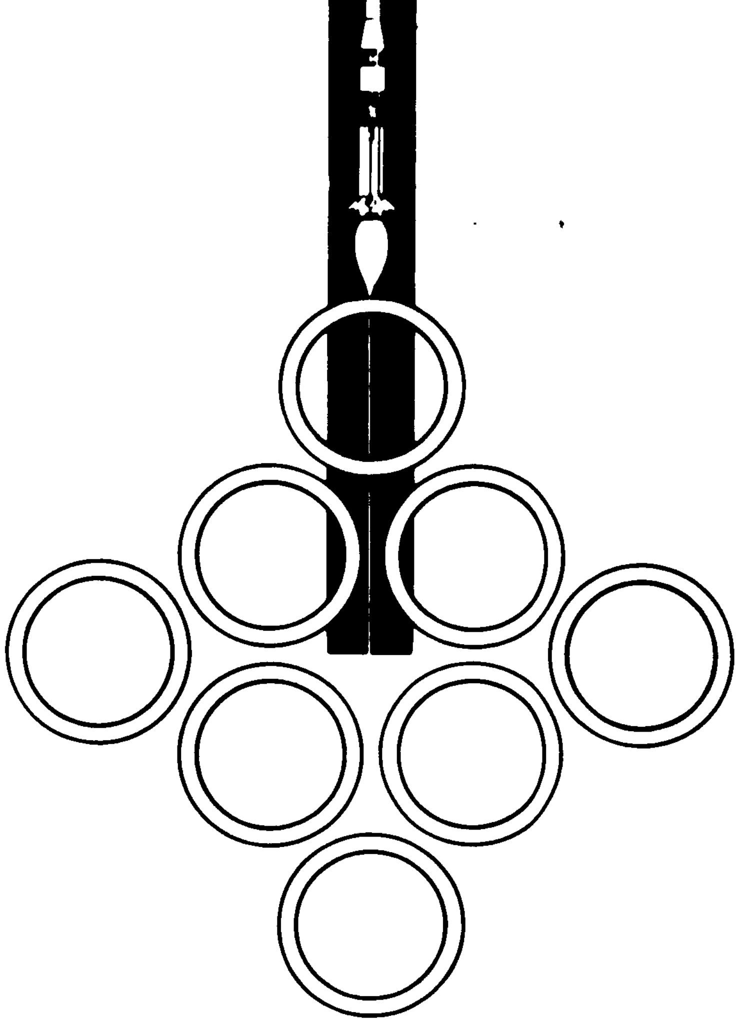

ENGINEERING DEPARTMENT

TECHNICAL REPORT

TR-P&VE-68-69

FINAL FLIGHT PERFORMANCE PREDICTION FOR SATURN AS-207 (MISSION 276) PROPULSION SYSTEM, S-IB-7 STAGE

SATURN S-IB STAGE AND SATURN IB PROGRAM

SPACE DIVISION CHRYSLER CORPORATION

TECHNICAL REPORT

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FINAL
FLIGHT PERFORMANCE PREDICTION
FOR
SATURN AS-207 (MISSION 276) PROPULSION SYSTEM
S-IB-7 STAGE

June 15, 1968

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ABSTRACT

This report covers the prediction of the S-IB-7 propulsion system flight performance and supersedes CCSD Technical Report TR-P&VE-67-46, due to changes in propulsion criteria and launch schedule.

Analyses of the prediction data indicate that inboard and outboard engine cutoffs will occur approximately 136.94 seconds and 139.94 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-207 (fourth quarter of 1968).

FOREWORD

This report presents the flight performance prediction data for the Saturn AS-207 (Mission 276) Propulsion System, S-IB-7 stage, and is authorized by Contract NAS8-4016, DRL 039, Revision C, Item 35.

The prediction data were determined by simulating the first stage powered flight of the Saturn AS-207 with the Mark IV computation procedure. The data presented in this report supersedes those presented in CCSD Technical Report TR-P&VE-67-46.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

Section 1

SUMMATION

1.1 INTRODUCTION

This report presents the flight performance prediction of the S-IB-7 propulsion system and a discussion of the data and methods used in making the prediction.

The AS-207 configuration used in this prediction is to be part of the Mission 276 dual launch. AS-206 will carry a Lunar Module as a payload, while AS-207 will place an Apollo Command Service Module into orbit to be mated with the Lunar Module.

1.2 OBJECT

The object of this report is to present the predicted performance parameters of the S-IB-7 propulsion system.

1.3 CONCLUSIONS

Analyses of the available data indicate that nominal inboard and outboard engine cutoff (IECO and OECO) will occur approximately 136.94 seconds and 139.94 seconds after first motion, respectively. These times are based on the following assumptions:

a. A nominal fuel load specific weight of 50.25 lbm/ft^3.

b. A nominal LOX load specific weight of 70.574 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.

d. Stage nominal fill weights of 631,932 pounds of LOX and 279,177 pounds of fuel.

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Section 2

DISCUSSION

2.1 VEHICLE DESCRIPTION

The AS-207 vehicle will consist of the S-IB-7 first stage, S-IVB second stage, the S-IU-207 instrument unit, and an Apollo command/service module payload. The vehicle is scheduled for launch during the fourth quarter of 1968 as part of a dual launch Apollo support mission.

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 1.

Changes in criteria from those used in reference 1 are revisions to the H-1 engine table of influence coefficients, Rocketdyne single engine acceptance test data, launch date, axial force coefficients, stage trajectory, and engine performance biasing factors.

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 3-sigma propellant density dispersions for that month; and one case represents a minimum residual dispersion.

2.2.1 Nominal Prediction

Specific performance data were recorded on magnetic tapes B5 and B6, reels 3775 and 6140, respectively. These tapes were delivered to CCSD Aerospace Physics Branch (Department 2780). A duplicate copy of the B6 tape (reel 6291), required by the Aero-Astrodynamics Laboratory (R-P&VE-FMT), MSFC, was submitted to the Performance Analysis Section (R-P&VE-PPE), MSFC. The weights cards have been given to the CCSD Weight Control Group (Section 2733) for evaluation.

Weight data are presented in table 1. Stage parameters, including predicted fill weights, ullage volumes, and engine cutoff times, are shown in table 2. 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 engine performance curves 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 consisted of fuel density dispersions due to 3-sigma prelaunch ambient air temperature and LOX-proximity chilldown rate 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 2.

The minimum residual dispersion is commonly referred to as the -3-sigma engine mixture ratio (EMR) residual propellant dispersion. The data for this dispersion reflects an approximate shift of -0.67 percent in propellant mixture ratio while holding the 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 800 pounds of fuel available prior to OECO; as a result, 1800 pounds of additional fuel will be consumed with the nominal LOX consumption. This case simulates a simultaneous OECO signal from the thrust OK pressure switches and the fuel depletion probes.

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

Condition	Tape B5 Reel No.	Tape B6 Reel No.	Tape B7 Reel No.	Duplicate Tape B6 Reel No.
3-Sigma Low Fuel Density	2539	1613	1413	7680
3-Sigma High Fuel Density	8889	9137	6871	3156
3-Sigma Low LOX Density	3269	6101	6952	4969
3-Sigma High LOX Density	3783	7082	2243	3464
-3-Sigma Mixture Ratio	1880	1911	1895	6751

The weights cards 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 copies of tape B6 (previously listed) were submitted to the Performance Analysis Section (R-P&VE-PPE) MSFC.

2.2.3 Propellant Usage

The nominal stage fill weights shown in table 3 were determined for a LOX volume of approximately 66,990 gallons, having a specific weight of 70.574 lbm/cu ft, and a corresponding amount of fuel (required for simultaneous depletion of consumable propellants) at a specific weight of 50.25 lbm/cu ft (reference 2). The fill weights shown in the table will be required for the depletion of nominally defined consumable propellants.

Variations from the predicted fuel density will require adjustments to the predicted propellant loads to ensure defined 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 all previous S-IB flights.

The LOX specific weight is based on a predicted wind velocity of 9.8 knots at launch time. The fuel specific weight was determined by using an estimated ambient air temperature for the month of launch during the fourth 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. The same fuel density vs. temperature information was used as that for AS-206. When a fuel sample is available for AS-207 the data will be evaluated and this report will be updated if necessary.

All LOX in the tanks, sumps, and interchange lines (except approximately 3 gallons trapped in the center tank sump) can 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 1.

It is predicted that the fuel level (for the nominal case) 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 suction lines is shown as fuel residual in table 1.

A portion of the predicted fuel residual is the 1000-pound fuel bias available for consumption prior to IECO. Approximately 800 pounds more of the residual can be consumed prior to OECO if a significantly lower than predicted consumption ratio is experienced. If nominal performance occurs, this 1800 pounds of fuel will not be consumed.

2.2.4 Engine Performance

S-IB-7 is the second S-IB stage that has the 205K thrust H-1 engines. Engine data from Rocketdyne individual engine acceptance tests, the short and long duration stage static tests, and comparison of these data with other H-1 engine data were analyzed to predict stage flight propulsion performance. The various data for S-IB-7 are shown in table 3. A summary of the individual engine data has been made in table 4 by averaging the data from table 3.

Rocketdyne has revised the H-1 engine power balance computer program (engine mathematical model) and table of influence coefficients (gain table) since the last S-IB-7 Propulsion System Prediction was published (reference 1). The revisions are a result of Rocketdyne's latest gain study (reference 3). The mathematical model is used to reduce Rocketdyne single engine acceptance test data to rated pump inlet conditions (sea level data). The gain table is used in propulsion performance predictions and also in the site reduction of MSFC stage static test firings. The data presented in table 3 is a summation of all S-IB-7 engine site data reduced to standard sea level conditions with the latest mathematical models.

When the stage static test data were reduced with the latest 205K thrust gain table, no attempt was made to adjust engine propellant flowrates according to tank discrete probe data. The flowrates quoted for the stage static tests are calculated values that were obtained by the "rpm-match" method of reconstructing stage static test data. This method determines individual engine flowrates by adjusting the Rocketdyne flowrates to be consistent with the power level of the engines during stage static test, using measured turbopump speed. Therefore, the flowrate data shown in table 3 for the stage tests are not necessarily exact.

The engine histories for the majority of 200K and 205K H-1 engines have indicated an upward shift in performance from Rocketdyne acceptance tests to stage static tests. A further increase from stage static test to flight has occurred for the 200K engine powered stage flights. However, during the stage static test of S-IB-7, three engines (positions 1, 6, and 8) exhibited lower performance levels than Rocketdyne acceptance test data. The performance of the engine in position 2 was lower during the short duration static test (SA-38) than during the Rocketdyne acceptance test, but was slightly higher during the long duration static test (SA-39). Two engines (positions 4 and 5) were replaced after static test, and no comparison can be made for them. This leaves only two engines (positions 1 and 7) with the usual upward shift in performance. The cause of the lower power levels on the three engines is not known, but the lower levels are supported by decreases in chamber pressures in all three engines, and lower pump speeds on two of the three engines. These data are shown in table 3. S-IB-6, the first stage with 205K thrust engines, had seven engines that showed lower performance during static test (see reference 4).

Biasing factors have been used on Rocketdyne acceptance test data in previous predictions because of the correlation (consistent deviation) between the Rocketdyne data and actual flight data. The biasing factors merely adjust the Rocketdyne data to agree with actual flight data. However, since it cannot be definitely concluded that the lower than usual power levels of the three engines during stage static test are not valid data, and there is no 205K flight data available, the performance biasing factors used for S-IB-7 are more conservative than those derived from the flight data of S-IB-1 through S-IB-4. The propellant flowrate adjustments (LOX and fuel flight biasing factors) were made since there is no direct evidence that the mixture ratio shift will not occur during flight even if the power levels are low. The shift in mixture ratio seen during past flights has a significant effect on stage performance and must be at least conservatively considered in this prediction. The predicted individual engine flight data reduced to sea level, and the rated pump inlet conditions at 30 seconds after first motion, are shown in table 5 and were used to predict flight performance. The flight biasing factors used in this prediction are as follows:

Parameter	Biasing Factor
Chamber Pressure	1.0050
Thrust	1.005598
Turbopump RPM	1.003987
LOX Flowrate	1.007305
Fuel Flowrate	1.002841

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-207 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 four 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 133.94 seconds after 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) 3.0 seconds after initiation of the time base two (T_2) 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 4 seconds, and the OECO mode can be either fuel depletion or LOX pump starvation.

The time base two (T_2) sequence, expected to start 133.94 seconds after first motion, is summarized as follows:

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

T_2 + 3.0 sec - IECO signal given by LVDC.

T_2 + 4.5 sec - Outboard engine thrust OK pressure switches grouped.

T_2 + 5.5 sec - Fuel depletion sensors armed.

T_2 + 6.0 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 in order to minimize the possibility of OECO caused by a premature sensor signal.

Table 1. Weight Breakdown For AS-207 Vehicle

Parameter	Miscellaneous (lb)	LOX (lb)	Fuel (lb)	Total (lb)
Consumption During Ignition and Holddown		11,006	3,273	14,279
Mainstage Consumption		614,088	267,537	881,625
Consumption During Inboard Engine Thrust Decay*		763	1,411	2,174
Consumption During Outboard Engine Thrust Decay•		634	1,352	1,986
Propellant Residual**		2,883	4,901	7,784
Gearbox Fuel Consumption			703	703
GOX Generated During Flight		2,558		2,558
Ice	1,100			1,100
Initial LOX Tank Pressurant	33			33
Hydraulic Oil	28			28
Oronite (Fuel additive for lubrication)	32			32
Initial Weight of Helium in Fuel Tanks	4			4
Initial Weight of Nitrogen and Helium in All Spheres (for fuel container pressurization, S-IB stage purge, etc.)	94			94
Total Upperstage Weight Plus S-IB Stage Dry Weight	394,356			394,356
Total Weight at Ignition Command	395,647	631,932	279,177	1,306,756

• 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 2. Stage Parameters For Propulsion Performance Predictions

Parameter	3σ Low LOX Density	3σ High LOX Density	Nominal Prediction	3σ Low Fuel Density	3σ High Fuel Density	-3σ Mixture Ratio*
Average Fuel Density (lb/ft^3) Average Fuel Temperature (°F)	50.25 60.	50.25 60.	50.25 60.	49.98 71.	50.80 38.	50.25 60.
Total Load LOX Density (lb/ft^3) Mean LOX Pump Inlet Temperature During Flight (°F)	70.287 -290.25	70.785 -293.36	70.574 -291.90	70.574 -291.90	70.574 -291.90	70.574 -291.90
Average Thrust (kips)	1,784.40	1,811.82	1,798.96	1,813.75	1,768.73	1,798.45
Average Specific Impulse (sec)	281.82	282.43	282.16	282.51	281.35	282.14
Average LOX Flowrate (lb/sec)	4,397.92	4,473.54	4,437.66	4,478.11	4,356.79	4,428.77
Average Fuel Flowrate (lb/sec)	1,933.84	1,941.72	1,937.97	1,942.20	1,929.82	1,945.51
Average Mixture Ratio	2.27413	2.30385	2.28980	2.30563	2.25757	2.27635
IECO (sec)	137.696	135.850	136.940	135.674	138.690	136.874
OECO (sec)	141.498	138.930	139.940	138.674	143.149	140.631
Fuel Load (lb)	279,177	279,177	279,177	277,296	283,096	279,177
LOX Load (lb)	631,309	632,205	631,932	631,932	631,932	631,932
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 (%) (pressurized)	3.44	3.44	3.44	3.58	3.14	3.44
LOX Ullage at Fill (%)	1.20	1.77	1.50	1.50	1.50	1.50

* Represents the fuel depletion or LOX starvation cutoff mode dispersion.

Table 3. Sea Level Test Data for S-IB-7 Stage Engines

Engine H-7077 Position 1	Static Test Analysis SA-38	Static Test Analysis SA-39	Average Rocketdyne Engine Logs From PAST-076 Program	Prediction*
Thrust (kips)	200.78	201.50	205.64	206.79
Chamber Pressure (psia)	694.75	696.98	708.09	711.63
Specific Impulse (sec)	261.34	260.27	262.35	262.27
LOX Flowrate (lbm/sec)	531.04	535.23	542.04	546.00
Fuel Flowrate (lbm/sec)	237.21	238.95	241.79	242.48
Mixture Ratio	2.2387	2.2399	2.2418	2.2518
Turbopump Speed (rpm)	6666.8	6704.0	6764.2	6791.2
Engine H-7078 Position 2				
Thrust (kips)	202.66	205.78	205.58	206.73
Chamber Pressure (psia)	697.72	707.34	705.08	708.60
Specific Impulse (sec)	262.95	263.03	263.07	262.98
LOX Flowrate (lbm/sec)	531.97	540.18	539.57	543.51
Fuel Flowrate (lbm/sec)	238.76	242.18	241.89	242.58
Mixture Ratio	2.2281	2.2305	2.2306	2.2406
Turbopump Speed (rpm)	6638.7	6711.8	6713.6	6740.4
Engine H-7076 Position 3				
Thrust (kips)	207.69	206.89	205.48	206.63
Chamber Pressure (psia)	712.33	709.88	705.62	709.15
Specific Impulse (sec)	264.99	263.78	264.02	263.93
LOX Flowrate (lbm/sec)	541.65	542.04	537.78	541.71
Fuel Flowrate (lbm/sec)	242.12	242.28	240.50	241.18
Mixture Ratio	2.2371	2.2372	2.2362	2.2460
Turbopump Speed (rpm)	6771.4	6774.7	6736.3	6763.2
Engine H-7074 Position 4				
Thrust (kips)	Not Applicable. Engine No. H-7080 was on stage during static test.		204.84	205.98
Chamber Pressure (psia)			706.89	710.42
Specific Impulse (sec)			262.55	262.46
LOX Flowrate (lbm/sec)			539.98	543.92
Fuel Flowrate (lbm/sec)			240.21	240.89
Mixture Ratio			2.2480	2.2580
Turbopump Speed (rpm)			6705.0	6731.8

Table 3. Sea Level Test Data for S-IB-7 Stage Engines (Continued)

Engine H-4078 Position 5	Static Test Analysis SA-38	Static Test Analysis SA-39	Average Rocketdyne Engine Logs From PAST-076 Program	Prediction*
Thrust (kips)	Not Applicable. Engine No. H-4073 was on stage during static test.		204.64	205.78
Chamber Pressure (psia)			700.80	704.30
Specific Impulse (sec)			263.70	263.62
LOX Flowrate (lbm/sec)			535.68	539.59
Fuel Flowrate (lbm/sec)			240.34	241.02
Mixture Ratio			2.2288	2.2388
Turbopump Speed (rpm)			6720.6	6747.4
Engine H-4074 Position 6				
Thrust (kips)	203.75	203.11	204.64	205.78
Chamber Pressure (psia)	699.97	698.01	702.72	706.23
Specific Impulse (sec)	263.76	262.86	262.98	262.90
LOX Flowrate (lbm/sec)	532.64	532.81	536.64	540.56
Fuel Flowrate (lbm/sec)	239.84	239.91	241.50	242.19
Mixture Ratio	2.2208	2.2209	2.2221	2.2320
Turbopump Ratio (rpm)	6632.7	6634.1	6668.0	6694.5
Engine H-4075 Position 7				
Thrust (kips)	206.37	207.80	205.84	206.99
Chamber Pressure (psia)	706.98	711.34	705.34	708.87
Specific Impulse (sec)	265.03	264.25	264.18	264.09
LOX Flowrate (lbm/sec)	537.61	543.02	537.93	541.86
Fuel Flowrate (lbm/sec)	241.09	243.34	241.22	241.91
Mixture Ratio	2.2300	2.2315	2.2300	2.2400
Turbopump Speed (rpm)	6698.5	6746.7	6700.8	6727.6
Engine H-4076 Position 8				
Thrust (kips)	207.12	206.26	207.30	208.46
Chamber Pressure (psia)	713.76	711.10	714.32	717.89
Specific Impulse (sec)	262.61	261.50	263.54	263.45
LOX Flowrate (lbm/sec)	545.55	545.61	544.08	548.05
Fuel Flowrate (lbm/sec)	243.15	243.18	242.53	243.22
Mixture Ratio	2.2437	2.2437	2.2434	2.2533
Turbopump Speed (rpm)	6749.3	6749.6	6735.4	6762.2

*See Section 2.2.4

Table 4. Summary of Sea Level Test Data for S-IB-7 Stage Engines

Average S-IB-7 Engines	Static Test Analysis SA-38	Static Test Analysis SA-39	Average Rocketdyne Engine Logs From PAST-076 Program	Prediction*
Thrust (kips)	204.73	205.22	205.50	206.64
Chamber Pressure (psia)	704.25	705.78	706.11	709.64
Specific Impulse (sec)	263.45	262.62	263.30	263.21
LOX Flowrate (lbm/sec)	536.74	539.82	539.21	543.15
Fuel Flowrate (lbm/sec)	240.36	241.64	241.25	241.93
Mixture Ratio	2.2331	2.2340	2.2351	2.2451
Turbopump Speed (rpm)	6692.9	6720.2	6718.0	6744.8

*See Section 2.2.4

Table 5. Predicted Sea Level Performance of S-IB-7 Stage Engines at 30 Seconds of Flight Time

Parameters	Nominal Value	Engine H-7077 Pos. 1	Engine H-7078 Pos. 2	Engine H-7076 Pos. 3	Engine H-7074 Pos. 4	Engine H-4078 Pos. 5	Engine H-4074 Pos. 6	Engine H-4075 Pos. 7	Engine H-4076 Pos. 8	Vehicle Parameters
Engine Thrust (kips)	205.00	206.79	206.73	206.63	205.98	205.78	205.78	206.99	208.46	1,647.43*
Engine Specific Impulse (sec)	263.63	262.27	262.98	263.93	262.46	263.62	262.90	264.09	263.45	262.13**
Chamber Pressure (psia)	704.71	711.63	708.60	709.15	710.42	704.30	706.23	708.87	717.89	---
Engine LOX Flowrate (lbm/sec)	536.86	546.00	543.51	541.71	543.92	539.59	540.56	541.86	548.05	4,345.20
Engine Fuel Flowrate (lbm/sec)	240.74	242.48	242.58	241.18	240.89	241.02	242.19	241.91	243.22	1,940.51**
Engine Mixture Ratio	2.2300	2.2518	2.2406	2.2460	2.2580	2.2388	2.2320	2.2400	2.2533	2.2392**
Turbopump Speed (rpm)	6691.3	6791.2	6740.4	6763.2	6731.8	6747.4	6694.5	6727.6	6762.2	---
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	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	---

* Thrust along longitudinal axis.
** Includes fuel used as lubricant.

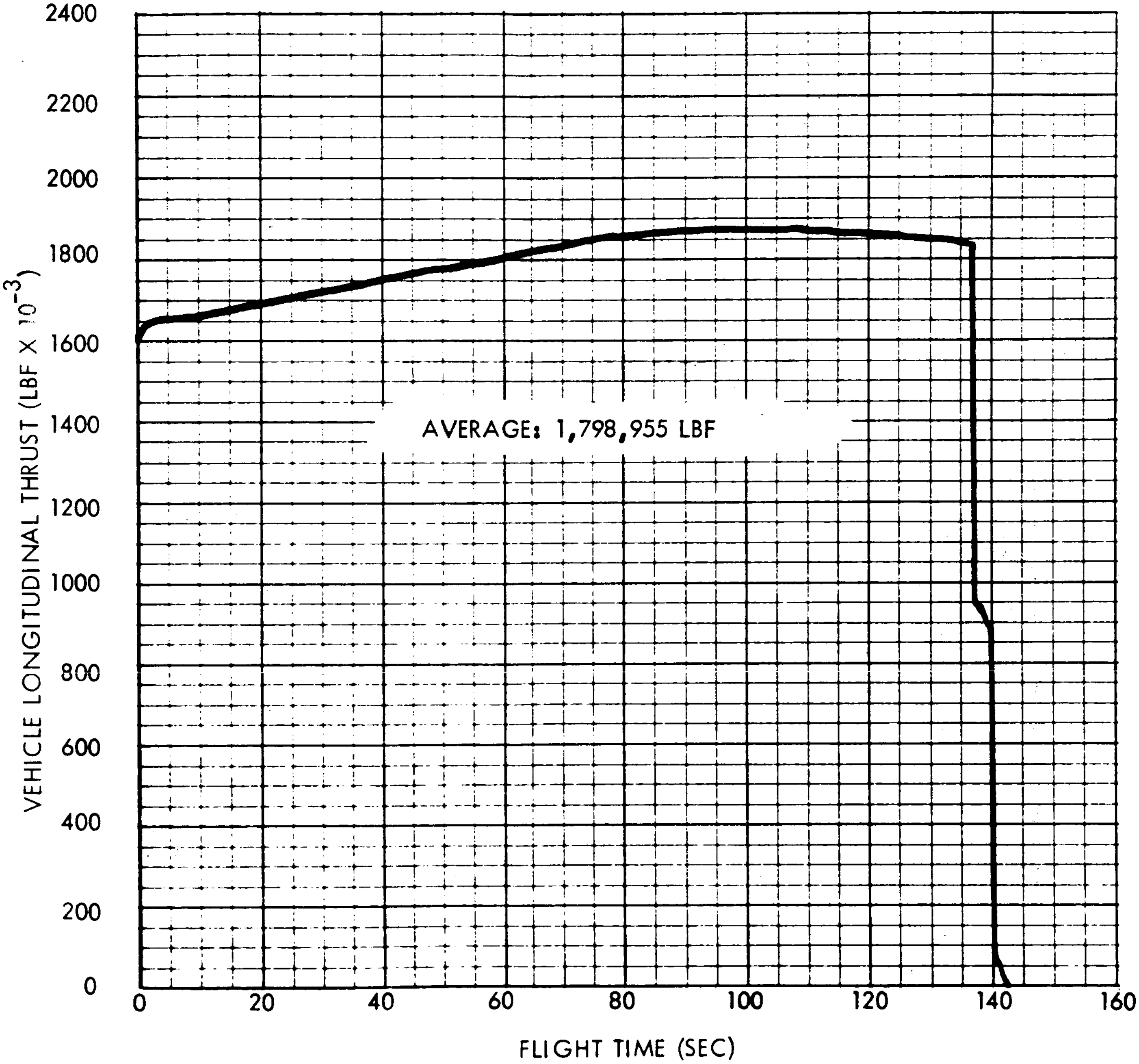

Figure 1. Vehicle Longitudinal Thrust Versus Flight Time

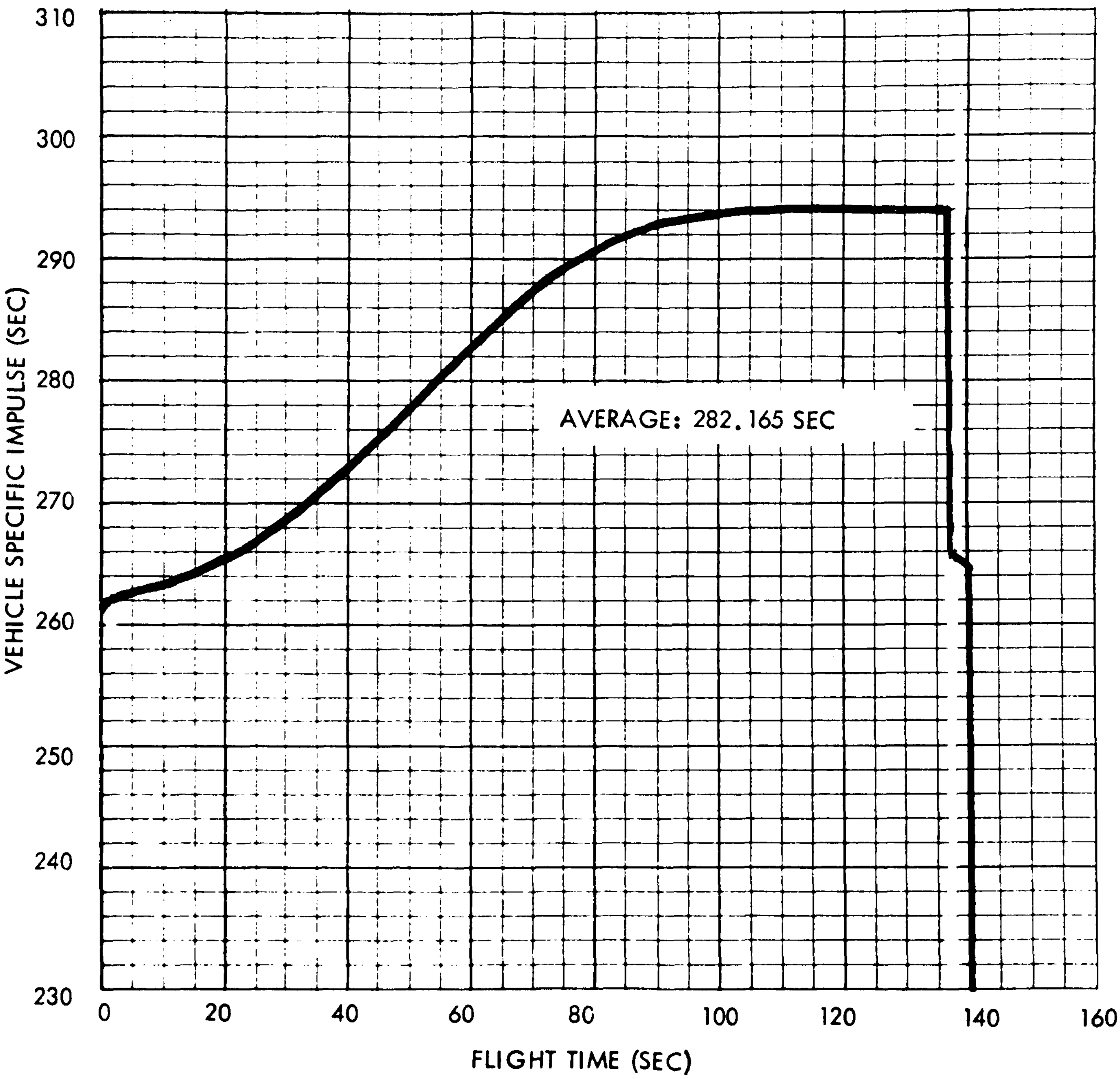

Figure 2. Vehicle Specific Impulse Versus Flight Time

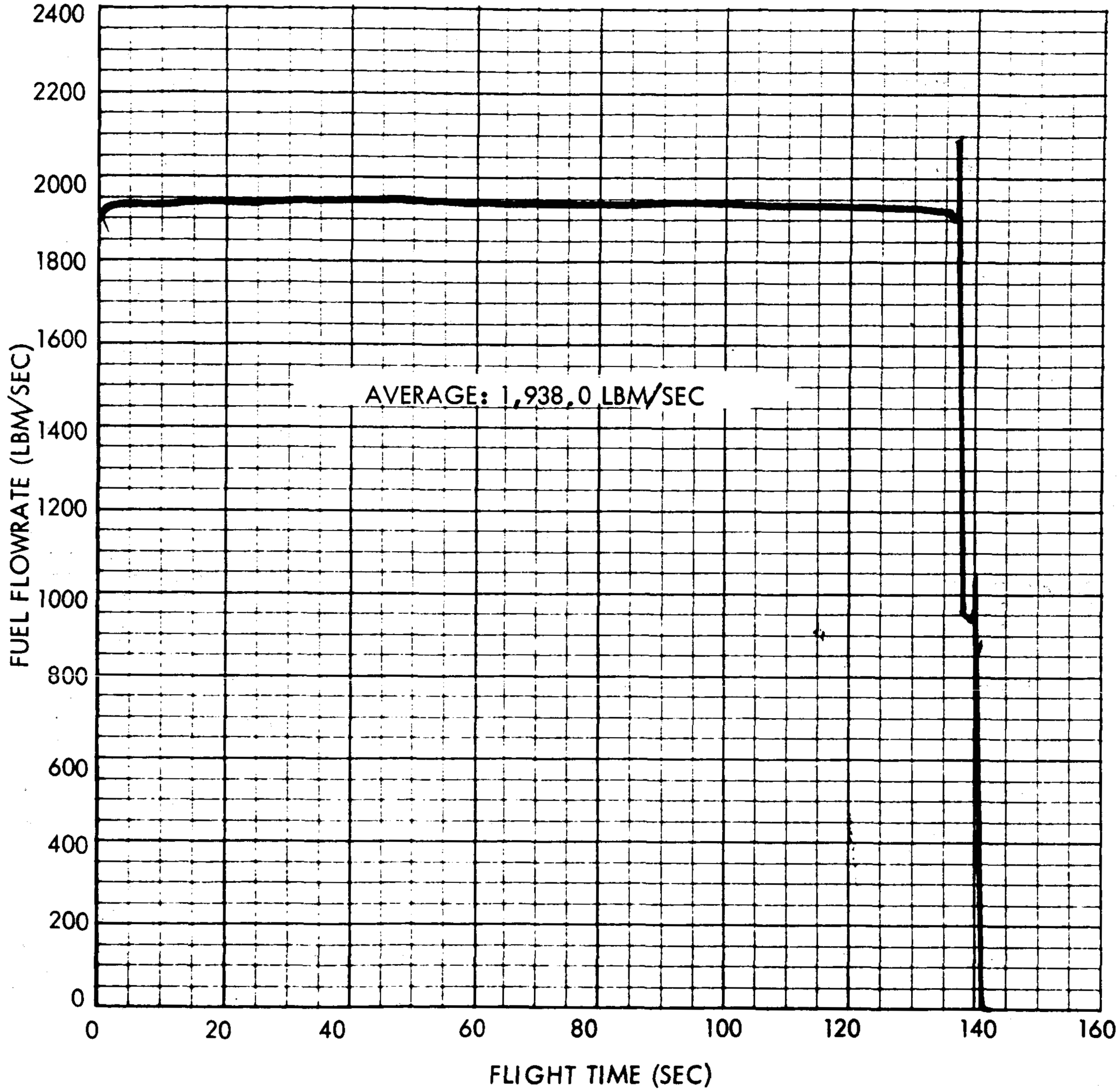

Figure 3. Total Vehicle Fuel Flowrate Versus Flight Time

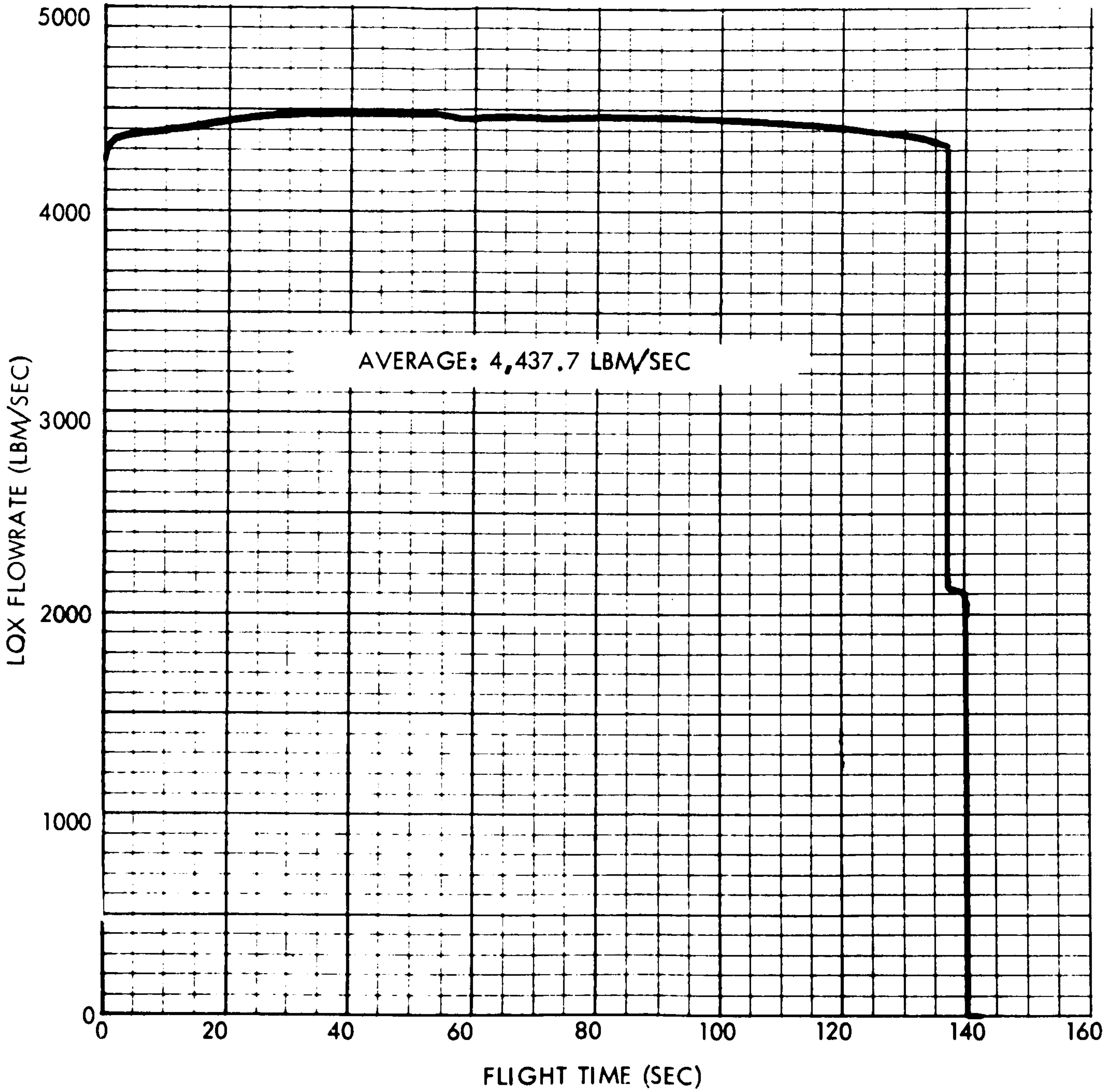

Figure 4. Total Engine LOX Flowrate Versus Flight Time

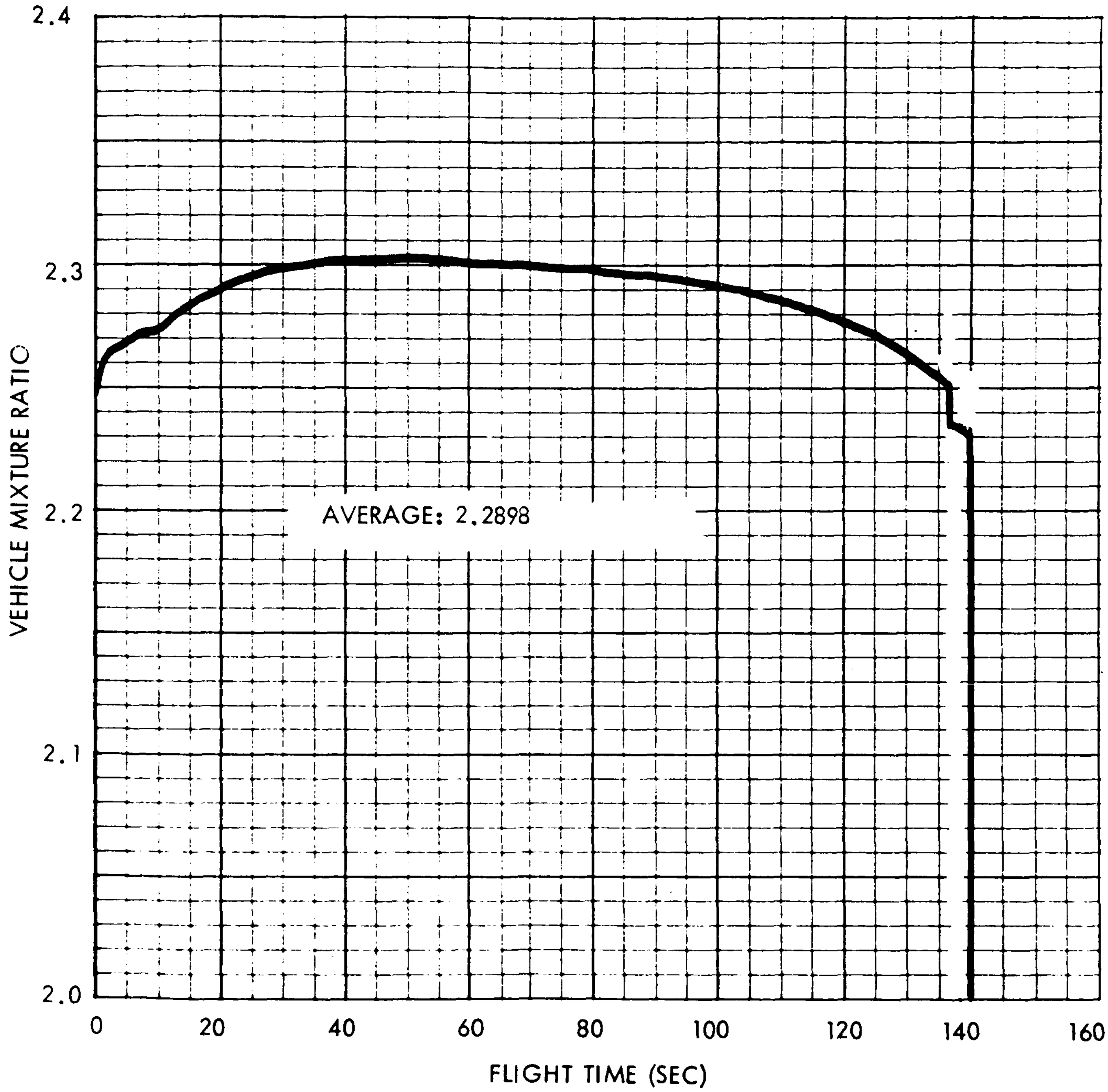

Figure 5. Vehicle Mixture Ratio Versus Flight Time

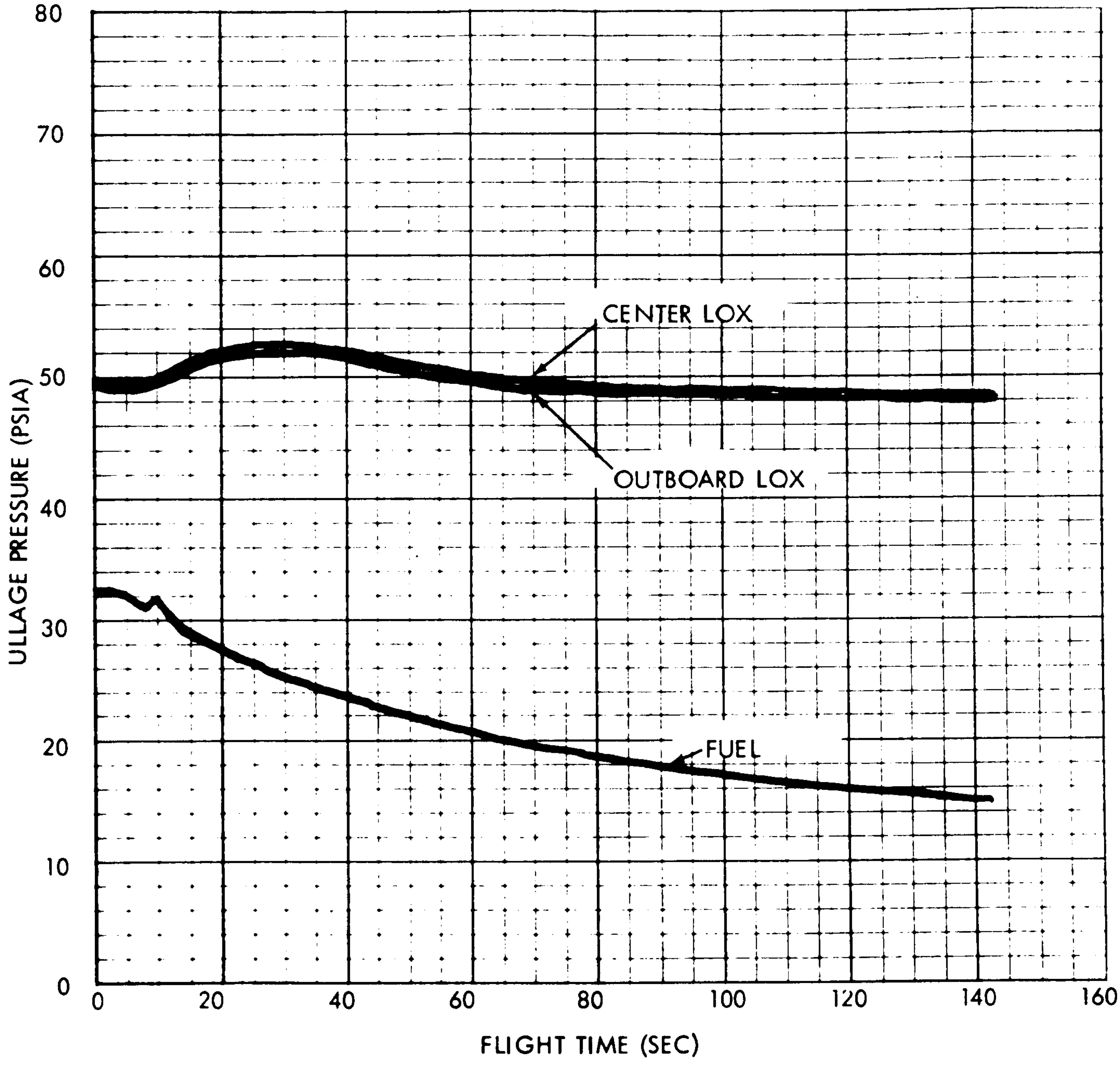

Figure 6. LOX and Fuel Tank Ullage Pressures Versus Flight Time

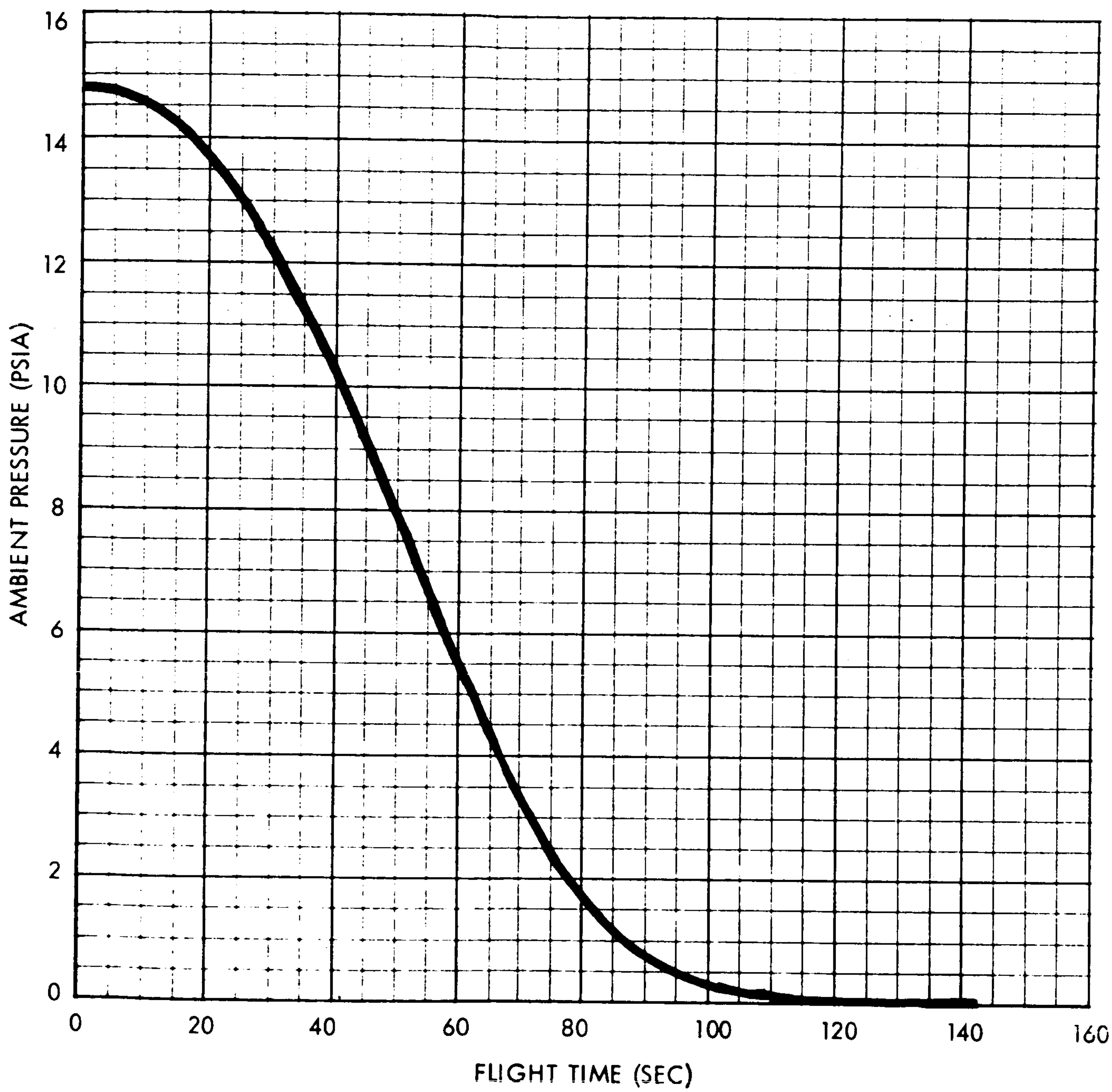

Figure 7. Ambient Pressure Versus Flight Time

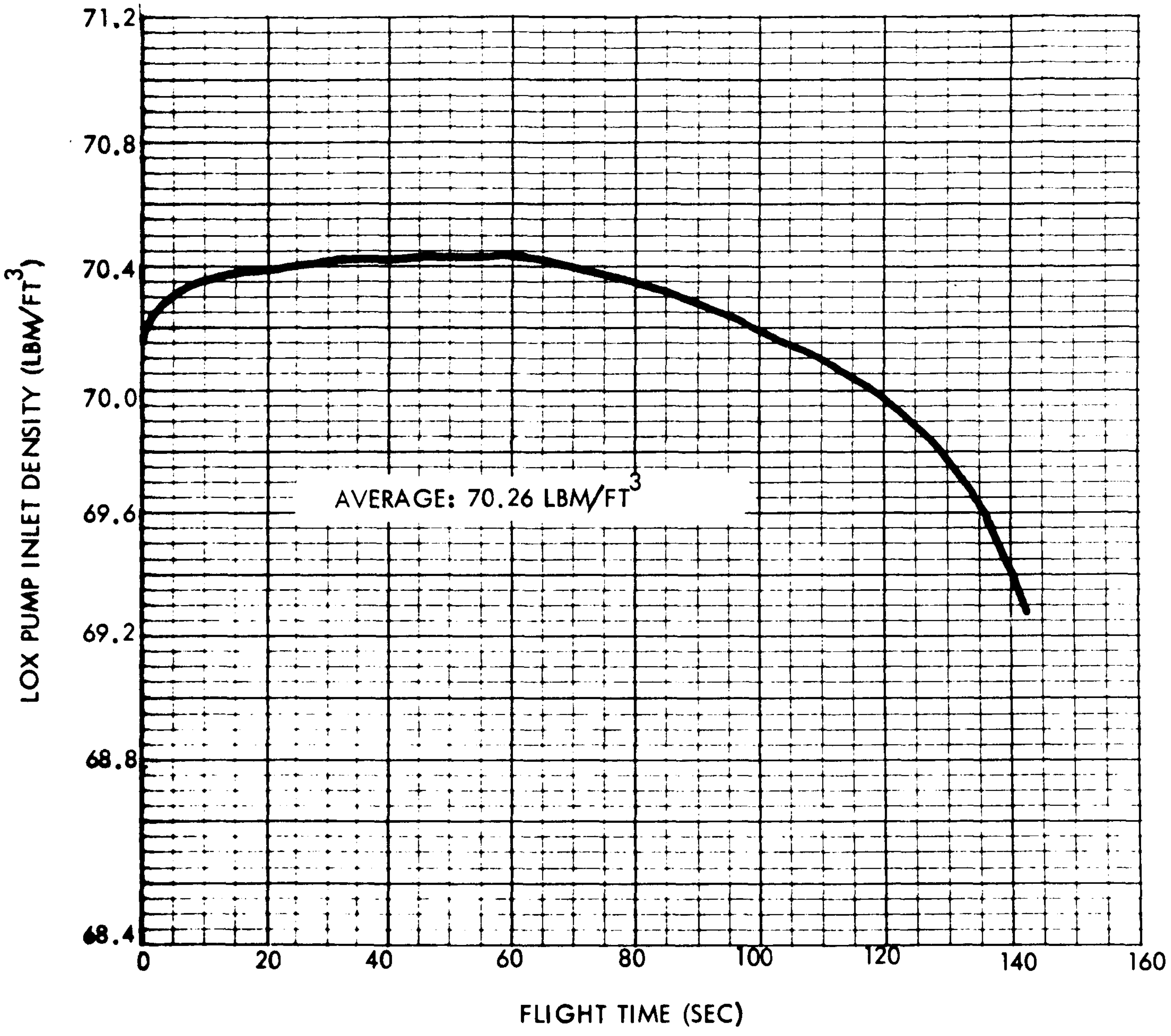

Figure 8. Engine LOX Pump Inlet Specific Weight Versus Flight Time

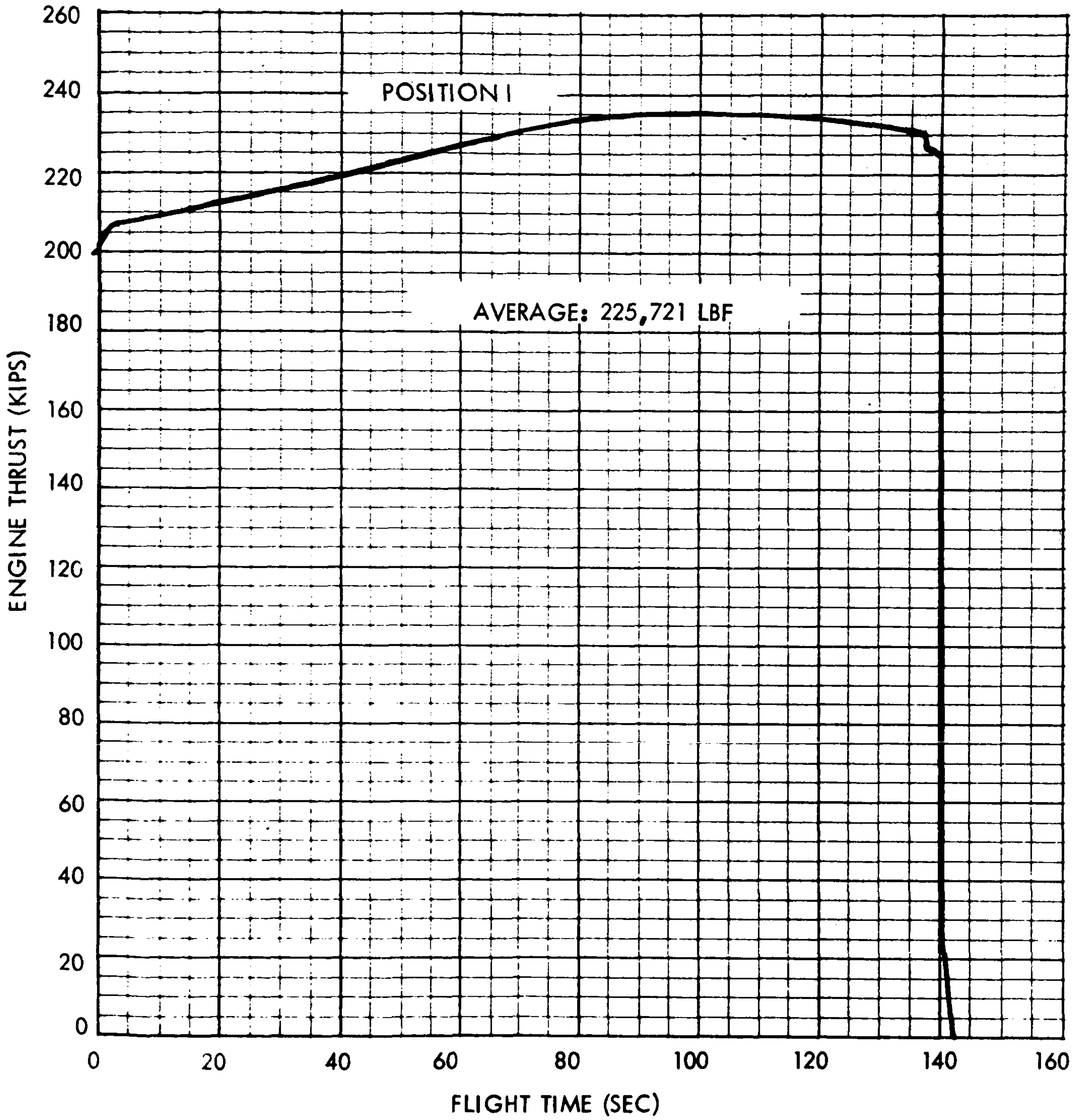

Figure 9. Typical Engine Thrust Versus Flight Time

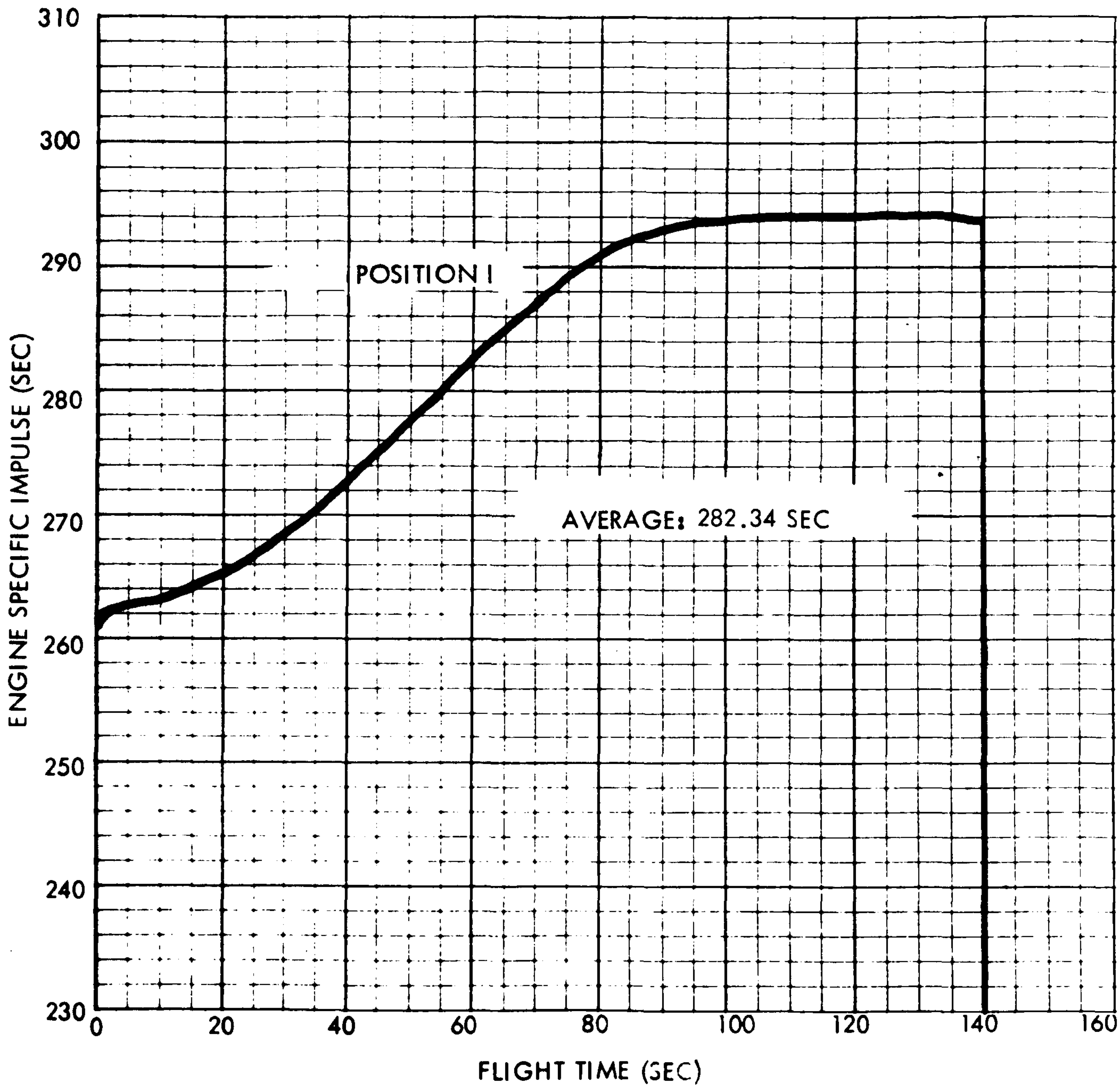

Figure 10. Typical Engine Specific Impulse Versus Flight Time

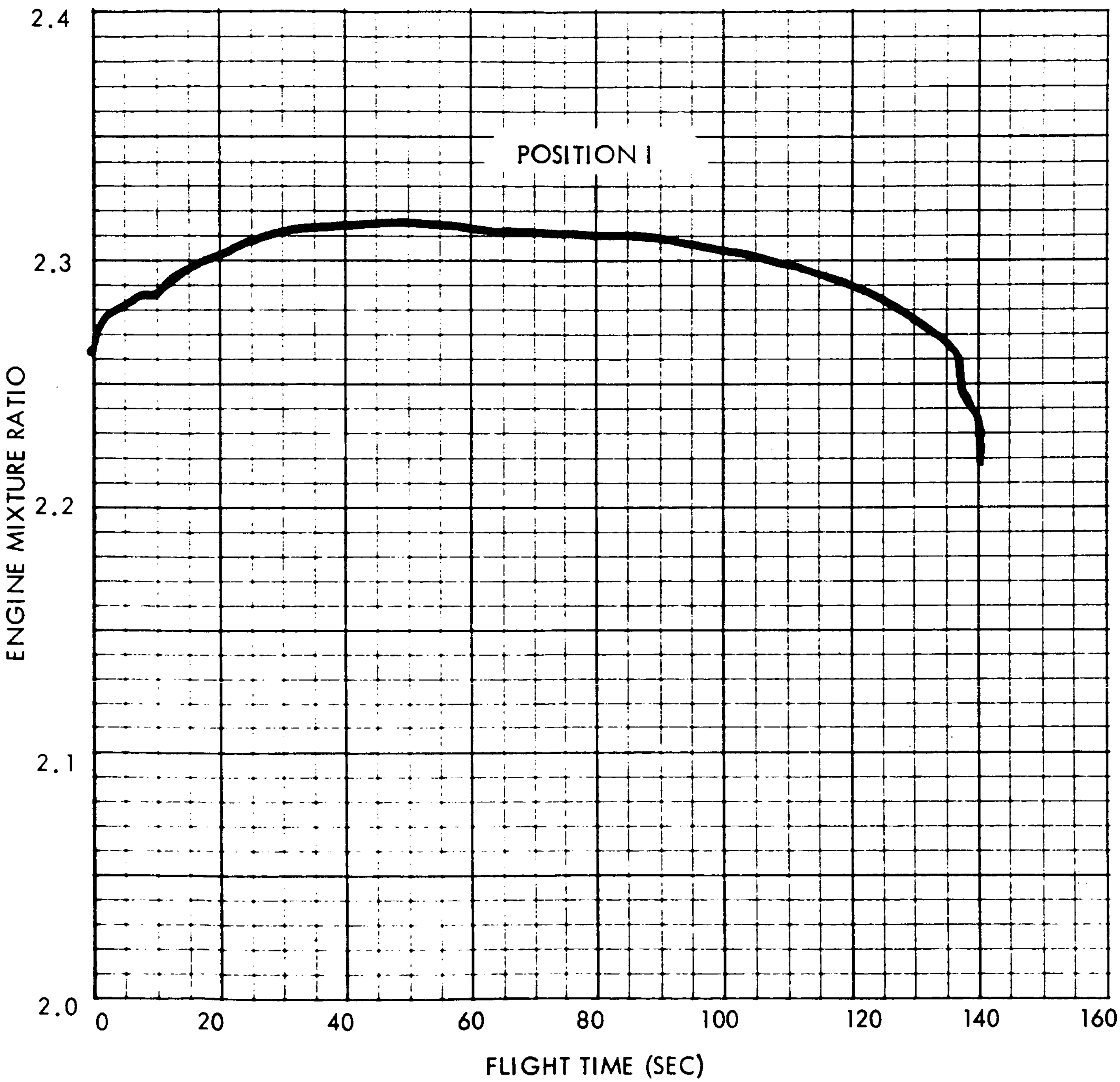

Figure 11. Typical Engine Mixture Ratio Versus Flight Time

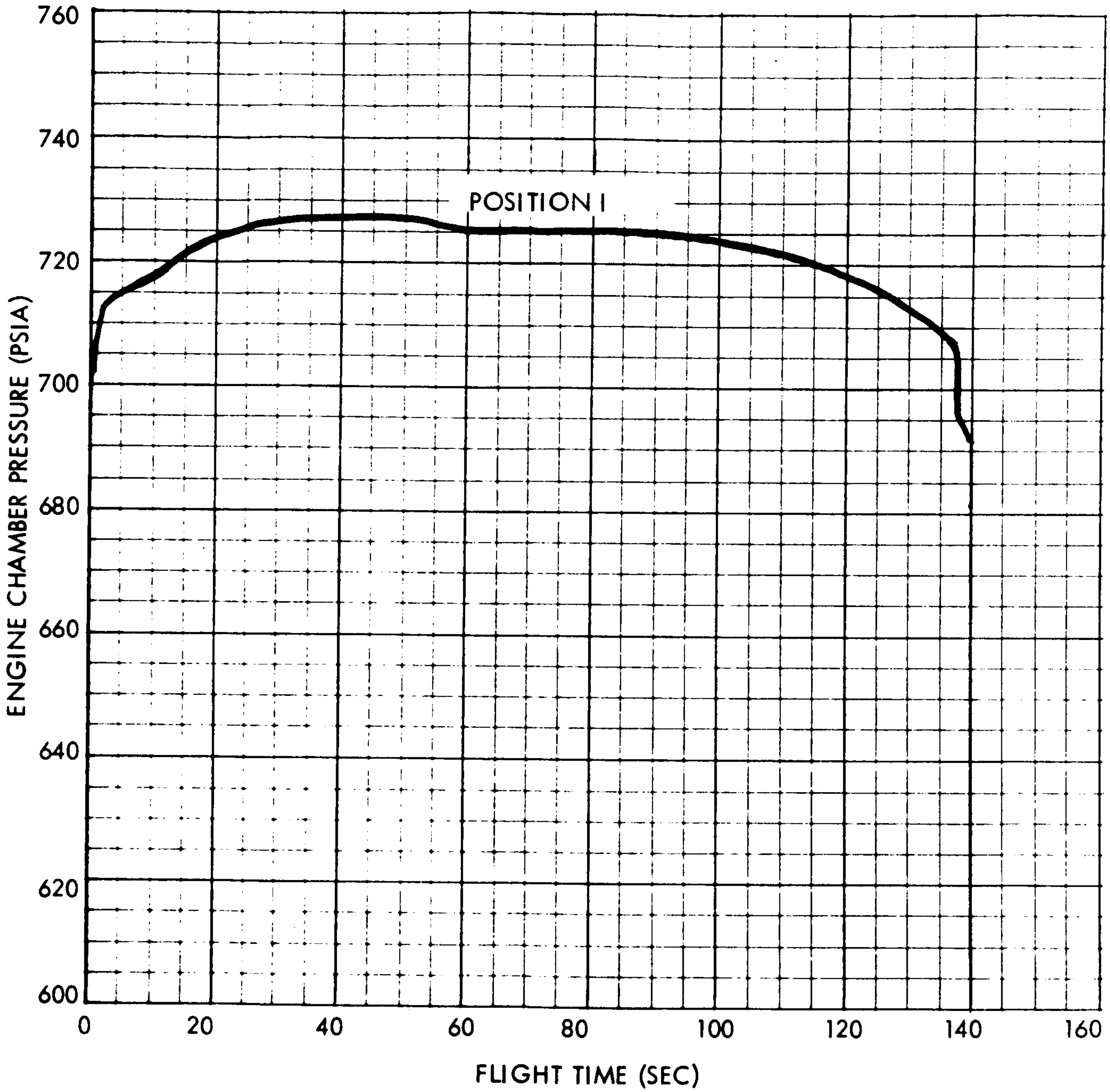

Figure 12. Typical Engine Chamber Pressure Versus Flight Time

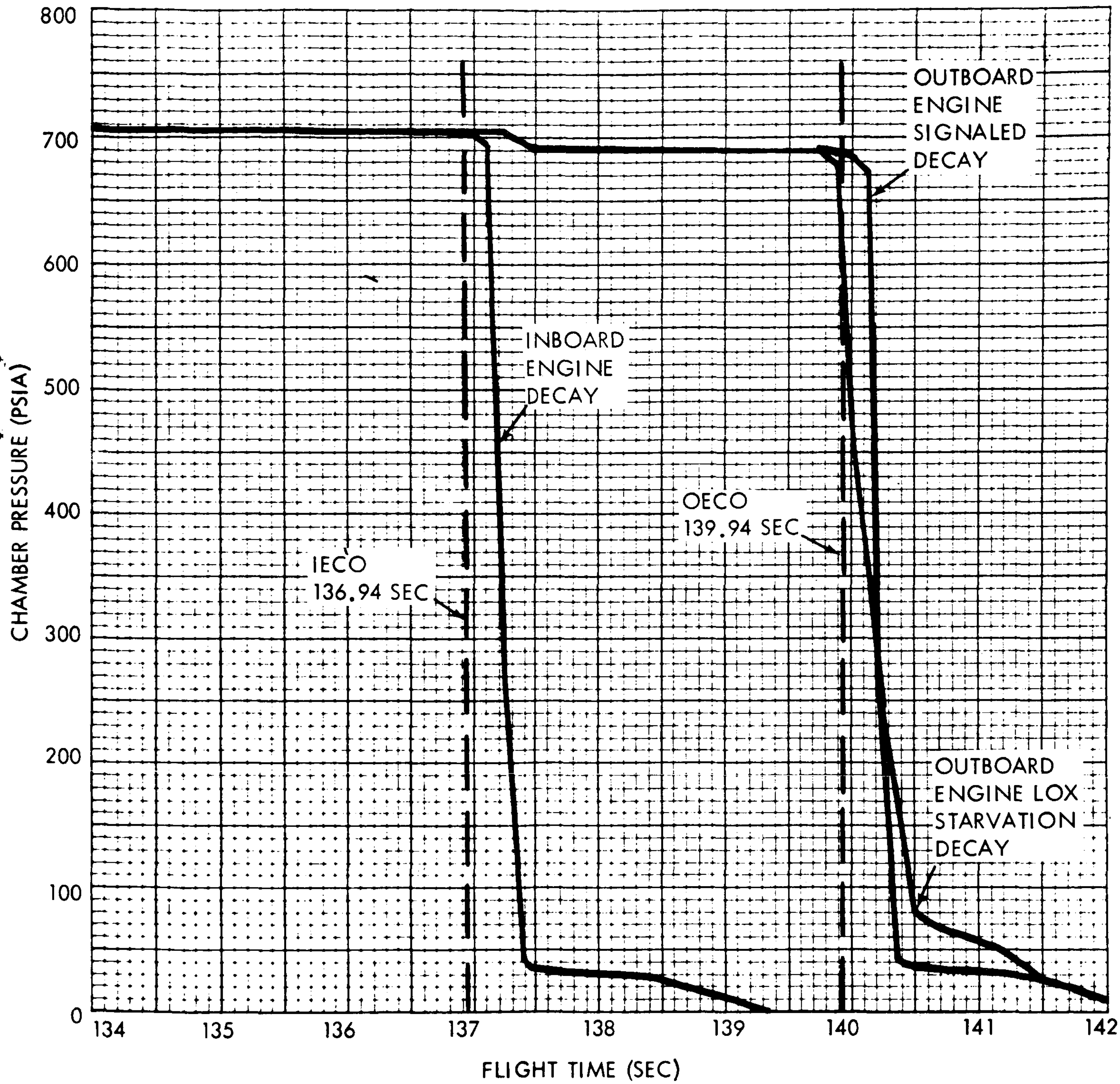

Figure 13. Typical Inboard and Outboard Engine Chamber Pressure Decay Relative to IECO

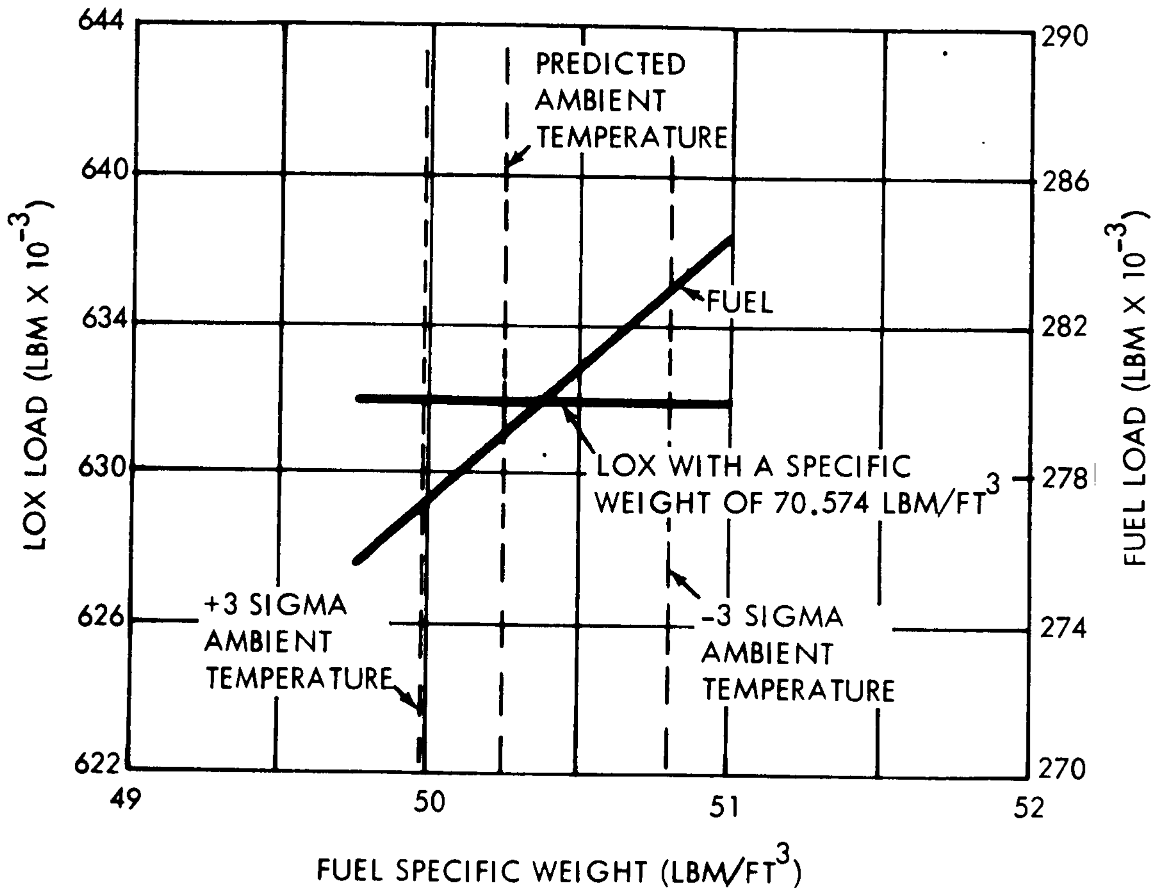

Figure 14. Propellant Load Versus Fuel Specific Weight

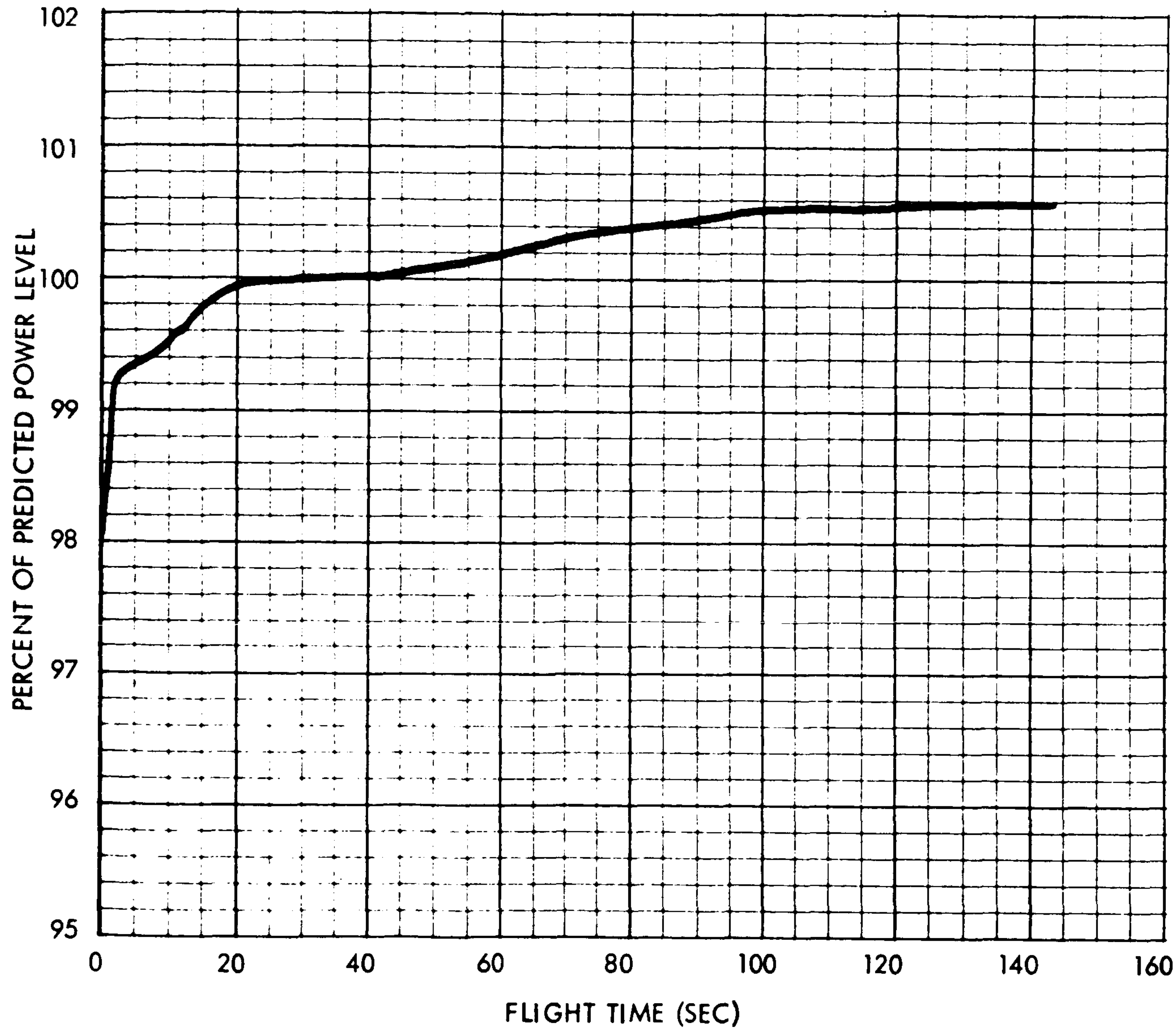

Figure 15. Predicted Sea Level Power Level Shift Versus Flight Time

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