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TECHNICAL REPORT
69-59-GP

DESIGN MANUAL FOR GROUND-MOUNTED AIR-SUPPORTED STRUCTURES (SINGLE-AND DOUBLE-WALL) (REVISED)

by

A. E. Dietz
R. B. Proffitt
R. S. Chabot
and
E. L. Moak

Hayes International Corporation
Birmingham, Alabama

Contract No. DA19-129-AMC-953(N)

January 1969

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NATICK LABORATORIES
Natick, Massachusetts 01760

GENERAL EQUIPMENT & PACKAGING LABORATORY

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FOREWORD

This design manual for ground-mounted air-supported, single- and double-wall structures was prepared by the Hayes International Corporation and provides the Military and Government suppliers with design information to fabricate functional and reliable air-supported structures at the lowest possible weight. The data and design information presented is based on wind tunnel tests and analytical determinations reported in Natick Technical Report 67-36-ME entitled "Wind Tunnel Test and Analyses of Ground Mounted Air Supported Structures". Wind tunnel tests were conducted in the six foot by six foot stability tunnel at Virginia Polytechnic Institute, Blacksburg, Virginia. Initial work was conducted for the U. S. Army Natick Laboratories, Natick, Massachusetts under Contract DA19-129-AMC-129(N), during the period from July 1963 to October 1966. Additional analyses and tests were conducted under Contract DA19-129-AMC-953(N) from May 1966 to May 1968. Data presented supplement and supersede information shown in Natick Technical Report 67-35-ME dated October 1966.

Mr. Constantin J. Monego of the General Equipment & Packaging Laboratory at the Natick Laboratories was the Army Project Engineer for this program. Mr. A. E. Dietz was the Program Manager and Messrs. R. B. Proffitt, R. S. Chabot, and E. L. Moak were the principal investigators for the Hayes International Corporation. The assistance provided by Mr. C. J. Monego of the Natick Laboratories, Dr. R. T. Keefe and Prof. F. G. Maher of the Virginia Polytechnic Institute, and the personnel of the Technical Engineering Department at Hayes International Corporation are gratefully acknowledged. In particular, many thanks are due Mr. Joseph I. Bluhm, Chief, Applied Mechanics Research Laboratory and his staff at the U. S. Army Materials and Mechanics Research Center, Watertown, Massachusetts, for review and analysis of this report which resulted in many valuable comments and recommendations, and to Messrs. J. H. Flanagan, W. C. Whittlesey, and C. W. Weikert for their encouragement and support of this work.

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ABSTRACT

The objective of this design manual is to provide industry and Government suppliers with design information to fabricate functional and reliable air-supported structures at the lowest possible weight. The data and design information presented are based on wind tunnel tests and analytical determinations reported in a previous investigation.

Design information is given for spherical and cylindrical (single- and double-wall) air-supported structures. The data in general are presented in nondimensional coefficient form and, therefore, are applicable to full-scale structures within the range of parameters tested. Design information is presented as charts and tables on tent aerodynamic force and moment coefficients, anchor and guyline coefficients, structural deflections, material stresses, packaged volume, and weight.

SECTION 1

INTRODUCTION

In March 1956, a revised edition of the Design Manual for Spherical Air-Supported Radomes was published by Cornell Aeronautical Laboratory. Since its publication, air-supported structures of other than spherical shapes have been adopted by the Army. Design and fabrication of these tents have generally been limited to the semi-empirical methods outlined in the revised Design Manual for Spherical Air-Supported Radomes and data estimated to cover other basic configurations.

To assist the tentage engineer to more accurately define the criteria for design of air-supported structures, the U. S. Army Natick Laboratories contracted with Hayes International Corporation to formulate practical design criteria for single- and double-wall air-supported structures. The program included a comprehensive analytical study and model wind tunnel tests resulting in a design manual for ground-mounted air-supported structures. A more rigorous solution to the analytical determination of fabric stresses is included in this investigation which, combined with the latest materials and accessory equipment information furnished by the Army, has produced more precise tentage design criteria than has heretofore been available to the Army designer.

This design manual presents the results of these tests and analyses in a concise form of design tables and curves for both single- and double-wall structures with sample problems illustrating the use of the data.

SECTION 2

GENERAL DISCUSSION

BACKGROUND

The art of tent making is thousands of years old. For centuries, through trial and error, man has constructed effective shelters for habitation and housing of equipment. The evolution of this art has covered myriad configurations, but only recently has a way been found to eliminate the cumbersome weight of the supports through the use of inflation techniques. The forerunner of air-supported tents dates back to early World War II days when an external enclosure over a radar antenna was found desirable. This use was motivated by the necessity for protection of the radar installation from high winds. These early installations were small in size and the material used ranged from single sheets of molded plexiglass or plywood to multiple layers of sandwich-type construction. The first reported use of a resin-impregnated glass fabric as a radome material stemmed from an attempt to reduce the moisture absorption properties of plywood on the earlier models through the application of a thin protective overlay on the external surface of the radome.

Larger radomes were dictated for use on later World War II radar installations. The advent of radomes ranging in diameter from 35 to 55 feet arose from the necessity to extend the United States Air Defense after World War II to include radar detection systems located in arctic zones of operation. Operational radars of that time were designed to withstand only the wind loads and weather conditions encountered in temperate zones. Wind conditions in the Arctic were known to impose greater loads upon an antenna system and upon its pedestal than those for which the structure was designed. Therefore, it was decided to utilize radomes for environmental protection. Up until this time, the large radomes had been used as an expedient alternative to modification and strengthening of existing radar antenna structures. With the advent of arctic usage, the intrinsic merits of the lightweight radome soon became obvious; i.e., environmental protection, reduction in power required to rotate large antenna systems in high winds, and reduction in size and weight of structural members at the cost of a small degradation in system performance due to the presence of the radome.

Modern scientific and technological developments made in military equipment and in support of a mobile army have resulted in the need for new type tentage. The need for new tentage varies from highly specialized items for the missile program to large maintenance tents for ground vehicles and aircraft. Figures 1 through 6 present some existing single- and double-wall air-supported structures and Table I provides general tentage information.

The use of air-supported tents, other than radomes, represents one approach taken by the Army to provide shelters of reduced weight, cost and cubage which can be easily transported, erected, and struck for more mobile

Table I

General Tent Data - Single and Double Wall Tents

Tent Type	Dimensions	Shape	Fabric Weight*
Single Wall			
Pentadome - 100 ft. dia.	h - 50 ft.	Spherical	Base - 5.5 Dome - 18
Pentadome - 150 ft. dia.	h - 85 ft.	Spherical	Base - 10 Dome - 24
Air House - 40 x 80 ft.	h - 15 ft.	Cylindrical Spherical Ends	18
Radome - 27 ft. dia.	h - 19 ft. 8 in. Base Dia. 24 ft.	Spherical	19-20
Above Ground Launcher	h - 13 ft. W - 17 ft. 6 in. ℓ_h - 61 ft.	Cylindrical Spherical Ends	18
Double Wall			
Assembly Area	h - 27 ft. W - 54 ft. ℓ_h - 12 ft. Wall Depth - 3 ft.	Cylindrical	20
Aviation Maintenance	h - 18 ft. - 4 in. W - 28 ft. ℓ_h - 10 ft. - 3 in. Wall Depth - 2 ft.	Cylindrical	Roof - 14 End - 16
Shelter Set Small	h - 13 ft. 8 in. W - 23 ft. 4 in. ℓ_h - 13 ft.	Cylindrical	Roof - 14 End - 16

*Fabric Weight, oz/yd^2

army operations. With the development of these air supported shelters the technology of tent making is developing, step by step, from a traditional craft to a branch of scientific engineering.

Cornell Aeronautical Laboratories and Massachusetts Institute of Technology have performed several scale tests on radome and missile shelter models. Cornell has produced a Radome Design Manual for spherical radomes based on these tests. Design and fabrication of other than spherical tents has been accomplished largely by extrapolation of the design data contained in the Radome Design Manual and the individual designer's personal "feel" for the problem. A wind tunnel program was initiated to investigate a wide variety of tents, both spherical and cylindrical, single- and double-wall. The data obtained from these tests have been reduced and put in parametric form to facilitate future tent design.

GENERAL CHARACTERISTICS

Air-supported tents present the modern mobile army with many advantages over rigid structures. Some of the more important advantages are listed below:

Radio-frequency Transmissibility - The air-supported tent, as used to house radar antenna, due to its thin-walled construction, very nearly approaches the ideal shelter, i.e., a thin-walled homogeneous sphere. For this reason the same radome can be used for several radar systems of different frequencies.

Light Weight, Low Bulk, and Cubage - The inherent characteristics of an air-supported structure provides a high structural efficiency, which results in very low package weight. Use of thin flexible material for the envelope permits the entire unit to be folded into a small package which facilitates shipment and storage.

Ease of Handling and Logistic Support - Due to its low weight and compactness, the air-supported structure is one of the most portable of all presently available shelters. The durability of the material used for the envelope minimizes logistic requirements and maintenance. Standardization of the basic tent sizes reduces the inventory requirement and makes the air-supported structure adaptable to nearly all shelter requirements.

SECTION 3

DESIGN PARAMETERS

GENERAL

This part of the design manual contains the mathematical equations and figures necessary to compute tent design parameters. Basic tent design parameters included are as follows:

Aerodynamic: Lift, Drag, and Pitching (Overturning) Moment
Tent Deflection
Fabric Weight and Stress
Anchor Loads
Blower Characteristics: Pressure and Volume
Estimated Weight and Package Cube of the Tents.

The graphical presentation of the design parameters shown in this manual is based on wind tunnel tests, the details of which are fully described in U. S. Army Natick Laboratories Technical Report 67-36-ME entitled "Wind Tunnel Tests and Analyses for Ground Mounted Air-Supported Structures" dated October 1966.

AERODYNAMIC

Fabric shelters subjected to winds of high velocity can experience aerodynamic forces of considerable magnitude. These forces can be altered and minimized by proper shape design. Thirty-six single- and double-wall tents were tested to 110 miles per hour and the resulting data prepared, which facilitates the task of optimizing tent shape. It should be noted that the single-wall cylindrical shapes differed from the double-wall shapes in that the ends were hemispherical or ellipsoidal for single-wall and flat for double-wall. The aerodynamic force data are presented in nondimensional coefficient form by dividing the force data by a reference area, A_p, and the dynamic or impact pressure, q. The tent planform area, A_p, was selected as the reference area and is defined as the maximum area in a horizontal plane. For design convenience, planform areas for tents with radii up to 80 feet are shown in Table II.

The impact pressure due to wind velocity for use in the design equations is defined by the following mathematical expression:

$$q = 1/2\ \rho\ U^2$$

where q = Impact pressure, lb/ft^2

ρ = Density of air, $slugs/ft^3$ and equals 0.00238 for a standard day at sea level

U = Wind velocity, ft/sec

Table II

Tent Planform Area, A_p

Spherical and Cylindrical Tents with Hemispherical Ends

Tent Radius, r Ft.	Tent Planform Area, A_p, Sq. Ft. Spherical	Cylindrical 1/2, W/ℓ_h	Cylindrical 1/3, W/ℓ_h	Cylindrical 1/4, W/ℓ_h
10	314	714	1114	1514
12	452	1028	1604	2180
14	615	1399	2183	2967
16	804	1828	2852	3876
18	1017	2313	3609	4905
20	1256	2856	4456	6056
22	1520	3456	5392	7328
24	1809	4113	6417	8721
26	2123	4827	7531	10235
28	2463	5599	8735	11871
30	2827	6427	10027	13627
32	3216	7312	11409	15505
34	3631	8255	12879	17503
36	4071	9255	14439	19623
38	4536	10312	16088	21864
40	5026	11426	17826	24226
42	5541	12597	19653	26709
44	6082	13826	21570	29314
46	6647	15111	23575	32039
48	7238	16454	25670	34886
50	7853	17854	27854	37854
52	8494	19310	30126	40942
54	9160	20824	32488	44152
56	9852	22396	34940	47484
58	10568	24024	37480	50936
60	11309	25709	40109	54509
62	12076	27452	42828	58204
64	12868	29252	45636	62020
66	13684	31108	48532	65956
68	14526	33022	51518	70014
70	15393	34993	54593	74193
72	16286	37022	57758	78494
74	17203	39107	61011	82915
76	18145	41249	64353	87457
78	19113	43449	67785	92121
80	20106	[illegible]	71306	96906

Note: $A_p = \pi r^2 + 2r(\ell_h - 2r)$

The variation of impact pressure with wind speed at sea level and 59°F. is shown in Figure 7. The variation of impact pressure with pressure altitude and temperature is shown in Figure 8. This figure presents a correction factor, k_p, which, when multiplied by the standard day impact pressure, will correct for variations in design atmospheric conditions:

$$q = k_p \, q \text{ std}, \ lb/ft^2$$

Lift

The aerodynamic lift coefficient is defined as follows:

$$C_L = \frac{L}{A_p q}$$

where C_L = Lift coefficient, non-dimensional

L = Total lift, lb

q = Impact pressure, lb/ft^2

A_p = Planform area, ft^2

The variation in lift coefficient with tent height-to-diameter ratio and width-to-length ratio is shown in Figure 9 for single-wall tents and Figure 10 for double-wall tents.

Drag

The aerodynamic drag coefficient is defined as follows:

$$C_D = \frac{D}{q A_p}$$

where C_D = Drag coefficient, non-dimensional

D = Total drag, lb

q = Impact pressure, lb/ft^2

A_p = Planform area, ft^2

The variation in drag coefficient with tent height-to-diameter ratio and width-to-length ratio is shown in Figure 11 for single-wall tents and Figure 12 for double-wall tents.

Overturning Moment

The aerodynamic overturning moment coefficient is defined as follows:

$$C_M = \frac{M}{qA_p d}$$

where C_M = Moment coefficient - non-dimensional

M = Overturning moment, ft-lb

q = Impact pressure, lb/ft^2

A_p = Planform area, ft^2

d = Reference length, ft

The variation in overturning moment with tent height-to-diameter ratio and width-to-length ratio are shown in Figure 13 for single-wall tents and in Figure 14 for double-wall tents.

In order to calculate the total aerodynamic lift, drag and moments acting on the tent, it is necessary to rearrange the equations which define the coefficients as follows:

Lift $L = C_L qA_p$

Drag $D = C_D qA_p$

Moment $M = C_M qA_p d$

The coefficients C_L, C_D and C_M are obtained from the appropriate curves. The impact pressure, q, is obtained from Figures 7 and 8. The reference area A_p is obtained from Table V or by calculation, using the equations provided and dimensions of the tent. The reader is referred to SECTION 4, SAMPLE DESIGN PROBLEMS, for examples in which the aerodynamic coefficient data are used.

TENT DEFLECTION

The maximum tent deflection resulting from 110 miles per hour winds are shown in Figures 15 through 19 with inflation pressure equal to q or 6" w.g. The data are plotted as a ratio of tent deflection-to-tent radius, δ/r versus the ratio of tent height-to-tent diameter, h/d. The maximum tent deflection imposes limitations on the usable tent radius.

If the t size is known, the maximum tent deflection data can be used to establish the maximum usable tent radius, r', in accordance with the following:

$$r' = r\left(1 - \frac{\delta}{r}\right)$$

where

r' = Usable tent radius, ft

r = Radius of tent, ft

$\frac{\delta}{r}$ = Deflection ratio

If the required size is not known a minimum acceptable tent radius is established for a usable volume, and allowances made to include the maximum tent deflection. This may be accomplished as follows:

$$r' = \frac{r}{(1 - \delta/r)}$$

where

r' = Minimum acceptable radius, ft

$\frac{\delta}{r}$ = Deflection ratio

r = Required tent radius, ft

Tent Anchor Loads

The general anchor load coefficient due to aerodynamic forces is defined as follows:

$$C_{AL} = \frac{P_{AL}}{qA_p}$$

where

C_{AL} = Anchor load coefficient

P_{AL} = Anchor Load, lb

q = Impact pressure, lb/ft^2

A_p = Tent planform area, ft^2

Single-Wall Tents

For single wall tents, the lift due to inflation pressure must be added to the aerodynamic lift to determine total lift. The load on the anchors due to inflation pressure can be calculated from the following expression:

$$P_{IL} = P_e A_f$$

where P_e = Tent enclosure pressure, lb/ft^2

A_f = Floor area, ft^2

Using the anchor load coefficient from Figure 20, the total anchor load for single-wall tents is calculated as follows:

$$\text{Total } P_{AL} = C_{AL}\, q\, A_p + P_e A_f = P_{AL} + P_{IL}$$

To find the maximum load per foot of perimeter it is necessary to divide the total anchor load by the perimeter of the tent:

$$\frac{\text{Anchor Load}}{\text{Foot}} = \frac{\text{Total } P_{AL}}{\text{Tent perimeter}}$$

The anchor spacing to secure the tent at the design wind load can be calculated as follows:

$$\text{No. of base anchors} = \frac{\text{Total } P_{AL}}{\text{Anchor holding capacity*}}$$

$$\text{Anchor spacing} = \frac{\text{(Tent perimeter) (Anchor holding capacity)}}{\text{Total } P_{AL}}\text{, ft}$$

Double-Wall Tents

The anchor load coefficients for double-wall tents are defined as follows:

$$C_{BL} = \frac{P_{BL}}{qA_p}$$

$$C_{GL} = \frac{P_{GL}}{qA_p}$$

*Anchor holding capacity @ 1500 lb/ anchor where C_{BL} = Anchor load coefficient for the base of tent

C_{GL} = Anchor load coefficient for the guy lines

P_{BL} = Anchor load on base, lb

P_{GL} = Anchor load on guy lines, lb

q = Impact pressure, lb/ft^2

A_p = Tent planform area, ft^2

The variation of anchor loads with tent height-to-diameter ratios and width-to-length ratio is shown in Figure 21 for the base anchors and Figure 22 for the guy lines.

The total base anchor load can be calculated as follows:

Total $P_{BL} = C_{BL}qA_p$ for base anchor loads, and

Total $P_{GL} = C_{GL}qA_p$ for guy line loads

The number of anchors required to secure the double-wall tent at the design wind loads can be calculated as follows:

$$\text{No. of base anchors} = \frac{P_{BL}}{\text{Anchor holding capacity*}}$$

$$\text{No. of guy line anchors} = \frac{P_{GL}}{\text{Anchor holding capacity*}}$$

TENT STABILITY

Tent instability, defined as the conditions of tent deflection and oscillation that combine to produce objectional tent motion, has been studied with respect to fabric porosity, enclosure pressure, cell size, cell pressure and guy line locations. This evaluation is subjective and the

*Anchor holding capacity @ 1500 lb/anchor evaluation of tent stability becomes a matter of individual determination. However, the following general conclusions may be made relative to single- and double-wall tent stability.

Single-Wall Tents

The single tent configurations, with the exception of the 7/8 sphere and all 1:4 width to-length ratio cylindrical tents, were found to be very stable. For the cylindrical single-wall tents, motion is more pronounced with a wind at 45 degrees attitude. Other spherical and the 1:2 width-to-length ratio cylindrical configurations exhibited very stable properties at all test conditions. The elliptical end tent appeared to be more stable than the hemispherical end tents.

Single-wall tents with low porosity fabric exhibited lower deflections, in general, than tents made from coated fabric and possessed equal or better stability characteristics.

The enclosure pressure for single-wall tents is an important factor in controlling tent motion. Although permissible tent deflections, as required by tent usage, could establish pressure requirements, tests indicate that only with enclosure pressures equal to or greater than the test dynamic pressure, q, did both good stability and deflection characteristics exist.

Double-Wall Tents

The double-wall tents had flat ends which contributed to flow separation and less stability than the single-wall tents with spherical ends. The 3/4 cylindrical, 1:1 width-to-length tents were not 'true' cylindrical tents but, rather, had flat sides which may have contributed to this configuration's exceptionally low stability.

The ratio of tent deflection-to-tent radius versus cell pressure in inches water gage for double-wall tents is shown in Figure 18. Cell pressure is an important factor in controlling tent motion. Although permissible tent deflection, as required by tent usage, could establish pressure requirements; tests indicated that only for cell pressure equal to or in-excess-of the wind impact pressure did both good stability and deflection characteristics exist. From a stability standpoint at 110 miles per hour, no significant gains were achieved beyond an inflation pressure of 16 inches water gage since insignificant deflection reductions occurred for cell pressures up to 30 inches water gage.

The best guy line configuration consists of a combination high (0.8 height) and low (0.4 tent height) line arrangement, with the upper guy lines angled 45 degrees to the tent side and the lower guy lines perpendicular to the tent side when viewed from the top of the tent.

To minimize double-wall tent corner deflection and motion, which occurs primarily when the tent is oriented 45 degrees to the wind (corner into the wind), guy lines angled 45 degrees to the tent side should be attached to each corner of the tent at a point 0.8 tent height and make an angle of approximately 45 degrees with the ground. Corner and end deflections were more pronounced on the double-wall tents. That deflection is believed to be aggravated by the flat ends of the double-wall tents and no solution to corner deflection at the 45 degree attitude was found.

Tent cell size was also observed to be a factor in providing better tent stability since an increase in cell size was more rigid for the same cell inflation pressure. A prime consideration in increasing cell size is that, for the same enclosure volume, the tent overall size and weight increase rapidly.

Double-wall tent enclosure pressure should be maintained at ambient or low positive pressure to preclude cell buckling tendency on the windward (forward) side of the tent.

STRUCTURAL

The air-supported structure designer of previous years has had to use crude stress analyses and a large factor-of-safety to assure structure capable of withstanding a design wind load. The importance of optimized tent structures created the need for a more refined analysis of the stresses involved. Fabric stress distribution was determined analytically through the use of wind tunnel measured pressure distributions about many basic tent shapes and applying suitable shell theory. Tent shapes included spherical and cylindrical single-wall tents, with hemispherical and ellipsoidal ends, and double-wall tents with flat ends - with and without guy lines attached. Basic tent design data are presented here while detail derivation can be found in Reference 1.

Single-Wall Spherical Tents

The design curves for spherical tents are included as Figures 23 and 24. The design procedure is as follows.

1) From design requirements, select tent size and shape and design value of dynamic pressure.

2) Enter Figure 23 at the required h/d and read N_ϕ/qr, N_θ/qr, and $N_{\phi\theta}/qr$.

3) Multiply stress coefficients by dynamic pressure in pounds per square inch and tent radius in inches.

$$N_\phi = (N_\phi/qr)\ q\ r$$

$$N_\theta = (N_\theta/qr)\ q\ r$$

$$N_{\phi\theta} = (N_{\phi\theta}/qr)\ q\ r$$

4) The maximum stress resultants are obtained by adding the effect of internal pressure to the stress obtained from step 3.

$$\bar{N}_\phi = N_\phi + P_e r/2$$

$$\bar{N}_\theta = N_\theta + P_e r/2$$

$$\bar{N}_{\phi\theta} = N_{\phi\theta}$$

These are the maximum design stress resultants in pounds per inch. The coordinate system is shown in Figure 25.

Should any other than the maximum value of N_θ be desired, enter Figure 24 and read the stress ratio for the desired h/d and ϕ. Multiply this stress ratio by the value of N_θ from step 3. Add to this the effect of internal pressure, yielding the desired value of $\bar{N}_\theta(\phi)$.

$$\bar{N}_\theta(\phi) = \left[N_\theta(\phi)/N_\theta(\text{peak})\right] N_\theta + P_e r/2$$

Single-Wall Cylindrical Tents with Hemispherical Ends

The design curves for cylindrical tents with hemispherical ends are included as Figures 26 through 30. The design procedure is as follows.

1) From design requirements determine tent size and shape and design value for dynamic pressure.

2) Find the stress coefficients for the required h/d and W/ℓ_h ratios from Figures 26 through 30. Coefficients for both the cylindrical portion and the hemispherical end are given in these design curves.

3) Multiply stress coefficients by the design dynamic pressure in pounds per square inch and tent radius in inches.

Cylindrical Center:

$$N_\phi = (N_\phi/qr)_{cyl}\ q\ r$$

$$N_x = (N_\theta/qr)_{cyl}\ q\ r$$

Hemispherical End:

$$N_\phi = (N_\phi/qr)_{sph}\ q\ r$$

$$N_\theta = (N_\theta/qr)_{sph}\ q\ r$$

$$N_{\phi\theta} = (N_{\phi\theta}/qr)\ q\ r$$

4) The maximum stress resultants are found by adding the effect of internal pressure as follows.

Cylindrical Center:

$$\bar{N}_\phi = N_\phi + P_e r$$

$$\bar{N}_x = N_x + P_e r/2$$

Hemispherical End:

$$\bar{N}_\phi = N_\phi + P_e r/2$$

$$\bar{N}_\theta = N_\theta + P_e r/2$$

$$\bar{N}_{\phi\theta} = N_{\phi\theta}$$

These are the maximum design stress resultants in pounds per inch. The coordinate system is shown in Figure 31.

<u>Single-Wall Cylindrical Tents with Ellipsoidal Ends</u>

The design curves for cylindrical tents with ellipsoidal ends are included as Figures 32 through [illegible] . The design procedure is as follows.

1) From design requirements determine tent size and shape and dynamic pressure design value.

2) Enter Figure 32 and read the basic stress coefficients for the design dynamic pressure.

3) Enter Figures 33 through 35 and read the correction factors for P_e/q, h/d, W/ℓ_h, and b/r for the cylindrical portion and ellipsoidal end.

4) Multiply corresponding correction factors with the basic stress coefficients and the dynamic pressure in pounds per square inch and tent radius in inches to get the total stress resultant.

Cylindrical Center; using the correction factors for the cylindrical portion:

$$\bar{N}_\phi = C_{q\phi} C_{h\phi} C_{W\phi} C_{b\phi} (N_\phi/qr)\, qr$$

$$\bar{N}_x = C_{q\theta} C_{h\theta} C_{W\theta} C_{b\theta} (N_\theta/qr)\, qr$$

Ellipsoidal Ends; using the correction factors for the ends;

$$\bar{N}_\phi = C_{q\phi} C_{h\phi} C_{W\phi} C_{b\phi} (N_\phi/qr)\, qr$$

$$\bar{N}_\theta = C_{q\theta} C_{h\theta} C_{W\theta} C_{b\theta} (N_\theta/qr)\, qr$$

$$\bar{N}_{\phi\theta} = C_{q\phi\theta} C_{h\phi\theta} C_{W\phi\theta} C_{b\phi\theta} (N_{\phi\theta}/qr)\, qr$$

These are the maximum design stress resultants in pounds per inch. The coordinate system is shown in Figure 36.

Double-Wall Cylindrical Tents with Flat Ends

The design curves for double-wall tents with flat ends are included as Figures 37 through 48. The design procedure is as follows.

1) From the design requirements, determine the tent size and shape and the dynamic pressure design value.

2) Determine cell width-to-tent diameter ratio; $w/d = 0.123$ was found to be the best of the models tested in the wind tunnel from a stability and weight standpoint.

3) Enter Figure 37 with h/d and w/d and find the basic pressure coefficient, P_c/q. Find the correction factors, C_q and C_W for the design values of q and W/ℓ_h. The required cell pressure is given by

$$P_c = C_q C_W (\bar{P}_c/q)\, q$$

P_c should never be less than 7 in. w.g.

4) Enter Figure 38 to obtain web stress, N_w.

5) Enter Figure 39 to obtain hoop stress, N_h.

6) Find the meridional stress N_ϕ, from Figures 40 through 48.

These are the maximum design stress resultants in pounds per inch. The coordinate system is shown in Figure 49.

FABRIC STRESS

Single-Wall Tent

The stress resultants are all given in terms of orthogonal coordinate systems: Spherical, ellipsoidal, or cylindrical. Only in the cylindrical coordinates, however, can the stresses be related directly to the warp and filling directions of the fabric. In general, it will not be known just what orientation the fabric weave will have with regard to the pertinent coordinate system at the point(s) of maximum stress. Because of this, the fabric should be designed to withstand the maximum principal stress. Using the maximum stress resultants obtained from the design curves, a slightly conservative value of the principal stress is given by

$$N_{max} = \frac{1}{2} (\bar{N}_\phi + \bar{N}_\theta) + \frac{1}{2} \sqrt{(\bar{N}_\phi - \bar{N}_\theta)^2 + 4\bar{N}_{\phi\theta}^{\,2}}$$

Double-Wall Tent

The stress resultants are given in terms of meridional, hoop, and web directions. The fabric for the inside and outside surfaces should be designed to the largest of the hoop and meridional stress. The web fabric should be designed to withstand the largest of the web and meridional stress.

Safety Factors

The stress values provided in this manual are those stresses which develop under design wind load. In selecting a material to meet the design stresses, allowance must be made for other factors such as the following:

a. Uniformity of product
b. Weathering resistance
c. Handling
d. Stress-strain characteristics of the fabric and its ultimate rupture strength.

To obtain the maximum reduction in weight and still have good durability and reliability, each of the factors listed must be accurately evaluated with respect to its effect on the strength of the material. This information can be obtained from References 2 and 3 and from the fiber manufacturers.

However, in situations where detailed information on the above factors are not available, Reference 4 recommends that a safety factor of 3 be used. The design strength of the fabric is, then, three times the maximum stress resultant.

FABRIC WEIGHTS

Weight of Base Fabric

The weight-strength relationship, η, of plain weave fabrics made from different fibers is shown in Table III. The unit of measure is

$$\eta = \frac{\text{lbs-sq yd}}{\text{inch-oz}}$$

The weight of base fabric is calculated as follows:

$$\frac{(\text{safety factor})\ (\text{maximum stress})}{\eta} = \text{Wt of base fabric}$$

Weight of Coated Fabric

The estimated weight of coating required versus weight of base fabric for single-and two-ply coated fabric is shown in Figure 50.

The weight of coated fabric is obtained by adding the weight of the base fabric and the weight of coating as determined from the graph.

Wt base fabric + Wt of coating = Wt of coated fabric

BLOWER CHARACTERISTICS

The blower pressure-volume relationships for single and double wall tents differ and will be considered separately.

Table III

Weight-Strength Relationship
of Plain Weave Fabrics

Fiber Type	Specific Gravity	Weight-Strength Relationship, η $\frac{\text{lb}}{\text{in}} - \frac{\text{sq yd}}{\text{x oz}}$
Polyester*	1.37	35
Nylon	1.14	38
Spun Acrylic	1.17	12
Filament Acrylic	1.17	15
Glass Fiber**	2.56	19
Polypropylene***	0.98	48

*Strip tensile test. Other tensile test data calculated from grab tensile data using the relationship;
Grab tensile test x 0.66 = Strips tensile test.

**Base fabric prepared for coating.

***High initial test degrades rapidly in weathering. Satisfactory coating adhesion difficult to attain.

Single-Wall Tent:

Pressure: An internal pressure equal to the wind impact pressure, q, is recommended for good tent stability and minimum tent deflection. It should be pointed out that pressures of less than q can be tolerated from a stability standpoint. However, should pressures lower than q be used, the greater deflections and lower usable volume resulting from these lower pressures must be accounted for in the anticipated usage.

Blower volume: The blower must have sufficient volume to account for all air losses and still maintain the required internal pressure. Air losses which can be calculated are fabric porosity, ventilating ports, slide fasteners, and other orifices which are necessary for proper operation of the tent. The air losses through the ground seal, doors, and other closures are, for the most part, not amenable to calculations and must be determined on an individual basis.

Fabric porosity is generally known or can be determined for any given pressure in terms of air loss in cubic feet/per square foot/per minute.

Air losses, Q, through ventilating ports, slide fasteners, and other orifices can be calculated from the following expression:

$$Q = 1096.5\ C_o A_o \sqrt{\frac{\Delta P}{g \rho}}$$

where

Q = Discharge, cu ft/min

A_o = Area of orifice, sq ft

ΔP = Differential Pressure, inches w.g.

$g\rho$ = Density of Air, lb/cu ft

C_c = Coefficient of contraction

C_v = Coefficient of velocity

$C_o = C_c \times C_v = 0.65$

The leakage through a number 10 crown slide fastener was calculated in terms of cubic feet per minute/per inch of slide fastener chain. The results are plotted as Figure 51.

Air losses through the ground seal, doors, and other closures must be determined experimentally.

The following air losses were found for doors with metal frames and ground seals typical for Military type air-supported tents.

Item	Cubic feet/minute
Door	503
Ground catenary with seal skirt	26 per perimeter foot
Ground, pipe seal	6 per perimeter foot

The air loss values listed above are typical and can be expected for Military tentage installed under field conditions.

The volume capacity of the blower then becomes a summation of all air loss factors.

Double-Wall Air-Supported Tents

Pressure: The pressure required for double-wall tents is related to the size of the tent, and the depth of cell walls. The larger the depth of cell wall for a given size tent, the lower the pressure requirement for the design wind load.

Experience with Military double-wall tents has shown that up to 7 inches w.g. was required to erect itself. It was also found that with tents having a cell depth to tent width ratio of 0.08 to 0.12, the minimum tube pressure which could be tolerated was "q" for survival, and 3q for good stability and minimum deflection.

Blower Volume: The air volume required for double-wall air supported tents is much less than that required for the single-wall type. The double-wall tent is airtight and, ideally, once inflated the tent will retain its pressure with the blower turned off. In this situation the operation requirements for air volume is minimum and blower volume capacity can be gaged on other tent characteristics. Two such characteristics can be defined as time for erection, and air capacity to compensate for air losses which may occur when the cell wall is punctured. Air losses may be estimated as for single-wall tents.

The air volume capacity required to erect the tent in a given time can be estimated as follows:

$$\frac{\text{Cell Volume } (\text{ft})^3}{\text{Inflation Time (min)}} = \text{Volumetric Capacity of Blower at zero inches water gage.}$$

TENT WEIGHT AND CUBE

Tent Weight

Single-Wall Tents

Total weight-lbs = (Fabric Area-yds^2)(Coated Fabric Weight-oz/yd^2)
(1.5/16)

Double-Wall Tents

Wall and roof section

Total weight of Wall & Roof Sections-lbs =(Fabric Area-yd^2)(Coated
(Fabric Weight-oz/yd^2)(1.33/16)

End Curtain

Total Weight of End Curtains = (Fabric Area-yd^2)(Coated Fabric
Weight oz-yd^2)(1.5/16)

Package Cube

Single-Wall Tents

Package cube-ft^3 = (Total Weight of tent-lbs)(0.1 ft^3/lb)

Double-Wall Tents

Package cube-ft^3 = (Total Weight of Roof & Wall + Total Weight
of End Curtains)(0.065)

SECTION 4

SAMPLE DESIGN PROBLEMS

GENERAL EQUATIONS

Lift $L = C_L\, qA_p$

Drag $D = C_D\, qA_p$

Moment $M = C_M\, qA_p d$

Anchor Load $P_{AL} = C_{AL}\, qA_p$

Guy Line Load $P_{GL} = C_{GL}\, qA_p$

Inflation Load (Single-Wall Tent) $P_{IL} = P_e\, A_f$

Planform Area

Single-Wall Sphere $A_p = \pi r^2$

Single-Wall Cylinder with Hemispherical Ends

$$A_p = \pi r^2 + 2r(\ell_h - 2r)$$

Single-Wall Cylinder with Ellipsoidal Ends

$$A_p = \pi br + 2r(\ell_h - 2b)$$

Double-Wall Cylinder $A_p = W\ell_h$

Floor Area

Single-Wall Sphere $A_f = \pi(r \sin \phi_B)^2$

Single-Wall Cylinder with Hemispherical Ends

$$A_f = \pi(r \sin \phi_B)^2 + 2r \sin \phi_B(\ell_h - 2r)$$

Single-Wall Cylinder with Ellipsoidal Ends

$$A_f = \pi br \sin^2 \phi_B + 2r \sin \phi_B(\ell_h - 2r)$$

Double-Wall Cylinder $A_f = W\, \ell_h$

Note: On all single-wall tents and circular cylindrical double-wall tents: $\phi_B = 75^\circ$ for $h/d = 3/8$; $\phi_B = 90^\circ$ for $h/d = 1/2$; $\phi_B = 120^\circ$ for $h/d = 3/4$; and $\phi_B = 140^\circ$ for $h/d = 7/8$. For double-wall tents with straight sides ϕ_B must be specified as shown in Figure 52.

Surface Area

Single-Wall Sphere $A_s = \pi dh$

Single-Wall Cylinder with Hemispherical Ends

Cylindrical Portion $A_s = (\ell_h - 2r)\, d(\phi_B/57.3)$

Hemispherical Ends $A_s = \pi dh$

Single-Wall Cylinder with Ellipsoidal Ends

Cylindrical Portion $A_s = (\ell_h - 2b)\, d(\phi_B/57.3)$

Ellipsoidal Ends $A_s = \pi\frac{h}{d}\left|2r^2 + \frac{b^2}{e}\ln\frac{1+e}{1-e}\right|$

with $e = \sqrt{1 - (b/r)^2}$

Double-Wall Cylinder

Circular Sided

Walls $A_s = 4\ell_h\, r(\phi_B/57.3)$

Web $A_s = 2nwr(\phi_B/57.3)$

End Curtains $A_s = 2r^2\left(\frac{2\phi_B}{57.3} - \sin\phi_B \cos\phi_B\right)$

Flat Sided

Walls $A_s = 4\ell_h\, \frac{r\phi_B}{57.3} + h_r)$

Web $A_s = 2nw\left(\frac{r\phi_B}{57.3} + h_r\right)$

End Curtains $A_s = 2r^2\left(\frac{2\phi_B}{57.3} - \sin\phi_B \cos\phi_B\right) + 4rh_r$

Perimeter

Single-Wall Sphere $P_\ell = 2\pi r \sin\phi_B$

Single-Wall Cylinder with Hemispherical Ends

$$P_\ell = 2\pi r \sin\phi_B + 2(\ell_h - 2r)$$

Single-Wall Cylinder with Ellipsoidal Ends

$$P_\ell = \pi r \sin\phi_B \sqrt{2\left|1 + \left(\frac{b}{r}\right)^2\right|} + 2(\ell_h - 2b)$$

Double-Wall Cylinder $P_\ell = 2\ell_h$

Number of Anchors Required*

Single-Wall Tents $NA = \frac{P_{IL} + P_{AL}}{1500}$

Double-Wall Tents $NA = \frac{P_{AL} + P_{GL}}{1500}$

Anchor Spacing $AS = P_\ell / NA$

Dynamic Pressure $q = k_p \, q_{std}$

Fabric Stress

Single-Wall Sphere

$$\bar{N}_\phi = \left(\frac{N_\phi}{qr}\right) qr + P_e r/2$$

$$\bar{N}_\theta = \left(\frac{N_\theta}{qr}\right) qr + P_e r/2$$

$$\bar{N}_{\phi\theta} = \left(\frac{N_{\phi\theta}}{qr}\right) qr$$

$$\bar{N}_\theta(\phi) = \left(\frac{N_\theta(\phi)}{N_\theta(\text{peak})}\right) \left(\frac{N_\theta}{qr}\right) qr + \frac{P_e r}{2}$$

Single-Wall Cylinder with Hemispherical Ends

Cylindrical Portion

$$\bar{N}_\phi = \left(\frac{N_\phi}{qr}\right) qr + p_e r$$

$$\bar{N}_x = \left(\frac{N_\theta}{qr}\right) qr + P_e r/2$$

Hemispherical End

$$\bar{N}_\phi = \left(\frac{N_\phi}{qr}\right) qr + P_e r/2$$

$$\bar{N}_\theta = \left(\frac{N_\theta}{qr}\right) qr + P_e r/2$$

$$\bar{N}_{\phi\theta} = \left(\frac{N_{\phi\theta}}{qr}\right) qr$$

---

*Based on an allowable individual anchor load of 1500 lb.

Single-Wall Cylinder with Ellipsoidal Ends

Cylindrical Portion (Using Cylinder Correction Factors)

$$\overline{N}_{\phi} = C_{q\phi}\, C_{h\phi}\, C_{W\phi}\, C_{b\phi} \left(\frac{N_{\phi}}{qr}\right) qr$$

$$\overline{N}_{x} = C_{q\theta}\, C_{h\theta}\, C_{W\theta}\, C_{b\theta} \left(\frac{N_{x}}{qr}\right) qr$$

Ellipsoidal End (Using End Correction Factors)

$$\overline{N}_{\phi} = C_{q\phi}\, C_{h\phi}\, C_{W\phi}\, C_{b\phi} \left(\frac{N_{\phi}}{qr}\right) qr$$

$$\overline{N}_{\theta} = C_{q\theta}\, C_{h\theta}\, C_{W\theta}\, C_{b\theta} \left(\frac{N_{\theta}}{qr}\right) qr$$

$$\overline{N}_{\phi\theta} = C_{q\phi\theta}\, C_{h\phi\theta}\, C_{W\phi\theta}\, C_{b\phi\theta} \left(\frac{N_{\phi\theta}}{qr}\right) qr$$

Double-Wall Cylinder

$$\overline{N}_{w} = \left(\frac{N_{w}}{q}\right) q$$

$$\overline{N}_{h} = \left(\frac{N_{h}}{q}\right) q$$

Fabric Weight

Maximum Principal Stress $\quad N_{max} = \frac{1}{2}(\overline{N}_{\phi} + \overline{N}_{\theta}) + \frac{1}{2}\sqrt{(\overline{N}_{\phi} - \overline{N}_{\theta})^2 + 4\overline{N}_{\phi\theta}^{\,2}}$

Base Fabric Weight $\quad W_{bf} = SF\, N_{max}/\eta$

Slide Fastener Length for Single-Wall Tents

Cylinder with Hemispherical Ends

$$L_{sf} = 2r\,\frac{\phi_B}{57.3} + (\ell_h - 2r)$$

Cylinder with Ellipsoidal Ends

$$L_{sf} = \pi r\,\frac{h}{d}\sqrt{2\left|1 + \left(\frac{b}{r}\right)^2\right|} + (\ell_h - 2b)$$

Spherical $\quad L_{sf} = \pi h$

Cell Volume of Double-Wall Tents

Circular $\quad V_c = 2w\ell_h r\,\frac{\phi_B}{57.3}$

Flat Sided $\quad V_c = 2w\ell_h\left(\frac{r\phi_B}{57.3} + h_r\right)$

SINGLE-WALL TENT

Known Shape

Spherical Tent

Given:

Width = 30 ft
Height = 22.5 ft
Height/Diameter Ratio = 3/4
Design pressure altitude - Sea level
Temperature Range = $-30^{\circ}F$ to $+60^{\circ}F$
Wind Velocity = 90 knots

Solution:

1. Find dynamic pressure, q

   a. q_{std} = 5.3 in w.g. = 28 psf = 0.19 psi Figure 7

   b. $k_p = 1.22$ Figure 8

   c. $q = 1.22\ q_{std}$ = 6.46 in w.g.

   = 34.2 psf = 0.232 psi

2. Find planform area, A_p

   $A_p = \pi r^2 = \pi(15)^2 = 709$ sq ft

3. Find floor area, A_f

   $A_f = \pi(r^2 \sin \phi_B) = \pi|15 (\sin 120^{\circ})|^2 = 177$ sq ft

4. Find external surface area, A_s

   $A_s = \pi dh = \pi(30)(22.5) = 2120$ sq ft = 235.6 sq yd

5. Find perimeter, P_ℓ

   $P_\ell = 2\pi r \sin \phi_B = 2\pi\ (15)(\sin 120^{\circ}) = 47.2$ ft

6. Find aerodynamic loads; L, D, and M

   a. Lift = $C_L\ q\ A_p$

   where $C_L = 0.763$ Figure 9

   L = (0.763)(34.2)(709) = 18,500 lb

b. Drag = $C_D\ q\ A_p$

where C_D = 0.437 — Figure 11

D = (0.437) (34.2) (709) = 10,596 lb

c. Overturning moment = $C_M\ q\ A_p$

where C_M = -0.140 — Figure 13

M = (-0.140) (34.2) (709) = -3,395 ft-lb

7. Find maximum tent deflection; δ_F, δ_H, δ_B

a. $\frac{\delta_F}{r} = 0.198$, $\frac{\delta_H}{r} = 0.083$ $\frac{\delta_B}{r} = 0.128$ — Figure 15

b. $\delta_F = (\frac{\delta_F}{r})\ (r) = (0.198)\ (15) = 2.97$ ft

$\delta_H = (\frac{\delta_H}{r})\ (r) = (0.083)\ (15) = 1.25$ ft

$\delta_B = (\frac{\delta_B}{r})\ (r) = (0.128)\ (15) = 1.92$ ft

8. Find inflation load, P_{IL}

$P_{IL} = P_e A_f$

since P_e = q for stability P_e = 34.2 psf

P_{IL} = (34.2)(177) = 6053 lb

9. Find anchor load, P_{AL}

$P_{AL} = C_{AL}\ q\ A_p$

where C_{AL} = 1.50 — Figure 20

P_{AL} = (1.50)(34.2)(709) = 36,372 lb

10. Find number of anchors required, NA

$$NA = \frac{P_{IL} + P_{AL}}{1500^*}$$

*Based on an allowable individual anchor load of 1500 lb for a 4" arrowhead anchor.

$$NA = \frac{6,053 + 36,372}{1500} = \frac{42.425}{1500} = 28.3$$

NA = 29 required

11. Find anchor spacing, AS

$AS = P_e/NA$

AS = 47.2/29 = 16.3 ft between anchors

12. Find fabric stress resultants

a. Peak stress resultants, $N_{(\ )}$

for h/d = 3/4:

$$\frac{N_\theta}{qr} = 1.72, \quad \frac{N_\phi}{qr} = 1.67, \quad \frac{N_{\phi\theta}}{qr} = 1.02 \qquad \text{Figure 23}$$

$$N_\theta = (1.72)qr = (1.72)(0.232)(15)(12) = 71.83 \text{ lb/in}$$

$$N_\phi = (1.67)qr = (1.67)(0.232)(15)\ (12) = 69.74 \text{ lb/in}$$

$$N_{\phi\theta} = 1.02\ qr = (1.02)(0.232)(15)(12) = 42.60 \text{ lb/in}$$

b. Maximum stress resultants, $\overline{N}_{(\ )}$

$$\overline{N}_\theta = N_\theta + \frac{P_e r}{2} = 71.83 + \frac{(0.232)(15)(12)}{2}$$

$$\overline{N}_\theta = 71.83 + 20.88 = 92.71 \text{ lb/in}$$

$$\overline{N}_\phi = N_\phi + \frac{P_e r}{2} = 69.74 + 20.88$$

$$\overline{N}_\phi = 90.62 \text{ lb/in}$$

$$\overline{N}_{\phi\theta} = N_{\phi\theta} = 42.60 \text{ lb/in}$$

c. Stress resultant at $\phi = 45^{o}$, $\overline{N}_{\theta}(\phi)$

$$\overline{N}_{\theta}(\phi) = \left(\frac{N_{\theta}\ (\phi)}{N_{\theta}(peak)}\right)(N_{\theta}) + \frac{P_{e}r}{2}$$

where $\dfrac{N_{\theta}(\phi)}{N_{\theta}(peak)} = 0.50$ Figure 24

$$\overline{N}_{\theta}(\phi) = (0.50)(71.83) + 20.88$$

$$N_{\theta}(\phi) = 35.92 + 20.88 = 56.80 \text{ lb/in}$$

d. Maximum principal stress, N_{max}

$$N_{max} = 1/2(\overline{N}_{\phi} + \overline{N}_{\theta}) + 1/2\sqrt{(\overline{N}_{\phi} - \overline{N}_{\theta})^{2} + 4\overline{N}_{\phi\theta}^{\ 2}}$$

$$N_{max} = 1/2(90.62 + 92.71) + 1/2\sqrt{(90.62 - 92.71)^{2} + 4(42.60)^{2}}$$

$$N_{max} = 91.67 + 42.62 = 134.29 \text{ lb/in}$$

13. Find coated fabric weight, W_{cf}

a. Determine fiber type from other considerations, select polyester

b. Weight-strength relationship of fiber, η

$$\eta = 35\ \frac{\text{lb-yd}^{2}}{\text{in oz}}$$ Table III

c. Weight of base fabric, W_{bf}

$$W_{bf} = SF\ N_{max}/\eta$$

Using a safety factor of 3,

$$W_{bf} = \frac{3(134.29)}{35} = \frac{402.87}{35}$$

$$W_{bf} = 11.50 \text{ oz/yd}^2$$

d. Weight of fabric coating, W_c
(Assuming vinyl coating, single ply)

$W_c = 16 \text{ oz/yd}^2$ Figure 50

e. Fabric surface area

Tent surface area = 2120 sq ft

Catenary curtain = (A_p)(1 ft high) = (709)(1)
= 709 sq ft

Ground seal skirt = (A_p)(2 ft wide) = (709)(2)
= 1418 sq ft

Total fabric surface area = 2120 + 709 + 1418
= 4247sq ft = 471.9sq yd

f. Coated fabric weight, W_{cf}

W_{cf} = (total surface area)$(W_{bf} + W_c)$

W_{cf} = (471.9 sq yd)(11.50oz/yd^2 + 16oz/yd^2)
(1.5/16)

W_{cf} = (471.9)(27.5)(0.0937) = 1217.5 lb

14. Find package cube, V

Estimated cube = (W_{cf}) (0.1 ft^3/lb)
Estimated cube = (1217.51)(0.1) = 121.75 ft^3

15. Find blower requirements, Q

a. Air loss per inch of slide fastener at P_e = 6.46 in w.g. equals 2.6 ft^3/min/in

Figure 51

b. Total length of slide fastener, if employed, L_{sf}

$L_{sf} = \pi h = \pi(22.5) = 70.69$ ft = 848.28 in

c. Air loss through slide fastener

Air loss = (air loss/inch)(length)

Air loss = (2.6)(848.28) = 2205.5 ft^3/min

d. Air loss through ground seal skirt

Air loss = 26 ft^3/ft(perimeter)/min

where P_e = 47.2 ft

Air loss = (26) (47.2) = 1227.2 ft^3/min

e. Air loss through door is 503 ft^3/min

f. Total air loss (from c, d and e)

Total air loss = 2205.5 + 1227.2 + 503

= 3935.7ft^3/min @ 6.46 in w.g.

g. Total blower requirement, Q

Q = (2) (total air loss)

Q = (2) (3936) = 7872 ft^3/min @ 6.46 in w.g.

Cylindrical Tent with Hemispherical Ends

Given:

Width = 50 ft
Height = 25 ft
Length = 100 ft
Height-to-Diameter Ratio = 1/2
Width-to-Length Ratio = 1/2
Design pressure altitude - 3000 ft
Temperature Range - $25^\circ F$ to + $100^\circ F$
Wind Velocity = 110 mph

Solution:

1. Find dynamic pressure, q

   a. q_{std} = 5.9 in w.g. = 31 psf = 0.22 psi Figure 7

   b. k_p = 1.075 Figure 8

   c. $q = 1.075\, q_{std}$ = 6.34 in w.g.

      = 33.33 psf = 0.24 psi

2. Find planform area, A_p

   $A_p = \pi r^2 + 2r(\ell_h - 2r)$

   $A_p = \pi(25)^2 + 2(25)(100 - (2)(25))$

   $A_p = \pi(625) + (50)(50)$

   A_p = 4463.5 sq ft

3. Find floor area, A_f

   $A_f = \pi(r \sin \phi_B)^2 + 2r \sin \phi_B(\ell_h - 2r)$

   where $\sin \phi_B = \sin 90^\circ = 1.0$

   $A_f = \pi((25)(1))^2 + 2(25)(1)(100 - 50)$

   A_f = 4463.5 sq ft

4. Find external surface area, A_s

   $A_s = \pi dh + (\ell_h - 2r)(d)(\phi_B/57.3)$

   $A_s = (\pi)(50)(25) + (100 - 2(25))\ (50)\left(\frac{90}{57.3}\right)$

   A_s = 7852 sq ft

5. Find perimeter, P_ℓ

$P_\ell = 2\pi r \sin \phi_B + 2 (\ell_h - 2r)$

$P_\ell = 2\pi(25)(\sin 90^\circ) + 2 (100 - 2(25))$

$P_\ell = 157.1 + 100 = 257.1$ ft

6. Find aerodynamic loads; L, D and M

a. Lift = $C_L\, q\, A_p$

where $C_L = 0.540$ — Figure 9

L = (0.540)(33.33)(4463.5) = 80,335 lb

b. Drag = $C_D\, q\, A_p$

where $C_D = 0.450$ — Figure 11

D = (0.450(33.33)(4463.5) = 66,946 lb

c. Overturning moment = $C_M\, q\, A_p$

where $C_M = 0.390$ — Figure 13

M = (-0.390)(33.33)(4463.5) = -58,020 ft-lb

7. Find maximum tent deflection; δ_F, δ_H, δ_B

a. $\frac{\delta_F}{r} = 0.103$, $\frac{\delta_H}{r} = 0.103$, $\frac{\delta_B}{r} = 0.030$ — Figure 16

b. $\delta_F = (\frac{\delta_F}{r})(r) = (0.103)(25) = 2.58$ ft

$\delta_H = (\frac{\delta_H}{r})(r) = (0.103)(25) = 2.58$ ft

$\delta_B = (\frac{\delta_B}{r})(r) = (0.030)(25) = 0.75$ ft

8. Find inflation load, P_{IL}

$P_{IL} = P_e A_f$

Since $P_e = q$ for stability; $P_e = 33.33$ psf

$P_{IL} = (33.33)(4463.5) = 148,769$ lb

9. Find anchor load, P_{AL}

$P_{AL} = C_{AL}\ q\ A_p$

where $C_{AL} = 1.58$ Figure 20

$P_{AL} = (1.58)(33.33)(4463.5) = 235{,}054$ lb

10. Find number of anchors required, NA

$$NA = \frac{P_{AL} + P_{IL}}{1500*}$$

$$NA = \frac{148{,}769 + 235{,}054}{1500} = \frac{383{,}823}{1500}$$

NA ≃ 256 required

11. Find anchor spacing, AS

$AS = P_e/NA$

$AS = \frac{257.1}{256}$ 1.004 ft between anchors

12. Find fabric stress resultants

a. Cylindrical portion

1) Peak stress resultants, $N_{(\ )}$ for $h/d = 1/2$, $W/\ell_h = 1/2$

$\frac{N_\phi}{qr} = 0.83$ Figure 27

$\frac{N_\theta}{qr} = 1.40$ Figure 29

$N_\phi = (0.83)(0.24)(25)(12) = 59.76$ lb/in

$N_\theta = (1.40)(0.24)(25)(12) = 100.80$ lb/in

2) Maximum stress resultants, $\overline{N}_{(\ )}$

*Based on an allowable individual anchor load of 1500 lb for 4" arrowhead anchor.

$$\overline{N}_\phi = N_\phi + P_e r$$

$$\overline{N}_\phi = 59.76 + (0.24)(25)(12)$$

$$\overline{N}_\phi = 131.76 \text{ lb/in}$$

$$\overline{N}_x = N_\theta + \frac{P_e r}{2}$$

$$\overline{N}_x = 100.80 + \frac{(0.24)(25)(12)}{2}$$

$$\overline{N}_x = 100.80 + 36.00 = 136.80 \text{ lb/in}$$

b. **Hemispherical ends**

1) Peak stress resultants, $N_{(\;)}$ for $h/d = 1/2$, $W/\ell_h = 1/2$

$$\frac{N_\phi}{qr} = 1.50 \qquad \text{Figure 27}$$

$$\frac{N_\theta}{qr} = 1.40 \qquad \text{Figure 29}$$

$$\frac{N_{\phi\theta}}{qr} = 0.66 \qquad \text{Figure 30}$$

$$N_\phi = (1.50)(0.24)(25)(12) = 108.00 \text{ lb/in}$$

$$N_\theta = (1.40)(0.24)(25)(12) = 100.80 \text{ lb/in}$$

$$N_{\phi\theta} = (0.66)(0.24)(25)(12) = 47.52 \text{ lb/in}$$

2) Maximum stress resultants, $\overline{N}_{(\;)}$

$$\overline{N}_\phi = N_\phi + \frac{P_e r}{2}$$

$$\overline{N}_{\phi} = 108.00 + \frac{(0.24)(25)(12)}{2}$$

$$\overline{N}_{\phi} = 108.00 + 36.00 = 144.00 \text{ lb/in}$$

$$\overline{N}_{\theta} = N_{\theta} + \frac{P_e r}{2}$$

$$\overline{N}_{\theta} = 100.80 + \frac{(0.24)(25)(12)}{2}$$

$$\overline{N}_{\theta} = 100.80 + 36.00 = 136.80 \text{ lb/in}$$

$$\overline{N}_{\phi\theta} = N_{\phi\theta} = 47.52 \text{ lb/in}$$

3) Maximum principal stress, N_{max}

for hemispherical ends:

$$N_{max} = \frac{1}{2} (\overline{N}_{\phi} + \overline{N}_{\theta}) + \frac{1}{2} \sqrt{(\overline{N}_{\phi} - \overline{N}_{\theta})^2 + 4\overline{N}_{\phi\theta}{}^2}$$

$$N_{max} = \frac{1}{2} (144.0 + 136.8) + \frac{1}{2} \sqrt{(144 - 136.8)^2 + 4(47.52)^2}$$

$$N_{max} = 140.4 + \frac{1}{2} \sqrt{9084.44} = 188.07 \text{ lb/in}$$

13. Find coated fabric weight, W_{cf}

a. Determine fiber type from other consideration, select polyester

b. Weight-strength relationship of fiber, η

$\eta = 35 \ \frac{\text{lb-yd}^2}{\text{in oz}}$ Table III

c. Weight of base fabric, W_{bf}, using N_{max} for hemispherical ends:

$$W_{bf} = SF\ N_{max}/\eta$$

Using a safety factor of 3,

$$W_{bf} = \frac{3(188.07)}{35} = \frac{564.21}{35}$$

$$W_{bf} = 16.12 \text{ oz/yd}^2$$

d. Weight of fabric coating, W_c

(Assuming vinyl coating, two ply)

W_c = 32 oz/yd² Figure 50

e. Fabric surface area

Tent surface area, A_s = 7852 sq ft

Catenary curtain = (A_p)(1 ft high) = (4463.5)(1)
= 4463.5 sq ft

Ground seal skirt = (A_p)(2 ft wide) = (4463.5)(2)
= 8927 sq ft

Total fabric surface area = 7852 + 4463.5 + 8927
= 21,242.5 sq ft
= 2,360.3 sq yd

f. Coated fabric weight, W_{cf}, using W_{bf} requirements of hemispherical ends:

W_{cf} = (total surface area) $(W_{bf} + W_c)$

W_{cf} = (2,360.3)(16.12 oz/yd² + 32 oz/yd²)(1.5/16)

W_{cf} = (2,360.3)(48.12)(0.0937) = 10,647.9 lb

14. Find package cube, V

Estimated cube = (W_{cf}) (0.1 ft³/lb)

Estimated cube = (10,647.9)(0.1) = 1,064.8 ft³

15. Find blower requirements, Q

a. Air loss per inch of slide fastener at P_e = 6.34 in w.g. equals 2.58 ft³/min/in

Figure 51

b. Total length of slide fastener, if employed, L_{sf}

$$L_{sf} = 2r \frac{\phi_B}{53.3} + (\ell_h - 2r)$$

$$L_{sf} = (2)(25)\left(\frac{90}{57.3}\right) + (100 - 50)$$

L_{sf} = 78.5 + 50 = 128.5 ft = 1542 in

c. Air loss through slide fastener

Air loss = (air loss/inch)(length)

Air loss = (2.58)(1542) = 3978.4 ft^3/min

d. Air loss through ground seal skirt

Air loss = 26 ft^3/ft(perimeter)/min

where P_{ℓ} = 257.1 ft

Air loss = (26)(257.1) = 6684.6 ft^3/min

e. Air loss through door is 503 ft^3/min

f. Total air loss (from c, d and e)

Total air loss = 3978.4 + 6684.6 + 503

Total air loss = 11,166 ft^3/min @ 6.34 in w.g.

g. Total blower requirement, Q

Q = 2(air loss) = 22,332 ft^3/min @ 6.34 in w.g.

Cylindrical Tent with Ellipsoidal Ends

Given:

Width = 50 ft
Height = 25 ft
Length = 100 ft with b/a = 1/2 = b/r
Height-to-Diameter Ratio = 1/2
Width-to-Length Ratio = 1/2
Design pressure altitude - 3000 ft
Temperature Range - 25°F to + 100°F
Wind Velocity = 110 mph

Solution:

1. Find dynamic pressure, q

   a. q_{std} = 5.9 in w.g. = 31 psf = 0.22 psi   Figure 7

   b. k_p = 1.075

   c. $q = 1.075\, q_{std}$ = 6.34 in w.g.

      = 33.33 psf = 0.24 psi

2. Find planform area, A_p

   Since a = tent radius, r, and b/a = 1/2:

   $\frac{b}{25} = \frac{1}{2}$ or b = 12.5 ft

   $A_p = \pi br + 2r(\ell_h - 2b)$

   $A_p = \pi(12.5)(25) + 2(25)(100-2(25))$

   $A_p = 981.8 + 2500$

   A_p = 3481.8 sq ft

3. Find floor area, A_f

   $A_f = \pi br \sin^2\phi_B + 2r \sin\phi_B\ (\ell_h - 2r)$

   where $\sin\phi_B = \sin 90° = 1.0$

   $A_f = \pi(12.5)(25)(1) + 2(25)(1)(100-50)$

   A_f = 3481.8 sq ft

4. Find external surface area, A_s

$$A_s = (\ell_h - 2b)(d)(\phi_B/57.3) + \pi\frac{h}{d}\left|2r^2 + \frac{b^2}{e}\ln\frac{1+e}{1-e}\right|$$

where $e = \sqrt{1-(b/r)^2}$

$$e = \sqrt{1-(\frac{12.5}{25})^2} = \sqrt{0.75} = 0.866$$

$$A_s = (100 - 25)(50)(90/57.3) + \pi\,\frac{25}{50}\left|\,2(25)^2 + \frac{(12.5)^2}{0.866}\ln\frac{1+0.866}{1-0.866}\right|$$

$$A_s = 5887.5 + 2286.77 = 8174.27 \text{ sq ft}$$

5. Find perimeter, P_ℓ

$$P_\ell = \pi r \sin\phi_B \sqrt{2\left|1 + (\frac{b}{r})^2\right|} + 2\,(\ell_h - 2b)$$

$$P_\ell = \pi(25)\sin 90^\circ \sqrt{2\left|\,1 + (\frac{12.5}{25})^2\right|} + 2\,(100 - 2(12.5))$$

$$P_\ell = 25\,\pi\,.\sqrt{2.5}\ + 150 = 274 \text{ ft}$$

6. Find aerodynamic loads; L, D and M

a. Lift = $C_L\, q\, A_p$

where $C_L = 0.904$ Figure 9

L = (0.904)(33.33)(3481.4) = 104,896 lb

b. Drag = $C_D\, q\, A_p$

where $C_D = 0.500$ Figure 11

D = (0.500)(33.33)(3481.4) = 58,018 lb

c. Overturnimg moment = C_M a A_p

where $C_M = -0.648$ Figure 13

M = (-0.648)(33.33)(3481.4) = -75,191 lb

7. Find maximum tent deflection: δ_F, δ_H, δ_B

a. $\frac{\delta_F}{r} = 0.175$, $\frac{\delta_H}{r} = 0.098$, $\frac{\delta_B}{r} = 0.052$ Figure 16

b. $\delta_F = (\frac{\delta_F}{r})(r) = (0.175)(25) = 4.38$ ft

$\delta_H = (\frac{\delta_H}{r})(r) = (0.098)(25) = 2.45$ ft

$\delta_B = (\frac{\delta_B}{r})(r) = (0.052)(25) = 1.30$ ft

8. Find inflation load, P_{IL}

$P_{IL} = P_e A_f$

Since $P_e = q$ for stability; $P_e = 33.33$ psf

$P_{IL} = (33.33)(3481.8) = 116{,}048$ lb

9. Find anchor load, P_{AL}

$P_{AL} = C_{AL}\ q\ A_p$

where $C_{AL} = 2.30$ — Figure 20

$P_{AL} = (2.30)(33.33)(3481.8) = 266{,}910$ lb

10. Find number of anchors required, NA

$$NA = \frac{P_{IL} + P_{AL}}{1500^*}$$

$$NA = \frac{116{,}048 + 266{,}910}{1500} = \frac{382{,}958}{1500}$$

NA = 256 required

11. Find anchor spacing, AS

$$AS = \frac{P_\ell}{NA}$$

$$AS = \frac{274}{256} = 1.07 \text{ ft between anchors}$$

*Based on an allowable individual anchor load of 1500 lb for a 4" arrowhead anchor.

12. Find fabric stress resultants

a. Cylindrical section

1) Peak stress resultants, $N_{(\ )}$ for h/d = 1/2 W/ℓ_h = 1/2 and b/r = 1/2

$\frac{N_\phi}{qr} = 1.90, \frac{N_\theta}{qr} = 1.73$ Figure 32

$N_\phi = (1.90)(0.24)(25)(12) = 136.8$ lb/in

$N_\theta = (1.73)(0.24)(25)(12) = 124.6$ lb/in

2) Maximum stress resultants, $\bar{N}_{(\ )}$

Since $P_e/q = 1.0$, $b/r = 1.0$, $W/\ell_h = 1.0$;

$C_{q\phi} = 1.0$, $C_{b\phi} = 1.0$, $C_{w\phi} = 1.0$, $C_{h\phi} = 1.0$

Figure 33

$C_{q\theta} = 1.0$, $C_{b\theta} = 1.0$, $C_{w\theta} = 1.0$, $C_{h\theta} = 1.0$

Figure 34

$\bar{N}_\phi = (1.0)(1.0)(1.0)(1.0)(1.90)(0.24)(25)(12) = 136.8$ lb/in

$\bar{N}_\theta = (1.0)(1.0)(1.0)(1.0)(1.73)(0.24)(25)(12) = 124.6$ lb/in

b. Ellipsoidal ends

1) Peak stress resultants, $N_{(\ )}$

$\frac{N_\phi}{qr} = 2.72, \frac{N_\theta}{qr} = 2.20, \frac{N_{\phi\theta}}{qr} = 1.82$ Figure 32

$N_\phi = (2.72)(0.24)(25)(12) = 195.8$ lb/in

$N_\theta = (2.20)(0.24)(25.)(12) = 158.4$ lb/in

$N_{\phi\theta} = (1.81)(0.24)(25)(12) = 131.0$ lb/in

2) Maximum stress resultants, $\bar{N}_{(\ )}$

Since $P_e/q = 1.0$, $b/r = 1.0$, $W/\ell_h = 1.0$,

$h/d = 1.0$;

$C_{q\phi} = 1.0$, $C_{b\phi} = 1.0$, $C_{w\phi} = 1.0$, $C_{h\phi} = 1.0$

Figure 33

$C_{q\theta} = 1.0$, $C_{b\theta} = 1.0$, $C_{w\theta} = 1.0$, $C_{h\theta} = 1.0$

Figure 34

$C_{q\phi\theta} = 1.0$, $C_{b\phi\theta} = 1.0$, $C_{w\phi\theta} = 1.0$, $C_{h\phi\theta} = 1.0$

Figure 35

$$\overline{N}_\phi = (1.0)(1.0)(1.0)(1.0)(2.72)(0.24)(25)(12) = 195.8 \text{ lb/in}$$

$$\overline{N}_\theta = (1.0)(1.0)(1.0)(1.0)(2.20)(0.24)(25)(12) = 158.4 \text{ lb/in}$$

$$\overline{N}_{\phi\theta} = (1.0)(1.0)(1.0)(1.0)(1.82)(0.24)(25)(12) = 131.0 \text{ lb/in}$$

c. Maximum stress, N_{max}

1) Cylindrical portion

$$N_{max} = \overline{N}_\phi = 136.8 \text{ lb/in}$$

2) Ellipsoidal end stress resultant

$$N_{max} = \frac{1}{2}(\overline{N}_\phi + \overline{N}_\theta) + \frac{1}{2}\sqrt{(\overline{N}_\phi - \overline{N}_\theta)^2 = 4\overline{N}_{\phi\theta}^{\,2}}$$

$$N_{max} = \frac{1}{2}(195.8 + 158.4) + \frac{1}{2}\sqrt{(195.8 - 158.4)^2 + 4(131.0)^2}$$

$$N_{max} = 177.1 + \frac{1}{2}\sqrt{70042.8} = 309.5 \text{ lb/in}$$

13. Find coated fabric weight, W_{cf}

a. Determine fiber type from other considerations, select polyester

b. Weight-strength relationship of fiber, η

$$\eta = 35 \frac{\text{lb-yd}^2}{\text{in oz}}$$ Table III

c. Weight of base fabric, W_{bf}

$$W_{bf} = SF\ N_{max}/\eta$$

Using a safety factor of 3,

1) Cylindrical portion

$$W_{bf} = \frac{(3)(136.8)}{35} = \frac{410.4}{35} = 11.72 \text{ oz/yd}^2$$

2) Ellipsoidal ends

$$W_{bf} = \frac{3(309.5)}{35} = \frac{928.5}{35} = 26.5 \text{ oz/yd}^2$$

d. Weight of fabric coating, W_c
(Assuming vinyl coating, two-ply)

$W_c = 32 \text{ oz/yd}^2$ Figure 50

e. Fabric surface area

Tent surface area, $A_s = 8174.27$ sq ft

Catenary curtain = $(A_p)(1 \text{ ft high}) = 3481.8)(1)$
$= 3481.8$ sq ft

Ground seal skirt = $(A_p)(2 \text{ ft wide}) = 3481.8)(2)$
$= 6963.6$ sq ft

Total fabric surface area = $8174.3 + 8481.8 + 6963.6$
$= 23{,}619.7$ sq ft
$= 2{,}624.1$ sq yd

f. Coated fabric weight, W_{cf}, using W_{bf} requirements of elliptical ends:

W_{cf} = (total surface area) $(W_{bf} + W_c)$

$W_{cf} = (2{,}624.1)(26.5 + 32.0)\ (1.5/16)$

$W_{cf} = (2{,}624.1)(58.5)(0.0937) = 14{,}392$ lb

14. Find package cube, V

Estimated cube = $(W_{cf})\ (0.1 \text{ ft}^3/\text{lb})$

Estimated cube = $(14{,}392)(0.1) = 1439 \text{ ft}^3$

15. Find blower requirements, Q

a. Air loss per inch of slide fastener at P_e = 6.34 in w.g. equals 2.58 ft^3/min/in

Figure 51

b. Total length of slide fastener, if employed, L_{sf}

$$L_{sf} = \pi r \frac{h}{d} \sqrt{2 \left| 1 + \left(\frac{h}{r}\right)^2 \right|} + (\ell_h = 2' ,$$

$$L_{sf} = (\pi)(25) \left(\frac{25}{50}\right) \sqrt{2 \left| 1 + \left(\frac{12.5}{25}\right)^2 \right|}$$

$$L_{sf} = (39.27)(1.58) + 75$$

$$L_{sf} = 137.1 \text{ ft} = 1645.2 \text{ in}$$

c. Air loss through slide fastener

Air loss = (air loss/inch)(length)

Air loss = (2.58)(1645.2) = 4244.6 ft^3/min

d. Air loss through ground seal skirt

Air loss = 26 ft^3/ft(perimeter)/min

where P_ℓ = 274 ft

Air loss = (26)(274) = 7124 ft^3/min

e. Air loss through door is 503 ft^3/min

f. Total air loss (from c, d and e)

Total air loss = 4245 + 7124 + 503

Total air loss = 11,872 ft^3/min @ 6.34 in w.g.

g. Total blower requirement, Q

Q = 2(air loss) = 23,744 ft^3/min @ 6.34 in w.g.

Unknown Shape

Required:

A cylindrical enclosure with a storage area of 600 sq ft to contain a package cube having a height, y, of 8 feet. Anticipated environmental conditions are:

Pressure altitude, 2000 ft
Temperature, +125° to - 50° F
Wind velocity, 105 mph

Solution:

1. Find optimum W/ℓ_h and h/d ratios from a stability and aerodynamic loads standpoint.

   a. Due to high wind environment a $W/\ell_h = 1/2$ is recommended.

   b. To minimize aerodynamic loads with a $W/\ell_h = 1/2$, a tent with hemispherical ends and a h/d = 1/2 is recommended.

Figures 9, 11, 13

2. Find the tent radius, r, to enclose the required package cube.

   a. Since the enclosure has hemispherical ends and a $W/\ell_h = 1/2$, the package length must equal twice the radius, or

   $(2r)(2x) = 4xr = 600 \text{ ft}^2$

   where x = 1/2 package width

   b. Also the tent radius equals the square root of the sum of the squares of x and y (package height) or,

   $r = \sqrt{x^2 + y^2}$

   c. Combining equation in "a" and "b" and solving for x and r yields

   x = 11.0 ft and r = 13.6 ft

d. Also, since $W/\ell_h = 1/2$, $\ell_h = 4r = 54.4$ ft and since $h/d = 1/2$, $h = 13.6$ ft

3. Find dynamic pressure, q

a. $q_{std} = 5.4$ in w.g $= 28.1$ psf $= 0.159$ psi for a sea level standard day — Figure 7

b. $k_p = 1.18$ — Figure 8

c. $q = 1.18\, q_{std} = 6.37$ in w.g. $= 33.16$ psf $= 0.188$ psi

4. Find planform area, A_p

$$A_p = \pi r^2 + 2r(\ell_h - 2r)$$

$$A_p = \pi(13.6)^2 + 2(13.6)(54.4 - 27.2)$$

$$A_p = 581.1 + 739.8$$

$$A_p = 1320.9 \text{ sq ft}$$

5. Find floor area, A_f

$$A_f = \pi(r \sin\phi_B)^2 + 2r \sin\phi_B\ (\ell_h - 2r)$$

where $\sin\phi_B = \sin 90^{\circ} = 1.0$

$$A_f = \pi((13.6)(1))^2 + 2(13.6)(1)(54.4 - 27.2)$$

$$A_f = \pi(185) + (27.2)(27.2)$$

$$A_f = 581.1 + 739.8 = 1320.9 \text{ sq ft}$$

6. Find external surface area, A_s

$$A_s = \pi dh + (\ell_h - 2r)(d)(\phi_B/57.3)$$

$$A_s = (\pi)(27.2)(13.6)+(54.4 - 27.2)(27.2)(90/57.3)$$

$$A_s = 1162.1 + 739.8 = 1901.9 \text{ sq ft}$$

7. Find perimeter, P_ℓ

$$P_\ell = 2\pi r \sin\phi_B + 2(\ell_h - 2r)$$

$$P_\ell = 2\pi(13.6)(\sin 90^{\circ}) + 2(54.4 - 27.2)$$

$$P_\ell = 85.5 + 54.4 = 139.9 \text{ ft}$$

8. Find aerodynamic loads; L, D and M

a. Lift = $C_L\, q\, A_p$

where $C_L = 0.540$ Figure 9

$L = (0.540)(33.16)(1320.9) = 23{,}652.5$ lb

b. Drag = $C_D\, q\, A_p$

where $C_D = 0.450$ Figure 11

$D = (0.450)(33.16)(1320.9) = 19{,}710.5$ lb

c. Overturning moment = $C_M\, q\, A_p$

where $C_M = -0.390$ Figure 13

$M = (-0.390)(33.16)(1320.9) = 17{,}082.4$ ft-lb

9. Find maximum tent deflection; δ_F, δ_H, and δ_B

a. $\frac{\delta_F}{r} = 0.103$, $\frac{\delta_H}{r} = 0.103$, $\frac{\delta_B}{r} = 0.030$ Figure 16

b. $\delta_F = (\frac{\delta_F}{r})(r) = (0.103)(13.6) = 14.0$ ft

$\delta_H = (\frac{\delta_H}{r})(r) = (0.103)(13.6) = 14.0$ ft

$\delta_B = (\frac{\delta_B}{r})(r) = (0.030)(13.6) = 0.41$ ft

10. Find inflation load, P_{IL}

$P_{IL} = P_e A_f$

Since $P_e = q$ for stability, $P_e = 33.16$ psf

$P_{IL} = (33.16)(1320.9) = 43{,}801$ lb

11. Find anchor load, P_{AL}

$P_{AL} = C_{AL}\, q\, A_p$

where $C_{AL} = 1.58$ Figure 20

$P_{AL} = (1.58)(33.16)(1320.9) = 69{,}205.6$ lb

12. Find number of anchors required, NA

$$NA = \frac{P_{TL} + P_{AL}}{1500^{*}}$$

$$NA = \frac{43{,}801 + 69{,}206}{1500} = \frac{113{,}007}{1500}$$

NA = 75.3 required

13. Find anchor spacing, AS

$$AS = P_{\ell}/NA$$

$$AS = \frac{139.9}{75.3} = 1.85 \text{ ft between anchors}$$

14. Find fabric stress resultants

a. Cylindrical portion

1) Peak stress resultants, $N_{(\ )}$ for h/d = 1/2, $W/\ell_h = 1/2$

$$\frac{N_\phi}{qr} = 0.83 \qquad \text{Figure 27}$$

$$\frac{N_\theta}{qr} = 1.40 \qquad \text{Figure 29}$$

$$N_\phi = (0.83)(0.188)(13.6)(12) = 25.47 \text{ lb/in}$$

$$N_\theta = (1.40)(0.188)(13.6)(12) = 42.95 \text{ lb/in}$$

2) Maximum stress resultants, $\overline{N}_{(\ )}$

$$\overline{N}_\phi = N_\phi + P_e r$$

$$\overline{N}_\phi = 25.47 + (0.188)(13.6)(12)$$

$$\overline{N}_\phi = 25.47 + 30.68 = 56.15 \text{ lb/in}$$

$$\overline{N}_x = N_\theta + \frac{P_e r}{2}$$

*Based on an allowable individual anchor load of 1500 lb for a 4" arrowhead anchor.

$$\overline{N}_x = 42.95 + \frac{(0.188)(13.6)(12)}{2}$$

$$\overline{N}_x = 42.95 + 15.34 = 58.29 \text{ lb/in}$$

b. Hemispherical ends

1) Peak stress resultants, $N_{(\ )}$ for h/d = 1/2, W/ℓ_h

$$\frac{N_\phi}{qr} = 1.50 \qquad \text{Figure 27}$$

$$\frac{N_\theta}{qr} = 1.40 \qquad \text{Figure 29}$$

$$\frac{N_{\phi\theta}}{qr} = 0.66 \qquad \text{Figure 30}$$

$$N_\phi = (1.50)(0.188)(13.6)(12) = 46.02 \text{ lb/in}$$

$$N_\theta = (1.40)(0.188)(13.6)(12) = 42.95 \text{ lb/in}$$

$$N_{\phi\theta} = (0.66)(0.188)(13.6)(12) = 25.01 \text{ lb/in}$$

2) Maximum stress resultants, $\overline{N}_{(\ )}$

$$\overline{N}_\phi = N + \frac{P_e r}{2}$$

$$\overline{N}_\phi = 46.02 + \frac{(0.188)(13.6)(12)}{2}$$

$$\overline{N}_\phi = 46.02 + 15.34 = 61.36 \text{ lb/in}$$

$$\overline{N}_\theta = N_\theta + \frac{P_e r}{2}$$

$$\overline{N}_\theta = 42.95 + \frac{(0.188)(13.6)(12)}{2}$$

$$\overline{N}_\theta = 42.95 + 15.34 = 58.29 \text{ lb/in}$$

$$\overline{N}_{\phi\theta} = N_{\phi\theta} = 25.01 \text{ lb/in}$$

3) Maximum principal stress, N_{max}

for hemispherical ends:

$$N_{max} = \frac{1}{2} (\overline{N}_\phi + \overline{N}_\theta) + \frac{1}{2} \sqrt{(\overline{N}_\phi - \overline{N}_\theta)^2 + 4N_{\phi\theta}{}^2}$$

$$N_{max} = \frac{1}{2} (61.36 + 58.29) + \frac{1}{2} \sqrt{(61.36 - 58.29)^2 + 4\ (25.01)^2}$$

$$N_{max} = 59.82 + \frac{1}{2} \sqrt{2511.42} = 84.88 \text{ lb/in}$$

15. Find coated fabric weight, w_{cf}

a. Determine fiber type from other considerations, select polyester

b. Weight-strength relationship of fiber, η

$$\eta = 35 \frac{\text{lb-yd}^3}{\text{in oz}}$$ Table III

c. Weight of base fabric, w_{bf}, using N_{max} for hemispherical ends:

$$w_{bf} = SF\ N_{max}/\eta$$

Using a safety factor of 3,

$$w_{bf} = \frac{3(84.88)}{35} \quad \frac{254.64}{35}$$

$$w_{bf} = 7.28 \text{ oz/yd}^2$$

d. Weight of fabric coating, w_c (Assuming vinyl coating, two ply)

$$w_c = 32.0 \text{ oz/yd}^2$$ Figure 50

e. Fabric surface area

Tent surface area, A_s = 1901.9 sq ft

Catenary curtain area = (A_p)(1 ft high)

= (1320.9)(1) = 1320.9 sq ft

Ground seal skirt area = (A_p)(2 ft wide)

= (1320.9)(2) = 2641.8 sq ft

Total fabric surface area = 1901.9 + 1320.9 + 2641.8

= 5864.6 sq ft

= 651.0 sq yd

f. Coated fabric weight, w_{cf}, using w_{bf} requirements of hemispherical ends:

w_{cf} = (total surface area)$(w_{bf} + w_c)$

$w_{cf} = (651.0)(7.28\ oz/yd^2 + 35\ oz/yd^2)(1.5/16)$

$w_{cf} = (651.0)(42.28)(0.0937) = 2579$ lb

16. Find package weight and cube

Adjusted package wt = 1.5 w_{cf} = 3869 lb

Estimated cube = (adjusted package wt)(0.1 ft^3/lb

Estimated cube = (3869)(0.1) = 386.9 ft^3

17. Find blower requirements, Q

a. Air loss per inch of slide fastener at P_e = 6.37 in w.g. equals 2.59 ft^3/min/in

Figure 51

b. Total length of slide fastener, if employed, L_{sf}

$$L_{sf} = 2\ r\ (\frac{\phi_B}{57.3}) + (\ell_h - 2r)$$

$$L_{sf} = 2\ (13.6)(\frac{90}{57.3}) + (54.4 - 27.2)$$

$$L_{sf} = 42.7 + 27.2 = 69.9 \text{ ft} = 838.8 \text{ in}$$

c. Air loss through slide fastener

Air loss = (air loss/inch)(length)

Air loss = (2.59)(838.8) = 2172.5 ft^3/min

d. Air loss through ground seal skirt

Air loss = 26 ft^3/ft(perimeter)/min

where P_ℓ = 139.9 ft

Air loss = (26)(139.9) = 3637.4 ft^3/min

e. Air loss through door is 503 ft^3/min

f. Total air loss (from c, d and e)

Total air loss = 2172.5 + 3637.4 + 503

Total air loss = 6312.9 ft^3/min @ 6.37 in w.g.

g. Total blower requirements, Q

Q = 2(air loss) = 12,625.8 ft^3/min @ 6.37 in w.g.

DOUBLE-WALL TENT

Known Shape

Given:

Double-wall cylinder with flat ends
Width = 100 ft
Length = 200 ft
Height = 50 ft
Height:Diameter Ratio = 1/2
Width:Length Ratio = 1/2
Cell Radius = 2 ft
Sea Level Standard Atmosphere
Wind Velocity = 90 knots

Solution:

1. Find dynamic pressure q

   a. q_{std} = 5.3 in w.g. = 28 psf ~ 0/19 psi Figure 7

2. Find planform area, A_p

   $A_p = W\ell_h$

   A_p = (100) (200) = 20,000 sq ft

3. Find floor area, A_f

   $A_f = W\ell_h$

   A_f = (100) (200) = 20,000 sq ft

4. Find surface area, A_s, of circular sided tent

   a. Walls

   $$A_s = 4\ \ell_h\ r\ (\frac{\phi_B}{57.3})$$

   $$A_s = 4\ (200)(50)\ (\frac{90}{57.3})$$

   A_s = 62,800 sq ft = 6,980 sq yd

   b. Webs

   With cell radius, r_c = 2 ft, w = 4 ft and setting $\alpha_c = 30^o$

Web spacing = (2) (r_C) (sin α_C)

Web spacing (2) (2) (sin 30^o) = 2 ft

Number of webs = $\frac{200}{2}$ = 100

$A_s = 2 n w r \frac{\phi_B}{57.3}$

A_s = (2) (100) (4) (50) $(\frac{90}{57.3})$ = 62,800 sq ft
= 6,980 sq ft

c. End curtains

$A_s = 2r^2 (2 \frac{\phi_B}{57.3} - \sin \phi B \cos \phi B)$

$A_s = 2(50)^2 \quad (2) \; (\frac{90}{57.3} - \sin 90^o \cos 90^o)$

A_s = 2(2500) (2) (1.57) - 0

A_s = 15,700 sq ft = 1,745 sq yd

d. Total surface area, A_s,

A_s = 62,800 + 62,800 + 15,700

A_s = 141,300 sq ft - 15,700 sq yd

5. Find length of anchored sides

$P_\ell = 2\ell_h$ = 400 ft

6. Final aerodynamic loads; L, D, and M (assume tent anchored and guyed)

a. Lift = $C_L \; q \; A_p$

where C_L = 0.566 Figure 10

L = (0.566) (28) (20,000) = 316,960 lb

b. Drag = $C_D \; q \; A_p$

where C_D = 0.275 Figure 12

$D = (0275)\ (28)\ (20{,}000) = 154{,}000$ lb

c. Overturning moment $= C_M\ q\ A_p$

where $C_M = -0.508$ — Figure 14

$M = (-0.508)\ (28)\ (20{,}000) = -284{,}480$ ft lb

7. Find maximum tent deflection; δ_F, δ_H, δ_B

Figure 18

a. $\frac{\delta_F}{r} = 0.102, \quad \frac{\delta_H}{r} = 0.100, \quad \frac{\delta_B}{r} = 0.080$

b. $\delta_F = (\frac{\delta_F}{r})\ (r) = (0.102)\ (50) = 5.1$ ft

$\delta_H = (\frac{\delta_H}{r})\ (r) = (0.100)\ (50) = 5.0$ ft

$\delta_B = (\frac{\delta_B}{r})\ (r) = (0.080)\ (50) = 4.0$ ft

8. Find base anchor load, P_{BL}

$P_{BL} = C_{BL}\ q\ A_p$

where $C_{BL} = 1.0$ — Figure 21

$P_{BL} = (1.0)\ (28)\ (20{,}000) = 560{,}000$ lb

9. Find number of base anchors required,

$NA = \frac{P_{BL}}{1500^*}$

$NA = \frac{560{,}000}{1500} = 374$

10. Find base anchor spacing, AS

$AS = \frac{P_\ell}{NA}$

$AS = \frac{400}{374} = 1.07$ ft

11. Find guy line load, P_{GL}

$P_{GL} = C_{GL}\ q\ A_p$

* Based on an allowable individual anchor load of 1500 lb for a 4" arrowhead anchor.

where $C_{GL} = 0.450$ Figure 22

$P_{GL} = (0.450)\ (28)\ (20{,}000) = 252{,}000$ lb

12. Find number of guy lines required

$$NGL = \frac{252{,}000}{1500^*}$$

$NGL = 168$

(Reference test stability discussion for best guy line arrangement)

13. Find cell pressure required, P_c

a. Cell width to diameter ratio, $w/d = \frac{4}{50} = 0.08$

b. $\frac{P_c}{q} = 3.2$ $C_q = 1.05$ and $C_W = 1.0$ Figure 37

c. $P_c = C_q\ C_W\ (P_c/q)\ q$

$P_c = (1.05)\ (1.0)\ (3.2)(5.3)$

$P_c = 17.8$ in w.g.

14. Find the fabric stress resultants $N_{(\ )}$

a. The web stress, N_w

$\frac{N_w}{q} = 3.4$ (interpolated) Figure 38

$N_w = (\frac{N_w}{q})\ (q) = (4.0)\ (5.3) = 21.2$ lb/in

b. The loop stress, N_h

$\frac{N_h}{q} = 3.8$ (interpolated) Figure 39

$N_h = (\frac{N_h}{q})\ (q) = (3.9)\ (5.3) = 20.6$ lb/in

c. The meridional stress, N_ϕ

$N_\phi = 14.2$ Figure 42

---

* Based on an allowable individual anchor load of 1500 lb for a 4" arrowhead anchor.

15. Find coated fabric weight, W_{cf}

a. Determine fiber type from other considerations, select polyester.

b. Weight - strength relationship of fiber, N

$N = 35 \frac{lb - yd^2}{in\ oz}$ — Table III

c. Weight of base fabric, W_{bf}

$W_{bf} = SF\ N_{max}/N$ using $SF = 3.0$

1. Inner and outer skin fabric

$$W_{bf} = (SF)(N_h/N)$$

$$W_{bf} = (3.0)(20.6/35) = 1.77\ oz/yd^2$$

2. Web fabric

$$W_{bf} = (SF)\ (N_w/N)$$

$$W_{bf} = (3.0)\ (21.2/35) = 1.81\ oz/yd^2$$

d. Weight of fabric coating, W_c
(Assuming vinyl coating, single-ply)

$W_c = 8.5\ oz/yd^2$ — Figure 50

e. Coated fabric weight, W_{cf}

1. Walls and webs

$$W_{cf} = (\text{wall and web area})\ (W_{bf} + W_c)(1.33/16)$$

Assuming $W_{bf} = 1.81\ oz/yd^2$

$$W_{cf} = (13{,}960)\ (1.81 + 8.5)\ (1.33/16)$$

$$W_{cf} = (13{,}960)\ (10.31)\ (0.083) = 11{,}930\ lb$$

2. End curtains

$$W_{cf} = (\text{end curtain area})\ (W_{bf} + W_c)\ (1.5/16)$$

$$W_{cf} = (1{,}745)\ (10.31)\ (0.094) = 1{,}696\ lb$$

3. Total coated fabric weight, W_{cf}

W_{cf} = (15.e.1 + 15.e.2)

W_{cf} = (11,930 + 1,696) = 13,626 lb

16. Find package cube, V

Estimated cube = (total W_{cf}) (0.065 ft^3/lb)

Estimated cube = (13,626) (0.065) = 885.7 ft^3

17. Find blower requirements, Q

a. Cell volume, $V_c = 2\ w\ \ell_h\ r\ (\frac{\phi_B}{57.3})$

$$V_c = 2\ (4)\ (200)\ (50)\ (\frac{90}{57.3})$$

$$V_c = 125,600\ ft^3$$

b. Volumetric flow, $Q = \frac{\text{cell volume}}{\text{inflation time}}$

Assuming an inflation time of 30 minutes

$$Q = \frac{125,600}{30}$$

Q = 4,187 ft^3/min at zero in w.g.

DOUBLE-WALL TENT

Unknown Shape

Required:

A cylindrical enclosure with a storage floor area of 900 sq ft and a minimum height of 11 ft. Anticipated environmental conditions are:

Pressure altitude, 2000 ft
Temperature range, +125° to -50°F
Wind velocity, 110 mph

Solution:

1. Find optimum tent shape, W/ℓ_h and h/d ratios, to minimize anchor loads, assuming guy lines.

   a. Select $W/\ell_h = 1/4$ and $h/d = 0.375$ for minimum C_{BL} — Figure 21

   b. From a geometric point of view, it can be shown that a tent having an $h/d = 0.375$ will more than double the width to meet the requirement for the 11-foot height, leading to excessive size and weight. To arrive at the optimum tent size and shape requires extensive geometric study, the extent of which is beyond the scope of this manual.

   c. To continue this example problem, a tent with a higher h/d would lead to a lighter weight structure. A tent of optimum h/d and W/ℓ_h can be arrived at as follows.

   d. Find the enclosure dimensions to house the required storage cube.

      a. Storage cube = (width)(length)(height)
      Since W/ℓ_h is assumed 1/4, the minimum length = 4 (width). Therefore, cube = 4 (height)(width)^2
      Since floor area = 900 sq ft and the height = 11 ft, the storage cube = (900)(11) = 9900 cu ft
      Thus:

$$9900 = (4)(11)(\text{width})^2$$

or Storage width $= \sqrt{\frac{9900}{44}} = \sqrt{225} = 15$ ft

and Storage length = 4(width) = 60 ft

e. Find the smallest tent radius to enclose the storage cross-sectional area. The smallest radius would be the one which circumscribes the four corners of the storage area. Hence the radius, r, is

$$r = \sqrt{\left(\frac{width}{2}\right)^2 + \left(\frac{height}{2}\right)^2}$$

$$r = \sqrt{\overline{7.5}^2 + \overline{5.5}^2}$$

$$r = \sqrt{86.50}$$

$$r = 9.3 \text{ ft}$$

Hence diameter, d, = 2r = 18.6 ft

Tent height, $h = r + \frac{\text{storage height}}{2}$

$$h = 9.3 + 5.5 = 14.8 \text{ ft}$$

Approximate $h/d \approx \frac{14.8}{18.6} \approx 0.8$

and $W/\ell_h = \frac{18.6}{60} \approx 1/3$

f. Adjust the tent radius to provide for wind deflection and cell depth.

Since $\frac{\delta_F}{r} = 0.275$ Figure 18

for the approximate h/d and W/ℓ_h

$$\delta_F = \left(\frac{\delta_F}{r}\right) r = (0.275)(9.3) = 2.56 \text{ ft}$$

and cell width $w \approx 0.123\ (d + 2\delta_F)$

$$w = (0.123)(23.72)$$

$$w = 2.92 \text{ ft}$$

Therefore, final tent radius, r is

$$r = \frac{\text{approx } d}{2} + \delta_F + w$$

$$r = 9.3 + 2.56 + 2.92$$

$$r = 14.78 \text{ ft}$$

Thus, $d = 2r = W = 29.56$ ft

Since required length, ℓ_h is 60 ft, the tent $W/\ell_h = \frac{29.56}{60}$ or 1/2.

g. Find final h/d ratio

$$\frac{h}{d} = \frac{\text{outside tent radius} + 5.5}{\text{outside tent diameter}}$$

Hence final h/d follows:

$$h/d = \frac{14.78 + 5.5}{29.56} = \frac{20.28}{29.56}$$

$$h/d = 0.7$$

h. Find planform area, A_p

$$A_p = W\ell_h$$

$$A_p = (29.56)(60)$$

$$A_p = 1774 \text{ sq ft}$$

2. Find the surface area, A_s, of circular sided tent.

a. Walls

$$A_s = 4\ell_h \, r \, \phi_B$$

where

$$\phi_B = 2 \sin^{-1} \frac{C}{2r}$$

and

$$\frac{C}{2} = \sqrt{r^2 - \overline{5.5}^2}$$

$$\frac{C}{2} = \sqrt{218 - 30.25}$$

$$\frac{C}{2} = \sqrt{180}$$

$$\frac{C}{2} = 13.4$$

$$C = 26.8$$

Therefore

$$\phi_B = 2 \sin^{-1} \frac{26.8}{29.6}$$

$$\phi_B = 2 \sin^{-1} 0.9$$

$$\phi_B = 2\ (64) = 128^\circ$$

$$A_s = 4\ (60)(29.6)\ \frac{128}{57.3}$$

$$A_s = (240)(29.6)(2.24)$$

A_s = 15,913 sq ft = 1766 sq yds

b. Webs

With cell radius, r_c = 1.46 ft and setting cell angle, $\alpha_c = 30^\circ$

web spacing = $2\ r_c \sin \alpha_c$

web spacing = $(2)(1.46)(\sin 30^\circ) = 1.46$ ft

Number of webs = ℓ_h/spacing = $\frac{145}{1.46} = 100$

$$A_s = 2\ n\ w\ r\ \frac{\phi_B}{57.3}$$

$$A_s = (2)(100)(2.92)(14.78)(\frac{128}{57.3})$$

A_s = 19,250 sq ft = 2,140 sq yd

c. End Curtains

$$A_s = 2r^2 \left[2\ \frac{\phi_B}{57.3} - \sin \phi_B \cos \phi_B\right]$$

$$A_s = 2(14.78)^2 \left[(2)\ (\frac{128}{57.3}) - (.7880)(.6157)\right]$$

$$A_s = 436 \left[4.47 - .482\right]$$

A_s = 1740 sq ft = 193 sq yd

d. Total surface area, A_s

A_s = 1766 + 2140 + 193 = 4,099 sq yd

3. Find length of anchored sides

$P_\ell = 2\ \ell_h = 2\ (60) = 120$ ft

4. Find the dynamic pressure, q

a. $q_{std} = 2.4$ in w.g. = 14.5 psf = 0.11 psi for a sea level standard day — Figure 7

b. $K_p = 1.18$ — Figure 8

c. $q = 1.18\ q_{std} = 2.84$ in w.g.

= 17.1 psf = 0.13 psi

5. Find aerodynamic loads; L, D, and M (assume tent anchored and guyed)

a. Lift = $C_L\ q\ A_p$

where $C_L = 0.725$ — Figure 10

L = (0.725)(17.1)(1771) = 22,000 lb

b. Drag = $C_D\ q\ A_p$

where $C_D = 0.550$ — Figure 12

D = (0.550)(17.1)(1771) = 16,670 lb

c. Overturning moment = $C_M\ q\ A_p$

where $C_M = -0.588$ — Figure 14

M = (-0.588)(17.1)(1771) = -17,820 ft lb

6. Find maximum tent deflection δ_F, δ_H, δ_B

a. $\frac{\delta_F}{r} = 0.187$, $\frac{\delta_H}{r} = 0.107$, $\frac{\delta_B}{r} = 0.113$ — Figure 18

b. $\delta_F = (\frac{\delta_F}{r})(r) = (0.187)(14.78) = 2.77$ ft

$\delta_H = (\frac{\delta_H}{r})(r) = (0.107)(14.78) = 1.58$ ft

$\delta_B = (\frac{\delta_B}{r})(r) = (0.113)(14.78) = 1.67$ ft

7. Find base anchor load, P_{BL}

$P_{BL} = C_{BL}\, q\, A_p$

where $C_{BL} = 1.04$ Figure 21

$P_{BL} = (1.04)(17.1)(1771) = 31{,}500$ lb

8. Find number of base anchors required, NA

$NA = \frac{P_{BL}}{1500^*}$

$NA = \frac{31{,}500}{1500} = 21$ (Say 22, 11 each side)

9. Find base anchor spacing, AS

$AS = \frac{P_{\ell}}{NA}$

$AS = \frac{120}{22} = 5.45$ ft

10. Find guy line load, P_{GL}

$P_{GL} = C_{GL}\, q\, A_p$

where $C_{GL} = 0.566$ Figure 22

$P_{GL} = (0.566)(17.1)(1771) = 17{,}150$ lb

11. Find number of guy lines required

$NGL = \frac{P_{GL}}{1500^*}$

$NGL = \frac{17{,}150}{1500} = 11.5$ (Say 12)

(Reference tent stability discussion for best guy-line arrangement)

12. Find cell pressure required, P_c

a. Cell width to tent diameter ratio, w/d

$w/d = \frac{2.92}{29.56} = 0.099$, Use h/d = 3/8 curve

* Based on an allowable individual anchor load of 1500 lb for a 4" arrowhead anchor

b. $\frac{P_c}{q} = 3.3,\ C_q = 1.4$ and $C_w = 1.0$ Figure 37

c. $P_c = C_q\ C_W\ (P_c/q)\ q$

$P_c = (1.4)(1.0)(3.3)(2.84)$

$P_c = 13.1$ in w.g. or $4.6\ q$

13. Find the fabric stress resultants $N_{(\ )}$

a. The web stress, N_w

$\frac{N_w}{q} = 3.95$, Since $r_c = 17.5$ in Figure 38

and $P_c \approx 5q$

$N_w = (\frac{N_w}{q})(q) = (3.95)(2.84) = 11.2$ lb/in

b. The hoop stress, N_h

$\frac{N_h}{q} = 3.98$ Figure 39

$N_h = (\frac{N_h}{q})(q) = (3.98)(2.84) = 11.3$ lb/in

c. The meridional stress, N_ϕ

$N_\phi \approx 7.8$ lb/in Figure 41

14. Find coated fabric weight, W_{cf}

a. Determine fiber type from other considerations, select polyester

b. Weight - strength relationship of fiber, η

$\eta = 35\ \frac{\text{lb-yd}^2}{\text{in oz}}$ Table III

c. Weight of base fabric, W_{bf}

$W_{bf} = SF\ N\ max/\eta$ using $SF = 3.0$

1) Inner and outer skin fabric

$W_{bf} = (SF)(N_h/n)$

$W_{bf} = (3.0)\ (11.3/35) = 0.97\ oz/yd^2$

2) Web fabric

$W_{bf} = (SF)(N_w/n)$

$W_{bf} = (3.0)(11.2/35) = 0.96\ oz/yd^2$

d. Weight of fabric coating, W_c
(assuming vinyl coating, single ply)

$W_c = 8.5\ oz/yd^2$ Figure 50

e. Coated fabric weight, W_{cf}

1) Walls and webs

$W_{cf} = (\text{wall and web area})(W_{bf}+W_c)(1.33/16)$

using $W_{bf} = 0.97\ oz/yd^2$

$W_{cf} = (3906)(9.47)(1.33/16)$

$W_{cf} = (3906)(9.47)(0.083) = 3060\ lb$

2) End curtains

$W_{cf} = (\text{end curtain area})(W_{bf} + W_c)(1.5/16)$

$W_{cf} = (193)(9.47)(0.094) = 172\ lb$

3) Total coated fabric weight, W_{cf}

$W_{cf} = (15.e.1. + 15.e.2)$

$W_{cf} = (3060 + 172) = 3232\ lb$

15. Find package cube, V

Estimated cube = (total W_{cf})(0.065 ft^3/lb)

Estimated cube = (3232)(0.065) = 210 ft^3

16. Find blower requirements, Q

a. Cell volume, $V_c = 2w\ \ell_h\ r\ (\frac{\phi_B}{57.3})$

$$V_c = (2)(2.92)(60)(14.78)(\frac{128}{57.3})$$

$$V_c = 11,600\ ft^3$$

b. Volumetric flow, Q

(assuming an inflation time of 30 minutes)

$$Q = \frac{\text{cell volume}}{\text{inflation time}}$$

$$Q = \frac{11,600}{30}$$

$Q = 387\ ft^3/min$ at zero in w.g.

SUMMARY

The objective of this program is to provide tentage information based on wind tunnel test data that can be applied either to the evaluation and improvement of existing ground-mounted, air-supported structures or to the design of such future structures. The data presented are the results of a program conducted by the Hayes International Corporation of Birmingham, Alabama for the U. S. Army Natick Laboratories, Natick, Massachusetts.

The program consisted of study, test, and analytical investigation phases which began in July 1963 and concluded in May 1968. During the study phase, a review was made of pertinent literature on experimental techniques, data, and analyses applicable to determining maximum aerodynamic forces on and stresses in fabric structures. The wind tunnel investigations consisted of detailed testing of thirty-six tent models to include seventeen single-wall structures (eleven with nonporous and six with porous fabric) and nineteen double-wall structures. Tests were conducted at stabilized wind speeds up to 110 miles per hour in the Virginia Polytechnic Institute's 6' x 6' stability tunnel. In the analytical phase, test data were used to develop fabric stress and aerodynamic coefficient data variation with tent parameters.

The results of the wind tunnel investigations and the stress analyses have been incorporated into this design manual and include comprehensive, practical design data suitable for engineering reliable, stable, single- and double-wall, air-supported structures. Data, in general, are presented in nondimensional coefficient form, and, therefore, are applicable to full scale structures within the range of parameters investigated. Design information is presented as charts and tables on such items as tent aerodynamic force and moment coefficients, anchor and guy line coefficients, surface deflections, material stresses and specifications, usable volume, and weight.

REFERENCES

1. A. E. Dietz, R. B. Proffitt, and R. S. Chabot, "Wind Tunnel Tests and Analyses of Ground Mounted Air-Supported Structures" U. S. Army Natick Laboratories Technical Report No. 67-36-ME (AD 651954), under Contract No. DA19-129-AMC-129(N) with Hayes International Corporation, Birmingham, Alabama, October 1966.

2. Wellington Sears Handbook of Industrial Textiles, Wellington Sears Company, Inc., 1963.

3. Textile World, Man-Made Fiber Chart, McGraw-Hill Publishing Company, Inc., New York, 1964.

4. Walter W. Bird, "Design Manual for Spherical Air-Supported Radomes" (Revised), Report No. UH-909-0-2, Cornell Aeronautical Laboratory, March 1956.

GLOSSARY OF TERMS

Coefficient - A dimensionless parametric ratio which is a function of tent shape and inertia and viscous forces acting on the tent.

Dynamic Pressure - That portion of the stagnation pressure which results from the motion of the fluid. Also referred to as impact pressure or velocity pressure. The mathematical expression for dynamic pressure is

$$q = \frac{1}{2} \rho U^2$$

In. w.g. - Gage pressure expressed in inches of water.

Planform Area - Maximum projection area of a structure in a horizontal plane.

SYMBOLS

A_f	Floor Area (l^2)
A_o	Orifice area (l^2)
A_p	Planform area (l^2)
A_s	Surface area (l^2)
AS	Anchor spacing (l)
a	Ellipsoidal semimajor axis (l)
b	Ellipsoidal semiminor axis (l)
C_{AL}	Anchor load coefficient, single-wall tent
C_{BL}	Base anchor load coefficient, double-wall tent
$C_b(\ )$	Ellipsoidal end single-wall tent stress resultant correction factor
C_c	Coefficient of contraction
C_D	Drag coefficient
C_{GL}	Guy line coefficient, double-wall tent
$C_h(\ )$	Ellipsoidal end single-wall tent stress resultant correction factor
C_L	Lift coefficient
C_M	Pitching, overturning, moment coefficient
C_o	Orifice coefficient
C_q	Cell pressure correction factor, double-wall tent
$C_q(\ )$	Ellipsoidal end single-wall tent stress resultant correction factor
C_v	Velocity coefficient
C_W	Cell pressure correction factor, double-wall tent
$C_W(\ )$	Ellipsoidal end single-wall tent stress resultant correction factor
c	Tent floor chord-width (l)

D	Drag (f)
d	Tent diameter (l)
e	Ellipsoidal end eccentricity, single-wall tent
h	Tent height (l)
h_r	Distance from ground plane to center of curvature (l)
k_p	Impact pressure correction factor
L	Lift (f)
L_{sf}	Slide fastener length (l)
ℓ_h	Tent length (l)
M	Bending moment(l-f)
NA	Number of anchors
N_h	Hoop stress resultant (fl^{-1})
N_w	Web stress resultant (fl^{-1})
N_x	Longitudinal stress resultant (fl^{-1})
N_θ	Circumferential stress resultant (fl^{-1})
N_ϕ	Meridional stress resultant (fl^{-1})
$N_{\phi x}$, $N_{\phi\theta}$	Shear stress resultants (fl^{-1})
$\overline{N}_{( )}$	Maximum stress resultant (fl^{-1})
n	Number of cells
P_{AL}	Anchor load, single-wall tent (f)
P_{BL}	Anchor load on base, double-wall tent (f)
P_c	Cell pressure (fl^{-2})
P_e	Tent enclosure pressure (fl^{-2})
P_{GL}	Guy line load, double-wall tent (f)
P_ℓ	Tent perimeter (l)

Q	Volume flow (l^3t^{-1})
q	Dynamic (impact) pressure (fl^{-2})
r	Tent radius (l)
r_c	Cell radius (l)
SF	Safety factor
U	Velocity (lt^{-1})
V	Package cube (l^3)
$\overline{V}$	Tent enclosed volume (l^3)
V_c	Cell volume (l^3)
W	Tent width (l)
w_{bf}	Weight of base fabric (fl^{-2})
w_{cf}	Weight of coated fabric (fl^{-2})
W_c	Weight of fabric coating (fl^{-2})
w	Cell width (l)
x	One-half package width (l)
y	Package height (l)

GREEK SYMBOLS

α_c	Cell angle
δ_B	Rear tent deflection (l)
δ_F	Front tent deflection (l)
δ_H	Top tent deflection (l)
η	Fabric weight-strength ratio $(\frac{f - l^2}{l-f})$
θ, ϕ	Curvilinear coordinates
π	Numerical constant, 3.1416
ρ	Density of air (fl^{-3})
ϕ_B	Angle subtended by curved beam, degrees

Dimensional Notation:

f denotes units of force

l denotes units of length

t denotes units of time

τ denotes units of temperature

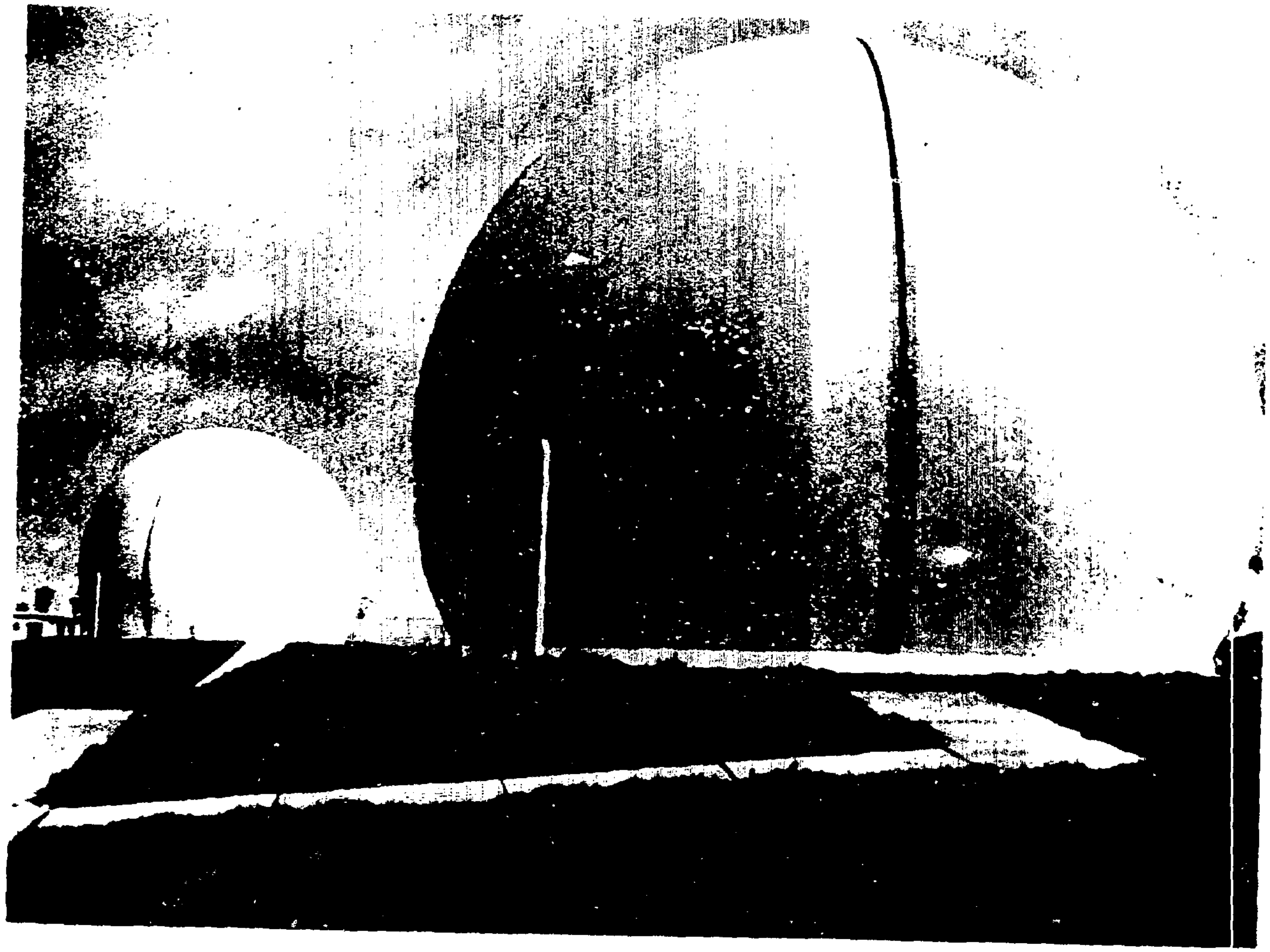


Figure 1. Single-Wall,
Air-Supported Radome, Nike Hercules System

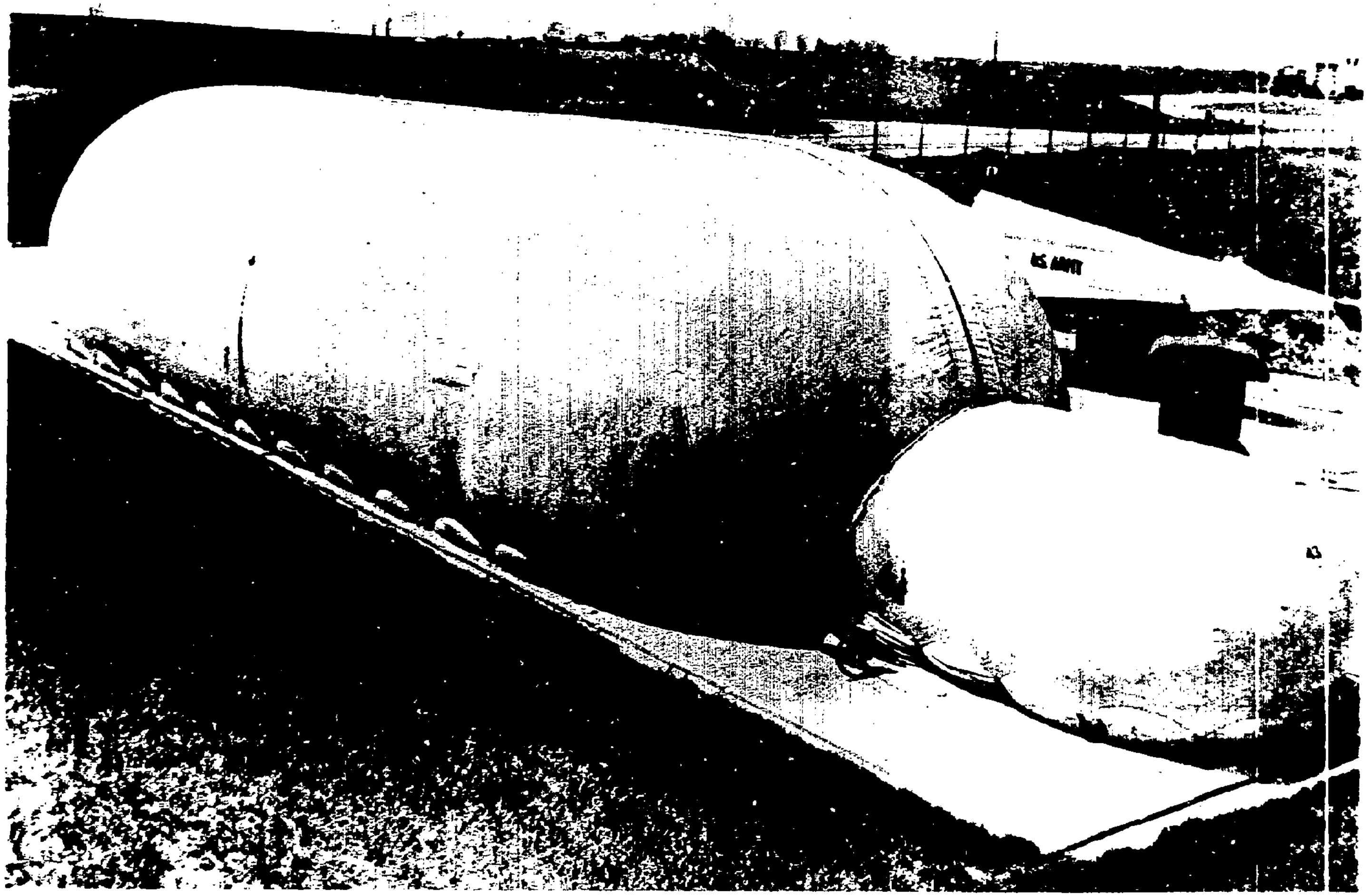


Figure 2. Single-Wall, Air-Supported Tent, Above-Ground, Launcher, Nike Hercules System.

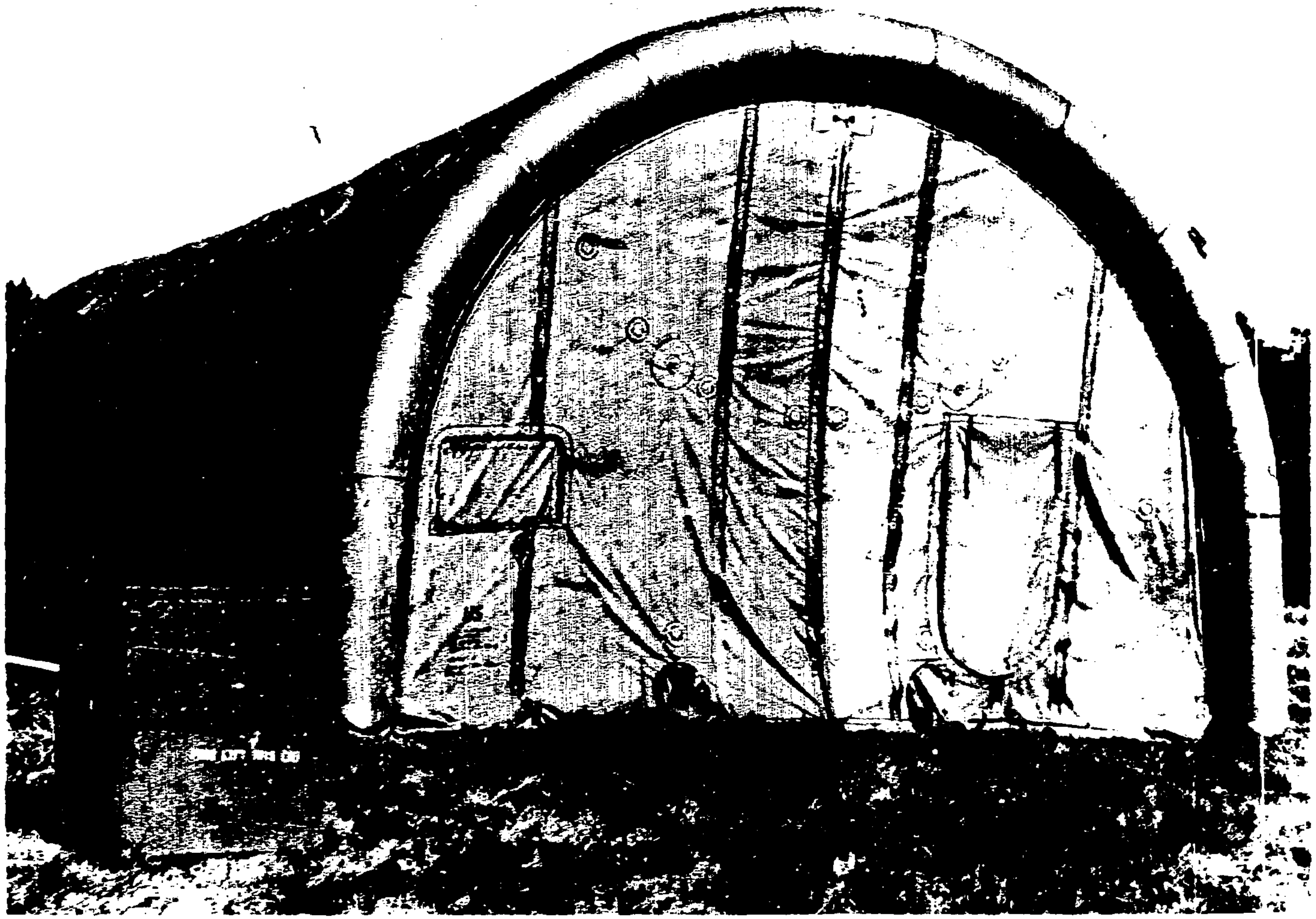


Figure 3. Double-Wall, Air-Supported Tent, Maintenance, Multi-Purpose, Sectionalized (Pershing Missile).

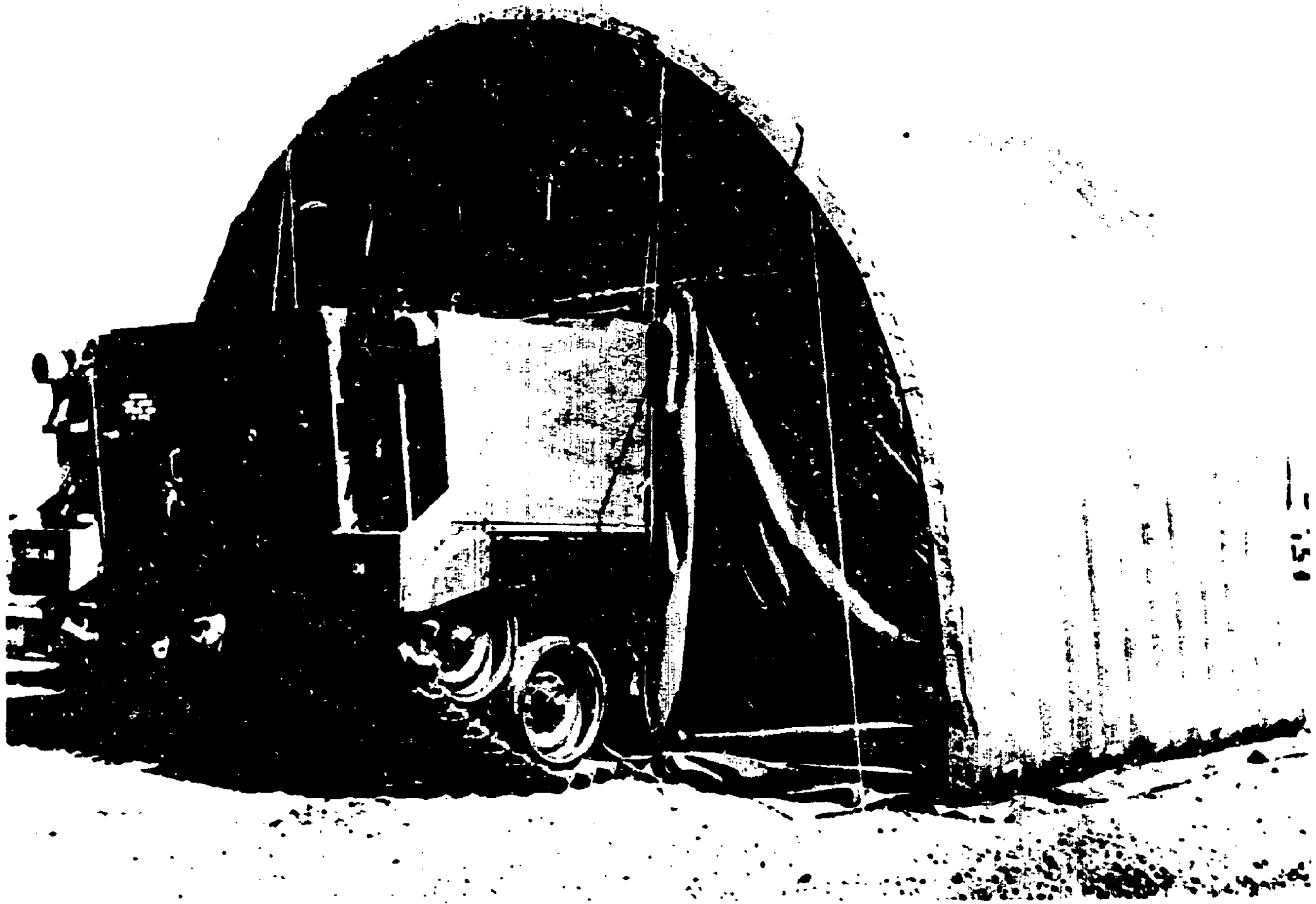


Figure 4. Double-Wall,
Air-Supported Tent, Vehicle Maintenance, Small (Arctic).

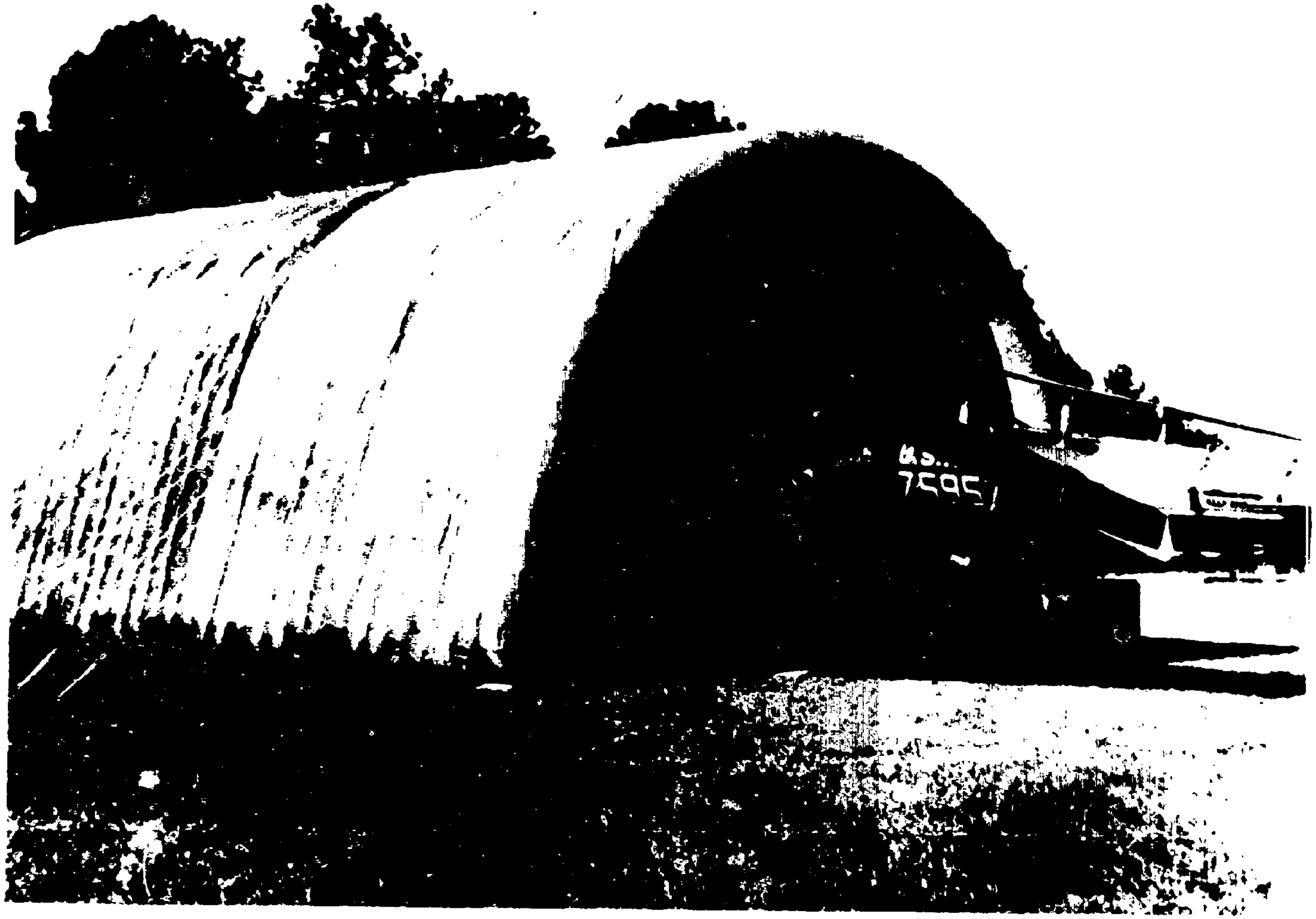


**Figure 5. Double-Wall,
Air-Supported Tent, Aviation Maintenance, Medium, Sectionalized.**

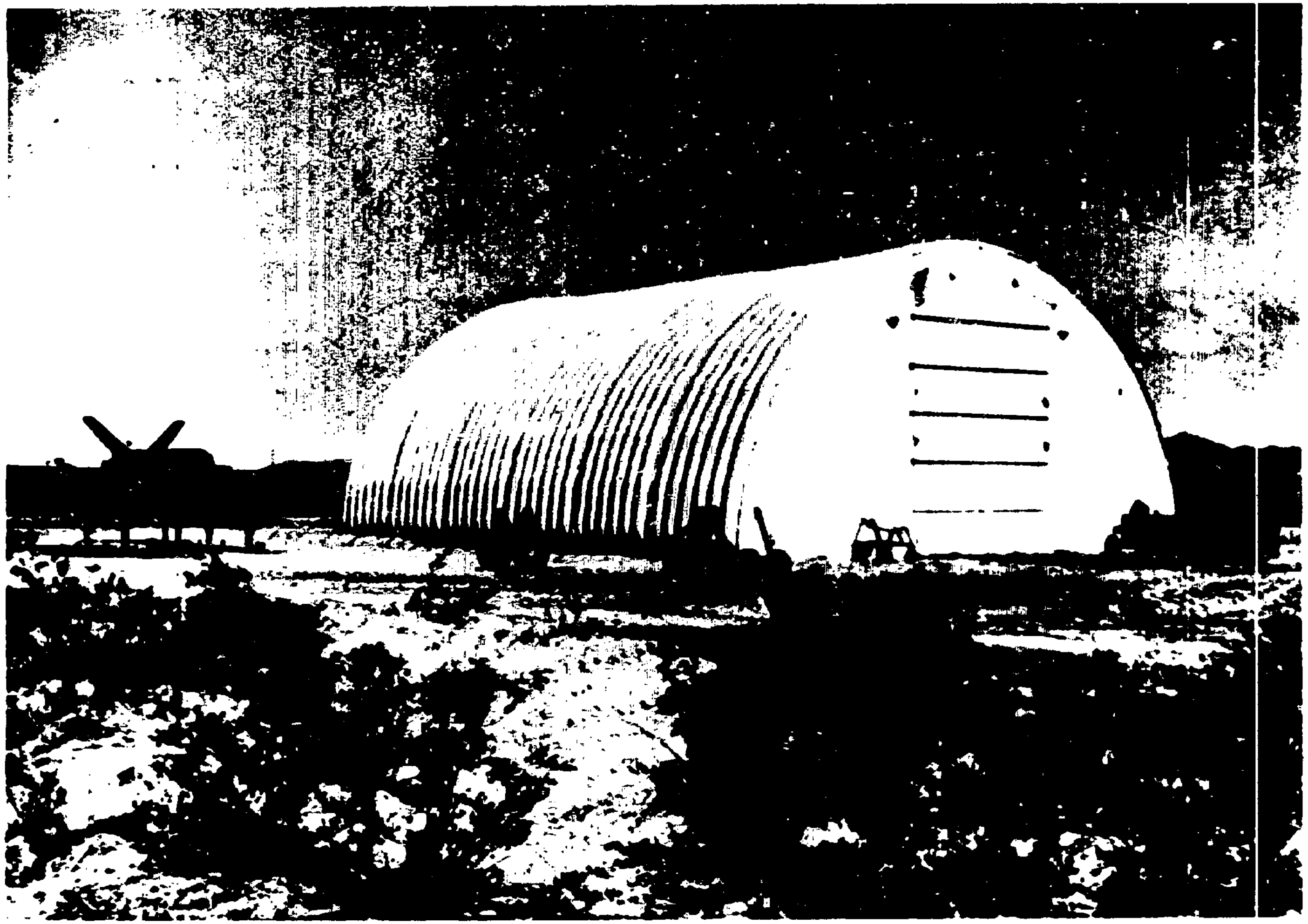


Figure 6. Double-Wall,
Air-Supported Tent, Assembly Area, Nike Hercules Mobile System.

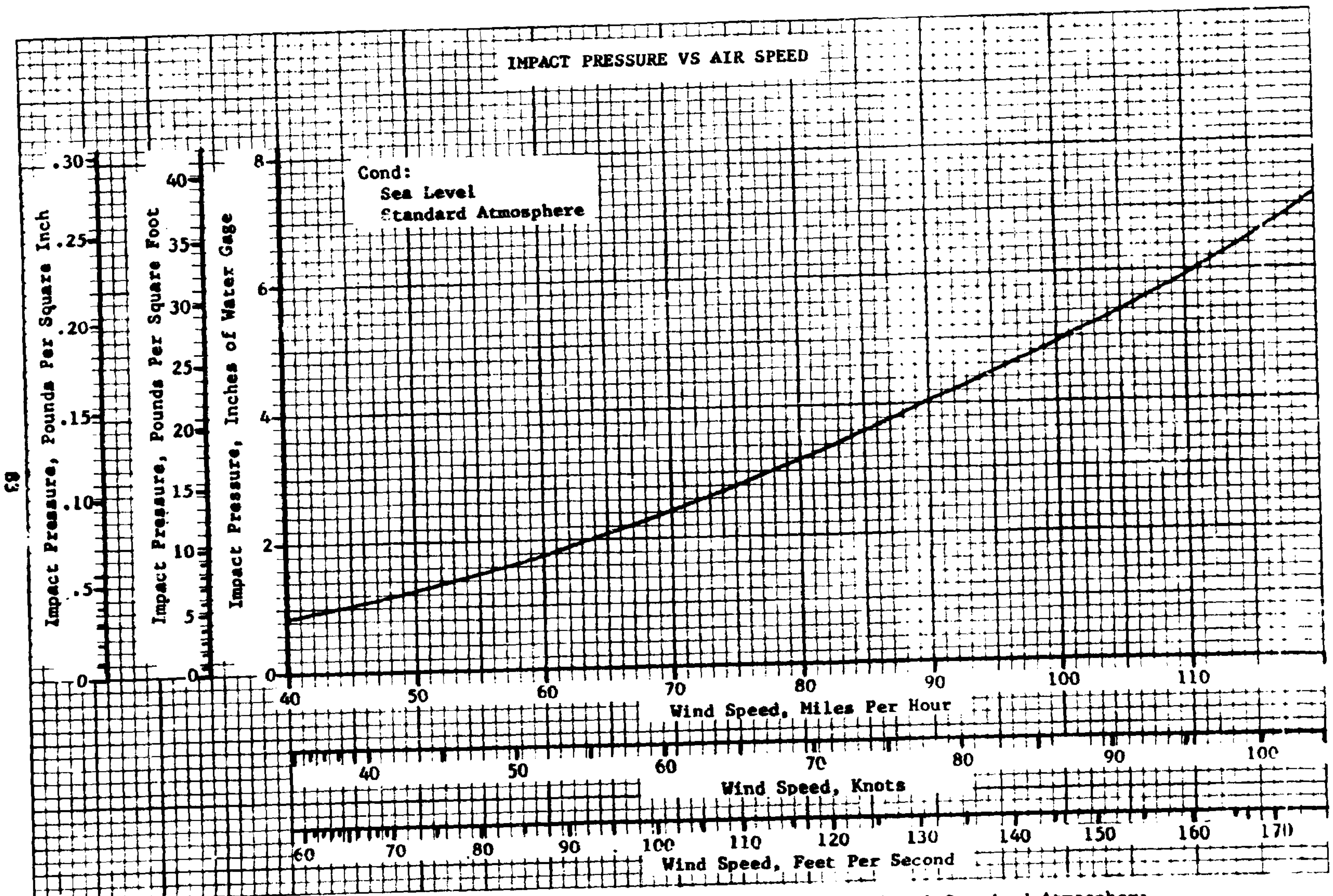


Figure 7. Variation of Impact Pressure with Air Speed, Sea Level Standard Atmosphere.

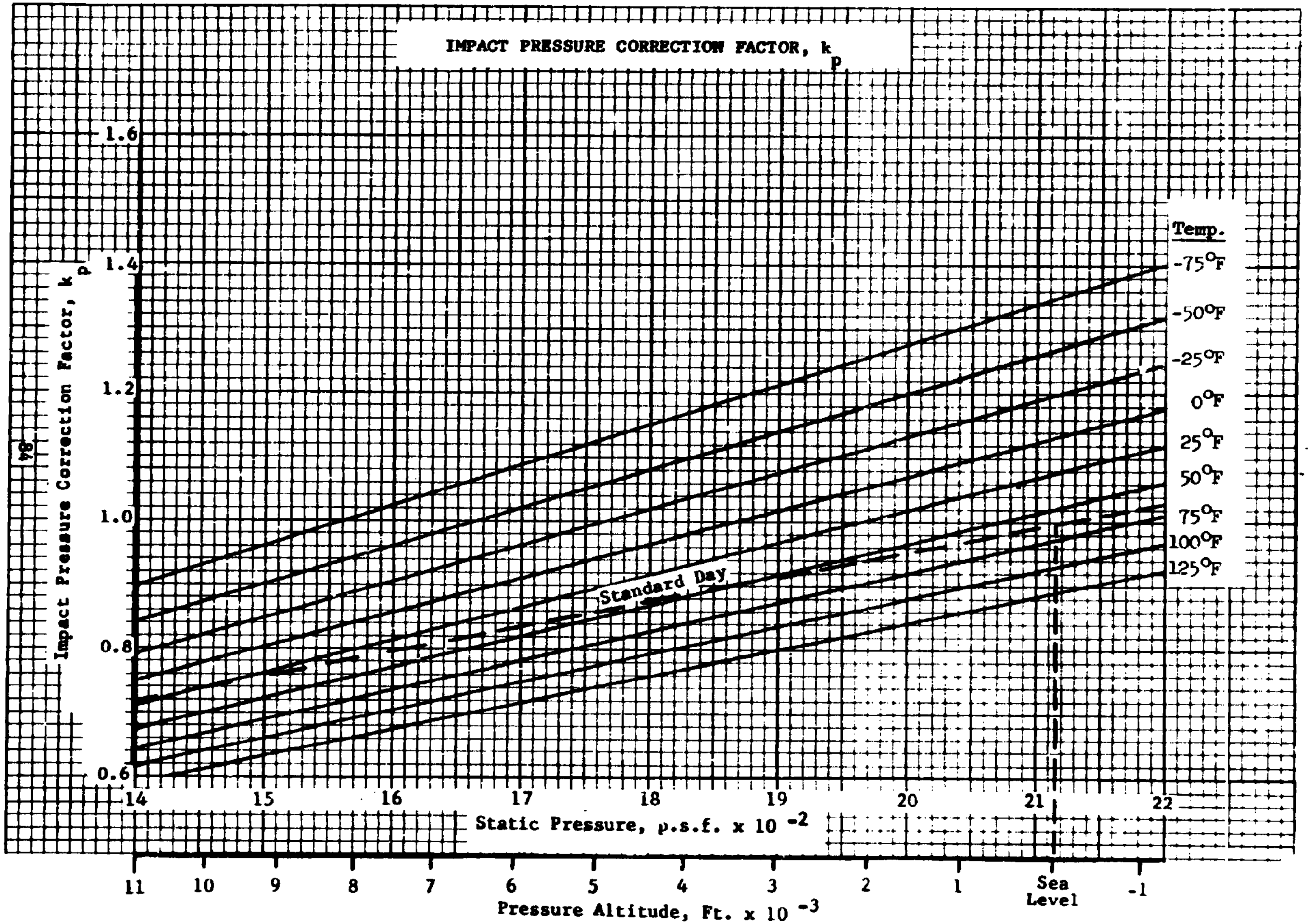


Figure 8. Impact Pressure Correction Factor, k_p, Variation With Altitude & Temperature

MAXIMUM LIFT COEFFICIENT
SINGLE-WALL SPHERES AND CYLINDERS

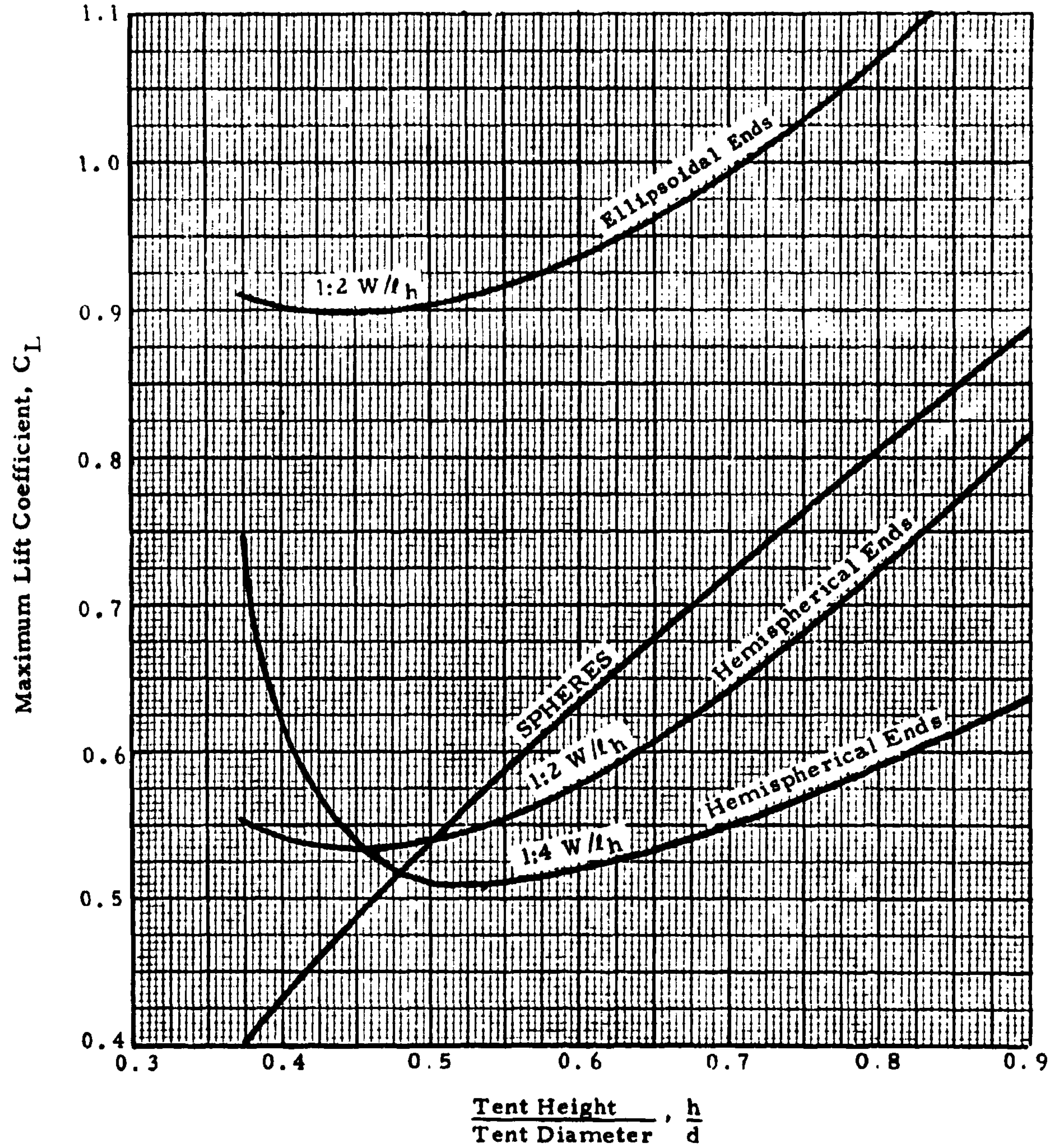


Figure 9. - Variation of Lift Coefficient with Shape (Non-Porous Spherical and Cylindrical Single-Wall Tents; 1:2, 1:4, W/ℓ_h)

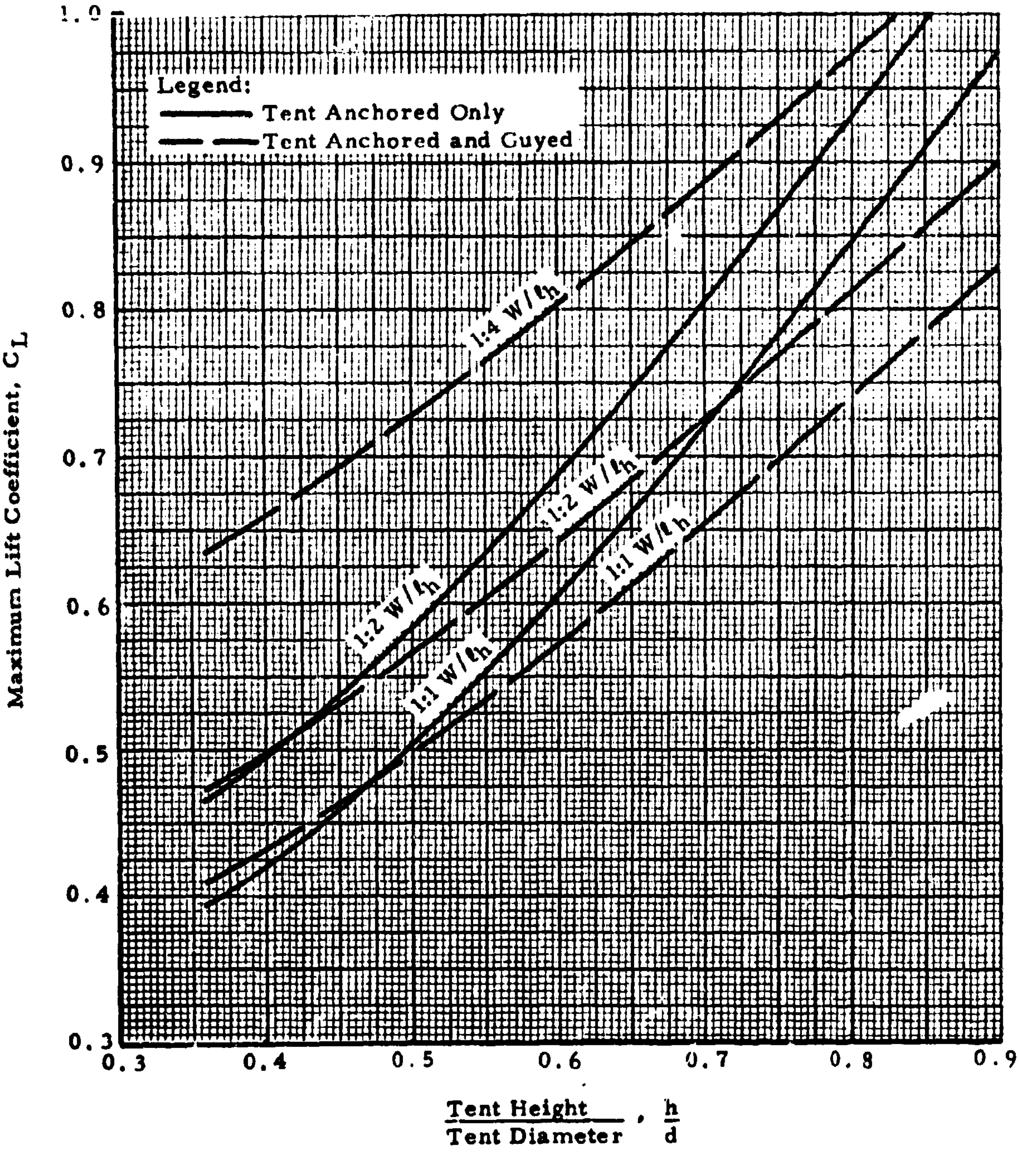


Figure 10. Variation of Lift Coefficient With Shape (Non-Porous Double-Wall Tents; 1:1, 1:2, 1:4 W/ℓ_h)

MAXIMUM DRAG COEFFICIENT
SINGLE-WALL SPHERES AND CYLINDERS

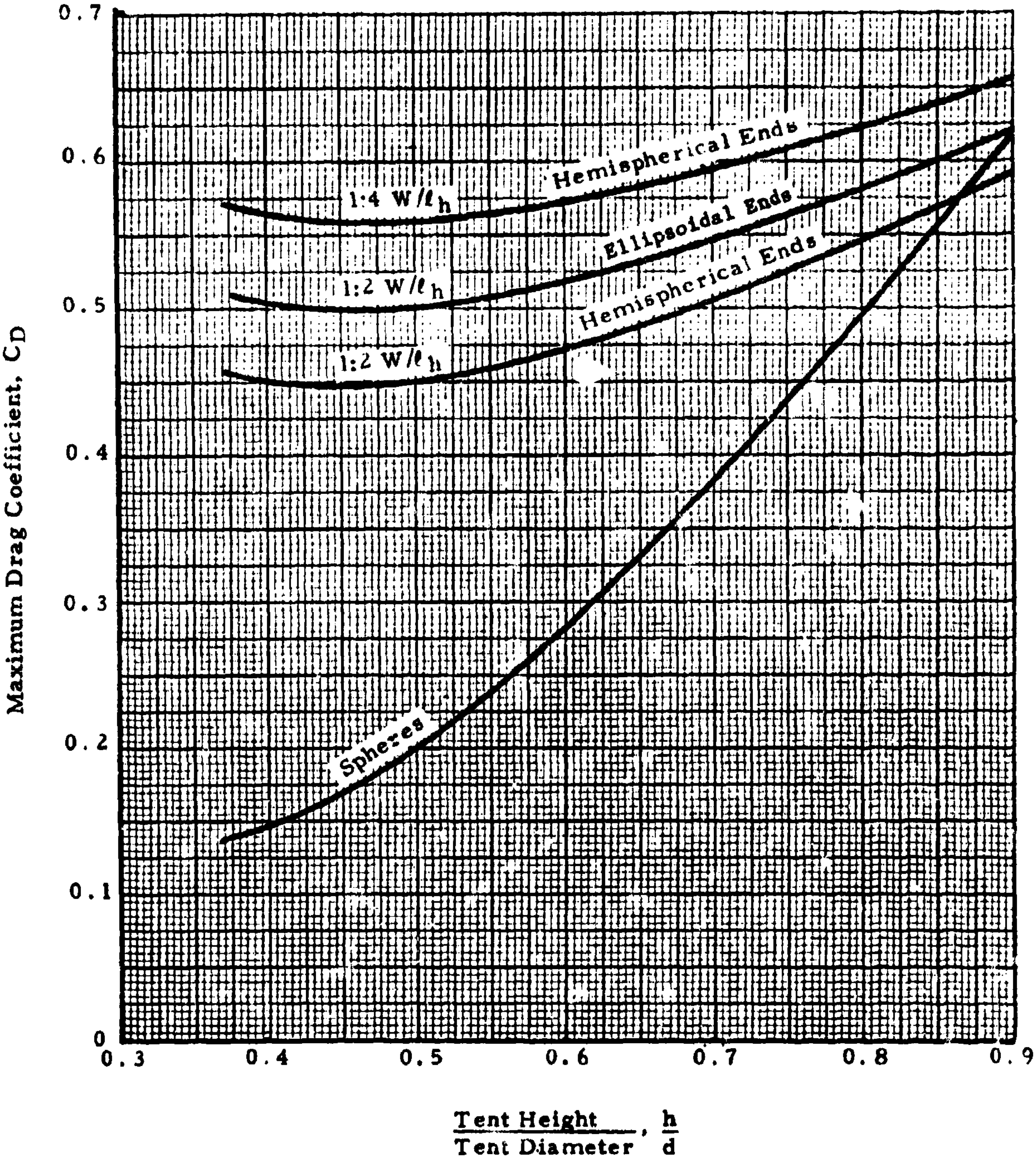


Figure 11. Variation of Drag Coefficient With Shape (Spherical and Cylindrical Single-Wall Tents; 1:2, 1:4 W/ℓ_h)

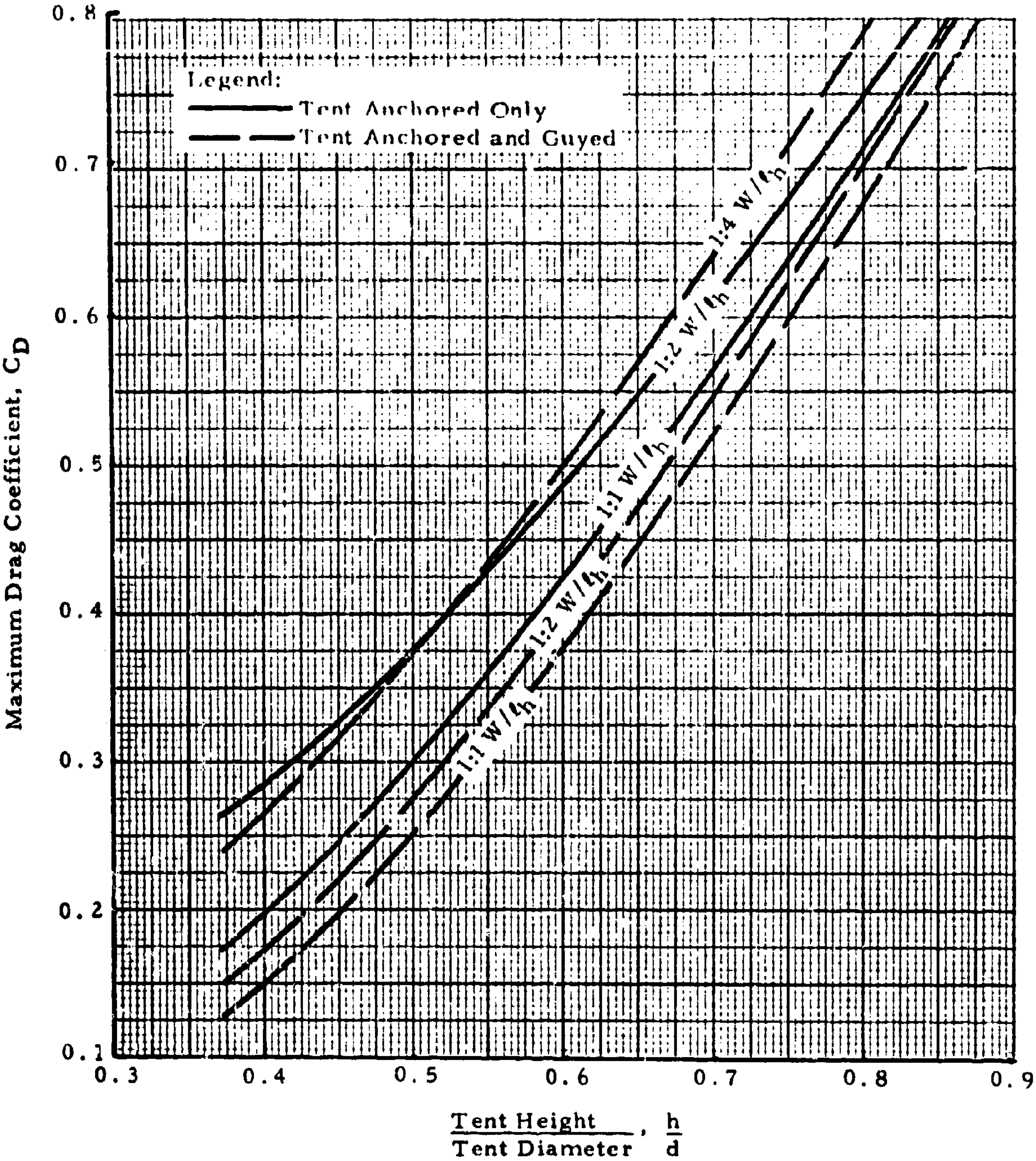


Figure 12. Variation of Drag Coefficient with Shape
(Non-Porous Double-Wall Tents; 1:1, 1:2, 1:4 W/ℓ_h)

MAXIMUM MOMENT COEFFICIENT
SINGLE-WALL SPHERES AND CYLINDERS

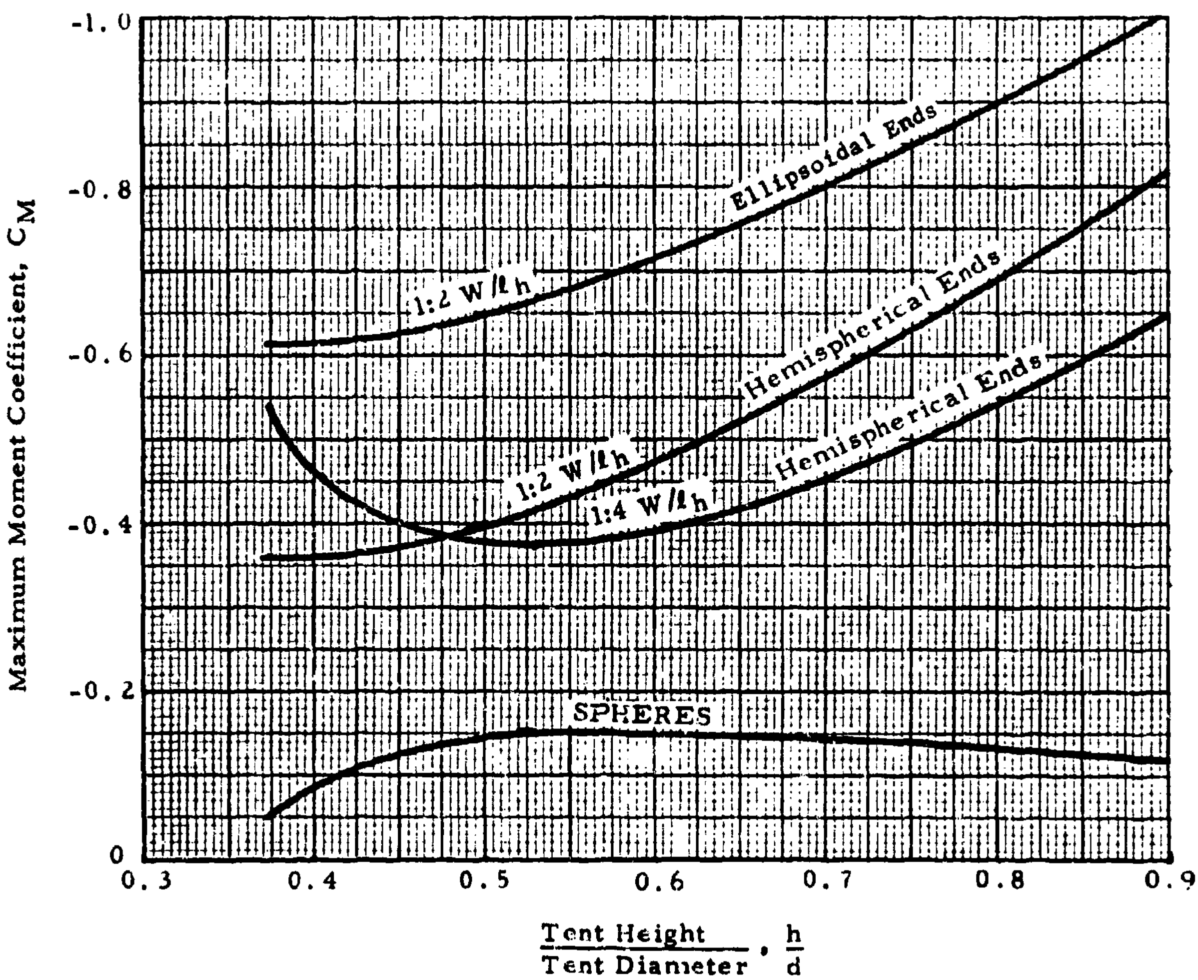


Figure 13. Variation of Moment Coefficient with Shape (Spherical and Cylindrical Single-Wall Tents; 1:2, 1:4, W/ℓ_h)

MAXIMUM MOMENT COEFFICIENT
DOUBLE-WALL CYLINDERS

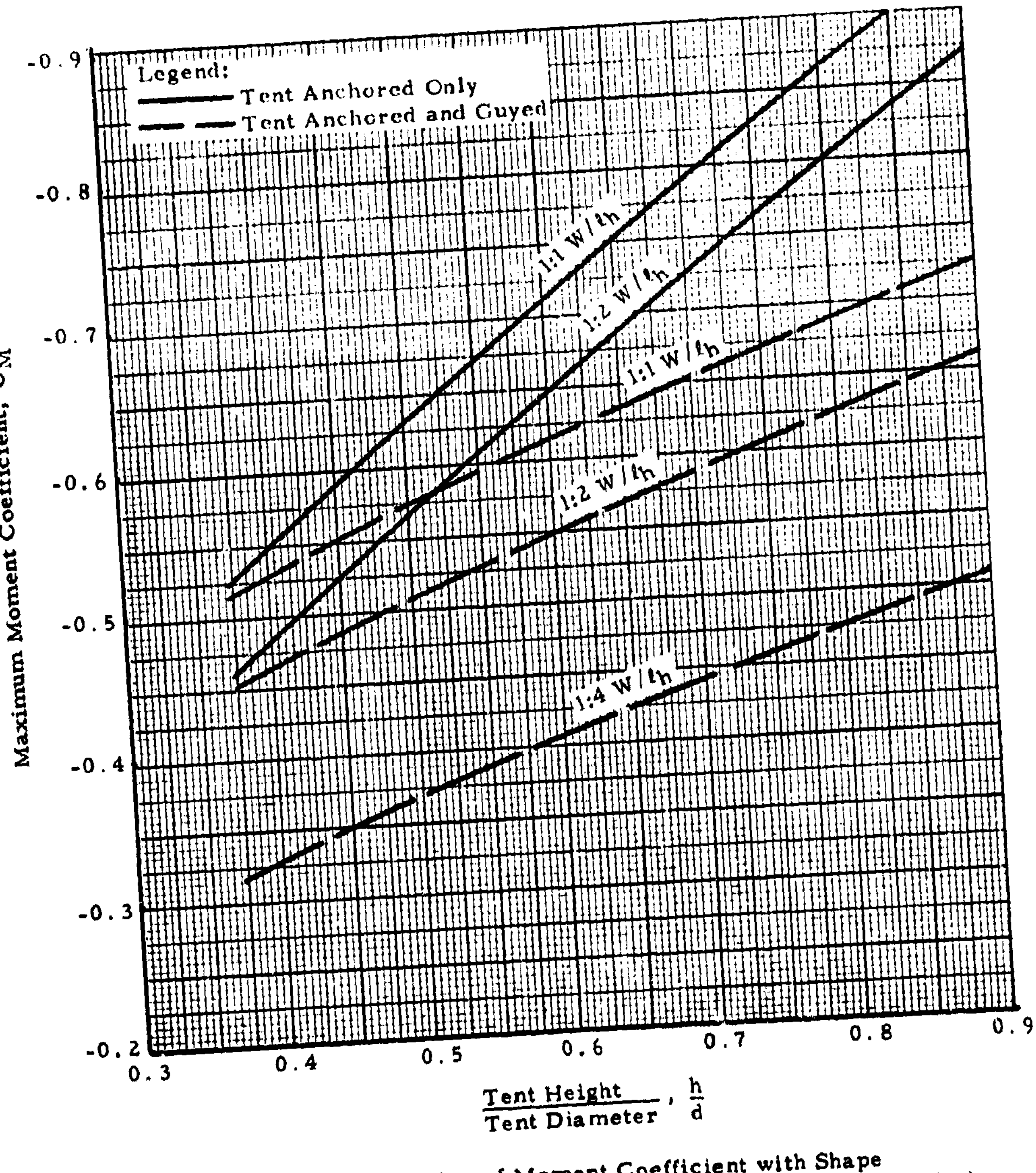


Figure 14. Variation of Moment Coefficient with Shape (Non-Porous Double-Wall Tents; 1:1, 1:2, 1:4 W/ℓ_h)

MAXIMUM TENT DEFLECTION
SINGLE-WALL SPHERES

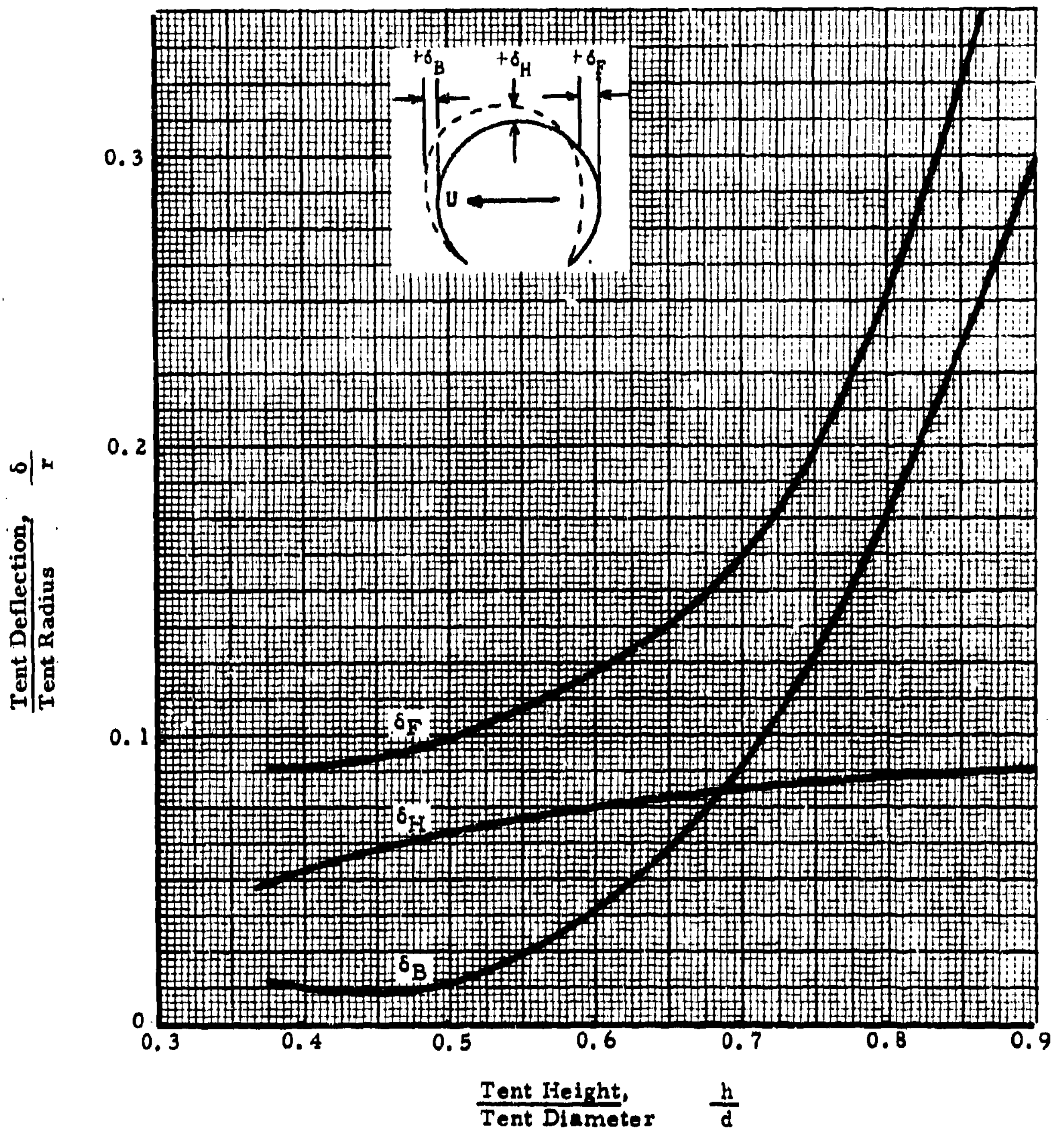


Figure 15. Variation of Tent Deflection with Shape (Spherical Single-Wall Tents).

MAXIMUM TENT DEFLECTION
SINGLE-WALL 1:2 CYLINDERS

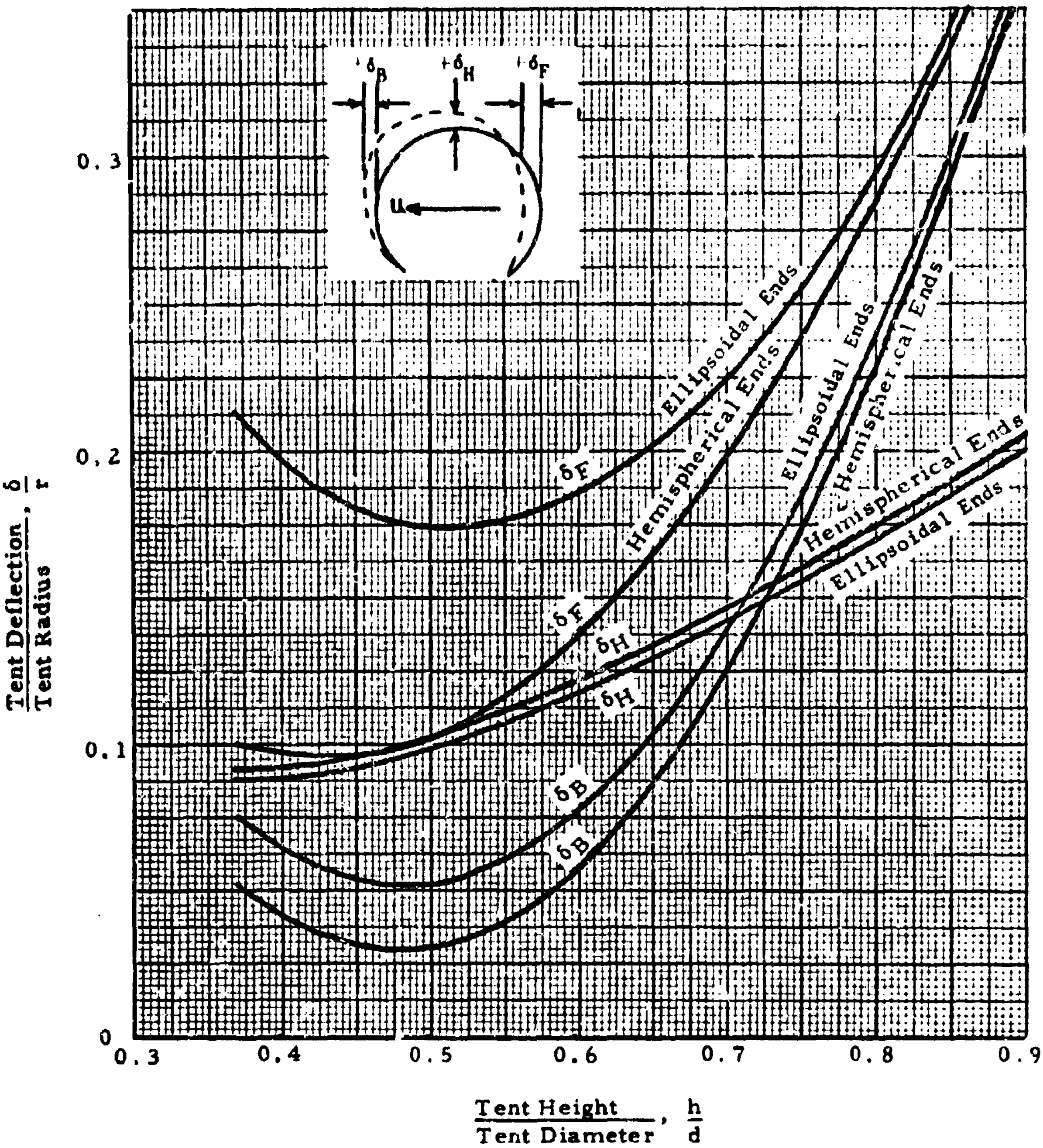


Figure 16. Comparison of Non-Porous Tent Deflection with Shape (Cylindrical Single-Wall Tents, 1:2 W/ℓ_h)

MAXIMUM TENT DEFLECTION
SINGLE-WALL 1:4 CYLINDERS
(Hemispherical Ends)

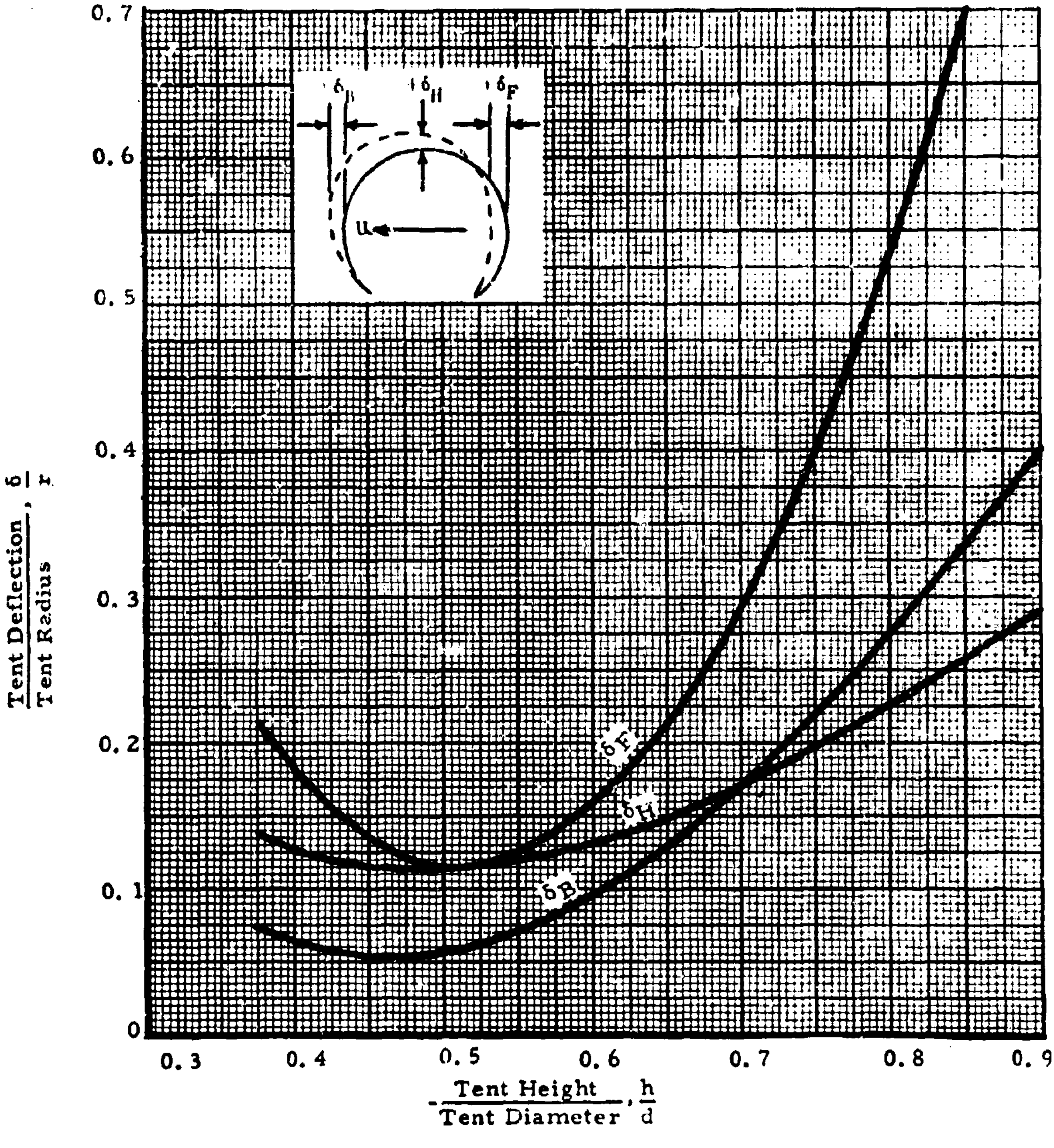


Figure 17. Variation of Tent Deflection with Shape
(Non-Porous Cylindrical Single-Wall Tents, 1:4 W/ℓ_h)

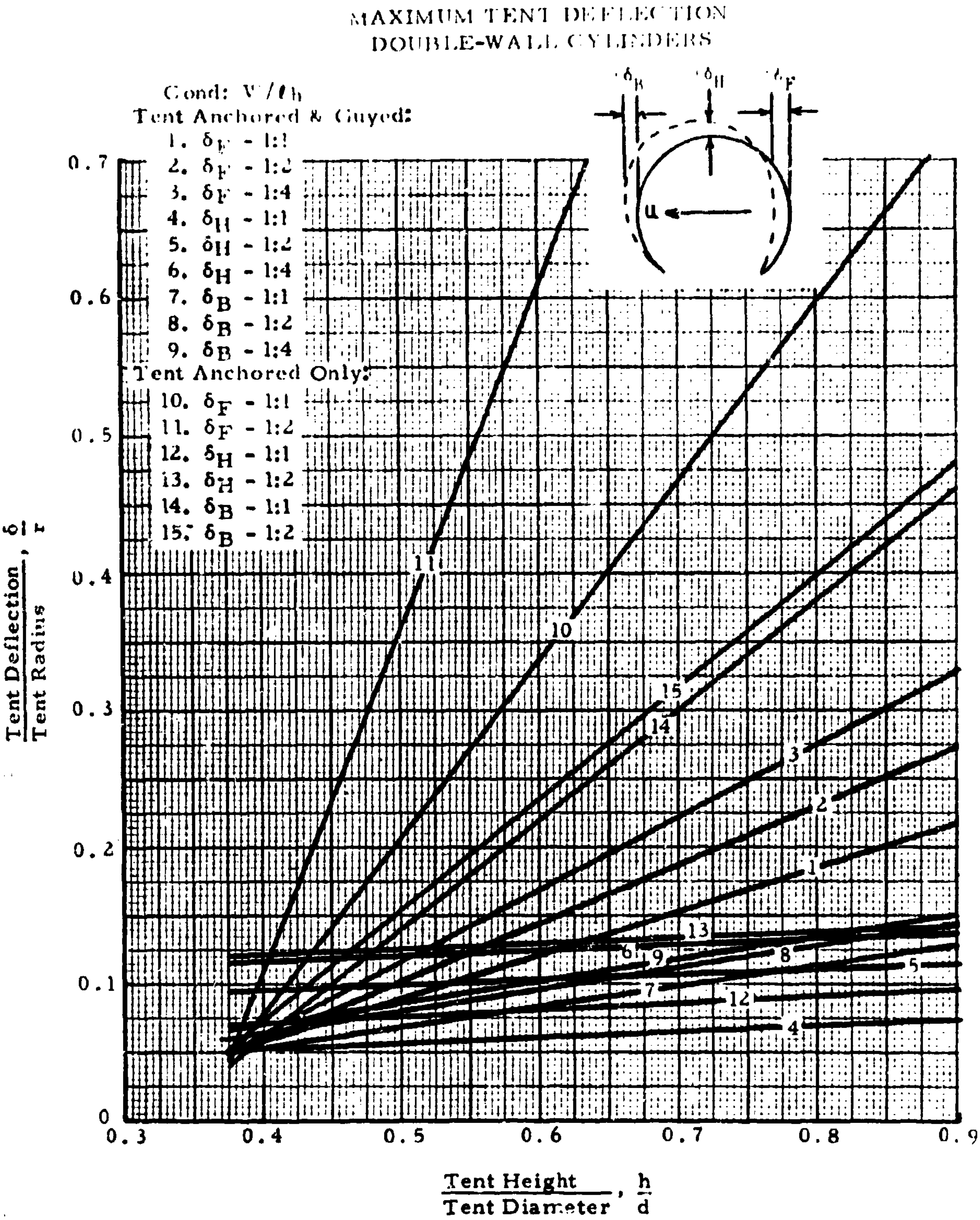


Figure 18. Variation of Tent Deflection with Shape (Non-Porous Double-Wall Tents 1:1, 1:2, 1:4 (W/ℓ_h)

DOUBLE-WALL, 3/4 CYLINDER, 1:1 WIDTH/LENGTH RATIO
GUY LINES ATTACHED 0.80 and 0.40 TENT HEIGHT

Note: Cell Width/Enclosure Diameter 0.123

Cond: q 6.0" w.g.

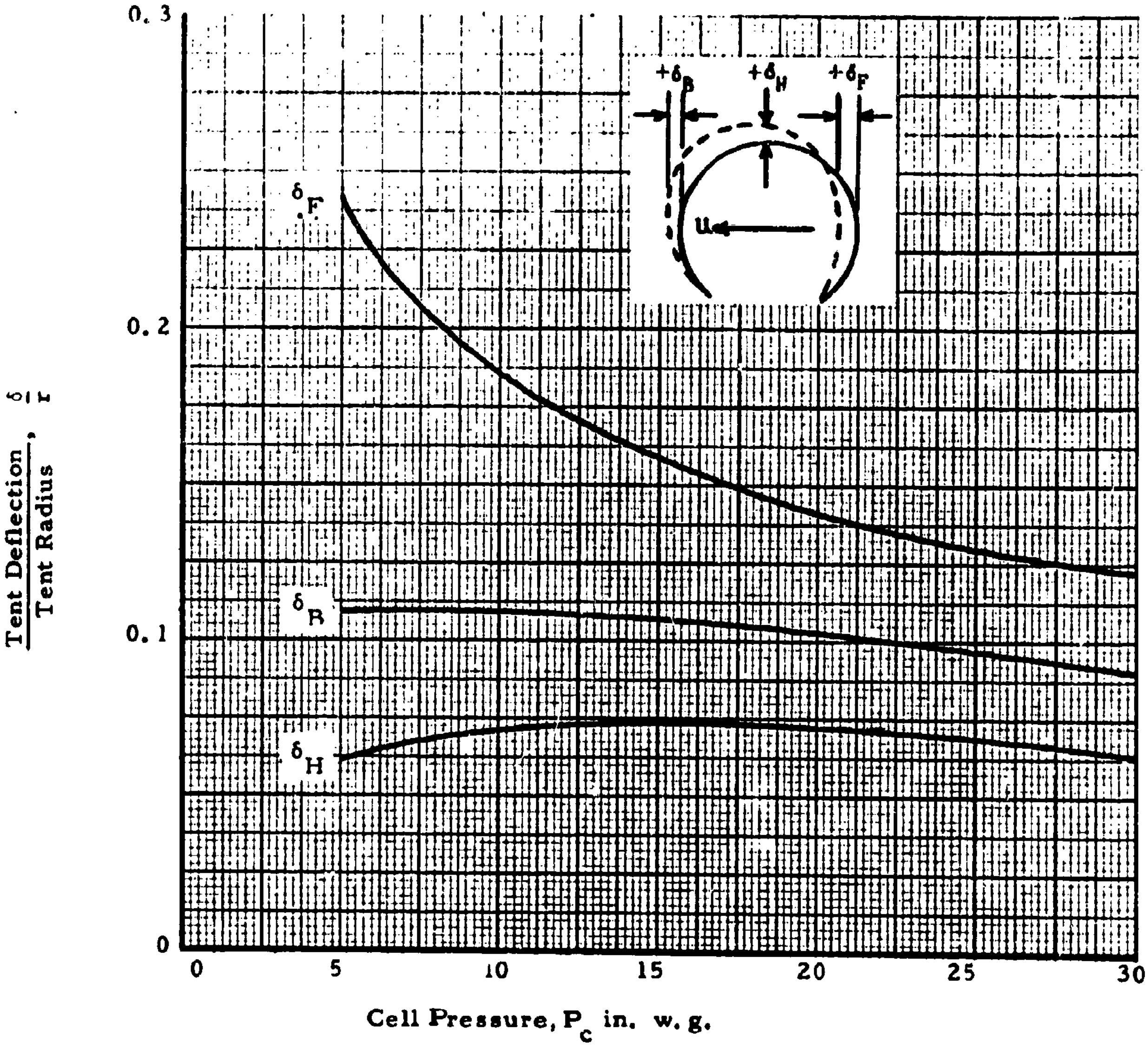


Figure 19. Variation of Tent Deflection with Cell Pressure. Guy Lines Attached at 0.80 and 0.40 Tent Height.

MAXIMUM AERODYNAMIC ANCHOR LOAD COEFFICIENT
SINGLE-WALL SPHERES AND CYLINDERS

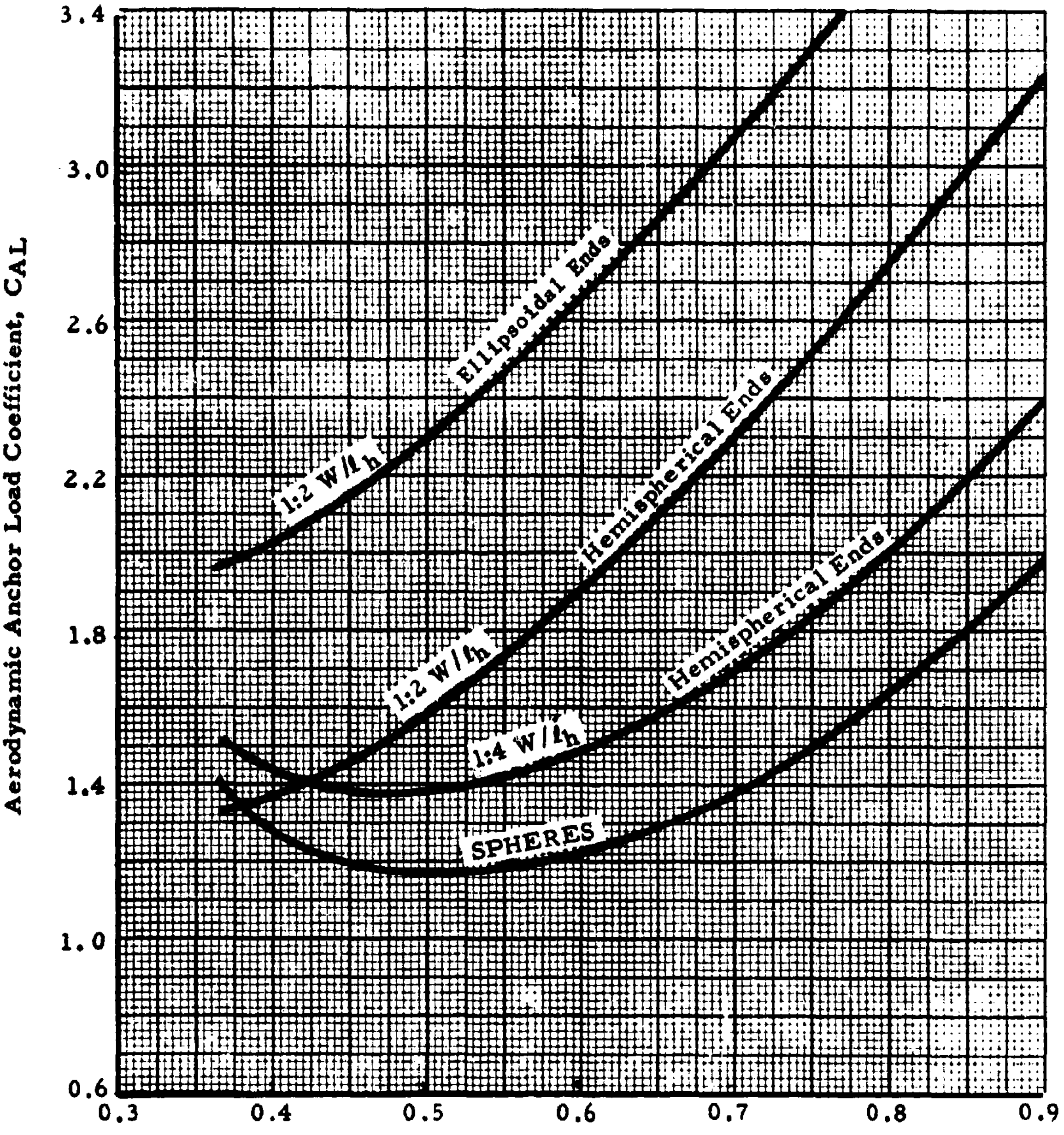


Figure 20. Variation of Anchor Load Coefficient with Shape (Spherical and Cylindrical Single Wall Tents, 1:2, 1:4 W/ℓ_h)

MAXIMUM BASE ANCHOR LOAD COEFFICIENTS
DOUBLE-WALL CYLINDERS

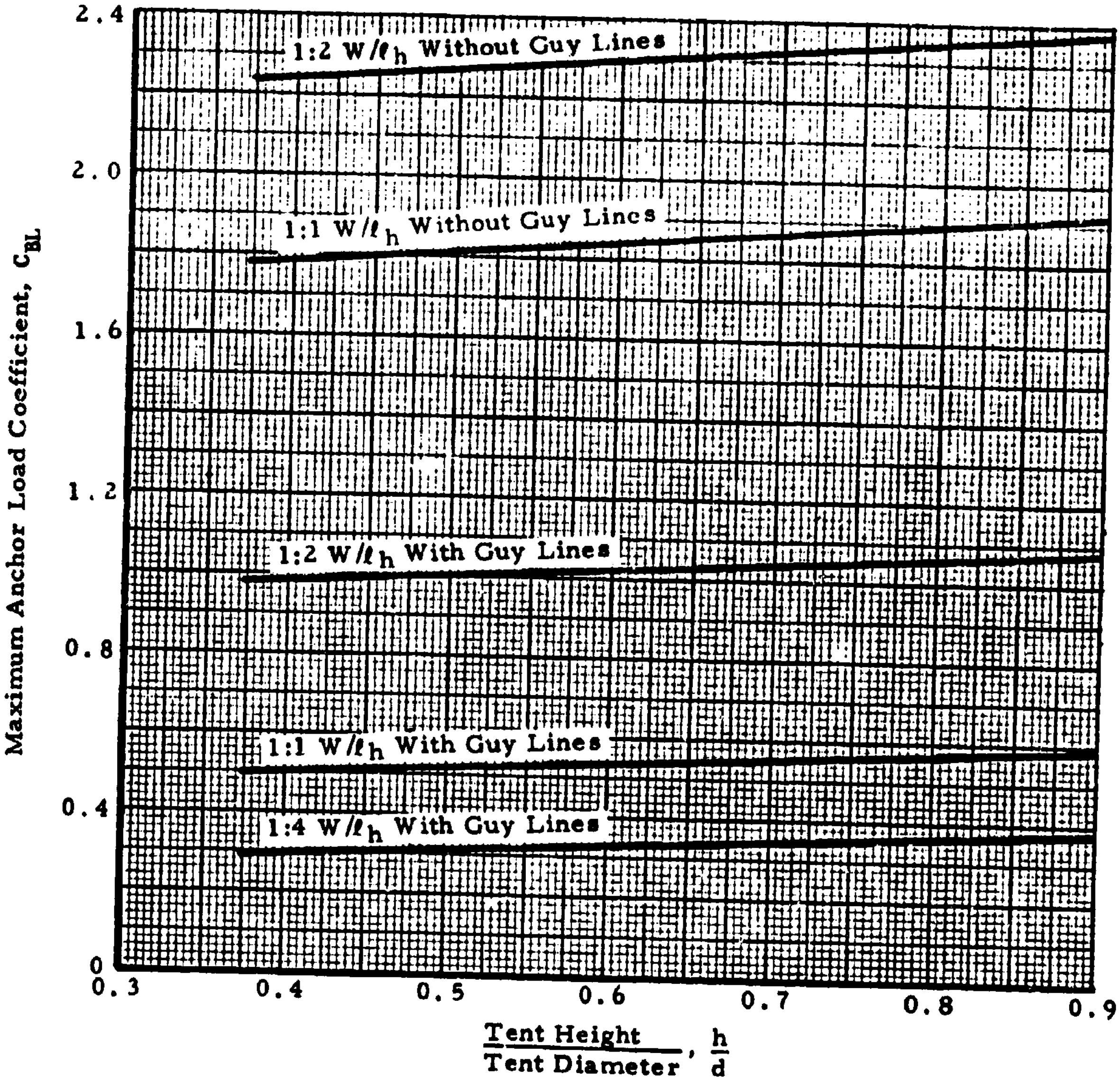


Figure 21. Variation of Base Anchor Load Coefficient with Shape

MAXIMUM GUY LINE LOAD COEFFICIENT
DOUBLE-WALL CYLINDER

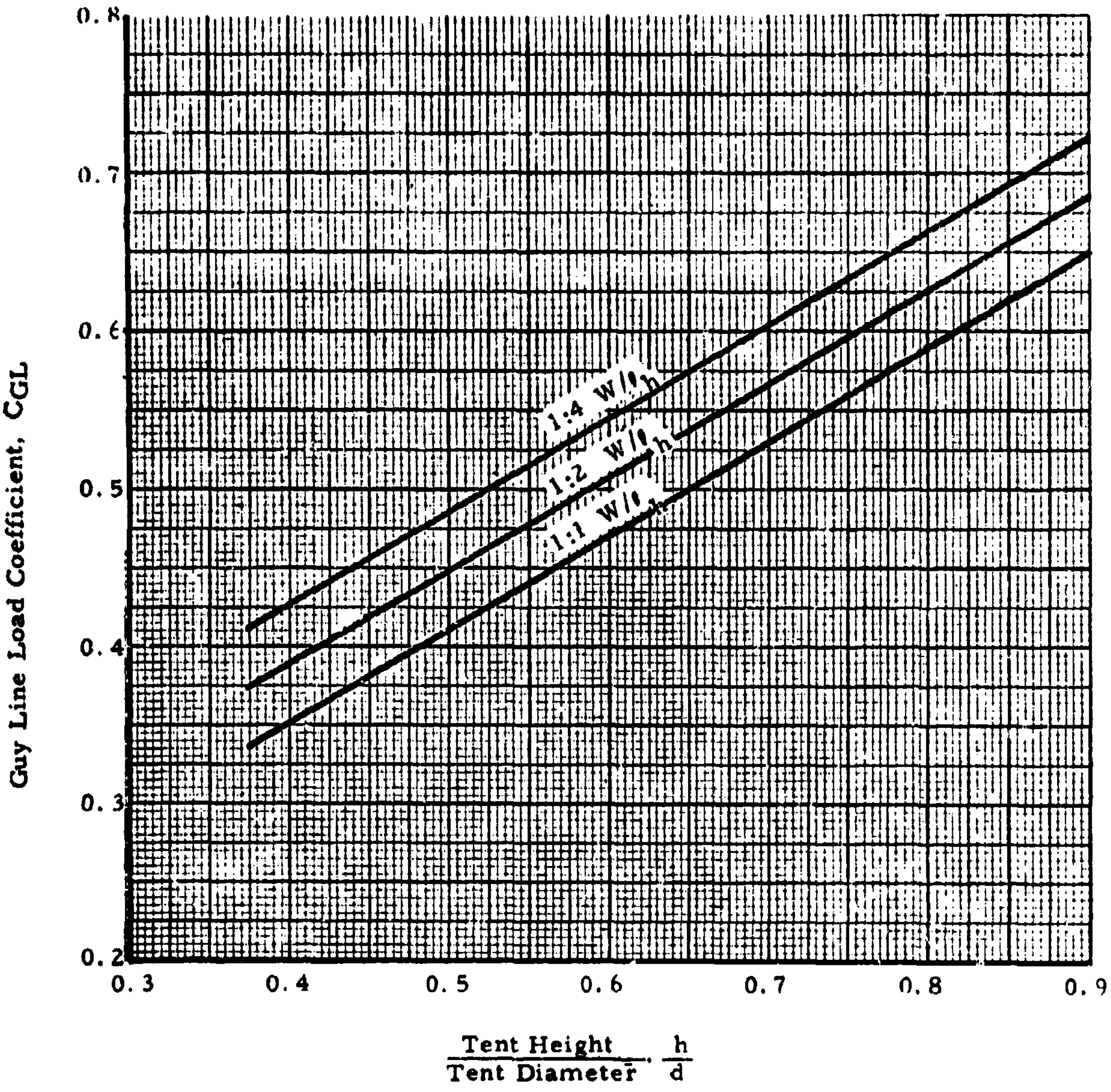


Figure 22. Variation of Guy Line Load Coefficient With Shape.

PEAK STRESS COEFFICIENTS
SINGLE-WALL SPHERES

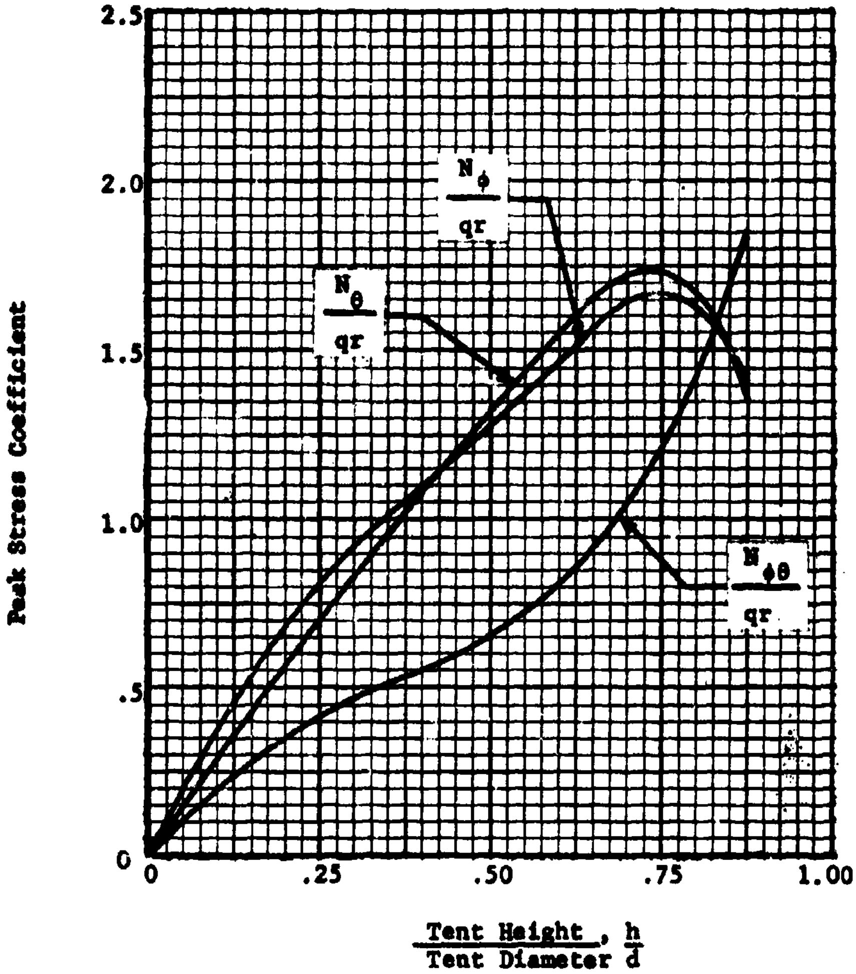


Figure 23. Variation of Peak Stress Coefficients with Shape (Spherical Single-Wall Tents).

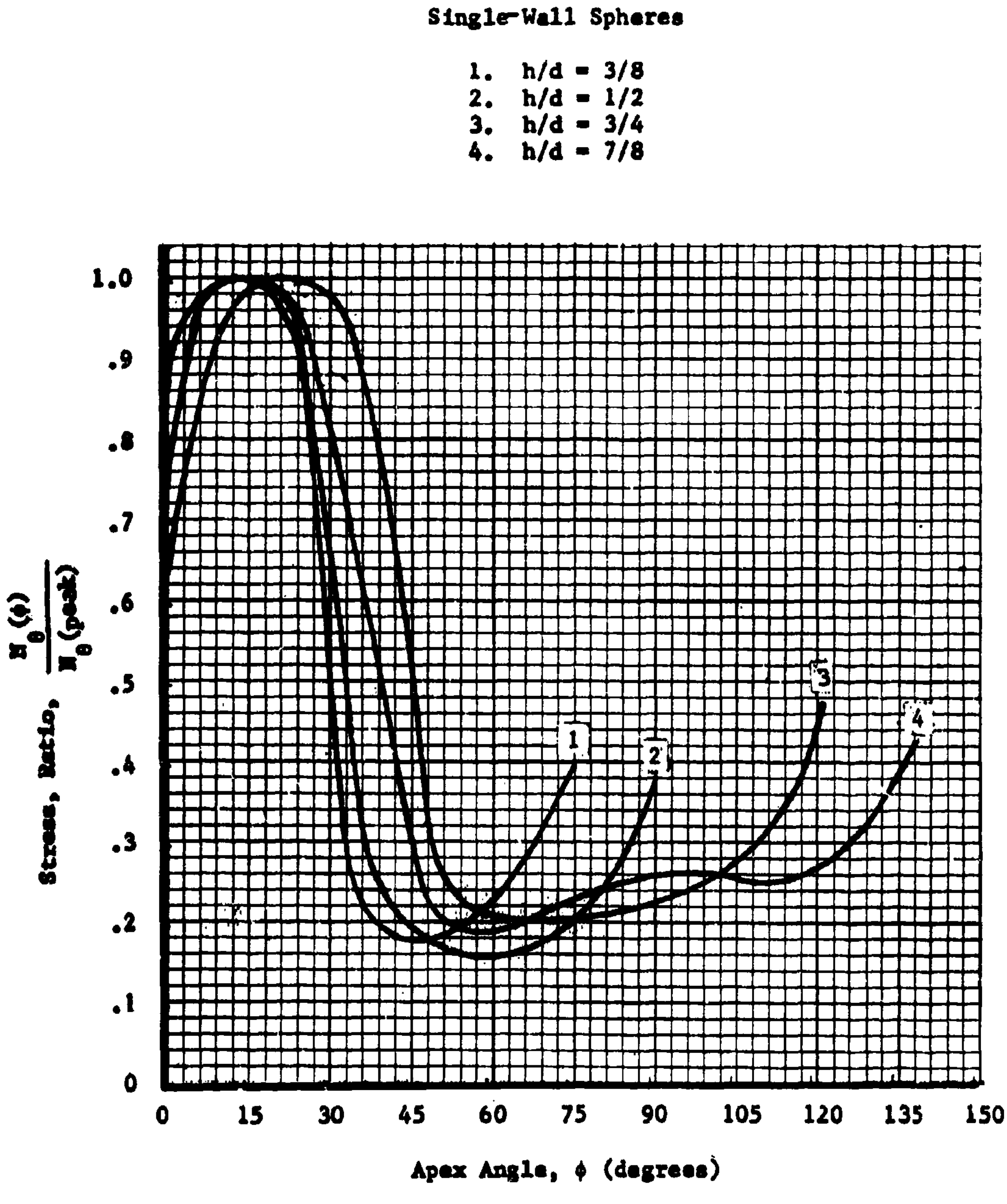


Figure 24. Variation of Stress Ratio with Apex Angle (Spherical Single Wall Tents)

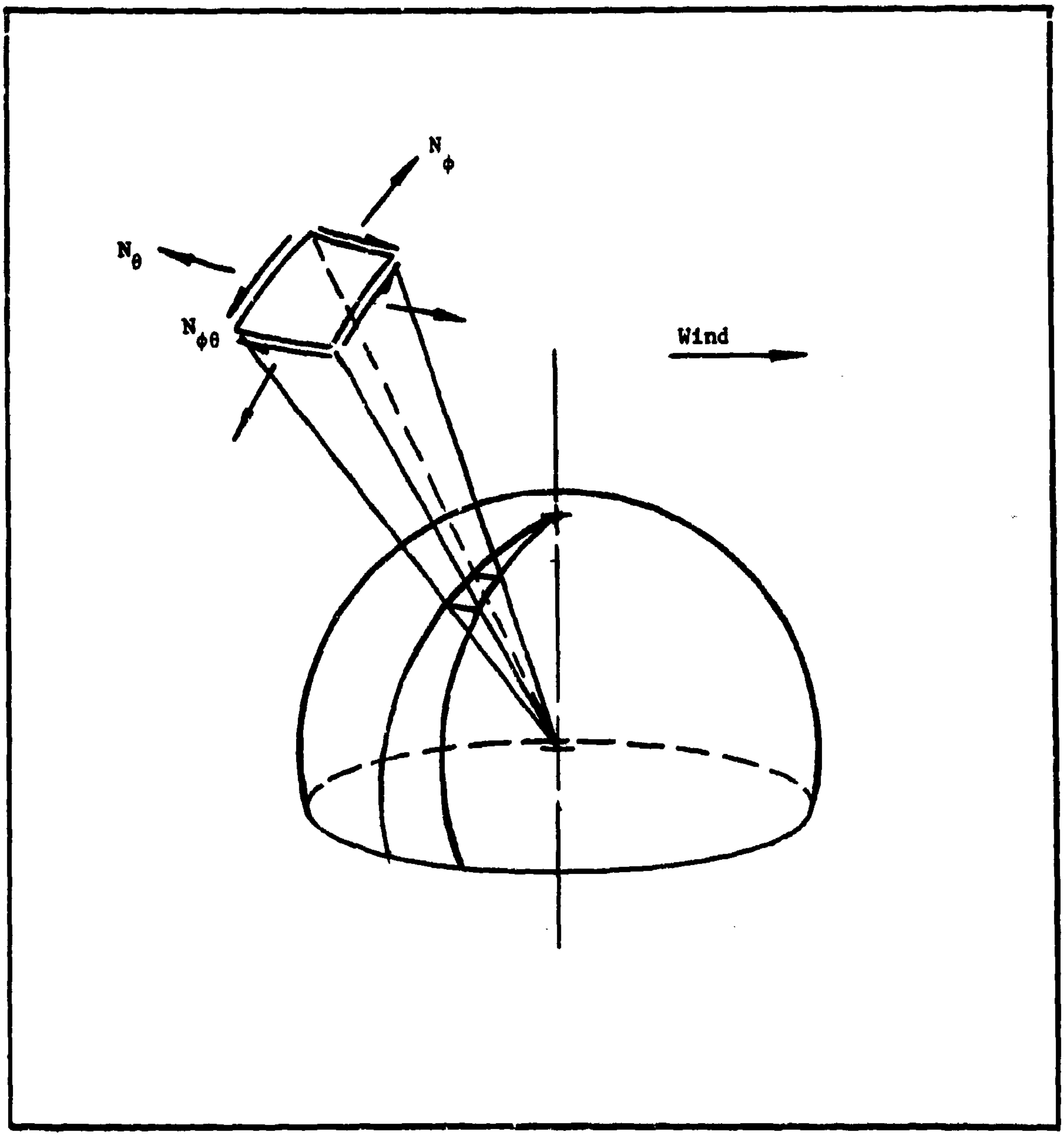


Figure 25. Coordinate System and Membrane Stresses for a Truncated Spherical Shell

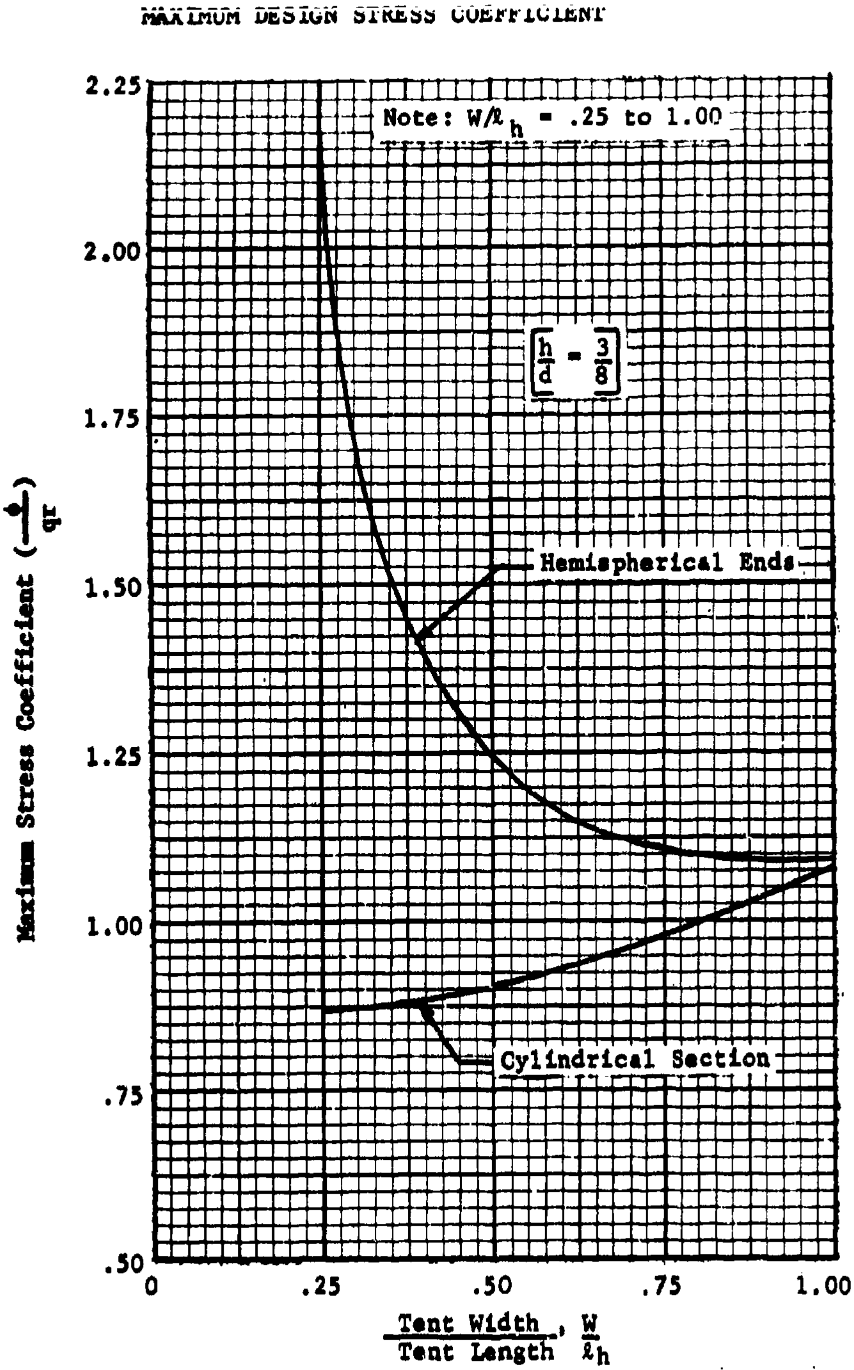


Figure 26. Variation of Maximum Design Stress Coefficient With Tent Width-to-Length Ratio; $h/d = 3/8$, N_ϕ/qr

MAXIMUM DESIGN STRESS COEFFICIENT

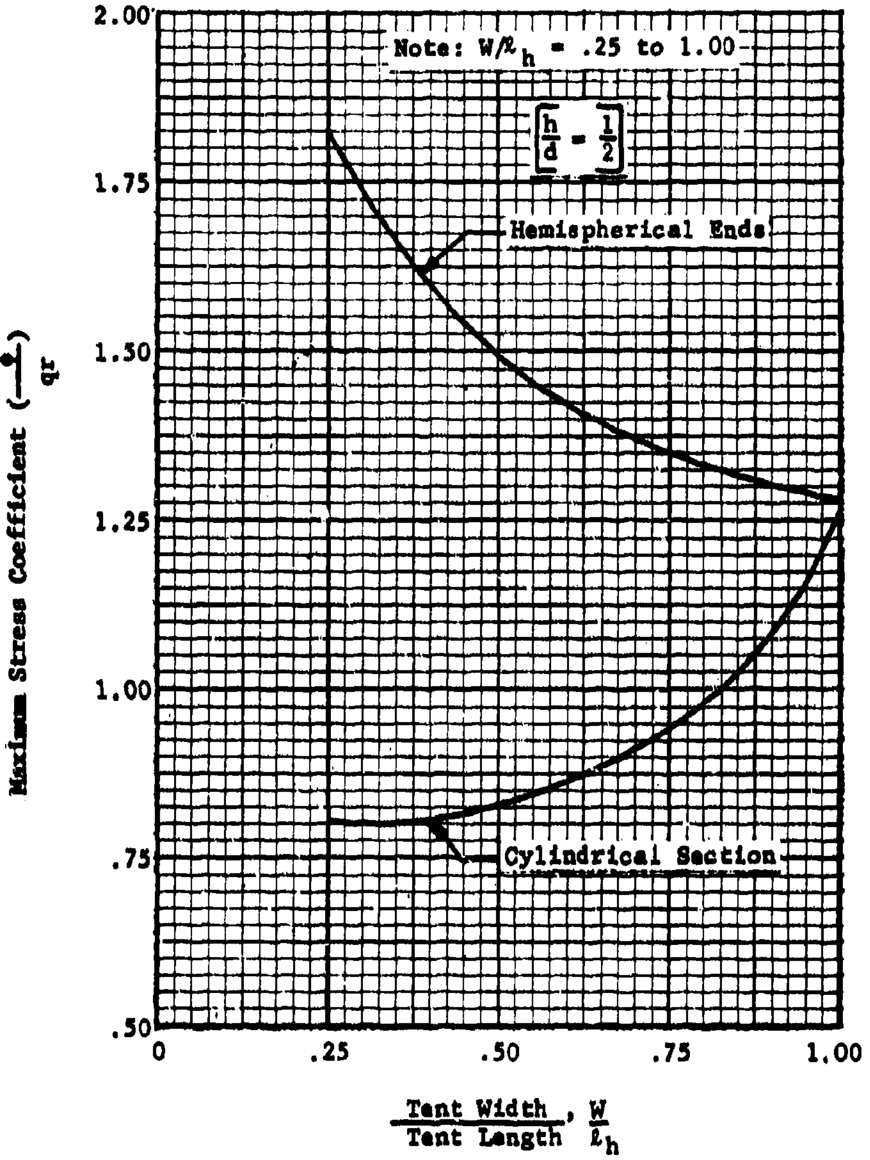


Figure 27. Variation of Maximum Design Stress Coefficient With Tent Width-to-Length Ratio; $h/d = 1/2$, N_{ϕ}/qr

MAXIMUM DESIGN STRESS COEFFICIENT

Note: W/ℓ_h = .25 to 1.00

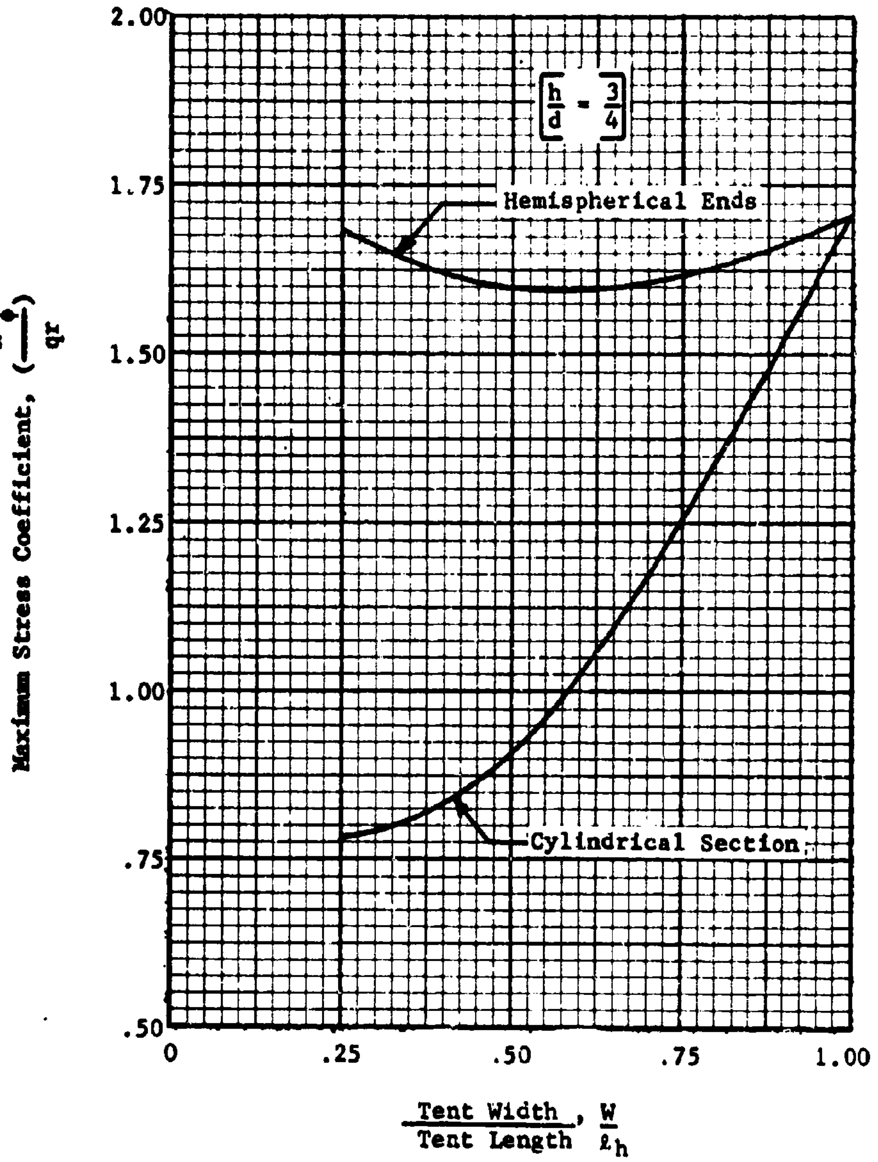


Figure 28. Variation of Maximum Design Stress Coefficient With Tent Width-to-Length Ratio; h/d = 3/4, N_ϕ/qr

MAXIMUM DESIGN STRESS COEFFICIENT

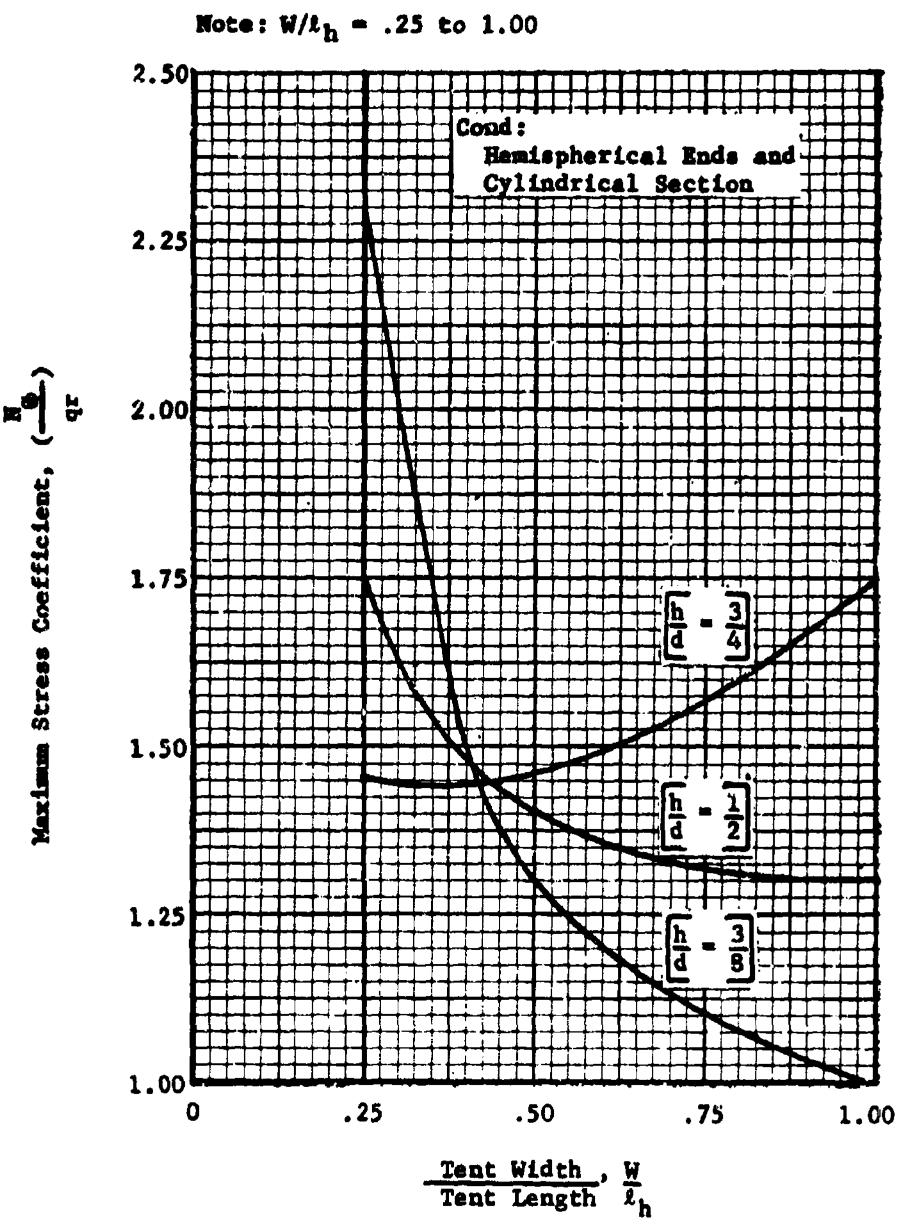


Figure 29. Variation of Maximum Design Stress Coefficient With Tent Width-to-Length Ratio; h/d = 3/8, 1/2, 3/4, N_ϕ/qr

MAXIMUM DESIGN STRESS COEFFICIENT

Note: W/ℓ_h = .25 to 1.00

Cond: Hemispherical Ends

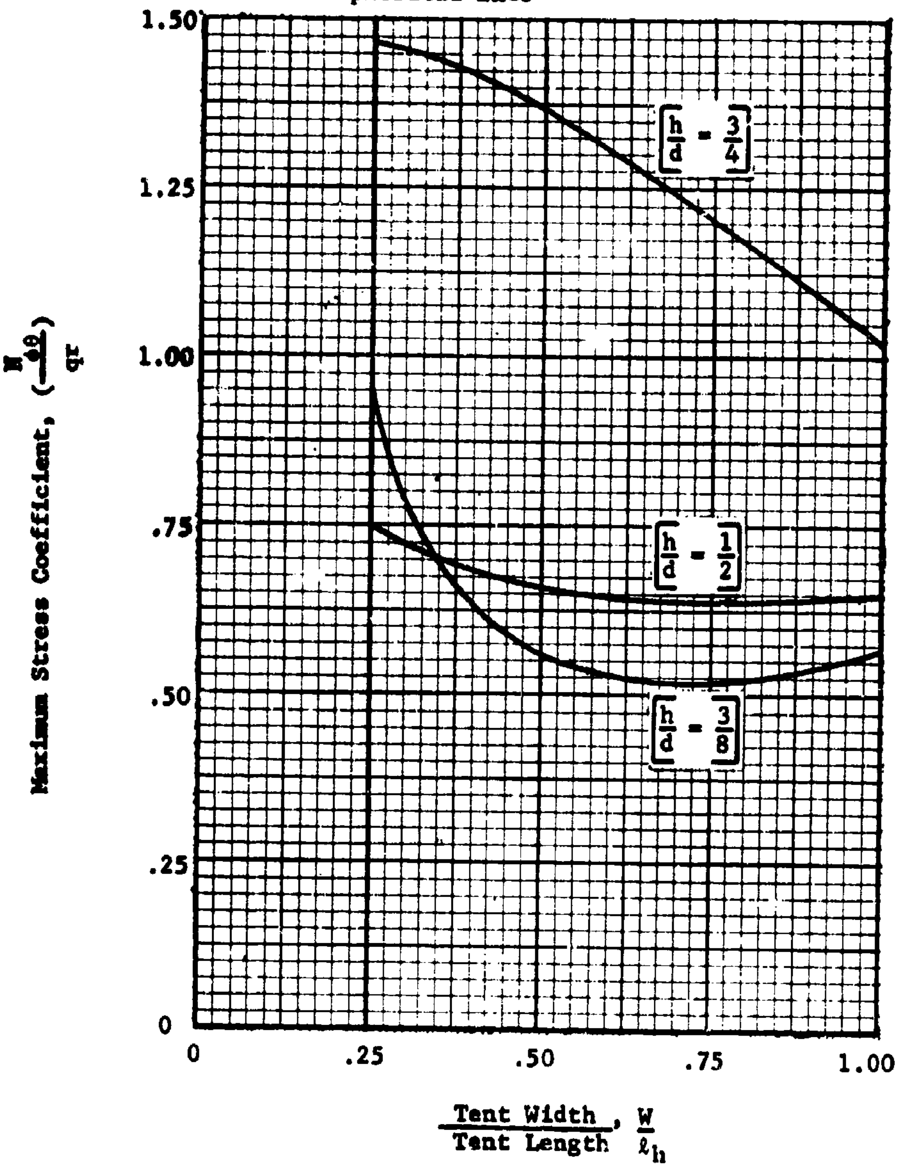


Figure 30. Variation of Maximum Design Stress Coefficient With Tent Width-to-Length Ratio; $\bar{h}/d$ = 3/8, 1/2, 3/4, $N_{\phi\theta}/qr$

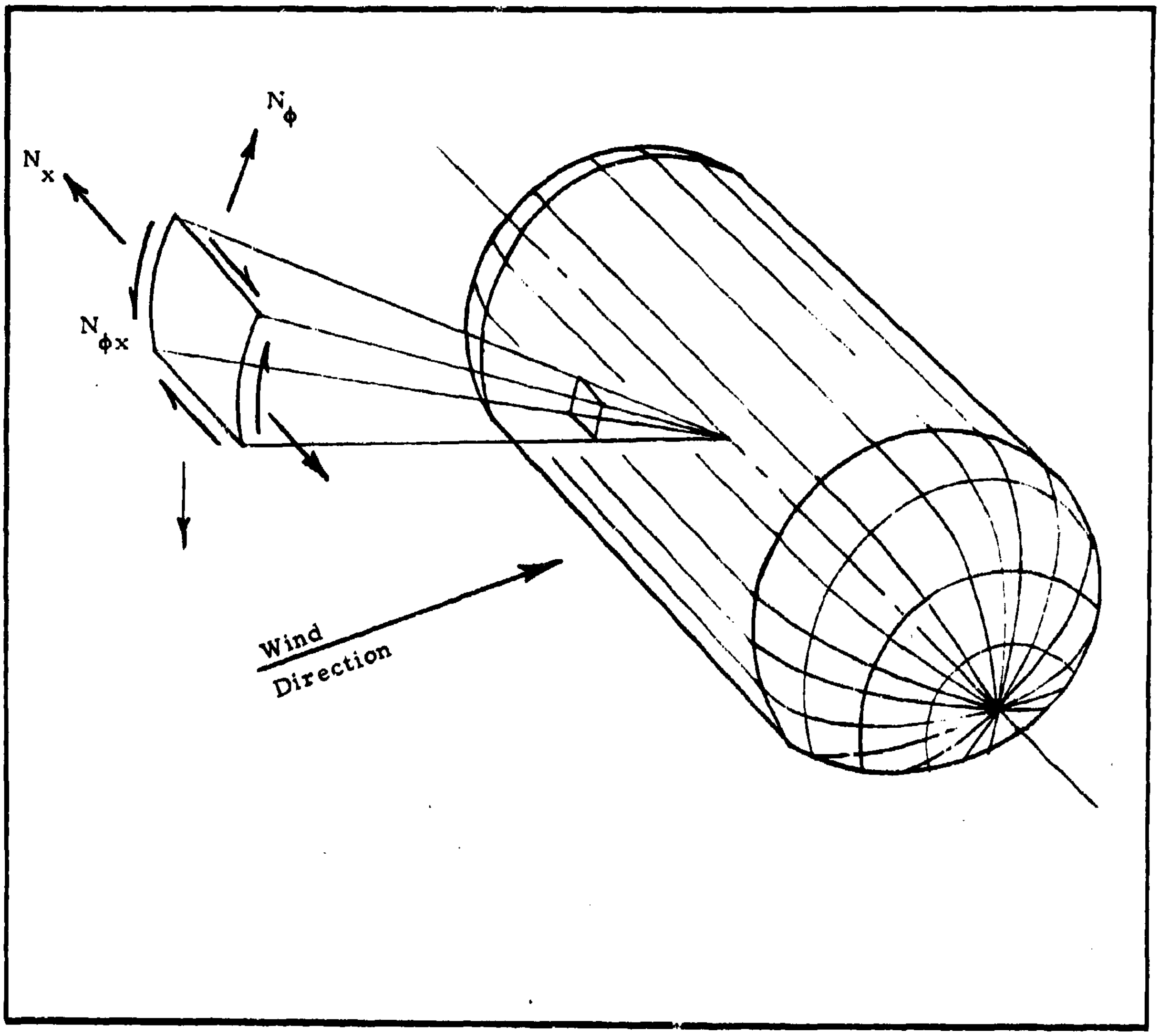
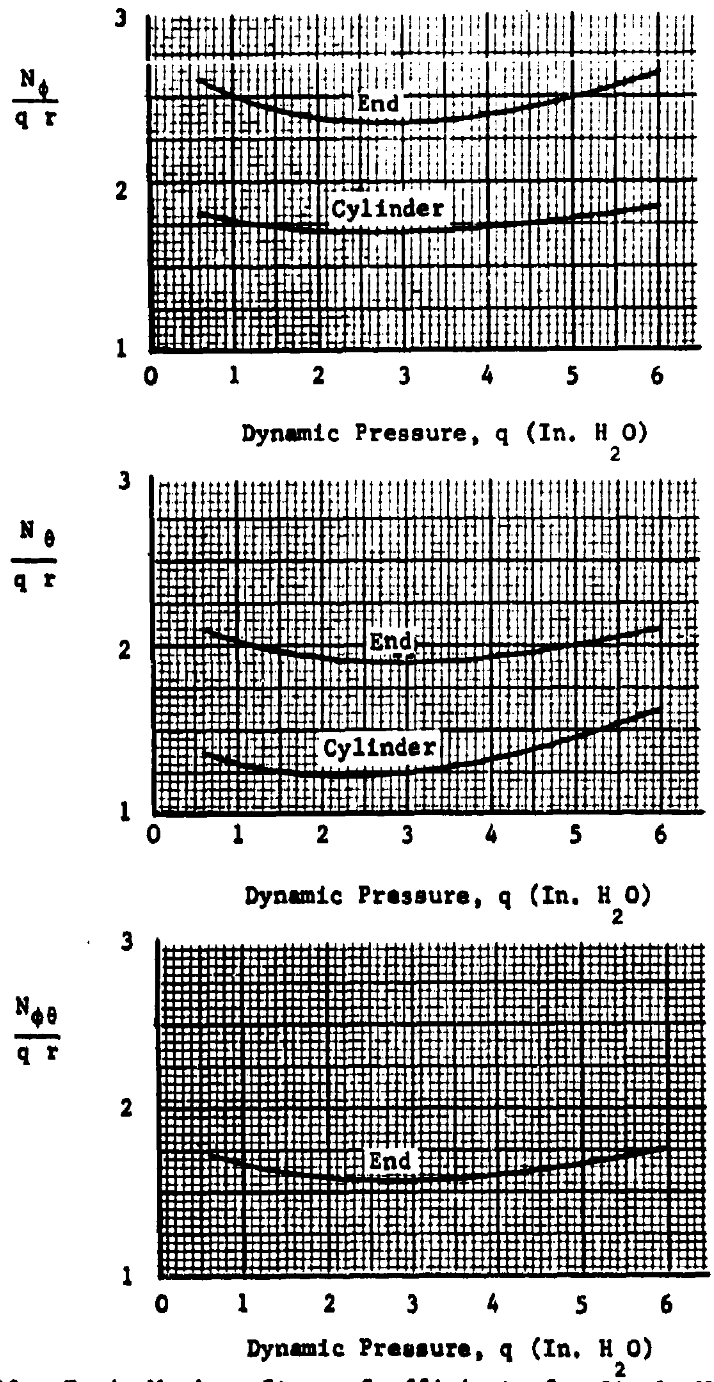


Figure 31. Coordinate System and Membrane Stresses for a Cylindrical Shell with Hemispherical Ends.



Basic Maximum Stress Coefficients

for

$h/d = 1/2$

$W/\ell_h = 1/2$

$b/r = 1/2$

$P_e/q = 1$

Figure 32. Basic Maximum Stress Coefficients for Single-Wall Cylindrical Tents with Ellipsoidal Ends

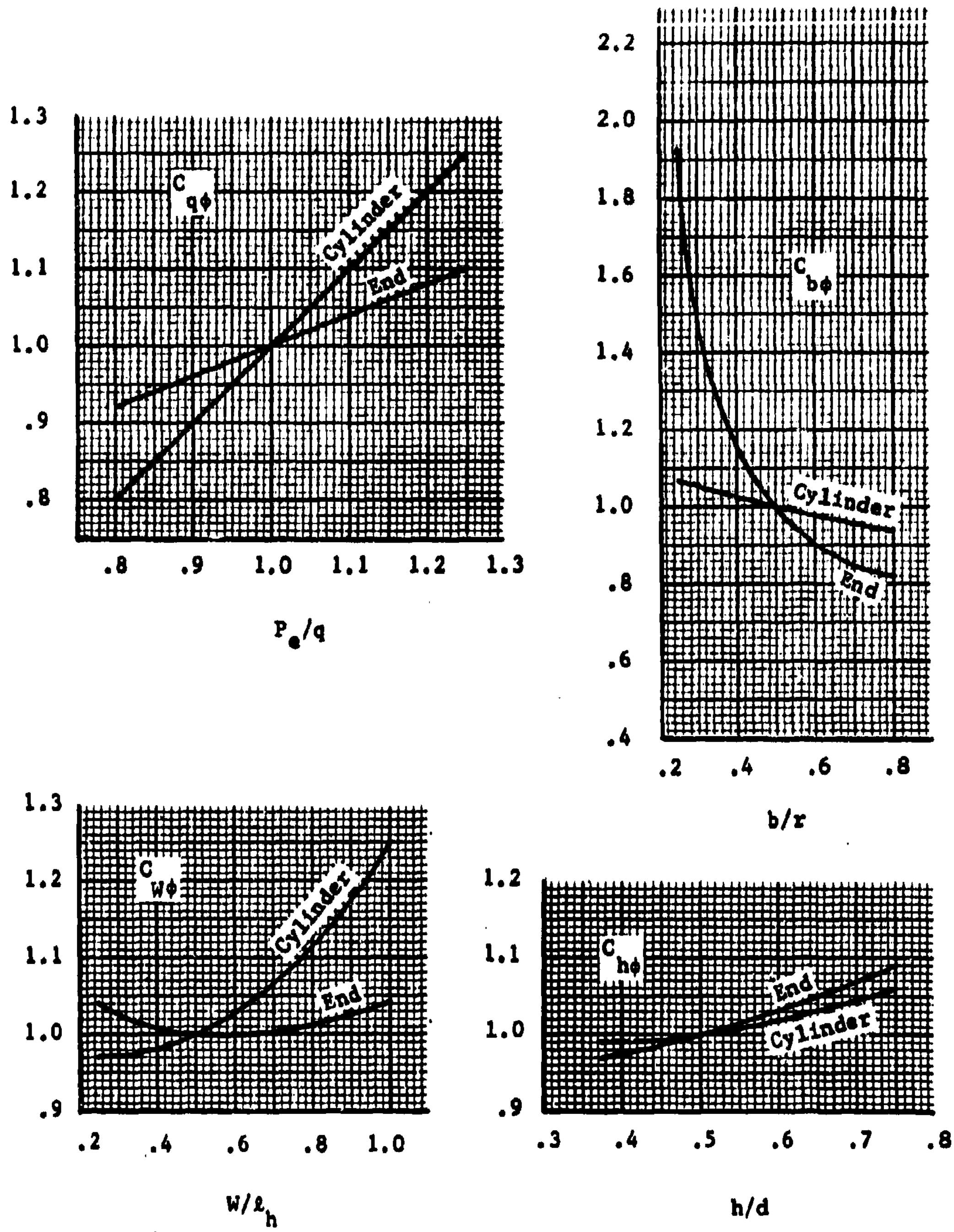


Figure 33. Correction Factors for Single-Wall Cylindrical Tents with Ellipsoidal Ends; ϕ

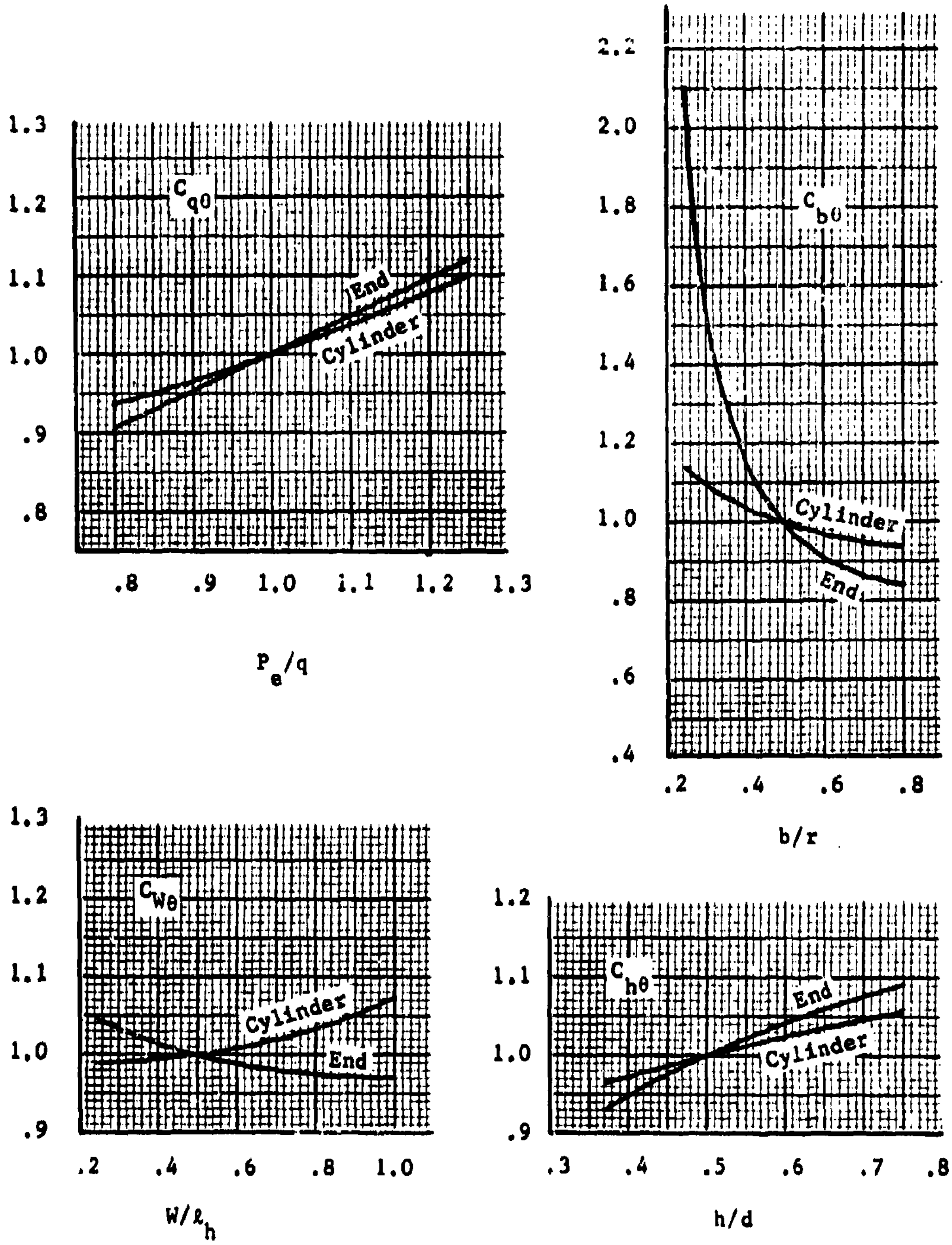


Figure 34. Correction Factors for Single-Wall Cylindrical Tents with Ellipsoidal Ends; θ

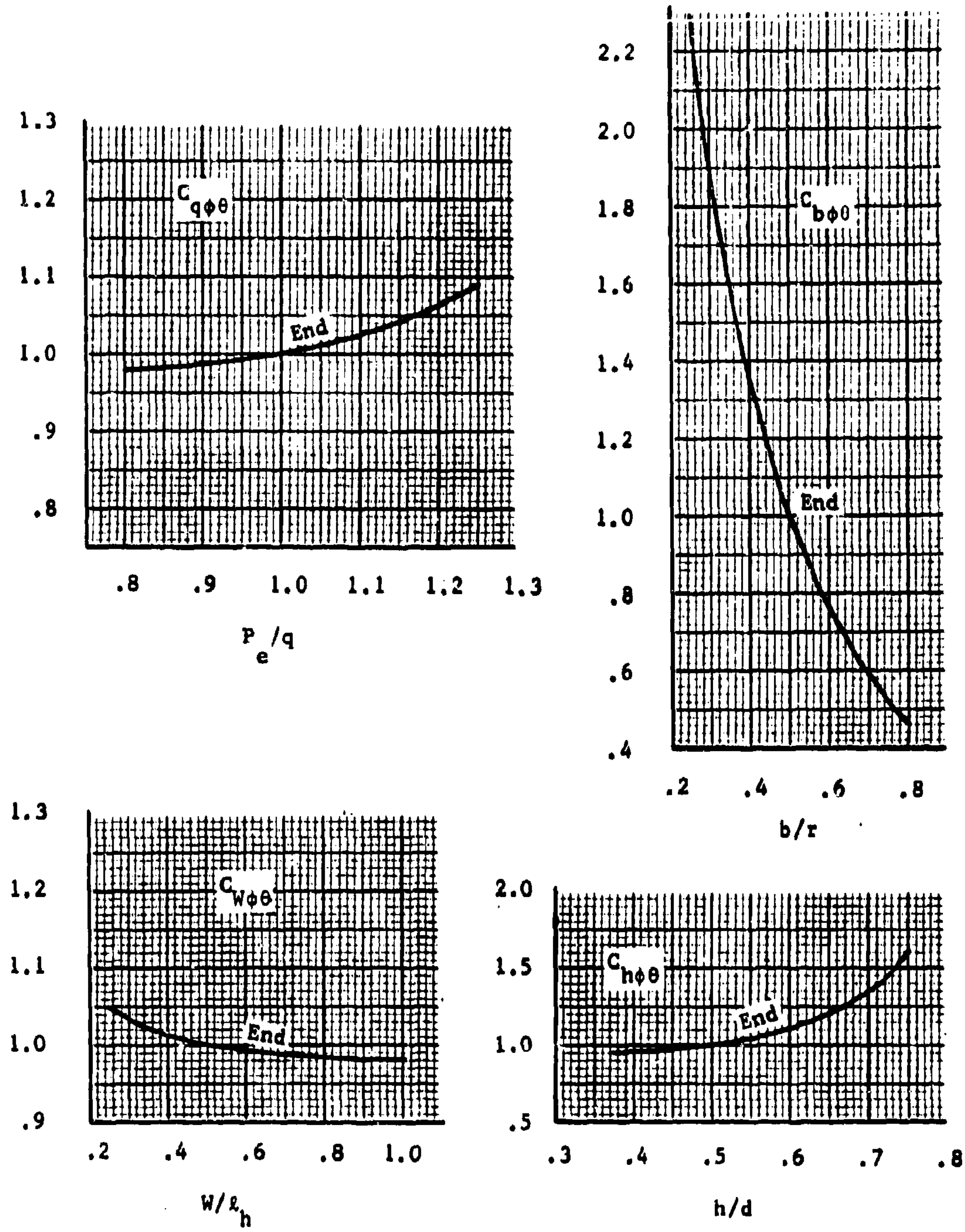


Figure 35. Correction Factors for Single-Wall Cylindrical Tents with Ellipsoidal Ends; $\phi\theta$

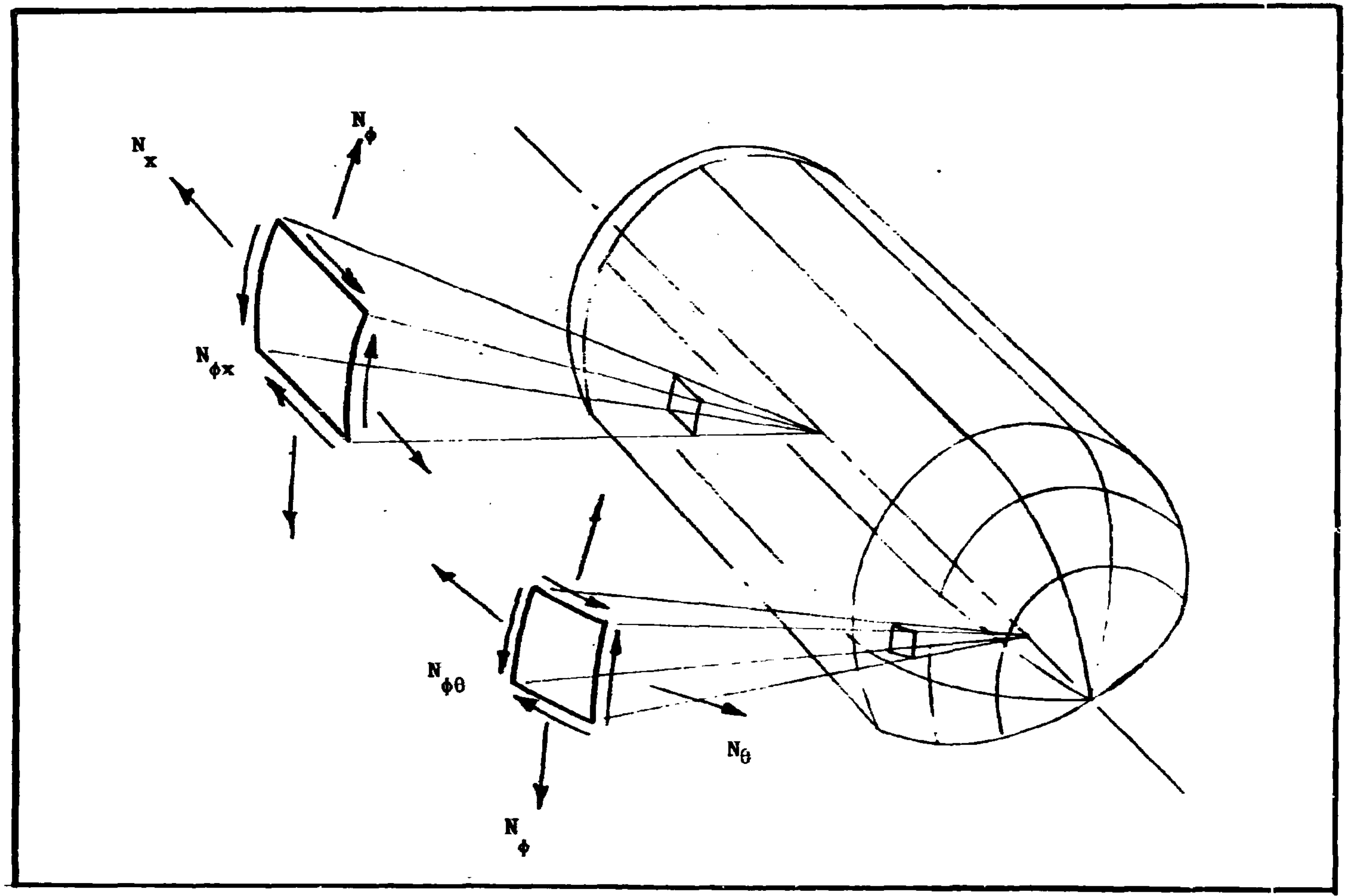


Figure 36. Coordinate System and Membrane Stresses for a Cylindrical Shell with Ellipsoidal Ends

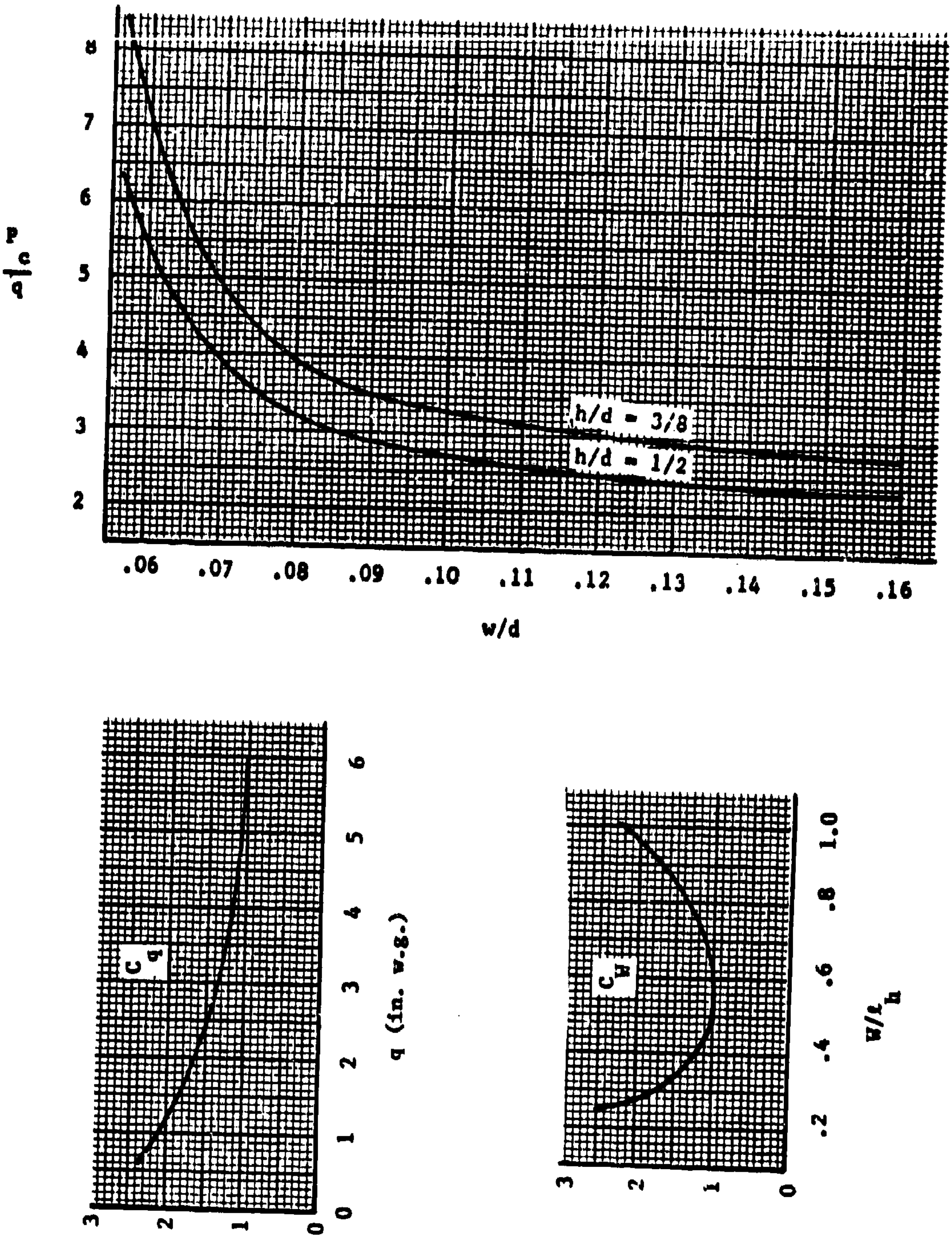


Figure 37. Double-Wall Tent Cell Pressure Correction Factors

DOUBLE-WALL CYLINDERS

Cond:	P_c	α_c
1.	5q	30°
2.	4q	30°
3.	3q	30°

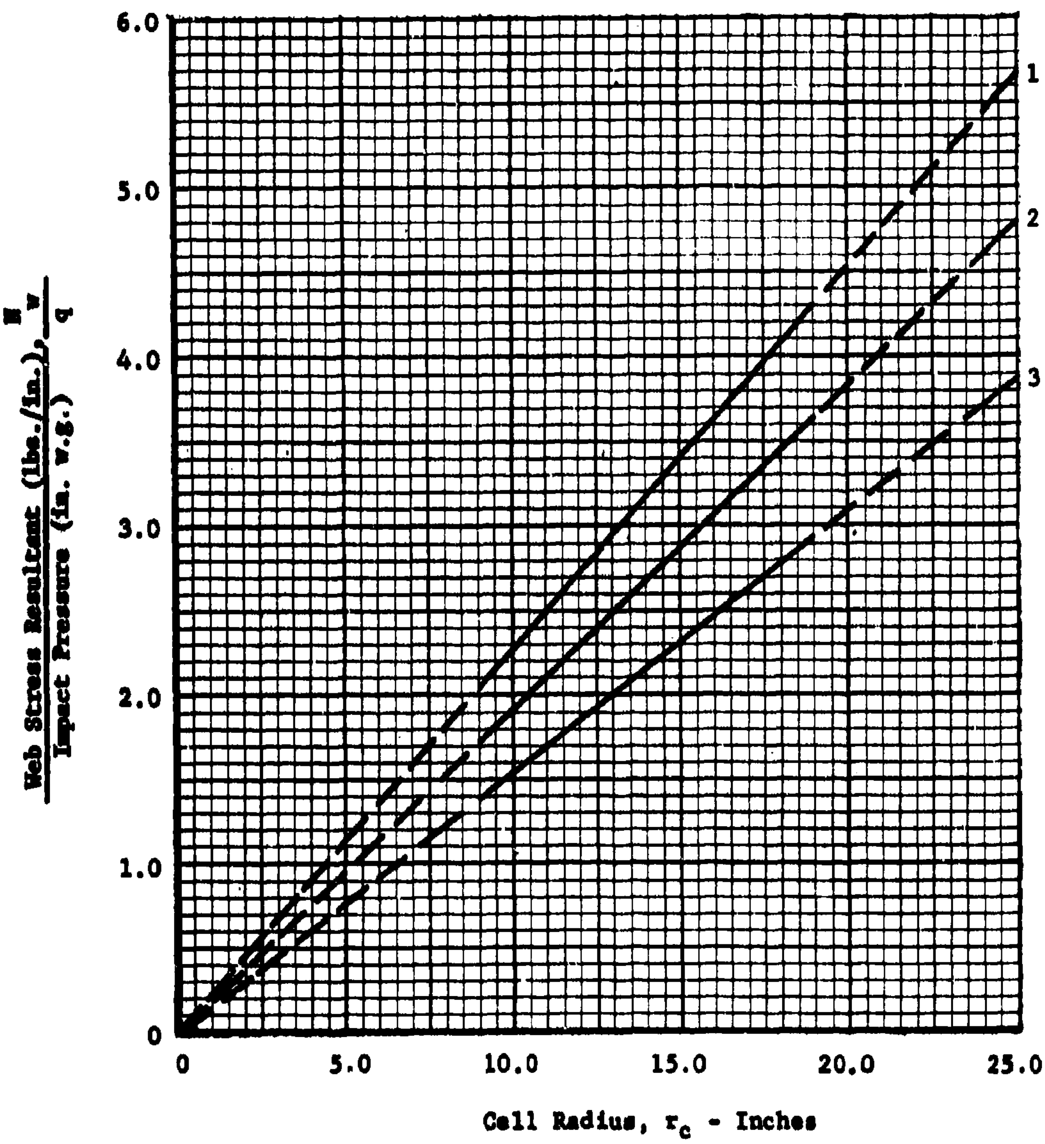


Figure 38. Variation of Web Stress Coefficient with Cell Radius.

Cond.	P_c	α_c
1.	5q	30°
2.	4q	30°
3.	3q	30°

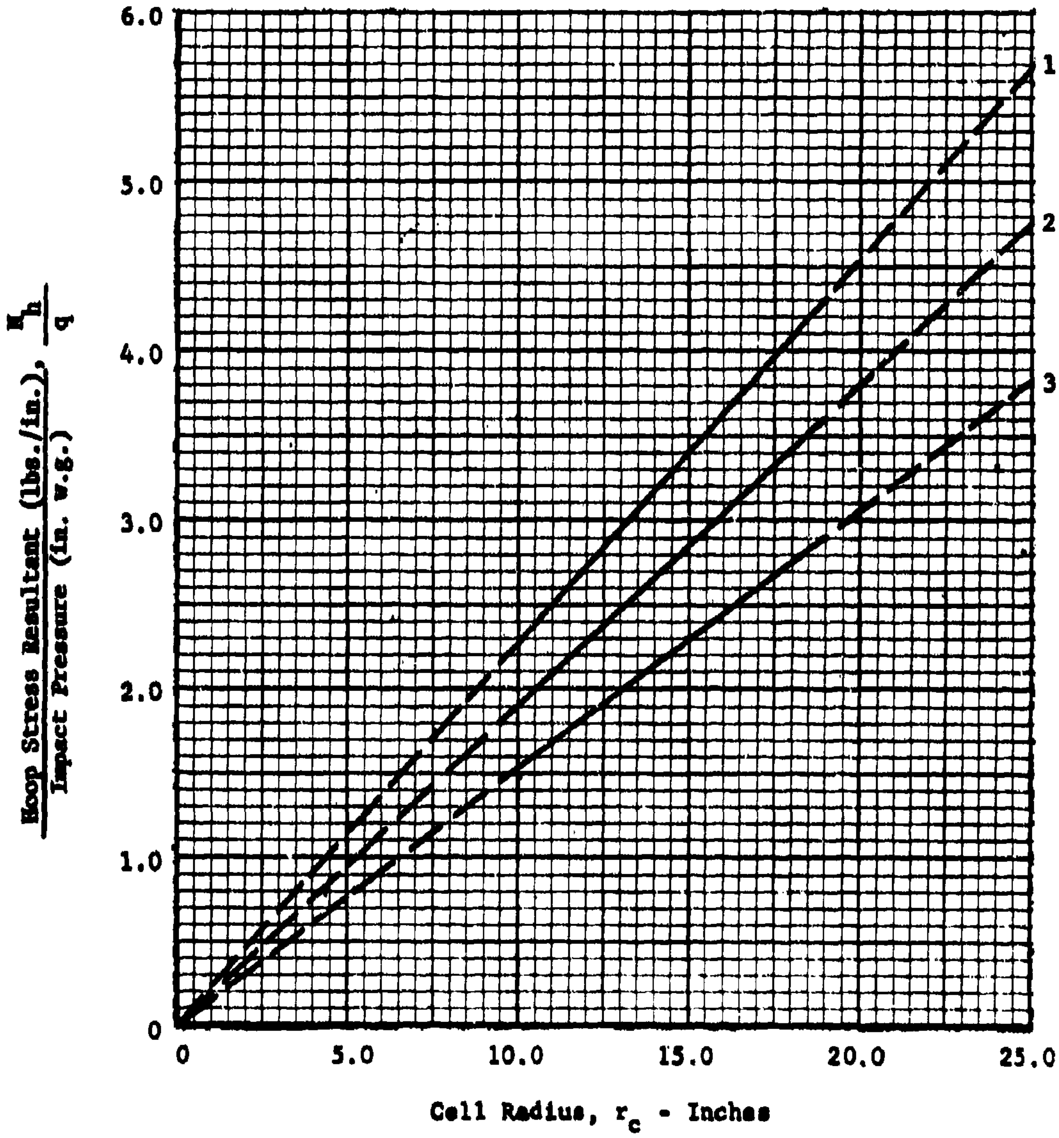


Figure 39. Variation of Hoop Stress Coefficient with Cell Radius.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

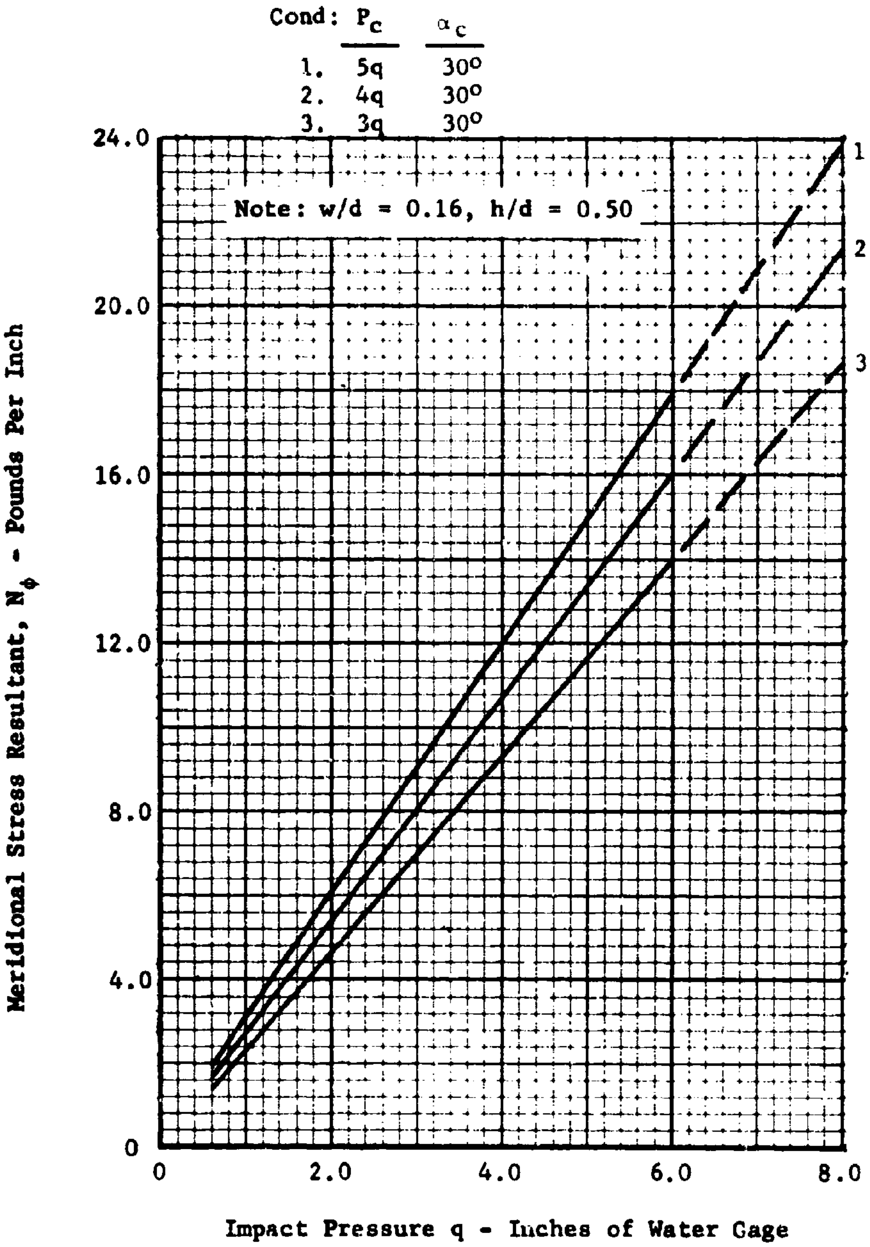


Figure 40. Variation of Meridional Stress Resultant with Impact Pressure, q, w/d = 0.16, h/d = 0.50

DOUBLE-WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

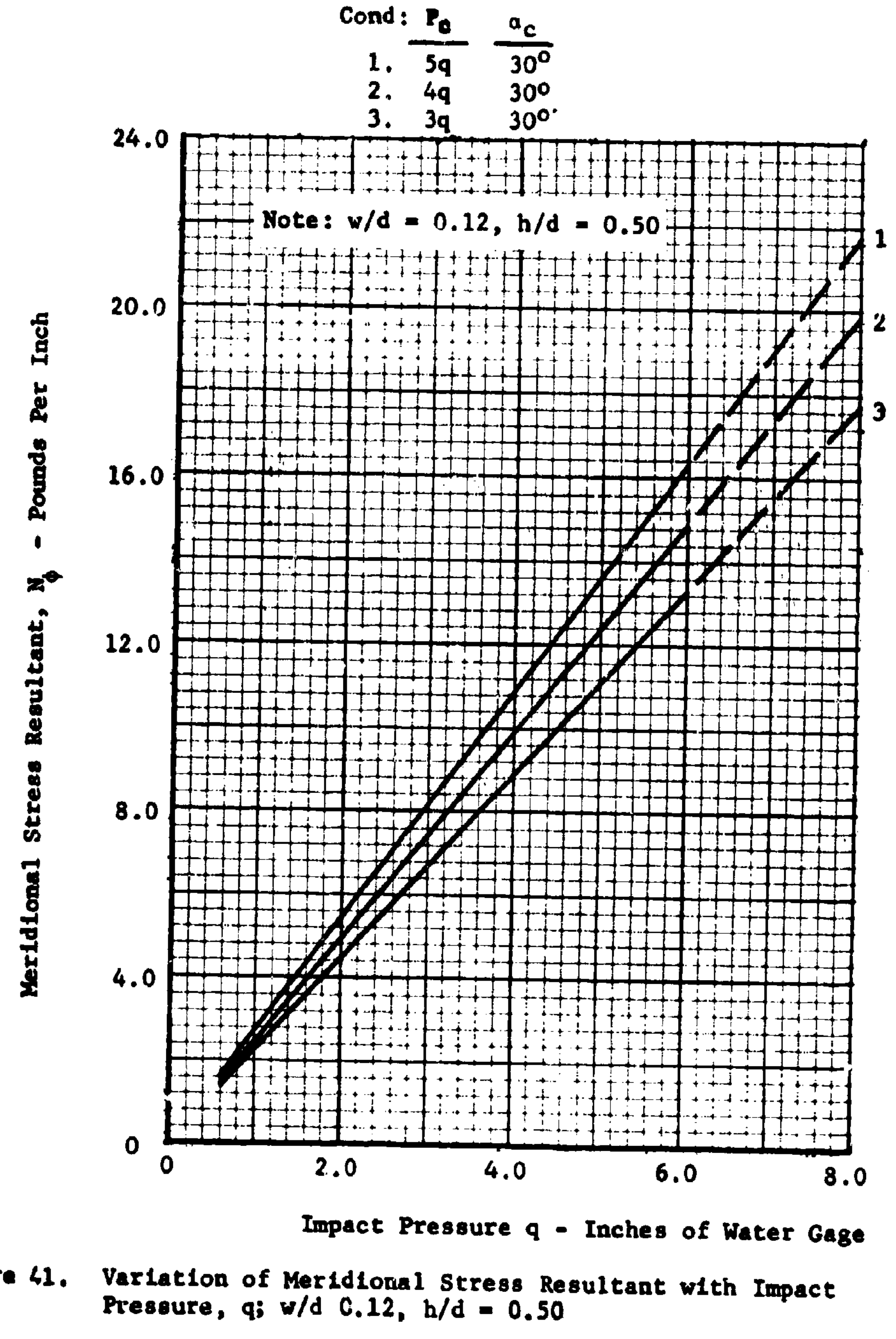


Figure 41. Variation of Meridional Stress Resultant with Impact Pressure, q; w/d 0.12, h/d = 0.50

DOUBLE-WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

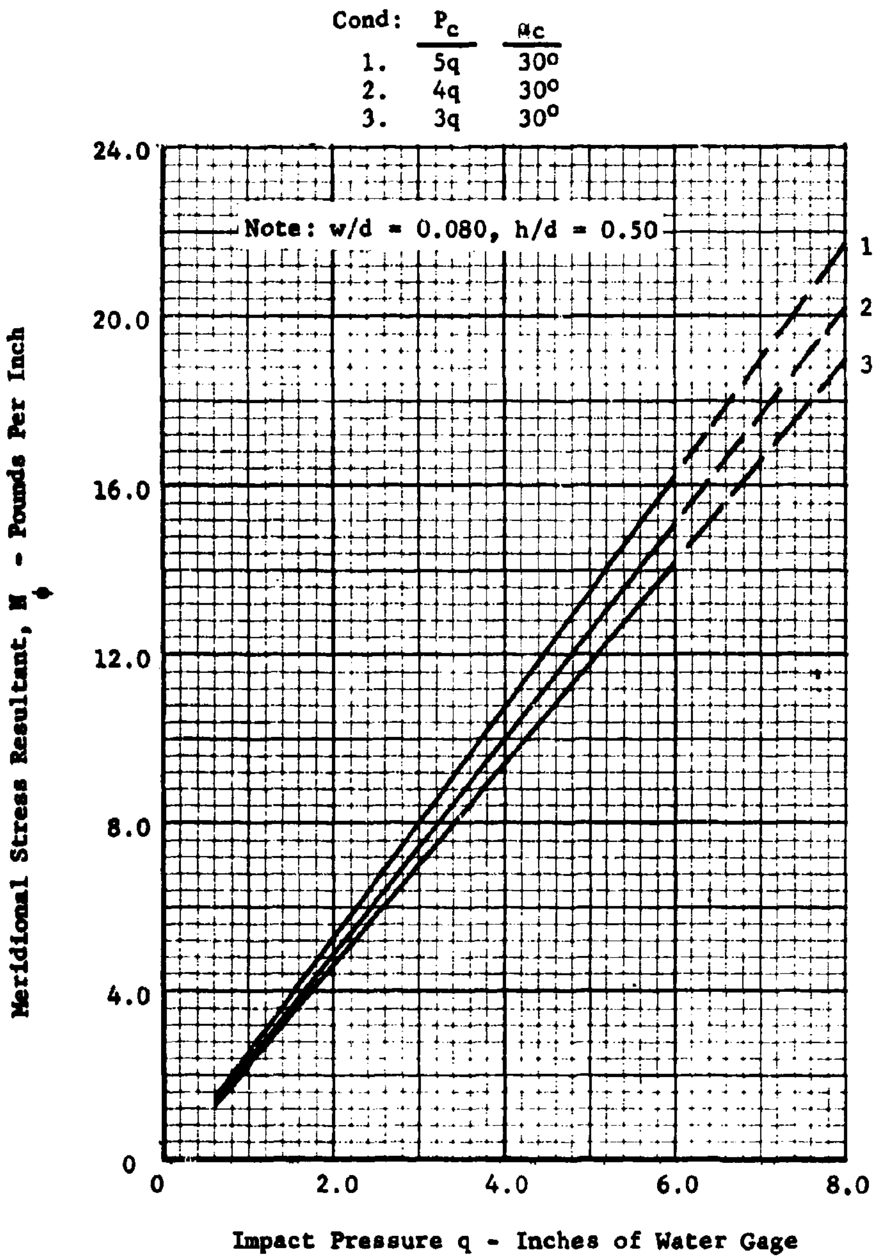


Figure 42. Variation of Meridional Stress Resultant with Impact Pressure, q; w/d 0.08, h/d = 0.50

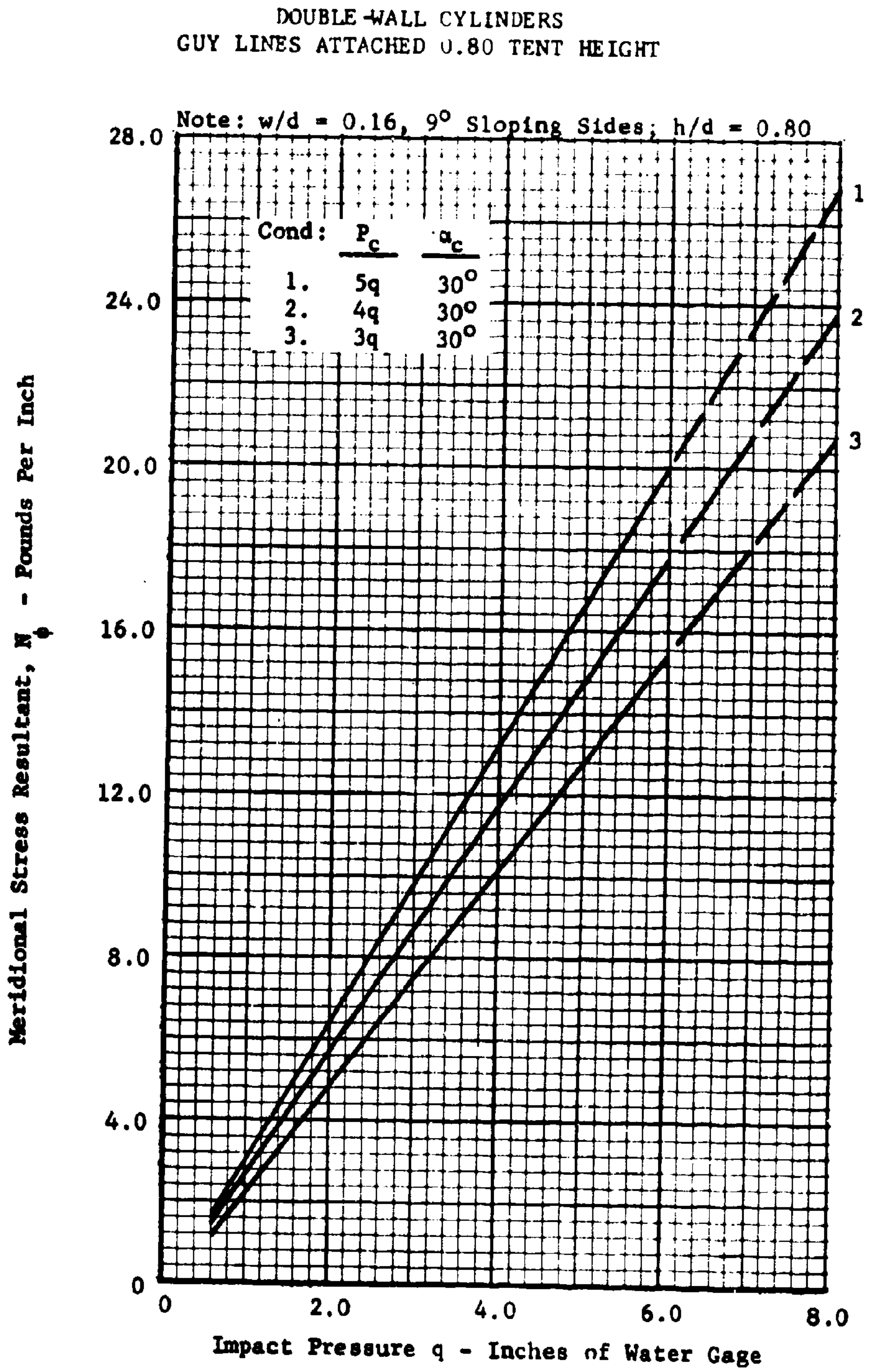


Figure 43. Variation of Meridional Stress Resultant with Impact Pressure, q; Sloping Sides, w/d = 0.16, h/d = 0.80

DOUBLE-WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

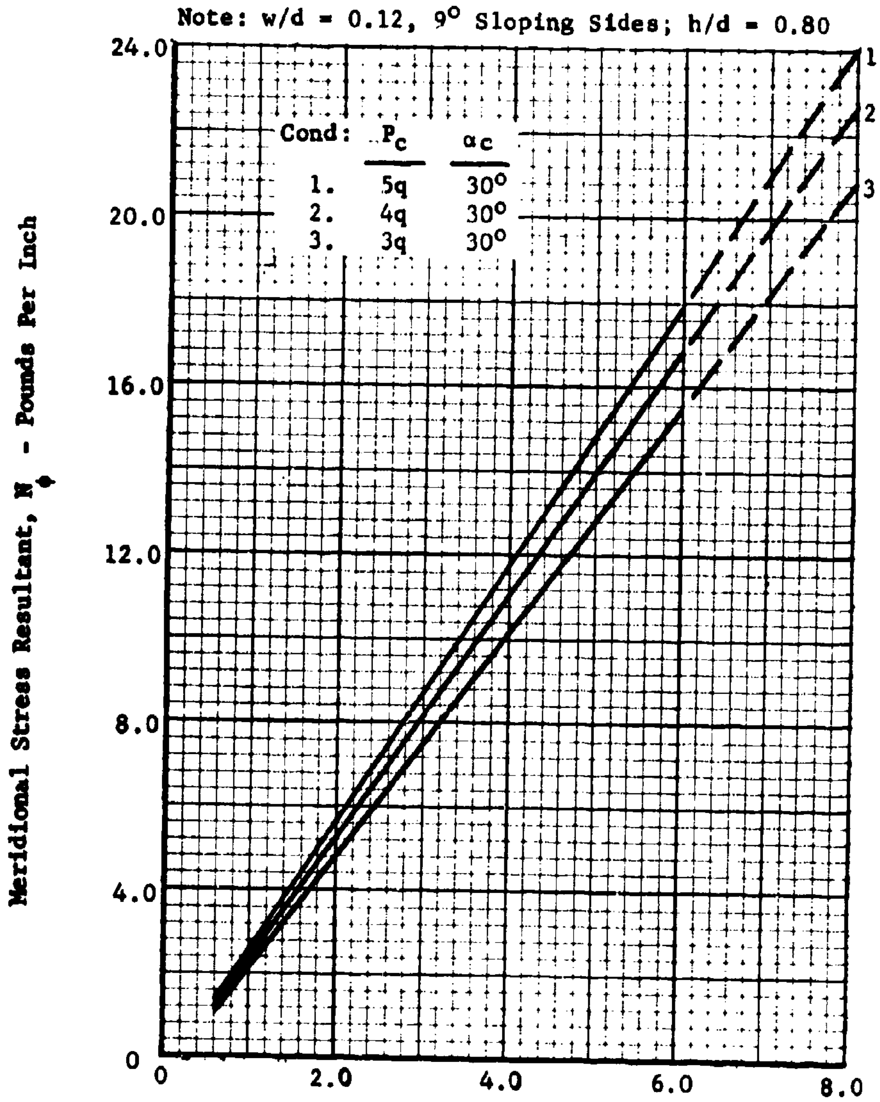


Figure 44. Variation of Meridional Stress Resultant with Impact Pressure, q; Sloping Sides, w/d = 0.12, h/d 0.80

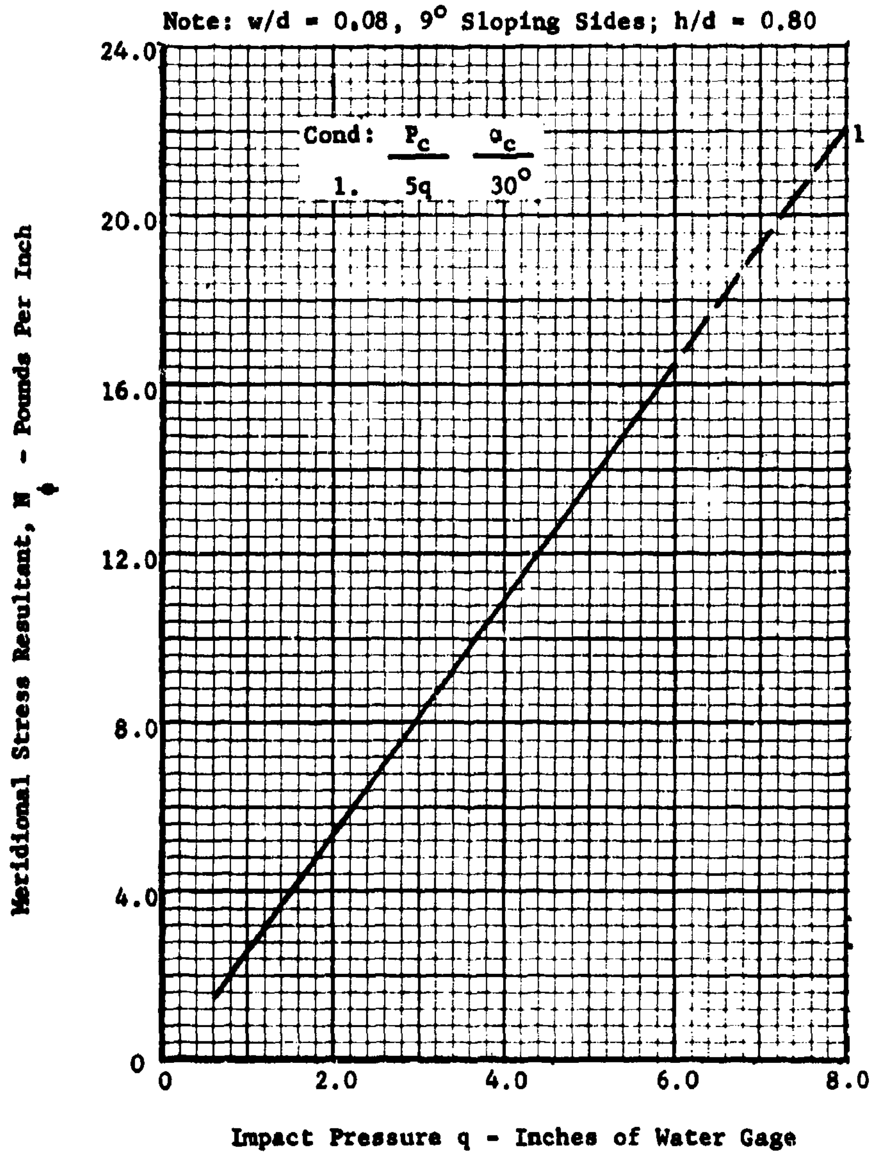


Figure 45. Variation of Meridional Stress Resultant with Impact Pressure, q; Sloping Sides, w/d = 0.08, h/d = 0.80

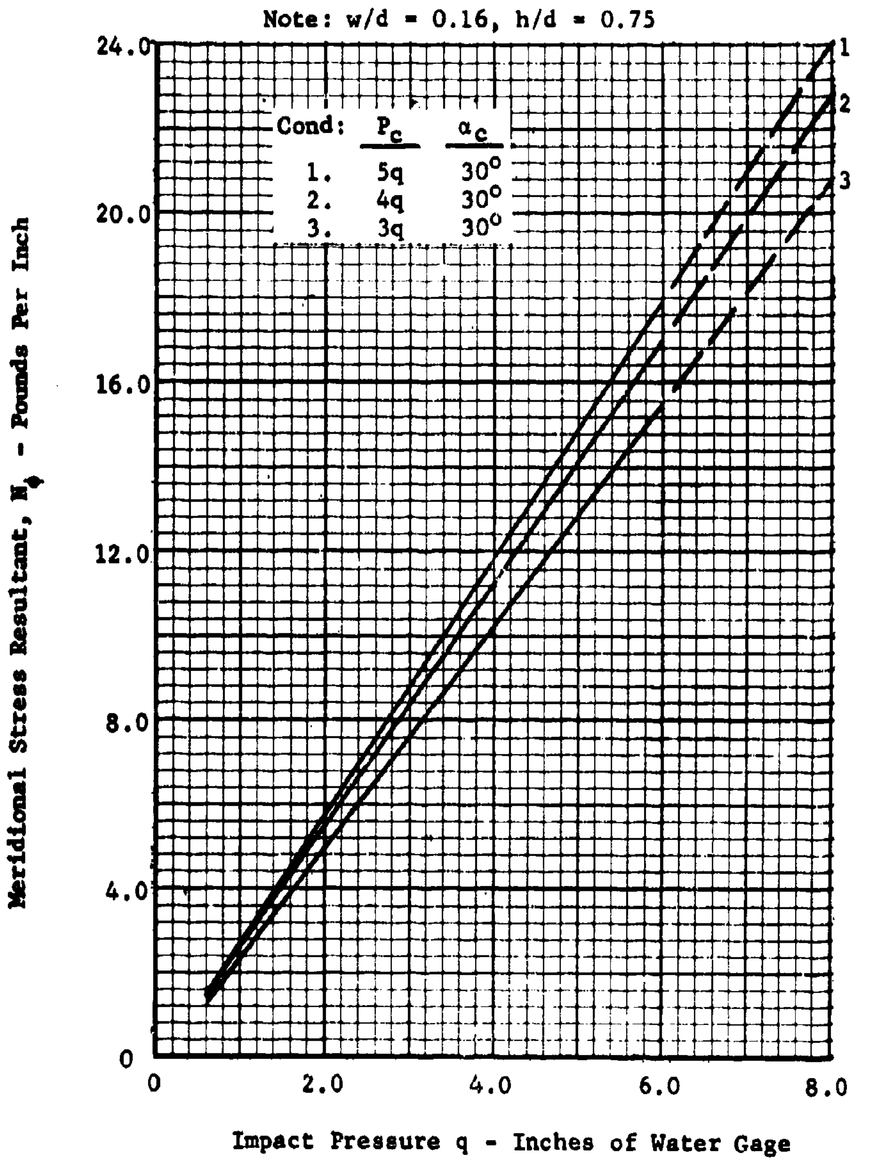


Figure 46. Variation of Meridional Stress Resultant with Impact Pressure, q; w/d 0.16, h/d = 0.75

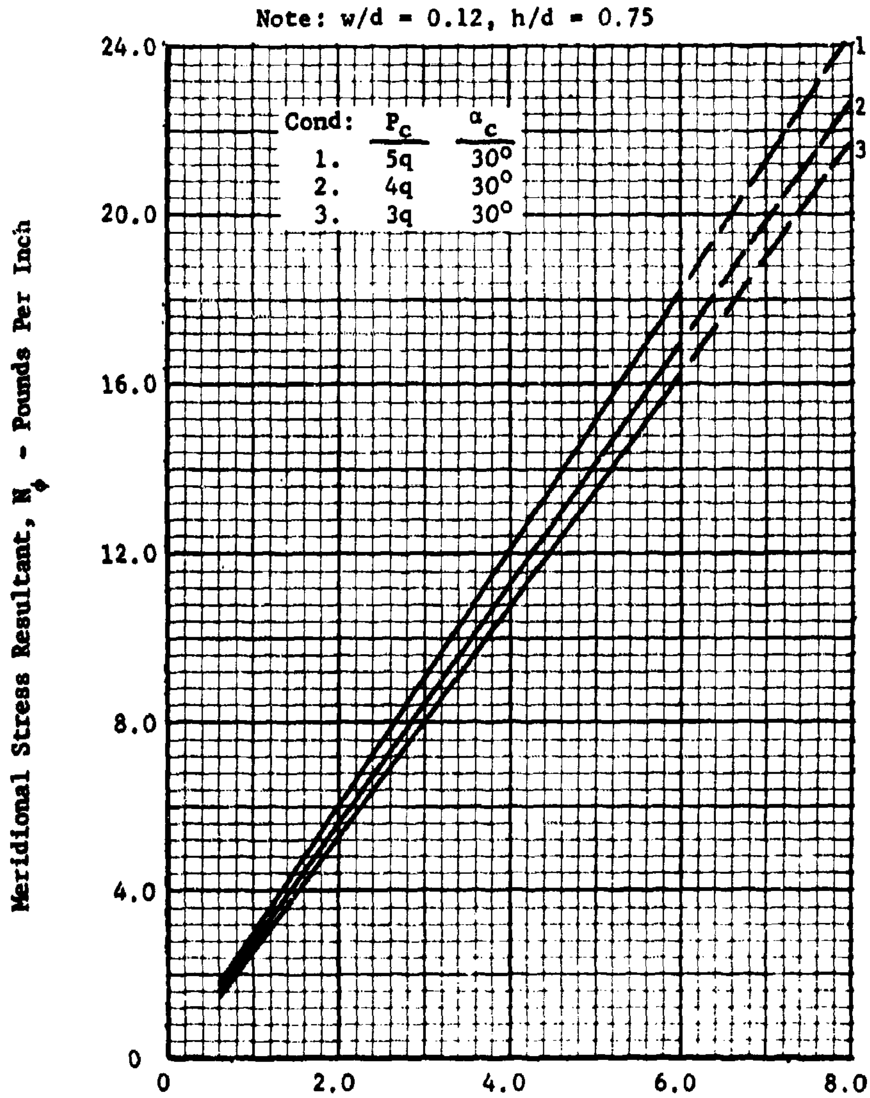


Figure 47. Variation of Meridional Stress Resultant with Impact Pressure, q; w/d = 0.12, h/d = 0.75

DOUBLE-WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

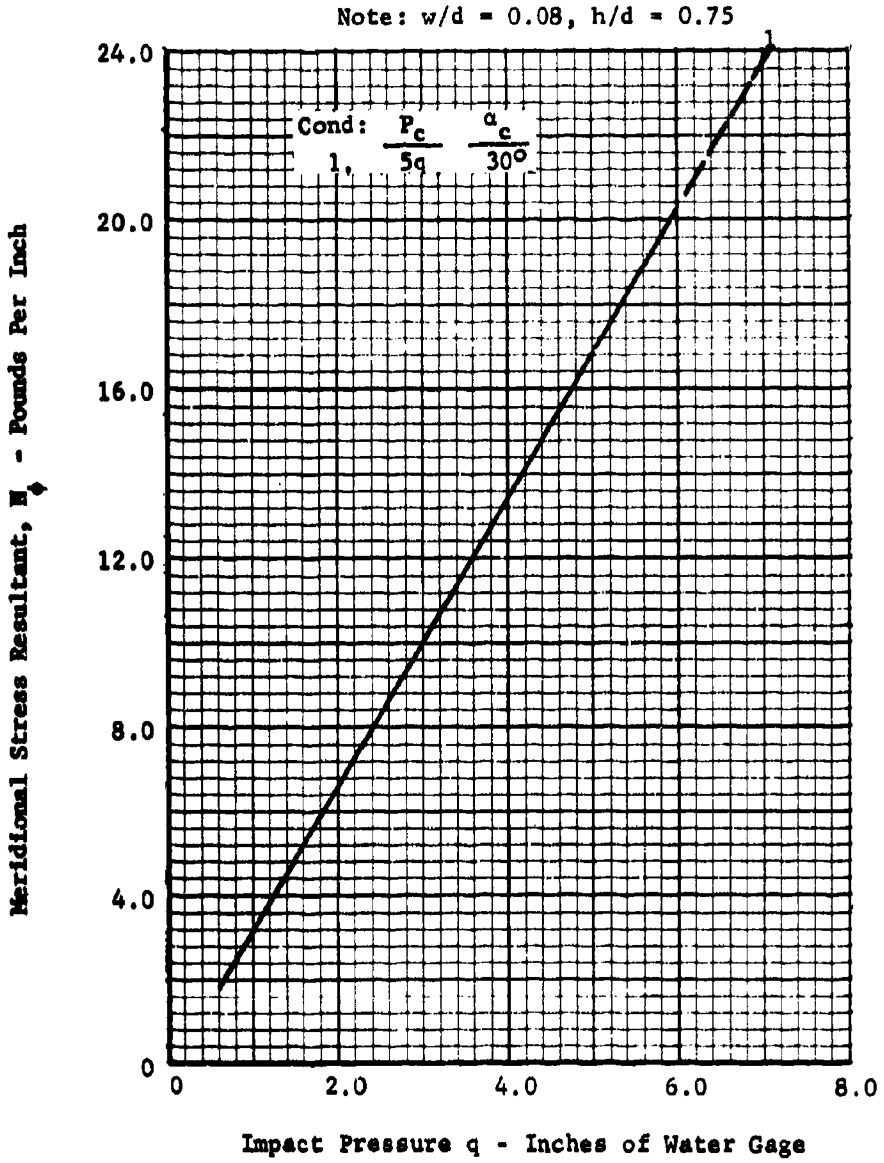


Figure 48. Variation of Meridional Stress Resultant with Impact Pressure, q; w/d = 0.08, h/d = 0.75

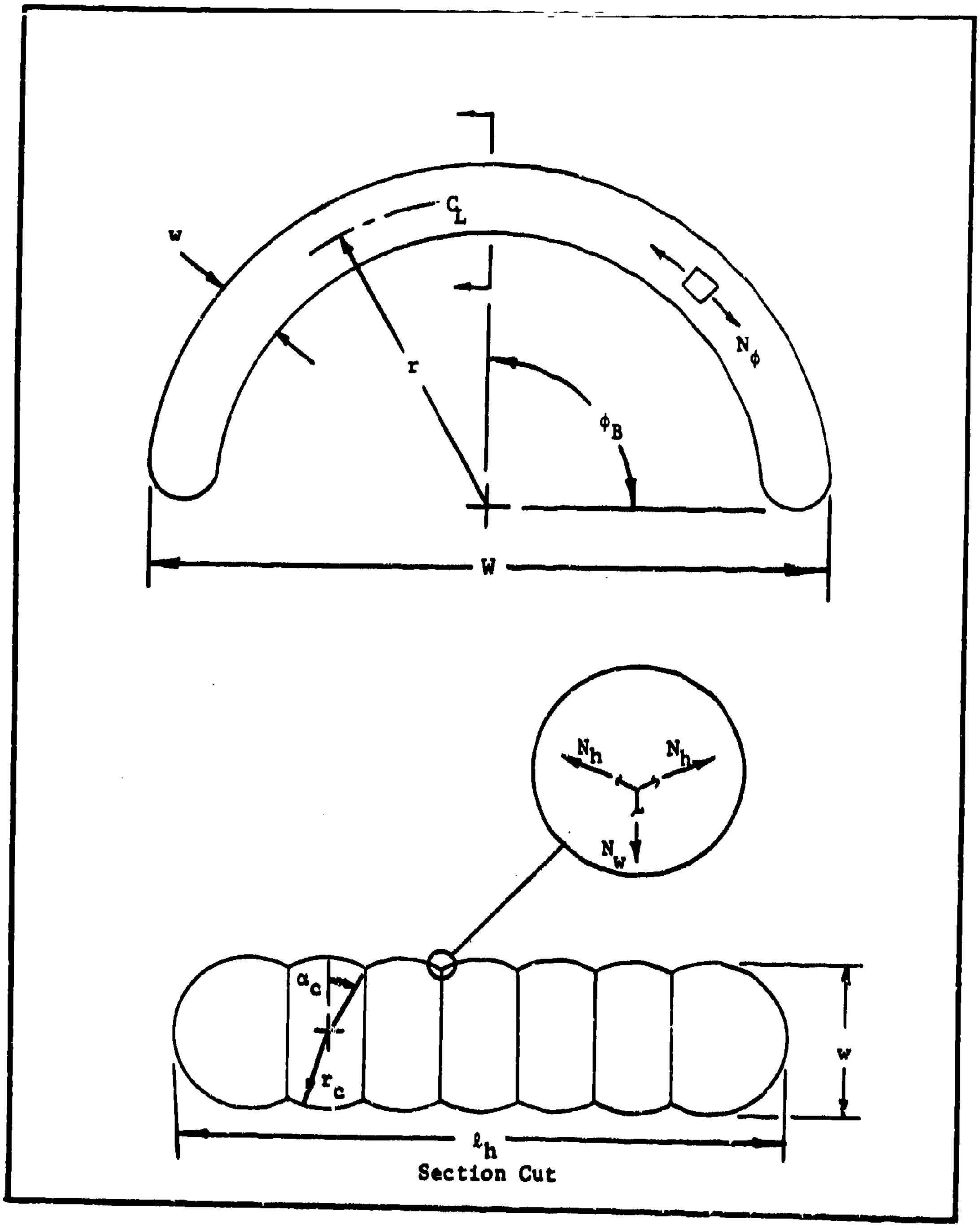


Figure 49. Coordinate System and Stress Resultants for a Double-Wall Cylindrical Tent with Circular Cross Section

FABRIC COATING WEIGHT

Legend:
———Vinyl Coating, Single-Ply, MIL-C-43086
— — —Vinyl Coating, Two-Ply Bias
-----Chloroprene, Single-Ply, MIL-C-43285
— - —Chloroprene, Two-Ply Bias

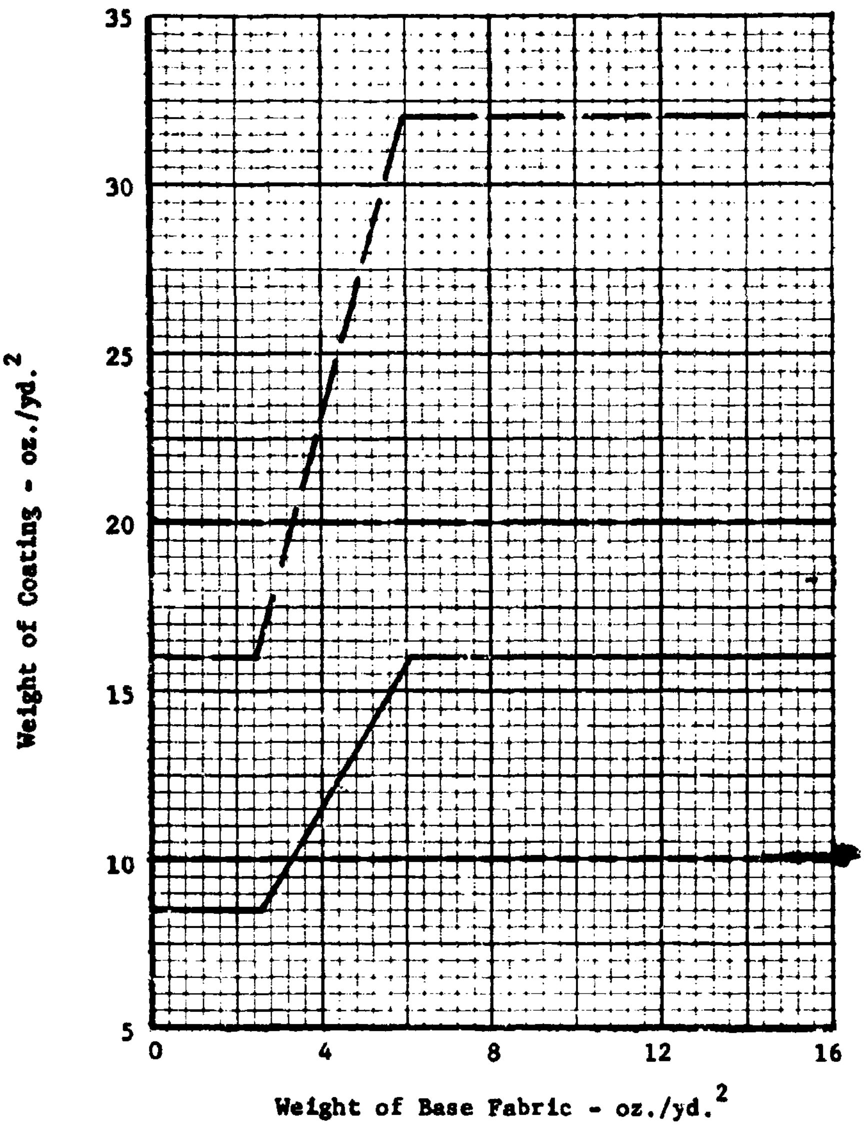


Figure 50. Weight of Coating for Single-and Two-Ply Coated Fabric.

SLIDE FASTENER AIR LOSS

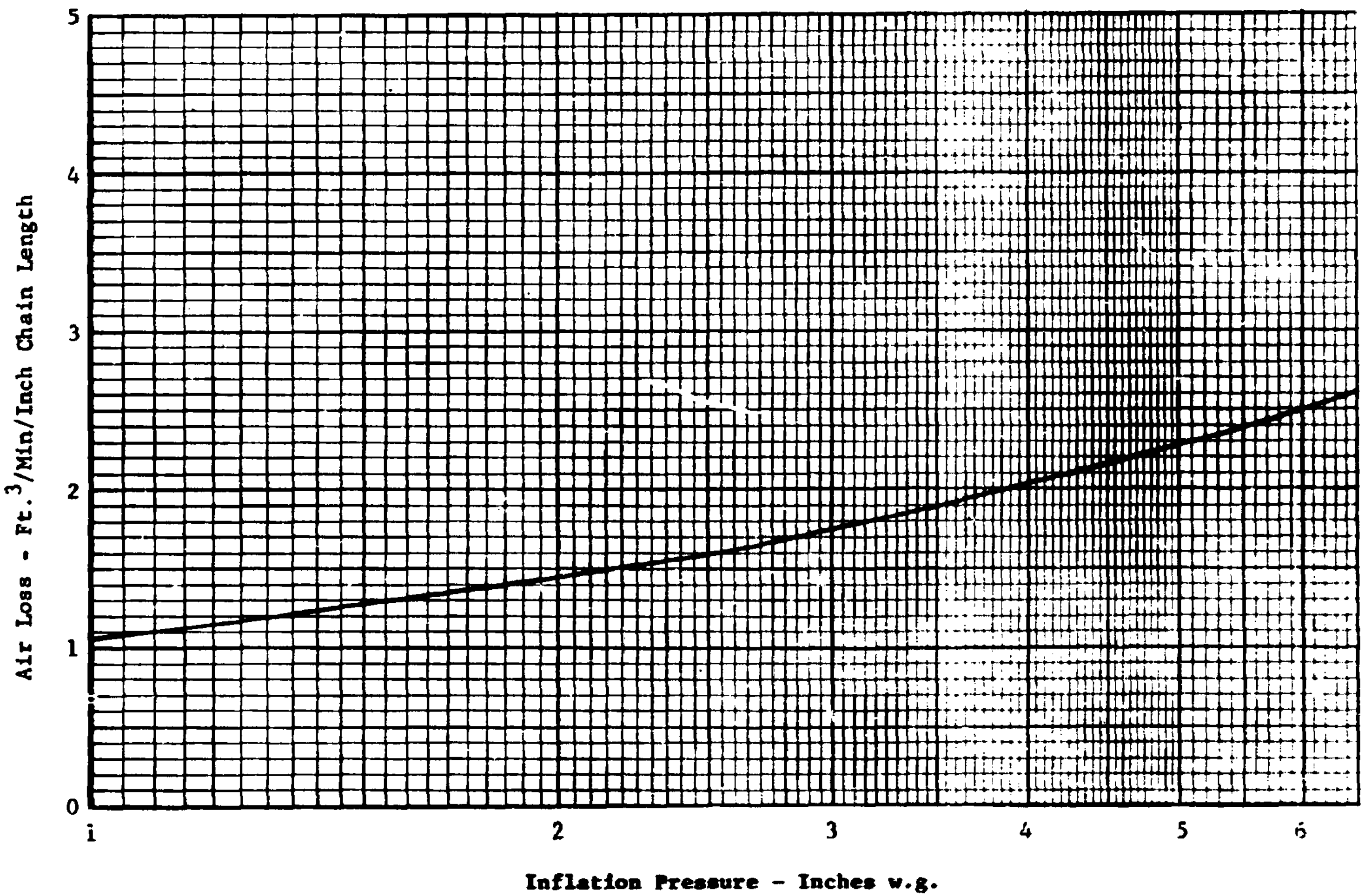


Figure 51. Air Loss through a #10 Crown Slide Fastener

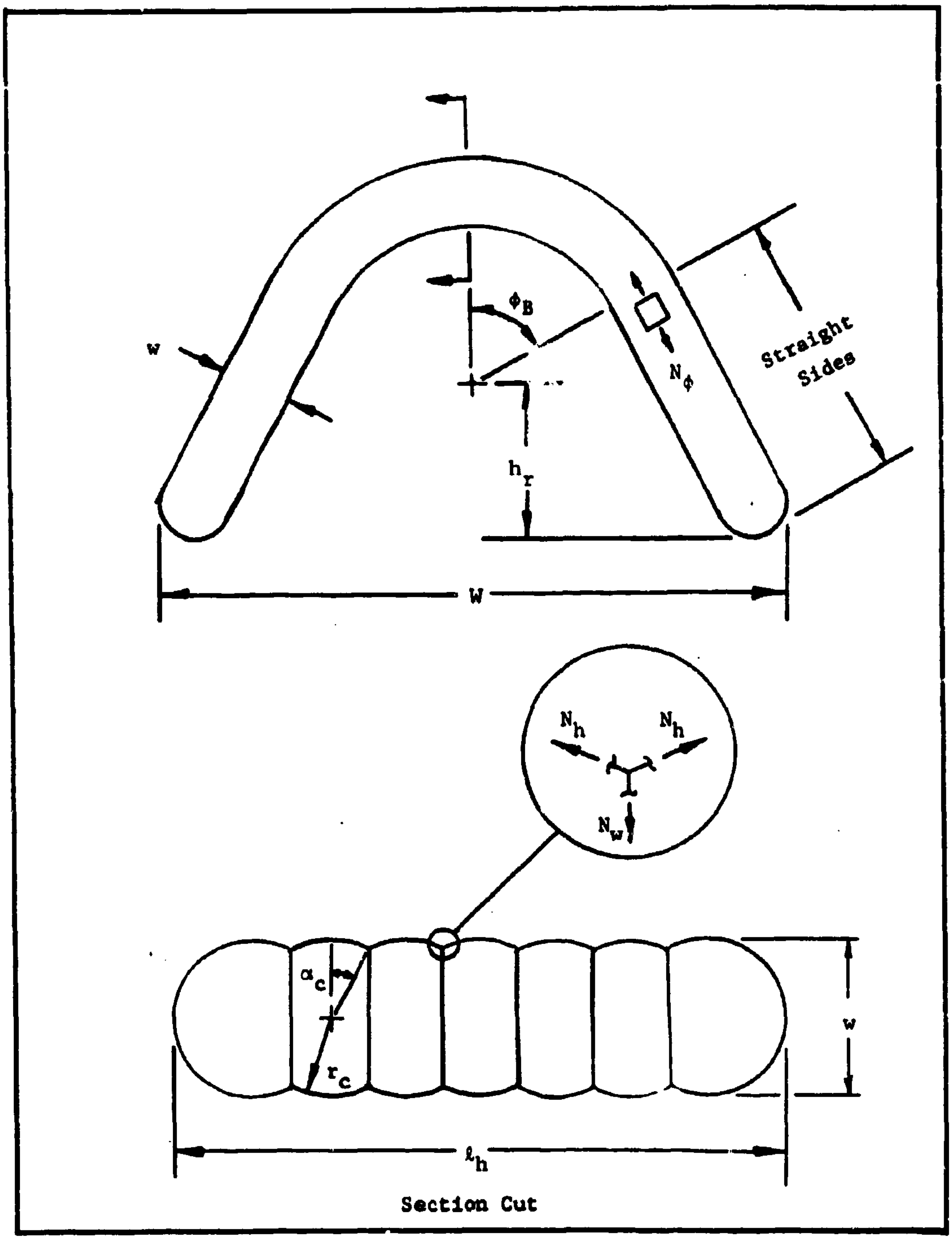


Figure 52. Coordinate System and Stress Resultants for a Double-Wall Cylindrical Tent with Straight Sides

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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3. REPORT TITLE

Design Manual for Ground-Mounted Air-Supported Structures (Single- and Double-Wall) (Revised)

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13. ABSTRACT

The objective of this design manual is to provide industry and Government suppliers with design information to fabricate functional and reliable air-supported structures at the lowest possible weight. The data and design information presented are based on wind tunnel tests and analytical determinations reported in a previous investigation.

Design information is given for spherical and cylindrical (single- and double-wall) air-supported structures. The data in general are presented in nondimensional coefficient form and, therefore, are applicable to full-scale structures within the range of parameters tested. Design information is presented as charts and tables on tent aerodynamic force and moment coefficients, anchor and guyline coefficients, structural deflections, material stresses, packaged volumes, and weight.

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