

Zelazak

DESIGN REPORT FOR RL10A-3-1 ROCKET ENGINE

CONTRACT NO. NAS8-5623



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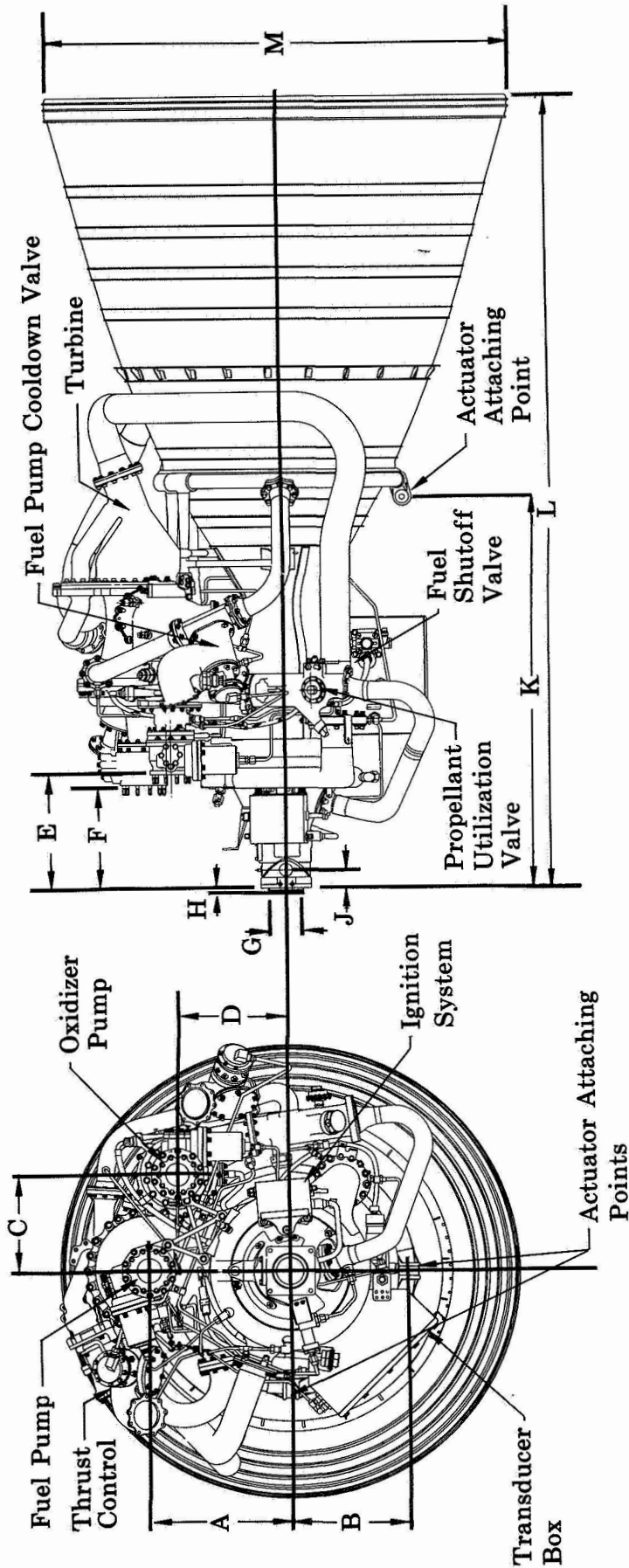
Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION

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SECTION II
INSTALLATION DRAWING

The installation drawing of the RL10A-3-1 engine assembly is shown in figure II-1.



A — 11.750	D — 9.419	G — 2.876	K — 32.874
B — 10.172	E — 9.603	H — 0.240	L — 67.485
C — 8.128	F — 8.738	J — 1.500	M — 38.668

Dimensions are Nominal in Inches at Room Temperature

FD 8895

Figure II-1. Engine Installation

SECTION III
ASSEMBLY DRAWING

The assembly drawing for the RL10A-3-1 engine assembly is shown in figure III-1.

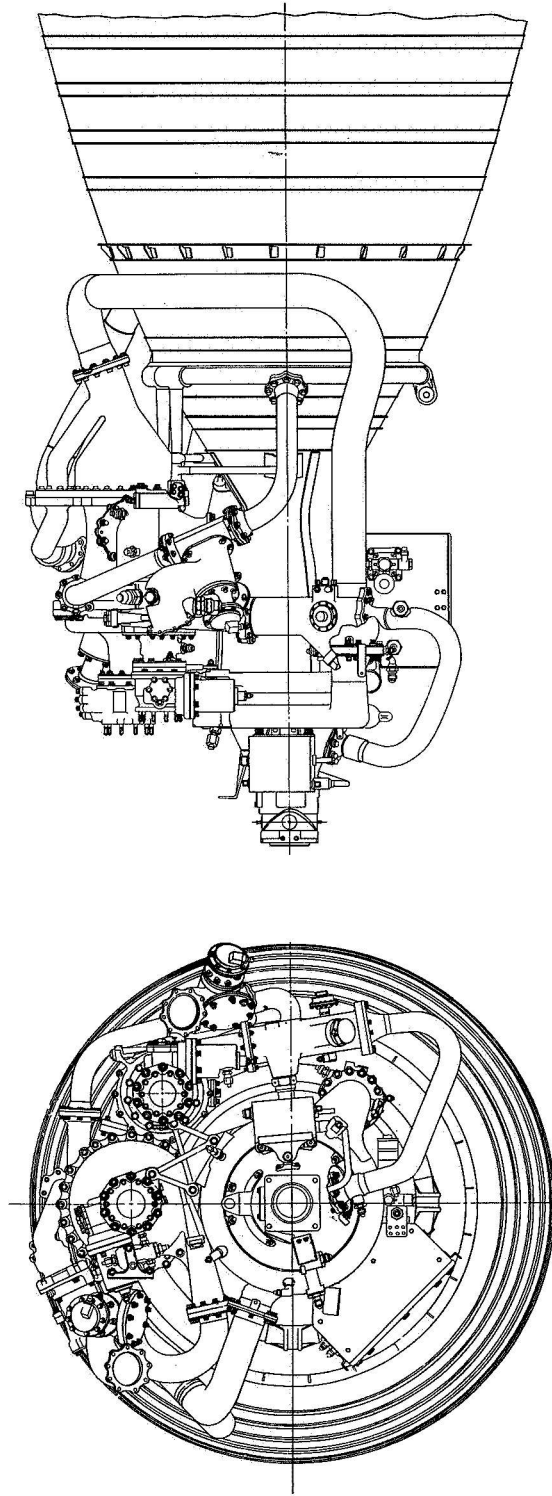


Figure III-1. RL10A-3-1 Engine Assembly

SECTION IV
WEIGHT BREAKDOWN

The weight breakdown of the RL10A-3-1 engine assembly is shown in table IV-1.

Table IV-1. RL10A-3-1 Assembly Weight Breakdown

Component	Weight, lb
Injector Assembly	13.88
Thrust Chamber	101.30
Turbopump	75.39
Turbopump Mounts	3.64
Engine Mount	11.15
Ignition System	6.30
Oxidizer Inlet Shutoff Valve	5.62
Fuel Inlet Shutoff Valve	5.89
Oxidizer Flow Control Valve	6.85
Fuel Cooldown Valve Interstage	8.20
Fuel Cooldown Valve Downstream	7.39
Thrust Control Valve	5.37
Main Fuel Shutoff Valve	4.21
Solenoid Valves	7.93
Oxidizer Flow Control Valve to Injector	2.56
Fuel Pump to Downstream Cooldown Valve	1.27
Downstream Cooldown Valve to Thrust Chamber	1.50
Thrust Chamber to Turbine	6.45
Turbine to Main Fuel Shutoff Valve	6.16
Small Lines	2.81
Connecting and Miscellaneous Hardware	6.97
 TOTAL CHARGEABLE WEIGHTS	 290.84
 Instrumentation	 13.30
Hydraulic Line Brackets	1.92
 TOTAL ENGINE WEIGHT	 306.06

SECTION V
ANALYSIS OF STEADY-STATE AND TRANSIENT PERFORMANCE

A. STEADY-STATE PERFORMANCE

The steady-state performance characteristics of the RL10A-3-1 engine are given in table V-1.

Table V-1. Estimated RL10A-3-1 Centaur Engine Design Data

Parameter	Ratings			
Mixture ratio	4.4	5.0	5.6	
Altitude, ft	200,000	200,000	200,000	
Thrust, lb	14,689	15,000	15,253	
Nominal specific impulse, sec	436.8	433.0	427.6	
Fuel flow, lb/sec	6.23	5.77	5.40	
Oxidizer flow, lb/sec	27.40	28.86	30.27	
Chamber pressure (throat total), psia	289.1	291.6	293.1	
Chamber pressure (injector face static), psia	298.9	301.8	303.5	
Oxidizer Pump				
Inlet pressure (total), psia	59.8	59.8	59.8	
Inlet temperature, °R	176.6	176.6	176.6	
Inlet density, lb/ft ³	69.0	69.0	69.0	
Flow rate, gpm	178.3	189.7	196.8	
Head rise, ft	894	869	841	
Speed, rpm	11,497	11,327	11,165	
Efficiency, percent	59.8	59.5	58.9	
Horsepower	74.4	76.5	78.4	
Discharge pressure, psia	488	476	463	
Specific speed	938	970	1003	
Fuel Pump	Mixture Ratio	4.4	5.0	5.6
Inlet pressure (total), psia		38.4	38.4	38.4
Inlet temperature, °R		38.8	38.8	38.8
Inlet density, lb/ft ³		4.34	4.34	4.34
Discharge density, lb/ft ³		4.190	4.182	4.169
Flow rate		644.7	597.4	559.1
Fuel leakage, lb/sec		.09	.09	.09
Head rise, ft		30,888	30,222	29,583
Speed, rpm		28,742	28,317	27,912
Efficiency, percent		56.5	55.4	54.18
Horsepower		585	539	503
Discharge pressure, psia		949	926	903
Specific speed (per stage)		526	507	492

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PWA FR-1042

Turbine	Mixture Ratio	4.4	5.0	5.6
Inlet total pressure, psia		676	652	633
Inlet total temperature, °R		288.6	323.8	355.6
Discharge static pressure, psia		420	420	419
Downstream total pressure, psia		387	387	385
Speed, rpm		28,742	28,317	27,912
Efficiency, percent		58.7	58.8	58.7
Horsepower		664	620	586
Turbine flow, lb/sec		6.12	5.47	5.01
Percent bypass flow		0.17	3.61	5.62
Effective area, in ²		1.125	1.125	1.125
Thrust control bypass area, in ²		0.0019	0.0422	0.0669

Thrust Chamber Assembly

Chamber pressure (injector static), psia		298.9	301.8	303.5
Chamber pressure, (throat total), psia		289.1	291.6	293.1
Fuel flow, lb/sec		6.14	5.68	5.31
Oxidizer flow, lb/sec		27.40	28.86	30.27
Chamber mixture ratio		4.46	5.08	5.70
C* efficiency, percent of shifting		98.9	98.5	98.0
C* (actual), ft/sec		7,810	7,640	7,460
Combustion temperature (ideal), °R		5,550	5,810	6,000
Gas constant (ideal), ft/°R		143.3	130.7	120.8
Specific heat ratio		1.216	1.210	1.206
C _s (thrust coefficient efficiency), percent		97.59	97.25	96.90
Characteristic length (L*), in.		31.6	31.6	31.6
Chamber area (injector end), in ²		83.4	83.4	83.4
Chamber throat area, in ²		28.1	28.1	28.1
Effective expansion ratio, A/A*		40.0	40.0	40.0

Pressure Drop Summary

Fuel

Pump pressure rise, psid		910	887	864
Downstream orifice, psid		92.9	80	70.2
Cooldown valve, psid		.39	.34	.29
Liquid line, psid		4.1	3.5	3.1
Jacket, psid		146.9	149.8	149.4
Gas line upstream venturi, psid		3.3	3.2	3.2
Venturi, psid		24.6	36.6	43.6
Turbine (total to static), psid		256	232	214
Turbine discharge casing (total to static), psid		33.6	33.6	33.5
Gas line, turbine discharge to main fuel shutoff valve, psid		16.2	15.8	15.2
Main fuel shutoff valve, psid		11.0	10.7	10.3
Injector, psid		60.3	58.4	56.3

Oxidizer

Pump pressure rise, psid	428	416	403
Mixture ratio control valve, psid	139.5	117.4	94.8
Liquid line, psid	5.6	6.2	6.8
Injector, psid	44.0	50.6	57.5

Temperature Rise Summary

Fuel

Pump rise, °R	16.3	16.4	16.5
Jacket, °R	233.5	268.7	300.3
Turbine, °R	-19.9	-20.4	-21.1

Oxidizer

Pump rise, °R	2.8	2.7	2.6
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B. TRANSIENT PERFORMANCE

The transient performance characteristics of the RL10A-3-1 engine are shown in figures V-1 through V-3.

C. SEQUENCE OF ENGINE OPERATION

The design sequence of operation for the RL10A-3-1 engine is shown in figure V-4.

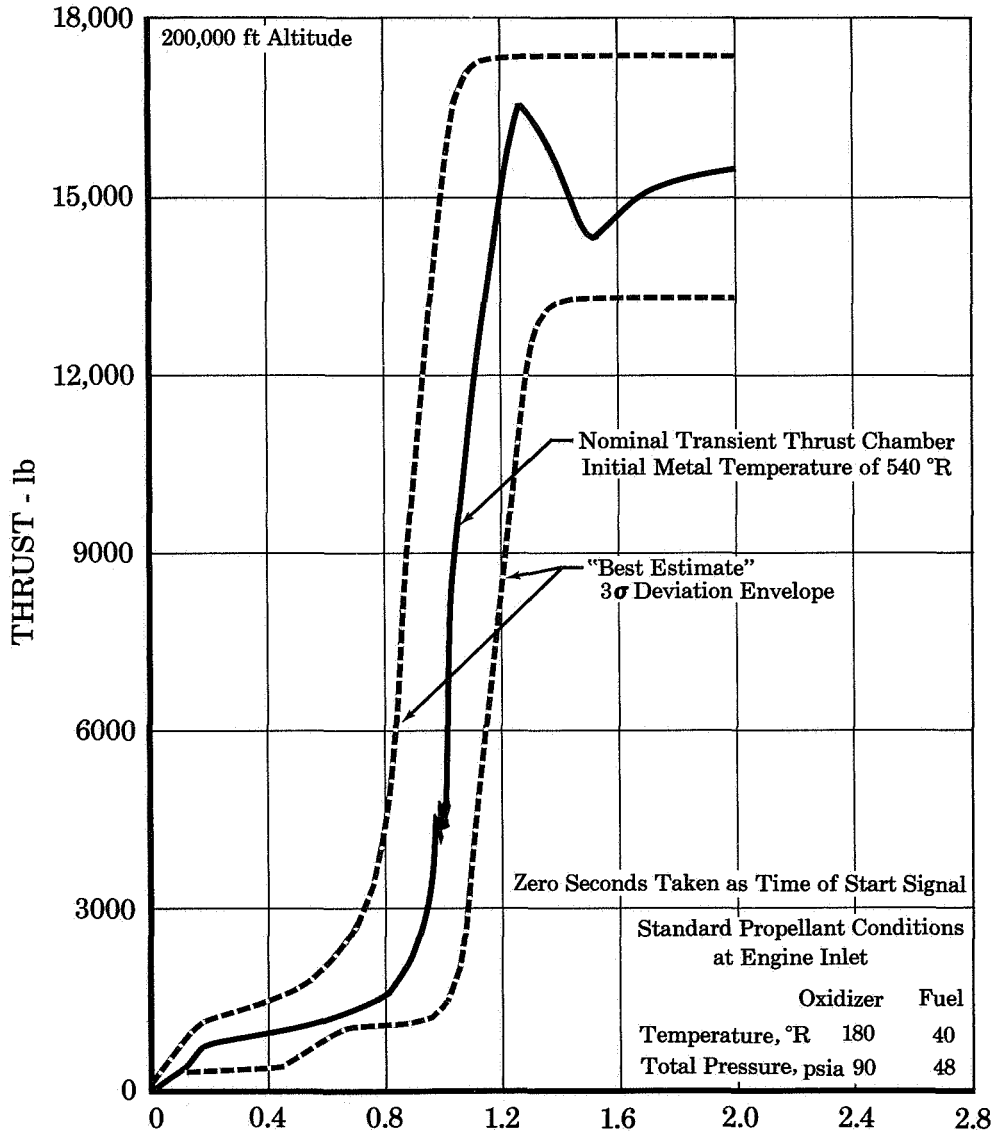


Figure V-1. Estimated Starting Transient Showing "Best Estimate" 3σ Deviation Envelope

FD 8876

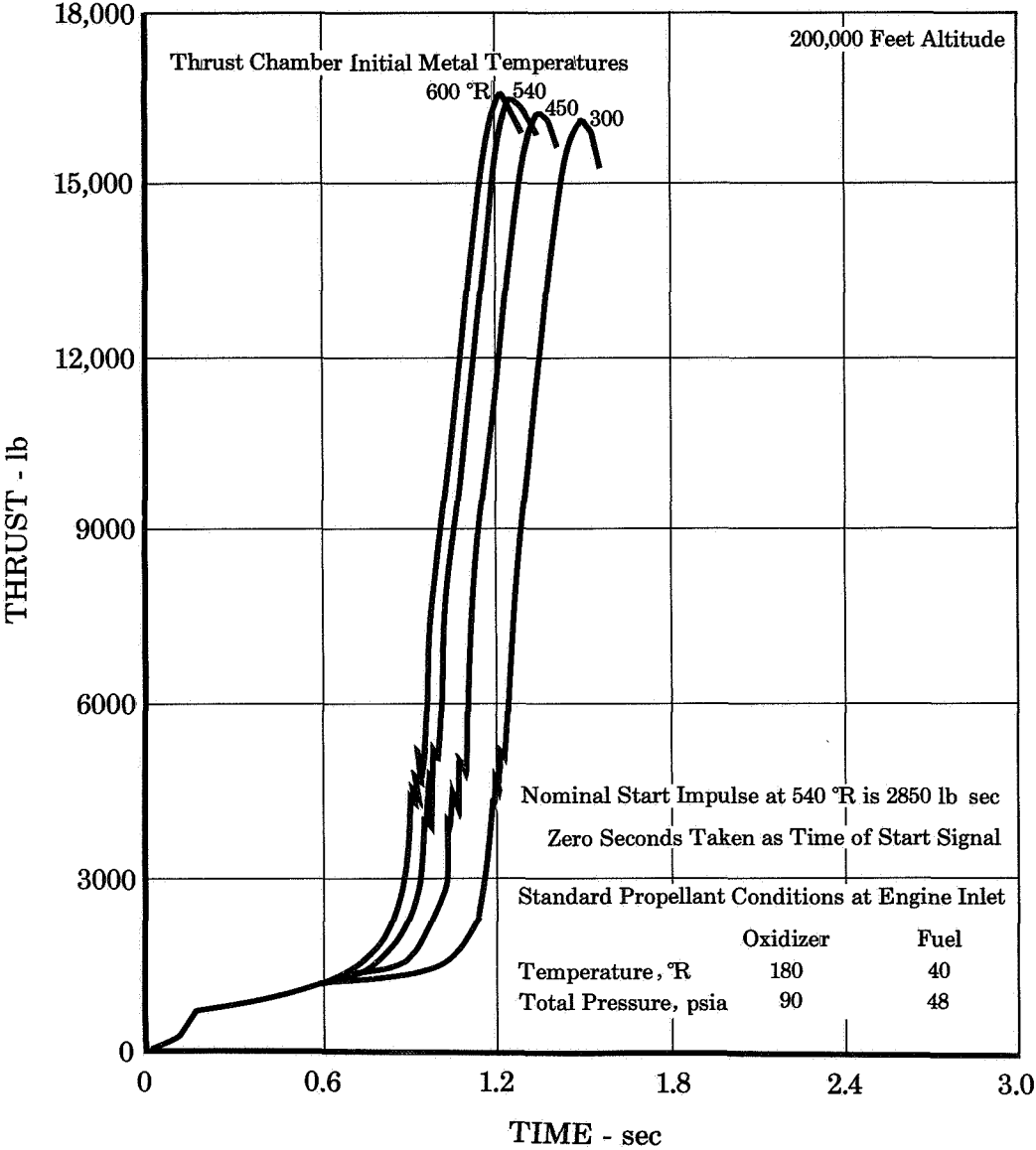


Figure V-2. Estimated Starting Transient Showing Effects of Initial Thrust Chamber Wall Temperatures FD 8877

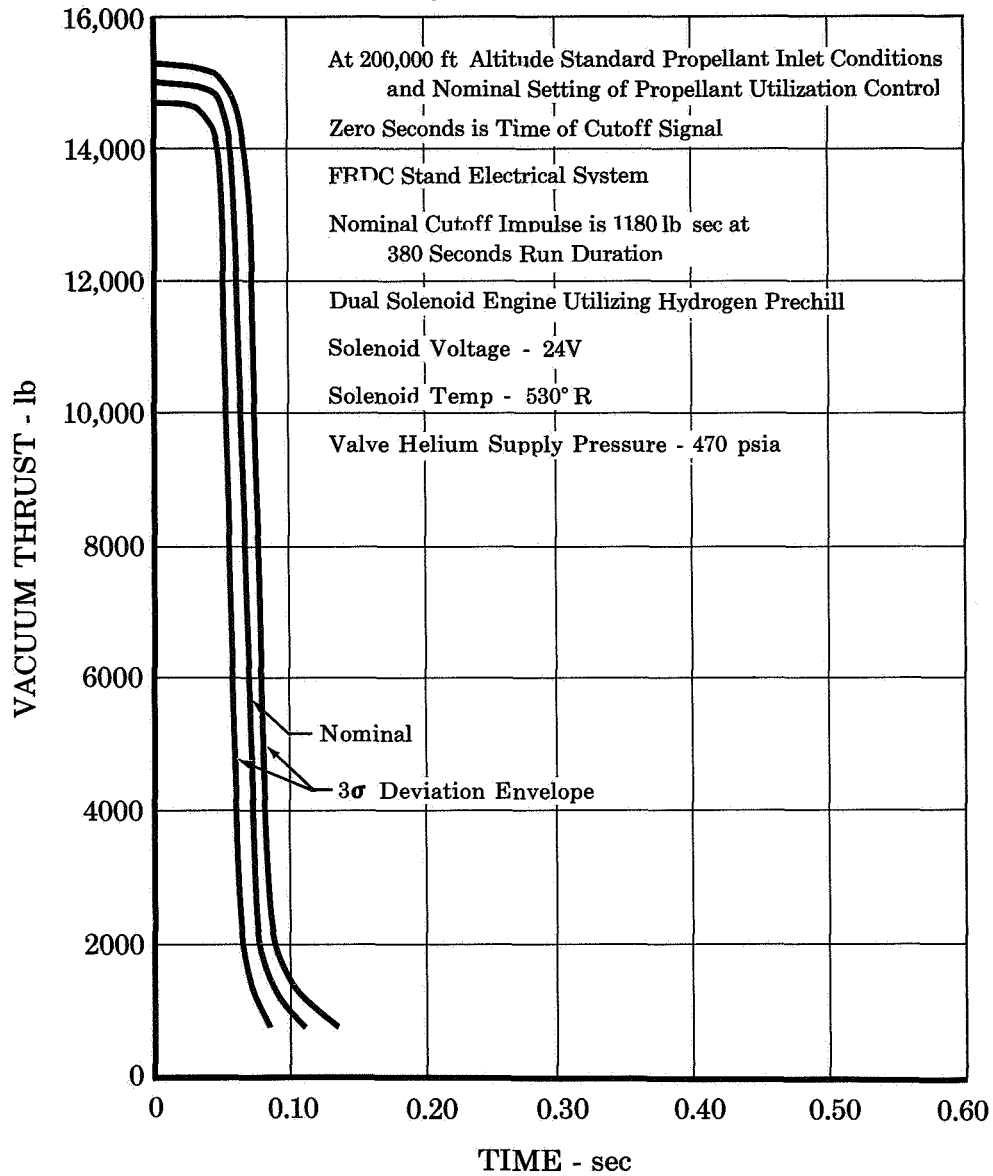


Figure V-3. Estimated Shutdown Transient Thrust vs Time

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