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TECHNICAL REPORT
67-35-ME

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

by

A. E. Dietz, R. B. Proffitt
and R. S. Chabot

Hayes International Corporation
Birmingham, Alabama

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

October 1966

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Mechanical Engineering Division

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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. The manual 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 a separate text. "Wind Tunnel Tests and Analyses of Ground Mounted Air Supported Structures". Wind tunnel tests were conducted in the six foot stability tunnel at Virginia Polytechnic Institute, Blacksburg, Virginia. The work was conducted for the U.S. Army Natick Laboratories, Natick, Massachusetts under Contract DA-19-129-AMC-129(N), during the period of July 1963 to October 1966.

Mr. Constantin J. Monego of the Mechanical Engineering Division 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 and R. S. Chabot 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 of the Virginia Polytechnic Institute and the personnel of the Technical Engineering Department of 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 Watertown Arsenal, Watertown, Massachusetts, for review and analysis of this report which resulted in many valuable comments and recommendations; to Mr. James H. Flanagan, Deputy Scientific Director for Engineering and Acting Chief of the Mechanical Engineering Division at the U. S. Army Natick Laboratories, for his constructive suggestions; and to Messrs. W. C. Whittlesey and C. W. Weikert for their encouragement and support of this work.

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SYMBOLS

A_o - Orifice area

A_c - Cross sectional area

A_s - Surface area

A_p - Planform Area

A_f - Floor area

A_e - Cell enclosed cross sectional area

AL - Anchor load

C_{AL} - Anchor load coefficient, single wall

C_{BL} - Base anchor load coefficient, double-wall

C_c - Coefficient of contraction

C_D - Drag coefficient

C_{GL} - Guy line coefficient

C_L - Lift coefficient

C_M - Pitching moment coefficient

C_N - Yawing moment coefficient

C_R - Rolling moment coefficient

C_Y - Side force coefficient

C_o - Orifice coefficient (0.65)

D - Drag

D_B - Data correction due to horizontal buoyancy

d - Reference length - Tent diameter

E - Modulus of elasticity

F - Force

f_b - Bending load

h - Tent height

h_r - Distance from ground plane to center of curvature

I - Moment of inertia about centroidal axis

K - Tent model shape factor

k_p - Impact pressure correction factor

L - Lift

L_B - Lift along body axis

ℓ_h - Length of tent

ℓ_m - Reference length for computing yawing moment coefficient

ℓ_r - Reference length for computing pitching moment coefficient

M - Moment

M_b - Initial buckling moment

M_c - Ultimate collapse moment

M_m - Yawing moment

M_y - Rolling moment

N_ϕ - Meridional stress resultant

$\overline{N}_\phi$ - Total meridional stress resultant

N_θ - Circumferential stress resultant

$\overline{N}_\theta$ - Total circumferential stress resultant

$N_{\phi\theta}$ - Shear stress resultant

N_{xe} - Stress resultant due to internal pressure

N_x - Longitudinal stress resultant

N'_{0x} - **Shear stress resultant**

n - **Number of cells in a tent**

P - **Static pressure**

P_c - **Cell Pressure**

P_e - **Tent enclosure pressure**

P_{ext} - **External pressure**

$P_{(\phi, \theta)}$ - **Radial load**

P_A - **Axial load**

P_r - **External loading**

P_T - **Axial load + Pressure load**

P_t - **Stagnation pressure**

P_y - **Side force**

P_{yB} - **Side force in body coordinate system**

q - **Dynamic (impact) pressure**

Q - **Volume flow**

r - **Tent radius**

r_o - **Outside tent radius**

r_i - **Inside tent radius**

r_c - **Cell radius**

R - **Universal gas constant,**

R_N - **Reynolds number, dimensionless**

S_ϕ - **Arc length in ϕ direction**

S_α - **Arc length in α direction**

S_β - **Arc length in β direction**

N_w - Web stress resultant

N_h - Hoop stress resultant

T - Absolute temperature

U - Velocity

$\overline{V}$ - Tent enclosed volume

V - Shear load

V_c - Cell volume

W - Tent width

w - Cell width

m - Distance from neutral axis

x, y, z - Cartesian coordinates

GREEK SYMBOLS

α_c - Cell reference angle

α - Tent reference angle

β - Tent reference angle

δ_F - Tent deflection - front

δ_H - Tent deflection, top

δ_B - Tent deflection, rear

ϵ_{SB} - Correction factor for solid blocking of wind tunnel due to presence of model

γ - Ratio of tent volume to tent weight

μ - Viscosity of air

θ - Curvelinear coordinate

ψ - Tent yaw angle

ρ - Density of air

ζ - Additional correction factor for wake gradients

ν - Poisson's ratio

λ - Tent geometry reference angle

ϕ - Curvelinear coordinate

Ω - Fabric weight/unit area

χ - Unit vector

ξ - Unit vector

Υ - Unit vector

ϵ_θ - Meridional strain

GLOSSARY OF TERMS

Reynold's Number - A dimensionless parametric ratio of th inertia forces and the viscous forces acting on a body immersed in a moving fluid. The mathematical expression for Reynold's Number is

$$R_N = \frac{\rho U l}{\mu}$$

Critical Reynold's Number - The Reynold's Number at which the boundary layer upstream of a point of separation changes from laminar to turbulent flow. The critical Reynold's Number for both spheres and cylinder is approxinately 500,000.

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

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

Potential Flow - A theoretical treatment of fluid flow which assumes the fluid to be inviscid. Consequently, a body in motion with potential flow has a symmetrical pressure distribution which results in zero drag forces.

Horizontal Bouyancy - The general tendency for the model in a closed jet wind tunnel to be "drawn" downstream due to the longitudinal static pressure gradient that exists in the test section.

Solid Blocking - The increase in air velocity due to the presence of a model in a wind tunnel test section caused by the reduction in the area through which the air is allowed to flow.

Planform Area - Maximum projected area in horizontal plane.

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

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 another publication.

Design information is given for spherical cylindrical air-supported tents. 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 coefficient. Anchor and guideline coefficients, structural deflections, material stresses, packaged volume, and weight.

SECTION I

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 Tents and data estimated to cover other basic configurations.

In order 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 tents. 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 document presents the results of the tests and analyses in a concise form of design tables and curves for both single and double-wall tents and sample problems illustrating the use of the data.

SECTION 2

GENERAL DISCUSSION

2.1 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 plexiglas 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 light weight 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 photographs of some existing single and double-wall air-supported structures and Table 1 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 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.

2.2 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:

RF 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.

Lightweight, 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

3.1 GENERAL

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

Aerodynamic forces; Lift, Drag and 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 Part I of this manual.

3.2 AERODYNAMIC FORCES

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. Twenty-six single and double-wall tents were tested to 105 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 tested differed from the double-wall shapes in that the ends were spherical for single-wall and flat for double-wall. The aerodynamic force data is presented in non-dimensional coefficient form by dividing the force data by a reference area, A_p, and the dynamic 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. Planform areas are given by the following expressions for different tent types:

Sphere $A_p = \pi \left(\frac{w}{2}\right)^2$

Cylinder with spherical ends

$$A_p = \pi \left(\frac{W}{2}\right)^2 + W \left(\ell_h - W\right)$$

$$A_p = W\ell_h$$

where A_p = Planform area in ft.^{2}

W = Width of tent in ft.

ℓ_h = Length of tent in ft.

The planform areas for tents with radii up to 80 feet are shown in Table II.

The dynamic pressure due to wind velocity is defined by the following mathematical expression:

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

where q = Dynamic pressure in lbs. /ft.^{2}

ρ = Density of air in slugs/ft.^{3} or

ρ = 0.00238 for a standard day at sea level

U = wind velocity, ft/sec

The variation of dynamic pressure with wind speed at sea level and 59° F. is shown in Figure 9. The variation of dynamic pressure with pressure,altitude and temperature is shown in Figure 10.

3.2.1 Lift

The lift coefficient is defined as follows:

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

where C_L = Lift coefficient, non dimensional

L = Total lift in pounds

q = Dynamic pressure in pounds/ft.^{2}

A_p = Planform area in ft.^{2}

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

3.2.2 Drag

The drag coefficient is defined as follows:

$$C_D = \frac{D}{qA_p}$$

where C_D = Drag coefficient, non dimensional

D = Total Drag in pounds

q = Dynamic pressure in pounds/ft.^{2}

A_p = Planform area in ft.^{2}

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

3.2.3 Moments

The moment coefficient is defined as follows:

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

where C_M = Moment coefficient - non dimensional

M = Moment in foot pounds

q = Dynamic pressure in pounds per square foot

A_p = Planform area in square feet

ℓ_m = Reference length feet.

The variation in pitching moment with tent height to diameter ratio and width to length ratio are shown in Fig. 15 for single wall tents and in Fig. 16 for double wall tents.

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

Lift $L = C_L q A_p$

Drag $D = C_D q A_p$

Moment $M = C_M q A_p \ell_m$

The coefficients C_L, C_D and C_M are obtained from the appropriate curves. The dynamic pressure, q, is obtained from Figure 9. The reference area A_p is obtained from Table V or by calculation using the dimensions of the tent. The reader is referred to Section 4 sample problems for examples in which graphs 9, 11, 13 and 15 are used.

3.3 TENT DEFLECTION AND STABILITY

3.3.1 Tent Deflection

The maximum tent deflection resulting from 105 miles per hour wind are shown in Figures 17 through 20 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 tent size is known the maximum tent deflection data can be used to establish the maximum usable tent radius, in accordance with the following:

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

where r = radius of tent known

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

r' = usable tent radius

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

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

where r' = minimum radius established

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

r = Radius of tent.

3.3.2 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 evaluation of tent stability becomes a matter of individual determination. However the following general conclusion may be made for single-and double-wall tents:

Single wall tents

The single-wall tent configurations, with the exception of the 7/8 sphere and all tents with a width to length ratio of 1: 4 were found to be stable.

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.

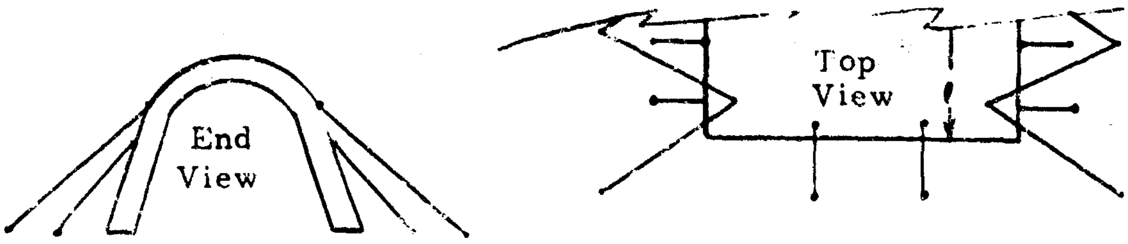
The enclosure pressure for single-wall tents is an important factor in controlling tent motion. Although permissible tent deflections, as required by tent usage, could establish pressure requirements, tests indicate that only with enclosure pressures equal to or greater than the test dynamic pressure,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

Double Wall Tents

The ratio of tent deflection to tent radius versus cell pressure in inches water gage for double wall tents is shown in Figure 21 . With double wall tents, the cell pressure 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 for cell pressures equal to or greater than the test dynamic pressure did both good stability and deflection characteristics exist. The stability of double wall tents improved as the cell inflation pressure was increased from 6 to 16 inches w. g. No significant gains in stability were achieved beyond an inflation pressure of 16 inches water gage.

Tent-cell size was also observed to be a factor in tent stability since an increase in cell size increased the rigidity of the tube for the same cell pressure.

To minimize double wall tent corner deflections, guy lines 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 and tent side. The best guy line configuration consists of a combination high (0. 8 tent height) and low (0. 4 tent height) line arrangement, with the upper guy lines angles 45 degrees to the tent side and the lower guy lines perpendicular to the tent side when viewed from the top of the tent.



Double Wall Guy Line Arrangement

3.4 ANCHOR LOADS

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

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

where: C_{AL} = Anchor load coefficient

AL = Anchor Load, lbs.

q = Dynamic pressure, lbs./ft.^{2}

A_p = Reference area, ft.^{2}

3.4.1 Single-Wall Tents

In single-wall tents the lift due to internal pressure must be added to the aerodynamic lift. The load on the anchors due to internal pressure can be calculated from the following expression .

$$P_e A_f = AL_e$$

where P_e = Internal pressure, lbs./ft.^{2}

A_f = Floor area, ft.^{2}

The total anchor load for single-wall tents is calculated as follows (Fig. 22):

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

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

$$\frac{\text{Total } AL}{2\pi y + 2(\ell_h - 2r)}$$

where $y = \sqrt{2hr - h^2}$ (h = height of tent)

r = Radius of tent in feet

ℓ_h = length of tent in feet

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

$$\frac{\text{Total } P_{AL}}{\text{* Anchor Holding Capacity}} = \text{No Anchors}$$

$$\frac{2\pi y + 2(\ell - 2r)\ (\text{ft.}) \times \text{anchor holding capacity}}{\text{TOTAL AL}} = \text{anchor spacing in feet}$$

where π = 3.1416

ℓ_h = Length of tent in feet

r = Tent radius in feet

P_{AL} = Total anchor load for tent in pounds.

3.4.2 Double-Wall Tents

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

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

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

where C_{AL} = Anchor load coefficient for the base of tent

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

BL = Anchor load on base, lbs.

GL = Anchor load on guy lines, lbs.

q = Dynamic pressure, lbs/ft.^{2}

A_p = Reference area, ft.^{2}

The variation of anchor loads with tent height to diameter ratios and width to length ratio is shown in Figure 23 for the base anchors and Figure 24 for the guy lines.

The total anchor load can be calculated as follows:

$P_{AL} = C_{AL} q A_p$ for base anchors load,

---

* Anchor holding capacity @ 1500 lbs.

and GL $= C_{GL} q A_p$ for guy line loads

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

$$\frac{C_{BL}\, qA_p}{\text{Anchor holding capacity-lbs.}} = \text{No. of base anchors}$$

$$\frac{C_{GL}\, qA_p}{\text{Anchor holding capacity -lbs.}} = \text{No. of guy line anchors}$$

Anchor holding capacity is taken at 1500 lbs.

3.5 STRUCTURAL STRESSES

The fabric stress design curves are presented in three parts:

1. Single-wall spherical tents
2. Single-wall cylindrical tents with spherical ends.
3. Double-wall cylinders with flat ends.

For qualifications regarding stresses, see Ref. 4.

3.5.1 Single-Wall Spherical Tents

The design curves for spherical tents generated in this study are shown in Figures 25 through 27 inclusive.

The design curves are used in the tent analysis as follows:

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

2. Enter figure 25 at the required h/d and read the stress coefficients.

$$\frac{N_\phi}{qr} \text{ and } \frac{N_\theta}{qr}$$

where N_ϕ = meridional stress resultant in pounds per inch

N_θ = Circumferential stress resultant in pounds per inch

q = Dynamic pressure in pounds per square inch

r = Tent radius in inches

3. Enter Figure 27 and read stress factors:

$$\frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)} \quad \text{and} \quad \frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)}$$

where ν = assumed Poisson's ratio.

4. Multiply stress coefficients by stress factors to get stress for material with Poisson's ratio

$\nu = 0.5$

$$\text{correct } \frac{N_\phi}{qr} = \frac{N_\phi}{qr} \cdot \frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)}$$

$$\text{correct } \frac{N_\theta}{qr} = \frac{N_\theta}{qr} \cdot \frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)}$$

5. Multiply corrected stress coefficient by design dynamic pressure, q in p.s.i. and tent radius, r, in inches to get stress resultants N_ϕ and N_θ in pounds per inch of aerodynamic load.

$$N_\phi \text{ lbs/inch} = \frac{N_\phi}{qr}_{\text{correct}} \, qr$$

$$N_\theta \text{ lbs/inch} = \frac{N_\theta}{qr}_{\text{correct}} \, qr$$

6. If variation in N_θ with apex angle ϕ (Stress distribution) is desired, determine stress ratio as follows:

$$\frac{N_\theta(\phi)}{N_\theta(\text{peak})} \times N_\theta$$

The stress ratio $\frac{N_\theta(\phi)}{N_\theta(\text{peak})}$ is obtained from Figure 26 depending on appropriate h/d. Multiply stress ratios by N_θ to get variation (stress distribution) of N_θ versus apex angle ϕ.

7. The total stress resultant is the sum of aerodynamic stress as calculated above and the internal pressure as follows

$$\overline{N_\phi} = N_\phi \text{ (from 5)} + \frac{P_e r}{2}$$

$$\overline{N_\theta} = N_\theta \text{ (from 6)} + \frac{P_e r}{2}$$

where $\overline{N_\phi}$ = Resultant meridional stress in pounds per inch

$\overline{N_\theta}$ = Resultant circumferential stress in pounds per inch

P_e = Internal pressure in pounds per square inch

r = Radius in inches

The fabric to be used must withstand these stresses.

3.5.2 Single-Wall Cylindrical Tents With Spherical Ends

The design curves for single wall cylindrical tents with spherical ends presented in this study and analysis are included as Figures 28 through 32.

The design curves are utilized in the analysis of the tent as follows:

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

2. Enter Figures 28 through 32 (choosing the appropriate Figure by the h/d ratio of the tent) at the required W/ℓ_h ratio and read stress coefficients for both the cylindrical section and the spherical ends. This will provide the following stress coefficients:

   $$\frac{N_\phi}{qr} \text{ maximum and } \frac{N_\theta}{qr} \text{ maximum}$$

   for cylinder and spherical ends where

   N_ϕ = meridional stress resultant in pounds per inch

   N_θ = circumferential stress resultant in pounds per inch.

   q = Dynamic pressure in pounds per square inch

   r = Radius in inches

   For stress coefficients for other sizes than those presented, linear interpolation within the range given will yield corresponding results.

3. Enter Figure 27 and read the stress factor $\frac{N_\phi\ (\nu = 0.5)}{N_\phi\ (\nu = 1.0)}$

and $\frac{N_\theta \ (\nu = 0.5)}{N_\theta \ (\nu = 1.0)}$.

where ν = Poisson's ratio.

N_ϕ = Meridional stress resultant

N_θ = Circumferential stress resultant

4. Multiply the stress coefficients by the stress factors to get stress factors for material with Poisson's ratio $\nu = 0.5$. Products are corrected stress coefficients

$$\frac{N_\phi}{qr} \text{ corrected} = \frac{N_\phi}{qr} \cdot \frac{N_\phi \ (\nu = 0.5)}{N_\phi \ (\nu = 1.0)} \quad \text{cylinder}$$

$$\frac{N_\phi}{qr} \text{ corrected} = \frac{N_\phi}{qr} \cdot \frac{N_\phi \ (\nu = 0.5)}{N_\phi \ (\nu = 1.0)} \quad \text{sphere}$$

$$\frac{N_\theta}{qr} \text{ corrected} = \frac{N_\theta}{qr} \cdot \frac{N_\theta \ (\nu = 0.5)}{N_\theta \ (\nu = 1.0)} \quad \text{cylinder and sphere}$$

5. Multiply corrected stress coefficient by the design dynamic pressure in lbs./in. and tent radius, r, in inches. The products are stress resultants N_ϕ and N_θ in pounds per inch for the aerodynamic forces acting on the tent

$$N_\phi = \frac{N_\phi}{qr}_{\text{corrected}} qr \quad \text{cylinder}$$

$$N_\phi = \frac{N_\phi}{qr}_{\text{corrected}} qr \quad \text{sphere}$$

$$N_\theta = \frac{N_\theta}{qr}_{\text{corrected}} qr \quad \text{cylinder and sphere}$$

6. The total stress resultant is the sum of the aerodynamic stress and the stress on the fabric due to internal pressure

$$\overline{N_\phi} = N_\phi + P_e r \quad \text{cylinder}$$

$$\overline{N_\phi} = N_\phi + P_e r \quad \text{sphere}$$

$$\overline{N_\theta} = N_x = N_\theta + \frac{P_e r}{2} \quad \text{cylinder and sphere}$$

where N_x = Stress resultant at junction of cylinder and spherical end. Axial stress on cylinder = N_θ circumferential stress of spherical end in pounds per inch.

$\overline{N}_\phi$ = Meridional stress resultant in pounds per inch

$\overline{N}_\theta$ = Circumferential stress resultant in pounds per inch

P_e = Internal pressure in pounds per square inch

r = Radius of the tent in inches

3.5.3 Double-Wall Cylindrical Tents With Flat Ends

The design curves generated for double-wall tents with flat ends in this analysis are presented herein as Fig. 33-35. The meridional stress resultants were computed and plotted versus q, dynamic pressure in inches water gauge. The fabric web and hoop loads were plotted as a function of cell radius, internal pressure and cell angle.

The design curves are utilized in the analysis of the tent 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 w/d, and inflation pressure. w/d = 0.12 was found to be the best ratio from a stability and weight standpoint.
3. Enter Figure 33 to obtain web stress in pounds/inch.
4. Enter Figure 34 to obtain hoop stress in pounds per inch.
5. Enter Figures 35 through 43 to find meridional stress resultant in pounds per inch.

3.6 FABRIC STRESS

The structural stresses were resolved in two orthogonal directions. This is convenient since it can be related to the warp and filling directions of a fabric. Therefore for single wall tents the meridional stress resultant, N_ϕ and the circumferential stress resultant, N_θ are assumed to be the warp and filling stress in a fabric. Which stress relates to warp or which to the filling stress will depend on the orientation or the fabric with respect to the directional stresses of the structure.

In double-wall tents, it is assumed that the warp direction is oriented along the length of the tube while the filling direction is oriented in the hoop direction. Therefore the longitudinal stress is equivalent to the fabric warp stress while the hoop stress is equivalent to the filling stress in a fabric.

3.6.1 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, allowances 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 their 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, Ref. 1 recommends that a safety factor of three (3) be used. So that

$$N_\phi \times 3 = \text{Design strength of material}$$

$$N_\theta \times 3 = \text{Design strength of material}$$

3.7 FABRIC WEIGHTS

3.7.1 Weight of Base Fabric

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

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

The weight of base fabric is calculated as follows:

$$(\text{safety factor})(\text{maximum stress}) \div \frac{\text{lbs}}{\text{in}} \cdot \frac{\text{sq yd}}{\text{oz}} = \text{Wt of base fabric}$$

3.7.2 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 15 .

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

3.8 BLOWER CHARACTERISTICS

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

3.8.1 Single Wall Tents:

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 which are, for the most part, not amenable to calculations but 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:

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

where

Q = Discharge in cu. ft./min

A = Area of orifice in sq. ft.

ΔP = Differential Pressure, in inches w.g.

$g\rho$ = Density of Air in lbs./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 44 .

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.

3.8.2 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. Present technology for the development of double wall tents requires that an empirical determination be made of the relationship between cell depth and inflation pressure for each tent. Studies are underway to develop the necessary constants for establishing an accurate and working relationship among tent size, cell depth inflation pressure and free stream dynamic pressure. The results of these studies will be included in the manual when they become available.

Experience with Military double wall tents have 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:

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

3.9 TENT WEIGHT AND CUBE

3.9.1 Tent Weight

Single-Wall Tents

$$\text{Total weight-lbs.} = (\text{Fabric Area -yds.}^2)(\text{Coated Fabric Weight-oz/yd}^2)(1.5/16)$$

Double-Wall Tents

Wall and roof section

$$\text{Total weight of Wall \& Roof Sections-lbs} = \text{Fabric Area-yds.}^2)(\text{coated Fabric Weight-oz/yd.}^2)(1.33/16).$$

End Curtain

$$\text{Total Weight of End Curtains} = (\text{Fabric Area-yd.}^2)(\text{Coated Fabric Weight oz/yd.})(1.5/16)$$

3.9.2 Package Cube

Single-Wall Tents

$$\text{Package cube-ft}^3 = (\text{Total Weight of tent - lbs})(0.1\ \text{ft}^3/\text{lb})$$

Double-Wall Tents

$$\text{Package cube-ft}^3 = (\text{Total Weight of Roof \& Wall + Total Weight of End Curtains})(0.065)$$

TABLE I

GENERAL 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	W - 17 ft. 6 in. H - 13 ft. L - 61 ft.	Cylindrical Spherical Ends	18
Double Wall			
Assembly Area	H - 27 ft. W - 54 ft. L - 12 ft. Wall Depth - 3 ft.	Cylindrical	20
Aviation Maintenance	H - 18 ft. - 4 in. W - 28 ft. L - 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 - 13 ft.	Cylindrical	Roof - 14 End - 16

* Fabric Weight, oz/yd^2

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	45706	71306	96906

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

Table III
Weight Strength Relationship of Plain Weave Fabrics

Fiber Type	Specific Gravity	Weight-Strength Relationship $\frac{\text{lbs.} - \text{sq yd}}{\text{in.} \times \text{oz.}}$
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

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* 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.

SECTION 4
SAMPLE DESIGN PROBLEMS

4.1 GENERAL EQUATIONS

1. LIFT = $C_L q A_p$

2. DRAG = $C_C q A_p$

3. MOMENT = $C_M q A_p r$

4. ANCHOR LOAD = $C_{AL} q A_p$

5. GUY LINE LOAD = $C_{GL} q A_p$

6. PLANFORM AREA

   Single-Wall Spheres and Cylinders = $A_p = \pi \left(\frac{W}{2}\right)^2 + W (\ell - W)$

   Double-Wall Cylinders = $A_p = W \ell_h$

7. FLOOR AREA

   Single-Wall Spheres and Cylinders = $S_f = \pi y^2 + 2y (\ell - 2r)$

   where $y = (2hr - h^2)^{1/2}$

   Double Wall Cylinders - $A_f = W \ell_h$

8. SURFACE AREA

   Single-Wall Spheres and Cylinders

   $$A_f = 2 \pi r - r \lambda (\ell - 2r) + 4\pi r^2 - 2\pi r (r - x) \left(\frac{1}{9}\right) \text{yds}^2$$

   where $\lambda = \tan^{-1} y/x$, $y = (2rh - h^2)^{1/2}$, $x = (r^2 - y^2)$

   Double-Wall Cylinders

   $$A_f = \pi r \ell + 4 \ell (h - r) + \pi r^2 + 4 r (h - r)$$

9. PERIMETER (To determine Anchor Spacing)

   Single-Wall Cylinders and Spheres, $P = 2\ell - 4r + 2 \pi y$

Double-Wall Cylinders $P = 2\ell_h$

10. INFLATION LOADS

Single-Wall Cylinders and Spheres

$$\text{Load} = P_e A_f$$

11. NUMBER OF ANCHORS REQUIRED (Based on an 1500 lb/anchoring device)

Single-Wall Cylinders and Spheres

$$\text{No.} = \frac{\text{Inflation Load} + \text{Anchor Load}}{1500}$$

Double-Wall Cylinders

$$\text{No.} = \frac{\text{Anchor Load}}{1500} + \frac{\text{Guy Line Load}}{1500}$$

12. ANCHOR SPACING

Single-Wall Cylinders and Spheres

$$\text{Spacing} = \frac{\text{Perimeter}}{\text{No. Anchors}}$$

Double-Wall Cylinders -

13. DYNAMIC PRESSURE

$$q = q\ (\text{Standard Day})\ (k_p)$$

where k_p is correction factor
for non-standard day found in fig. 10

14. FABRIC STRESS

Single-Wall Cylinders and Spheres

$$\text{Uncorrected } N_\theta = qr\left(\frac{N_\theta}{qr}\right)$$

$$\text{Uncorrected } N_\phi = qr\left(\frac{N_\phi}{qr}\right)$$

$$N_\theta = N_\theta \text{ (Uncorrected) } \frac{N_\theta (\nu = 0.5)}{N_\theta (\nu = 1.0)}$$

$$N_\phi = N_\phi \text{ (Uncorrected) } \frac{N_\phi (\nu = 0.5)}{N_\phi (\nu = 1.0)}$$

Total Stress Resultant, $\overline{N_\phi}$

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

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

Double-Wall Cylinders

Meridional Stress Resultant, N_ϕ is read from Figs. 35-43.

Hoop Stress Resultant, $N_h = q \left(\frac{N_h}{q}\right)$ read from Fig. 34.

Web Stress Resultant, $N_w = q \left(\frac{N_w}{q}\right)$ read from Fig. 33.

15. FABRIC WEIGHT

Fibre Weight - Strength Constant, $\frac{\# - \text{yd.}^2}{\text{in.} - \text{oz.}}$ read from Table III.

Weight of Base Fabric $= 3 \, (N\phi \text{ or } N\theta) \div \left(\frac{\# - \text{yd.}^2}{\text{in.} - \text{oz.}} \right)$

or, for Double Wall Weight $= 3 \, (N_\phi \text{ or } N_h) \div \left(\frac{\# - \text{yd.}^2}{\text{in.} - \text{oz.}} \right)$

and wt $= 3 \, N_W \div \left(\frac{\# - \text{yd.}^2}{\text{in.} - \text{oz.}} \right)$

16. SLIDE FASTENER LENGTH

Single-Wall

$$\text{length} = \pi r - r\lambda + \ell_h - 2\sqrt{2rh - h^2}$$

where $\lambda = \tan^{-1} y/x$

and $y = \sqrt{2rh - h^2}$

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

17. CELL VOLUME

$$V_c = \frac{\pi r^2 \ell_h - \pi \ell_h (r-w)^2}{2} + 2\ell_h (h-r)\, w$$

SAMPLE DESIGN PROBLEMS

4.2 KNOWN TENT SHAPE

4.2.1 Single-Wall Sphere

Given: Width - 30', height - 22.5', $h/d = 3/4$,
Pressure altitude - Sea level
Temperatures expected - 30° F to + 60° F
Wind velocity - 90 kts

1. Determine Dynamic Pressure, q.

   A. At 90 kts, q (standard day) = 27 psf. Fig. 9 *

   B. Correction factor = 1.21 Fig. 10

   C. q (corrected) = (27)(1.21) = 32.7 psf.

2. Determine Aerodynamic Loads.

   A. Lift = $C_L q A_p$

   $C_L = 0.65$ Fig. 11

   $q = 32.7$

   $A_p = \pi r^2 = \pi (15)^2 = 709 \text{ ft.}^2$

   Lift = $(0.65)(32.7)(709) = 15,050$ lb.

   B. Drag = $C_D q A_p$

   $C_D = 0.38$ Fig. 13

   $qS_t = 32,200$ lb.

   Drag = $C_D q A_p = (0.38)(23,200) = 8,810$ lb.

3. Determine Anchor Spacing.

   A. Load due to wind force

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* Figure numbers refer to appropriate chart providing the variables required for inclusion in the equation. See List of Illustrations, pg vi, for location within the text.

C_{AL} = 1. 5 Fig. 22

qA_p = 23, 200 lb.

wind load = $C_{AL} qA_p$ = (1. 5)(708)(32. 7) = 34, 700 lbs.

B. Load due to inflation pressure

since P_e = q for stability, P_e = 32. 7 psf.

Floor area of tent is given by

$$A_f = \pi y^2 + 2y(\ell_h - 2r) = \pi y^2 = \pi \left[\left[(2)(22.5)(15) - (22.5)^2 \right]^{1/2} \right]^2$$

$$= 531 \text{ ft.}^2$$

Inflation load = $P_e A_f$ = (32.7)(531) = 17, 400 lb.

C. Total load on tent

Inflation load + wind load =	17, 400 lb.
	34, 700 lb.
total load	52, 200 lb.

D. Perimeter of tent = $2\ell_h - 4r + 2\pi y$

$$= 2(30) - 4(15) + 2\pi \left[(2 \times 22.5)(15) - (22.5)^2 \right]^{1/2}$$

$$= 82 \text{ ft.}$$

E. Since nominal load per 4" arrowhead anchor is 1500 lbs.,

then no. anchors = 52, 400/1500 = 34. 9

F. Anchor spacing = perimeter/no. anchors

82/35 = 2. 34 ft. per anchor

4. Determine Fabric Stress.

A. Determine wind impact pressure, q, in lb./in.^{2} and in. w. g. Fig. 9

q = 0. 187 lb./in.^{2} = 5. 2 in. w. g.

B. Determine peak stress coefficient, N/qR Fig. 25

$$\text{for } h/d = 3/4, \quad \frac{N_\theta}{qR} = 1.72, \quad \frac{N_\phi}{qR} = 1.65$$

C. Determine stress factors if Poisson's ratio is nearer 0.5 than it is 1.0. If Poisson's ratio is not known, delete steps C and D. Fig. 27

$$\frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)} = 1.006, \qquad \frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)} = 1.01$$

D. Determine corrected stress coefficient for material with Poisson's ratio, $\nu = 0.5$

$$\frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)} \quad \frac{N_\theta}{qr} = (1.01)(1.72) = 1.736$$

$$\frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)} \quad \frac{N_\phi}{qr} = (1.006)(1.65) = 1.66$$

E. Determine stress resultants from wind loading, N_ϕ and N_θ

$$N_\phi = (1.66)\,qR = \frac{(1.66)(32.7)(15)(12)}{144} = 67.9 \text{ lb./in.}$$

$$N_\theta = (1.736)\,qR = \frac{(1.736)(32.7)(15)(12)}{144} = 70.9 \text{ lb./in.}$$

F. Determine total stress resultant

$$N_\phi = N_\phi \text{ (from E)} + \frac{P_e r}{2} = 67.9 + \frac{(32.7)(15)(12)}{(2)\,(144)}$$

$$N_\phi = 67.9 + 20.4 = 88.3 \text{ lb./in.}$$

$$N_\theta = N_\theta \text{ (from E)} + \frac{P_e r}{2} = 70.9 + 20.4 = 91.3 \text{ lb./in.}$$

5. Determine Fabric Weight Required.

A. Determine fiber type from oth onsiderations - select polyester.

B. Determine weight - strength relationship η, of fiber

$$\eta = \frac{35 \text{ lb.} - \text{yd.}^2}{\text{in. oz.}} \qquad \text{Table 1}$$

C. Using a safety factor of 3, weight of base fabric

$$\text{wt.} = 3(\overline{N}_\theta) \div \frac{35 \text{ lb.} - \text{yd.}^2}{\text{in. oz.}}$$

$$\text{wt.} = 3\,\frac{(91.3)}{(35)} = 7.82 \text{ oz./yd.}^2$$

D. Determine weight of coated fabric

Weight of coating (single ply) = 16 oz. /yd.^{2} Fig. 45

Total weight = base fabric + coating = 7.82 + 16 = 23.82 oz/yd.^{2}

SAMPLE DESIGN PROBLEMS

4.2.2 Single Wall Cylinders

Given: Single Wall Cylinder with Spherical Ends.

Width - 50 ft., length - 100 ft., height - 25 ft.
Sea Level Standard Atmosphere
Wind Velocity - 105 mph

1. Determine Dynamic Pressure, q.

   A. At 105 mph, q (standard day) $= 28.1$ lb./ft.^{2} Fig. 9

2. Determine Aerodynamic Loads.

   A. Lift $= C_L q A_p$

   $C_L = 0.475$ Fig. 11

   $q = 28.1$ lb./ft.^{2}

   $$A_p = \pi \left[\frac{W}{2}\right]^2 + W\ (\ell - W)$$

   $$= (3.14) \left[\frac{50 \text{ ft.}}{2}\right]^2 + 50 \text{ ft. } (100 \text{ ft. } - 50 \text{ ft.})$$

   $= 44$[illegible]^2

   Lift $= (0.475)(28.1$ lb./ft.$^2)(4465$ ft.$^2)$

   $= 59,600$ lb.

   B. Drag $= C_D q A_p$

   $C_D = 0.25$ Fig. 13

   $qA_p = (28.1$ lb./ft.$^2)(4462$ ft.$^2)$

   $= 125,400$ lb.

   Drag $= (0.25)(125,400$ lb.$)$

   $= 31,400$ lb.

3. Determine Anchor Spacing.

A. Load Due to Wind Force

C_{AL} = 1.6 **Fig. 22**

qA_p = 125,400 lb.

Wind Load = $C_{AL}\, qA_p$

= (1.6) (125,400 lb.)

= 200,600 lb.

B. Load Due to Inflation Pressure.

Since $P_e = q$ for stability, $P_e = 28.1$ lb./ft.^{2}

Floor area of tent is given by

$$S_f = \pi y^2 + 2y\,(\ell - 2r)$$

$$= 3.14 \left[2 \left[(25 \text{ ft.})(25 \text{ ft.}) - (25 \text{ ft.})^2 \right]^{1/2} \right]^2$$

$$+ \; 2 \left[2 \;\; (25 \text{ft.})(25 \text{ ft.}) - (25 \text{ft.})^2 \right]^{1/2} \; (100 \text{ ft.} - 50 \text{ ft.})$$

$$= 1962 \text{ ft.}^2 + 2500 \text{ ft.}^2 = 4462 \text{ ft.}^2$$

Inflation Load = $P_e A_f$

= (28.1 lb./ft.^{2})(4462 ft.^{2})

= 125,400 lb.

C. Total Load on Tent

Inflation load + wind load = 125,400 lb.
200,600 lb.
326,000 lb.

D. Perimeter of Tent = $2\ell - 4r + 2\pi y$

= 2 (100 ft.) - 4 (25 ft.) + 6.28 (25 ft.) = 256 ft.

E. Since normal load per 4 in. arrowhead anchor is 1500 lb., then number of anchors

$$= 326{,}000 \text{ lb.}/1500 \text{ lb. anchor}$$

$$= 217$$

F. Anchor spacing = perimeter/number anchors

$$= 256 \text{ ft.}/217$$

$$= 1.18 \text{ ft.}$$

4. Determine Fabric Stress.

A. Spherical Ends

1. Determine wind impact pressure, q, in lb/in.^{2} and in. w. g. Fig. 9

$$q = 0.195 \text{ lb./in.}^2 = 6.0 \text{ in. w.g.}$$

2. Determine peak stress coefficient, Fig. 31

for h/d = 1/2, $\frac{N_\theta}{q\,r} = 1.120 \quad \frac{N_\phi}{q\,r} = 1.650$ Fig. 29

3. Determine stress factors if necessary. Fig. 27

$$\frac{N_\theta\,(\nu = 0.5)}{N_\theta\,(\nu = 1.0)} = 1.026 \qquad \frac{N_\phi\,(\nu = 0.5)}{N_\phi\,(\nu = 1.0)} = 1.048$$

4. Determine corrected stress coefficient for material with Poisson's ratio, $\nu = 0.5$ if necessary.

$$\frac{N_\theta\,(\nu = 0.5)}{N_\theta\,(\nu = 1.0)} \quad \frac{N_\theta}{q\,r} = (1.026)(1.120) = 1.149$$

$$\frac{N_\phi\,(\nu = 0.5)}{N_\phi\,(\nu = 1.0)} \quad \frac{N_\phi}{q\,r} = (1.048)(1.650) = 1.730$$

5. Determine stress resultants, N_ϕ and N_θ, from wind loading.

$$N_\phi = (1.730)\,q\,r = \frac{(1.730)(28.1 \text{ lb./ft.}^2)(25 \text{ ft.})(12 \text{ in./ft.})}{144 \text{ in.}^2/\text{ft.}^2}$$

$$= 101 \text{ lb./in.}$$

$$N_\theta = (1.149)\,q\,r = \frac{(1.149)(28.1 \text{ lb./ft.}^2)(25 \text{ ft.})(12 \text{ in./ft.})}{144 \text{ in.}^2/\text{ft.}^2}$$

$$= 67 \text{ lb./in.}$$

6. Determine total stress resultant.

$$\overline{N}_\phi = N_\phi \text{ (from 5)} + \frac{P_e r}{2}$$

$$= 101 \text{ lb./in.} + \frac{(28.1 \text{ lb./ft.}^2)(25 \text{ ft.})(12 \text{ in./ft.})}{(2)(144 \text{ in.}^2/\text{ft.}^2)}$$

$$= 131 \text{ lb./in.}$$

$$\overline{N}_\theta = N_\theta \text{ (from 5)} + \frac{P_e r}{2}$$

$$= 67 \text{ lb./in.} + 30 \text{ lb./in.}$$

$$= 97 \text{ lb./in.}$$

B. Cylindrical Section

1. Determine wind impact pressure, q, in lb./in.^{2} and in. w. g. — Fig. 9

   $q = 0.195 \text{ lb./in.}^2 = 6.0 \text{ in. w. g.}$

2. Determine peak stress coefficient, — Fig. 25

   for $h/d = 1/2$, $N_\theta/qr = 1.120$ $N_\phi/qr = 0.555$

3. Determine stress factors if necessary. — Fig. 27

$$\frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)} = 1.026 \qquad \frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)} = 1.048$$

4. Determine corrected stress coefficient for material with Poisson's ratio, $\nu = 0.5$ if necessary.

$$\frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)} \quad \frac{N_\theta}{q\,r} = (1.026)(1.120) = 1.149$$

$$\frac{N_\phi\,(\nu = 0.5)}{N_\phi\,(\nu = 1.0)} \; \frac{N_\phi}{q\,r} = (1.048)\,(0.555) = 0.582$$

5. Determine stress resultants, N_ϕ and N_θ, from wind loading.

$$N_\phi = (0.582)\,qr = \frac{(0.582)(28.1\text{ lb. ft.}^2)\,(25\text{ ft.})(12\text{ in./ft.})}{144\text{ in.}^2/\text{ft.}^2}$$

$$= 34\text{ lb./in.}$$

$$N_\theta = (1.149)\,qr = \frac{(1.149((28.1\text{ lb./ft.}^2)(25\text{ ft.})(12\text{ in./ft.})}{144\text{ in.}^2/\text{ft.}^2}$$

$$= 68\text{ lb./in.}$$

6. Determine total stress resultant.

$$\overline{N}_\phi = N_\phi\text{ (from 5)} + \frac{P_e\,r}{2}$$

$$= 59\text{ lb./in.} + \frac{(28.1\text{ lb./ft.}^2)(25\text{ ft.})(12\text{ in./ft.})}{2\,(144\text{ in.}^2/\text{ft.}^2)}$$

$$= 63\text{ lb./in.}$$

$$N_\theta = N_\theta\text{ (from 5)} + \frac{P_e\,r}{2}$$

$$= 68\text{ lb./in.} + \frac{(28.1\text{ lb./ft.}^2)(25\text{ ft.})(12\text{ in./ft.})}{2\,(144\text{ in.}^2/\text{ft.}^2)}$$

$$= 97\text{ lb./in.}$$

5. Determine Fabric Weight Required.

A. Spherical ends.

1. Determine fiber type from other considerations - select polyester.

2. Determine weight-strength relationship of fiber

$$= 35\;\frac{\text{lb. - yd.}^2}{\text{in. - oz.}}$$ Table 1

3. Using a safety factor of 3, weight of base fabric

$$= 3(\overline{N}_{\phi}) \div \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$

$$= 3(131 \text{ lb./in.}) \div \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$

$$= 11.2 \text{ oz./yd.}^2$$

4. Determine weight of coated fabric,

   weight of coating (single ply vinyl)

   $= 16 \text{ oz./yd.}^2$

   total weight = base fabric + coating

$$= 11.2 \text{ oz./yd.}^2 + 16.0 \text{ oz./yd.}^2$$

$$- 27.2 \text{ oz./yd.}$$

B. Cylindrical Section

1. Determine fiber type from other considerations - select polyester.

2. Determine weight - strength relationship of fiber

$= 35 \frac{\text{lb. - yd.}^2}{\text{in. oz.}}$ Table 1

3. Using a safety factor of 3, weight of base fabric

$$= 3(\overline{N}_{\theta}) \div \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$

$$= 3(97 \text{ lb./in.}) \div \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$

$$= 8.32 \text{ oz./yd.}^2$$

4. Determine weight of coated fabric.

weight of coating (single ply vinyl)

$= 16.0$ oz./yd.^{2}

total weight = base fabric + coating

$= 8.32$ oz./yd.^{2} + 16.0 oz./yd.^{2}

$= 24.32$ oz./yd.^{2}

6. Maximum Deflection for Single Wall Tent.

$W/\ell_h = 1:2$ and $h/d = 0.5$

$\delta_H/r = \delta_F/r = 0.105$ Fig. 20

so that maximum deflection $= r\,(\delta_F/r)$

$$\delta_{max} = 25\,(.105) \quad 2.51 \text{ ft.}$$

7. Blower Requirements

Enclosure pressure, P_e, = 6.0 in. w.g.

Air loss per inch of slide fastener at P_e = 6 in. w.g.

equals 2.5 ft.^{3}/min./in. Fig. 44

Total length of slide fastener:

$$L = 2\pi r - r\lambda + \ell - 2r$$

$$= 2(3.14)(25 \text{ ft.}) - 25 \text{ ft.}(3.14) + 100 \text{ ft.} - 2\,(25 \text{ ft.})$$

$$= 128.5 \text{ ft. or } 1550 \text{ in.}$$

Air loss through slide fastener

$$= (2.5 \text{ ft.}^3/\text{min./in.})\,(1550 \text{ in.})$$

$$= 3860 \text{ ft.}^3/\text{min.}$$

Air loss through ground seal at

26 ft.^{3}/ft./min.

= (257 ft.)(26 ft.^{3}/ft./min.)

= 6700 ft.^{3}/min.

Air loss through door = 503 ft.^{3}/min.

Total Air Loss

= 3860 ft.^{3}/min. + 6700 ft.^{3}/min. + 503 ft.^{3}/min.

= 11,063 ft.^{3}/min., at 6.0 in. w.g.

Total Blower Requirement,

Q = 2 Air Loss = 22126 ft.^{3}/min.

8. Package Weight and Cube.

Surface area of material:

$$A_s = \left[(2\pi r - r2\lambda)(\ell - 2r) + 4\pi r^2 - 2\pi r(r-x)\right]\frac{1}{9}$$

$$= \Big[\left[2(3.14)(25\text{ ft.}) - (25\text{ ft.})(3.14)\right](100\text{ ft.} - 50\text{ ft})$$

$$+ 4(3.14)(25\text{ ft.})^2 - 2(3.14)(25\text{ ft.})(25\text{ ft.} - 25\text{ ft.})\Big]\frac{1\text{ yd.}^2}{9\text{ ft.}^2}$$

$$= 1300\text{ yd.}^2$$

Assume weight of material = 25.8 oz./yd.^{2}

Calculated wt. = (1300 yd.^{2})(25.8 oz./yd.^{2})(lb./16 oz.)

= 2100 lb.

Adjusted wt. = (1.5)(2100 lb.)

= 3150 lb.

Estimated cube = (0.1 ft.^{3}/lb.) (1950 lb.)

= 315 ft.^{3}

SAMPLE DESIGN PROBLEMS

4.2.3 Double Wall Cylinders

Given: Double Wall Cylinder with Flat Ends

Width - 100 ft., length - 200 ft., height - 50 ft.
$h/d = 1/2 \quad W/\ell_h = 1/2$
Sea Level Standard Atmosphere
Wind Velocity - 105 mph
Cell Radius = 15 in.

1. Determine Dynamic Pressure, q.

At 105 mph, q (standard day) = 28.1 lb./ft. Fig. 9

2. Determine Aerodynamic Loads.

A. Lift = $C_L q A_p$

C_L = 0.432 Fig. 12

q = 28.1 lb./ft.

A_p = $W\ell_h$

= (100 ft.) (200 ft.)

= 20,000 ft.

Lift = (0.432)(28.1 lb./ft.)(20,000 ft.)

= 243,000 lb.

B. Drag = $C_D q A_p$

C_D = 0.275 Fig. 14

Drag = (0.275)(28.1 lb./ft.)(20,000 ft.)

= 155,000 lb.

3. Determine Anchor Spacing.

A. Base anchor load

$C_{BL} = 1.08$ Fig. 23

$qA_P = 562,000$ lb.

wind load = $C_{BL}qA_P$

= (1.08)(562,000 lb.)

= 607,000 lb.

B. Guy Line load

$C_{GL} = 0.44$ Fig. 24

$qA_P = 562,000$ lb.

wind load = $C_{GL}qA_P$

= (0.44)(562,000 lb.)

= 249,000 lb.

C. Length of anchored sides = 400 ft.

D. Since nominal load per 4 in. arrowhead anchor is 1500 lb., then number of anchors

= 607,000 lb./1500 lb./anchor

= 405 anchors

E. Anchor spacing = anchored length/no. anchors

$$= \frac{400 \text{ ft.}}{405 \text{ anchors}}$$

= 0.989ft./anchor

F. Number of guy line anchors = 249,000 lb./1500 lb./ anchor

= 166 guy line anchors

4. Determine Inflation Pressure, P_c

To minimize deflection, choose $P_c = 3q$ Fig. 21

or $P_c = 18$ inches w. g.

5. Determine Fabric Stress.

A. Determine wind impact pressure, q, in lb. /in.^{2} and inches w. g.

$q = 0.195$ lb. /in. = 6.0 in. w. g. Fig. 9

B. Determine stress resultant, N_ϕ Fig. 36

= 14.0 lb. /in.

C. Determine stress coefficient, $\frac{N_h}{q}$ Fig. 34

= 2.19

D. Determine stress resultant, N_h,

$N_h = q\,(N_h/q) = (6.0)\,(2.19)$

$N_h = 13.1$ lb. /in.

N_w is determined in like manner and equals to 13.1 lb. /in.

6. Determine Fabric Weight Required.

A. Determine fabric type from other considerations - select polyester.

B. Determine weight - strength relationship of

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

C. Determine weight of base fabric using a safety factor of 3.

1. Weight of base fabric for outer skin

$$= 3N \div \frac{35\text{ lb. - yd.}^2}{\text{in. oz.}} = 3(14.0\text{ lb. /in.}) \div \frac{35\text{ lb. - yd.}^2}{\text{in. oz.}}$$

$= 1.20$ oz. /yd.^{2}

2. Weight of base fabric for web

$$= 3\ N_w \div 35 \frac{\text{lb.} - \text{yd.}^2}{\text{in. oz.}}$$ Fig. 33

$$= 3\ \ 13.1\ \text{lb./in.} \div 35 \frac{\text{lb.} - \text{yd.}^2}{\text{in. oz.}}$$

$$= 1.18\ \text{oz./yd.}^2$$

D. Determine weight of coated fabric using heaviest fabric.

Weight of coating (single ply vinyl) = 8.5 oz./yd.^{2} Fig. 45

Total weight = base fabric + coating

$$= 1.20\ \text{oz./yd.}^2 + 8.5\ \text{oz./yd.}^2$$

$$= 9.70\ \text{oz./yd.}^2$$

7. Maximum Deflection. Fig. 20

$$\delta_F/r = 0.102$$

$$\delta_F = (50\ \text{ft.})(0.102) = 5.1\ \text{ft.}$$

8. Blower Requirements.

$$\text{Volume capacity, } Q = \frac{\text{total cell volume}}{\text{erection time}}$$

$$V_C = \frac{\pi r^2 \ell_h - \pi \ell_h (r-w)^2}{2} + 2\ell_h (h-r)W$$

$$= \frac{(3.14)(50\ \text{ft.})^2\ (200\ \text{ft.}) - (3.14)(200\ \text{ft.})(50\ \text{ft.}) - 12\ \text{ft.})^2}{2} +$$

$$2(200)\ (50-50)100$$

$$= 332,000\ \text{ft.}^3$$

Choose inflation time of 30 min. so that

$$\text{Blower volume capacity} = \frac{\text{cell volume}}{30\ \text{min.}} \text{ or}$$

$$Q = \frac{332{,}000\ \text{ft.}^3}{30\ \text{min.}}$$

$$= 11{,}100\ \text{ft.}^3/\text{min.}$$

9. Package Weight and Cube.

Surface area of cylindrical section is

$$A_s = \pi\, r \ell_h + 2\ell\ (h-r)$$

$$= (3.14)(50\ \text{ft.})\ (200\ \text{ft.}) + 2\ (200\ \text{ft.})\ (50\ \text{ft.}\ -\ 50\ \text{ft.})\ 1/9$$

$$= 3488\ \text{yd.}^2$$

Surface area of end curtains is

$$A_s = \pi\ r^2 + 2\ r\ (h-r)$$

$$= \left[(3.14)(50\ \text{ft.})^2 + 2\ (50\ \text{ft.})(50\ \text{ft.}\ -\ 50\ \text{ft.})\right] 1/9 = 872\ \text{yd.}^2$$

Assume unit weight of material = 9.70 oz. /yd.^{2}

Calculated wt. of cylindrical section

$$= (3488\ \text{yd.}^2)(9.70\ \text{oz.}/\text{yd.}^2)(\text{lb.}/16\ \text{oz.})$$

$$= 2110\ \text{lb.}$$

Adjusted wt. of cylindrical section

$$= 2(1.5)\ (2110)\ \text{lb.}$$

$$= 6{,}340\ \text{lb.}$$

Calculated wt. of end curtains

$$= (872\ \text{yd.})(9.70\ \text{oz.}/\text{yd.})(\text{lb.}/16\ \text{oz.})$$

$$= 528\ \text{lb.}$$

Adjusted wt. of end curtains = (1.33)(528 lb.) = 702 lb.

Total adjusted wt

= (cylindrical section wt.) + (end curtain wt.)

= 6,340 lb. + 702 lb.

= 8,042 lb.

Estimated cube

= (0.065 ft. /lb.)(8,042 lb.)

= 522 ft.

SAMPLE DESIGN PROBLEMS

4.3 UNKNOWN TENT SHAPE

4.3.1 Single-Wall

Given: Required enclosed planform area - 600 ft.^{2} to contain a cubical package with a height of 8 ft. Anticipated environmental conditions:

Pressure altitude, 2000 ft.

Temperature, - 50° F

Wind Velocity, 105 mph

1. Determine optimum W/ℓ_h and h/d ratios to minimize aerodynamic loads.

   Select $W/\ell_h = 1/2$ for minimum C_L and C_D values Figs. 11, 13

   Select $h/d = 0.5$ for minimum C_L and C_D values Figs. 11, 13

2. Determine tent radius, r, to enclose required area with 8 ft. height.

   From figure, $x^2 + y^2 = r^2$

   and $y = 8$ ft. from above requirements.

Also, since tent has spherical ends, package length must equal 2r so that Area = $(2x)(2r) = 2xr = 600$ ft.^{2}

Combining equations and solving for x and r

$x = 11.0$ ft., $r = 13.6$ ft.

But deflection from Fig. 17 is $\delta = 0.105\ r$

so that $r' = 0.105\ r = 13.6$ ft. where r' is final

tent radius, and final tent radius, $r' = 15.2$ ft.

3. Determine impact pressure, q.

A. At wind velocity of 105 mph, $q = 28.1$ lb./ft.^{2} for a sea level standard day. Fig. 9

B. To correct for altitude and temperature deviation, obtain correction factor, k_p, $k_p = 1.18$. Fig. 10

C. q (corrected) $= (28.1 \text{ lb./ft.}^2)(1.18)$

$$= 33.2 \text{ lb./ft.}^2 = 6.4 \text{ in. w.g.}$$

4. Determine aerodynamic loads.

A. Lift $= C_L q A_p$

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

$= (3.14)(15.2 \text{ ft.})^2 + 2(15.2 \text{ ft.})(60.8 \text{ ft.} - 30.4 \text{ ft.})$

$= 1650 \text{ ft.}^2$

$C_L = 0.475$ Fig. 12

$q = 33.2 \text{ lb./ft.}^2$

Lift $= (0.475)(33.2 \text{ lb./ft.}^2)(1650 \text{ ft.}^2)$

$= 26,000$ lb.

B. Drag $= C_D q A_p$

$C_D = 0.25$ Fig. 14

Drag $= (0.25)(33.2 \text{ lb./ft.}^2)(1650 \text{ ft.}^2)$

$= 13,700$ lb.

5. Determine anchor spacing.

A. Load due to wind force

$C_{AL} = 1.6$ Fig. 22

$qA_p = 53,100$ lb.

wind load = $C_{AL} q A_p$ = (1.6)(53,100)

$= 85,000$ lb.

B. Load due to inflation pressure since

$P_e = q$ for stability, $P_e = 33.2$ lb./ft.^{2}

Floor area of tent is given by

$$A_f = \pi y^2 + 2y\,(l-2r)$$

$$= (3.14)\left[\left[(2)(15.2 \text{ ft.})^2 - (15.2 \text{ ft.})^2\right]^{1/2}\right]^2$$

$$+ (2)\left[(2)(15.2 \text{ ft.})^2 - (15.2 \text{ ft.})^2\right]^{1/2}\left[60.8 \text{ ft.} - 2(15.2 \text{ ft.})\right]$$

$$= 1650 \text{ ft.}^2$$

Inflation load $= P_e A_f$

$= (33.2 \text{ lb./ft.}^2)(1650 \text{ ft.}^2)$

$= 54,800$ lb.

C. Total load on tent = inflation load + wind load

= 54,800 lb. + 85,000 lb.

= 139,800 lb.

D. Perimeter of tent, P, $= 2l - 4r + 2\pi y$

$= 2(60.8 \text{ ft.}) - 4\,(15.2 \text{ ft.}) + 2\,(3.14)(15.2 \text{ ft.})$

$= 156$ ft.

E. Since nominal load per 4 in. arrowhead anchor is 1500 lb.,
then number of anchors = 139,800 lb./1500 lb.

= 94

F. Anchor spacing = perimeter/no. anchors

= 156 ft. / 94 anchors

= 1.66 ft.

6. Determine fabric stress.

A. Spherical ends

1. Determine wind impact pressure, q, in. lb. /in.^{2} and in. w. g.

$q = 0.231$ lb. /in.^{2} = 7.1 in. w. g. Fig. 9

2. Determine peak stress coefficients, $\frac{N}{qr}$,

for $h/d = 1/2$, $\frac{N_\theta}{qr} = 1.40$, $\frac{N_\phi}{qr} = 1.50$ Fig. 25

3. Determine stress factors if necessary.

$$\frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)} = 1.025 \qquad \frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)} = 1.05$$ Fig. 27

4. Determine corrected stress coefficient for material with Poisson's ratio, $\nu = 0.5$ if necessary.

$$\frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)} \quad \frac{N_\theta}{qr} = (1.40)(1.025) = 1.44$$

$$\frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)} \quad \frac{N_\phi}{qr} = (1.50)(1.05) = 1.58$$

5. Determine stress resultants, N_ϕ and N_θ, from wind loading.

$$N_\phi = (1.58)qr = \frac{(1.58)(33.2 \text{ lb./ft.}^2)(15.2 \text{ ft.})12}{144} = 66.4 \text{ lb./in.}$$

$$N_\theta = (1.44)qr = \frac{(1.44)(33.2 \text{ lb./ft}^2)(15.2 \text{ ft.})12}{144} = 60.6 \text{ lb./in.}$$

6. Determine total stress resultant

$$\overline{N_\theta} = N_\theta \text{ (from 5)} + \frac{P_a r}{2}$$

$$= 60.6 \text{ lb./in.} + \frac{(33.2 \text{ lb./ft.}^2)(15.2 \text{ ft.})(12)}{2\ (144)}$$

$$= 81.6 \text{ lb./in.}$$

$$\overline{N_\phi} = N_\phi \text{ (from 5)} + \frac{P_e r}{2}$$

$$= 66.4 \text{ lb./in.} + \frac{(33.2 \text{ lb./ft.}^2)(15.2 \text{ ft.})\ 12}{2\ (144)}$$

$$= 87.4 \text{ lb./in.}$$

B. Cylindrical section

1. Determine wind impact pressure, q, in lb./in.^{2} and inches w.g., q = 0.231 lb./in.^{2} = 7.1 in. w.g. Fig. 9

2. Determine peak stress coefficients, $\frac{N}{q\,r}$, for

$$h/d = 1/2, \quad \frac{N_\theta}{q\,r} = 1.40, \quad \frac{N_\phi}{q\,r} = 0.83.$$ Fig. 31

3. Determine stress factors if necessary. Fig. 29

$$\frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)} = 1.025 \qquad \frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)} = 1.05$$ Fig. 27

4. Determine corrected stress coefficients for material with Poisson's ratio, $\nu = 0.5$ if necessary.

$$\frac{N_\theta(\nu = 0.5)}{N_\theta(\nu = 1.0)} \quad \frac{N_\theta}{q\,r} = (1.025)(1.40) = 1.44$$

$$\frac{N_\phi(\nu = 0.5)}{N_\phi(\nu = 1.0)} \quad \frac{N_\phi}{q\,r} = (1.05)(0.83) = 0.87$$

5. Determine stress resultants, N_ϕ and N_θ, from wind loading.

$$N_\phi = (0.87)qr = \frac{(0.87)(33.2 \text{ lb./ft.}^2)(15.2 \text{ ft.})\,12}{144}$$

$$= 30.5 \text{ lb./in.}$$

$$N_\theta = (1.44)qr = \frac{(1.44)(33.2 \text{ lb./ft.}^2)(15.2 \text{ ft.})\,12}{144}$$

$$= 60.6 \text{ lb./in.}$$

6. Determine total stress resultants

$$\overline{N}_\theta = N_\theta \text{ (from 5)} + \frac{P_e r}{2}$$

$$= 60.6 \text{ lb./in.} + 21.0 \text{ lb./in.}$$

$$= 81.6 \text{ lb./in.}$$

$$\overline{N}_\phi = N_\phi \text{ (from 5)} + \frac{P_e r}{2}$$

$$= 30.5 \text{ lb./in.} + 21.0 \text{ lb./in.}$$

$$= 61.5 \text{ lb./in.}$$

7. Determine fabric weight required.

A. Spherical ends

1. Determine fabric type from other considerations - select polyester.

2. Determine weight - strength relationship of fiber

$$= 35 \; \frac{\text{lb.} - \text{yd.}^2}{\text{in. oz.}} \qquad \text{Table 1}$$

3. Using a safety factor of 3, weight of base fabric

$$= 3 \;\; \overline{N}_\phi \div \frac{35 \text{ lb.} - \text{yd.}^2}{\text{in. oz.}}$$

$$= 3(87.4 \text{ lb./in.} \div \frac{35 \text{ lb.} - \text{yd.}^2}{\text{in. oz.}}$$

$$= 7.50 \text{ oz./yd.}^2$$

4. Determine weight of coated fabric.

weight of coating (two-ply vinyl) = 32.0 oz. /yd.^{2} Fig. 45

total weight = base fabric + coating

= 7.5 oz. /yd.^{2} + 32.0 oz. /yd.^{2}

= 39.5 oz. /yd.

B. Cylindrical section

1. Determine fabric type from other considerations - select polyester.

2. Determine weight - strength relationship of fiber

$$= 35 \frac{\text{lb. - yd.}^2}{\text{in. oz.}}$$ Table 1

3. Using a safety factor of 3, weight of base fabric

$$= 3\ \overline{N}_\theta \div \frac{35\ \text{lb. - yd.}^2}{\text{in. oz.}}$$

$$= 3(81.6\ \text{lb./in.}) \div \frac{35\ \text{lb. - yd.}^2}{\text{in. oz.}}$$

$$= 6.98\ \text{oz/yd.}^2$$

4. Determine weight of coated fabric.

weight of coating(two-ply vinyl) = 32.0 oz. /yd.^{2}) Fig. 45

total weight = base fabric + coating

= 6.98 oz. /yd.^{2} + 32.0 oz. /yd.^{2}

= 38.98 oz. /yd.^{2}

8. Blower requirements.

Air loss through slide fastener

Length of slide fastener $= \ell_h - 2\,r\,\theta + \ell_h - 2\,r$

$= (60.8 \text{ ft.}) - 2\,(15.2 \text{ ft.})(3.14) + 60.8 \text{ ft.} - 2(15.2 \text{ ft.})$

$= 79 \text{ ft.}$

Loss per inch, # 10 slide fastener = $2.6 \text{ ft.}^3/\text{min.}$ Fig. 44

Air loss $= (79 \text{ ft.})(2.6 \text{ ft.}^3/\text{min.})(12 \text{ in.}/\text{ft.})$

$= 2470 \text{ ft.}^3/\text{min.}$

Air loss through ground seal $26 \text{ ft.}^3/\text{min.}/\text{ft.}$

Perimeter $= 2\,\ell_h - 4\,r + 2\,\pi\,y$

$= 2\,(60.8 \text{ ft.}) - 4\,(15.2 \text{ ft.}) + 2\,(3.14)(15.2 \text{ ft.})$

$= 156 \text{ ft.}$

Air loss $= (26 \text{ ft.}^3/\text{min.}/\text{ft.})(156 \text{ ft.}) = 4050 \text{ ft.}^3/\text{min.}$

Air loss through door is approximately $500 \text{ ft.}^3/\text{min.}$

Blower requirements = sum of air losses

$Q = 2470 \text{ ft.}^3/\text{min.} + 4050 \text{ ft.}^3/\text{min.} + 500 \text{ ft.}^3/\text{min.}$

$= 7020 \text{ ft.}^3/\text{min.}$ at 6.4 in. w. g.

9. Package weight and cube.

Determine total surface area.

$$A_s = \left[(2\pi\,r - r\,2\theta)\,(\ell_h - 2\,r) + 4\pi\,r^2 - 2\pi\,r(r-x)\right]\,1/9 \text{ yd.}^2$$

$$A_s = \Big[\left[(2)(3.14)(15.2 \text{ ft.}) - (15.2 \text{ ft.})(2)\,(3.14)\right]\,(60.8 \text{ ft.} - 30.4 \text{ ft.})$$

$$+ \;4\,(3.14)(15.2 \text{ ft.})^2 - 2(3.14)(15.2 \text{ ft.})(15.2 \text{ ft.} - 15.2 \text{ ft.})\Big]\,1/9 \text{ yd.}^2$$

$$= 483 \text{ yd.}^2$$

Assuming a base fabric weight of $8.1 \text{ oz.}/\text{yd.}^2$

Weight of coating (two ply vinyl) = 32 oz. /yd. ^{2}

Total fabric weight = 32 oz. /yd. ^{2} + 8.1 oz. /yd. ^{2}

= 40.1 oz. /yd. ^{2}

Total calculated wt

= (483 yd. ^{2})(40.1 oz. /yd. ^{2})(lb/16 oz.)

= 1210 lb.

Total adjusted wt

= (1.5)(1210 lb.)

= 1815 lb.

Estimated cube

= (0.1 ft. ^{3}/lb.) (1815 lb.)

= 182 ft. ^{3}

SAMPLE DESIGN PROBLEMS

4.3.2 Double-Wall

Given: Required enclosed area - 900 ft.^{2} with minimum height of 11 ft.

Wind velocity - 105 mph, standard sea level conditions

1. Determine Optimum W/ℓ and h/d Ratios to minimize anchor loads.

   Select $W/\ell = 1/4$ for minimum C_{BL} Fig. 23

   Select $h/d = 0.5$ for minimum C_{BL} Fig. 23

2. Determine Tent Radius, r, to enclose required area with 11 ft. height.

   From figure $x^2 + y^2 = r^2$

   and $y = 11$ ft. from above requirements.

   Also, since $\ell_h = 4W = 8r$,

   $\text{Area} = 8rx$

   Combining equations and solving for

   x and r, $x = 11.0$ ft., $r = 15.5$ ft.

   But deflection from Fig. is $\delta/r = 0.105 r$

   so that $r' - 0.105 r' = 15.5$ ft., where

   r' = final tent radius = 17.3 ft.^{2}

3. Determine Dynamic Pressure, q.

   At 105 mph, q, (standard day) = 28.1 lb./ft.^{2} Fig. 9

4. Determine Aerodynamic Loads.

   A. $\text{Lift} = C_L q A_p$

C_L = 0.76 Fig. 12

q = 28.1 lb./ft.^{2}

A_p = $W\ell_h$

= (34.6 ft.)(139 ft.)

= 4800 ft.^{2}

Lift = (0.76)(28.1 lb./ft.^{2})(4800 ft.^{2})

= 103,000 lb.

B. Drag = $C_D q A_p$

C_D = 0.35 Fig. 14

Drag = (0.35)(28.1 lb./ft.^{2})(4800 ft.^{2})

= 47,300 lb.

5. Determine Anchor Spacing.

A. Base anchor load.

C_{BL} = 0.35 Fig. 23

qA_p = 135,000 lb

= $C_{BL} q A_p$

= (0.35)(135,000 lb.)

= 47,300 lb.

B. Guy line load.

C_{GL} = 0.485 Fig. 24

qA_p = 135,000 lb.

= $C_{GL} q A_p$ = (0.485)(135,000 lb.) = 65,500 lb.

C. Length of anchored sides = 278 ft.

D. Since normal load per 4 in. arrowhead anchor is 1500 lb., then number of anchors

= 47,000 lb./1500 lb./anchor

= 31 anchors

E. Anchor spacing = anchored length/no. anchors

= 278 ft./31 anchors

= 9 ft./anchor

F. Number of guy line anchors

= 65,600 lb./1500 lb./anchor

= 44 anchors

G. Guy line spacing = anchored length/no. anchors

= 278 ft./44 anchors

= 6.3 ft./anchor

6. Determine Inflation Pressure, P_c.

To minimize deflection, choose $P_c = 3q$ Fig. 19

or P_c = 18 inches w.g.

7. Determine Fabric Stress.

A. Determine wind impact pressure, q,

in lb./in.^{2} and inches w.g. = 0.195 lb./in.^{2} = 5.35 in. w.g. Fig. 9

B. Determine stress resultant, N_ϕ Fig. 36

= 13.3 lb./in.

C. **Determine stress coefficient, $\frac{N_h}{q}$** Fig. 5·1

$= 7.60$

D. **Determine stress resultant, N_h**

$$N_h = q\,(N_h/q) = (6.0)\,(7.60)$$

$$N_h = 45.6 \text{ lb./in.}$$

8. Determine Fabric Weight Required.

A. Determine fabric type from other considerations - select polyester.

B. Determine weight - strength relationship of fiber

$$= \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$ Table 1

C. Determine weight of base fabric using a safety factor of 3.

1. Weight of base fabric for outer skin

$$= 3N_h \div \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$

$$= 3(45.6 \text{ lb./in.}) \div \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$

$$= 3.9 \text{ oz./yd.}^2$$

2. Weight of base fabric for web

$$= 3\left[N_w\right] \div \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$

$$= 3\left[45.6 \text{ lb./in.}\right] \div \frac{35 \text{ lb. - yd.}^2}{\text{in. oz.}}$$

$$= 3.9 \text{ oz./yd.}^2$$

D. Determine weight of coated fabric using heaviest fabric.

Weight of coating (single ply vinyl) = 11.5 oz./yd.^{2} Fig. 45

Total weight = 3.9 oz./yd.^{2} + 11.5 oz./yd.^{2}

= 15.4 oz./yd.^{2}

9. Blower Requirements.

Volume capacity, Q, $\frac{\text{total cell volume}}{\text{erection time}}$.

$$V_c = \frac{\pi r^2 \ell - \pi \ell (r-w)^2 + 4 \ell (h-r)}{2} W$$

$$= \frac{(3.14)(17.3 \text{ ft.})^2 (139 \text{ ft.}) - (3.14)(139 \text{ ft.})(17.3 \text{ ft.} - 4.2 \text{ ft.})^2}{2}$$

$$= 27,700 \text{ ft.}^3$$

Choose inflation time of 30 minutes so that

Blower volume capacity = $\frac{\text{cell volume}}{30 \text{ min.}}$ or

$$Q = \frac{27,700 \text{ ft.}^3}{30 \text{ min.}}$$

$$= 9233 \text{ ft.}^3/\text{min.}$$

10. Package Weight and Cube.

Surface area of cylindrical section is

$$S = \pi r \ell + 2 \ell (h-r)$$

$$= \left[(3.14)(17.3 \text{ ft.})(139 \text{ ft.}) + 2 (139 \text{ ft.})(17.3 \text{ ft.} - 17.3)\right] 1/9$$

$$= 840 \text{ yd.}^2$$

Surface area of end curtains is

$$S = \pi r^2 + 2 r (h-r)$$

$$= \left[(3.14)(17.4)^2 + 2 (17.4)(17.4 - 17.4)\right] 1/9$$

$$= 106 \text{ yd.}^2$$

Assume unit weight of material = 15.4 oz./yd.^{2}

Calculated wt. of cylindrical section

= (840 yd.^{2})(15.4 oz./yd.^{2})(lb./16 oz.) = 809 lb.

Adjusted wt. of cylindrical section

= 2 (1.5)(809 lb.)

= 2430 lb.

Calculated wt. of end curtains

= (106 yd.^{2})(15.4 oz./yd.^{2})(lb./16 oz.)

= 102 lb.

Adjusted wt. of end curtains

= (1.33)(102 lb.)

= 136 lb.

Total adjusted wt.

= (cylindrical section wt.) + (end curtain wt.)

= 2430 lb. + 136 lb.

= 2570 lb.

Estimated cube

= (0.065 ft.^{3}/lb.)(2570 lb.)

= 167 ft.^{3}

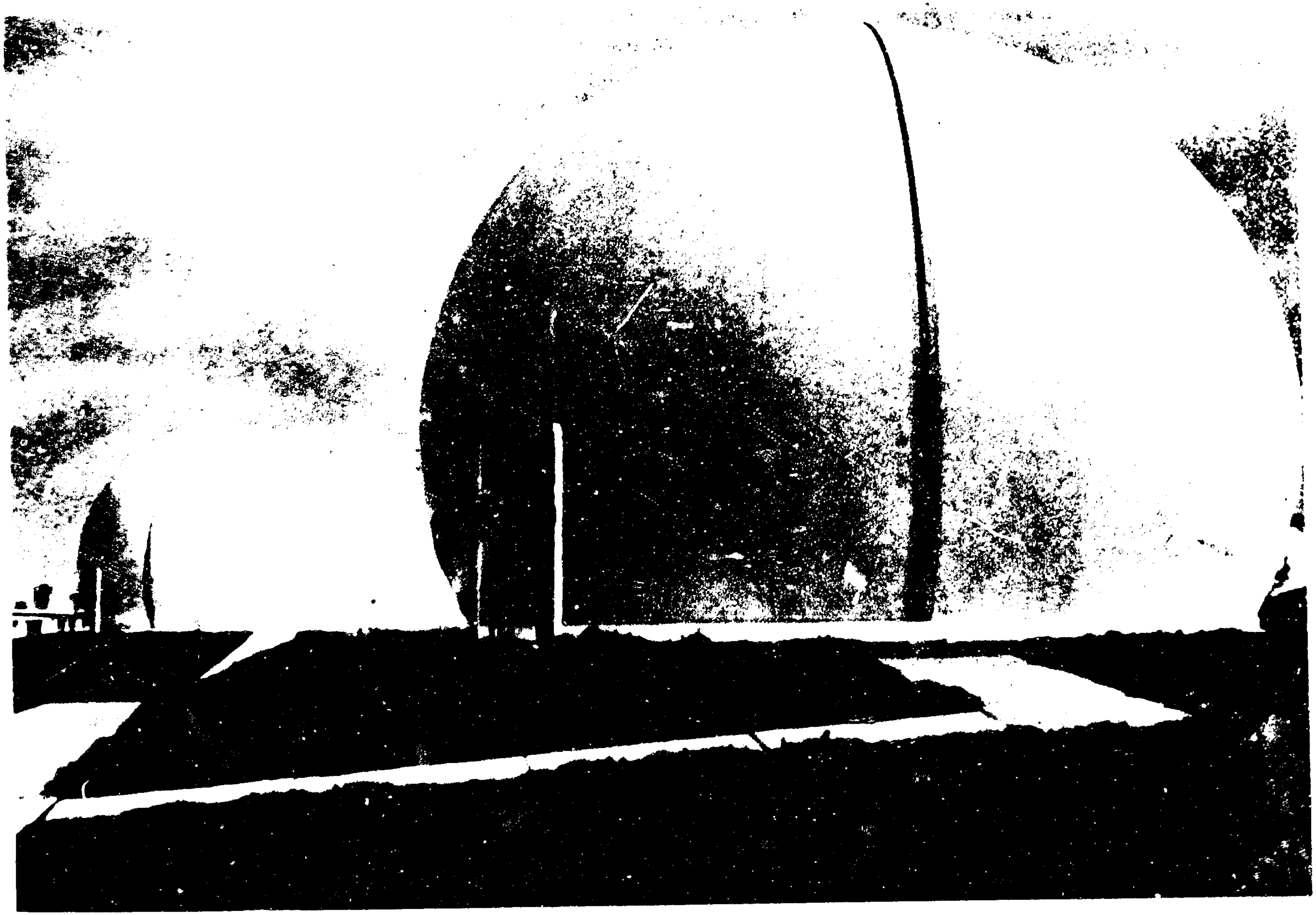


Figure 1. - Photograph of a Single Wall,
Air Supported Radome, Nike Hercules System

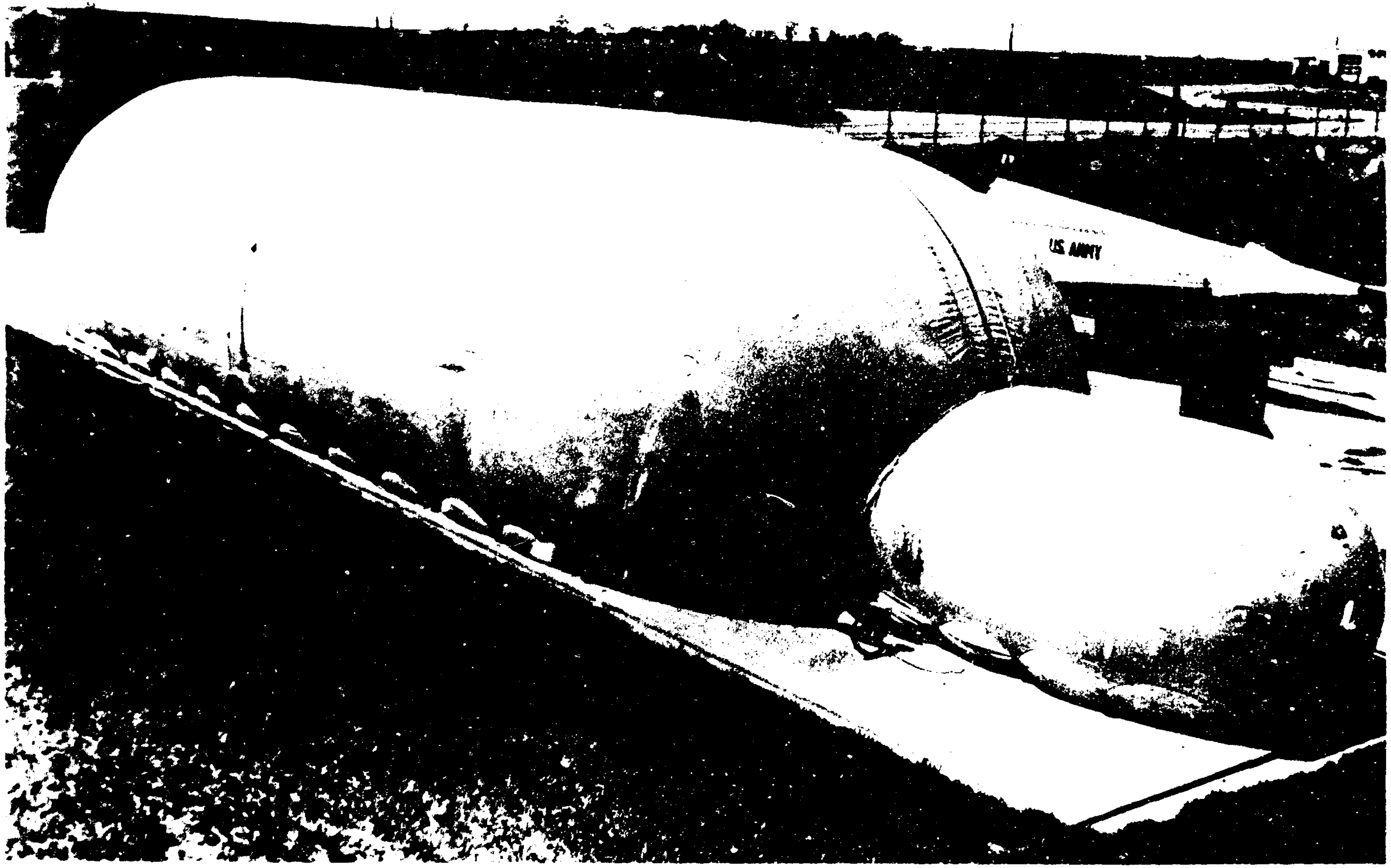


Figure 2. - Photograph of a Single Wall,
Air Supported Tent, Above-Ground, Launcher, Nike Hercules System

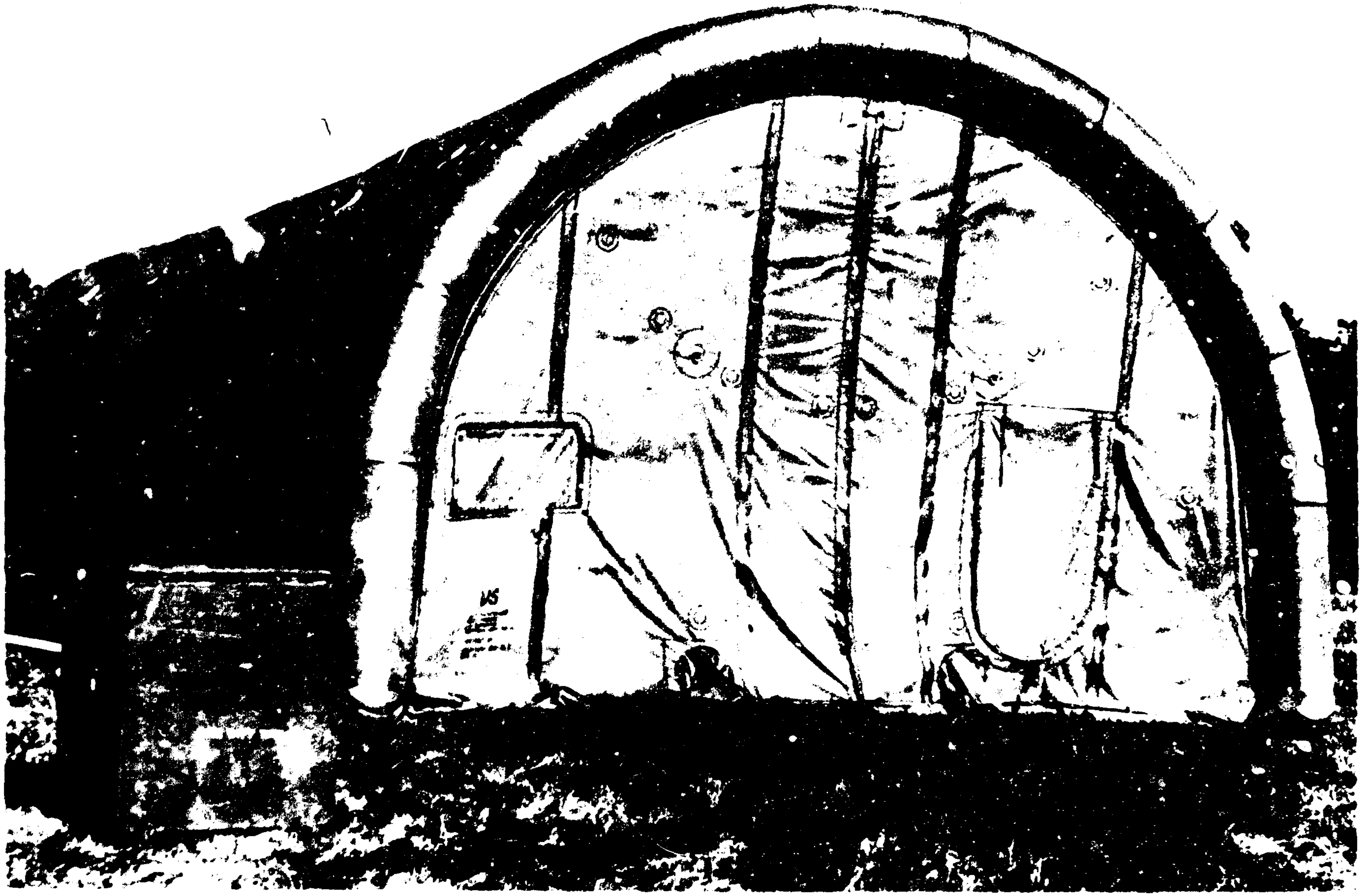


Figure 3. - Photograph of a Double Wall, Air Supported Tent, Maintenance, Multi-Purpose, Sectionalized (Pershing Missile).

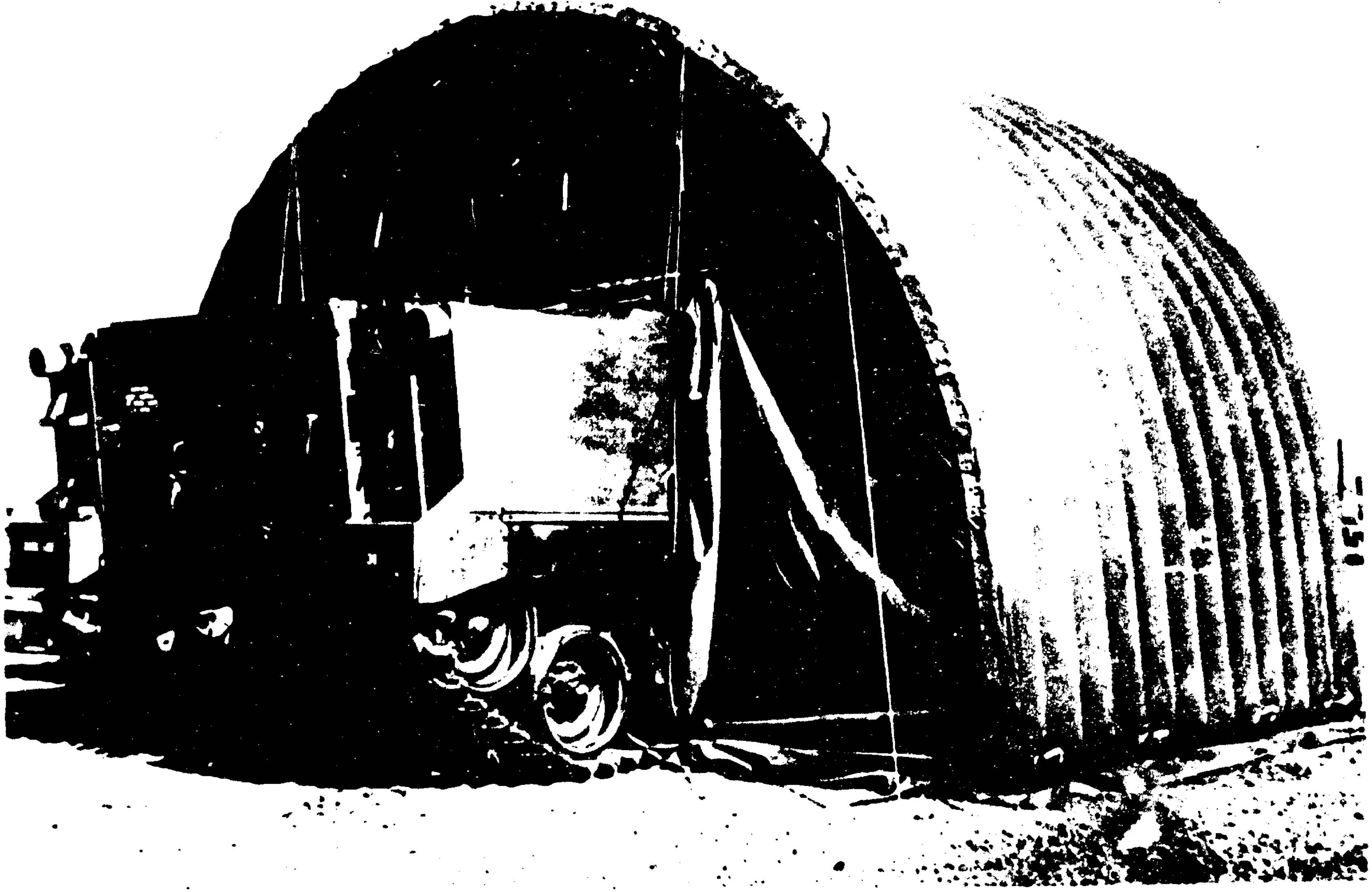


Figure 4. - Photograph of a Double Wall, Air Supported Tent, Vehicle Maintenance, Small (Arctic).

Figure 5. - Photograph of a Double Wall,
Air Supported Tent, Aviation Maintenance, Medium, Sectionalized

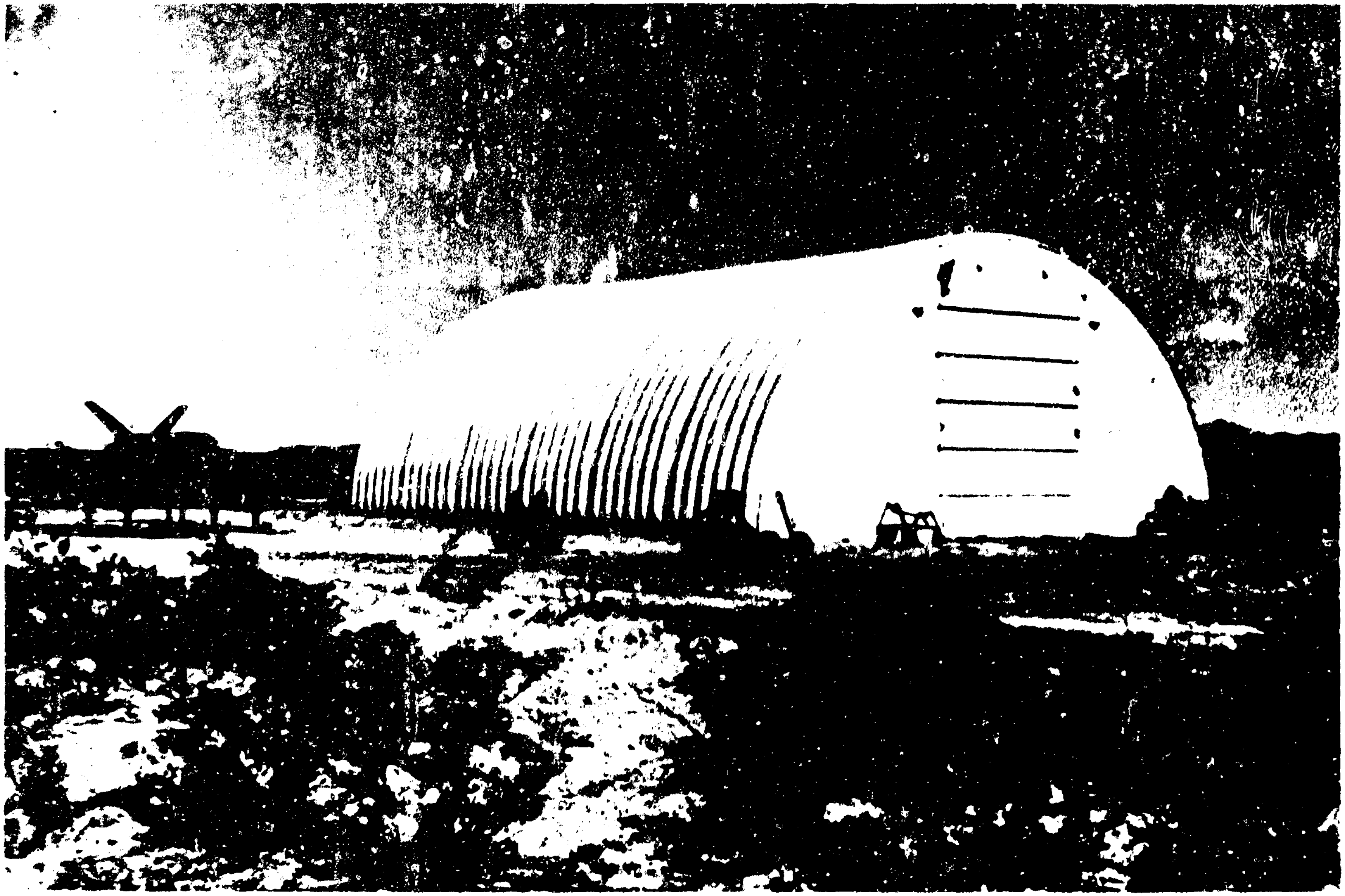


Figure 6. - Photograph of a Double Wall,
Air Supported Tent, Assembly Area, Nike Hercules Mobile System

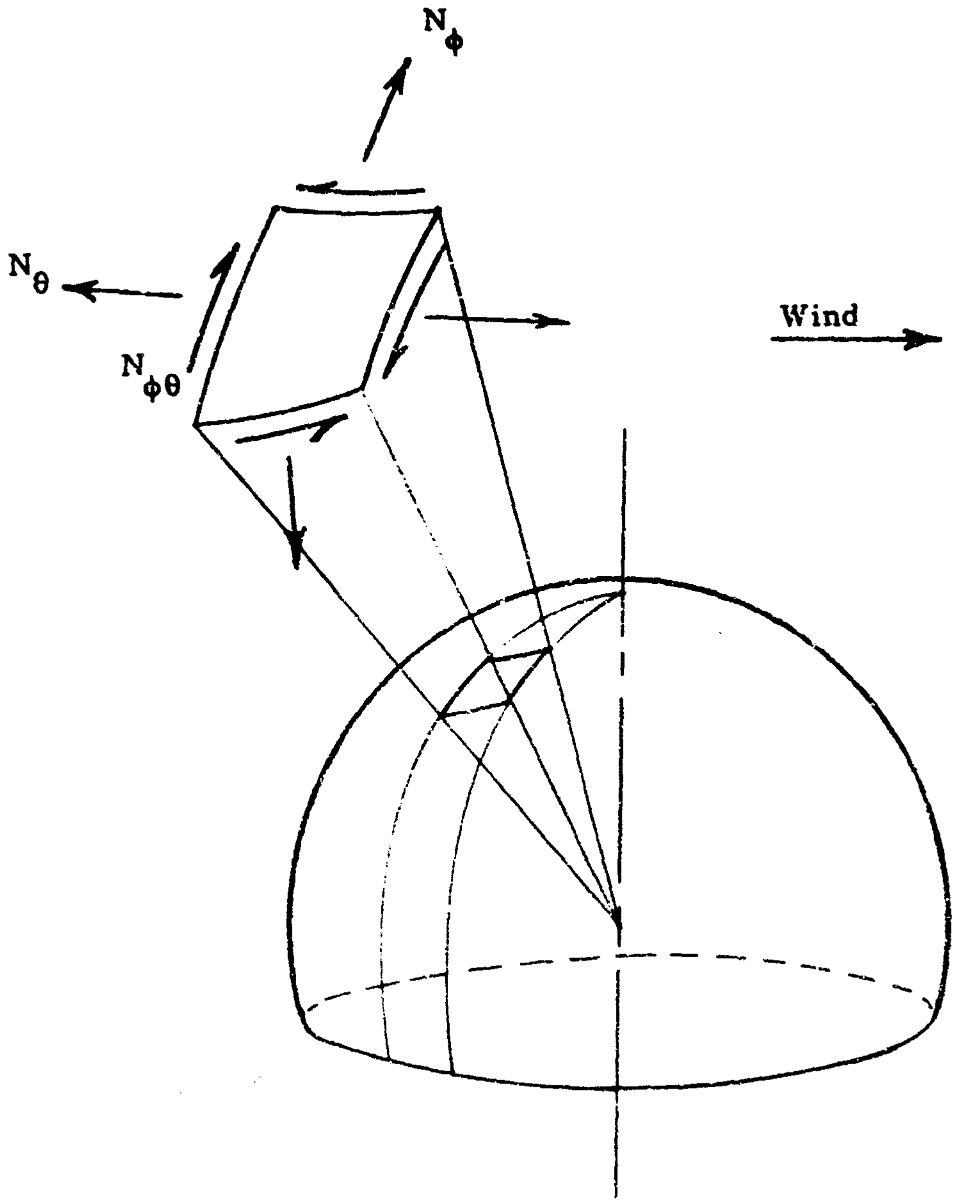


Figure 7. - Coordinate System and Membrane Stresses for a Truncated Spherical Shell.

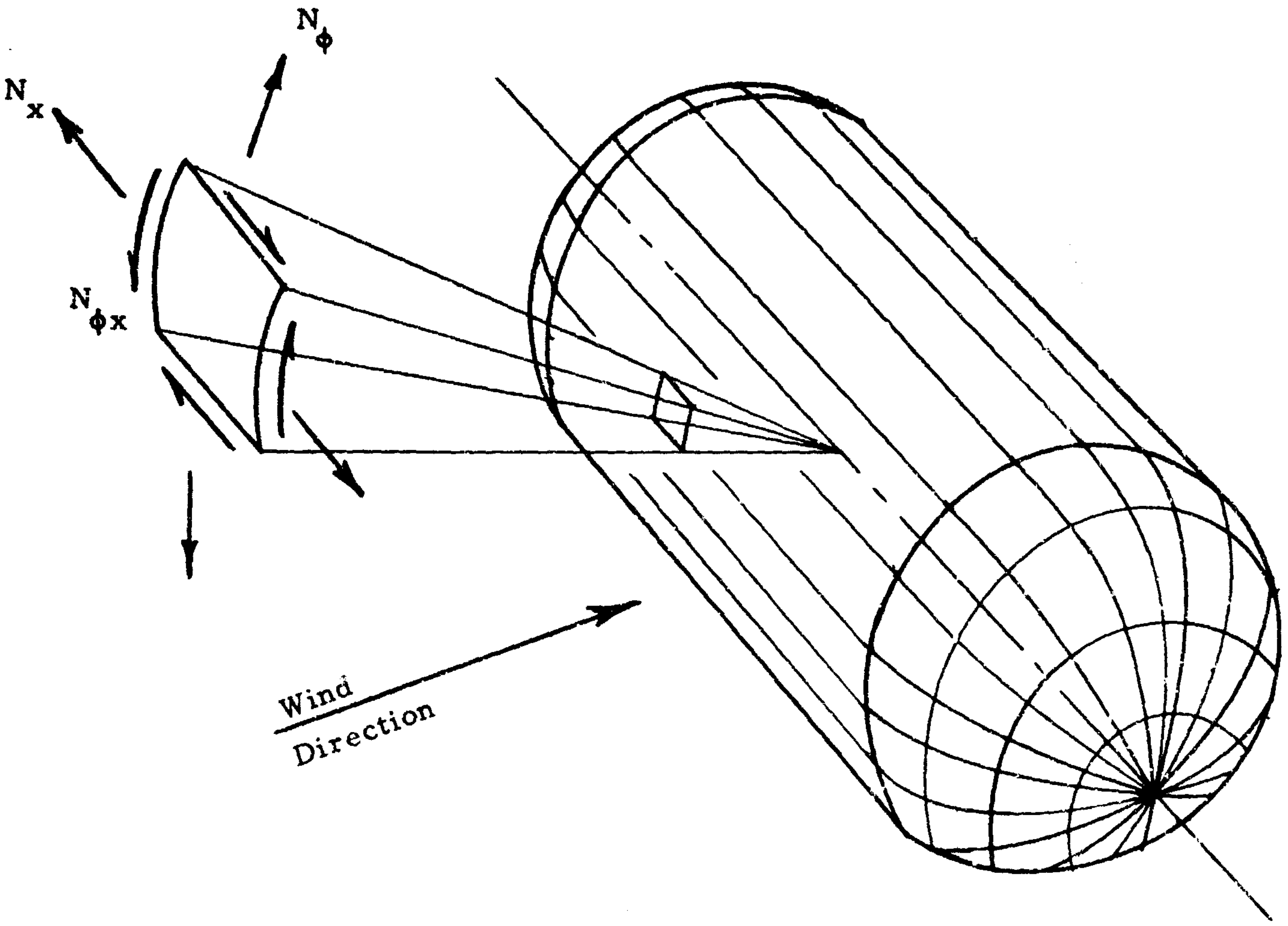


Figure 8. - Coordinate System and Membrane Stresses for a Cylindrical Shell with Hemispherical Ends.

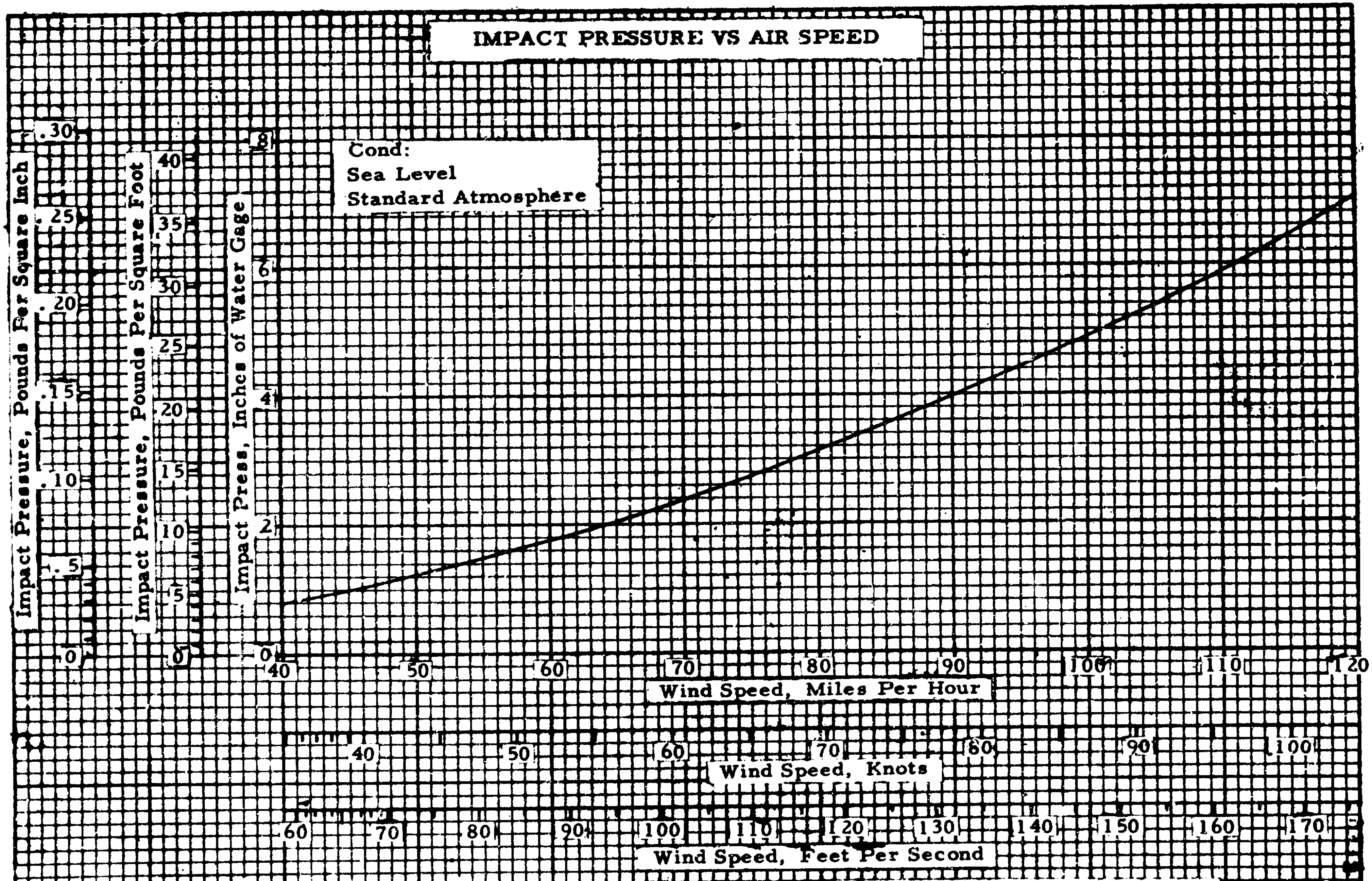


Figure 9. - Variation of Impact Pressure with Air Speed, Sea Level Standard Atmosphere.

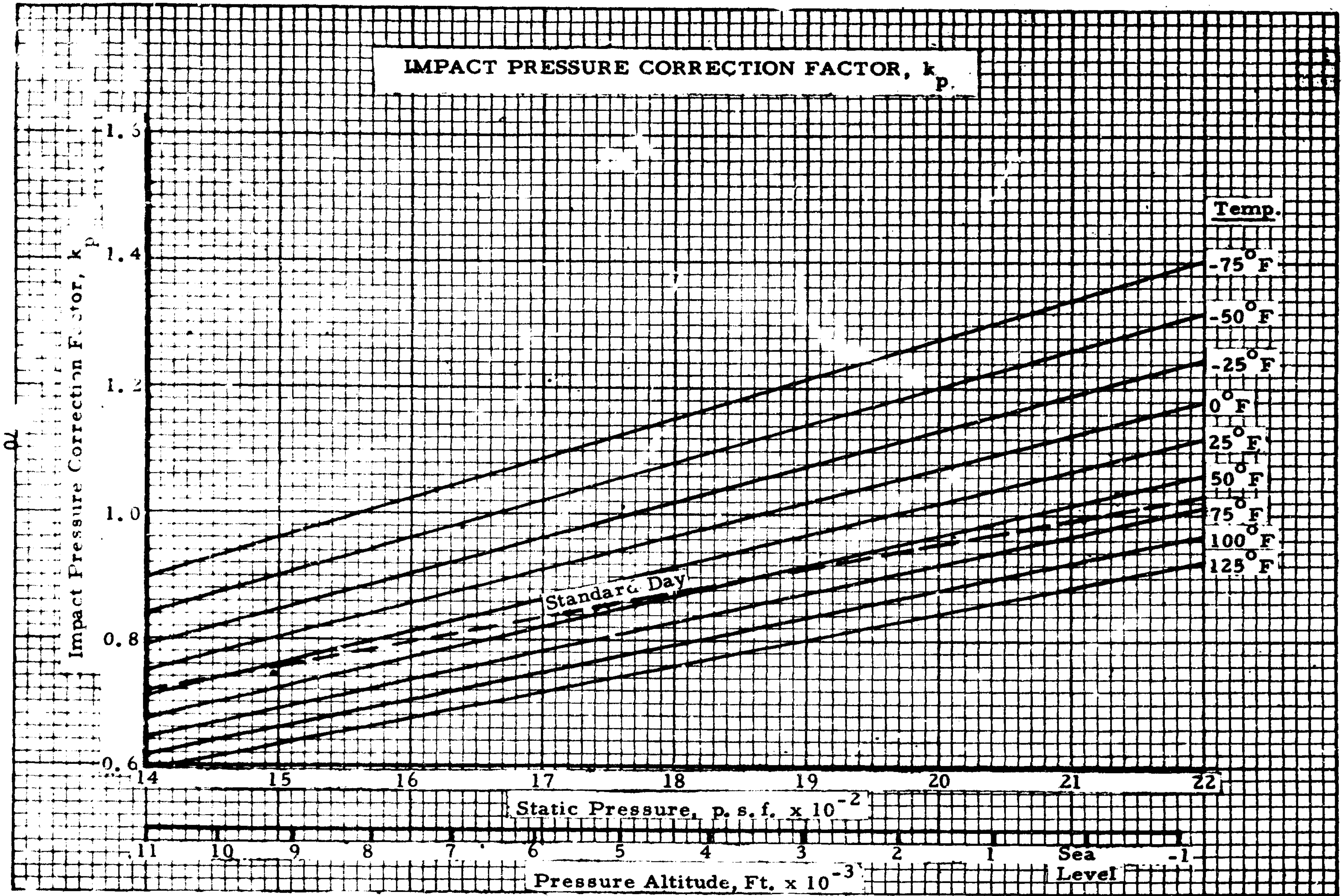


Figure.10. - Impact Pressure Correction Factor, k_p, Variation with Altitude & Temperature

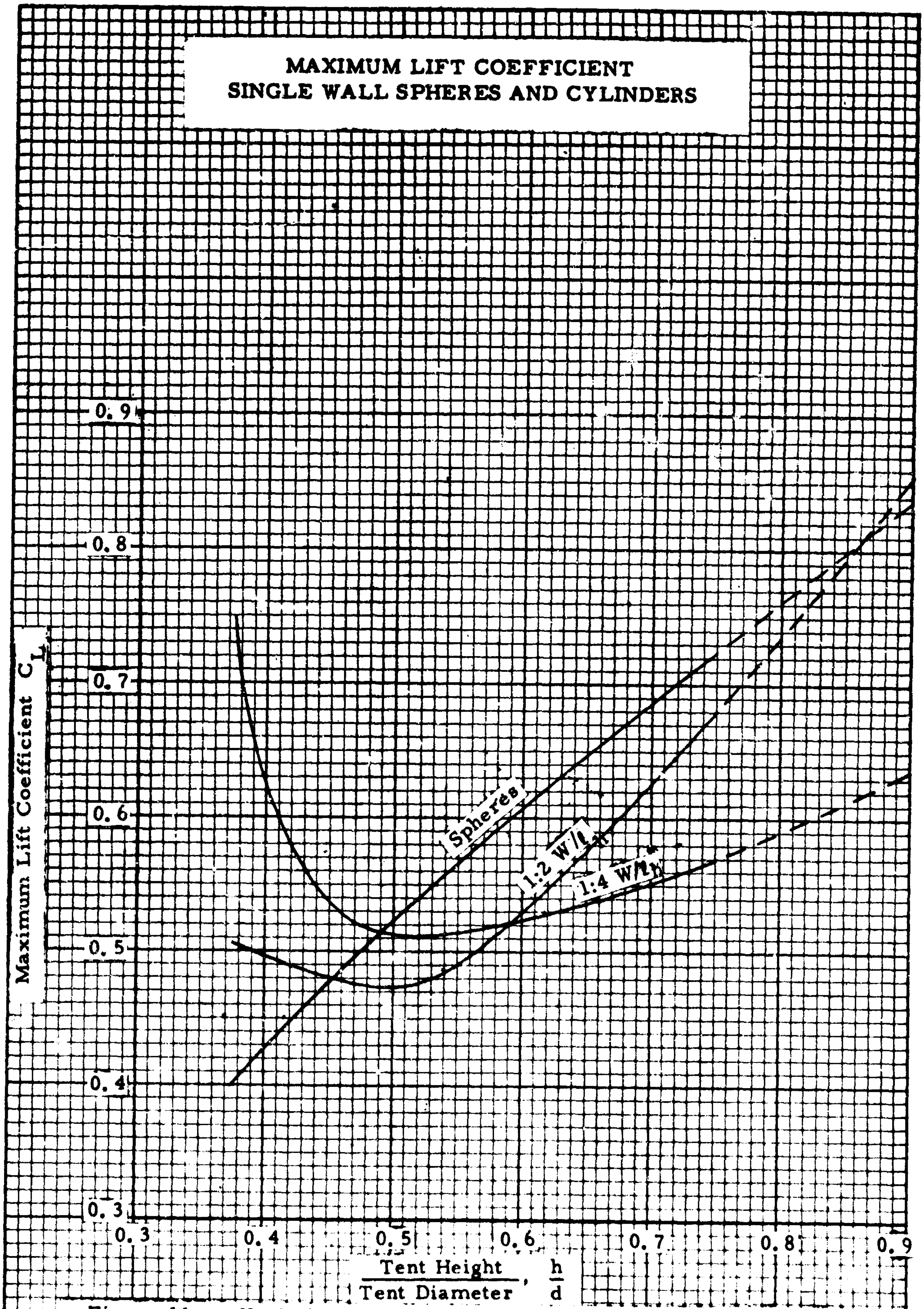


Figure 11. - Variation of Lift Coefficient with Shape (Spherical and Cylindrical Single Wall Tents; 1:2, 1:4, W/ℓ_h)

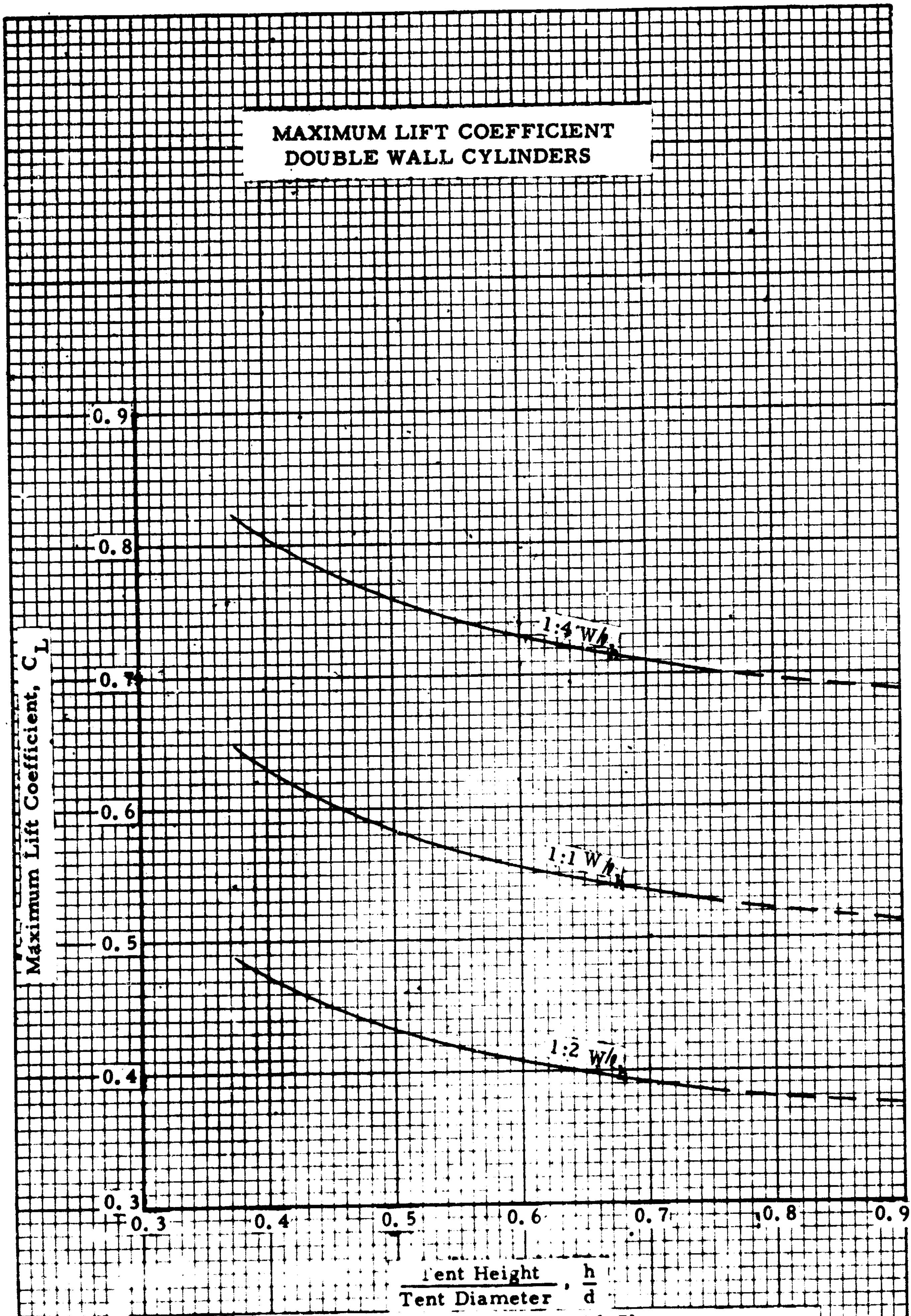


Figure 12. - Variation of Lift Coefficient with Shape
(Non Porous Double Wall Tents; 1:1, 1:2, 1:4 W/ℓ_h)

MAXIMUM DRAG COEFFICIENT
SINGLE WALL SPHERES AND CYLINDERS

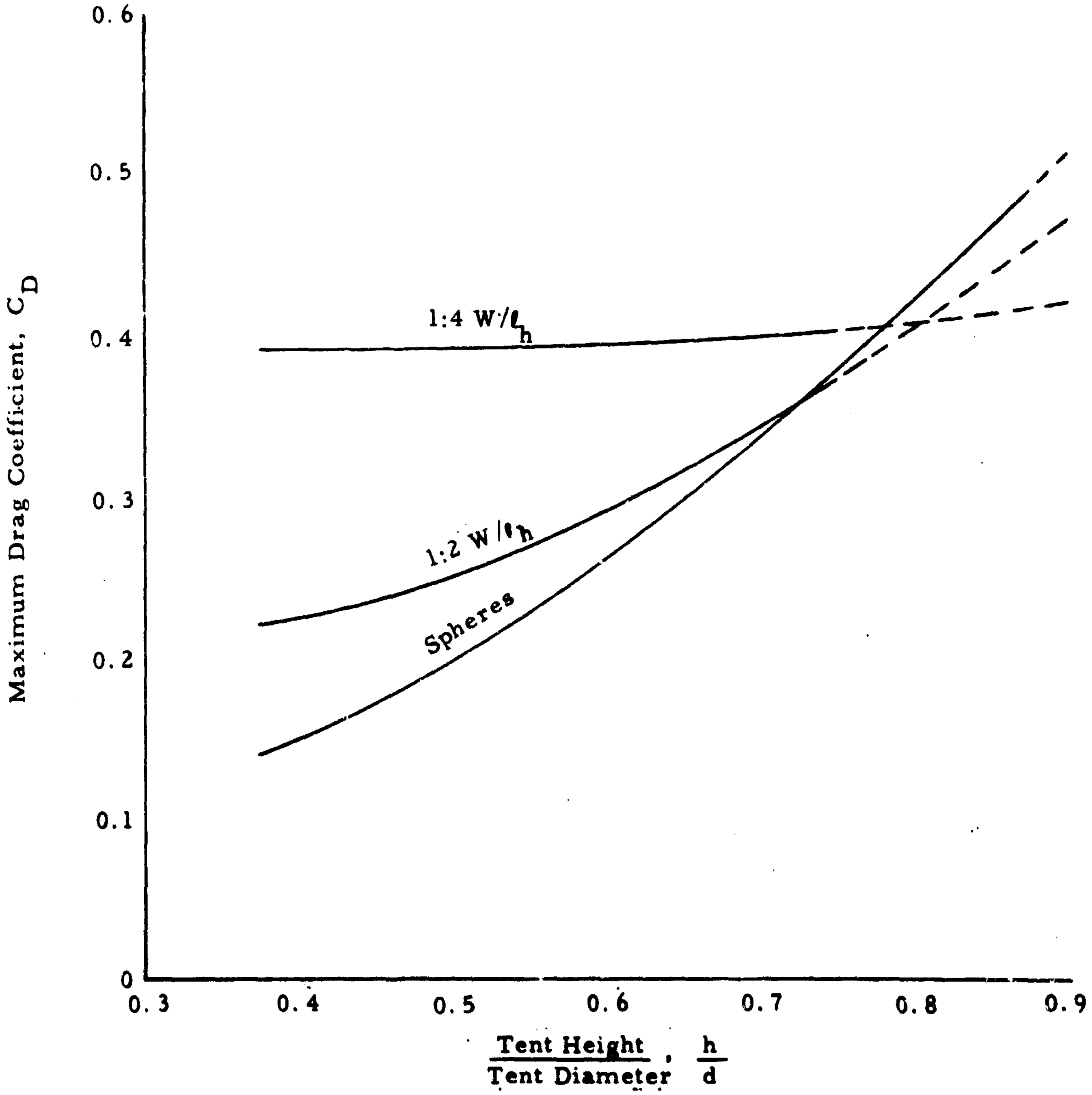


Figure 13. - Variation of Drag Coefficient With Shape (Spherical And Cylindrical Single Wall Tents; 1:2, 1:4, W/ℓ_h)

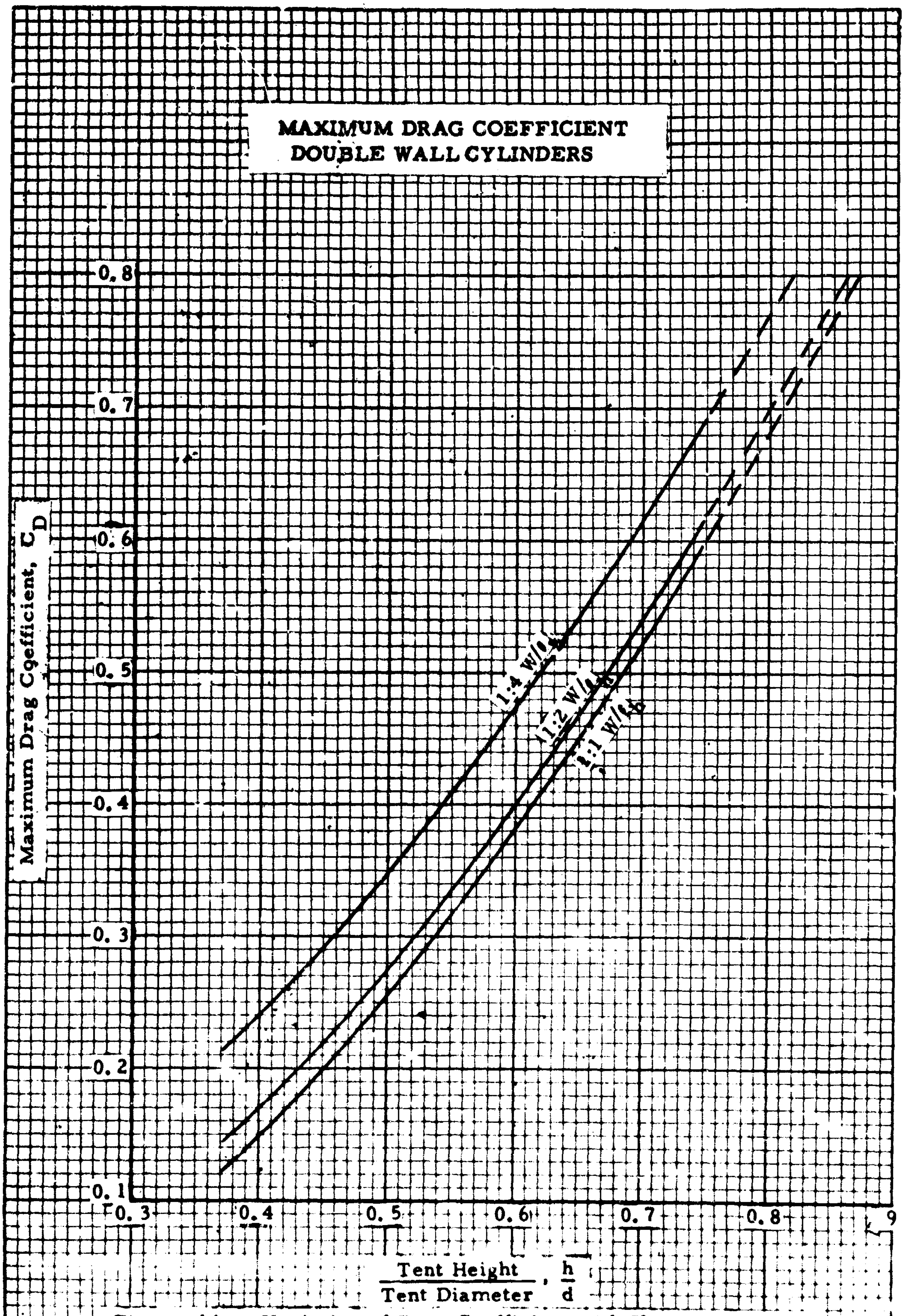


Figure 14. - Variation of Drag Coefficient with Shape (Non Porous Double Wall Tents; 1:1, 1:2, 1:4 W/ℓ_h)

MAXIMUM MOMENT COEFFICIENT
SINGLE WALL SPHERES AND CYLINDERS

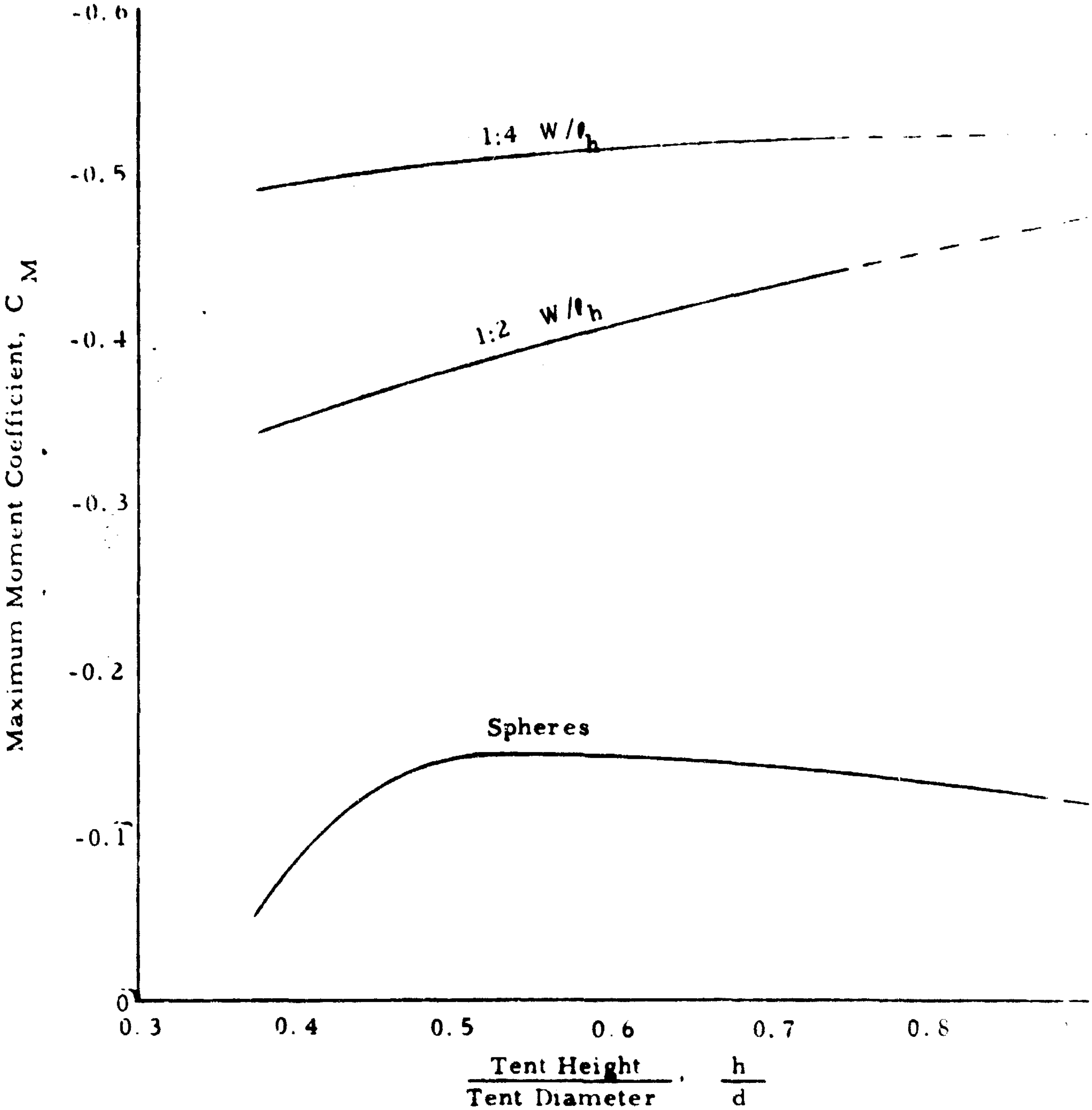


Figure 15.- Variation of Moment Coefficient With Shape (Spherical And Cylindrical Single Wall Tents; 1:2, 1:4, W/ℓ_h)

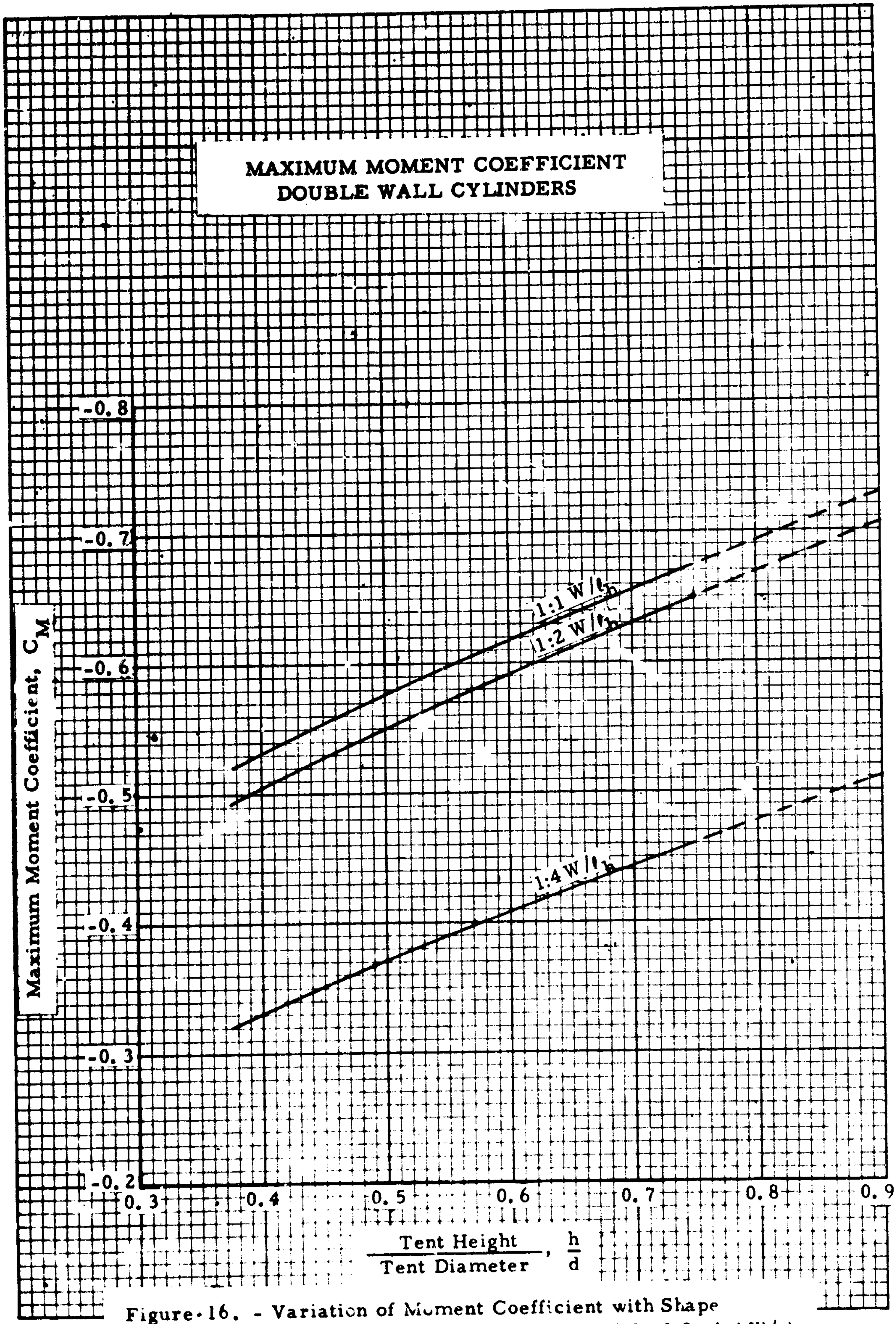


Figure-16. - Variation of Moment Coefficient with Shape (Non Porous Double Wall Tents; 1:1, 1:2, 1:4 W/ℓ_h).

MAXIMUM TENT DEFLECTION
SINGLE WALL SPHERES

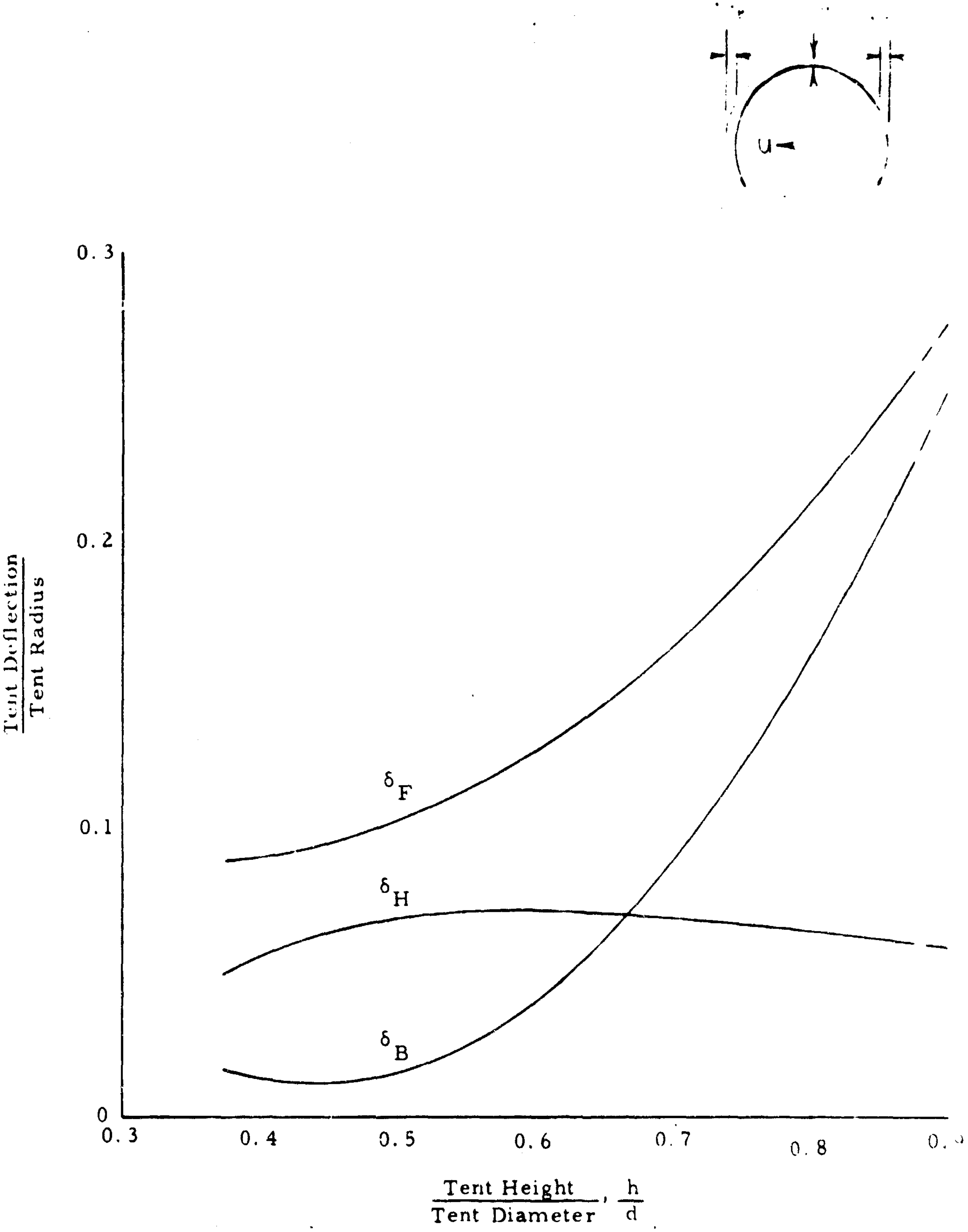


Figure 17.- Variation of Tent Deflection With Shape (Spherical Single Wall Tents).

MAXIMUM TENT DEFLECTION
SINGLE WALL 1 : 2 CYLINDERS

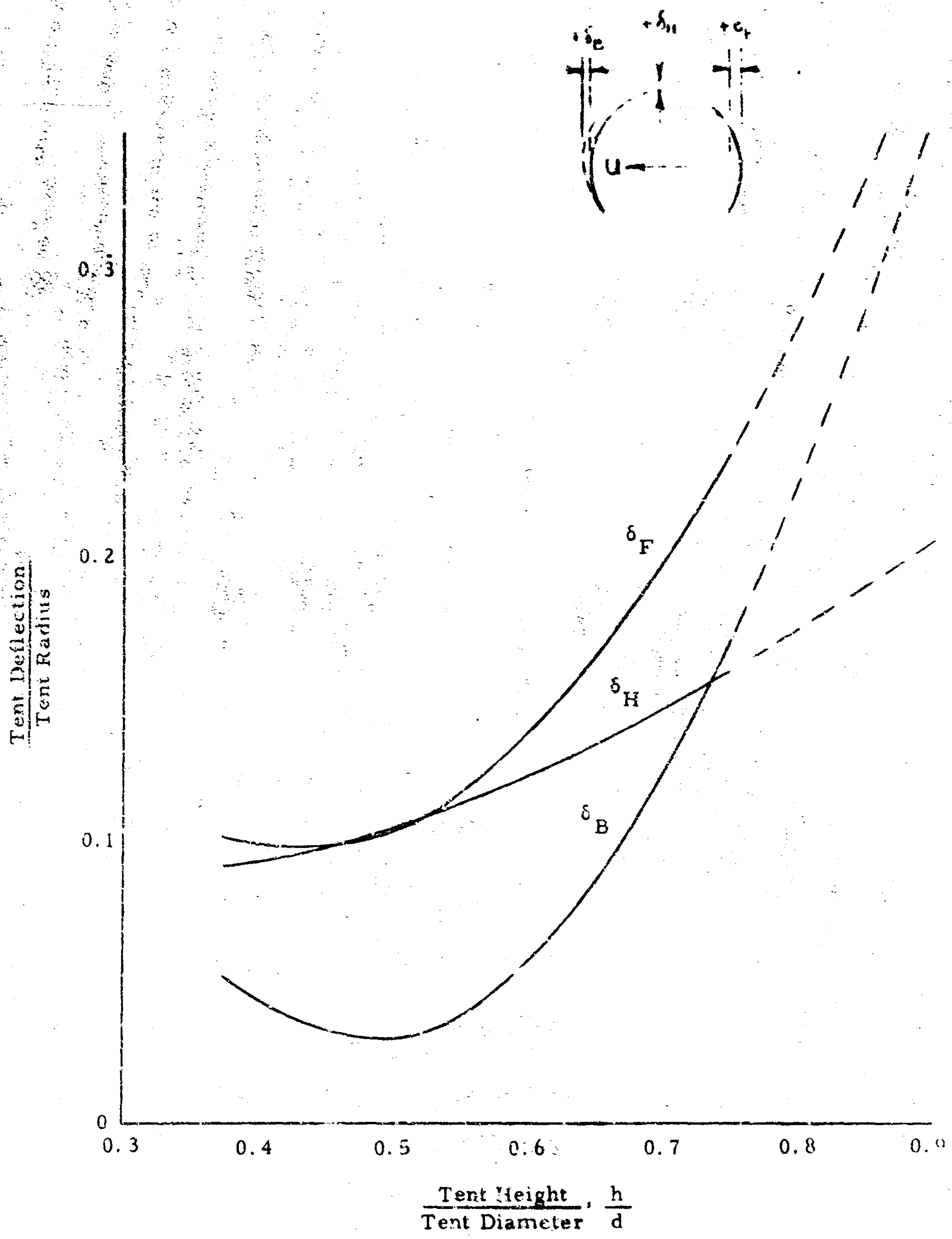


Figure 18- Variation of Tent Deflection With Shape (Cylindrical Single Wall Tents, 1:2 W/ℓ_h)

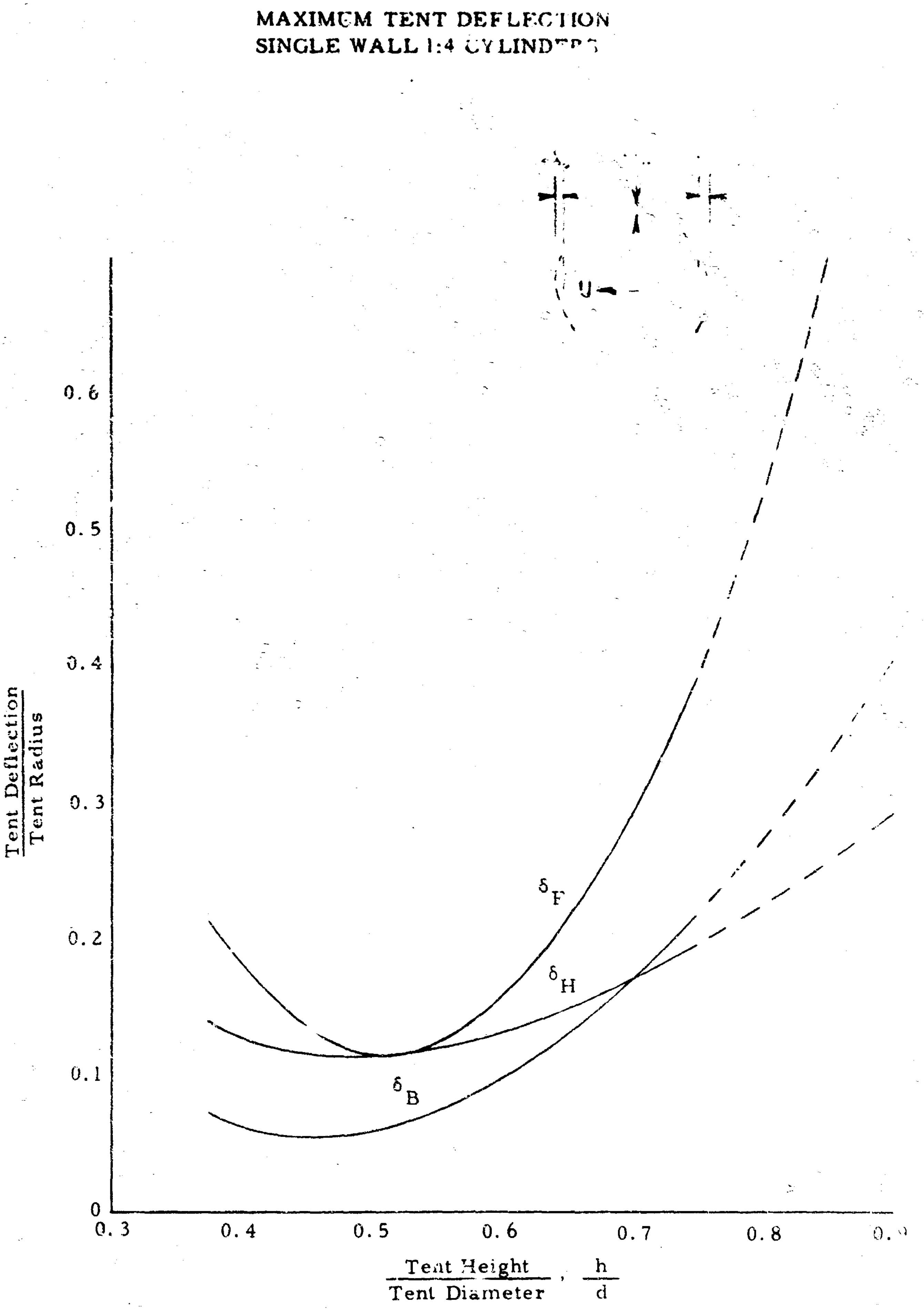


Figure 19. - Variation of Tent Deflection With Shape (Cylindrical Single Wall Tents 1:4 W/ℓ_h)

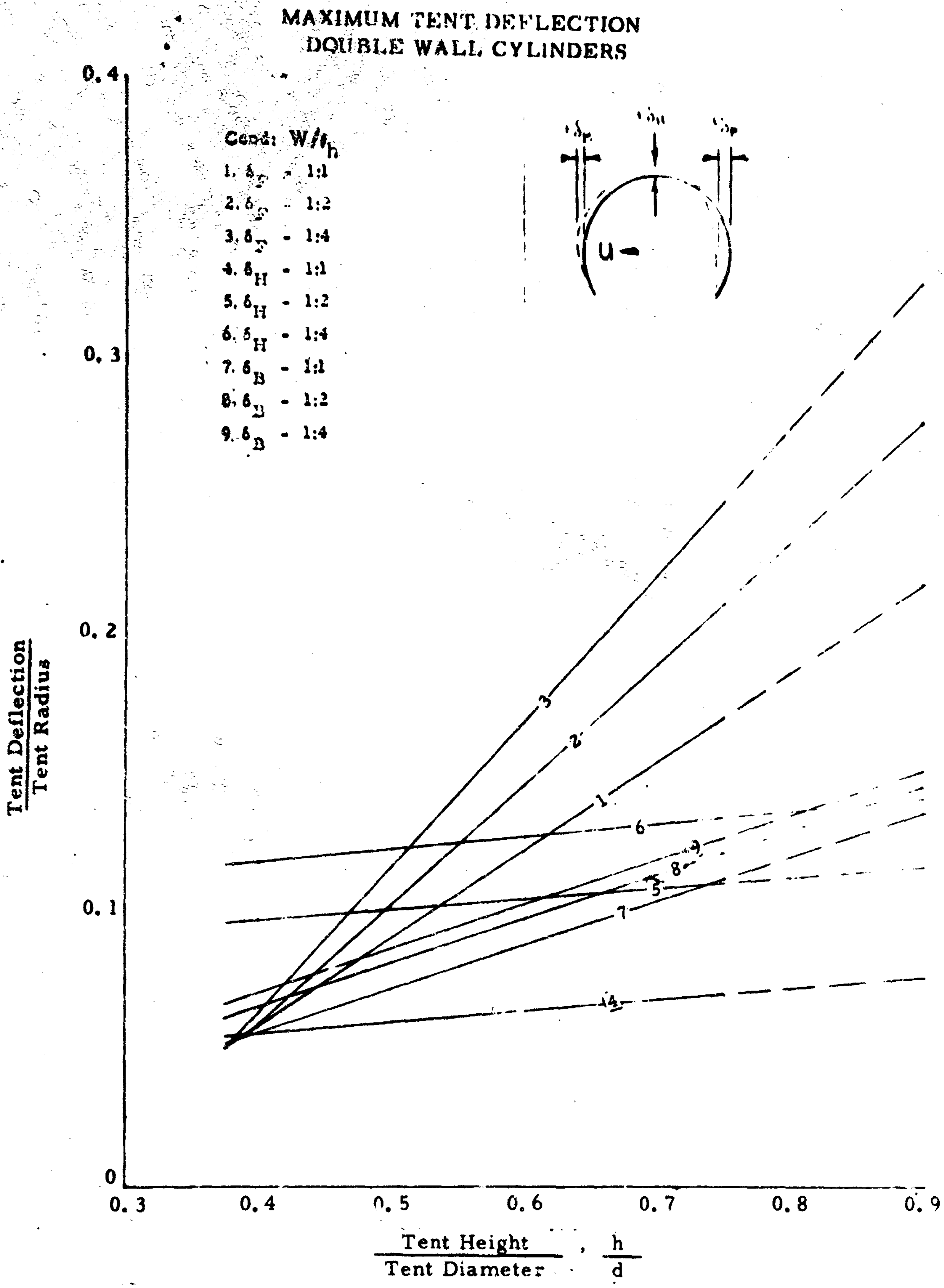


Figure 20 . - Variation of Tent Deflection with Shape
(Non Porous Double Wall Tents; 1:1, 1:2, 1:4 W/ℓ_h)

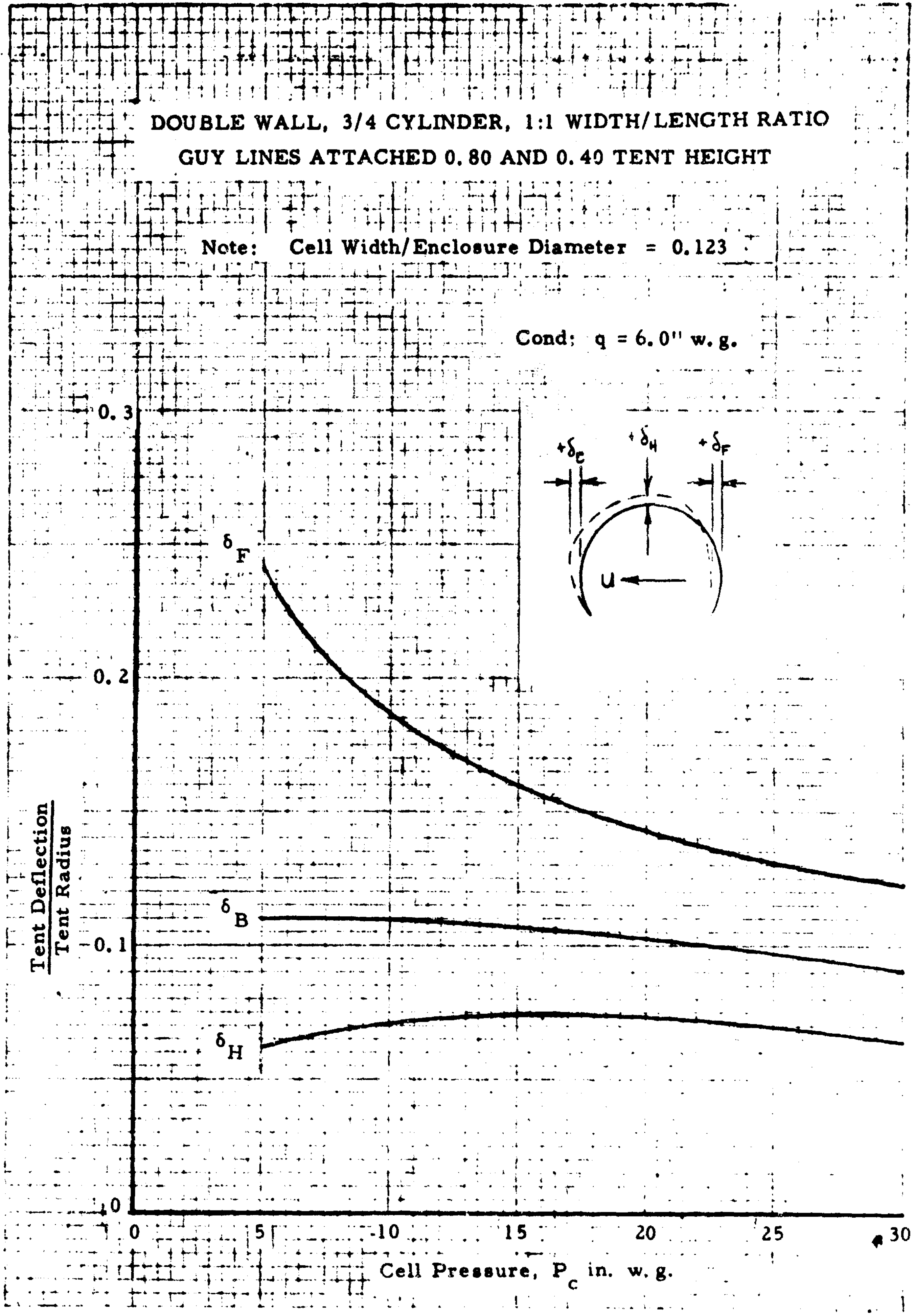


Figure 21. - Variation of Tent Deflection with Cell Pressure. Guy Lines Attached at 0. 80 and 0. 40 Tent Height.

MAXIMUM AERODYNAMIC ANCHOR LOAD COEFFICIENT
SINGLE WALL SPHERES AND CYLINDERS

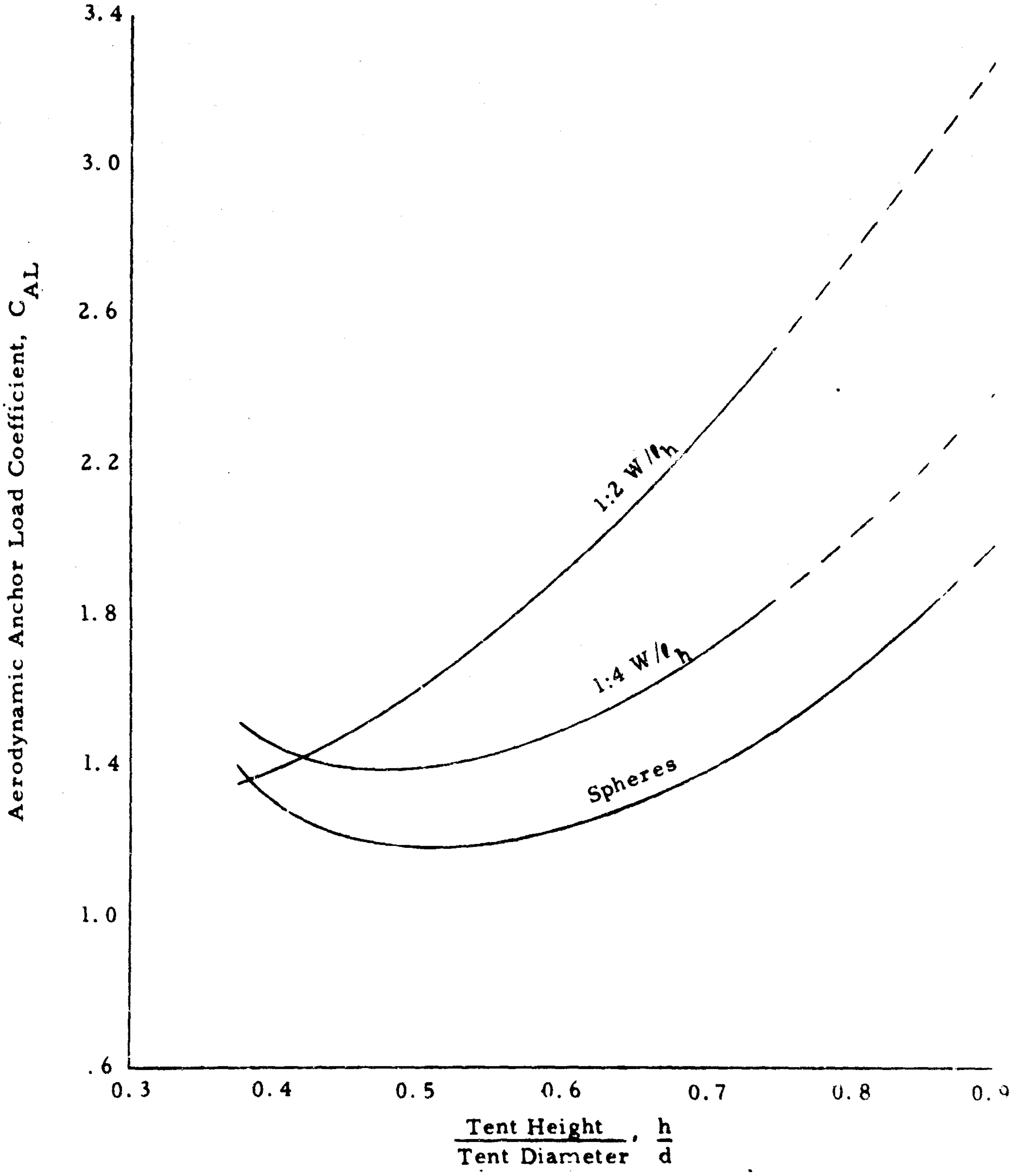


Figure 22.- Variation of Anchor Load Coefficient With Shape. (Spherical And Cylindrical Single Wall Tents, 1:2, 1:4 W/ℓ_h)

MAXIMUM BASE ANCHOR LOAD COEFFICIENTS
DOUBLE WALL CYLINDERS

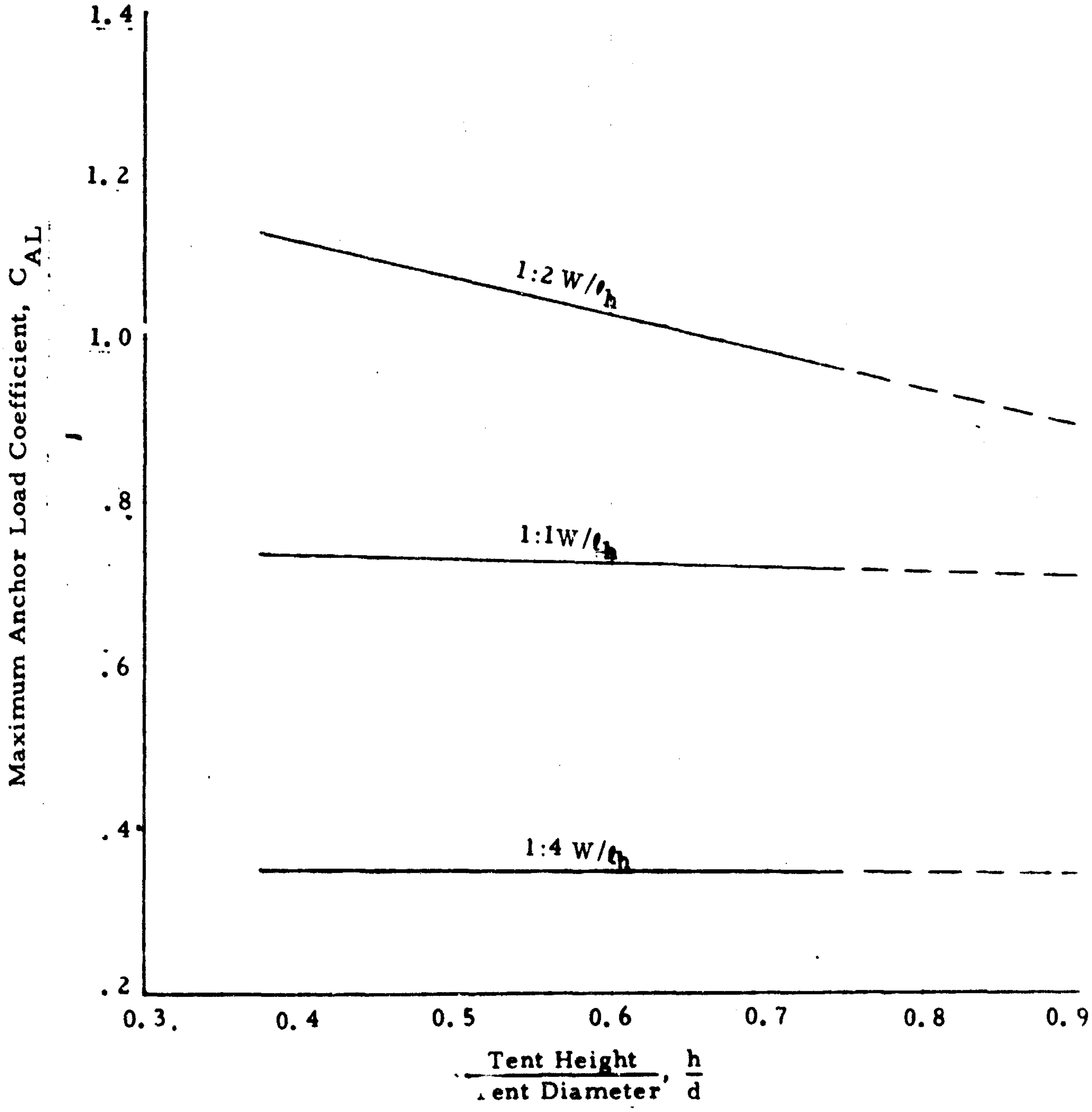


Figure 23. - Variation of Base Anchor Load Coefficient with Shape.

MAXIMUM GUY LINE LOAD COEFFICIENT
DOUBLE WALL CYLINDER

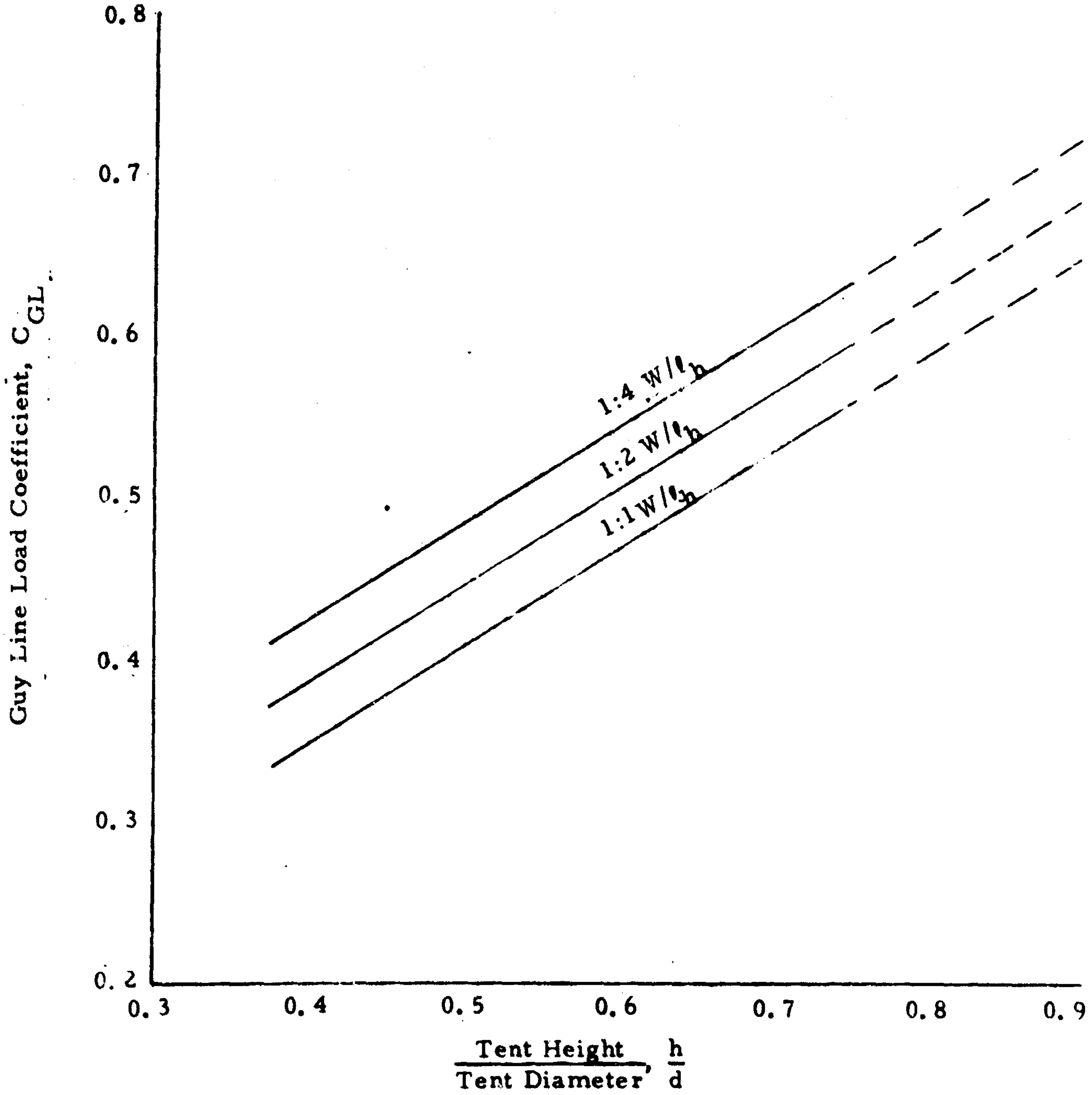


Figure 24. - Variation of Guy Line Load Coefficient with Shape.

PEAK STRESS COEFFICIENTS
SINGLE WALL SPHERES

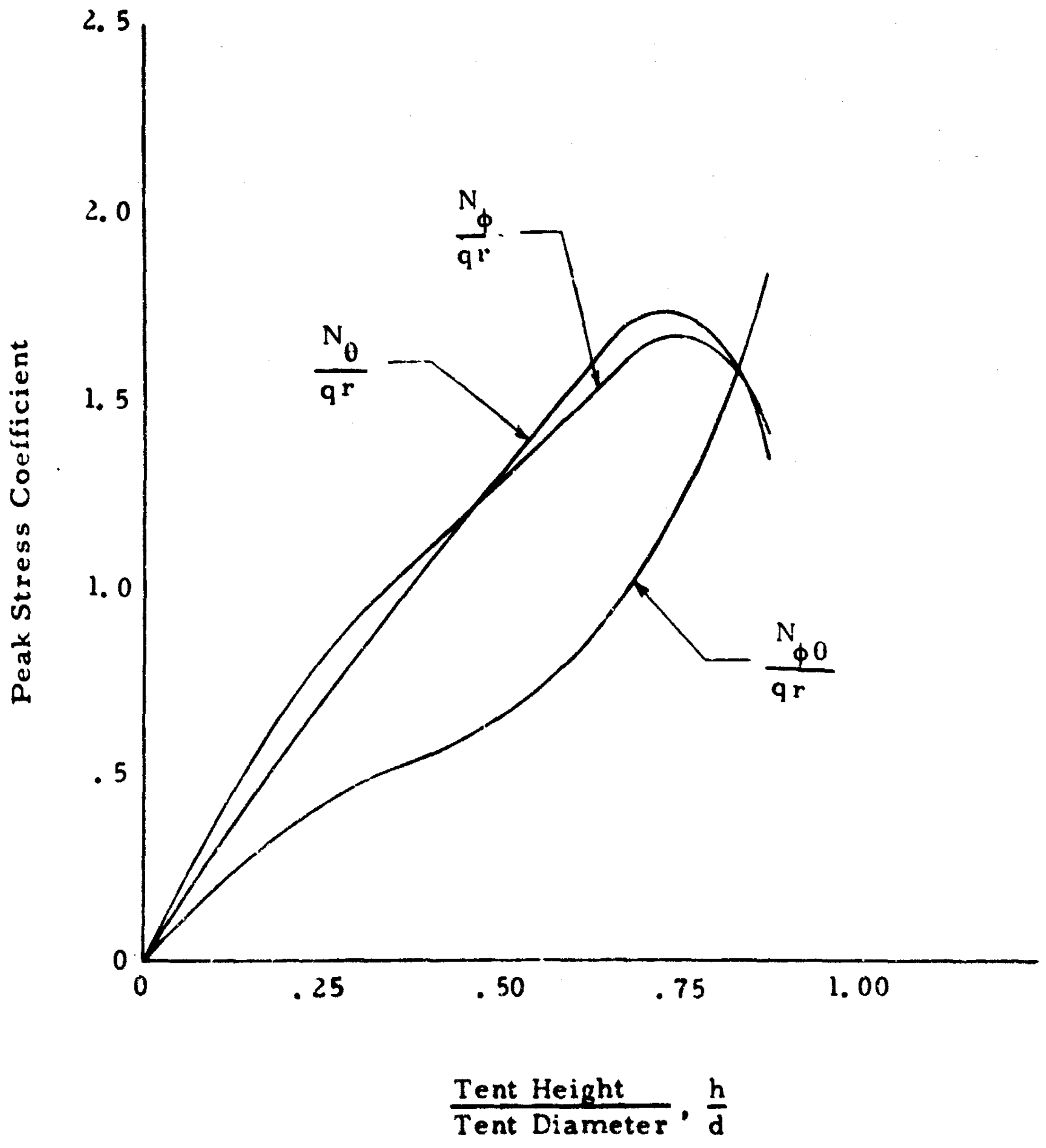


Figure 25. - Variation of Peak Stress Coefficients With Shape (Spherical Single Wall Tents).

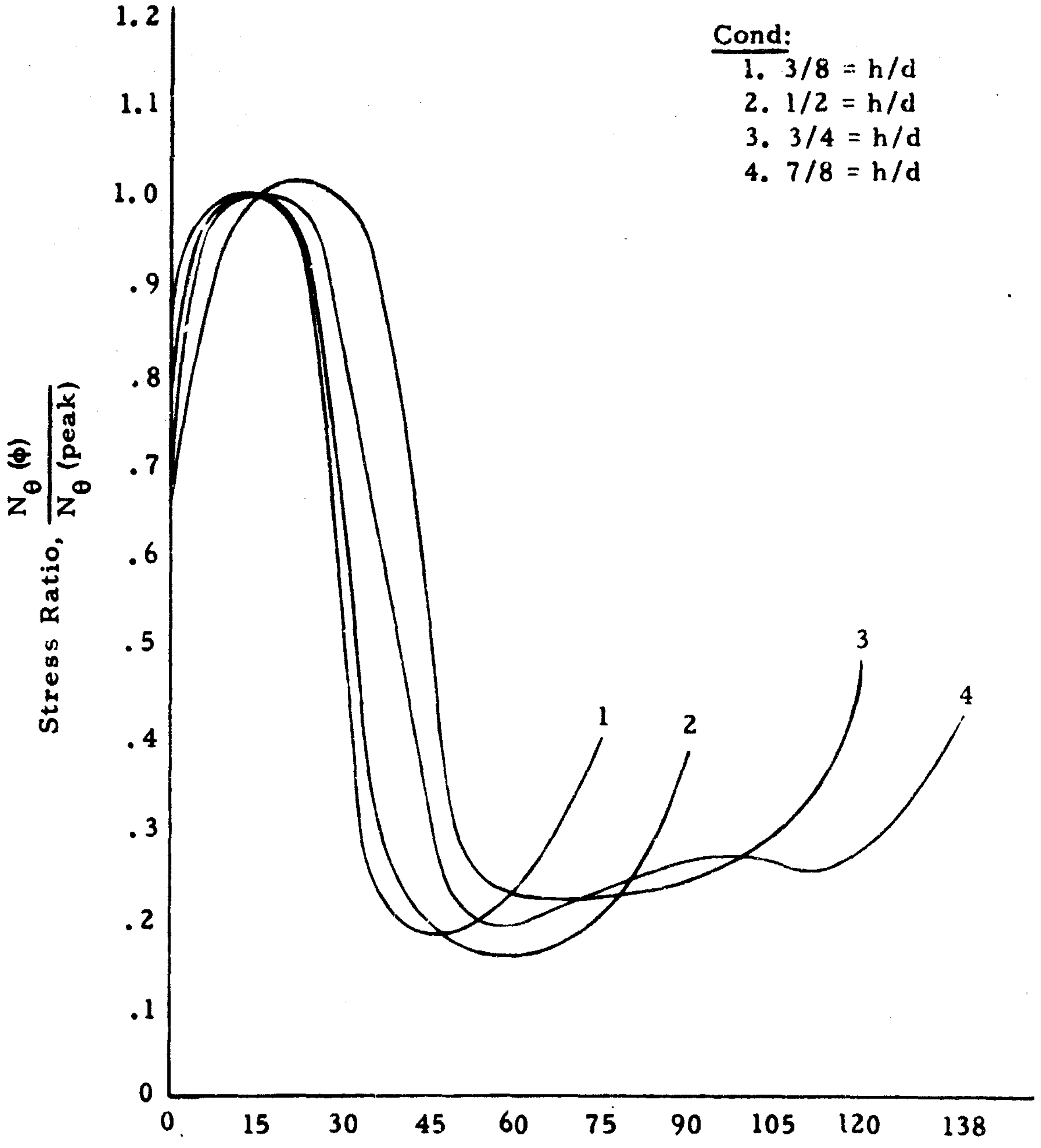


Figure 26.- Variation of Stress Ratio With Apex Angle (Spherical Single Wall Tents).

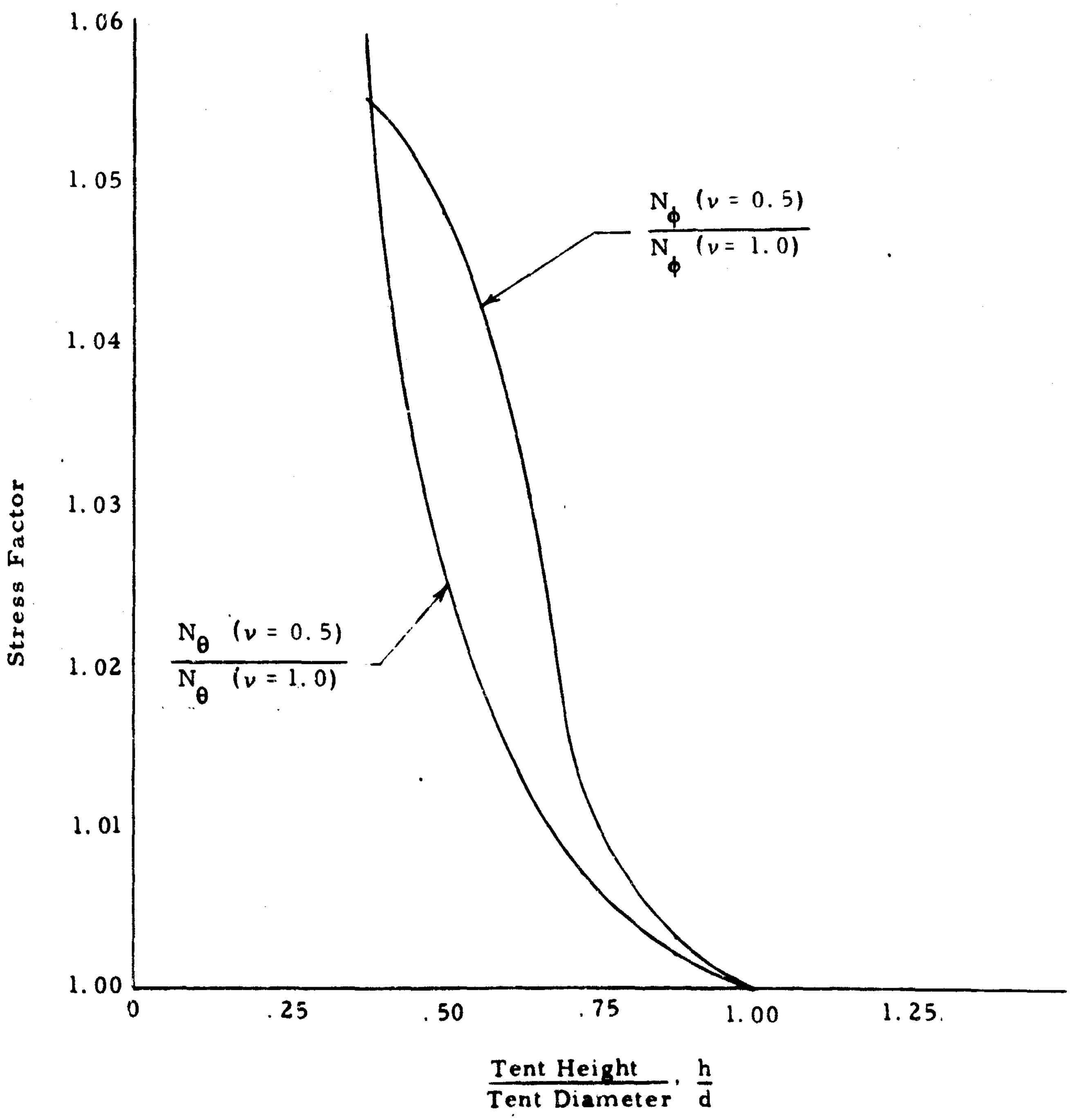

FABRIC STRESS FACTOR
WITH POISSONS RATIO $\nu = 0.5$

Figure 27.- Variation of Stress Factor With Tent Shape

MAXIMUM DESIGN STRESS COEFFICIENT

Note: $W/\ell_h = .25$ to 1.00

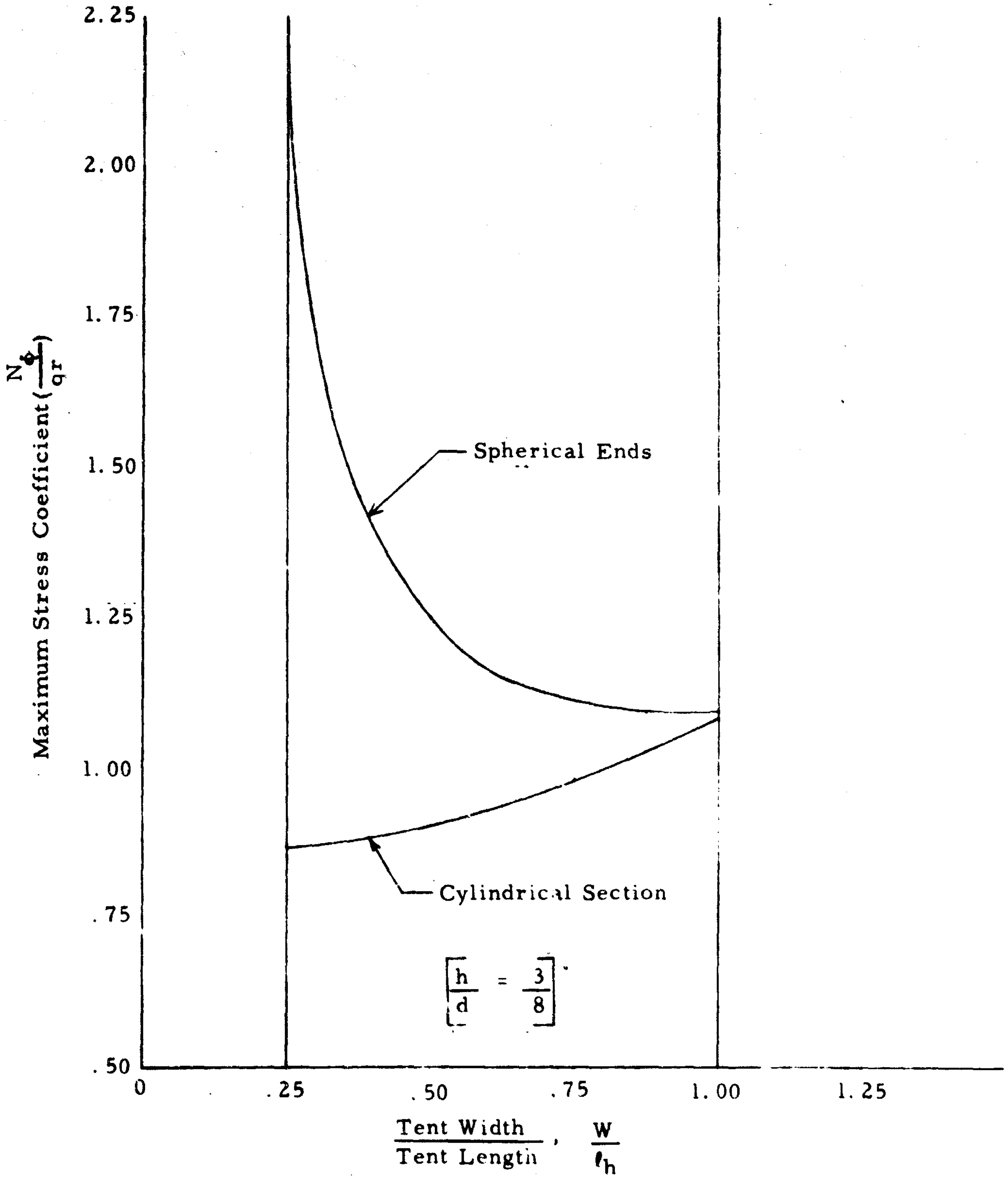


Figure 28. - Variation of Maximum Design Stress Coefficient With Tent Width To Length Ratio.

MAXIMUM DESIGN STRESS COEFFICIENT

Note: $W/\ell_h = .25$ to 1.00

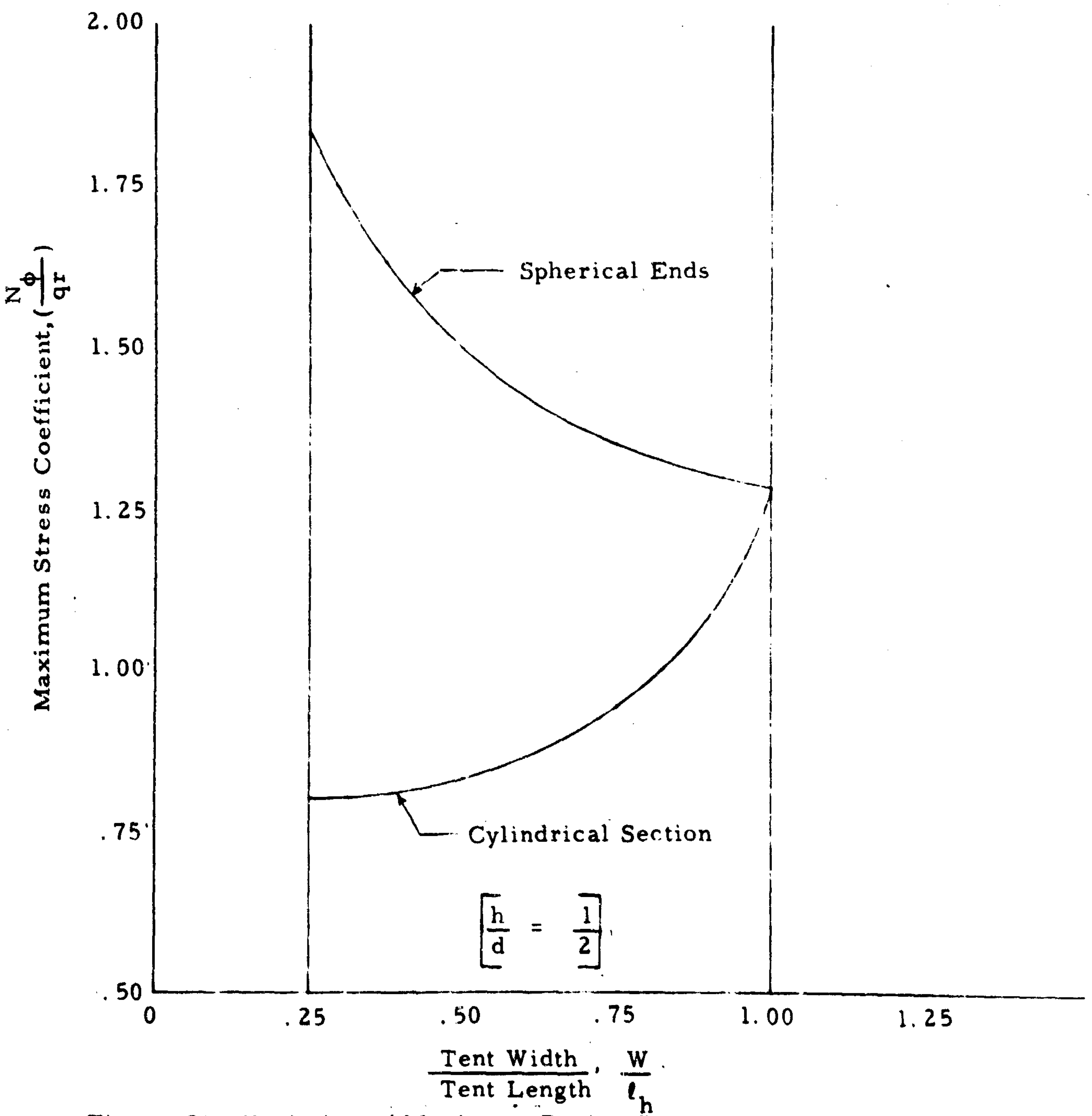


Figure 29.- Variation of Maximum Design Stress Coefficient With Tent Width to Length Ratio.

MAXIMUM DESIGN STRESS COEFFICIENT

Note: W/ℓ_h = .25 to 1.00

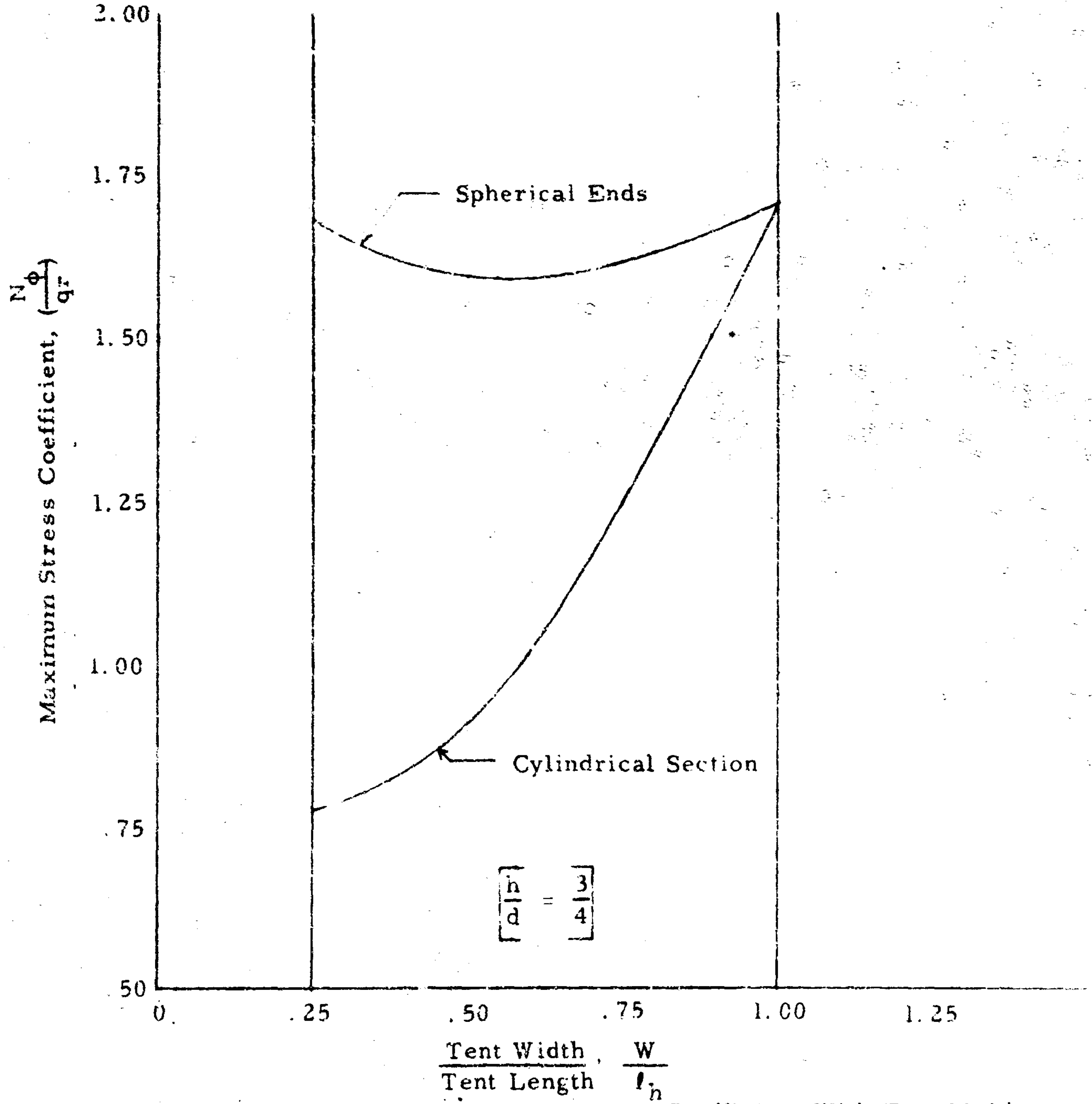


Figure 30- Variation of Maximum Design Stress Coefficient With Tent Width To Length Ratio.

Note: W/ℓ_h .25 to 1.00

Cond:
Spherical Ends and
Cylindrical Section

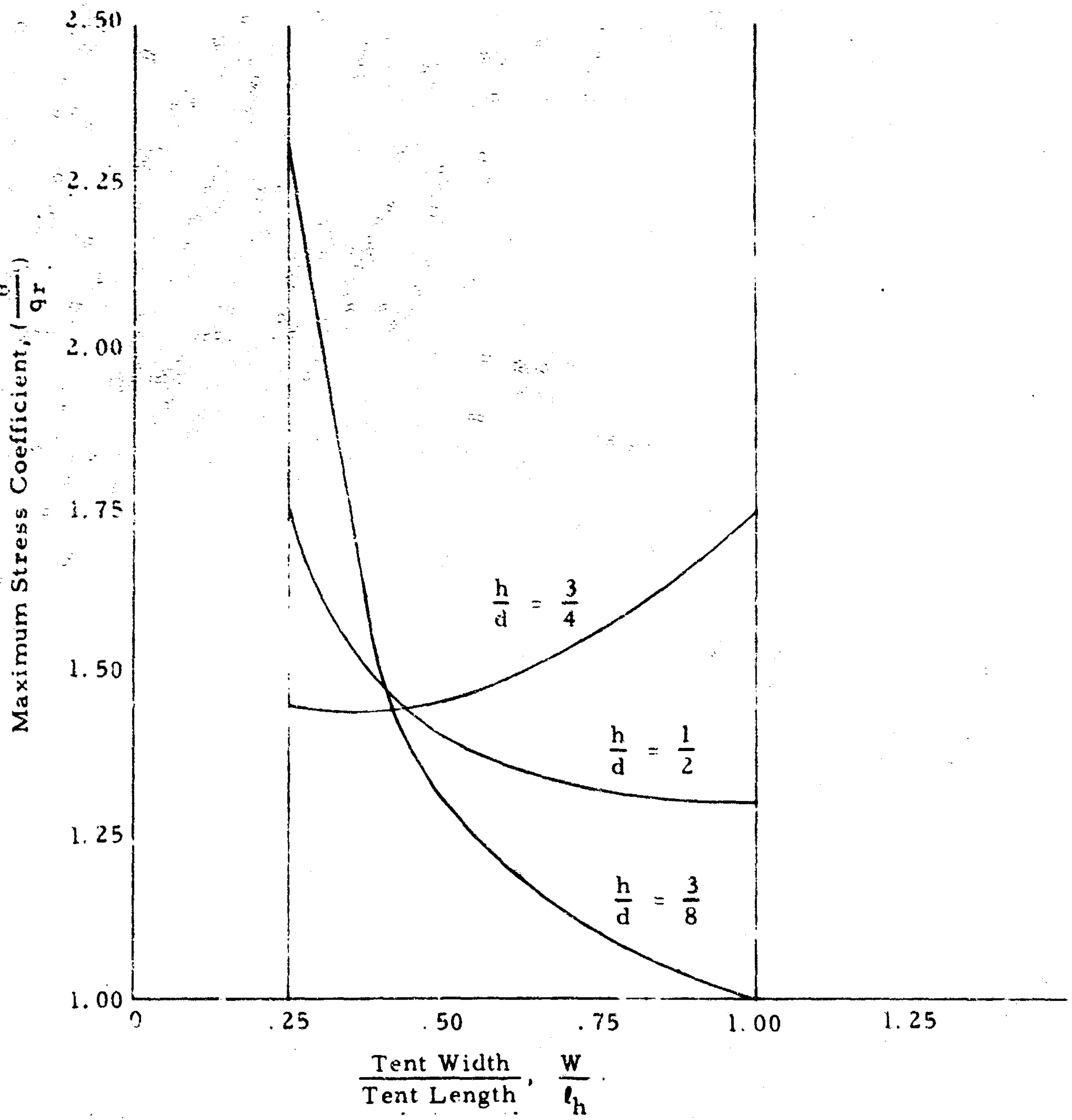


Figure 31.- Variation of Maximum Design Stress Coefficient With Tent Width To Length Ratio

MAXIMUM DESIGN STRESS COEFFICIENT

Note: W/ℓ_h = .25 to 1.00

Cond: Spherical Ends

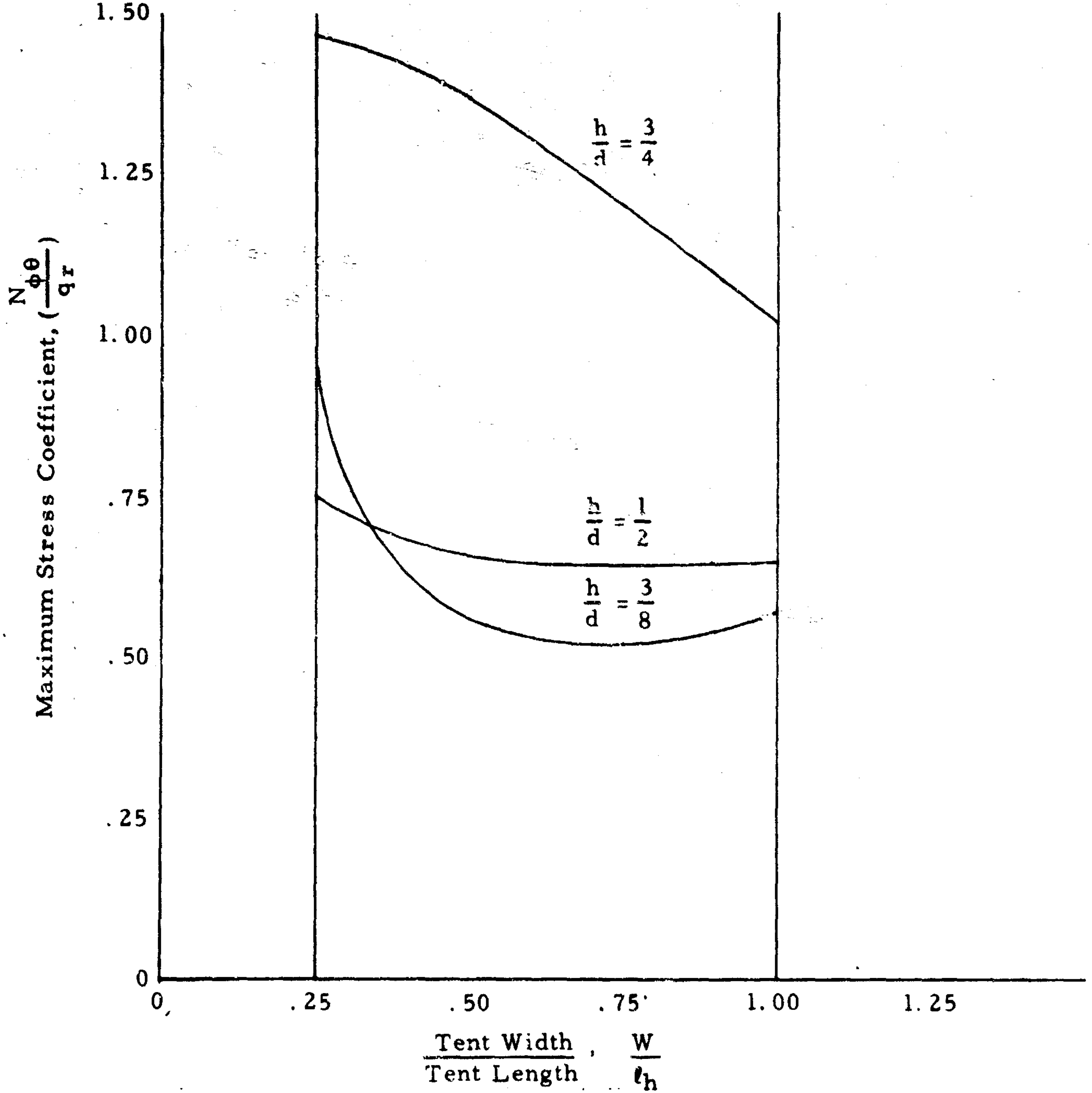


Figure 32. - Variation of Maximum Design Stress Coefficient With Tent Width To Length Ratio.

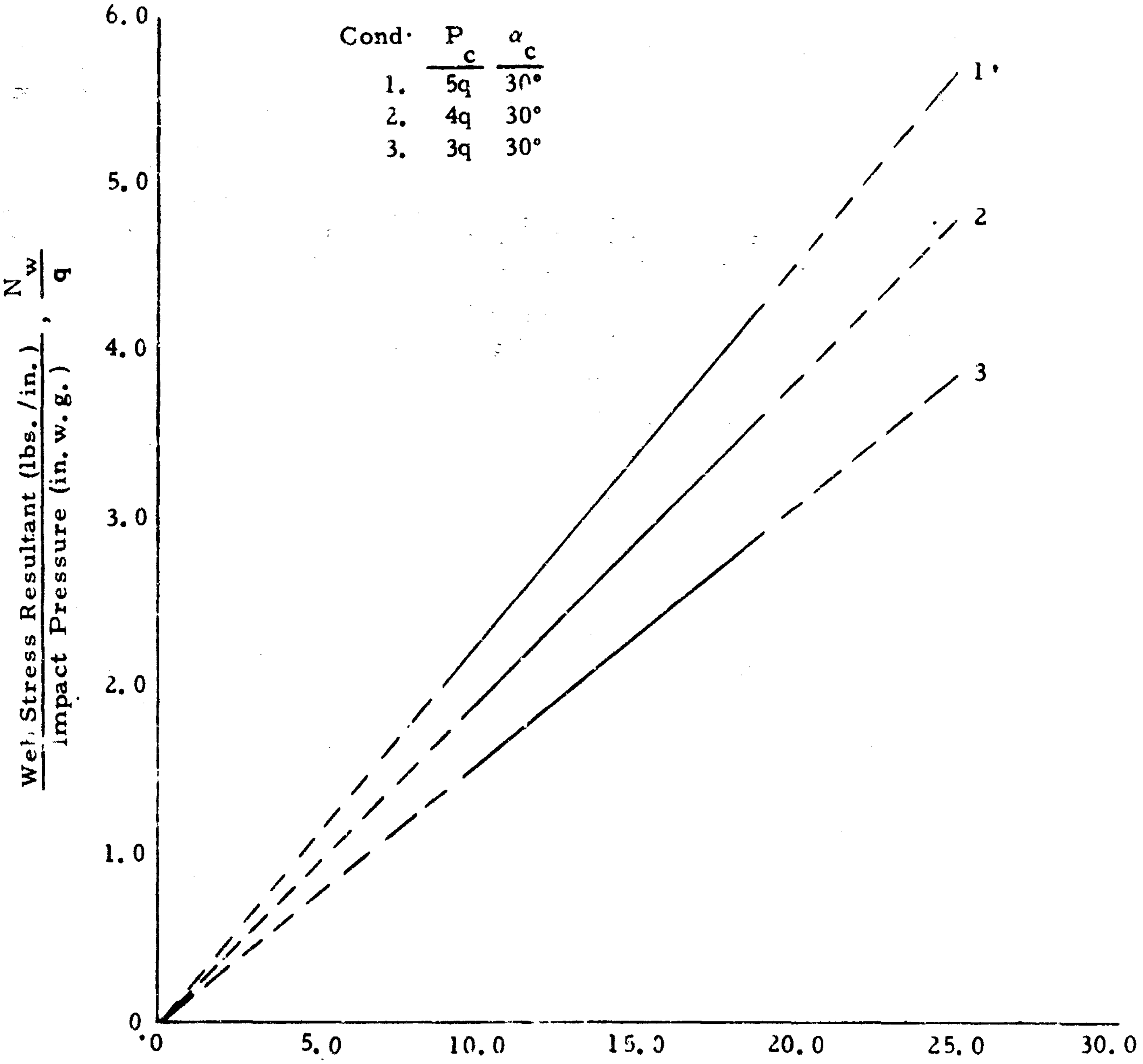


Figure 33. - Variation of Web Stress Coefficient with Cell Radius.

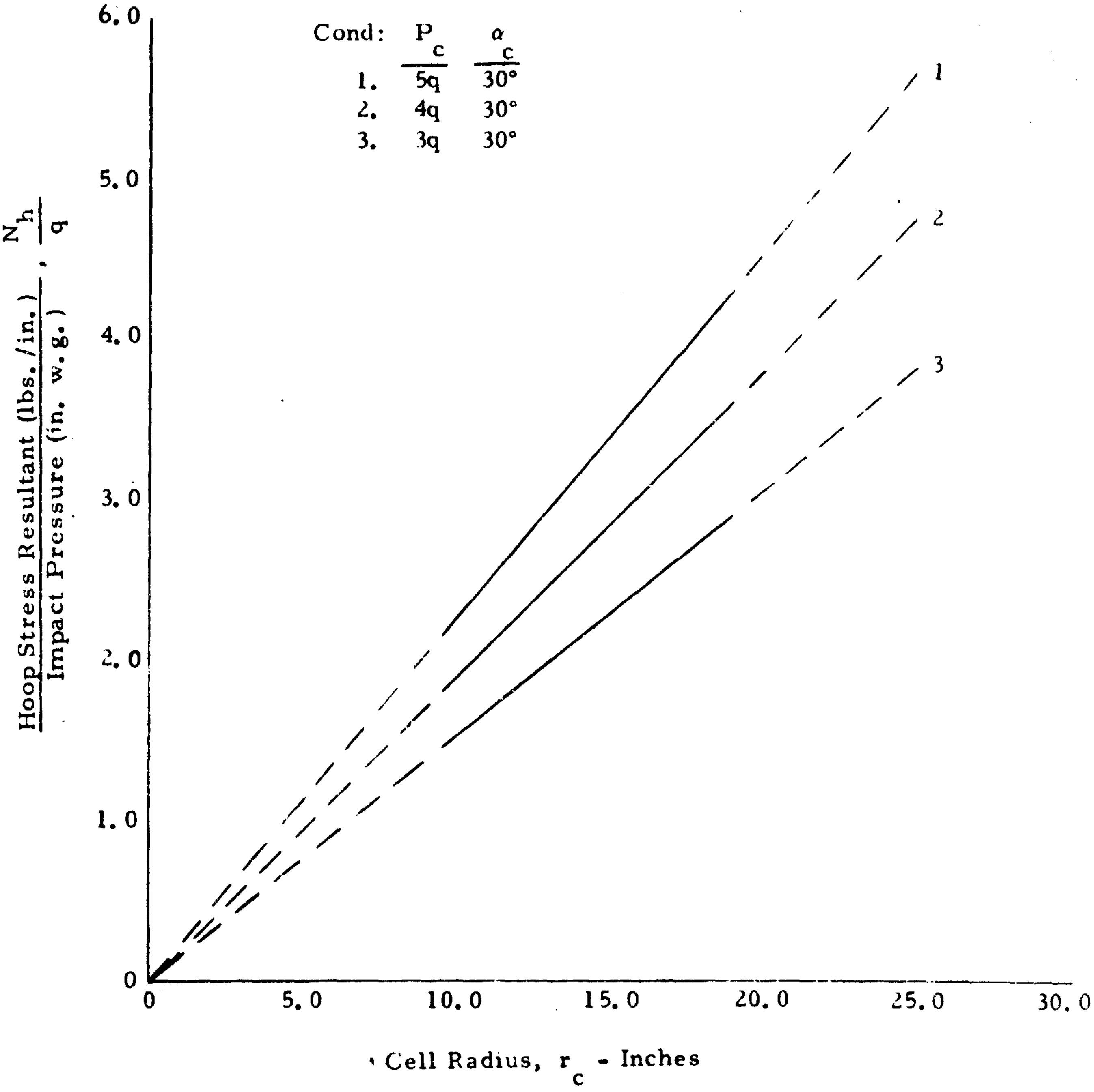


Figure 34. - Variation of Hoop Stress Coefficient with Cell Radius.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note: $w/d = 0.16$, $h/d = 0.50$

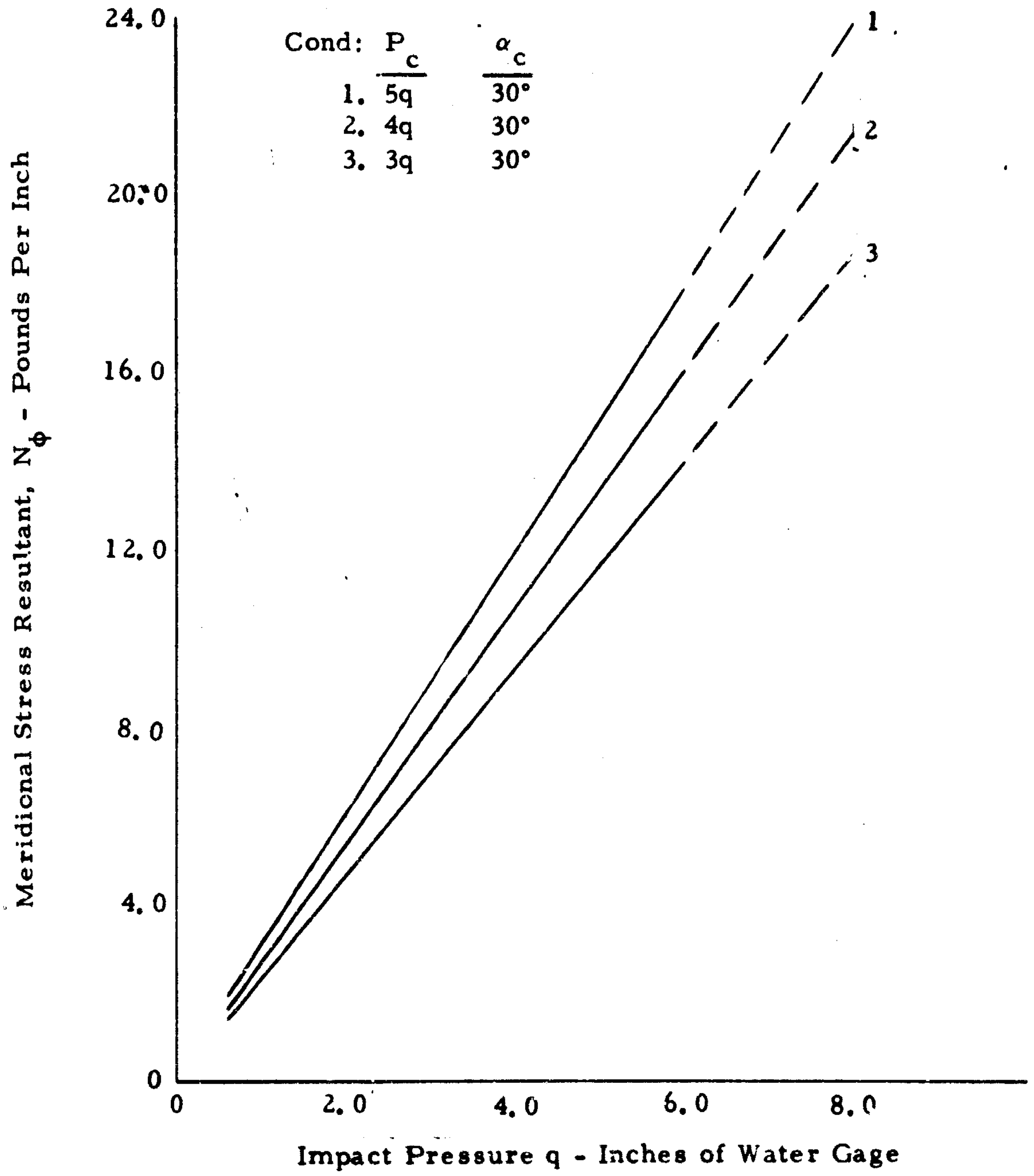


Figure 35. - Variation of Meridional Stress Resultant with Impact Pressure, q.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note: w/d = 0.12, h/d = 0.50

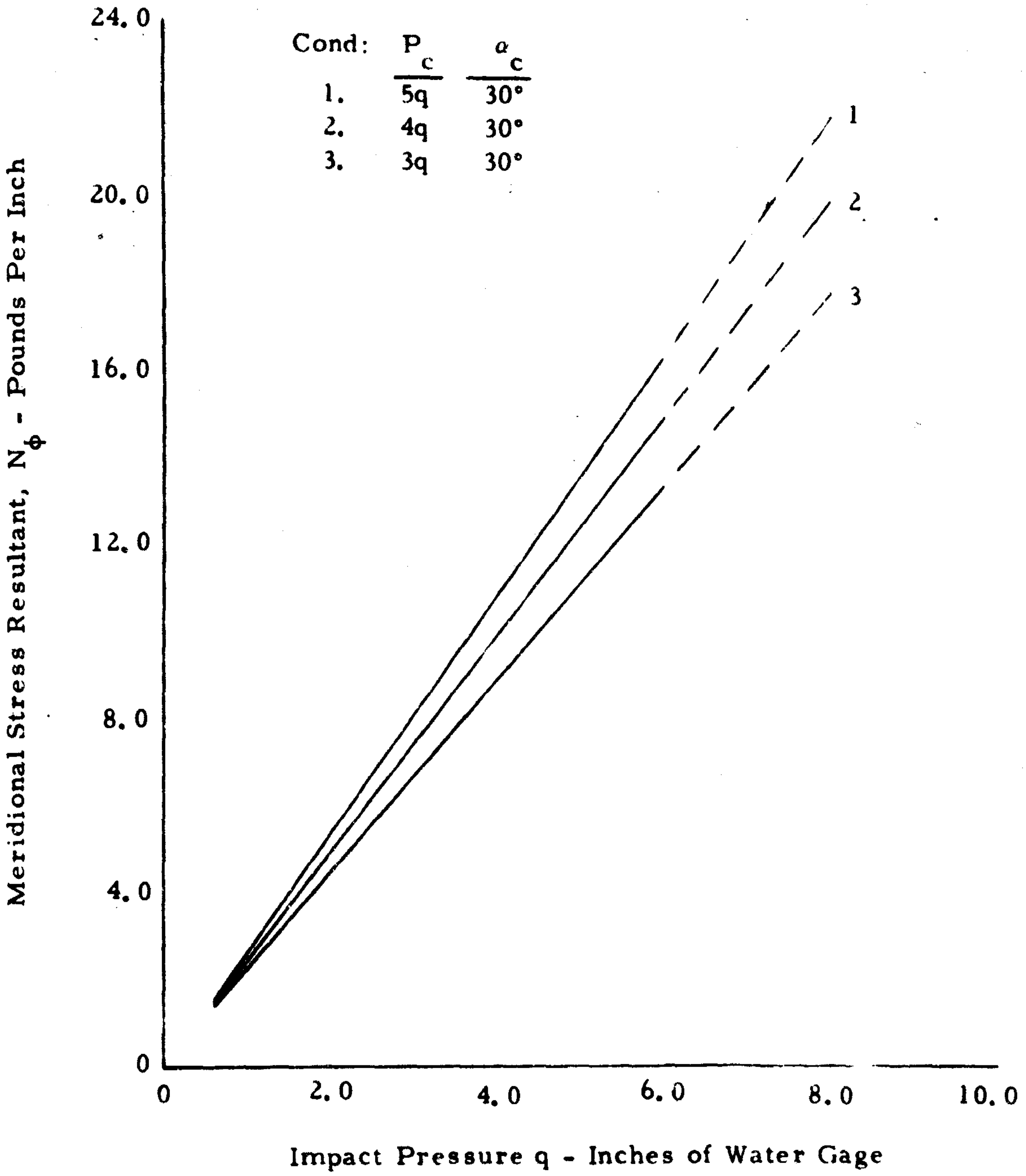


Figure36. - Variation of Meridional Stress Resultant with Impact Pressure, q.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note: w/d = 0.080, h/d = 0.50

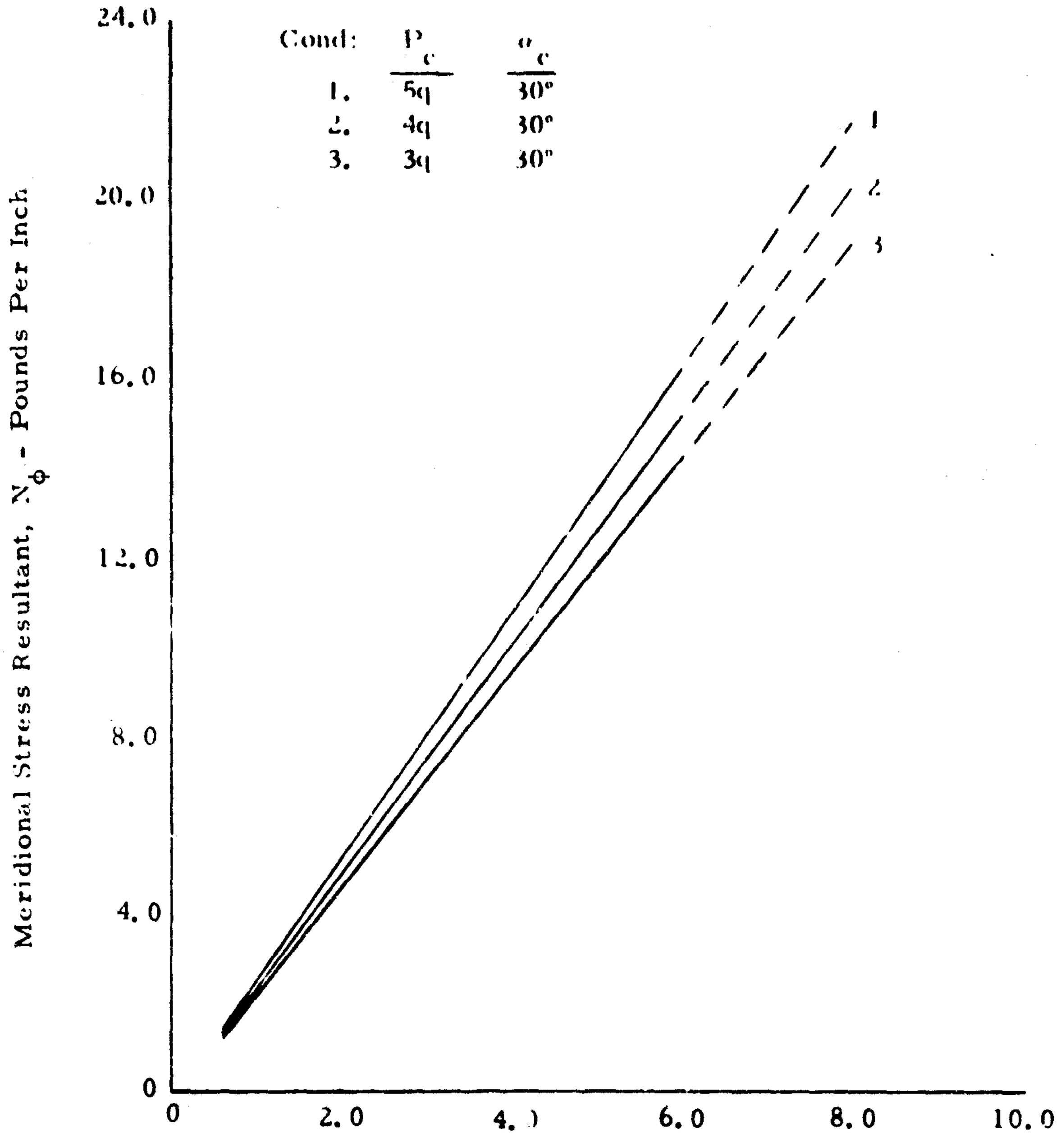


Figure 37. - Variation of Meridional Stress Resultant with Impact Pressure, q.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note: w/d 0.16, 9° Sloping Sides; h/d - 0.80

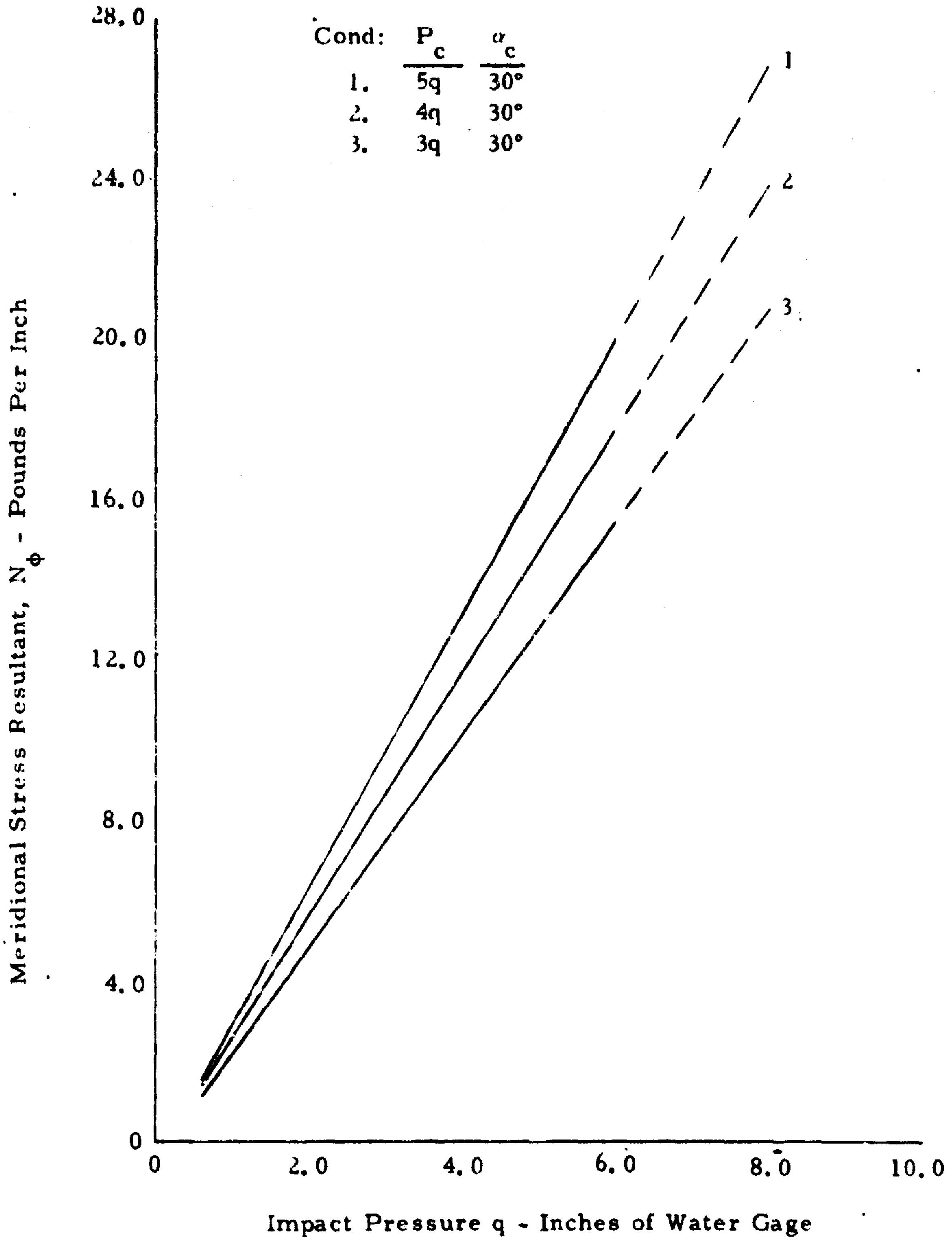


Figure38. - Variation of Meridional Stress Resultant with Impact Pressure, q.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note: w/d = 0.12, 9° Sloping Sides; h/d = 0.80

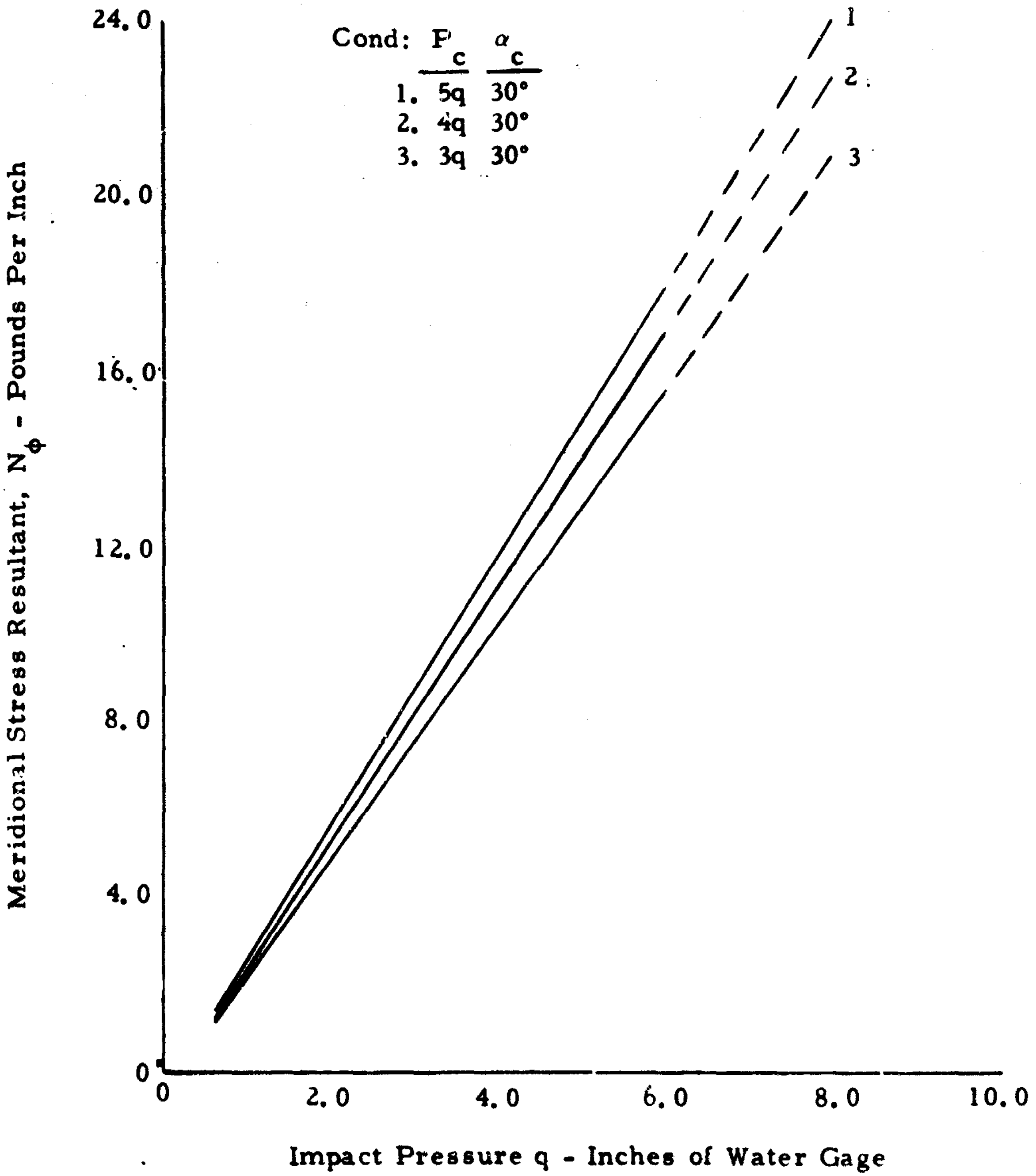


Figure 39. - Variation of Meridional Stress Resultant with Impact Pressure, q.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note: w/d = 0.08, 9° Sloping Sides; h/d = 0.80

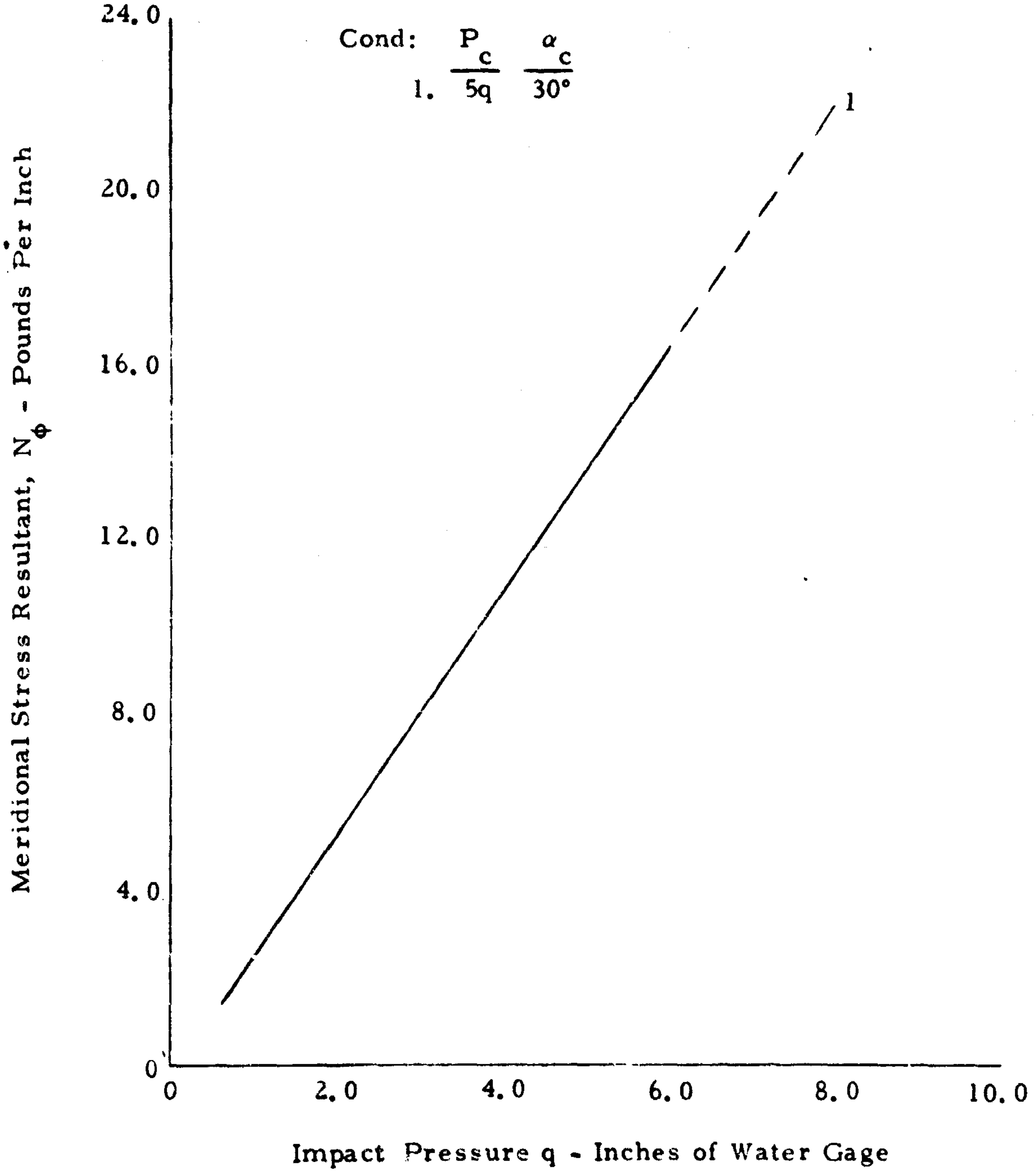
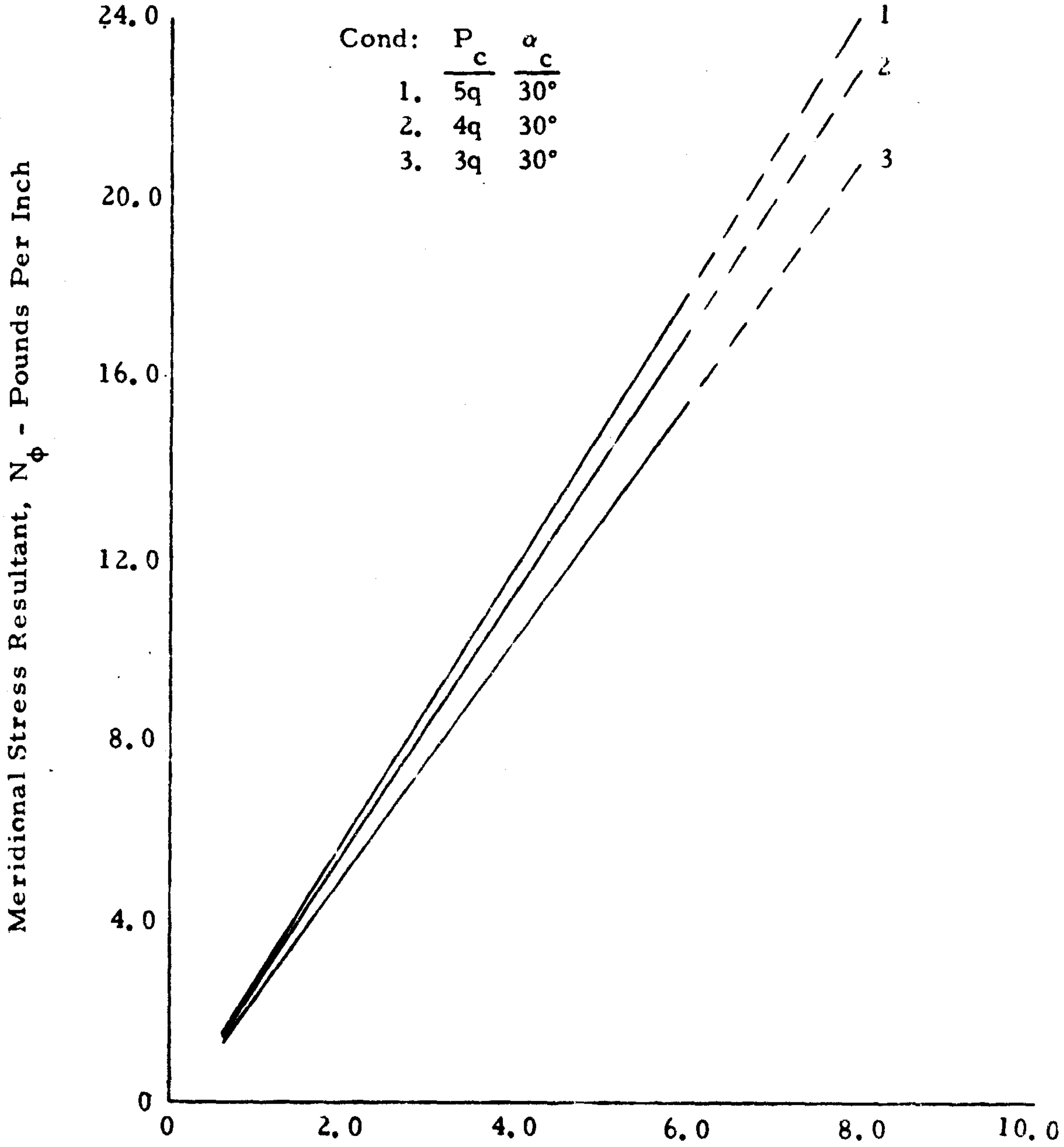


Figure 40. - Variation of Meridional Stress Resultant with Impact Pressure, q.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note: w/d = 0.16, h/d = 0.75



Impact Pressure q - Inches of Water Gage

Figure41. - Variation of Meridional Stress Resultant with Impact Pressure, q.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note: w/d = 0.12, h/d = 0.75

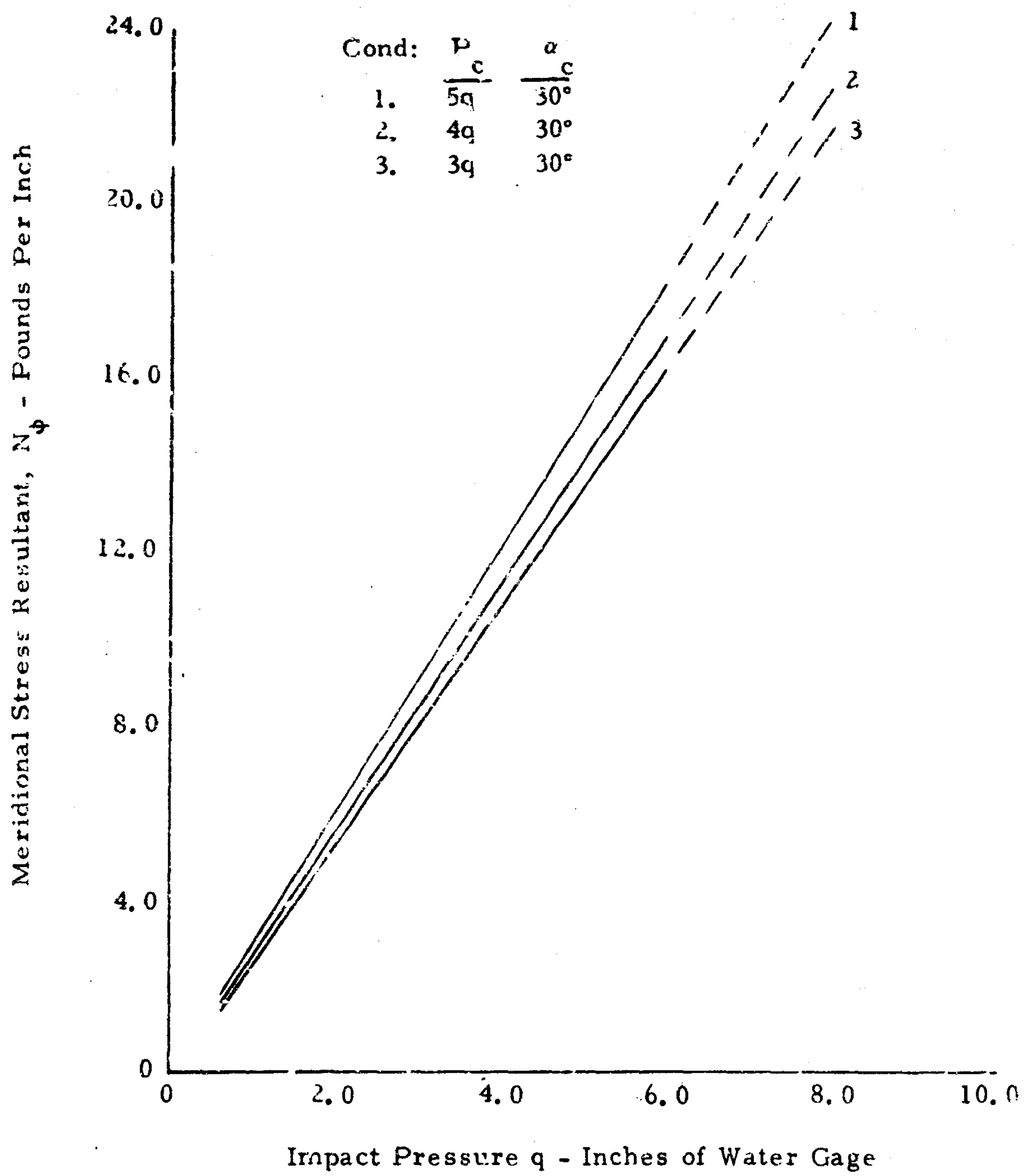


Figure 42 - Variation of Meridional Stress Resultant with Impact Pressure, q.

DOUBLE WALL CYLINDERS
GUY LINES ATTACHED 0.80 TENT HEIGHT

Note w/d = 0.08, h/d = 0.75

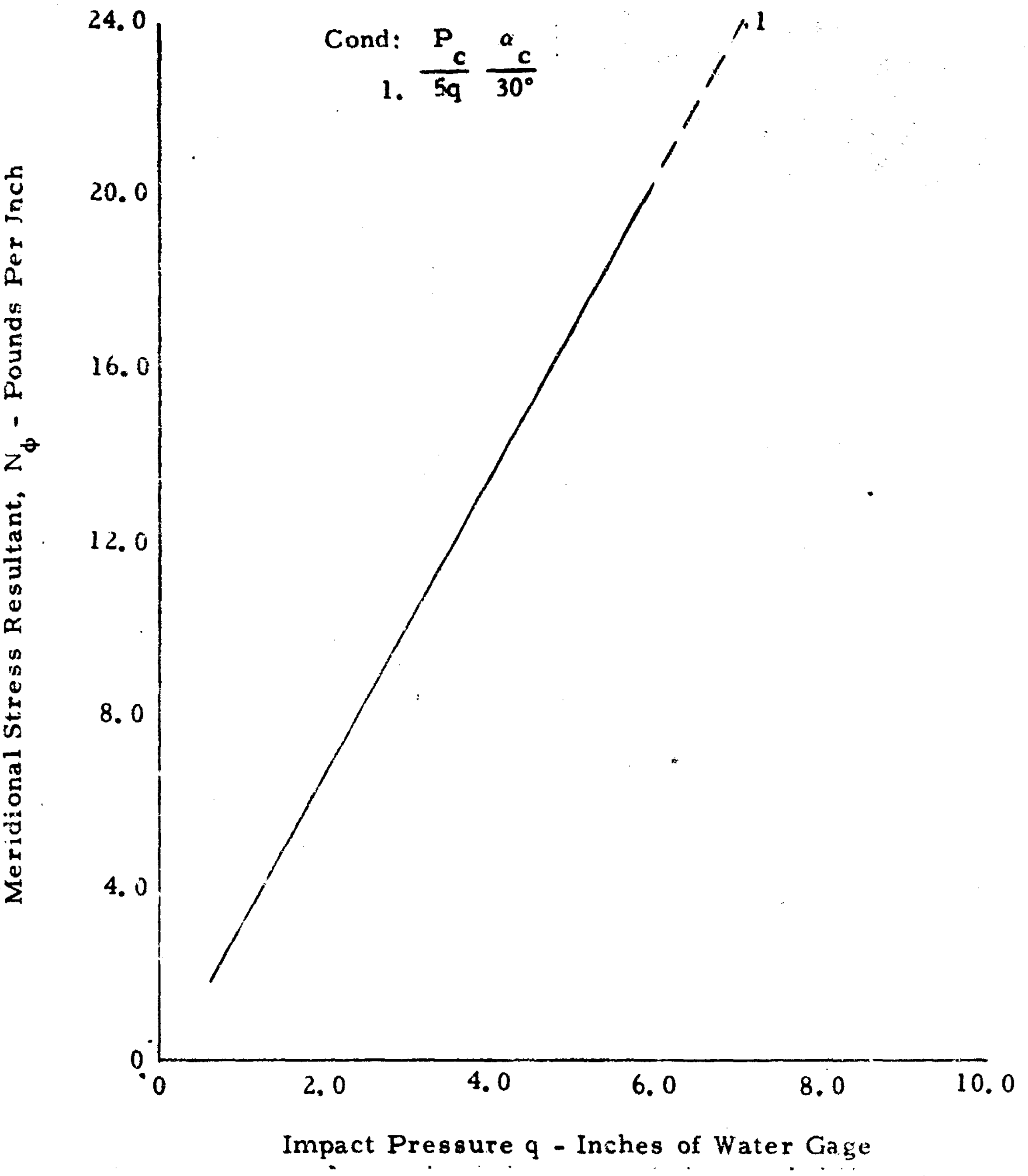


Figure 43 - Variation of Meridional Stress Resultant with Impact Pressure, q.

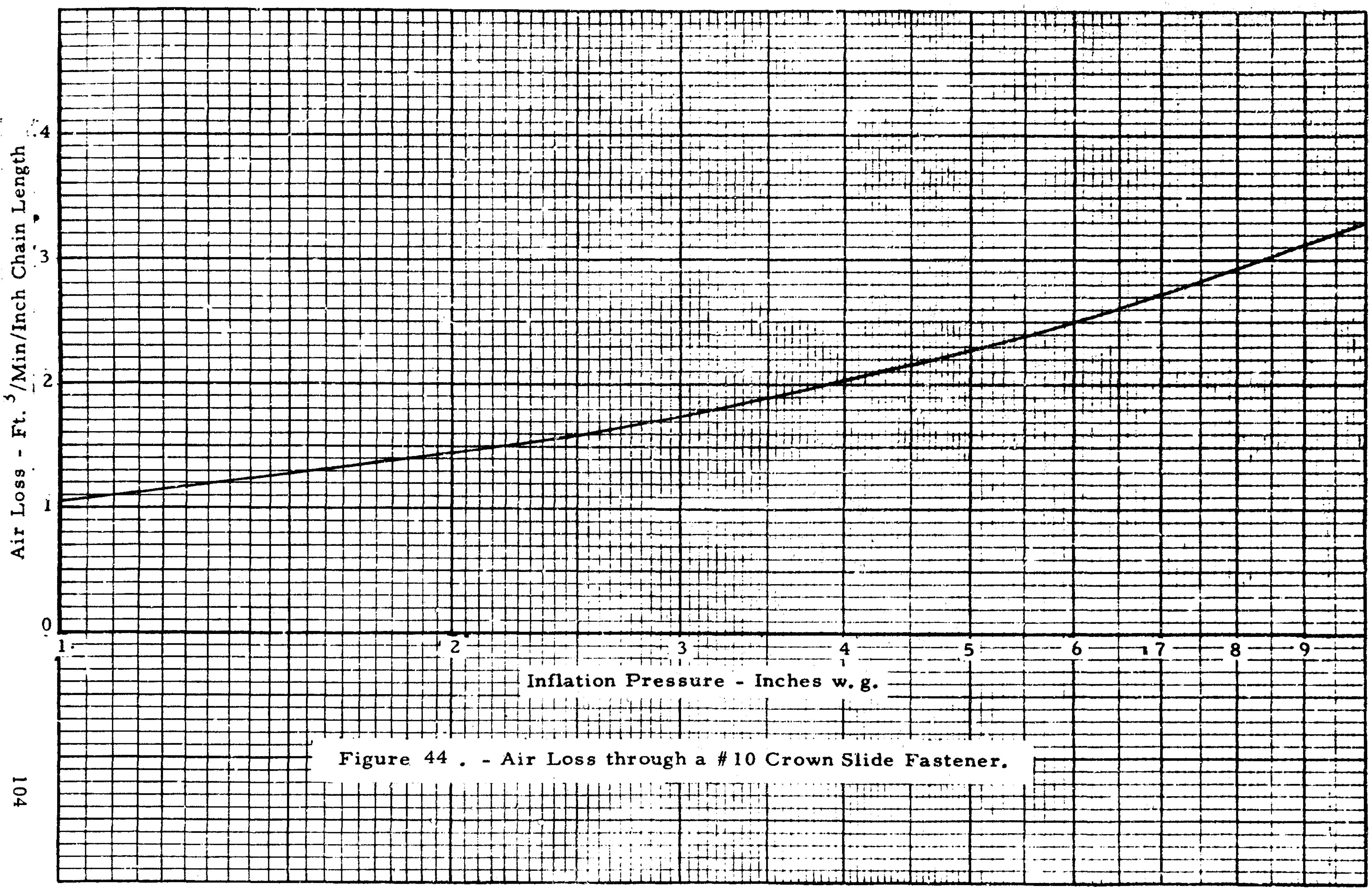


Figure 44 . - Air Loss through a #10 Crown Slide Fastener.

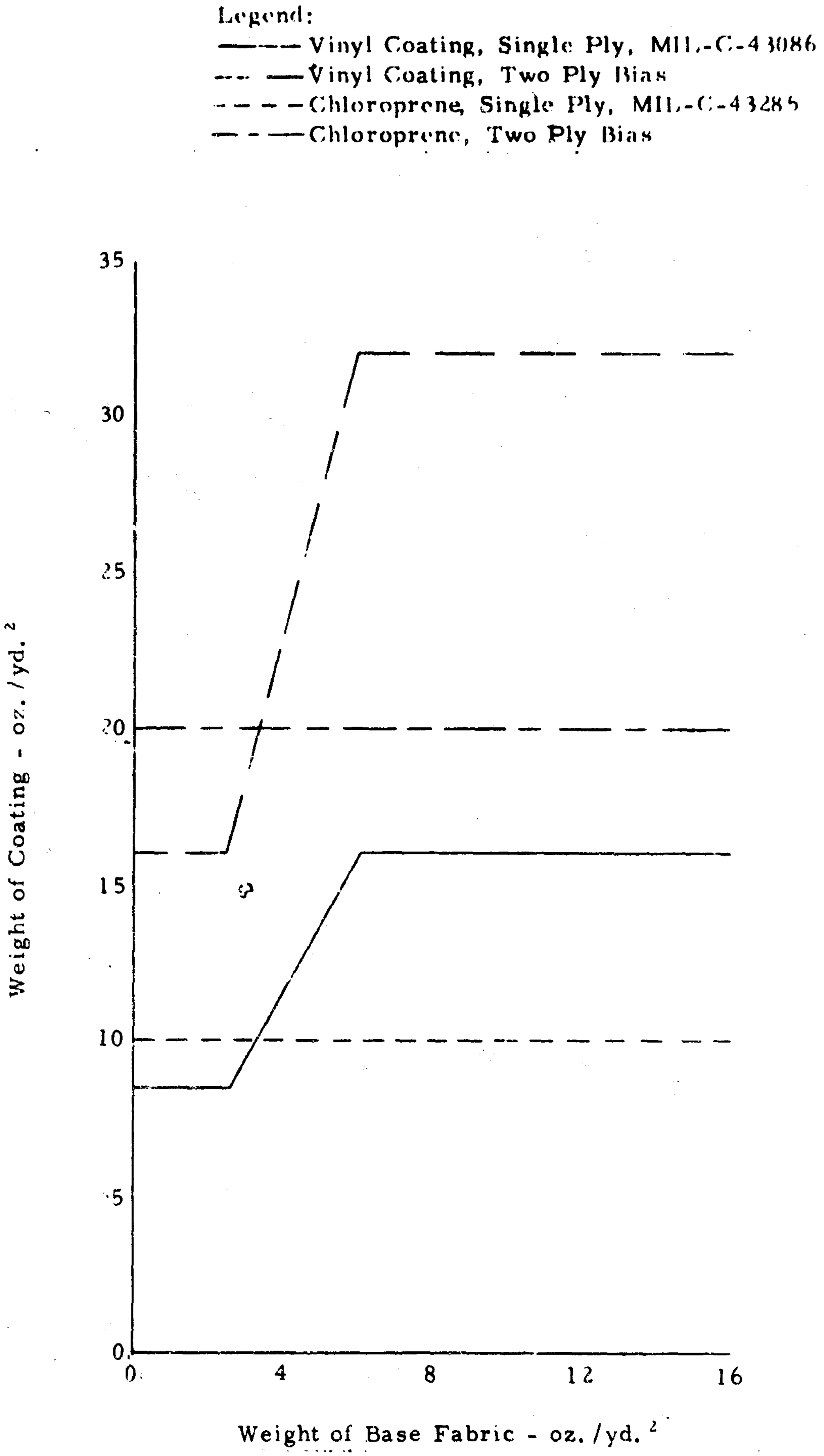


Figure 45. - Weight of Coating for Single and Two Ply Coated Fabric.

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 under Contract DA 19-129-AMC-129(N) 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 October 1966. During the study phase, a review was made of pertinent literature on experimental techniques, data and analyses applicable to determining maximum aerodynamic force on and stresses in fabric structures. The wind tunnel investigations consisted of detailed testing of twenty-six tent models to include sixteen single wall structures (ten with non-porous and six with porous fabric) and ten double wall structures. Tests were conducted at stabilized wind speeds up to 105 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 includes comprehensive, practical design data suitable for engineering reliable, stable, single and double-wall, air-supported structures. Data, in general, are presented in non-dimensional 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 deflection, material stresses and specifications, usable volume, and weight.

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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 another publication.

Design information is given for spherical cylindrical air-supported tents. 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 coefficient. Anchor and guideline coefficients, structural deflections, material stresses, packaged volume, and weight.

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