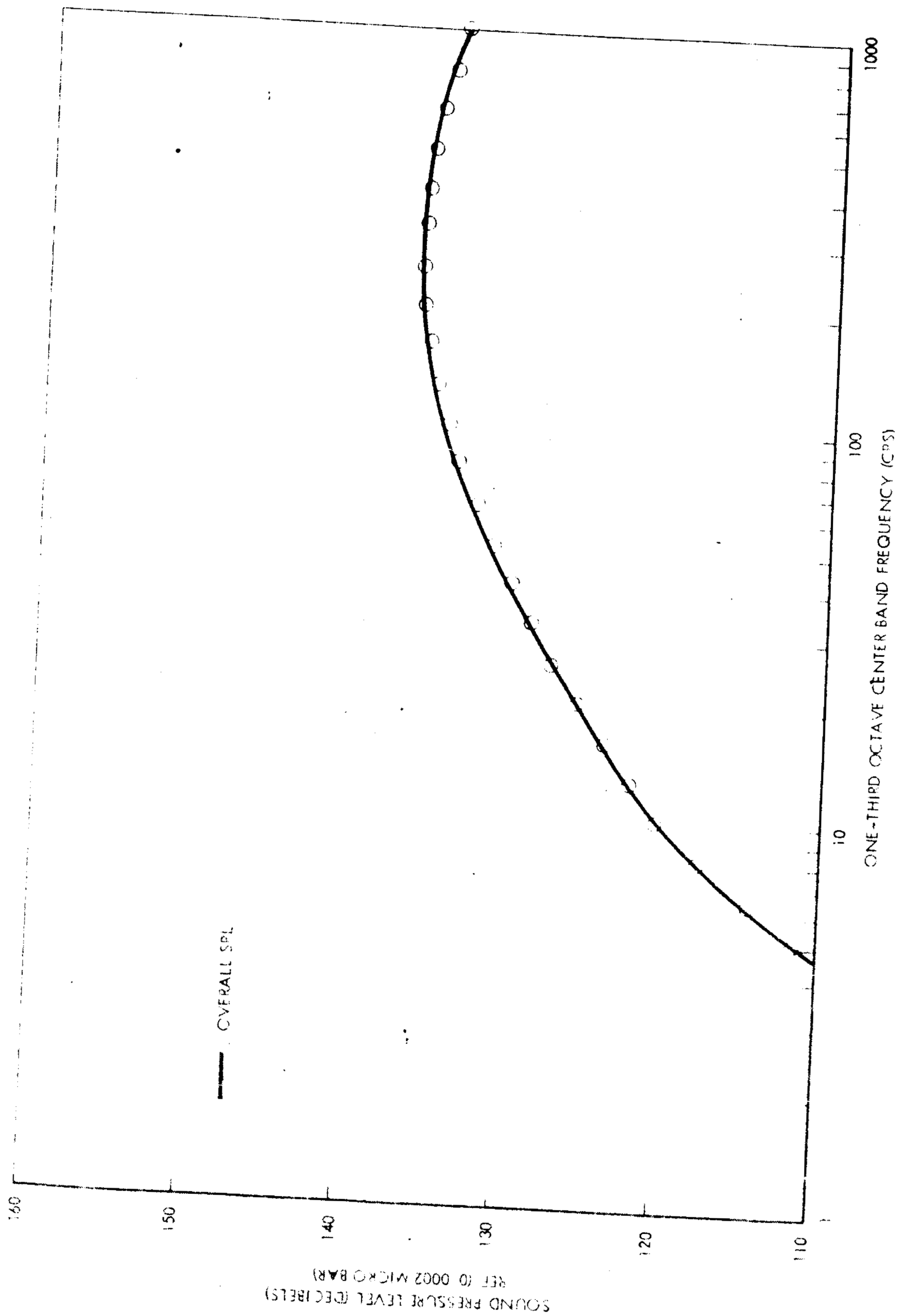


Figure 12. Frequency Spectrum at Station 499, C-1 Configuration (188 K)

[redacted]

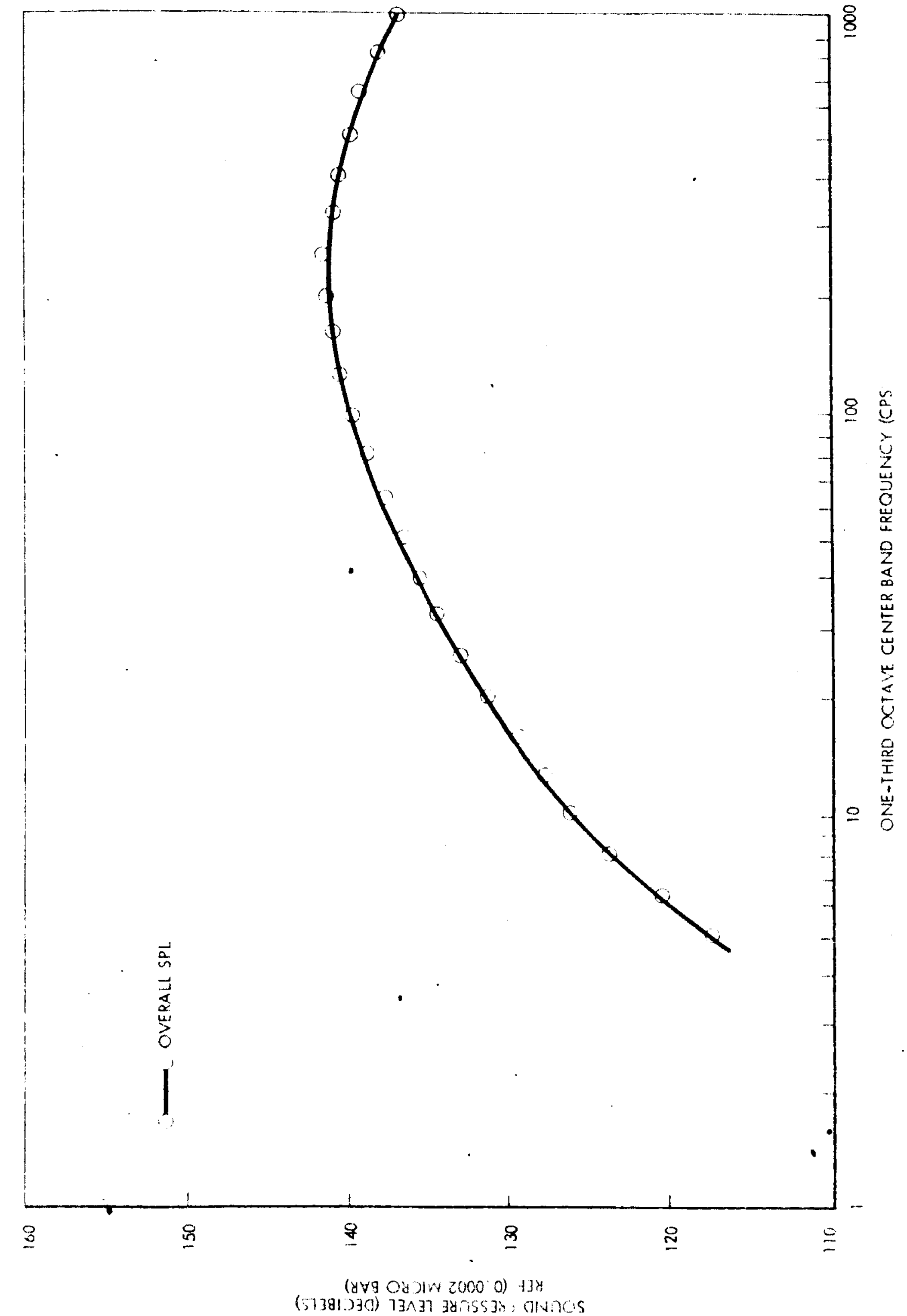


Figure 20. Frequency Spectrum at Station 1000, C-1 Configuration (188 K)

[redacted]

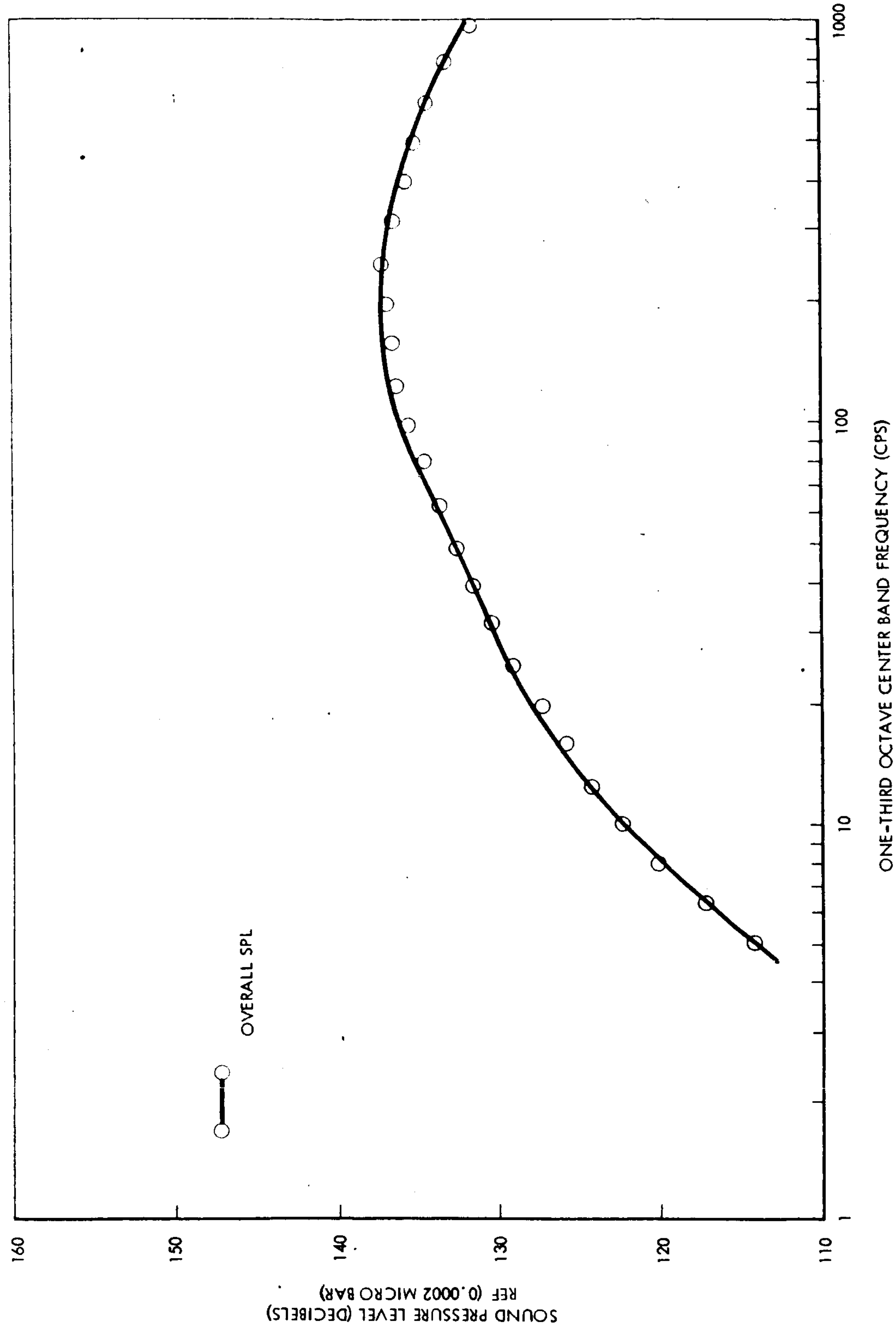


Figure 21. Frequency Spectrum at Station 1800, C-1 Configuration (188 K)

~~CONFIDENTIAL~~

In defining the acoustic environment, the values are based on eight 188,000-pound-thrust engines using a bilateral blast deflector. The acoustic levels specified in the Tables 14 through 17 are the anticipated overall sound pressure levels (SPL_{oa}) in decibels (Ref. 0.0002 dynes/cm^2). All radial distances are measured from the vertical axis of the vehicle on launch pad "B". The sound pressure level profile is symmetrical about horizontal centerlines of the bilateral exhaust deflector. The angular measurements in Tables 14 through 17 are measured from either exhaust stream in either direction from 0 to 180 degrees. The acoustic levels are given in 1 decibel increments measured on radius lines every 10 degrees around the launch complex. These tables can be used to determine the launch phase overall sound pressure level of pad "B" up to radii of approximately 2500 feet from the vehicle vertical axis.

The results in Table 18 are the launch phase overall sound pressure levels for the major items of GSE and launch facilities already located on the launch complex and pad "B".

The results in Table 19 are the maximum expected flight sound pressure levels for the GSE and launch facilities equipment due to the flight of the vehicle. These values do not occur simultaneously. They occur at some definite vehicle altitude and should be considered present only for a short time duration.

The results in Table 20 are maximum anticipated sound pressure levels for the early flight phase (up to 2000 feet altitude) of the Saturn vehicle and are only present for a short time duration.

AERODYNAMIC CHARACTERISTICS

Gradient of normal force coefficient and center of pressure versus Mach number are shown in Figures 22 through 25 for first- and second-stage flight configurations. Mean base pressure versus Mach number is shown in Figure 26. Total drag coefficient, mean base drag coefficient, and forebody drag coefficient versus Mach number are shown in Figures 27 through 29. Distribution of local normal force coefficient and viscous crossflow normal force coefficient are shown in Figures 30 through 33. Local axial force coefficient versus vehicle station are shown in Figures 34 and 35.

STABILITY ANALYSIS

Maximum angle of attack α and the maximum gimbal angle β curves used in the design of the C-1 launch vehicle were based on a fin plan form area of 181.9 square feet. The present concept is to use a fin plan form area of 121.2 square feet.

[redacted]

Table 16. Sound Pressure Loading for Different Radii and Angles From Exhaust Direction

Angle (deg)	*130	*131	*132	*133	*134	*135	*136	*137	*138	*139	*140
	Radii (ft)										
0 - 180	1390	1240	1102	983	876	782	696	621	553	493	439
10 - 170	1556	1390	1235	1103	981	876	781	695	619	552	492
20 - 160	1970	1759	1564	1397	1242	1109	989	880	785	699	623
30 - 150	2500	2230	1985	1773	1579	1406	1254	1119	995	887	791
40 - 140	2610	2320	2067	1840	1640	1462	1305	1162	1037	923	822
50 - 130	2500	2230	1985	1773	1579	1406	1254	1119	995	887	791
60 - 120	2160	1930	1716	1532	1362	1217	1084	966	860	767	684
70 - 110	1798	1603	1428	1276	1135	1011	902	805	716	638	568
80 - 100	1647	1470	1308	1169	1038	928	825	733	655	585	521
90 - 90	1582	1415	1256	1123	1000	892	795	708	631	562	501

*SPL_{oa} (db) Ref 0.0002 dynes/cm^2

~~CONFIDENTIAL~~

[redacted]

Table 17. Sound Pressure Loading for Different Radii and Angles From Exhaust Direction

Angle (deg)	*141	*142	*143	*144	*145	*146	*147	*148	*149	*150
	Radii (ft)									
0 - 180	392	349	311	278	247	210	197	171	156	139
10 - 170	439	391	348	311	277	247	220	196	175	156
20 - 160	556	495	441	393	350	313	279	248	221	197
30 - 150	706	628	560	500	444	397	454	315	281	250
40 - 140	734	654	583	520	463	413	468	327	292	261
50 - 130	706	628	560	500	444	397	454	315	281	250
60 - 120	610	543	484	432	385	343	306	272	242	217
70 - 110	507	452	403	360	320	285	255	226	202	180
80 - 100	465	414	369	329	293	262	233	207	185	165
90 - 90	446	398	355	316	282	251	224	199	178	159

*SPL_{OA} (db) Ref 0.0002 dynes/cm^2

~~CONFIDENTIAL~~

Table 18. Sound Pressure Loading for Different Radii and Angles From Exhaust Direction

Angle (deg)	*151	*152	*153	*154	*155	*156	*157	*158	*159	*160
					Radii (ft)					
0 - 180	124	110	98	87	78	70	62	55	49	44
10 - 170	139	124	110	98	88	78	70	62	55	49
20 - 160	176	156	140	124	111	99	88	79	70	62
30 - 150	223	199	177	158	141	125	112	100	89	79
40 - 140	232	207	184	164	146	131	116	104	92	82
50 - 130	223	199	177	158	141	125	112	100	89	79
60 - 120	193	172	153	136	122	108	97	86	77	68
70 - 110	160	143	128	114	101	90	81	72	64	57
80 - 100	147	131	117	104	93	83	73	66	59	52
90 - 90	141	126	112	100	89	80	71	63	56	50

$^*SPL_{oa}$ (db) Ref 0.0002 dynes/cm^2

Table 19. Sound Pressure Loading for Different Radii and Angles From Exhaust Direction

Angle (deg)	*161	*162	*163	*164	*165	*166	*167	*168	*169	*170
					Radii (ft)					
0 - 180	39	35	31	28	25	21	20	17	16	14
10 - 170	44	39	35	31	28	25	22	20	18	16
20 - 160	56	50	44	39	35	31	28	25	22	20
30 - 150	71	63	56	50	44	40	45	32	28	25
40 - 140	73	65	58	52	46	41	47	33	29	26
50 - 130	71	63	56	50	44	40	45	32	28	25
60 - 120	61	54	48	43	39	34	31	27	24	22
70 - 110	51	45	40	36	32	29	26	23	20	18
80 - 100	47	41	37	33	29	26	23	21	19	17
90 - 90	45	40	36	32	28	25	22	20	18	16

$*SPL_{oa}$ (db) Ref 0.0002 dynes/cm^2

Table 20. Maximum Sound Pressure Loading for Major Ground Support Equipment and Facilities During Launch Phase (Before Lift-Off)

Identification	Location From Vehicle Axis (ft)	SPL_{oa} (db) Ref 0.0002 dynes/cm^2
Launch pedestal	0	*
Umbilical tower	58	159.7
Automatic ground control station	110	154.4
Periphery camera pad B-1	250	150.8
Periphery camera pad B-4	250	149.6
Periphery camera pad B-2	285	149.4
Periphery camera pad B-3	285	149.5
Generator pad	300	145.1
Power pedestal pad	340	148.1
Cooling tower	420	144.0
High pressure gas storage area	500	141.5
RP-1 storage area	680	138.3
LO_2 storage area	740	139.3
LH_2 storage area	875	136.6
Camera station 37-2	875	139.8
Camera station 37-4	875	139.3
Camera station 37-1	930	139.3
Camera station 37-3	930	139.0
Electrical equipment building B	960	135.1
Launch control building	1175	136.2
Operations support building	1645	133.4

*No value listed because of particle impingement in the immediate exhaust stream.

[redacted]

Table 21. Maximum Sound Pressure Loading for Major Ground Support Equipment and Facilities During Flight Phase (After Lift-Off)

Identification	SPL_{oa} (db) Ref 0.0002 dynes/cm^2
Launch pedestal	
Umbilical tower	157.3
Automatic ground control station	151.8
Periphery camera pad B-1	144.7
Periphery camera pad B-4	144.7
Periphery camera pad B-2	143.5
Periphery camera pad B-3	143.5
Generator pad	142.9
Power pedestal pad	142.0
Cooling tower	140.2
High pressure gas storage area	138.7
RP-1 storage area	136.0
LO_2 storage area	135.3
LH_2 storage area	133.8
Camera station 37-2	133.8
Camera station 37-4	133.8
Camera station 37-1	133.3
Camera station 37-3	133.3
Electrical equipment building B	133.0
Launch control building	131.2
Operations support building	128.3

*No value listed because of particle impingement in the immediate exhaust stream.

CONFIDENTIAL

[redacted]

Table 22. Launch Complex 37, Maximum Sound Pressure Loading for Various Vehicle Altitudes (After Lift-Off)

Vehicle Altitude (ft)*	Radial Distance From Vehicle Vertical Axis (ft)	Max SPL_{oa} (db) Ref 0.002 dynes/cm^2
80	67.3	156.1
90	75.6	155.1
100	84.0	154.2
120	100.7	152.6
140	117.7	151.7
160	134.6	150.1
180	151.5	149.1
200	168.0	148.1
250	210.0	146.2
300	252.0	144.6
350	294.0	143.3
400	336.1	142.1
500	420.0	140.2
600	504.0	138.6
750	630.0	136.7
1000	840.0	134.2
1500	1257.0	130.6
2000	1680.0	128.3

*Feet above nozzle exit plane.

Maximum angle of attack versus burning time for a 2 sigma wind is shown in Figure 36. Maximum gimbal angle versus burning time for a 2 sigma wind is shown in Figure 37.

STRUCTURAL CHARACTERISTICS

Load Data

Curves on shear and bending moment versus vehicle station during various flight times are shown in Figures 38 through 43. Longitudinal force versus vehicle station at rebound, liftoff, and various flight times are shown in Figures 44 through 46.

Bending Frequencies

Free-free frequency versus flight time curves are shown in Figure 47. Relative amplitude versus vehicle stations for first and second free-free bending modes are shown in Figures 48 and 49.

[redacted]

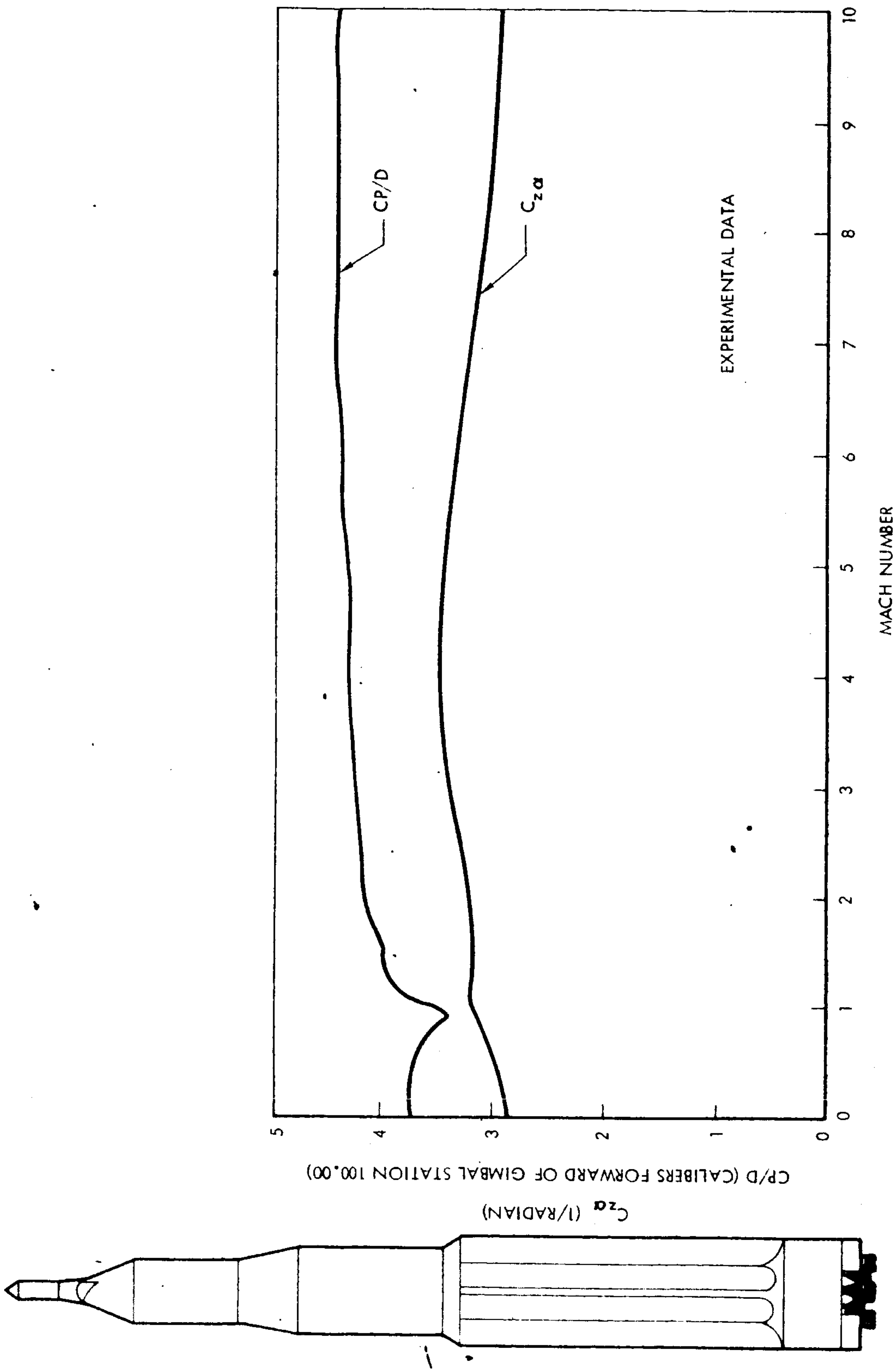


Figure 22. Normal Force and Center of Pressure Versus Mach Number, C-1 Apollo First Stage, No Stubs or Fins

[redacted]

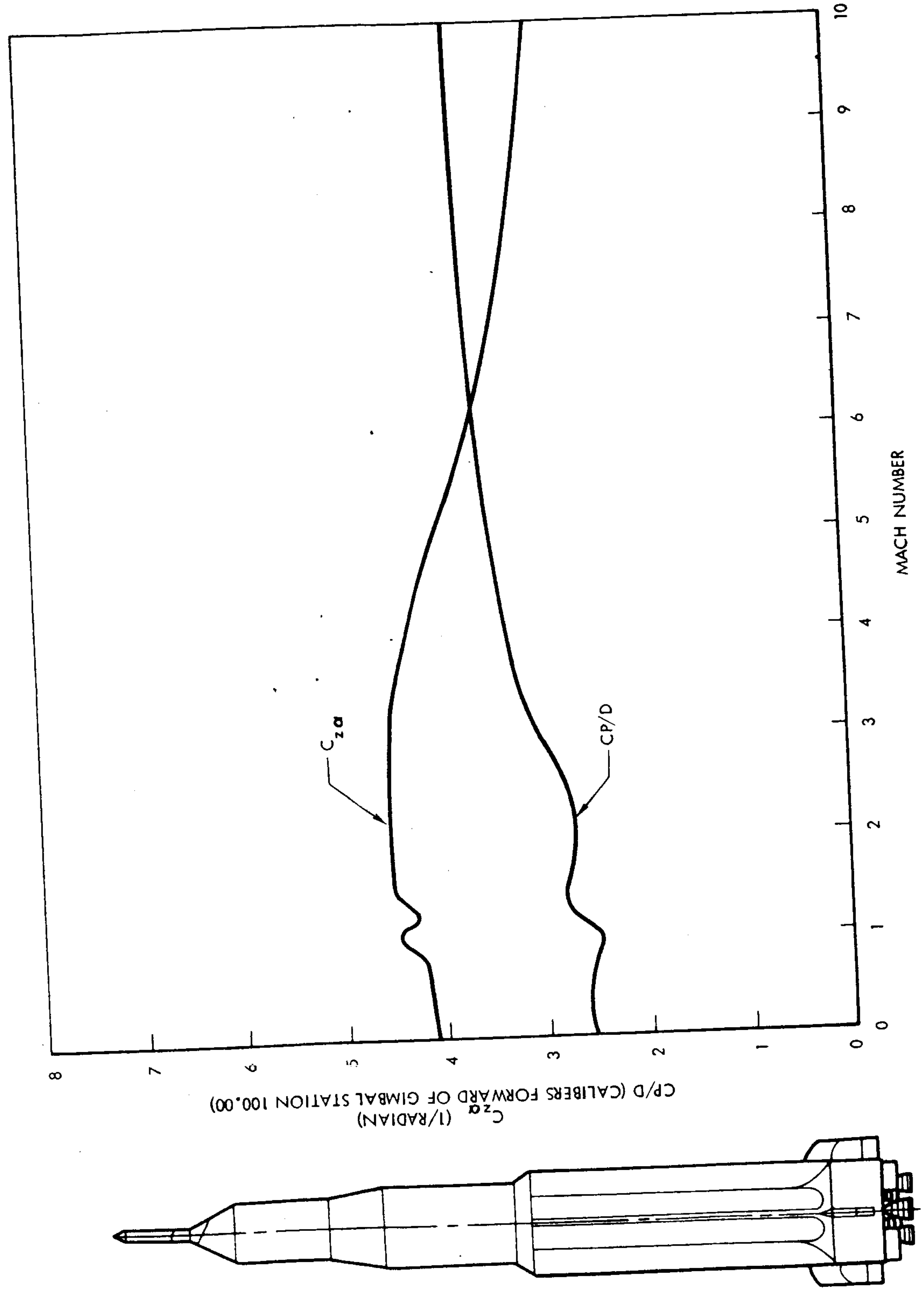


Figure 23. Normal Force and Center of Pressure Versus Mach Number, C-1 Apollo First Stage, Stubs Only

[redacted]

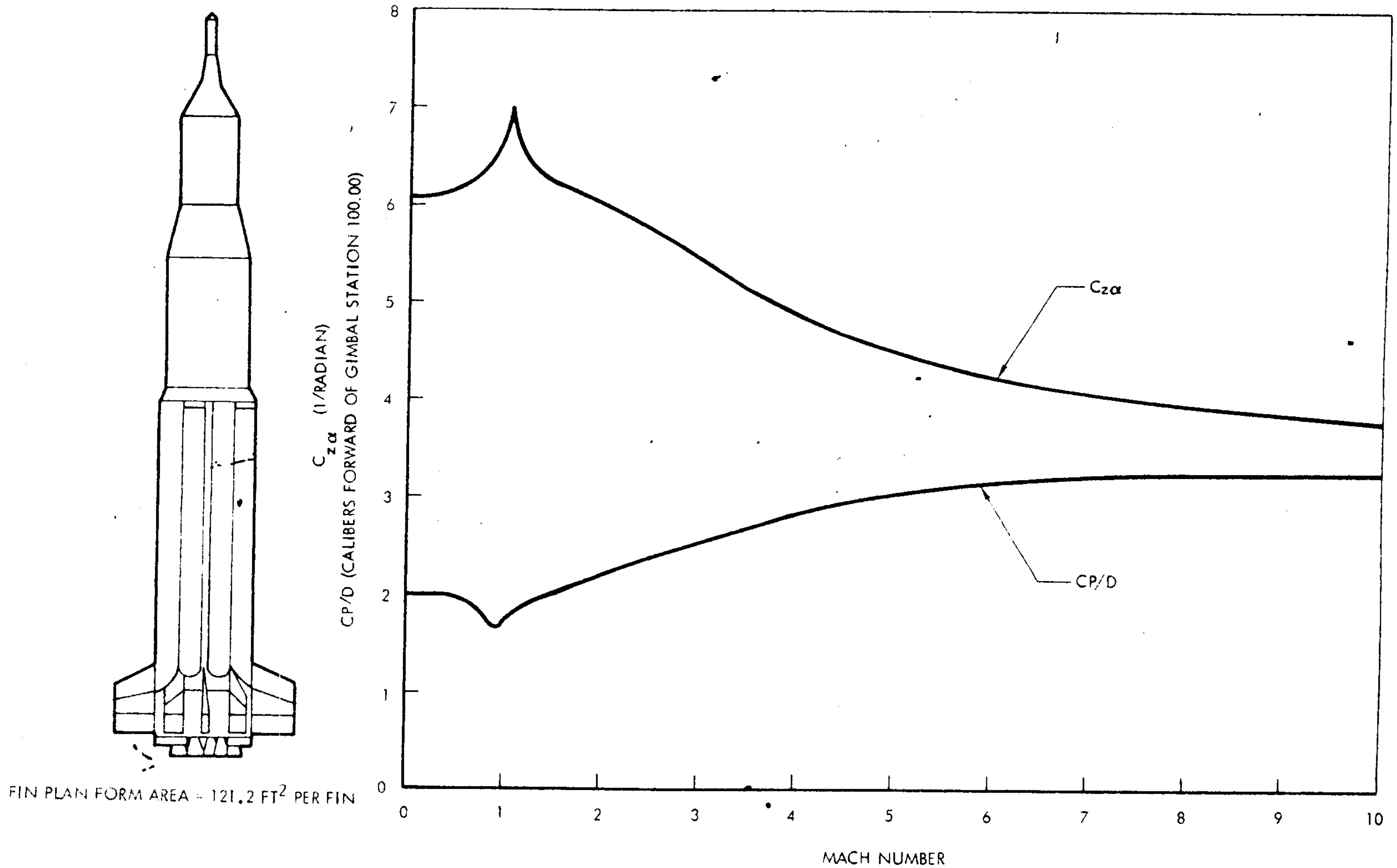


Figure 24. Normal Force and Center of Pressure Versus Mach Number, C-1' Apollo First Stage, Fins and Stubs

[redacted]

~~CONFIDENTIAL~~

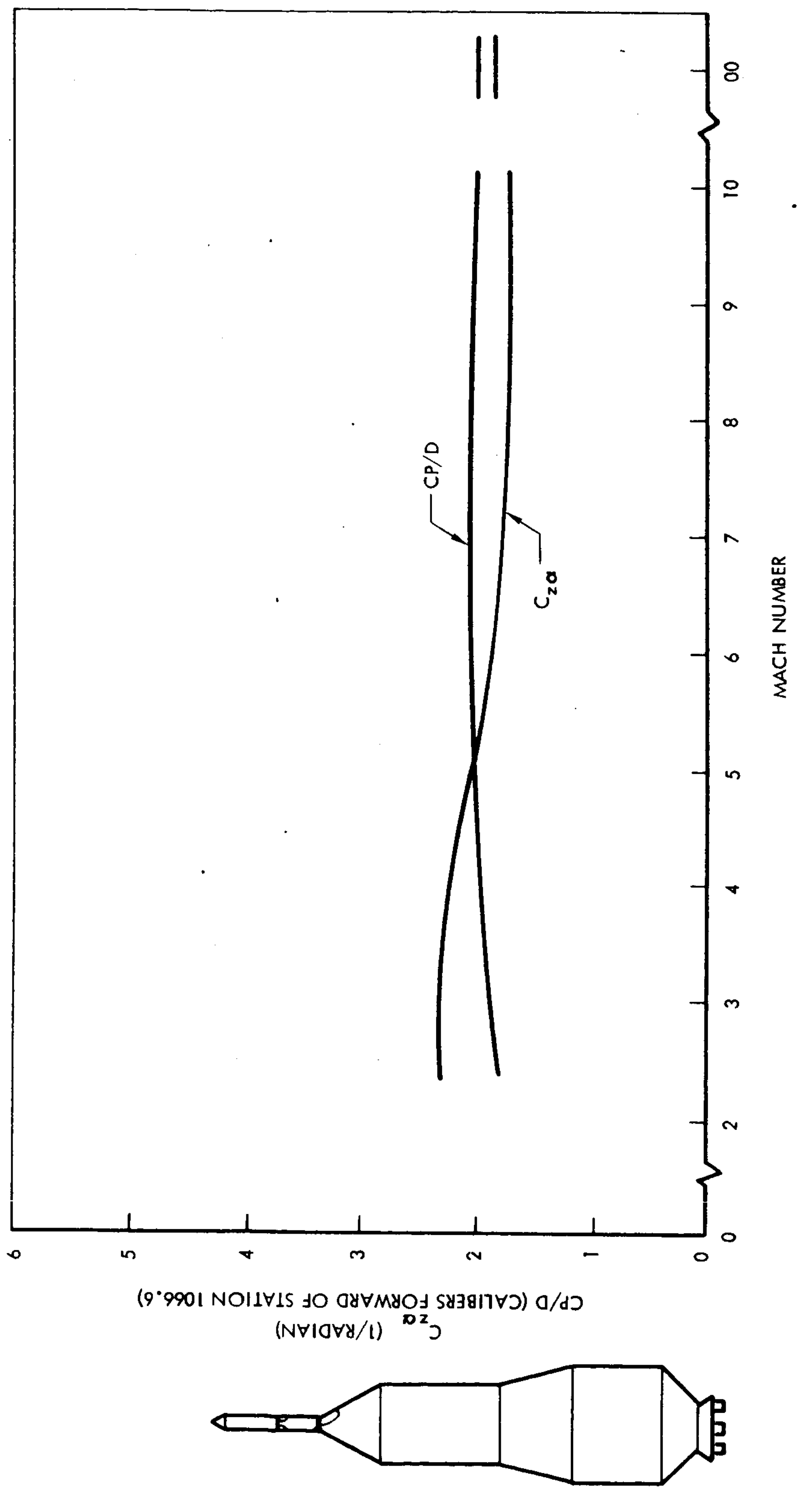


Figure 25. Normal Force and Center of Pressure Versus Mach Number, C-1 Apollo Second Stage

~~CONFIDENTIA~~

[redacted]

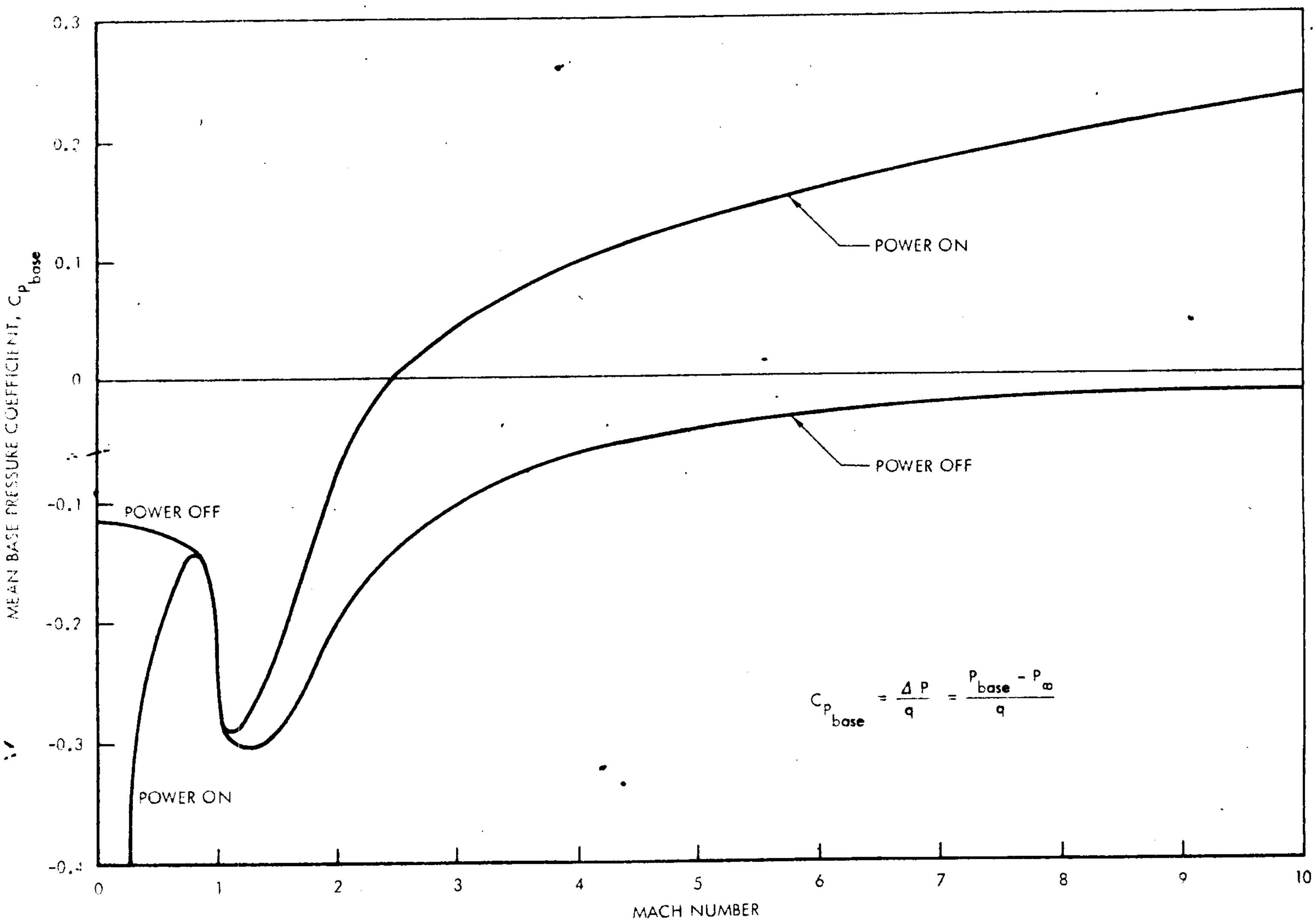


Figure 26. Mean Base Pressure Versus Mach Number, Saturn C-1 Apollo (α = 0 Degrees)

[redacted]

[redacted]

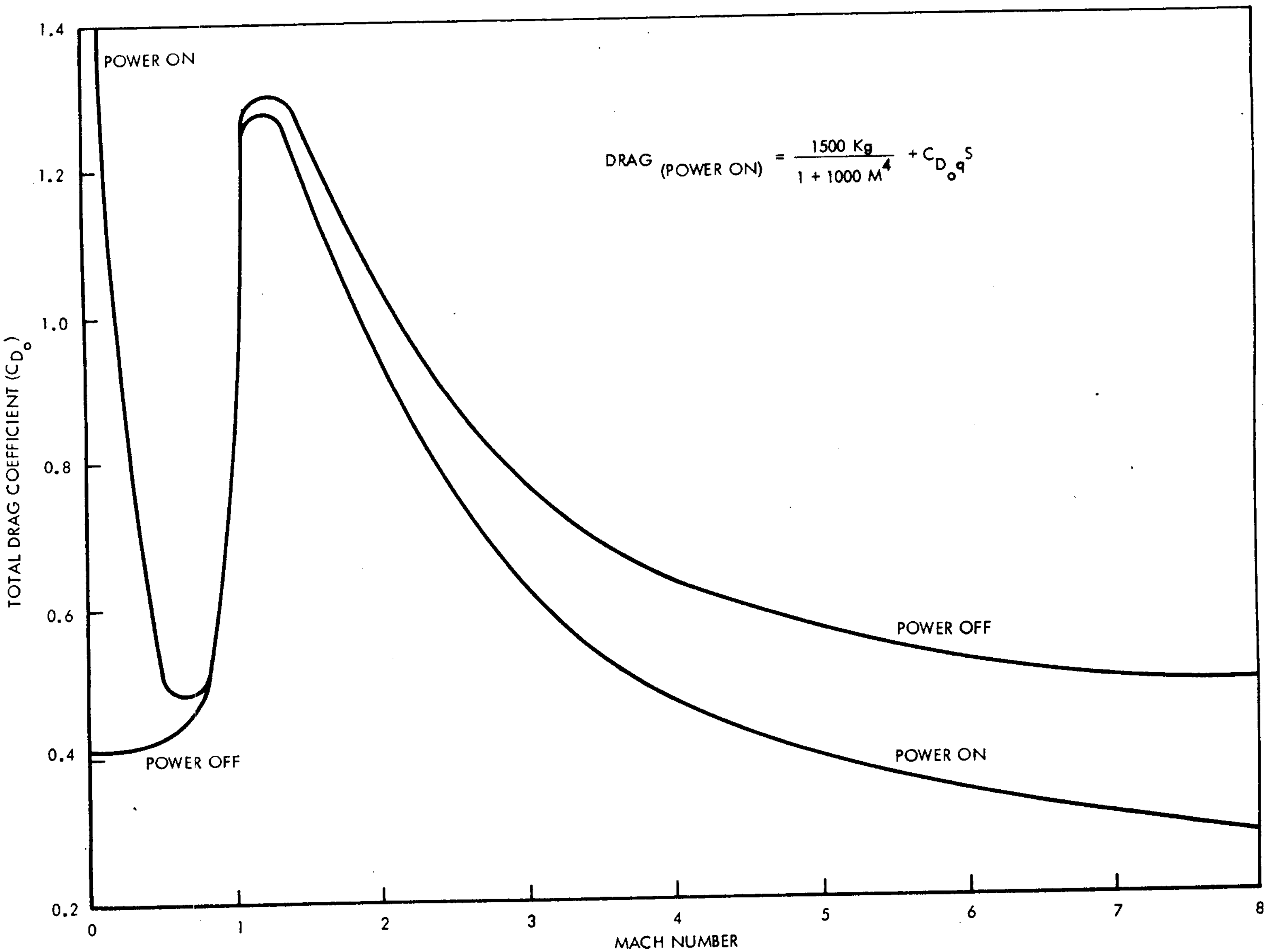


Figure 27. Total Drag Versus Mach Number, C-1 Apollo First Stage, Fins and Stubs Included

~~CONFIDENTIAL~~

[redacted]

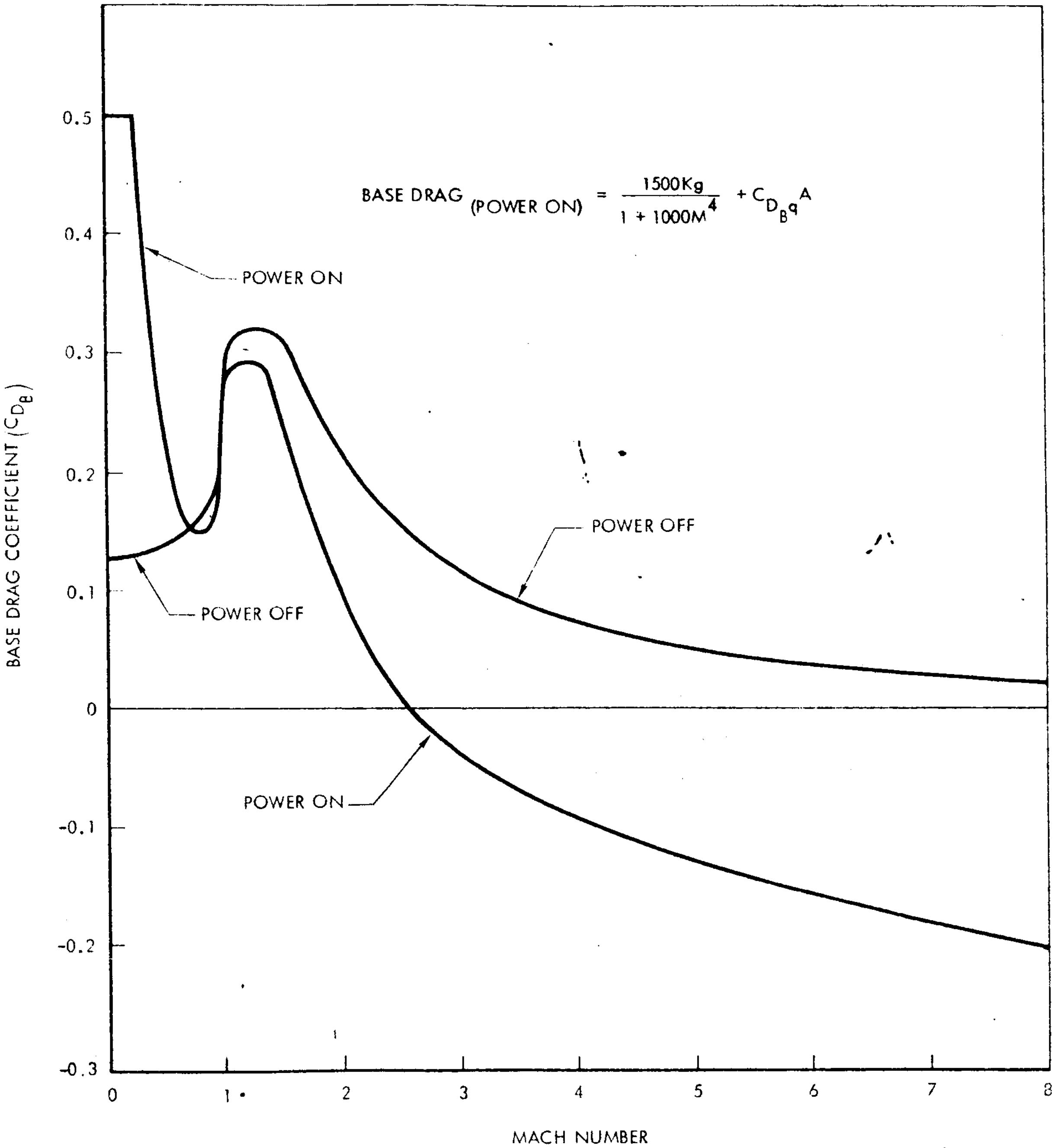


Figure 28. Mean Base Drag Versus Mach Number, C-1 Apollo First Stage

~~CONFIDENTIAL~~

[redacted]

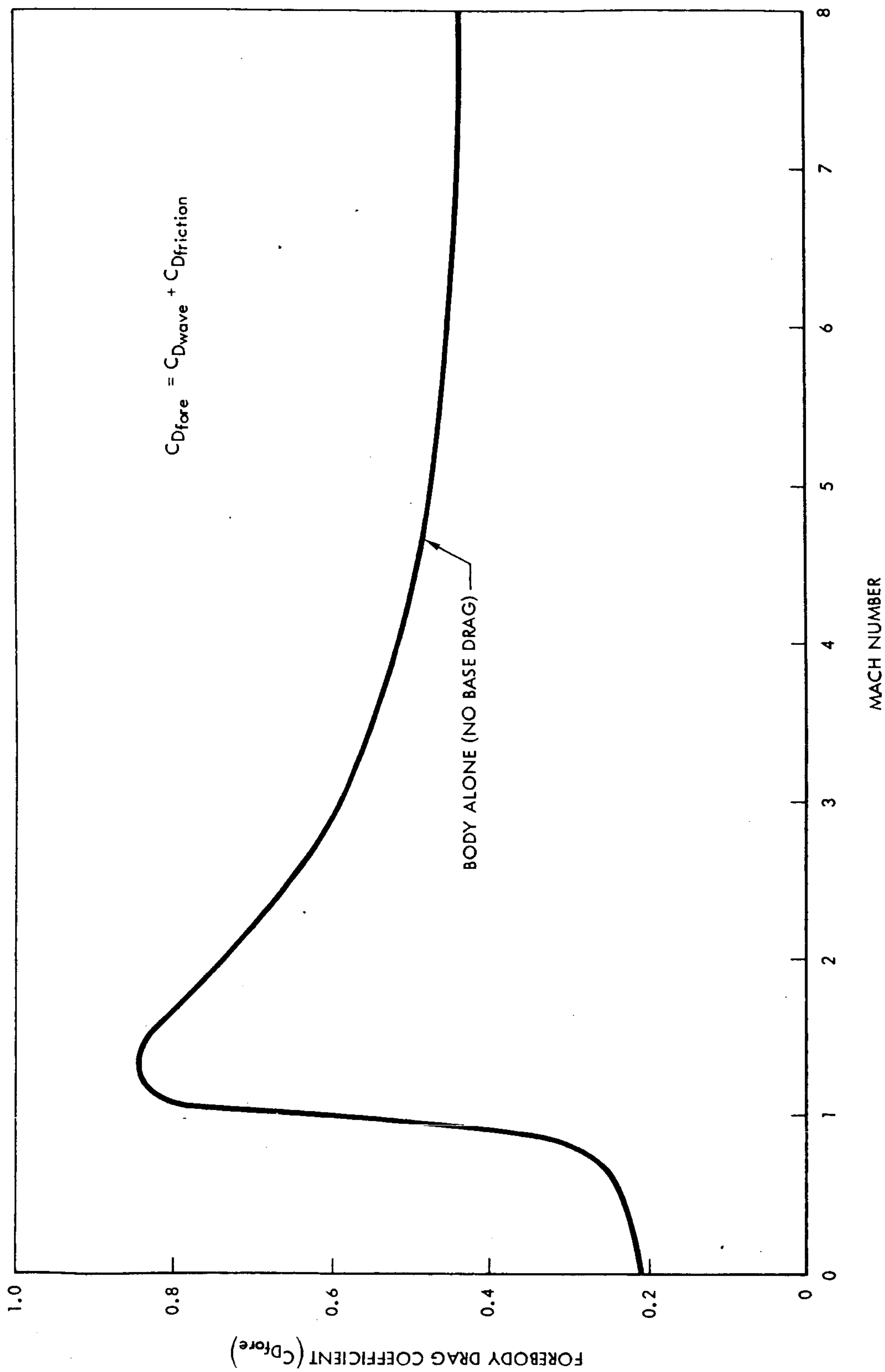


Figure 29. Forebody Drag Versus Mach Number, C-1 Apollo First Stage, No Stubs and Fins

[redacted]

[redacted]

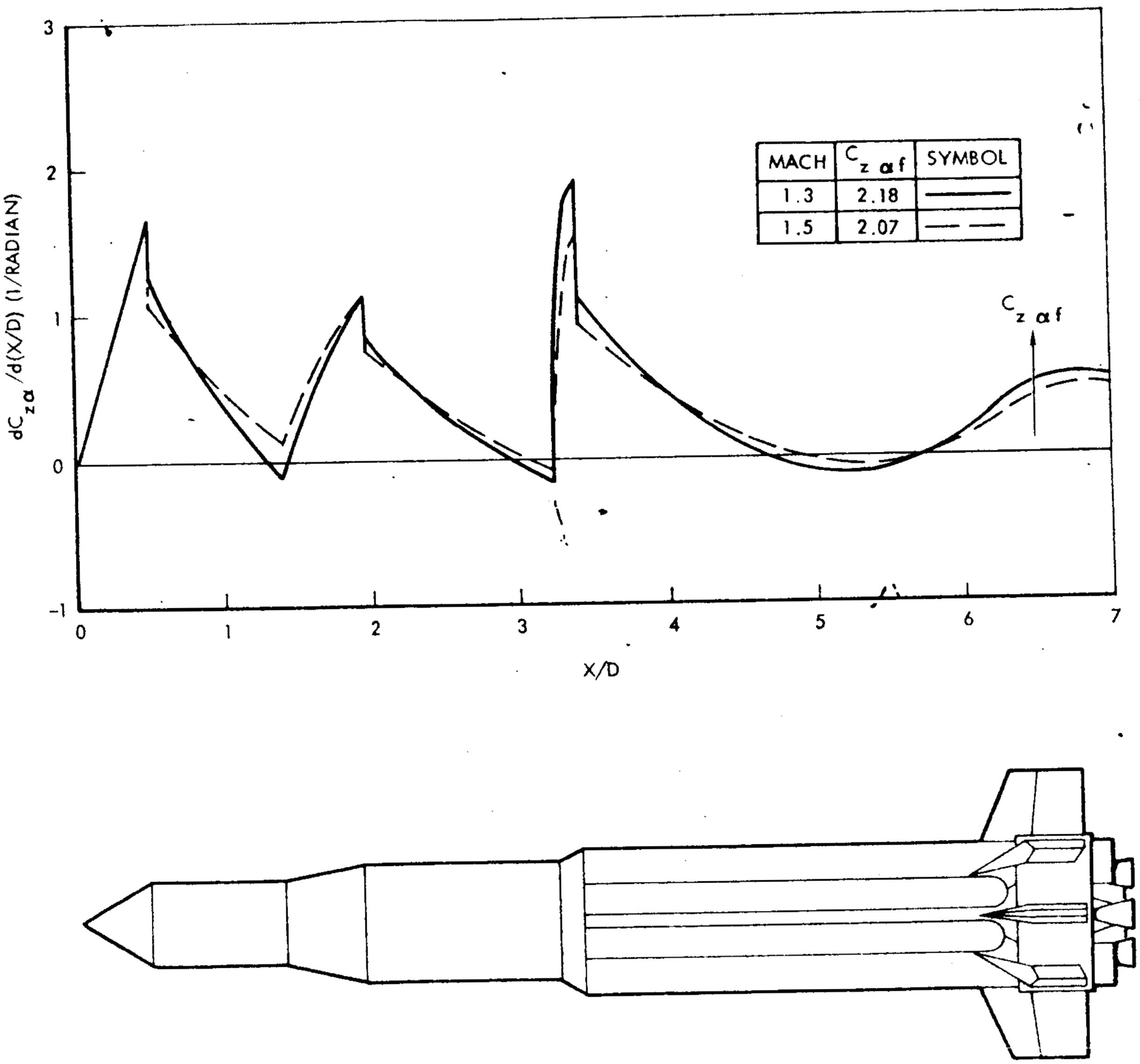


Figure 30. Distribution of Local Normal Force, C-1 Apollo First Stage, No Stubs and Fins (By Linear Theory)

[redacted]

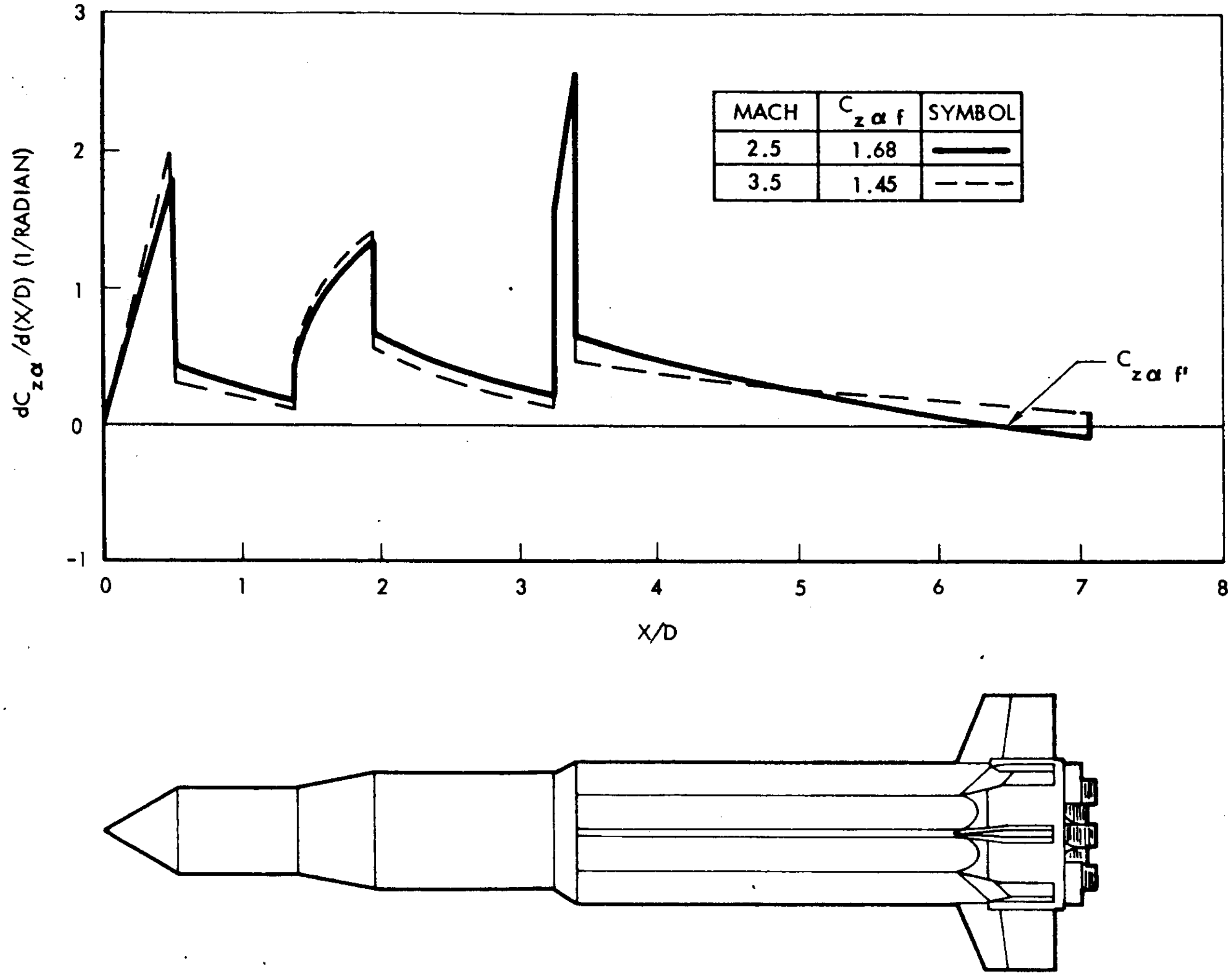


Figure 31. Distribution of Local Normal Force, C-1 Apollo First Stage (By Second-Order Shock Expansion Theory)

[redacted]IAL

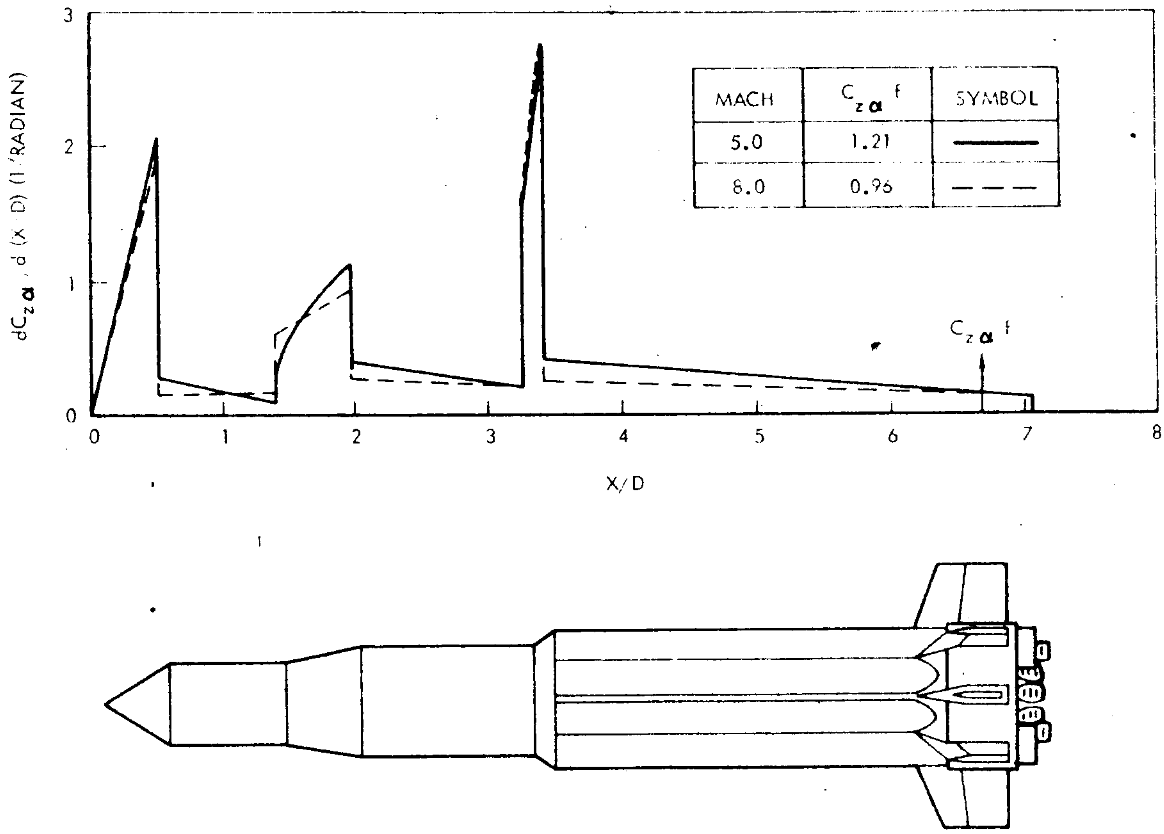
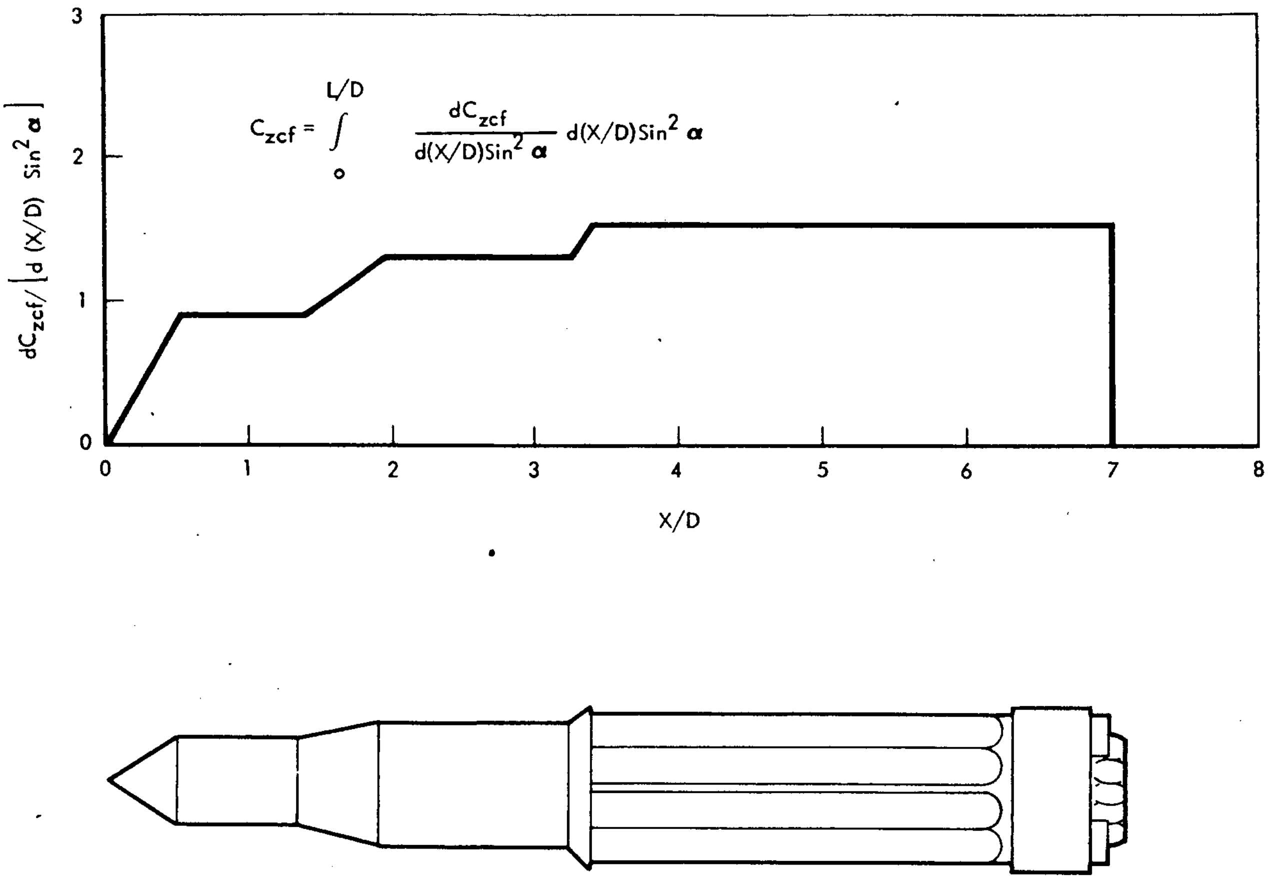


Figure 32. Distribution of Local Normal Force, C-1 Apollo First Stage (By Second-Order Shock Expansion Theory)

[redacted]



DISTRIBUTION BASED ON $Cd_c = 1.20 \neq f\,(M, \alpha)$

Figure 33. Distribution of Viscous Crossflow Normal Force, C-1 Apollo First Stage

[redacted]

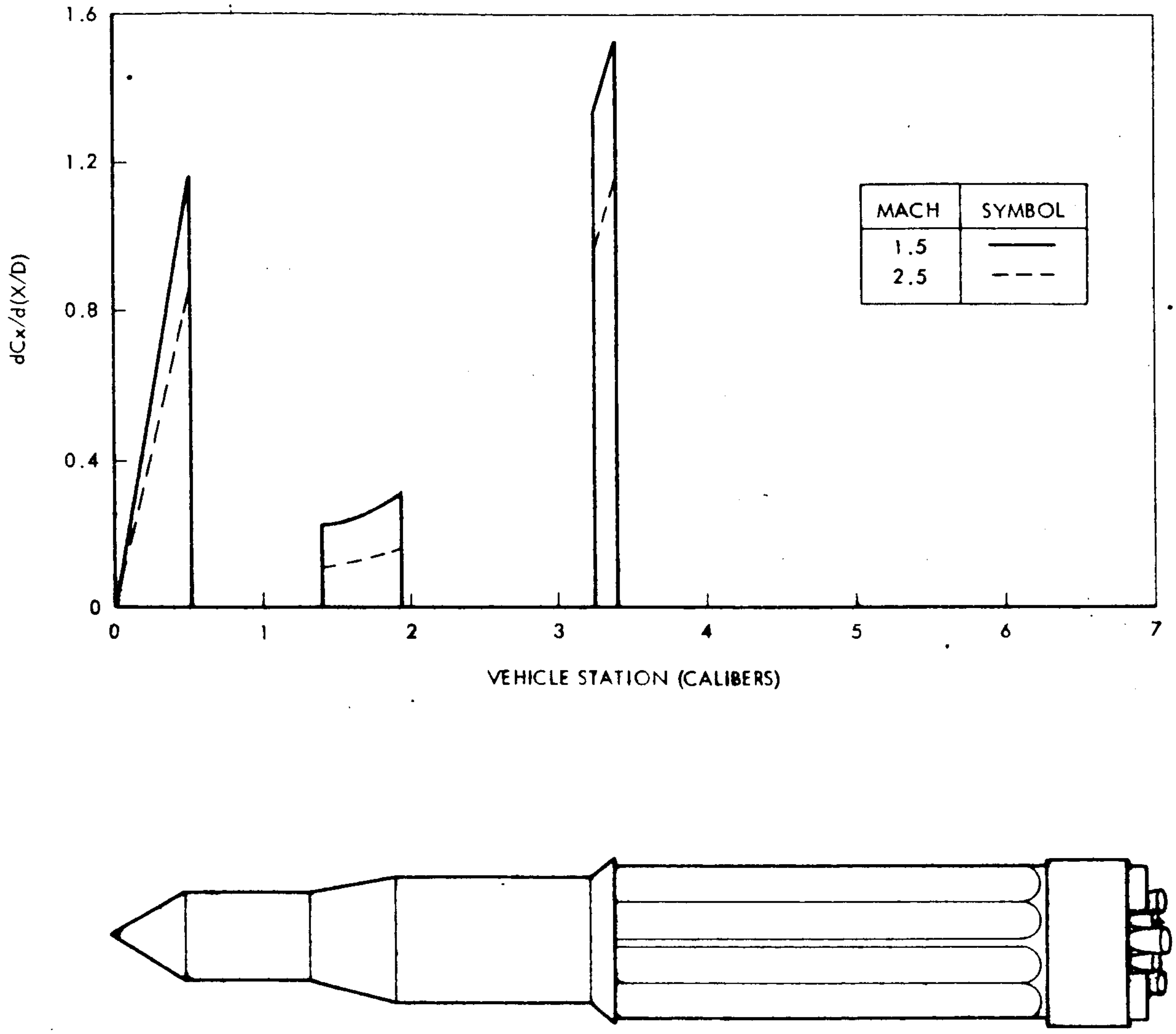


Figure 34. Local Axial Force Versus Vehicle Station, C-1 Apollo First Stage

[redacted]

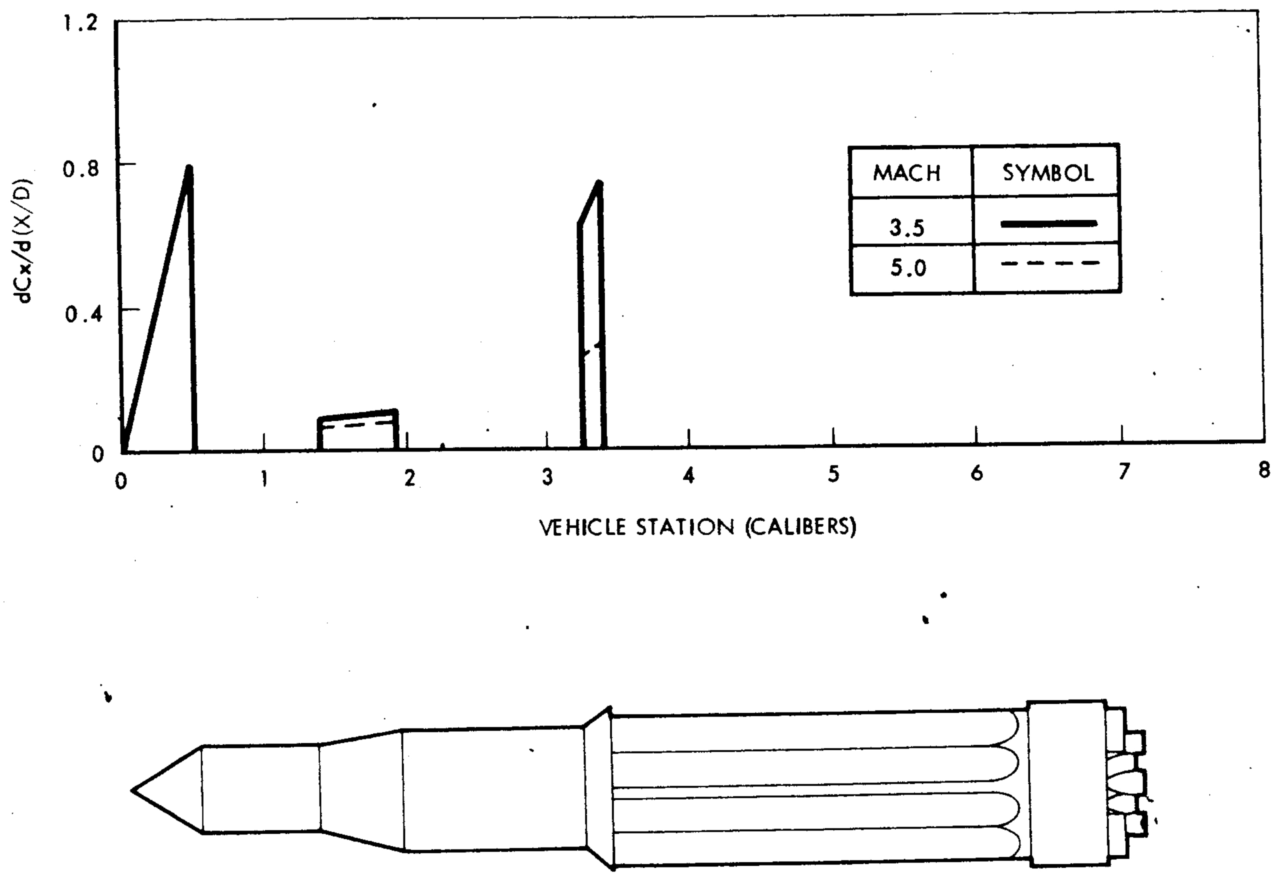


Figure 35. Local Axial Force Versus Vehicle Station, C-1 Apollo First Stage

[redacted]

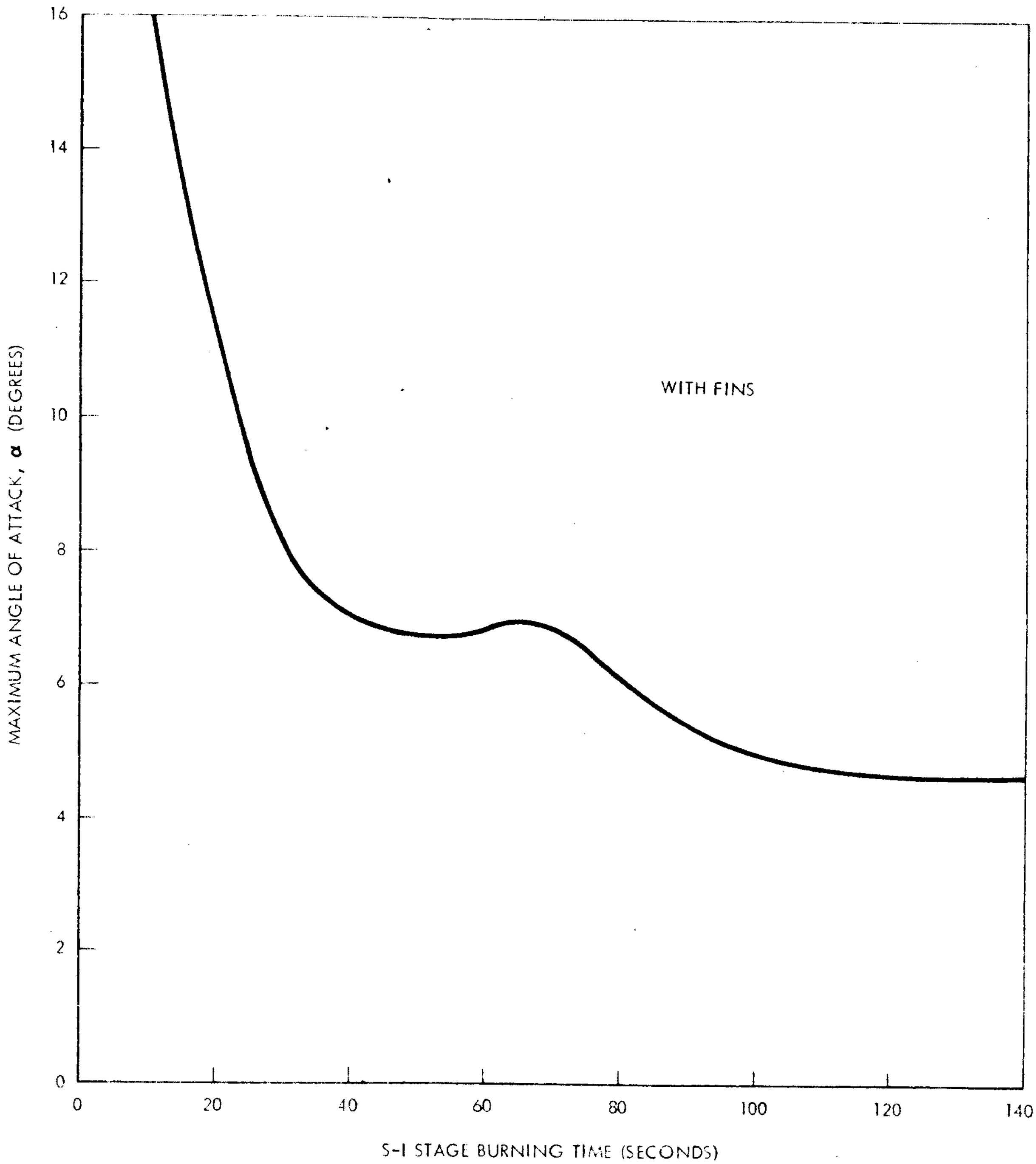


Figure 36. Maximum Angle of Attack Versus Burning Time S-I Stage, Saturn C-1 Apollo (Two-Sigma Winds)

[redacted]

[redacted]

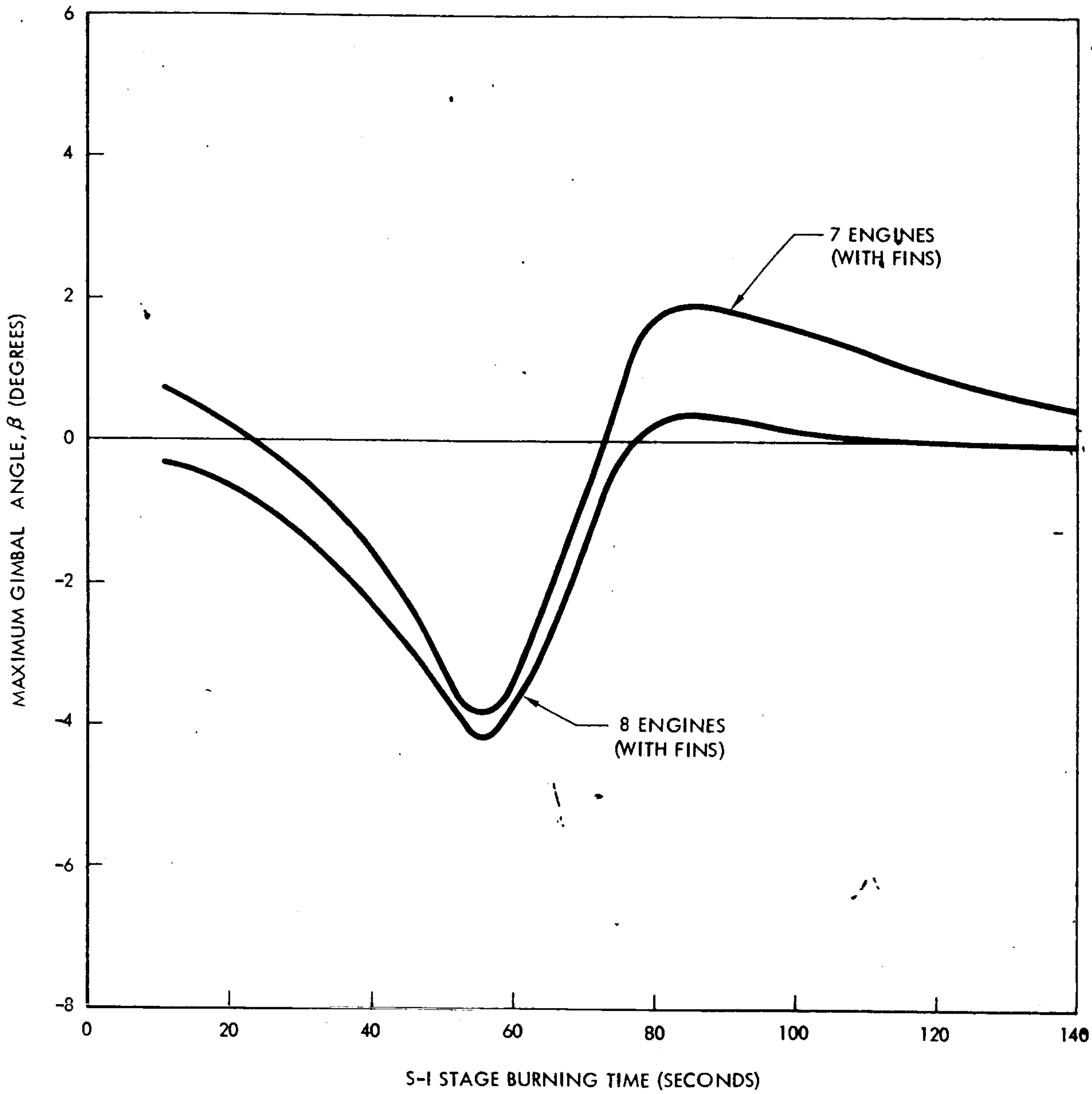
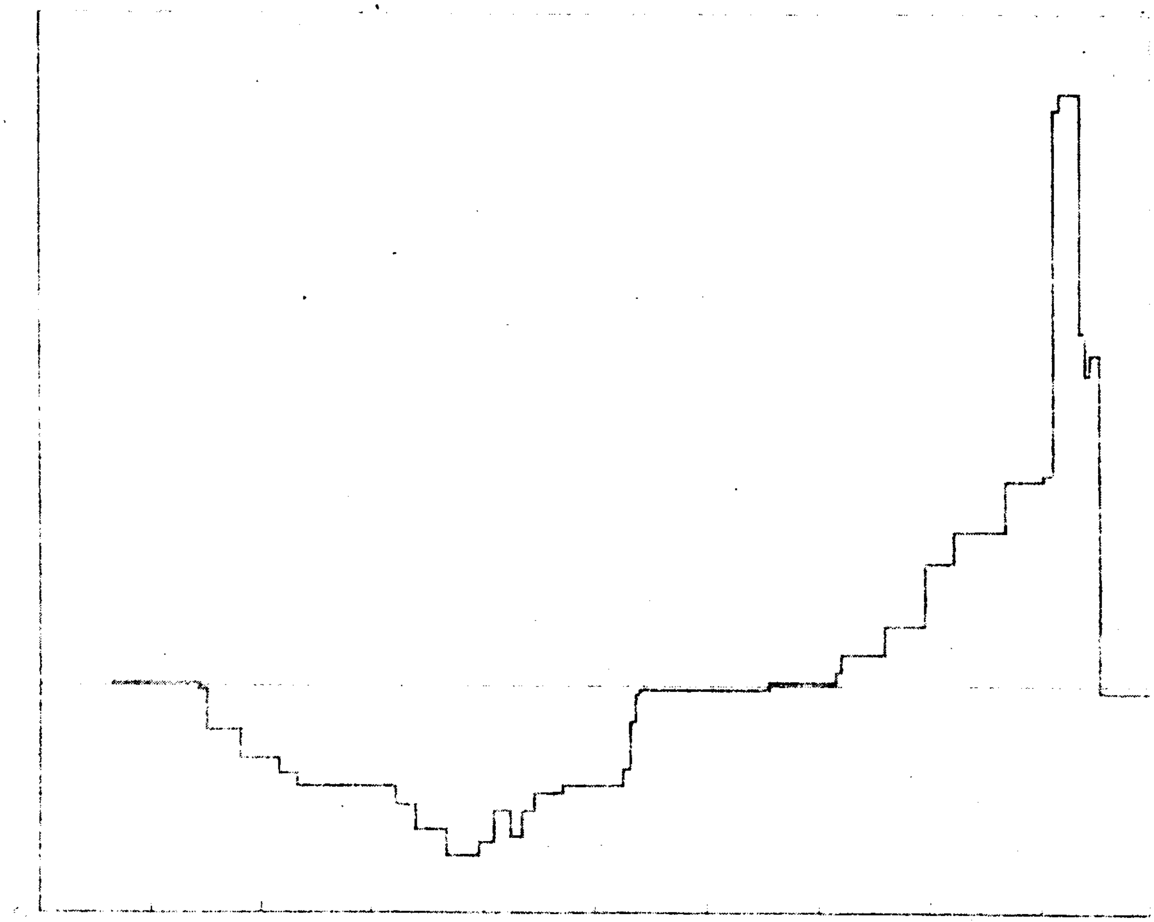


Figure 37. Maximum Gimbal Angle Versus Burning Time S-I Stage, Saturn C-1 Apollo (Two-Sigma Winds)

[redacted]



[illegible] Versus Vehicle Station, [illegible] (t = 60 Sec [illegible])

[redacted]

[redacted]

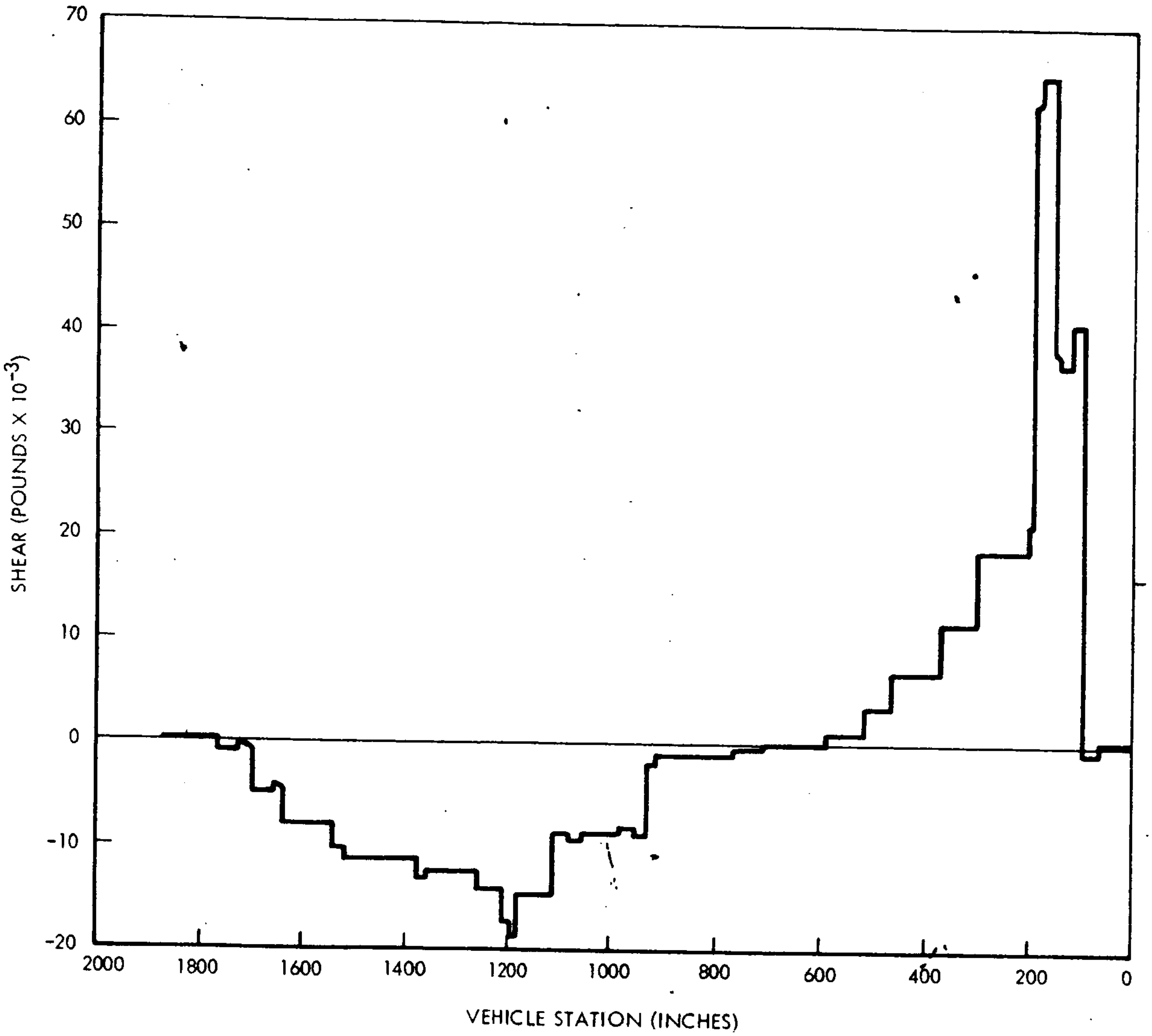


Figure 39. Shear Versus Vehicle Station, Saturn C-1 Apollo (t = 75 Seconds)

[redacted]

[redacted]

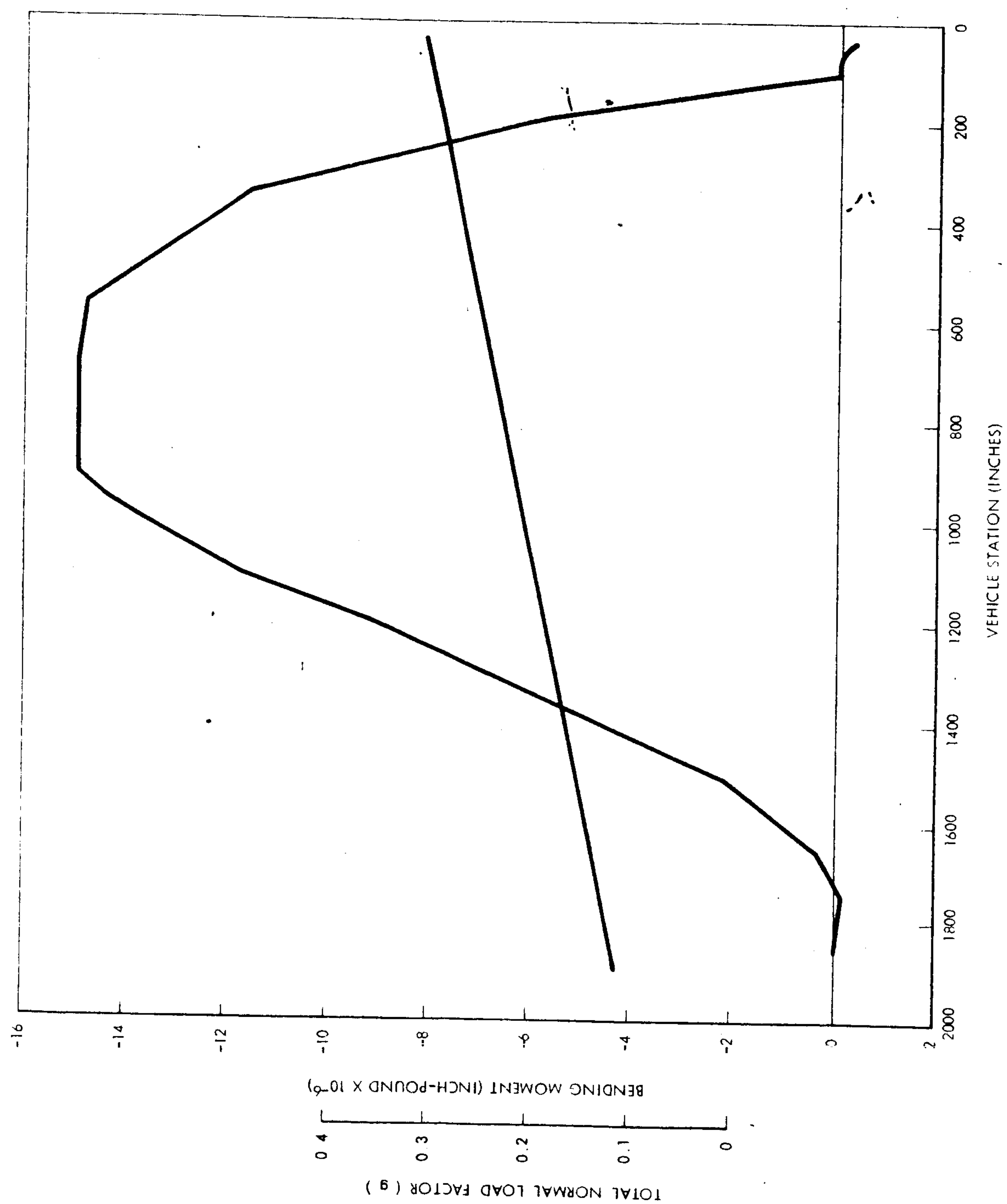


Figure 40. Bending Moment Versus Vehicle Station, Saturn C-1 Apollo (t = 60 Seconds)

[redacted]

[redacted]

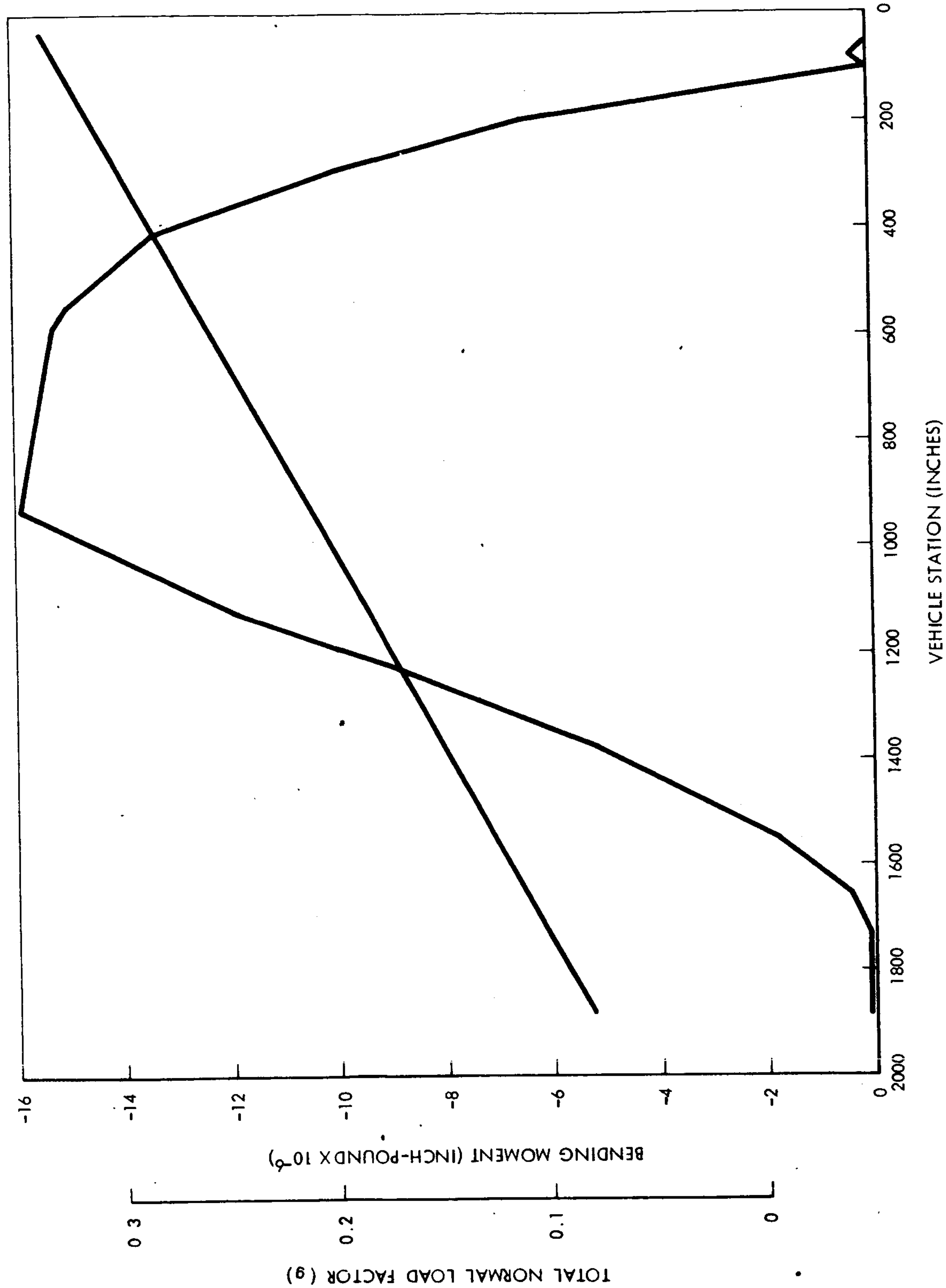
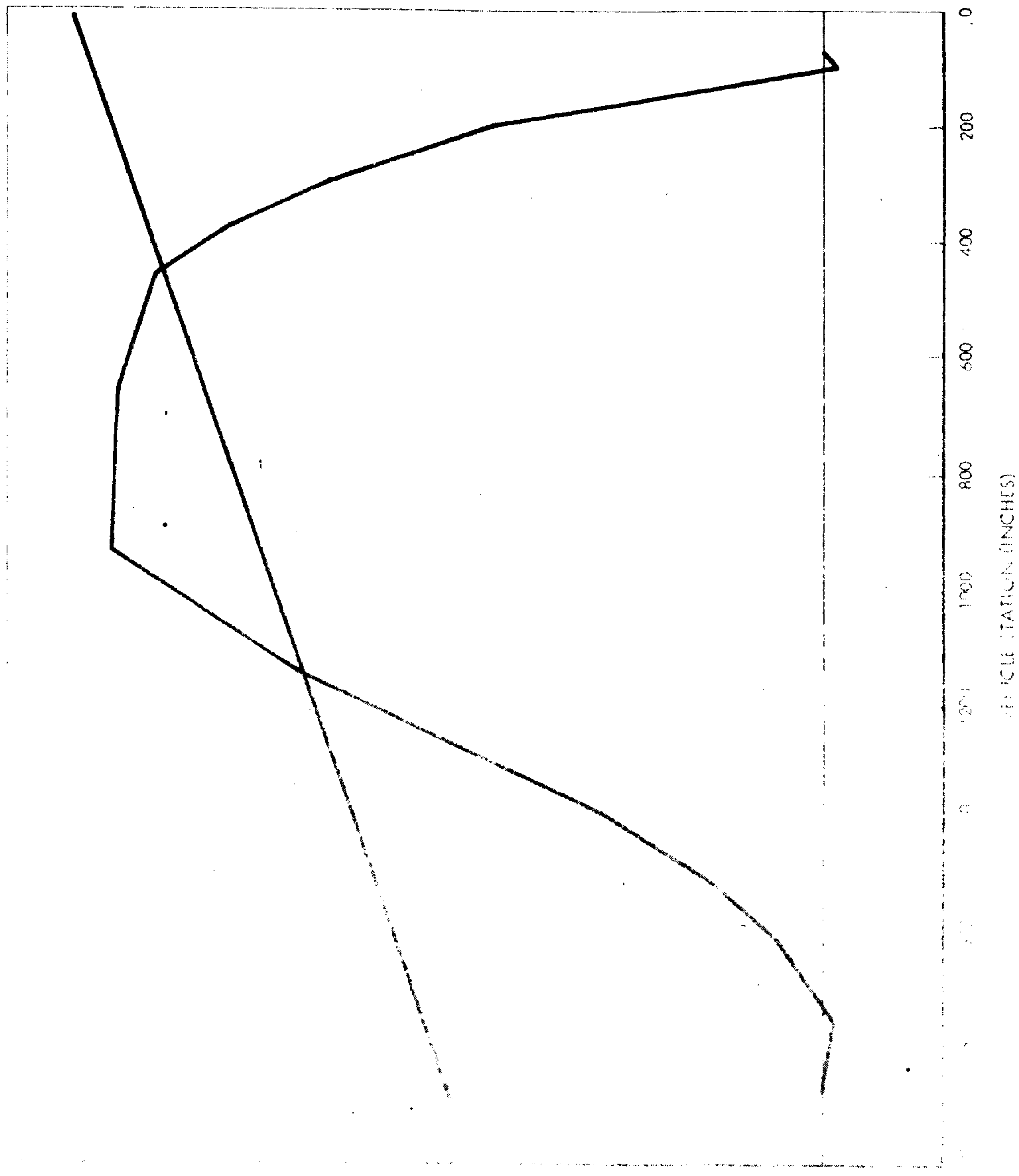


Figure 41. Bending Moment Versus Vehicle Station, Saturn C-1 Apollo (t = 65 Seconds)

[redacted]

~~CONFIDENTIAL~~



Saturn C-1 Apollo (t = .70 Seconds).

~~CONFIDENTIAL~~

[redacted]

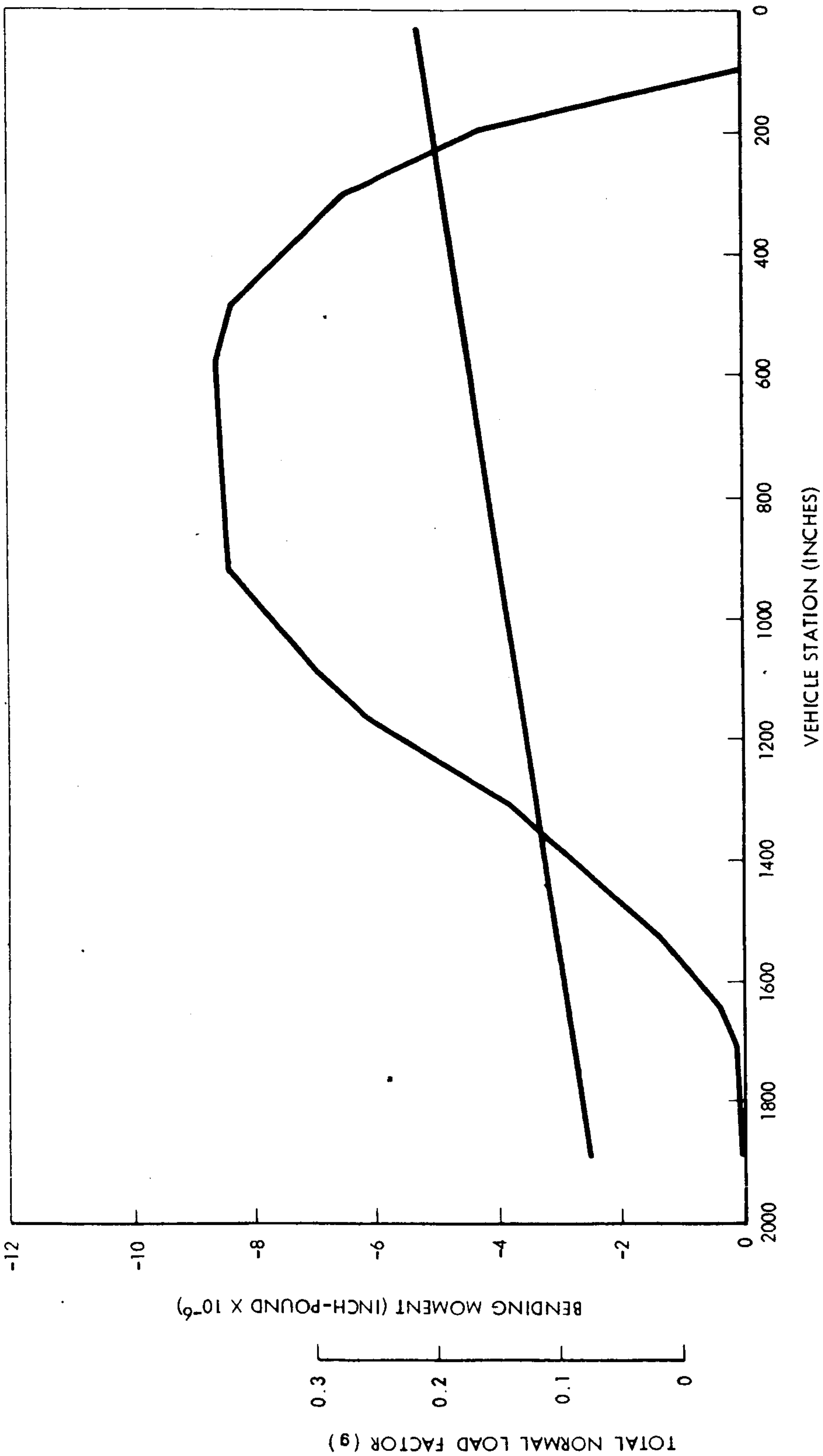


Figure 43. Bending Moment Versus Vehicle Station, Saturn C-1 Apollo (t = 75 Seconds)

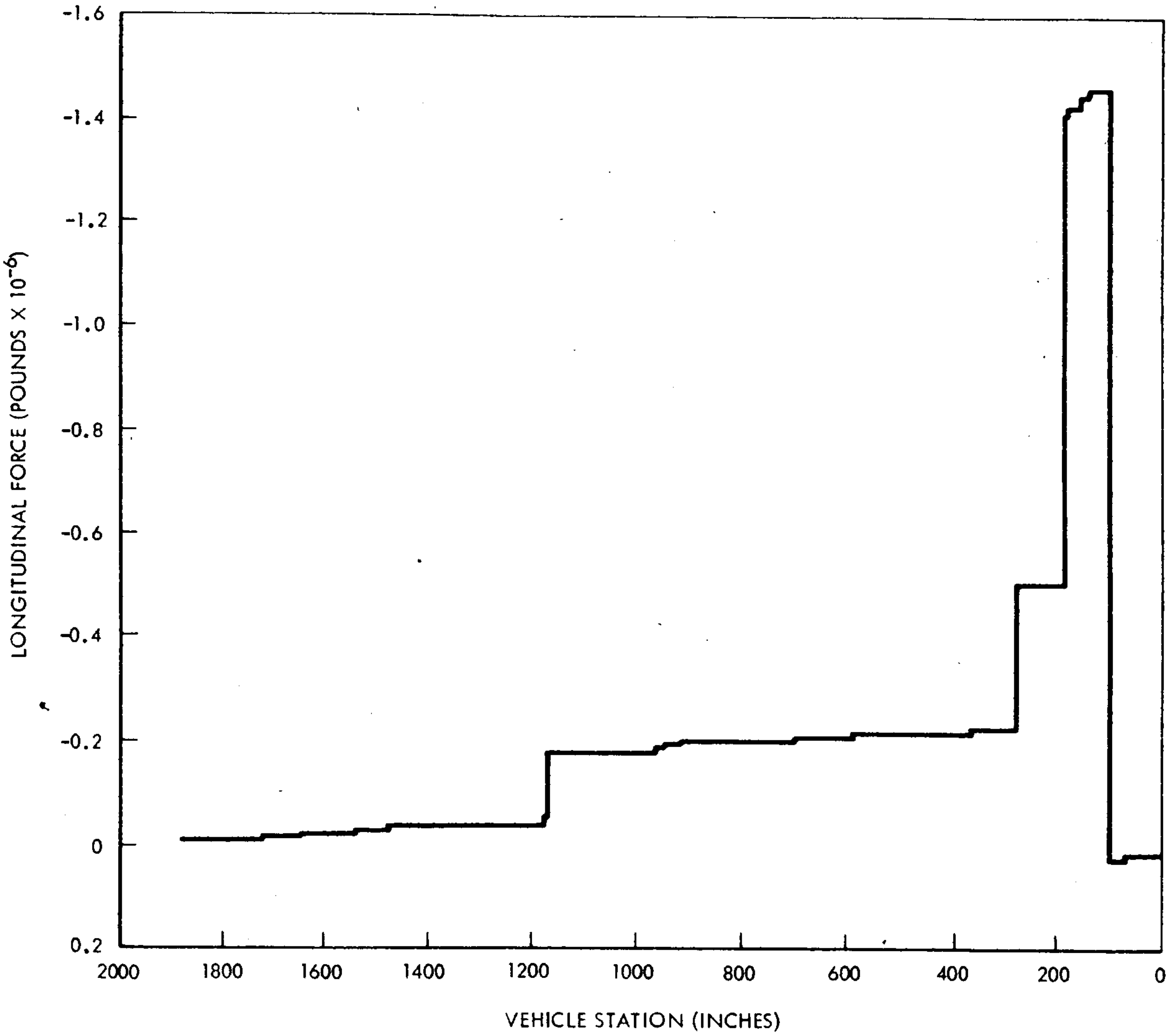


Figure 44. Longitudinal Force Versus Vehicle Station, Saturn C-1 Apollo (t = Liftoff)

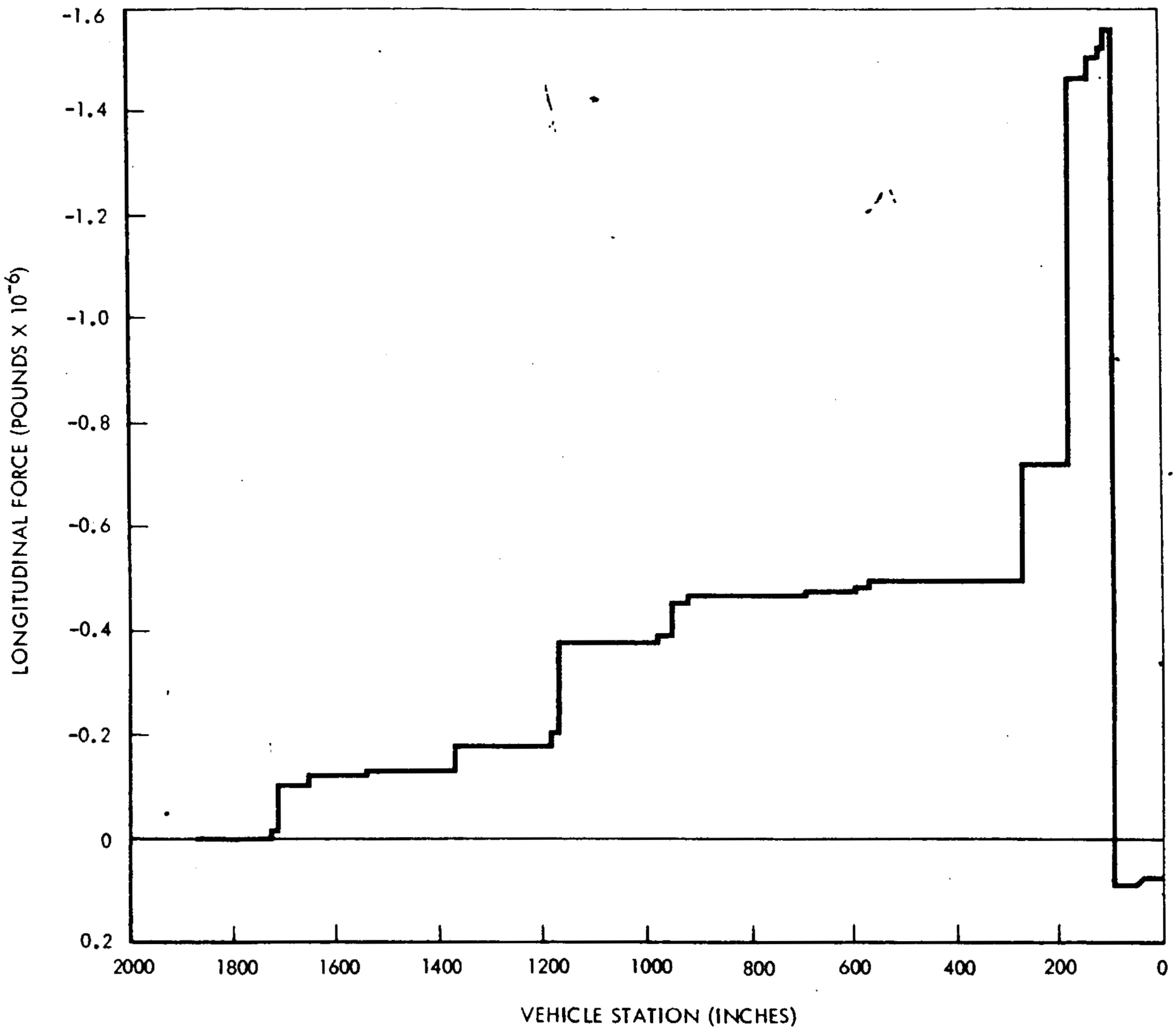


Figure 45. Longitudinal Force Versus Station, Saturn C-1 Apollo (t = 60 Seconds)

[redacted]

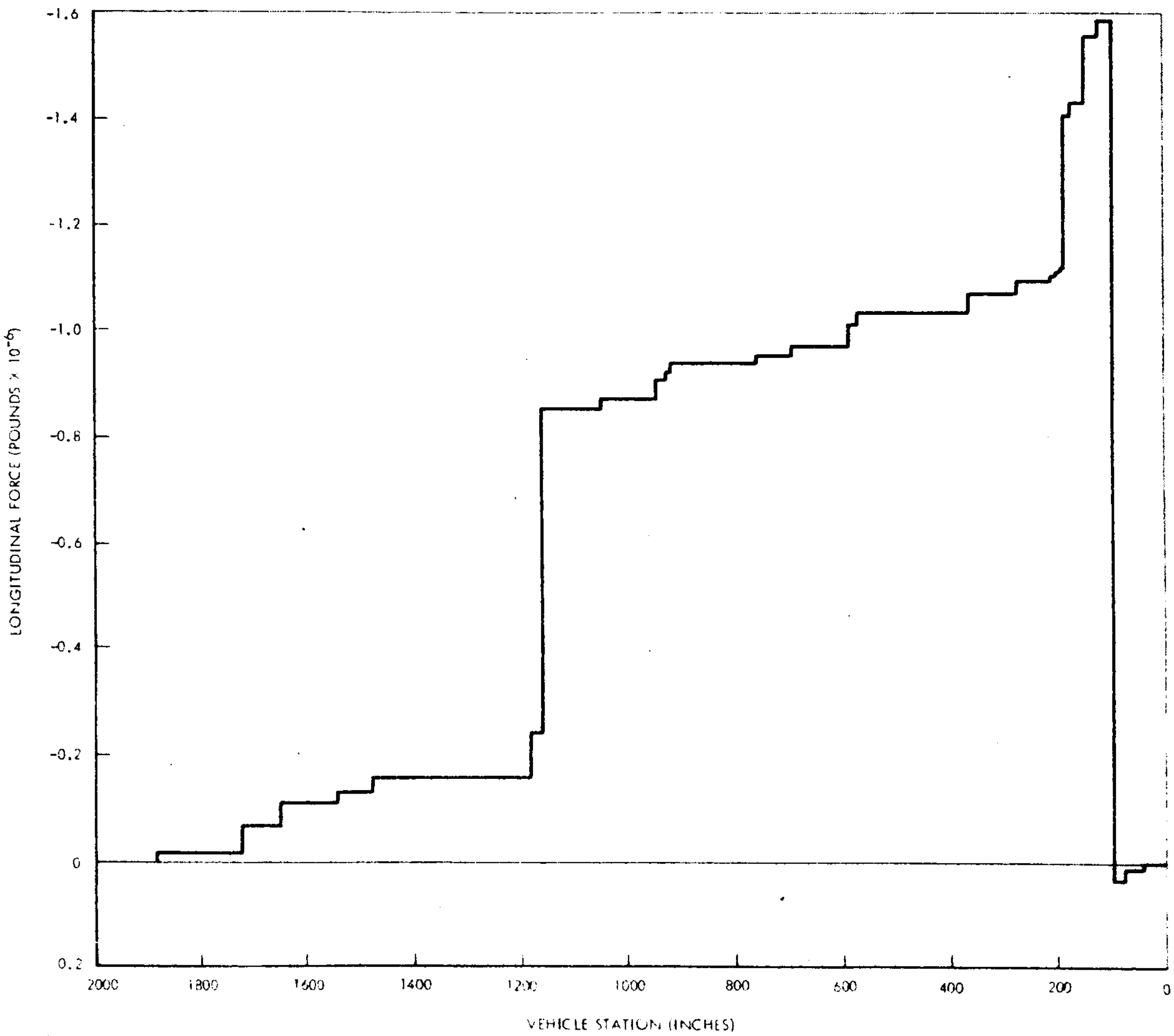


Figure 46. Longitudinal Force Versus Station, Saturn C-1 Apollo (t =141.4 Seconds)

[redacted]

~~CONFIDENTIAL~~

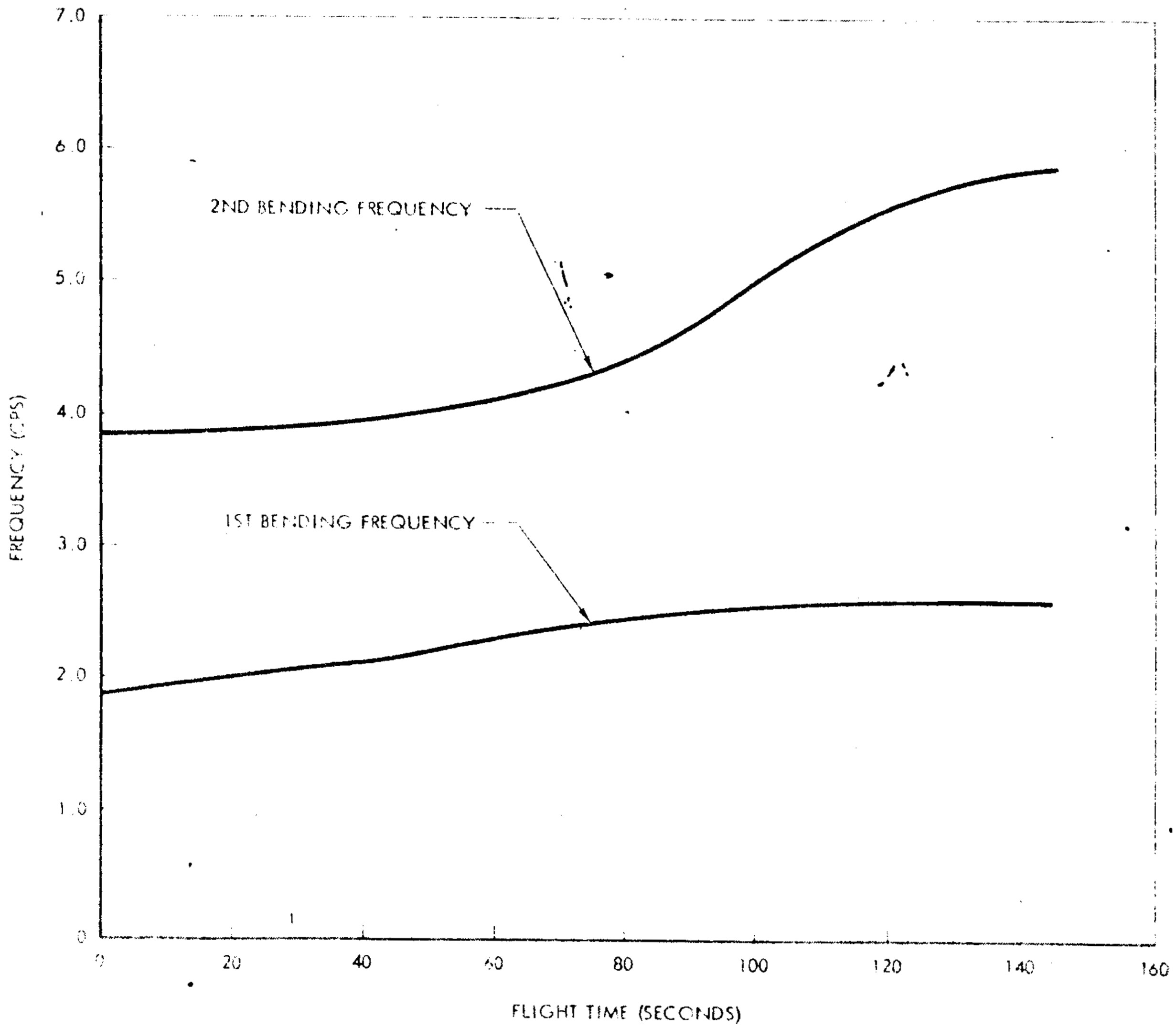


Figure 37. Saturn C-1 Apollo Space Vehicle Free-Free Frequency Versus Flight Time

[redacted]

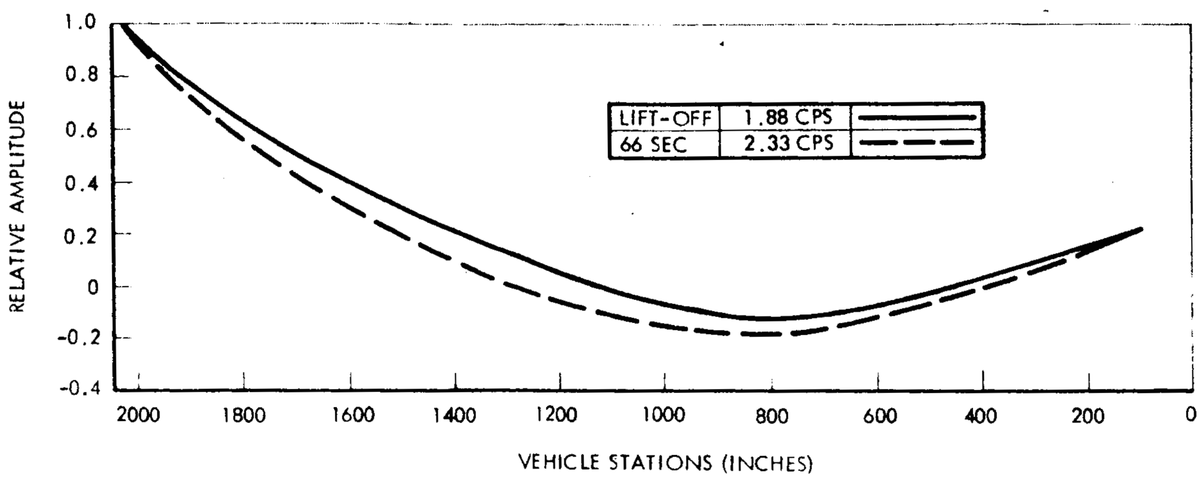


Figure 48. Saturn C-1 Apollo Space Vehicle Relative Amplitude Versus Vehicle Stations First Free-Free Bending Modes

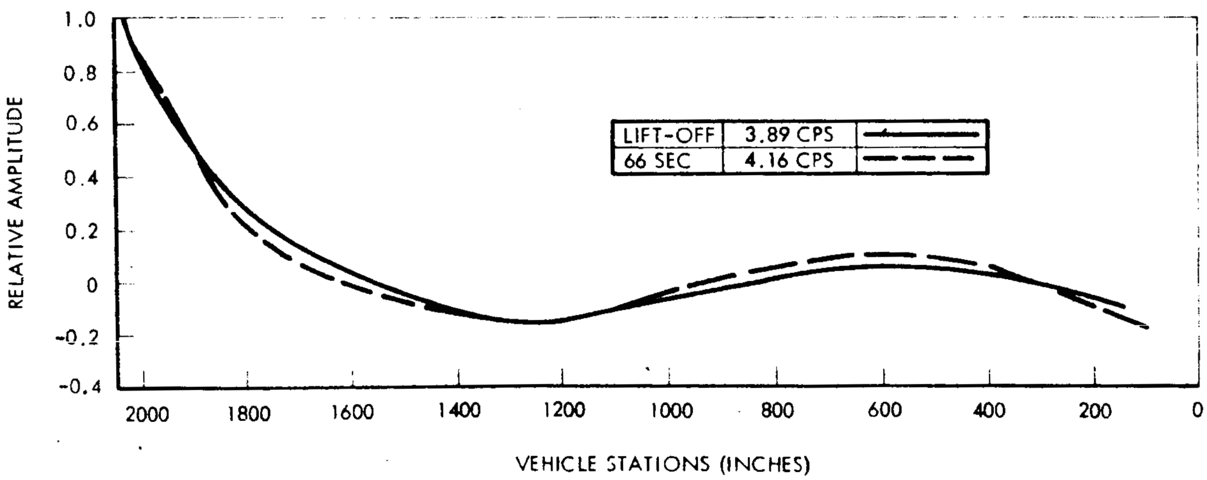


Figure 49. Saturn C-1 Apollo Space Vehicle Relative Amplitude Versus Vehicle Stations Second Free-Free Bending Modes

[redacted]

[redacted]

III. C-5 LAUNCH VEHICLE

OBJECTIVE

The primary purpose of the Saturn C-5 vehicle will be to provide the Apollo spacecraft with the necessary guidance and propulsion for circumlunar, circumlunar with lunar orbit, and lunar landing missions.

DESCRIPTION

The Saturn C-5 vehicle will be capable of performing a two-stage, low-orbit (primary) mission and a three-stage direct-escape (secondary) mission. For the primary mission, the C-5 configuration consists of an S-IC stage, an S-II stage, an Apollo spacecraft (command, service, and lunar landing modules) and a refueling tanker. The S-IVB is used as the third stage for the three-stage direct-escape mission. (See Figure 50.)

STAGE S-IC

The first stage (S-IC) will be powered by five F-1 engines developing a total thrust of 7.5 million pounds. Propellants for these engines will consist of RP-1 and LO_2.

S-IC/S-II INTERSTAGE SECTION

STAGE S-II

The second stage (S-II) will be powered by five J-2 engines developing a total thrust of 1 million pounds. Propellants for these engines will consist of LO_2 and LH_2. The S-II stage will be 396 inches in diameter.

S-II/S-IVB INTERSTAGE SECTION

STAGE S-IVB

The third stage (S-IVB) will be powered by one J-2 engine developing a total thrust of 200,000 pounds. Propellant for this engine will consist of

[redacted]

[redacted]

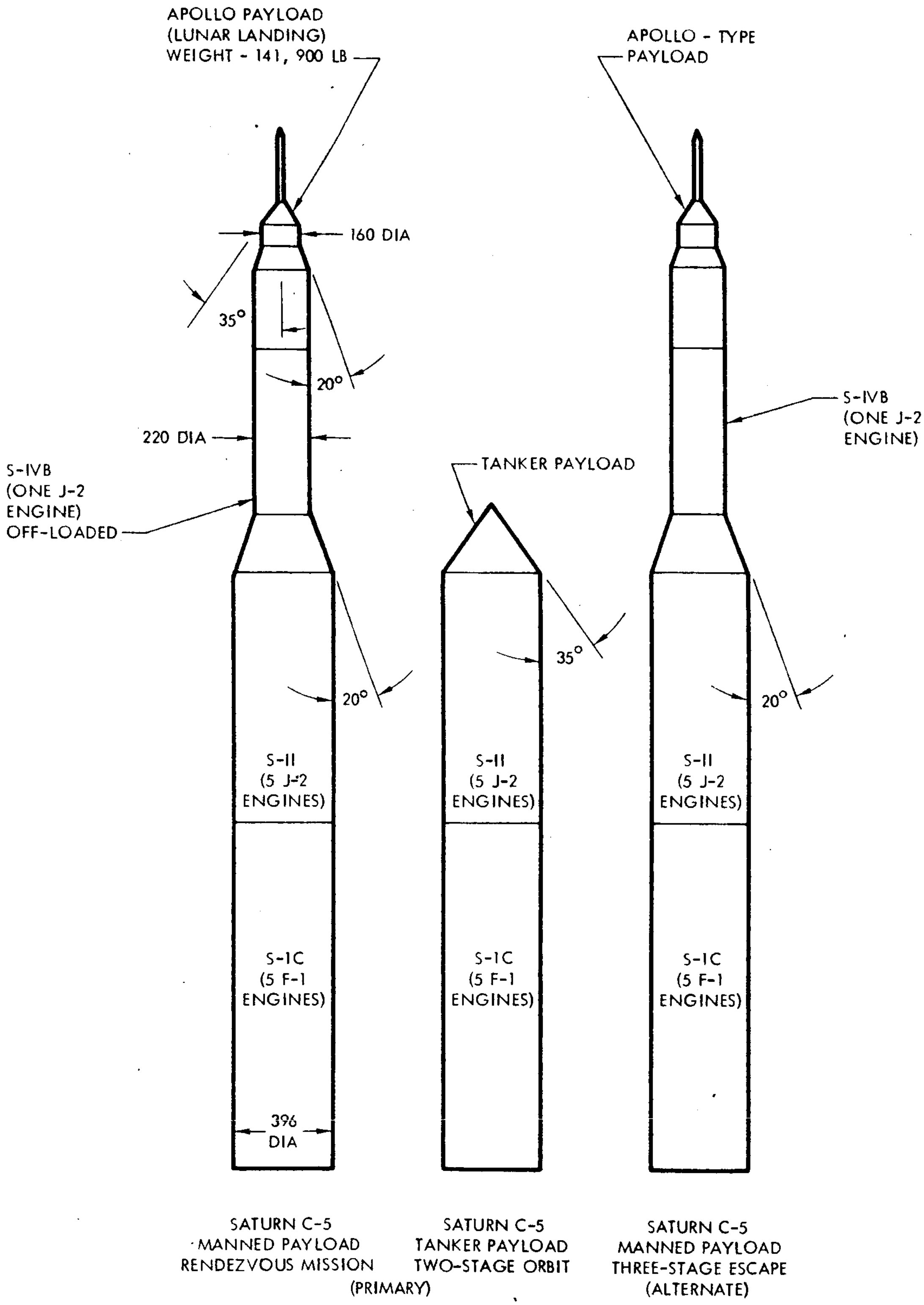


Figure 50. C-5 Vehicles

[redacted]

LO_2 and LH_2. The S-IVB stage is 220 inches in diameter, but a 260-inch diameter configuration is presently under study.

Instrument Unit

STAGING

PROPULSION

FIRST STAGE (S-IC)

Engines

The S-IC stage power plant will consist of five engines. Four outer engines will be mounted parallel to the centerline (zero cant angle) on a 364-inch circle and will be gimbaled for control. The fixed center engine will be mounted to the thrust structure on the centerline of the stage.

Propellants

The S-IC stage propellants will be RP-1 and LO_2. The fuel fill rate will be 2000 gallons per minute, and the LO_2 fill rate will be 10,000 gallons per minute. The propellant containers will have a capacity for 4,600,000 pounds of propellants.

Control System

The gimbal angle requirement (per engine model specification) is ±5 degrees (square pattern) of unrestricted control travel and 1 degree for snubbing, overtravel, misalignment, etc. The structural clearance for the gimbaling engines will be 7 degrees.

SECOND STAGE (S-II)

Engines

The four outer engines of the S-II will be mounted parallel to the stage centerline and will be equally spaced on a 210-inch circle. The fifth engine will be mounted on the stage centerline. Each S-II engine will be vertically aligned with the corresponding F-1 engine on the S-IC stage. Table 23 summarizes the estimated nominal performance characteristics of the S-II stage for the two-stage and three-stage missions.

Table 23. Nominal Performance Characteristics for Two-Stage Low-Orbit and Three-Stage Escape Missions

Item	Two-Stage Low-Orbit Mission, Two-Stage C-5 Configuration: Engine-Out	Two-Stage Low-Orbit Mission, Two-Stage C-5 Configuration: No Engine-Out	Three-Stage Escape Mission, Three-Stage C-5 Configuration: No Engine-Out
S-II propellant loading, lb	800, 000	1, 000, 000	800, 000
Initial conditions			
Velocity (m/sec)	2803	2410	2670
Altitude (km)	66.728	60.22	57.36
Dynamic pressure (kg/sq m)	58	100.3	169.0
*Flight path angle (deg)	68.47	66.31	72.28
(T - D)/W ratio	0.718	0.744	0.818
End-boost conditions			
Velocity (m/sec)	7391	7391	6836
Altitude (km)	185.2	185.2	120.60
*Flight path angle (deg)	90.0	90.0	90.67
(T - D)/W ratio	2.455	2.848	2.437
Mission payload weight (lb)***	218, 000	235, 720	94, 500
Specific impulse, vacuum (sec)	422	422	422
Thrust, vacuum (lb)	800, 000	1, 000, 000	1, 000, 000
**Nominal burning time (sec)	413	414	338
Reliability			
Mission		95.0	95.0
Systems		99.0	99.0
Manned rating		99.9	99.9

*Measured from local vertical.

**Maximum burning time 422 sec if 100 percent of reserve propellant is used for correction.

***LH_2 tank sized for actual propellant loading. At 800, 000-lb loading, scar weight is included for 1, 000, 000-lb propellant loading.

Propellants

The propellants used in the S-II stage will be LO_2 and LH_2. The propellant containers will have a capacity of 940,000 pounds.

Control System

The four outer engines will gimbal for control, and the fifth engine will be fixed. The gimbal angle requirement is ±7 degrees for control and 1/2 degree for snubbing, overtravel, misalignment, etc.

THIRD STAGE (S-IVB)

Engine

The single J-2 engine will be located on the centerline of the stage directly in line with the center engines of the S-IC and the S-II stages.

Propellants

The propellants used in the S-IVB stage will be LO_2 and LH_2. The propellant container will have a capacity of 100,000 pounds.

Control System

The engine will gimbal ±7 degrees for control and 1/2 degree for snubbing, overtravel, misalignment, etc.

INSTRUMENT UNIT

DESCRIPTION

EQUIPMENT

[redacted]

GUIDANCE AND CONTROL

DESCRIPTION

CONCEPT

INSTRUMENTATION

DESCRIPTION

MONITORING

<u>Crew</u>

<u>Mission Control Center</u>

MEASUREMENT LIST

<u>Mandatory</u>

<u>Optional</u>

TELEMETRY AND RADIO FREQUENCY

<u>Description</u>

<u>Frequencies</u>

ABORT SENSING AND DESTRUCT SYSTEMS

ABORT SENSING SYSTEM

DESTRUCT SYSTEM

[redacted]

INTERFACES

MECHANICAL

<u>Propellant</u>

<u>Hydraulic</u>

ELECTRICAL

<u>Instrumentation System</u>

<u>Guidance and Control System</u>

<u>Electrical Power Systems</u>

<u>Abort Sensing and Destruct Systems</u>

AERODYNAMICS

APOLLO SPACECRAFT/C-5 LAUNCH VEHICLE AERODYNAMIC DATA

CONTROL DYNAMICS

RIGID BODY CONTROL PRINCIPLES

ELASTIC BODY CONTROL

MISSION-TRAJECTORY/PAYLOAD CAPABILITIES

CIRCUMLUNAR

LUNAR ORBITAL

LUNAR LANDING

[redacted]

ENVIRONMENTAL PROFILES

ATMOSPHERIC

Physical Properties

Wind Profiles

ACCELERATION

VIBRATION

SHOCK

AERODYNAMIC PRESSURE

TEMPERATURE

ACOUSTIC NOISE

PHYSICAL CONFIGURATION

OVERALL DIMENSIONS

WEIGHT AND CENTER OF GRAVITY LOCATION

LIMITATIONS

SURFACE WIND VELOCITIES

WIND SHEAR

LAUNCH ANGLE (NOT APPLICABLE)

PAYLOAD

Weight

Center of Gravity Locations

[redacted]

IV. LAUNCH FACILITY CRITERIA

The Saturn C-1 vehicles will be launched from AMR Complexes 34 and 37 under the overall direction of the Marshall Space Flight Center Launch Operations Directorate. Technical responsibility for preparation of each stage, spacecraft, or section of the total space vehicle to a flight readiness condition rests with each individual contractor.

LAUNCH COMPLEX

Launch Complex 34 basically consists of the launch control center, one launch pad, one service structure, propellant storage facilities, and one long cable mast. Launch Complex 37 basically consists of the launch control center, two launch pads, one service structure, propellant storage facilities, and two permanent umbilical towers. Launch Complex 34 service structure is moved to and from the pad on rails. Complex 37 service structure is moved from one pad to the other on rails. Hoisting and erecting equipment, elevators, and work platforms are contained in both service structures. Launch Complex 34 will be modified to meet the requirement for launching Saturn C-1 vehicles. Wind shields are provided on the service structure of Complex 37. An overall plan view of Launch Complex 37 is illustrated in Figures 51 and 52.

LAUNCH TASK SEQUENCE

The preliminary major task sequence for the S-I stage and the S-IV stage is shown in Figure 53. Time values are considered nominal with the automatic sequence starting 2 minutes before time zero.

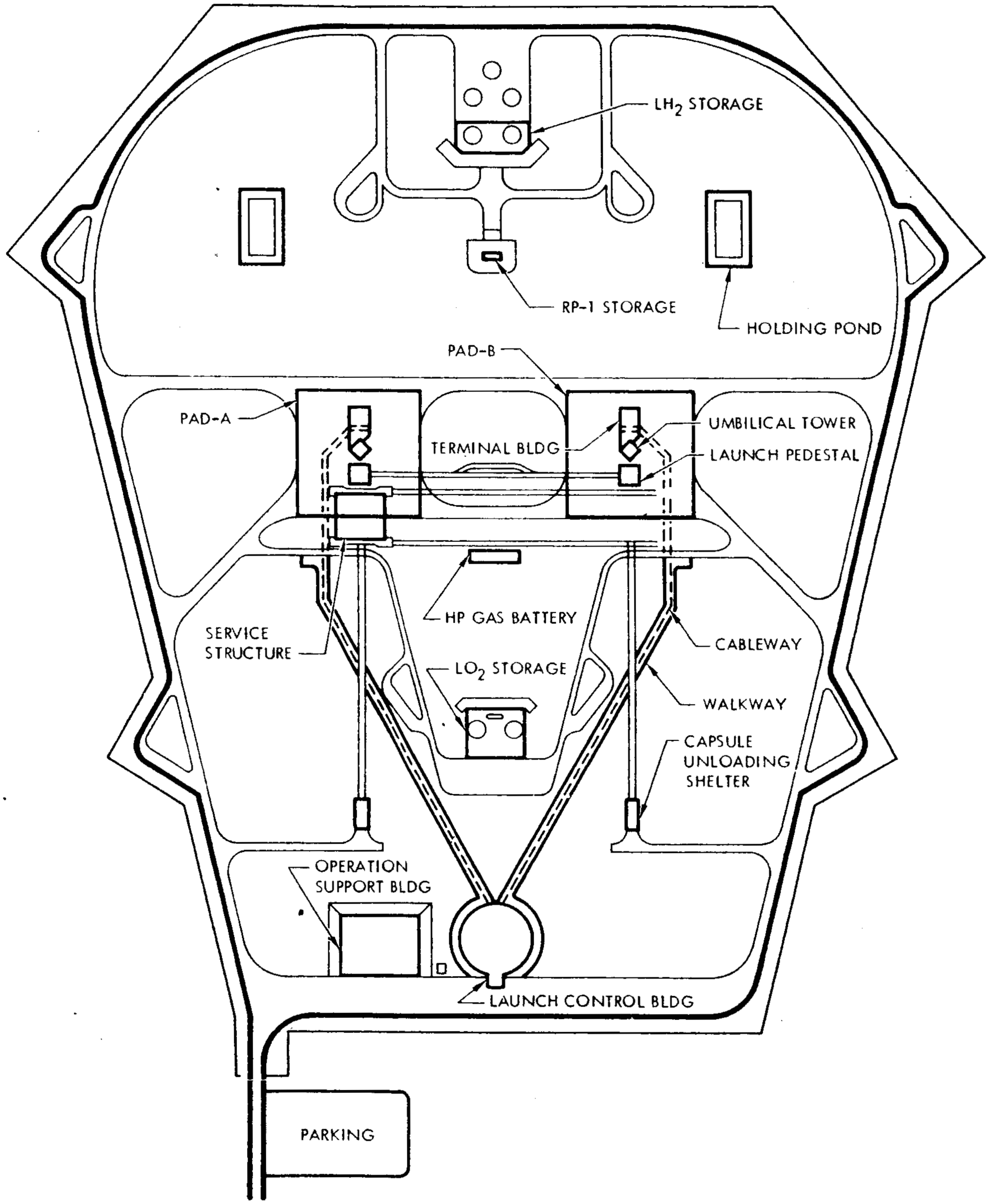


Figure 51. Saturn Facility II, Launch Complex 37

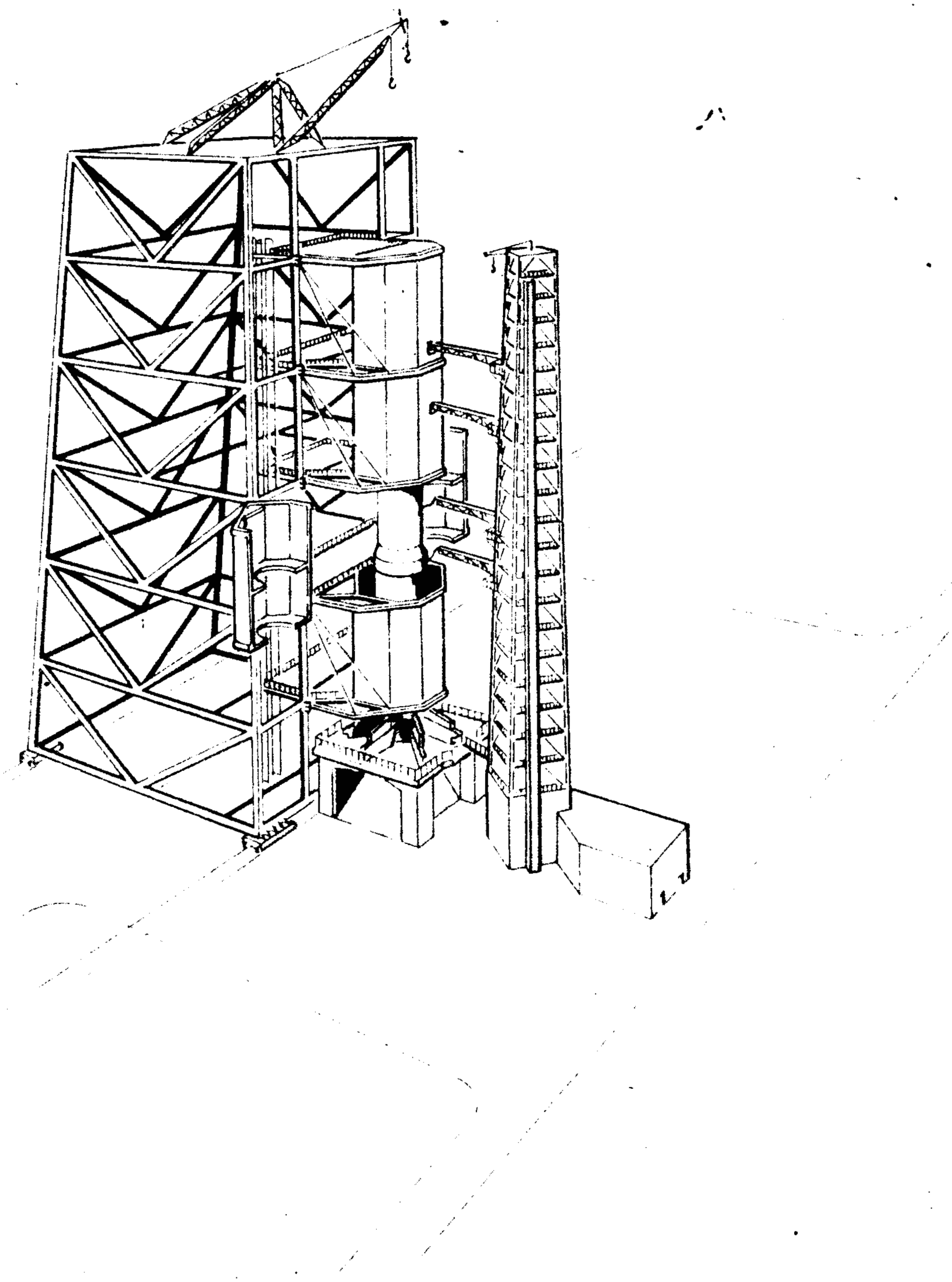


Figure 52. Concept of Service Tower Serving Two Pads

[redacted]

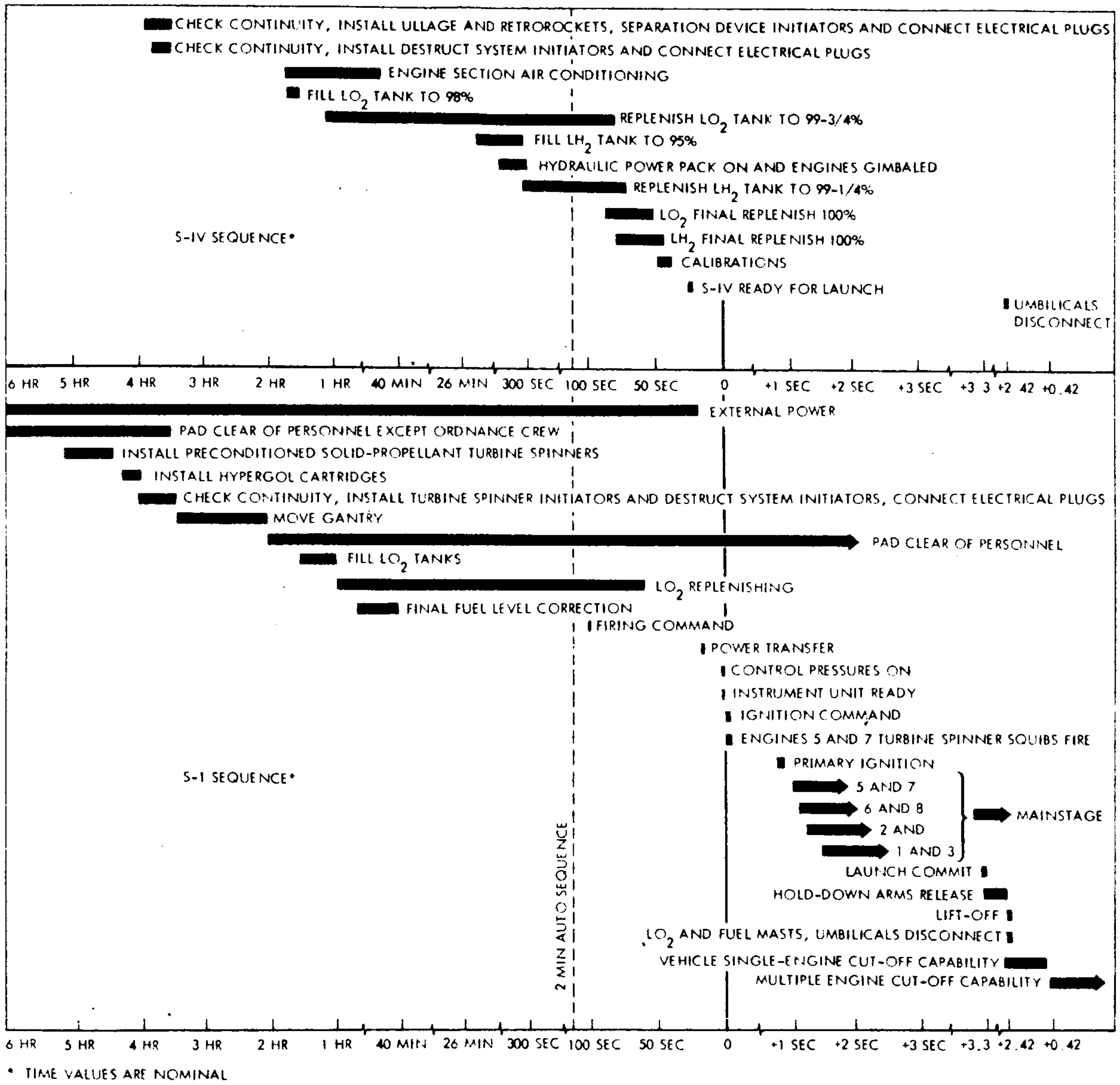


Figure 53. Saturn C-1 Major Task Sequence

[redacted]

APPENDIX

H-1 ENGINE PARAMETERS

H-1 engine parameters are shown in Table 2 and nominal thrust build-up is shown in Figure A-1. Thrust decay dispersion at altitude for H-1 engine is shown in Figure A-2.

RL10-A-3 ENGINE PARAMETERS

RL10-A-3 engine parameters are shown in Table 3. Estimated starting transient for RL10-A-3 engine is shown in Figure A-3 and estimated shutdown transient is shown in Figure A-4.

S-I STAGE RETROROCKETS PARAMETERS

S-I stage retrorocket parameters are shown in Table A-1. Typical mean altitude thrust time curve with limits for S-I stage retrorockets are shown in Figure A-5. Location of S-I stage retrorockets is shown in Figure A-6.

S-IV STAGE ULLAGE ROCKETS AND RETROROCKETS PARAMETERS

S-IV stage ullage rockets and retrorockets parameters are shown in Table 25 and thrust versus burning time is shown in Figure A-7.

Table A-1. Retrorocket Parameters

Length (overall)	64.28 in
Total weight (maximum)	500 lb
Total weight (nominal)	481 lb
Propellant weight (nominal)	327 lb
Time of burning (t_b at 60 F)	2.15 sec
Thrust (average during t_b at 250,000 ft)	37,000 lb
Total impulse	74,500 lb-sec
Propellant designation	ANP-512DS Mod 3
Flame temperature (adiabatic)	4600°F
Ignition	Exploding bridgewire (EBW)
Experimental specific impulse	224 lb-sec/lb
Theoretical specific impulse	232 lb-sec/lb

Table A-2. Rocket Parameters

Length (overall)	34.068 in
Total weight (approximate)	85.61 lb
Propellant weight	59.4 lb
Time of burning (nominal t_b at 100,000 ft and 70 F)	3.776 sec
Thrust (average during t_b at 100,000 ft and 70 F)	3450 lb/rocket
Total impulse (at 100,000 ft and 70 F)	14,570 lb-sec
Specific impulse (at 100,000 ft and 70 F)	225 lb-sec/lb
Nozzle expansion ratio	20.6:1
Nozzle expansion cone configuration	Bell

[redacted]

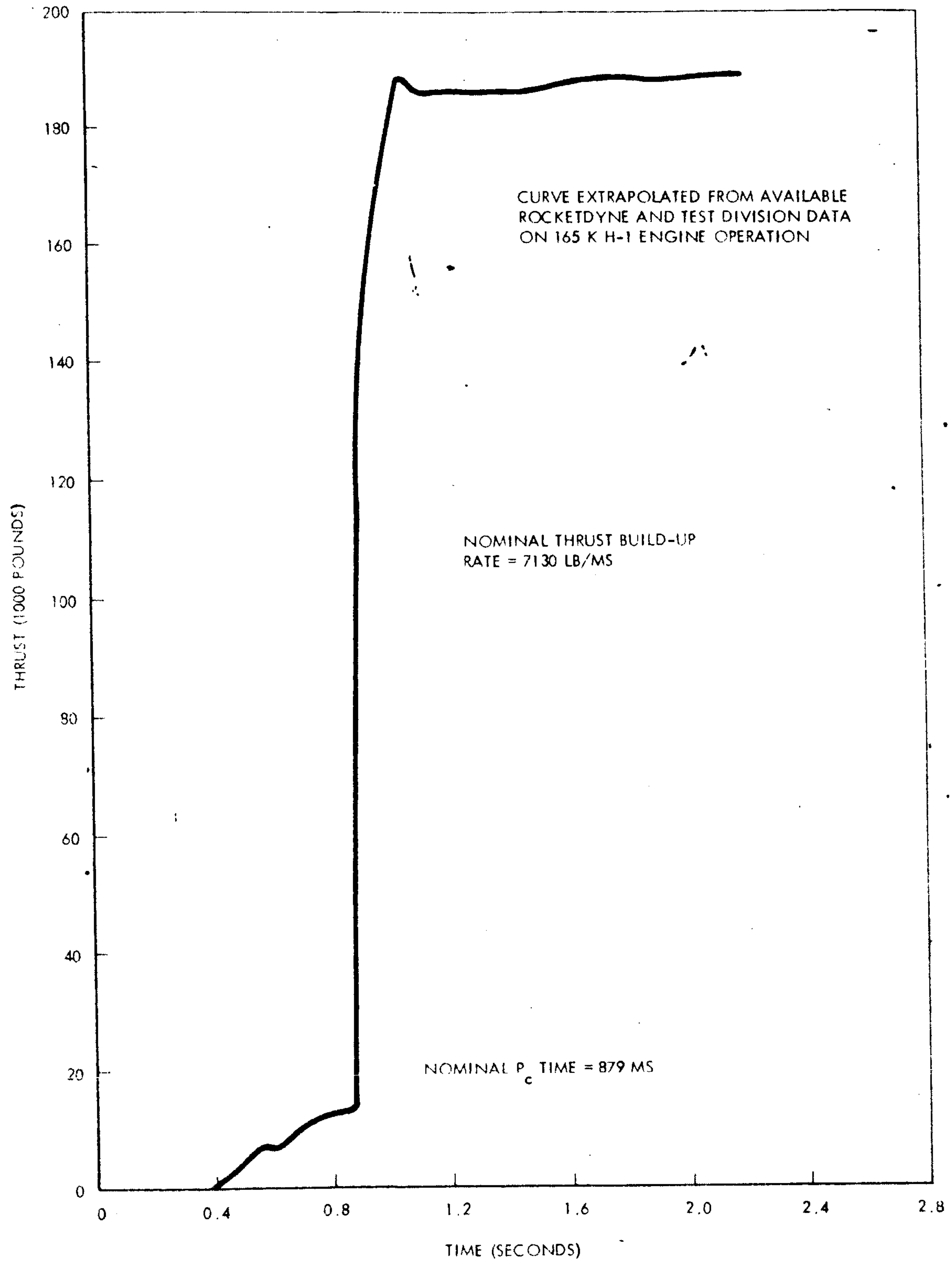


Figure A-1. Nominal Thrust Build-up for 188 K H-1 Engine

[redacted]

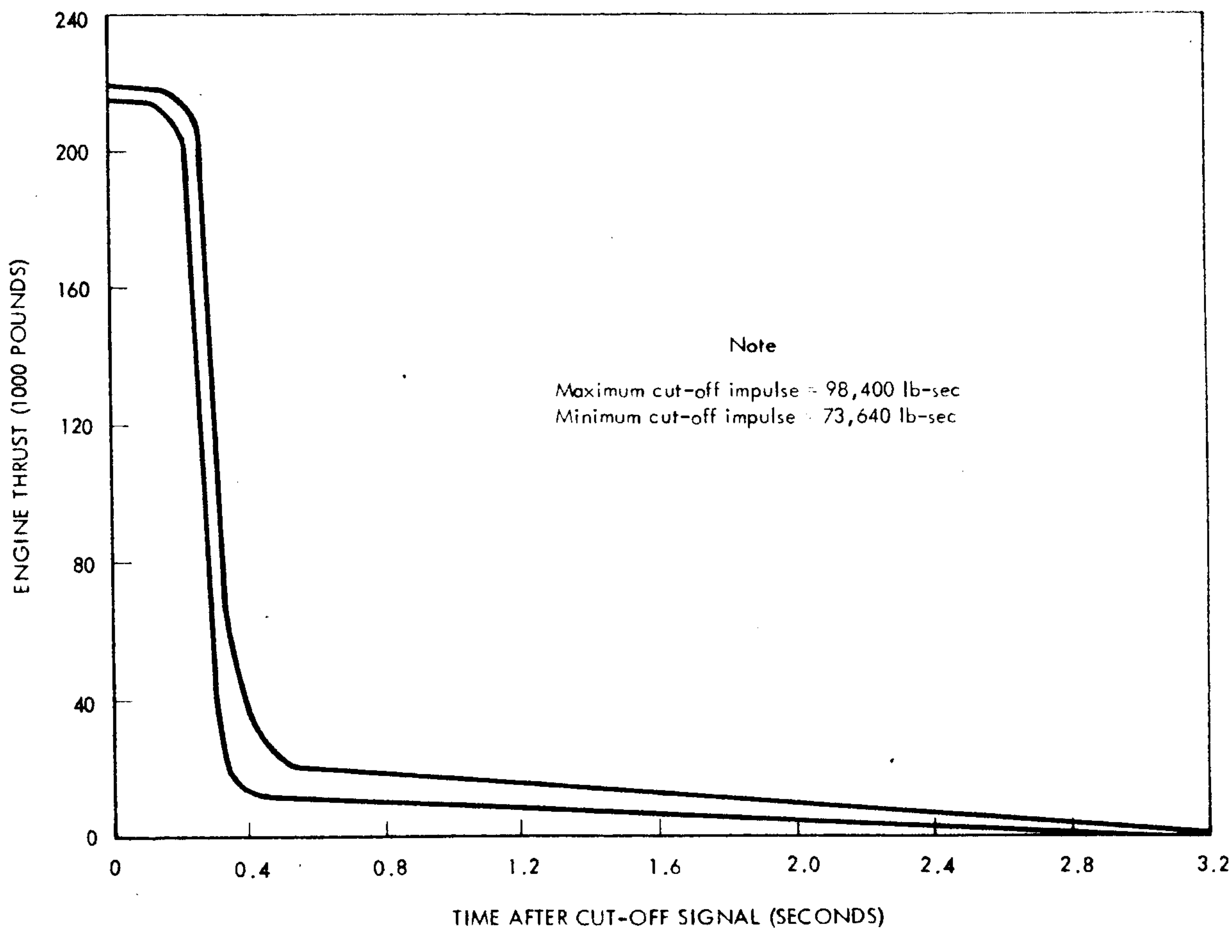


Figure A-2. Thrust Decay Dispersion at Altitude for 188 K H-1 Engine (Based on Saturn SA-1 Flight Test Data)

~~CONFIDENTIAL~~

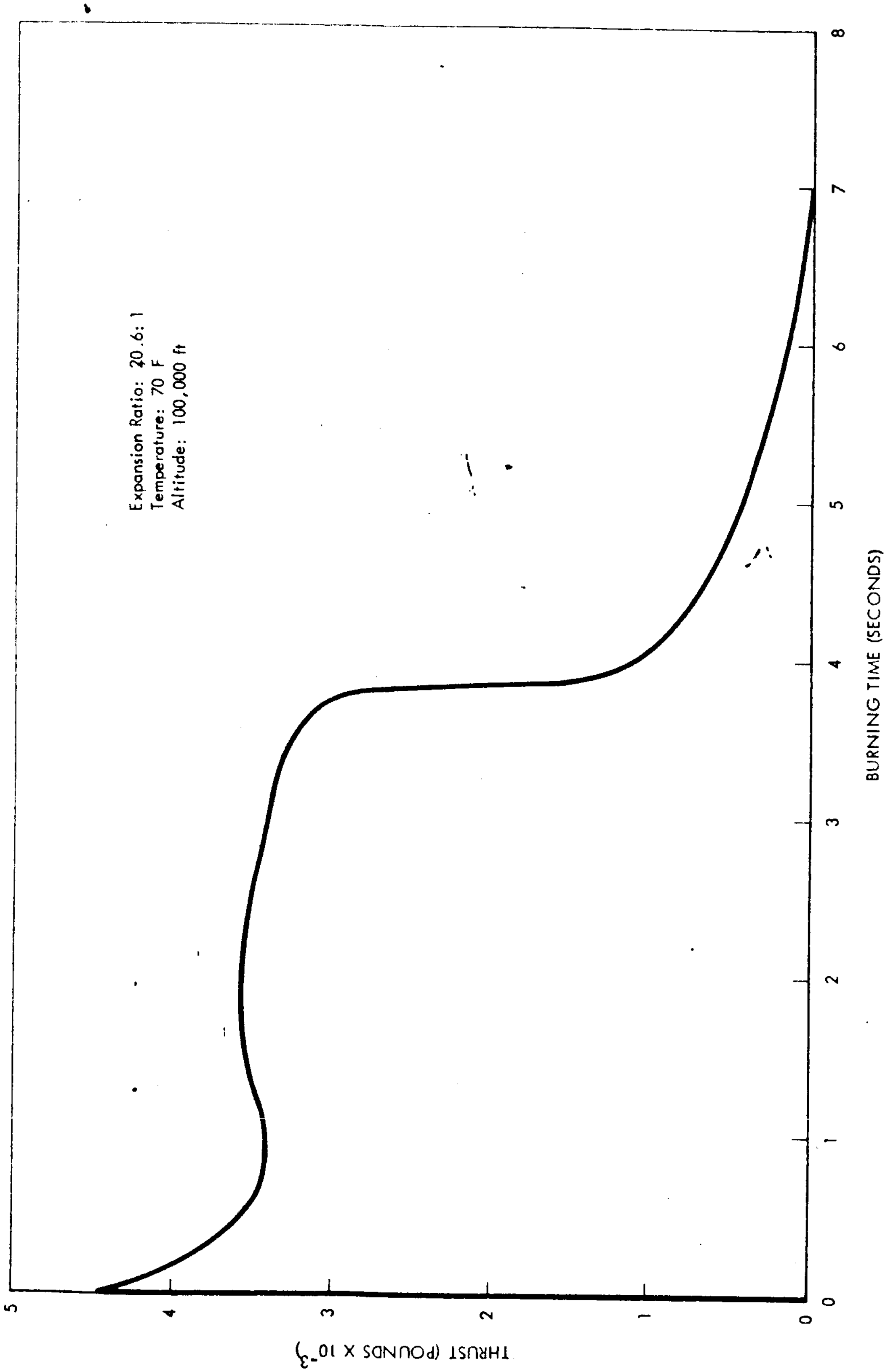


Figure A-3. Estimated Starting Transient for RL10-A-3 Engine (At 100,000-Foot Altitude)

~~CONFIDENTIAL~~

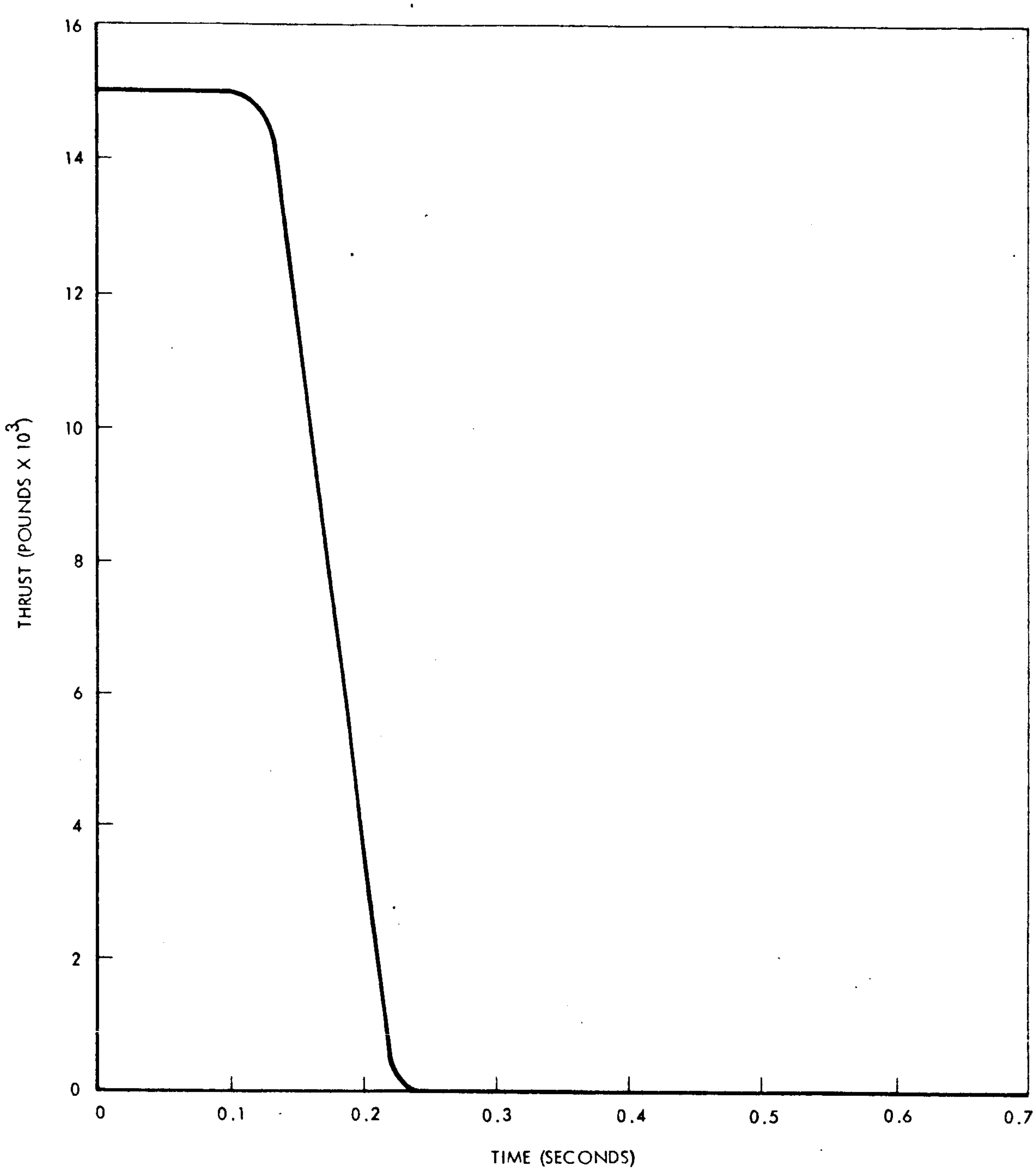


Figure A-4. Estimated Shut-Down Transient for the RL10-A-3 Engine (At 200,000-Foot Altitude)

[redacted]

[redacted]

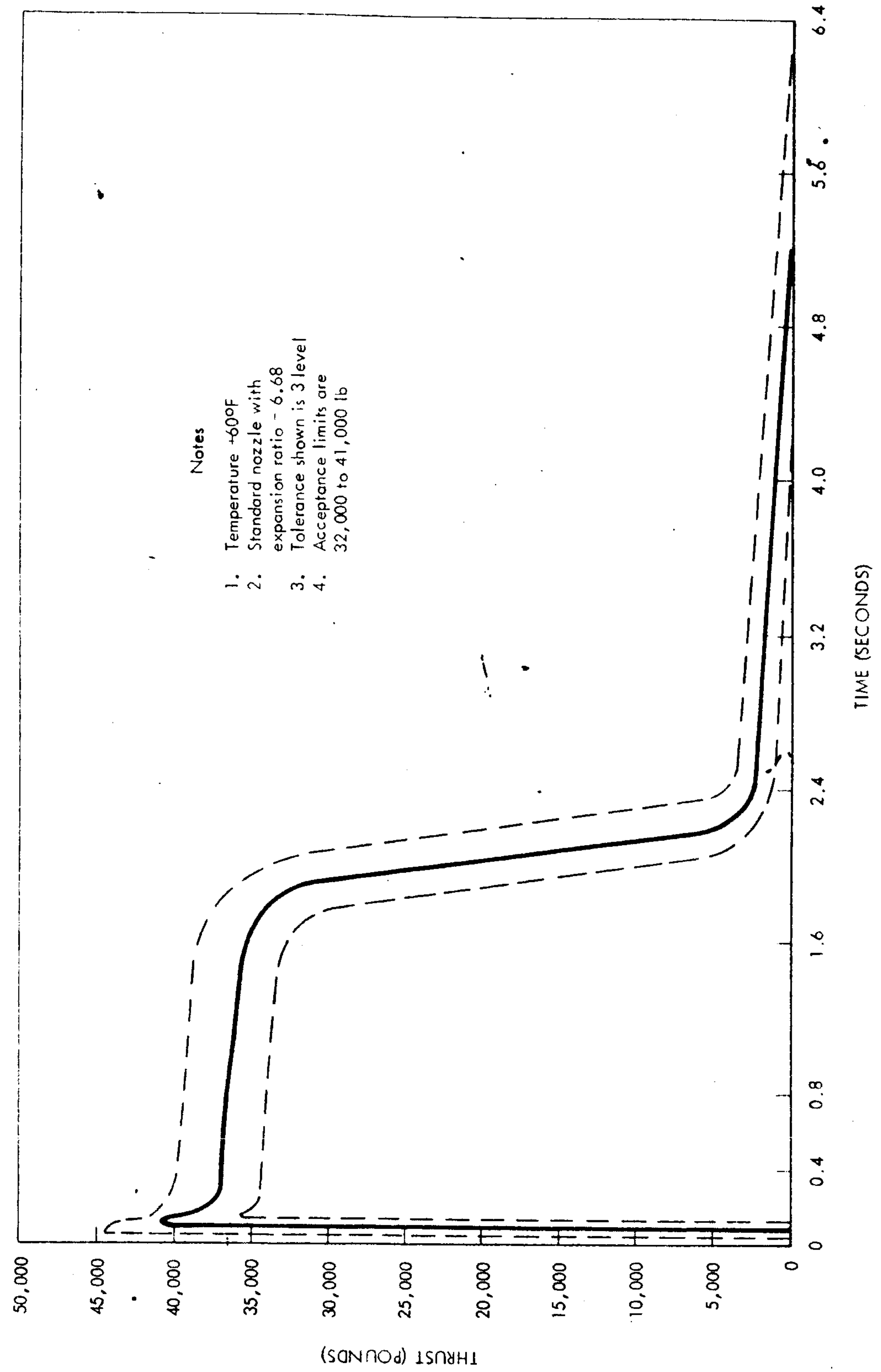
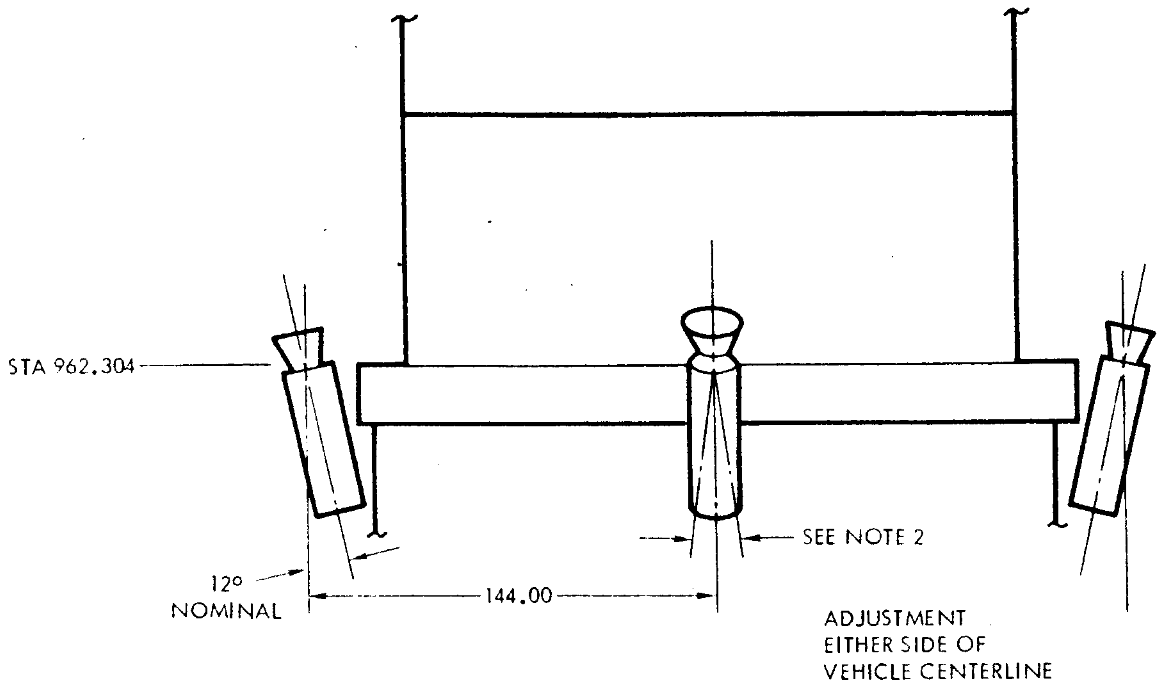


Figure A-5. Typical Mean Altitude Thrust Time Curve With Limits for 2 KS 36,250 Rocket Motor

[redacted]

[redacted]



Notes

1. Retrorockets are located 45° from the fin positions
2. Alignment tolerances are being developed

Figure A-6. Location of S-I Stage Retrorockets

[redacted]

[redacted]

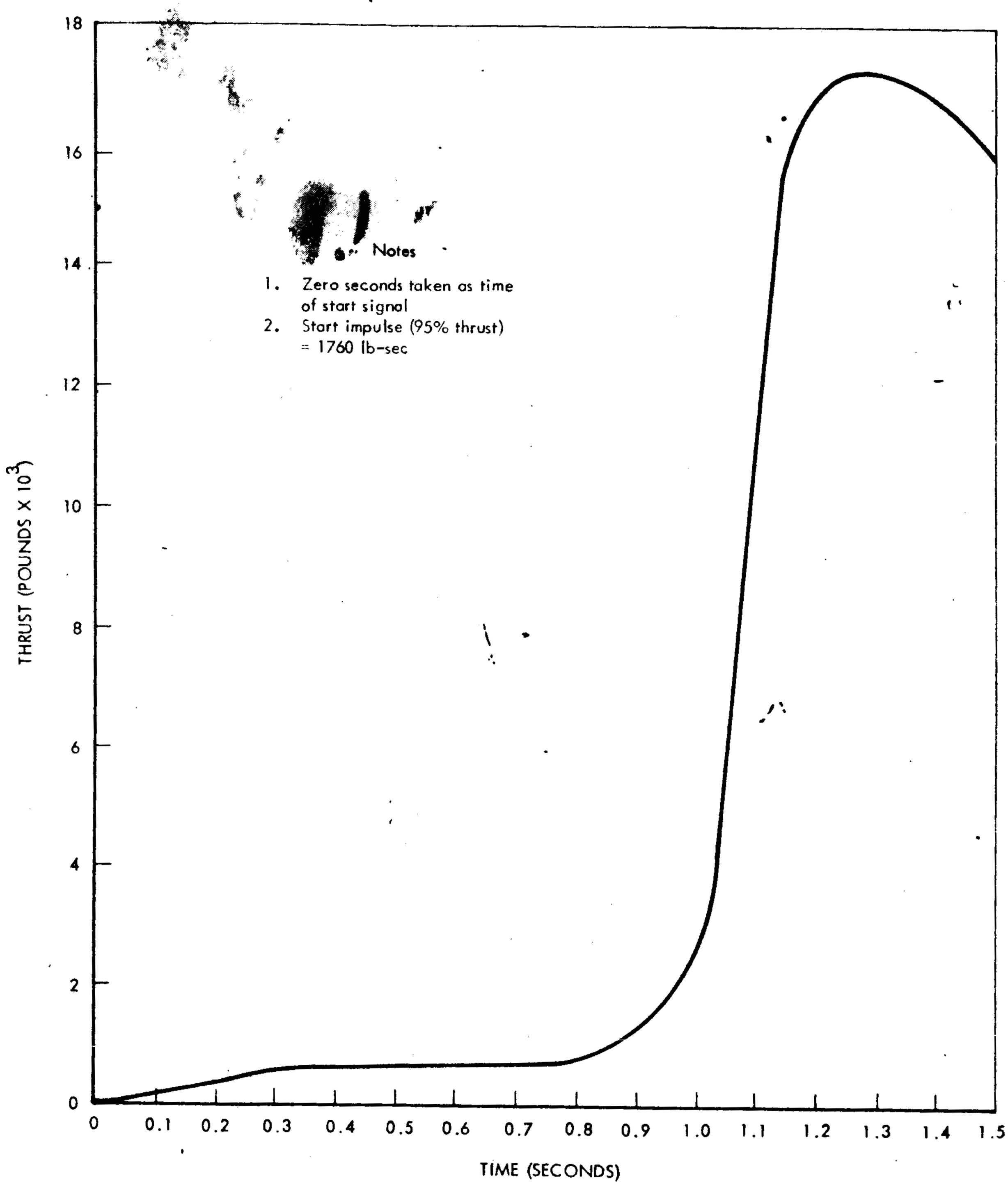


Figure A-7. Thrust Versus Burning Time, Thiokol TX-280 Solid-Propellant Rocket Motors

[redacted]

Table 6. Condensed Instrument Unit Measurement List

Parameter	Range
Q Ball, Internal Temperature	0 to 150 C
Total temperature	0 to 800 C
Wall temperature, density gage	0 to 100 C
Air temperature, density gage	0 to 100 C
Gas nitrogen manifold temperature	-50 to +50 C
Azusa temperature, internal	10 to 65 C
Instrument compartment pressure	0 to 20 psia
Air bearing supply ST-90 pressure	0 to 60 psid
Control equipment pressure, supply	0 to 3500 psi
Control equipment pressure, regulator	0 to 800 psia
Dynamic pressure (Q)	5 to 750 PSF
Q ball, Differential pressure, pitch	±5 psi
Q ball, Differential pressure, yaw	±5 psi
Differential pressure, Q compensation	15 psi
Pressure instrument compartment	0 to 20 psia
ST-90, Y Axis Vibration	±3 g
Instrument Panel, Lateral Vibration	±5 g
Lower Support, Longitudinal Vibration	±20 g
Instrument Panel, Pitch Vibration	±3 g
Angular Velocity, Pitch	±10 deg/sec
Angular Velocity, Yaw	±10 deg/sec
Longitudinal acceleration	0 to 5 g
Longitudinal coarse acceleration	0 to 5 g
Longitudinal acceleration	±1 g
Pitch control acceleration	±5 m/sec sq
Yaw control acceleration	±5 m/sec sq
Pitch control angular velocity	±10 deg/sec
Yaw control angular velocity	±10 deg/sec
Roll control angular velocity	±10 deg/sec
Local angle-of-attack	±10 deg.