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PROJECT APOLLO

A DESCRIPTION OF A SATURN C-3 AND NOVA VEHICLE [U]

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE TASK GROUP

Langley Field, Va.

JULY 25, 1961

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PROJECT APOLLO

A DESCRIPTION OF A SATURN C-3 AND NOVA VEHICLE [U]

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1.0 INTRODUCTION

The Saturn C series was conceived and recommended by the NASA Saturn Vehicle Study Group in December 1959. This Study Group recommended the initial development of the C-1 configuration to be followed by the C-2, using a new second stage. The Saturn C-3 vehicle, as originally envisioned, would have followed the C-2 vehicle, and would have utilized the upper stages developed for C-2. More recent concepts envision the Saturn C-3 vehicle as a large step forward, bridging the gap between the Saturn class of vehicles and the ultimate Nova class, and at the same time providing a heavy weight-lifting capability at an early date so that certain spacecraft missions can be met. The C-1 and a representative C-3 configuration are illustrated in figure 1. This report will give a brief description of a C-3 along with preliminary flight characteristics. In addition, a brief description of a probable Nova vehicle including preliminary weight and performance optimization information is presented. All of the information presented in this report was provided to the NASA Space Task Group, Langley Field, Virginia by NASA Marshall Space Flight Center, Huntsville, Alabama.

2.0 A SATURN C-3 VEHICLE

2.1 Mission requirement.-

2.1.1 Three-stage escape missions.- The Saturn C-3 vehicle is designed for the three-stage escape mission. The primary purpose of the vehicle is to accomplish escape of a spacecraft of about 39,000 pounds. Figure 2 illustrates a basic three-stage C-3 configuration including a possible Apollo spacecraft configuration.

2.2 Configuration.- The configuration shown in figure 2 is based on a preliminary study of the vehicle systems and its mission requirements. Basically the configuration consists of three stages and a payload. The first stage designated as S-IB will have a propellant loading of 1.6×10^6 pounds and will use two F-1 engines. The oxidizer and fuel used will be liquid oxygen and RP-1 respectively. The adjusted thrust level generated will be about 3×10^6 pounds. The second stage, which has been designated as S-II, has a design capacity of approximately 700,000-pound propellant loading, and will utilize four J-2 engines. This stage will use liquid oxygen and liquid hydrogen as an oxidizer and fuel respectively. The adjusted thrust level for this particular stage will be about 800,000 pounds. The third and final stage (S-IV) has a design capacity of 100,000-pound propellant loading, and will utilize six RL-10A-3 engines. Liquid oxygen and liquid hydrogen will also be used as an oxidizer and fuel for this stage. The adjusted thrust generated will be about 90,000 pounds. The payload on top of the S-IV stage is a representative shape of an Apollo spacecraft. With this C-3 configuration, payloads on the order of 100,000 pounds can be placed in low orbits, or payloads on the order of 39,000 pounds can be taken to escape velocities. The information presented in this report was based on a lift-off thrust-to-weight ratio of 1.25.

2.3 Flight sequence.- A typical flight sequence would be as follows:

(a) Vehicle countdown. S-IB stage ignition followed by approximately 3-second holddown during which the S-IB stage engine operation is monitored.

(b) After vehicle release, a normal boost flight occurs.

(c) At 10 percent mainstage thrust (tail-off) of the S-IB stage engines, the separation devices are actuated and retrorockets retard S-IB, $\frac{1}{4}$g relative to the upper stages. Retrorocket burning time is adequate to prevent "runup" of the S-IB stage.

(d) After separation of the S-IB from the vehicle, the second-stage engines are ignited.

(e) Second-stage cutoff is on a depletion signal or a signal provided by the guidance system. Eight seconds prior to predicted depletion, the tilt program is arrested, which reduces the pitch rate of the trajectory to zero. At approximately 0.7 second after the S-II stage cutoff, the S-IV stage separation devices and ullage rockets are fired. Simultaneously, S-II retrorockets fire, retarding the S-II stage. 1.7 seconds later the S-IV stage has cleared the interstage and S-IV stage start signal is given. (This separation time sequence data is tentative information pending flight experience.)

(f) S-IV stage and payload separation will be determined by the mission and payload characteristics.

2.4 General design characteristics.- Figures 3 through 6 and table I illustrate the general design characteristics of each stage system including rigidity (EI values), engine operating parameters, and mass data. An inboard profile of S-II stage is shown in figure 7.

2.5 Vehicle structural loads.- The loads presented in figures 8 through 11 are preliminary. Tables I and II illustrate the parameters used in computing these loads. Figures 8 through 11 show wind shear and bending moments for 28-knot and 40-knot velocity winds including gust factors with the vehicle flight ready and laterally unsupported. Figure 12 shows the longitudinal force distribution if the stage S-IB engines are cut off during the holddown sequence (rebound). Figure 13 indicates the longitudinal force distribution at lift-off. Figures 14 through 17 show the vehicle shear and bending moment at the maximum dynamic pressure point for two conditions: (a) Transient peak; $\alpha = 7.7^\circ$ and $\beta = 3.2^\circ$, and (b) $\alpha = 0^\circ$ and $\beta = 4^\circ$. Figure 18 presents the longitudinal force distribution at this point.

Figure 19 shows the longitudinal force distribution at cutoff of stage S-IB. The holddown and rebound reactions at the holddown point are 2,491,270 pounds (holddown) and 4,608,730 pounds (rebound). The base bending moment for a 28-knot wind is 16,600,000 inch-pounds as illustrated in figure 9.

A preliminary vibration analysis of the Saturn C-3 vehicle has been made to ascertain natural bending modes and frequencies at lift-off and maximum dynamic pressure. The lift-off frequencies were 1.60 cycles per second and 3.67 cycles per second for the first and second modes, respectively. Frequencies calculated for maximum dynamic pressure condition were 1.67 cps and 4.05 cps as illustrated in figures 20 and 21. Relative angular rotation at these frequencies is shown in figure 22.

Anticipated vibration levels on the payload are given below:

Steady state levels	Transient levels
20 to 45 cps at 1.14g vector	20 to 50 cps at 2.3g vector
45 to 100 cps at 0.011 in D.A.	50 to 112 cps at 0.018 in D.A.
100 to 2,000 cps at 5.7g vector	112 to 2,000 cps at 11.4g vector

The launch condition external sound pressure level spectrum for the payload section is plotted in figure 23. The over-all sound pressure level versus vehicle station length (for launch condition) is illustrated in figure 24.

2.6 Aerodynamics.-

2.6.1 Three-stage escape trajectory.- Two typical trajectories are illustrated in tables III and IV. The 1.25g lift-off thrust-to-weight ratio is shown in table III and employs the standard vehicle off-loaded and the 1.15g trajectory is shown in table IV. Although each of these preliminary trajectories were calculated assuming slightly different hardware weights, the velocity and path-angle data are representative of expected conditions. These trajectories represent a relatively "flat" ascent to injection.

2.6.2 Stage S-IB flight dynamics.- The Saturn stage S-IB control system is designed for wind speeds of at least two-sigma level (approximately 75 m/sec) at the jet-stream level at Patrick Air Force Base, Florida. Control of the attitude loop in pitch and yaw is referenced to an attitude sensor (gyro) and an airflow direction sensor (angle-of-attack meter or an accelerometer which is sensitive perpendicular to the longitudinal axis of the vehicle). Preliminary studies of the rigid body motion in response to winds and wind shears indicate that during the high dynamic pressure region (which coincides approximately with the highest wind region), the most favorable S-IB control frequency is between 0.15 and 0.3 cycle per second. Damping characteristics will be probably somewhat below critical for the S-IB configuration. S-IB engines gimbal up to the maximum allowable of 4°, and angles of attack up to 10° have to be considered during flight in the high dynamic pressure region. NASA Marshall Space Flight Center practice requires a control natural frequency of $\frac{1}{6}$ to $\frac{1}{10}$ of the vehicle natural bending frequency.

2.6.3 Coefficients.- Curves of the variation of normal-force coefficient versus longitudinal stations as a function of Mach numbers ranging from 1.30 to 4.0 are shown in figures 25 and 26. Figure 27 presents a variation of normal force and center of pressure with Mach number. The variation of forebody drag coefficient at $\alpha = 0^{\circ}$ with Mach number is shown in figure 28. Base drag coefficients versus Mach number for both power-on and power-off cases are shown in figure 29. Figure 30 shows a variation of the total drag coefficient versus Mach number for the power-on and power-off cases.

2.7 Guidance and control.-

2.7.1 Control scheme for C-3 vehicle.- Illustrated in figure 31 is a representation of the general plan for the C-3 vehicle actuator control.

2.8 Ground support operations.-

2.8.1 Launch site.- The Saturn C-3 vehicle will be launched from the Atlantic Missile Range. The vehicle will be launched from facilities utilizing automated, digital computer systems. The launch complex presently planned for the C-3 is Launch Complex 37. Figure 32 shows a C-3 on the launch pad. An over-all planview of Launch Complex 37 is illustrated in figure 33. Figure 34 shows the relative location of major facilities within Launch Complex 37, including the operations support building. Figures 35 and 36 show the first and second floor plans of the launch control center (blockhouse).

Space is provided in the enclosed lower decks of the service structure for measuring and check-out equipment, and in the automatic ground check-out station at the base of the umbilical tower. Figure 37 illustrates the service structure, launcher, and umbilical tower. Figure 38 shows the automatic ground control station which is the concrete base of the umbilical tower.

3.0 A NOVA VEHICLE

3.1 General.- The Nova vehicle configuration is now in the very preliminary stages of planning and design. Various configurations utilizing various engines and stages are being technically evaluated in order to obtain a near-optimum vehicle that can lift heavy weights to escape velocities. One of these Nova configurations is shown in figure 39 and should be considered as a representative Nova vehicle.

3.2 Configuration.- The Nova vehicle configuration shown in figure 39 consists of three stages and a payload. The first stage, which is a single tank, utilizes eight F-1 engines to generate an adjusted thrust level of 12×10^6 pounds. The oxidizer and fuel used will be liquid oxygen and RP-1. The second stage also has eight engines but of the J-2 type, and the adjusted thrust level generated is about 1.6×10^6 pounds. This stage will use liquid oxygen and liquid hydrogen as an oxidizer and fuel. The third and final stage has two J-2 engines that develop about 400,000 pounds of adjusted thrust.

3.3 Weight and propulsion data.- Optimization curves of propellant loading for the Nova vehicle configuration for 100-nautical-mile circular orbit are shown in figure 40. Figure 41 shows the optimization curves of propellant loading for the Nova vehicle for escape mission from 100-nautical-mile minimum altitude. Figure 42 shows the effect of net structure weight and specific impulse variations on the Nova vehicle for:

(a) 100-nautical-mile circular orbit

(b) Escape mission from 100-nautical-mile altitude

4.0 TABLES

TABLE I.- ENGINE OPERATING PARAMETERS

Item	Units	1st Stage	2d Stage	3rd Stage
Engine		F-1	J-2	RL 10A-3
Manufacturer		Rocketdyne	Rocketdyne	Pratt and Whitney
Stage association		S-IB, 2 engines	S-II, 4 engines	S-IV, 6 engines
Oxidizer		Lox	Lox	Lox
Fuel		RP-1	LH_2	LH_2
Nominal mixture ratio o/f		2.25:1	5.0:1	5.0:1
Nominal flow rate	lb/sec	5,661.4	470.21	36
NPSH, oxidizer	ft	71	25	30.3
NPSH, fuel	ft	114	130	260
Throat area	in.^{2}	962.11	169.7	28.106
Expansion ratio		16:1	27.5:1	40:1
Nominal thrust	lb	1,500,000	200,000	15,000
Specific impulse (min)	sec	260	422	420
Maximum gimbal angle	deg (square pattern)	$\pm 4^\circ$	$\pm 7^\circ$	$\pm 4^\circ$
Gimbal rate	deg/sec	10	30	15
Gimbal acceleration	rad/sec^2	1	25	38
Length, gimbal axis to exit plane	in.	215.7	116	69
Engine dry weight	lb	11,590	2,028	285
Engine wet weight	lb	14,438	2,155	291

TABLE II.- LOAD PARAMETERS

	Lift-off	Max q	Cutoff
Time (sec)	0	72	132.26
Vehicle weight (lb)	2,608,730	1,778,000	1,082,714
Total thrust (lb)	3,000,000	3,348,100	3,452,600
Usable booster propellants (lb)	1,600,000	769,270	73,984
Vehicle center-of-gravity station	532	895	1,197
Longitudinal load factor (g)	1.15	1.73	3.11
Angle of attack (deg) α	0	$7.7^{\circ}/0^{\circ}$	N.A.
Gimbal angle (deg) β	0	$3.2^{\circ}/4^{\circ}$	N.A.

Dynamic equation for rebound $R_r = 0.67\ (\text{thrust}) + (\text{weight})$

Dynamic equation for holddown $R_h = 1.7\ (\text{thrust}) - (\text{weight})$

TABLE III.- PRELIMINARY ASCENT TRAJECTORY

Three-stage escape mission
Injection at 200Km - 1.25g lift-off

S-IB Stage - Isp = 260 sec (sea level)
Flight propellant consumption - 1,526,000 lb
Lift-off weight - 2,400,000 lb
Lift-off thrust/weight ratio = 1.25
Thrust = 2 × 1500K

S-II Stage - Isp = 422 sec (vacuum)
Flight propellant consumption = 556,600 lb
Lift-off weight = 751,400 lb
Thrust = 4 × 200K

S-IV Stage - Isp = 420 sec (vacuum)
Flight propellant consumption = 91,750 lb
Lift-off weight = 152,783 lb
Thrust = 6 × 15K (engines canted 6°)

Time (sec)	Path angle (deg)	Velocity (m/sec)	Altitude (Km)	Range (Km)	$\frac{F - D}{M}$ (m/sec^2)	Dynamic pressure (Kg/m^2)	Tilt angle (deg)	Weight (lb)	Angle of attack (deg)
STAGE I									
0	0	0	0	0	12.23	0	0	2,400,000	0
10.25	.0015	28.07	.138	0	12.88	48.57	.027	2,281,731	.025
20.00	1.260	61.32	.568	.004	13.59	222.3	1.386	2,169,231	.120
40.00	10.43	156.8	2.665	.217	15.594	1,180.0	10.44	1,938,462	0
60.00	25.29	304.6	6.940	1.64	17.58	2,811.0	25.30	1,707,692	0
80.00	40.33	523.7	13.67	6.12	21.24	3,356.0	40.38	1,476,923	0
100.00	52.25	865.4	22.96	16.08	26.46	2,137.0	52.40	1,246,154	0
120.00	60.70	1,351.0	34.87	34.36	33.08	783.4	61.01	1,015,384	0
132.253	64.50	1,734.0	43.48	50.99	38.57	379.0	64.96	874,000	0
STAGE II									
132.253	64.50	1,734.0	43.48	50.99	10.32	379.60	64.96	751,400	0
140.0	67.61	1,811.0	51.92	69.87	10.70	195.10	65.65	736,714	-1.25
160.0	71.45	1,932.0	62.35	97.66	11.19	50.92	67.44	698,799	-4.66
180.0	75.62	2,107.0	73.72	135.94	11.84	13.24	69.23	660,884	-7.53
200.0	79.14	2,306.0	83.30	178.45	12.57	2.96	71.03	622,970	-9.70
220.0	82.06	2,530.0	91.13	225.50	13.38	0.741	72.82	585,055	-11.27
240.0	84.46	2,779.0	97.30	277.39	14.31	.246	74.60	547,140	-12.34
260.0	86.39	3,053.0	101.90	334.58	15.38	.126	76.40	509,226	-13.00
280.0	87.92	3,355.0	105.03	397.51	16.61	.088	78.19	471,311	-13.30
300.0	89.09	3,687.0	106.82	466.69	18.07	.079	79.98	433,396	-13.30
320.0	89.94	4,053.0	107.43	542.75	19.80	.083	81.77	395,481	-13.05
340.0	90.50	4,460.0	107.06	626.40	21.90	.109	83.56	357,567	-12.57
360.0	90.79	4,915.0	105.97	718.52	24.49	.162	85.36	319,652	-11.90
380.0	90.84	5,428.0	104.46	820.15	27.79	.254	87.15	281,737	-11.07
400.0	90.63	6,018.0	102.96	932.63	32.11	.404	88.94	243,823	-10.08
420.0	90.18	6,708.0	102.02	1,057.67	38.02	.593	90.73	205,908	-8.96
425.859	90.00	6,934.0	101.96	1,097.00	40.19	.640	91.25	194,801	-8.61
STAGE III									
425.859	90.00	6,934.0	101.96	1,097.0	5.73		92.70	152,783	-7.17
430.0	90.04	6,958.0	101.95	1,125.0	5.77		93.00	151,896	-7.17
450.0	90.24	7,074.0	101.59	1,263.0	5.94		94.46	147,610	-7.14
470.0	90.38	7,195.0	100.82	1,404.0	6.11		95.92	143,324	-7.08
490.0	90.48	7,320.0	99.72	1,547.0	6.30		97.40	139,039	-6.99
510.0	90.52	7,449.0	98.43	1,692.0	6.50		98.87	134,753	-6.87
530.0	90.52	7,583.0	97.04	1,840.0	6.71		100.35	130,467	-6.72
550.0	90.47	7,720.0	95.70	1,991.0	6.94		101.84	126,181	-6.54
570.0	90.38	7,862.0	94.53	2,144.0	7.19		103.33	121,896	-6.33
590.0	90.23	8,009.0	93.53	2,340.0	7.45		105.21	117,610	-6.03
610.0	90.03	8,161.0	93.29	2,460.0	7.73		106.34	113,324	-5.83
633.0	89.75	8,342.0	93.62	2,647.0	8.08		108.08	108,396	-5.48
653.0	89.45	8,505.0	94.78	2,813.0	8.41		109.59	104,110	-5.16
673.0	89.10	8,674.0	96.94	2,982.0	8.78		111.12	99,824	-4.81
693.0	88.70	8,850.0	100.30	3,155.0	9.17		112.64	95,538	-4.43
713.0	88.24	9,032.0	105.07	3,331.0	9.60		114.18	91,253	-4.03
733.0	87.74	9,222.0	111.46	3,510.0	10.07		115.71	86,967	-3.60
753.0	87.18	9,421.0	119.71	3,693.0	10.60		117.25	82,681	-3.15
773.0	86.57	9,628.0	130.09	3,880.0	11.17		118.80	78,396	-2.67
793.0	85.90	9,846.0	142.86	4,070.0	11.82		120.34	74,110	-1.43
813.0	85.18	10,076.0	158.31	4,264.0	12.55		121.89	69,824	-1.65
833.0	84.41	10,318.0	176.78	4,462.0	13.37		123.44	65,538	-1.11
853.0	83.59	10,576.0	198.60	4,664.0	14.30		124.99	61,253	-0.55
854.02	83.54	10,590.0	200.00	4,674.0	14.35		125.07	61,033	-.52

NOTES: 1. Path angle is the angle measured between the local vertical and the velocity vector.

2. Tilt angle is the angle measured between the launch vertical and the vehicle axis.

TABLE IV.- PRELIMINARY ASCENT TRAJECTORY

Three-stage escape mission
Injection at 200Km - 1.15g lift-off

S-IB Stage - Isp = 260 sec (sea level)
Flight propellant consumption = 1,600,000 lb
Lift-off weight = 2,608,730 lb
Lift-off thrust/weight ratio = 1.15
Thrust = 2 × 1500K

S-II Stage - Isp = 422 sec (vacuum)
Flight propellant consumption = 678,100 lb
Lift-off weight = 883,730 lb
Thrust = 4 × 200K

S-IV Stage - Isp = 420 sec (vacuum)
Flight propellant consumption = 94,144 lb
Lift-off weight = 154,630 lb
Thrust = 6 × 15K (engines canted 6°)

Time (sec)	Path angle (deg)	Velocity (m/sec)	Altitude (Km)	Range (Km)	$\frac{F-D}{M}$ (m/sec^2)	Dynamic pressure (Kg/m^2)	Tilt angle (deg)	Weight (lb)	Angle of attack (deg)
STAGE I									
0	0	0	0	0	11.26	0	0	2,608,730	0
10.25	.001	17.5	.09	0	11.80	19.07	.004	2,490,461	.003
20.00	.171	39.7	.359	0	12.38	95.22	.175	2,377,961	.004
40.04	3.61	106.2	1.77	.041	13.95	592.7	3.61	2,146,788	0
60.04	13.38	211.9	4.83	.503	16.07	1,717.0	13.38	1,916,018	0
80.04	26.61	369.0	10.18	2.50	18.17	2,808.0	26.64	1,685,249	0
100.04	39.39	608.4	18.14	7.80	22.32	2,248.0	39.46	1,454,480	0
120.04	49.50	965.0	29.09	18.74	27.34	980.9	49.67	1,223,710	0
138.67	56.42	1,420.0	42.22	36.29	33.42	302.1	56.74	1,008,726	0
STAGE II									
138.667	56.42	1,419.5	42.22	36.29	8.78	302.1	56.74	883,730	0
140.0	56.83	1,424.2	43.26	37.86	8.81	263.8	56.86	881,203	-.241
160.0	62.83	1,508.0	57.94	62.98	9.27	51.6	58.70	843,288	-4.46
180.0	68.20	1,617.0	70.82	91.11	9.72	11.9	60.53	805,374	-8.40
200.0	72.88	1,749.4	81.98	122.45	10.20	2.2	62.36	767,459	-11.60
220.0	76.89	1,903.7	91.44	157.21	10.73	0.4	64.19	729,544	-14.11
240.0	80.27	2,079.0	99.26	195.64	11.32	.1	66.02	691,630	-16.01
260.0	83.08	2,274.6	105.51	238.01	11.98	.0	67.85	653,715	-17.37
280.0	85.39	2,490.5	110.25	284.60	12.71	.0	69.68	615,800	-18.26
300.0	87.25	2,727.3	113.55	335.73	13.55	.0	71.51	577,885	-18.76
320.0	88.73	2,986.0	115.52	391.78	14.50	.0	73.35	539,971	-18.91
340.0	89.86	3,268.3	116.25	453.16	15.59	.0	75.18	502,056	-18.76
360.0	90.70	3,576.7	115.87	520.34	16.87	.0	77.01	464,141	-18.37
380.0	91.27	3,914.6	114.55	593.86	18.37	.0	78.84	426,227	-17.77
400.0	91.58	4,286.5	112.49	674.34	20.16	.0	80.67	388,312	-16.98
420.0	91.67	4,698.8	109.91	762.55	22.34	.1	82.50	350,397	-16.03
440.0	91.54	5,160.0	107.12	859.36	25.06	.1	84.33	312,483	-14.93
460.0	91.19	5,682.2	104.51	965.86	28.52	.3	86.16	274,568	-13.71
480.0	90.63	6,283.1	102.59	1,083.40	33.08	.5	87.99	236,653	-12.38
496.365	90.00	6,852.1	101.99	1,189.11	38.08	.6	89.49	205,630	-11.20
STAGE III									
496.365	90.00	6,852.1	101.99	1,189.11	5.66		91.78	154,630	-8.91
506.0	90.11	6,906.6	101.92	1,254.35	5.74		92.52	152,565	-8.87
516.0	90.20	6,964.2	101.73	1,322.61	5.82		93.28	150,422	-8.81
536.0	90.36	7,082.2	101.03	1,460.86	5.99		94.82	146,137	-8.68
556.0	90.48	7,204.2	99.97	1,601.50	6.18		96.37	141,851	-8.51
576.0	90.55	7,330.2	98.66	1,744.60	6.37		97.92	137,565	-8.31
596.0	90.57	7,460.5	97.22	1,890.25	6.57		99.49	133,280	-8.08
616.0	90.54	7,595.0	95.75	2,038.54	6.79		101.06	128,994	-7.82
636.0	90.47	7,733.9	94.40	2,189.56	7.02		102.64	124,708	-7.53
656.0	90.35	7,877.3	93.27	2,343.40	7.27		104.24	120,422	-7.20
676.0	90.18	8,025.6	92.53	2,500.13	7.54		105.82	116,137	-6.85
698.0	89.94	8,194.5	92.32	2,675.99	7.86		107.59	111,422	-6.43
718.0	89.67	8,353.7	92.87	2,839.10	8.18		109.20	107,137	-6.01
738.0	89.36	8,518.5	94.28	3,005.36	8.52		110.82	102,851	-5.57
758.0	88.99	8,689.4	96.74	3,174.87	8.89		112.45	98,565	-5.10
778.0	88.58	8,866.9	100.45	3,347.71	9.29		114.09	94,280	-4.61
789.0	88.12	9,051.5	105.60	3,523.96	9.73		115.73	89,994	-4.09
818.0	87.60	9,244.0	112.42	3,703.70	10.22		117.38	85,708	-3.54
838.0	87.04	9,445.0	121.13	3,887.02	10.76		119.03	81,423	-2.97
858.0	86.43	9,655.6	132.00	4,073.99	11.36		120.69	77,137	-2.38
878.0	85.76	9,876.9	145.29	4,264.69	12.02		122.35	72,851	-1.77
898.0	85.05	10,110.3	161.29	4,459.23	12.78		124.02	68,565	-1.14
918.0	84.28	10,357.4	180.31	4,657.68	13.63		125.69	64,280	-0.49
935.704	83.55	10,589.3	199.96	4,836.70	14.48		127.16	60,486	+.10

NOTES: 1. Path angle is the angle measured between the local vertical and the velocity vector.

2. Tilt angle is the angle measured between the launch vertical and the vehicle axis.

[redacted]

TABLE V.- SINGLE TANK NOVA, OPTIMIZED LOADINGS WITH PAYLOAD FOR ESCAPE MISSION THROUGH MINIMUM 100 N.M. ALTITUDE WEIGHT AND PROPULSION DATA, CONFIGURATION

STAGE	I	II	III	IV
Engine	8(F-1)	8(J-2)	2(J-2)	
Propellant	LOX/RP-1	LOX/LH-	LOX/LH	
Thrust (lb)	8 × 1,500,000	8 × 200,000	2 × 200,000	
Adjusted thrust (lb)	12,000,000	1,600,000	400,000	
I_{sp}(sec)	260 (sl) 299 (vac)	422	422	
Flow rate (lb/sec)	46,154	3,792	94,787	
Exit area $(in.)^2$	123,136			
Missile diameter (in.)	520	396	260	
$W_{11,15,}$ Payload, lb			180,500	
$W_{16,}$ Guid. compartment, lb			500	
$W_{2,}$ Guid. and control, lb	1,000	500	2,000	
$W_{3,}$ Fuselage, lb	170,300	48,730	15,450	
$W_{4,}$ Propulsion, lb	156,550	22,210	4,900	
$W_{5,}$ Recovery equip., lb	40,000	8,000	0	
$W_{6,}$ Trapped prop., lb	65,200	11,390	3,420	
$W_{7,}$ Usable residuals, lb	35,150	6,670	119,530 FPR 2,200 MRS	
$W_{8,}$ Prop. consumption, lb	7,030,000	1,333,000	442,800	
$W_{s,16,}$ Structure wt, lb	367,850	79,440	22,850	
$W_{n,16,}$ Struc. net wt, lb	468,200	97,500	48,000	
$W_{a,16,}$ Stage wt, lb	7,498,200	1,430,500	490,800	
$W_{o,}$ Lift-off wt, lb	9,600,000	2,101,800	671,300	
$W_{o,}$ Cutoff wt, lb	2,570,000	768,800	228,500	
r, Mass ratio	3,735	2,734	2,938	
Δu, Charac. vel. (m/sec)	3,692	4,156	4,454	
F_o/W_o	1.25	0.761	0.596	
F_{vac}/W_c				

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5.0 FIGURES

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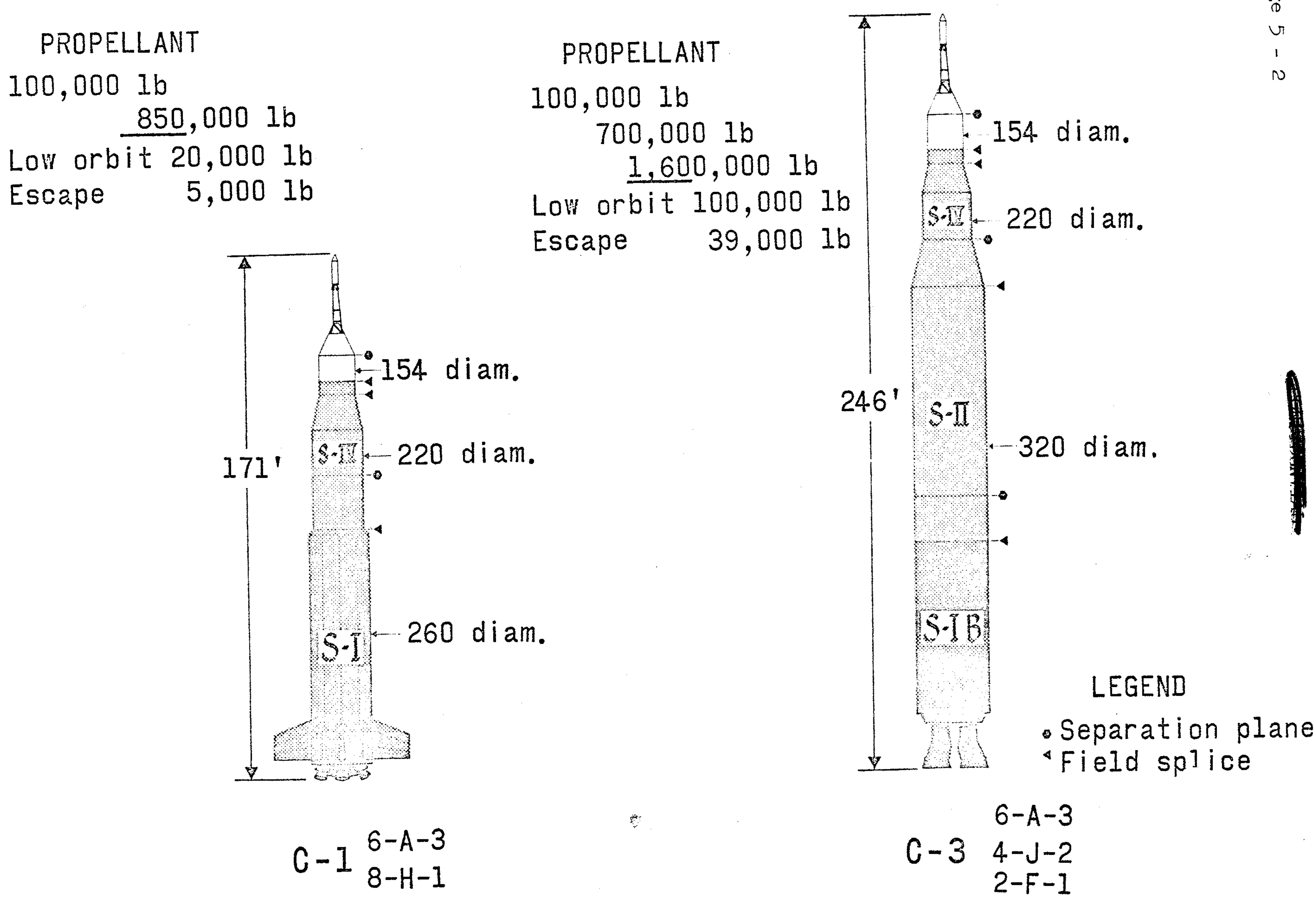

Figure 1.- Saturn C-1 and C-3 vehicles.

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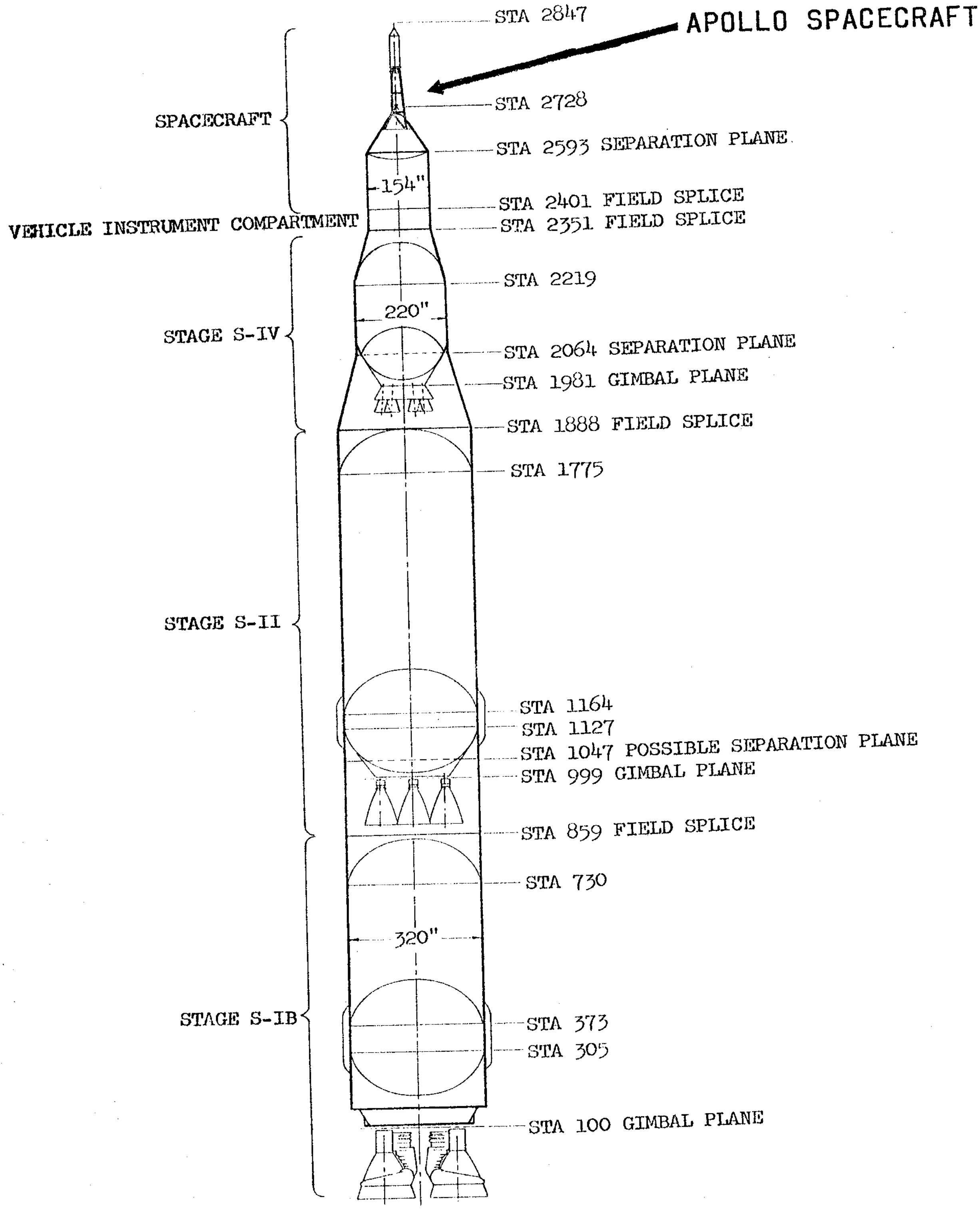

Figure 2.- Saturn C-3 vehicle.

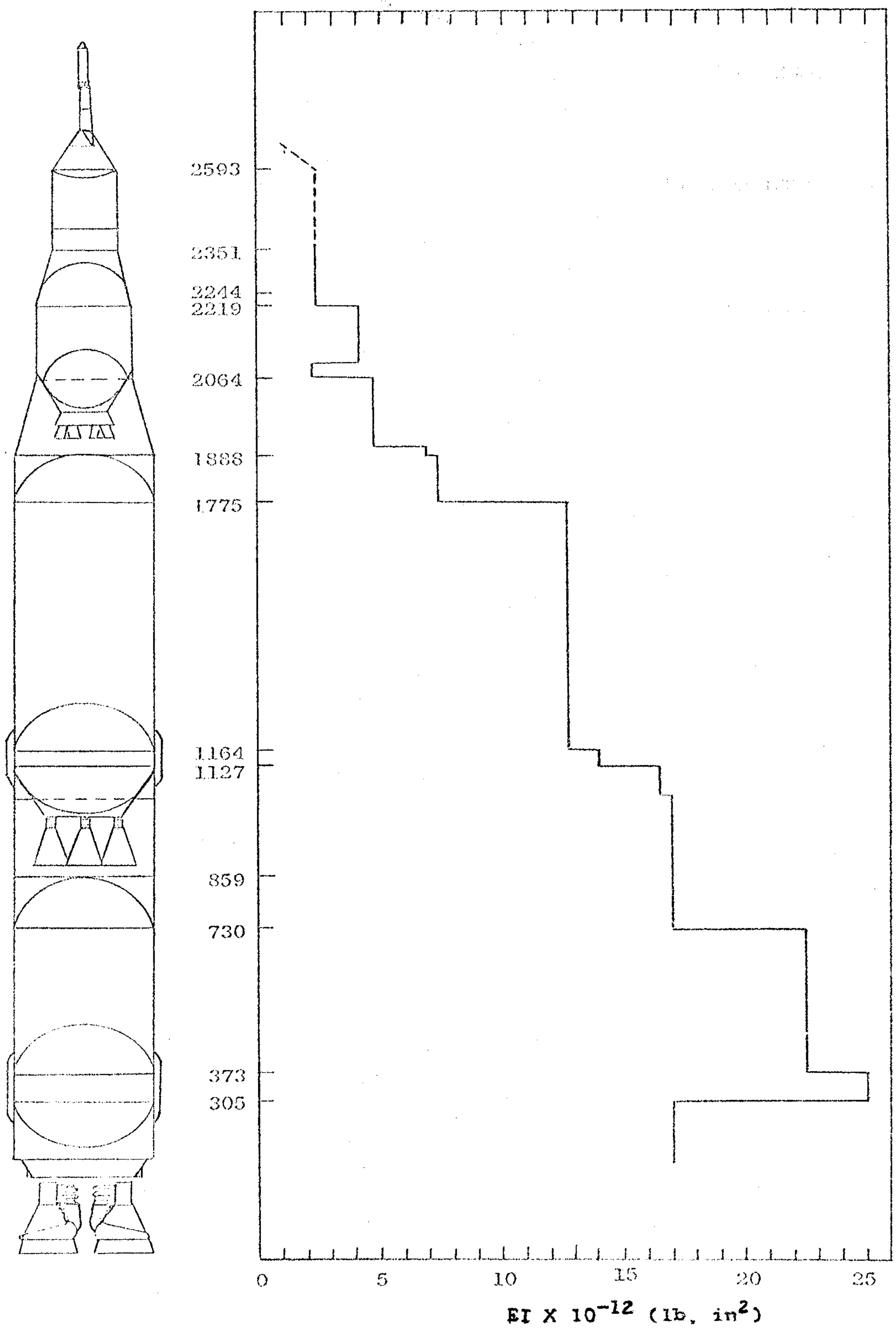

Figure 3.- EI versus longitudinal station for complete C-3 vehicle

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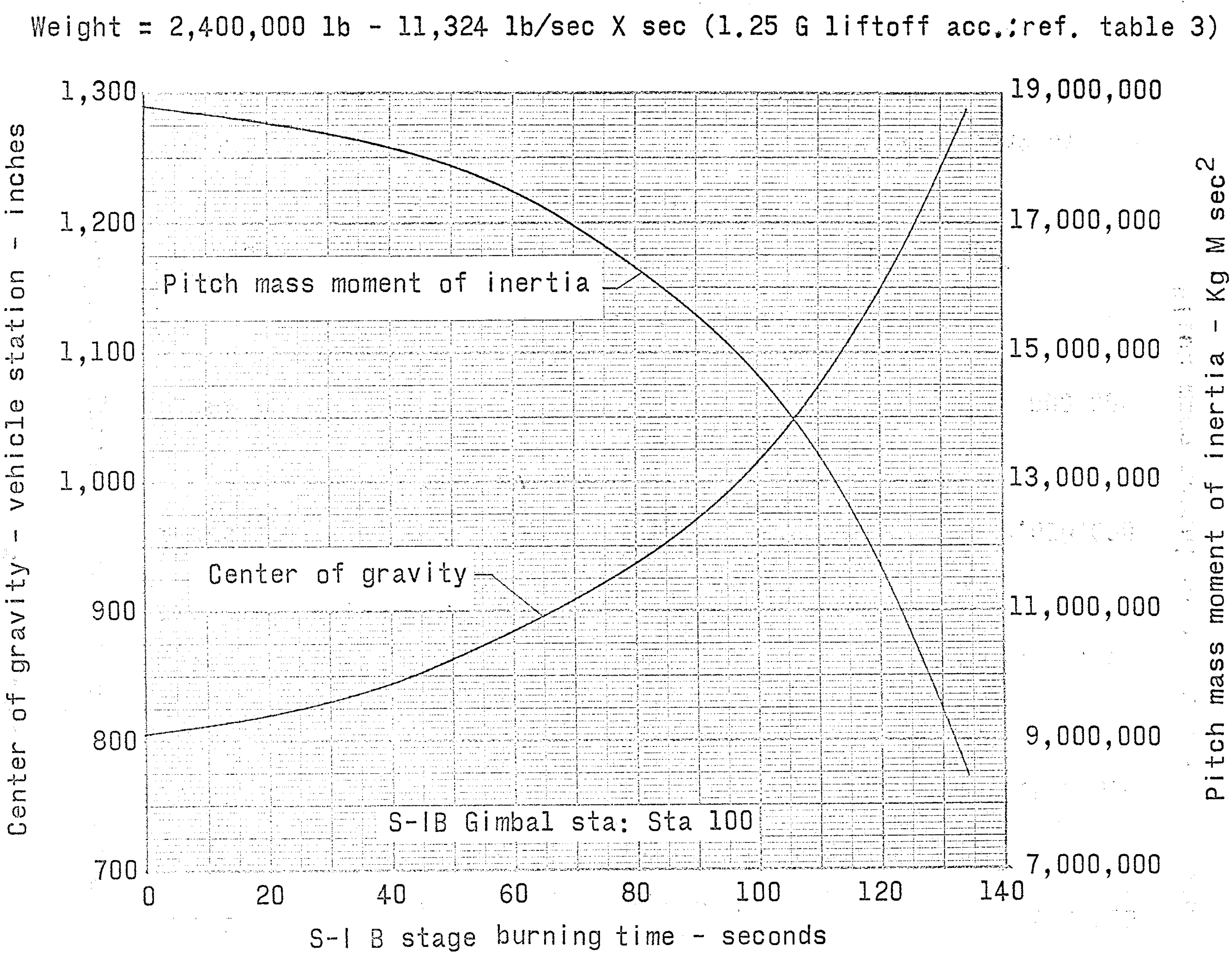

Figure 4.- Center-of-gravity shift and pitch-mass moment of inertia versus burning time. First stage.

[redacted]

Weight = 747,270 lb - 1880.84 lb/sec Xsec (1.25 G vehicle liftoff acc.:ref. Table 3)

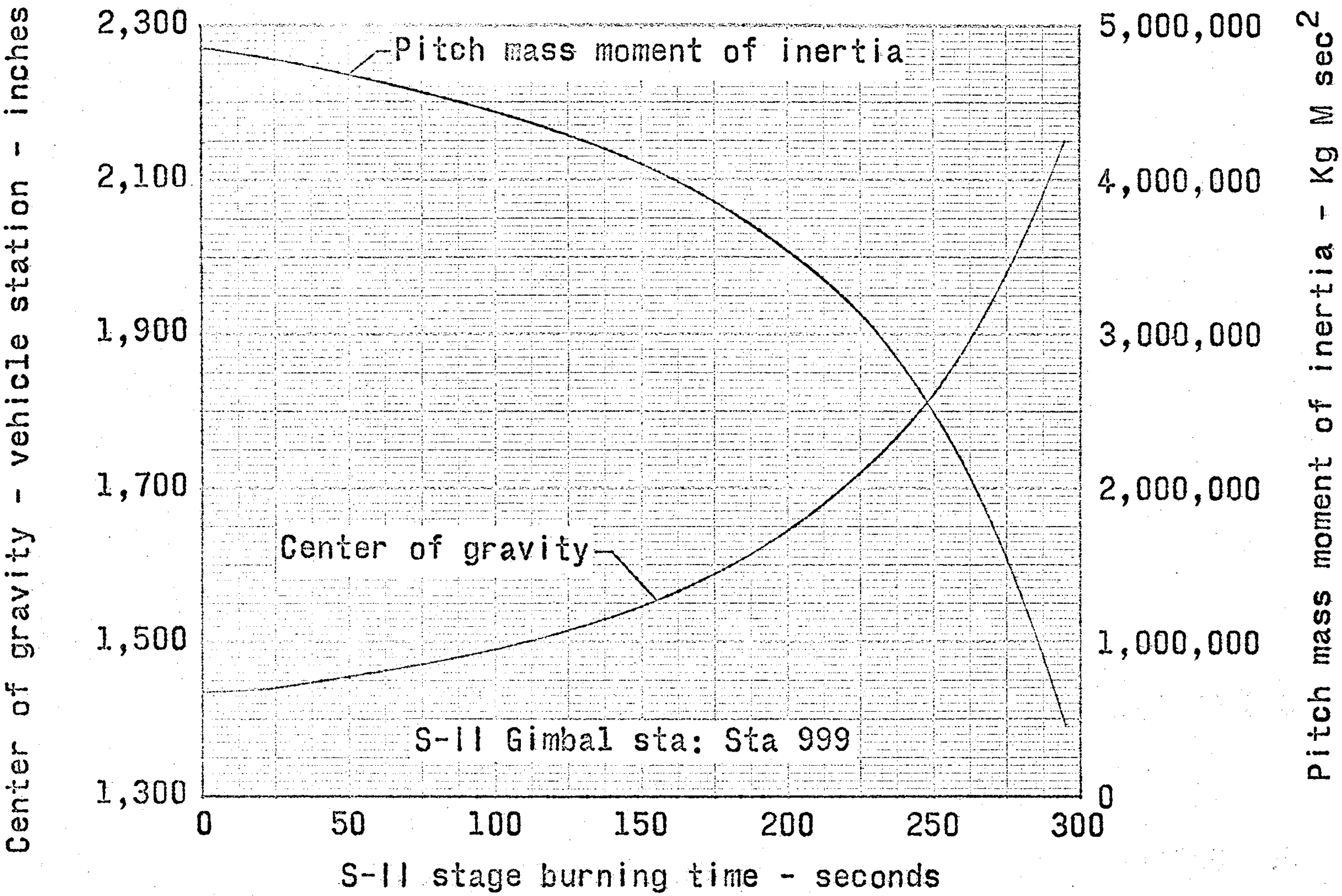

Figure 5.- Center—of—gravity shift and pitch—mass moment of inertia versus burning time. Second stage.

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Weight = 152,783 lb - 216 lb/sec (1.25 G vehicle liftoff acc.:ref. table 3)

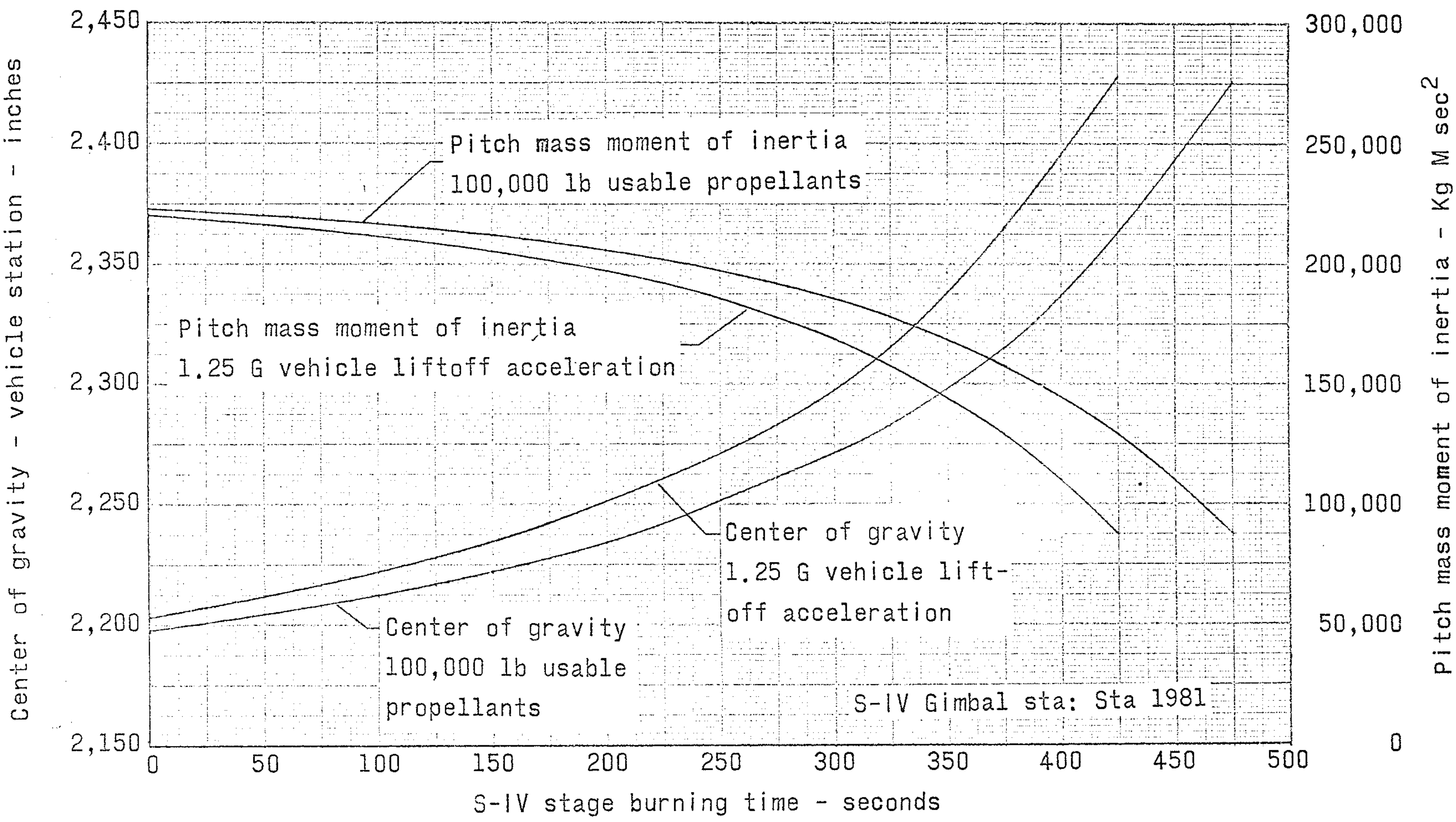

Figure 6.- Center-of-gravity shift and pitch-mass moment of inertia versus burning time.

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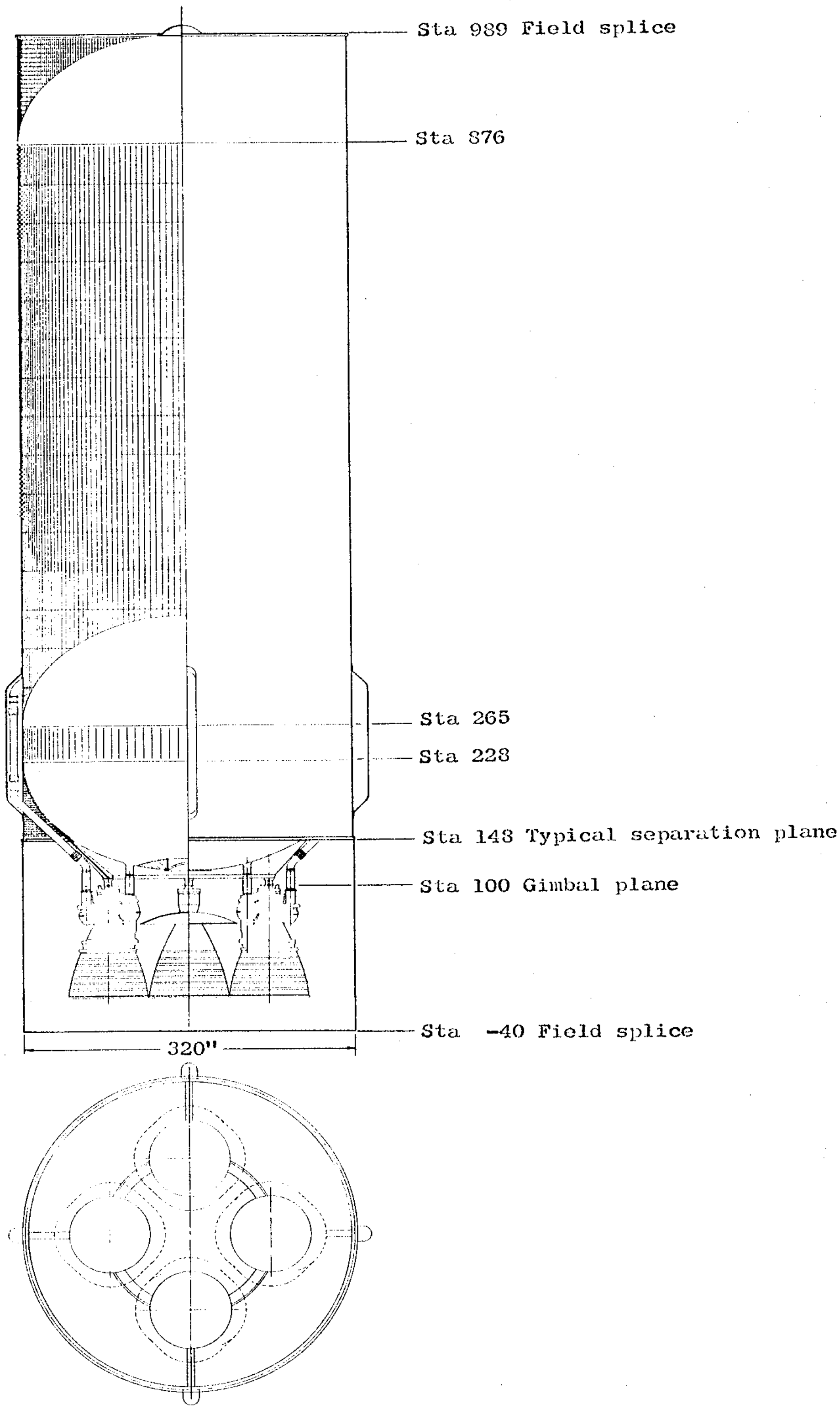

Figure 7.- S-II stage inboard profile.

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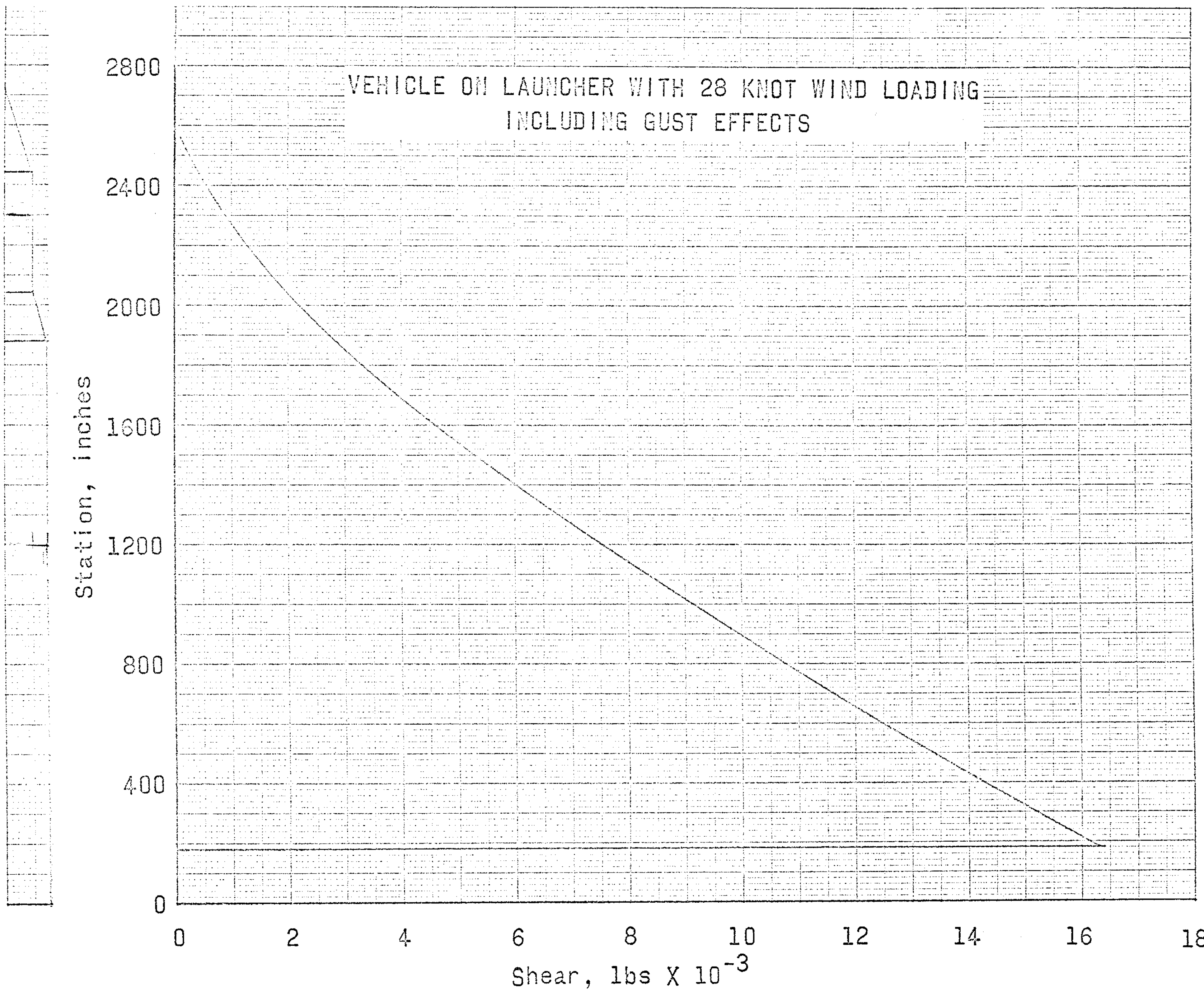

[redacted]

Figure 8.- Wind shear versus longitudinal station. Launch condition.

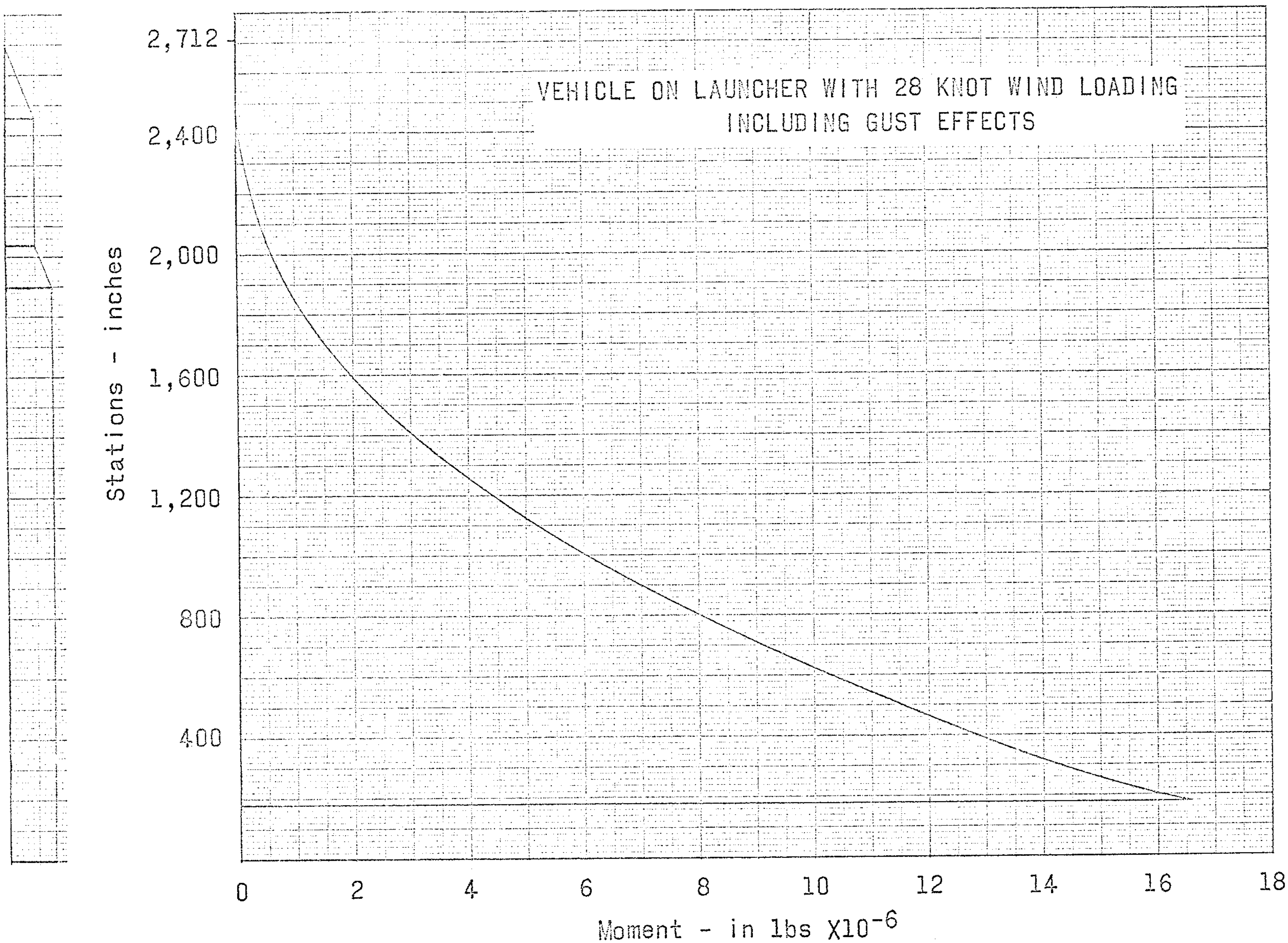

Figure 9.- Bending moment versus longitudinal station. Launch condition.

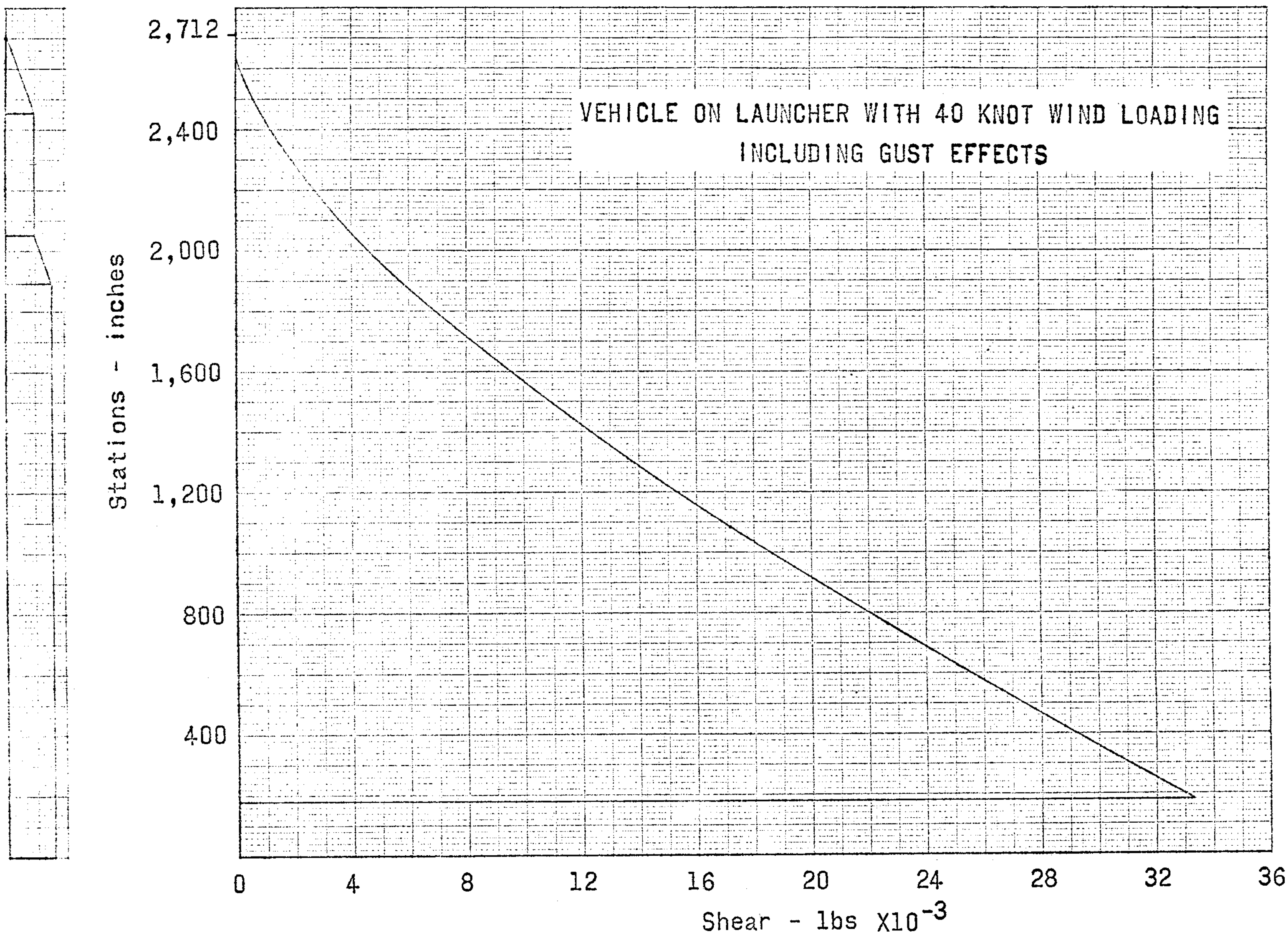

Figure 10.- Wind shear versus longitudinal station. Launch condition.

[redacted]

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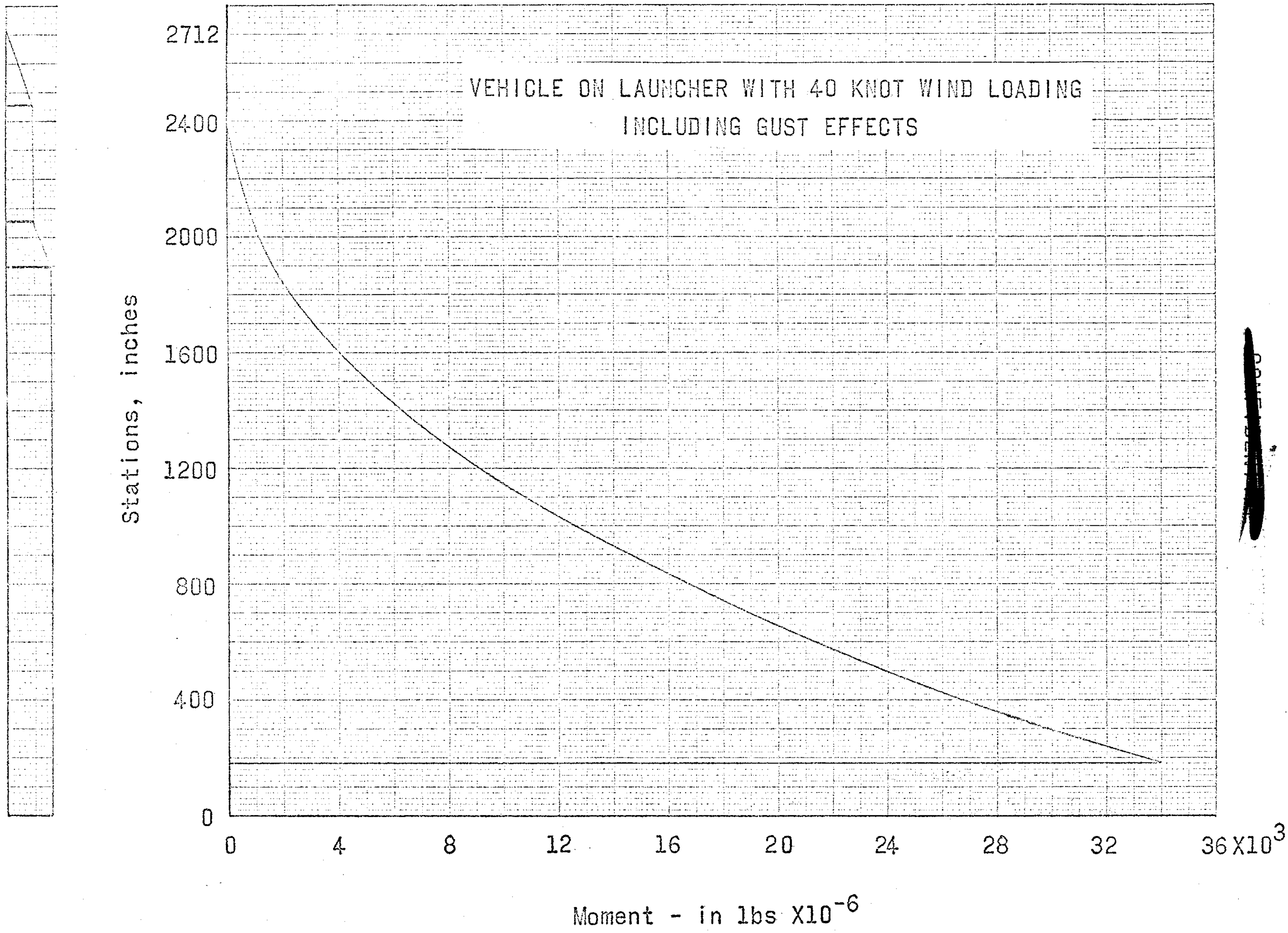

Figure 11.- Bending moment versus longitudinal station. Launch condition.

[redacted]

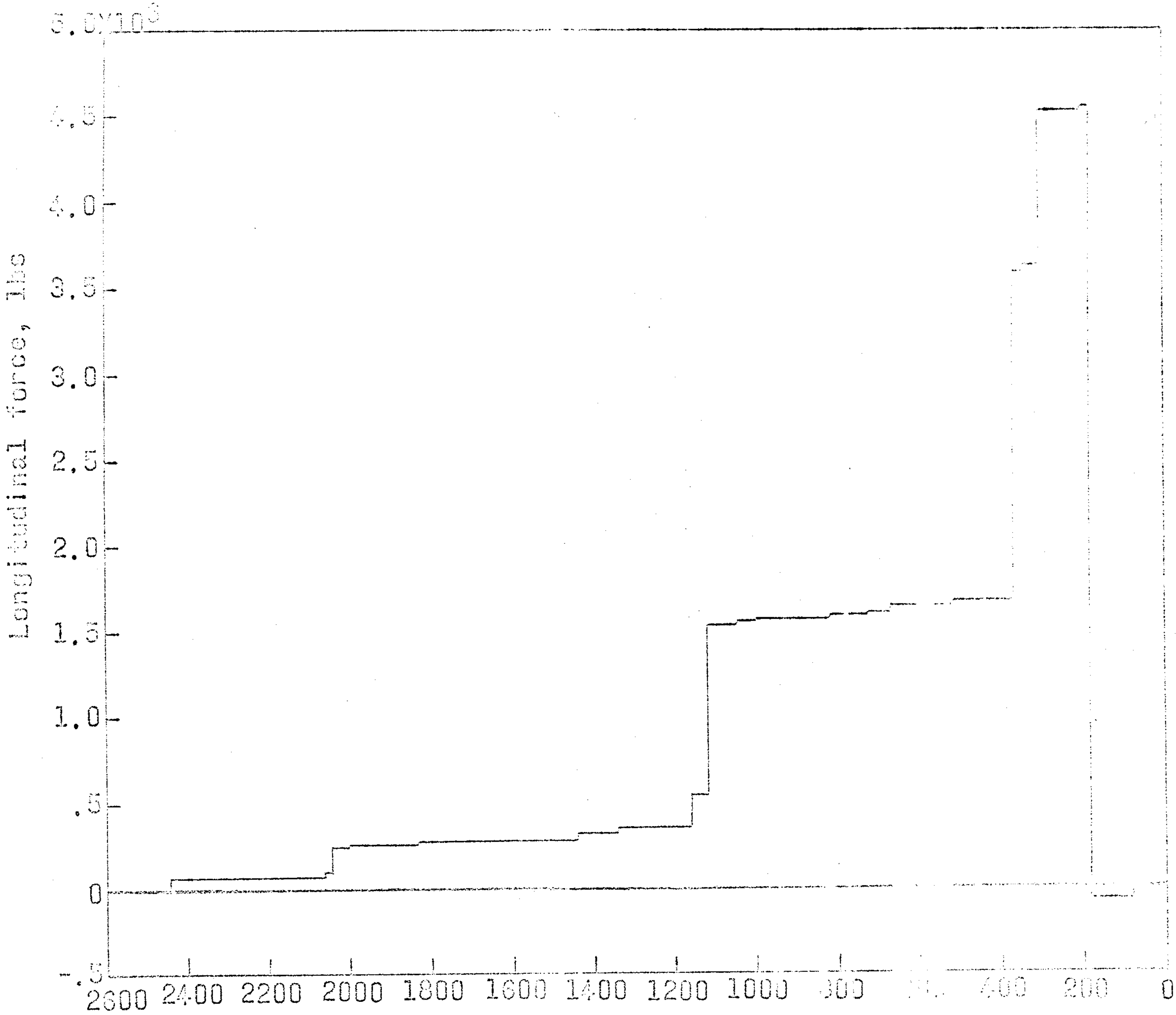

Figure 12.- Longitudinal force distribution versus longitudinal station. Rebound condition.

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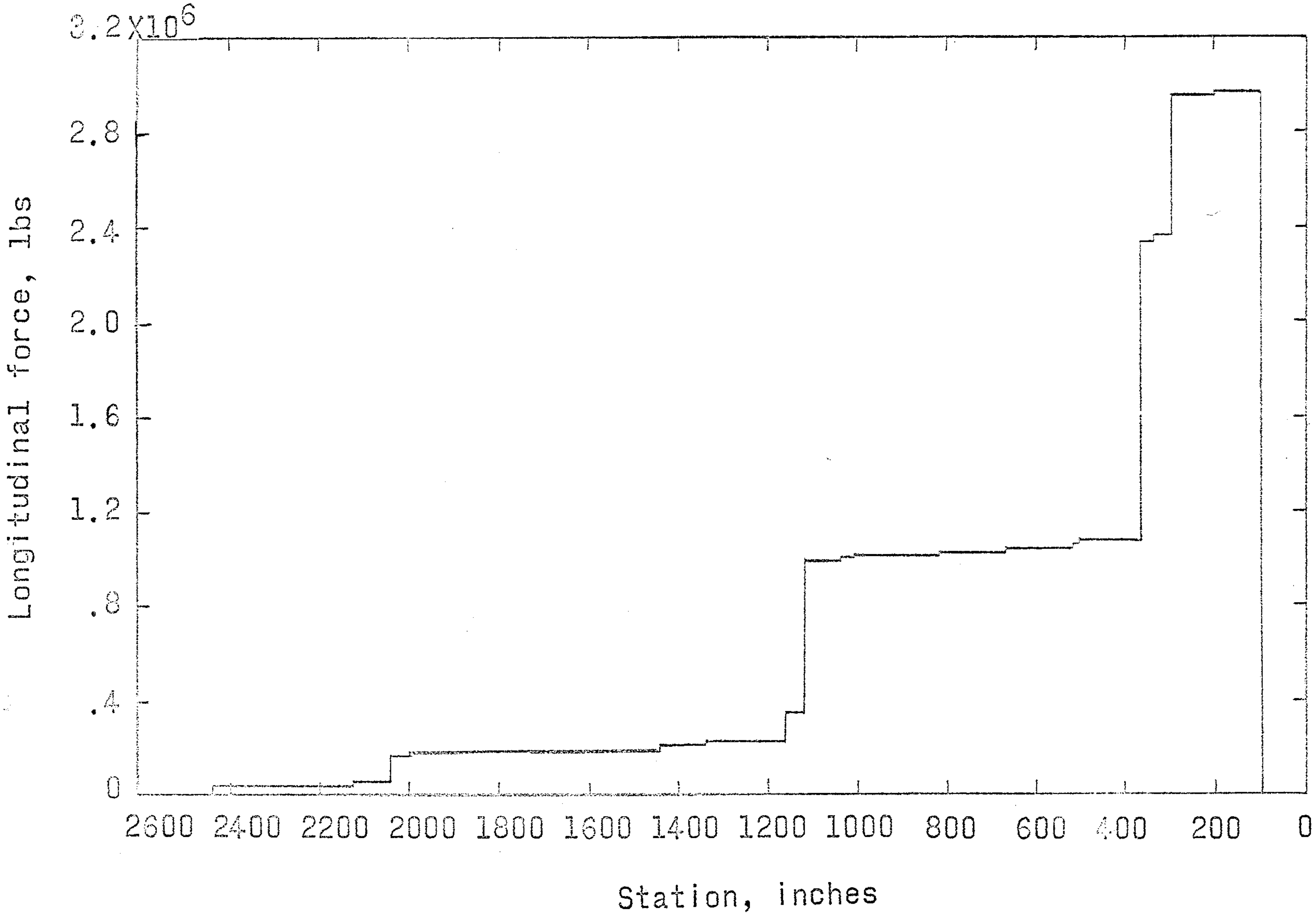

Figure 13.- Longitudinal force distribution versus longitudinal station. t = lift-off.

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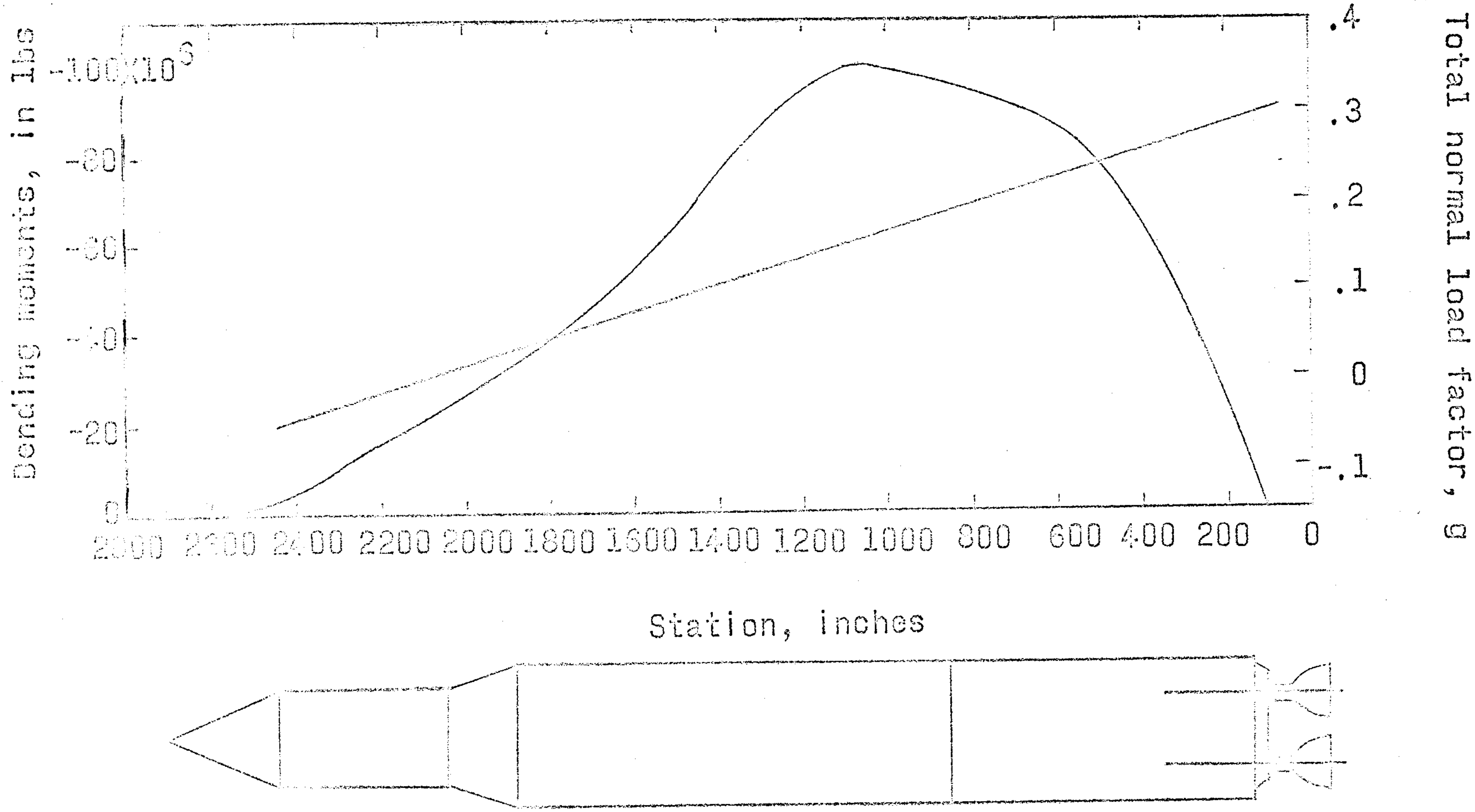

Figure 14.- Bending moment versus longitudinal station at maximum dynamic pressure. $\alpha = 7.7^0$, $\beta = 3.2^0$, $t = 72$ sec.

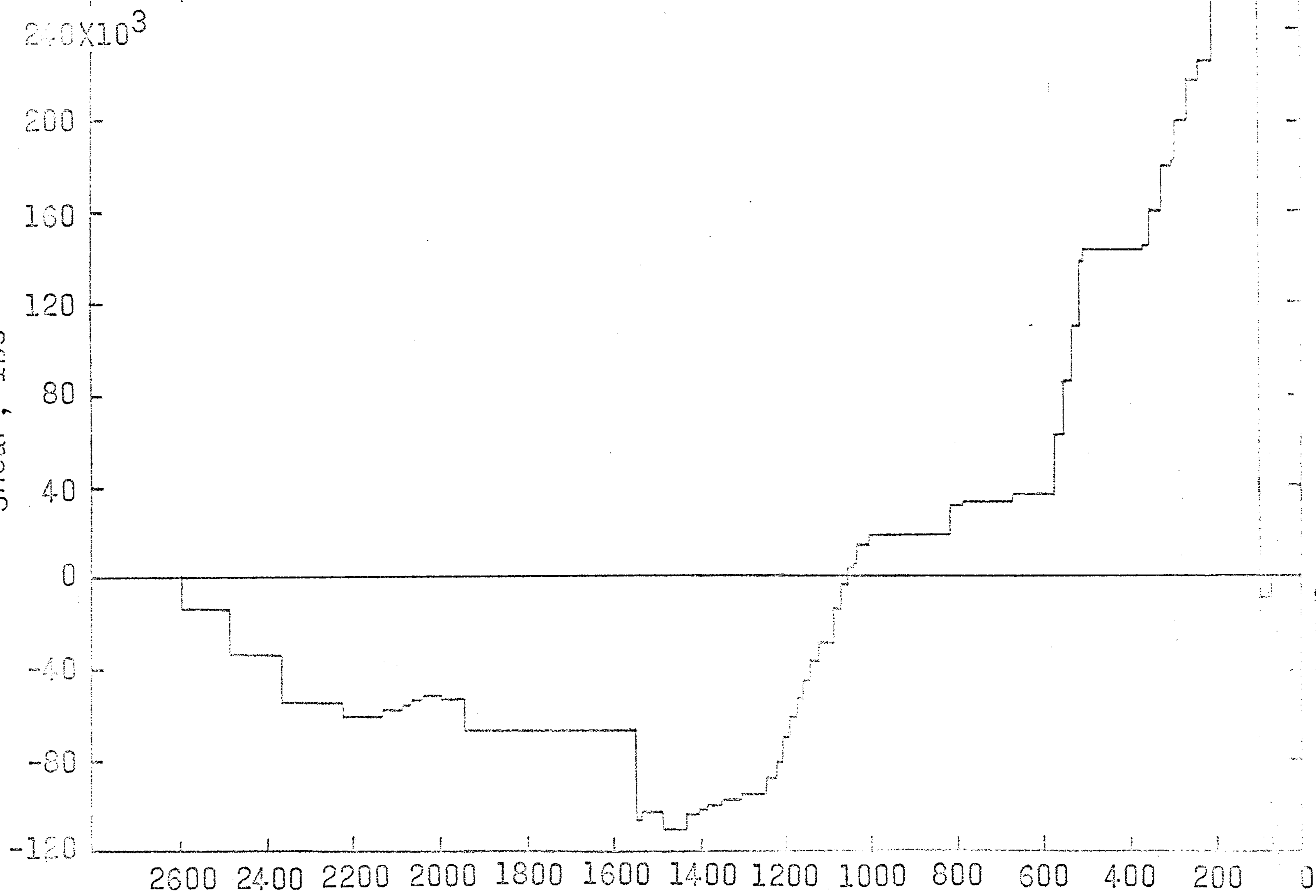

Figure 15.- Shear versus longitudinal station for the condition of maximum dynamic pressure. $\alpha = 7.7^{\circ}$, $\beta = 3.2^{\circ}$, $t = 72$ sec.

[redacted]

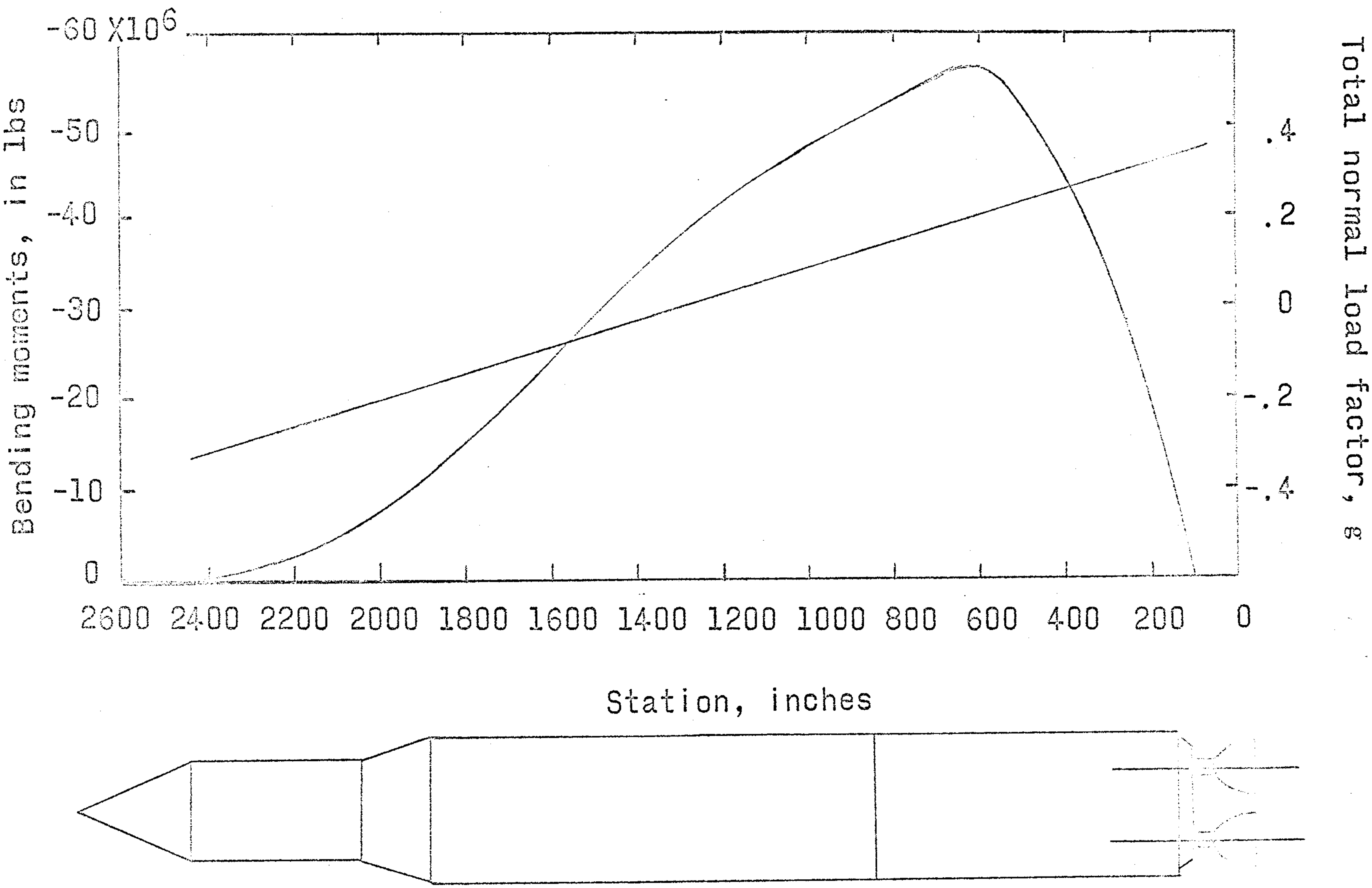

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Figure 16.- Bending moment versus longitudinal station for the condition of maximum dynamic pressure. $\alpha = 0^{o}$, $\beta = 4^{o}$, $t = 72$ sec.

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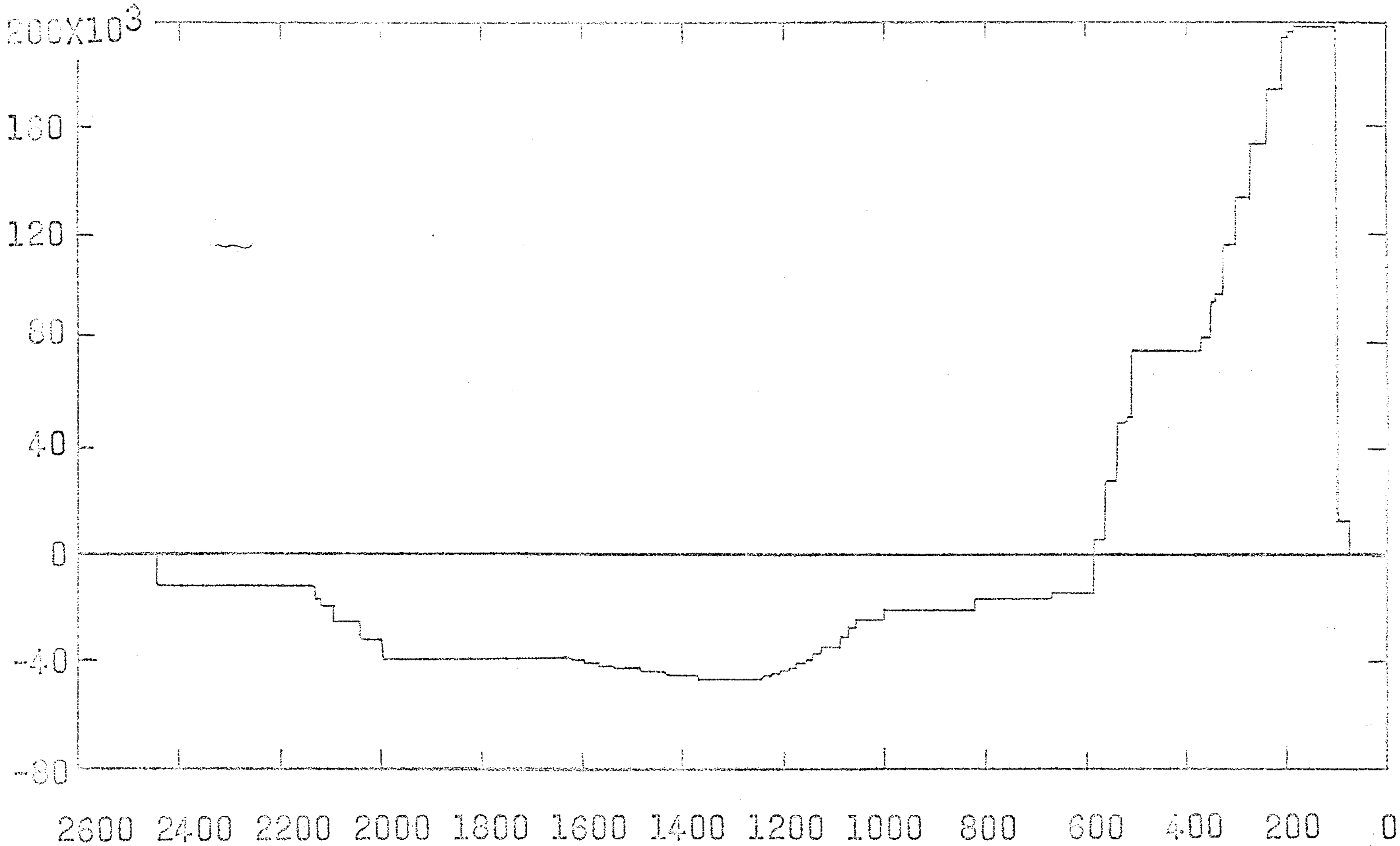

Figure 17.- Shear versus longitudinal station for the condition of maximum dynamic pressure. $\alpha = 0^{\circ}$, $\beta = 4^{\circ}$, $t = 72$ sec.

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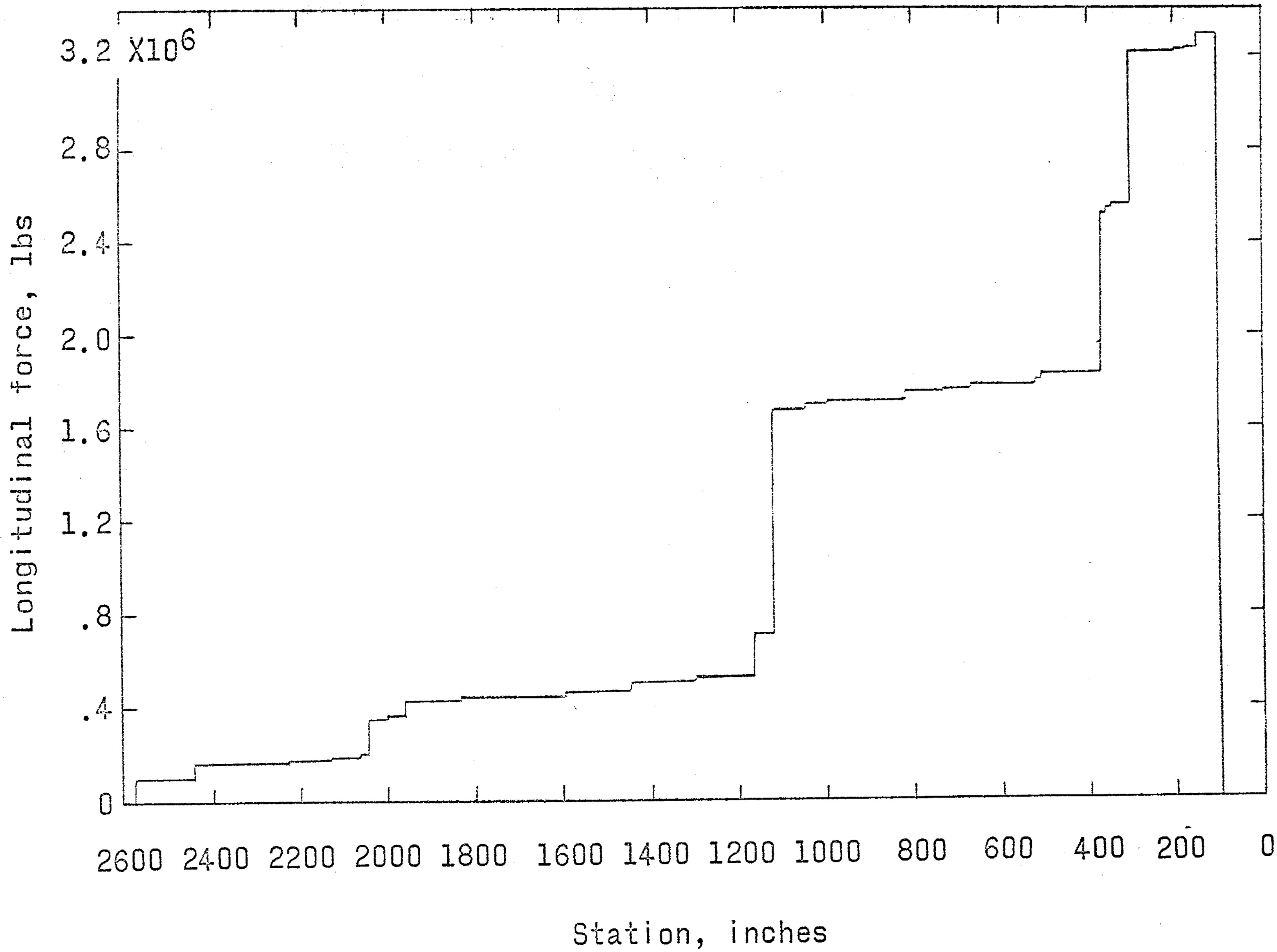

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Figure 18.- Longitudinal force distribution versus longitudinal station for the condition of maximum dynamic pressure.

$t = 72$ sec.

[redacted]

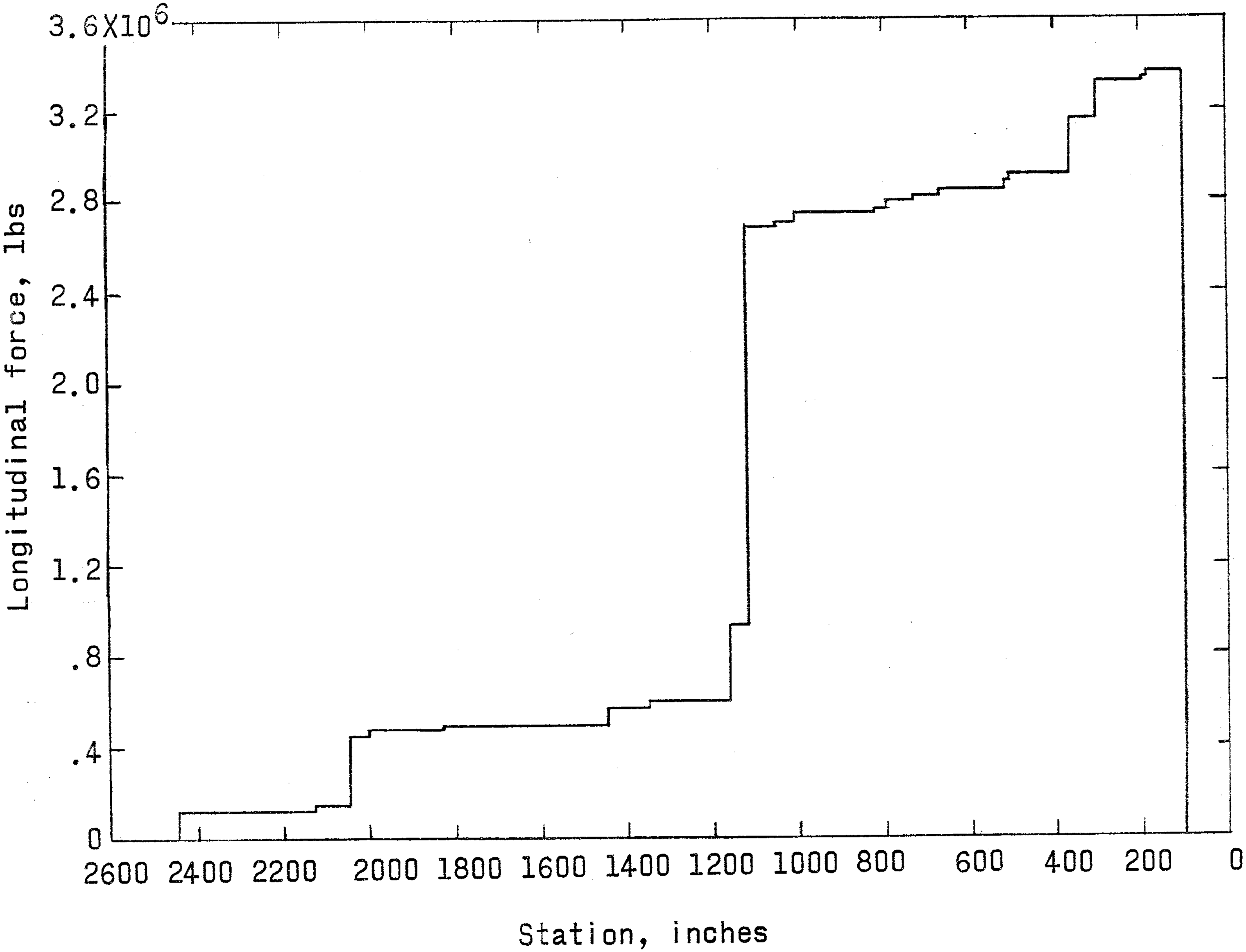

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Figure 19.- Longitudinal force distribution versus longitudinal station. t = cut-off.

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FIRST FREE-FREE BENDING MODES AT LIFT-OFF & MAX q

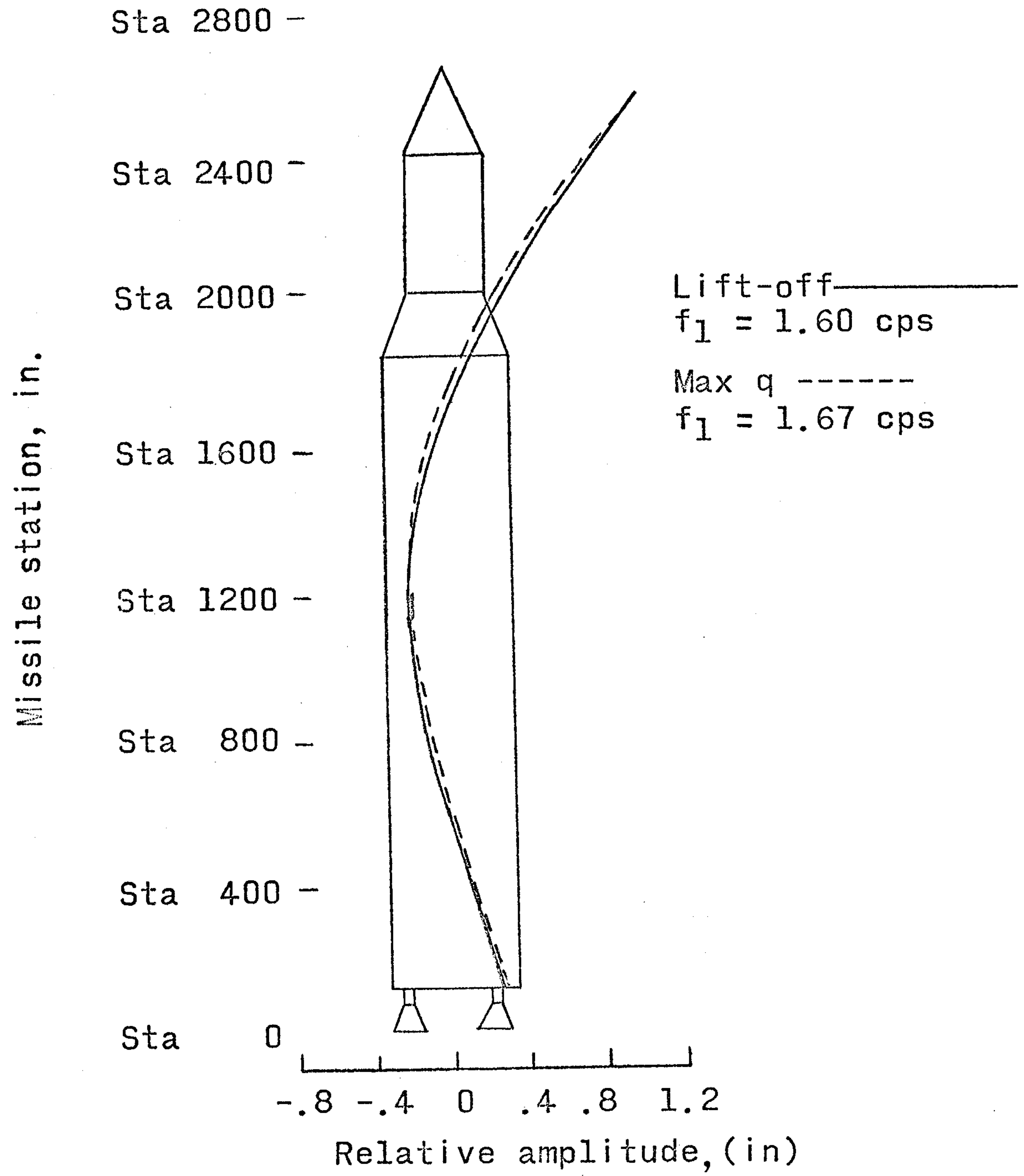

Figure 20.- First free-free bending modes at lift-off and maximum dynamic pressure.

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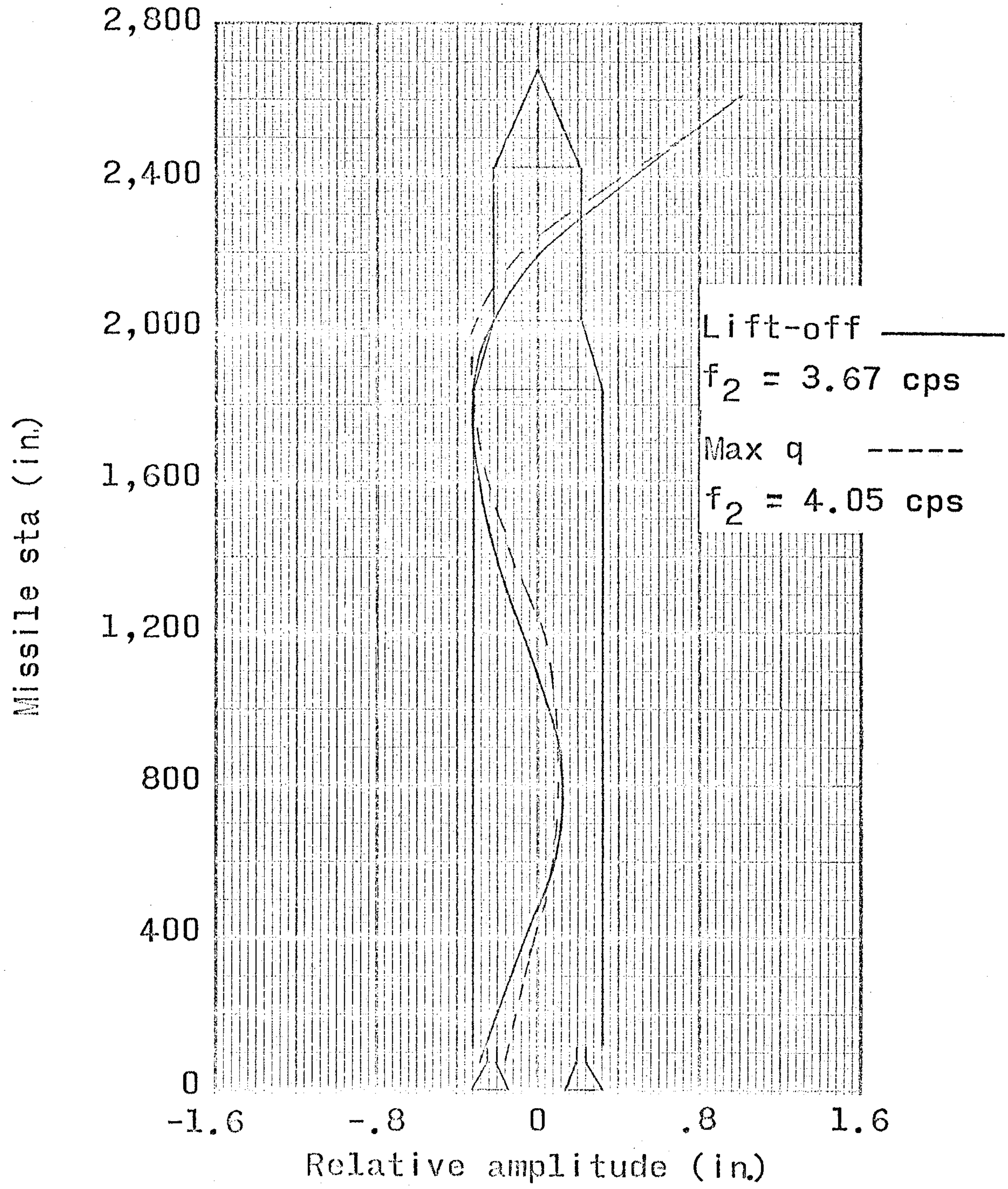

Figure 21.- Second free-free bending modes at lift-off and maximum dynamic pressure.

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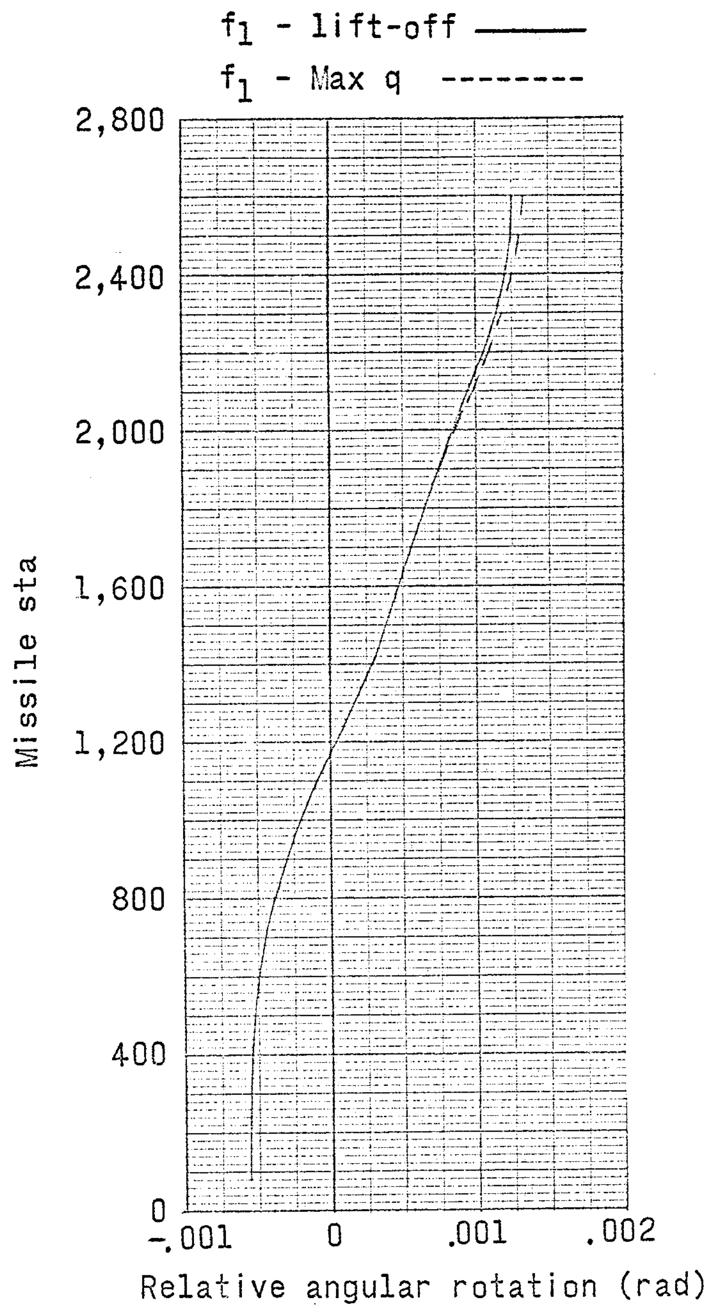

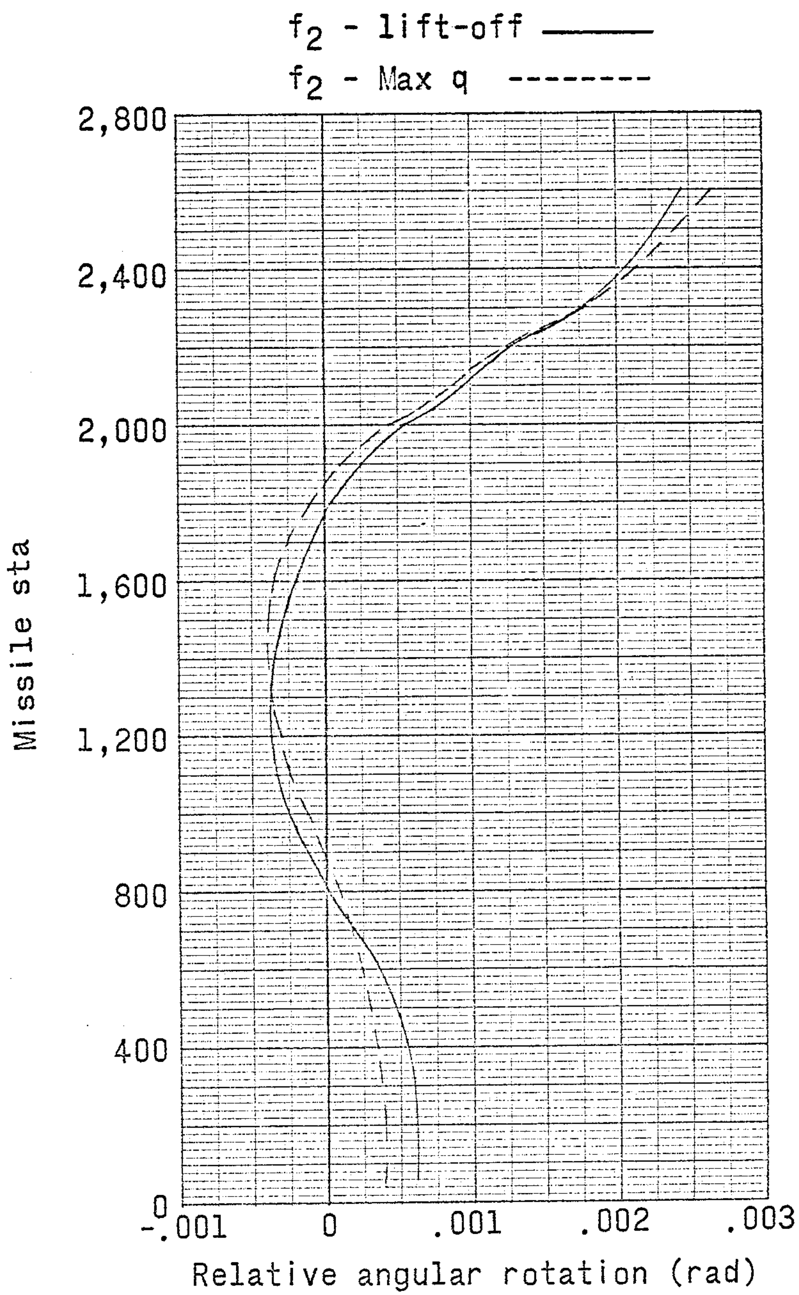

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Figure 22.- Relative angular rotation versus longitudinal station for lift-off and maximum dynamic pressure.

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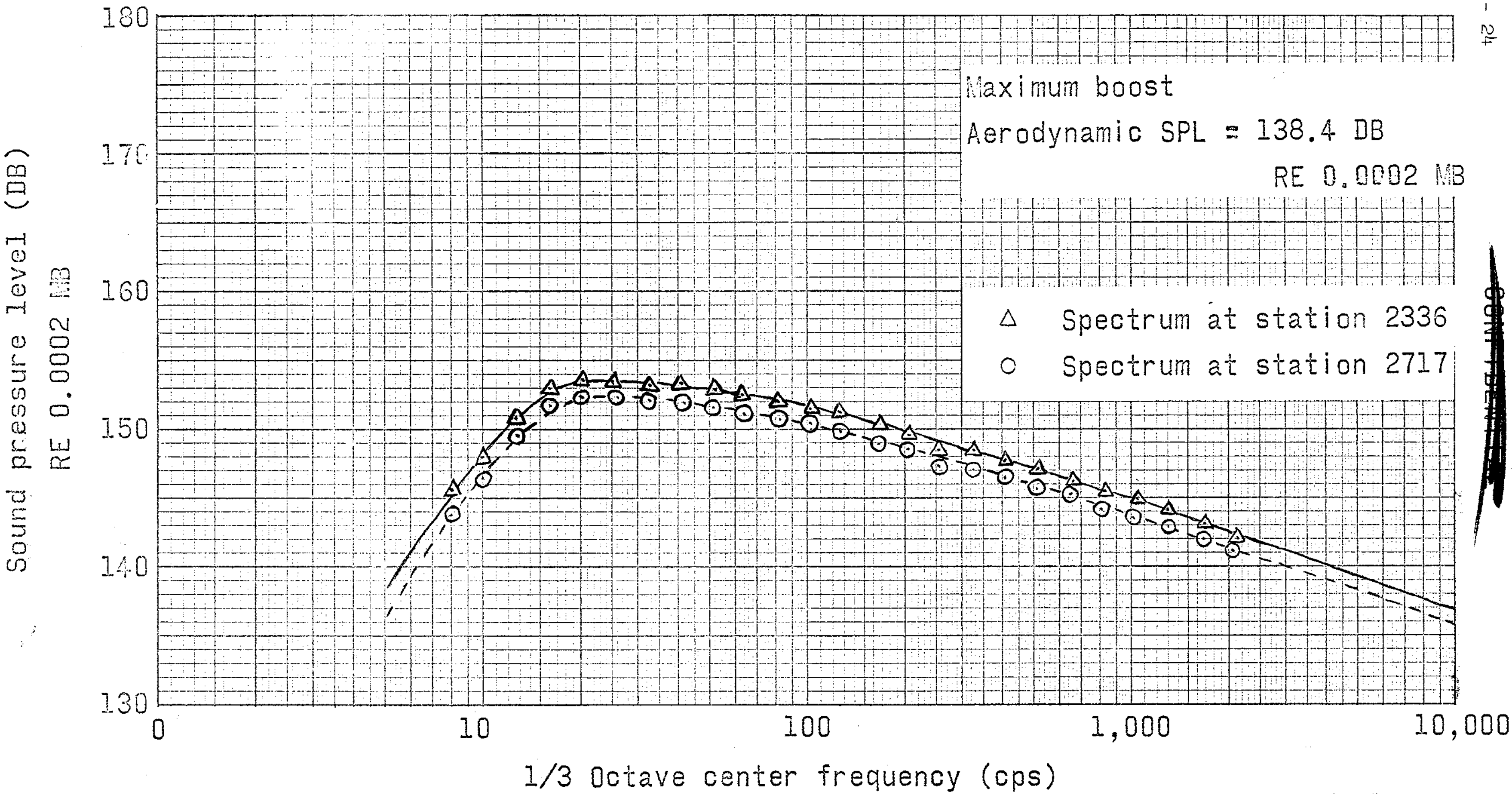

Figure 23.- Launch condition external sound pressure level spectrum for the payload section of the C-3 configuration.

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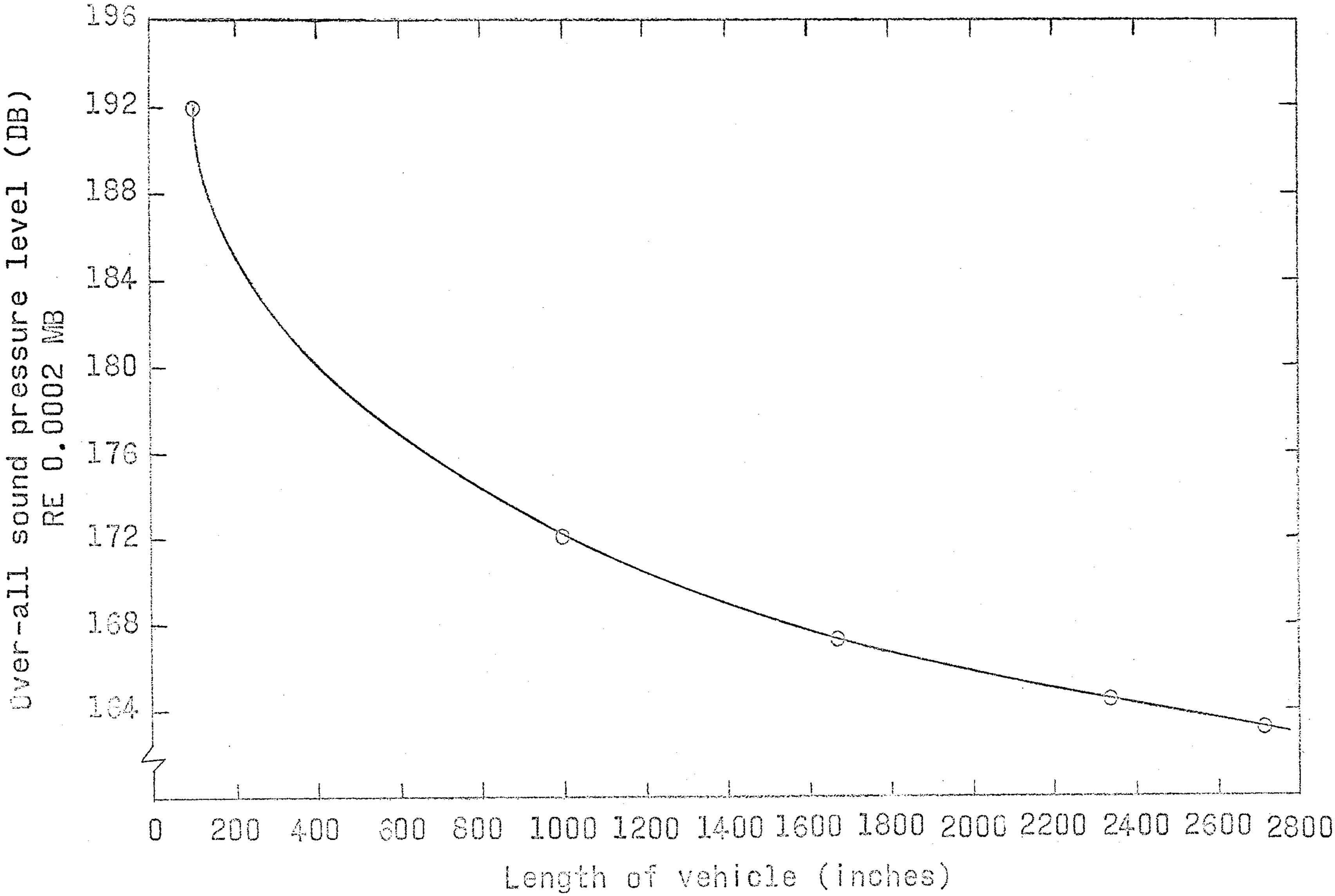

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Figure 24.- Launch condition over-all sound pressure level versus vehicle length for the C-3 configuration.

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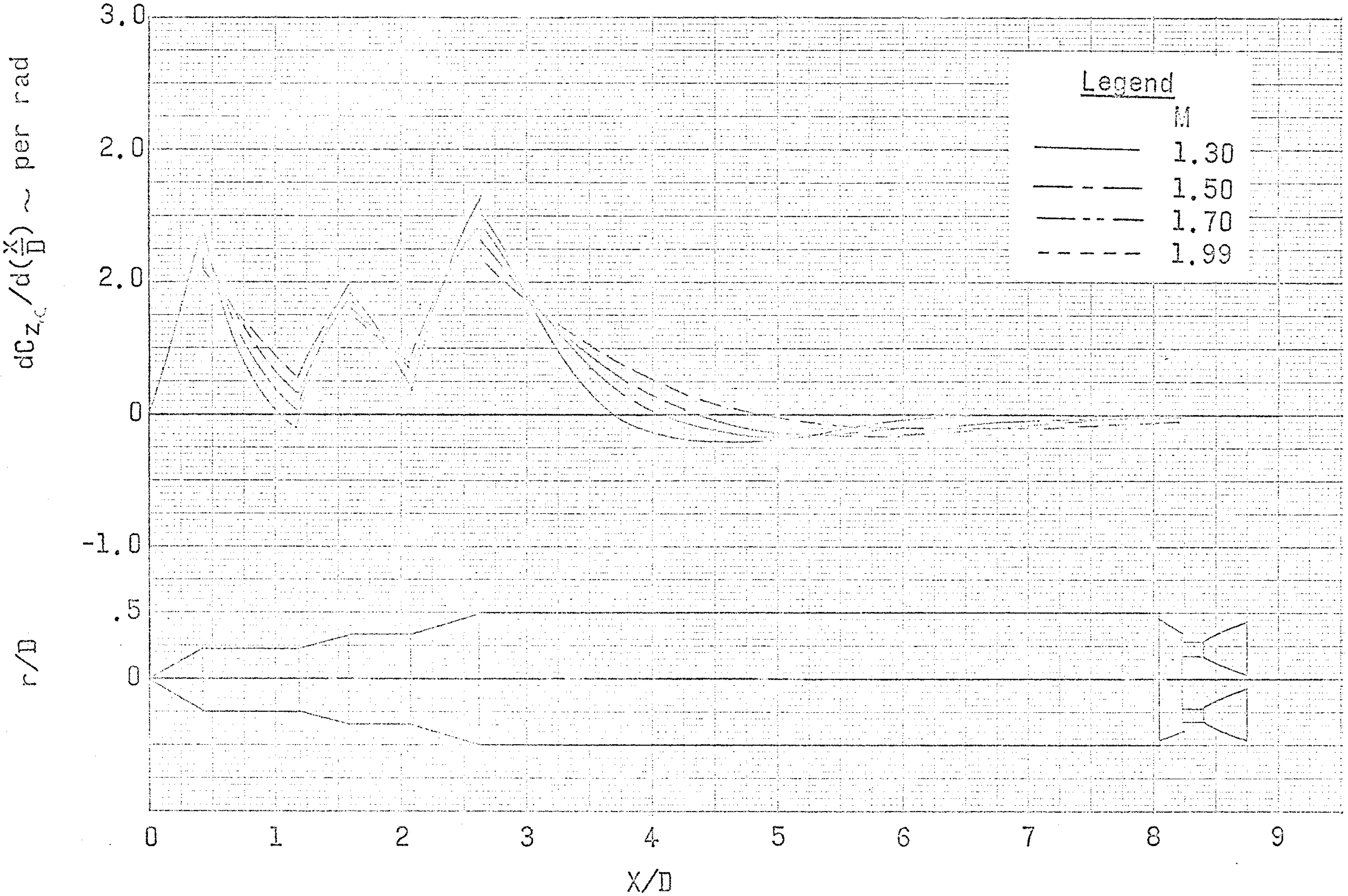


Figure 25.- Saturn C-3 vehicle with Apollo payload. Distribution of local normal-force coefficient. First-stage flight configuration, D ref. = 320 inches.

[redacted]

[redacted]

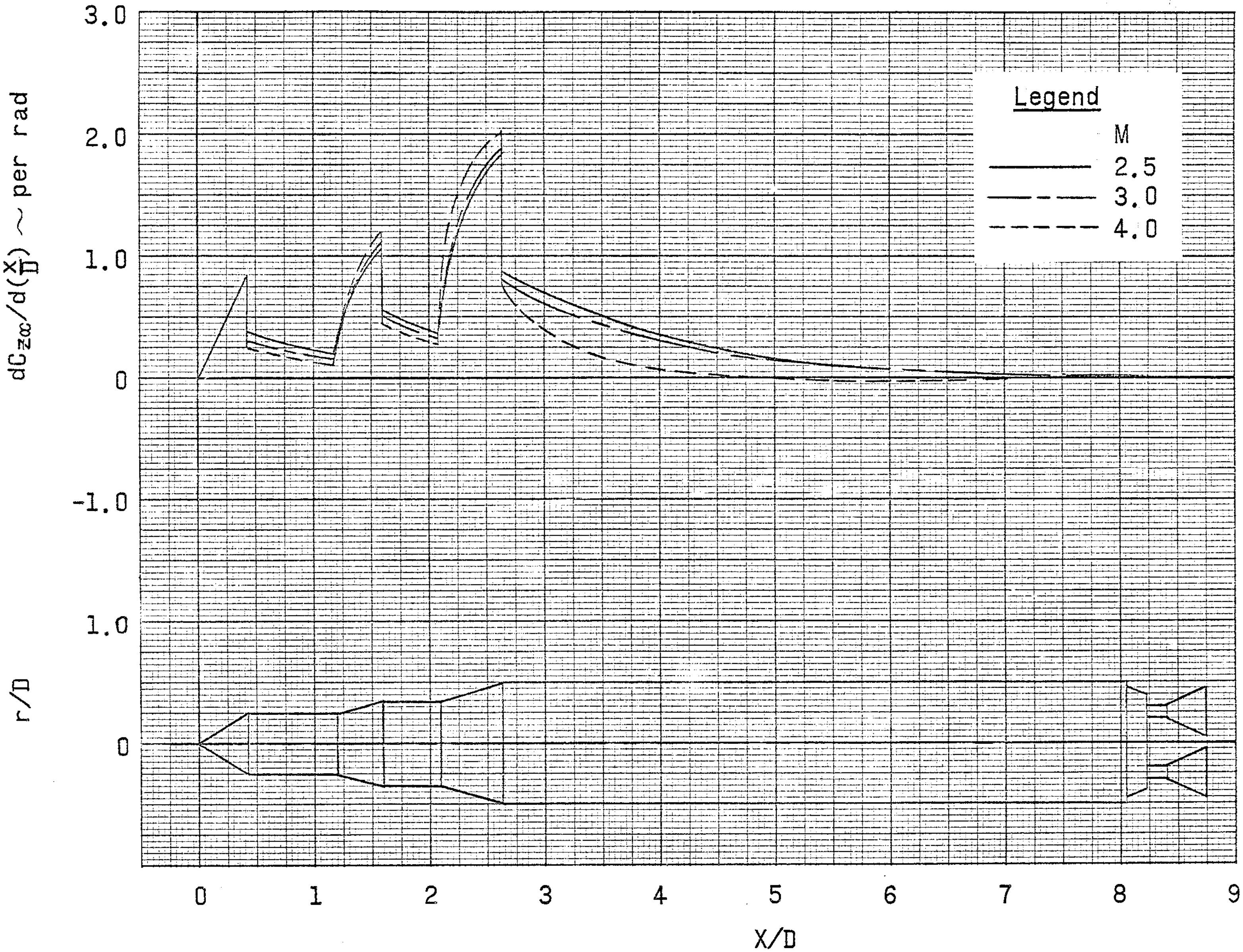
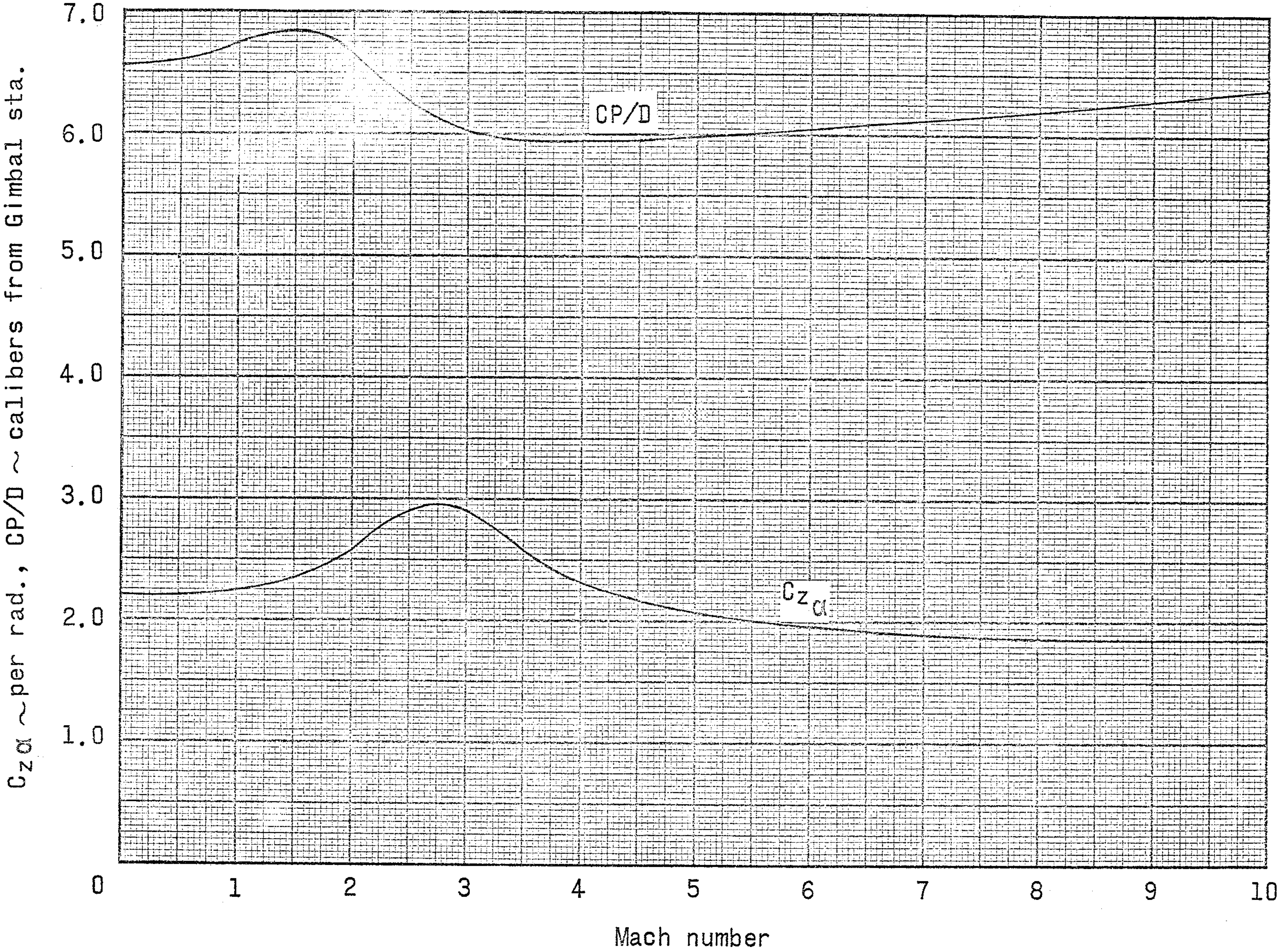


Figure 26.- Saturn C-3 vehicle with Apollo payload. Distribution of local normal-force coefficient, First-stage flight configuration, D ref. = 320 inches.

[redacted]

[redacted]



[redacted]

Figure 27.- Saturn C-3 vehicle with Apollo payload. Variation of normal force and center of pressure with Mach number. First-stage flight configuration, D ref. = 320 inches.

[redacted]

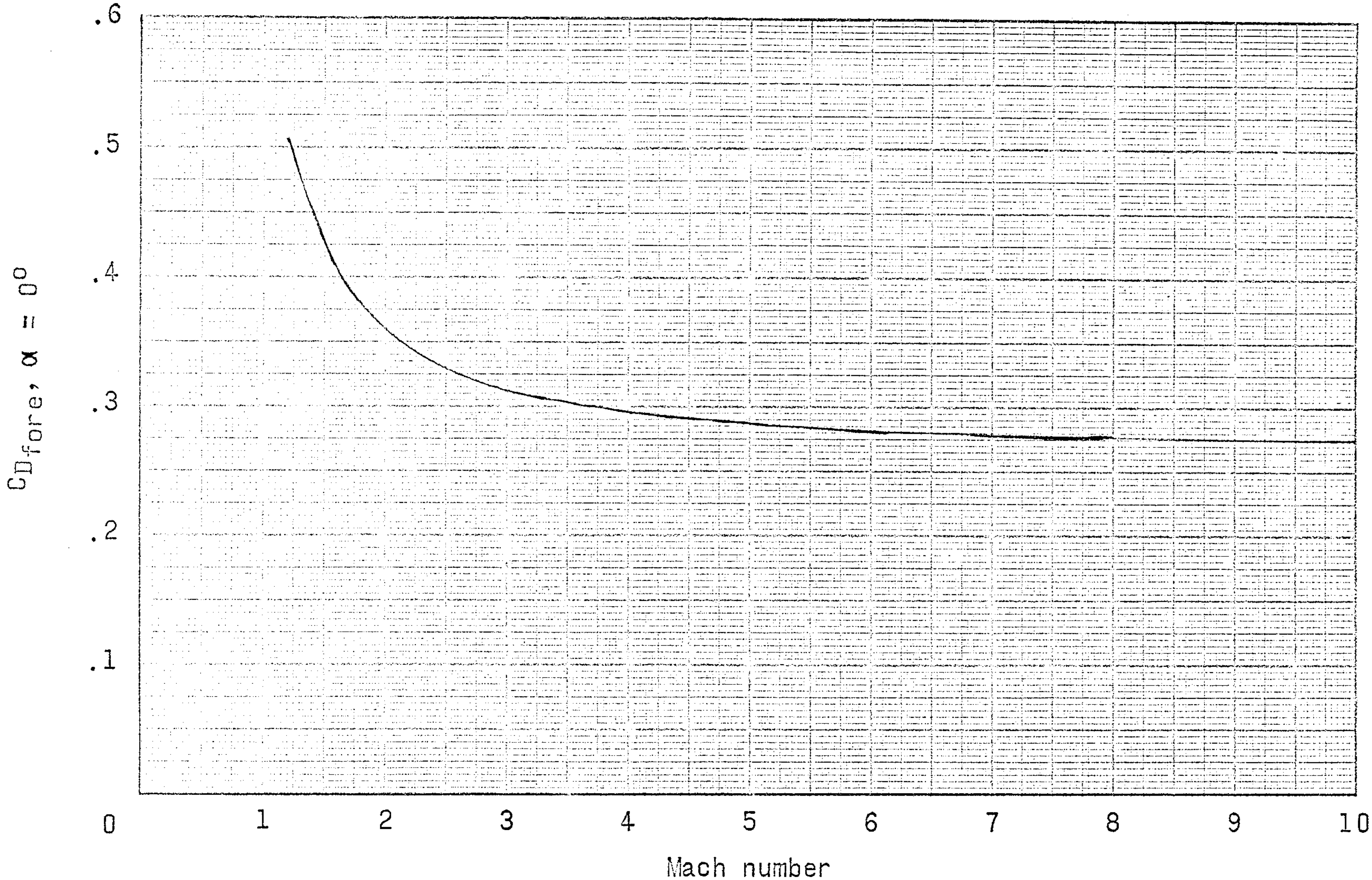


Figure 28.- Saturn C-3 vehicle. Variation of forebody drag coefficient with Mach number.

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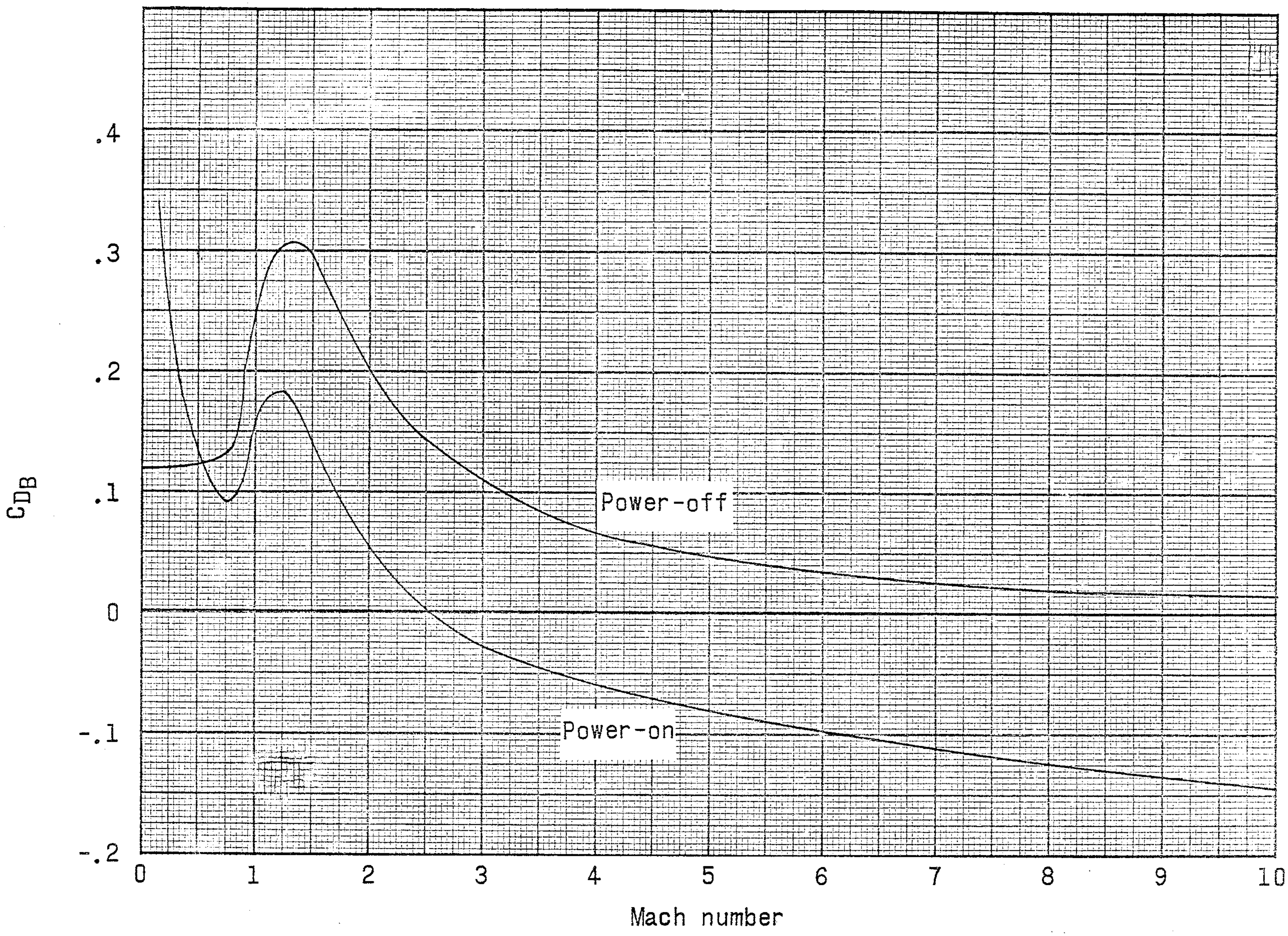

Figure 29.- Saturn C-3 vehicle. Variation of base drag coefficient with Mach number for power-on and power-off cases.

[redacted]

[redacted]

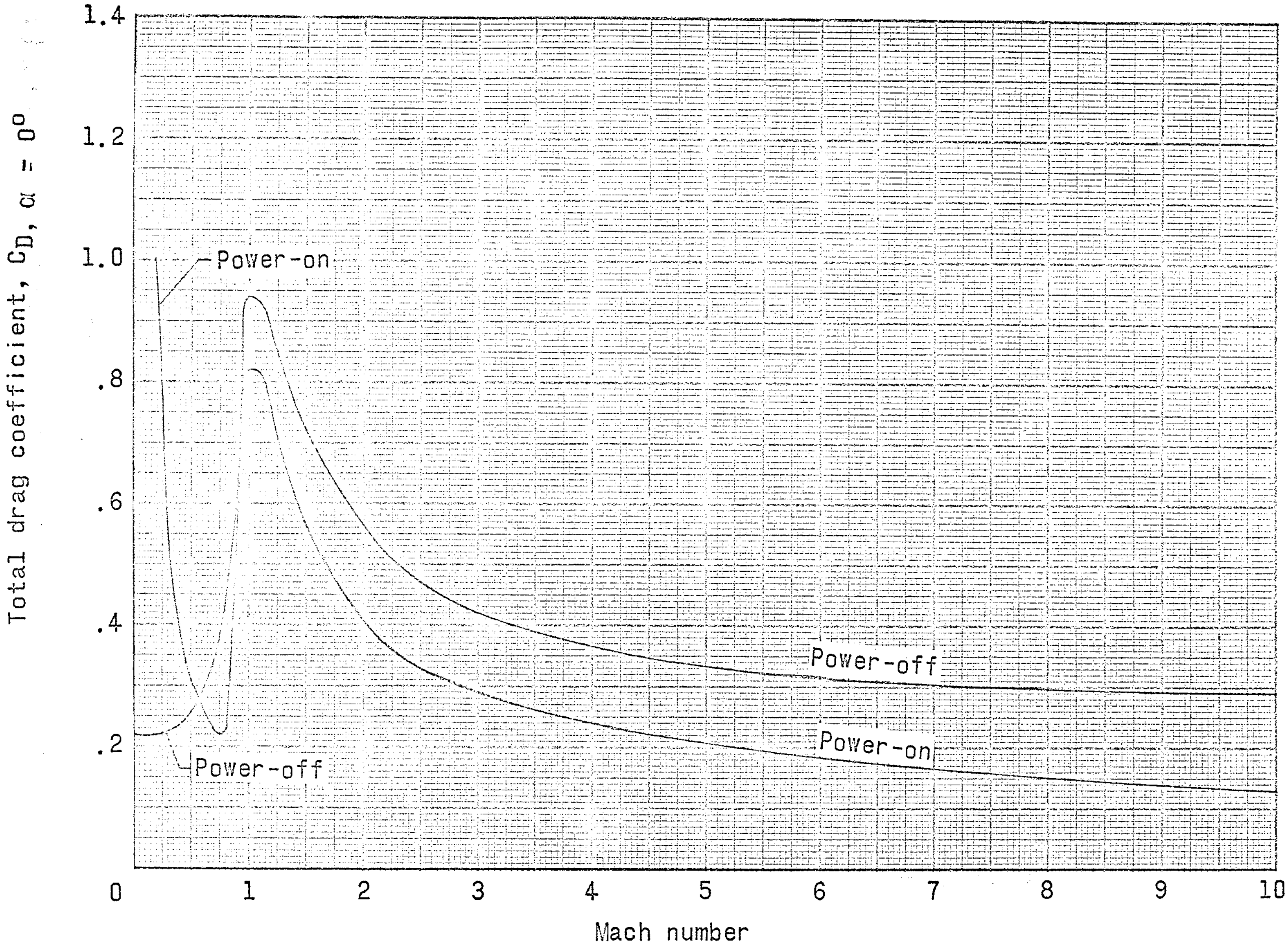

Figure 30.- Saturn C-3 vehicle. Variation of total drag coefficient with Mach number.

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CONTROL SCHEME FOR SATURN C 3 CONFIGURATION

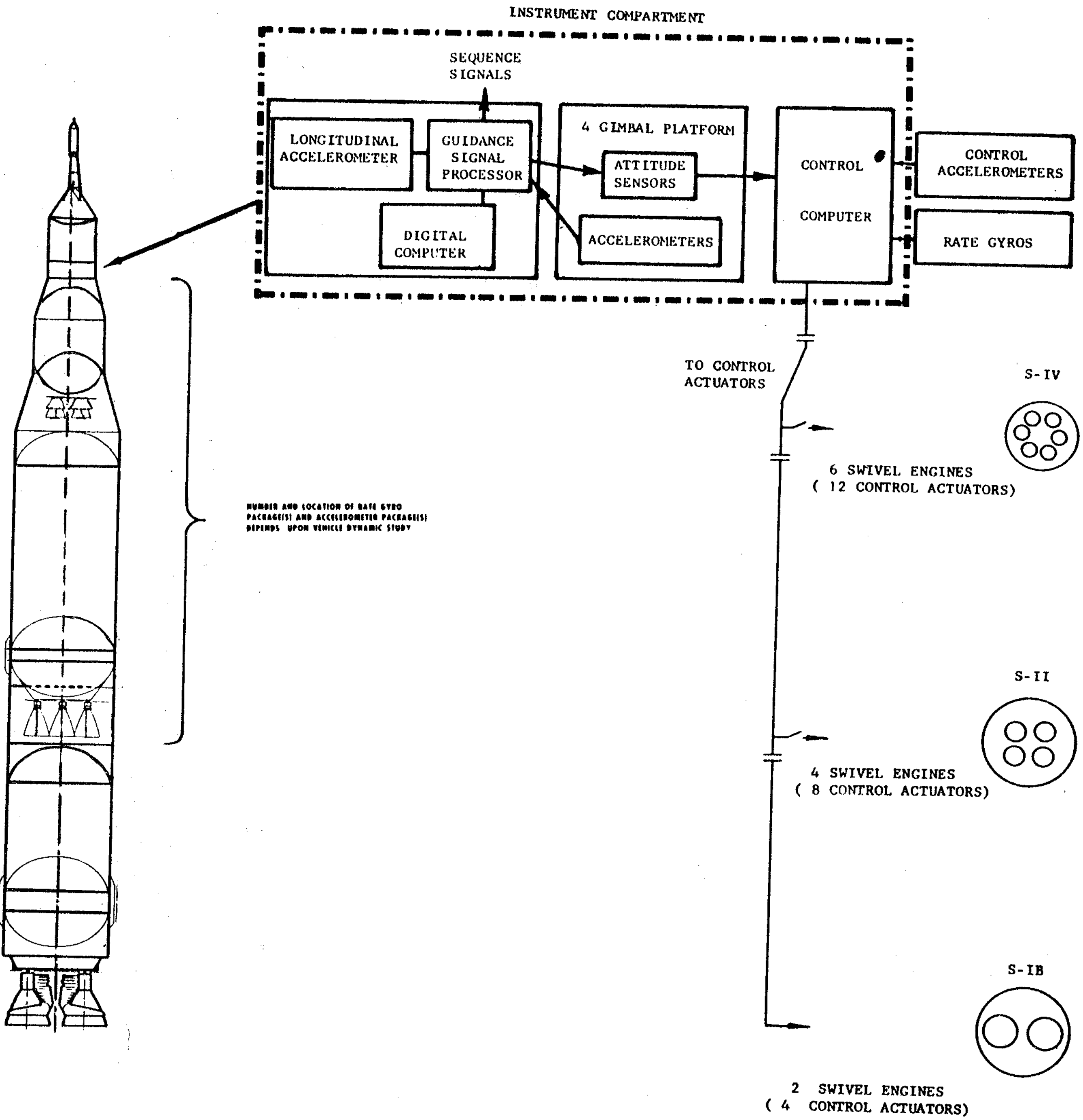

Figure 31.- Control scheme for Saturn C-3 configuration.

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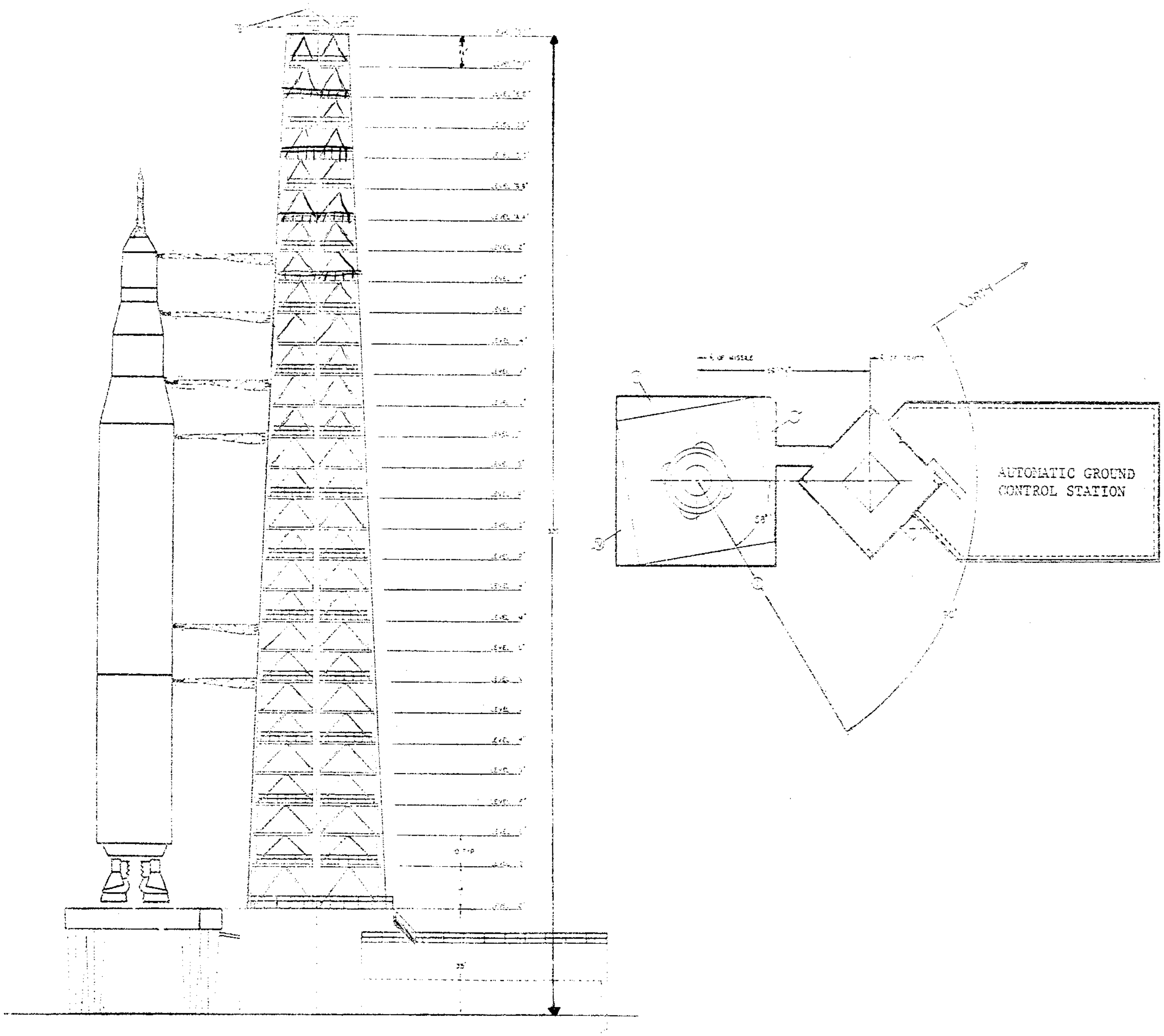

Figure 32.- C-3 on launch pad.

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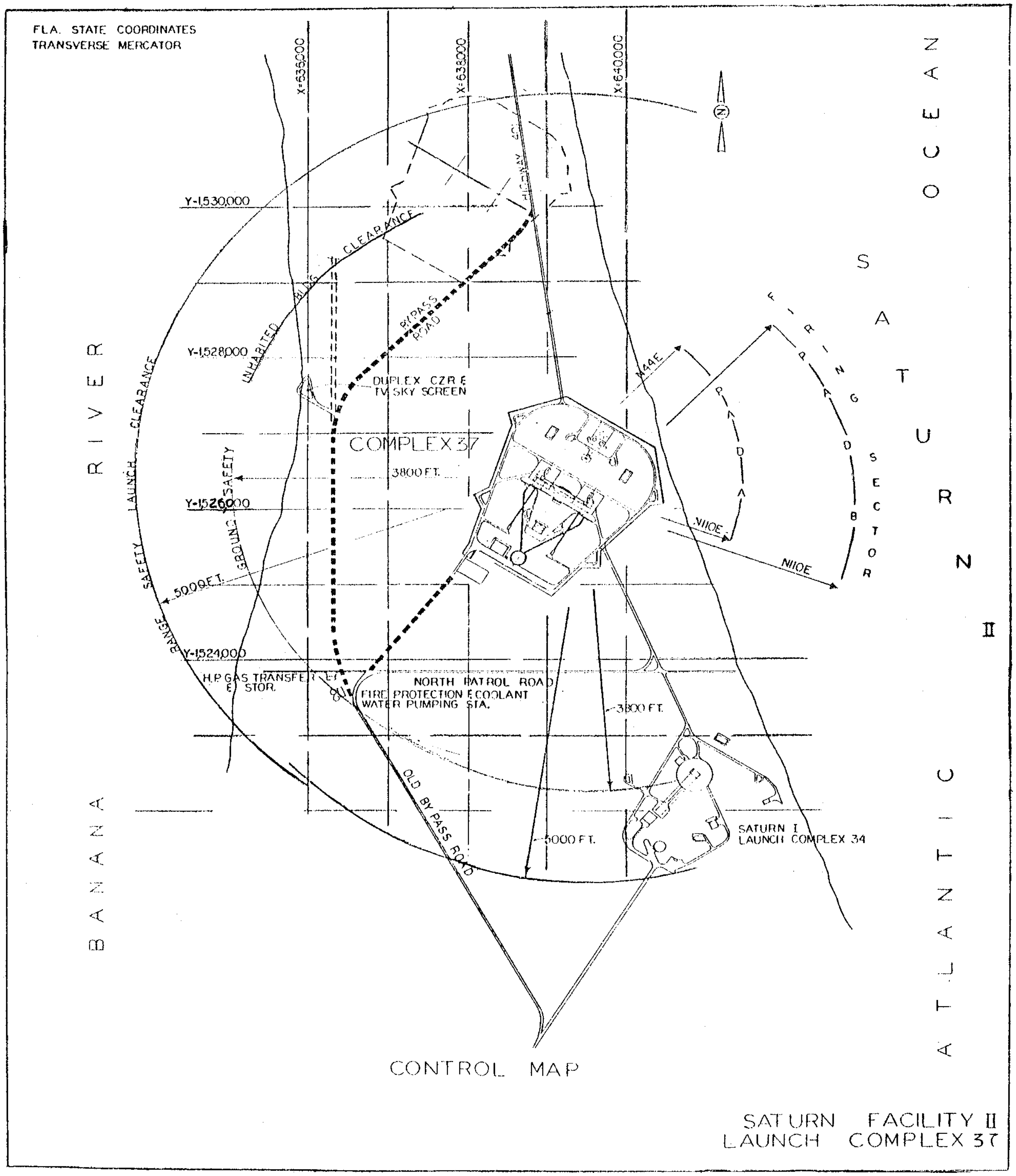
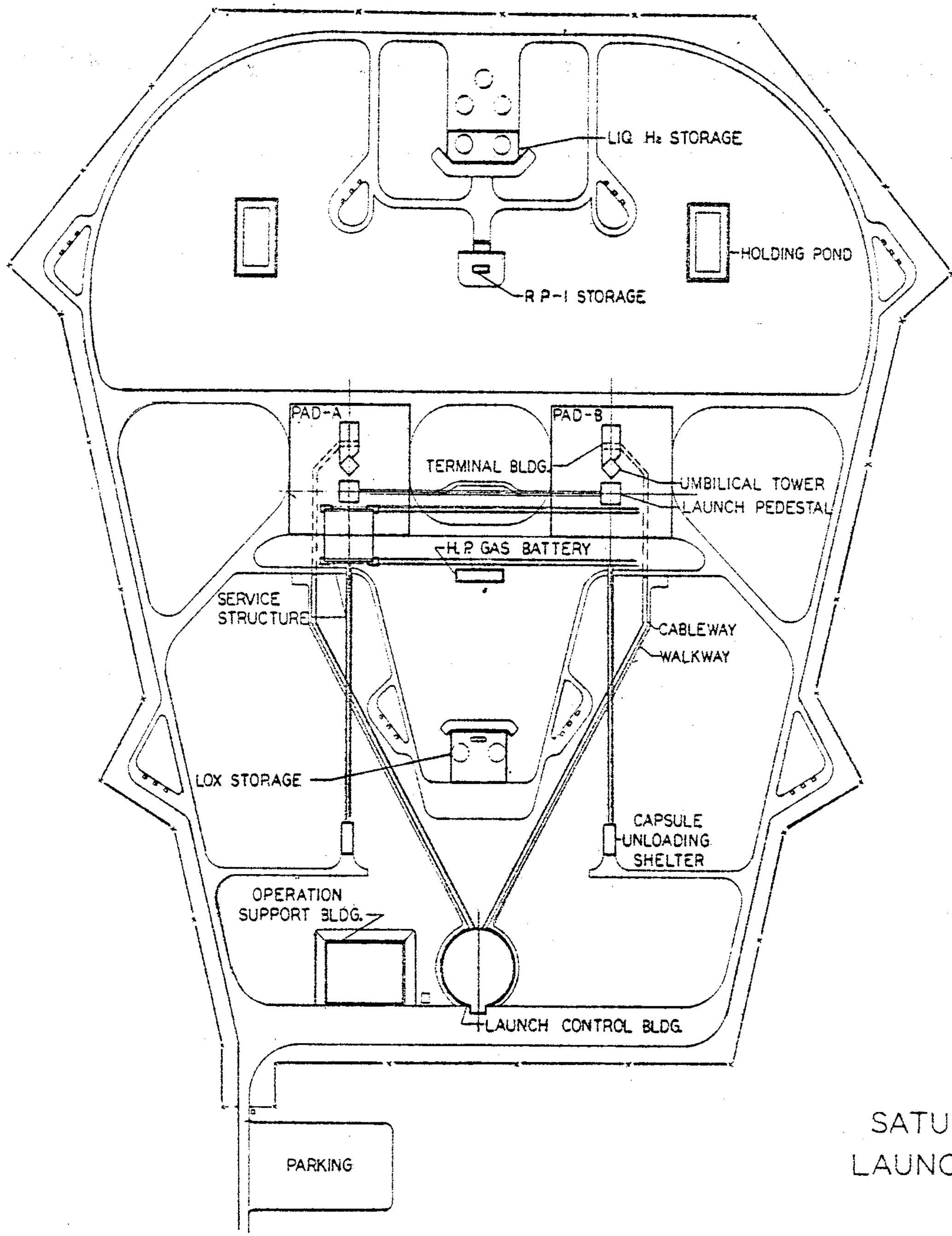


Figure 33.- Overall plan view of launch complex 37.

[redacted]

[redacted]



SATURN FACILITY II
LAUNCH COMPLEX 37

Figure 34.- Relative location of major facilities with launch complex 37.

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[redacted]

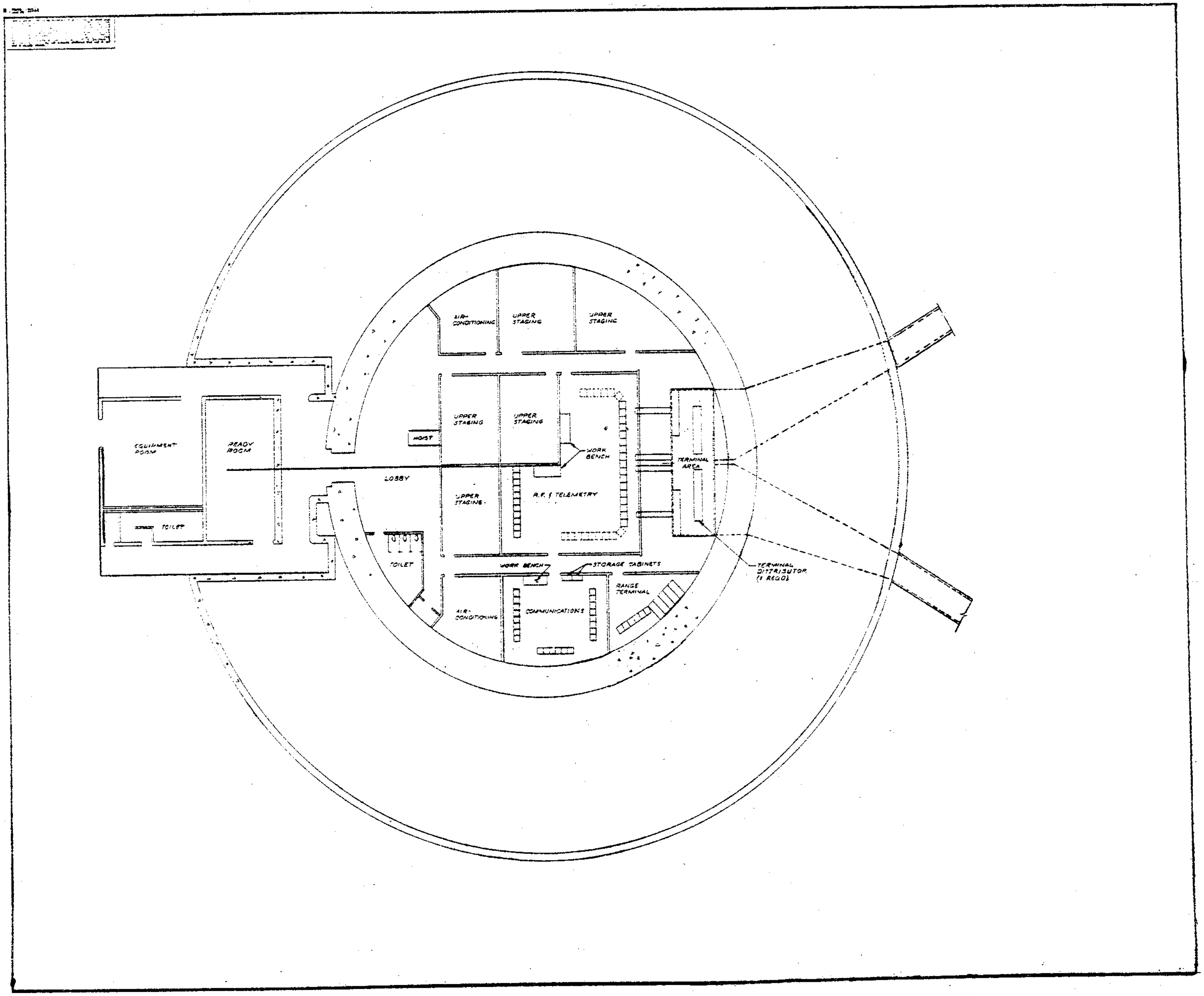


Figure 35.- First floor plan of launch control center.

[redacted]

[redacted]

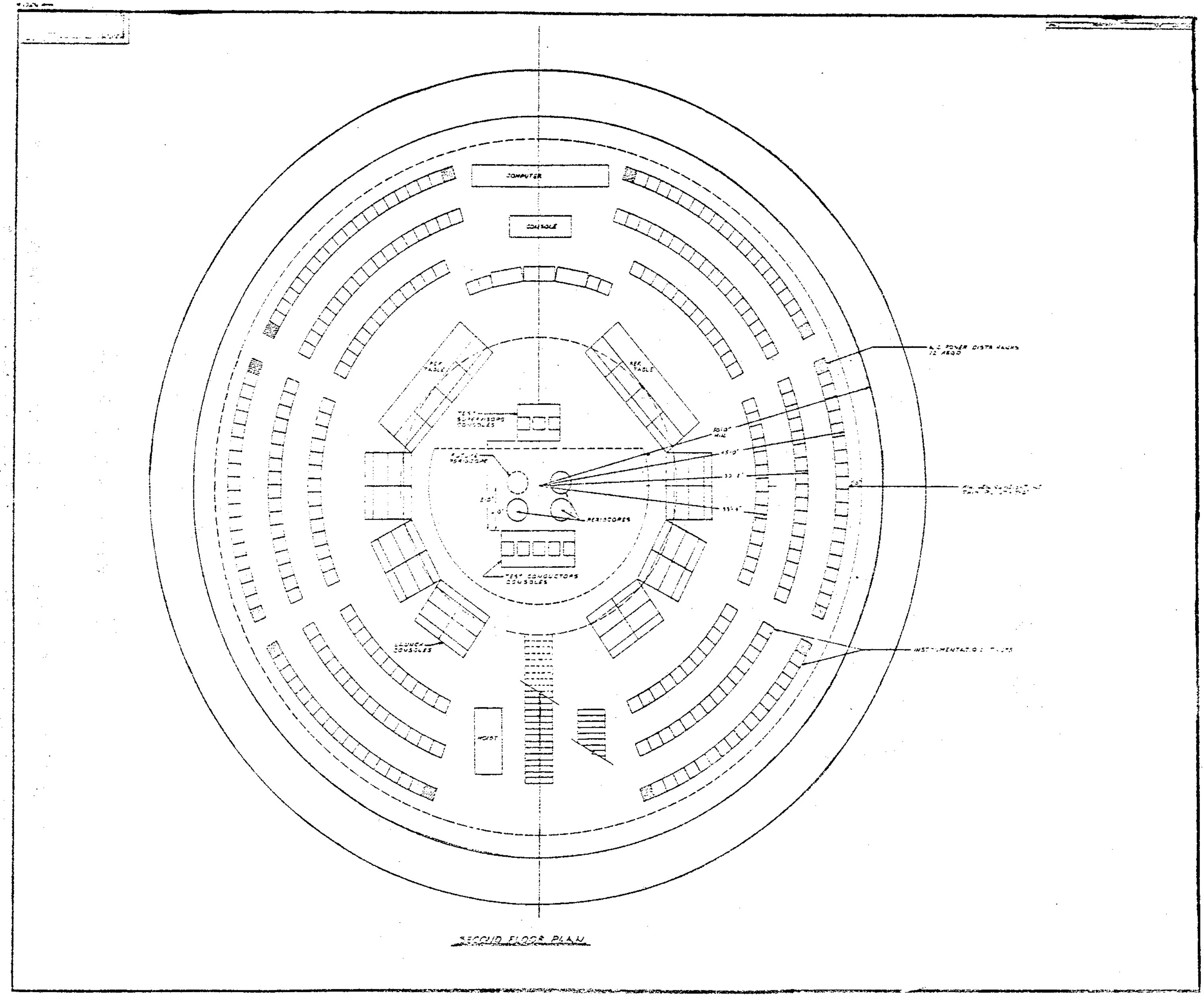
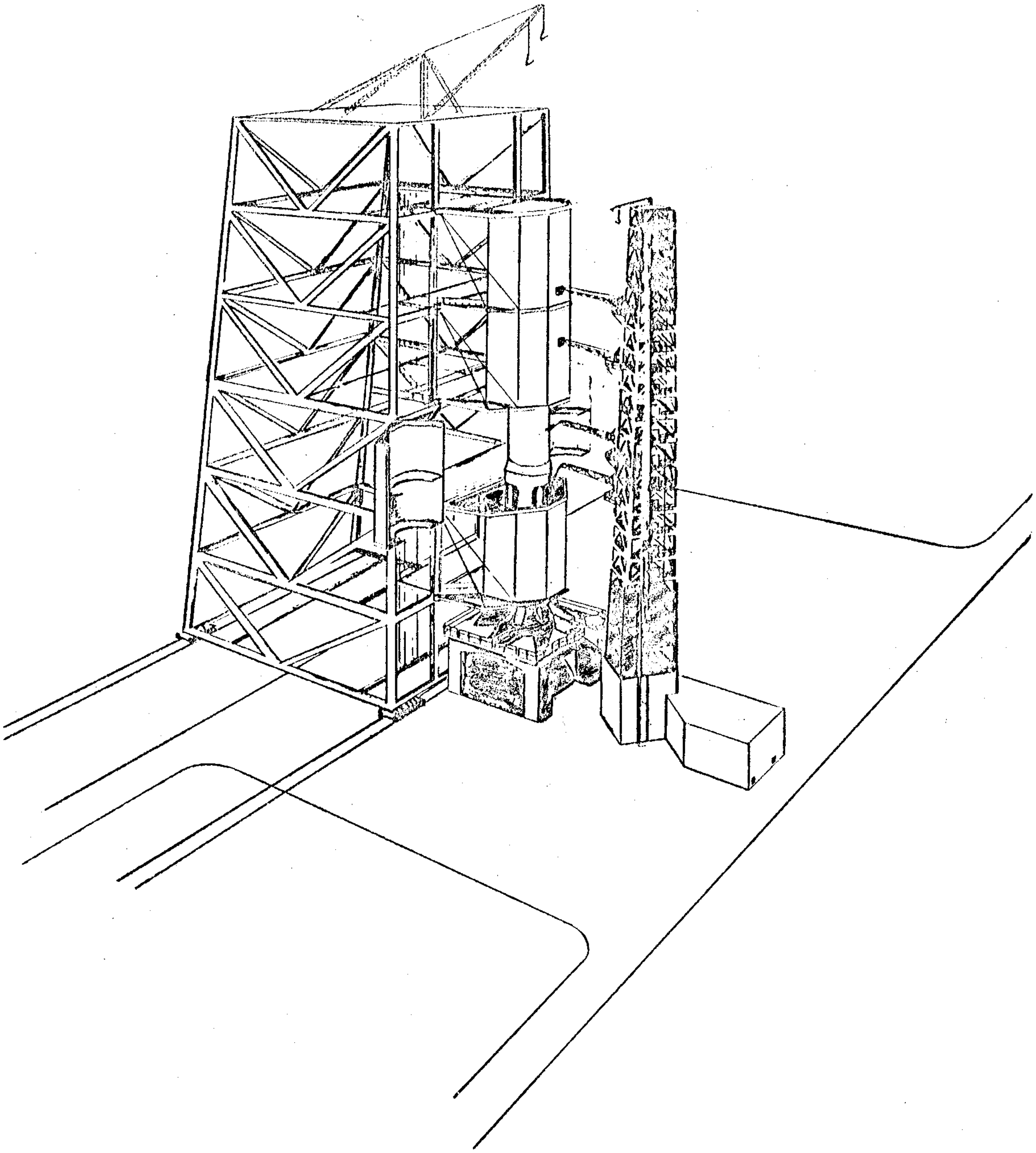


Figure 36.- Second floor plan of launch control center.

[redacted]



Service structure

Figure 37.- Service structure, launcher and umbilical tower for launch complex 37.

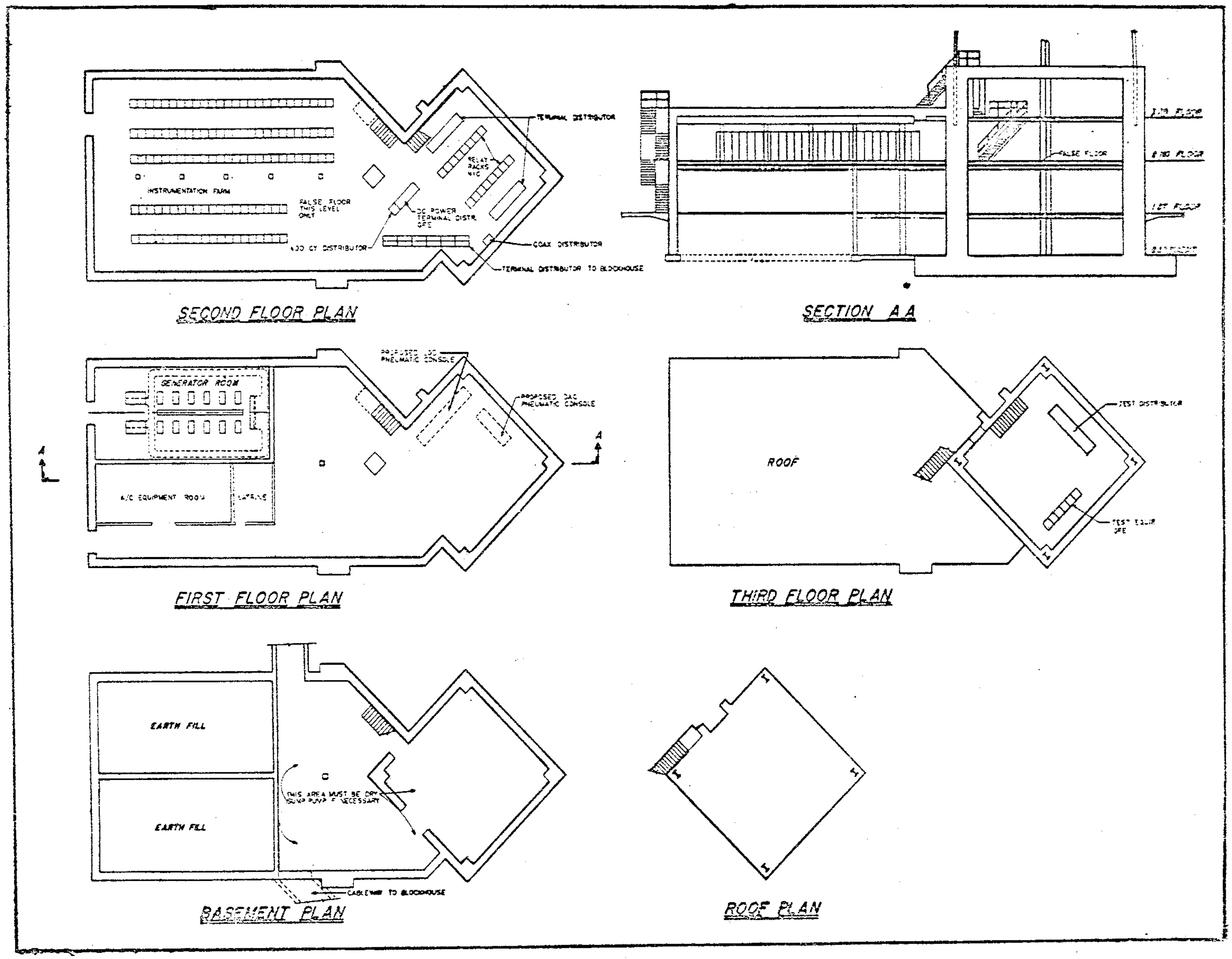


Figure 38.- Automatic ground control station for launch complex 37.

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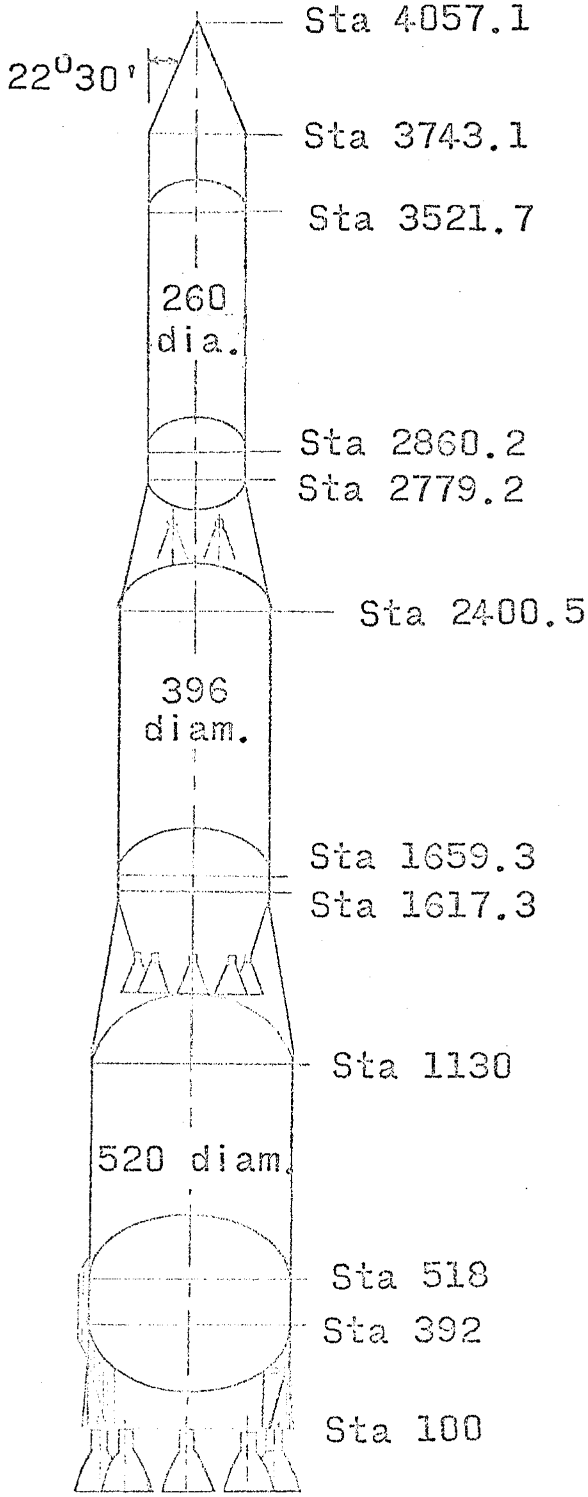

Figure 39.- Nova vehicle configuration.

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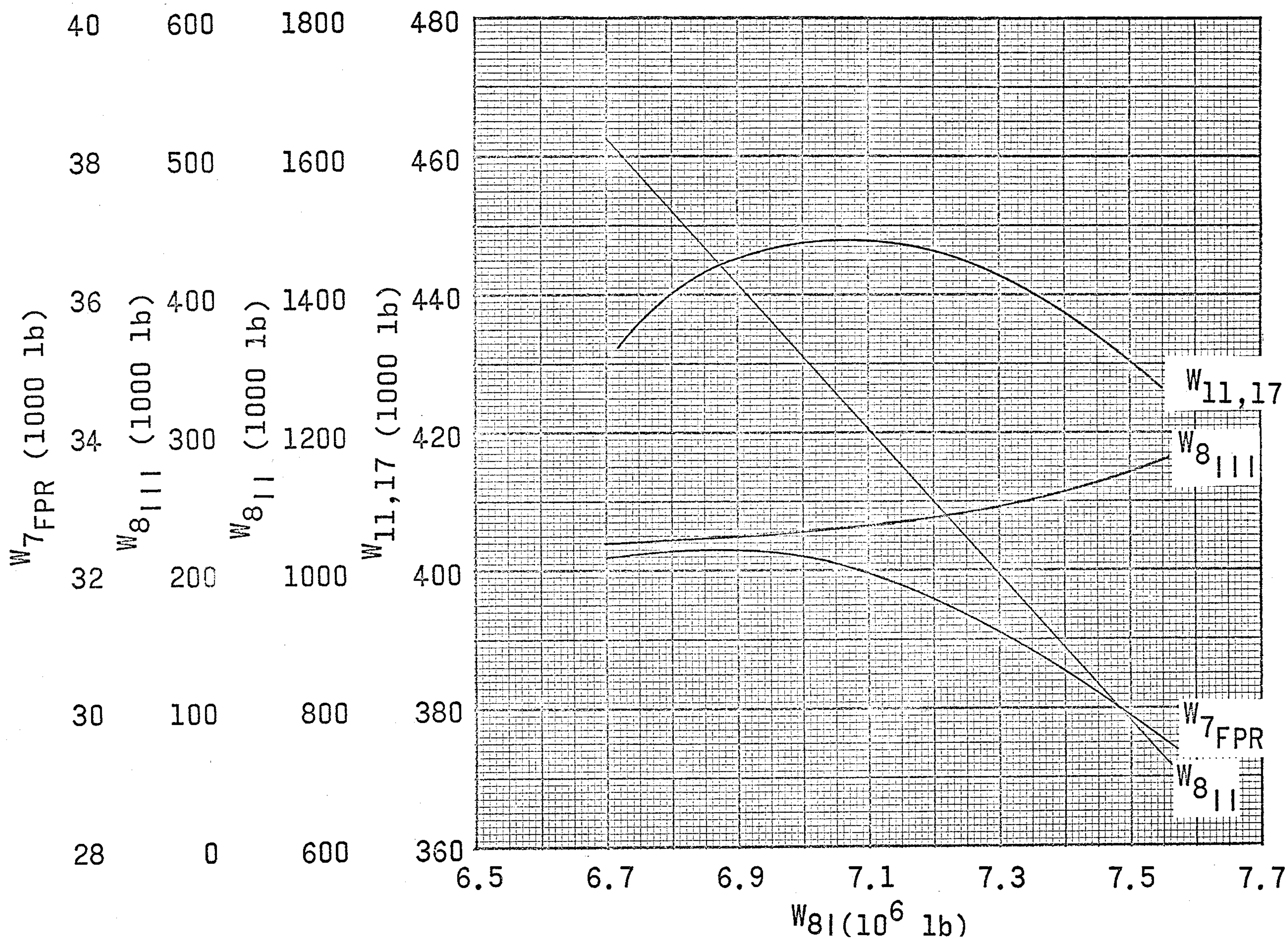

Figure 40.- Optimization of propellant loadings, 8(F-1) + 8(J-2) + 2(J-2), for 100 N. miles circular orbit.

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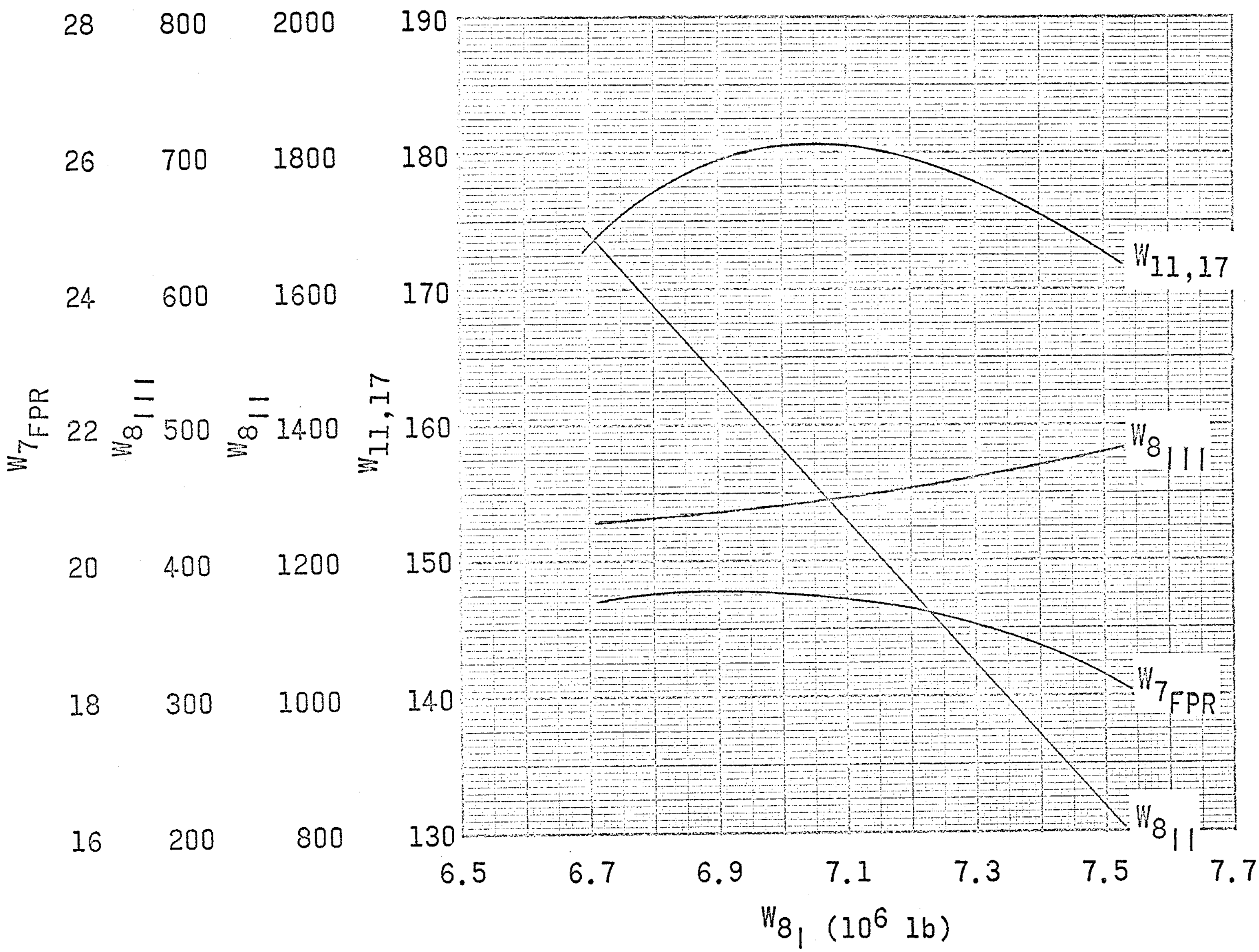

Figure 41.- Optimization of propellant loadings, 8(F-1) ÷ 8(J-2) ÷ 2(J-2), for escape mission from 100 N. mile minimum altitude

[redacted]

[redacted]

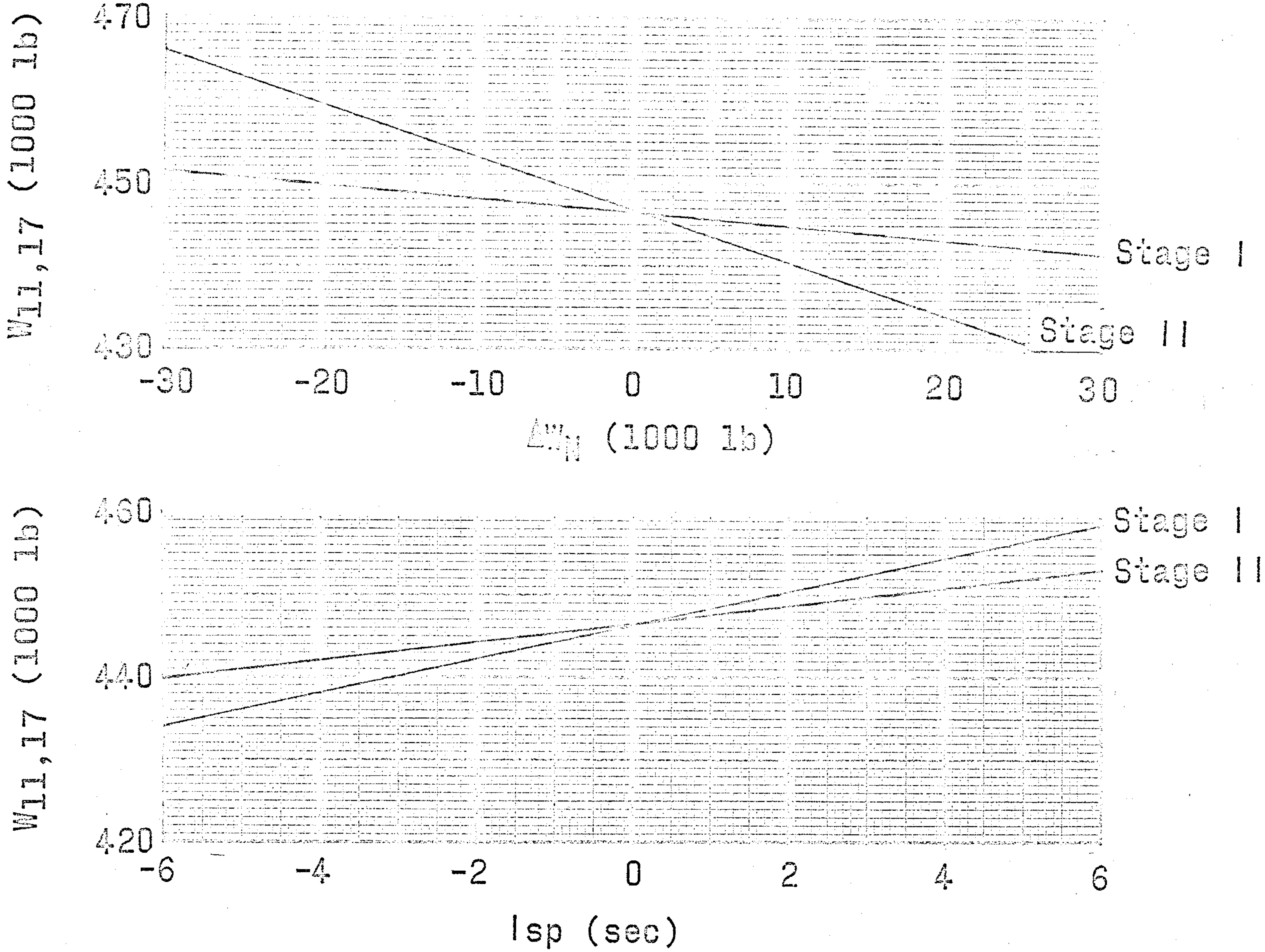

Figure 42.- Effect of net structure weight and specific impulse variations, 8(F-1) + 8(J-2) + 2(J-2) for 100 N. mile orbit.

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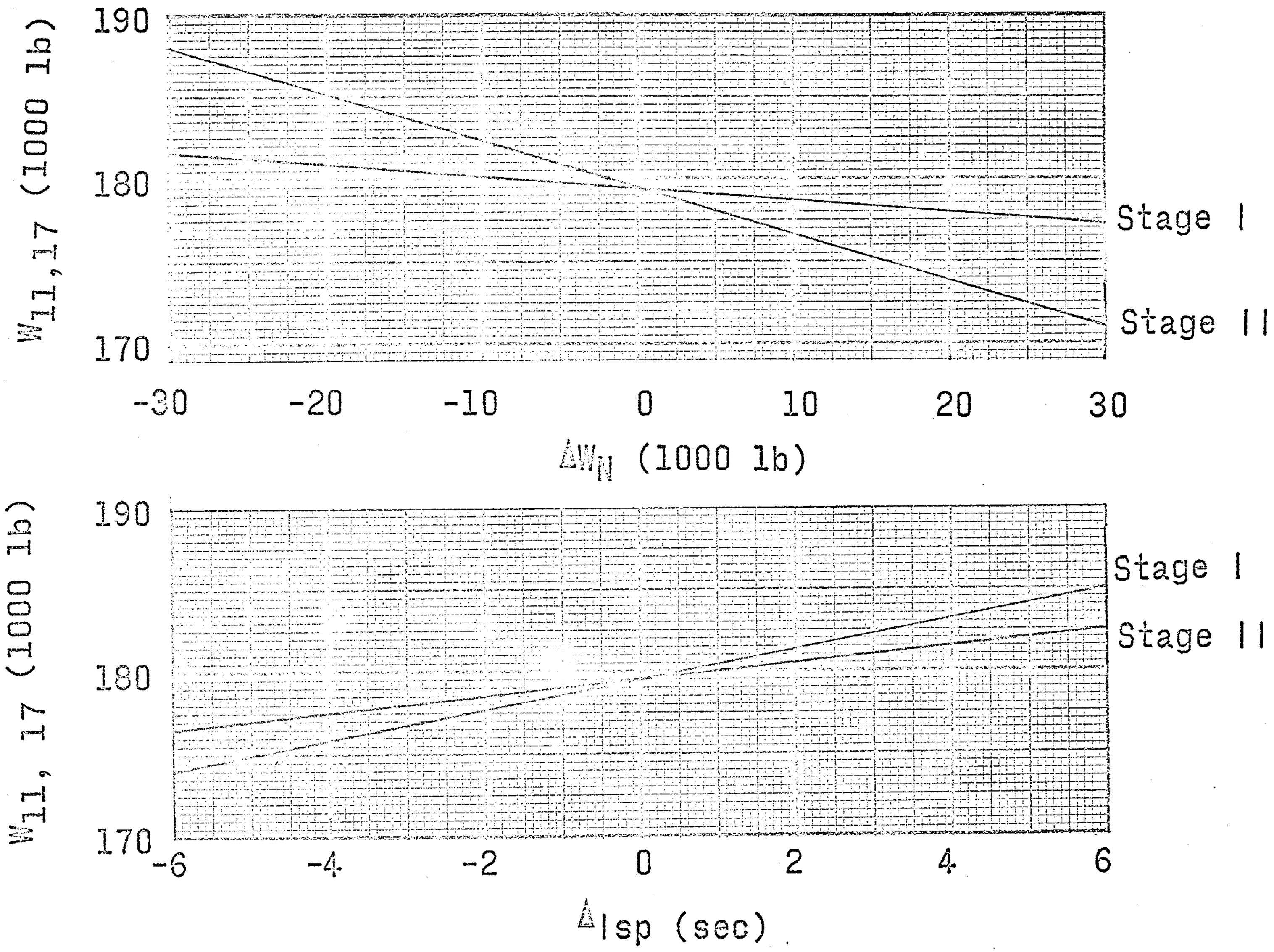

Figure 43.- Effect of net structure weight and specific impulse variation, 8(F-1) + 8(J-2) + 2(J-2) for escape mission from 100 N. mile altitude.