NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA PROGRAM APOLLO WORKING PAPER NO. 1211

WARNING TIME REQUIRED BY THE APOLLO SPACECRAFT TO SUCCESSFULLY ABORT IN THE EVENT OF A LAUNCH VEHICLE EXPLOSION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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WARNING TIME REQUIRED BY THE APOLLO SPACECRAFT

TO SUCCESSFULLY ABORT IN THE EVENT OF A LAUNCH

VEHICLE EXPLOSION

By Charles Teixeira

SUMMARY

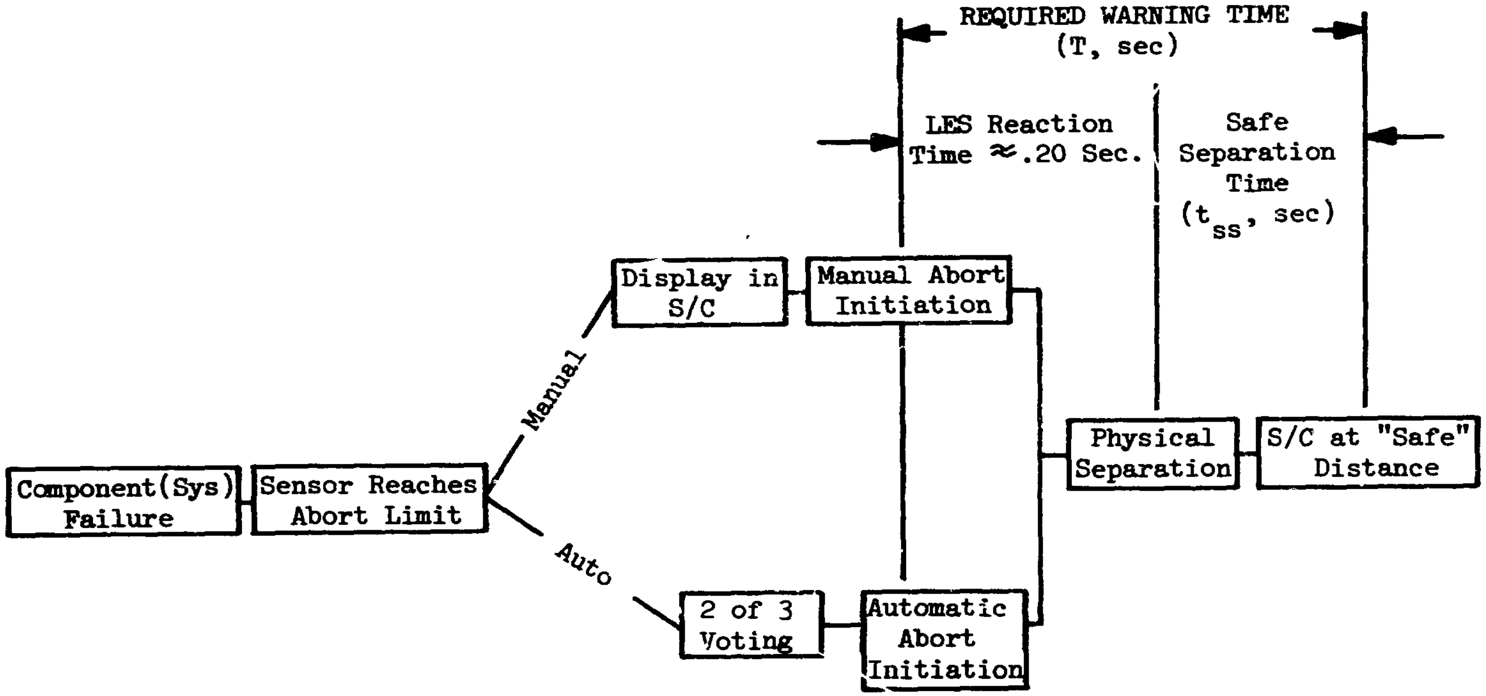
Explosion of a Saturn Launch Vehicle stage will result in pressures which exceed the Apollo Command Module's pressure limits if a sufficient separation does not exist between the command module and the explosion. The objective of the study was to determine the separation (in terms of time from abort initiation to the time of explosion) required in order that the command module pressure limits are not exceeded. This time is referred to as the required warning time. The study considered the individual explosion of the three Saturn V stages and the two Saturn IB stages from the pad to an altitude of 60 000 feet.

The required warning times are the longest on the pad and in the 25 000 to 30 000 foot regime. The maximum warning time required for the S-IB, S-IVB (Saturn IB), S-IC, S-II and S-IVB (Saturn V) are 2.68, 3.31, 3.30, 5.88, and 3.50 seconds, respectively.

Sensitivity of the required warning times to changes in such parameters as launch escape motor thrust, command module pressure limit, and the TNT equivalent yield, were also considered.

INTRODUCTION

The "safe" separation is defined as the separation required by the Apollo Command Module (CM) from the exploding launch vehicle (LV) in order that the total external pressures do not exceed the CM's pressure limits. These pressures include the overpressure produced by the assumed explosion of the LV's propellants (specifically of a single stage) and the aerodynamic pressures associated with the abort. The safe separation, given more conveniently in terms of time, plus the 0.20-seconds Launch Escape System (LES) reaction time, establishes the required warning times as illustrated on page 2.


REQUIRED WARNING TIME
(T, sec)
LES Reaction
Time ≈ .20 Sec.
Safe
Separation
Time
(t_ss, sec)
Component (Sys)
Failure
Sensor Reaches
Abort Limit
Manual
Auto
Display in
S/C
2 of 3
Voting
Manual Abort
Initiation
Automatic
Abort
Initiation
Physical
Separation
S/C at "Safe"
Distance

The required warning times were determined on the basis of pressure hazards only. Fireball hazards were not considered during the early phase of the abort studied (first 10 seconds) due to the short exposure time anticipated and the temperature capability of the CM. The fragmentation hazards are considered to be highly problematical. However, the overpressure hazard is real and definable and consequently was used as the explosive hazard criteria for the purposes of this study.

Knowledge of the required warning times is necessary in order to:

1. Aid in the establishment of the Emergency Detection System (EDS) abort limits.

2. Enable evaluation of the overall abort system including the EDS and the Launch Escape System (LES).

3. Define critical abort regimes in terms of the warning time available and the warning time required in order that the criticalities of LV failure modes may be viewed in their proper perspective.

SYMBOLS

C_P	pressure coefficient
C_T	escape motor thrust coefficient
M#	Mach number
P_A	aerodynamic pressure, psi $\left(= C_p q - \left(P_c\right)\right)$
P_C	cavity pressure from ambient, psi
P_{TOT}	sum of aerodynamic pressure $\left(P_A\right)$ and static equivalent of pressure associated with shock front (2 ΔP), psi
$\bar{P}_{TOT}$	average of above, psi
P_{oo}	ambient pressure, psi
ΔP	peak pressure associated with the shock front (above ambient), psi

q	dynamic pressure, psi
q_o	CM pitch rate at separation, deg/sec
R	separation between command module and center of detonation at time of shock front passage, ft
T	required warning time, sec
t_d	time of detonation in seconds after command module - launch vehicle separation
t_{sa}	time shock wave reaches command module in seconds after command module - launch vehicle separation
tss	time to achieve safe separation, seconds after spacecraft/ launch vehicle separation
α	command module angle of attack during abort, deg
α_o	initial command module angle of attack at separation, deg
ϕ	circumferential position on command module, deg

GROUNDRULES

Abort Trajectories

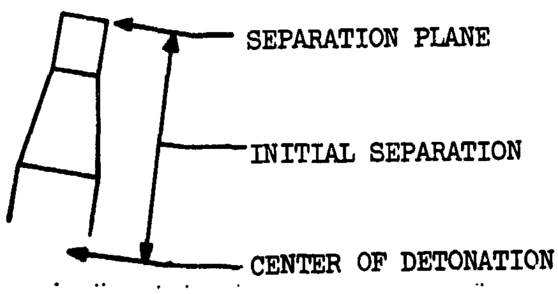
CM abort trajectories were obtained through use of a G. E. Mass computer program. The attitude at the time of abort was assumed to be a pitch-up condition of -15° angle of attack (α_o) and $-5^{\circ/sec}$ pitch rate q_o for each of the altitude cases. The pitch-up abort condition was assumed (with exception of pad abort) as a result of a previous study (ref. 9) which indicated that a pitch-up abort condition generally requires slightly longer warning times than for a nominal or pitch-down abort condition. An abort at $\alpha_o = 0°$, $q_o = 0^{\circ/sec}$ was assumed for the pad case as it is a more reasonable assumption.

The configuration assumed consists of a launch escape vehicle (LEV) (LEV = LES + CM) with an 11 000-pound CM and utilizing a pitch control motor. Nominal escape motor thrust (≈ 155 000 lb) and thrust alinement (1.80°) were assumed in all cases with the exception of the data presented in the appendix for various LES thrust levels.

In computing the CM-LV stage separation-time histories the assumption was made that the LV maintained a constant velocity and flight path angle after CM-LV separation. This assumption was made in order to obtain general results which are independent of LV failure modes and the resulting off-nominal LV trajectories. The assumption is reasonable for the several seconds after abort under consideration.

The CM-LV separation-time histories are generally relative to the CM-LV separation plane. As a result, the separation-time histories were modified by allowing for the inherent separation between the CM-LV separation plane and the assumed center of explosion for each stage. The separations used are given below:

Stage	Initial Separation, ft
S-I	140
S-IVB	57
S-IC	230
S-II	140



CM Pressure Limits

The load limits assumed for this study were predicated on the following objectives:

1. Maintain capability to deploy recovery gear.

2. Maintain pressure integrity of the crew compartment.

The capability to deploy the recovery gear requires that the forward heat shield be successfully jettisoned. In order to insure that the forward heat shield can be jettisoned, the assumption was made that no deformation would be allowed in the external heat shield, particularly in the region of the forward heat shield separation plane. The crew compartment heat shield (which terminates at the separation plane) has the lowest pressure capability (table I) according to available data and consequently the corresponding pressure limits were used as the limiting criteria. By insuring that the integrity of the external heat shield be maintained, the second objective, namely, integrity of the internal crew compartment, will in general be satisfied.

Figure 1 illustrates the CM-LES combination and the required deployment of the forward heat shield. The boost protective cover which will be put over the CM (as defined at the time of the study) will not improve the load-carrying ability of the CM's heat shield significantly. The integrity of the aft heat shield, which is also of importance because of its energy absorption function at landing, did not pose any problems since the load limits of the aft heat shield are considerably higher than the crew compartment heat shield limits.

The influence of the CM pressure limit on the required warning times is shown in the appendix.

Aerodynamic Loads

The aerodynamic pressure loads on the CM during an abort are functions of the Mach number (M#), dynamic pressure (q), angle of attack (α), and escape motor thrust level $\left(C_T\right)$. These loads generally reach a maximum at around 3.5 seconds after abort and vary considerably from station to station. Since the area around the forward heat shield separation plane was considered to be critical, the loads were computed for this region using the pressure coefficients given in references 1 through 3.

During an abort the CM will normally oscillate in angle of attack. For the abort cases studied, the maximum angle of attack (α_{max}) generally reached but did not exceed 20° for aborts from the pad to 10 000 feet. Above 15 000 feet the maximum angle of attack reached but did not exceed 25°. Since the aerodynamic pressures at a given station generally increase with an increasing angle of attack, the CM was assumed to be at the maximum angle associated with that particular abort at the time (t_{sa}) the shock front passed over the CM. Consequently, the aerodynamic loads were computed for $\alpha = 20°$ from the pad to 10 000 feet and $\alpha = 25°$ above 15 000 feet.

The pressure limits given in table I are for differential pressures across the external heat shield. Consequently, the pressure in the cavity between the external heat shield and the crew compartment must be considered. The pressure in the cavity is maintained at ambient ±1 psi. In each case studied shock-front passage occurred when the pressure in the cavity was below ambient due to the passive venting which occurs. This below ambient cavity pressure acts essentially as a static external (positive) pressure and is consequently added to the aerodynamic pressures. The cavity pressures were obtained from reference 4.

Overpressure Loads

The methods of H. L. Brode (ref. 5) were used to calculate the overpressures and the shock wave velocities. The following assumptions were made:

1. Individual detonation of each stage of the Saturn IB (S-IB, S-IVB) and the Saturn V (S-IC, S-II, S-IVB) launch vehicles.

2. Single propellant source at the stages approximate geometric center.

3. 10 percent TNT equivalent yield - LOX/RP-1 (S-IB, S-IC).
   60 percent TNT equivalent yield - LOX/H_2 (S-II, S-IVB).

4. Reflection factor = 2.0 for the pad case.

In the altitude regime considered, the S-IC and the S-IB are believed to be the most likely to malfunction since they are the thrusting stages and are subject to propulsion system failures. However, all LV stages were considered in order to illustrate the relative explosive hazard of each.

The equivalent TNT yields of 10 percent and 60 percent are the commonly used equivalencies for LOX/RP-1 and LOX/H_2, respectively. These yields are generally believed to be conservative (high), however, the degree of conservatism could not be adequately established. The influence of the TNT yields on the warning times is shown in the appendix.

The reflection factor of 2.0 is used for the pad case to account for the explosive energy being expended in a hemispherical shock wave rather than in a spherical shock as assumed in reference 5. Actually the shock will be spherical during the early stages of the expansion. The portion of the shock wave (lower hemisphere) that is reflected from the earth's surface will catch up to the upper half of the shock wave rather quickly due to the higher speed of the reflected shock. This higher speed is due to the higher air temperature caused by the original expansion and to a larger extent by the very high temperature that will exist due to the fireball that will occur. Merging of the reflected shock and the shock consisting of the upper half of the initial sphere will result in one reinforced shock wave. The reflection factor of 2.0 which accounts for the merging of the two shocks has the effect of doubling the yield and was used for the pad case only.

The propellant quantity available for each altitude case was determined by considering the propellant depletion that would occur during a nominal boost trajectory.

The CM pressure limits given previously (table I) are static pressure limits. The shock wave induces a dynamic load on the CM and consequently the overpressure load must be equated to an equivalent static load. Studies by North American Aviation and MSC have indicated a load factor of 2.0 is applicable, that is, the pressure associated with the shock wave is twice as severe as the pressure associated with a static load. Consequently a given overpressure is doubled to obtain an equivalent static pressure.

PROCEDURE

A total of five explosion cases were studied: explosion of the S-IB S-IVB (Saturn IB), S-IC, S-II and the S-IVB (Saturn V). Each case was studied from the pad to 60 000 feet at 5000 feet increments. In each case, detonation times (t_d) were assumed and the resulting total pressure loads acting on the CM at the time the shock front passed over the CM were calculated and compared to the CM's pressure limits. In order to compute the pressure loads two unknowns had to be determined:

1. Shock arrival time - the time (t_{sa}) at which the shock front reaches the CM had to be determined for each assumed detonation time. This established the flight parameters $(q, M\# \text{ and } C_T)$ which were needed to calculate the aerodynamic pressure distribution acting on the CM at the instant of shock front passage.

2. CM - center of detonation (CD) separation - the distance (R) between the CM and CD at the time of shock arrival had to be established for each detonation time in order to compute the overpressure acting on the CM.

The shock arrival time and the corresponding CM - CD separations, over-pressure, et cetera, were determined for each assumed detonation time with the aid of a computer subroutine which was run in conjunction with the abort trajectory program. The computations were made using a reiteration scheme and the stored abort trajectory data. The reiteration scheme is discussed in more detail in reference 6.

Tables II through VI summarize the shock arrival time t_{sa}, q, M#, C_T, R, and the ΔP experienced by the CM for each assumed detonation time and LV stage. Around 25 000 to 30 000 feet the aborting CM begins to attain sufficient velocity during the abort to remain ahead of the shock front for sufficient time to allow the overpressure to drop to very low values (tenths of a psi). As the abort altitude increases, the CM eventually is able to outrun the shock front during the entire time span under consideration ($\approx$10 seconds). The only pressure loads acting on the CM during this time period are the aerodynamic pressure loads which are within the CM's pressure limits.

The aerodynamic pressure distribution present at the time of shock arrival was calulated using the flight conditions listed in tables II through VI, the pressure coefficients from references 1 through 3, and the cavity pressure data from reference 4.* The resulting aerodynamic pressures (P_A) were then totaled with the static equivalent of the

*Aerodynamic pressure distributions were not calculated for the cases where the CM was able to outrun the shock front or when the overpressures had dropped to such a low level that it was obvious the CM's pressure limits were not exceeded.

overpressure (2 ΔP) for each assumed detonation time (t_d) in tables VII through XI. In all cases, the total pressures (P_{TOT}) were relatively evenly distributed and were averaged $(\bar{P}_{TOT})$ around the entire CM (ϕ = 0 - 360°). The loads that were computed and given in the tables were for ϕ = 0 - 180° since the loads are symmetrical about the pitch plane.

The average total pressure load was plotted as a function of detonation time in figures 3 through 7. The detonation times which resulted in total pressures which did not exceed the symmetrical limit of 6.1 psi were then determined acceptable (safe) detonation times. The loads at these times were then rechecked to insure that the unsymmetrical pressure limits were not exceeded. In each case if the average pressures did not exceed the symmetrical limit, the unsymmetrical limit was also not exceeded.

The safe separation times are summarized in table XVII and are added to the 0.20 seconds LES reaction time to obtain the required warning time. The resulting required warning times are plotted as functions of the abort altitude in figures 8 and 9.

RESULTS AND DISCUSSION

The warning times required by the Apollo CM are given in figures 8 and 9. The curves show relatively large time requirements on the pad due primarily to the assumed reflection factor and the large quantity of propellant available at this time. However, the longest warning time requirements for the non-thrusting stages are generally in the 20 000- to 30 000-foot regime where the CM - LV separation-time histories are the poorest due to the high drag environment. The thrusting stages (S-IB, S-IC) require the longest times on the pad since propellant depletion results in warning time requirements in the 20 000- to 30 000-foot regime which are not quite as high as those on the pad.

As the abort altitude increases and the CM speed during the abort exceeds sonic speeds, the CM is able to remain ahead of the expanding shock for progressively longer periods of time. Consequently, when shock arrival does occur the overpressures are quite low. As a result, the warning time requirements drop off appreciably after passage through the 30 000-foot regime.

Extrapolation of the data presented in figures 8 and 9 should be avoided due to the highly non-linear nature of the data involved. In particular, the curves for the thrusting stages (S-IB, S-IC) appear to level off in the 50 000- to 60 000-foot regime and extrapolation to higher altitudes may appear reasonable. However, check cases have shown the warning times decrease markedly above 60 000 feet. In the limiting case, the available propellant (thrusting stages) approaches zero at staging and consequently the warning time required would also approach zero. The S-IB curve given in figure 8, for example, does not suggest such a decrease.

The large warning time requirements for the S-II stage (fig. 9) are due to the large propellant loading and the 60-percent equivalency.

Explosion of a given stage can conceivably inititate explosion of an adjoining stage. Consequently, the aborting CM may have to contend with more than one explosion. Obviously, if the secondary explosion(s) occurred after the primary explosion, sufficient separation may exist between the CM and LV. The time that may in reality elapse between explosion of adjoining stages is extremely difficult to estimate at this time. It is possible, however, to estimate the minimum time that should elapse between the primary and the secondary explosions in order that the CM pressure limits will not be exceeded due to the secondary explosion. For example, if the S-IB explodes (10 000 ft, fig. 8) 2.25 seconds after abort initiation, the CM pressure limits will not be exceeded as a result of the S-I explosion since only 2.00 seconds are required for safe separation. However, if the S-IVB (non-thrusting stage) explodes (at the same altitude) before 2.60 seconds after abort initiation, the CM pressure limits will be exceeded due to the S-IVB overpressures. This corresponds to .35 seconds between explosions (2.60 - 2.25). Thus, if the time between explosions is less than .35 seconds, CM pressure limits will be exceeded by the secondary explosion. This procedure can be carried on throughout the altitude regime in question and for various explosion times, abort times, et cetera.

CONCLUSIONS

Explosion of a Saturn LV stage can result in pressures which exceed the CM's pressure limits. Deformation of the CM's external structure can impair or even prevent deployment of the forward heat shield and subsequent deployment of the recovery gear. The time that must elapse between abort initiation and the time of explosion (warning time) in order that CM pressure limits will not be exceeded has been determined for the Saturn IB and V stages from the pad to an altitude of 60 000 feet. The maximum warning times required during the launch phase considered are 2.68, 3.31, 3.30, 5.88, and 3.50 seconds for explosion of the S-IB, S-IVB (Saturn IB), S-IC, S-II, and the S-IVB (Saturn V) stages, respectively.

The effects of increased CM pressure capability, LES thrust and of various TNT yields on the warning times were also studied. Increased pressure capability of the CM by factors of almost 2 and 3 did not show a large decrease in the required warning times. Increasing the LES thrust did not improve the situation at the lower altitudes but did decrease the required warning times appreciably in the 20 000- to 30 000-foot regime. Reductions by a factor of 2 in the TNT yields did not show major reductions in the required warning times below 30 000 feet. However, considerable reductions in the required warning times can occur above 30 000 feet.

REFERENCES

1. NAA Report, SID63-754, Data Report for the Wind Tunnel Test of the Apollo Launch Escape Vehicle Jet Effect Model FSJ-1 in the Langley 16' Transonic Tunnel. July 1963.

2. NAA Report, SID63-1460, Vol. 2, Data Report for the Apollo Model FSJ-3 Wind Tunnel Test in Tunnel A of the von Karman Gas Dynamic Facility. AEDC (1st Series), December 1963.

3. NAA Report, SID63-1464, Data Report for the Wind Tunnel Test of the Apollo Launch Escape Vehicle Jet Effect Model FSJ-1 in the Langley 16' Transonic Tunnel. December 1963.

4. NAA Memo to MSC, CM Cavity Pressure Data During Aborts at Various Altitudes from Saturn IB and V Nominal Boost Trajectory. Reference 65MA15136, December 20, 1965.

5. Brode, H. L: A Calculation of the Blast Wave from A Spherical Charge of TNT. Rand Corp. Report No. RM-1965, August 21, 1957.

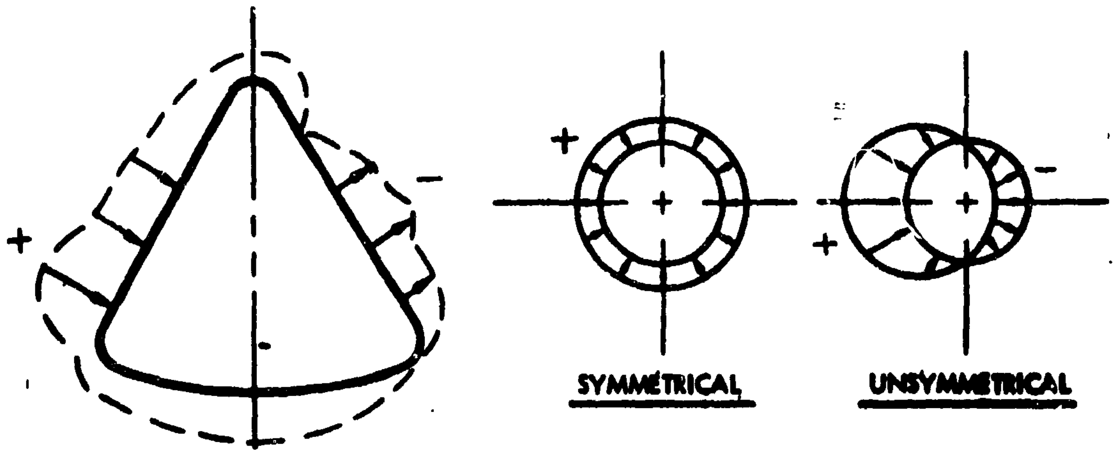
6. Aeronutronic Technical Report No. U-108:98. Explosive Hazards of Rocket Launchings. November 30, 1960.

7. MSC Internal Note - 64-ET-69: Procedure for Calculating the Overpressure Experienced by a Spacecraft Aborting from a Detonating Launch Vehicle. November 3, 1965.

8. NASA Program Apollo Working Paper No. 1161: Apollo Range Safety Destruct Time Delay - Saturn IB and Saturn V. January 26, 1965.

9. Addendum - NASA Program Apollo Working Paper No. 1161: Apollo Range Safety Destruct Time Delay - Saturn IB and Saturn V (Off-Nominal Initial Attitudes and Thrust Dispersions). August 3, 1965.

TABLE I.- MAXIMUM ALLOWABLE LIMIT DIFFERENTIAL PRESSURES



	Forward heat shield (stations 81-133)	Crew compartment heat shield (stations 23-81)	Aft heat shield (stations 0-23)
Symmetrical pressure limit, psi			
Crush (+)	+6.1	+6.1	+12.0
Burst (-)	-10.0	-4.5	-5.7
Unsymmetrical pressure limit, psi			
Crush (+)	+12.1	+11.1	+16.6
Burst (-)	-4.7	-5.8	-5.7

P_A = Aerodynamic pressure (psi)

$$= P_{External} - P_{Cavity}$$

$$P_{External} = P_{\infty} + C_p q$$

$$P_{Cavity} = P_{\infty} - \left(\pm P_c\right)$$

$$P_A = C_p q - \left(\pm P_c\right)$$

TABLE II.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IB STAGE EXPLOSION (SATURN IB)

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
			Pad			
1.50	1.59	286	21.46	0.28	9.78	0.82
2.00	2.25	528	6.01	0.39	4.64	1.58
2.50	3.09	951	2.31	0.51	2.40	2.57
3.00	4.04	1515	1.25	0.55	0.83	2.98
			5000 ft			
1.00	1.08	246	14.37	0.48	4.10	1.96
1.50	1.72	440	4.47	0.58	2.80	2.81
2.00	2.52	800	1.75	0.67	1.91	3.69
2.50	3.44	1335	0.89	0.73	1.10	4.26
			10 000 ft			
1.00	1.08	246	12.70	0.65	2.75	2.92
1.50	1.73	446	3.79	0.73	2.17	3.61
2.00	2.56	848	1.39	0.80	1.64	4.26
2.50	3.54	1441	0.69	0.84	0.96	4.46
			15 000 ft			
1.00	1.08	246	11.41	0.79	2.31	3.49
1.50	1.72	432	3.56	0.86	1.94	4.03
2.00	2.60	892	1.13	0.91	1.57	4.43
2.50	3.65	1556	0.54	0.92	0.85	4.36

TABLE II.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IB STAGE EXPLOSION (SATURN IB) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
			20 000 ft			
1.00	1.07	221	13.16	0.91	2.11	3.77
1.50	1.68	383	4.03	0.96	1.95	4.06
1.80	2.20	648	1.57	0.99	1.75	4.22
2.00	2.61	897	0.98	1.00	1.63	4.27
			25 000 ft			
1.50	1.58	253	8.81	1.06	1.97	4.05
1.80	1.95	356	4.20	1.08	1.85	4.15
2.00	2.32	558	1.78	1.10	1.72	4.20
2.50	4.10	2041	0.27	1.08	0.64	3.76
			30 000 ft			
1.00	1.04	186	16.27	1.20	1.92	4.18
1.50	1.57	236	9.38	1.22	1.90	4.25
1.80	1.94	333	4.33	1.24	1.77	4.31
1.90	6.62	5551	0.01	0.93	0.10	1.94
			35 000 ft			
1.00	1.05	198	12.79	1.38	1.85	4.35
1.30	1.37	239	8.28	1.39	1.85	4.36
1.40	1.49	268	6.38	1.40	1.85	4.38
1.50	11.07	10830	0.00	0.78	0.00	0.89

TABLE II.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IB STAGE EXPLOSION (SATURN IB) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
			40 000 ft			
0.00	0.04	< 180	> 13.00	1.50	0.00	4.29
0.50	0.54	188	13.01	1.49	0.69	4.24
0.80	0.85	200	11.24	1.49	1.00	4.21
1.10	1.19	280	5.21	1.56	1.88	4.29
1.20	--	--	--	--	--	--
			45 000 ft			
0.00	0.04	< 190	> 12.00	1.61	0.00	3.91
0.30	0.34	190	11.59	1.61	0.50	3.88
0.60	0.64	199	10.44	1.60	0.75	3.87
0.80	0.86	234	7.12	1.60	1.00	3.85
0.90	--	--	--	--	--	--
			50 000 ft			
0.00	0.04	< 195	> 10.00	1.76	0.00	3.65
0.30	0.34	194	9.94	1.75	0.50	3.63
0.60	0.66	226	7.02	1.75	0.65	3.61
0.70	--	--	--	--	--	--
			55 000 ft			
0.00	0.04	< 195	> 9.00	1.91	0.00	3.41
0.30	0.34	196	8.90	1.90	0.55	3.39
0.60	0.65	232	5.99	1.90	0.90	3.38
0.70	--	--	--	--	--	--

TABLE II.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IB STAGE EXPLOSION (SATURN IB) - Concluded

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
			60 000 ft			
0.00	0.04	< 195	> 8.00	2.07	0.00	3.14
0.30	0.34	197	7.89	2.06	0.65	3.12
0.60	0.65	239	5.06	2.06	1.20	3.11
0.70	--	--	--	--	--	--

TABLE III.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IVB STAGE EXPLOSION (SATURN IB)

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
			Pad			
2.00	2.19	466	10.04	0.37	5.25	1.42
2.30	2.65	680	4.86	0.45	3.34	2.06
2.50	3.00	861	3.29	0.50	2.64	2.48
3.00	3.93	1414	1.63	0.55	0.94	2.99
			5000 ft			
1.50	1.58	269	19.02	0.56	3.06	2.62
2.00	2.28	552	4.35	0.65	2.12	3.43
2.30	2.80	822	2.27	0.70	1.72	3.93
2.50	3.18	1041	1.63	0.73	1.38	4.20
			10 000 ft			
1.50	1.56	234	24.98	0.71	2.34	3.44
2.00	2.22	483	5.21	0.78	1.81	4.03
2.50	3.16	1016	1.53	0.84	1.31	4.53
3.00	4.15	1617	0.83	0.81	0.57	4.09
			15 000 ft			
2.00	2.15	381	8.01	0.88	1.75	4.24
2.20	2.45	525	4.15	0.90	1.62	4.37
2.50	3.08	917	1.60	0.93	1.37	4.53
3.00	4.11	1551	0.79	0.89	0.60	4.01

TABLE III.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IVB STAGE EXPLOSION (SATURN IB) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
			20 000 ft			
2.00	2.07	264	17.31	0.98	1.78	4.19
2.20	2.32	356	8.78	0.99	1.71	4.25
2.50	2.78	572	3.28	1.00	1.58	4.27
2.80	3.46	1016	1.25	1.00	1.13	4.15
			25 000 ft			
2.50	2.59	301	12.27	1.11	1.65	4.21
2.80	2.98	443	5.17	1.12	1.55	4.21
3.00	3.32	629	2.54	1.11	1.26	4.15
3.30	4.08	1153	0.93	1.07	0.67	3.67
			30 000 ft			
2.50	2.56	260	16.39	1.27	1.60	4.36
2.70	2.80	330	9.44	1.28	1.54	4.37
3.00	3.23	527	3.36	1.29	1.26	4.31
3.10	5.69	3206	0.19	1.03	0.25	2.50
			35 000 ft			
2.50	2.59	322	9.50	1.46	1.55	4.49
2.60	2.73	392	6.03	1.47	1.52	4.46
2.70	9.93	8318	0.00	0.84	0.00	1.06

TABLE III.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IVB STAGE EXPLOSION (SATURN IB) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
			40 000 ft			
2.10	2.15	244	17.14	1.63	1.68	4.42
2.20	2.27	291	11.33	1.63	1.64	4.44
2.30	2.41	369	6.55	1.64	1.61	4.46
2.40	--	--	--	--	--	--
			45 000 ft			
1.80	1.83	198	25.92	1.75	1.89	4.11
1.90	1.94	243	16.28	1.77	1.85	4.12
2.00	2.07	298	10.18	1.78	1.80	4.15
2.10	--	--	--	--	--	--
			50 000 ft			
1.60	1.62	184	28.31	1.90	2.08	3.84
1.70	1.73	207	21.93	1.92	2.04	3.95
1.80	1.85	259	13.28	1.93	1.99	3.88
1.90	--	--	--	--	--	--
			55 000 ft			
1.50	1.52	186	25.48	2.07	2.26	3.57
1.60	1.63	210	19.73	2.09	2.22	3.59
1.70	1.74	263	11.97	2.10	2.17	3.61
1.80	--	--	--	--	--	--

TABLE III.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IVB STAGE EXPLOSION (SATURN IB) - Concluded

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
60 000 ft						
1.50	1.52	203	19.66	2.25	2.46	3.28
1.60	1.64	253	12.33	2.26	2.41	3.29
1.70	1.76	316	7.44	2.27	2.37	3.30
1.80	--	--	--	--	--	--

TABLE IV.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IC STAGE EXPLOSION (SATURN V)

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
Pad						
1.50	1.58	345	47.72	0.28	10.38	0.78
2.00	2.19	548	16.67	0.38	4.90	1.51
3.00	3.89	1473	2.67	0.55	1.02	2.99
4.00	5.74	2551	1.28	0.48	0.26	2.23
5000 ft						
1.00	1.10	344	22.10	0.49	4.05	1.99
1.50	1.71	518	9.29	0.58	2.84	2.78
2.00	2.45	855	3.74	0.67	1.94	3.60
2.80	3.99	1752	1.26	0.70	1.72	4.07
10 000 ft						
1.30	1.10	347	19.79	0.64	2.82	2.85
1.50	1.72	522	7.57	0.72	2.22	3.53
2.00	2.49	876	2.97	0.79	1.69	4.16
2.50	3.49	1475	1.36	0.83	1.00	4.46
15 000 ft						
1.00	1.10	349	17.56	0.79	2.28	3.54
1.50	1.69	495	8.03	0.85	1.98	3.98
2.00	2.44	843	2.92	0.90	1.61	4.39
2.50	3.55	1533	1.12	0.93	0.96	4.43

TABLE IV.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT: S-IC STAGE EXPLOSION (SATURN V) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
20 000 ft						
1.50	1.65	437	9.68	0.97	1.90	4.16
2.00	2.32	674	3.83	1.00	1.68	4.33
2.50	3.36	1334	1.23	1.00	1.19	4.26
3.00	4.34	1793	0.76	0.94	0.54	3.53
25 000 ft						
1.00	1.07	297	21.21	1.06	1.95	4.10
1.50	1.59	349	14.40	1.08	1.89	[illegible].22
2.00	2.16	466	7.56	1.11	1.71	4.33
3.00	4.44	1976	0.61	1.04	0.49	3.44
30 000 ft						
1.50	1.59	337	13.56	1.26	1.78	4.50
2.00	2.15	450	7.45	1.28	1.62	4.56
2.20	2.45	595	3.97	1.29	1.55	4.59
2.30	6.71	5338	0.09	0.94	0.09	2.00
35 000 ft						
1.00	1.07	323	14.60	1.43	1.71	4.70
1.50	1.60	382	9.96	1.46	1.70	4.71
1.70	1.85	454	6.71	1.47	1.63	4.76
1.80	11.44	> 11000	0.00	0.78	0.00	0.92

TABLE IV.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IC STAGE EXPLOSION (SATURN V) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
40 000 ft						
0.50	0.57	325	13.32	1.59	1.67	4.66
1.00	1.09	365	10.09	1.62	1.71	4.70
1.30	1.45	477	5.49	1.64	1.71	4.71
1.40	--	--	--	--	--	--
45 000 ft						
0.00	0.09	< 350	> 9.60	1.77	1.24	4.66
0.50	0.58	358	9.62	1.80	1.68	4.66
0.80	0.91	401	7.42	1.82	1.70	4.70
0.90	--	--	--	--	--	--
50 000 ft						
0.40	0.44	197	9.70	1.97	1.67	4.48
0.50	0.54	201	9.22	1.99	1.73	4.50
0.60	0.66	226	7.02	2.00	1.74	4.51
0.70	--	--	--	--	--	--
55 000 ft						
0.50	0.54	205	8.06	2.16	1.79	4.20
0.60	0.65	233	5.99	2.17	1.85	4.21
0.70	--	--	--	--	--	--

TABLE IV.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IC STAGE EXPLOSION (SATURN V) - Concluded

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
60 000 ft						
0.50	0.54	207	7.04	2.25	2.18	3.59
0.60	0.65	240	5.06	2.27	2.18	3.60
0.70	--	--	--	--	--	--

TABLE V.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT, S-II STAGE EXPLOSION (SATURN V)

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
Pad						
2.00	2.13	477	27.18	0.38	4.94	1.44
2.50	2.86	822	8.39	0.48	2.87	2.28
3.00	3.78	1358	3.41	0.55	1.16	2.97
3.50	4.73	1932	2.04	0.53	0.48	2.75
5000 ft						
1.60	1.71	395	23.70	0.58	2.84	2.78
2.00	2.24	607	9.21	0.64	2.15	3.40
2.50	3.09	1061	3.23	0.72	1.47	4.15
3.00	4.08	1666	1.65	0.72	0.65	4.06
10 000 ft						
1.60	1.69	362	27.71	0.72	2.25	3.50
2.00	2.19	548	10.85	0.77	1.87	3.95
2.50	3.02	976	3.44	0.83	1.47	4.45
3.00	4.05	1622	1.55	0.81	0.61	4.15
15 000 ft						
2.00	2.13	450	16.04	0.89	1.75	4.26
2.50	2.86	792	4.76	0.92	1.48	4.52
3.00	3.92	1465	1.63	0.91	0.71	4.20
3.50	4.77	1882	1.14	0.84	0.39	3.45

TABLE V.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT, S-II STAGE EXPLOSION (SATURN V) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
20 000 ft						
2.80	3.07	677	6.19	1.01	1.43	4.34
3.00	3.38	825	4.10	1.01	1.15	4.25
3.50	4.26	1282	1.83	0.95	0.58	3.62
4.00	4.92	1471	1.47	0.88	0.38	3.07
25 000 ft						
3.50	3.82	755	4.61	1.11	0.84	3.99
4.00	4.49	973	2.76	1.04	0.47	3.41
4.50	5.07	1071	2.31	0.97	0.36	2.91
5.00	5.57	1079	2.27	0.92	0.28	2.57
27 500 ft						
3.00	3.12	448	14.43	1.22	1.37	4.42
3.50	3.72	625	6.76	1.19	0.90	4.11
4.00	4.34	799	3.97	1.12	0.53	3.58
7.00	7.50	997	2.54	0.80	0.03	1.63
30 000 ft						
3.70	4.01	763	4.25	1.26	0.65	4.03
4.00	4.43	921	2.87	1.20	0.49	3.57
4.50	5.00	1008	2.39	1.14	0.34	3.13
5.50	5.96	960	2.63	1.02	0.19	2.43

TABLE V.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT, S-II STAGE EXPLOSION (SATURN V) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
32 500 ft						
2.50	2.56	332	27.51	1.41	1.47	4.74
3.00	3.13	486	11.40	1.42	1.28	4.70
3.40	3.69	744	4.35	1.40	0.85	4.40
3.50	7.22	4624	0.23	0.97	0.05	1.82
35 000 ft						
2.80	2.90	444	13.68	1.52	1.40	4.75
3.10	3.32	643	5.84	1.52	1.09	4.64
3.20	9.79	7795	0.07	0.87	0.00	1.14
40 000 ft						
2.30	2.36	358	21.35	1.71	1.49	4.81
2.40	2.48	405	16.09	1.71	1.47	4.81
2.50	2.60	455	12.25	1.72	1.45	4.80
2.60	2.73	517	9.12	1.72	1.42	4.80
2.70	--	--	--	--	--	--
45 000 ft						
2.00	2.05	329	24.31	1.91	1.56	4.82
2.10	2.16	359	19.95	1.92	1.54	4.83
2.20	2.28	415	14.32	1.93	1.51	4.84
2.30	2.42	503	9.18	1.94	1.48	4.83
2.40	--	--	--	--	--	--

TABLE V.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT, S-II STAGE EXPLOSION (SATURN V) - Concluded

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
50 000 ft						
1.80	1.84	323	23.62	2.11	1.67	4.64
1.90	1.95	354	19.33	2.12	1.64	4.66
2.00	2.08	415	13.49	2.13	1.63	4.67
2.10	--	--	--	--	--	--
55 000 ft						
1.70	1.74	328	21.29	2.30	1.81	4.32
1.80	1.85	360	17.32	2.31	1.78	4.35
1.90	1.97	426	11.96	2.33	1.74	4.37
2.00	--	--	--	--	--	--
60 000 ft						
1.70	1.75	374	14.92	2.41	2.10	3.73
1.80	1.87	442	10.32	2.43	2.05	3.75
1.90	--	--	--	--	--	--

TABLE VI.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IVB STAGE EXPLOSIONS (SATURN V)

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
Pad						
2.20	2.49	599	6.12	0.43	3.75	1.89
2.50	3.00	861	3.29	0.50	2.64	2.48
2.70	3.36	1070	2.38	0.53	1.91	2.77
3.00	3.93	1414	1.63	0.55	0.94	2.99
5000 ft						
1.90	2.13	478	5.68	0.63	2.25	3.30
2.00	2.28	552	4.35	0.65	2.10	3.44
2.20	2.63	729	2.75	0.68	1.83	3.77
2.50	3.18	1042	1.63	0.73	1.38	4.20
10 000 ft						
1.70	1.6[illegible]	318	12.53	0.73	2.16	3.60
2.00	2.23	494	4.99	0.77	1.85	3.95
2.20	2.59	685	2.77	0.80	1.64	4.23
2.50	3.18	1038	1.48	0.83	1.27	4.50
15 000 ft						
2.00	2.15	384	7.87	0.89	1.74	4.26
2.20	2.47	543	3.89	0.91	1.60	4.43
2.40	2.88	795	2.00	0.93	1.47	4.53
2.70	3.52	1210	1.09	0.93	1.00	4.46

TABLE VI.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IVB STAGE EXPLOSIONS (SATURN V) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
20 000 ft						
2.20	2.30	318	11.35	1.00	1.68	4.33
2.40	2.57	426	5.96	1.00	1.59	4.35
2.70	3.09	708	2.22	1.02	1.41	4.34
3.00	3.75	1124	1.08	1.00	0.88	4.03
25 000 ft						
2.50	2.57	280	14.46	1.12	1.61	4.35
2.80	2.96	422	5.73	1.13	1.51	4.35
3.10	3.45	660	2.32	1.13	1.11	4.21
3.40	4.14	1114	0.98	1.07	.623	2.71
30 000 ft						
2.70	2.79	319	10.18	1.31	1.47	4.58
3.00	3.19	466	4.38	1.31	1.26	4.53
3.10	3.37	577	2.79	1.31	1.09	4.46
3.30	5.88	3194	0.19	1.03	0.20	2.47
35 000 ft						
2.50	2.58	298	11.34	1.50	1.46	4.77
2.60	2.69	330	8.94	1.51	1.44	4.76
2.70	2.83	397	5.85	1.51	1.40	4.76
2.80	10.44	878	0.00	0.83	0.00	1.06

TABLE VI.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IVB STAGE EXPLOSIONS (SATURN V) - Continued

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
40 000 ft						
2.30	2.37	302	10.46	1.70	1.49	4.81
2.40	2.54	413	5.08	1.71	1.49	4.81
2.50	--	--	--	--	--	--
45 000 ft						
1.90	1.93	196	26.26	1.91	1.59	4.80
2.00	2.04	242	16.44	1.91	1.58	4.81
2.10	2.16	297	10.24	1.92	1.54	4.82
2.20	--	--	--	--	--	--
50 000 ft						
1.70	1.72	183	28.51	2.10	1.69	4.61
1.80	1.84	228	17.67	2.11	1.67	4.64
1.90	1.96	283	10.80	2.13	1.64	4.66
2.00	--	--	--	--	--	--
55 000 ft						
1.60	1.62	185	25.87	2.29	1.85	4.32
1.70	1.73	209	19.85	2.30	1.82	4.33
1.80	1.85	267	11.59	2.32	1.77	4.35
1.90	--	--	--	--	--	--

TABLE VI.- SHOCK ARRIVAL TIMES, OVERPRESSURES AND FLIGHT PARAMETERS AT TIME OF SHOCK ARRIVAL:

PAD - 60 000 FT; S-IVB STAGE EXPLOSIONS (SATURN V) - Concluded

t_d, sec	t_{sa}, sec	R, ft	ΔP, psi	M#	C_T	q, psi
60 000 ft						
1.60	1.63	220	16.71	2.39	2.14	3.73
1.70	1.75	280	9.80	2.41	2.09	3.73
1.80	--	--	--	--	--	--

TABLE VII.- LOAD SUMMARY - S-IB EXPLOSION (SATURN IB)

Pad												
	t_{sa} = 1.59 (t_d = 1.50)			t_{sa} = 2.25 (t_d = 2.00)			t_{sa} = 3.09 (t_d = 2.50)			t_{sa} = 4.03 (t_d = 3.00)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	0.03		21.49	0.04		12.06	0.18		4.80	0.40		2.90
67.5	-0.04		21.42	-0.10		11.92	0.23		4.85	1.31		3.81
82.5	-0.13	21.46	21.33	-0.26	12.02	11.76	0.20	4.62	4.82	1.11	2.50	3.61
97.5	0.27		21.73	0.51		12.53	1.10		5.72	1.90		4.40
112.5	0.67		22.13	1.28		13.30	1.80		6.42	2.19		4.69
157.5	0.92		22.38	1.75		13.77	2.88		7.50	3.42		5.92
180.0	0.72		22.18	1.38		13.40	2.35		6.97	3.08		5.58
	$\bar{P}_{TOT}$ = 21.80 psi			$\bar{P}_{TOT}$ = 12.67 psi			$\bar{P}_{TOT}$ = 5.87 psi			$\bar{P}_{TOT}$ = 4.45 psi		
5000 ft												
	t_{sa} = 1.08 (t_d = 1.00)			t_{sa} = 1.72 (t_d = 1.50)			t_{sa} = 2.52 (t_d = 2.00)			t_{sa} = 3.44 (t_d = 2.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.09		28.65	-0.11		8.83	-0.07		3.43	0.13		1.91
67.5	-0.27		28.47	-0.51		8.43	-0.09		3.41	-0.10		1.68
82.5	-0.48	28.74	28.26	-0.47	8.94	8.47	-0.15	3.50	3.35	0.74	1.78	2.52
97.5	0.49		29.23	1.07		10.01	2.03		5.53	2.06		3.84
112.5	1.45		30.19	2.18		11.12	3.35		6.85	2.83		4.61
157.5	2.03		30.77	2.57		11.91	3.94		7.44	4.64		6.42
180.0	1.57		30.31	2.43		11.37	3.19		6.69	2.98		4.76
	$\bar{P}_{TOT}$ = 29.40 psi			$\bar{P}_{TOT}$ = 10.00 psi			$\bar{P}_{TOT}$ = 5.27 psi			$\bar{P}_{TOT}$ = 3.73 psi		

TABLE VII.- LOAD SUMMARY - S-IB EXPLOSION (SATURN IB) - Continued

10 000 ft												
	t_{sa} = 1.08 (t_d = 1.00)			t_{sa} = 1.73 (t_d = 1.50)			t_{sa} = 2.56 (t_d = 2.00)			t_{sa} = 3.54 (t_d = 2.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.28		25.12	-0.20		7.38	-0.33		2.45	0.03		1.41
67.5	-1.10		24.30	-0.52		7.06	-0.11		2.67	0.91		2.29
82.5	-1.00		24.40	-0.54		7.04	0.74		3.52	1.19		2.57
97.5	1.13	25.40	26.53	1.76	7.58	9.34	--	2.78	5.44	2.88	1.38	4.26
112.5	2.58		27.98	3.19		10.77	4.09		6.87	3.89		5.27
157.5	3.04		28.44	3.81		11.39	4.38		7.16	3.28		4.66
180.0	2.59		27.99	3.03		10.61	3.21		5.99	2.27		3.65
	$\bar{P}_{TOT}$ = 26.37 psi			$\bar{P}_{TOT}$ = 9.11 psi			$\bar{P}_{TOT}$ = 4.98 psi			$\bar{P}_{TOT}$ = 3.60 psi		

15 000 ft												
	t_{sa} = 1.08 (t_d = 1.00)			t_{sa} = 1.72 (t_d = 1.50)			t_{sa} = 2.60 (t_d = 2.00)			t_{sa} = 3.65 (t_d = 2.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.46		22.36	-0.56		6.56	-0.58		1.68	-0.15		0.93
67.5	-0.68		22.14	-0.69		6.43	-0.35		1.91	1.11		2.19
82.5	-0.39		22.43	-0.15		6.97	1.29		3.55	1.76		2.84
97.5	1.93	22.82	24.75	2.16	7.12	9.28	2.96	2.26	5.22	3.56	1.08	4.64
112.5	3.41		26.23	3.68		10.80	4.69		6.95	4.82		5.90
157.5	3.50		26.32	3.28		10.40	4.38		6.64	2.14		3.22
180.0	3.17		25.99	3.14		10.26	3.42		5.68	1.77		2.85
	$\bar{P}_{TOT}$ = 24.3 psi			$\bar{P}_{TOT}$ = 8.72 psi			$\bar{P}_{TOT}$ = 4.66 psi			$\bar{P}_{TOT}$ = 3.45 psi		

TABLE VII.- LOAD SUMMARY - S-IB EXPLOSION (SATURN IB) - Concluded

20 000 ft												
	t_{sa} = 1.07 (t_d = 1.00)			t_{sa} = 1.68 (t_d = 1.50)			t_{sa} = 2.20 (t_d = 1.80)			t_{sa} = 2.61 (t_d = 2.00)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.60		25.72	-0.24		7.82	-0.12		3.02	-0.05		1.91
67.5	-0.71		25.61	-0.27		7.79	0.03		3.17	0.19		2.15
82.5	-0.12		26.20	1.92		9.98	0.75		3.89	0.90		2.86
97.5	2.37	26.32	28.69	3.00	8.06	11.06	3.21	3.14	6.35	3.31	1.96	5.27
112.5	4.01		30.33	4.74		12.80	4.90		8.04	4.96		6.92
157.5	3.58		29.90	4.13		12.19	3.99		7.13	3.90		5.86
180.0	3.43		29.75	4.08		12.14	3.94		7.08	3.72		5.68
	$\bar{P}_{TOT}$ = 28.08 psi			$\bar{P}_{TOT}$ = 10.63 psi			$\bar{P}_{TOT}$ = 5.61 psi			$\bar{P}_{TOT}$ = 4.48 psi		

25 000 ft												
	t_{sa} = 1.58 (t_d = 1.50)			t_{sa} = 1.95 (t_d = 1.80)			t_{sa} = 2.32 (t_d = 2.00)			t_{sa} = 4.10 (t_d = 2.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.21		17.41	-0.73		8.17	-0.10		3.46	0.46		1.00
67.5	-0.24		17.38	-0.26		8.14	-0.13		3.43	1.45		1.99
82.5	1.93		19.55	0.47		8.87	0.99		4.55	1.99		2.53
97.5	3.01	17.62	20.63	3.08	8.40	11.48	3.55	3.56	7.11	3.33	0.54	3.87
112.5	4.74		22.36	4.85		13.25	5.34		8.90	4.28		4.82
157.5	4.13		21.75	4.22		12.62	4.30		7.86	2.61		3.15
180.0	4.09		21.71	4.18		12.58	4.07		7.63	2.52		3.06
	$\bar{P}_{TOT}$ = 20.21 psi			$\bar{P}_{TOT}$ = 10.79 psi			$\bar{P}_{TOT}$ = 6.23 psi			$\bar{P}_{TOT}$ = 3.07 psi		

TABLE VIII.- LOAD SUMMARY - S-IVB EXPLOSION (SATURN IB)

Pad												
	t_{sa} = 2.19 (t_d = 2.00)			t_{sa} = 2.65 (t_d = 2.30)			t_{sa} = 3.00 (t_d = 2.50)			t_{sa} = 3.93 (t_d = 3.00)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.04		20.12	0.10		9.82	0.17		6.75	0.39		3.65
67.5	-0.02		20.06	0.03		9.75	0.22		6.80	1.30		4.56
82.5	-0.15	20.08	19.93	-0.06	9.72	9.66	0.19	6.58	6.77	1.11	3.26	4.37
97.5	0.61		20.69	0.87		10.59	1.06		7.64	1.90		5.16
120.0	1.44		21.52	1.74		11.46	1.73		8.31	2.19		5.45
157.5	1.52		21.60	2.25		11.97	2.77		9.35	3.43		6.69
180.0	1.15		21.23	1.76		11.48	2.26		8.84	3.08		6.34
	$\bar{P}_{TOT}$ = 20.75 psi			$\bar{P}_{TOT}$ = 10.68 psi			$\bar{P}_{TOT}$ = 7.77 psi			$\bar{P}_{TOT}$ = 5.20 psi		
5000 ft												
	t_{sa} = 1.58 (t_d = 1.50)			t_{sa} = 2.28 (t_d = 2.00)			t_{sa} = 2.80 (t_d = 2.30)			t_{sa} = 3.18 (t_d = 2.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.02		38.02	-0.04		8.66	-0.03		4.51	-0.05		3.21
67.5	-0.03		38.01	-0.10		8.60	0.10		4.64	0.02		3.28
87.5	-0.09	38.04	37.95	-0.12	8.70	8.58	0.12	4.54	4.66	1.15	3.26	4.41
97.5	0.93		38.97	1.48		10.18	2.30		6.84	2.29		5.55
120.0	1.81		39.85	2.55		11.25	3.51		8.05	3.33		6.59
157.5	2.73		40.77	3.71		12.41	4.26		8.80	4.57		7.83
180.0	2.15		40.19	3.04		11.74	3.12		7.66	3.16		6.42
	$\bar{P}_{TOT}$ = 39.11 psi			$\bar{P}_{TOT}$ = 10.87 psi			$\bar{P}_{TOT}$ = 6.51 psi			$\bar{P}_{TOT}$ = 5.41 psi		

TABLE VIII.- LOAD SUMMARY - S-IVB EXPLOSION (SATURN IB) - Continued

10 000 ft												
	$t_{sa} = 1.56$ $(t_d = 1.50)$			$t_{sa} = 2.22$ $(t_d = 2.00)$			$t_{sa} = 3.16$ $(t_d = 2.50)$			$t_{sa} = 4.15$ $(t_d = 3.00)$		
ϕ	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}
0.0	-0.19		49.77	-0.37		10.05	-0.15		2.91	0.19		1.85
67.5	-0.52		49.44	-0.34		10.08	0.51		3.57	1.13		2.79
82.5	-0.61		49.35	-0.03		10.39	0.82		3.88	1.31		2.97
97.5	1.64	49.96	51.60	2.39	10.42	12.81	2.89	3.06	5.95	2.21	1.66	3.87
120.0	3.08		53.04	3.89		14.31	4.15		7.21	2.79		4.45
157.5	3.59		53.55	4.06		14.48	4.16		7.22	3.41		5.07
180.0	3.04		53.00	3.32		13.74	2.88		5.94	2.74		4.40
	$\bar{P}_{TOT}$ = 51.39 psi			$\bar{P}_{TOT}$ = 12.33 psi			$\bar{P}_{TOT}$ = 5.38 psi			$\bar{P}_{TOT}$ = 3.71 psi		
15 000 ft												
	$t_{sa} = 2.15$ $(t_d = 2.00)$			$t_{sa} = 2.45$ $(t_d = 2.20)$			$t_{sa} = 3.08$ $(t_d = 2.50)$			$t_{sa} = 4.11$ $(t_d = 3.00)$		
ϕ	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}
0.0	-0.64		15.38	-0.58		7.72	-0.48		2.72	0.16		1.74
67.5	-0.61		15.41	-0.36		7.94	0.43		3.63	1.28		2.86
82.5	0.07	16.02	16.09	0.36	8.30	8.66	1 12	3.20	4.32	1.45	1.58	3.03
97.5	0.49		16.51	2.91		11.21	3.98		7.18	2.10		3.68
120.0	4.46		20.48	4.61		12.91	5.84		9.04	2.43		4.01
157.5	4.07		20.09	4.31		12.61	4.90		8.10	3.75		5.33
180.0	3.41		19.43	3.37		11.67	3.42		6.62	3.49		5.07
	$\bar{P}_{TOT}$ = 17.66 psi			$\bar{P}_{TOT}$ = 10.50 psi			$\bar{P}_{TOT}$ = 6.16 psi			$\bar{P}_{TOT}$ = 3.72 psi		

TABLE VIII.- LOAD SUMMARY - S-IVB EXPLOSION (SATURN IB) - Continued

20 000 ft												
	t_{sa} = 2.07 (t_d = 2.00)			t_{sa} = 2.32 (t_d = 2.20)			t_{sa} = 2.78 (t_d = 2.50)			t_{sa} = 3.46 (t_d = 2.80)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.18		34.44	-0.12		17.44	-0.05		6.51	0.34		2.84
67.5	0.12		34.74	0.04		17.60	0.19		6.75	1.12		3.62
82.5	0.60	34.62	35.22	0.76	17.56	18.32	0.90	6.56	7.46	1.74	2.50	4.24
97.5	3.13		37.75	3.24		20.80	3.31		6.87	3.54		6.04
120.0	4.87		39.49	4.94		22.50	4.96		11.52	4.81		7.31
157.5	4.09		38.71	4.03		21.59	3.90		10.46	2.98		5.48
180.0	4.05		38.67	3.98		21.54	3.72		10.28	2.90		5.40
	$\bar{P}_{TOT}$ = 37.08 psi			$\bar{P}_{TOT}$ = 20.05 psi			$\bar{P}_{TOT}$ = 9.08 psi			$\bar{P}_{TOT}$ = 5.14 psi		

25 000 ft												
	t_{sa} = 2.59 (t_d = 2.50)			t_{sa} = 2.98 (t_d = 2.80)			t_{sa} = 3.32 (t_d = 3.00)			t_{sa} = 4.08 (t_d = 3.30)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.11		24.43	-0.12		10.22	0.05		5.18	0.04		1.90
67.5	0.13		24.67	-0.15		10.19	0.47		5.55	1.38		3.24
82.5	0.98	24.54	25.52	0.97	10.34	11.31	1.14	5.08	6.22	1.91	1.86	3.77
97.5	3.55		28.09	3.57		13.91	3.29		8.37	3.26		5.12
120.0	5.35		29.89	5.37		15.71	4.78		9.86	4.23		6.09
157.5	4.30		28.84	4.32		14.66	3.49		8.57	2.25		4.11
180.0	4.08		28.62	4.10		14.44	3.42		8.50	2.18		4.04
	$\bar{P}_{TOT}$ = 27.26 psi			$\bar{P}_{TOT}$ = 13.02 psi			$\bar{P}_{TOT}$ = 7.57 psi			$\bar{P}_{TOT}$ = 4.22 psi		

TABLE VIII.- LOAD SUMMARY - S-IVB EXPLOSION (SATURN IB) - Concluded

30 000 ft												
	t_{sa} = 2.56 (t_d = 2.50)			t_{sa} = 2.80 (t_d = 2.70)			t_{sa} = 3.23 (t_d = 3.00)			t_{sa} = 5.69 (t_d = 3.10)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.12		32.66	-0.07		18.81	-0.04		6.68	-0.04		0.32
67.5	-0.32		32.46	-0.07		18.81	0.34		7.06	0.74		1.12
82.5	1.25	32.78	34.03	1.41	18.88	20.29	1.71	6.72	8.43	0.80	0.38	1.18
97.5	4.01		36.79	4.04		22.92	4.04		10.76	1.05		1.43
120.0	6.00		38.78	5.83		24.71	5.54		12.26	1.66		2.04
157.5	4.77		37.55	4.56		24.44	4.16		10.88	2.46		2.84
180.0	4.36		37.14	4.17		23.05	3.76		10.48	2.35		2.73
	$\bar{P}_{TOT}$ = 35.75 psi			$\bar{P}_{TOT}$ = 22.02 psi			$\bar{P}_{TOT}$ = 9.66 psi			$\bar{P}_{TOT}$ = 1.69 psi		

TABLE IX.- LOAD SUMMARY - S-IC EXPLOSION (SATURN V)

Pad												
	t_{sa} = 1.58 (t_d = 1.50)			t_{sa} = 2.19 (t_d = 2.00)			t_{sa} = 3.89 (t_d = 3.00)			t_{sa} = 5.74 (t_d = 4.00)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	0.03	95.44	95.47	0.0	33.34	33.38	0.35	5.34	5.69	-0.05	2.56	2.51
67.5	-0.04		95.40	-0.09		33.25	1.00		6.34	0.23		2.19
82.5	-0.12		95.32	-0.25		33.09	0.86		6.20	0.40		2.96
97.5	0.26		95.70	0.49		33.83	1.81		7.15	0.69		3.25
112.5	0.64		96.08	1.23		34.57	2.25		7.59	0.58		3.14
157.5	0.88		96.32	1.68		35.02	3.4[illegible]		8.77	2.32		4.88
180.0	0.69		96.13	1.33		34.67	3.04		8.38	2.03		4.59
	$\bar{P}_{TOT}$ = [illegible]7.77			$\bar{P}_{TOT}$ = 33.96			$\bar{P}_{TOT}$ = 7.18			$\bar{P}_{TOT}$ = 3.43		
5000 ft												
	t_{sa} = 1.10 (t_d = 1.00)			t_{sa} = 1.71 (t_d = 1.50)			t_{sa} = 2.45 (t_d = 2.00)			t_{sa} = 3.99 (t_d = 2.80)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.16	44.20	44.04	-0.24	18.58	18.34	-0.28	7.48	7.20	0.07	2.52	2.59
67.5	-0.34		43.86	-0.63		17.95	-0.30		7.18	0.21		2.73
82.5	-0.5[illegible]		43.65	-0.66		17.98	-0.39		7.09	0.[illegible]2		2.74
97.5	0.42		44.6[illegible]	0.93		19.51	1.77		9.35	2.49		5.01
112.5	1.40		45.60	2.02		20.60	3.05		10.53	3.74		6.26
157.5	1.99		46.19	2.80		21.38	3.85		11.33	4.51		7.03
180.0	1.52		45.72	2.38		20.96	2.90		10.38	3.34		5.86
	$\bar{P}_{TOT}$ = 44.80			$\bar{P}_{TOT}$ = 19.51			$\bar{P}_{TOT}$ = 9.05			$\bar{P}_{TOT}$ = 4.67		

TABLE IX.- LOAD SUMMARY - S-IC EXPLOSION (SATURN V) - Continued

10 000 ft												
	t_{sa} = 1.10 (t_d = 1.00)			t_{sa} = 1.72 (t_d = 1.50)			t_{sa} = 2[illegible] (t_d = 2.00)			t_{sa} = 3.49 (t_d = 2.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.7[illegible]		39.33	-0.27		14.87	-0.42		5.52	-0.06		2.66
67.5	-0.65		38.93	-0.59		14.55	-0.25		5.69	0.29		3.01
82.5	-0.61	39.58	38.97	-0.61	15.14	14.53	0.10	5.94	[illegible].04	1.10	2.72	3.82
97.5	0.96		40.54	1.63		16.77	2.45		8.39	2.79		5.51
112.5	2.08		41.66	3.03		18.17	3.93		9.87	3.80		6.52
157.5	2.87		42.45	3.64		18.78	4.17		10.11	3.19		5.91
180.0	2.33		41.91	2.87		18.01	3.1[illegible]		9.11	2.18		4.90
	$\bar{P}_{TOT}$ = 40.53			$\bar{P}_{TOT}$ = 16.54			$\bar{P}_{TOT}$ = 7.90			$\bar{P}_{TOT}$ = 4.76		

15 000 ft												
	t_{sa} = 1.10 (t_d = 1.00)			t_{sa} = 1.69 (t_d = 1.50)			t_{sa} = 2.44 (t_d = 2.00)			t_{sa} = 3.55 (t_d = 2.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.50		34.62	-0.70		15.36	-0.62		5.22	-0.05		2.19
67.5	-0.73		34.39	-0.85		15.21	-0.40		5.44	0.95		3.19
82.5	-0.43	35.12	34.69	-0.23	16.06	15.83	0.32	5.84	5.52	1.66	2.24	4.00
97.5	1.92		37.04	2.40		18.46	2.88		8.72	3.58		5.82
112.5	3.42		38.54	4.12		20.18	4.59		10.43	4.79		7.03
157.5	3.51		38.63	3.68		19.74	4.29		10.13	1.87		4.11
180.0	3.71		38.29	3.52		19.58	3.34		9.1[illegible]	1.56		3.80
	$\bar{P}_{TOT}$ = 36.62			$\bar{P}_{TOT}$ = 17.82			$\bar{P}_{TOT}$ = 7.91			$\bar{P}_{TOT}$ = 4.52		

TABLE IX.- LOAD SUMMARY - S-IC EXPLOSION (SATURN V) - Concluded

20 000 ft												
	t_{sa} = 1.65 (t_d = 1.50)			t_{sa} = 2.32 (t_d = 2.00)			t_{sa} = 3.36 (t_d = 2.50)			t_{sa} = 4.34 (t_d = 3.00)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.23		19.53	-0.11		7.55	0.36		2.82	-0.23		1.29
67.5	-0.27		19.49	0.05		7.71	1.17		3.63	0.93		2.45
82.5	0.47	19.76	20.23	0.78	7.66	8.44	1.80	2.46	4.26	1.98	1.52	3.50
97.5	3.07		22.83	3.26		10.92	3.65		6.11	3.13		4.65
112.5	4.85		24.61	5.05		12.71	4.95		7.41	3.74		5.26
157.5	4.22		23.98	4.10		11.76	3.08		5.54	2.97		4.49
180.0	4.18		23.94	4.06		11.72	2.99		5.45	2.82		4.34
	$\bar{P}_{TOT}$ = 22.15			$\bar{P}_{TOT}$ = 10.20			$\bar{P}_{TOT}$ = 5.18			$\bar{P}_{TOT}$ = 3.86		

25 000 ft												
	t_{sa} = 1.07 (t_d = 1.00)			t_{sa} = 1.59 (t_d = 1.50)			t_{sa} = 2.16 (t_d = 2.00)			t_{sa} = 4.44 (t_d = 3.00)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.28		42.14	-0.29		28.51	-0.18		14.94	0.30		1.52
67.5	-0.32		42.10	-0.33		28.47	-0.02		15.10	1.43		2.65
82.5	0.41	42.42	42.83	0.42	28.80	29.22	0.71	15.12	14.41	1.80	1.22	3.02
97.5	2.97		45.39	3.0t		31.85	3.25		18.37	2.92		4.14
112.5	4.72		47.14	4.85		33.65	4.98		20.10	3.51		4.73
157.5	4.11		46.53	4.22		33.02	4.05		19.17	2.75		3.97
180.0	4.06		46.48	4.17		32.97	3.99		19.11	2.61		3.83
	$\bar{P}_{TOT}$ = 44.72			$\bar{P}_{TOT}$ = 31.16			$\bar{P}_{TOT}$ = 17.36			$\bar{P}_{TOT}$ = 3.53		

TABLE X.- LOAD SUMMARY - S-II EXPLOSION (SATURN V)

Pad												
	t_{sa} = 2.13 (t_d = 2.00)			t_{sa} = 2.86 (t_d = 2.50)			t_{sa} = 3.78 (t_d = 3.00)			t_{sa} = 4.73 (t_d = 3.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	0.03		54.39	0.15		16.93	-0.48		6.34	0.52		4.60
67.5	-0.10		54.26	0.13		16.91	0.59		7.41	0.84		4.92
82.5	-0.25		54.11	0.08		16.86	0.73		7.55	1.02		5.10
97.5	0.46	54.36	54.82	0.97	16.78	17.75	1.34	6.82	8.16	1.43	4.08	5.51
112.5	1.16		55.52	1.73		18.51	1.52		8.34	1.36		5.44
157.5	1.59		55.95	2.54		19.32	4.28		11.10	3.44		7.52
180.0	1.25		55.61	2.02		18.80	3.00		9.82	3.06		7.14
	$\bar{P}_{TOT}$ = 54.94			$\bar{P}_{TOT}$ = 17.87			$\bar{P}_{TOT}$ = 8.44			$\bar{P}_{TOT}$ = 5.73		

5000 ft												
	t_{sa} = 1.71 (t_d = 1.60)			t_{sa} = 2.24 (t_d = 2.00)			t_{sa} = 3.09 (t_d = 2.50)			t_{sa} = 4.08 (t_d = 3.00)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.16		47.24	-0.09		18.33	-0.03		6.43	0.24		3.54
67.5	-0.55		46.85	-0.15		18.27	-0.17		6.29	1.03		4.33
82.5	-0.51		46.89	-0.16		18.26	0.91		7.37	1.02		4.32
97.5	1.01	47.40	48.41	1.42	18.42	19.84	2.38	6.46	8.84	1.69	3.30	4.99
112.5	2.10		49.50	2.48		20.90	3.49		9.95	2.16		5.46
157.5	2.86		50.26	3.65		22.05	4.38		10.84	3.76		7.06
180.0	2.35		49.75	2.97		21.39	3.17		9.63	2.70		6.00
	$\bar{P}_{TOT}$ = 48.40			$\bar{P}_{TOT}$ = 19.86			$\bar{P}_{TOT}$ = 8.55			$\bar{P}_{TOT}$ = 5.66		

TABLE X.- LOAD SUMMARY - S-II EXPLOSION (SATURN V) - Continued

10 000 ft

	t_{sa} = 1.69 (t_d = 1.60)			t_{sa} = 2.19 (t_d = 2.00)			t_{sa} = 3.02 (t_d = 2.50)			t_{sa} = 4.05 (t_d = 3.00)		
ϕ	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}
0.0	-0.27		55.15	-0.47		21.23	-0.31		6.57	0.09		3.19
67.5	-0.61		54.81	-0.52		21.18	0.09		6.97	1.04		4.14
87.5	-0.70		54.72	-0.34		21.36	0.43		7.31	1.23		4.33
97.5	1.60	55.42	57.02	2.20	21.70	23.90	2.75	6.88	9.63	2.14	3.10	5.24
120.0	3.06		58.48	2.76		24.46	4.16		11.04	2.74		5.84
157.5	3.58		59.00	3.87		25.57	4.47		11.35	3.36		6.46
180.0	3.03		58.45	3.22		24.92	3.23		10.11	2.69		5.79
			$\bar{P}_{TOT}$ = 56.81			$\bar{P}_{TOT}$ = 23.26			$\bar{P}_{TOT}$ = 9.11			$\bar{P}_{TOT}$ = 5.08

15 000 ft

	t_{sa} = 2.13 (t_d = 2.00)			t_{sa} = 2.86 (t_d = 2.50)			t_{sa} = 3.92 (t_d = 3.00)			t_{sa} = 4.77 (t_d = 3.50)		
ϕ	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}
0.0	-0.56		31.52	-0.41		9.11	0.42		3.68	0.18		2.46
67.5	-0.43		31.65	0.19		9.71	1.29		4.55	1.06		3.34
82.5	0.27		32.35	0.77		10.29	1.73		4.99	1.15		3.43
97.5	2.73	32.08	34.81	3.19	9.52	12.71	3.06	3.26	6.32	1.68	2.28	3.96
120.0	4.45		36.53	4.78		13.30	3.99		7.25	2.02		4.30
157.5	4.11		36.19	4.40		13.92	2.89		6.15	3.25		5.53
180.0	3.30		35.38	3.15		12.67	2.50		5.76	2.63		4.91
			$\bar{P}_{TOT}$ = 34.16			$\bar{P}_{TOT}$ = 11.80			$\bar{P}_{TOT}$ = 5.66			$\bar{P}_{TOT}$ = 4.04

TABLE X.- LOAD SUMMARY - S-II EXPLOSION (SATURN V) - Continued

20 000 ft												
	$t_{sa} = 3.07$ $(t_d = 2.80)$			$t_{sa} = 3.38$ $(t_d = 3.00)$			$t_{sa} = 4.26$ $(t_d = 3.50)$			$t_{sa} = 4.92$ $(t_d = 4.00)$		
ϕ	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}
0.0	0.09	12.38	12.47	0.29	8.20	8.49	0.53	3.66	4.19	-0.20	2.94	3.08
67.5	0.54		12.92	1.16		9.36	1.49		5.15	0.65		3.94
87.5	0.82		13.20	1.80		10.00	2.01		5.67	0.89		4.17
97.5	3.49		15.87	3.64		11.84	3.30		6.96	1.61		4.90
120.0	3.68		16.06	4.94		13.14	4.22		7.88	2.03		5.32
157.5	3.69		16.07	3.07		11.27	2.60		6.26	2.19		5.48
180.0	3.63		16.01	2.98		11.18	2.52		6.18	1.99		5.28
	$\bar{P}_{TOT} = 14.73$			$\bar{P}_{TOT} = 10.91$			$\bar{P}_{TOT} = 6.18$			$\bar{P}_{TOT} = 4.67$		

25 000 ft												
	$t_{sa} = 3.82$ $(t_d = 3.50)$			$t_{sa} = 4.49$ $(t_d = 4.00)$			$t_{sa} = 5.07$ $(t_d = 4.50)$			$t_{sa} = 5.57$ $(t_d = 5.00)$		
ϕ	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}
0.0	0.42	9.22	9.64	0.30	5.52	5.82	0.02	4.62	4.64	-0.05	4.54	4.49
67.5	1.37		10.59	1.41		6.93	1.16		5.78	0.86		5.40
87.5	1.97		11.19	1.79		7.31	1.38		6.00	0.80		5.34
97.5	3.47		12.69	2.89		8.41	2.23		6.85	0.81		5.35
120.0	4.59		13.81	3.49		9.01	2.51		7.13	0.67		5.21
157.5	2.07		11.29	2.74		8.26	2.52		7.14	3.03		7.57
180.0	1.98		11.20	2.59		8.11	2.35		6.97	2.94		7.48
	$\bar{P}_{TOT} = 11.67$			$\bar{P}_{TOT} = 7.81$			$\bar{P}_{TOT} = 6.45$			$\bar{P}_{TOT} = 5.81$		

TABLE X.- LOAD SUMMARY - S-II EXPLOSION (SATURN V) - Concluded

27 500 ft												
	$t_{sa} = 3.12$ $(t_d = 3.00)$			$t_{sa} = 3.72$ $(t_d = 3.50)$			$t_{sa} = 4.34$ $(t_d = 4.00)$			$t_{sa} = 7.50$ $(t_d = 7.00)$		
ϕ	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}
0.0	-0.12		28.74	0.15		13.67	0.24		8.18	0.05		5.13
67.5	1.28		30.14	0.93		14.45	1.42		9.36	0.46		5.54
87.5	1.67	28.86	30.43	2.13	13.52	15.65	1.81	7.94	9.75	0.51	5.08	5.59
97.5	4.06		32.92	3.89		17.41	2.97		10.91	0.76		5.84
120.0	5.61		34.47	4.55		18.07	3.59		11.53	0.92		6.00
157.5	4.20		33.06	2.62		16.14	2.80		10.74	1.51		6.59
180.0	3.77		32.63	2.41		15.93	2.65		10.59	1.21		6.29
		$\bar{P}_{TOT} = 31.95$			$\bar{P}_{TOT} = 16.09$			$\bar{P}_{TOT} = 9.45$			$\bar{P}_{TOT} = 5.88$	
30 000 ft												
	$t_{sa} = 4.01$ $(t_d = 3.70)$			$t_{sa} = 4.43$ $(t_d = 4.00)$			$t_{sa} = 5.00$ $(t_d = 4.50)$			$t_{sa} = 5.96$ $(t_d = 5.50)$		
ϕ	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}
0.0	0.08		8.58	0.09		5.83	0.07		4.85	-0.14		5.12
67.5	1.62		10.12	1.45		7.19	1.30		6.08	0.62		5.88
87.5	2.53	8.50	11.03	2.17	5.74	7.91	1.54	4.78	6.32	0.68	5.26	5.94
97.5	3.86		12.36	3.33		9.07	2.45		7.23	0.93		6.19
120.0	4.50		13.00	3.87		9.61	2.75		7.53	1.51		6.77
157.5	1.97		10.47	2.19		7.93	2.76		7.54	2.30		7.56
180.0	2.34		10.84	2.51		8.25	2.57		7.35	2.19		7.45
		$\bar{P}_{TOT} = 11.12$			$\bar{P}_{TOT} = 8.13$			$\bar{P}_{TOT} = 6.80$			$\bar{P}_{TOT} = 6.44$	

TABLE XI.- LOAD SUMMARY - S-IVB EXPLOSION (SATURN V)

Pad												
	$t_{sa} = 2.49$ $(t_d = 2.20)$			$t_{sa} = 3.00$ $(t_d = 2.50)$			$t_{sa} = 3.36$ $(t_d = 2.70)$			$t_{sa} = 3.93$ $(t_d = 3.00)$		
ϕ	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}
0.0	0.09		12.33	0.17		6.75	0.24		5.00	0.39		3.65
67.5	0.02		12.24	0.22		6.80	0.32		5.08	1.30		4.56
82.5	-0.06	12.24	12.18	0.19	6.58	6.77	0.43	4.76	5.19	1.11	3.26	4.37
97.5	0.79		13.03	1.06		7.64	1.21		5.97	1.90		5.16
120.0	1.60		13.84	1.73		8.31	1.68		6.44	2.19		5.45
157.5	2.06		14.30	2.77		9.35	3.26		8.02	3.43		6.69
180.0	1.61		13.85	2.26		8.84	2.66		7.42	3.08		6.34
	$\bar{P}_{TOT}$ = 13.11 psi			$\bar{P}_{TOT}$ = 7.78 psi			$\bar{P}_{TOT}$ = 6.15 psi			$\bar{P}_{TOT}$ = 5.20 psi		
5000 ft												
	$t_{sa} = 2.13$ $(t_d = 1.90)$			$t_{sa} = 2.20$ $(t_d = 2.00)$			$t_{sa} = 2.63$ $(t_d = 2.20)$			$t_{sa} = 3.18$ $(t_d = 2.50)$		
ϕ	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}
0.0	-0.10		11.26	-0.09		9.61	-0.08		5.38	0.01		3.27
67.5	-0.16		11.20	-0.15		9.55	0.04		5.50	-0.03		3.23
82.5	-0.17	11.36	11.19	-0.16	9.70	9.54	0.06	5.46	5.52	0.35	3.26	3.61
97.5	1.37		12.73	1.44		11.14	2.15		7.61	3.23		5.49
120.0	2.40		13.76	2.52		12.22	3.31		8.77	3.28		6.54
157.5	3.51		14.87	3.67		13.37	4.02		9.48	4.51		7.77
180.0	2.87		14.23	3.01		12.71	2.94		8.40	3.12		6.38
	$\bar{P}_{TOT}$ = 12.75 psi			$\bar{P}_{TOT}$ = 11.16 psi			$\bar{P}_{TOT}$ = 7.30 psi			$\bar{P}_{TOT}$ = 5.24 psi		

TABLE XI.- LOAD SUMMARY - S-IVB EXPLOSION (SATURN V) - Continued

10 000 ft												
	t_{sa} = 1.81 (t_d = 1.70)			t_{sa} = 2.23 (t_d = 2.00)			t_{sa} = 2.59 (t_d = 2.20)			t_{sa} = 3.16 (t_d = 2.50)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.27		24.79	-0.46		9.52	-0.05		5.49	-0.23		2.33
67.5	-0.62		24.44	-0.51		9.47	0.92		6.46	0.43		2.99
82.5	-0.71	25.06	24.35	-0.33	9.98	9.65	1.11	5.54	6.65	0.73	2.56	3.29
97.5	1.65		26.71	2.21		12.19	2.04		7.58	2.79		5.35
120.0	3.16		28.22	3.77		13.75	2.64		8.18	4.05		6.61
157.5	3.69		28.75	3.88		13.86	3.28		8.82	4.05		6.61
180.0	3.12		28.18	3.24		13.22	2.59		8.13	2.78		5.34
		$\bar{P}_{TOT}$ = 26.49 psi			$\bar{P}_{TOT}$ = 11.72 psi			$\bar{P}_{TOT}$ = 7.42 psi			$\bar{P}_{TOT}$ = 4.78 psi	

15 000 ft												
	t_{sa} = 2.15 (t_d = 2.00)			t_{sa} = 2.47 (t_d = 2.20)			t_{sa} = 2.88 (t_d = 2.40)			t_{sa} = 3.52 (t_d = 2.79)		
ϕ	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}	P_A	2 ΔP	P_{TOT}
0.0	-0.66		15.08	-0.62		7.16	-0.41		3.59	-0.18		2.00
67.5	-0.58		15.16	-0.40		7.38	0.19		4.19	0.86		3.04
82.5	-0.73	15.74	15.01	1.25	7.78	9.03	0.77	4.00	4.77	1.59	2.18	3.77
97.5	2.72		18.46	2.92		10.70	3.19		7.19	3.60		5.78
120.0	4.45		20.19	4.65		12.43	4.80		8.80	4.79		6.97
157.5	4.09		19.83	4.34		12.12	4.40		8.40	1.69		3.87
180.0	3.44		19.18	3.39		11.17	3.15		7.15	1.41		3.59
		$\bar{P}_{TOT}$ = 17.63 psi			$\bar{P}_{TOT}$ = 10.14 psi			$\bar{P}_{TOT}$ = 6.45 psi			$\bar{P}_{TOT}$ = 4.37psi	

TABLE XI.- LOAD SUMMARY - S-IVB EXPLOSION (SATURN V) - Continued

20 000 ft												
	$t_{sa} = 2.30$ $(t_d = 2.20)$			$t_{sa} = 2.57$ $(t_d = 2.40)$			$t_{sa} = 3.09$ $(t_d = 2.70)$			$t_{sa} = 3.75$ $(t_d = 3.00)$		
ϕ	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}
0.0	-0.11		22.59	-0.04		11.88	0.09		4.53	0.36		2.52
67.5	0.04		22.74	0.21		12.13	0.54		4.98	1.13		3.29
82.5	1.24	22.70	23.94	0.93	11.92	12.85	0.82	4.44	5.26	1.73	2.16	3.89
97.5	3.13		25.83	3.38		15.30	3.49		7.93	3.48		5.64
120.0	4.11		26.81	5.07		16.99	4.68		9.12	4.70		6.86
157.5	4.68		27.38	3.99		15.91	3.70		8.14	2.94		5.10
180.0	4.06		26.76	3.81		15.73	3.63		8.07	2.86		5.02
	$\bar{P}_{TOT}$ = 25.23 psi			$\bar{P}_{TOT}$ = 14.50 psi			$\bar{P}_{TOT}$ = 6.96 psi			$\bar{P}_{TOT}$ = 4.76 psi		
25 000 ft												
	$t_{sa} = 2.57$ $(t_d = 2.50)$			$t_{sa} = 2.96$ $(t_d = 2.80)$			$t_{sa} = 3.45$ $(t_d = 3.10)$			$t_{sa} = 4.14$ $(t_d = 3.40)$		
ϕ	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}	P_A	$2\ \Delta P$	P_{TOT}
0.0	-0.12		28.80	-0.09		11.37	-0.33		4.31	0.34		2.30
67.5	0.13		28.79	0.22		11.68	-0.37		4.27	1.06		3.02
82.5	0.85	28.92	29.77	0.94	11.46	12.40	1.90	4.64	6.54	1.45	1.96	3.41
97.5	3.30		32.22	3.33		14.79	3.02		7.66	2.41		4.37
120.0	5.00		33.92	5.00		16.46	4.82		9.46	3.10		5.06
157.5	3.91		32.83	3.81		15.27	4.18		8.82	1.89		3.85
180.0	3.73		32.65	3.76		15.22	4.14		8.78	1.83		3.79
	$\bar{P}_{TOT}$ = 31.38 psi			$\bar{P}_{TOT}$ = 13.98 psi			$\bar{P}_{TOT}$ = 7.22 psi			$\bar{P}_{TOT}$ = 3.79 psi		

TABLE XI.- LOAD SUMMARY - S-IVB EXPLOSION (SATURN V) - Concluded

30 000 ft												
	$t_{sa} = 2.79$ ($t_d = 2.70$)			$t_{sa} = 3.19$ ($t_d = 3.00$)			$t_{sa} = 3.37$ ($t_d = 3.10$)			$t_{sa} = 5.88$ ($t_d = 3.30$)		
ϕ	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}	P_A	$2\Delta P$	P_{TOT}
0.0	0.26		20.62	-0.12		8.64	0.10		5.68	0.14		0.52
67.5	0.51		20.87	0.11		8.87	0.95		6.53	0.62		1.00
82.5	1.32	20.36	21.68	1.70	8.76	10.46	2.24	5.58	7.82	0.68	0.38	1.06
97.5	4.08		24.44	4.05		12.81	4.15		9.73	0.94		1.32
120.0	6.08		[illegible]6.44	5.55		14.31	4.87		10.45	1.53		1.91
157.5	4.56		[illegible].32	3.98		12.74	2.78		3.36	2.33		2.71
180.0	4.12		2[illegible].48	3.62		12.38	2.55		8.13	2.21		2.59
	$\bar{P}_{TOT}$ = 23.48 psi			$\bar{P}_{TOT}$ = 11.62 psi			$\bar{P}_{TOT}$ = 8.30 psi			$\bar{P}_{TOT}$ = 3.54 psi		

TABLE XII.- REQUIRED WARNING TIMES - PAD TO 60 000 FT - SATURN IB AND V

	SATURN IB				SATURN V					
	S-IB		S-IVB		S-IC		S-II		S-IVB	
ALTITUDE ft x 10^{-3}	t_{ss}, sec	$T = t_{ss} + .20$, sec	t_{ss}, sec	$T = t_{ss} + .20$, sec	t_{ss}, sec	$T = t_{ss} + .20$, sec	t_{ss}, sec	$T = t_{ss} + .20$, sec	t_{ss}, sec	$T = t_{ss} + .20$, sec
0	2.47	2.67	2.65	2.85	3.10	3.30	3.31	3.51	2.68	2.88
5	1.89	2.09	2.35	2.55	2.26	2.46	2.83	3.03	2.33	2.53
10	1.83	2.03	2.40	2.60	2.18	2.38	2.80	3.00	2.30	2.50
15	1.76	1.96	2.50	2.70	2.18	2.38	2.93	3.13	2.43	2.63
20	1.78	1.98	2.71	2.91	2.38	2.58	3.50	3.70	2.76	2.96
25	2.10	2.30	3.08	3.28	2.67	2.87	4.55	4.75	3.13	3.33
27.5	—	—	—	—	—	—	5.17	5.37	—	—
30	1.90	2.10	3.05	3.25	2.30	2.50	5.68	5.88	3.20	3.50
35	1.50	1.70	2.70	2.90	2.00	2.20	3.20	3.40	2.80	3.00
40	1.20	1.40	2.40	2.60	1.40	1.60	2.70	2.90	2.50	2.70
45	0.90	1.10	2.10	2.30	0.90	1.10	2.40	2.60	2.20	2.40
50	0.70	0.90	1.90	2.10	0.70	0.90	2.10	2.30	2.00	2.20
55	0.70	0.90	1.80	2.00	0.70	0.90	2.00	2.20	1.90	2.10
60	0.70	0.90	1.80	2.00	0.60	0.80	1.90	2.10	1.80	2.00

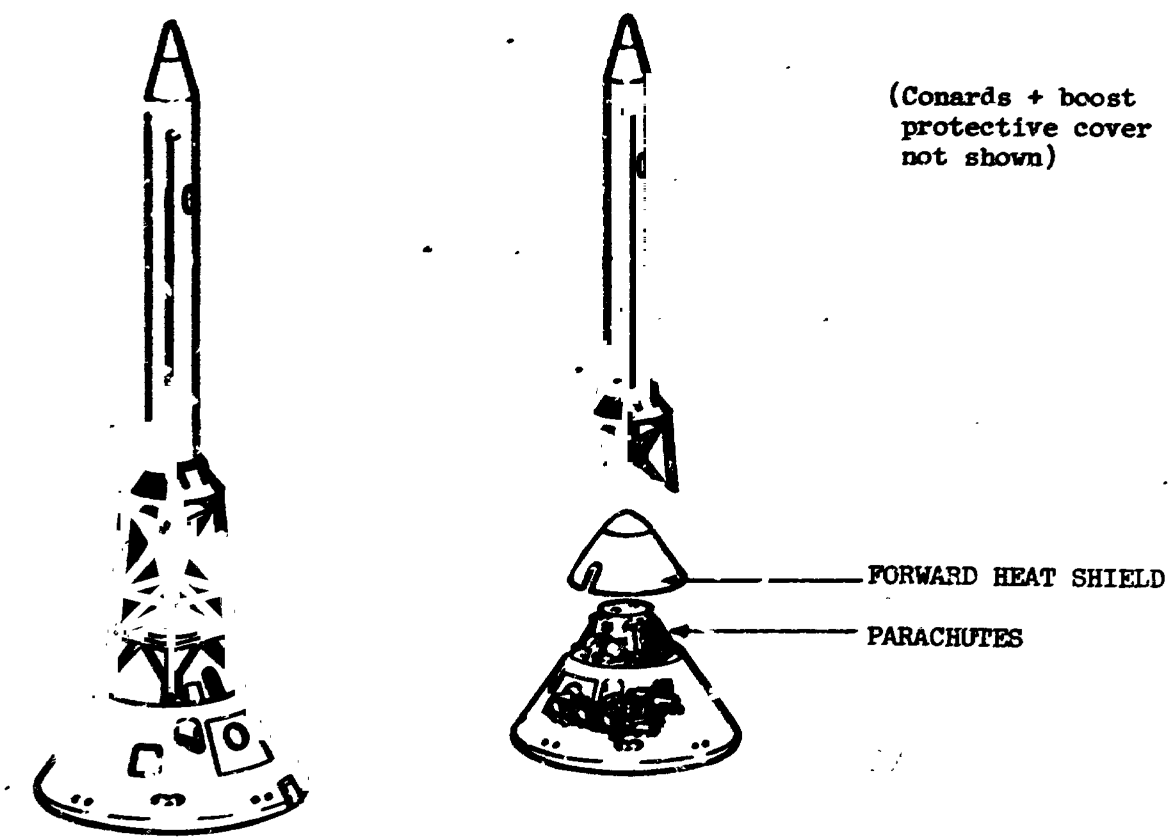


Figure 1.- Forward heat shield deployment.

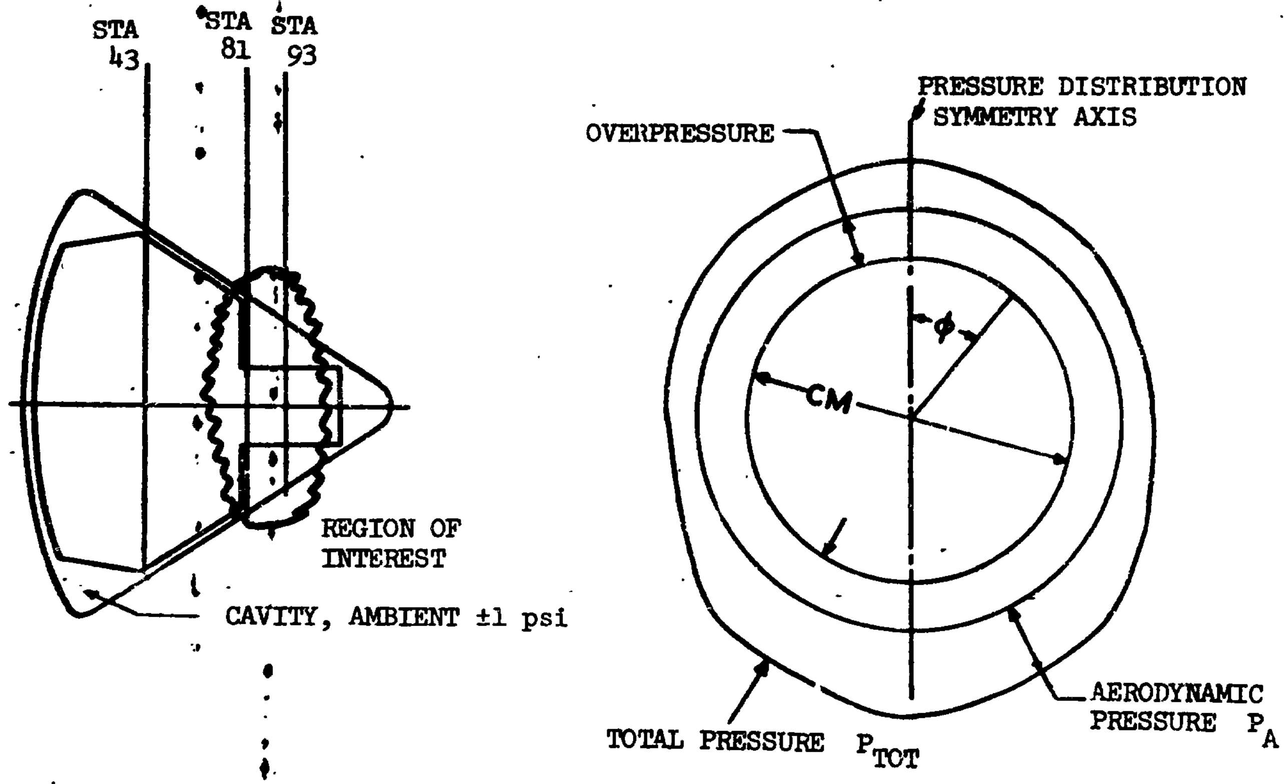


Figure 2.- Total pressure distribution.

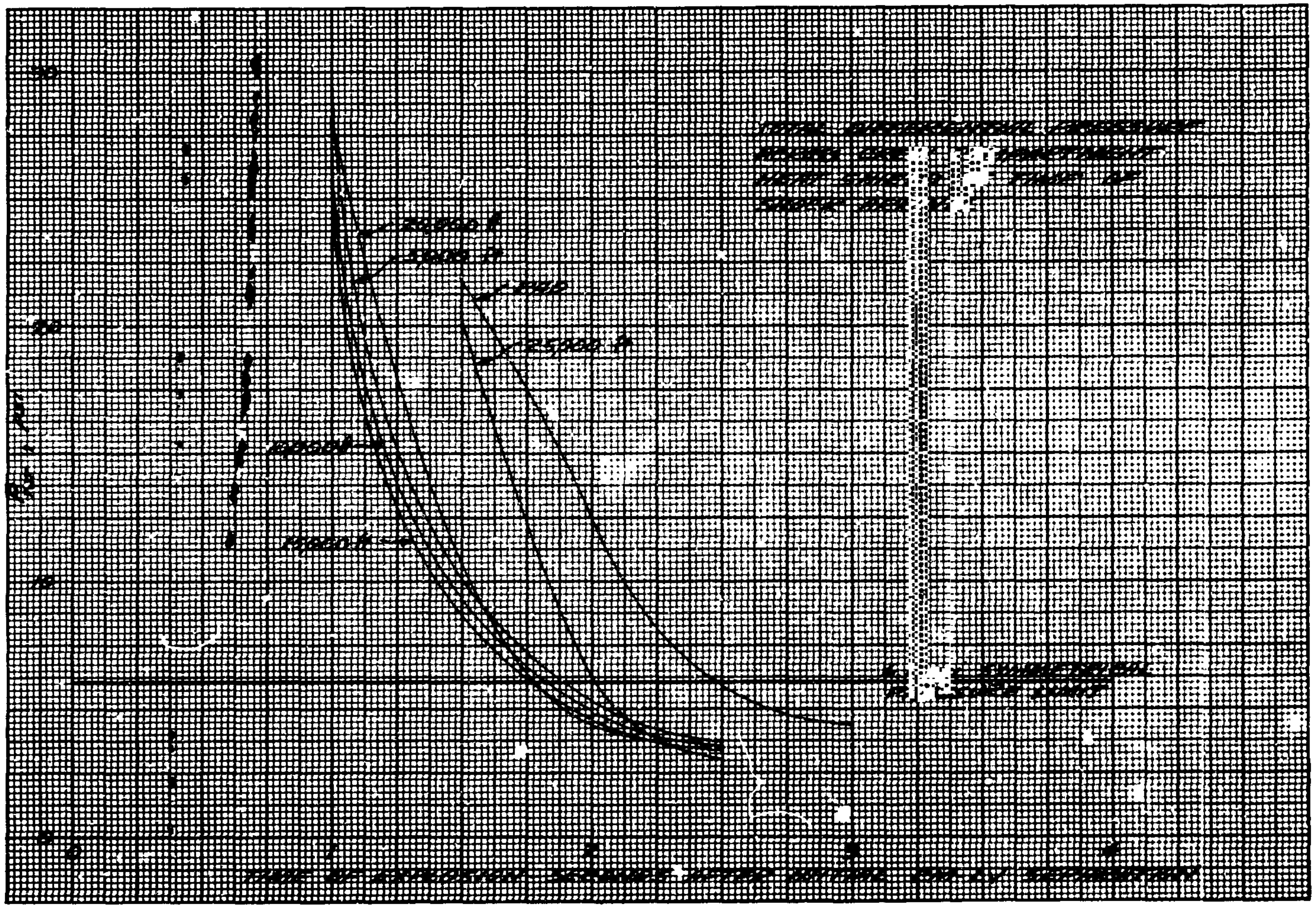


Figure 3.- Total pressure loads - explosion of S-IB stage (Saturn IB).

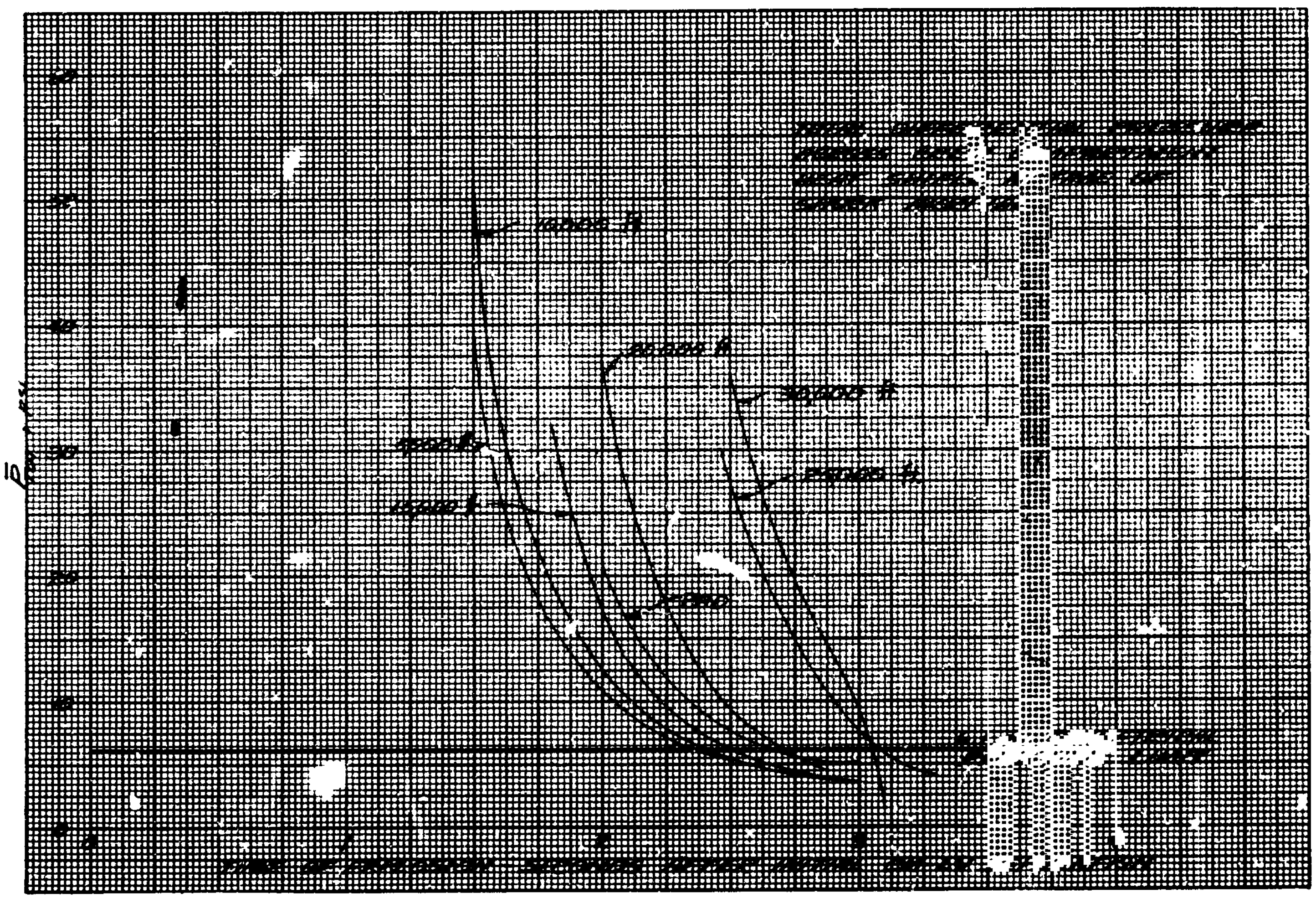


Figure 4.- Total pressure loads - explosion of S-IVB stage (Saturn IB).

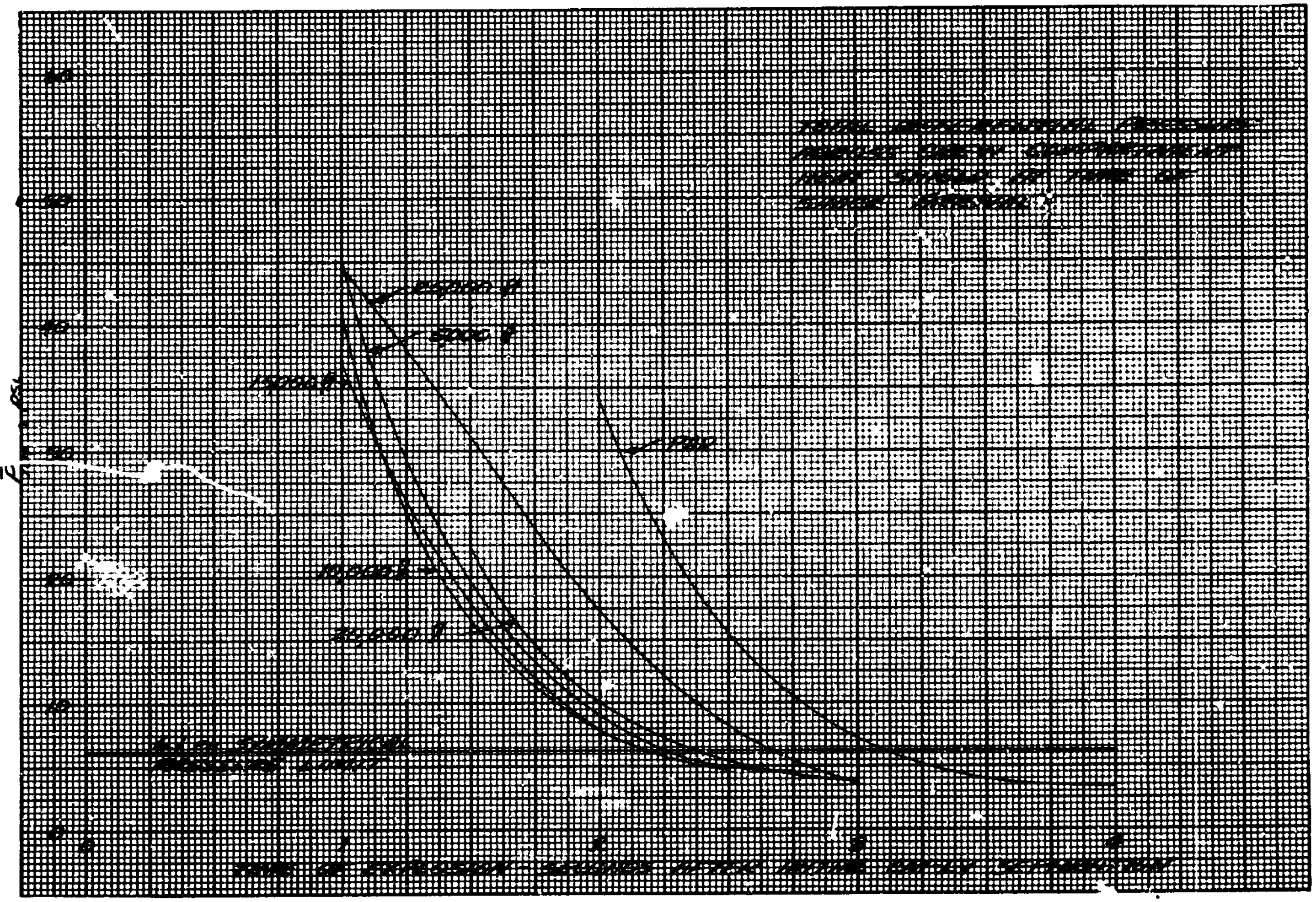


Figure 5.- Total pressure loads - explosion of S-IC stage (Saturn V).

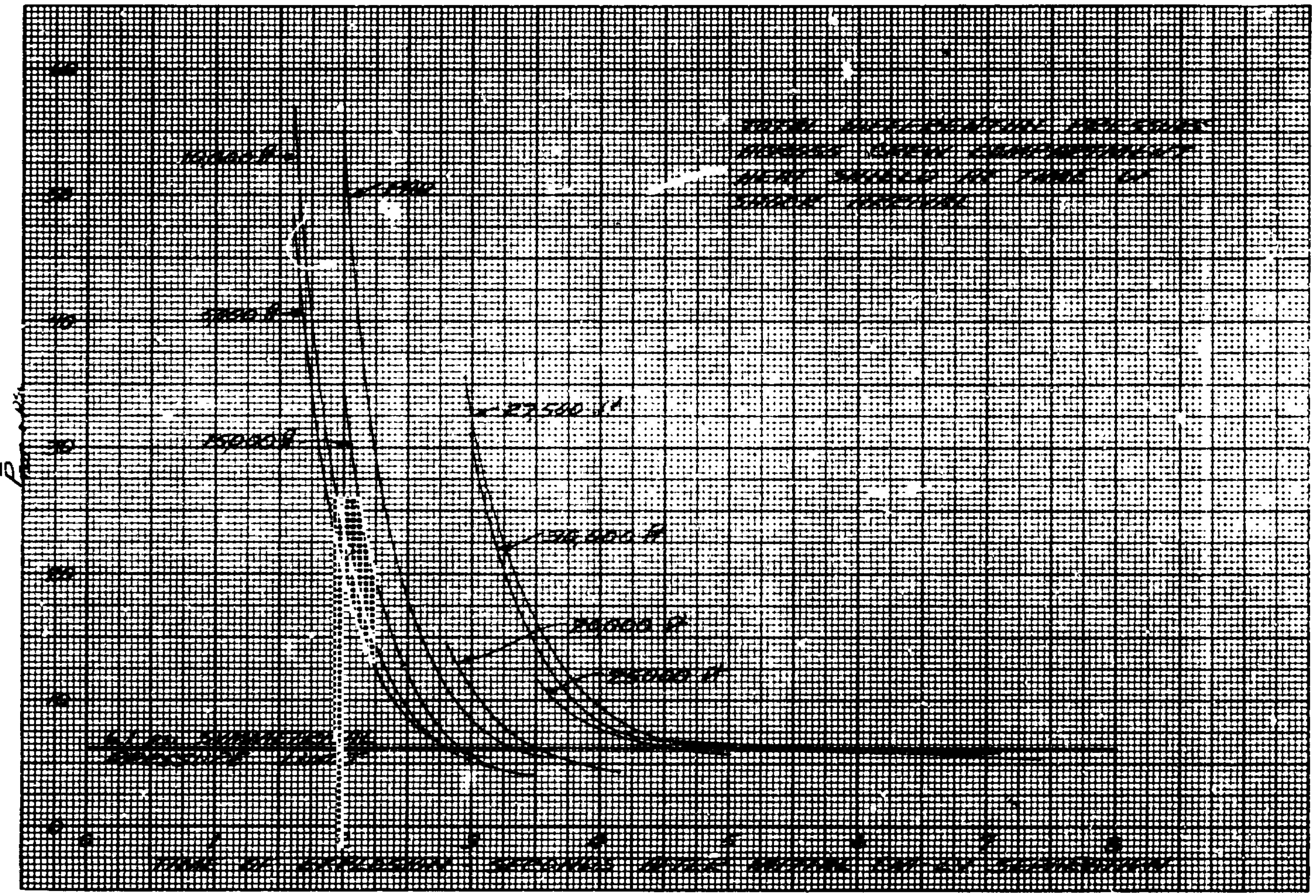


Figure 6.- Total pressure loads - explosion of S-II stage (Saturn V).

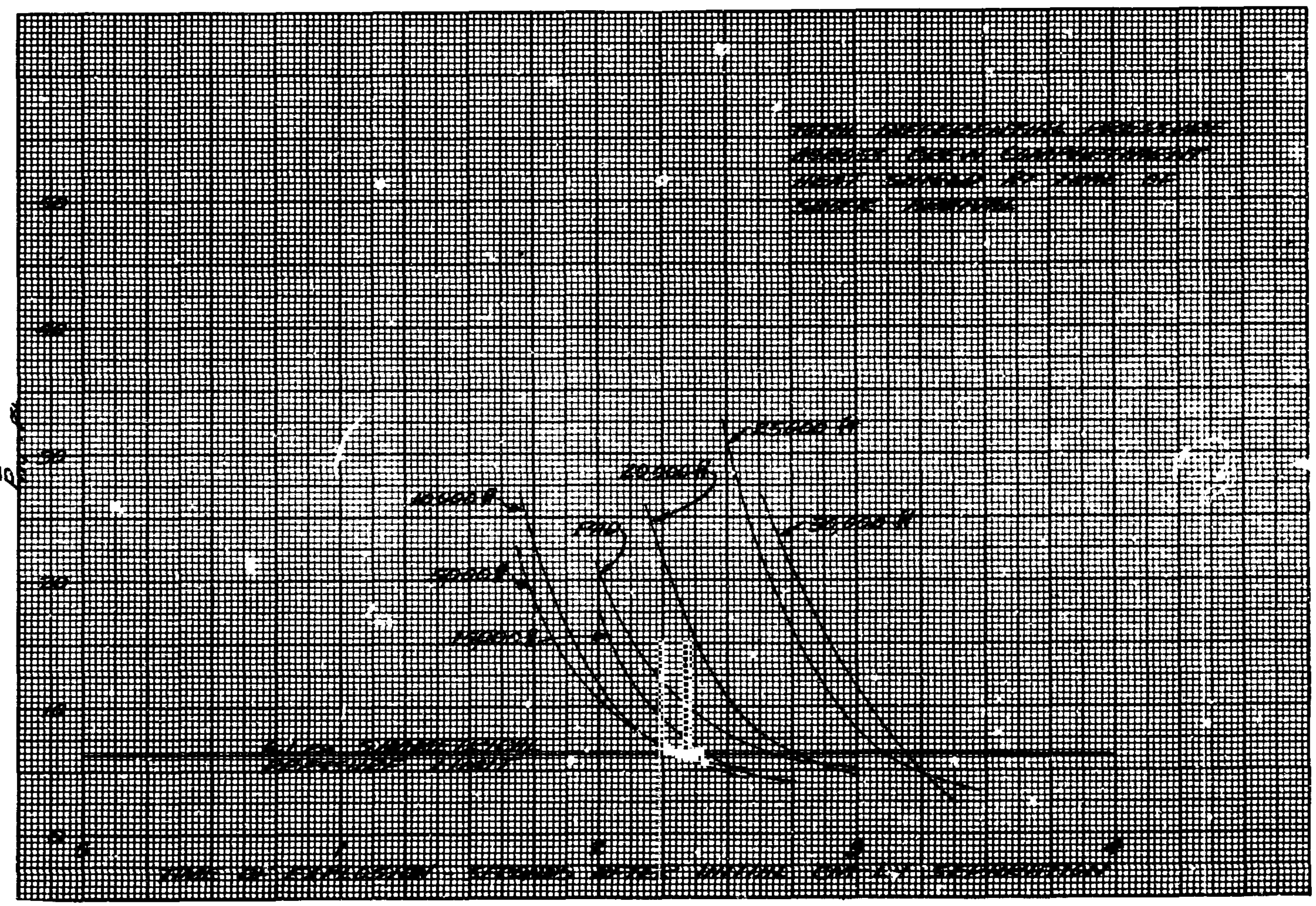


Figure 7.- Total pressure loads - explosion of S-IVB stage (Saturn V).

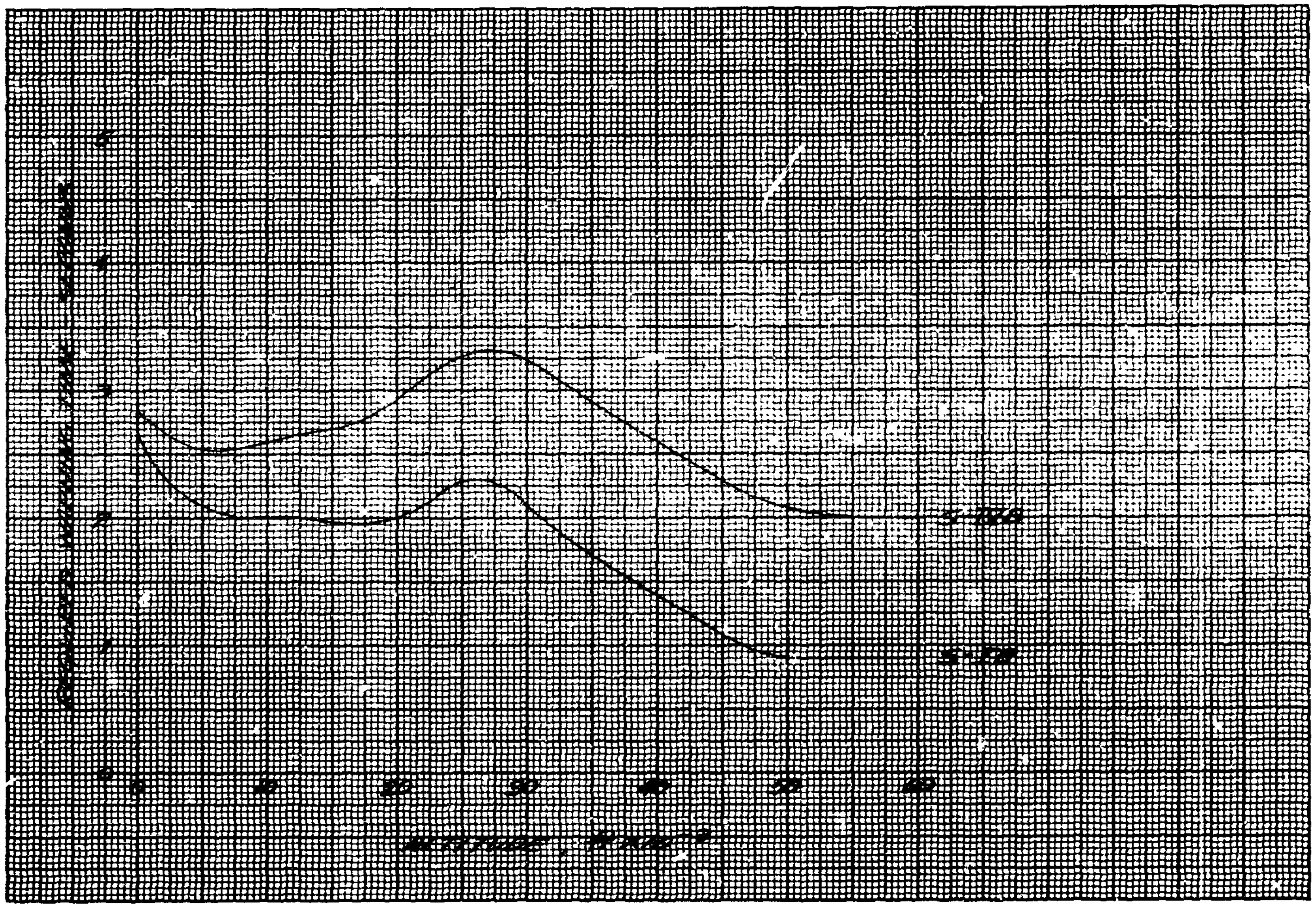


Figure 8.- Required warning time - explosion of Saturn IB stages.

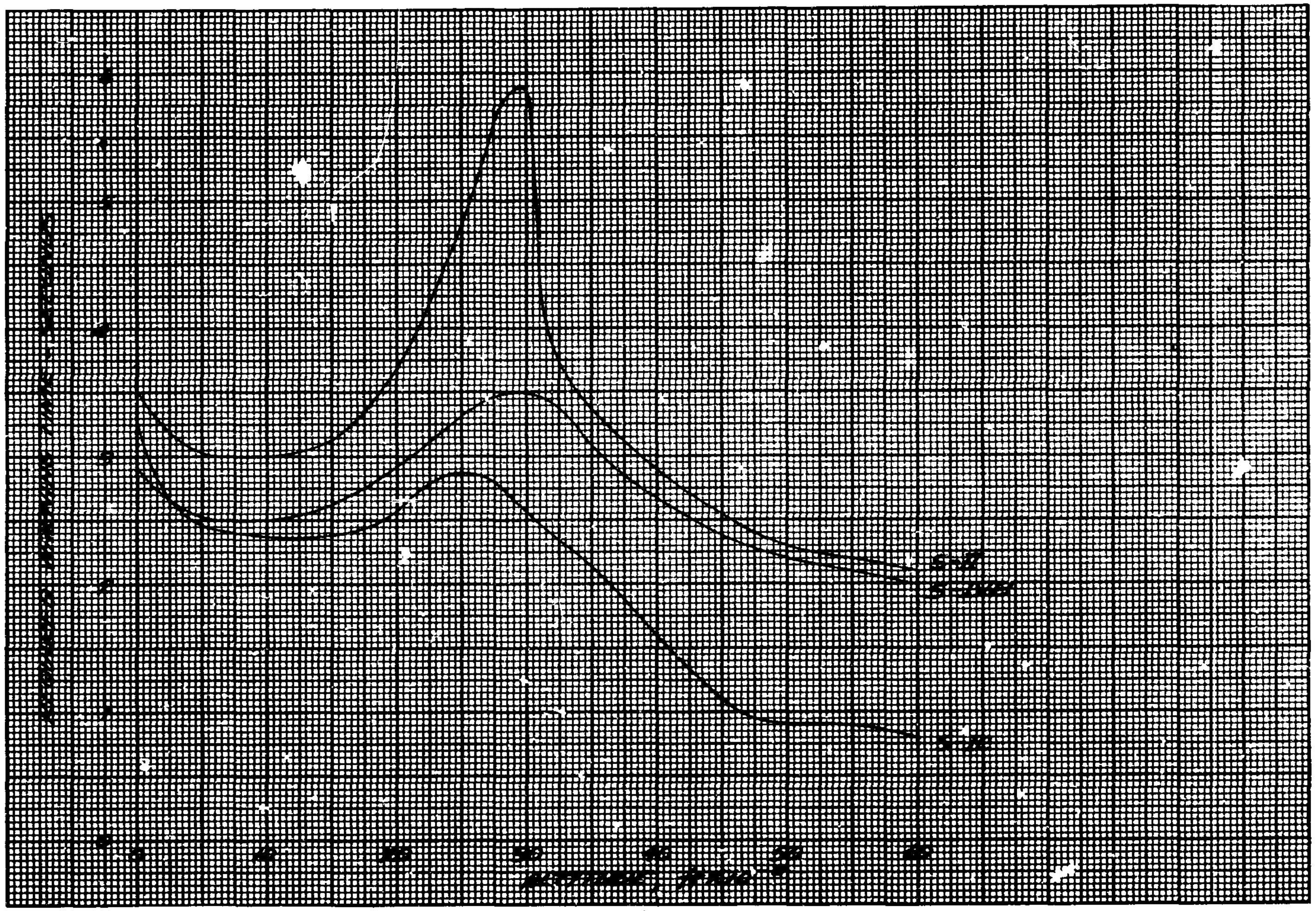


Figure 9.- Required warning time - explosion of Saturn V stages.

APPENDIX

The required warning times are dependent to varying degrees on the following factors:

1. CM pressure limit

2. LES thrust (total impulse)

3. TNT explosive yield

In the main body of the study current values for the CM pressure limit (6.1 psi) and LES thrust (155 000 lb) were used as were the frequently used TNT yields of 10 percent and 60 percent for LOX/RP-1 and LOX/H_2, respectively. Values for these three parameters were varied in order to illustrate their influence on the required warning times. The case of an S-IC stage explosion was considered. The resulting warning times are given in figures A-1, A-2, and A-3, together with the warning time curves for the nominal conditions considered previously. The increased LES thrust cases required that approximations be made since wind tunnel data was not available at these higher thrust levels. As a result, the pressure distributions obtained from the nominal thrust cases were modified to account for the higher dynamic pressures associated with the increased thrust cases. In addition, the LES thrust cases did not consider the corresponding LEV weight increase that would necessarily have to occur. However, the results, though not exact, do illustrate the relative influence of the thrust on the required warning times.

It is apparent from figures A-1, A-2 and A-3 that drastic improvements in CM and LES capabilities would in most cases not reduce the required warning times significantly. Increasing the CM's pressure limits from 6.1 to 15 psi reduces the required warning time by only .55 seconds (25 000 ft). This is a rather modest return for what would require a major CM modification. Above 30 000 feet the CM pressure limit has a diminishing effect on the required warning times due to the CM's ability to outrun the shock front.

Increasing the LES thrust by 25 percent and 50 percent results in an appreciable reduction in the required warning times in the 20 000- to 30 000-foot regime. However, on the pad, the warning times are not reduced significantly.

Reduction of the TNT equivalent yield shows a marked decrease (figure A-3) in the required warning times after approximately 25 000 feet (5 percent and 3 percent cases). An even more drastic decrease occurs for the 1 percent case. However, the pad and lower altitude regime in general still require considerable warning times.

The above results indicate the rather insensitive nature of the required warning times. Increasing the CM pressure limit and the LES thrust would require major redesign to significantly reduce the required warning times. Above 30 000 feet, lower TNT yields could reduce the required warning times significantly, particularly if the yields are in the order of 3 to 5 percent (LOX/RP-1).

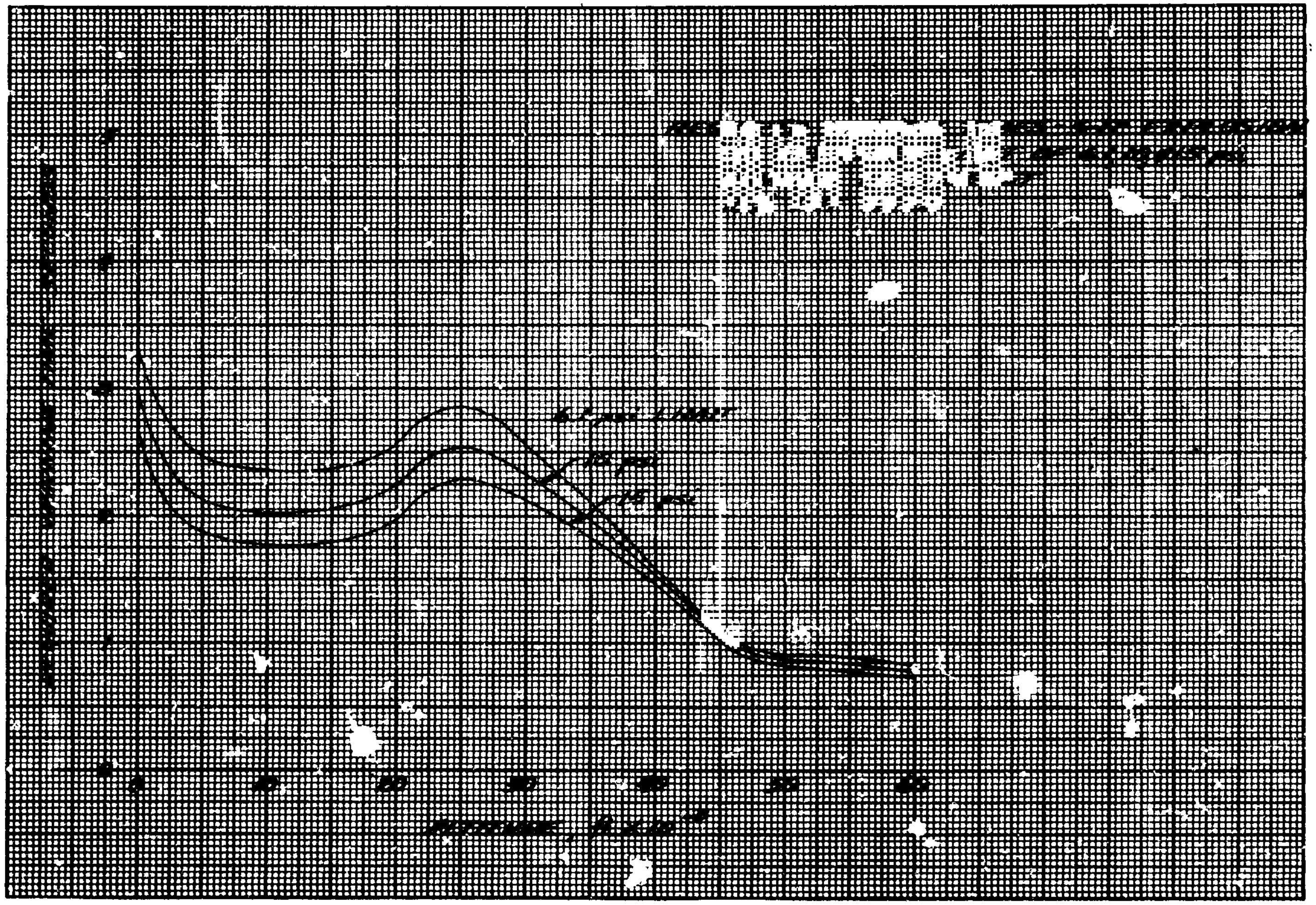


Figure A-1.- Required warning times - various CM pressure limits.

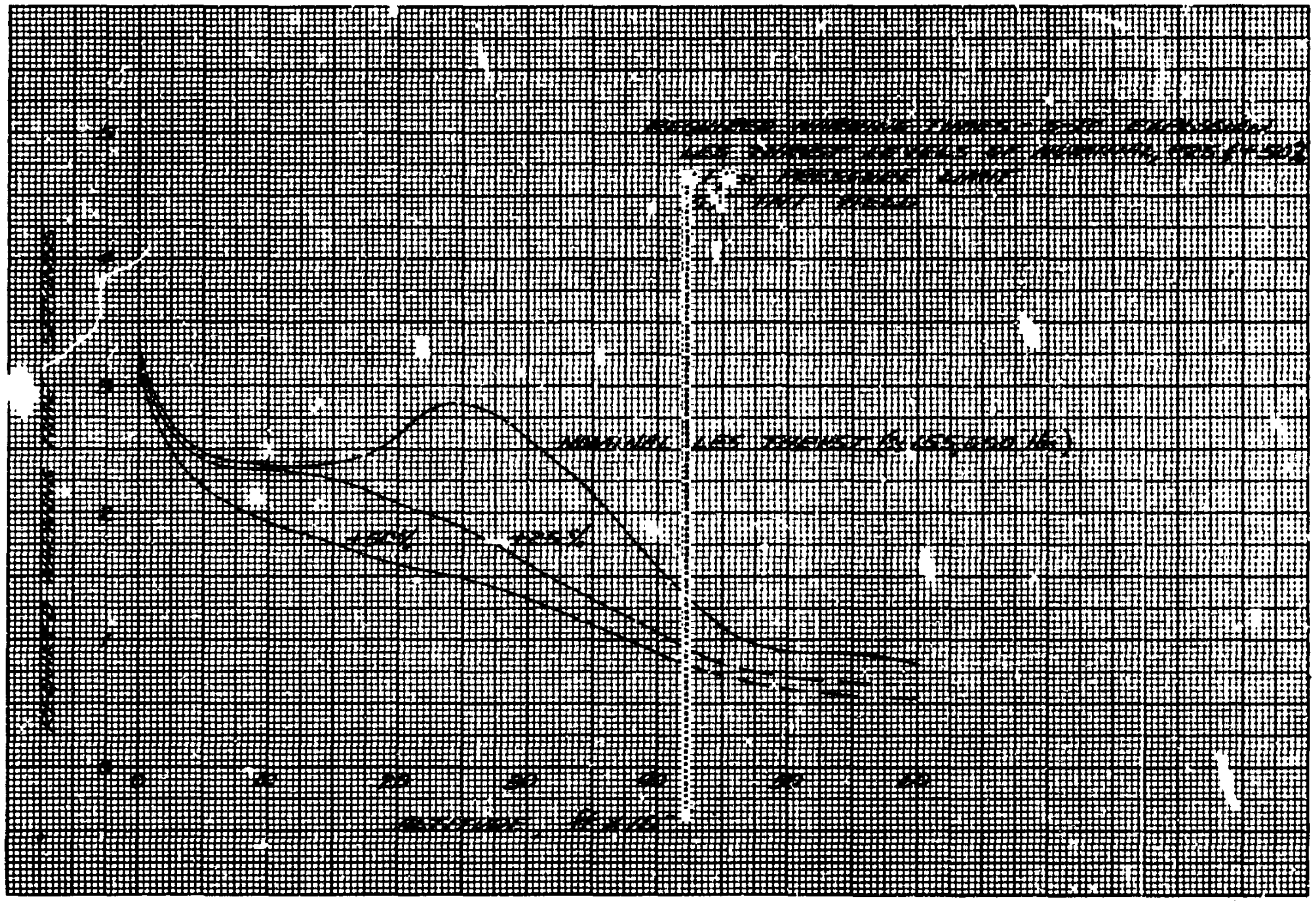


Figure A-2.- Required warning times - various LES thrust levels.

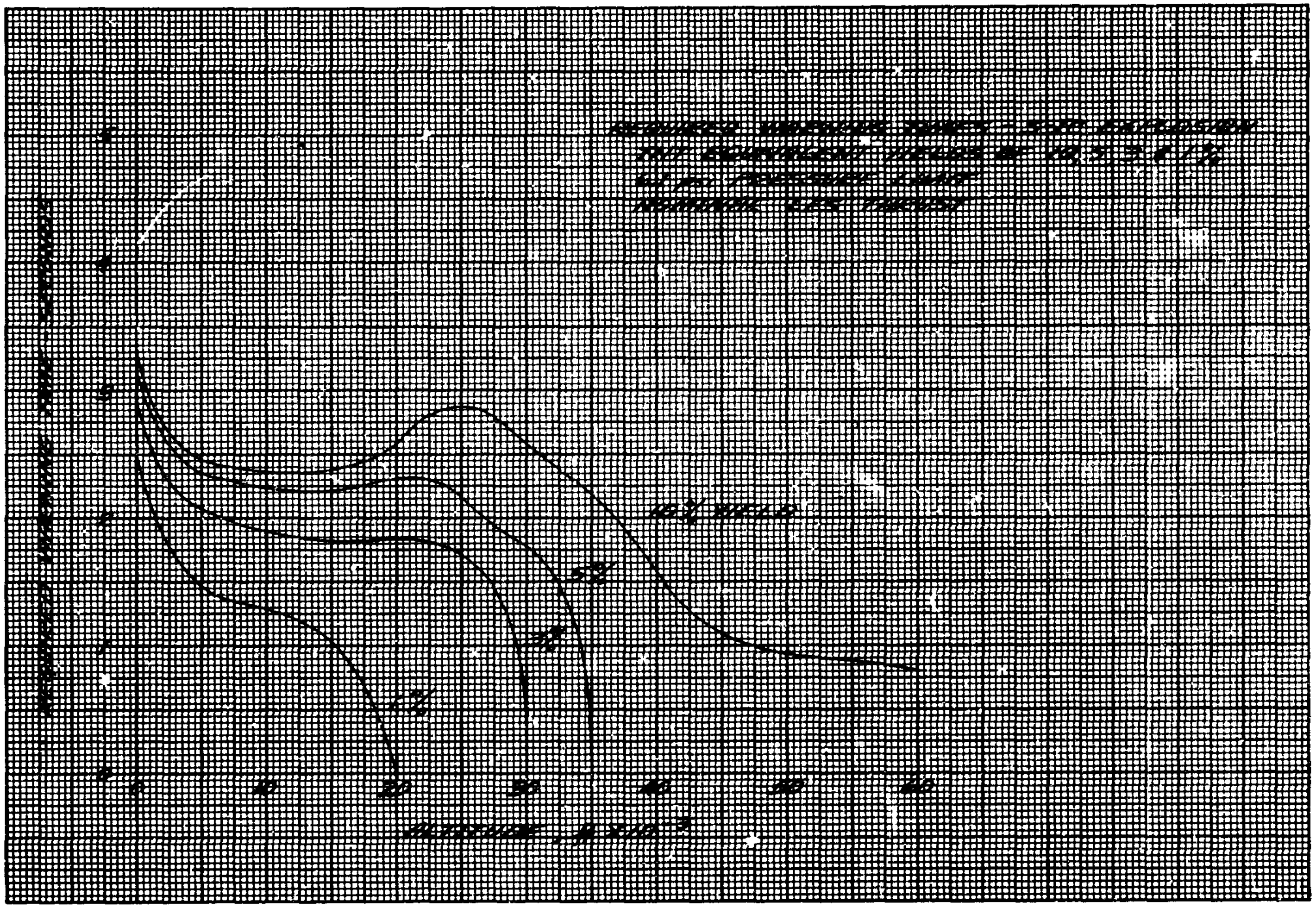


Figure A-3.- Required warning times - various TNT yields.