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N69-80251

D5-15530-3 A

SATURN V S-II FINAL PROPULSION SYSTEM PERFORMANCE PREDICTION FLIGHT SA-503

VOLUME II OF III

JULY 15, 1968

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July 15, 1968

5-9350-H-120

To: National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812

Attention: R-P&VE-PPE, Mr. P. E. Black

Subject: S-II/503 and S-IVB/503 Final Propulsion System Performance Prediction Update for the SA-503 Manned Mission, SSR-207

Reference: Contract NAS8-5608, Schedule II, Part V, Exhibit AA, Task 1.0, Special Support Request No. 207

1. This memo transmits the results of the S-II/503 and S-IVB/503 Final Propulsion System Performance Prediction Update for the SA-503 Manned Mission in accordance with the referenced Special Support Request No. 207.

2. The results of this study completely revise and replace Boeing documents D5-15530-3, Volumes II of III and III of III dated February 2, 1968.

3. The purpose of this study is to provide compatible S-II/503 and S-IVB/503 propulsion data for use in the final operational trajectory for the SA-503 manned mission.

4. The attached documents, in conjunction with magnetic data tapes and weights cards that were delivered on July 1, 1968, fulfill the requirements of the referenced contract.

for John W. Allen
E. G. Cowart

Attachment:
SATURN V S-II AND S-IVB FINAL PROPULSION SYSTEM PERFORMANCE PREDICTION, FLIGHT SA-503, D5-15530-3A Volume II of III and Volume III of III, Dated July 15, 1968

DOCUMENT NO. D5-15530-3A VOLUME II of III

TITLE SATURN V S-II FINAL PROPULSION SYSTEM PERFORMANCE PREDICTION, FLIGHT AS-503

MODEL NO. SATURN V CONTRACT NO. NAS8-5608, SCHEDULE II TASK 8.3.1

Prepared by: SATURN V PROPULSION SYSTEMS

Revision A JULY 15, 1968

for John W. Allen
E. G. COWART

ISSUE NO. H-57 ISSUED TO Tech Library Boeing/Houston

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REFERENCES

1. Boeing Memo 5-9360-H-21, "S-IC Stage Propulsion Performance Digital Simulation (MARK VIIA - MOD 1) Baseline Computer Program", November 28, 1967.

2. Boeing Memo 5-9360-H-80, "S-II Stage Propulsion Performance Digital Simulation (MARK IX - MOD 4) Baseline Computer Program", May 3, 1968.

3. Boeing Memo 5-9360-H-23, "S-IVB Stage Propulsion Performance Digital Simulation (MARK X - MOD 1) Baseline Computer Program", November 29, 1967.

4. Boeing Document D5-15506-3, "Saturn V Preliminary Propulsion System Performance Prediction with Dispersions, Flight AS-503 (U)", March 15, 1967.

5. Attachment to GFDA 0257.03.131, "Ground Rules for Propulsion System Performance Analysis", January 12, 1968.

6. Boeing Drawing 60B37301, Revision E, "Start Times - F-1 Engine, S-IC," August 10, 1967.

7. Rocketdyne Letter 67RC9054, "F-1 Engine Performance Values for Vehicle 503 (S-IC-3 Stage)", August 3, 1967 (Confidential).

8. MSFC Drawing 10M30633, Revision C, "Saturn V/SA-503 Flight Sequence of Events (BP-30 Mission)," December 18, 1967.

9. R-P&VE-VAW Weights Data, "Saturn V/SA-503 Weight Buildup for Propulsion Flight Simulation", December 21, 1967.

10. Boeing Document, D5-15530-3, "Saturn V S-II Final Propulsion System Performance Prediction Flight SA-503," Volume II of III, dated February 2, 1968.

11. Douglas Report DAC-56358, "Saturn S-IVB-503N Stage Acceptance Firing Report", June 1967.

SOURCE DATA PAGE

The following list of government furnished documentation were used in the preparation of this document release (Volume II S-II Stage):

Exhibit FF Line Item No.	GFD Title	Date of Issue	Revision Date
I-E-J; 1	Rocketdyne J-2 Engine Log Book, J-2051	January 10, 1966	April 3, 1967
I-E-J; 1	Rocketdyne J-2 Engine Log Book, J-2053	January 27, 1966	April 13, 1967
I-E-J; 1	Rocketdyne J-2 Engine Log Book, J-2059	May 18, 1966	May 19, 1967
I-E-J; 1	Rocketdyne J-2 Engine Log Book, J-2045	August 3, 1966	May 19, 1967
I-E-J; 1	Rocketdyne J-2 Engine Log Book, J-2055	February 18, 1966	None
I-E-J; 6	Rocketdyne J-2 Engine Manual R-3825-1	August 6, 1965	September 20, 1967
R-P&VE; 36	S-II Work-Around Data, Brown Engineering Memo BSVD-P5-67-135	October 31, 1967	None
R-P&VE; 36	Saturn V/SA-503 Flight Sequence, NASA Memo 10M30633, Rev. B	July 25, 1966	April 20, 1967
R-P&VE; 36	NASA Saturn V Weight Buildup for Propulsion Flight Simulation, SA-503	December 31, 1967	None
R-P&VE; 36	S-II Work-Around Data, NASA Massa Taq Program Output	January 8, 1968	None
R-P&VE; 36	Stage Contractor, S-II/503 Final Prediction	January 18, 1968	None
R-P&VE; 39	MSFC S-II MARK IX - MOD 0 Propulsion Performance Prediction Program	December 9, 1966	January 30, 1967

SOURCE DATA PAGE (Continued)

Exhibit FF Line Item No.	GFD Title	Date of Issue	Revision Date
R-P&VE; 39	S-II Propulsion Control System, 20M97009	September 1965	February 10, 1966
R-P&VE; 115	S-II Stage Contractor Final Propulsion System Flight Performance Prediction Data Tape	January 18, 1968	None
R-P&VE; 116	S-II Stage First Firing Hardwire and Telemetry Data Tapes	October 15, 1967	None
R-P&VE; 116	S-II Stage Second Firing Data Tapes	October 15, 1967	None
P-P&VE; 116	S-II Stage Second Firing Telemetry Data Tapes and Work-Around Data	December 4, 1967	None

SECTION 4

S-II STAGE

4.0 GENERAL

This section presents the Boeing S-II final propulsion system performance prediction for the 503 manned mission. This prediction was made with the MARK IX - MOD 4, S-II Propulsion Performance Computation Procedure and is based on the final S-II stage hardware configuration, and the results of the S-II stage Final Static Test No. 203532.

A comparison of the Boeing and stage contractor propulsion system performance predictions for the 503 manned mission is given in Appendix A. The data tapes of both the Boeing and stage contractor predictions are on file in the MSFC Computation Laboratory and the Boeing Simulation Center under the tape identification numbers listed below. The R-P&VE Laboratory of MSFC will recommend the prediction that is to be used for the 503 final operational trajectory for the manned mission and provide the users with the appropriate tape numbers.

TABLE 4-I S-II DATA TAPE IDENTIFICATION NUMBERS

S-II 503 MANNED FINAL PREDICTION	R-COMP NO.	BOEING SIM. CTR. NO.
Boeing Saturn V Prediction Data	*	H-2651
Stage Contractor Prediction Data	0-6942	*

*Not Available

4.1 S-II STAGE PERFORMANCE

4.1.1 Vehicle Performance

The S-II propulsion system performance prediction was based on the flight sequence, stage weights and engine characteristics given in Table 4-II through 4-VI and References 8 through 10. The flight sequence of events for the 503 manned mission is given in Table 4-II for flight times referenced to both mainstage time and J-2 engine start command. A stage weight history for various flight times is given in Table 4-III. The engine serial numbers for the S-II/503 mission and their relative positions with reference to the vehicle pitch and yaw planes are shown in Figure 4-1. Detailed engine data are given in paragraph 4.1.2.

The pressurization system performance was calculated using the MARK IX pressurization subroutine, assuming initial LOX ullage and fuel ullage temperatures of 200.0°R and 100.0°R, respectively. Table 4-IV lists the main pressurization system constants and charactersitics.

The major vehicle performance characteristics are shown in Figures 4-2 through 4-[illegible]. These parameters are compared to the stage contractor 503 manned mission final prediction in Appendix A. The remainder of the

4.1.1 (Continued)

vehicle performance characteristics predicted by Boeing are shown in Figures 4-9 through 4-22, and 4-40 through 4-42.

The vehicle thrust of Figure 4-2 and the vehicle specific impulse of Figure 4-3 do not include engine clustering effects at altitude. Figure 4-6 also illustrates the effect of the fuel tank pressurization flowrate step at 297.0 seconds. The two irregularities in Figure 4-4 represent the effects of the S-IC/S-II interstage and LES weight drops on overall vehicle performance.

4.1.2 Engine Performance

This section provides individual engine performance data, at standard inlet conditions, that were used in the final propulsion system performance prediction for the 503 manned flight. Single engine and stage static firing performance histories are presented in Tables 4-Va through 4-Ve.

The first column in these tables contains the average performance of the single engine acceptance data from the Rocketdyne J-2 engine log books. These data differ from the stage static firing values shown in columns 2, 3 and 4 in part, because the LOX pump on each engine was changed after the single engine acceptance tests were completed. The data in column 2 are the performance values of the final stage static test calculated by the stage contractor. The data in columns 3 and 4 are values from the two stage static tests calculated by Boeing.

The engine performance presented in column 3 were obtained from test 203531 data by lowering the chamber pressure so that the calculated specific impulse would be within the desired limit of ±1 LBF-SEC/LBM when comparing single engine and stage test performance. The engine performance presented in column 4 from test 203523 did not require any adjustment because the calculated specific impulse was within the desired limit. Since the data from test 203523 did not require any adjustment, it was used as the basis to develop engine tag values for this prediction.

Predicted flight performance for J-2 engines number 1 and 5 are shown in Figures 4-23 through 4-40. These plots represent typical S-II stage engine performance for the 503 vehicle. The predicted performance levels of thrust (Figure 4-23), specific impulse (Figure 4-28), chamber pressure (Figure 4-26), and mixture ratio (Figure 4-33) for these two engines are higher than the final stage test performance at standard inlet conditions (at altitude) given in Tables 4-Va through 4-Ve. These differences are due to higher inlet conditions and the use of less than nominal auxiliary horsepower for the prediction.

The predicted available NPSH data for the fuel and LOX pumps are shown in Figures 4-38 and 4-39, respectfully. Values for fuel pump NPSH are above the required value by at least 100 feet at any mixture ratio level. The values for LOX pump NPSH are higher than required, but engine 5 shows a difference of only one foot at the high mixture ratio stop. Higher than required NPSH levels indicate that the pumps will not cavitate.

4.1.3 Propellant Loading and Residuals

The total propellant loads for optimum S-II stage performance for the 503 manned mission are 792,623 LB_M LOX and 152,149 LB_M fuel. These loads represent the liquid propellant masses in the tanks only and were determined in accordance with the criteria of burning 930,000 LB_M of propellants during mainstage, achieving a P.U. valve step at 246 seconds after 90% J-2 engine thrust is achieved, and terminating engine burn by a LOX depletion. The 930,000 LB_M mainstage loading includes only propellants used for propulsion purposes, that is propellants burned in the thrust chamber and gas generator, and does not include the propellants vented or used to pressurize the LOX and fuel tank ullage. Table 4-VI lists a weight breakdown of usable and unusable propellants and shows a total of 785,304 LB_M of usable LOX and 147,876 LB_M of usable fuel. Totals of both the usable and unusable LOX and fuel are equal to the initial tank liquid loads plus the initial trapped propellants.

J-2 engine cutoff is initiated by a propellant depletion when any two of the five cutoff sensors in either tank are activated. The cutoff levels for the 503 mission are 4,200 LB_M LOX and 2,610 LB_M fuel. Since a fuel rich cutoff is desired, a 530 LB_M fuel bias was added to insure a LOX depletion cutoff. The predicted cutoff masses were 4,200 LB_M LOX and 3,709 LB_M fuel.

4.1.4 Propellant Utilization System

The Propellant Utilization (P.U.) system is activated at 5.5 seconds after J-2 engine start signal. Previous to this time, the control valves are locked in the null position (0°) which corresponds to a mixture ratio of 5.0. After activation, the control valves move to the fully closed position (60°) and obtain a mixture ratio of 5.48 in about 2.5 seconds.

The P.U. valves move from the high mixture ratio stop at 246 seconds as shown in Figure 4-40. The mixture ratio shift occurs about 15 seconds later for the parameters of thrust, fuel flowrate and LOX flowrate (Figures 4-2, 4-6, and 4-7) due to the nature of the P.U. system. The first 15 degrees of PU valve movement takes about 16 seconds and produces no appreciable change in bypass flowrate; therefore, all propulsion parameters remain relatively constant. After step time, the P.U. valves partially open to obtain the desired reference mixture ratio of 4.65 for the remainder of the burn. This reference mixture ratio is the ratio of LOX to fuel in the tanks, and does not include the fuel bias.

The curves of probe-to-tank mismatch, plotted in Figures 4-41 and 4-42, were derived from the second Stage Static Test 203532. Due to the probe-to-tank mismatch nonlinearities, the mass sensing probes do not indicate the true tank mass. To derive the probe sensed mass for this prediction, the probe error (Figures 4-41 and 4-42) was added to the true tank mass. The effect of the probe-to-tank non-linearities on the P.U. system near the end of burn is shown in Figure 4-40.

4.2 S-II FINAL PREDICTION RESULTS

The Boeing propulsion system performance prediction data presented in this document reflect the best engineering estimate of the S-II/503 flight. A comparison of the Boeing and stage contractor final predictions is given in Appendix A.

The Boeing S-II stage final propulsion prediction results are shown in Figures 4-2 through 4-42, and are based on the data in Tables 4-I through 4-VI. Vehicle parameters are presented in Figures 4-2 through 4-22; engine parameter data are shown in Figures 4-23 through 4-40; and the probe-to-tank propellant mismatch curves are given in Figures 4-41 and 4-42.

A comparison of the predicted propulsion performance parameters for the manned flight presented in this document revision and the estimate for the unmanned flight indicate that the overall vehicle performance levels are generally higher for the manned prediction. This higher performance can be primarily attributed to the revised J-2 engine performance which is based on the second S-II-503 acceptance test rather than an average of the two acceptance tests.

It should be noted that this prediction does not include an engine performance degradation due to engine clustering effect.

TABLE 4-II

S-II SEQUENCE OF EVENTS

EVENT	J-2 ENGINE BURN TIME (SEC)	S-II MAINSTAGE TIME (SEC)
Ullage Rocket Ignition	-0.90	-3.90
S-IC/S-II Stage Separation	-0.70	-3.70
S-II Engine Start Command	0.00	-3.00
Ullage Rocket Cutoff	2.49	-0.51
90% J-2 Engine Thrust (Mainstage)	3.00	0.00
PU System Initial Activation	5.50	2.50
Interstage Hardware Jettison	29.25	26.25
Launch Escape System Jettison	35.25	32.25
Fuel Tank Pressurization Flowrate Step	300.00	297.00
Programmed Mixture Ratio Shift	249.00	246.00
J-2 Engine Cutoff Signal	362.83	359.83
Thrust Decay Termination	363.22	360.22

TABLE 4-III
S-II STAGE WEIGHT BREAKDOWN

PARAMETER	S-IC LIFTOFF	S-II IGNITION -3.0 sec	MAINSTAGE 0 sec	CUTOFF 359.834 sec	S-II/S-IVB SEPARATION 360.224 sec
Weight above S-II (With Les)	378,397.0	378,097.0	378,097.0	371,497.0	371,497.0
S-II-503 Stage Dry	88,400.0	88,400.0	88,400.0	88,400.0	88,400.0
S-II-503/S-IC Interstage*	9,237.0	9,237.0	9,237.0	0.0	0.0
Launch Escape System	6,600.0	6,600.0	6,600.0	0.0	0.0
Miscellaneous Dry Weight Items**	129.0	129.0	129.0	129.0	129.0
GOX Used for Pressurization	0.0	0.0	0.0	2,814.3	2,816.7
GH_2 Used for Pressurization	0.0	0.0	0.0	1,070.2	1,071.3
LOX in Tank	792,621.0	792,131.0	790,555.0	4,200.0	4,013.3
Fuel in Tank	152,149.0	152,101.0	151,476.3	3,709.2	3,591.4
LOX Contained Below Tank	1,073.0	1,563.0	1,563.0	1,563.0	1,563.0
Fuel Contained Below Tank	196.0	244.0	244.0	244.0	244.0
Prepressurizing Helium in LOX Tank	78.9	78.9	78.9	78.9	78.9
Prepressurizing Helium in Fuel Tank	303.0	300.1	298.3	275.4	275.2
Total Vehicle Weight	1,418,664.4	1,417,984.4	1,414,812.9	465,849.3	465,548.0

* W/O ULLAGE ROCKET PROPELLANT (PROPELLANT WT. = 2720 LBM)
** ABLATIVE THERMOLAG + HYDRAULIC FLUID + AFT FRAME + DETONATION PACKAGE

TABLE 4-IV

S-II PRESSURIZATION SYSTEM DATA

SPECIFICATION	UNITS	VALUE
LOX Ullage Pressure Upper Control Pressure	PSIA	37.5
LOX Ullage Pressure Lower Control Pressure	PSIA	36.0
Fuel Ullage Pressure Upper Control Pressure	PSIA	30.0
Fuel Ullage Pressure Lower Control Pressure	PSIA	28.5
LOX Ullage Pressure Prior to Prepressurization	PSIA	15.0
Fuel Ullage Pressure Prior to Prepressurization	PSIA	15.0
LOX Ullage Pressure at J-2 Ignition	PSIA	37.5
Fuel Ullage Pressure at J-2 Ignition	PSIA	31.1
LOX Vent Valve Upper Control Pressure	PSIA	42.0
Fuel Vent Valve Upper Control Pressure	PSIA	33.0
LOX Vent Valve Cracking Pressure	PSIA	40.0
Fuel Vent Valve Cracking Pressure	PSIA	30.5
Maximum LOX Vent Rate (2 Valves)	LBM/SEC	24.3
Maximum Fuel Vent Rate (2 Valves)	LBM/SEC	10.5
Initial Helium Mass in LOX Tank	LBM	78.9
Initial Helium Mass in Fuel Tank	LBM	303.0
Initial GOX Mass in LOX Ullage	LBM	420.7
Initial GH_2 Mass in Fuel Ullage	LBM	138.7
Total Mass of GOX Vented	LBM	0.0
Total Mass of GH_2 Vented	LBM	92.6

TABLE 4-Va
J-2 ENGINE PERFORMANCE AT STANDARD INLET CONDITIONS AT ALTITUDE

SERIAL NO. J-2051
ENGINE POSITION NO. 1

TIME SLICE: 60 SECONDS

PARAMETER	ROCKETDYNE ACCEPTANCE TEST DATA [1]	NAR-SD STAGE TEST 203532 DATA	BOEING DATA STAGE TEST 203531	BOEING DATA STAGE TEST 203532 [2]
Thrust, lbf	226,292.6	225,165.6	231,724.3	225,143.0
Fuel Pump Speed, rpm	26,960.3	26,657.0	27,152.2	26,607.0
LOX Pump Speed, rpm	8,612.7	8,550.4	8,739.3	8,569.6
Injector End Pressure, psia	758.9	755.4	773.9	755.2
Injector Fuel Flowrate, lbm/sec	78.67	76.28	79.28	78.11
Injector LOX Flowrate, lbm/sec	447.55	445.21	458.54	446.09
C* at Injector, ft/sec	7,913.5	7,938.3	7,896.4	7,906.1
Injector End Thrust Coefficient	1.7485	1.7477	1.7556	1.7479
Engine Mixture Ratio	5.479	5.568	5.569	5.499
Engine Fuel Flowrate, lbm/sec	82.31	80.57	82.98	81.74
Engine LOX Flowrate, lbm/sec	450.96	448.58	462.12	449.47
Engine Specific Impulse, (lbf-sec)/lbm	424.4	425.5	425.1	423.8
Throat Area, in^2	170.56	170.56	170.56	170.56
Expansion Ratio	27.04	27.04	27.04	27.04

1 Average of the two Rocketdyne Acceptance Tests
2 Time Slice at 64.8 Seconds After Engine Start Command

TABLE 4-Vb

J-2 ENGINE PERFORMANCE AT STANDARD INLET CONDITIONS AT ALTITUDE

SERIAL NO. J-2053
ENGINE POSITION NO. 2

TIME SLICE: 60 SECONDS

PARAMETER	ROCKETDYNE ACCEPTANCE TEST DATA [1]	NAR-SD STAGE TEST 203532 DATA	BOEING DATA STAGE TEST 203531	BOEING DATA STAGE TEST 203532 [2]
Thrust, lbf	222,812.9	224,862.0	226,312.2	225,372.2
Fuel Pump Speed, rpm	26,842.6	26,916.8	27,015.2	26,907.0
LOX Pump Speed, rpm	8,496.8	8,550.4	8,579.6	8,56[illegible].1
Injector End Pressure, psia	766.7	773.2	778.7	774.7
Injector Fuel Flowrate, lbm/sec	77.35	77.79	78.09	77.72
Injector LOX Flowrate, lbm/sec	440.34	441.91	448.36	445.80
C* at Injector, ft/sec	8,125.3	8,162.7	8,116.1	8,118.8
Injector End Thrust Coefficient	1.7045	1.7054	1.7042	1.7060
Engine Mixture Ratio	5.477	5.465	5.524	5.517
Engine Fuel Flowrate, lbm/sec	81.52	81.49	81.80	81.44
Engine LOX Flowrate, lbm/sec	443.71	445.37	451.88	449.28
Engine Specific Impulse, (lbf-sec)/lbm	424.7	426.8	424.1	424.7
Throat Area, in^2	170.53	170.53	170.53	170.53
Expansion Ratio	27.14	27.14	27.14	27.14

1 Average of the two Rocketdyne Acceptance Tests
2 Time Slice at 64.8 Seconds After Engine Start Command

TABLE 4-Vc

J-2 ENGINE PERFORMANCE AT STANDARD INLET CONDITIONS AT ALTITUDE

SERIAL NO. J-2059
ENGINE POSITION NO. 3

TIME SLICE: 60 SECONDS

PARAMETER	ROCKETDYNE ACCEPTANCE TEST DATA [1]	NAR-SD STAGE TEST 203532 DATA	BOEING DATA STAGE TEST 203531	BOEING DATA STAGE TEST 203532 [2]
Thrust, lbf	221,988.5	223,796.1	223,097.0	223,279.6
Fuel Pump Speed, rpm	26,840.7	26,966.7	26,948.1	26,917.7
LOX Pump Speed, rpm	8,461.6	8,497.6	8,522.6	8,506.2
Injector End Pressure, psia	758.7	764.2	762.9	762.3
Injector Fuel Flowrate, lbm/sec	77.34	78.25	78.28	78.04
Injector LOX Flowrate, lbm/sec	439.04	441.17	441.79	440.62
C* at Injector, ft/sec	8,039.7	8,049.7	8,025.9	8,042.2
Injector End Thrust Coefficient	1.7205	1.7221	1.7196	1.7223
Engine Mixture Ratio	5.470	5.434	5.440	5.440
Engine Fuel Flowrate, lbm/sec	80.87	81.81	81.84	81.62
Engine LOX Flowrate, lbm/sec	442.34	444.55	445.22	444.00
Engine Specific Impulse, (lbf-sec)/lbm	424.3	425.2	423.3	424.8
Throat Area, in^2	170.06	170.06	170.06	170.06
Expansion Ratio	27.21	27.21	27.21	27.21

1 Average of the two Rocketdyne Acceptance Tests
2 Time Slice at 64.8 Seconds After Engine Start Command

TABLE 4-Vd
J-2 ENGINE PERFORMANCE AT STANDARD INLET CONDITIONS AT ALTITUDE

SERIAL NO. J-2045
ENGINE POSITION NO. 4

TIME SLICE: 60 SECONDS

PARAMETER	ROCKETDYNE ACCEPTANCE TEST DATA [1]	NAR-SD STAGE TEST 203532 DATA	BOEING DATA STAGE TEST 203531	BOEING DATA STAGE TEST 203532 [2]
Thrust, lbf	227,298.9	227,190.5	227,127.4	226,236.7
Fuel Pump Speed, rpm	26,906.0	26,807.7	26,953.7	26,915.7
LOX Pump Speed, rpm	8,723.0	8,737.9	8,684.1	8,739.9
Injector End Pressure, psia	777.4	776.8	776.8	773.0
Injector Fuel Flowrate, lbm/sec	78.77	78.88	77.57	78.01
Injector LOX Flowrate, lbm/sec	449.95	448.81	449.81	449.41
C* at Injector, ft/sec	8,061.4	8,070.0	8,075.1	8,034.3
Injector End Thrust Coefficient	1.7160	1.7165	1.7160	1.7178
Engine Mixture Ratio	5.499	5.475	5.578	5.543
Engine Fuel Flowrate, lbm/sec	82.44	82.60	81.26	81.69
Engine LOX Flowrate, lbm/sec	453.29	452.25	453.23	452.83
Engine Specific Impulse, (lbf-sec)/lbm	424.3	424.8	424.9	423.3
Throat Area, in^2	170.39	170.39	170.39	170.39
Expansion Ratio	27.13	27.13	27.13	27.13

1 Average of the two Rocketdyne Acceptance Tests
2 Time Slice at 64.8 Seconds After Engine Start Command

TABLE 4-Ve
J-2 ENGINE PERFORMANCE AT STANDARD INLET CONDITIONS AT ALTITUDE

SERIAL NO. J-2055
ENGINE POSITION NO. 5

TIME SLICE: 60 SECONDS

PARAMETER	ROCKETDYNE ACCEPTANCE TEST DATA [1]	NAR-SD STAGE TEST 203532 DATA	BOEING DATA STAGE TEST 203531	BOEING DATA STAGE TEST 203532 [2]
Thrust, lbf	227,667.7	230,088.1	231,079.4	231,496.6
Fuel Pump Speed, rpm	27,140.6	27,308.8	27,288.7	27,257.0
LOX Pump Speed, rpm	8,712.6	8,754.6	8,803.7	8,792.4
Injector End Pressure, psia	775.6	781.0	784.8	786.6
Injector Fuel Flowrate, lbm/sec	79.32	80.20	80.83	81.05
Injector LOX Flowrate, lbm/sec	453.15	453.92	457.66	455.34
C* at Injector, ft/sec	8,045.4	8,074.6	8,047.5	8,097.7
Injector End Thrust Coefficient	1.710	1.7165	1.7157	1.7148
Engine Mixture Ratio	5.500	5.450	5.452	5.410
Engine Fuel Flowrate, lbm/sec	83.02	83.94	84.59	84.81
Engine LOX Flowrate, lbm/sec	456.61	457.45	461.18	458.87
Engine Specific Impulse, (lbf-sec)/lbm	421.9	425.0	423.4	425.8
Throat Area, in^2	171.63	171.63	171.63	171.62
Expansion Ratio	26.99	26.99	26.99	26.99

1 Average of the two Rocketdyne Acceptance Tests
2 Time Slice at 64.8 Seconds After Engine Start Command

TABLE 4-VI

S-II-503 LIQUID PROPELLANT WEIGHTS

PROPELLANT WEIGHTS	FUEL (LBM)	LOX (LBM)
Usable Propellant:		
Mainstage	146,603.2	783,540.8
Bias	530.0	0.0
Thrust Buildup	624.7	1,576.0
Thrust Decay	117.8	186.7
Total Usable Propellant	147,875.7	785,303.5
Unusable Propellant:		
Trapped		
Engine	48.0	490.0
*Line	186.0	843.0
*Recirculation	10.0	230.0
*Initial Ullage Mass	138.7	420.7
Tank and Sump	3,061.4	4,013.3
Pressurization Gas	1,071.3	2,816.7
Vented	92.6	0.0
Total Unusable Propellant	4,608.0	8,813.7

* INITIAL TRAPPED PROPELLANT

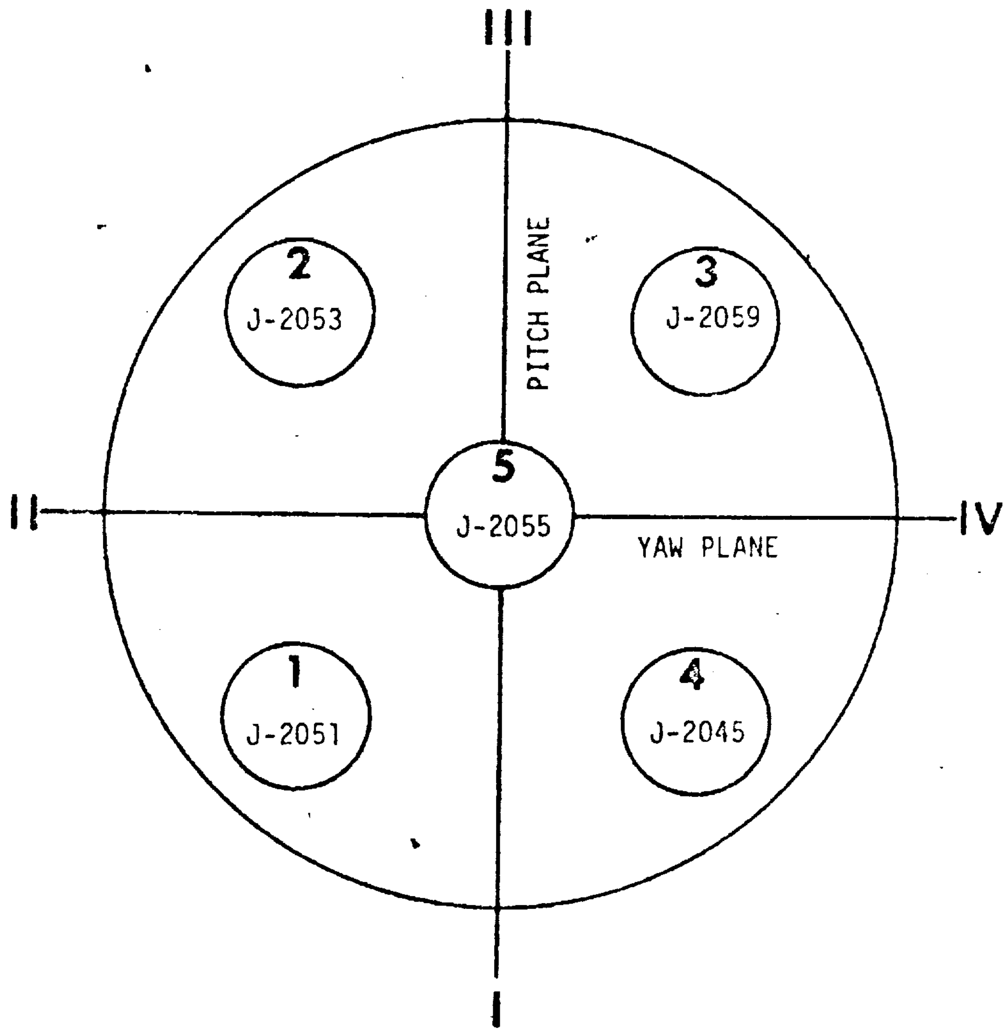


FIGURE 4-1 S-II STAGE AND ENGINE ORIENTATION

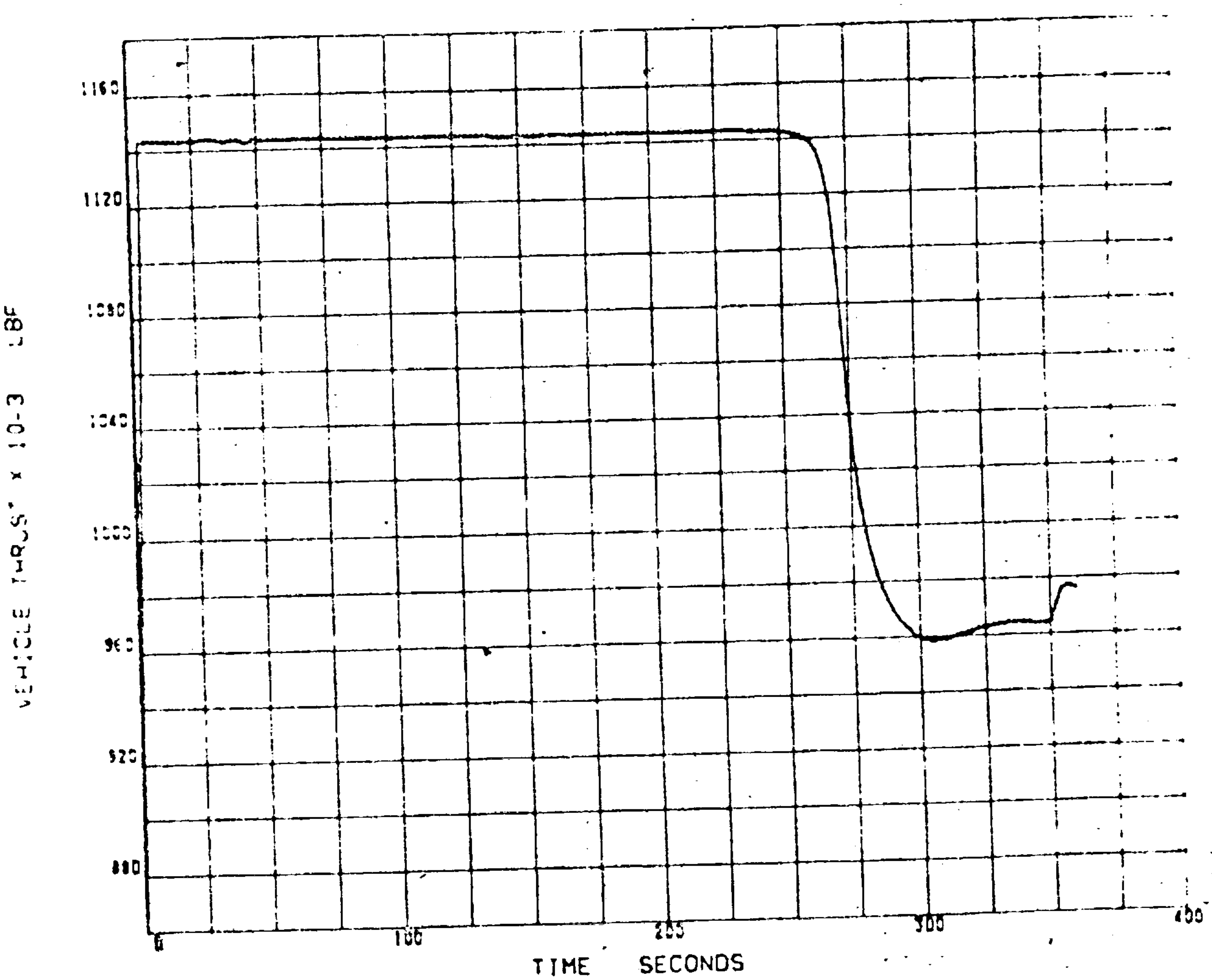


FIGURE 4-2 S-II VEHICLE THRUST

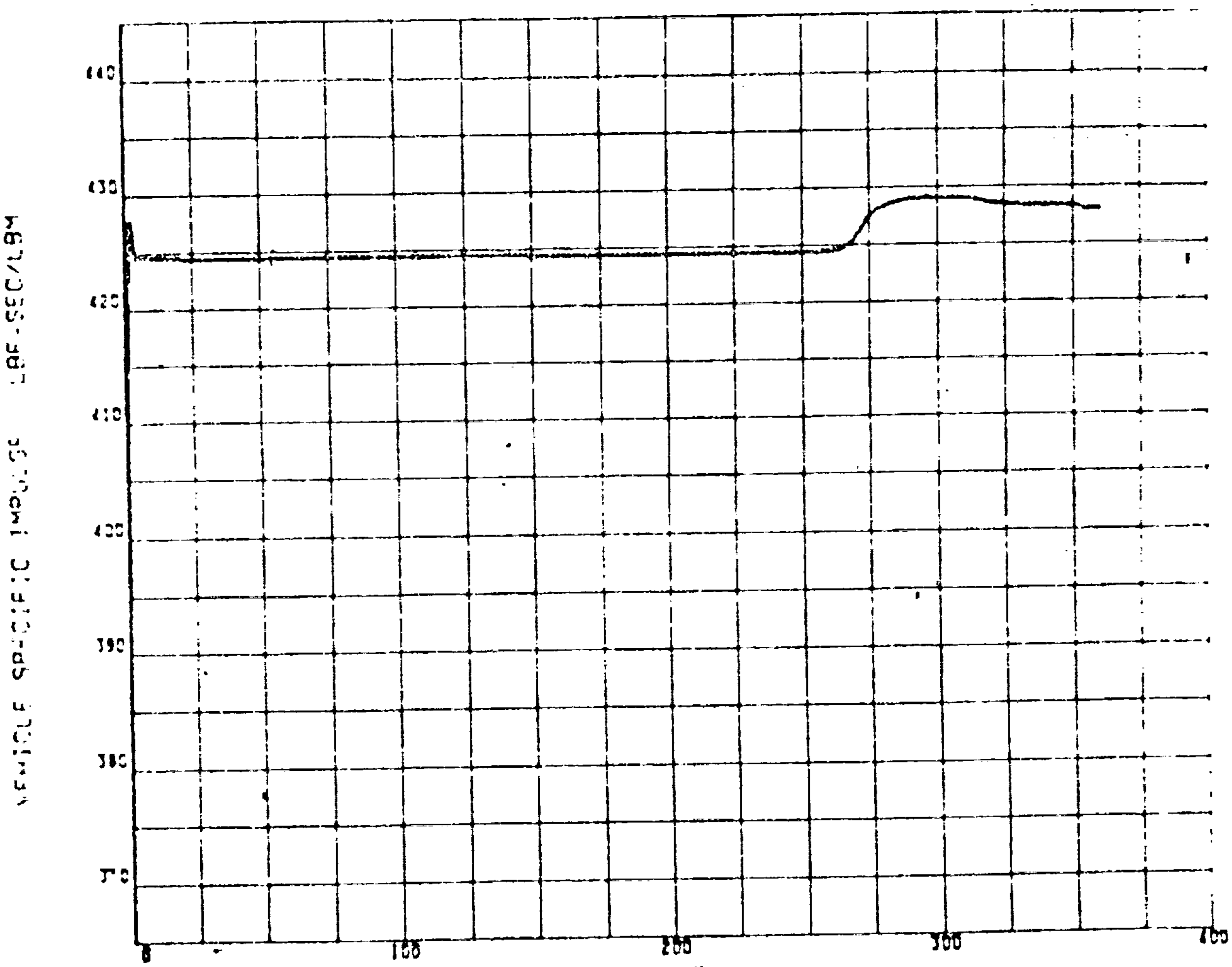


FIGURE 4-3 S-II VEHICLE SPECIFIC IMPULSE

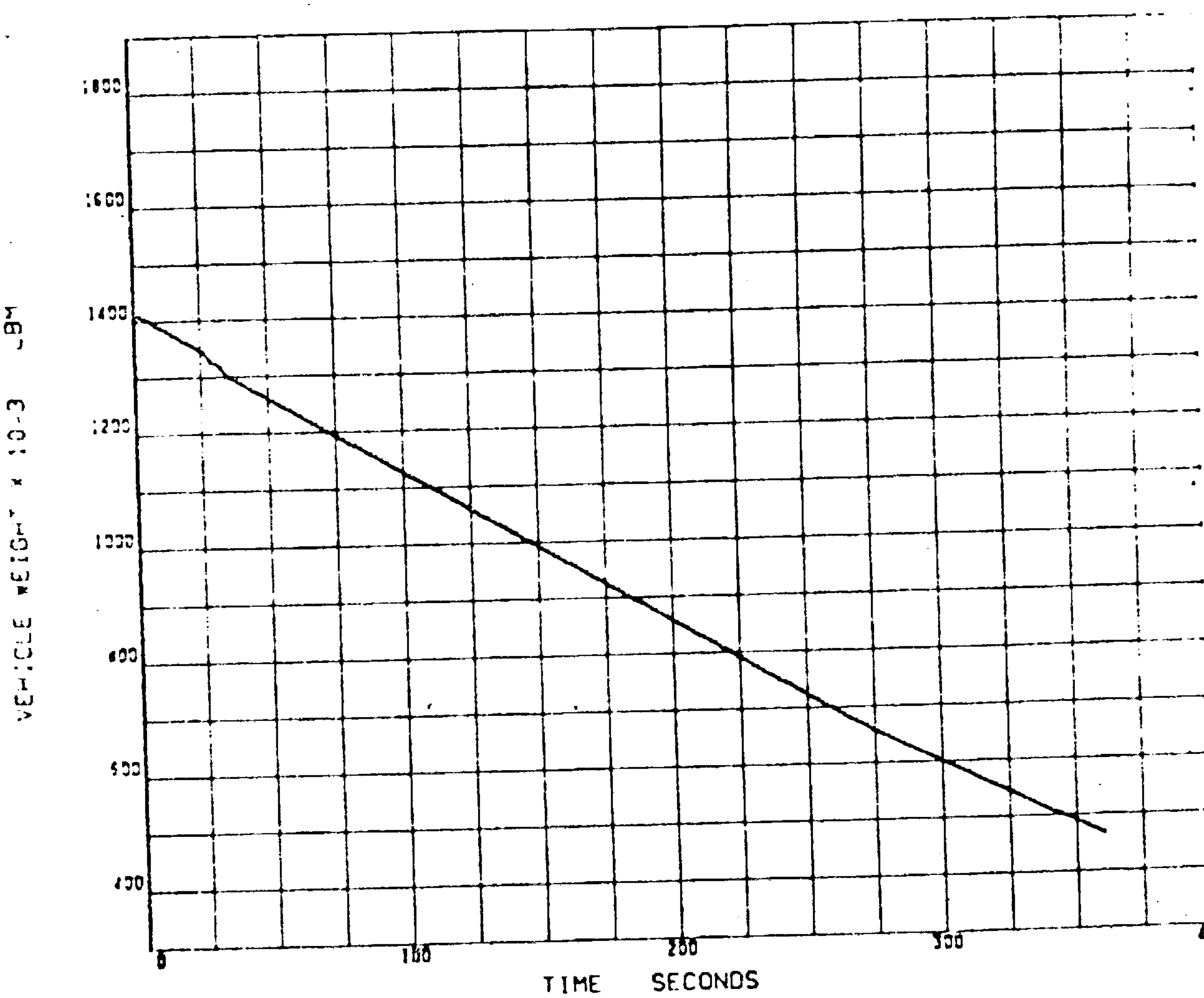


FIGURE 4-4 S-II VEHICLE WEIGHT

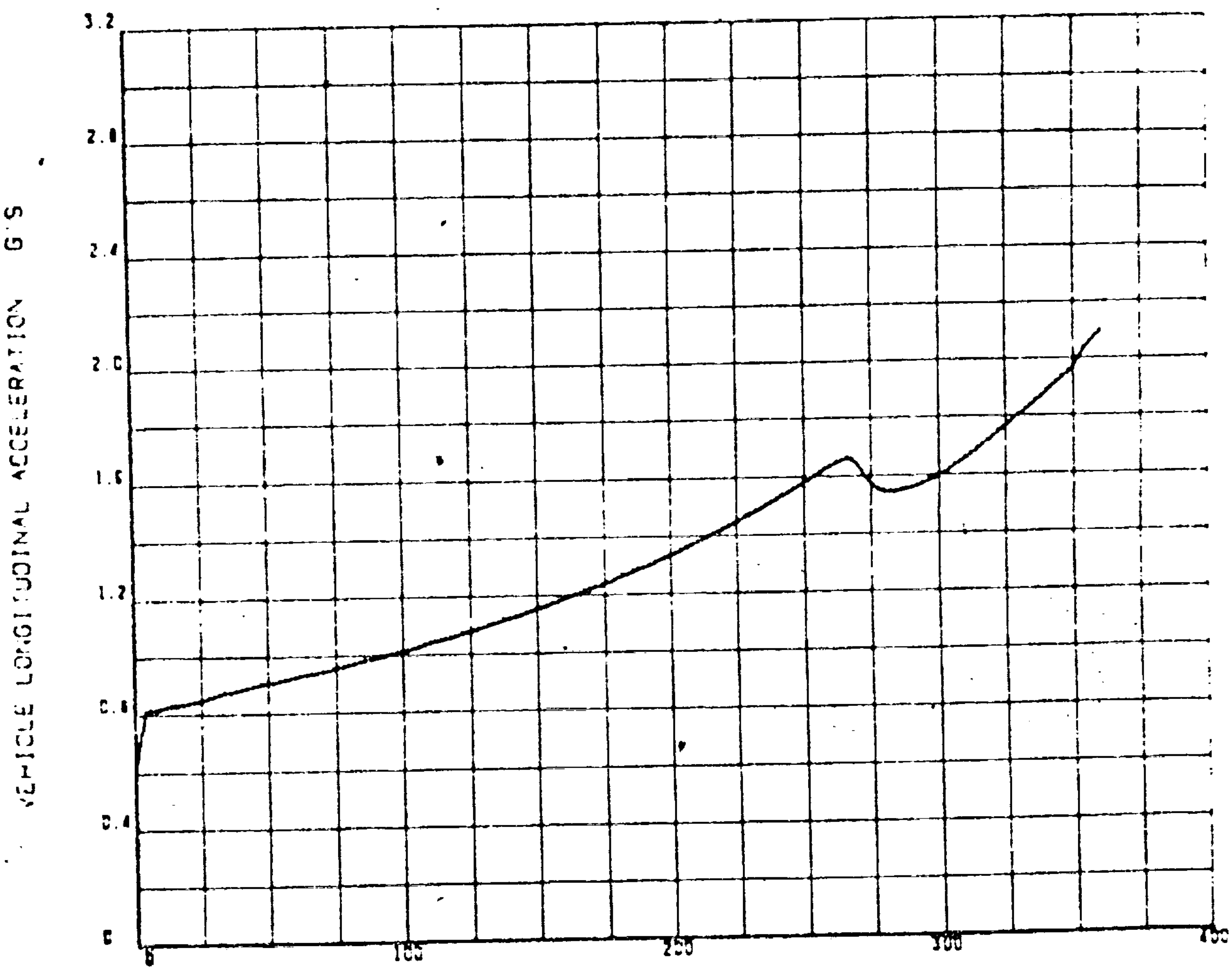


FIGURE 4-5 S-II VEHICLE LONGITUDINAL ACCELERATION

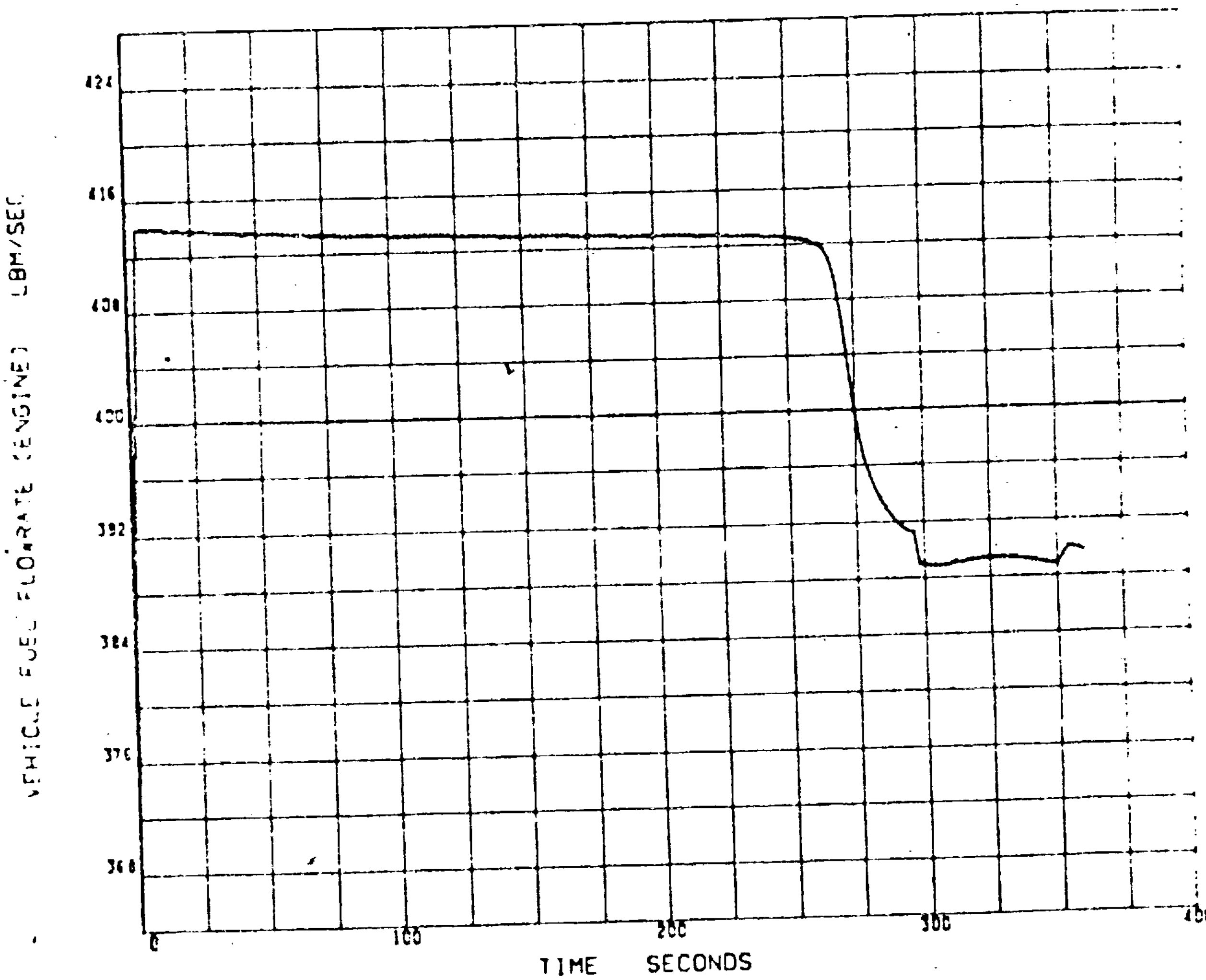


FIGURE 4-6 S-II VEHICLE FUEL FLOWRATE (ENGINE)

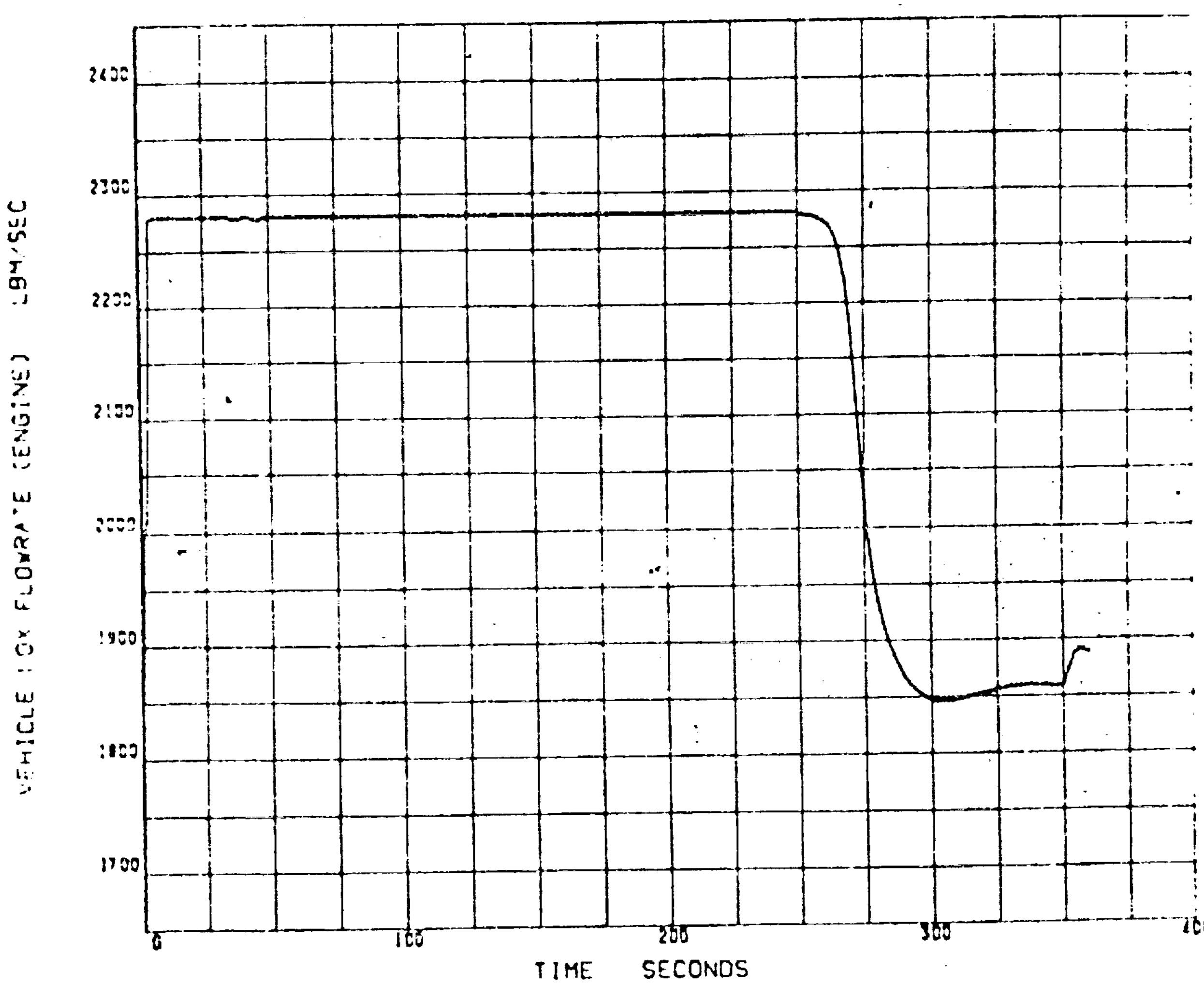


FIGURE 4-7 S-II VEHICLE LOX FLOWRATE (ENGINE)

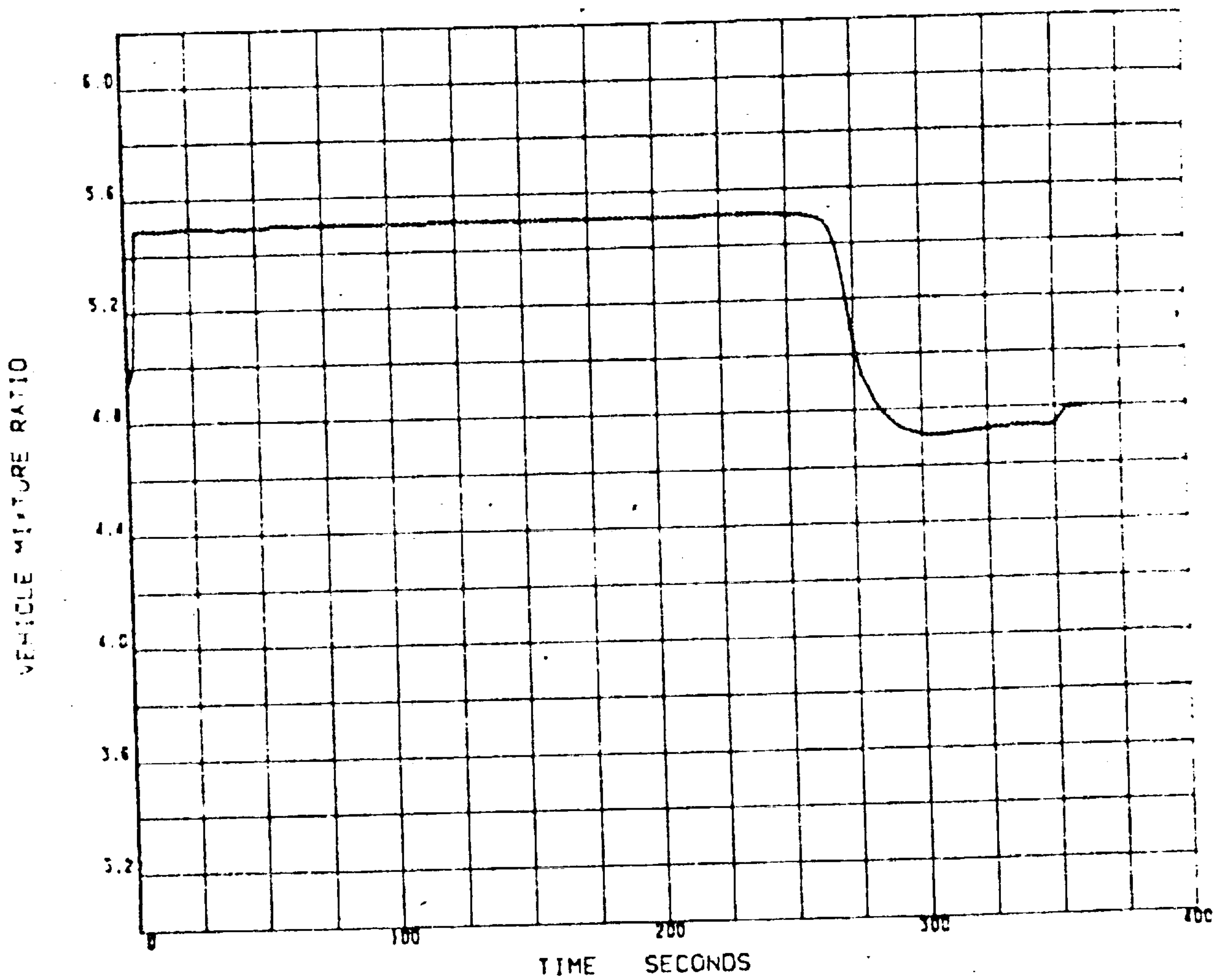


FIGURE 4-8 S-II VEHICLE MIXTURE RATIO

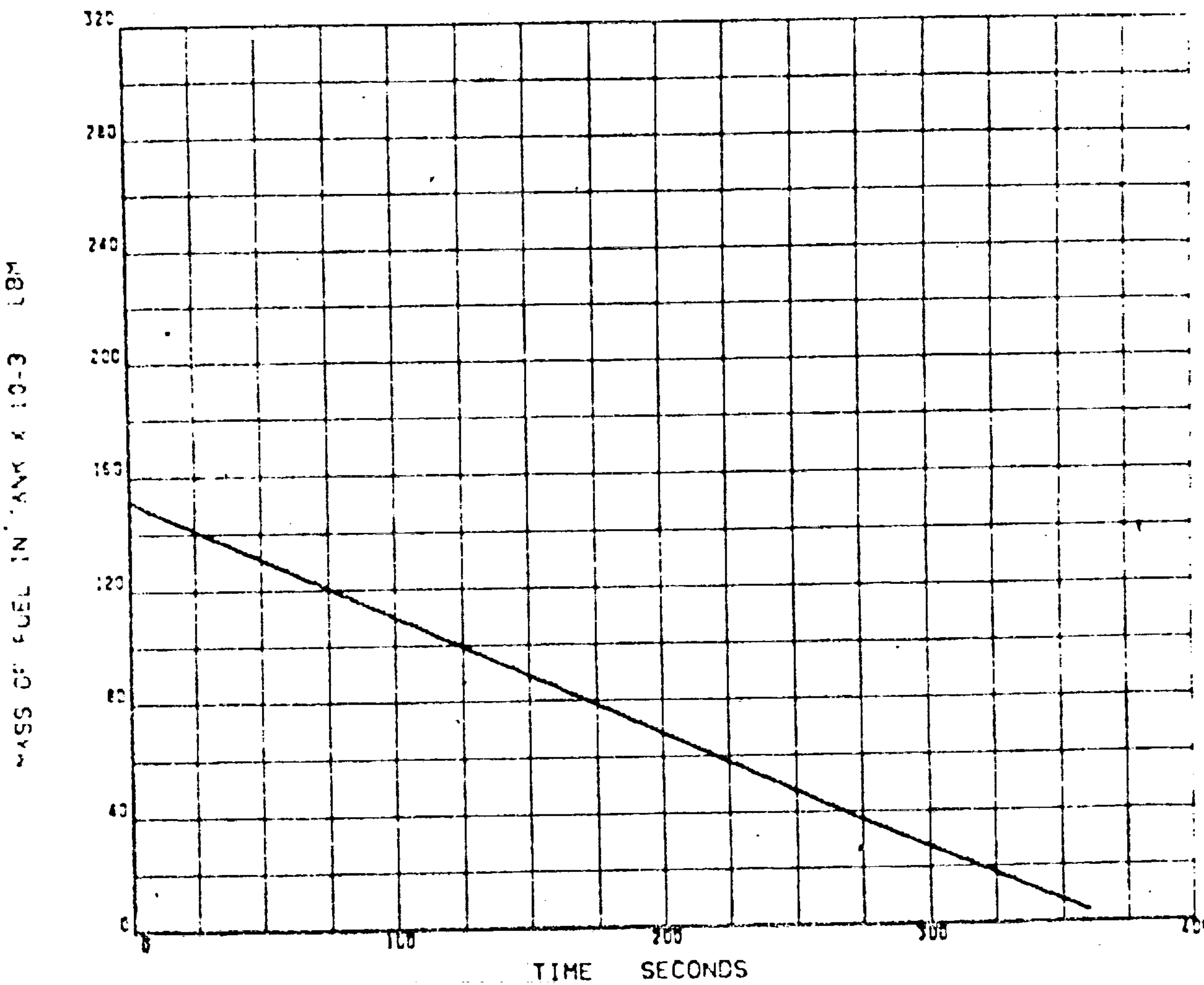


FIGURE 4-9 S-II MASS OF FUEL IN TANK

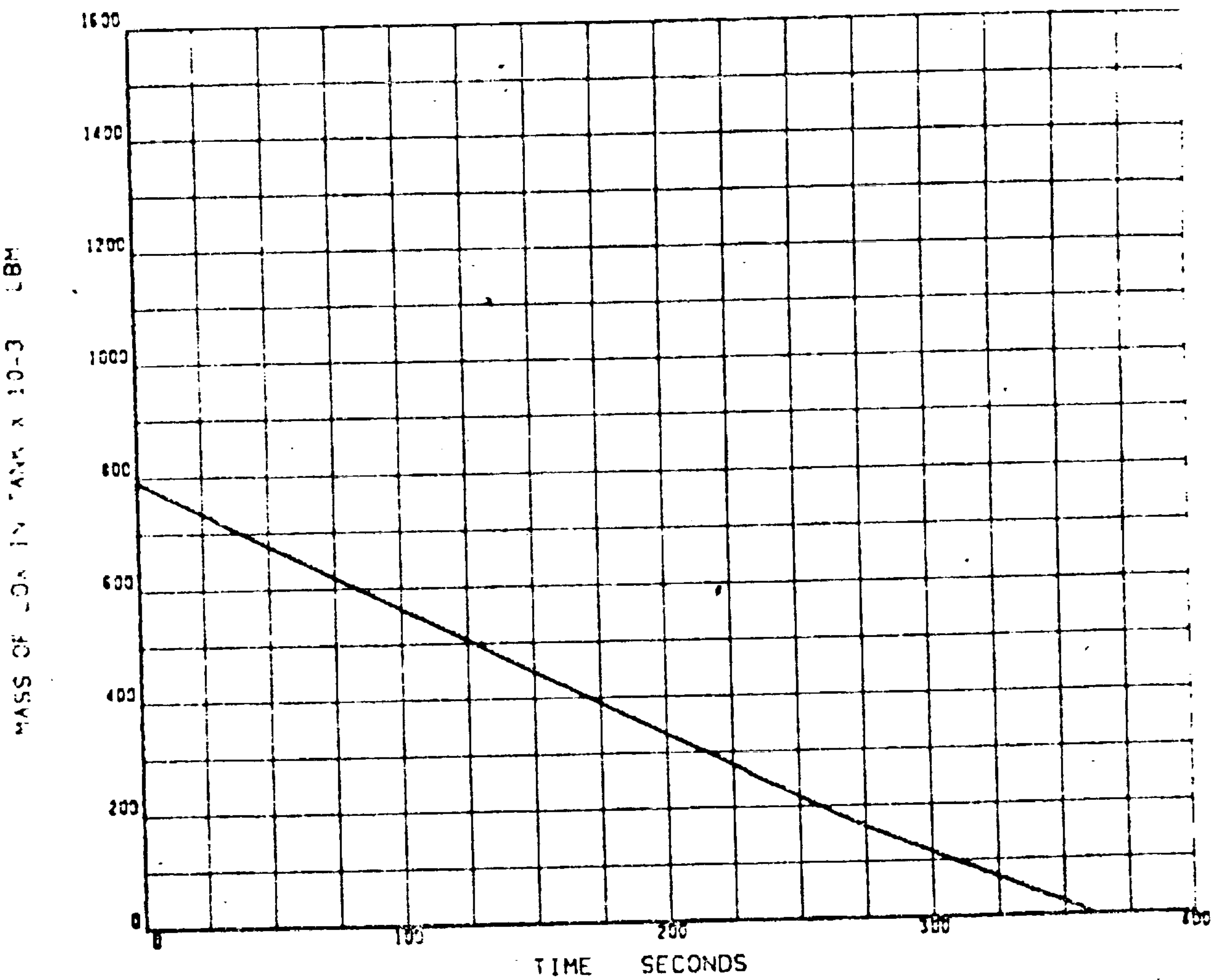


FIGURE 4-10 S-II MASS OF LOX IN TANK

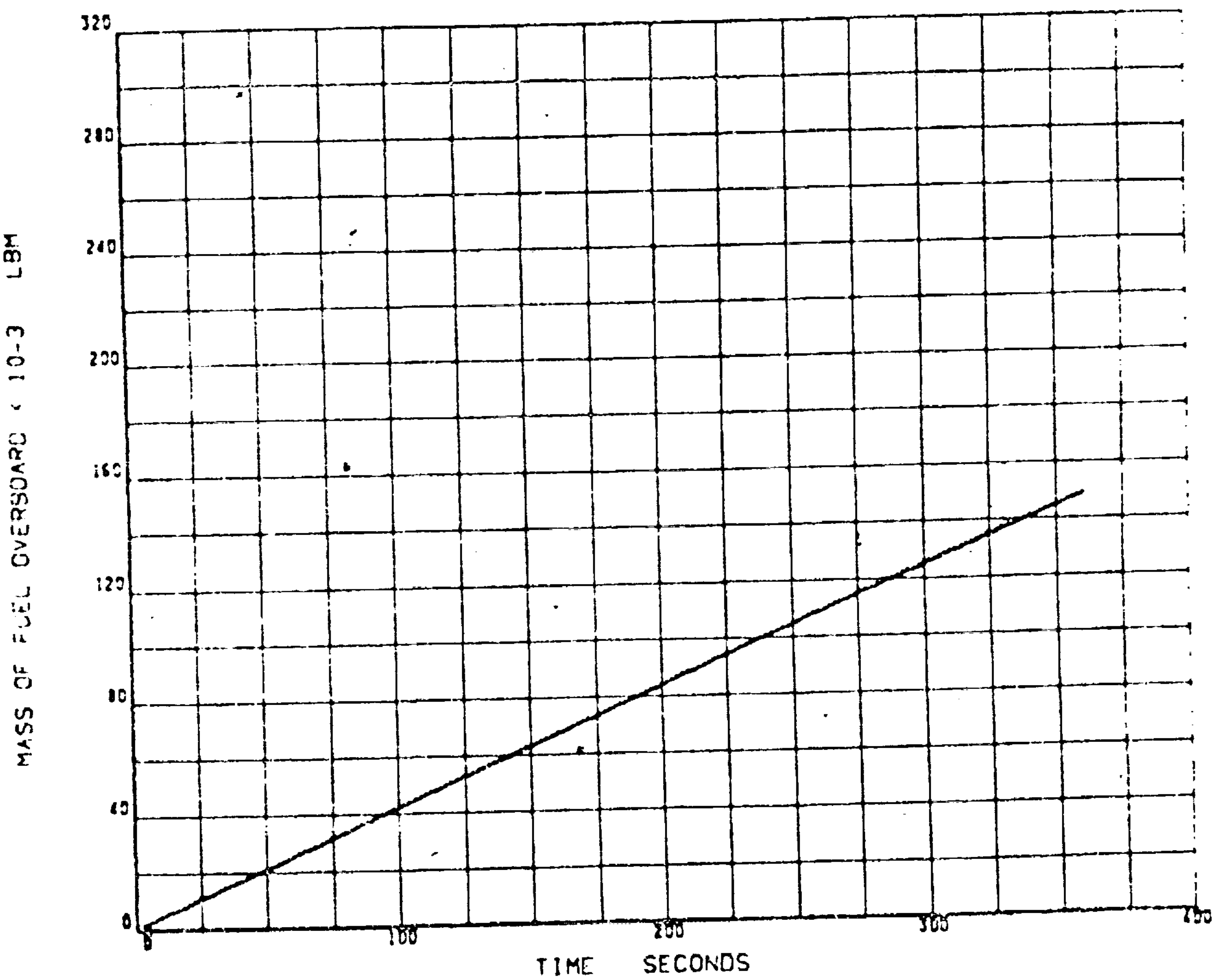


FIGURE 4-11 S-II MASS OF FUEL OVERBOARD

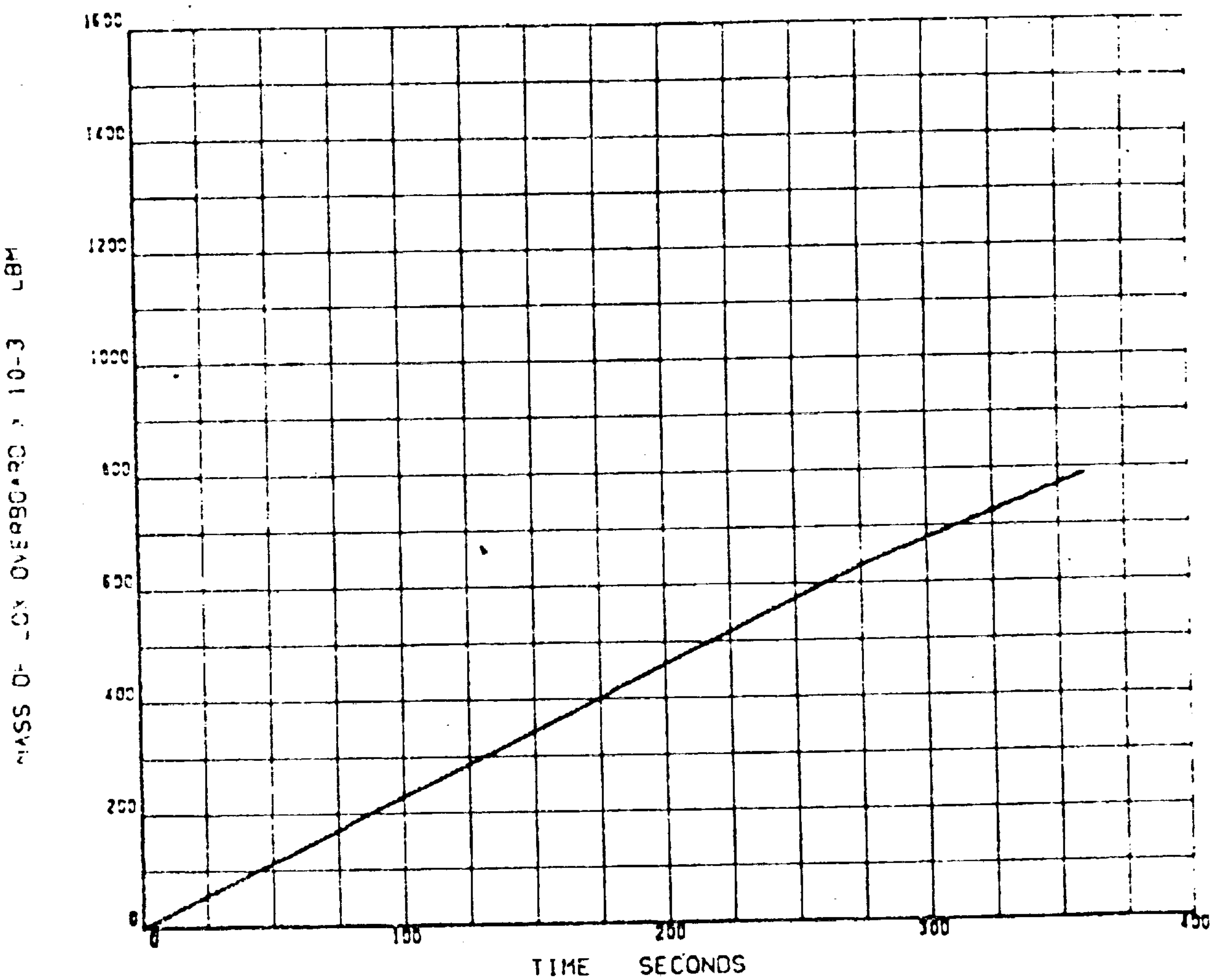


FIGURE 4-12 S-II MASS OF LOX OVERBOARD

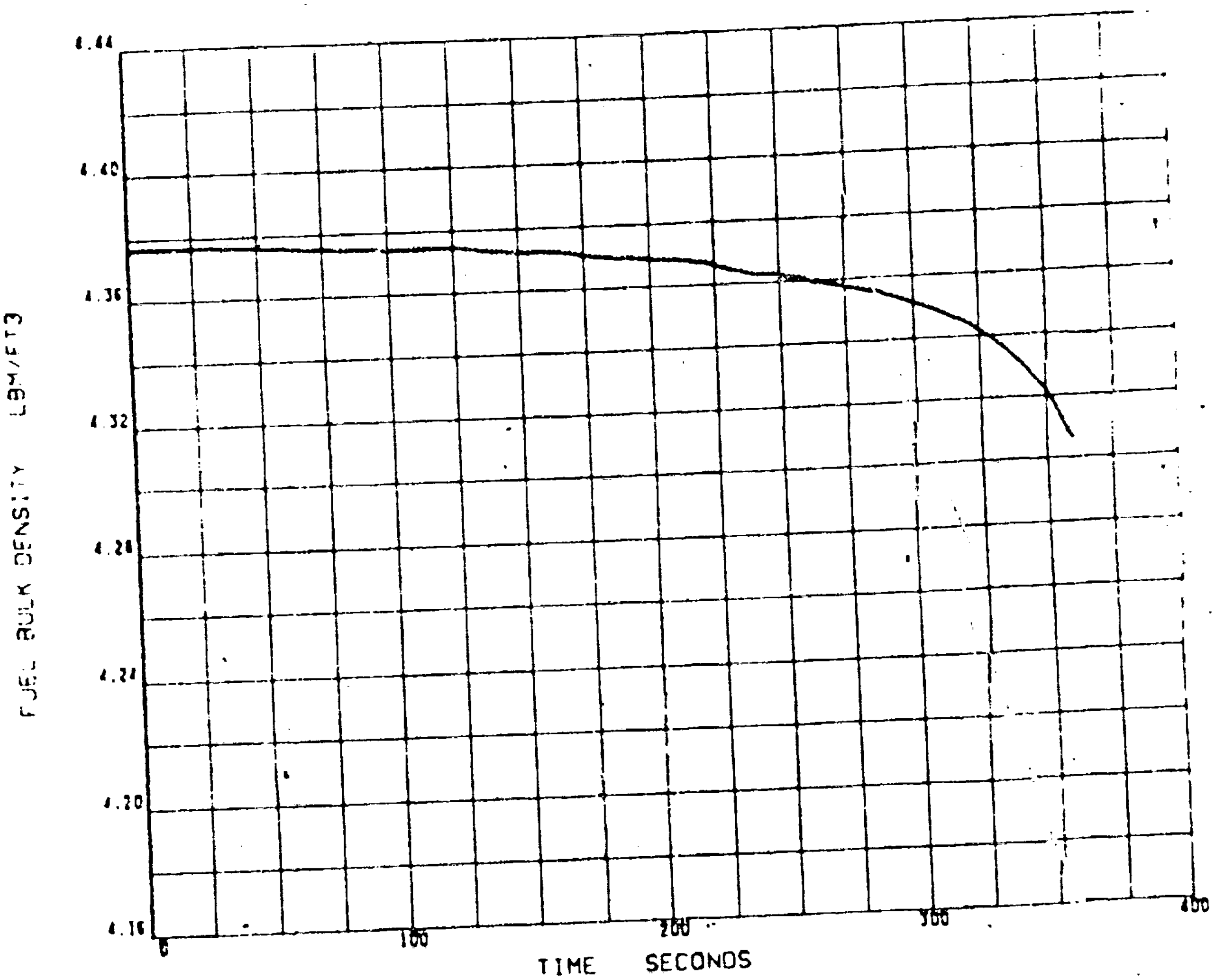


FIGURE 4-13 S-II FUEL BULK DENSITY

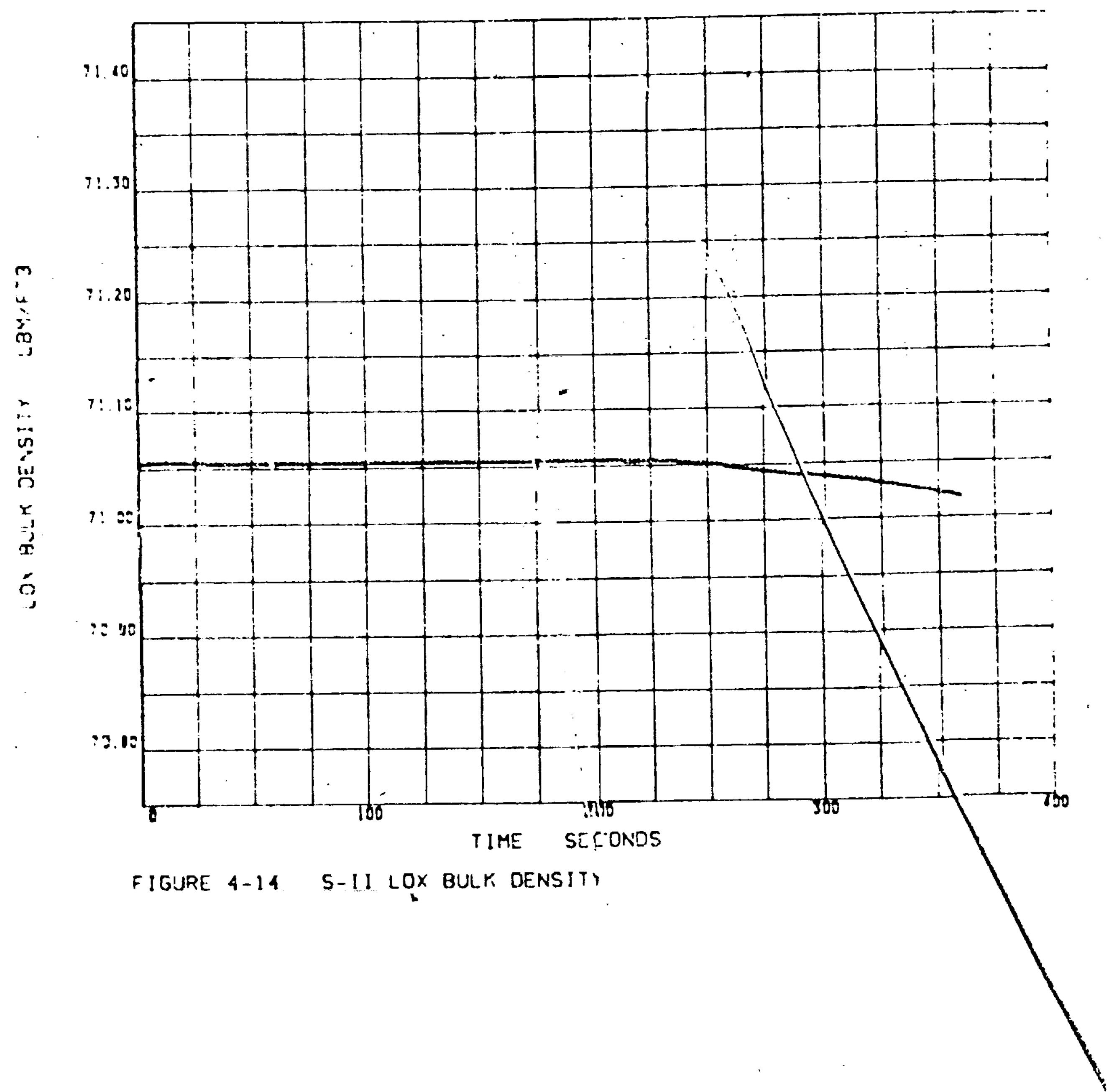


FIGURE 4-14 S-II LOX BULK DENSITY

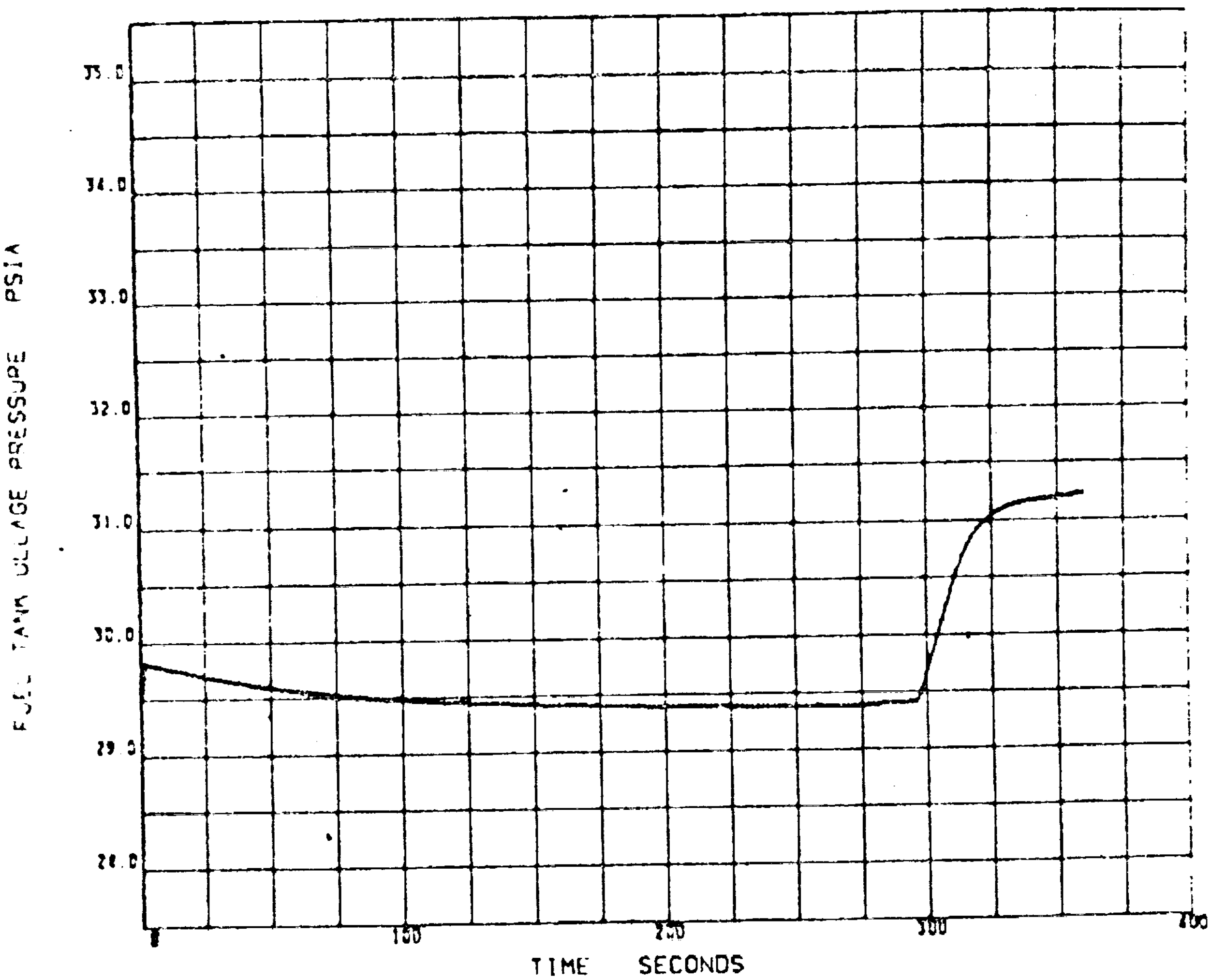


FIGURE 4-15 S-II FUEL TANK ULLAGE PRESSURE

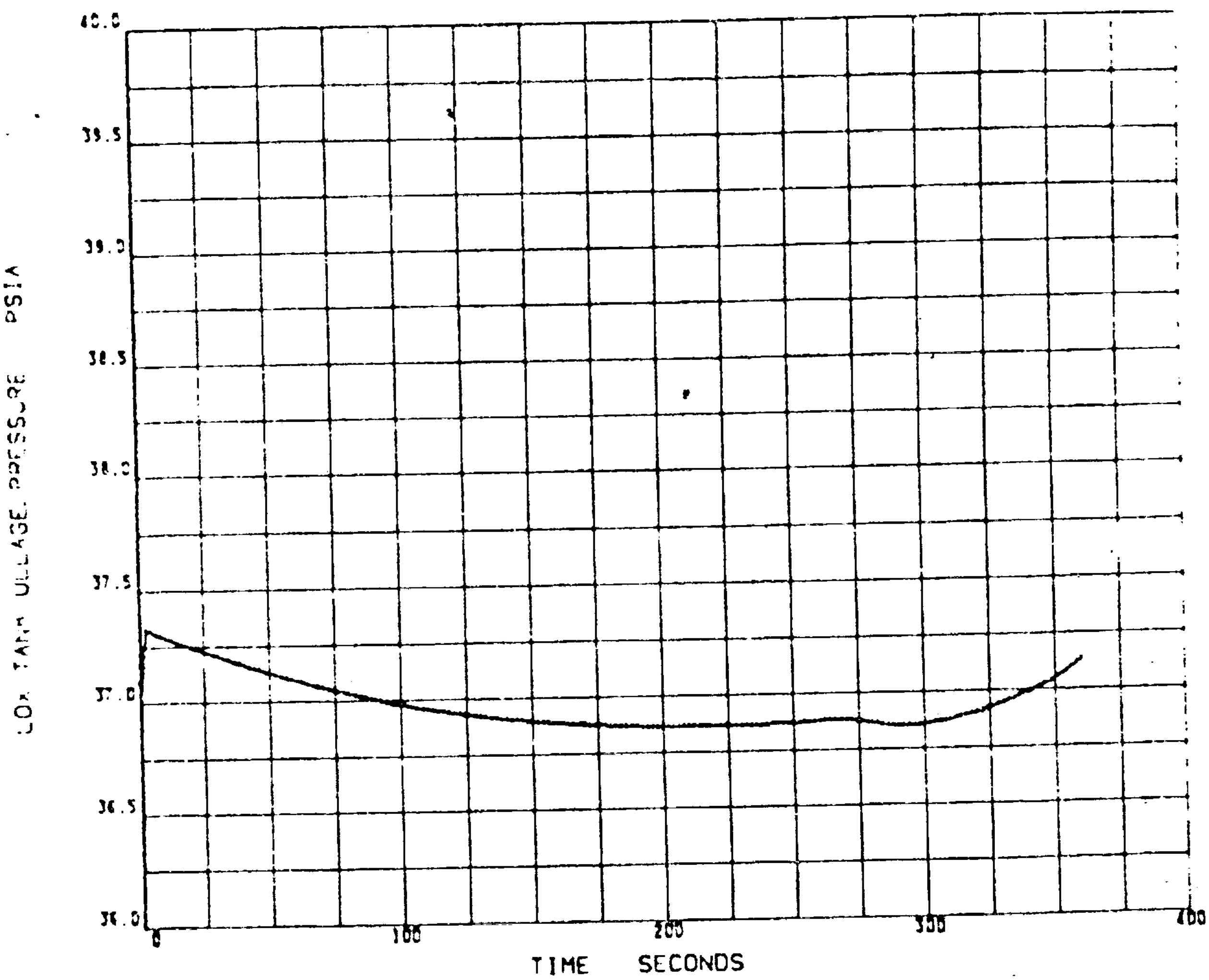


FIGURE 4-16 S-II LOX TANK ULLAGE PRESSURE

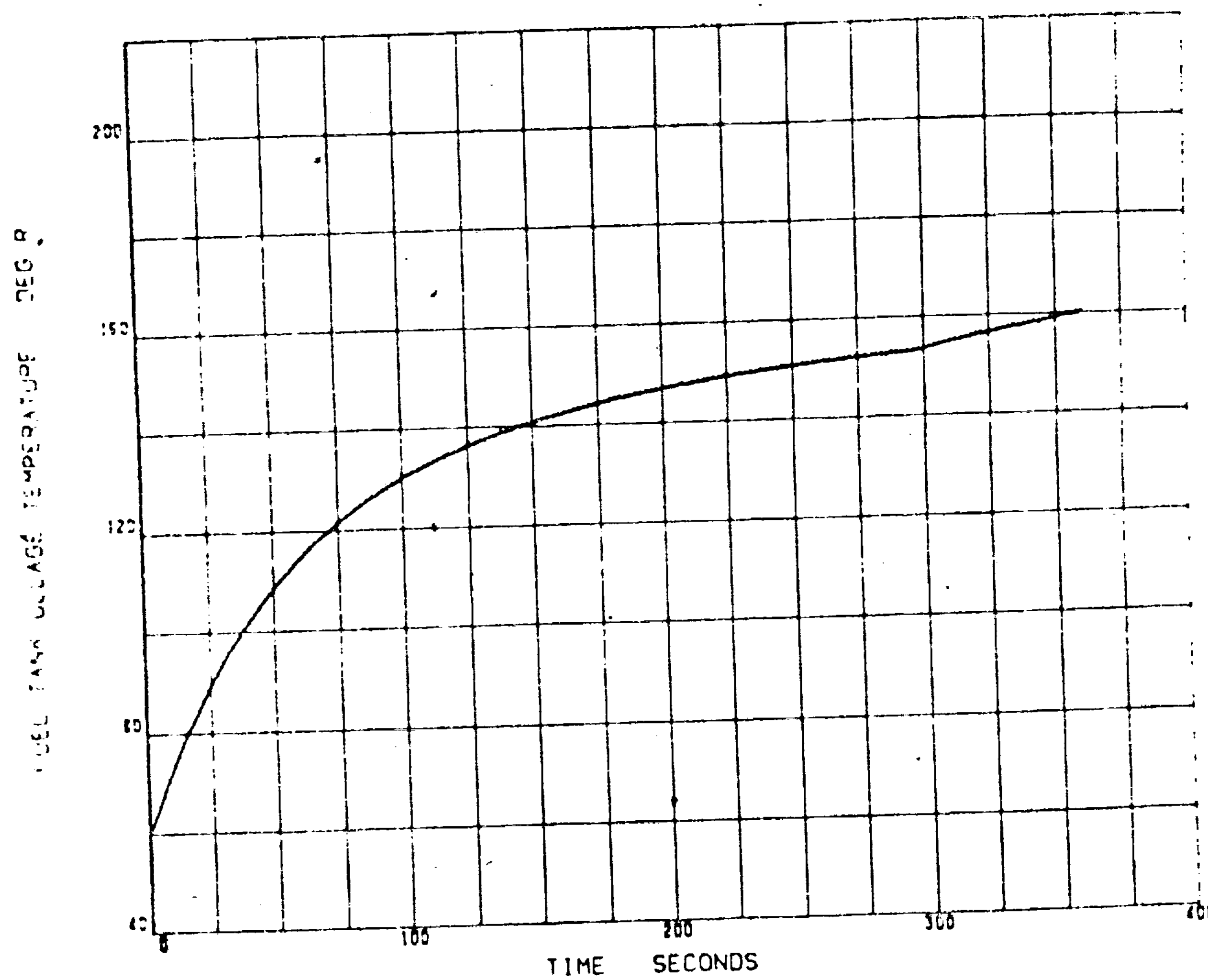


FIGURE 4-17 S-II FUEL TANK ULLAGE TEMPERATURE

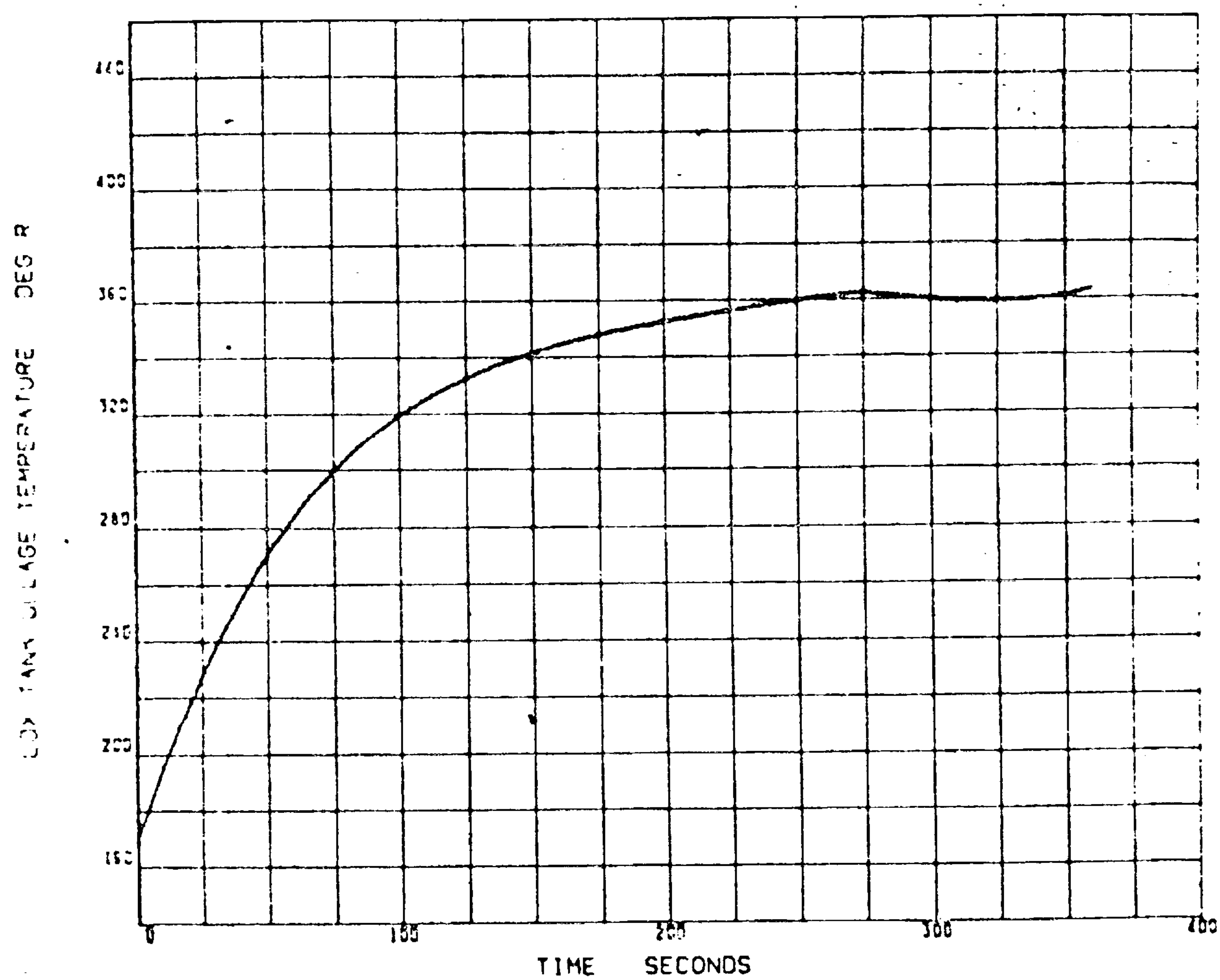


FIGURE 4-18 S-II LOX TANK ULLAGE TEMPERATURE

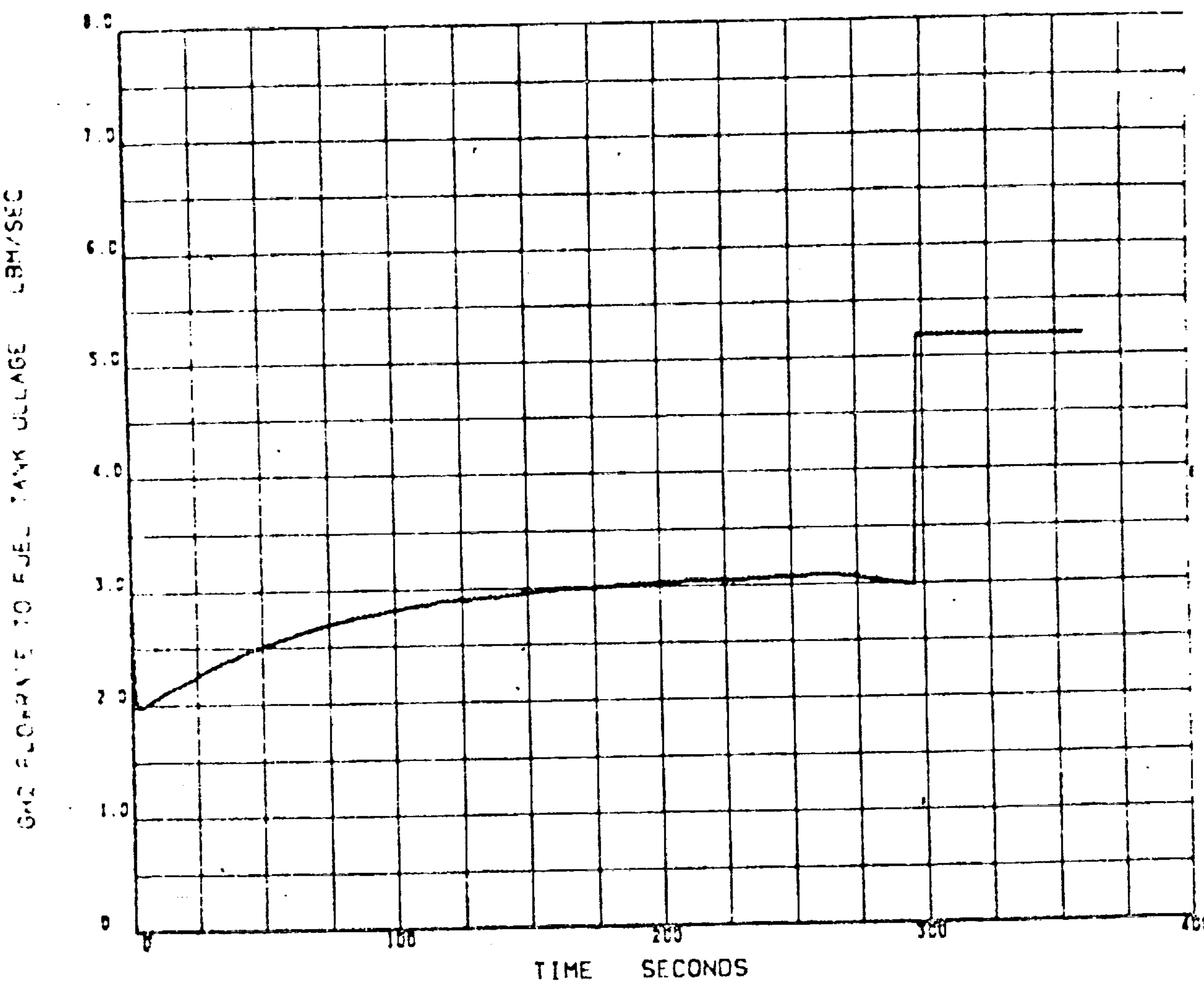


FIGURE 4-19 S-II GH2 FLOWRATE TO FUEL TANK ULLAGE

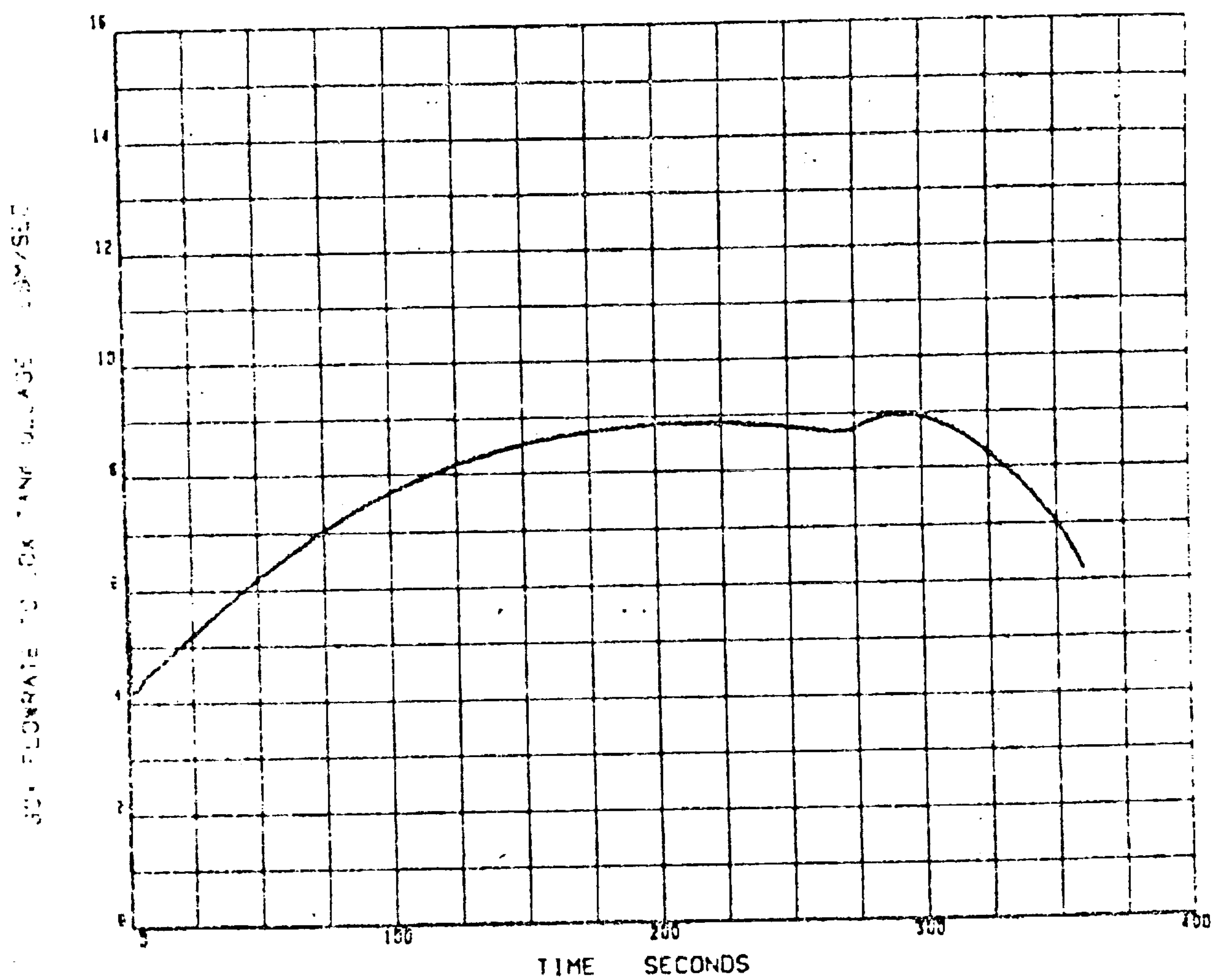


FIGURE 4-20 S-II GOX FLOWRATE TO LOX TANK ULLAGE

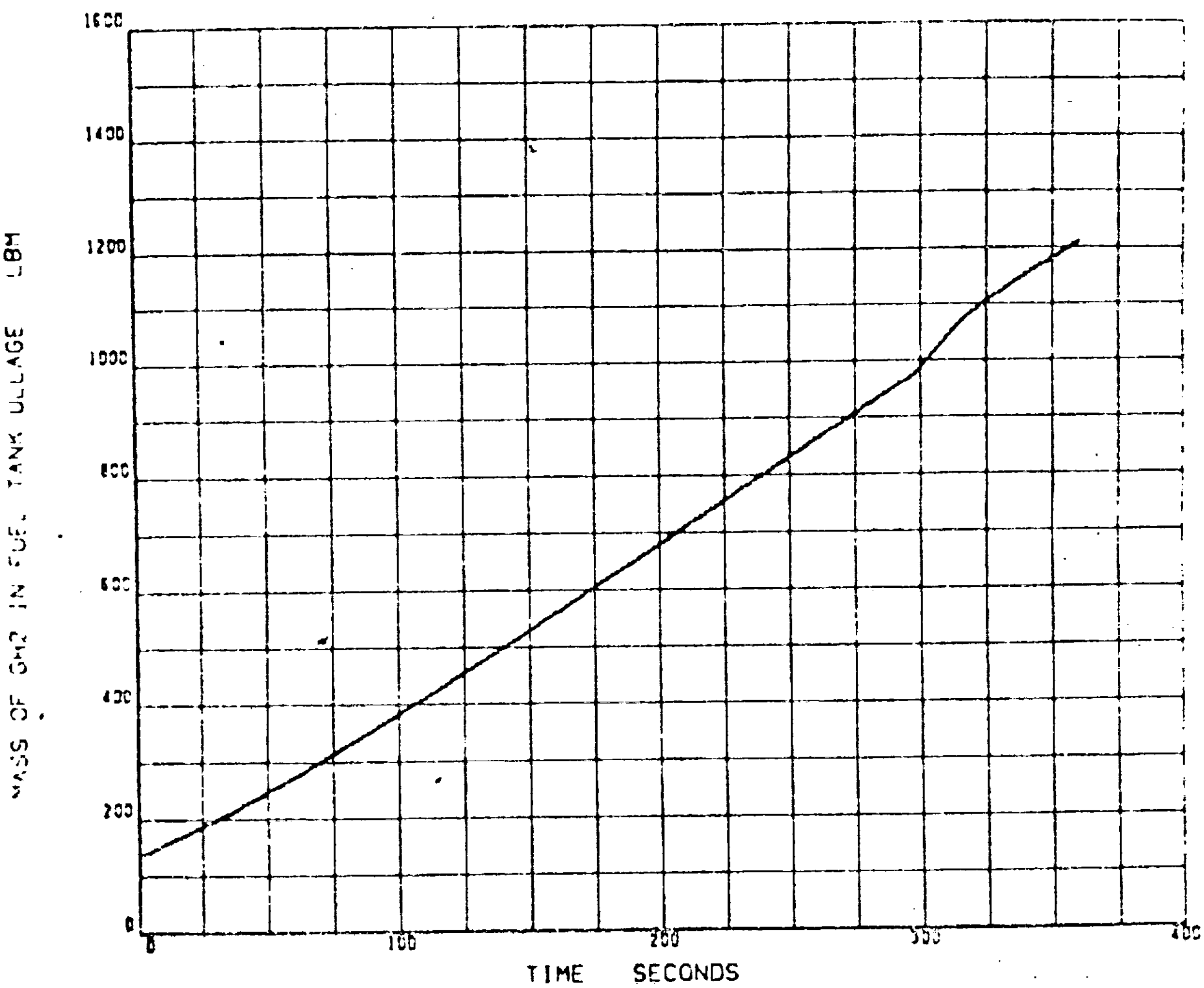


FIGURE 4-21 S-II MASS OF GH2 IN FUEL TANK ULLAGE

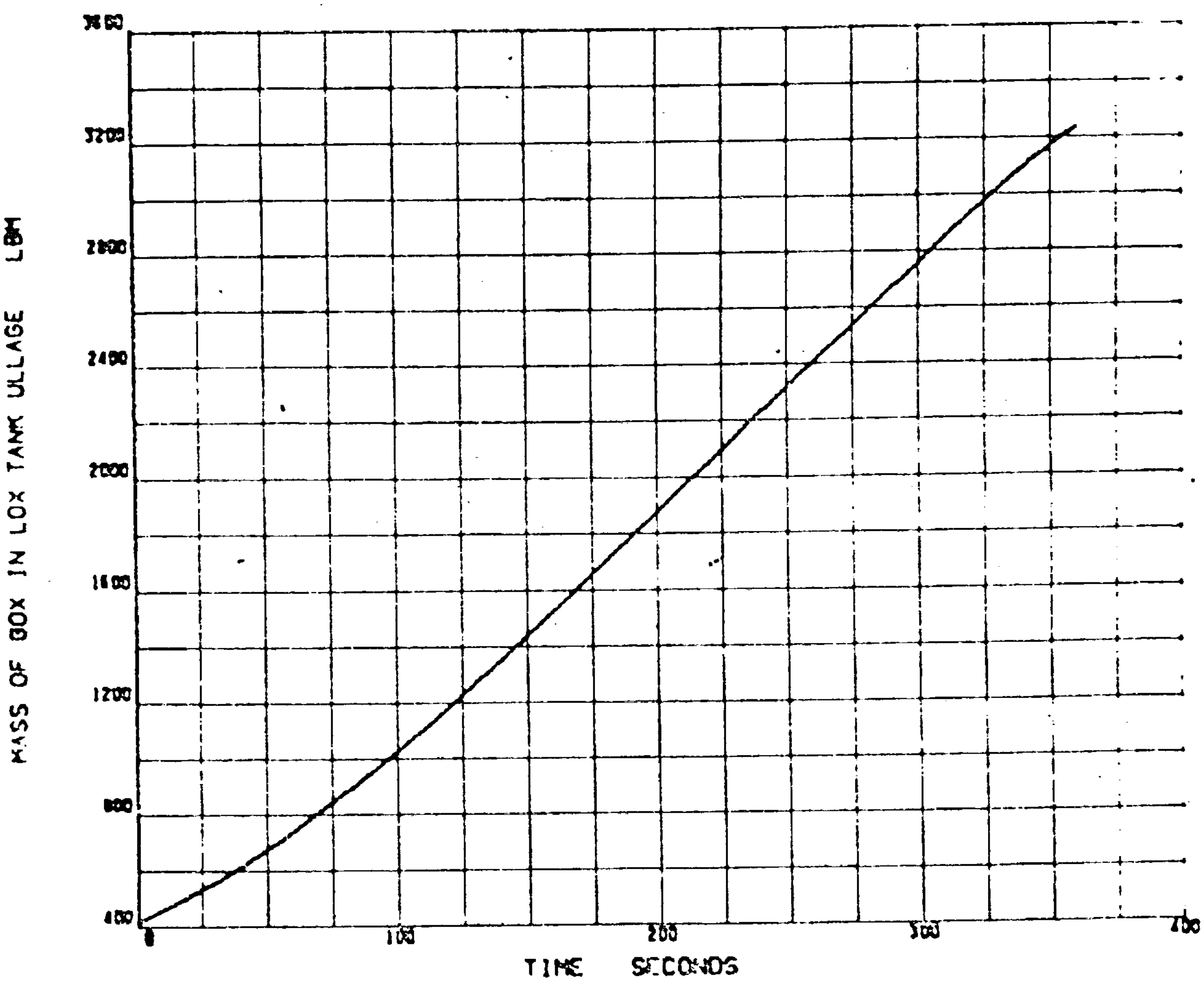


FIGURE 4-22 S-II MASS OF GOX IN LOX TANK ULLAGE

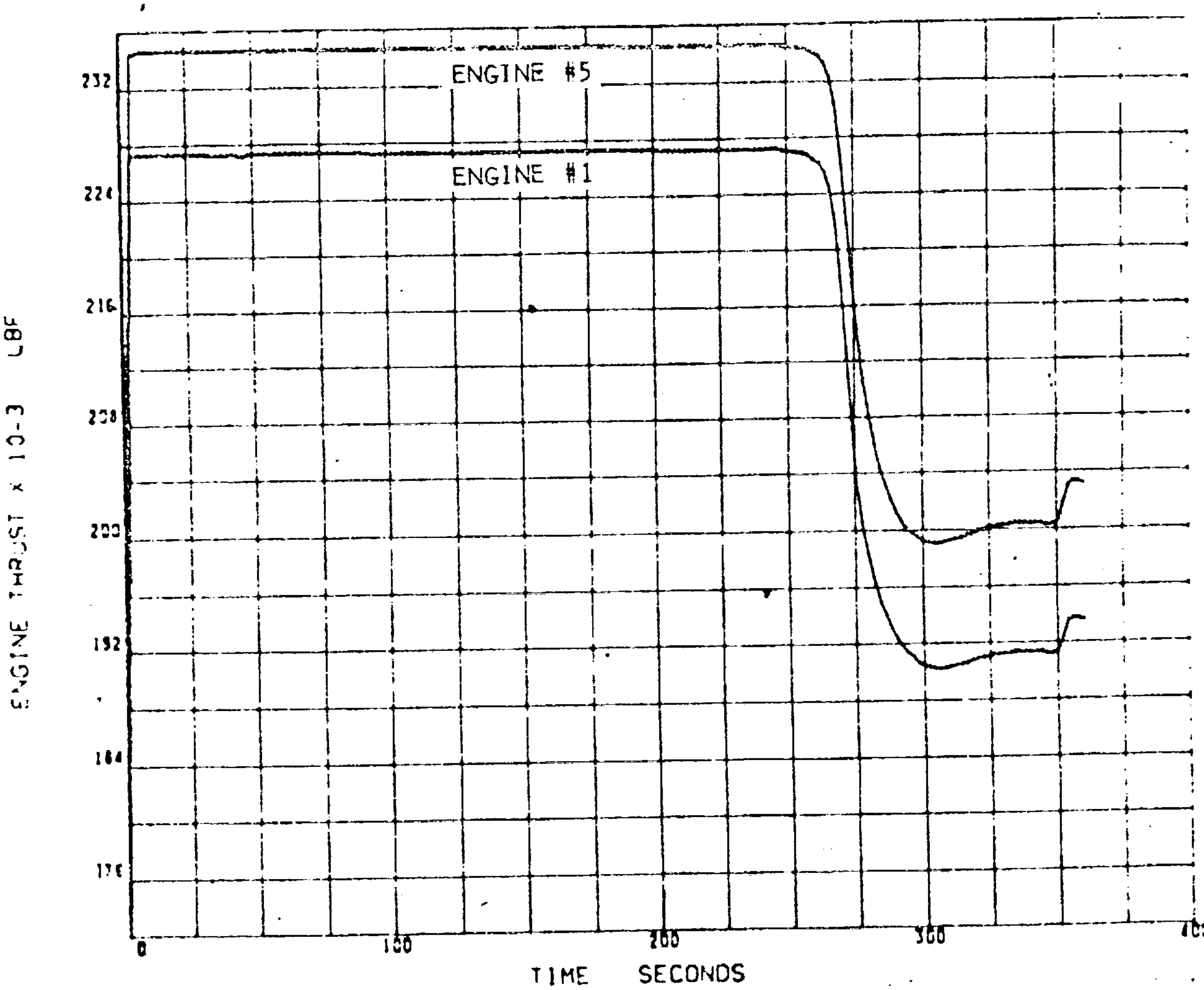


FIGURE 4-23 S-II ENGINE THRUST

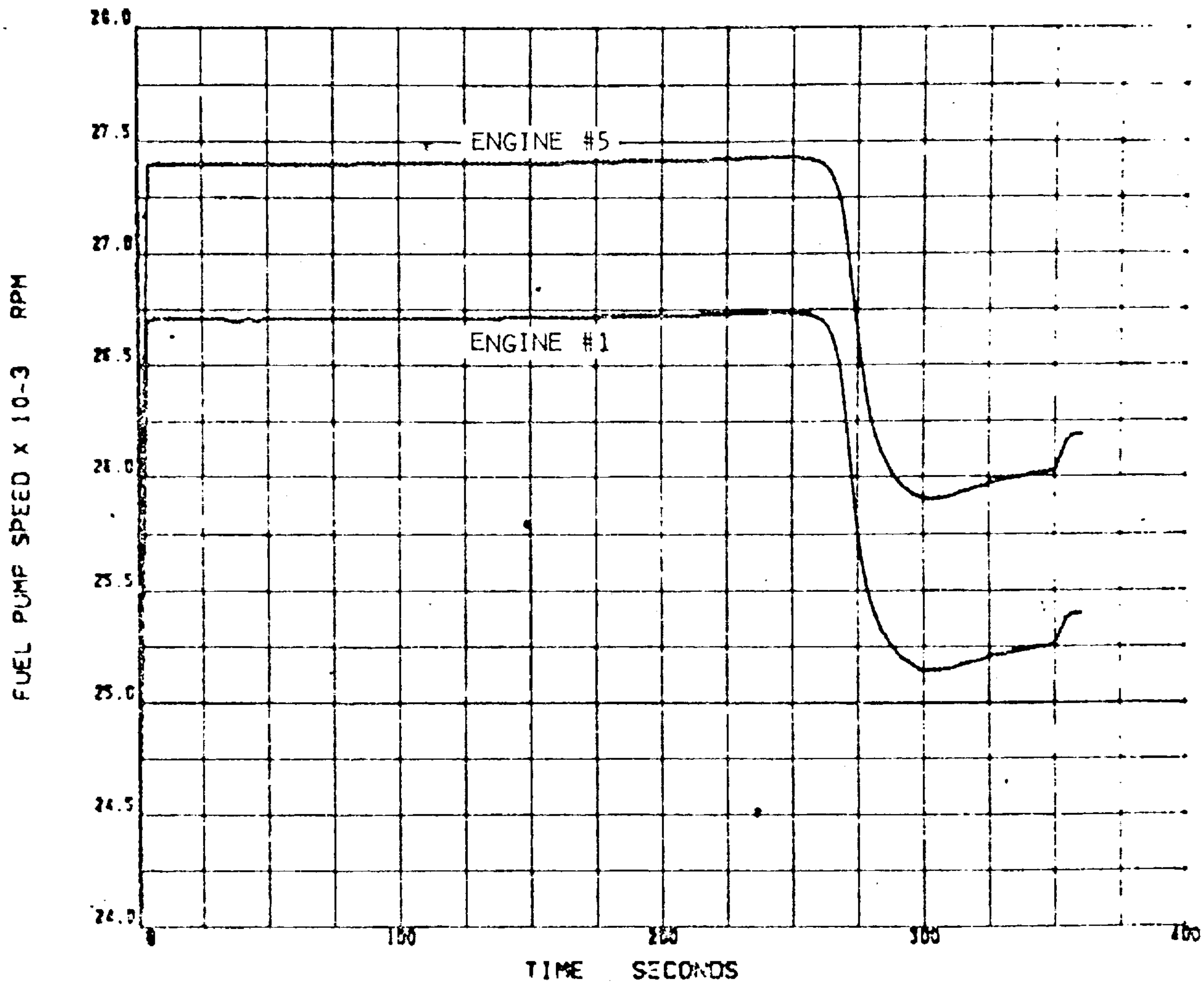


FIGURE 4-24 S-II FUEL PUMP SPEED

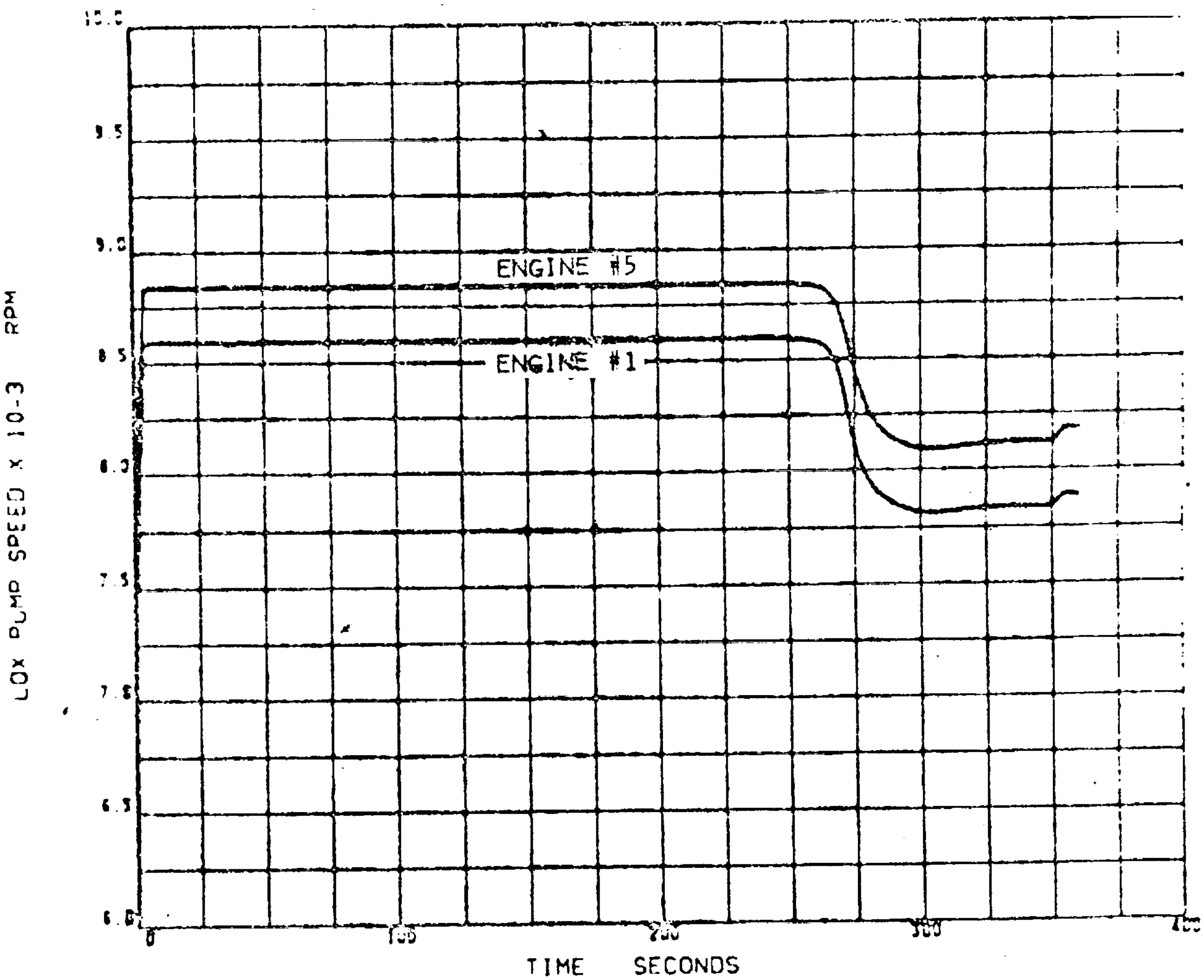


FIGURE 4-25 S-II LOX PUMP SPEED

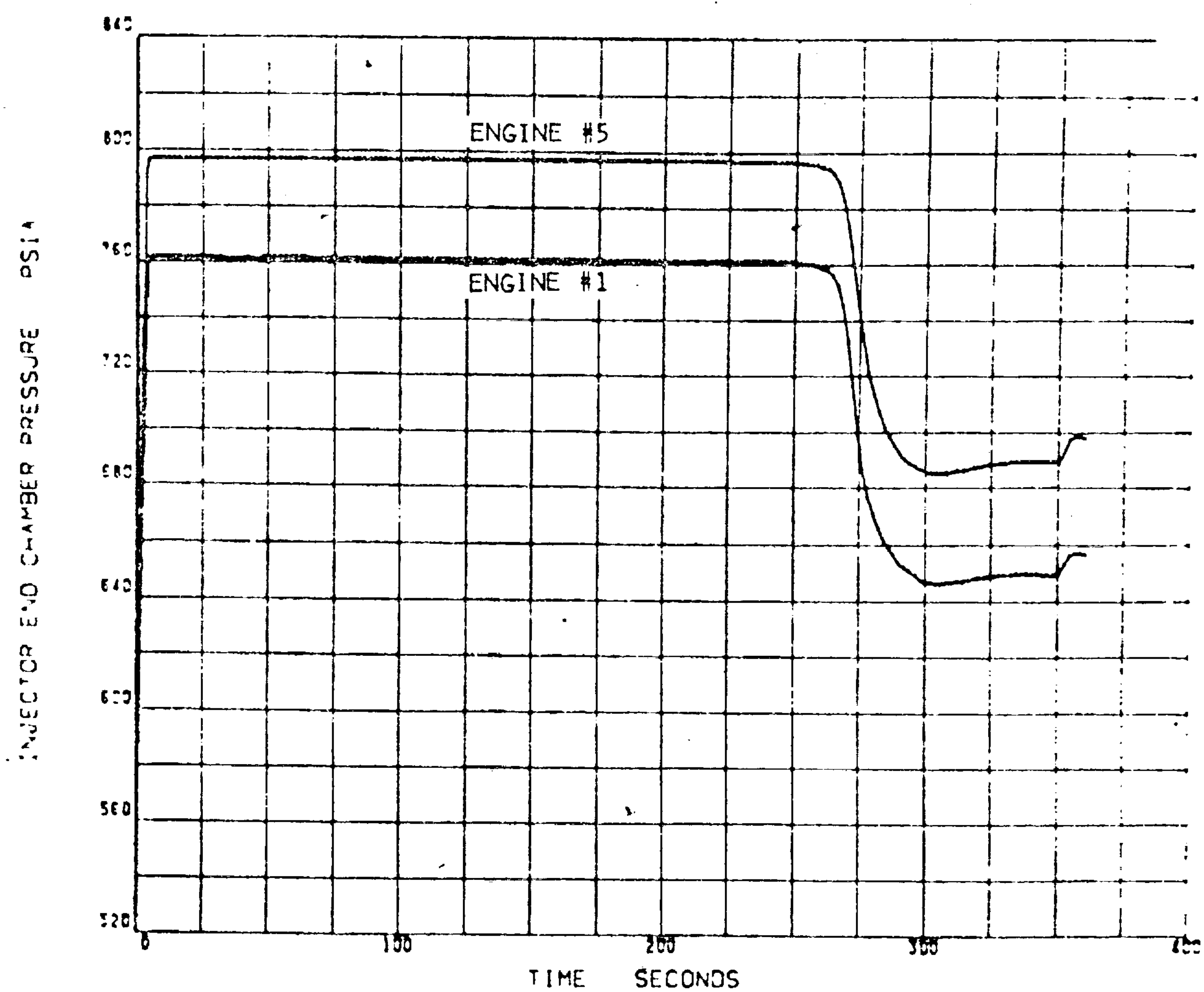


FIGURE 4-26 S-II INJECTOR END CHAMBER PRESSURE

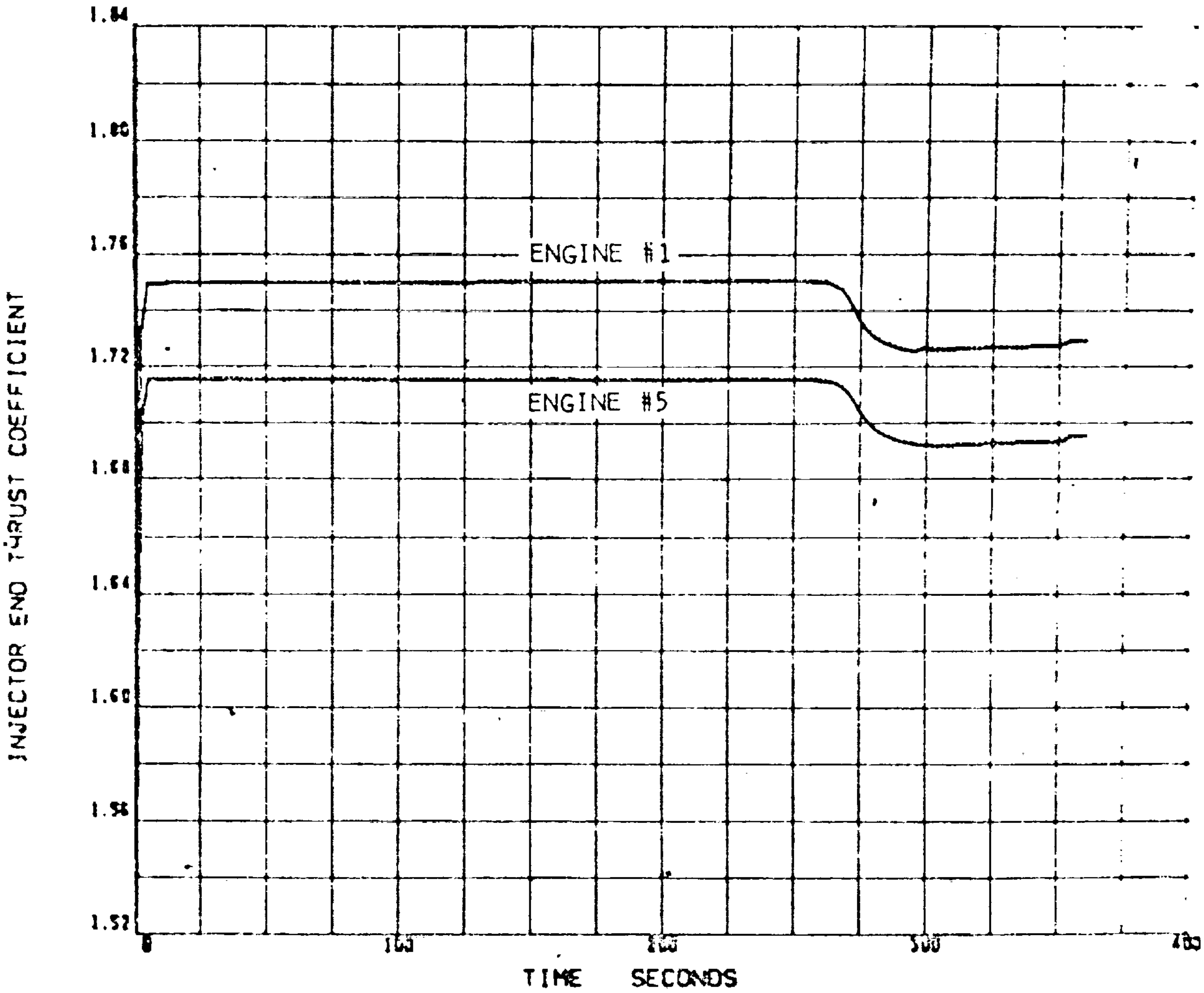


FIGURE 4-27 S-II INJECTOR END THRUST COEFFICIENT

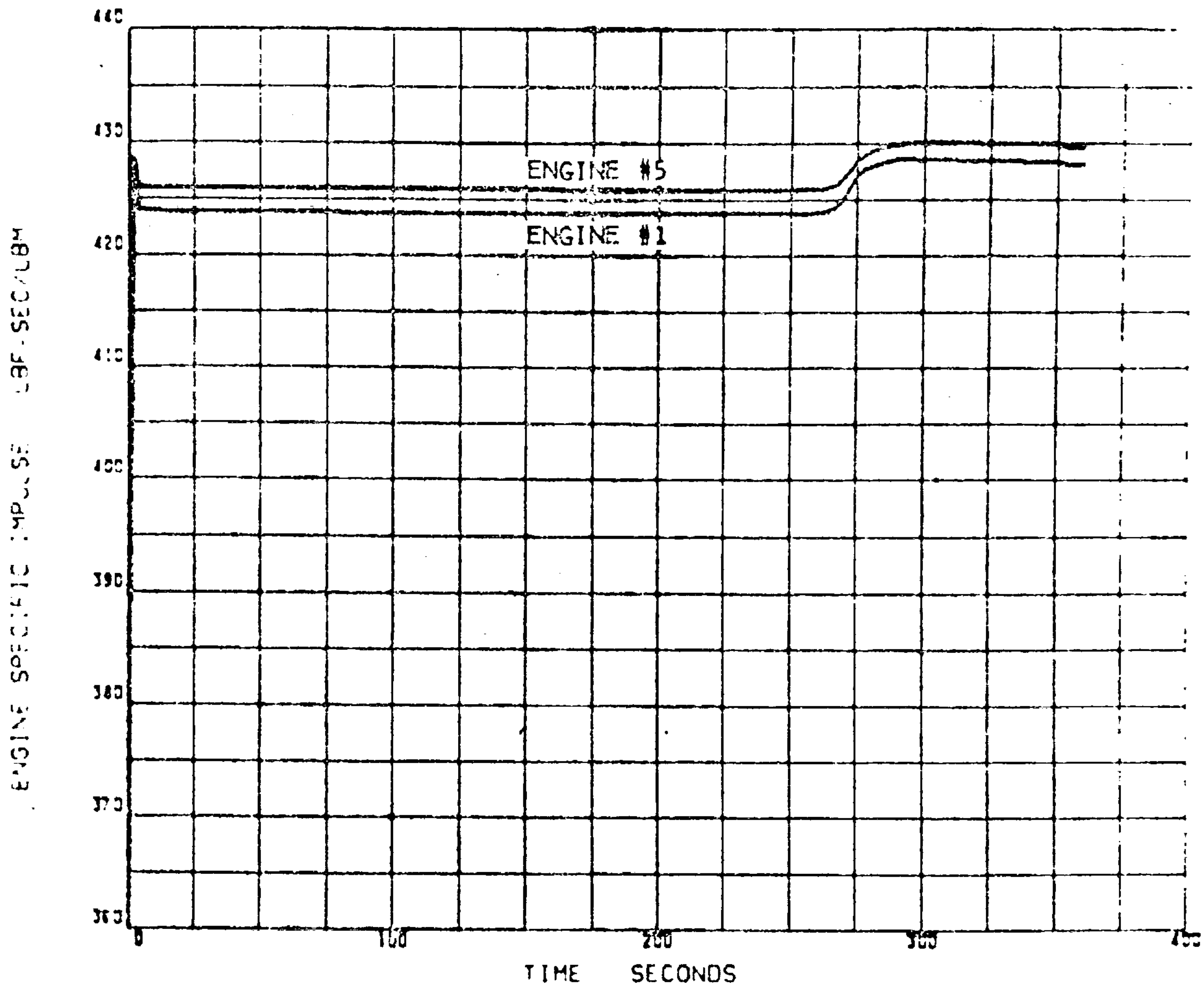


FIGURE 4-28 S-II ENGINE SPECIFIC IMPULSE

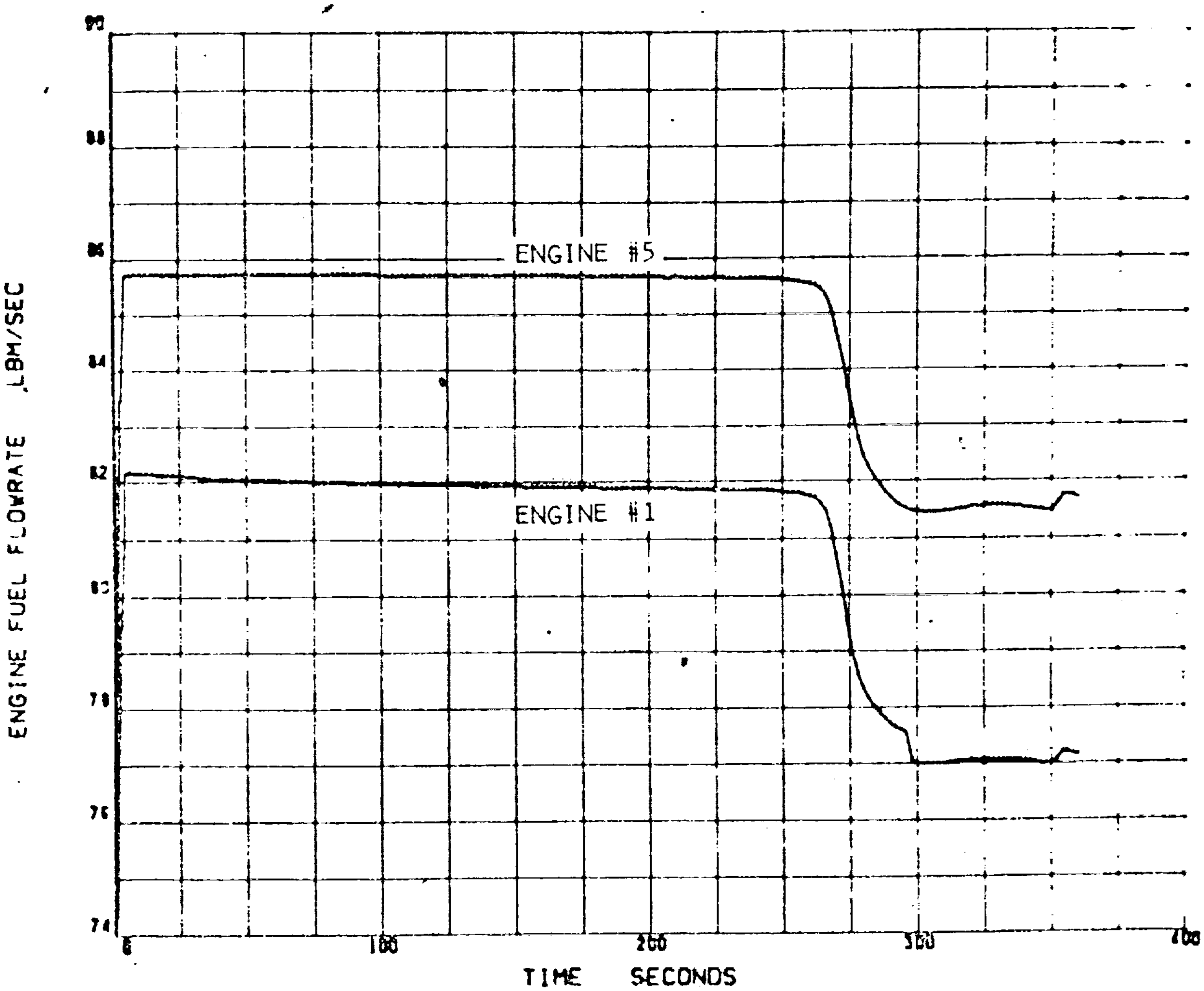


FIGURE 4-29 S-II ENGINE FUEL FLOWRATE

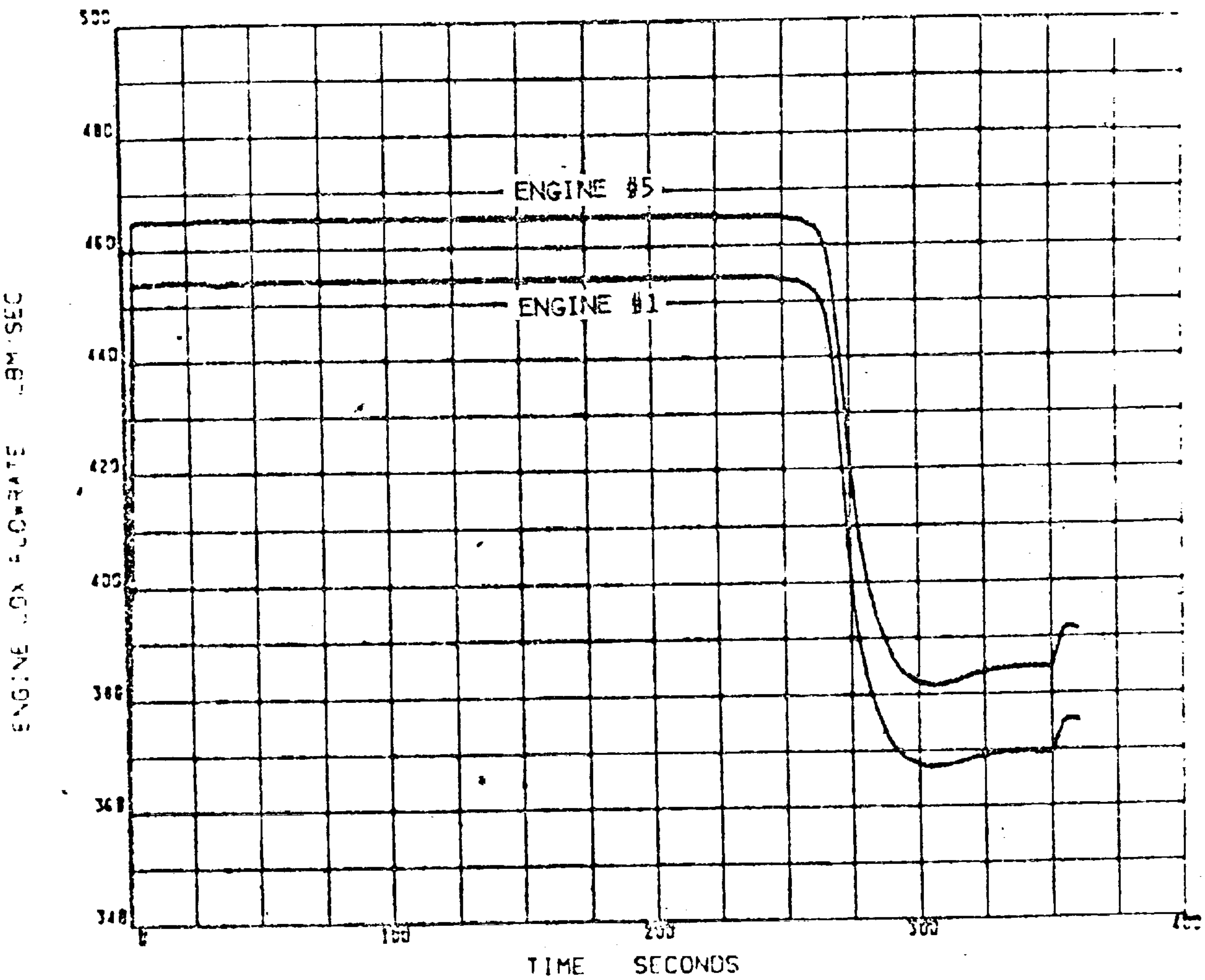


FIGURE 4-30 S-II ENGINE LOX FLOWRATE

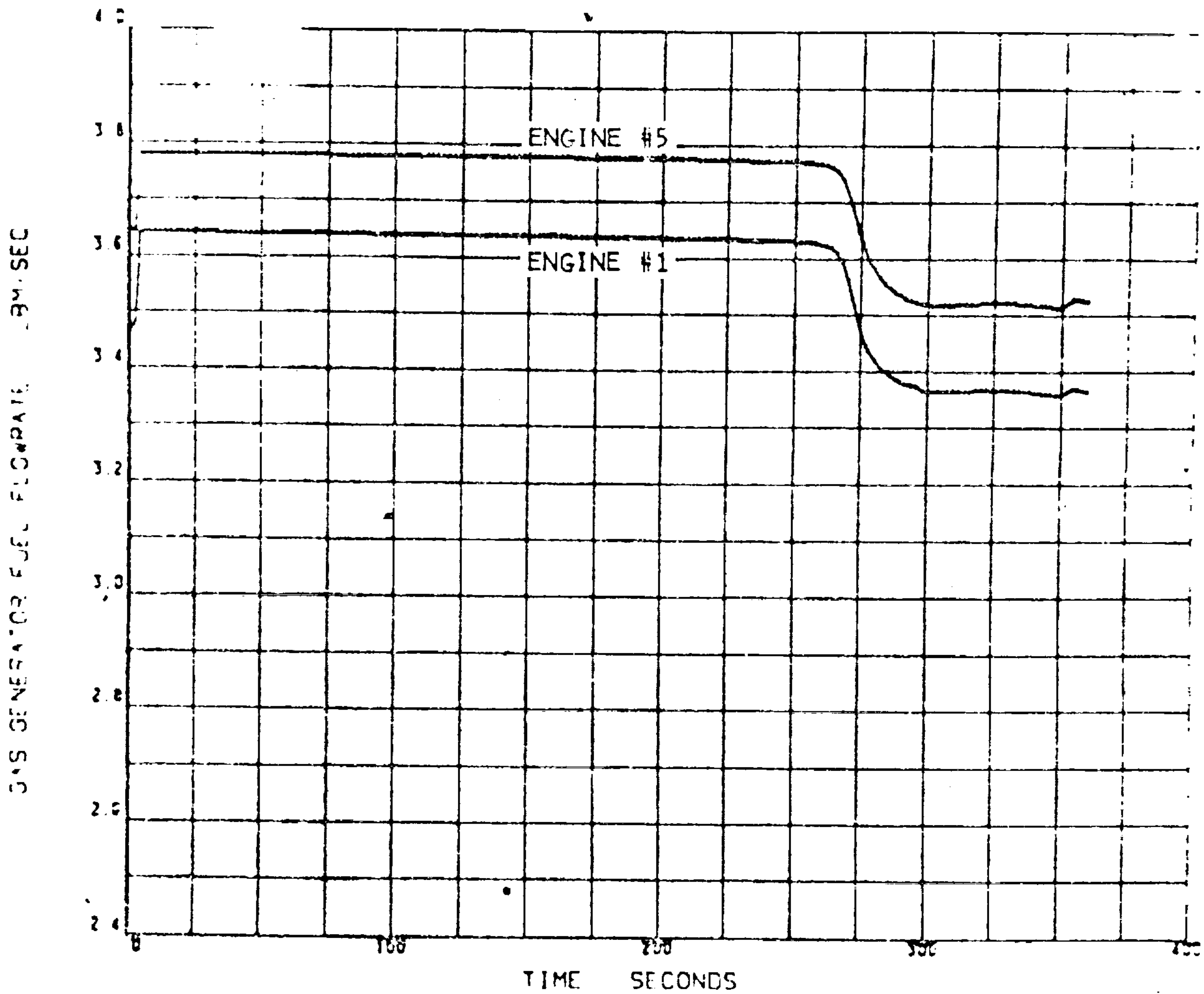


FIGURE 4-31 S-II GAS GENERATOR FUEL FLOWRATE

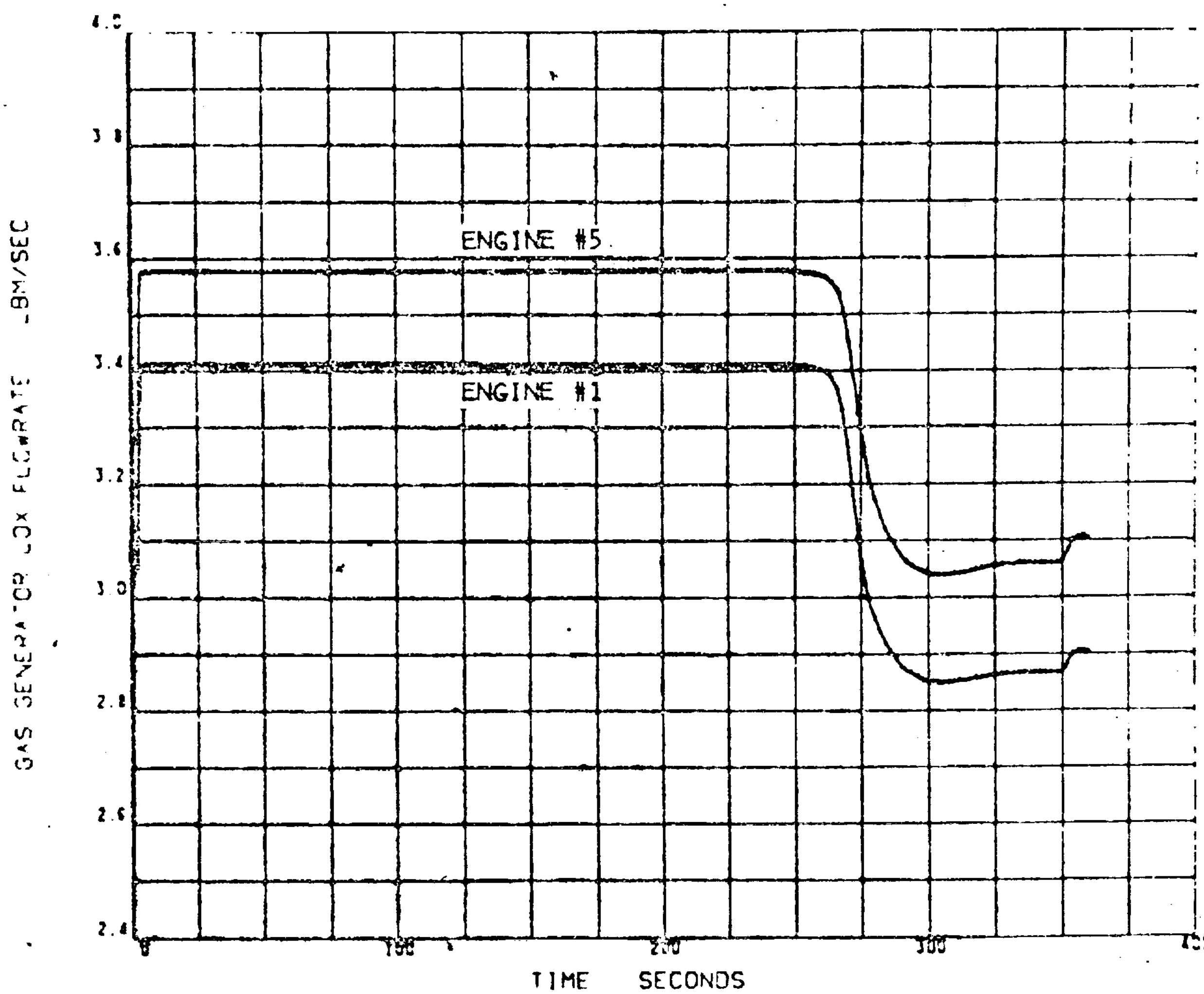


FIGURE 4-32 S-II GAS GENERATOR LOX FLOWRATE

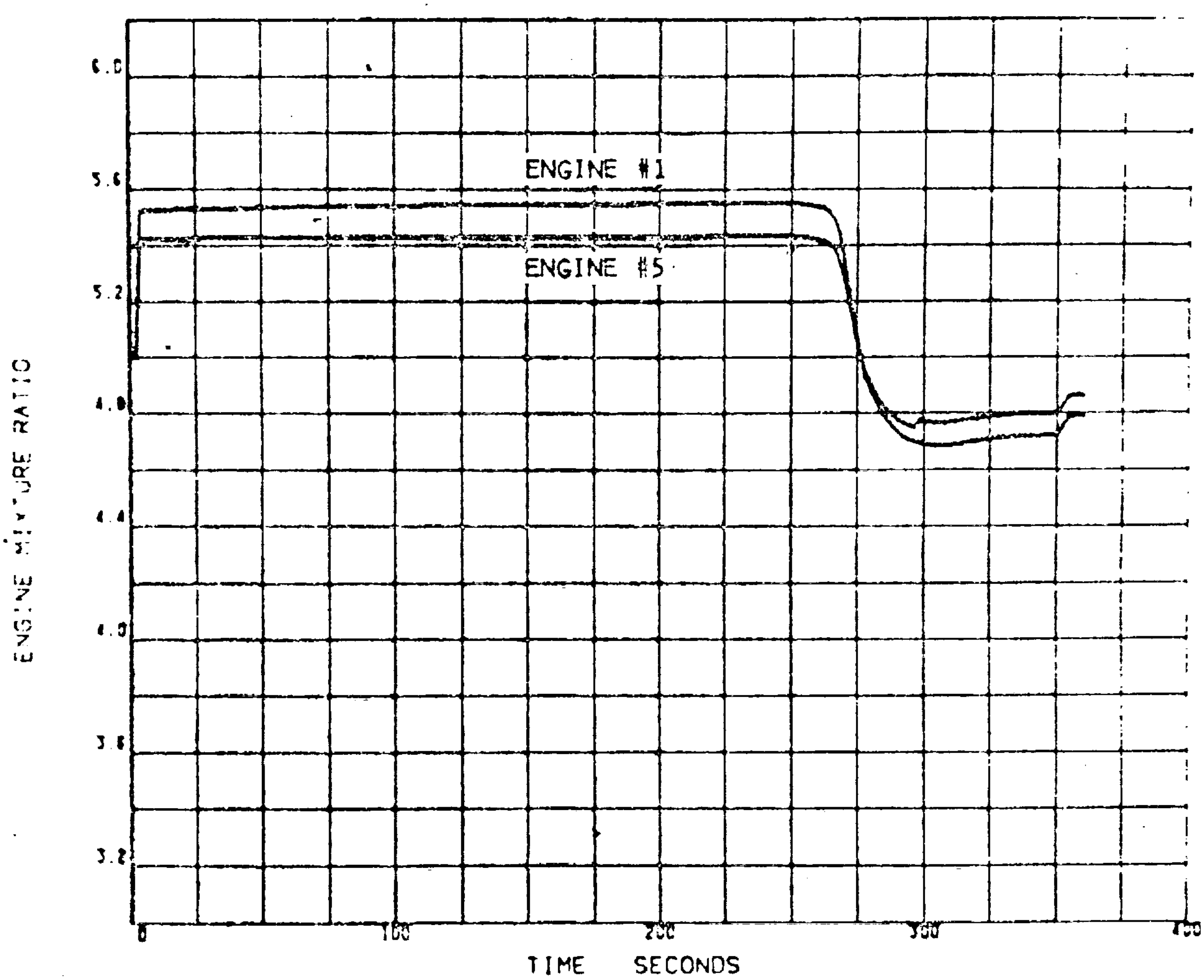


FIGURE 4-33 S-II ENGINE MIXTURE RATIO

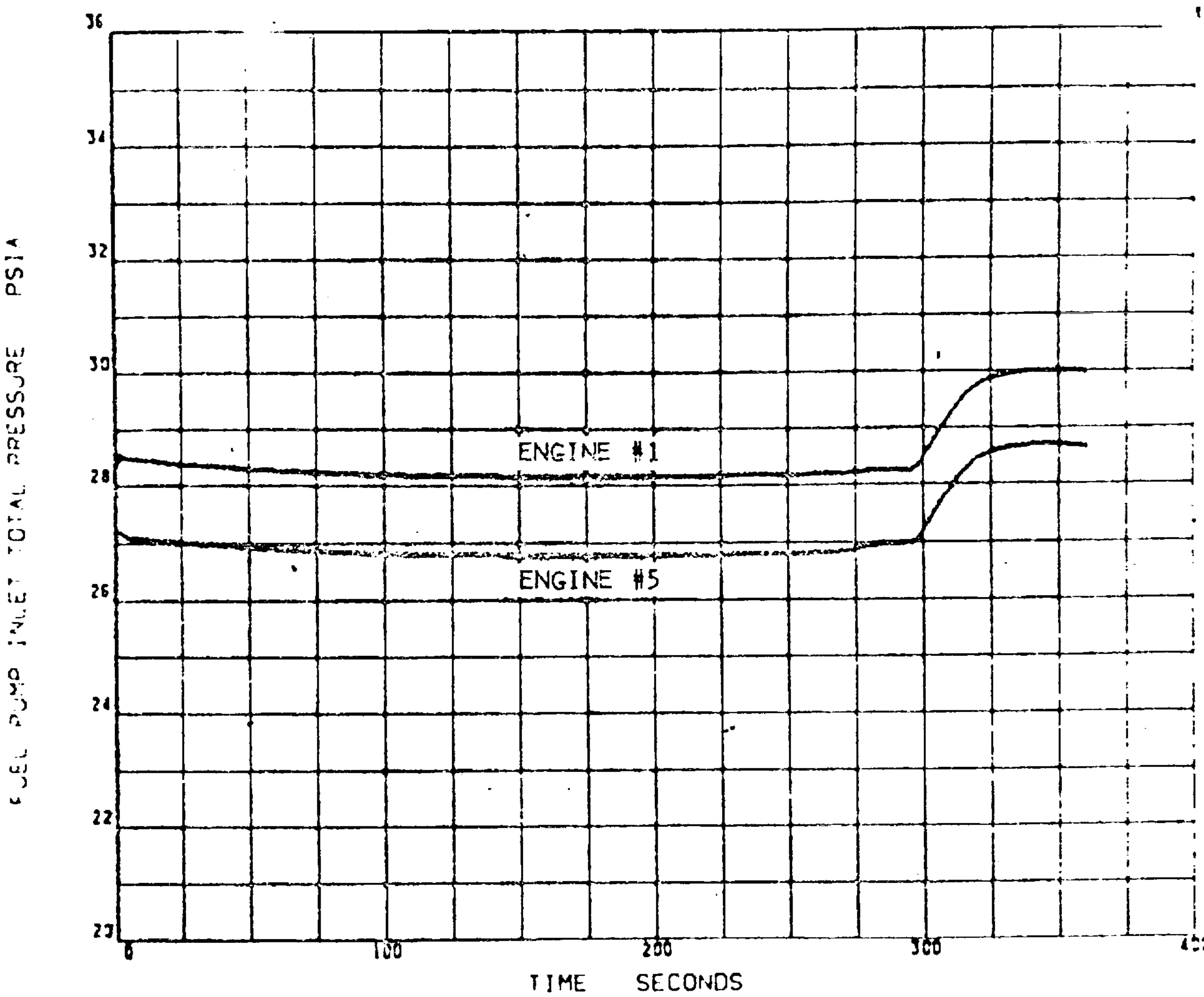


FIGURE 4-34 S-II FUEL PUMP INLET TOTAL PRESSURE

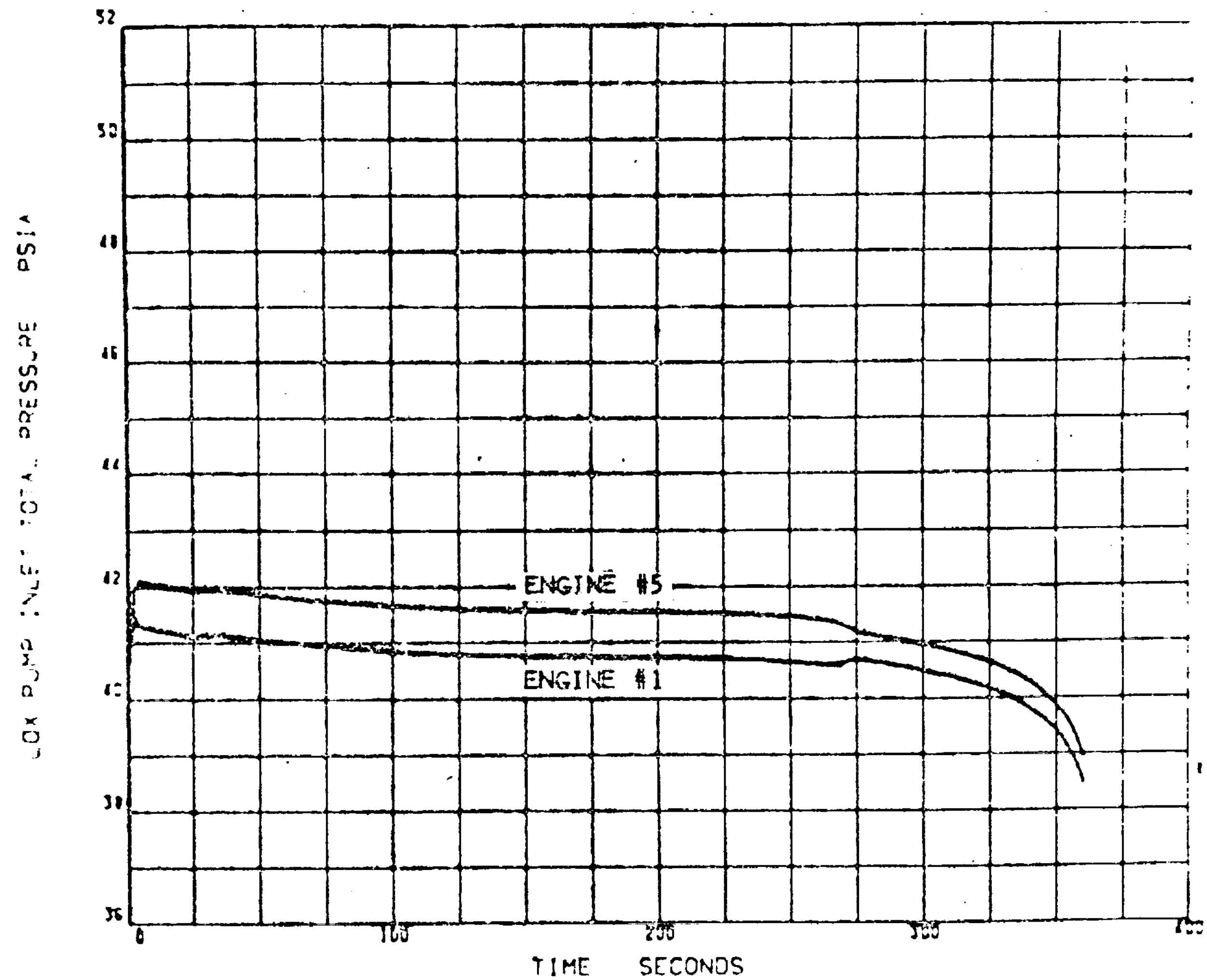


FIGURE 4-35 S-II LOX PUMP INLET TOTAL PRESSURE

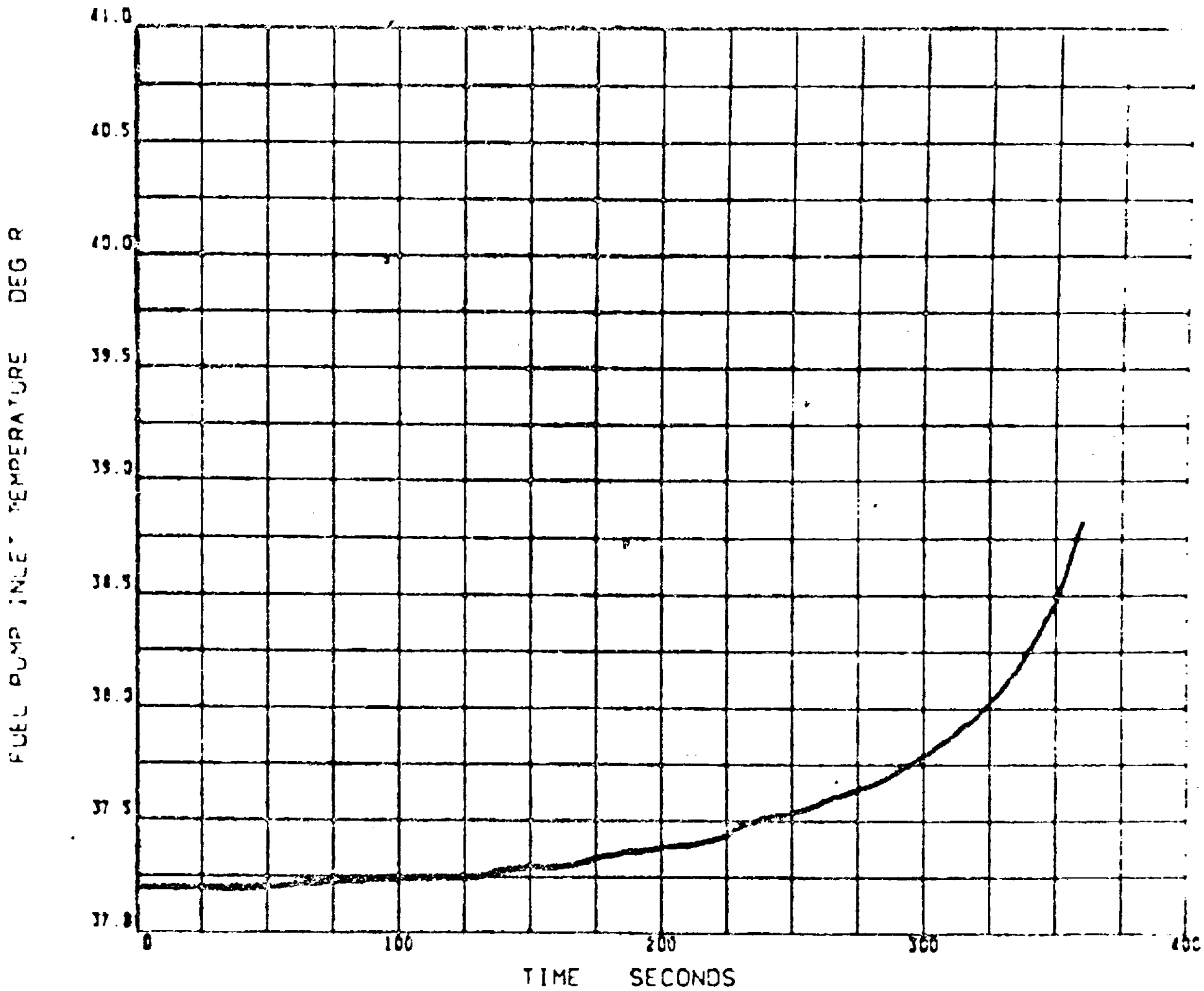


FIGURE 4-36 S-II FUEL PUMP INLET TEMPERATURE

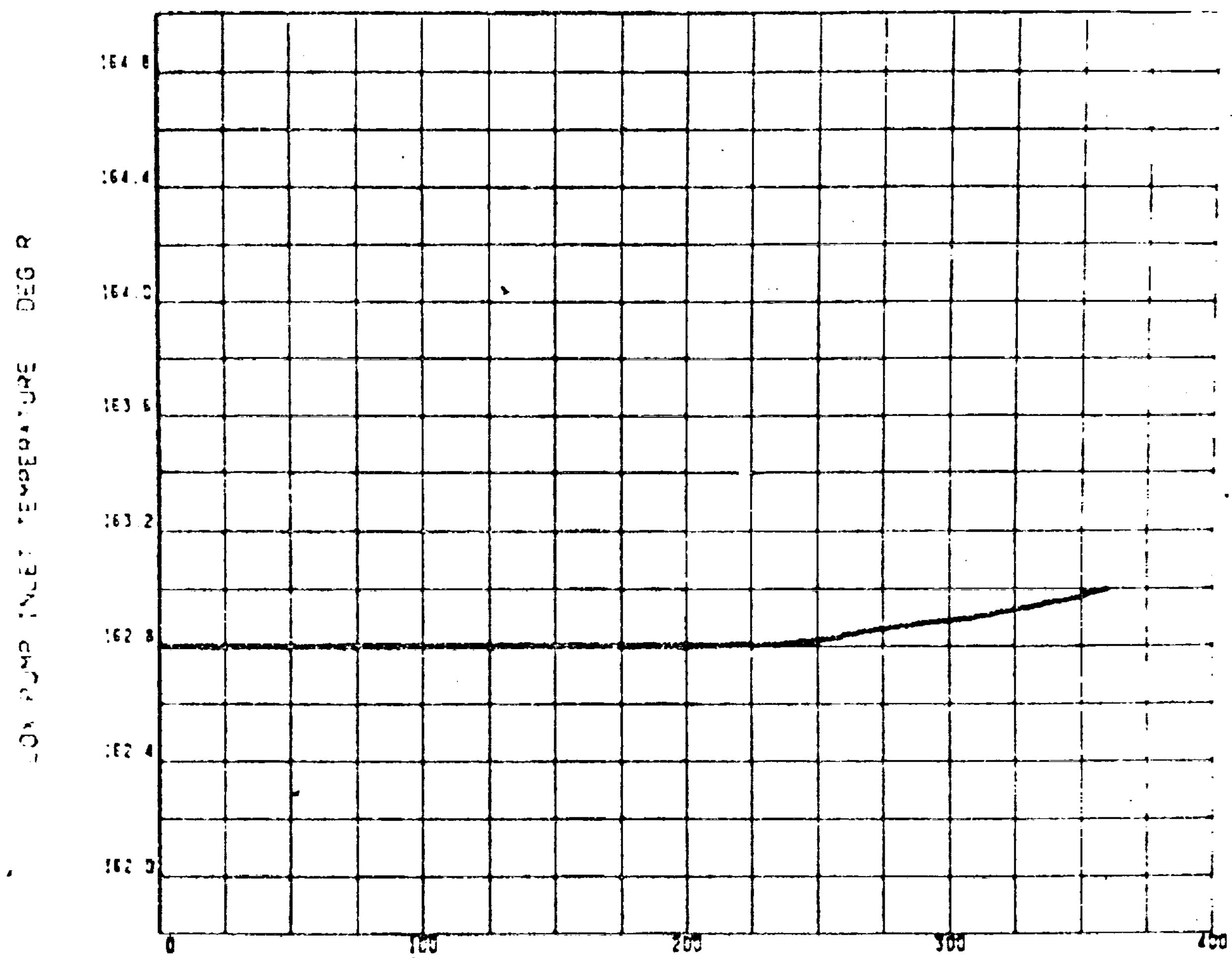


FIGURE 4-37 S-II LOX PUMP INLET TEMPERATURE

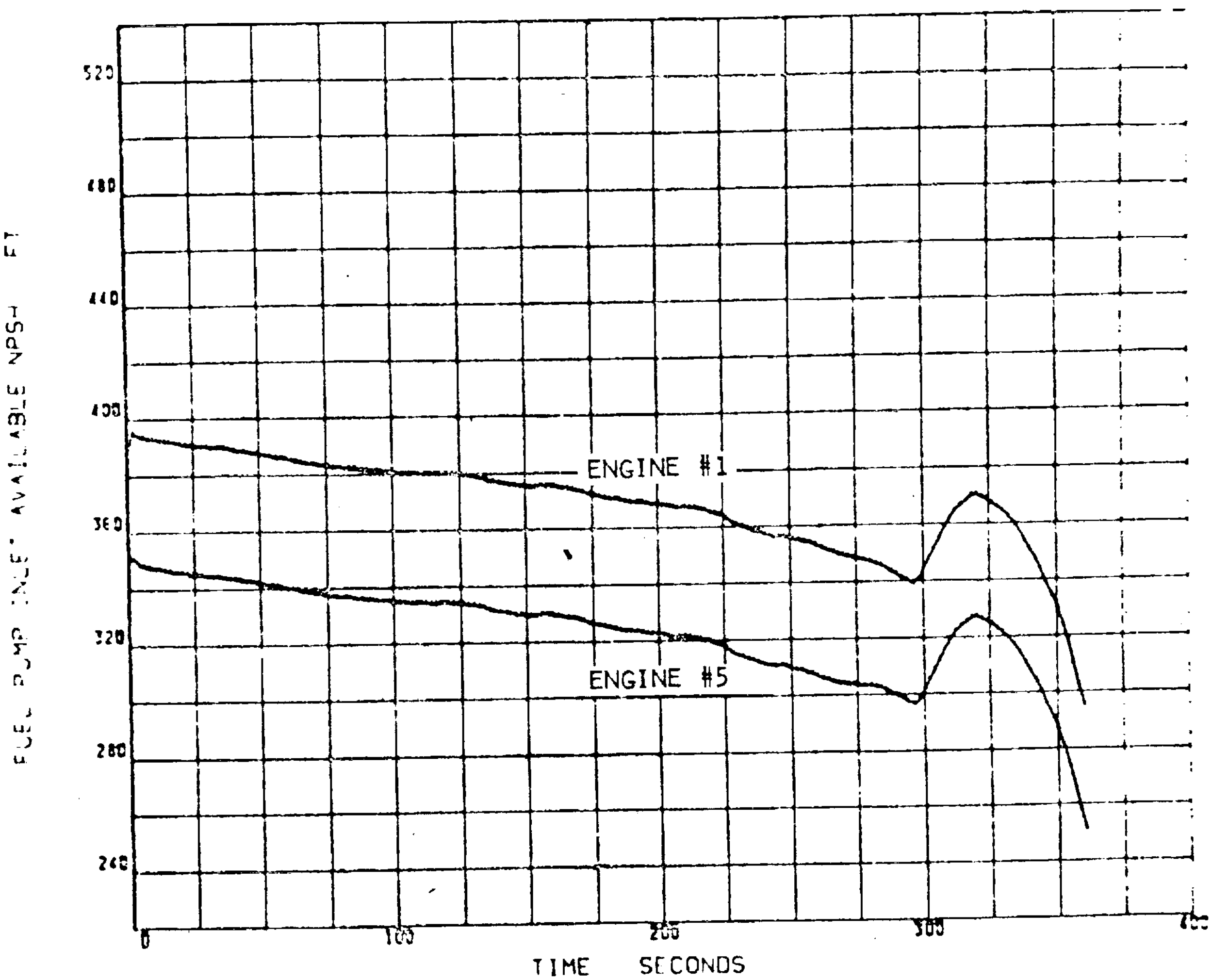


FIGURE 4-38 S-II FUEL PUMP INLET AVAILABLE NPSH

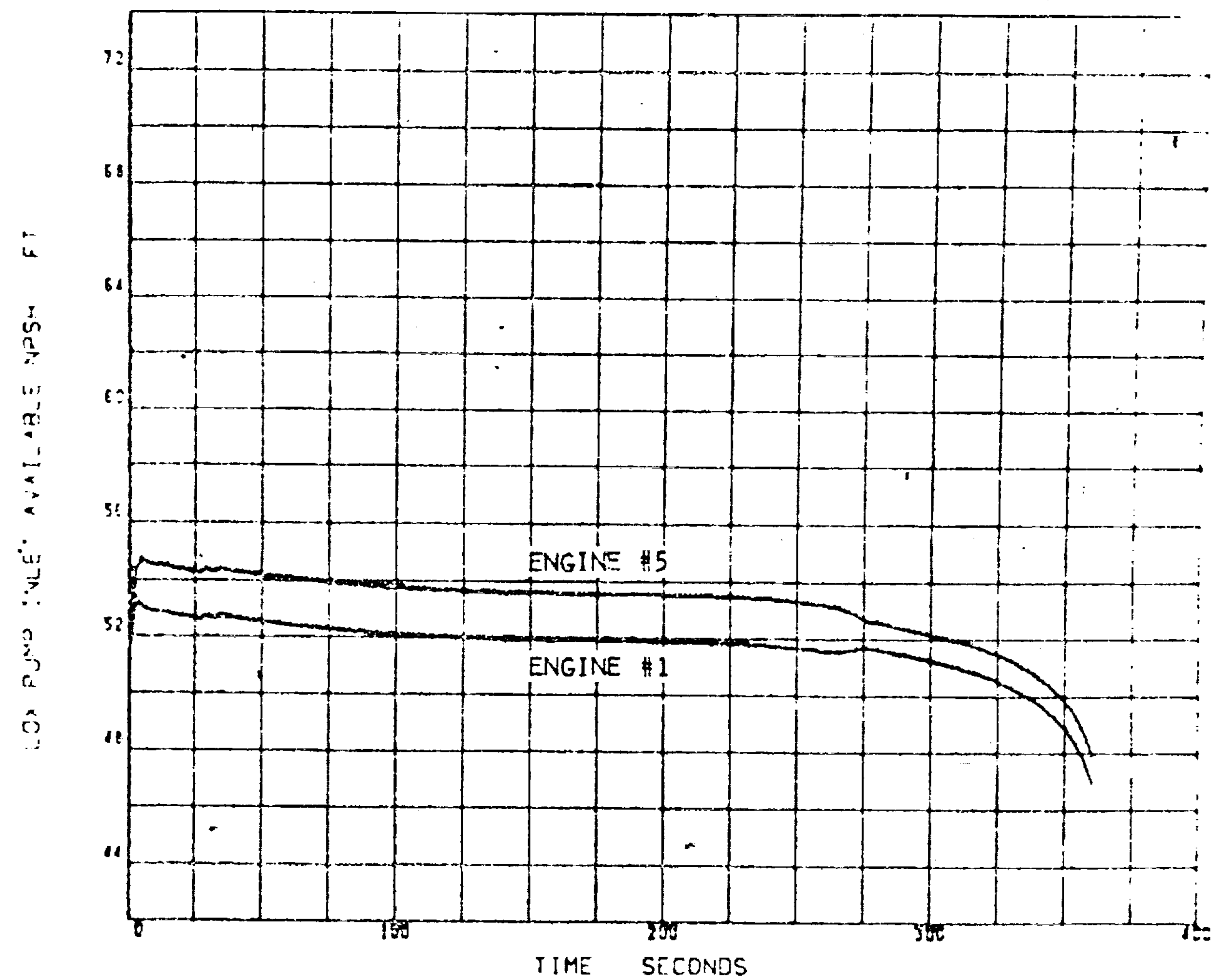


FIGURE 4-39 S-II LOX PUMP INLET AVAILABLE NPSH

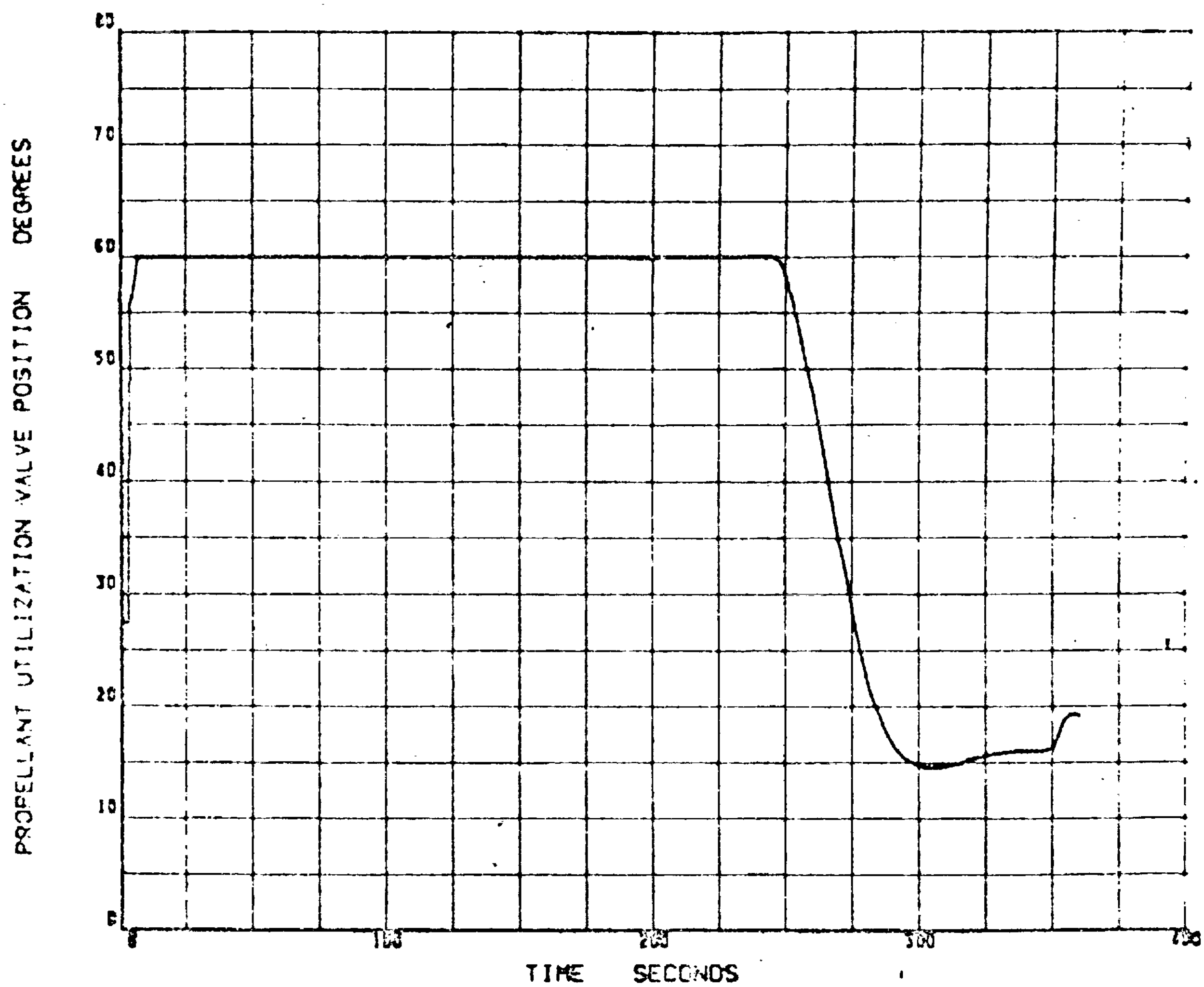


FIGURE 4-40 S-II PROPELLANT UTILIZATION VALVE POSITION

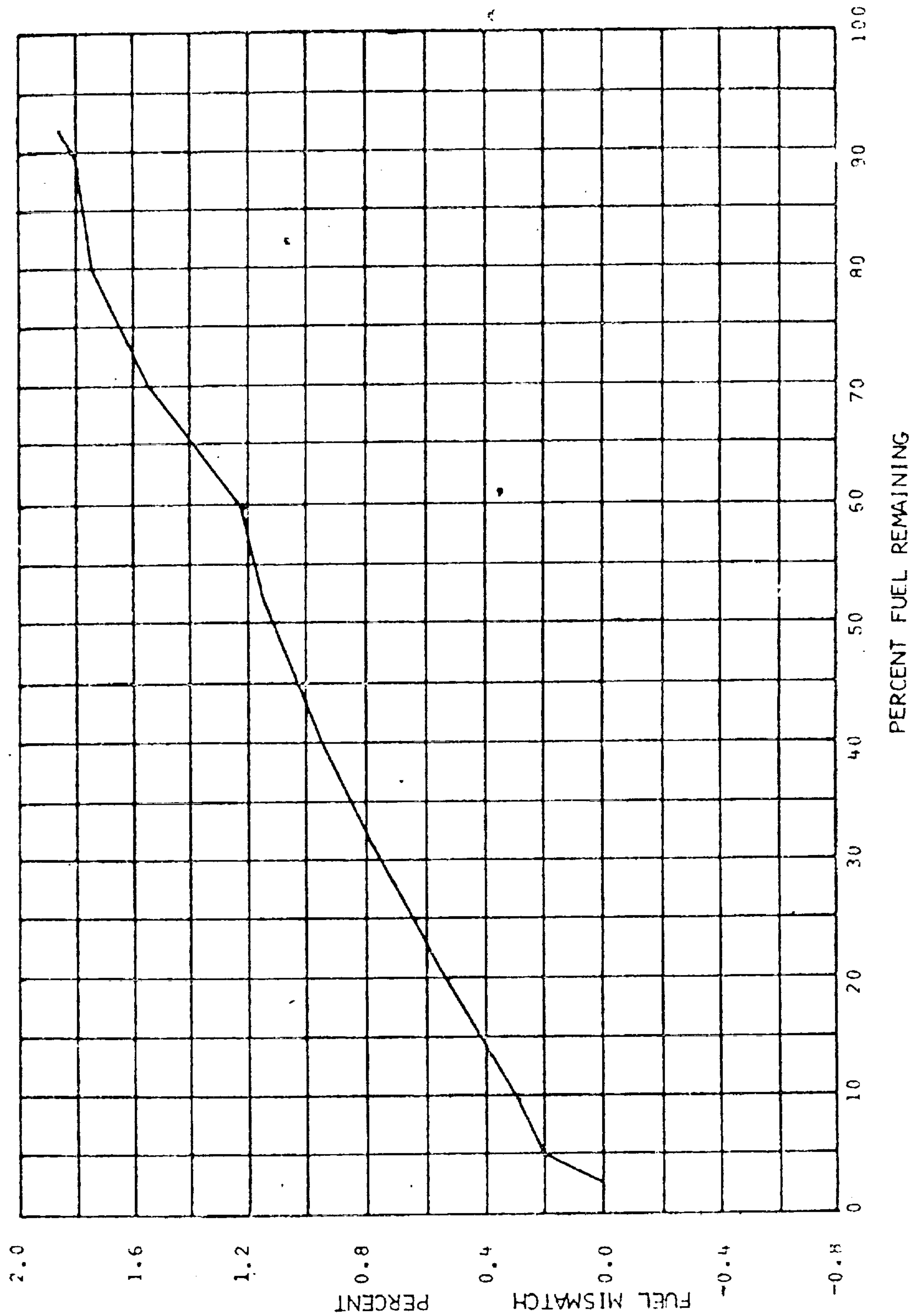


FIGURE 4-41 S-II FUEL PROBE-TO-TANK MISMATCH

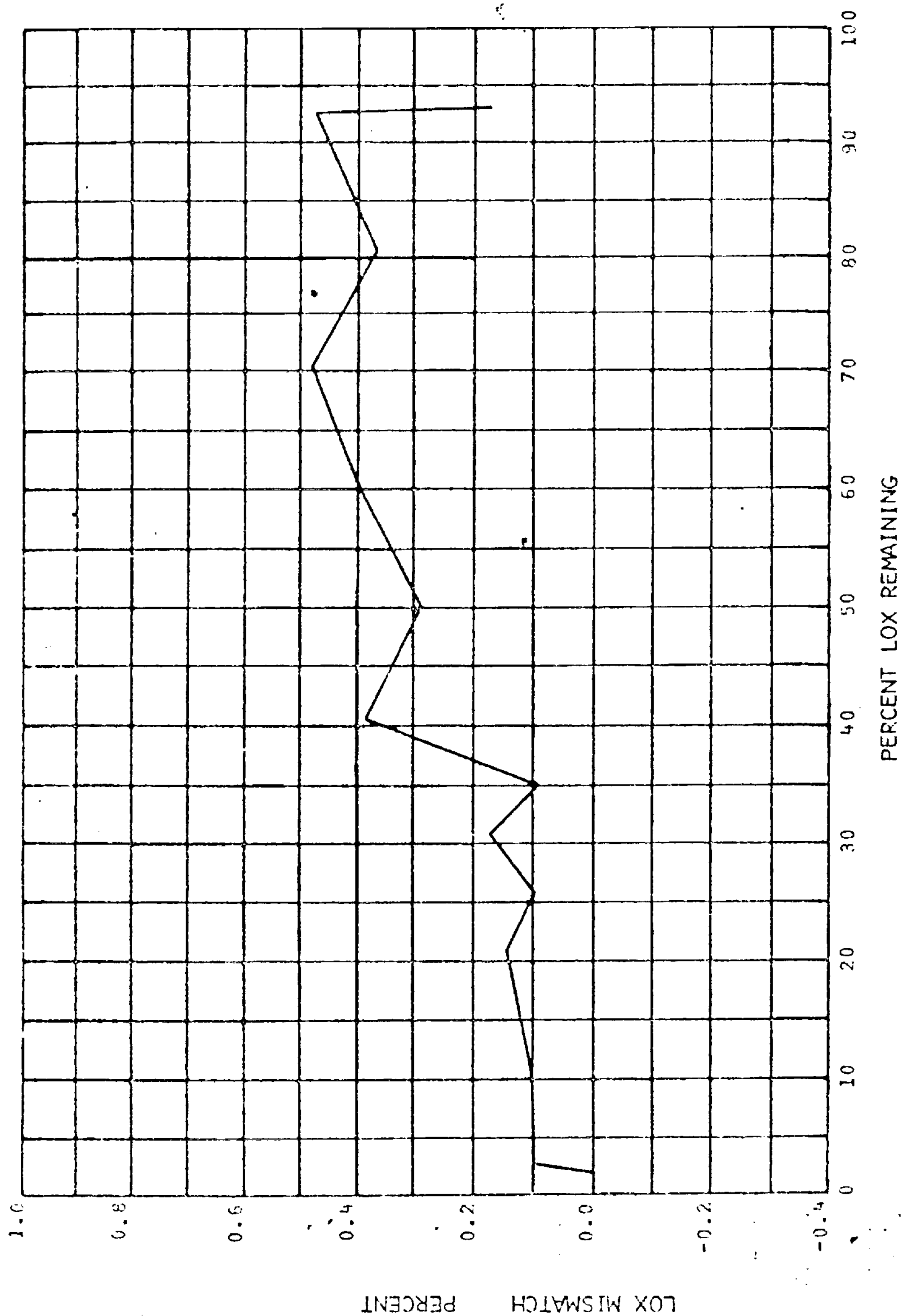


FIGURE 4-42 S-II LOX PROBE-TO-TANK MISMATCH

APPENDIX A

APPENDIX A

S-II/503 FINAL PREDICTION COMPARISON

1.0 GENERAL

This appendix presents a comparison of the Boeing and stage contractor (North American Rockwell, Space Division) final propulsion system performance predictions for the S-II/503 manned mission. The comparison is given for the major vehicle propulsion performance parameters only. Possible reasons for the deviations between the two predictions are given.

2.0 COMPARISON OF BOEING AND NAR-SD S-II/503 FINAL PREDICTIONS

A comparison of the Boeing and NAR-SD major vehicle propulsion performance parameters for the 503 manned mission are given in Figures A-1 through A-5. All of the data shown indicate that the vehicle performance parameters for the two predictions are in close agreement for the high mixture ratio portion of the burn. The drop in vehicle performance at 297 seconds (Boeing prediction) reflects the effects of a step in the fuel tank pressurization flowrate. The pressurization step in the NAR-SD prediction occurs at 294 seconds and does not have as profound an effect on vehicle performance.

The Boeing prediction shows the P.U. valve step occurs at 246 seconds as compared to 247 for the NAR-SD prediction. The differences in the level and shape of the performance parameters after the mixture ratio stop indicate differences in both the Propellant Utilization (P.U.) system response and the probe error characteristics.

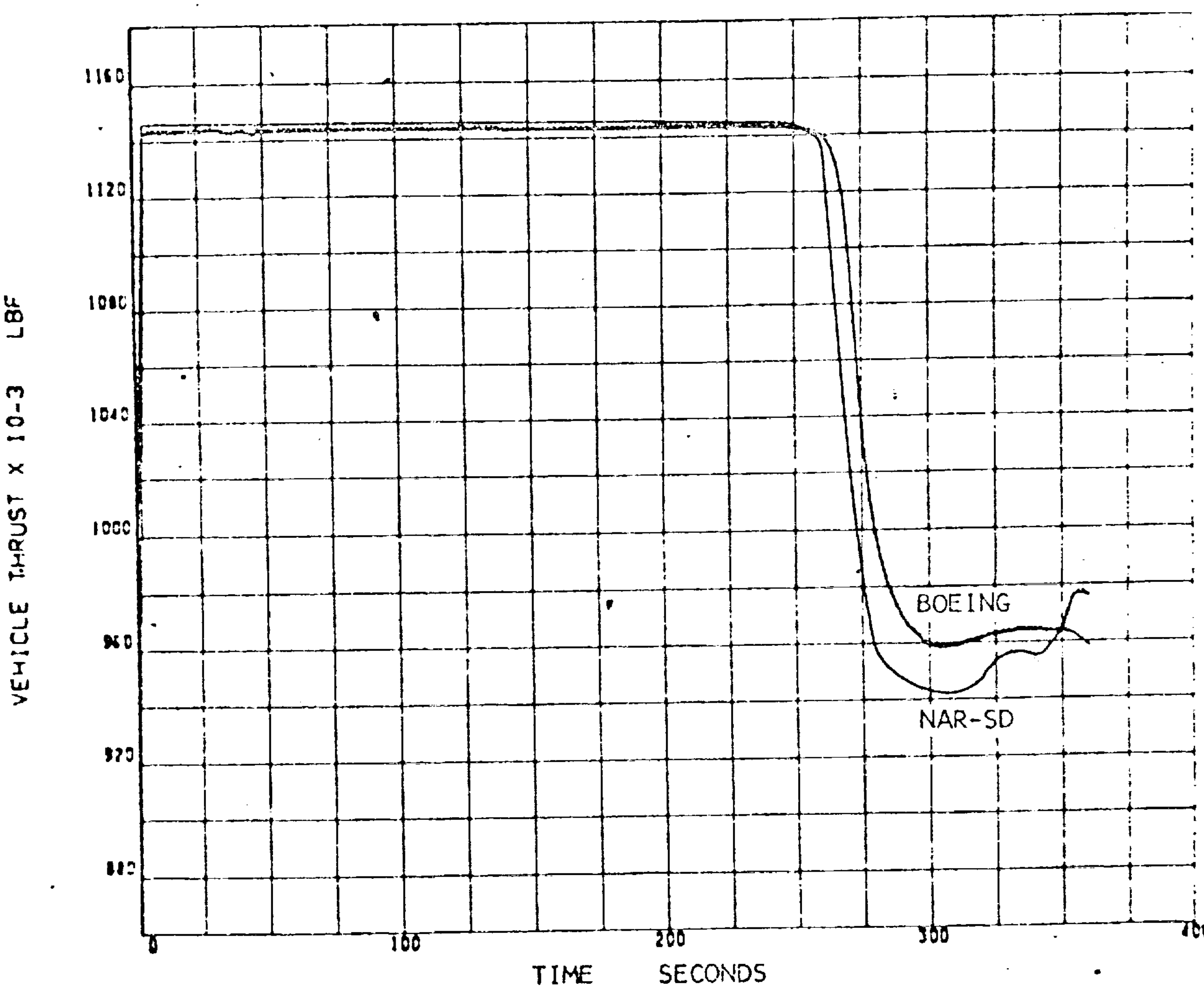


FIGURE A-1 VEHICLE THRUST COMPARISON

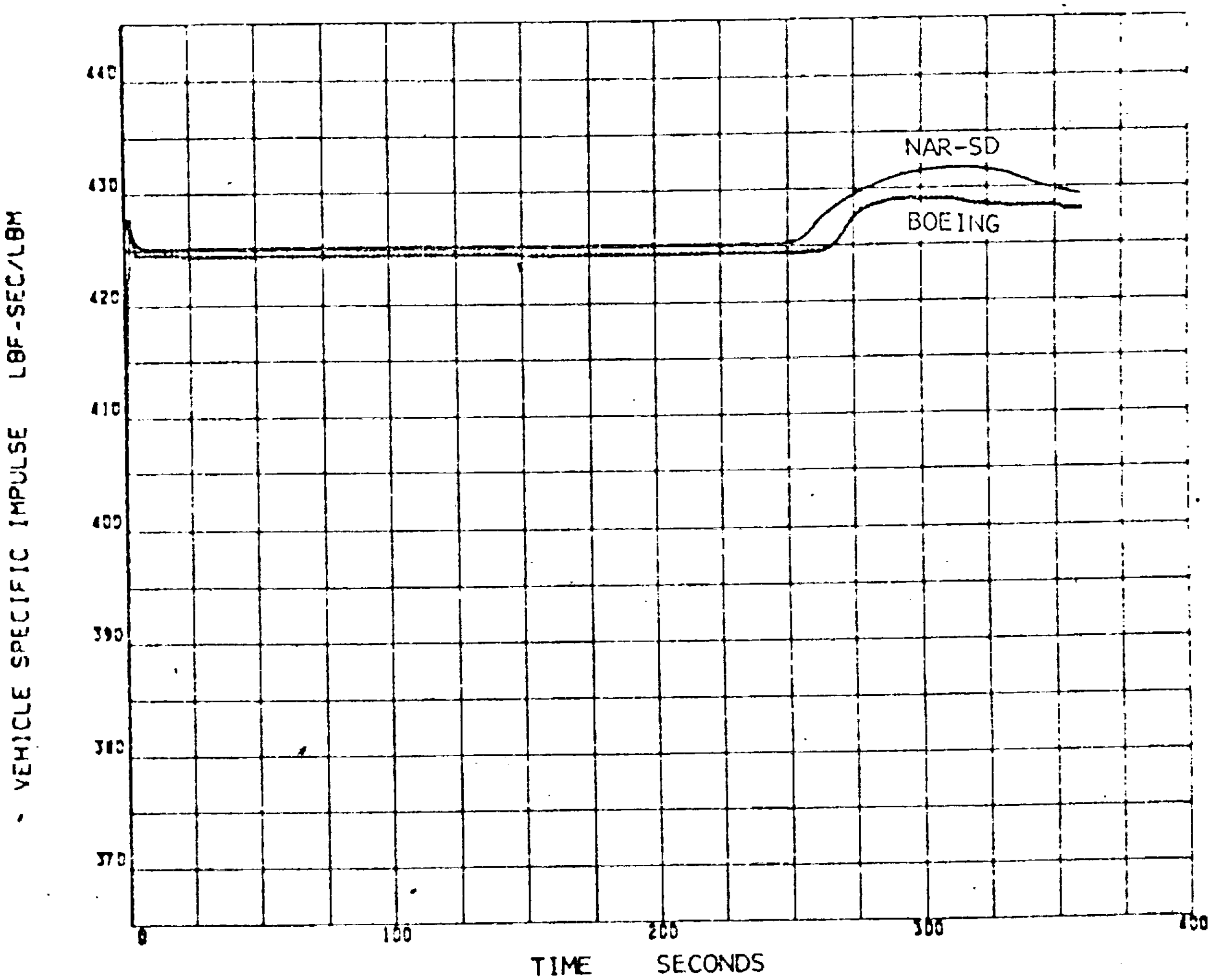


FIGURE A-2 VEHICLE SPECIFIC IMPULSE COMPARISON

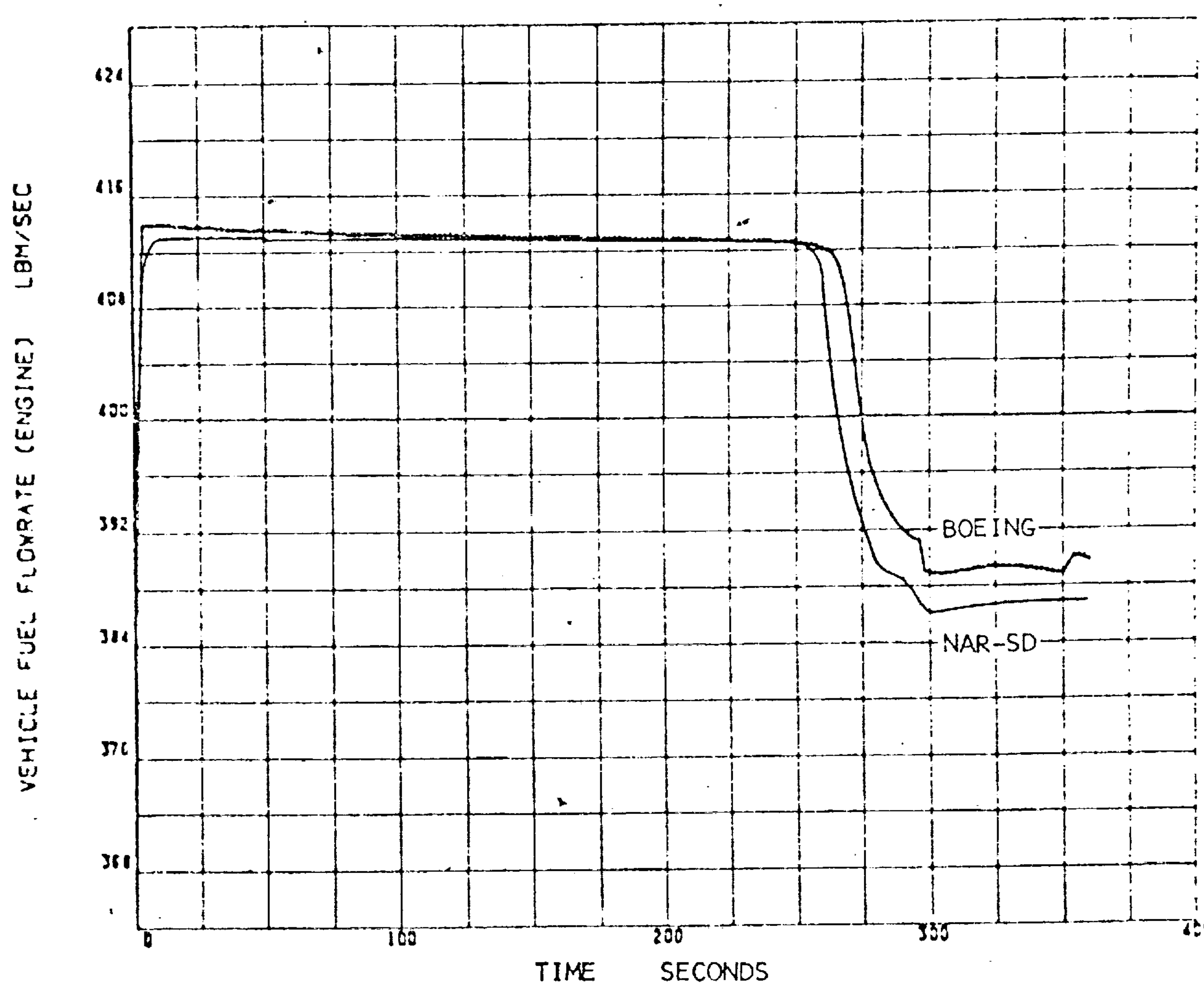
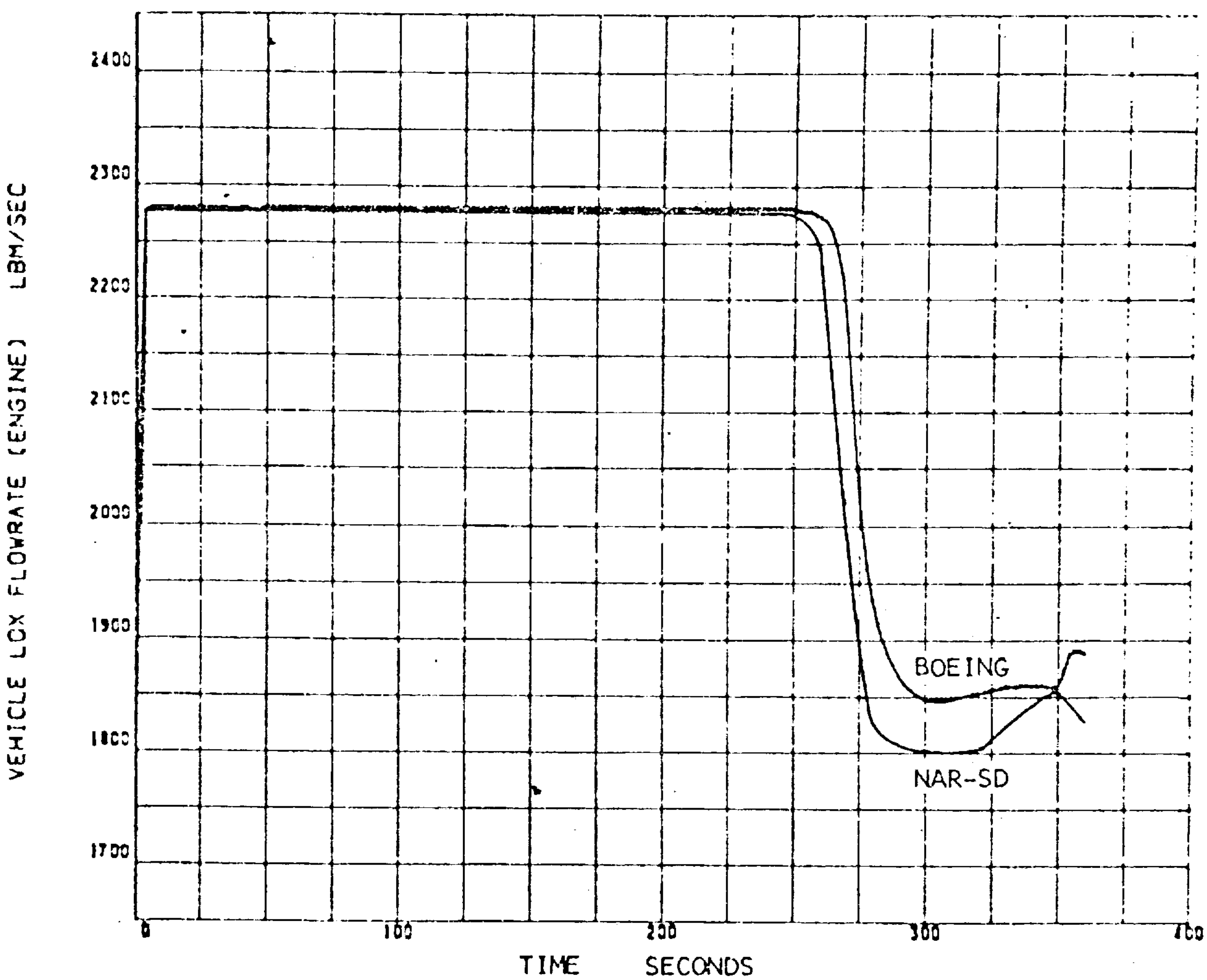


FIGURE A-3 VEHICLE FUEL FLOWRATE COMPARISON



FIGIRE A-4 VEHICLE LOX FLOWRATE COMPARISON

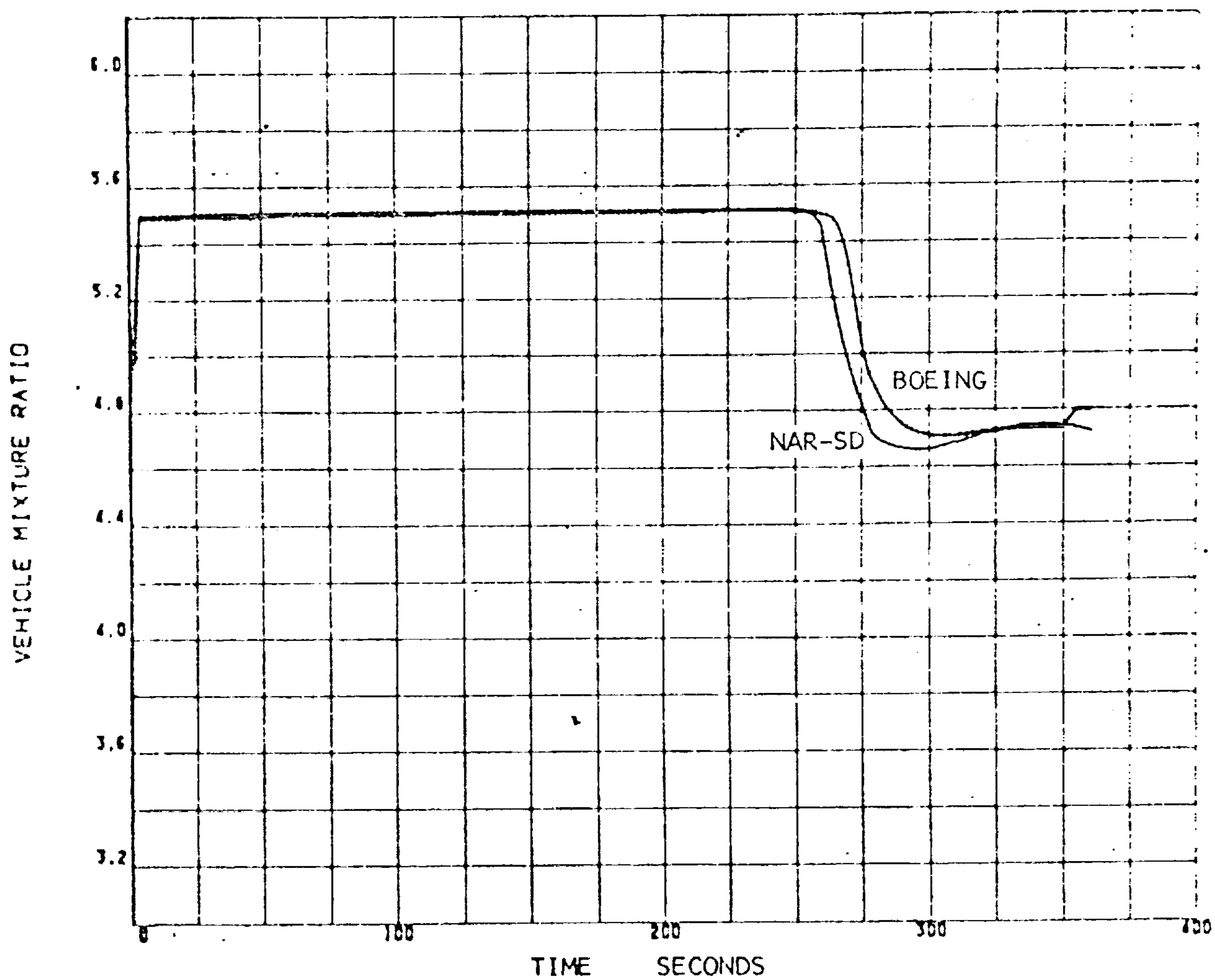


FIGURE A-5 VEHICLE MIXTURE RATIO COMPARISON