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SRB ATTRITION RATE STUDY OF THE AFT SKIRT DUE TO WATER IMPACT CAVITY COLLAPSE LOADING

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This report presents the methodology to eliminate all assessable conservatisms from the attrition analysis which was systematically developed so that realistic attrition prediction could aid in selecting an optimum design option for min zing the effects of updated loads on the Space Shuttle Solid Rocket Booster (SRB) aft skirt. The updated loads resulted in water impact attrition rates greater than 10 percent for the aft skirt structure. Adding weight to reinforce the aft skirt was undesirable. The refined method treats the occurrences of the load distribution probabilistically, radially and longitudinally, with respect to the critical structural response.

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
AFT SKIRT CONFIGURATION	2
METHODOLOGY DEVELOPMENT	2
LOADS	3
STRUCTURAL CAPABILITIES	4
COMPUTER PROGRAM SPLASH	5
PROBABILITY OF STRENGTH	5
ATTRITION	5
STRUCTURAL TESTING	6
STRUCTURAL BEEF-UP	6
TVC POWER SUPPLY	7
RESULTS AND CONCLUSIONS	7
REFERENCES	43

LIST OF ILLUSTRATIONS

Figure	Title	Page
1.	Configuration load effects of aft portion of SRB at cavity collapse loading	21
2.	Configuration 5/1/75 baseline SRB aft end at water impact	22
3.	Flow diagram of requirements for attrition assessment for the Shuttle SRB	23
4.	SRB aft skirt cavity collapse longitudinal equal probability of load peak	24
5.	Probability of strength as a function of verification testing	25
6.	SRB aft skirt radial (clocking) capability distribution for critical load peaks	26
7.	SRB aft skirt — attrition versus radial capability factor, CDN (clocking)	27
8.	SRB aft skirt — attrition versus differential pressure capability (clocking) for various CDN values	28
9.	SRB aft skirt attrition determination methodology comparisons, no test (V_V - 100 ft/s)	29
10.	Comparative effects of verification testing and random strength on SRB aft skirt attrition	30
11.	SRB aft skirt differential pressure capability improvement versus beef-up weight (yield criteria)	31
12.	SRB aft skirt differential pressure capability improvement versus beef-up weight (ultimate criteria)	32
13.	Baseline 11/1/74 SRB configuration for TVC power supply system location	33

LIST OF ILLUSTRATIONS (Concluded)

Figure	Title	Page
14.	TVC power supply pressure capability versus attrition as a function of vertical velocity (V_V)	34
15.	SRB aft skirt attrition determination methodology comparisons (no test)	35
16.	SRB aft skirt attrition determination methodology comparisons (standard test)	36
17.	SRB aft skirt attrition determination methodology comparisons, random strength not included for test and no test	37
18.	SRB aft skirt attrition methodology comparisons, random strength not included, including clocking and probability of axial location	38
19.	SRB aft skirt attrition methodology comparisons, random strength included, including clocking and probability of axial location	39
20.	SRB aft skirt attrition with inclusion of effects of longitudinal and radial locational probability of load peak capability (no test)	40
21.	SRB aft skirt attrition with inclusion of effects of longitudinal and radial locational probability of load peak capability (standard test)	41
22.	SRB aft skirt attrition versus vertical impact velocity (V_V)	42

LIST OF TABLES

Table	Title	Page
1.	SRB Aft Skirt Cavity Collapse Internal (P1) Pressure	11
2.	SRB Aft Skirt Cavity Collapse Peak External Pressure (Max Δ P-P1)	12
3.	SRB Aft Skirt Cavity Collapse Peak External ±36.5 Inches from Station 1877.43, as Shown in Load Document	13
4.	SRB Aft Skirt Cavity Collapse External Pressure at Station 1877.42, as Shown in Loads Document (Matrix 2 + P1)	14
5.	SRB Aft Skirt Cavity Collapse External Pressure at Station 1913.93, as Shown in Loads Document (Matrix 3 + P1), Equivalent to Load Shifted Forward 36.5 Inches	15
6.	SRB Aft Skirt Cavity Collapse External Pressure at Station 1840.93, as Shown in Loads Document (Matrix 1 + P1), Equivalent to Load Shifted Aft 36.5 Inches	16
7.	SRB Aft Skirt Cavity Collapse Peak Differential Pressure (Δ P) Shifted to Critical Axial Location Station 1877.43	17
8.	SRB Aft Skirt Cavity Collapse Peak Differential Pressure (Δ P) Matrices for Assessment of Probability of Axial Location	18
9.	SRB TVC Power Supply Water Impact Pressure Input Matrix	19
10	Cost Advantage of a Structural Verification Test of the Aft Skirt	19
11.	Summary of Baseline (10/1/75) Configuration Attrition Versus Vertical Velocity (V_V)	20

TECHNICAL MEMORANDUM X-73308

SRB ATTRITION RATE STUDY OF THE AFT SKIRT DUE TO WATER IMPACT CAVITY COLLAPSE LOADING

INTRODUCTION

Cost optimum design of the Solid Rocket Booster (SRB) requires adequate assessment of attrition resulting from reuse. The attrition assessment treats the water impact loadings probabilistically and determines if these loadings exceed the structural capabilities of the designed structure.

The critical loading for the aft skirt of the SRB during water impact is the cavity collapse condition. Seventy-five discrete loading cases have been empirically determined as functions of vertical impact velocity (V_V), horizontal velocity (V_H), and impact angle (θ).

Each discrete load case, as identified by the parameters $V_V/V_H/\theta$, varies longitudinally and radially in magnitude and distribution of the external pressure. The distributions are further required to be shifted forward or aft one-fourth the vehicle diameter to assure minimization of the effect of test instrumentation location for the load determinations. The asymmetrical load distributions result in large geometric nonlinearities in structural response. In addition, the loads are frequently more severe in a particular location (clocking) around the skirt, and the skirt itself has a definite preferred orientation due to the location of thrust posts.

This report discusses the methodology of attrition evaluation of the aft skirt. It traces the evolution of the data and develops the rationale around minimization of conservatism. It also evaluates the effects of structural reinforcement and verification test options on attrition.

This analysis was made necessary when changes in water impact loads (Fig. 1) resulted in reoptimization of the design due to high attrition rates. It formulated the data base [1] for the recommendation to reduce the nominal vertical water impact velocity to 85 ft/s. The effects of water impact cavity collapse on the motor case aft segment attrition are discussed in another document [2].

AFT SKIRT CONFIGURATION

The aft skirt configuration is shown in Figure 2. The skirt is essentially a truncated conical shell reinforced by internal rings and stringers. Four holddown/support posts which distribute the prelaunch loads to the mobile launch platform are mounted integrally to the skirt.

The aft skirts of the SRB's (2) provide the prelaunch support for the space Shuttle vehicle and are flight structured. They have been primarily designed for the flight loads (prelaunch). The structure must also withstand the water impact loads. The SRB vehicle on reentry impacts the water aft end first; however, since the vehicle is not manned at time of impact, failures are purely economic and the traditional factor of safety (1.25 for unmanned conditions) and worst case loads is inappropriate. Instead a cost optimization approach was established to define the design.

METHODOLOGY DEVELOPMENT

To design the aft skirt for optimum program cost, the structural capabilities of the aft skirt are established and attrition rates determined to resist each of the water impact loads. In general, this is an iterative process adjusting capabilities through hardware modification, testing, or refined analysis. The lowest program cost lies somewhere between the extremes of a structure not designed for water impact, and thus experiencing a high attrition, and the one designed for the worst case load with a factor of safety and thus requiring a high per unit cost to achieve low attrition. Therefore, a cost optimization approach defines the design (Fig. 3).

Cost optimum design of the aft skirt requires adequate assessment of attrition resulting from reuse. The attrition assessment treats these loadings probabilistically and determines if these loadings exceed the structural capabilities of the designed vehicle. The critical attrition rate for the aft skirt results from the water impact cavity collapse loading.

The assessment of the aft skirt attrition was performed in phases in accordance with refinements in load, capability, and structural beef-up potential.

Each discrete load case, as identified by the parameters $V_V/V_H/\theta$, varies in magnitude and distribution of the external pressure longitudinally and radially. In general, the peak differential pressure decreases with a decrease in vertical velocity. The distributions are further required to be shifted forward or aft one-fourth the vehicle diameter (D) to assure compensation for any effect of test instrumentation location for the load determinations.

Early evaluations considered two load models. The first assumed the peak pressure shifted aft could fall any place arbitrarily on the skirt. A second model assumed the pressure shifted to the worst location in the ±D/4 range. Reevaluation revealed that the shift was probabilistic and that there was an equal probability of the peak being anywhere in the ±D/4 range (Fig. 4).

LOADS

The load parameters utilized for the attrition assessment are documented in SE-019-057-2H, "Space Shuttle Solid Rocket Booster Design Loads, Revision A, September 12, 1975." They are appropriate for the SRB configuration of Figure 5. These loads have been empirically determined as functions of (V_V), (V_H), and (θ).

Table 1 is the matrix of 75 discrete peak internal pressures in the skirt cavity (identified as P1 in the loads document) during the cavity collapse water impact event. These pressures are subtractive from the external pressure loadings (Tables 2 through 6) to formulate the differential pressure (psid) values which form the input load matrices for the SPL. SH program (Tables 7 and 8).

Table 2 is the matrix of external cavity collapse pressure peaks as shown in the loads document which occur at any station location on the skirt aft of station 1823.85 (the forward-most point on the aft skirt), including peaks that if shifted aft 36.5 in. (D/4) would fall on the skirt.

Table 3 is a matrix of external cavity collapse pressure peaks that could fall within ±36.5 in.(±D/4) of station 1877.43 (the most critical location on the skirt for pressure peaks).

Tables 4, 5, and 6 are the matrices of external cavity collapse pressure as shown in the loads documentation at stations 1840.93, 1877.43, and 1913.93, respectively.

Tables 7 and 8 are the matrices of differential pressure (psid) used as input to SPLASH for attrition assessment of the aft skirts. Table 7 is the matrix of maximum differential pressure which can occur anywhere on the aft skirt. Results using these data are referred to in this document as the "MaxΔ P" method. Table 8 shows the three matrices of differential pressure used to assess the attrition for the method assuming an equal probability of the cavity collapse pressure shown in the loads document at station 1877.43 being fore or aft of that location 36.5 in. ($\pm$D/4).

STRUCTURAL CAPABILITIES

The structural capability of a structure for water impact loads is that load which will cause damage that is uneconomical to repair. This may be the onset of yielding, in the case of structures that require critical alignment to assemble, or it may be ultimate, fracture or stability type loading. The capability is established with no reduction due to factors of safety, in effect with a factor of safety of 1.0.

The structural capabilities used for this study were provided by the responsible design and analysis organizations. The capabilities were established for loads on the aft skirt that are directly subject to failure resulting from water impact. These capabilities are used to establish the attrition rates for the aft skirt. They were also used in the study [1] which established the design vertical impact velocity (V_V = 85 ft/s). Analysis showed cavity collapse peak differential pressures occurring at station 1877.43 to be the best measure of the structural capability of aft skirt components. Loading intensities at this station established the structural criticalities of the skin, aft ring, and aft and forward intermediate ring.

Figure 6 indicates the variations in circumferential capability of the aft skirt. Preliminary assessment indicates that the capability at the support posts is 20 percent greater than midway between the 120° arc span. It was assumed that the capability factor varied linearly from 1.0 at 21° either side of the post to 1.2 at the post. Figure 7 shows effects of variations of this peak capability. Figure 8 shows attrition versus variations in the circumferential capability.

COMPUTER PROGRAM SPLASH

Computer program SPLASH [3] (SRB Probabilistic Loads for Attrition of Subsystem Hardware) was utilized to assess the attrition rates of the SRB subassemblies. This program is a Monte Carlo analysis which treats the meteorological factors (wind, sea, etc.) and the strength of each element probabilistically. Each critical load condition is programmed as a table of loads input as a function of V_V, V_H, and θ. For each Monte Carlo trial, a water impact condition (V_V, V_H, θ) is randomly selected and the set of loads is computed by interpolation from the tables. The probability of strength is included in the analysis to increase or decrease the effective load.

A special version of SPLASH was developed for the aft skirt for the assessment of longitudinal and circumferential positional probability of the peak load occurrence and variation in strength capability based on test options.

PROBABILITY OF STRENGTH

The probability of strength accounts for the fact that the majority of the time a structure will actually be stronger than the stress analyst predicts and that occasionally (10 percent of the time) the structure will be weaker than predicted. This effect is due to a number of things: Conservatism in analysis, errors in manufacturing or analysis, variations in material properties, assumed load paths, etc. It has been quantified, based upon a number of Saturn tests [4], and is included in the SPLASH program (Fig. 9). Computations are made with and without the effects. The SPLASH program uses this distribution of strength to derate the loads. There are several distributions included, depending on what type of testing is done. The "standard test" is a test of a prototype structure to the design load. This test eliminates the population of design defects and reduces the attrition from that obtained when no test is planned. In some cases, the attrition benefits are so low or the tests are so expensive that the tests are not cost effective.

ATTRITION

Attrition rate, as utilized here, is defined as the percentage loss or damage to the SRB aft skirt which would result in replacement. In general, it is equivalent to the percentage of missions that a water impact load exceeds the structural capability.

The replacement quantity is determined by an attrition computer program which includes the effects of turnaround time, mission model, maximum uses a structure can experience, and other factors. It can be approximated by twice (two SRB's) the number of flight missions times the attrition rate.

The initial evaluation matrix (Table 7) was constructed of the peak external pressures which could fall on the aft skirt structure. This overly conservative assumption leads to excessively high attritions. Reevaluation with the worst case location of the peak within the ±D/4 shift range about station 1877.43 reduced the attrition significantly but was still considered overly conservative. This load matrix is shown in Table 8. Phase 2 evaluated the effect of shifting the peak with an equal probability of its lying anywhere in the ±D/4 band of station 1877.43. The load peak was assumed to fall at station 1877.43 nominally, as shown in the loads book, with the ±D/4 shifts made from that location. The input to SPLASH is shown in Table 9, and the shifts are illustrated in Figure 5. Phase 3 included the probability of the orientation of the peak falling radially on one of the thrust posts. Another special modification of SPLASH was made which incorporated the clocking capability shown in Figure 6 with the random orientation of the cavity collapse peak pressure relative to that capability. Figure 9 shows a comparison of these phases of refinement in the aft skirt analysis and the resulting reduction in attrition, as conservatism is removed, for a V_V of 100 ft/s.

STRUCTURAL TESTING

Consideration has also been given to the advantages of a structural test on the aft skirt. Since a test during the development phase will uncover any design weaknesses, the attrition probability is improved by conducting a test. However, the cost of the test may outweigh the benefits attained. Figure 10 illustrates the advantage, and Table 10 shows the cost benefits attainable from a test.

STRUCTURAL BEEF-UP

Figures 11 and 12 show the structural capability with respect to the cavity collapse differential pressure versus structural beef-up, based on a yield and ultimate criterion. The yield criterion was utilized for the aft skirt attrition. The ultimate criterion was utilized for attrition of the TVC.

Consideration was given to strengthening the aft skirt to reduce the attrition rate. Curve A (Fig. 11) represents beefing up the weakest areas of the rings and skin, as required, to obtain equal capability. Curve B (Fig. 11) represents beefing up the skin to a 165 psi capability and beefing up the rings to any desired intermediate point. Curve B (Fig. 11) was generated because it would be much more expensive to change the skin at some later date than to change the rings. An alternate beef-up investigated was: add 21 lb to the skin by introducing small integral stiffeners (the skin would then be good for 165 psi), and add 80 lb to the aft and aft intermediate rings. This point is located on curve B of Figure 11.

TVC POWER SUPPLY

The TVC power supply is sensitive to two sources of attrition. The power supply can be damaged by direct water impingement or it can be damaged as a result of an aft skirt failure. The TVC power supply installation is shown in Figure 13. Figure 14 shows the resulting capability versus attrition for velocities of 80, 85, 90, and 100 ft/s.

The failure rate for the power supply resulting from aft skirt failures was determined by judgement to be one-half the failure rate for the aft skirt. The cascading failures resulting from aft skirt failures are dominant at all velocities.

RESULTS AND CONCLUSIONS

Figures 15 and 16 show the attrition of the aft skirt versus differential pressure capability for a V_V of 85 ft/s assuming a structural verification test is and is not performed. Each figure shows three curves for comparison of methodology of their development. Each figure shows the curve (marked max ΔP) developed using the peak differential pressures shifted aft 36.5 in. as shown in Table 7. The curves marked $\pi D/4$, and $\pi D/4$ and clocking used the three matrix differential pressures shown in Table 8, and represent the effect of axial probability of load occurrence and the total effect of axial and radial (clocking) probability of load occurrence, respectively. The structural capability of the aft skirt structure as baselined and with a 100 lb beef-up are labeled. Figure 9 is similar except that it is for a V_V of 100 ft/s.

Figure 17 shows a comparison of attrition with and without the probability of random strength and with and without testing. Both curves indicating a test option include probability of strength. A plot of the results of the max Δ P method is shown which assumes a standard test and random strength to demonstrate the sensitivities of the various assumptions. Clocking is not shown so as to simplify the comparisons.

Figures 18 and 19 are plots of attrition versus capability pressure comparing methodology choices for considerations with and without probability of strength, respectively. Both figures are developed for the V_V of 85 ft/s, assuming no testing. Both figures identify the variation in attrition with respect to probabilities of load positioning axially and radially.

Figures 20 and 21 show the attrition assessments versus the cavity collapse differential pressure capability for V_V of 80, 85, 90, and 100 ft/s. The curves of Figure 20 assume no test and can be compared with Figure 21, which includes test considerations.

Figure 22 shows the aft skirt baseline attrition versus V_V.

Table 11 is a numerical summary of the assessed attrition for the aft skirt for V_V of 80, 85, 90, and 100 ft/s, test and no test options, and for the baselined and beefed-up (100 lb) skirt configurations.

It is concluded that attrition assessments based on peak load occurrence shifted to critical location, as evidenced by the results of the max Δ P method, is excessively conservative (78 percent for a V_V of 100 ft/s, no test).

The method assuming an equal probability of longitudinal location of the peak load shifted one-fourth the vehicle diameter (36.5 in.) forward or aft of a predetermined critical station is a justifiable rational approach which significantly reduces the attrition. For example, the attrition is reduced from 78 to 25 percent for the V_V of 100 ft/s condition (no test). The disadvantages of the method are in establishing the load null critical station (station 1877.43 used for the studies of this report) for which the structural capability interrelationship must be defined for each attrition-significant component.

The rationally justifiable assumption for equal probability of radial location of the peak load (clocking) with respect to radial variations in structural capabilities also significantly reduces attrition. Including clocking, the attrition assessment is reduced from 25 to 20 percent (no test). As is evident from the figures, the attrition is significantly more critical to positional location of the cavity collapse pressure peak in the longitudinal direction than in the radial.

The assessment of the magnitude of the reduction in the attrition is significant if structural verification testing is performed for the cavity collapse loads. The attrition at a V_V of 100 ft/s is 10.0 percent if tests are performed versus 20.0 percent without testing. The assumptions utilized are outlined in Reference 4 and are based on statistical data derived from Saturn test experience. Table 10 shows the cost benefits attainable from testing. A realistic test simulation of the cavity collapse load may not be obtainable within the cost benefits that wc..ld accrue.

For the baselined configuration, unreinforced structural capability (109 psi differential cavity collapse pressure), the random strength consideration increases the attrition. This indicates that the actual strength of the skirt,with respect to the subject loads will probably be less than analysis indicates, assuming no structural testing. The attrition is 7.2 percent including the strength probability; however, neglecting the strength probability, the attrition is 5.0 percent for the V_V = 85 ft/s condition. The data show a reverse of this trend if testing is performed. The attrition is 2.3 percent, assuming testing and random strength. Beefing up the aft skirt 100 lb reduces the no-test attrition to 4.2 percent; at that level of structural capability the attrition is the same, assuming or neglecting random strength. This would indicate that, at this point, the analysis would have the best agreement probabilistically with the actual structures capability. Confidence in the probabilistic methods data base is probably not mature enough to rely precisely on the previously mentioned refinements to the attrition analysis.

Consideration was given to strengthening the aft skirt to reduce the attrition rate. Curve A (Fig. 11) represents beefing up the weakest areas of the rings and skin, as required, to obtain equ. capability. Curve B (Fig. 11) represents beefing up the skin to 165 psi capability and beefing up the rings to any desired intermediate point. Curve B was generated because it would be much more expensive to change the skin at some later date than to change the rings.

SRB Project Management narrowed the choices to two options: Making no structural modifications or adding 21 lb to the skin by introducing small integral stiffeners (the skin would then be good for 165 psi), and adding 80 lb to the aft and aft intermediate rings. This point is located on curve B of Figure 11. The decision was made to not beef up the aft skirt because of weight margin and c.g. effects. Management concluded that weight, schedule, and cost constraints dictated no modification.

Compensation has been included for all conceived conservatism. This represents the most realistic assessment of the aft skirt attrition. With the conservatism removed, the attrition rate at 100 ft/s is still clearly unacceptable. Improvement is obtainable from any reduction in the V_V and significant improvement results from reductions to 80 ft/s.

The aft skirt production rate could be a critical factor if early funding to provide new facilities were required. This is a likely problem at 100 ft/s, but at 90 ft/s the facility is just adequate for the required production rate.

TABLE 1. SRB AFT SKIRT CAVITY COLLAPSE INTERNAL (P1) PRESSURE

CONDITION			MATRIX	CONDITION			MATRIX
V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)	V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)
80.	0.	−10.	.44000 + 02	100.	30.	5.	.56000 + 02
80	0.	− 5	.40000 + 02	100.	30.	10.	.18000 + 02
80	0.	0.	.16000 + 02	100.	45.	−10.	.14000 + 02
80.	0.	5.	.39000 + 02	100.	45.	−5.	.22000 + 02
80.	0.	10.	.44000 + 02	100.	45.	0.	.45000 + 02
80.	15.	−10.	.35000 + 02	100.	45.	5.	.50000 + 02
80.	15.	− 5.	.44000 + 02	100.	45.	10.	.40000 + 02
80.	15.	0.	.40000 + 02	100.	60.	−10.	.21000 + 02
80	15.	5.	.16000 + 02	100.	60.	− 5.	.16000 + 02
80	15	10.	.34000 + 02	100.	60.	0.	.34000 + 02
80.	30.	−10.	.21000 + 02	100.	60.	5.	.42000 + 02
80.	30.	− 5.	.32000 + 02	100.	60.	10.	.55000 + 02
80.	30.	0.	.43000 + 02	120.	0.	−10.	.74000 + 02
80.	30.	5.	.42000 + 02	120.	0.	− 5.	.68000 + 02
80	30.	10.	.16000 + 02	120.	0.	0.	.20000 + 02
80.	45.	−10.	.12000 + 02	120.	0.	5.	.66000 + 02
80.	45.	− 5.	.20000 + 02	120.	0.	10.	.74000 + 02
80.	45.	0.	.42000 + 02	120.	15.	−10.	.52000 + 02
80.	45.	5.	.72000 + 02	120.	15.	− 5.	.74000 + 02
80.	45.	10.	.37000 + 02	120.	15.	0.	.68000 + 02
80	60.	−10.	.18000 + 02	120.	15.	5.	.36000 + 02
80.	60.	− 5.	.12000 + 02	120.	15.	10.	.64000 + 02
80.	60.	0.	.26000 + 02	120.	30.	−10.	.58000 + 02
80.	60.	5.	.34000 + 02	120.	30.	− 5.	.52000 + 02
80.	60	10.	.42000 + 02	120.	30.	0.	.74000 + 02
100.	0.	−10.	.57000 + 02	120.	30.	5.	.69000 + 02
100.	0.	− 5.	.54000 + 02	120.	30.	10.	.20000 + 02
100.	0.	0.	.18000 + 02	120.	45.	−10.	.29000 + 02
100.	0.	5.	.53000 + 02	120.	45.	− 5.	.38000 + 02
100.	0.	10.	.57000 + 02	120.	45.	0.	.52000 + 02
100.	15.	−10.	.37000 + 02	120.	45.	5.	.40000 + 02
100.	15.	− 5.	.53000 + 02	120.	45.	10.	.50000 + 02
100.	15.	0.	.55000 + 02	120.	60.	−10.	.24000 + 02
100.	15.	5.	.24000 + 02	120.	60.	− 5.	.32000 + 02
100.	15.	10.	.45000 + 02	120.	60.	0.	.40000 + 02
100.	30.	−10.	.24000 + 02	120.	60.	5.	.52000 + 02
100.	30.	− 5.	.38000 + 02	120.	60.	10.	.7[illegible]00 + 02
100.	30.	0.	.52000 + 02				

TABLE 2. SRB AFT SKIRT CAVITY COLLAPSE PEAK EXTERNAL PRESSURE (MAX ΔP-P1)

	CONDITION		MATRIX		CONDITION		MATRIX
V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)	V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)
80.	0.	−10.	.13000 + 03	100.	30.	5.	.25500 + 03
80.	0.	− 5.	.13000 + 03	100.	30.	10.	.11800 + 03
80.	0.	0.	.90000 + 02	100.	45.	−10.	.10400 + 03
80.	0.	5.	.13000 + 03	100	45.	−5.	.11800 + 03
80.	0.	10.	.13000 + 03	100.	45.	[illegible]	.15000 + 03
80	15.	−10.	.14300 + 03	100.	45.	5.	[illegible]
80.	15	− 5.	.17500 + 03	100.	45.	10.	.25000 + 03
80.	15.	0.	.16500 + 03	100.	60.	−10.	[illegible]
80.	15.	5.	.78000 + 02	100.	60.	[illegible]	[illegible]
80.	15.	10.	.12800 + 03	100.	60.	0.	.11500 + 03
80.	[illegible]	−10.	.10000 + 03	100.	60.	5.	.15200 + 03
80	[illegible]	− 5	.13200 + 03	100.	60.	10.	.19800 + 03
80.	30.	0.	.16800 + 03	120.	0.	−10.	.28500 + 03
80.	30.	5.	.17500 + 03	120.	0.	− 5.	.26500 + 03
80.	30.	10.	.95000 + 02	120.	0.	0.	.14500 + 03
80.	45.	−10.	.92000 + [illegible]	120.	0.	5.	.26500 + 03
80.	45.	− 5.	.10000 + [illegible]	120.	0.	10.	.28500 + 03
80.	45.	[illegible]	.13500 + 03	120.	15.	−10.	.22000 + 03
80.	45.	[illegible]	.16200 + 03	120.	15.	− 5.	.33000 + 03
80.	45.	10.	.18200 + 03	120.	15.	0.	.28500 + 03
80.	60.	−10.	.95000 + 02	120.	15.	5.	.14000 + 03
80.	60.	− 5.	.10000 + 03	120.	15.	10.	.26000 + 03
80.	60.	0.	.10000 + 03	120.	30.	−10.	.13500 + 03
80.	60.	5.	.11500 + 03	120.	30.	− 5.	.20500 + 03
80.	60.	10.	.15000 + 03	120.	30.	0.	.32000 + 03
100.	0.	−10.	.21000 + 03	120.	30.	5.	.30200 + 03
100.	0.	− 5.	.20000 + 03	120.	30.	10.	.15000 + 03
100.	0.	0.	.12000 + 03	120.	45.	−10.	.11200 + 03
100.	0.	5.	.20000 + 03	120.	45.	− 5.	.13200 + 03
100.	0.	10.	.21000 + 03	120.	45.	0.	.19800 + 03
100.	15.	−10.	.17000 + 03	120.	45.	5.	.31800 + 03
100.	15.	− 5.	.24000 + 03	120.	45.	10.	.30200 + 03
100.	15.	0.	.21800 + 03	120.	60.	−10.	.10000 + 03
100.	15.	5.	.11000 + 03	120.	60.	− 5.	.11000 + 03
100.	15.	10.	.16000 + 03	120.	60.	0.	.13000 + 03
100.	30.	−10.	.11800 + 03	120.	60.	5.	.18500 + 03
100.	30.	− 5.	.16200 + 03	120.	60.	10.	.25400 + 03
100.	30.	0.	.24500 + 03				

NOTE: MAX ΔP SHOWN TABLE 7; P1 SHOWN TABLE 1.

TABLE 3. SRB AFT SKIRT CAVITY COLLAPSE PEAK EXTERNAL PRESSURE ±36.5 INCHES FROM STATION 1877.43, AS SHOWN IN LOADS DOCUMENT

CONDITION			MATRIX	CONDITION			MATRIX
V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)	V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)
80.	0.	−10.	.10000 + 03	100.	30.	5.	.20000 + 03
80.	0.	− 5.	.10000 + 03	100.	30.	10.	.10000 + 03
80.	0.	0.	.70000 + 02	100.	45.	−10.	.95000 + 02
80.	0.	5.	.10000 + 03	100.	45.	−5.	.12000 + 03
80.	0.	10.	.10000 + 03	100.	45.	0.	.12000 + 03
80.	15.	−10.	.14500 + 03	100.	45.	5.	.21500 + 03
80.	15.	− 5.	.16500 + 03	100.	45.	10.	.21000 + 03
80.	15.	0.	.15000 + 03	100.	60.	−10.	.75000 + 02
80.	15.	5.	.65000 + 02	100.	60.	− 5.	.1[illegible]00 + 02
80.	15.	10.	.12000 + 03	100.	60.	0.	.11500 + 03
80.	30.	−10.	.85000 + 02	100.	60.	5.	.15500 + 02
80.	30.	− 5.	.11500 + 03	100.	60.	10.	.16500 + 03
80.	30.	0.	.17000 + 03	120.	0.	−10.	.22000 + 03
80.	30.	5.	.15000 + 03	120.	0.	− 5.	.22000 + 03
80.	30.	10.	.75000 + 02	120.	0.	0.	.12000 + 03
80.	45.	−10.	.80000 + 02	120.	0.	5.	.22000 + 03
80.	45.	− 5.	.10000 + 02	120.	0.	10.	.22000 + 03
80.	45.	0.	.14500 + 03	120.	15.	−10.	.19000 + 03
80.	45.	5.	.16500 + 02	120.	15.	− 5.	.28000 + 03
80.	45.	10.	.15000 + 03	120.	15.	0.	.23000 + 03
80.	60.	−10.	.85000 + 02	120.	15.	5.	.13500 + 03
80.	60.	− 5.	.10000 + 02	120.	15.	10.	.22000 + 03
80.	60.	0.	.95000 + 02	120.	30.	−10.	.13500 + 02
80.	60.	5.	.11000 + 03	120.	30.	− 5.	.20000 + 03
80.	60.	10.	.15000 + 03	120.	30.	0.	.29000 + 03
100.	0.	−10.	.16500 + 03	120.	30.	5.	.26000 + 03
100.	0.	− 5.	.12500 + 03	120.	30.	10.	.13500 + 03
100.	0.	0.	.95000 + 02	120.	45.	−10.	.11000 + 02
100.	0.	5.	.12500 + 03	120.	45.	− 5.	.13000 + 02
100.	0.	10.	.16500 + 03	120.	45.	0.	.20000 + 03
100.	15.	−10.	.15000 + 03	120.	45.	5.	.27500 + 03
100.	15.	− 5.	.21000 + 03	120.	45.	10.	.26000 + 03
100.	15.	0.	.21000 + 03	120.	60.	−10.	.10000 + 02
100.	15.	5.	.90000 + 02	120.	60.	− 5.	.11500 + 03
100.	15.	10.	.14000 + 03	120.	60.	0.	.13500 + 02
100.	30.	−10.	.10000 + 03	120.	60.	5.	.17000 + 03
100.	30.	− 5	.14500 + 03	120.	60.	10.	.25400 + 03
100.	30.	0.	.21500 + 03				

TABLE 4. SRB AFT SKIRT CAVITY COLLAPSE EXTERNAL PRESSURE AT STATION 1877.42, AS SHOWN IN LOADS DOCUMENT (MATRIX 2 + P1)

V_V (FT/SEC)	CONDITION V_H (FT/SEC)	THETA (DEGREES)	MATRIX PRESSURE (PSIG)	V_V (FT/SEC)	CONDITION V_H (FT/SEC)	THETA (DEGREES)	MATRIX PRESSURE (PSIG)
80.	0.	−10.	.70000 + 02	100.	30.	5.	.15000 + 03
80.	0.	− 5.	.70000 + 02	100.	30.	10.	.75000 + 02
80.	0.	0.	.55000 + 02	100.	45.	−10.	.96000 + 02
80.	0.	5.	.70000 + 02	100.	45.	−5.	.12500 + 03
80.	0.	10.	.70000 + 02	100.	45.	0.	.10000 + 03
80.	15.	−10.	.14500 + 03	100.	45.	5.	.20000 + 03
80.	15.	− 5.	.10000 + 03	100.	45.	10.	.18600 + 03
80.	15.	0.	.12500 + 03	100.	60.	−10.	.70000 + 02
80.	15.	5.	.55000 + 02	100.	60.	− 5.	.11500 + 03
80.	15.	10.	.11500 + 03	100.	60.	0.	.11500 + 03
80.	30.	−10.	.75000 + 02	100.	60.	5.	.15500 + 03
80.	30.	− 5.	.10000 + 03	100.	60.	10.	.14600 + 03
80.	30.	0.	.17500 + 03	120.	0.	−10.	.19600 + 03
20.	30.	5.	.13000 + 03	120.	0.	− 5.	.18000 + 03
80.	30.	10.	.55000 + 02	120.	0.	0.	.96100 + 03
80.	45.	−10.	.50000 + 02	120.	0.	5.	.18000 + 03
80.	45.	− 5.	.10000 + 03	120.	0.	10.	.19600 + 03
80.	45.	0.	.14500 + 03	120.	15.	−10.	.15000 + 03
80.	45.	5.	.16000 + 03	120.	15.	− 5.	.24500 + 03
80.	45.	10.	.75500 + 02	120.	15.	0.	.17600 + 03
80.	60.	−10.	.80000 + 02	120.	15.	5.	.11500 + 03
80.	60.	− 5.	.95000 + 02	120.	15.	10.	.19600 + 03
80.	60.	0.	.85000 + 02	120.	30.	−10.	.13600 + 03
80.	60.	5.	.11500 + 03	120.	30.	− 5.	.19500 + 03
80.	60.	10.	.10000 + 03	120.	30.	0.	.25000 + 03
100.	0.	−10.	.10500 + 03	120.	30.	5.	.20000 + 03
100.	0.	− 5.	.10000 + 03	120.	30.	10.	.12000 + 03
100.	0.	0.	.65200 + 02	120.	45.	−10.	.11000 + 02
100.	0.	5.	.10000 + 03	120.	45.	− 5.	.14000 + 02
100.	0.	10.	.10500 + 03	120.	45.	0.	.20000 + 03
100.	15.	−10.	.11500 + 03	120.	45.	5.	.25000 + 03
100.	15.	− 5.	.18500 + 03	120.	45.	10.	.20000 + 03
100.	15.	0.	.19500 + 03	120.	60.	−10.	.10000 + 03
100.	15.	5.	.75000 + 02	120.	60.	− 5.	.10000 + 03
100.	15.	10.	.10000 + 03	120.	60.	0.	.13000 + 03
100.	30.	−10.	.11500 + 03	120.	60.	5.	.15000 + 03
100.	30.	− 5.	.12500 + 03	120.	60.	10.	.25000 + 03
100.	30.	0.					

TABLE 5. SRB AFT SKIRT CAVITY COLLAPSE EXTERNAL PRESSURE AT STATION 1913.93, AS SHOWN IN LOADS DOCUMENT (MATRIX 3 + P1), EQUIVALENT TO LOAD SHIFTED FORWARD 36.5 INCHES

CONDITION			MATRIX	CONDITION			MATRIX
V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)		V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)
80.	0.	−10.	.10000 + 03	100.	30.	5.	.20000 + 03
80.	0.	− 5.	.10000 + 03	100.	30.	10.	.10000 + 03
80.	0.	0.	.70000 + 02	100.	45.	−10.	.80000 + 02
80.	0.	5.	.10000 + 03	100.	45.	−5.	.11500 + 03
80.	0.	10.	.10000 + 03	100.	45.	0.	.12000 + 03
80.	15.	−10.	.13500 + 03	100.	45.	5.	.21530 + 03
80.	15.	− 5.	.16500 + 03	100.	45.	10.	.21000 + 03
80.	15.	0.	.15000 + 03	100.	60.	−10.	.46000 + 02
80.	15.	5.	.65000 + 02	100.	60.	− 5.	.75000 + 02
80.	15.	10.	.12000 + 03	100.	60.	0.	.11000 + 03
80.	30.	−10.	.85000 + 02	100.	60.	5.	.15500 + 02
80.	30.	− 5.	.11500 + 03	100.	60.	10.	.16500 + 03
80.	30.	0.	.16500 + 03	120.	0.	−10.	.22000 + 03
80.	30.	5.	.15000 + 03	120.	0.	− 5.	.22000 + 03
80.	30.	10.	.75000 + 02	120.	0.	0.	.12000 + 03
80.	45.	−10.	.45000 + 02	120.	0.	5.	.22000 + 03
80.	45.	− 5.	.75000 + 02	120.	0.	10.	.22000 + 03
80.	45.	0.	.13000 + 03	120.	15.	−10.	.19000 + 03
80.	45.	5.	.15500 + 02	120.	15.	− 5.	.28000 + 03
80.	45.	10.	.15000 + 03	120.	15.	0.	.22000 + 03
80.	60.	−10.	.15000 + 02	120.	15.	5.	.13500 + 03
80.	60.	− 5.	.55000 + 02	120.	15.	10.	.22000 + 03
80.	60.	0.	.70000 + 02	120.	30.	−10.	.13500 + 02
80.	60.	5.	.10500 + 03	120.	30.	− 5.	.20000 + 03
80.	60.	10.	.10000 + 03	120.	30.	0.	.29000 + 03
100.	0.	−10.	.16000 + 03	120.	30.	5.	.26000 + 03
100.	0.	− 5.	.12500 + 03	120.	30.	10.	.13500 + 03
100.	0.	0.	.95200 + 02	120.	45.	−10.	.11000 + 02
100.	0.	5.	.12500 + 03	120.	45.	− 5.	.13000 + 02
100.	0.	10.	.15000 + 03	120.	45.	0.	.18500 + 03
100.	15.	−10.	.15000 + 03	120.	45.	5.	.27500 + 03
100.	15.	− 5.	.21000 + 03	120.	45.	10.	.26000 + 03
100.	15.	0.	.21000 + 03	120.	60.	−10.	.85000 + 02
100.	15.	5.	.85000 + 02	120.	60.	− 5.	.10000 + 03
100.	15.	10.	.13500 + 03	120.	60.	0.	.12500 + 02
100.	30.	−10.	.10000 + 03	120.	60.	5.	.16500 + 03
100.	30.	− 5.	.14500 + 03	120.	60.	10.	.28000 + 03
100.	30.	0.	.21500 + 03				

TABLE 6. SRB AFT SKIRT CAVITY COLLAPSE EXTERNAL PRESSURE AT STATION 1840.93, AS SHOWN IN LOADS DOCUMENT (MATRIX 1 + P1), EQUIVALENT TO LOAD SHIFTED AFT 36.5 INCHES

CONDITION V_V (FT/SEC)	CONDITION V_H (FT/SEC)	THETA (DEGREES)	MATRIX PRESSURE (PSIG)	CONDITION V_V (FT/SEC)	CONDITION V_H (FT/SEC)	THETA (DEGREES)	MATRIX PRESSURE (PSIG)
80.	0.	−10.	.45000 + 02	100.	30.	5.	.90000 + 02
80.	0.	− 5.	.45000 + 02	100.	30.	10.	.50000 + 02
80.	0.	0.	.35000 + 02	100.	45.	−10.	.50000 + 02
80.	0.	5.	.45000 + 02	100.	45.	−5.	.65000 + 02
80.	0.	10.	.45000 + 02	100.	45.	0.	.50000 + 02
80.	15.	−10.	.70000 + 02	100.	45.	5.	.95000 + 02
80.	15.	− 5.	.55000 + 02	100.	45.	10.	.95000 + 02
80.	15.	0.	.55000 + 02	100.	60.	−10.	.80000 + 02
80.	15.	5.	.45000 + 02	100.	60.	− 5.	.11000 + 03
80.	15.	10.	.55000 + 02	100.	60.	0.	.10000 + 03
80.	30.	−10.	.50000 + 02	100.	60.	5.	.75000 + 02
80.	30.	− 5.	.55000 + 02	100.	60.	10.	.70000 + 02
80.	30.	0.	.9500C + 02	120.	0.	−10.	.95000 + 02
80.	30.	5.	.55000 + 02	120.	0.	− 5.	.10000 + 03
80.	30.	10.	.40000 + 02	120.	0.	0.	.50000 + 02
80.	45.	−10.	.75000 + 02	120.	0.	5.	.10000 + 03
80.	45.	− 5.	.55000 + 02	120.	0.	10.	.95000 + 02
80.	45.	0.	.65000 + 02	120.	15.	−10.	.80000 + 02
80.	45.	5.	.70000 + 02	120.	15.	− 5.	.12000 + 03
80.	45.	10.	.55000 + 02	120.	15.	0.	.10000 + 03
80.	60.	−10.	.85000 + 02	120.	15.	5.	.75000 + 02
80.	60.	− 5.	.10000 + 03	120.	15.	10.	.10000 + 03
80.	60.	0.	.95000 + 02	120.	30.	−10.	.75000 + 02
80.	60.	5.	.50000 + 02	120.	30.	− 5.	.95000 + 02
80.	60.	10.	.75000 + 02	120.	30.	0.	.11000 + 03
100.	0.	−10.	.70000 + 02	120.	30.	5.	.10000 + 03
100.	0.	− 5.	.50000 + 02	120.	30.	10.	.75000 + 02
100.	0.	0.	.45000 + 02	120.	45.	−10.	.50000 + 02
100.	0.	5.	.50000 + 02	120.	45.	− 5.	.65000 + 02
100.	0.	10.	.70000 + 02	120.	45.	0.	.10000 + 03
100.	15.	−10.	.60000 + 02	120.	45.	5.	.10500 + 03
100.	15.	− 5.	.80000 + 02	120.	45.	10.	.10000 + 03
100.	15.	0.	.95000 + 02	120.	60.	−10.	.10000 + 03
100.	15.	5.	.45000 + 02	120.	60.	− 5.	.55000 + 02
100.	15.	10.	.50000 + 02	120.	60.	0.	.65000 + 02
100.	30.	−10.	.60000 + 02	120.	60.	5.	.70000 + 02
100.	30.	− 5.	.70000 + 02	120.	60.	10.	.13000 + 03
100.	30.	0.	.95000 + 02				

TABLE 7. SRB AFT SKIRT CAVITY COLLAPSE PEAK DIFFERENTIAL PRESSURE (ΔP) SHIFTED TO CRITICAL AXIAL LOCATION STATION 1877.43

CONDITION			MATRIX	CONDITION			MATRIX
V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)	V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)
80.	0.	−10.	.86000 + 02	100.	30.	5.	.19900 + 03
80.	0.	− 5.	.90000 + 02	100.	30.	10.	.10000 + 03
80.	0.	0.	.74000 + 02	100.	45.	−10.	.90000 + 02
80.	0.	5.	.91000 + 02	100.	45.	−5.	.96000 + 02
80.	0.	10.	.86000 + 02	100.	45.	0.	.10500 + 03
80.	15.	−10.	.10800 + 03	100.	45.	5.	.19000 + 03
80.	15.	− 5.	.13100 + 03	100.	45.	10.	.21000 + 03
80.	15.	0.	.12500 + 03	100.	60.	−10.	.69000 + 02
80.	15.	5.	.62000 + 02	100.	60.	− 5.	.94000 + 02
80.	15.	10.	.94000 + 02	100.	60.	0.	.81000 + 02
80.	30.	−10.	.79000 + 02	100.	60.	5.	.99000 + 02
80.	30.	− 5.	.10000 + 03	100.	60.	10.	.14100 + 03
80.	30.	0.	.12500 + 03	120.	0.	−10.	.21100 + 03
80.	30.	5.	.13300 + 03	120.	0.	− 5.	.19700 + 03
80.	30.	10.	.79000 + 02	120.	0.	0.	.12500 + 03
80.	45.	−10.	.80000 + 02	120.	0.	5.	.20000 + 03
80.	45.	− 5.	.80000 + 02	120.	0.	10.	.21100 + 03
80.	45.	0.	.93000 + 02	120.	15.	−10.	.16800 + 03
80.	45.	5.	.90000 + 02	120.	15.	− 5.	.25600 + 03
80.	45.	10.	.14500 + 03	120.	15.	0.	.21700 + 03
80.	60.	−10.	.77000 + 02	120.	15.	5.	.10400 + 03
80.	60.	− 5.	.88000 + 02	120.	15.	10.	.19800 + 03
80.	60.	0.	.86000 + 02	120.	30.	−10.	.77000 + 02
80.	60.	5.	.61000 + 02	120.	30.	− 5.	.15300 + 03
80.	60.	10.	.86000 + 02	120.	30.	0.	.24600 + 03
100.	0.	−10.	.15300 + 03	120.	30.	5.	.23300 + 03
100.	0.	− 5.	.14600 + 03	120.	30.	10.	.13000 + 03
100.	0.	0.	.10200 + 03	120.	45.	−10.	.83000 + 02
100.	0.	5.	.14700 + 03	120.	45.	− 5.	.94000 + 02
100.	0.	10.	.15300 + 03	120.	45.	0.	.14600 + 03
100.	15.	−10.	.13300 + 03	120.	45.	5.	.27800 + 03
100.	15.	− 5.	.18700 + 03	120.	45.	10.	.25200 + 03
100.	15.	0.	.16300 + 03	120.	60.	−10.	.76000 + 02
100.	15.	5.	.86000 + 02	120.	60.	− 5.	.78000 + 02
100.	15.	10.	.11500 + 03	120.	60.	0.	.90000 + 02
100.	30.	−10.	.94000 + 02	120.	60.	5.	.13400 + 03
100.	30.	− 5.	.12600 + 03	120.	60.	10.	.17800 + 03
100.	30.	0.	.19300 + 03				

TABLE 8. SRB AFT SKIRT CAVITY COLLAPSE PEAK DIFFERENTIAL PRESSURE (ΔP) MATRICES FOR ASSESSMENT OF PROBABILITY OF AXIAL LOCATION

NOTE: MATRIX 1 (TABLE 6-TABLE 1); MATRIX 2 (TABLE 4 - TABLE 1); MATRIX 3 (TABLE 5 - TABLE 1)

CONDITION			DIFFERENTIAL PRESSURE (PSIG)		
V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	MATRIX 1	MATRIX 2	MATRIX 3
80.	0.	−10	10000 + 01	.26000 + 02	.56000 + 02
80.	0.	− 5.	50000 + 01	.30000 + 02	.60000 + 02
80.	0	0.	19030 + 02	39000 + 02	.54000 + 02
80	0	5	60000 + 01	.31000 + 02	.61000 + 02
80	0.	10.	10800 + 01	.26000 + 02	.56000 + 02
80	15	−10	.35000 + 02	.11000 + 03	10000 + 03
80	15	− 5.	.11000 + 02	.56000 + 02	.12100 + 03
80.	15.	0	.15000 + 02	.85000 + 02	.11000 + 03
80.	15.	5	.29000 + 02	.39000 + 02	.49000 + 02
80	15.	10.	.10000 + 01	.81000 + 02	.86000 + 02
80	30	−10	.29000 + 02	54000 + 02	.64000 + 02
80	30.	− 5	.23000 + 02	.68000 + 02	.83000 + 02
80	30.	0.	.52000 + 02	13200 + 03	.12200 + 03
80.	30.	5.	13000 + 02	.88000 + 02	10800 + 03
80.	30.	10	24000 + 02	.39000 + 02	.59000 + 02
80.	45.	−10.	.63000 + 02	.38000 + 02	.33000 + 02
80	45.	− 5.	.35000 + 02	.80000 + 02	.55000 + 02
80	45.	0	.23000 + 02	10300 + 03	.28000 + 02
80.	45.	5.	− 20000 + 01	.88000 + 02	83000 + 02
80	45.	10.	18000 + 02	.38000 + 02	.11300 + 03
80	60.	−10	.82000 + 02	.62000 + 02	−.30000 + 01
80	60.	− 5.	.88000 + 02	.83000 + 02	.43000 + 02
80	60.	0	.69000 + 02	59000 + 02	.44000 + 02
80.	60	5.	16000 + 02	.81000 + 02	.71000 + 02
80.	60.	10.	.33000 + 02	.58000 + 02	.58000 + 02
100	0.	−10.	.13000 + 02	48000 + 02	.10900 + 03
100	0.	− 5.	.34000 + 02	.46000 + 02	.71000 + 02
100	0.	0.	.27000 + 02	47000 + 02	.77000 + 02
100	0.	5.	−.30000 + 01	.47000 + 02	.72000 + 02
100.	0.	10.	.28000 + 02	.48000 + 02	.93000 + 02
100.	15.	−10.	.23000 + 02	.78000 + 02	.11300 + 03
100	15	− 5.	.27000 + 02	.13200 + 03	.15700 + 03
100.	15.	0.	40000 + 02	.14000 + 03	.15500 + 03
100	15.	5	.21000 + 02	.51000 + 02	.61000 + 02
100.	15.	10.	50000 + 01	.55000 + 02	.90000 + 02
100.	30	−10.	.36000 + 02	.91000 + 02	.76000 + 02
100	30.	− 5.	34000 + 02	.89000 + 02	.10900 + 03
100	30	0.	43000 + 02	.14300 + 03	.16300 + 03
100.	30.	5.	34000 + 02	.94000 + 02	14400 + 03
100.	30.	10.	32000 + 02	.57000 + 02	82000 + 02
100.	45.	−10.	36000 + 02	81000 + 02	66000 + 02
100.	45.	− 5.	43000 + 02	.10300 + 03	93000 + 02
100	45.	0.	[illegible]0000 + 01	.55000 + 02	75000 + 02
100.	45.	5.	45000 + 02	.15000 + 03	.16400 + 03
100.	45.	10	55000 + 02	14000 + 03	16500 + 03
100.	60.	−10.	.59000 + 02	.49000 + 02	24000 + 02
100.	60.	− 5.	94000 + 02	.99000 + 02	59000 + 02
100.	60.	0	66000 + 02	.81000 + 02	76000 + 02
100.	60	5.	22000 + 02	.11300 + 03	11300 + 03
100.	60	10.	.15000 + 02	.90000 + 02	11000 + 03
120.	0	−10.	.21000 + 02	.12100 + 03	14600 + 03
120.	0	− 5.	.32000 + 02	.11200 + 03	15200 + 03
120.	0.	0.	.30000 + 02	75000 + 02	.10000 + 03
120.	0.	5	.44000 + 02	11400 + 03	15400 + 03
120.	0.	10	21000 + 02	.12100 + 03	.14600 + 03
120.	15.	−10.	.28000 + 02	.98000 + 02	13800 + 03
120	15.	− 5	.46000 + 02	17100 + 03	20600 + 03
120.	15.	0.	32000 + 02	10700 + 03	15200 + 03
120.	15.	5.	39000 + 02	79000 + 02	99000 + 02
120.	15.	10	36000 + 02	13100 + 03	15600 + 03
120.	30.	−10.	17000 + 02	77000 + 02	77000 + 02
120.	30.	− 5.	.43000 + 02	.14300 + 03	14800 + 03
120.	30.	0.	.36000 + 02	17600 + 03	21600 + 03
120	30.	5.	60000 + 01	.13100 + 03	19100 + 03
120.	30	10.	55000 + 02	.10000 + 03	.11500 + 03
120	45.	−10.	21000 + 02	81000 + 02	.81000 + 02
120.	45.	− 5.	27000 + 02	.88000 + 02	92000 + 02
120.	45.	0.	48000 + 02	.14800 + 03	13300 + 03
120.	45.	5.	.65000 + 02	.21000 + 03	23500 + 03
120.	45.	10.	.50000 + 02	.19000 + 03	.21000 + 03
120.	60.	−10	76000 + 02	.76000 + 02	61000 + 02
120.	60.	− 5.	.23000 + 02	68000 + 02	.68000 + 02
120.	60.	0.	25000 + 02	.90000 + 02	.85000 + 02
120.	60.	5.	18000 + 02	.98000 + 02	.11300 + 03
120.	60	10.	54000 + 02	17400 + 03	

TABLE 9. SRB TVC POWER SUPPLY WATER IMPACT PRESSURE INPUT MATRIX

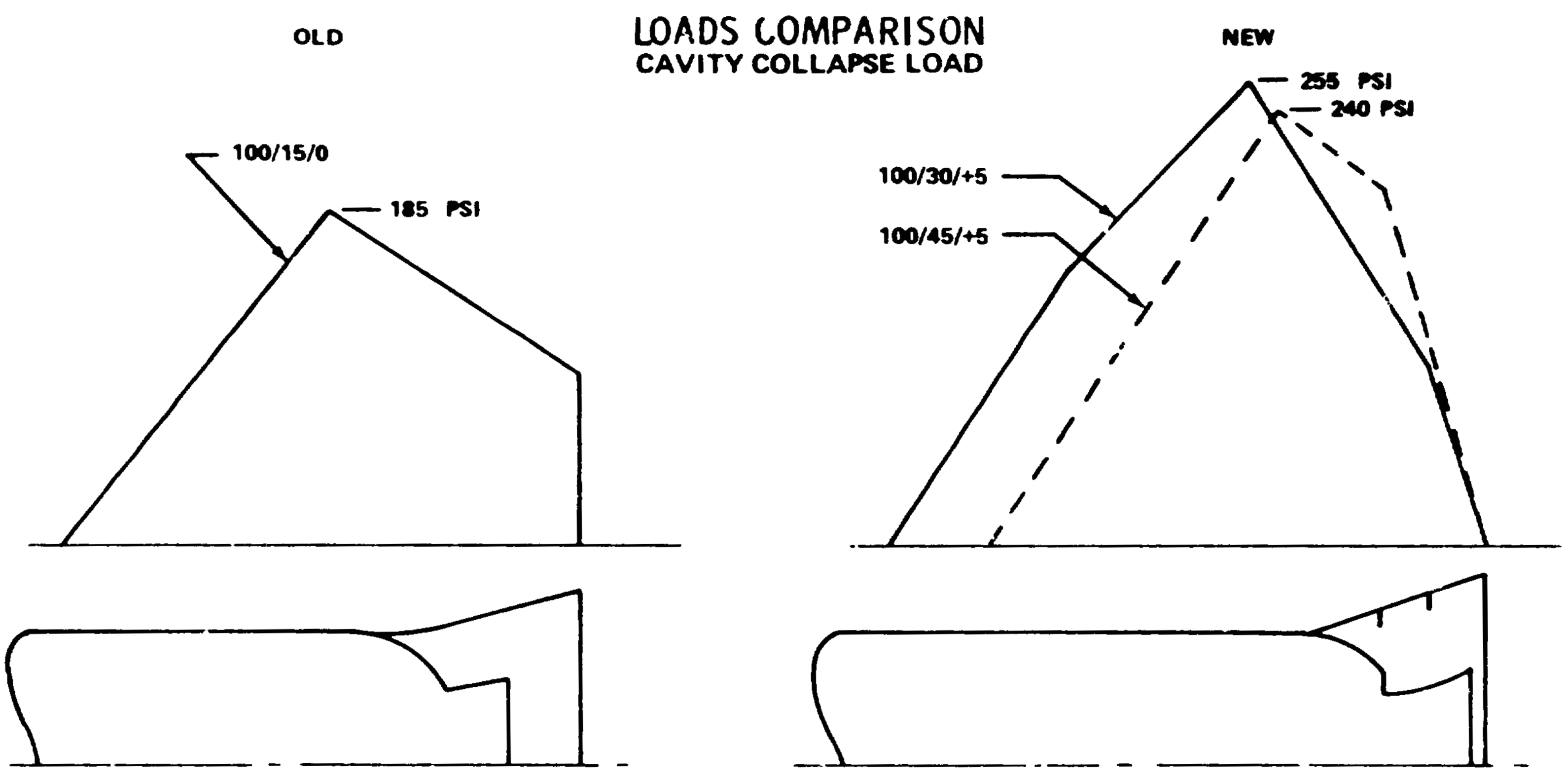
CONDITION			MATRIX
V_V (FT/SEC)	V_H (FT/SEC)	THETA (DEGREES)	PRESSURE (PSIG)
80.	0.	−10.	.65000 + 02
80.	0.	0.	.65000 + 02
80.	0.	10.	.65000 + 02
80.	30.	−10.	.65000 + 02
80.	30.	0.	.65000 + 02
80.	30.	10.	.65000 + 02
80.	60.	−10.	.65000 + 02
80.	60.	0.	.65000 + 02
80.	60.	10.	.65000 + 02
100.	0.	−10.	.90000 + 02
100.	0.	0.	.90000 + 02
100.	0.	10.	.90000 + 02
100.	30.	−10.	.90000 + 02
100.	30.	0.	.90000 + 02
100.	30.	10.	.90000 + 02
100.	60.	−10.	.90000 + 02
100.	60.	0.	.90000 + 02
100.	60.	10.	.90000 + 02
120.	0.	−10.	.12500 + 03
120.	0.	0.	.12500 + 03
120.	0.	10.	.12500 + 03
120.	30.	−10.	.12500 + 03
120.	30.	0.	.12500 + 03
120.	30.	10.	.12500 + 03
120.	60.	−10.	.12500 + 03
120.	60.	0.	.12500 + 03
120.	60.	10.	.12500 + 03

TABLE 10. COST ADVANTAGE OF A STRUCTURAL VERIFICATION TEST OF THE AFT SKIRT

	NO TEST	TEST
ATTRITION RATE	7.2	2.3
HARDWARE REQUIRED	123	78
DELTA COST (FY 75 $)	$ 7.0M	
DELTA COST (RY $)	$11.9M	
	V_V = 85 FT/S	

TABLE 11 SUMMARY OF BASELINE (10/1/75) CONFIGURATION ATTRITION RATES VERSUS VERTICAL VELOCITY (V_V)

ASSEMBLY	V_V (FT/SEC) 80	85	90	100
AFT SKIRT (NO BEEF-UP) NO TEST	4.8%	7.2%	11.0%	20.0%
STD. TEST	1.2%	2.3%	4.0%	10.0%
(100 LBS BEEF-UP) NO TEST	2.2%	4.2%	6.5%	12.0%
STD. TEST	0.3%	0.8%	1.6%	5.0%



- INCREASE IN PEAK PRESSURE AFFECTS AFT SRM SEGMENT
- AFT SHIFT OF LOAD PEAK AFFECTS AFT SKIRT STRUCTURE

Figure 1. Configuration load effects of aft portion of SRB at cavity collapse loading.

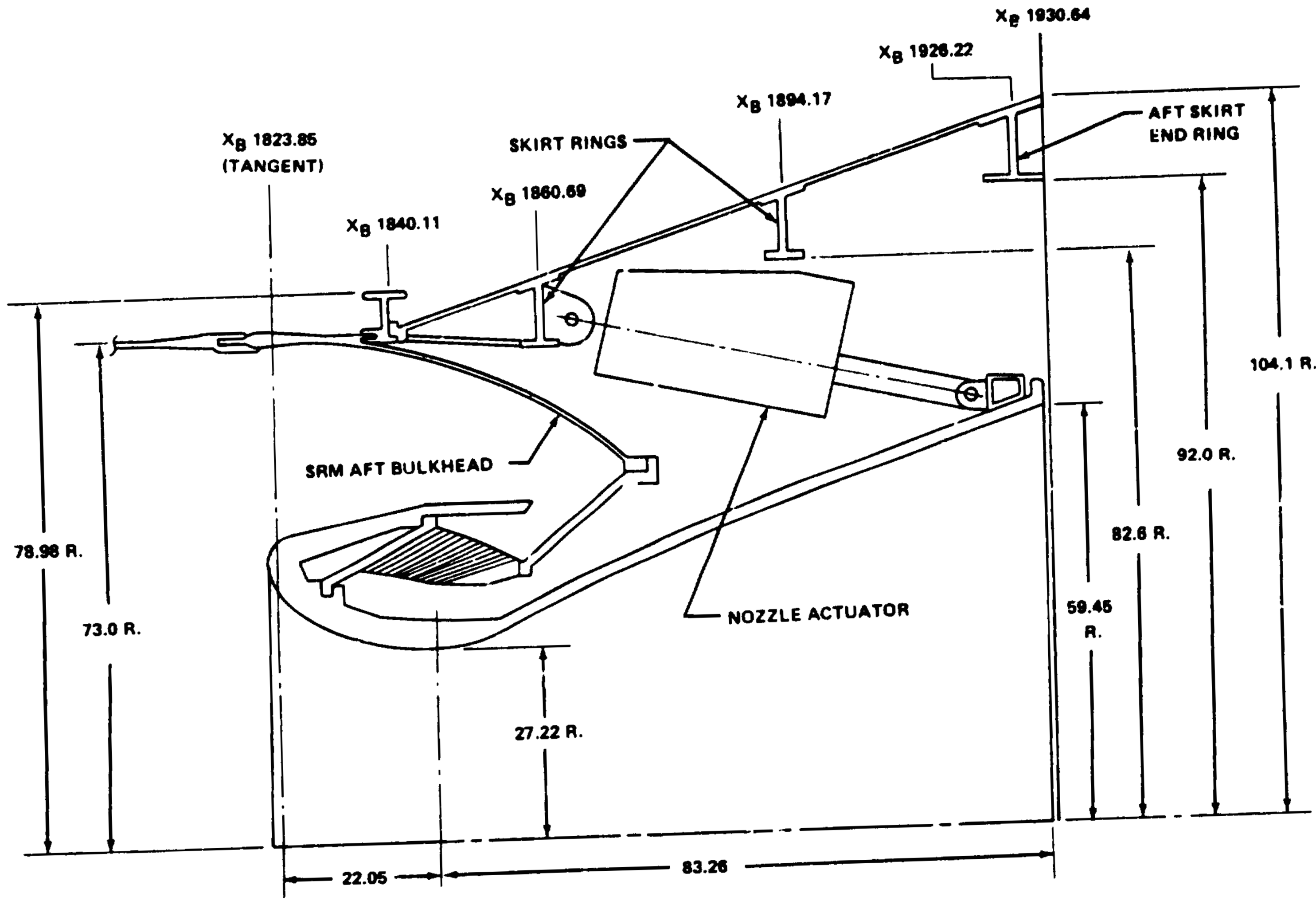


Figure 2. Configuration 5/1/75 baseline SRB aft end at water impact.

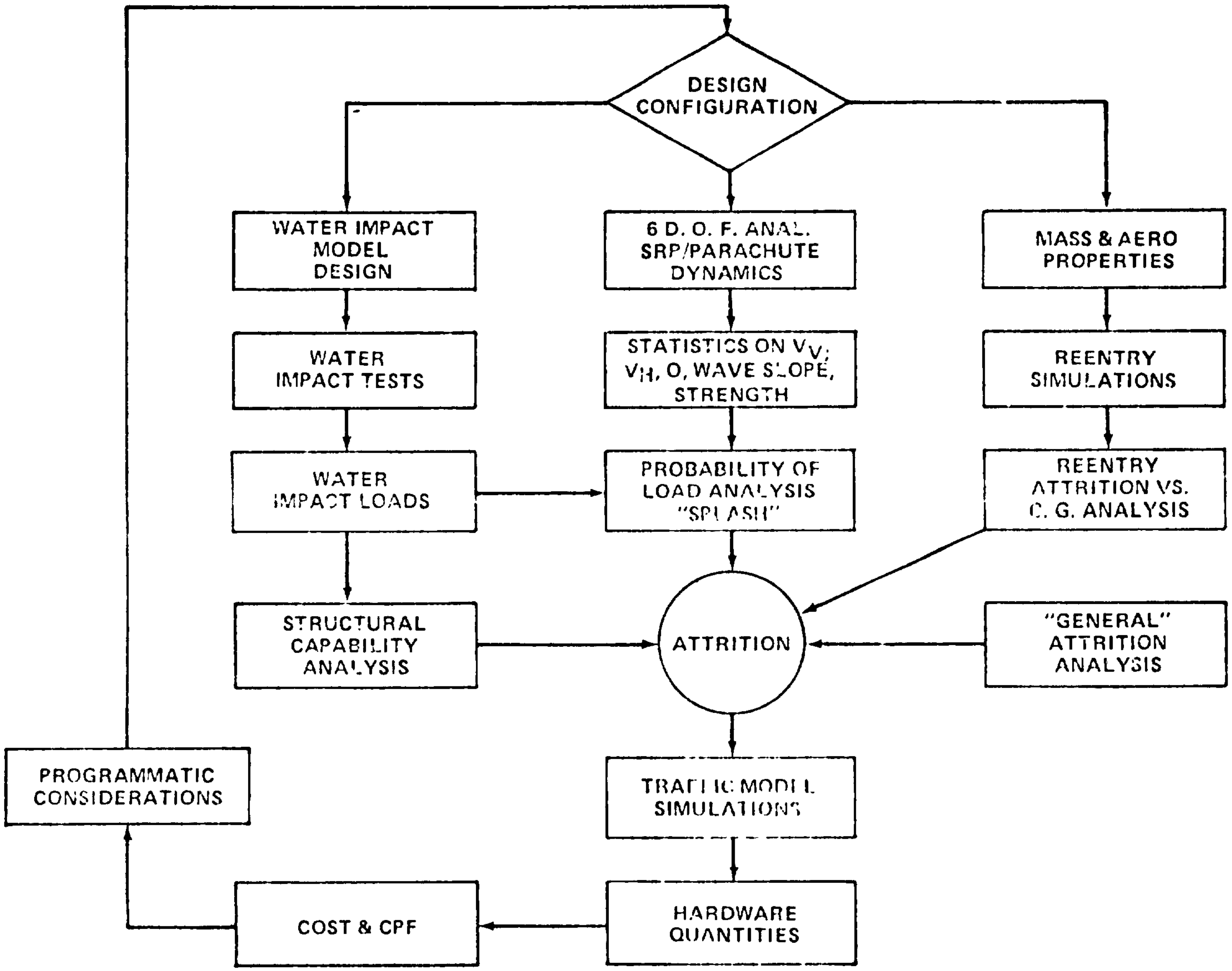


Figure 3. Flow diagram of requirements for attrition assessment for the Shuttle SRB.

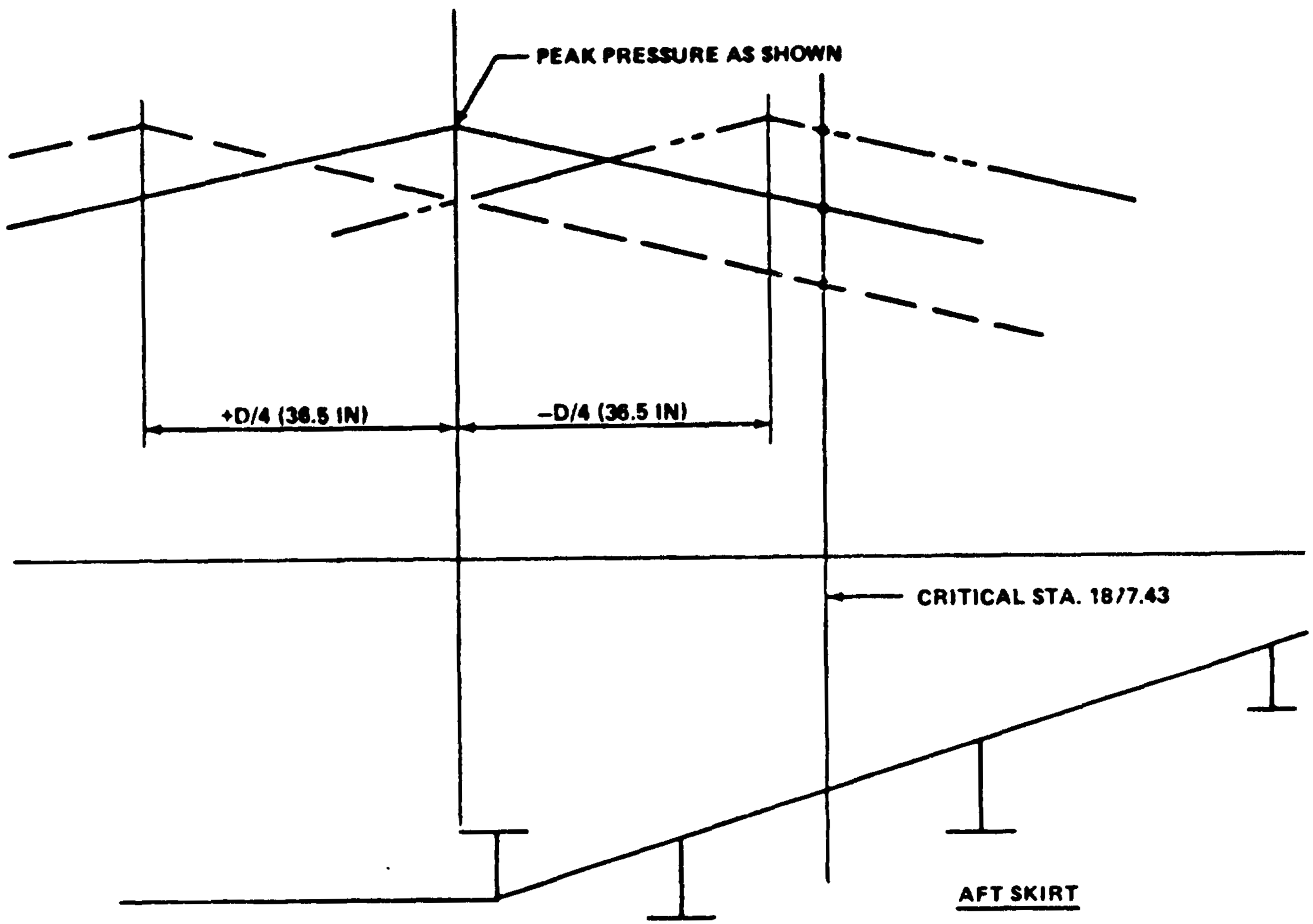


Figure 4. SRB aft skirt cavity collapse longitudinal equal probability of load peak.

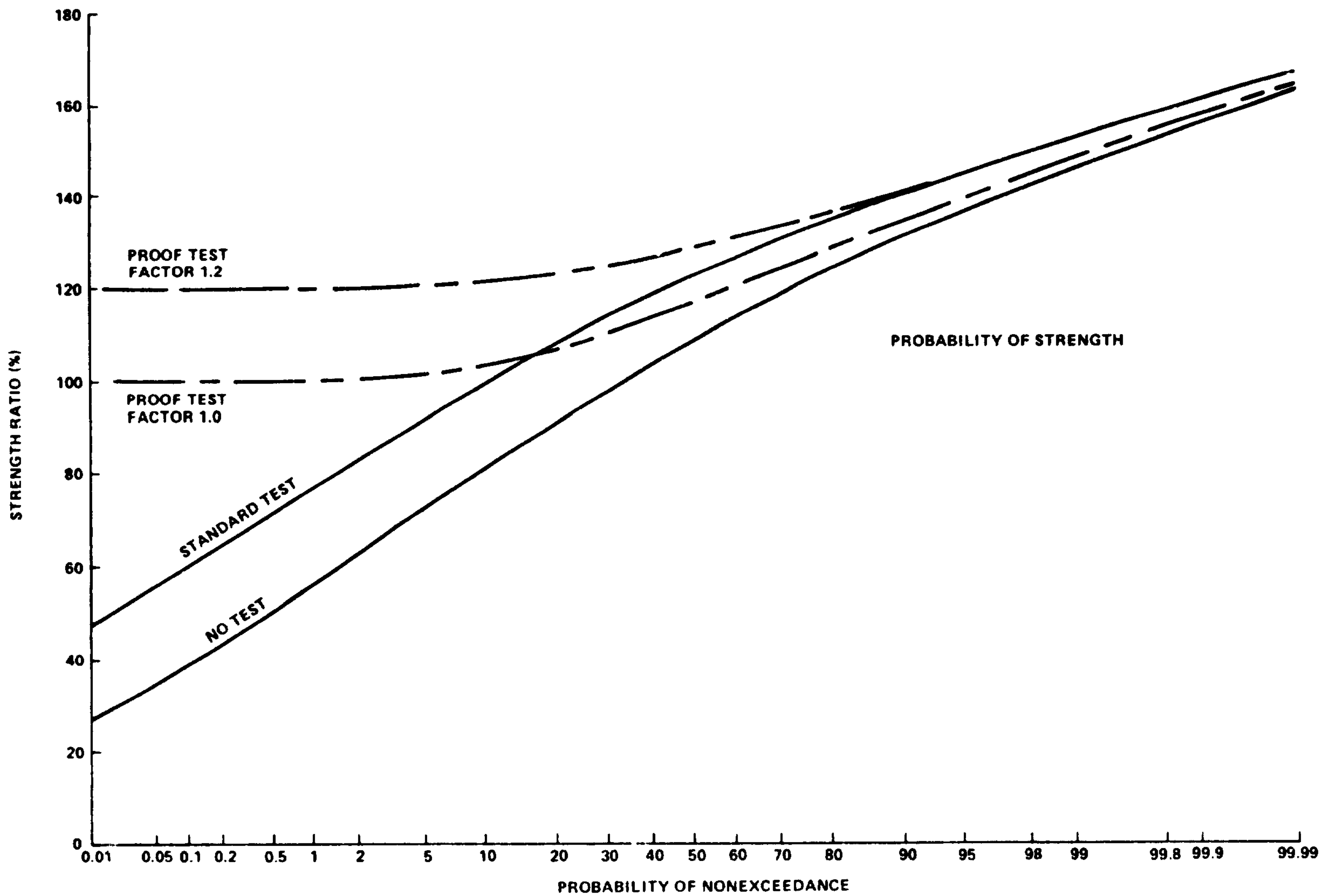


Figure 5. Probability of strength as a function of verification testing.

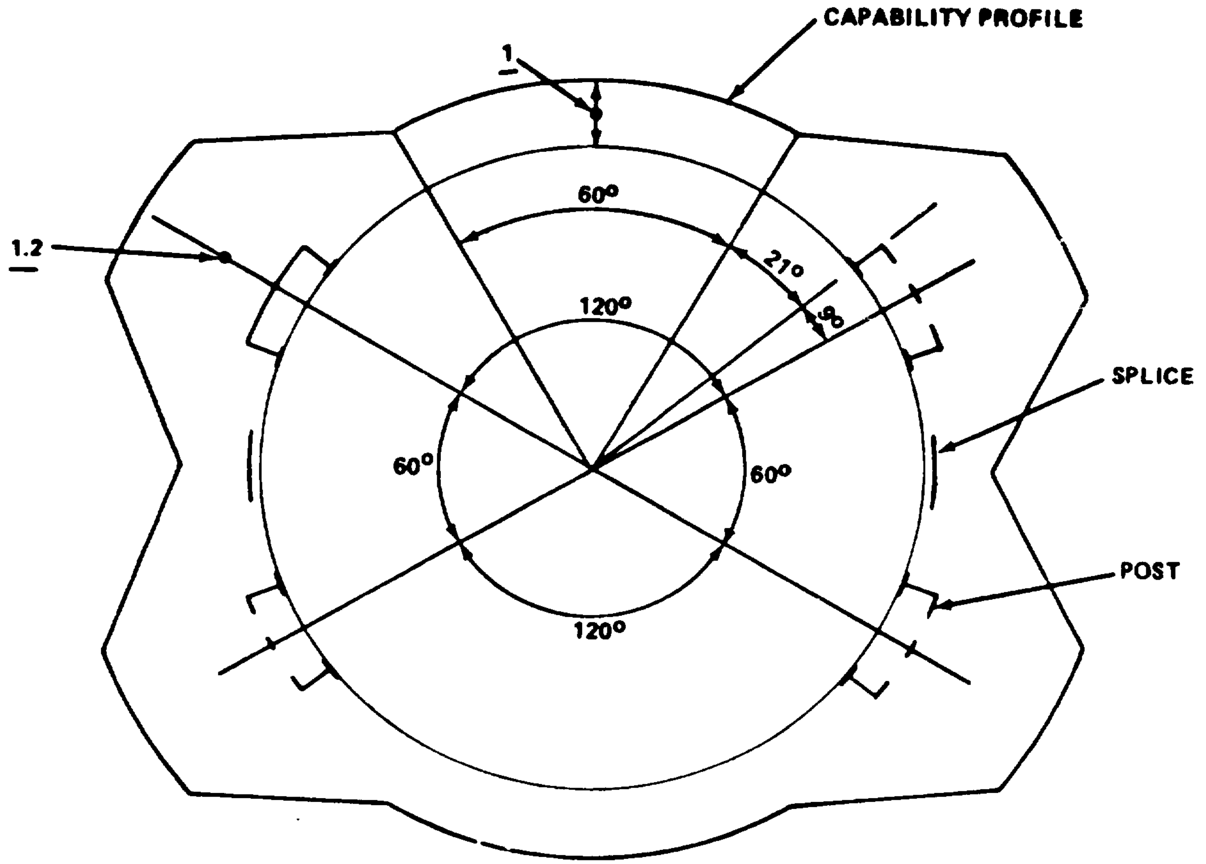


Figure 6. SRB aft skirt radial (clocking) capability distribution for critical load peaks.

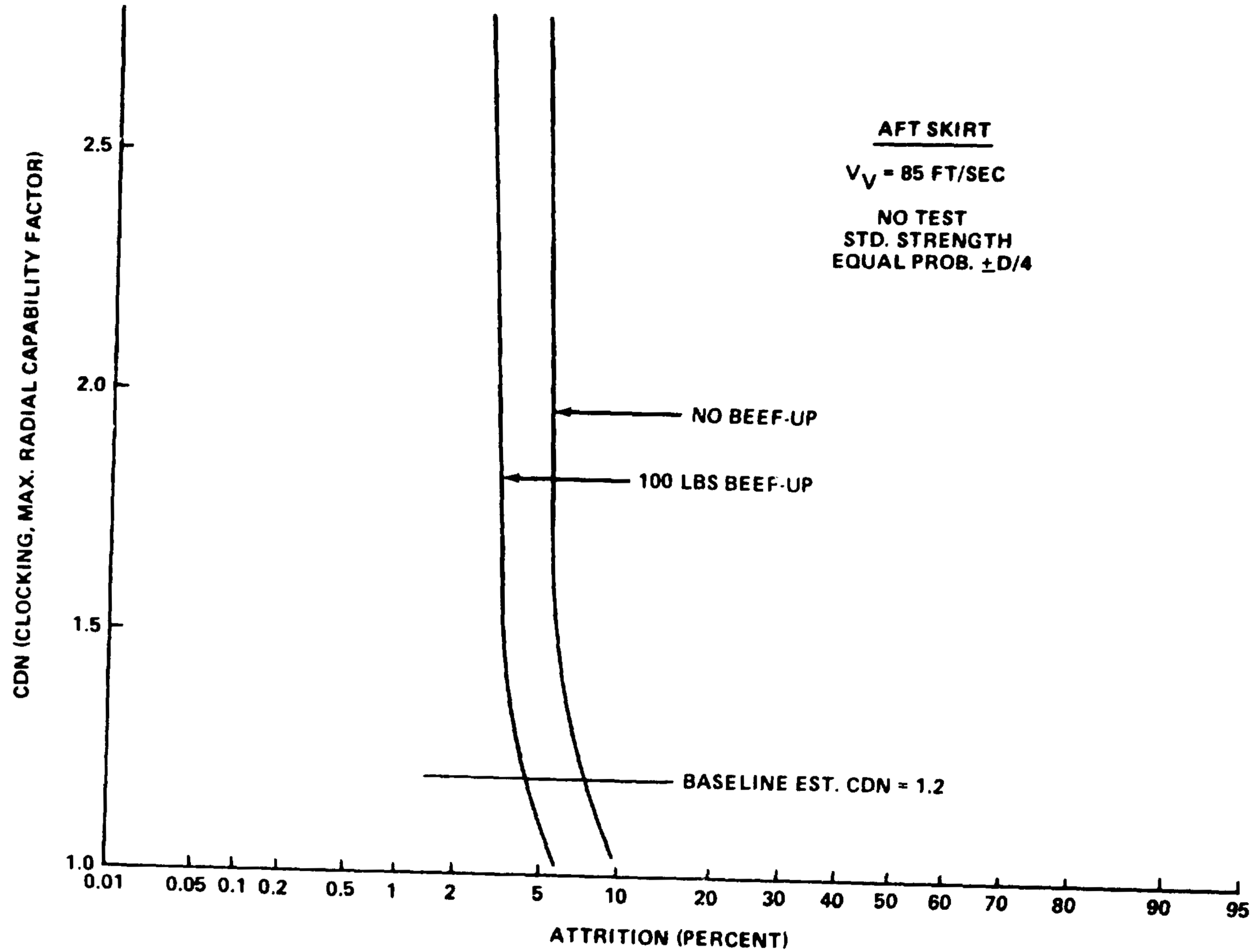


Figure 7. SRB aft skirt — attrition versus radial capability factor, CDN (clocking).

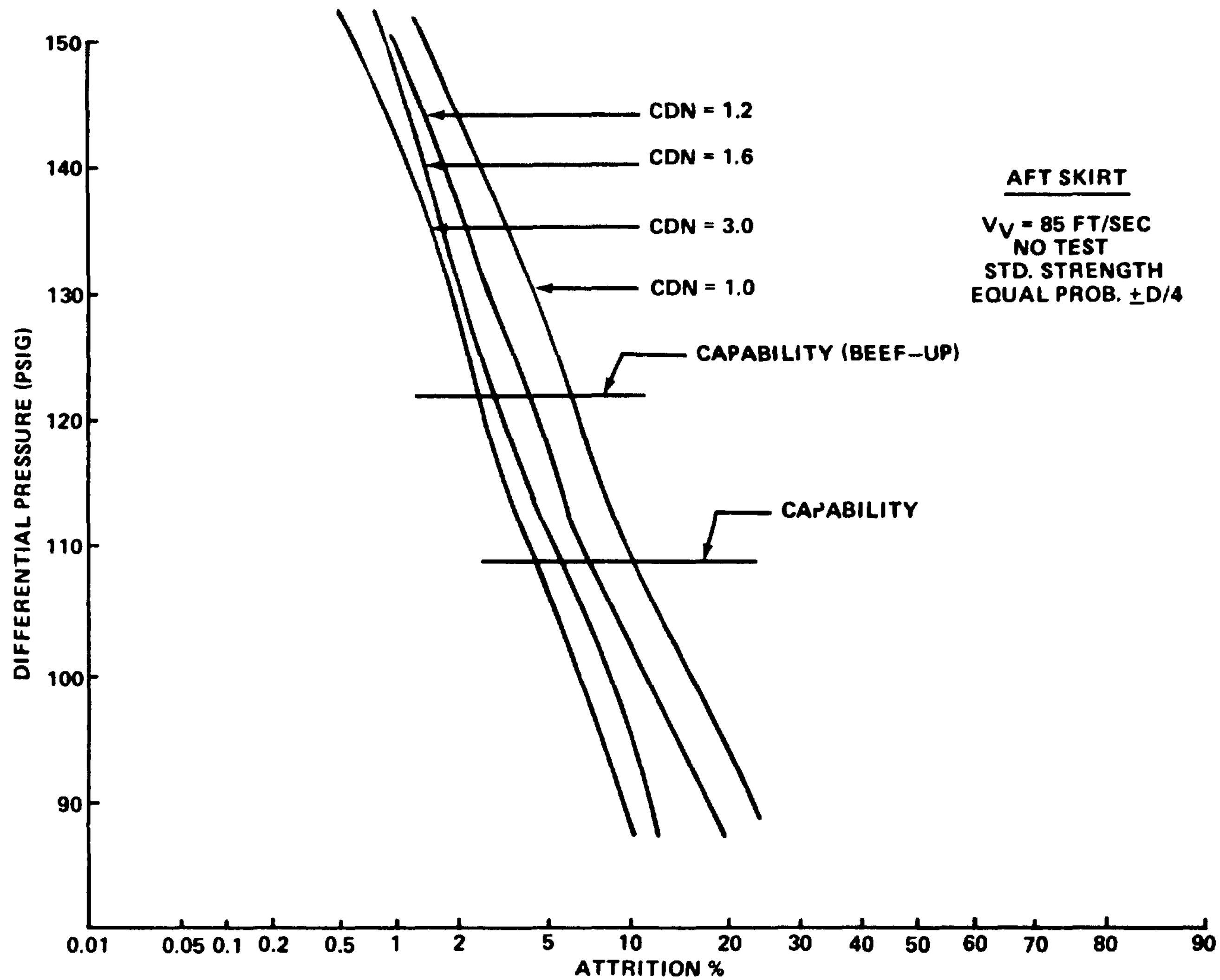


Figure 8. SRB aft skirt — attrition versus radial differential pressure capability (clocking) for various CDN values.

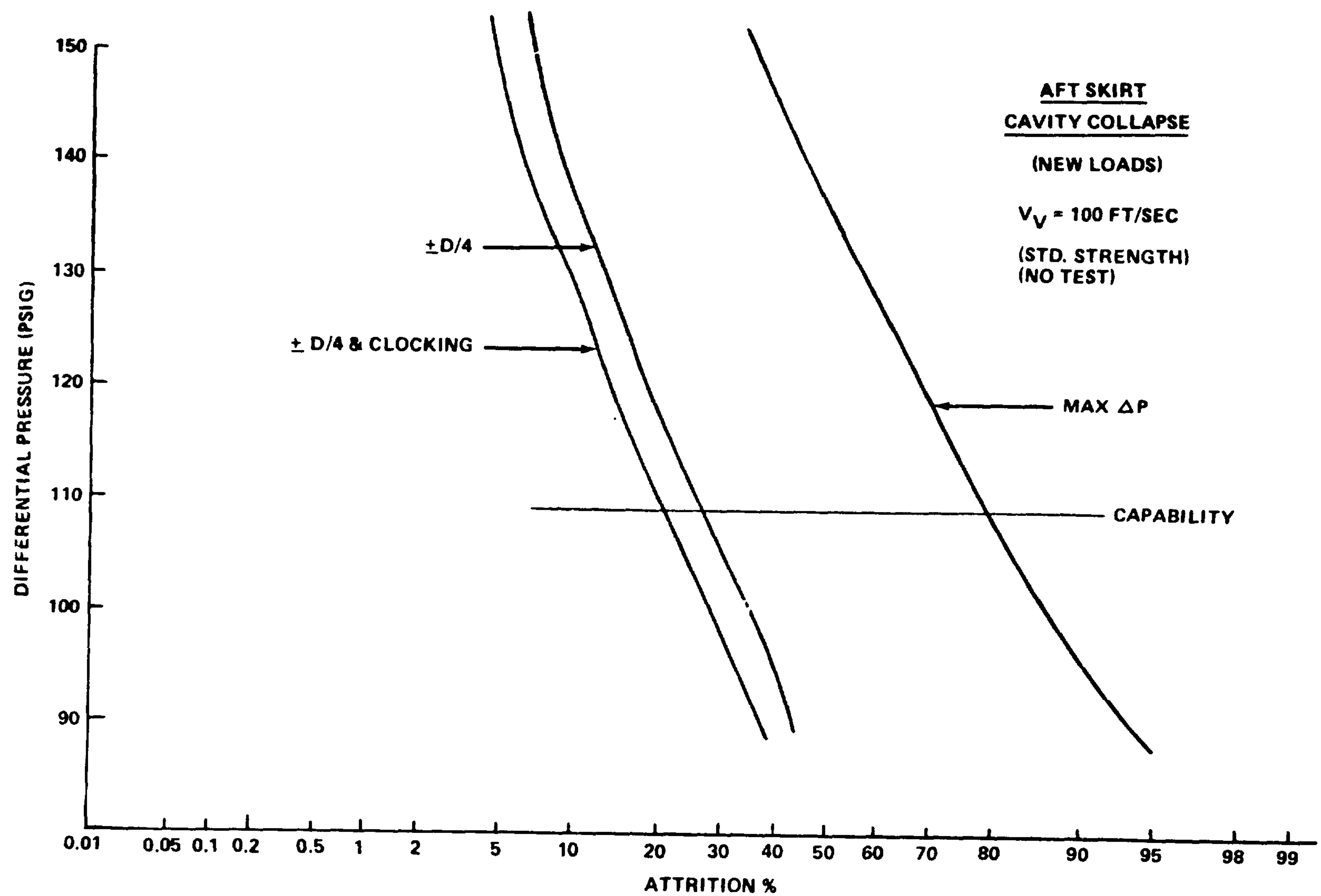


Figure 9. SRB aft skirt attrition determination methodology comparisons, no test ($V_V = 100$ ft/s).

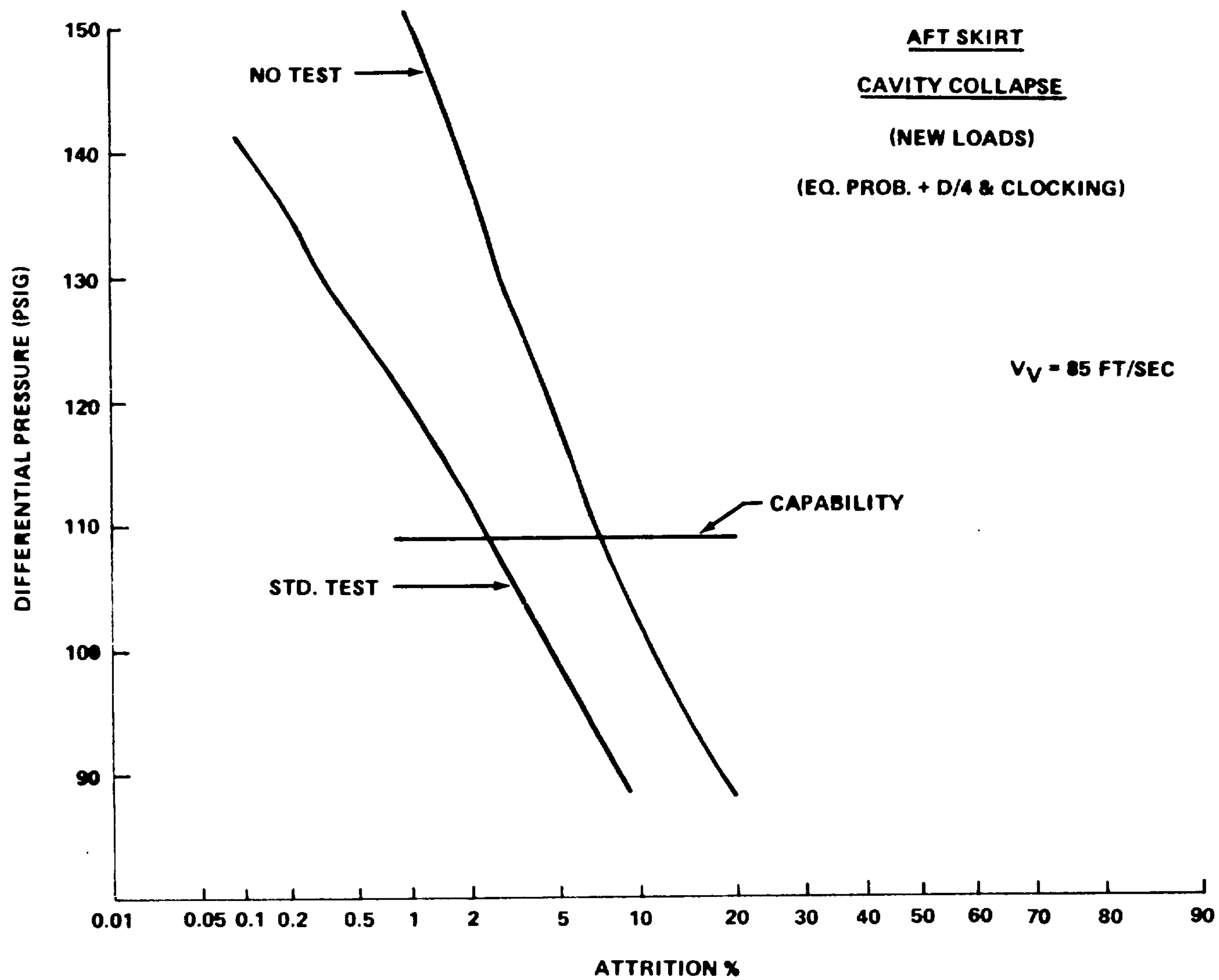


Figure 10. Comparative effects of verification testing and random strength on SRB aft skirt attrition.

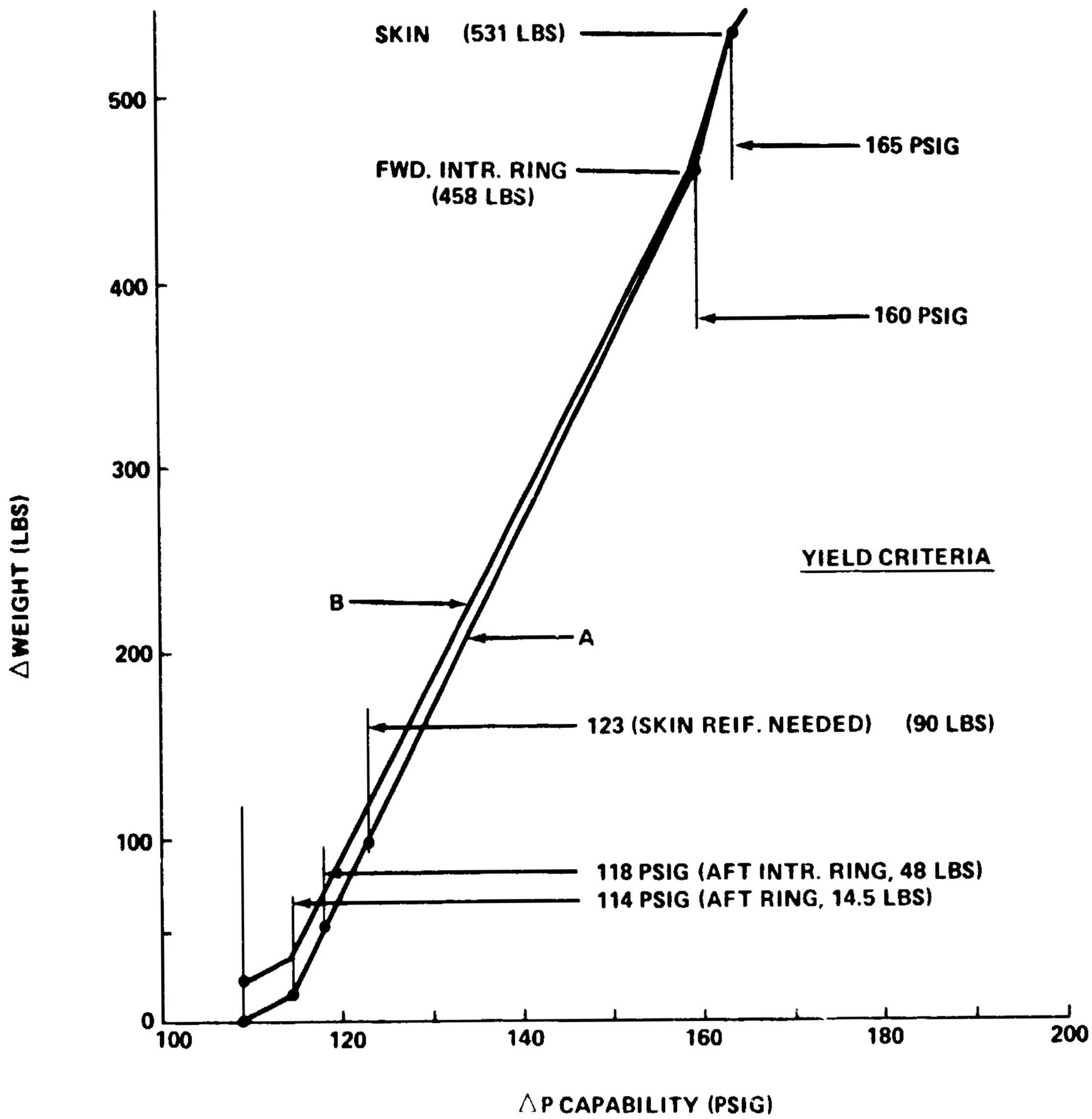


Figure 11. SRB aft skirt differential pressure capability improvement versus beef-up weight (yield criteria).

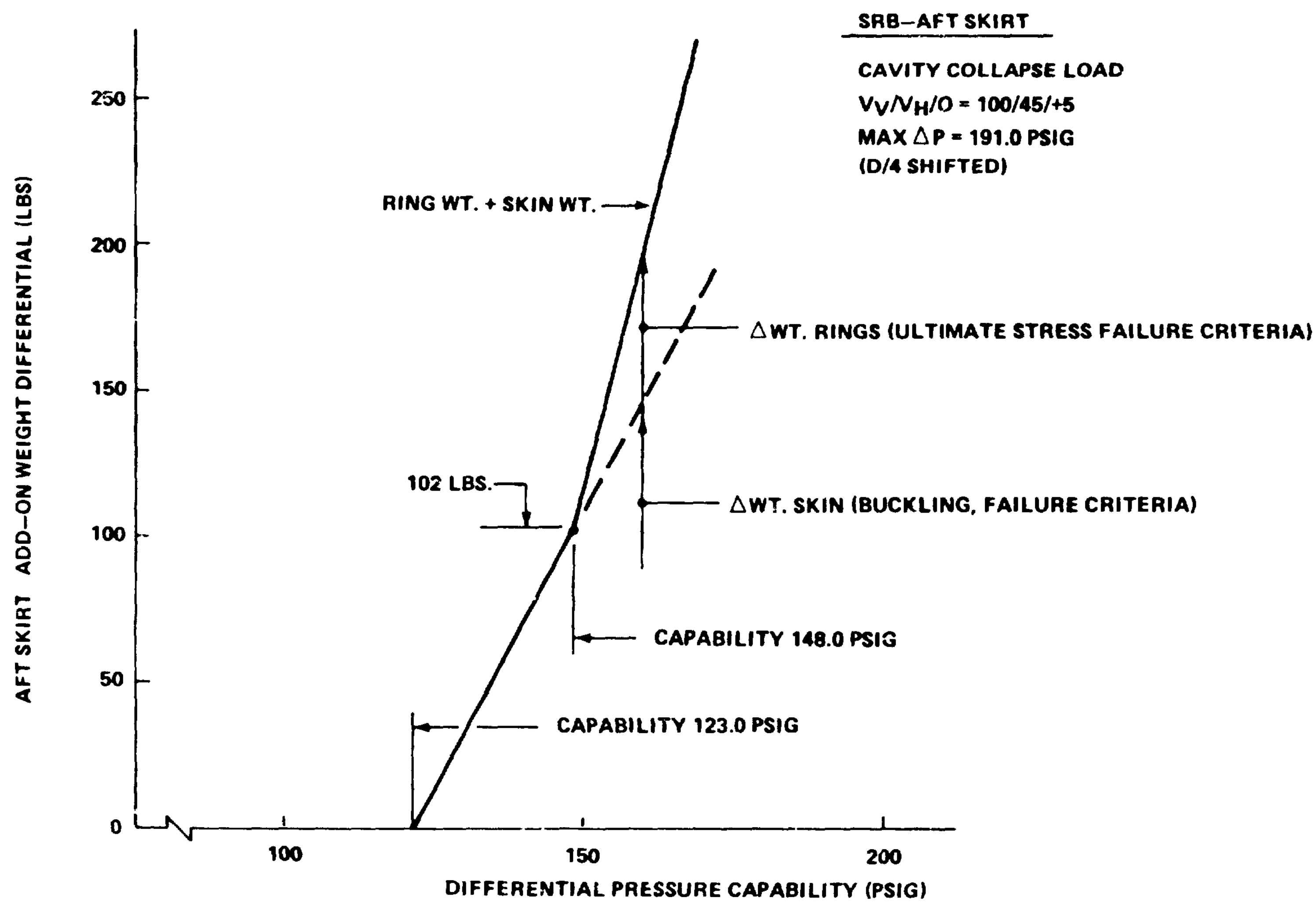


Figure 12. SRB aft skirt differential pressure capability improvement versus beef-up weight (ultimate criteria).

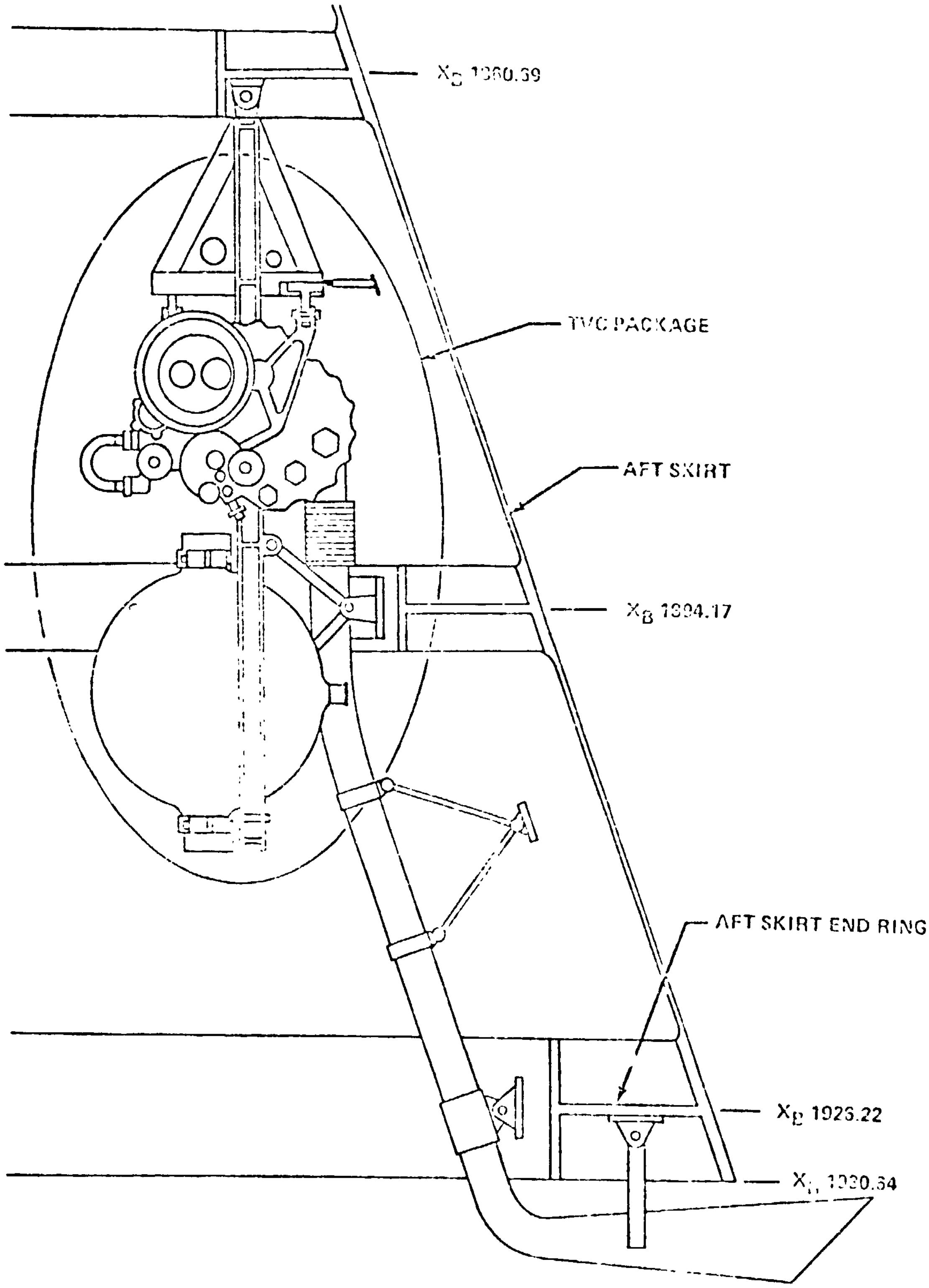


Figure 13. Baseline 11/1/74 SRB configuration for TVC power supply system location.

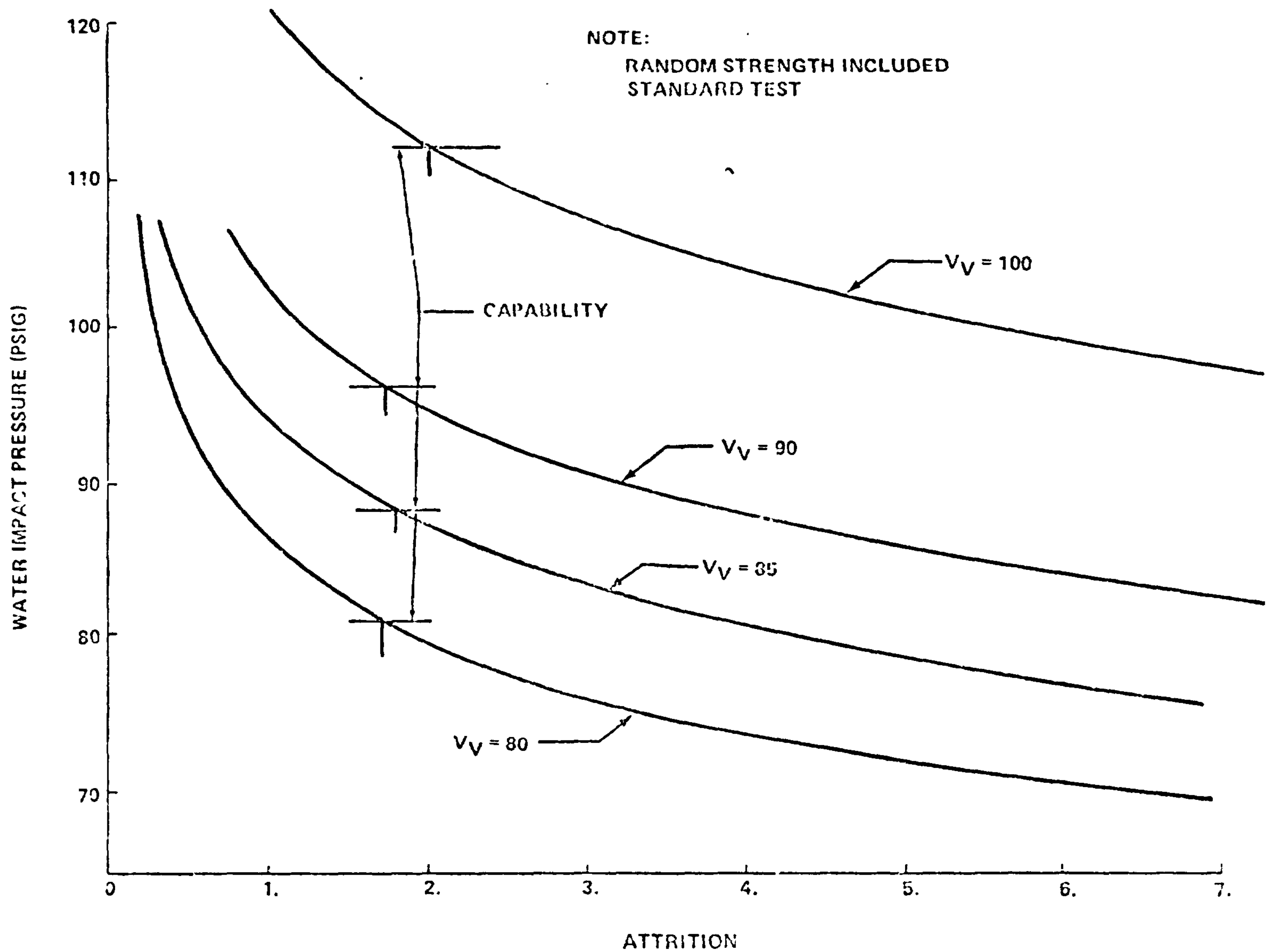


Figure 14. TVC power supply pressure capability versus attrition as a function of vertical velocity (V_V).

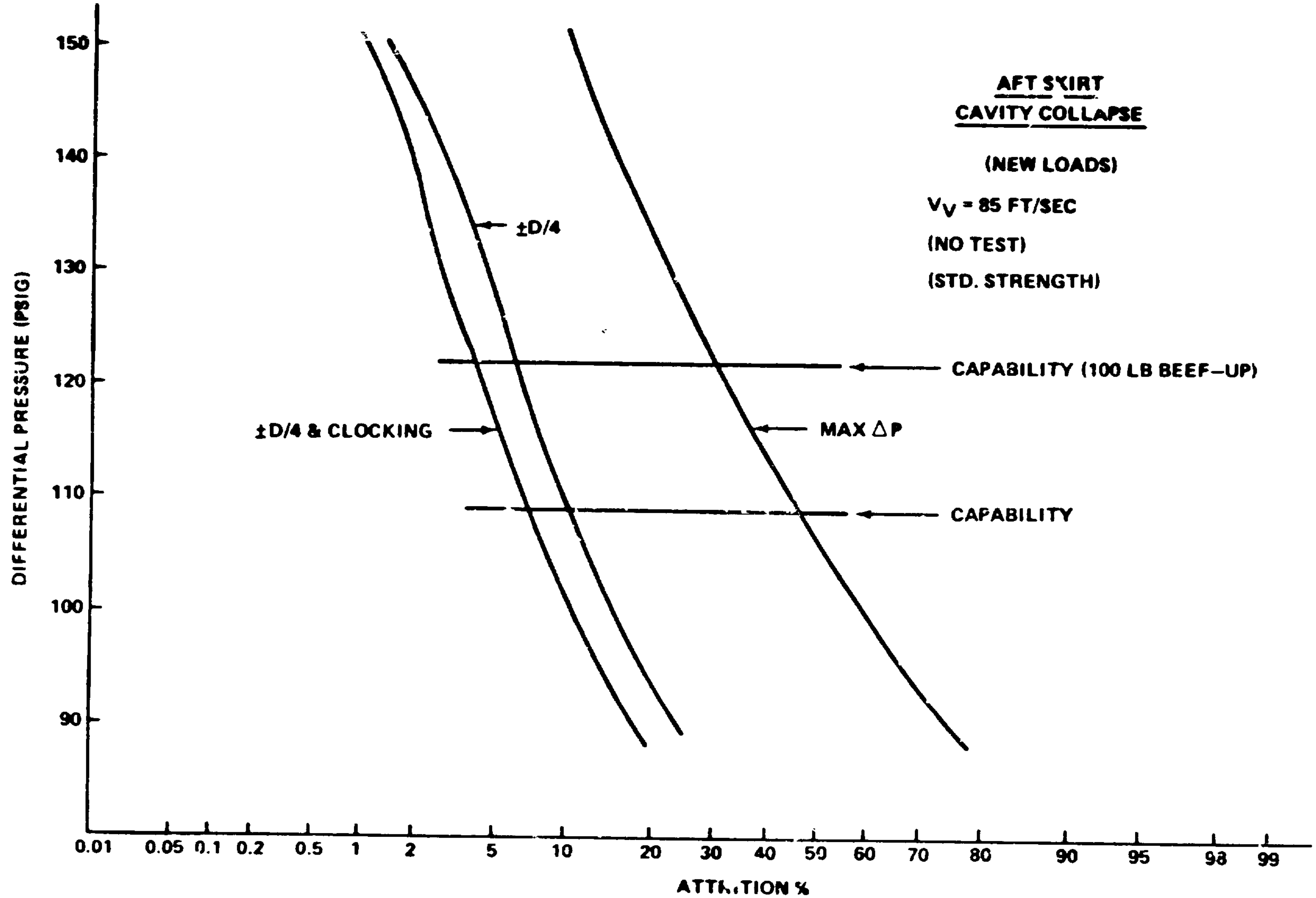


Figure 15. SRB aft skirt attrition determination methodology comparisons (no test).

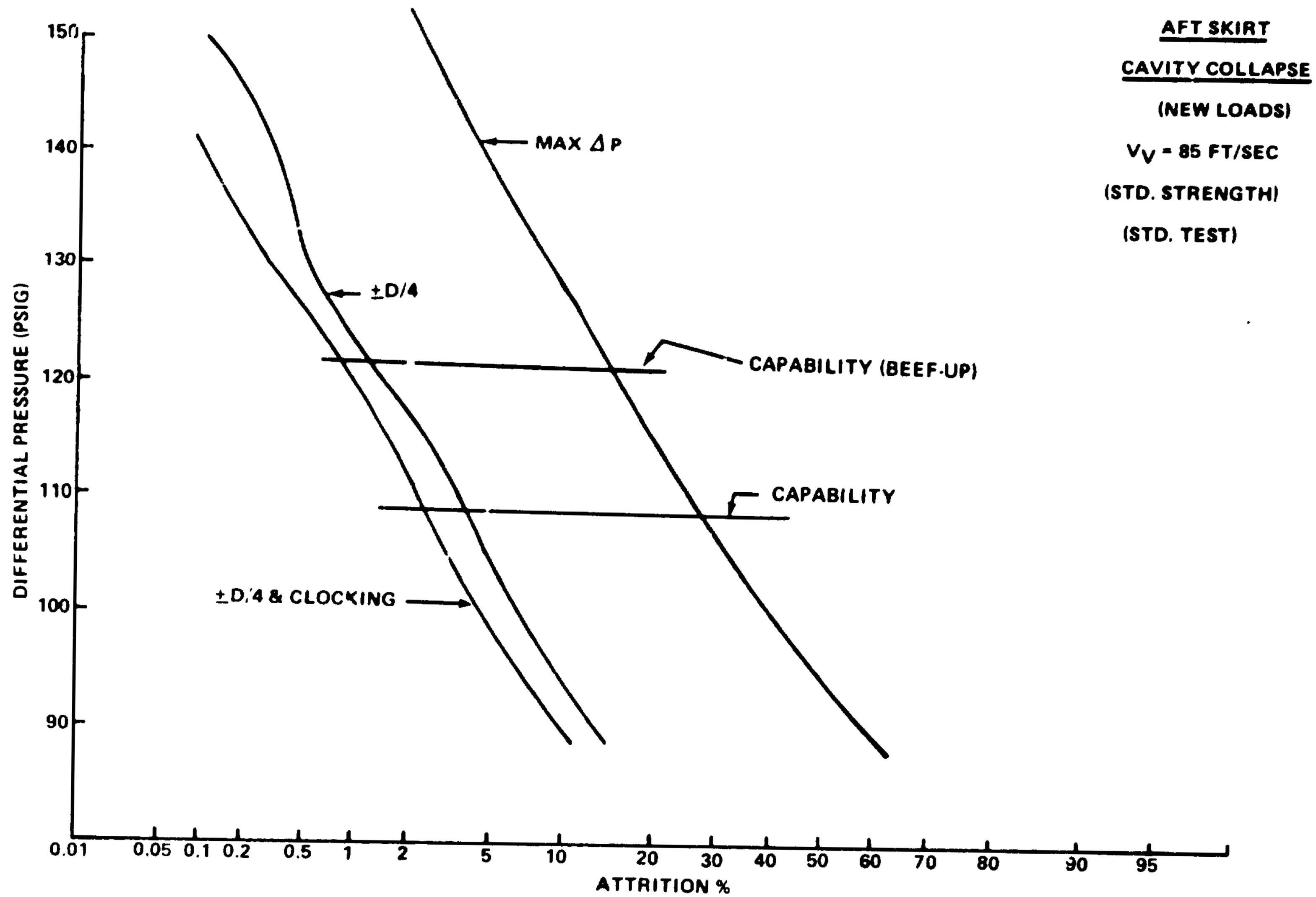


Figure 16. SRB aft skirt attrition determination methodology comparisons (standard test).

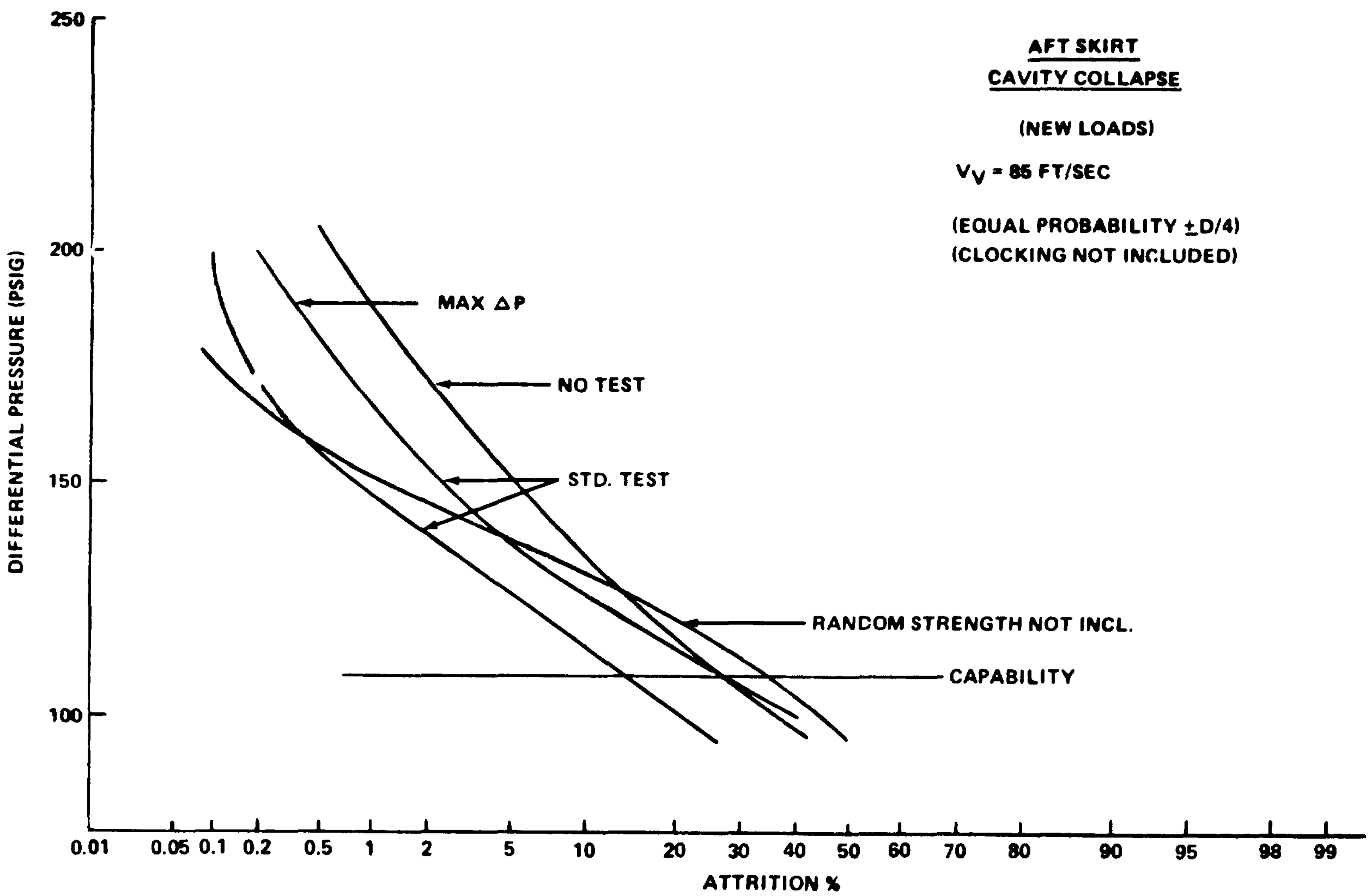


Figure 17. SRB aft skirt attrition determination methodology comparisons, random strength not included for test and no test.

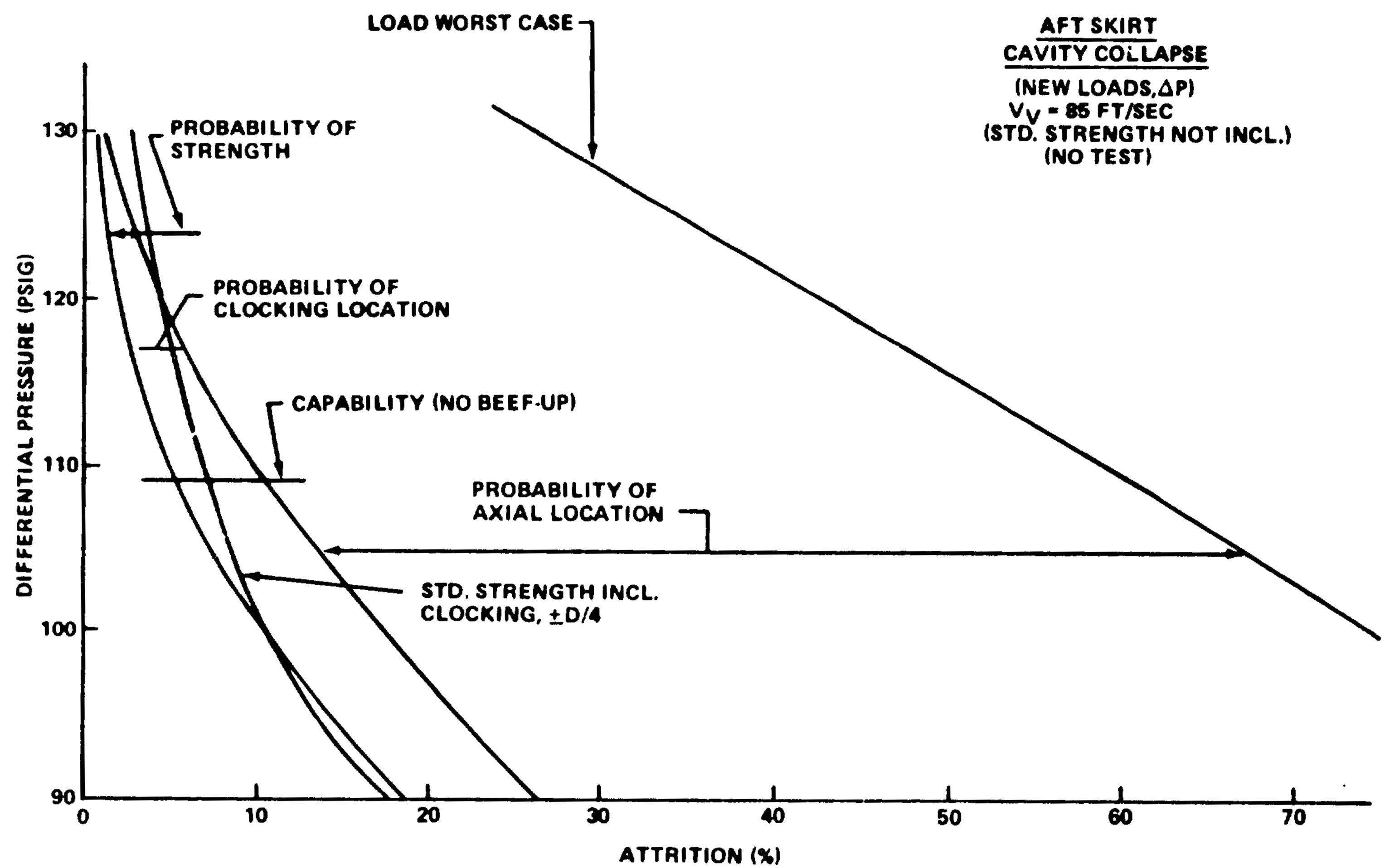


Figure 18. SRB aft skirt attrition methodology comparisons, random strength not included, including clocking and probability of axial location.

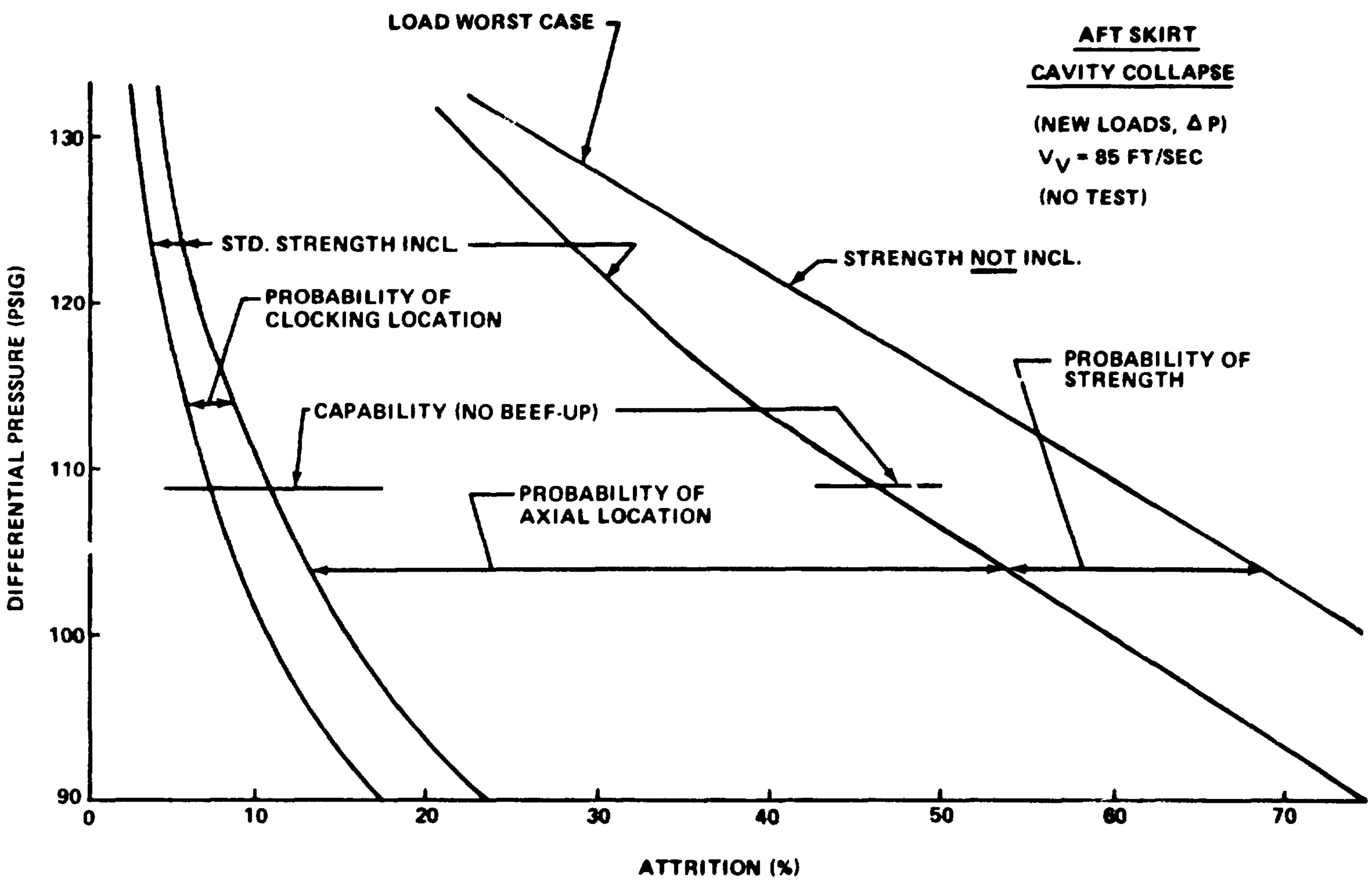


Figure 19. SRB aft skirt attrition methodology comparisons, random strength included, including clocking and probability of axial location.

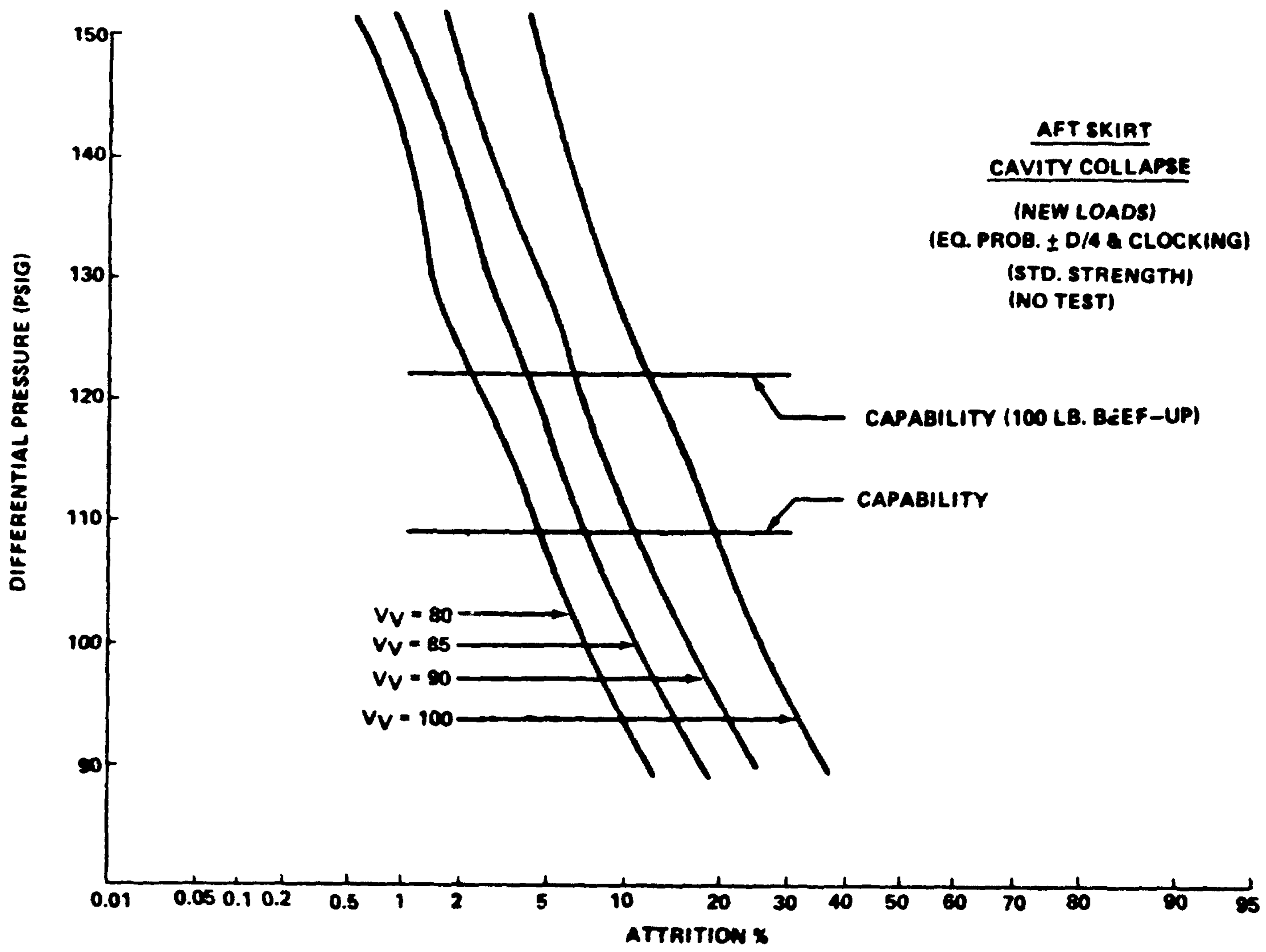


Figure 20. SRB aft skirt attrition with inclusion of effects of longitudinal and radial locational probability of load peak capability (no test).

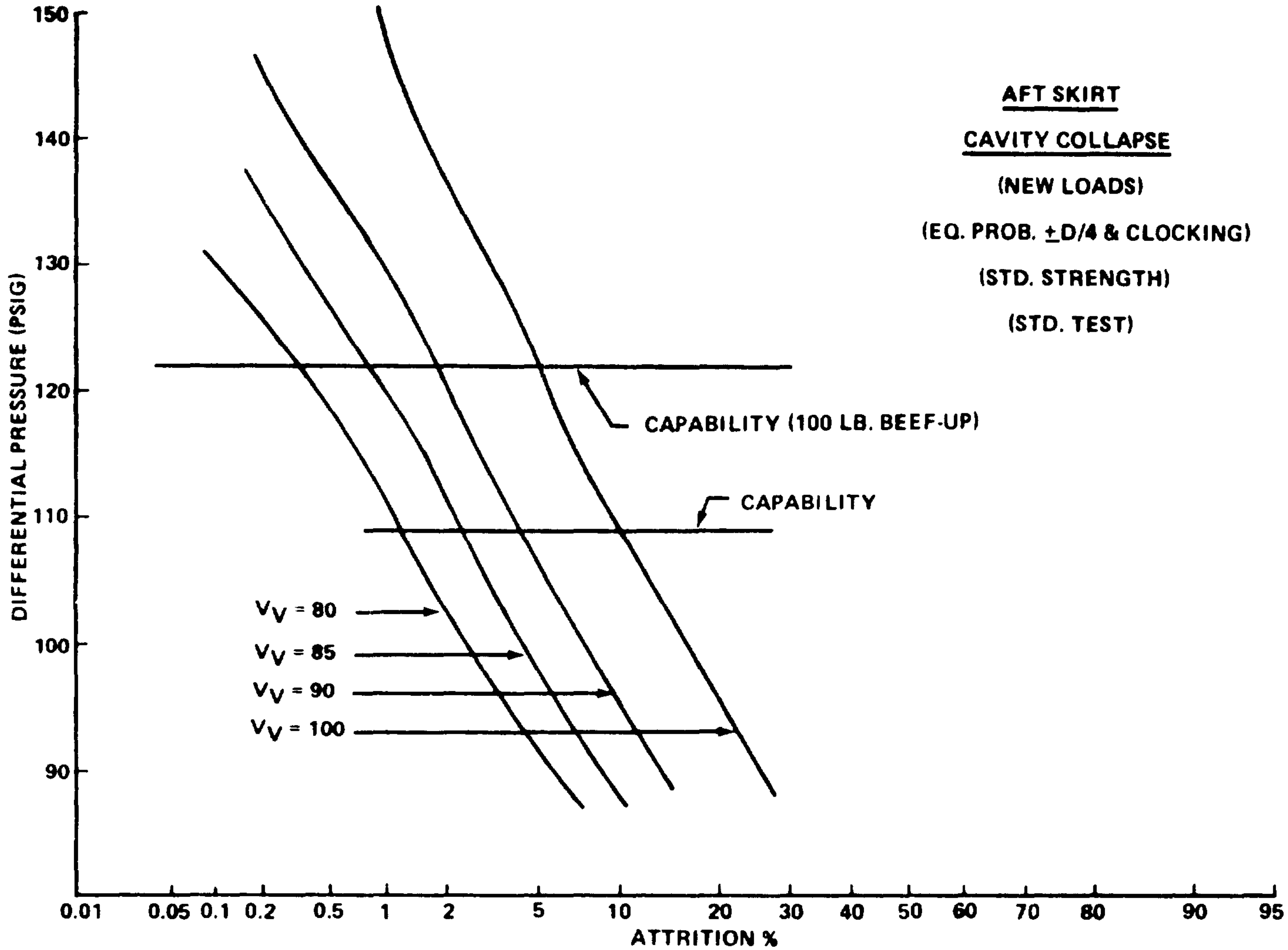


Figure 21. SRB aft skirt attrition with inclusion of effects of longitudinal and radial locational probability of load peak capability (standard test).

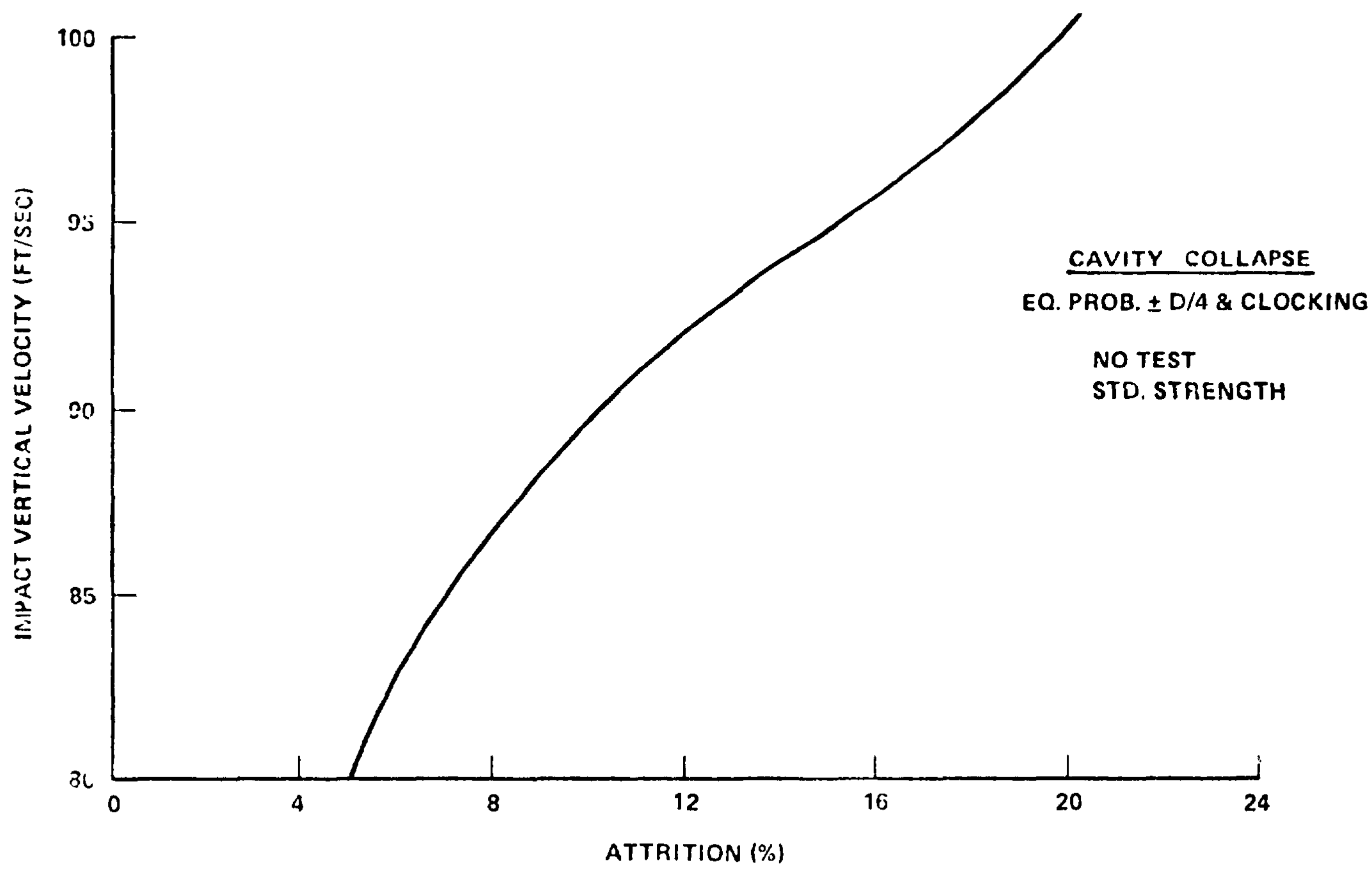


Figure 22. SRB aft skirt attrition versus vertical impact velocity (V_V).

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APPROVAL

SRB ATTRITION RATE STUDY OF THE AFT SKIRT DUE TO WATER IMPACT CAVITY COLLAPSE LOADING

By Charles D. Crockett

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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