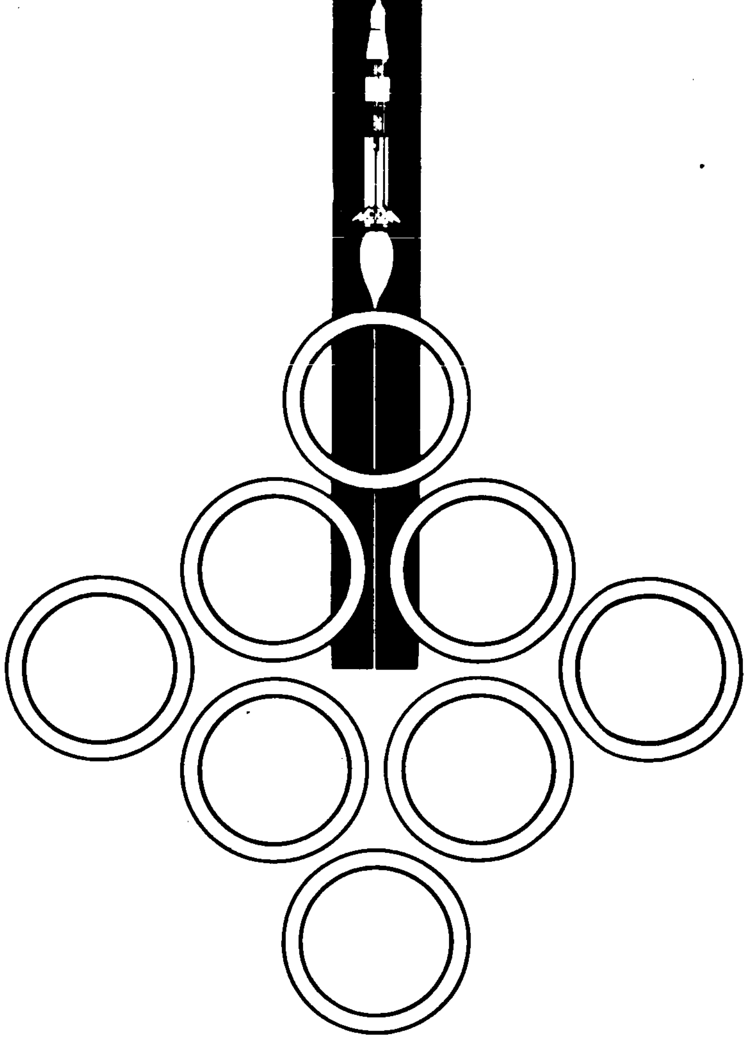

ENGINEERING DEPARTMENT

TECHNICAL REPORT

TR-P&VE-67-58

FINAL FLIGHT PERFORMANCE PREDICTION FOR SATURN AS-204 LM PROPULSION SYSTEM S-IB-STAGE

SATURN S-IB STAGE AND SATURN IB PROGRAM

SPACE DIVISION CHRYSLER CORPORATION

TECHNICAL REPORT TR-P&VE-67-58

FINAL FLIGHT PERFORMANCE PREDICTION FOR SATURN AS-204 LM PROPULSION SYSTEM S-IB-4 STAGE

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ABSTRACT

This report, covering prediction of the S-IB-4 propulsion system flight performance, supersedes CCSD Technical Report TR-P&VE-66-29, Revision B, due to the effects of recent changes in propulsion criteria and launch schedule. These changes also required the propulsion performance dispersions reported in TR-P&VE-66-29 to be revised.

Analyses of the prediction data indicate that inboard and outboard engine cutoffs will occur approximately 141.31 and 144.31 seconds after first motion, respectively. These times are based on defined LOX and fuel load specific weights and stage propellant fill weights for the revised launch schedule for AS-204 (first quarter of 1968).

FOREWORD

This report, authorized by contract NAS8-4016, Revision B, DRL 039, Item 35, presents the flight performance prediction data for the Saturn AS-204 Propulsion System, S-IB-4 Stage.

The prediction data were determined by simulating the first stage powered flight of the Saturn AS-204 LM Mission with the Mark IV computation procedure. The data presented in this report supersedes those presented in CCSD Technical Report TR-P&VE-66-29, Revision B.

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Section 1

SUMMATION

1.1 INTRODUCTION

This report presents the flight performance prediction of the S-IB-4 propulsion system and a discussion of the data and methods used in making the prediction.

The AS-204 configuration used in this prediction consists of an S-IB first stage, an S-IVB second stage, a vehicle instrument unit, and a lunar module payload that had originally been scheduled for the AS-206 mission.

1.2 OBJECT

The object of this report is to present the predicted performance parameters of the first stage propulsion system.

1.3 CONCLUSIONS

Six sets of predictions were made: the nominal case was based on the expected propellant density conditions for the launch month; four cases were based on the three-sigma propellant density dispersions for that month; and one case was based on a simultaneous fuel depletion and LOX starvation OECO for a minimum residual dispersion.

Analyses of the available data indicate that nominal inboard and outboard engine cutoffs will occur approximately 141.31 and 144.31 seconds after first motion, respectively. These times are based on the following assumptions:

a. A nominal fuel load specific weight of 50.520 lbm/ft^3.

b. A nominal LOX load specific weight of 70.323 lbm/ft^3.

c. A liquid level difference of 3 inches between the center LOX tank and the outboard LOX tanks at the time of inboard engine cutoff signal. The difference in level was caused by the 19-inch diameter orifice in the center tank sump.

d. Stage nominal fill weights of 629,764 pounds of LOX and 282,662 pounds of fuel.

The revised dispersions differ significantly from a propulsion aspect than the previously reported dispersion cases (reference 1) and the trajectory dispersion analysis for S-IB-4 should be revised to include these propulsion revisions. The differences are primarily due to the revisions to the table of influence coefficients rather than the change in launch schedule.

Rocketdyne single engine acceptance test data, adjusted to account for apparent shifts in engine performance parameters observed during previous S-IB flights, were used for predicting engine performance. Analysis shows that Rocketdyne adjusted acceptance test data correlate better with MSFC Stage Static test data (SA-32 and SA-33) than Rocketdyne unadjusted acceptance test data.

Section 2

DISCUSSION

2.1 VEHICLE DESCRIPTION

The AS-204 vehicle will consist of the S-IB-4 first stage, S-IVB-4 second stage, the S-IU-204 instrument unit, and an Apollo Lunar Module. The vehicle is scheduled for launch during the first quarter of 1968.

2.2 PREDICTED PERFORMANCE

The predicted performance includes all the latest changes in propulsion and stage criteria that have occurred since the last prediction reported in reference 2.

Rocketdyne recently revised the table of influence coefficients (gain table) that is used to predict and evaluate propulsion system flight performance. In addition, they also revised the H-1 engine power balance math model, which significantly affects the single engine acceptance test sea level data.

Other changes in criteria from that used in reference 2 are the launch date, axial force coefficients, stage trajectory, and engine performance biasing factors. Evaluation of the revised criteria is presented in reference 3.

The differences in predicted performance due to the revised criteria and that shown in the last released S-IB-4 prediction are given in table 1. Although the differences are significant from a propulsion aspect, the differences may have some compensating effects on trajectory parameters so that the operational trajectory may not require revision. However, the trajectory differences are sufficiently significant to use this prediction for the determination of S-IB-4 stage end conditions of flight.

2.2.1 Nominal Prediction

Specific performance data were recorded on magnetic tapes B5 and B6, reels 6329 and 9904, respectively. These tapes were delivered to CCSD Aerospace Physics Branch (Department 2780); a duplicate of tape B6 (reel 6430), required by the Aero-Astrodynamics Laboratory (R-P&VE-FMT), MSFC, was submitted to the Performance Analysis Section (R-P&VE-PPE), MSFC. The punched cards output of tape A5 (reel 3250) containing additional data for weight control was given to CCSD Weight Control Group (Section 2733) for evaluation. Duplicate punched cards output was submitted to the Weights Control Section (R-P&VE-VAW), MSFC.

Weight data are presented in table 2. Stage parameters, including predicted fill weights, ullage volumes, and engine cutoff times, are shown in table 3. Vehicle thrust, specific impulse, fuel flowrate, LOX flowrate, and mixture ratio as functions of flight time, referenced from first motion, are shown in figures 1 through 5, respectively.

LOX and fuel tank ullage pressures, ambient pressure, and LOX pump inlet specific weight as functions of flight time are shown in figures 6 through 8. Representative individual engine performance curves for a typical outboard engine (position 1) as a function of flight time are shown in figures 9 through 13. Average values for many of the parameters appear on these curves. The averages were calculated from first motion to IECO.

2.2.2 Dispersion Cases

In addition to the nominal prediction, five flights were simulated to show the effects of various propulsion performance dispersions. These flights consist of fuel density dispersions due to ±3-sigma prelaunch ambient air temperature deviations, LOX density variations caused by ±3-sigma prelaunch wind speed deviations, and the effect of a lower than expected consumption ratio on stage performance. Data obtained from the additional flight simulations are shown in table 4.

The revised propellant density dispersions provide significantly different stage performances than those previously reported in reference 1. The differences are primarily due to the revisions to the table of influence coefficients rather than the change in launch schedule.

The low-ambient air temperature case (-3 sigma fuel density) is expected to have a time base two (T_2) backup timer initiated IECO 143.06 seconds after first motion, and OECO is expected 149.96 seconds after first motion as a result of a backup timer cutoff command to start time base three (T_3).

As a result of a premature fuel depletion cutoff on S-IB-1, the fuel level sensor heights were adjusted by an amount which makes approximately 850 pounds of fuel available for consumption after IECO and prior to OECO if a significantly lower than predicted consumption ratio is experienced. Because of the possible consumption of this fuel, the time between IECO and OECO can be as much as four seconds and would result in significant differences in S-IB-4 flight performance from that predicted. Since the nominal performance prediction assumes a LOX starvation mode OECO with a 3-second differential between IECO and OECO, the possibility of a 4-second differential must be accounted for in the propulsion performance dispersions.

The cause of the erroneous and sporadic fuel depletion signals experienced on the S-IB-1 stage is believed to have been gas bubbles in the fuel impinging on the probe sensing tips. This condition is not expected to occur in the S-IB-4 stage because shrouded fuel depletion probes are installed to deflect gas bubbles from the probe sensing tips.

The correct dispersion to include this effect is in the engine mixture ratio (EMR) residual propellant dispersion. The data on the dispersion tape reflects an effective shift of -0.68 per cent in propellant mixture ratio while holding thrust and specific impulse values the same as for the nominal case. The effective mixture ratio shift accounts for consumption of the 1000-pound fuel bias prior to IECO and an additional 850 pounds of fuel which is available prior to OECO; as a result, 1850 pounds of additional fuel will be consumed with the nominal LOX consumption.

Data from the propulsion performance dispersion cases are recorded on tapes A5, B5, B6 and B7, which are stored at the Computer Operations Office. The reel numbers of the tapes are as follows:

Condition	Tape A5 Reel No	Tape B5 Reel No.	Tape B6 Reel No.	Tape B7 Reel No.
+3 Sigma High Ambient Air Temperature (Low Fuel Density)	6823	9659	0455	5800
-3 Sigma Low Ambient Air Temperature (High Fuel Density)	10864	9413	7602	5830
+3 Sigma High Wind Speed (Low LOX Density)	4699	8061	0861	9374
-3 Sigma Low Wind Speed (High LOX Density)	4922	0324	8465	10848
Low Consumption Ratio	6911	8750	6913	8092

The punched cards output of tape A5 were given to the CCSD Weight Control Group (Department 2733), and tapes B5 and B6 are for use by the CCSD Aerospace Physics Branch (Department 2780). Duplicate punched cards output of tape A5 was submitted to the Weights Control Section (R-P&VE-VAW), MSFC, and duplicate copies of tape B6 (listed below) were submitted to the performance analysis section (R-P&VE-PPE) MSFC.

Condition	Tape B6 Reel No.
+3 Sigma High Ambient Air Temperature (Low Fuel Density)	6735
-3 Sigma Low Ambient Air Temperature (High Fuel Density)	5455
+3 Sigma High Wind Speed (Low LOX Density)	9384
-3 Sigma Low Wind Speed (High LOX Density)	0172
Low Consumption Ratio	1618

2.2.3 Propellant Usage

The stage fill weights shown in table 3 were determined for a LOX volume of 66,990 gallons, having a specific weight of 70.323 lbm/cu. ft. and a corresponding amount of fuel at a specific weight of 50.520 lbm/cu. ft. (reference 4). The fill weights shown in the table will be required for simultaneous depletion of consumable propellants.

Variations from the predicted fuel density will require adjustments to the predicted propellant loads to ensure simultaneous depletion of propellants. The required propellant loads for any fuel density are presented in figure 14.

A fuel bias of 1000 pounds is included in the fuel load to minimize propellant residuals if there are deviations from the predicted propellant mixture ratio. The fuel bias for this flight is the same as that used for previous S-IB flights.

The LOX specific weight is based on a predicted wind velocity of 8.7 knots at launch time. The fuel specific weight was determined by using an estimated ambient air temperature for the month of launch during the first quarter of the year and an approximate 10-degree chilldown due to LOX exposure. Included in the total exposure time is an estimated 30 minutes of unscheduled holds.

All LOX in the tanks, sumps, and interchange lines (except approximately 3 gallons which will be trapped in the center tank sump) will be consumed. Approximately 75 gallons of the outboard engine suction line LOX volume will also be consumed if the predicted LOX starvation mode of OECO occurs. The remaining LOX in the suction lines is considered as unusable propellant and is shown as LOX residual in table 2.

It is predicted that the fuel level at the end of outboard engine thrust decay will be approximately at the bottom of the containers. The fuel in the sump, interchange lines, and the suction lines is shown as residual in table 2.

A portion of the predicted fuel residual is the 1000-pound fuel bias which is available for consumption prior to IECO. Approximately 850 pounds more of the residual can be consumed prior to OECO if a significantly lower than predicted consumption ratio is experienced. The difference in consumption ratios would result in a simultaneous OECO signal from the thrust OK pressure switches and the fuel depletion probes, which are located approximately 11 inches below the theoretical bottom of fuel tanks F-2 and F-4. If the predicted performance occurs, this total of 1850 pounds of fuel will not be consumed.

2.2.4 Engine Performance

Engine performance data from revised Rocketdyne acceptance test logs were analyzed as to their relationship with actual flight data for the flights of S-IB-1, S-IB-2, and S-IB-3. The study revealed that the Rocketdyne acceptance test data offered consistent correlation with the flight data. The average differences between the flight data and the Rocketdyne test data for the first three S-IB flights were determined and used to adjust the Rocketdyne data for this prediction.

The Rocketdyne data for the S-IB-4 engines were increased by the following percentages: thrust, 0.727 per cent; chamber pressure, 0.650 per cent; LOX Flowrate, 1.161 per cent; and fuel flowrate, 0.274 per cent. The predicted individual engine flight data reduced to sea level and rated pump inlet conditions at 30 seconds after first motion are shown in table 3 and were used to predict flight performance.

A comparison of the sea level average engine Rocketdyne data, adjusted Rocketdyne data and the stage static tests is shown in table 5. The table shows that the adjusted Rocketdyne data is in reasonable good agreement with the stage test data. This means that if the S-IB-4 engines perform in a manner similar to S-IB-1, S-IB-2, and S-IB-3, the stage test data would have provided more accuracy than the unadjusted Rocketdyne data, but a significant error would still occur in predicted mixture ratio.

The performance adjustments applied to the Rocketdyne data account for the performance differences noted at 30 seconds. Furthermore, previous S-IB flights have exhibited a shift throughout flight in engine performance referenced to sea level and rated pump inlet conditions. Included in this shift was a buildup to quasi - stable conditions at approximately 30 seconds with a slower buildup thereafter. This revised final prediction for AS-204 includes a performance shift equivalent to that noted in previous S-IB flights. Figure 15 shows the power level shift as a percentage of the predicted 30-second sea level thrust. The flight performance adjustments were used only to shift the curve upward. The shape of the curve was determined from analysis of the first three S-IB flights.

2.2.5 Engine Cutoff Criteria

The time base-two (T_2) cutoff sequence will be initiated when any one of the four liquid level sensors is uncovered. The predicted actuation time is 138.21 seconds after the first motion. Liquid level sensors are located in fuel tanks F-2 and F-4 and LOX tanks O-2 and O-4. IECO will be signaled by the launch vehicle digital computer (LVDC) 3.1 seconds after initiation of the time base-two cutoff sequence.

The OECO signal can be given by the deactuation of two of the three thrust OK pressure switches in any one of the outboard engines or by one of the fuel depletion probes located in the sumps of fuel tanks F-2 and F-4. The predicted performance is based on the assumption that LOX pump starvation of two of the four outboard engines will occur 3.0 seconds after the IECO signal, and that the OECO signal will be given by deactuation of the thrust OK pressure switches. A fuel depletion OECO can occur if the fuel bias and the fuel between the container bottoms and the depletion probes is consumed prior to a LOX pump starvation. Because of the possible consumption of the fuel between the theoretical tank bottom and the depletion probes, the time between IECO and OECO can be as much as four seconds, and the OECO mode can be either fuel depletion or LOX pump starvation.

The time base-two (T_2) sequence, expected to start 138.21 seconds after the first motion, is summarized as follows:

T_2 + 0.0 sec - LVDC activated. T_2 sequence begins with liquid level sensor actuation.

T_2 + 3.1 sec - IECO signal given by LVDC.

T_2 + 4.6 sec - Outboard engine thrust OK pressure switches grouped.

T_2 + 5.6 sec - Fuel depletion sensors armed.

T_2 + 6.1 sec - OECO signal expected due to LOX starvation.

This sequence was determined for the predicted performance with the LOX and fuel liquid level sensors located according to present stage documentation. The sequence separates thrust OK pressure switch grouping from fuel depletion sensor arming to minimize the possibility of OECO caused by a premature sensor signal.

Table 1. Comparison of Stage Predictions for Nominal Environmental Conditions

Parameter	Previous Prediction	Updated Prediction
Wind Speed (probability limit) (knots)	8.1	8.7
Ambient Temperature (probability limit) (°F)	81	62
Fuel Density (lb/ft^3)	50.07	50.52
LOX Density (lb/ft^3)	70.404	70.323
Average Thrust (Kips)	1,754.70	1,738.52
Average Specific Impulse (sec)	280.00	280.74
Average LOX Flowrate (lb/sec)	4,359.0	4,288.5
Average Fuel Flowrate (lb/sec)	1,907.7	1,904.0
Average Mixture Ratio	2.2849	2.2524
IECO (sec)	139.144	141.306
OECO (sec)	142.144	144.306
Fuel Load (lb)	279,065	282,662
LOX Load (lb)	630,491	629,764
Minimum Allowable Fuel Ullage (%)	2.00	2.00
Nominal Allowable LOX Ullage (%)	1.50	1.50
Fuel Ullage at Fill (%)	3.13	2.75
LOX Ullage at Fill (%)	1.50	1.50

Table 2. Weight Breakdown For AS-204 Vehicle

Parameters	Miscellaneous (lb)	LOX (lb)	Fuel (lb)	Total (lb)
1. Consumption During Ignition and Holddown		10,664	3,193	13,857
2. Mainstage Consumption		612,170	271,131	883,301
3. Consumption During Inboard Engine Thrust Decay*		727	1,392	2,119
4. Consumption During Outboard Engine Thrust Decay*		610	1,343	1,953
5. Propellant Residual**		2,947	4,878	7,825
6. Gearbox Fuel Consumption			725	725
7. GOX Generated During Flight		2,646		2,646
8. Ice	1,100			1,100
9. Initial LOX Tank Pressurant	34			34
10. Hydraulic Oil	28			28
11. Oronite (fuel additive for lubrication)	32			32
12. Initial Weight of Helium in the Fuel Tanks	3			3
13. Initial Weight of Nitrogen and Helium in all Spheres (for fuel container pressurization, S-IB stage purge, etc.)	94			94
14. Total Upperstage Weight Plus S-IB Stage Dry Weight	387,831			387,831
Total Weight at Ignition Command	389,122	629,764	282,662	1,301,548

* Thrust decay includes propellant below main valves that is not necessarily burned but ejected overboard after the valves close.

** The fuel residual includes 1000 pounds for biasing. The bias is available to provide an equal propellant weight at the 3-sigma mixture ratio limits.

Table 3. Sea Level Performance of S-IB-4 Stage Engines at 30 Seconds of Flight Time

Parameters	Nominal Value	Engine H-7062 Pos. 1	Engine H-7063 Pos. 2	Engine H-7064 Pos. 3	Engine H-7065 Pos. 4	Engine H-4058 Pos. 5	Engine H-4062 Pos. 6	Engine H-4060 Pos. 7	Engine H-4061 Pos. 8	Vehicle Parameters
Engine Thrust (Kips)	200.00	203.23	202.79	202.83	199.75	200.21	203.56	201.17	202.33	1,610.33*
Engine Specific Impulse (sec)	262.86	261.86	262.10	261.70	261.66	262.71	262.51	261.97	263.01	261.08**
Chamber Pressure (psia)	689.31	701.87	697.06	699.31	692.86	688.20	699.98	693.77	693.88	---
Engine LOX Flowrate (lb_m/sec)	525.27	536.32	534.97	535.61	526.94	526.02	536.33	530.56	532.01	4,258.76
Engine Fuel Flowrate (lb_m/sec)	235.54	239.80	238.75	239.42	236.47	236.09	239.11	237.35	237.27	1,909.30**
Engine Mixture Ratio	2.2301	2.2366	2.2408	2.2371	2.2283	2.2281	2.2430	2.2354	2.2422	2.2305**
Turbopump Speed (rpm)	6716.6	6823.1	6823.9	6765.5	6699.7	6663.7	6823.2	6719.5	6720.5	---
Engine Throat Area (sq. in.)	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	---
Engine Expansion Ratio	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	---

* Thrust along the longitudinal axis.

** Includes fuel used as lubricant.

Table 4. Stage Parameters for Propulsion Performance Predictions

Parameters	Case 1	Case 2	Case 3*	Case 4	Case 5	Case 6**
Wind Speed (probability limit) (knots)	(+3σ) 27	(−3σ) 0	Nominal 8.7	Nominal 8.7	Nominal 8.7	Nominal 8.7
Ambient Temperature (probability limit) (°F)	Nominal 62	Nominal 62	Nominal 62	(+3σ) 77	(−3σ) 35	Nominal 62
Fuel Density (lb/ft^3)	50.52	50.52	50.52	50.12	51.28	50.52
LOX Density (lb/ft^3)	70.154	70.466	70.323	70.323	70.323	70.323
Average Thrust (Kips)	1,729.01	1,744.94	1,738.52	1,760.13	1,695.96	1,738.33
Average Specific Impulse (sec)	280.486	280.884	280.737	281.293	279.351	280.691
Average LOX Flowrate (lb/sec)	4,262.82	4,306.31	4,288.54	4,347.23	4,178.32	4,280.49
Average Fuel Flowrate (lb/sec)	1,901.29	1,905.82	1,903.97	1,909.86	1,892.50	1,912.27
Average Mixture Ratio	2.2420	2.2595	2.2524	2.2761	2.2078	2.2384
IECO (sec)	141.930	140.678	141.306	139.360	143.056	141.122
OECO (sec)	145.374	143.909	144.306	142.360	149.956	144.987
Fuel Load (lb)	282,662	282,662	282,662	279,796	288,411	282,662
LOX Load (lb)	629,482	629,984	629,764	629,764	629,764	629,764
Minimum Allowable Fuel Ullage (%)	2.00	2.00	2.00	2.00	2.00	2.00
Nominal Allowable LOX Ullage (%)	1.50	1.50	1.50	1.50	1.50	1.50
Fuel Ullage at Fill (%)	2.75	2.75	2.75	2.97	2.23	2.75
LOX Ullage at Fill (%)	1.30	1.67	1.50	1.50	1.50	1.50

* Represents the nominal propulsion system flight performance prediction.
** Represents the low consumption ratio dispersion.

Table 5. Summary of Sea Level Test Data for the AS-204 Stage Engines

Source	Parameters	Static Test Analysis SA-32	Static Test Analysis SA-33	Rocketdyne Engine Logs From Past-76 Program	Prediction *
Engine H-7062 Position 1	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	201.57 262.25 2.2180	200.70 262.10 2.2170	201.76 262.27 2.2170	203.23 261.86 2.2366
Engine H-7063 Position 2	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	203.35 262.85 2.2238	203.32 262.86 2.2246	201.32 262.51 2.2211	202.79 262.10 2.2408
Engine H-7064 Position 3	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	202.44 262.29 2.2185	202.33 262.27 2.2187	201.36 262.11 2.2175	202.83 261.70 2.2371
Engine H-7065 Position 4	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	198.88 262.17 2.2093	199.41 262.26 2.2104	198.31 262.07 2.2088	199.75 261.66 2.2283
Engine H-4058 Position 5	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	199.18 263.20 2.2096	198.62 263.11 2.2092	198.76 263.12 2.2086	200.21 262.71 2.2281
Engine H-4062 Position 6	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	Engine H-4059 Replaced Post Static Test SA-33 Due to Faulty Turbine		202.10 262.92 2.2233	203.56 262.51 2.2430
Engine H-4060 Position 7	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	203.73 263.04 2.2188	203.15 262.96 2.2194	199.72 262.38 2.2158	201.17 261.97 2.2354
Engine H-4061 Position 8	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	201.83 263.59 2.2238	201.97 263.61 2.2239	200.88 263.43 2.2225	202.33 263.01 2.2422
Average Engine	Thrust (Kips) Specific Impulse (sec) Mixture Ratio (-)	201.57 262.77 2.2174	201.36 262.74 2.2176	200.53 262.60 2.2168	201.98 262.19 2.2364

* See paragraph 2.2.4

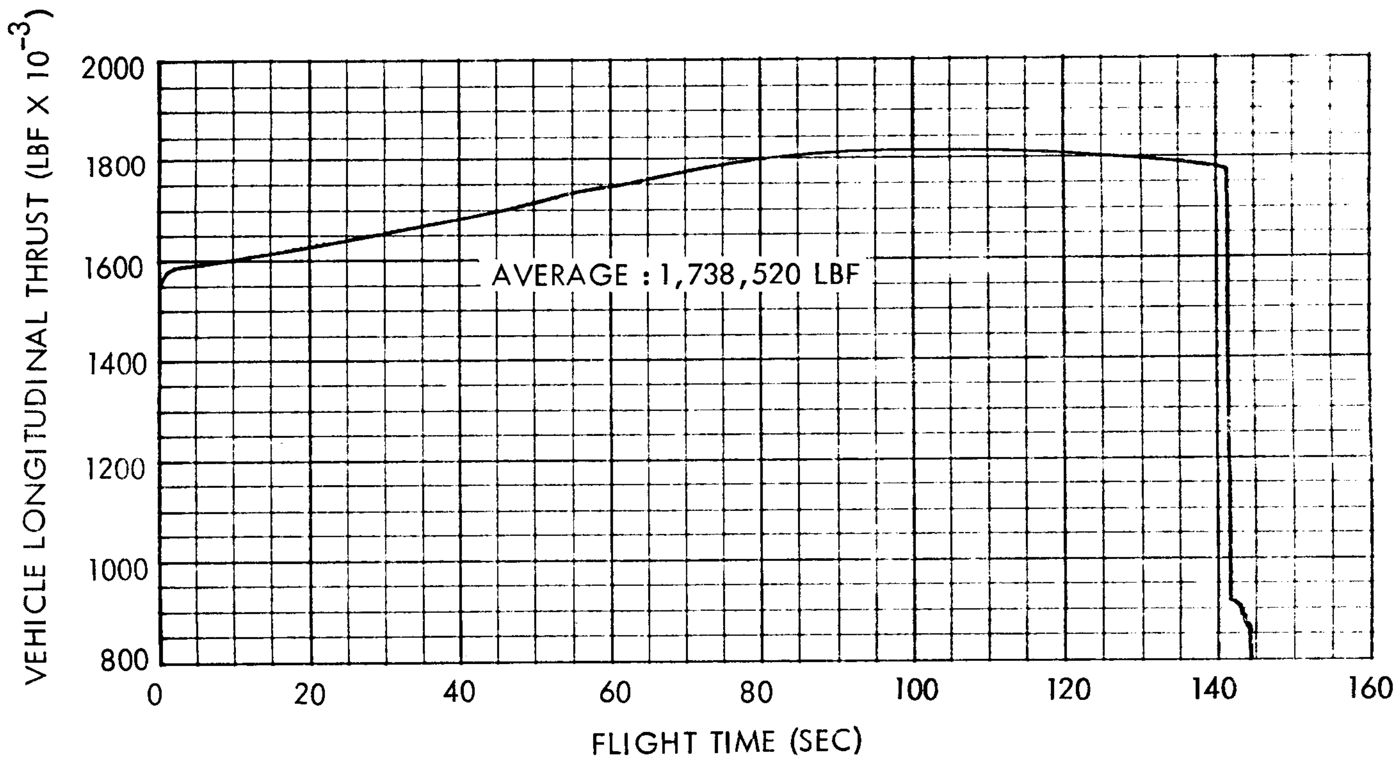

Figure 1. Vehicle Longitudinal Thrust vs Flight Time

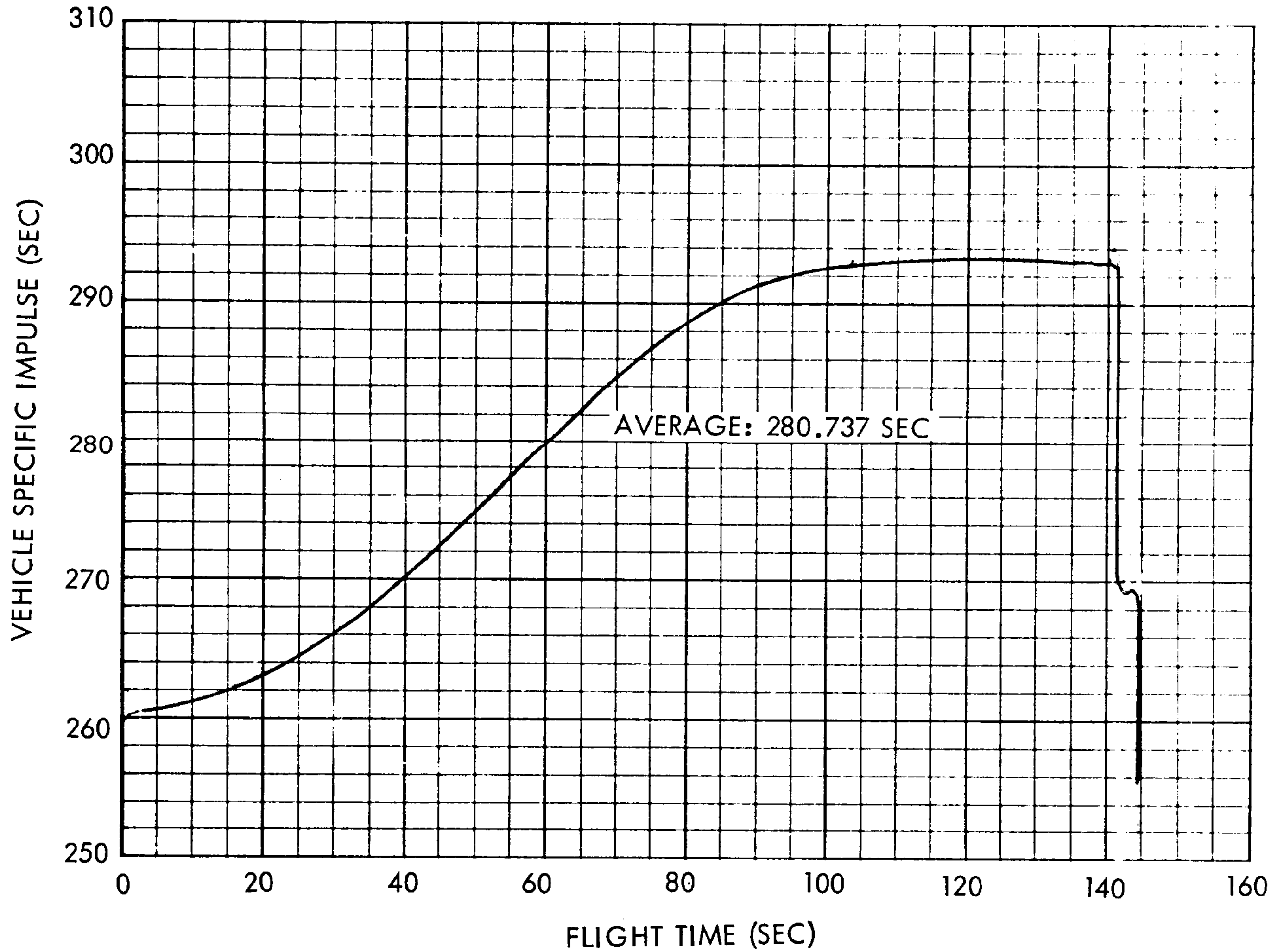

Figure 2. Vehicle Specific Impulse vs Flight Time

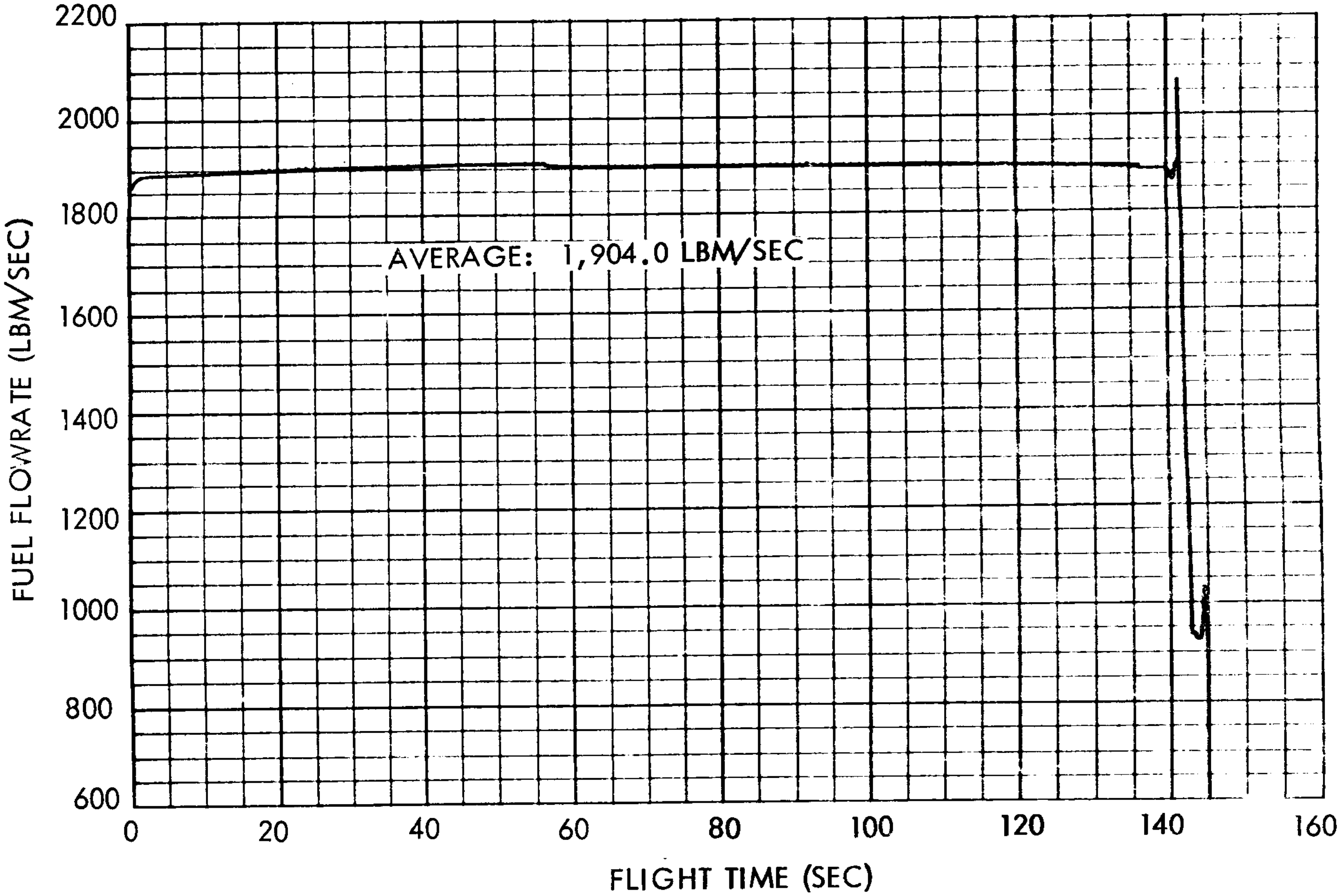

Figure 3. Total Vehicle Fuel Flowrate vs Flight Time

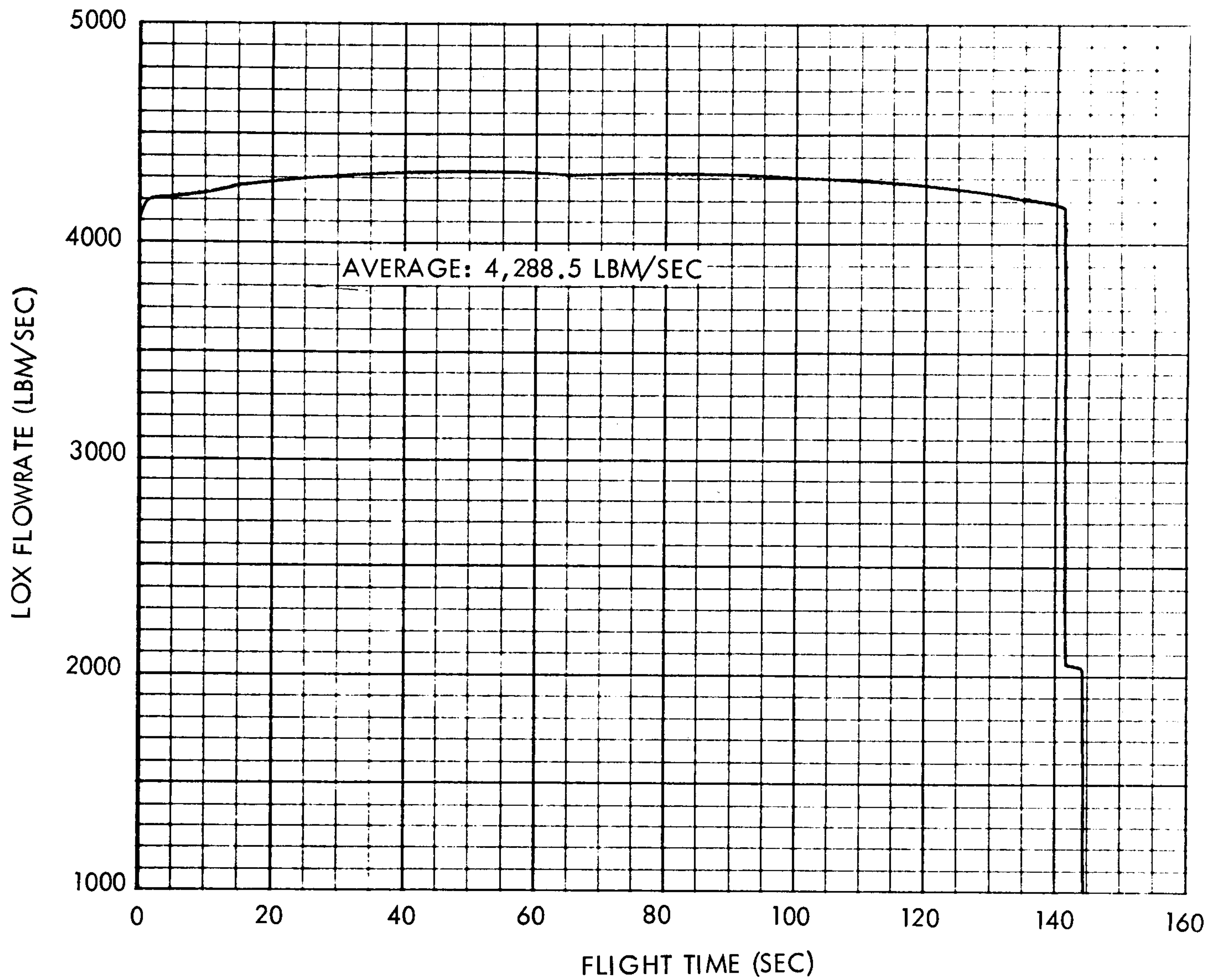

Figure 4. Total Engine LOX Flowrate vs Flight Time

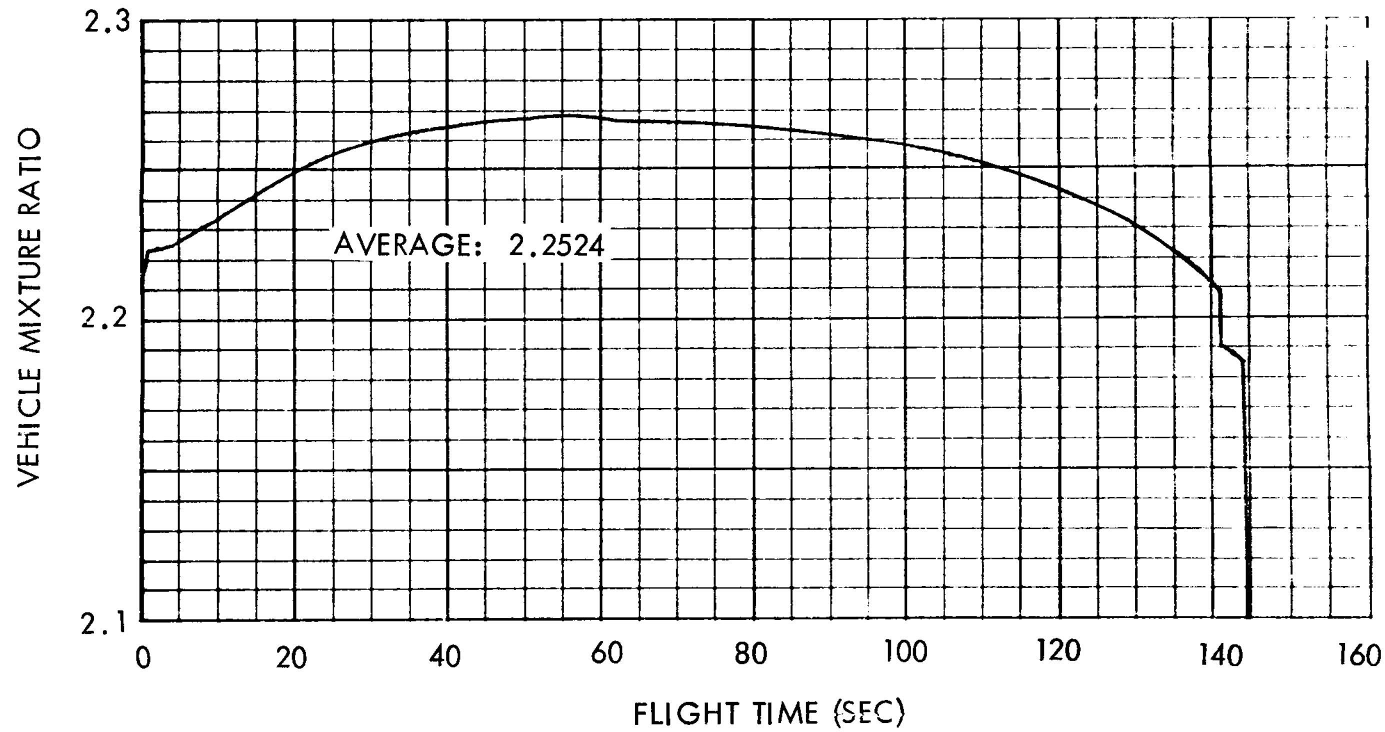

Figure 5. Vehicle Mixture Ratio vs Flight Time

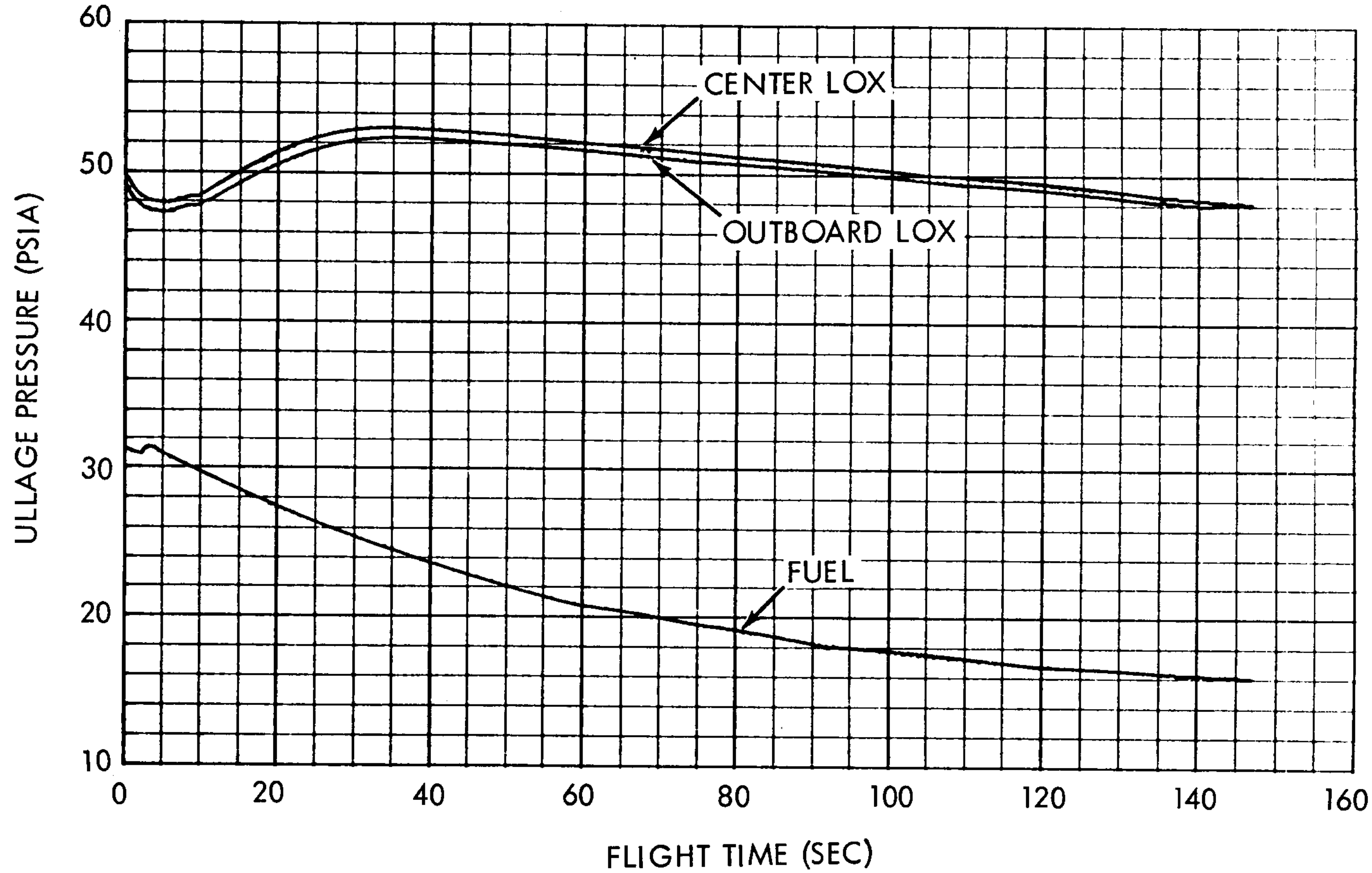

Figure 6. LOX and Fuel Tank Ullage Pressures vs Flight Time

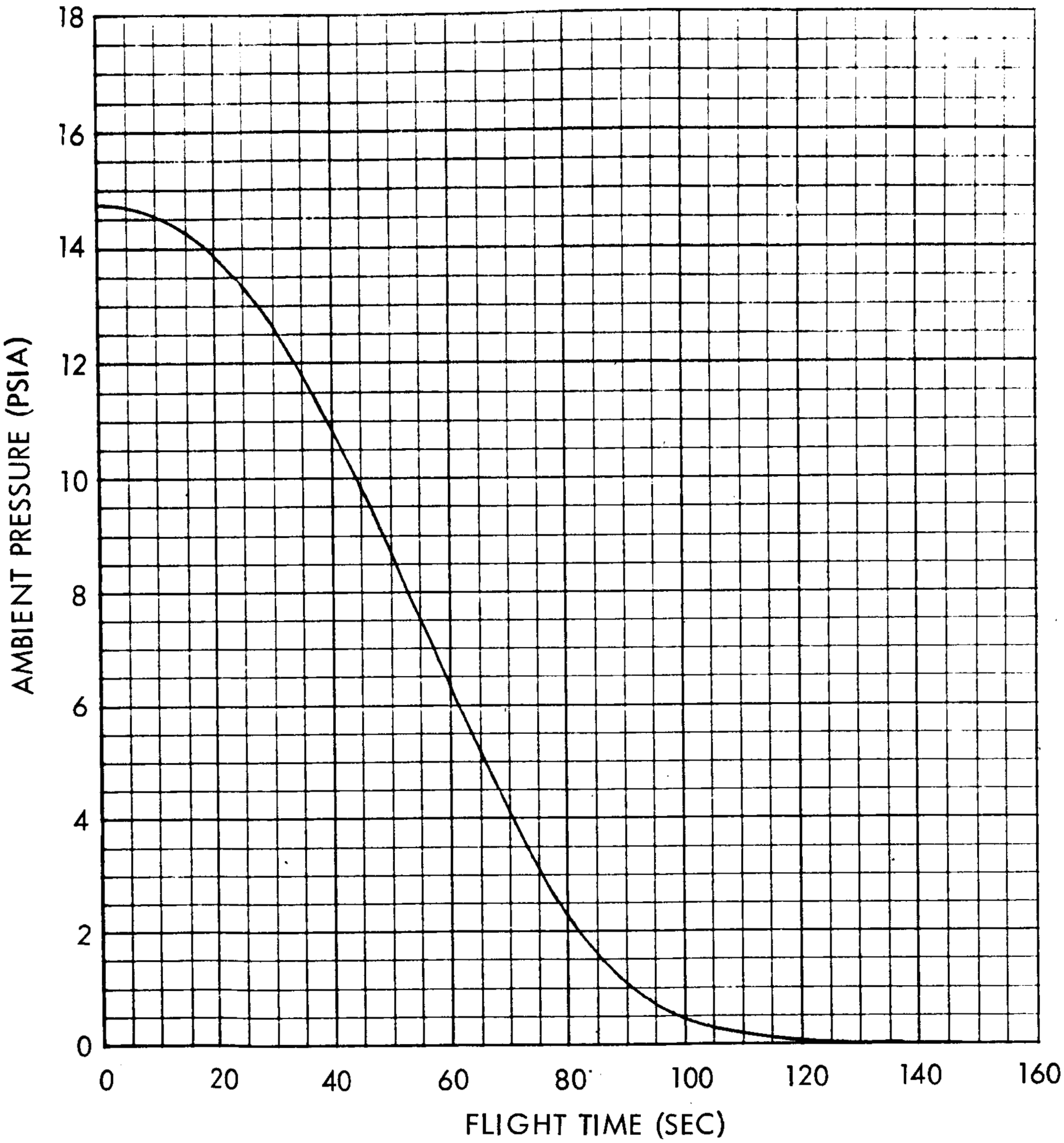

Figure 7. Ambient Pressure vs Flight Time

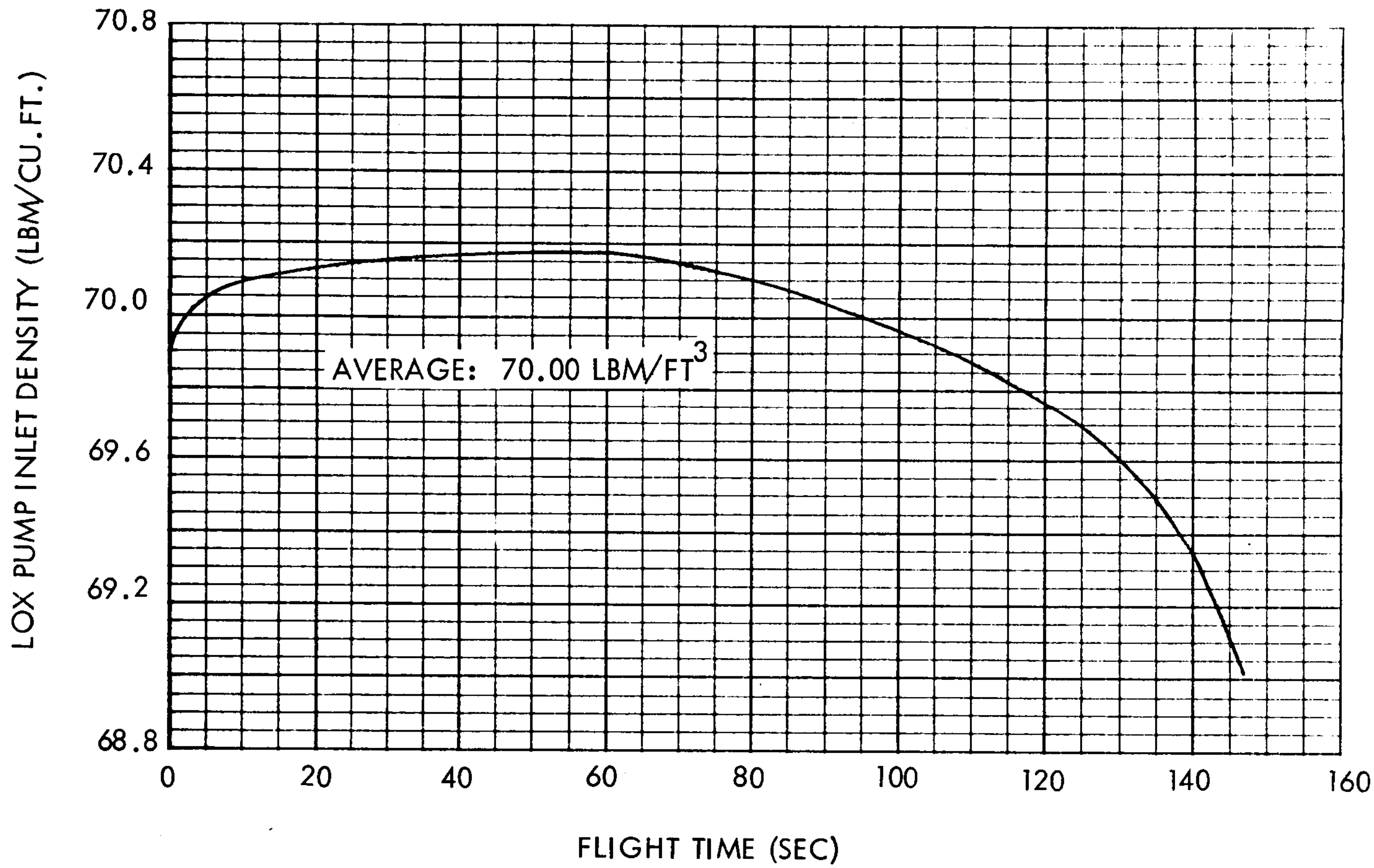

Figure 8. Engine LOX Pump Inlet Specific Weight vs Flight Time

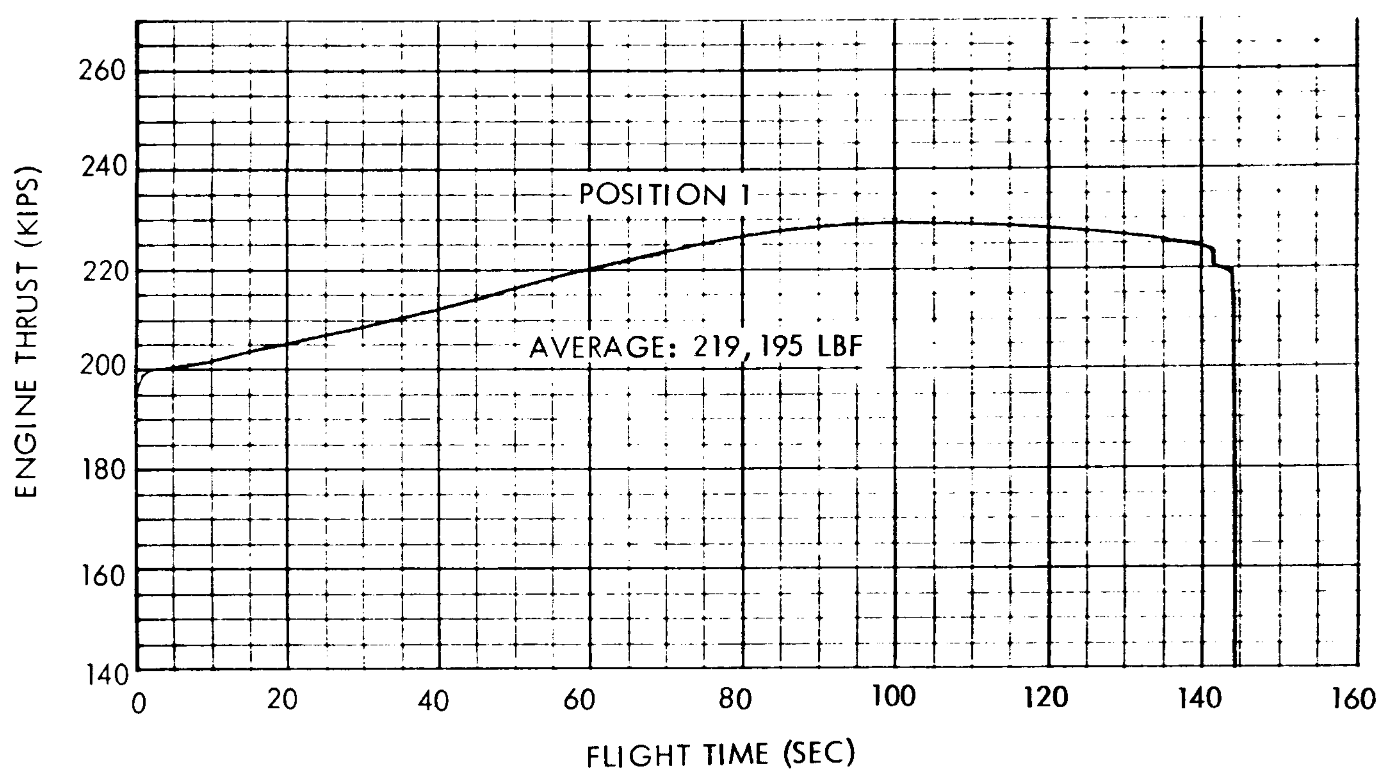

Figure 9. Typical Engine Thrust vs Flight Time

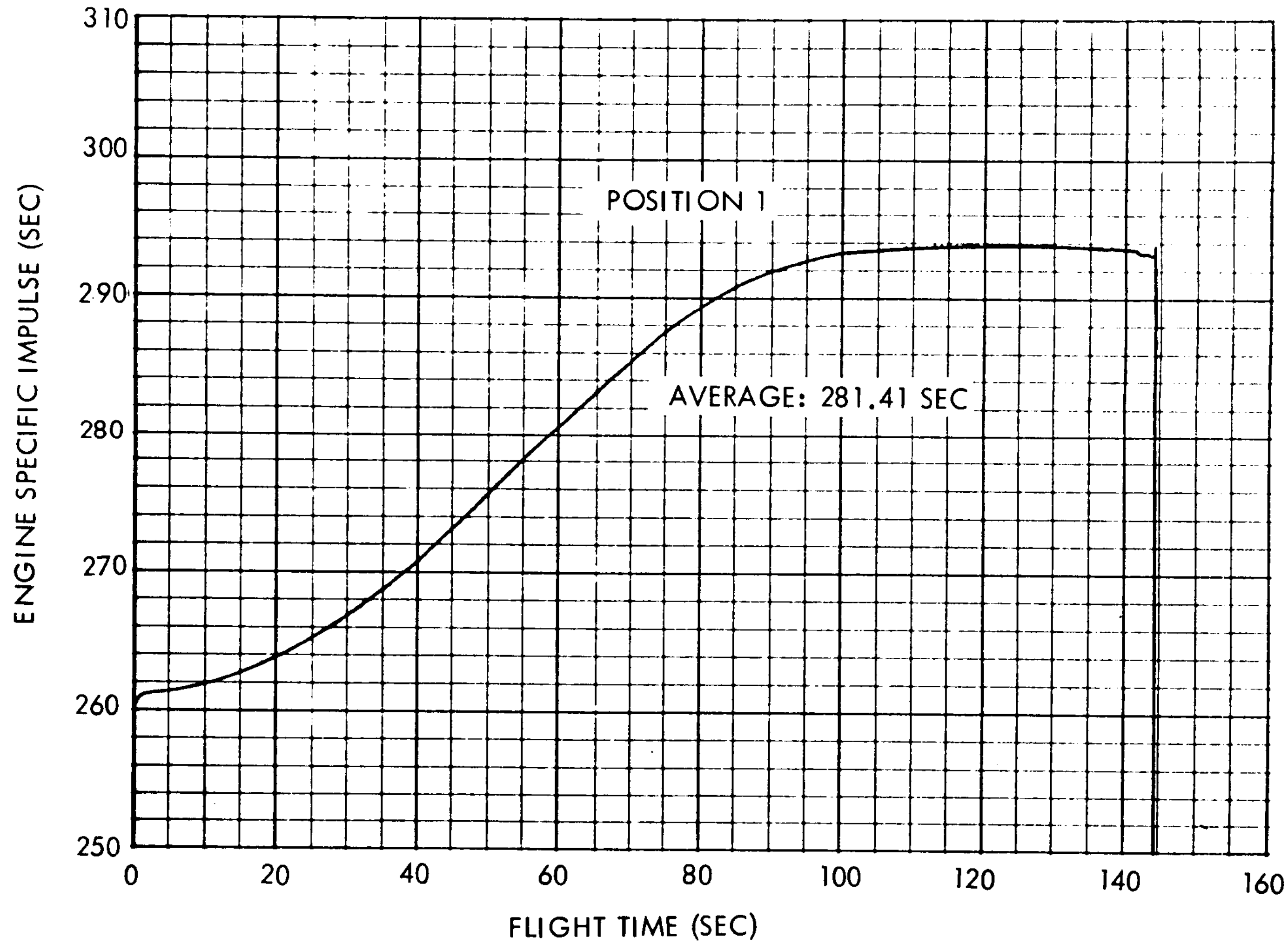

Figure 10. Typical Engine Specific Impulse vs Flight Time

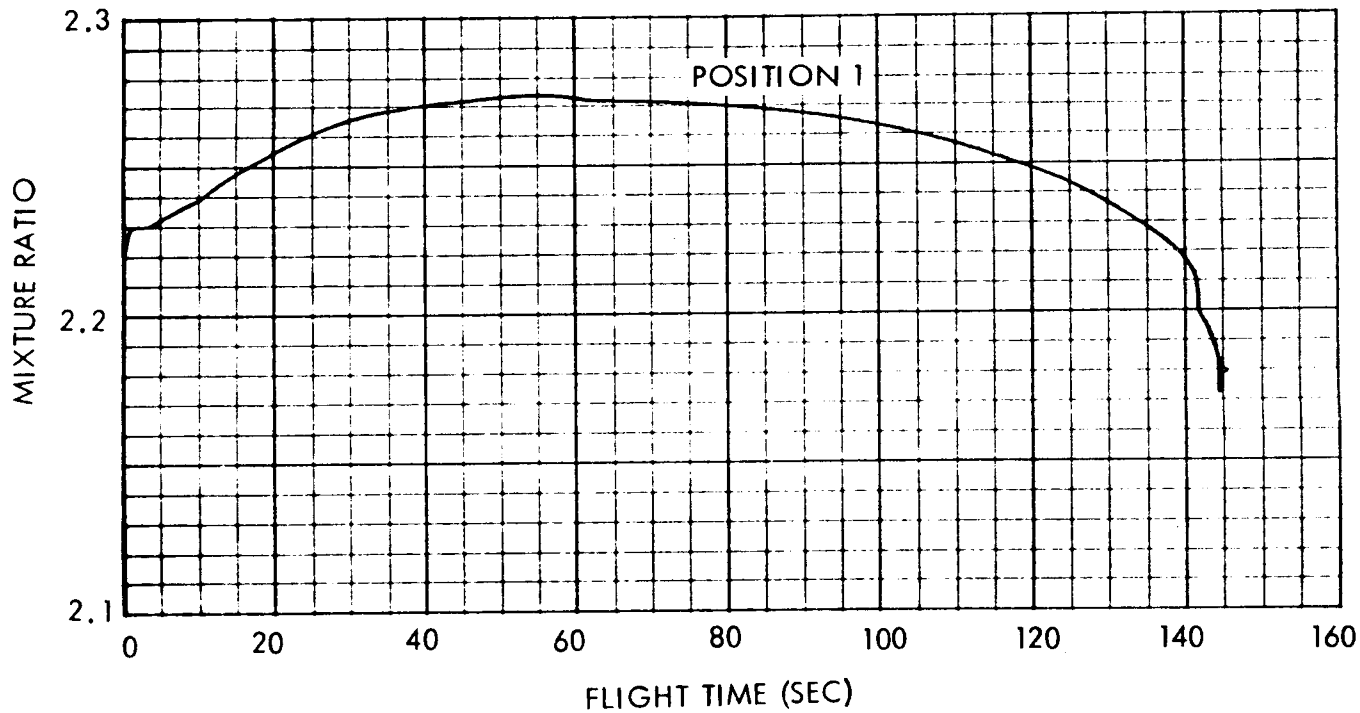

Figure 11. Typical Engine Mixture Ratio vs Flight Time

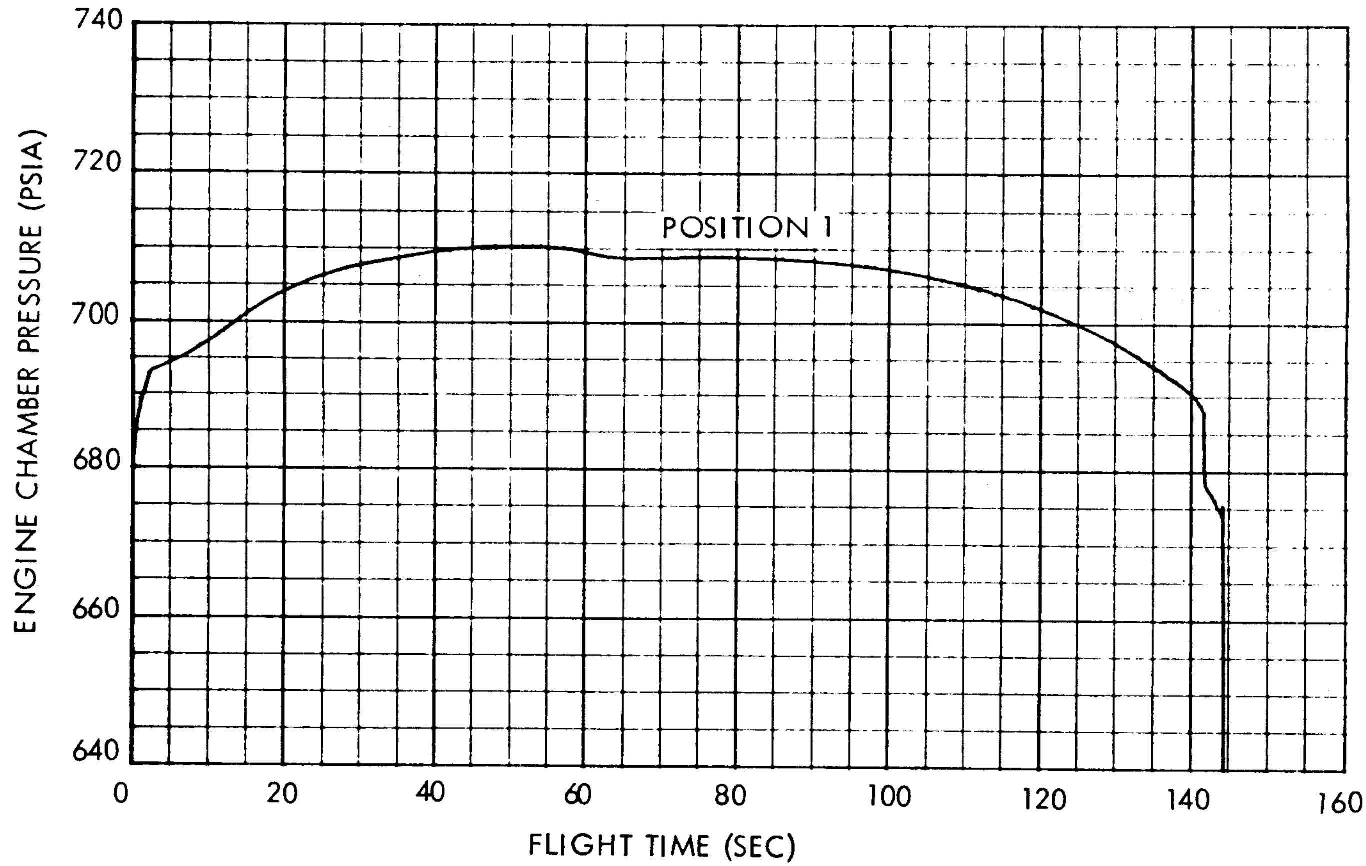

Figure 12. Typical Engine Chamber Pressure vs Flight Time

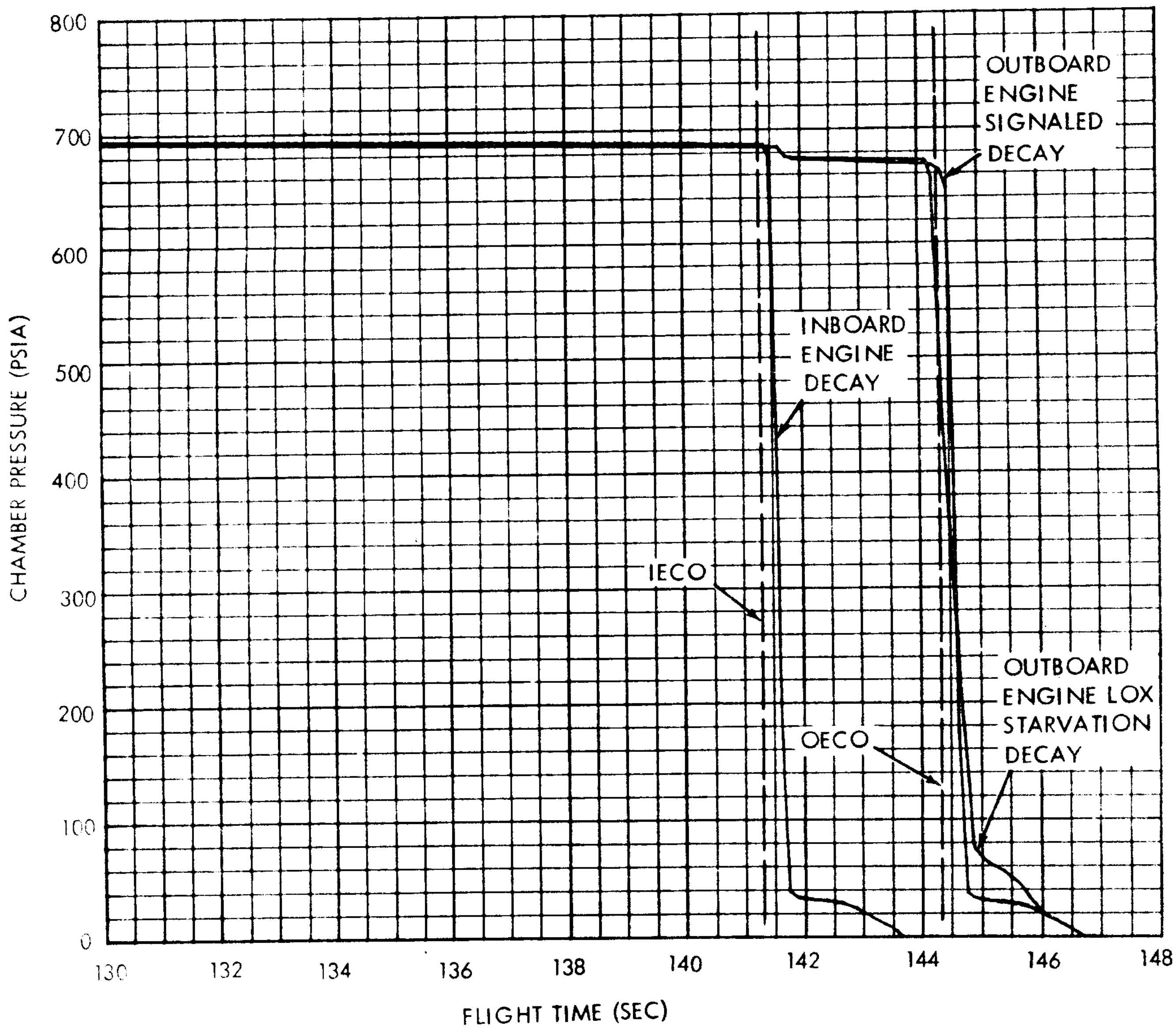

Figure 13. Typical Inboard and Outboard Engine Chamber Pressure Decay Relative to IECO

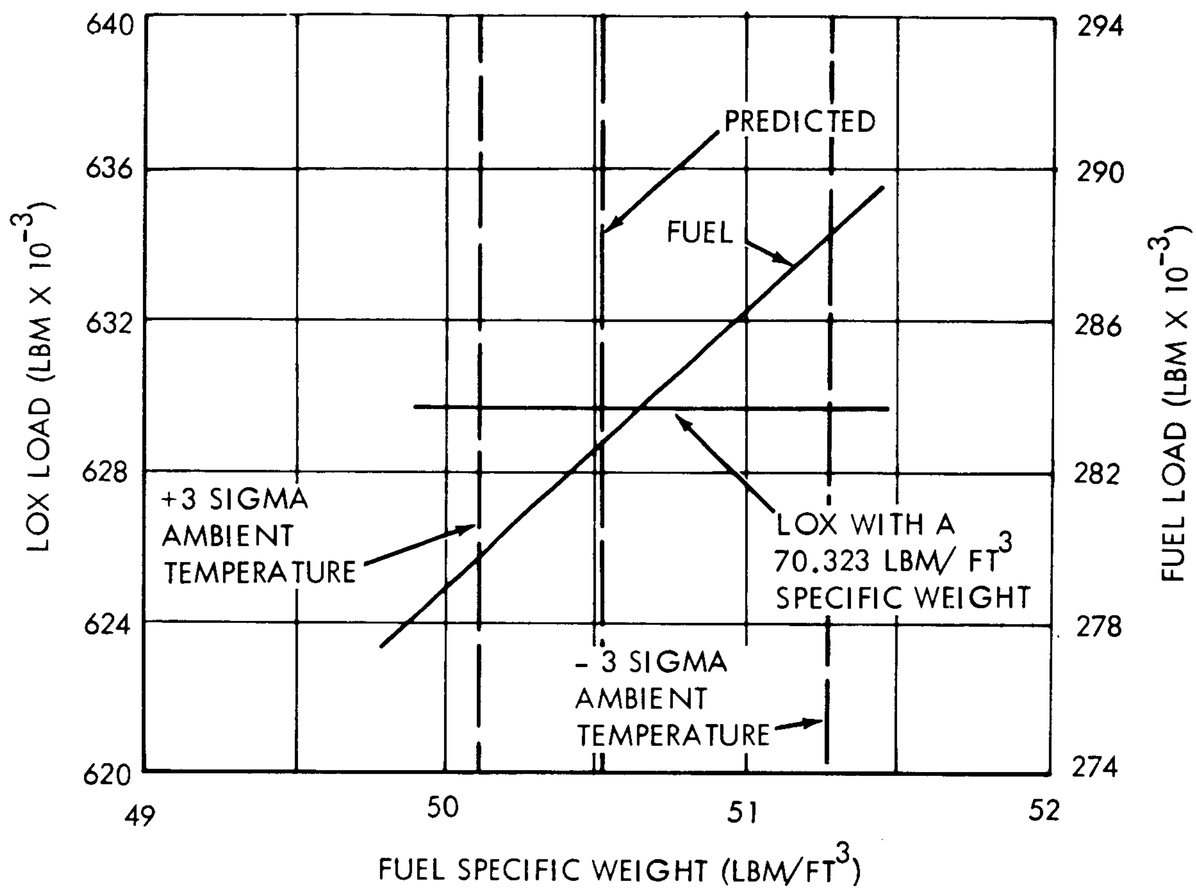

Figure 14. Propellant Load vs Fuel Specific Weight

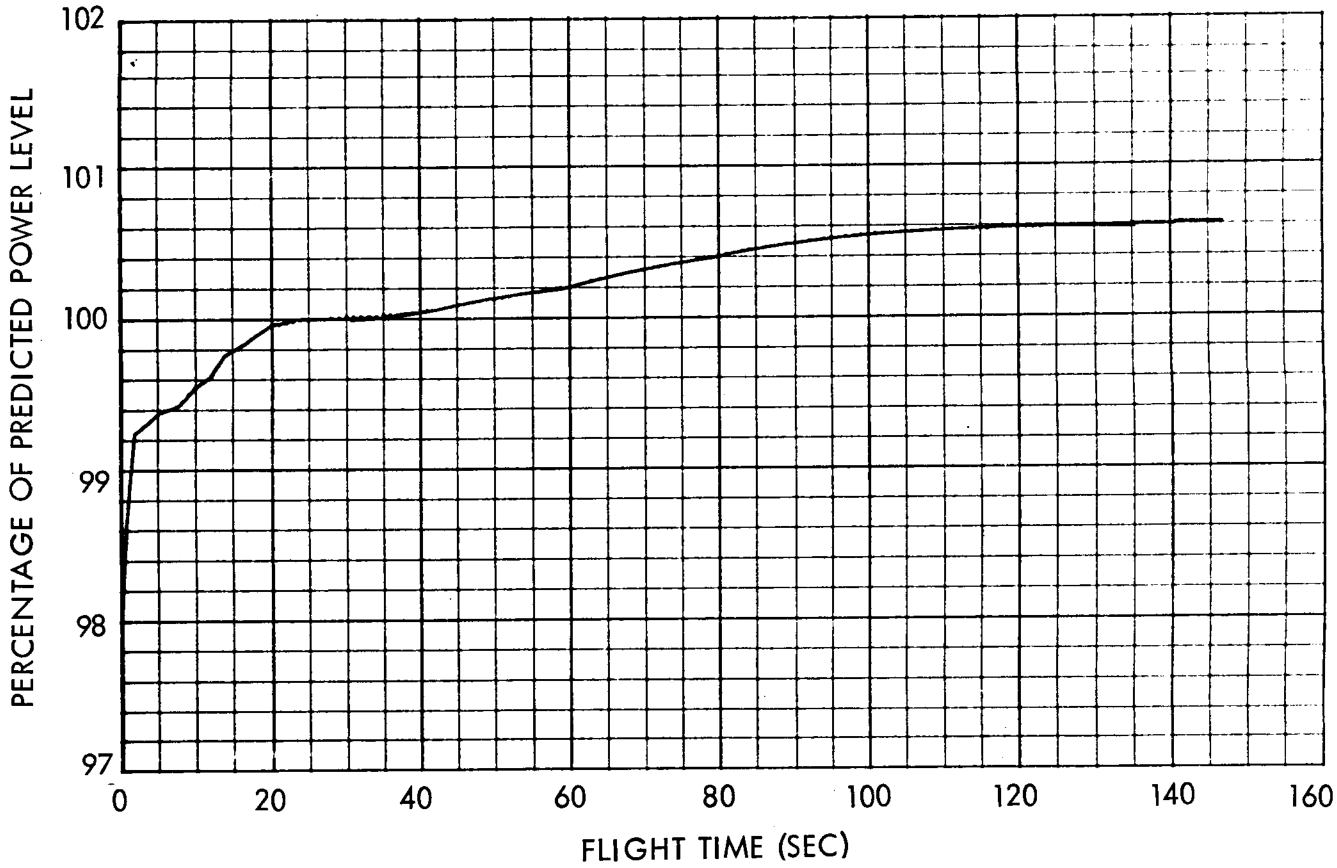

Figure 15. Predicted Sea Level Power Level Shift vs Flight Time

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