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MINIMUM WEIGHT DESIGN OF RING AND STRINGER STIFFENERS FOR AXIALLY COMPRESSED CYLINDRICAL SHELLS WITH AND WITHOUT INTERNAL PRESSURE

by David L. Block

Prepared by
FLORIDA TECHNOLOGICAL UNIVERSITY
Orlando, Fla.
for Langley Research Center

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16. Abstract

Results of analytical study to determine desirable ring and stringer stiffener parameters and proportions for axially compressed stiffened isotropic cylinders with and without internal pressure are presented. This investigation examines the panel and general instability buckling modes of a stiffened cylindrical shell and from this determines desirable stiffener parameters and proportions. For this analysis classical buckling equations are used which retain the important effects of the stiffeners. The results determined by using the simpler classical buckling equations are then spot checked and verified using buckling equations which considered discrete ring stiffeners and nonlinear prebuckling deformations. The results of the study indicate that in general for both rings and stringers, T-shaped stiffeners are preferable and that the effects of stiffener shape are much more pronounced at low or zero values of the internal pressure parameter. Simple analytical expressions are developed and presented which express the stiffener area parameter, the ratio of stiffener area and elastic modulus to shell wall area and elastic modulu modulus, in terms of the cylinder geometry and internal pressure parameter.

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FOREWORD

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Distribution of this report is provided in the interest of information exchange. Responsibility for the contents resides in the author or organization that prepared it.

INTRODUCTION

In order to maintain structural integrity of a great variety of vehicles, shell structures which are stiffened with rings (circumferential stiffeners) and stringers (longitudinal stiffeners) are required. The design of these stiffened shells is normally accomplished by judiciously selecting shell material and thickness and stiffener materials and shapes and then calculating the buckling strength for the selected configuration. If the calculated strength is greater than the actual loads the shell will experience, that is, the selected configuration meets its design or mission requirements, then this shell configuration may be used as a possible configuration. This procedure is then repeated for various stiffener shapes and sizes and shell materials, if a minimum weight or optimum structural efficiency is desired. This approach requires that the designer be experienced in choosing the various shapes, sizes, and materials. Thus, the designer of a stiffened shell needs to have a means of determining or to know desirable structural parameters and proportions so that the initial selection of stiffening elements and structural materials can easily be made.

Therefore, the purpose of the present investigation is to determine analytically the desirable ring and stringer parameters and proportions which give a minimum weight configuration for an axially compressed stiffened isotropic cylindrical shell with and without internal pressure.

A minimum weight investigation may be conducted by using either of two methods of approach. One of the methods of approach is structural synthesis as presented for example in Reference 1. In using this method, a set of initial design variables is selected and then these design variables are varied until a minimum weight configuration is achieved. This method of minimum weight design, an unconstrained minimization problem requires a large computer program solution and requires numerical specification of the design variables. Thus, it does not give general results for desirable parameters as desired in the present paper. However, it does have a distinct advantage whenever more than one loading condition must be considered in the design, since it does not assume simultaneous failure modes.

The other method of approach (References 2 and 3) and the one employed herein examines the variance of the instability modes of the stiffened shell configuration with respect to weight parameters. Using this method of approach, the present paper examines the general and panel instability of a stiffened shell and from this analysis determines desirable ring and stringer parameters and proportions. For this parametric analysis, the classical buckling equations of Reference 4 are used. These equations retain the important effects of the stiffener, such as eccentricity, bending, extensional, and twisting stiffnesses, but allow for simple calculation of the buckling load. The parametric results determined in this manner are spot checked and verified using the buckling analysis of Reference 5 which considers discrete ring stiffeners and nonlinear prebuckling deformations.

Once desirable stiffener parameters for general and panel instabililty are determined, the final design of the stiffener proportions and shell thickness is obtained by applying the equations governing the shell failure and instability modes (buckling and yielding of shell and stiffeners). The final design methodology is presented in Reference 6.

SYMBOLS

A	cross-sectional area of stiffener
D	bending stiffness of isotropic plate
E	Young's modulus
F_s	shape factor
G	shear modulus
$\bar{G}_r = \dfrac{G_r J_r}{D l}$	ring torsional parameter
$\bar{G}_s = \dfrac{G_s J_s}{D d}$	stringer torsional parameter
I	moment of inertia of stiffener about its centroid
J	torsional constant for stiffener
L	length of cylinder
N_x	axial buckling load
R	Radius of cylinder to skin middle surface
$\bar{R} = \dfrac{E_r A_r}{E t l}$	ring area parameter
$\bar{S} = \dfrac{E_s A_s}{E t d}$	stringer area parameter
$Z = \dfrac{L^2 \sqrt{1-\mu^2}}{R t}$	curvature parameter

c one-half the total flange width of stiffener

d stringer spacing

l ring spacing

h height of stiffener web

k ratio of area of flange material in bottom flange of stiffener to total flange area of stiffener

m number of half waves in cylinder buckle pattern in longitudinal direction

n number of full waves in cylinder buckle pattern in circumferential direction

p internal pressure

$\bar{P} = \frac{p}{E}\left(\frac{R}{t}\right)^2 \frac{12\sqrt{1-\mu^2}}{\pi^2}$ pressure parameter

t thickness of cylinder shell wall or stiffener flange or web

$\bar{t} = t\left(1 + \frac{\rho_s}{\rho}\bar{S} + \frac{\rho_r}{\rho}\bar{R}\right)$ effective thickness parameter

$\bar{y}$ distance from centroid of stiffener to attachment between stiffener and shell wall

z distance from centroid of stiffener to middle surface of shell, positive for stiffener on external surface

$\beta = \frac{nL}{m\pi R}$ buckle aspect ratio

γ ratio of material in flanges of stiffener to total material in stiffener, A_f/A

μ Poisson's ratio

ρ weight density

Subscripts:

s,r denote properties of stringers (longitudinal stiffening) and rings (circumferential stiffening), respectively

RESULTS

Analytical Development

The structural efficiency investigation of a stiffened isotropic cylindrical shell is conducted by using a method of approach which examines the variation of the general and panel instability of a stiffened cylindrical shell configuration with respect to weight parameters and from this determined desirable ring and stringer parameters and proportions. For the structural efficiency study, classical buckling equations are used. However, spot checks are made using buckling analyses which consider discrete ring stiffeners and prebuckling deformations to verify the results obtained.

The isotropic cylinder wall and stiffeners (either rings or stringers) studied are illustrated in Figure 1. By representing the stiffeners as an unsymmetric I section, the stiffener is representative of a large number of cross-sectional stiffener shapes; for example, T section, I section, hat section or modified hat section. All of the stiffener sections may also have lightening holes in the web. By using the stiffener cross-section of Figure 1, the stiffeners may be characterized in the buckling equations by the following five parameters:

1. The ratio of stiffener modulus and area to shell modulus and thickness and stiffener spacing, either $\bar{S} = \frac{E_s A_s}{Etd}$ or $\bar{R} = \frac{E_r A_r}{Et\,l}$

2. The ratio of the stiffener torsional stiffness to shell bending stiffness and stiffener spacing, either $\bar{G}_s = \frac{G_s J_s}{Dd}$ or $\bar{G}_r = \frac{G_r J_r}{Dl}$

3. The ratio of the height of the stiffener to thickness of shell, either h_s/t or h_r/t.

4. The ratio of amount of stiffener area in flange to total area of stiffener, either γ_s or γ_r.

5. The ratio of flange area in bottom flange of stiffener to total flange area of stiffener, either k_s or k_r.

Representing the stiffeners in the above manner is similar to the representation of the rings presented in Reference 2.

The governing equation for panel and general instability of an axially compressed ring and stringer stiffened isotropic cylinder is given by equation (17) of Reference 4. With the use of the stiffener representation of Figure 1. the reference equation may be written in terms of weight parameters as follows:

$$\frac{\bar{t}}{R} = \sqrt{\frac{\frac{N_x}{ER}}{F_s}} \qquad (1)$$

where

$$\bar{t} = t\left(1 + \frac{\rho_s}{\rho}\bar{S} + \frac{\rho_r}{\rho}\bar{R}\right)$$

R = cylinder radius
N_x = axial buckling load
E = Young's modulus for cylinder wall
F_s = shape factor defined in Appendix A

Equation (1) assumes classical simple support boundary conditions and assumes that the stiffeners are "smeared out" over the stiffener spacing and equally spaced. The buckling load from equation (1) is given in terms of the axial buckling load N_x. The minimum buckling load N_x is determined by minimizing the equation on the computer by varying the number of the axial waves m and the buckle aspect ratio β until a minimum is determined.

From equation (1) it can be seen that a maximum value of F_s will give minimum weight or maximum structural efficiency. Therefore, F_s can be considered a shape factor for the problem, i.e., for panel and general instability buckling modes. In a given design, the shape factor F_s is made as large as possible for a given loading N_x/ER by varying the cylindrical wall thickness and the stiffener geometry and properties. Note that F_s depends upon m and β; thus, the minimization of the buckling load with respect to m and β must be performed.

Note also that the variables used in the computation of the shape factor are $\bar{G}_s$, $\bar{G}_r$, $\bar{S}$, $\bar{R}$, γ_r, γ_s, k_r, k_s, h_s/t, h_r/t, Z and $\bar{P}$. The variables γ_r, γ_s, k_r and k_s are associated with the shape of the stiffeners; $\bar{G}_s$, $\bar{G}_r$, $\bar{S}$, $\bar{R}$, h_s/t and h_r/t with the ratios of stiffener properties to cylinder wall properties; Z with the cylinder geometry and $\bar{P}$ with the internal pressure loading. Thus, the problem may now be defined as to determine the stiffener variables which given an option value of the shape factor F_s for a fixed cylinder geometry and loading.

Stiffener Proportions and Parameters

The parametric studies to determine desirable stiffener (ring and stringer) proportions and parameters were accomplished by making countless computer computations. These computations were made by fixing the loading condition, the value of Z, the cylinder curvature parameter and the location of the stiffeners, either inside or outside. The stiffener parameters were then varied.

The first parameter to be evaluated was the stiffener torsional parameter, $\bar{G}$. By making computer runs which varied $\bar{G}$ up to a value of 1, the effect of $\bar{G}$ on the shape factor was found to be negligible for both ring and stringer stiffeners. Thus, $\bar{G}$ was made equal to zero for the remainder of the study. However, the effect of the torsional constant should be included when calculating final design buckling loads.

In conducting the parametric studies, the following parameter variations were considered:

I. <u>Loading Condition</u> - The Loading Conditions were axial compression and axial compression with internal pressure parameter values of 1, 5, and 10. Note that an internal pressure parameter value of 10 generally corresponds to an extremely large value of internal pressure.

II. <u>Cylinder Geometry</u> - The cylinder curvature parameter values of Z were set equal to 1, 10, 100, 1000, 10000, and 100000.

III. <u>Stringer Parameters</u> - The stringer parameters were as follows:

(1) Stringers located inside and outside.

(2) Stringer area parameter $\bar{S}$ of 0.5 and 1.5.

(3) Stringer ratio of height of stringer to thickness of shell, h_s/t, of 10 and 30.

(4) Stringer ratio of amount of stringer area in flange to total area of stringer, γ_s, of 0.1 and 0.9.

(5) Stringer ratio of area in bottom flange to total flange area of stringer, k_s, of 0.0, 0.5, and 1.0.

(6) Stringer torsional parameter $\bar{G}_s$ of 0.0.

IV. <u>Ring Parameters</u> - The ring parameters were as follows:

(1) Rings located inside and outside.

(2) Ring area parameter $\bar{R}$ of 0.1 and 0.5.

(3) Ring ratio of height of ring to thickness of shell, h_r/t, of 20 and 80.

(4) Ring ratio of amount of ring area in flange to total area of ring, γ_r, of 0.1 and 0.9.

(5) Ring ratio of area in bottom flange to total flange area of ring, k_r, of 0.0, and 0.5, and 1.0.

(6) Ring torsional parameter $\bar{G}_r$ of 0.0.

Note for the stringer and ring parameters that the area parameter and the ratio of the height to shell thickness values (Items 2 and 3) were chosen based on practical considerations and that the amount of flange area to total area and the area in bottom flange to total flange area (Items 4 and 5) may only have values from zero to one. The following sections present the results of the above parametric variations.

Desirable Stringer Proportions and Parameters

The results of the parametric studies for stringer stiffened cylinders are presented in Figures 2 through 7 and Table 1. These results apply to panel instability modes of buckling, i.e. buckling of the cylinder between rings, or apply to buckling of a cylinder with no rings. The values plotted in Figures 2 and 5 are for both inside and outside stringers and for a Z value of 1 while the values plotted in Figures 3 and 6 and 4 and 7 are for outside and inside stringers, respectively, and for a Z value of 1000. Figures 2 through 7 all have curves for pressure parameter values of 0 and 10. The shape of the curves of these figures are typical of all cases examined.

Figures 2, 3 and 4 show the variation of F_s, the shape factor, with respect to the stringer parameter k_s, the amount of bottom flange area, for selected values of $\bar{S}$, γ_s and h_s/t. The curves of Figure 2 show that the pressure parameter and the stiffeners location have negligible effect. However, this is not true in general as shown in Figures 3 and 4. Figures 2, 3 and 4 show that the maximum shape factor, i.e., maximum structural efficiency, occurs for a value of k_s equal to zero. The k_s value of zero implies T shaped stringers are most efficient. The k_s value of zero for maximum structural efficiency was found for all the stringer cases where there was a significant variation in the shape factor, for example, all the curves of Figure 2. The exception to k_s equal zero are curves which are almost flat; that is, those curves which have a very slight variation with respect to k_s. See for example the curve of Figure 4 for $\gamma_s = .1$, $h_s/t = 10$, and $\bar{P} = 0$. Also shown in these figures is the variation of F_s with respect to the stringer parameters γ_s and h_s/t and the pressure parameter $\bar{P}$. Considering these parameters, the maximum value of F_s occurs for the larger values of h_s/t, $\bar{P}$, and γ_s. Note also, that the larger values of γ_s only give maximum F_s at the optimum k_s values, that is, k_s values less than 0.6.

Figures 5, 6 and 7 show the variation of the shape factor F_s with respect to the stringer area parameter $\bar{S}$. The curves of Figures 5, 6 and 7 are for optimum k_s value, k_s equal to zero, and show the complete range of variations of $\bar{S}$. Figure 5 shows that the maximum F_s occurs for $\bar{S}$ values of 0.5 to 0.6 while Figures 6 and 7 have an $\bar{S}$ for maximum F_s ranging from 0 to 0.8. Again the maximum F_s occurs for the larger values of h_s/t, γ_s, and $\bar{P}$.

Presented in Table 1 is a tabulation of the $\bar{S}$ results for the complete range of parameters studied. Table 1 shows for each Z and $\bar{P}$ value, and the various h_s/t and γ_s values, the stiffener area parameter $\bar{S}$ which gives the maximum value of the shape factor

F_s. Note the values tabulated in Table 1 which correspond to the "X" marks on the curves in Figures 5, 6, and 7.

The primary objective of the present study is to determine desirable stiffener parameters easily; and thus, it would be very beneficial to a designer if the results of Table 1 could be presented by a single analytical expression for $\bar{S}$ in terms of the other variables. Due to the great variety of buckling modes which comprise the results of Table 1, there is not one single analytical expression which will define $\bar{S}$ in terms of the other parameters. However, an analytical expression for $\bar{S}$ may be developed if a statistical analysis, the method of least squares, is used. This process was employed herein. Initially a variety of functionals for $\bar{S}$ were assumed. These functionals were then minimized with respect to their standard deviation and $\bar{S}$ was determined to be presented best by the following functional form:

$$\bar{S} = A + B\ (\log_{10} Z) + C\sqrt{\bar{P}} \qquad (2)$$

By using the functional relationship of equation (2) the unknown constant coefficients A, B, and C are determined by applying the method of least squares. It was also noted that the functional relationship of equation (2) will give the best representation by writing one equation for Z less than 1000 and one equation for Z greater than or equal to 1000. This separation due to the cylinder curvature parameter value was determined by examining the buckling mode shapes. It was found that for both stringers inside and outside and for pressure parameter $\bar{P}$ values of zero or one that the m equal one buckling mode (buckling into one half wave in the axial direction) always occurred for Z values less than 1000 and for pressure parameter $\bar{P}$ values equal five or ten that the m equal one mode always occurred for Z values less than 100. Thus, the separation based on the Z value was made. Using equation (2) and the method least squares gives the following expressions for $\bar{S}$ from values of Table 1 and

for outside stringers:

$$\bar{S} = .65 - .098 \log_{10} (Z) - .038\sqrt{\bar{P}} \quad \text{for } Z<1000 \tag{3}$$

$$\bar{S} = .44 - .062 \log_{10} (Z) - .017\sqrt{\bar{P}} \quad \text{for } Z\geq 1000 \tag{4}$$

for inside stringers:

$$\bar{S} = .63 - .14 \log_{10} (Z) - .019\sqrt{\bar{P}} \quad \text{for } Z<1000 \tag{5}$$

$$\bar{S} = .15 - .022 \log_{10} (Z) + .043\sqrt{\bar{P}} \quad \text{for } Z\geq 1000 \tag{6}$$

The standard deviations for equations (3), (4), (5) and (6) are 0.10, 0.12, 0.10 and 0.07, respectively.

It should also be noted that Z values of 1000 or greater for stringer stiffened cylinders are not very practical since they imply long cylinders with an axial buckling mode of m larger than one and are cylinders which would in general be more efficiently designed with rings.

The results presented above for cylinders with no rings were also checked against the cases where rings are present on cylinders. When rings are present, the trends of Figures 2, 3 and 4 do not change; that is, k_s equal zero gives the maximum shape factor.

However, the $\bar{S}$ values of Figures 5, 6 and 7 and Table 1 do change somewhat when rings are present on the cylinder. If the assumption of simultaneous occurance of panel and general instability failure modes is made in the design, then these mentioned changes will not effect the design.

Desirable Ring Proportions and Parameters

The results of the parametric studies for ring stiffeners are presented in Figures 8 through 23 and Tables 2 through 30. These results apply to the general instability mode of buckling. The curves for ring stiffeners presented in the above mentioned figures and tables show the same type of results as the figures and tables presented in the previous section for stringer stiffened cylinders.

In particular, Figures 8 and 9, 12 and 13, 16 and 17, 20 and 21 present the variation of the shape factor F_s with respect to the amount of bottom flange material of the rings, k_r; for cylinder Z values of 100 and 10,000, and for stringers outside, rings inside; stringers inside, rings inside; stringers outside, rings outside; and stringers inside, rings outside; respectively. Figures 10 and 11, 14 and 15, 18 and 19, 22 and 23 present the variation of the shape factor with respect to ring area parameter $\bar{R}$ for the same Z values and stiffener locations as mentioned in the preceding sentence. The curves of Figures 8 through 23 are done for selected values of $\bar{S}$, $\bar{R}$, h_s/t, h_r/t, γ_s, γ_r, k_s and k_r, and for pressure parameter values of 0 and 10. The curves presented in these Figures are typical of all cases examined.

Tables 2 through 5, 10 through 13, 18, and 23 through 26 present the value of the amount of bottom flange material k_r which gives the maximum value of the shape factor and Tables 6 through 9, 14 through 17, 19 through 22, and 27 through 30 present the value of ring area parameter $\bar{R}$ which gives the maximum value of the shape factor. The values presented in Tables 2 through 30 are for the four combinations of stringer-ring locations mentioned above, and for the complete range of selected values of all the studied parameters.

Stringers Outside, Rings Inside

The results for stringers outside and rings inside are presented in Figures 8 through 11 and Tables 2 through 9.

Figures 8 and 9 present the variation of the amount of bottom flange material k_r with respect to the shape factor F_s and show that k_r equal zero gives the maximum value of the shape factor for the case where the pressure parameter is zero and that k_r equal one for the case where the pressure parameter is 10. Note that the curves for the pressure parameter of 10 have a very slight variation with respect to k_r and, thus, the variation in the k_r value has slight effect on the shape factor. This trend of slight variation occurs for all cases in which k_r is not equal to zero for the maximum value of the shape factor. Tables 2 through 5 present for the complete range of parameter values studied, the value of the amount of bottom flange material k_r for maximum structural efficiency. Note the variety of k_r values presented in these tables. The F values shown in the tables denote that the k_r results did not vary, i.e., $k_r = 0$, .5 and 1.0 all gave the same value of the shape factor.

Figures 10 and 11 present the variation of the ring area parameter $\bar{R}$ with respect to the shape factor and show that for a pressure parameter value of 10, the ring area parameter $\bar{R}$ is equal to zero for the maximum structural efficiency and that for a pressure parameter value of zero (axial compression only) the ring area parameter $\bar{R}$ is equal to approximately 0.05 for maximum structural efficiency. Note also that for $\bar{P}$ equal to zero, the maximum F_s occurs for larger values of h_r/t.

Tables 6 through 9 give the values of ring area parameter $\bar{R}$ which give the maximum shape factor for the complete range of the parametric values studied. Note the correspondence between the values of $\bar{R}$ denoted by the "X" on the curves in Figures 10 and 11 and the values tabulated in Table 7. By examining the results presented in the Tables 2 through 9 it can be noted that the majority of the cases where the maximum shape factor occurs for k_r equal one (Tables 2 through 5) correspond to the cases where $\bar{R}$ equal zero (Tables 6 through 9). An $\bar{R}$ value of zero implies that the cylinder is more efficiently designed with no ring stiffeners.

As in the case of the stringer stiffened shells it is desireable to obtain a simple analytical expression for the ring area parameter $\bar{R}$. This is accomplished for all ring and stringer inside or outside cases in the same manner as previously presented for stringer stiffened cylinders. That is, a variety of functionals for $\bar{R}$ are determined by the method of least squares and are then minimized with respect to their standard deviation; and a separation for different values of the cylinder curvature parameter Z is made based on the buckling mode shapes. For all combinations of rings and stringers inside or outside, minimization of the standard deviation of $\bar{R}$ gave the functional relationship of equation (2) as the best representation for $\bar{R}$ and for all combinations of stringers and rings inside or outside and for all values of the pressure parameter, the buckling mode of m equal one, buckling in one axial half wave, occurred for all Z values less than 1000. Please note that cases of m equal one buckling modes do occur for Z values of 1000 or greater but not in all cases. It should also be mentioned that ring stiffened cylinders are generally designed for Z values greater than 1000 since it is desirable to have more than one half wave in the axial general instability buckling mode.

Therefore, using equation (2) and determining the unknown coefficients by the method of least squares the $\bar{R}$ values presented in Tables 6 through 9 are expressed as:

$$\bar{R} = .010 + .012(\log_{10} Z) - .010\sqrt{\bar{P}} \quad \text{for } Z < 1000 \qquad (7)$$

$$\bar{R} = .088 + .0025(\log_{10} Z) - .035\sqrt{\bar{P}} \quad \text{for } Z \geq 1000 \qquad (8)$$

with standard deviations of 0.027 and 0.045, respectively.

Stringers Inside, Rings Inside

The results for stringers inside and rings inside are presented in Figures 12 through 15 and Tables 10 through 17.

Figures 12 and 13 present the variation of k_r with respect to the shape factor and show that k_r equal zero gives the optimum value of the shape factor for all cases. This k_r equal zero value is further confirmed by the k_r results presented in Tables 10 through 13 which present the k_r value which gives maximum structural efficiency for all the studied parameters and in which the majority of the k_r values are zero. Note in Tables 10 through 13 that for $\bar{R}$ equal 0.1, all the k_r values are zero except for a few cases in Table 10. Also shown in Figures 12 and 13 is the variation of the shape factor with respect to h_r/t, $\bar{P}$ and γ_r. That is, the maximum shape factor occurs for larger values of h_r/t, $\bar{P}$, and γ_r at k_r values of less than approximately 0.6.

Figures 14 and 15 show the variation of the ring area parameter $\bar{R}$ with respect to the shape factor and show the large variation in the optimum $\bar{R}$ value. Tables 14 through 17 present the ring area parameter $\bar{R}$ which gives the maximum shape factor for all the studied parameters. Note the correspondence between the values of $\bar{R}$ denoted by the X on the curves of Figures 14 and 15 and the corresponding values tabulated in Table 15. Again the $\bar{R}$ values of Tables 14 through 17 are expressed using the functional equation (2) and the method of least squares by the following equations:

$$\bar{R} = .024 + .038(\log_{10}Z) - .022\sqrt{\bar{P}} \qquad Z<1000 \qquad (9)$$

$$\bar{R} = .20 + .00076(\log_{10}Z) - .060\sqrt{\bar{P}} \qquad Z\geq 1000 \qquad (10)$$

with standard deviations of .052 and .070, respectively.

Stringers Outside, Rings Outside

The results for stringers outside and rings outside are presented in Figures 16 through 19 and Tables 18 through 22.

The results for the amount of bottom flange material k_r are presented in Figures 16 and 17 and Table 18. Figures 16 and 17 show that k_r equal zero gives the maximum shape factor and Table 18 shows that for all of the studied parametric values that k_r equal to zero gives the maximum shape factor. It should be noted in Table 18 that a large number of k_r values did not vary with respect to the shape factor, especially at the pressure parameter value of 10. For these cases k_r was taken as zero. Again maximum values of shape factor occur for larger values of h_r/t and of γ_r at k_r values less than 0.6.

The results for the ring area parameter $\bar{R}$ are presented in Figures 18 and 19 and Tables 19 through 22, and are similar to previously presented results. The $\bar{R}$ values of Tables 19 through 22 are expressed by the equations:

$$\bar{R} = .019 + .027(\log_{10}Z) - .017\sqrt{\bar{P}} \qquad Z<1000 \qquad (11)$$

$$\bar{R} = .16 - .0013(\log_{10}Z) - .05\sqrt{\bar{P}} \qquad Z\geq 1000 \qquad (12)$$

with standard deviations of 0.061 and 0.076, respectively.

Stringers Inside, Rings Outside

The results for stringers inside and rings outside are presented in Figures 20 through 23 and Tables 23 through 30, and are also similar to the results of the previous sections. Figures 20 and 21 show k_r equals zero for the maximum shape factor for most of the cases (See Tables 23 through 26 for the few exceptions), and Figures 22 and 23 show the variation of $\bar{R}$ with respect to the shape factor. The equations for the $\bar{R}$ values of Tables 27 through 30 are:

$$\bar{R} = .025 + .073(\log_{10}Z) - .03\sqrt{\bar{P}} \qquad Z < 1000 \qquad (13)$$

$$\bar{R} = .33 + .001(\log_{10}Z) - .078\sqrt{\bar{P}} \qquad Z \geq 1000 \qquad (14)$$

with standard deviations of .096 and .12, respectively.

In order to summarize the results for the stiffener area parameter in one location, Table 31 was constructed to present the expressions for $\bar{S}$ and $\bar{R}$ given by equations (5) through (14).

At this point the design methodology of a stiffened cylindrical shell needs to be discussed. The design of a particular shell configuration would be accomplished by equating the shell and stiffener failure modes of general and panel instability, local stiffener and skin buckling and stiffener and skin yielding. From the parametric study presented herein for general and panel instability, optimum stiffener parameters and proportions would first be selected. These parameters would then be used to determine the actual stiffener and shell wall dimensions by equating the failure modes using the process presented for example in Reference 6.

Other Results

In order to check and verify the optimum stiffener parametric results presented herein using a classical buckling analysis, a more sophisticated buckling analysis was used. For this check the buckling analysis of Reference 5 which considers discrete ring stiffeners and nonlinear prebuckling deformations was chosen. The buckling analysis of Reference 5 uses finite differences for solving the buckling equations and is a lengthy solution; thus, only spot checks were made. These checks were made by selecting a particular cylindrical configuration and varying the stiffener shapes (both stringer and rings) in order to get the desired stiffener variations. For the selected configurations, all checks verified the parametric results presented herein. That is, for stringer stiffened cylinders, k_s equal zero gave maximum value of the shape factor; and the stringer area parameter $\bar{S}$ when plotted against the shape factor F_s had the same shaped curve with the optimum value occurring at approximately the same location. Note for these results the shape of the curves for k_s and $\bar{S}$ are the same; however, the shape factor values are different. In the calculations for ring stiffened cylinders the results again had the same shapes and trends.

CONCLUDING REMARKS

In conclusion, the results of an analytical investigation to determine desirable ring and stringer stiffener parameters and proportions for minimum weight design of a stiffened cylinder are presented. The desirable stiffener parameters and proportions determined are intended for initial design selection and are obtained by analyzing the general and panel instability buckling modes of the cylinder using classical buckling equations. The loading conditions are axial compression with and without internal pressure. The results determined by using the classical buckling equations are spot checked and verified using a buckling analysis which considers nonlinear prebuckling deformations and discrete ring stiffeners.

The results presented indicate the following trends concerning desirable ring and stringer stiffener parameters and proportions.

1. The value for the parameter for the amount of bottom flange material of the stiffener (k_s and k_r) is, in most cases, equal to zero for maximum structural efficiency or minimum weight. This implies T shaped stiffeners are most desirable. For ring stiffened cylinders, the value of k_r has a much greater effect for

small or zero values of the pressure parameter.

2. The values of stiffener height to shell skin thickness, h/t, and of the pressure parameter, $\bar{P}$, should be made as large as possible for maximum structural efficiency.

3. The value of the amount of stiffener area in flange to total area of stiffener, γ, should be made as large as possible for stiffeners in which the amount of bottom flange area is small, stiffeners whose k_s and k_r values are less than 0.6. For stiffeners with k_s or k_r values larger than .6 the γ values should be as small as possible.

4. The desirable stiffener area to shell wall area (stiffener area parameter) is a function of all stiffener and shell variables. However, simply analytical expressions are developed by using statistical methods and are presented for this parameter. These expressions present the stiffener area parameter as a function of cylinder curvature parameter Z, and pressure parameter $\bar{P}$, and stiffener location. These equations are summarized in Table 31.

5. The effects of the stiffener parameters are much more pronounced at low or zero values of the internal pressure parameter.

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5. Block, David L.; Influence of Discrete Ring Stiffeners and Prebuckling Deformations on the Buckling of Eccentrically Stiffened Orthotropic Cylinders. NASA TN D-4283, January 1968.

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APPENDIX A

FORMULA FOR SHAPE FACTOR

The shape factor F_s appearing in equation (1) is as follows:

$$F_s = \frac{\pi^2}{12\sqrt{1-\mu^2}\,(1 + \frac{\rho_s}{\rho}\bar{S} + \frac{\rho_r}{\rho}\bar{R})^2} \left(\frac{m^2}{Z}\left[(1+\beta^2)^2 + \frac{E_s I_s}{Dd} + \beta^2(\bar{G}_r + \bar{G}_s) + \beta^4 \frac{E_r I_r}{Dl}\right] + \frac{12Z}{m^2\pi^4}\left[\frac{1 + \bar{S}\Lambda_s + \bar{R}\Lambda_r + \bar{S}\bar{R}\Lambda_{rs}}{\Lambda}\right] - \beta^2\bar{P} \right)$$

$$\Lambda = (1+\beta^2)^2 + 2\beta^2(1+\mu)(\bar{R}+\bar{S}) + (1-\mu^2)\left[\bar{S} + 2\beta^2\bar{R}\bar{S}(1+\mu) + \beta^4\bar{R}\right]$$

$$\Lambda_s = 1 + 2m^2\pi^2\frac{h_s}{t}\frac{z_s}{h_s}(\beta^2-\mu)\sqrt{\frac{1-\mu^2}{Z}} + m^4\pi^4\left(\frac{h_s}{t}\right)^2\left(\frac{z_s}{h_s}\right)^2(1+\beta^2)^2\frac{(1-\mu^2)}{Z^2}$$

$$\Lambda_r = 1 + 2m^2\pi^2\frac{h_r}{t}\frac{z_r}{h_r}\beta^2(1-\beta^2\mu)\sqrt{\frac{1-\mu^2}{Z}}$$

$$+ m^4\pi^4\left(\frac{h_r}{t}\right)^2\left(\frac{z_r}{h_r}\right)^2\beta^4(1+\beta^2)^2\frac{(1-\mu^2)}{Z^2}$$

$$\Lambda_{rs} = 1 - \mu^2 + 2m^2\pi^2\beta^2\frac{(1-\mu^2)^{3/2}}{Z}\left[\frac{h_s}{t}\frac{z_s}{h_s} + \frac{h_r}{t}\frac{z_r}{h_r}\right]$$

$$+ m^4\pi^4\frac{(1-\mu^2)}{Z^2}\beta^2\left\{\beta^2\left[1-\mu^2+2\beta^2(1+\mu)\right]\left(\frac{h_r}{t}\right)^2\left(\frac{z_r}{h_r}\right)^2\right.$$

$$+ 2\beta^2(1+\mu)^2\frac{h_r}{t}\frac{z_r}{h_r}\frac{h_s}{t}\frac{z_s}{h_s}$$

$$\left. + \left[2(1+\mu) + \beta^2(1-\mu^2)\right]\left(\frac{h_s}{t}\right)^2\left(\frac{z_s}{h_s}\right)^2\right\}$$

$$Z = \frac{L^2\sqrt{1-\mu^2}}{Rt}$$

$$\bar{S} = \frac{E_s A_s}{Etd}$$

$$\bar{R} = \frac{E_r A_r}{Etl}$$

$$\bar{G}_s = \frac{G_s J_s}{Dd}$$

$$\bar{P} = \frac{P}{E}\left(\frac{R}{t}\right)^2 \frac{12\sqrt{1-\mu^2}}{\pi^2}$$

$$\bar{G}_r = \frac{G_r J_r}{Dl}$$

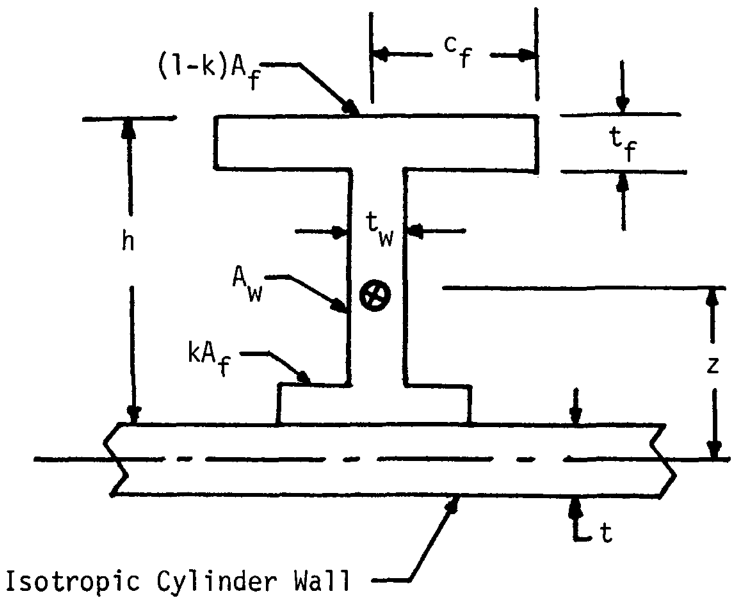
$$\frac{\bar{y}}{h} = \gamma(1-k) + \frac{1}{2}\ (1-\gamma)$$

$$\frac{z}{h} = \pm\left(\frac{\bar{y}}{h} + \frac{1}{2}\frac{t}{h}\right)$$

$$\frac{I}{Ah^2} = \gamma\left[(1-k)\left(1-\frac{\bar{y}}{h}\right)^2 + k\left(\frac{\bar{y}}{h}\right)^2\right] + (1-\gamma)\left[\frac{1}{3} - \frac{\bar{y}}{h} + \left(\frac{\bar{y}}{h}\right)^2\right]$$

$$\frac{E_s I_s}{Dd} = 12(1-\mu^2)\left(\frac{h_s}{t}\right)^2 \bar{S}\left(\frac{I_s}{A_s h_s^{\,2}}\right)$$

$$\frac{E_r I_r}{Dl} = 12(1-\mu^2)\left(\frac{h_r}{t}\right)^2 \bar{R}\left(\frac{I_r}{A_r h_r^{\,2}}\right)$$



$$\gamma = A_f/(A_w+A_f)$$

Figure 1. - Ring and stringer cross section representation.

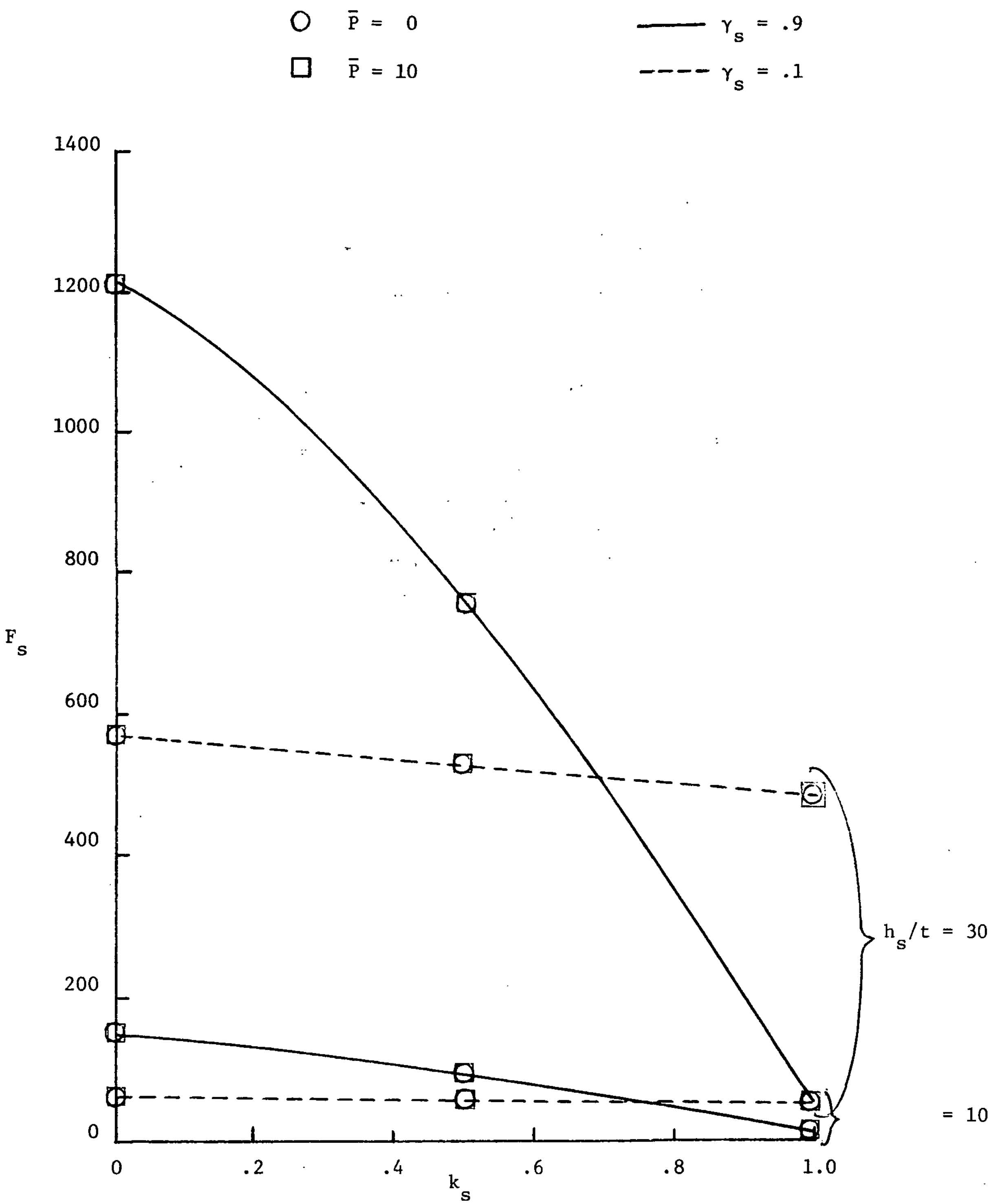


Figure 2. - Calculations to determine the amount of bottom flange material, k_s, for stringers outside and inside; Z = 1.; $\bar{S}$ = .5; $\bar{G}_s$ = 0.

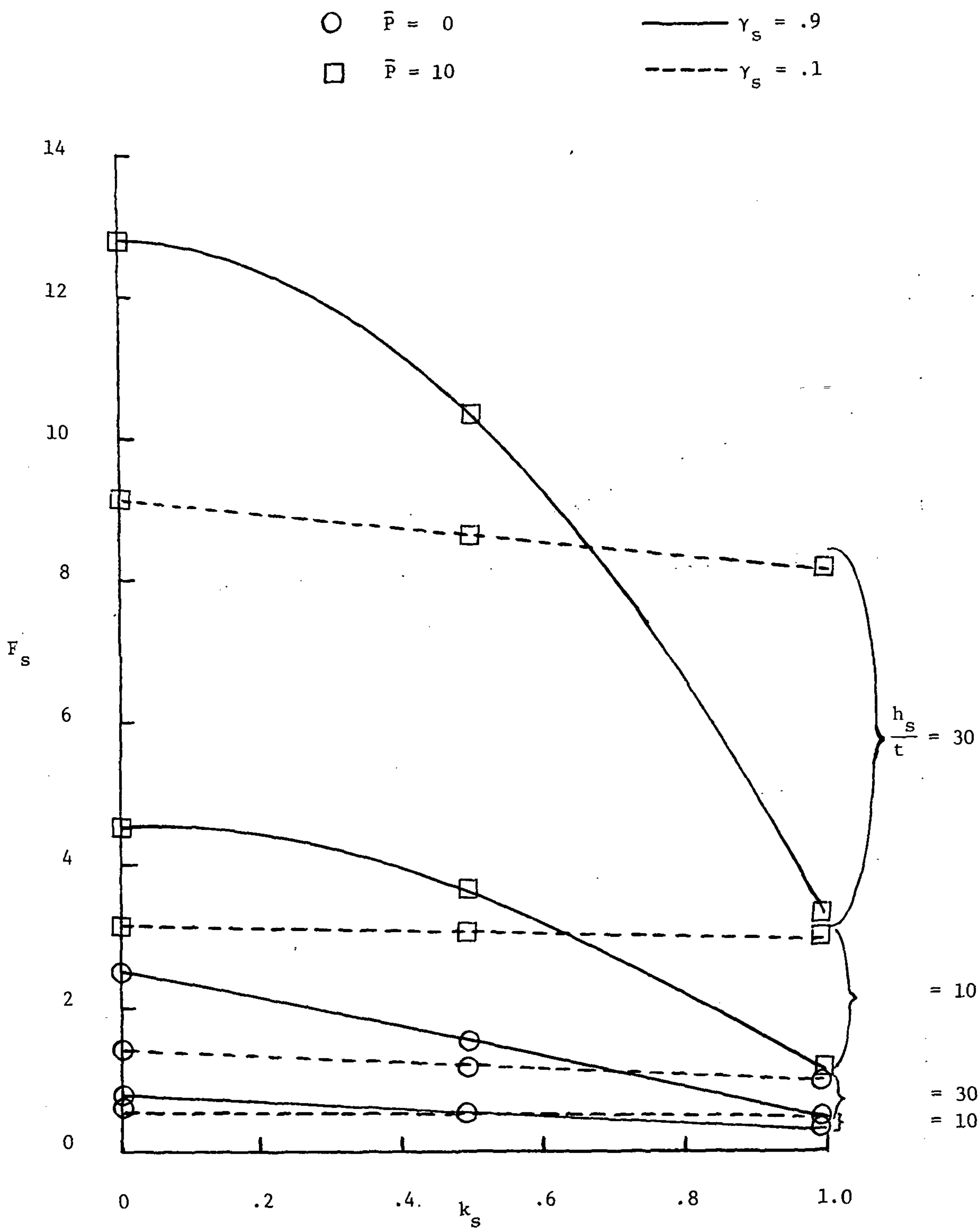


Figure 3. - Calculations to determine the amount of bottom flange material, k_s, for stringers outside and $Z = 1000.$; $\bar{S} = .5$; $\bar{G}_s = 0$.

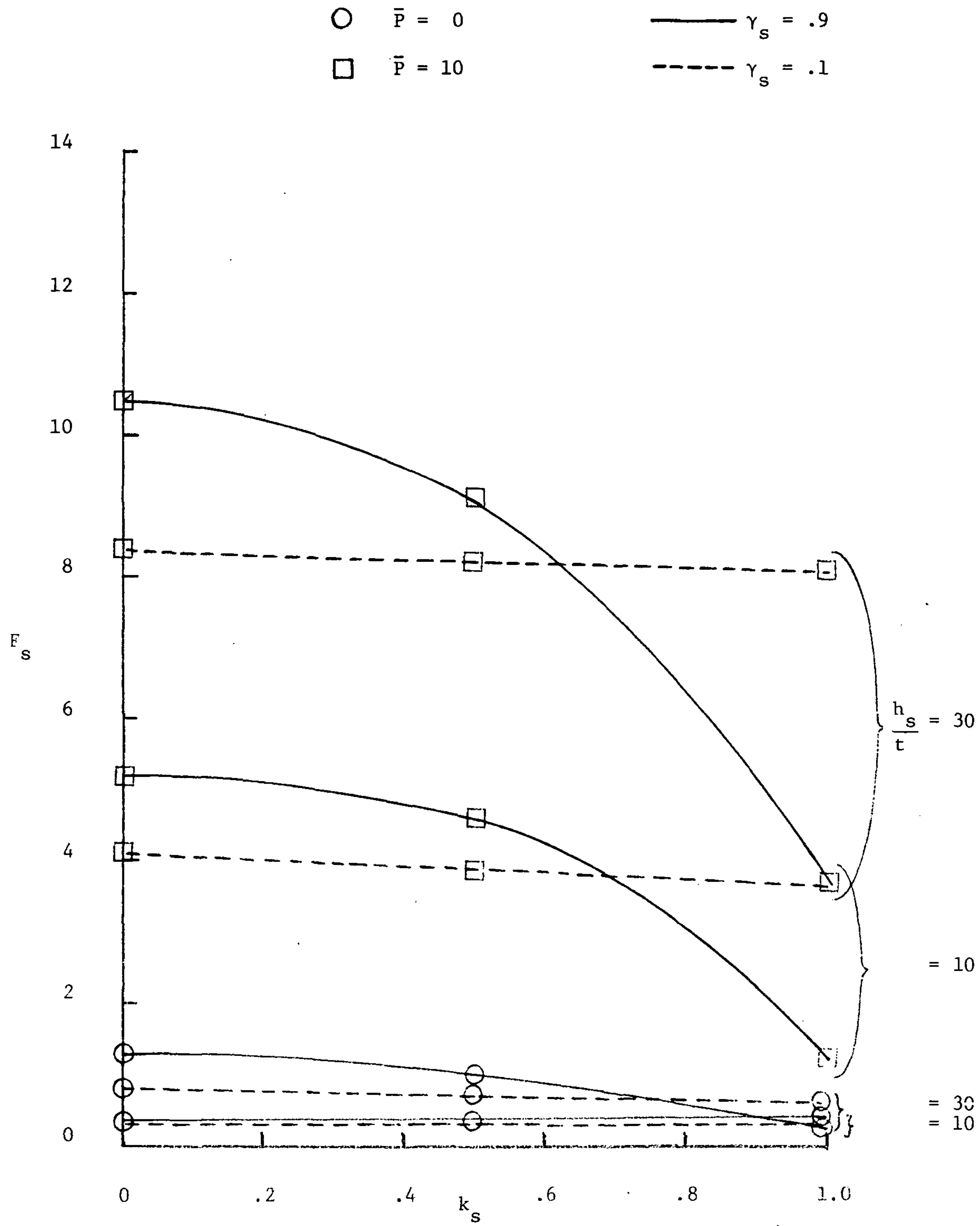


Figure 4. - Calculations to determine the amount of bottom flange material, k_s, for stringers inside and Z = 1000.; $\bar{S}$ = .5; $\bar{G}_s$ = 0.

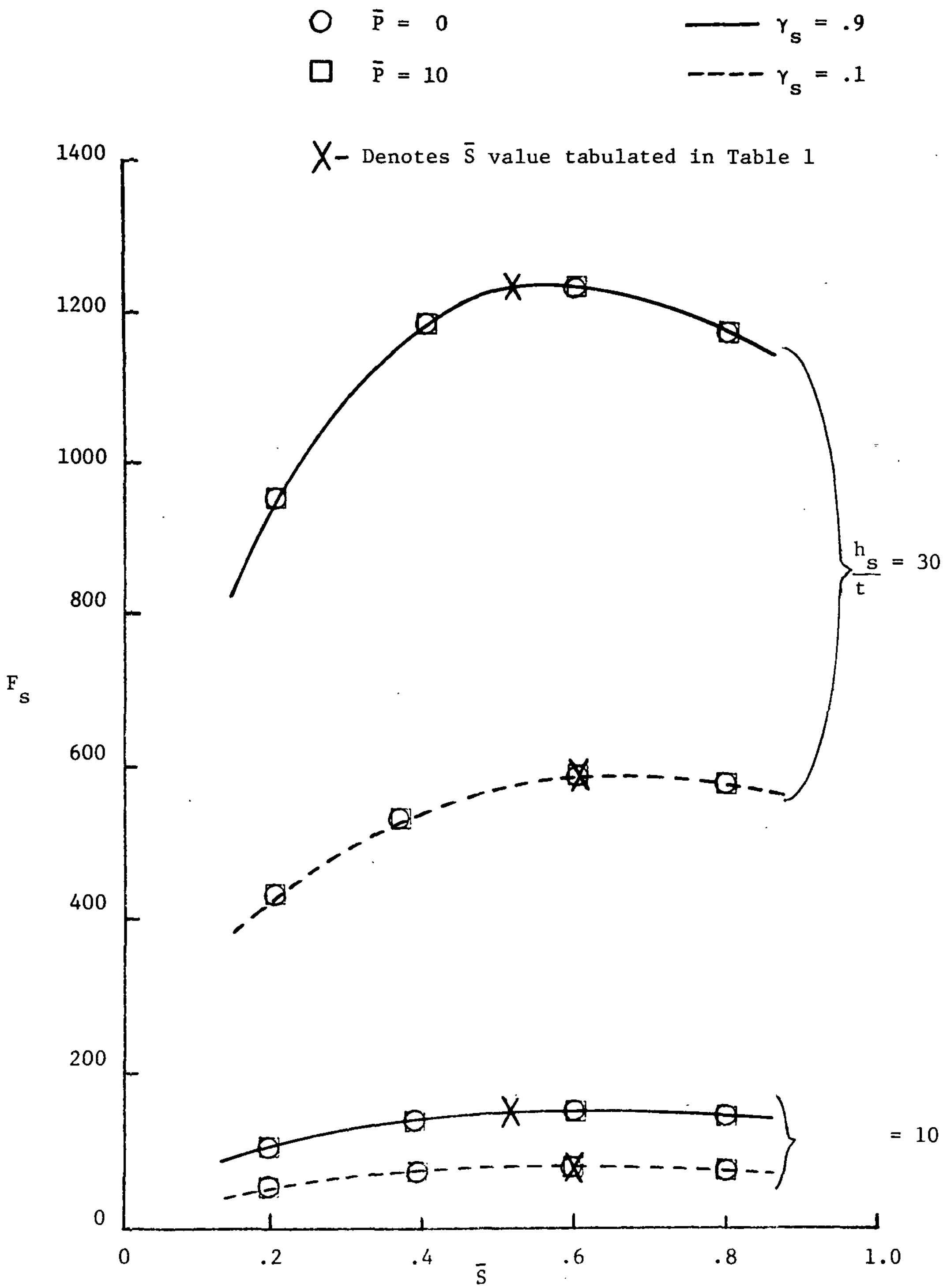


Figure 5. – Calculations to determine desirable stringer area parameter $\bar{S}$ for stringers outside and inside; Z = 1.; k_s = 0.; $\bar{G}_s$ = 0.

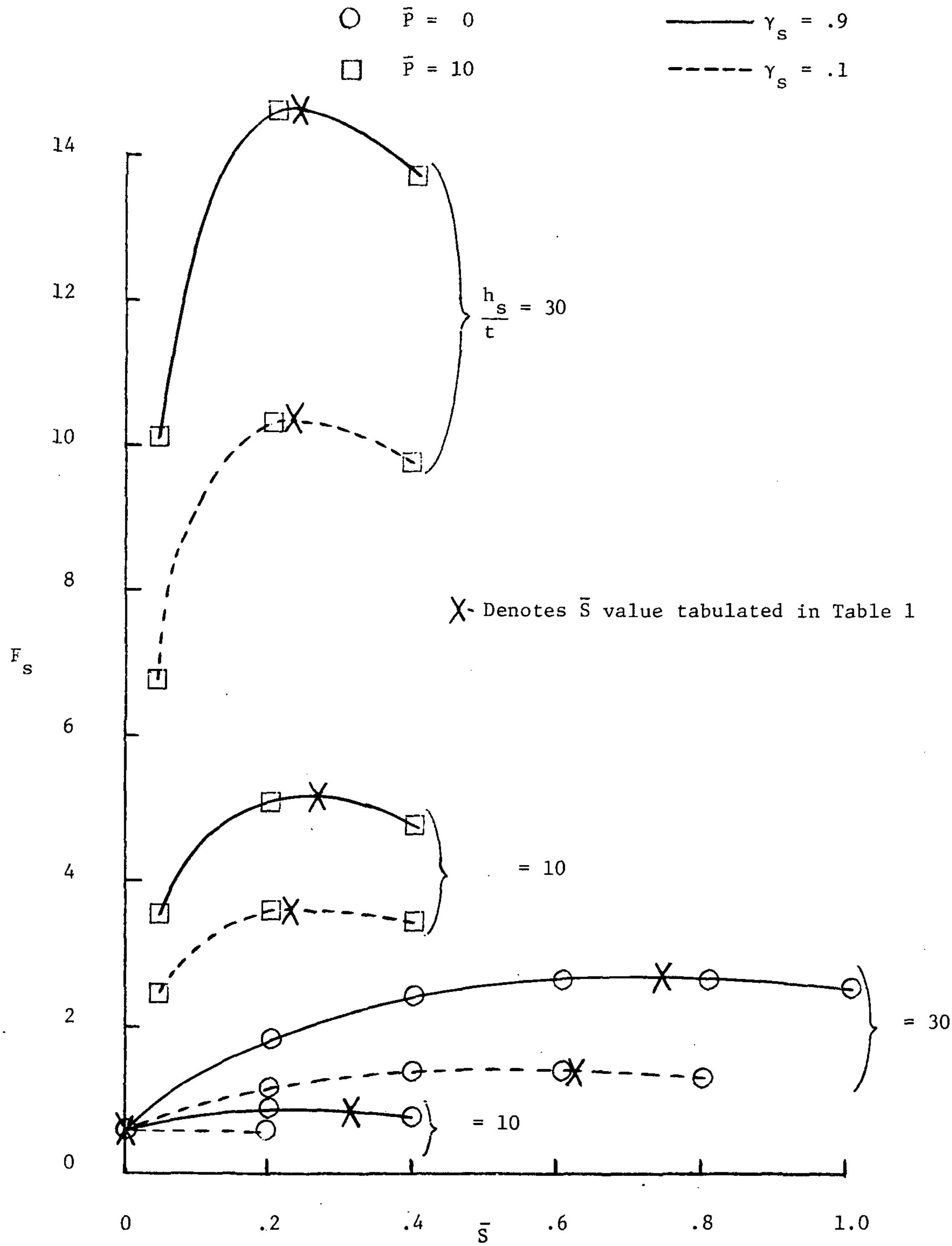


Figure 6. - Calculations to determine desirable stringer area parameter $\bar{S}$ for stringers outside and $Z = 1000$; $k_s = 0$; $\bar{G}_s = 0$.

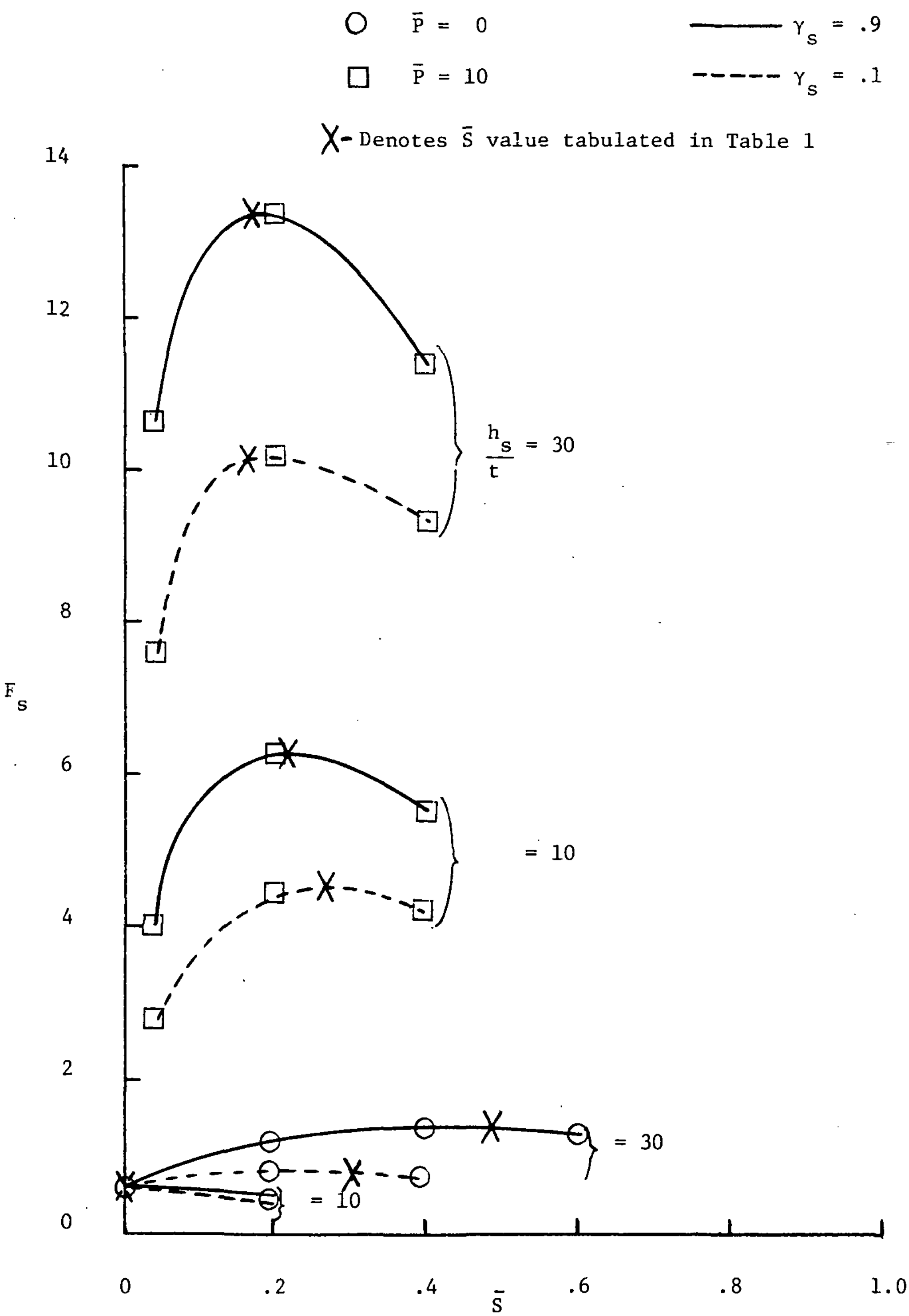


Figure 7. - Calculations to determine desirable stringer area parameter $\bar{S}$ for stringers inside and $Z = 1000$; $k_s = 0$; $\bar{G}_s = 0$.

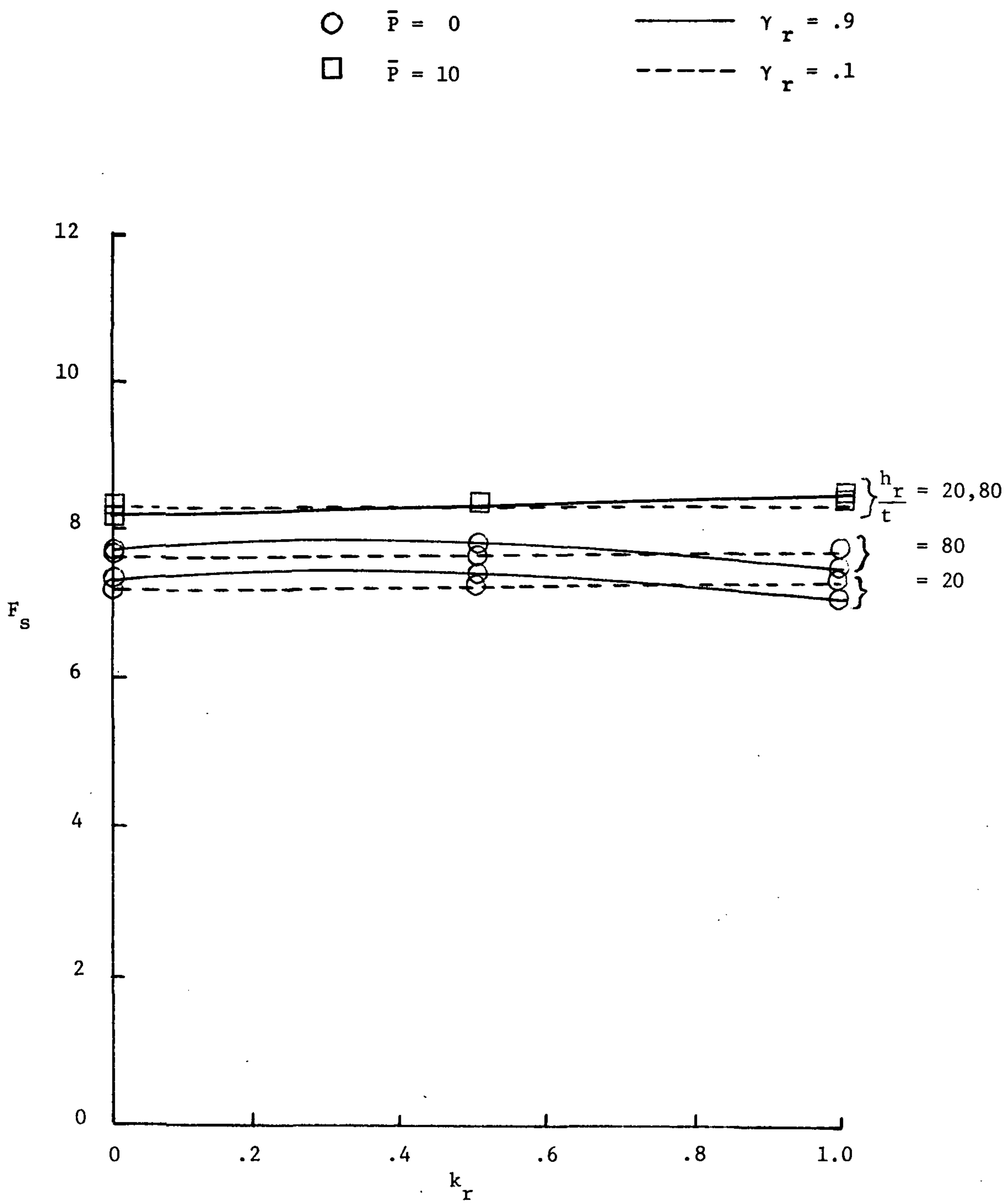


Figure 8. - Calculations to determine the amount of bottom flange material, k_r, for stringers outside, rings inside and $Z = 100.$; $\bar{S} = .5$; $k_s = 0.$; $h_s/t = 30$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{R} = .1$; $\bar{G}_r = 0.$

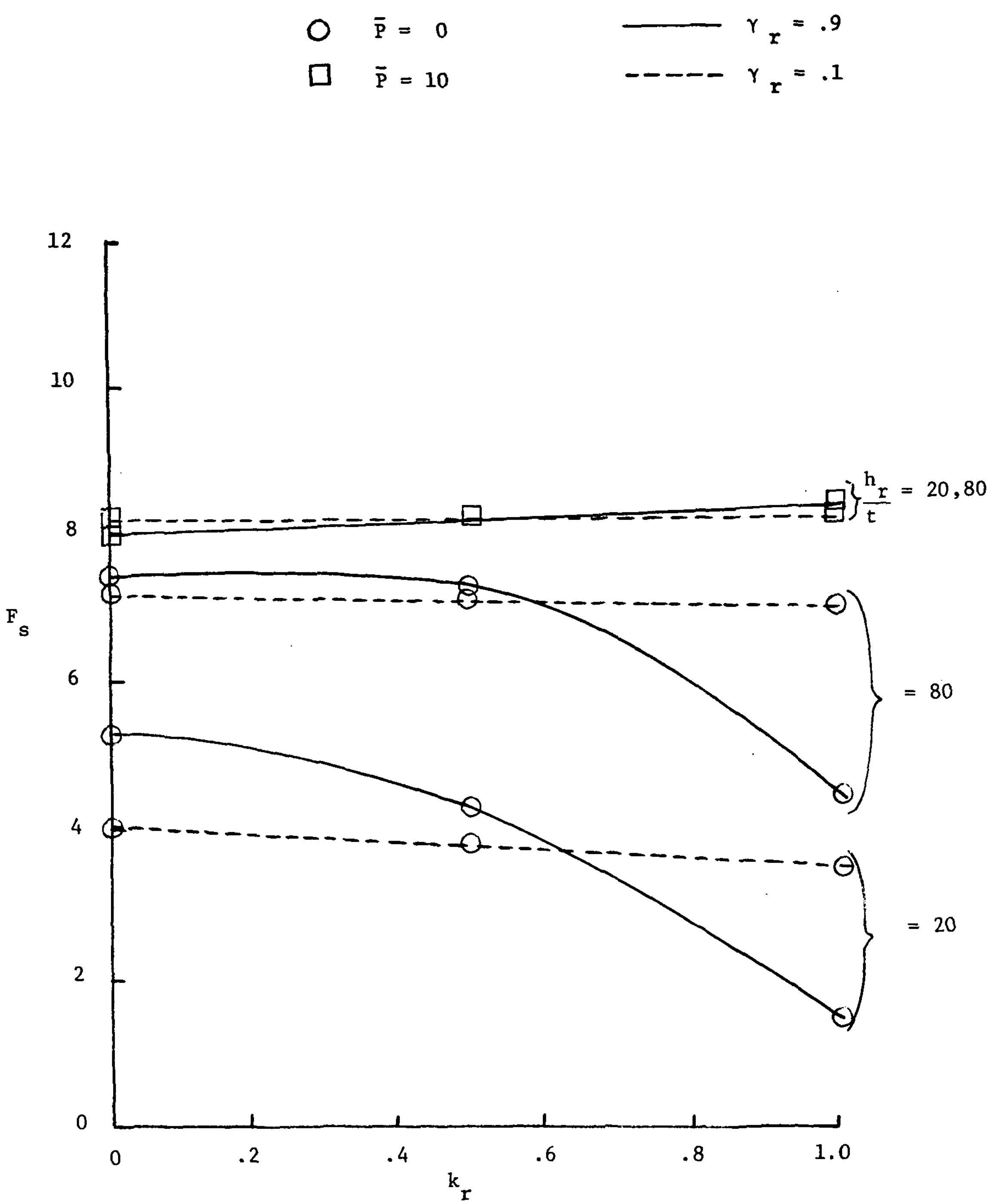


Figure 9. - Calculations to determine the amount of bottom flange material, k_r, for stringers outside, rings inside and $Z = 10000.$; $\bar{S} = .5$; $k_s = 0.$; $h_s/t = 30$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{R} = .1$; $\bar{G}_r = 0.$

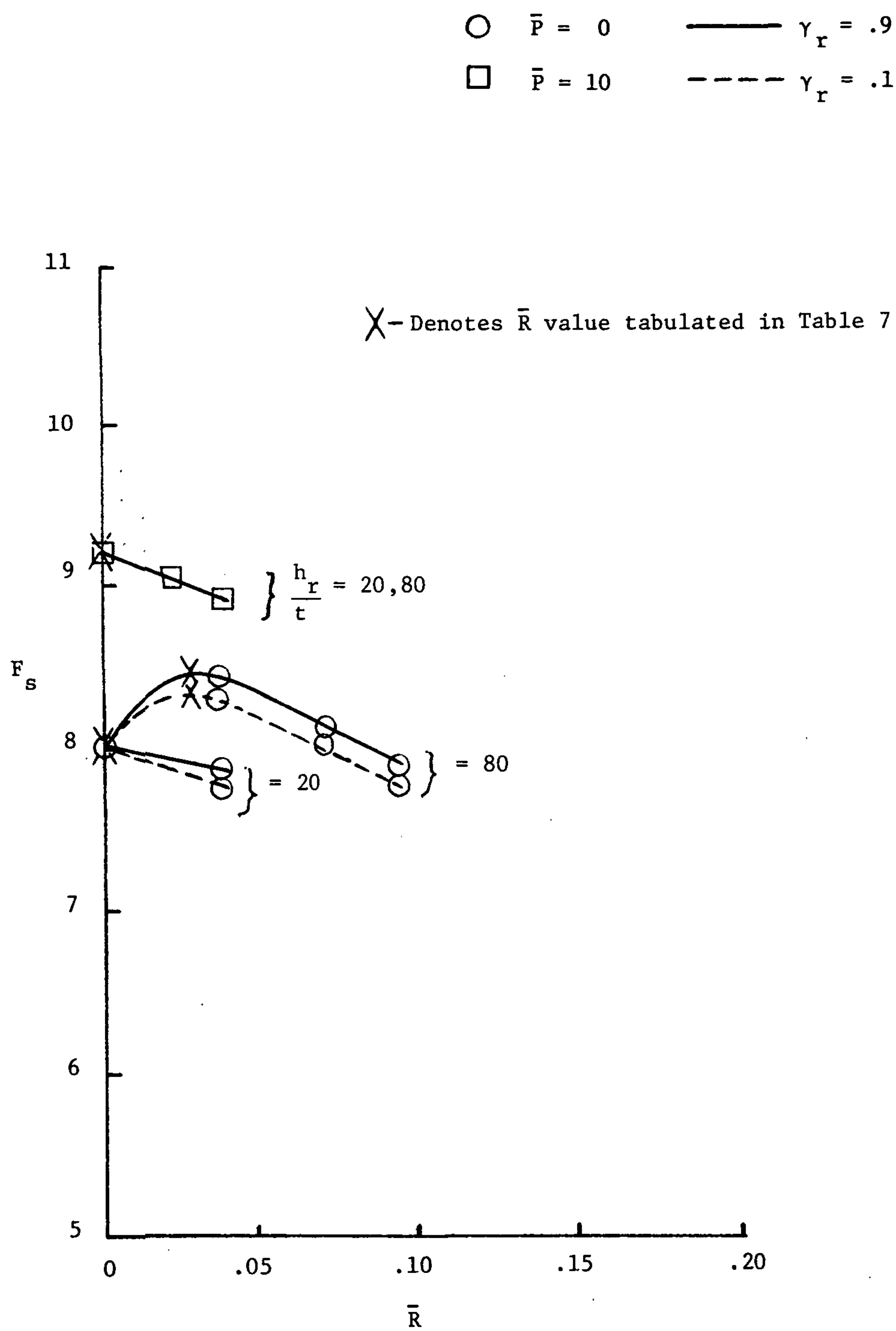


Figure 10. - Calculations to determine desirable ring area parameter $\bar{R}$ for stringers outside, rings inside and Z = 100.; $\bar{S}$=.5; k_s = 0.; h_s/t = 30; γ_s = .1; $\bar{G}_s$ = 0.; $\bar{G}_r$ = 0.; k_r = 0.

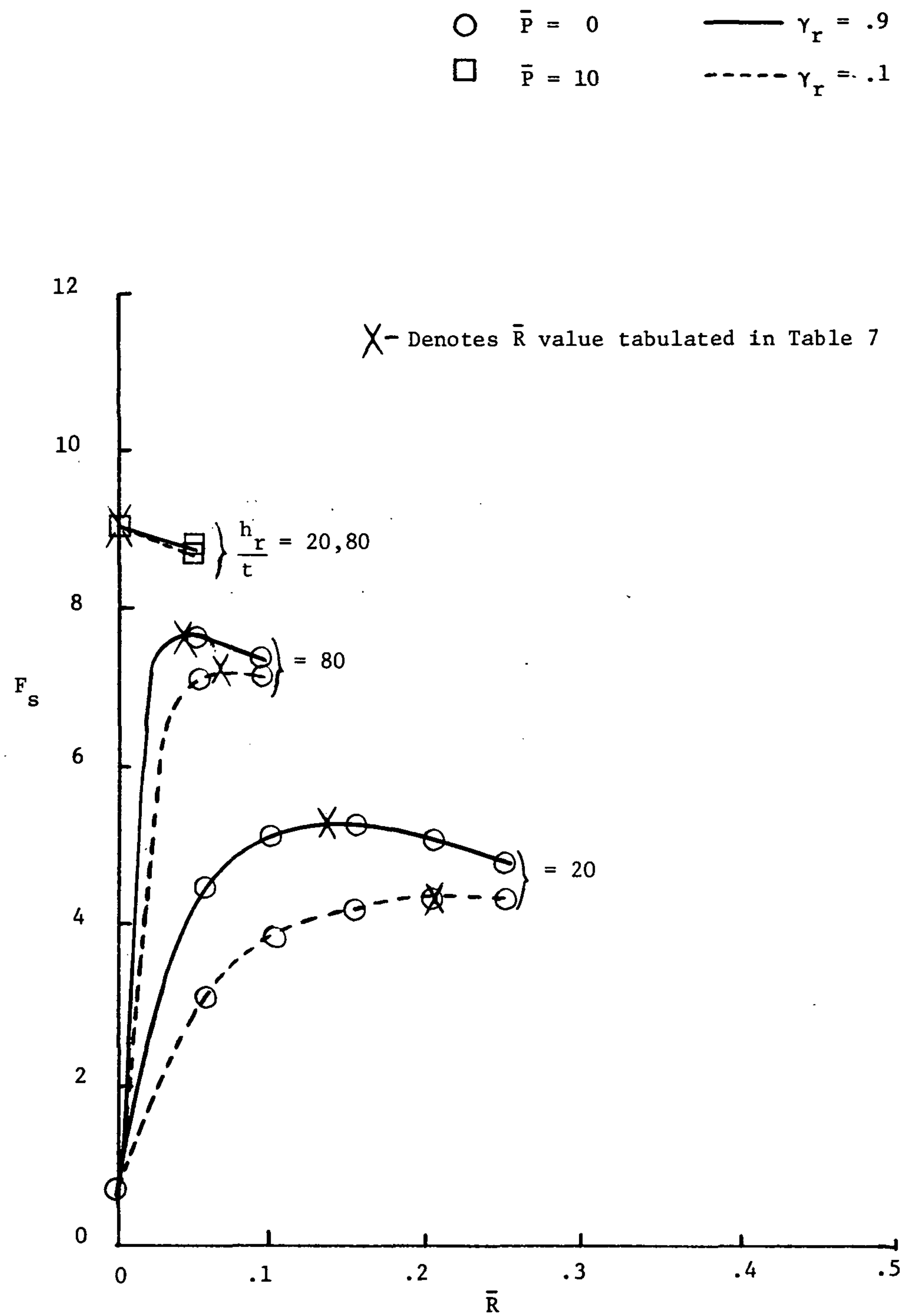


Figure 11. - Calculations to determine desirable ring area parameter $\bar{R}$ for stringers outside, rings inside and $Z = 10000.$; $\bar{S} = .5$; $k_s = 0.$; $h_s/t = 30$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{G}_r = 0.$; $k_r = 0.$

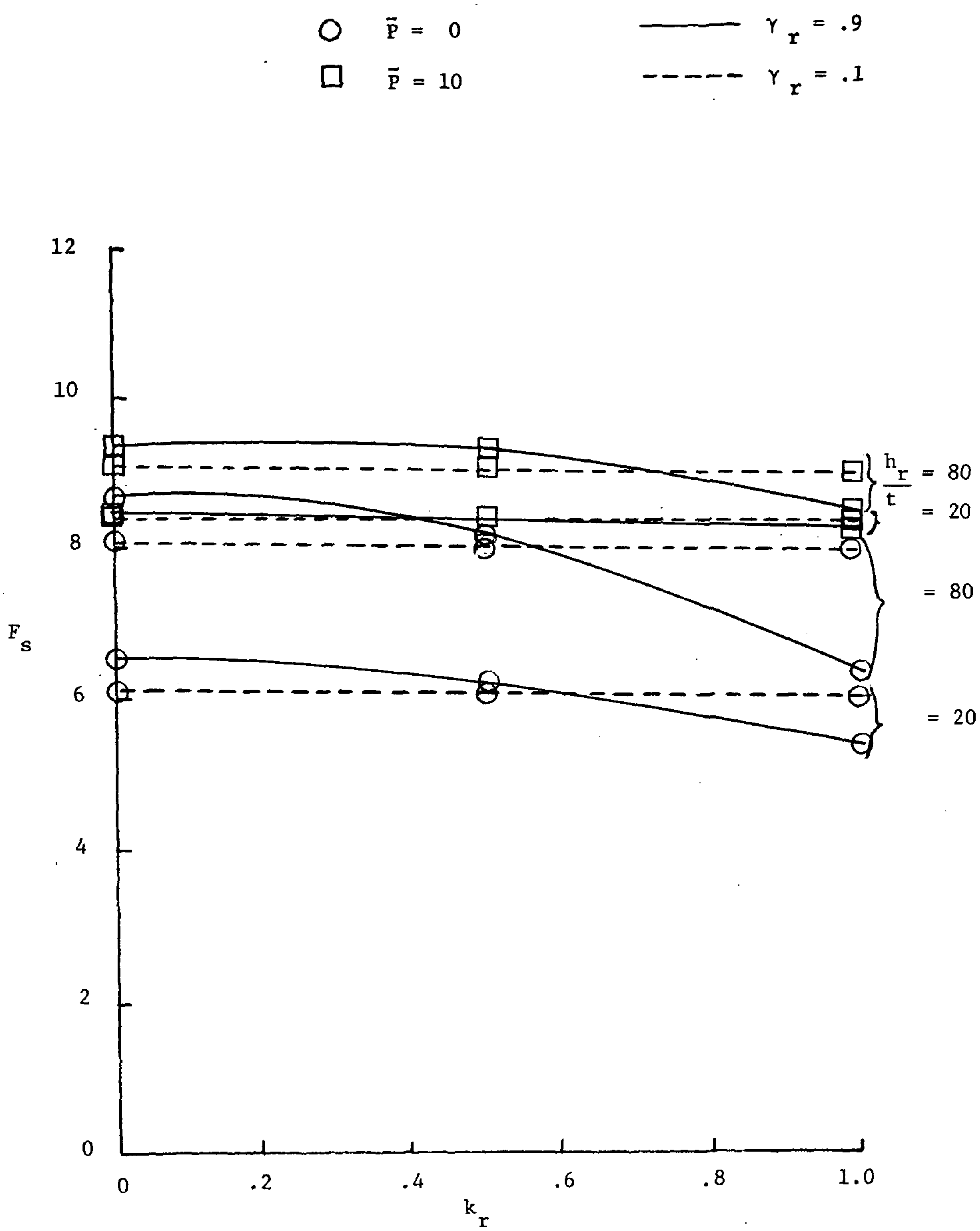


Figure 12. - Calculations to determine the amount of bottom flange material, k_r, for stringers inside, rings inside and $Z = 100.$; $\bar{S} = .5$; $k_s = 0.$; $h_s/t = 30$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{R} = .1$; $\bar{G}_r = 0.$

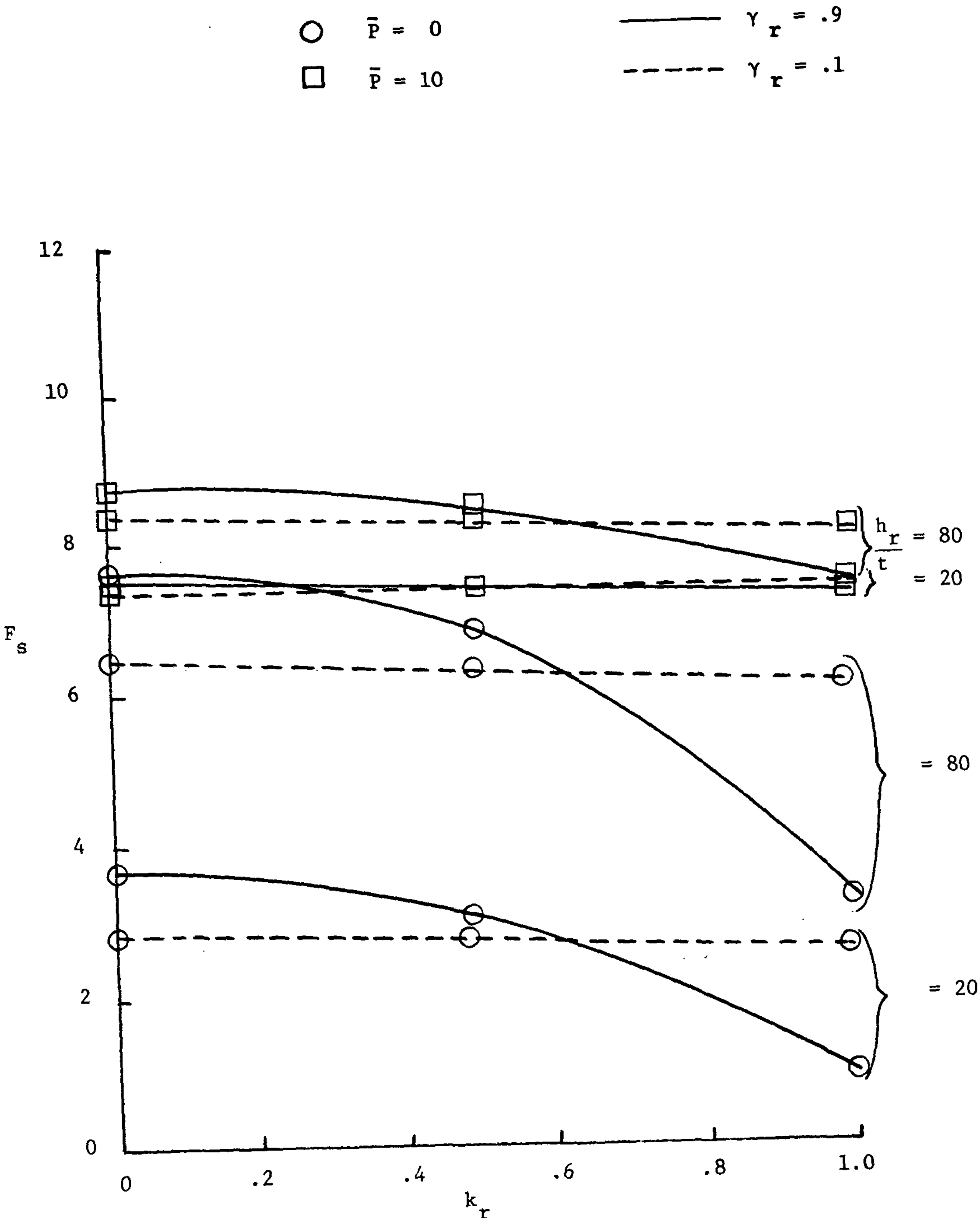


Figure 13. - Calculations to determine the amount of bottom flange material, k_r, for stringers inside, rings inside and $Z = 10000.$; $\bar{S} = .5$; $k_s = 0$; $h_s/t = 30.$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{R} = .1$; $\bar{G}_r = 0.$

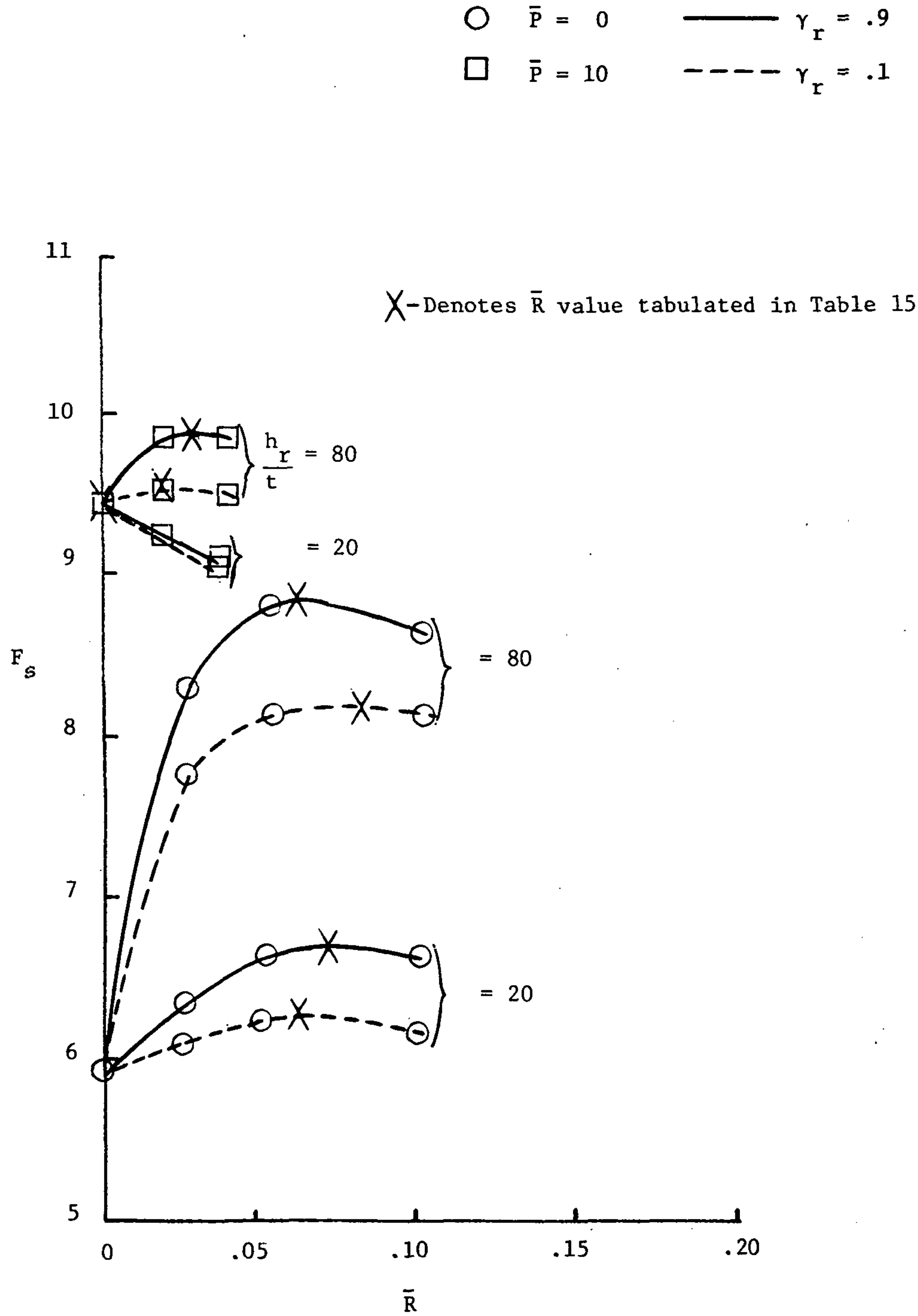


Figure 14. - Calculations to determine desirable ring area parameter $\bar{R}$ for stringers inside, rings inside and Z = 100.; $\bar{S}$ = .5; k_s = 0.; h_s/t = 30; γ_s = .1; $\bar{G}_s$ = 0.; $\bar{G}_r$ = 0.; k_r = 0.

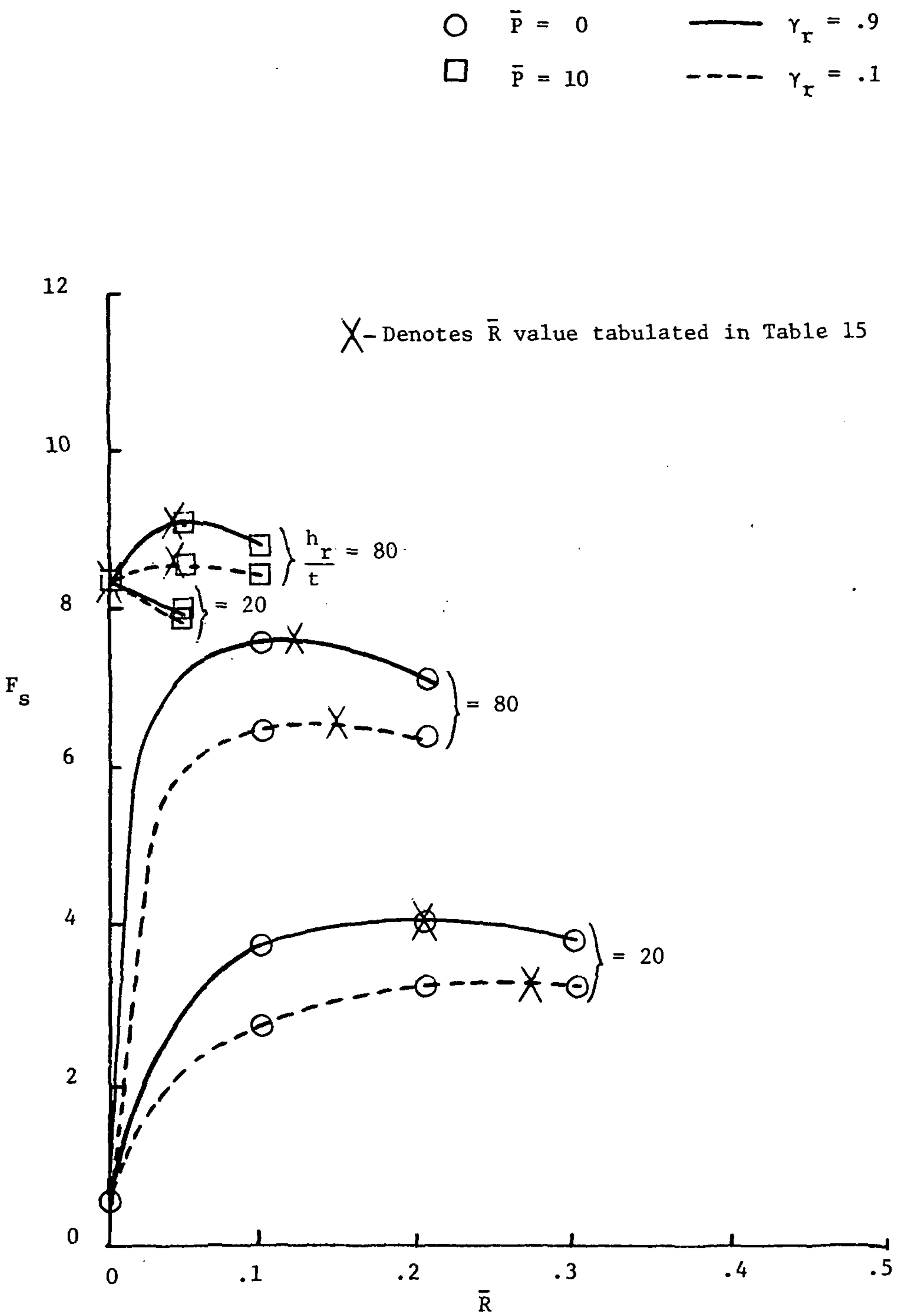


Figure 15. - Calculations to determine desirable ring area parameter $\bar{R}$ for stringers inside, rings inside and Z = 10000.; $\bar{S}$ = .5; k_s = 0.; h_s/t = 30; γ_s = .1; $\bar{G}_s$ = 0.; $\bar{G}_r$ = 0.; k_r = 0.

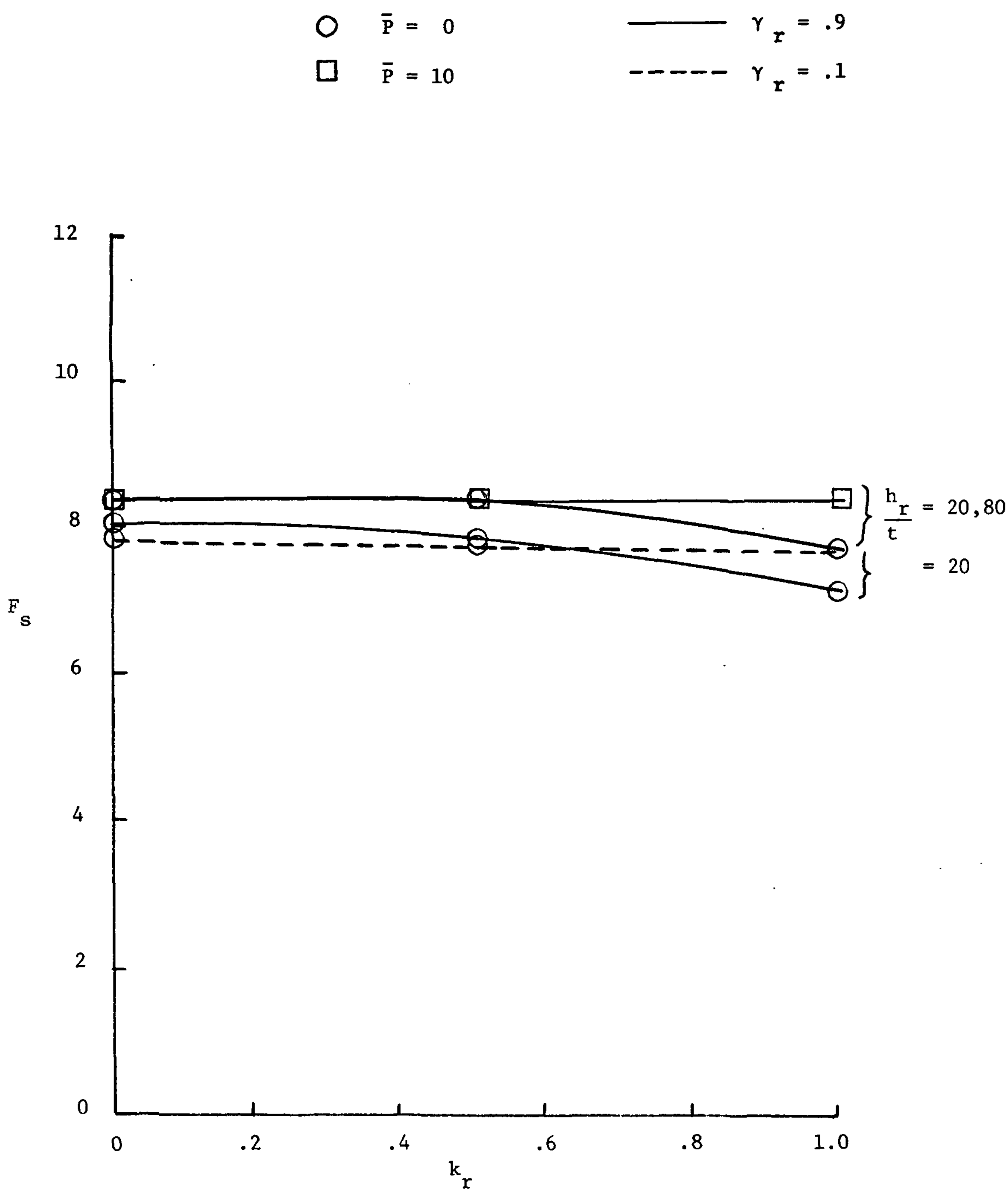


Figure 16. - Calculations to determine the amount of bottom flange material, k_r, for stringers outside, rings outside and $Z = 100.$; $\bar{S} = .5$; $k_s = 0.$; $h_s/t = 30.$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{R} = .1$; $\bar{G}_r = 0.$

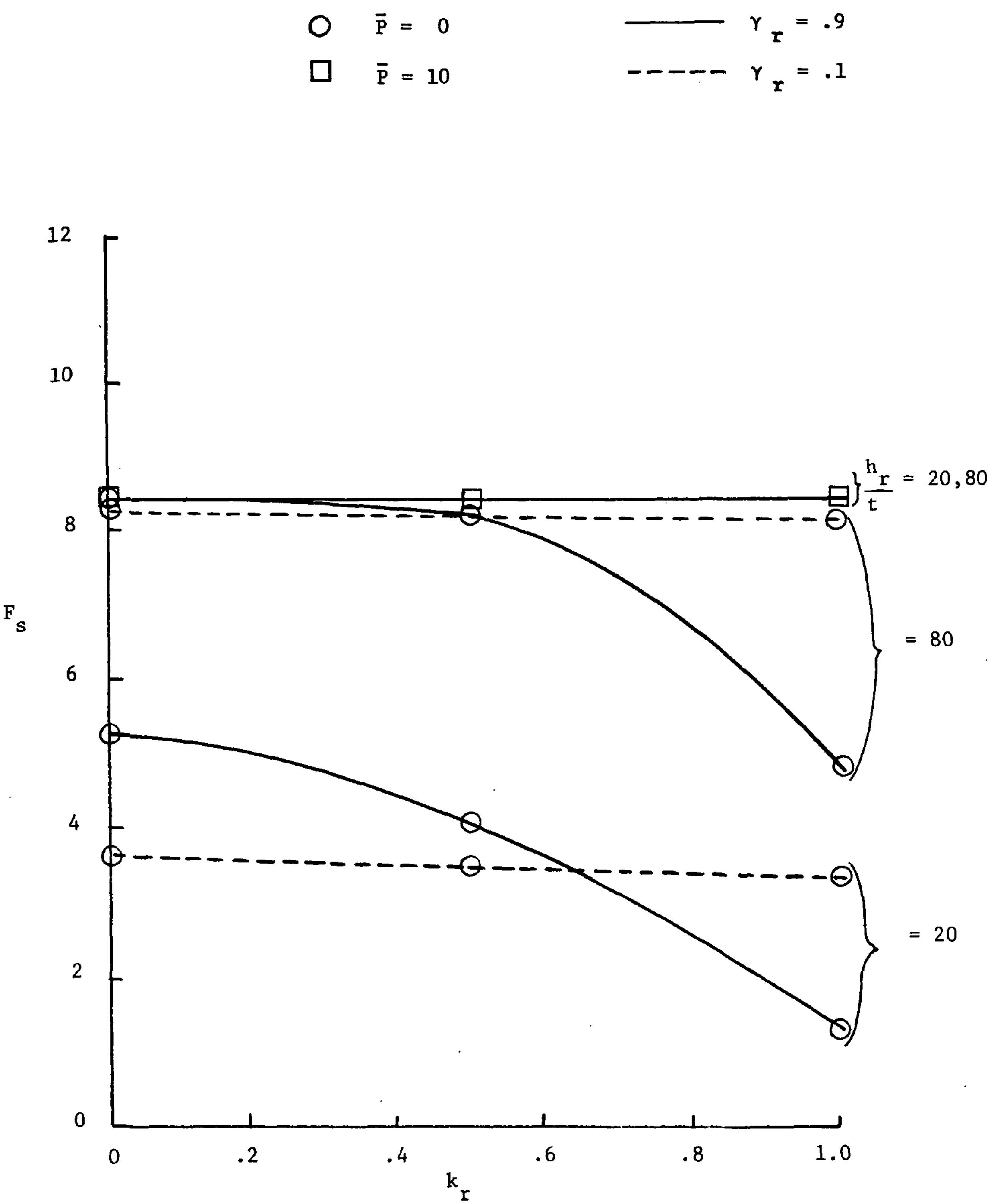


Figure 17. - Calculations to determine the amount of bottom flange material, k_r, for stringers outside, rings inside and $Z = 10000.$; $\bar{S} = .5$; $k_s = 0.$; $h_s/t = 30.$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{R} = .1$; $\bar{G}_r = 0.$

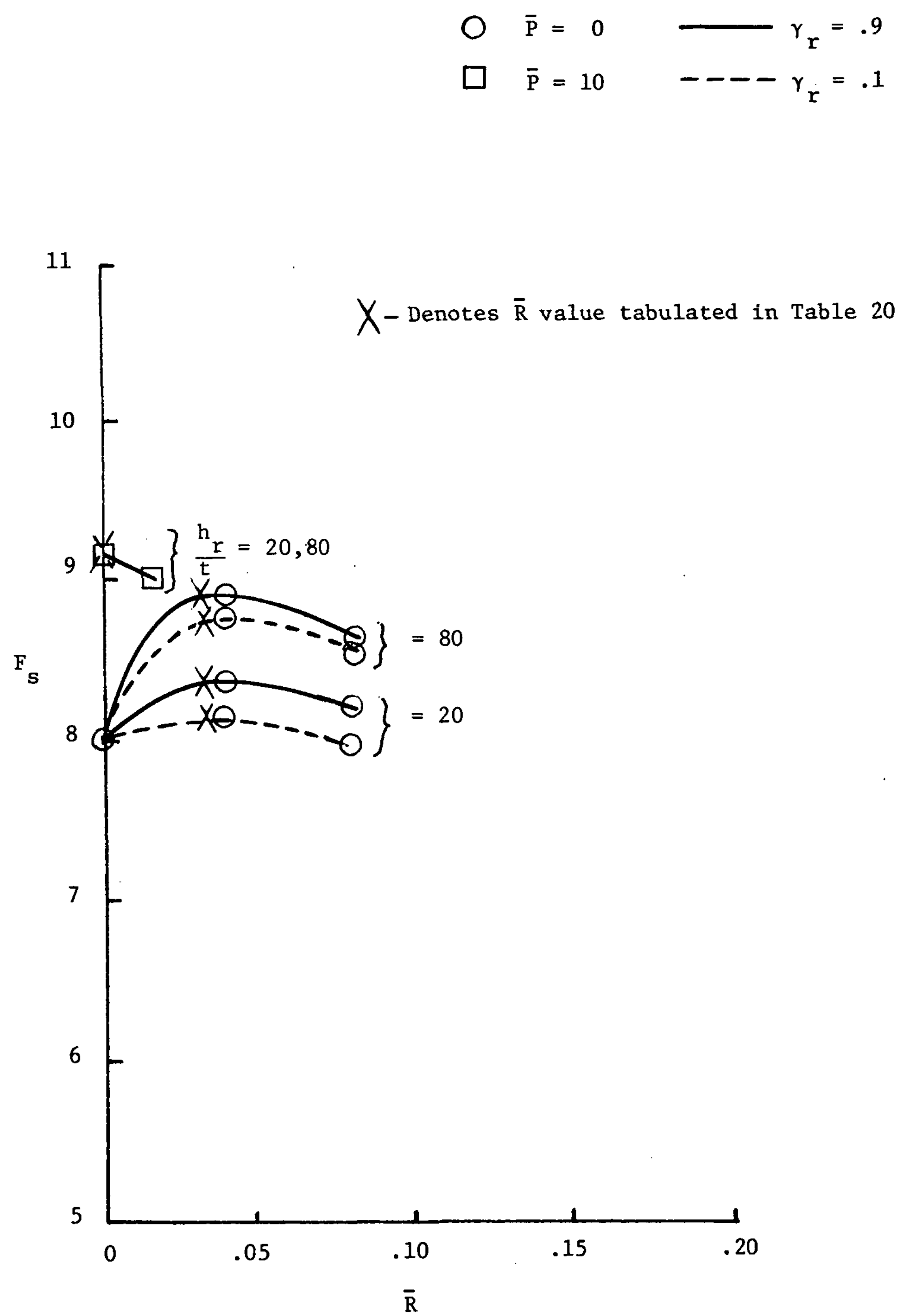


Figure 18. - Calculations to determine desirable ring area parameter $\bar{R}$ for stringers outside, rings outside and Z = 100.; $\bar{S}$ = .5; k_s = 0.; h_s/t = 30; γ_s = .1; $\bar{G}_s$ = 0.; $\bar{G}_r$ = 0.; k_r = 0.

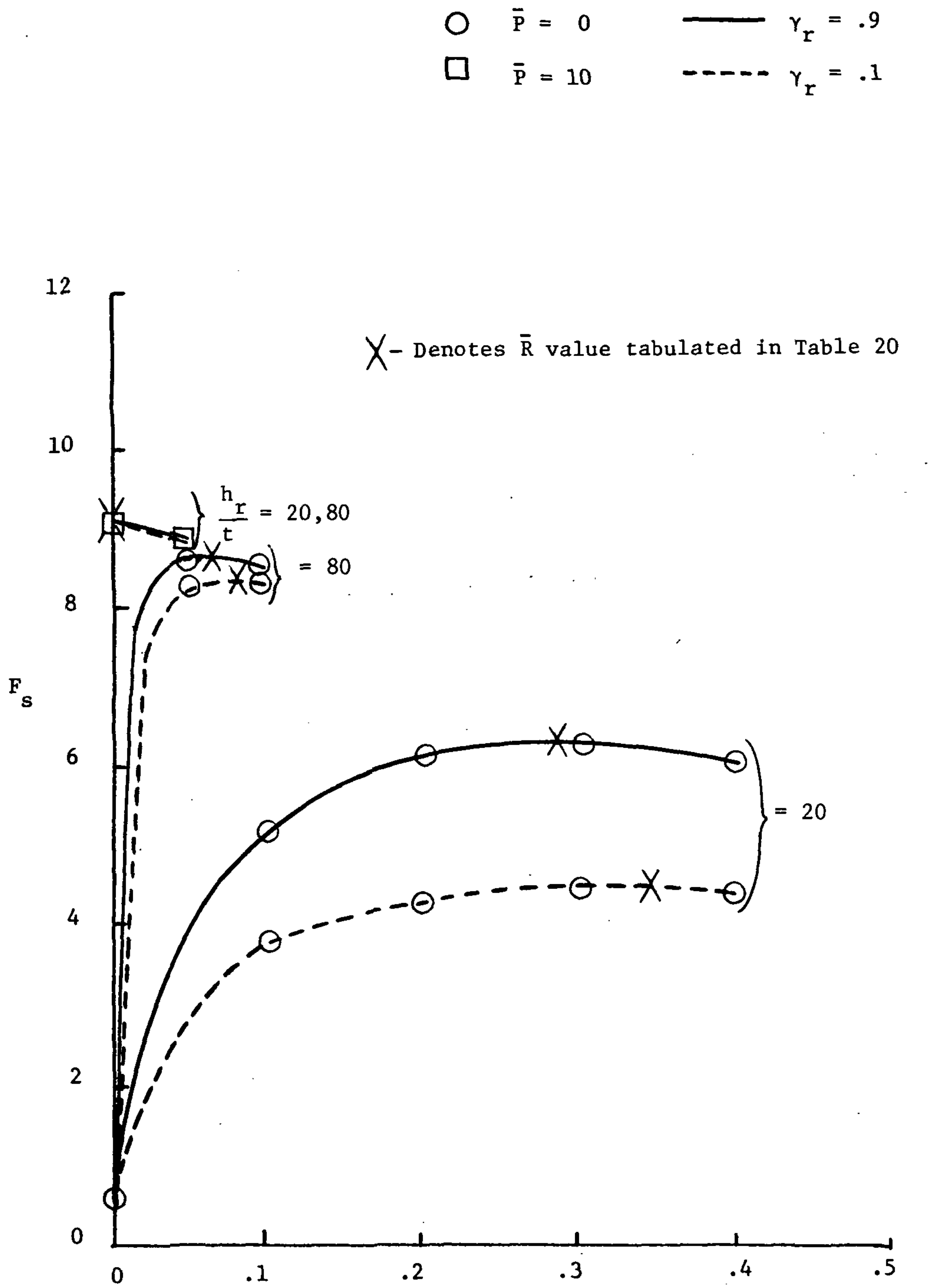


Figure 19. - Calculations to determine desirable ring area parameter $\bar{R}$ for stringers outside, rings outside and Z = 1000.; $\bar{S}$ = .5; k_s = 0.; h_s/t = 30; γ_s = .1; $\bar{G}_s$ = 0.; $\bar{G}_r$ = 0.; k_r = 0.

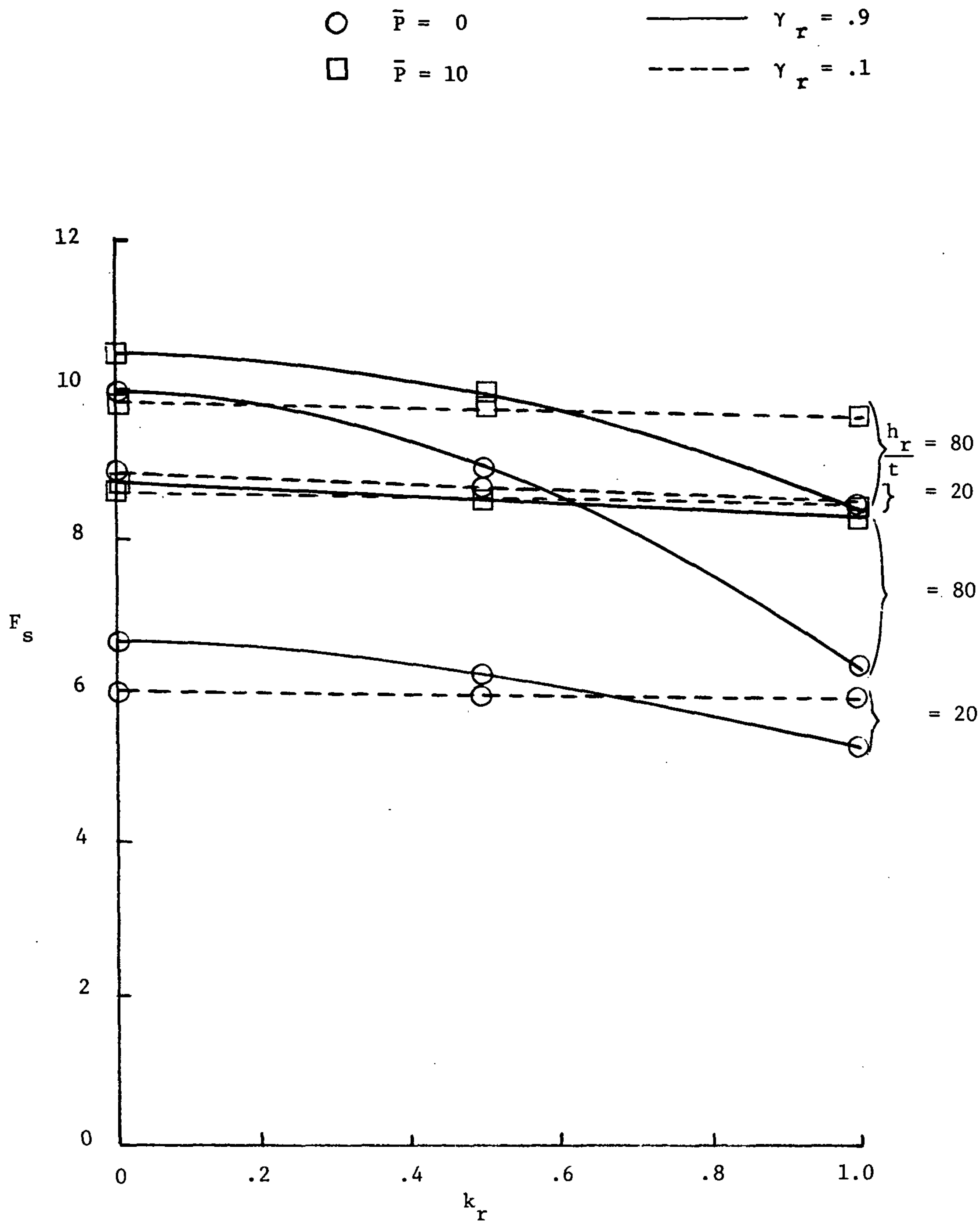


Figure 20. - Calculations to determine the amount of bottom flange material, k_r, for stringers inside, rings outside and $Z = 100.$; $\bar{S} = .5$; $k_s = 0.$; $h_s/t = 30.$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{R} = .1$; $\bar{G}_r = 0.$

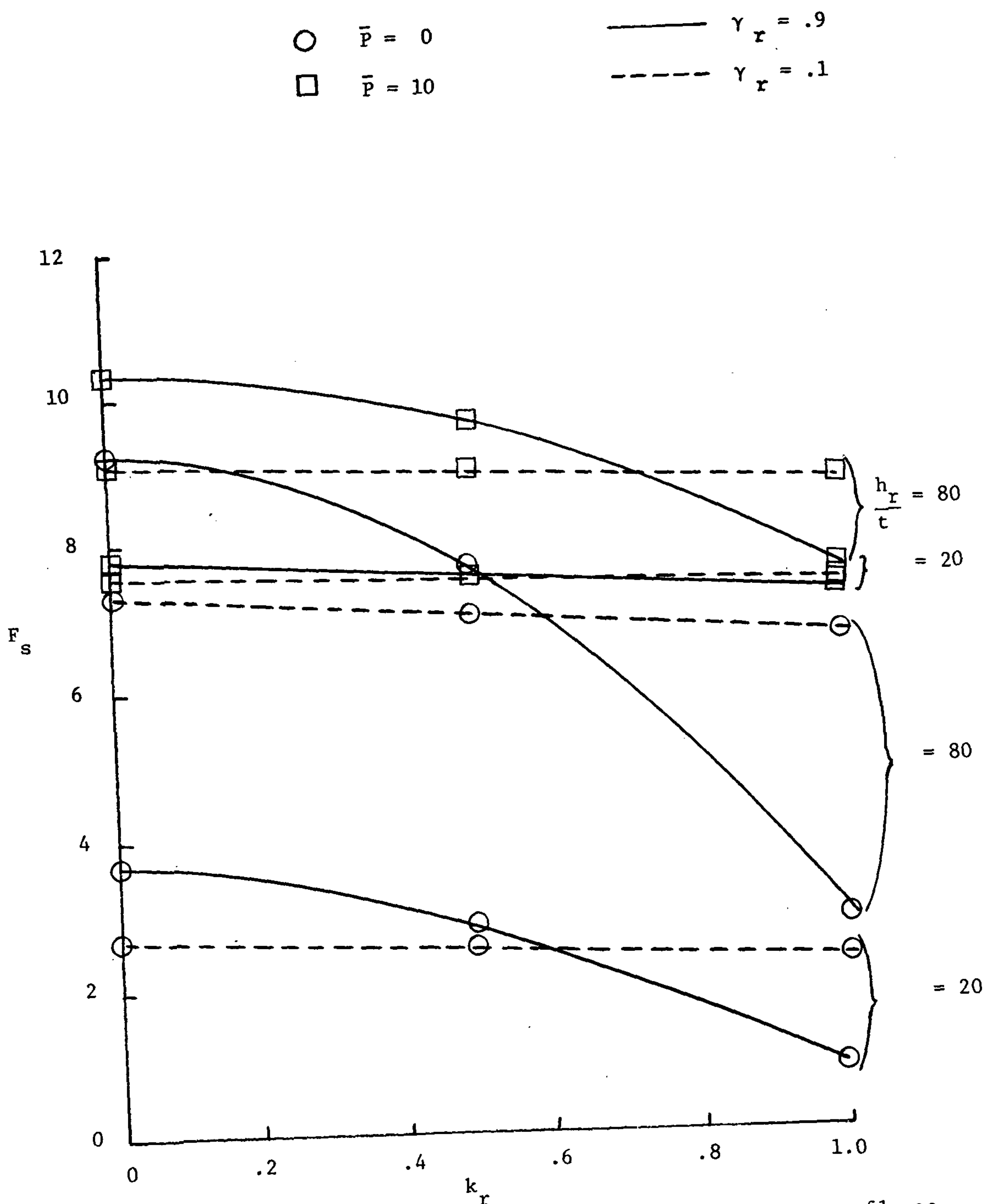


Figure 21. - Calculations to determine the amount of bottom flange material, k_r, for stringers inside, rings inside and $Z = 10000.$; $\bar{S} = .5$; $k_s = 0.$; $h_s/t = 30.$; $\gamma_s = .1$; $\bar{G}_s = 0.$; $\bar{R} = .1$; $\bar{G}_r = 0.$

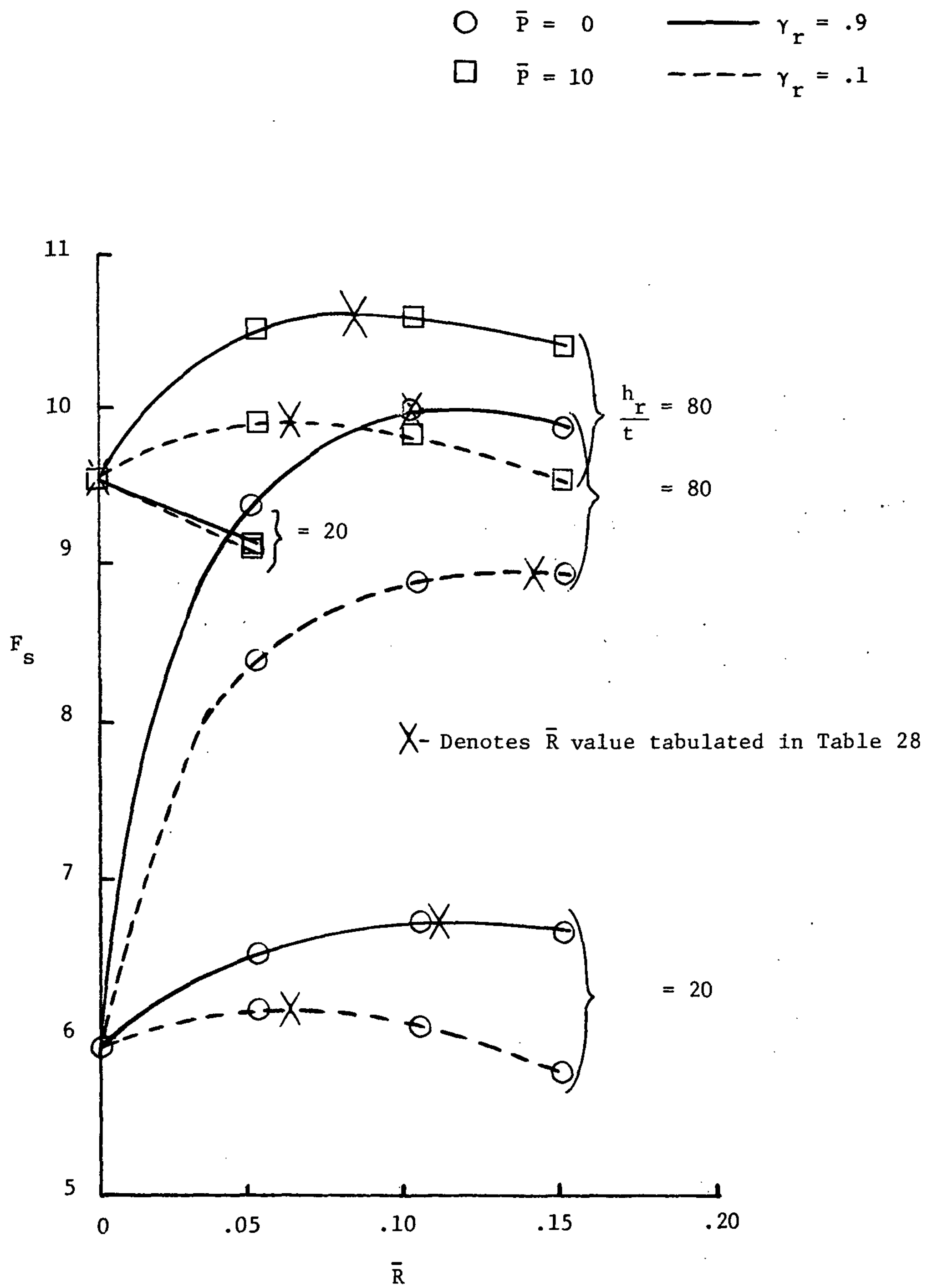


Figure 22. - Calculations to determine desirable ring area parameter $\bar{R}$ for stringers inside, rings outside and Z = 100.; $\bar{S}$ = .5; k_s = 0.; h_s/t = 30; γ_s = .1; $\bar{G}_s$ = 0.; $\bar{G}_r$ = 0.; k_r = 0.

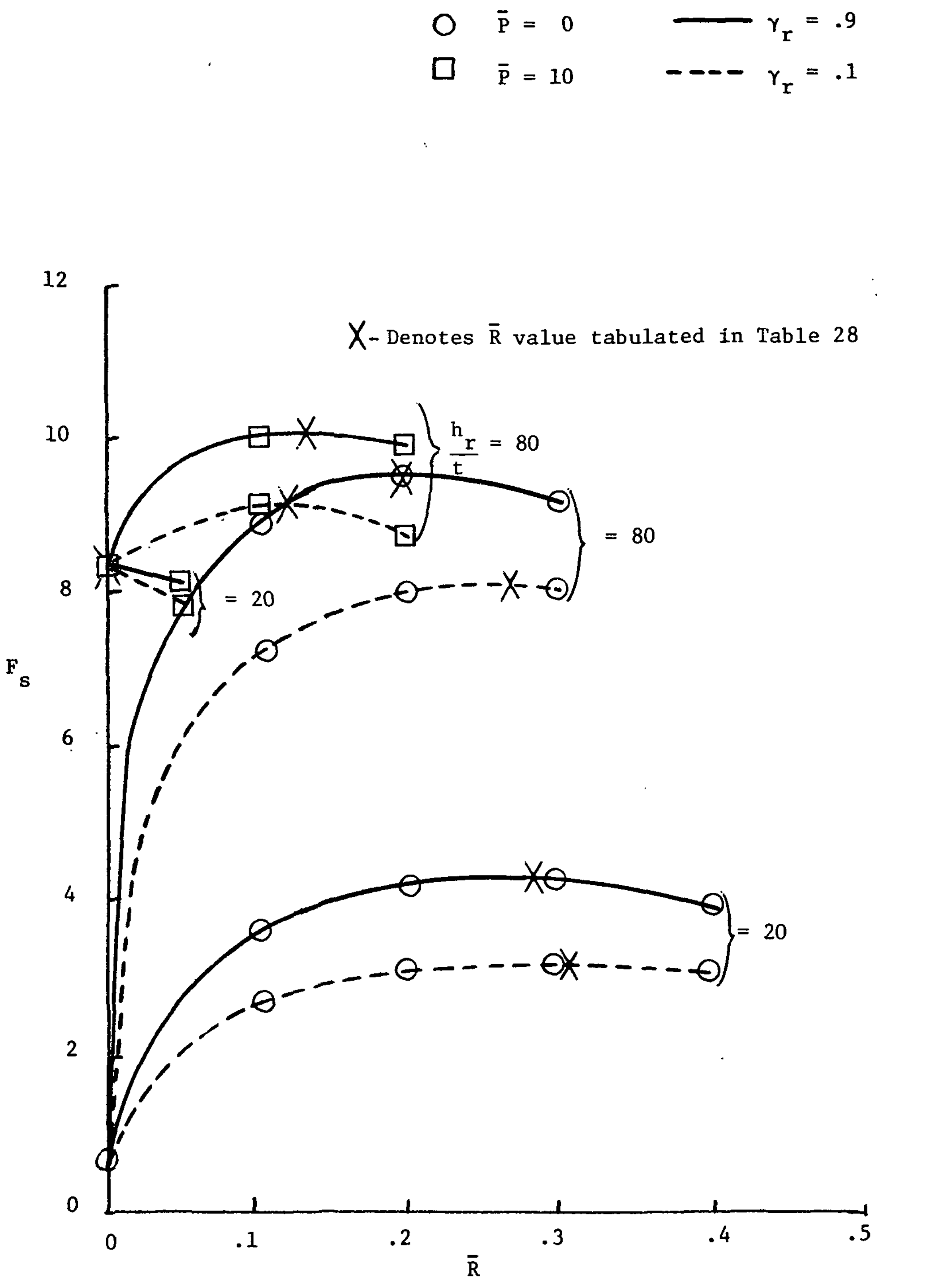


Figure 23. - Calculations to determine desirable ring area parameter $\bar{R}$ for stringers inside, rings outside and Z = 10000.; $\bar{S}$ = .5; k_s = 0.; h_s/t = 30; γ_s = .1; $\bar{G}_s$ = 0.; $\bar{G}_r$ = 0.; k_r = 0.

TABLE 1(A) - Stringer Area Parameter $\bar{S}$ for Maximum Structural Efficiency - Stringers Outside.

h_s/t	γ_s	$\bar{P}$	Z=1	10	10^2	10^3	10^4	10^5
10	.1	0	.58	.56	.55	0	0	0
		1	.58	.56	.16	.23	.21	.21
		5	.59	.56	.32	.26	.25	.24
		10	.59	.56	.32	.26	.24	.24
	.5	0	.56	.55	.59	.21	0	0
		1	.55	.55	.21	.19	.22	.22
		5	.55	.55	.34	.21	.25	.23
		10	.55	.55	.41	.21	.23	.23
	.9	0	.51	.51	.59	.31	0	0
		1	.51	.51	.27	.25	.22	.22
		5	.51	.51	.24	.23	.23	.22
		10	.51	.51	.32	.23	.23	.22
20	.1	0	.60	.59	.65	.44	0	0
		1	.59	.60	.39	.18	.21	.21
		5	.60	.60	.14	.26	.23	.23
		10	.60	.60	.18	.21	.24	.24
	.5	0	.56	.56	.59	.56	0	0
		1	.56	.56	.43	.26	.22	.22
		5	.56	.57	.23	.21	.23	.22
		10	.56	.57	.14	.30	.24	.24
	.9	0	.51	.51	.51	.62	0	0
		1	.51	.52	.41	.28	.22	.22
		5	.51	.51	.26	.25	.23	.22
		10	.51	.52	.17	.23	.22	.22
30	.1	0	.60	.60	.59	.61	0	0
		1	.60	.60	.46	.30	.21	.22
		5	.60	.60	.29	.27	.23	.21
		10	.60	.60	.20	.23	.24	.25
	.5	0	.56	.56	.48	.76	.18	0
		1	.56	.56	.43	.20	.21	.21
		5	.56	.56	.33	.18	.22	.22
		10	.56	.56	.26	.25	.23	.23
	.9	0	.51	.51	.40	.73	.30	0
		1	.51	.51	.37	.15	.24	.22
		5	.51	.51	.31	.23	.20	.22
		10	.51	.51	.31	.24	.22	.22

TABLE 1(B) - Stringer Area Parameter $\bar{S}$ for Maximum Structural Efficiency - Stringers Inside.

h_s/t	γ_s	$\bar{P}$	Z=1	10	10^2	10^3	10^4	10^5
10	.1	0	.59	.57	.37	.0	.0	0
		1	.58	.55	.13	.13	.13	.13
		5	.58	.52	.31	.20	.20	.20
		10	.58	.52	.34	.26	.25	.25
	.5	0	.56	.55	.47	0	0	0
		1	.56	.54	.09	.15	.13	.13
		5	.55	.51	.20	.19	.19	.19
		10	.55	.51	.28	.24	.23	.23
	.9	0	.51	.51	.45	0	0	0
		1	.51	.50	.09	.12	.13	.13
		5	.51	.48	.15	.17	.17	.17
		10	.51	.48	.21	.21	.21	.21
20	.1	0	.59	.59	.58	0	0	0
		1	.54	.55	.29	.16	.13	.13
		5	.59	.57	.10	.18	.16	.17
		10	.59	.56	.14	.23	.21	.20
	.5	0	.56	.56	.55	0	0	0
		1	.56	.56	.40	.12	.12	.12
		5	.56	.55	.18	.14	.15	.16
		10	.56	.54	.12	.17	.19	.18
	.9	0	.51	.51	.51	.24	0	0
		1	.51	.51	.41	.10	.12	.12
		5	.51	.51	.25	.19	.15	.15
		10	.51	.50	.19	.14	.17	.17
30	.1	0	.60	.60	.59	.30	0	0
		1	.60	.59	.48	.10	.12	.13
		5	.60	.59	.29	.20	.17	.16
		10	.60	.58	.22	.16	.18	.18
	.5	0	.56	.56	.55	.44	0	0
		1	.56	.56	.51	.20	.12	.12
		5	.56	.56	.39	.14	.15	.15
		10	.56	.55	.32	.20	.17	.17
	.9	0	.51	.51	.52	.45	0	0
		1	.51	.51	.48	.15	.12	.12
		5	.51	.51	.40	.12	.15	.14
		10	.51	.51	.35	.16	.16	.16

TABLE 2 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Outside, Rings Inside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
.5	10	.1	20	.1	0	0	½	1	1	0	0	0	0	0	0	0	0
					1	0	0	F	1	0	0	0	½	0	1	0	1
					5	0	0	F	1	F	1	1	1	1	1	1	1
					10	0	0	F	1	1	1	1	1	F	1	F	1
				.9	0	0	F	1	1	0	½	0	½	0	½	0	½
					1	0	½	1	1	0	½	0	½	½	½	½	½
					5	0	½	F	1	1	1	1	1	1	1	1	1
					10	0	½	F	1	1	1	1	1	F	1	F	1
			80	.1	0	0	0	1	1	1	1	0	0	½	0	0	0
					1	0	F	1	1	1	1	0	0	0	0	0	0
					5	0	F	1	1	1	1	1	1	1	1	1	½
					10	0	F	F	1	1	1	1	1	1	1	1	1
				.9	0	0	0	1	1	½	1	½	½	½	½	½	½
					1	0	0	1	1	½	1	½	½	½	½	½	½
					5	0	0	1	1	1	1	1	1	1	1	1	1
					10	0	0	F	1	1	1	1	1	F	1	F	1
		.9	20	.1	0	0	0	1	1	0	0	0	0	0	0	0	0
					1	0	0	F	1	0	0	0	0	0	½	0	½
					5	0	0	F	1	1	1	1	1	1	1	1	1
					10	0	0	F	F	1	1	1	1	F	1	1	1
				.9	0	0	0	1	1	0	½	0	½	0	½	0	½
					1	0	0	1	1	0	½	0	½	0	½	0	½
					5	0	0	F	1	1	1	1	1	1	1	1	1
					10	0	0	F	1	1	1	1	1	F	1	1	1
			80	.1	0	0	0	1	1	0	1	0	1	0		0	1
					1	0	0	1	1	0	1	1	1	1	1	1	1
					5	0	0	1	1	0	1	1	1	1	1	1	1
					10	0	0	1	1	1	1	1	1	1	1	1	1
				.9	0	0	0	1	1	0	½	½	½	½	½	½	½
					1	0	0	1	1	½	½	½	½	½	½	½	½
					5	0	0	1	1	½	½	1	1	1	1	1	1
					10	0	0	1	1	1	1	1	1	1	1	1	1

F - denotes F_s values did not vary with respect to k_r.

TABLE 3 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Outside, Rings Inside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
.5	30	.1	20	.1	0	0	0	1	1	0	1	0	0	0	0	0	0
					1	0	0	1	1	0	1	0	0	0	0	0	0
					5	0	0	1	1	1	1	0	0	0	1	0	1
					10	0	0	1	1	1	1	1	1	1	1	1	1
				.9	0	0	0	1	1	½	½	0	½	0	0	0	0
					1	0	0	1	1	½	½	0	½	0	½	0	½
					5	0	0	1	1	1	1	0	½	½	½	½	½
					10	0	0	1	1	1	1	1	1	1	1	1	1
			80	.1	0	0	0	F	1	0	1	0	1	0	½	0	1
					1	0	0	F	1	0	1	0	1	0	1	0	1
					5	0	0	1	1	1	1	1	1	0	1	0	1
					10	0	0	1	1	1	1	1	1	1	1	1	1
				.9	0	0	0	½	1	½	½	½	½	0	½	0	½
					1	0	0	½	1	½	½	½	½	0	½	½	½
					5	0	0	1	1	1	1	½	½	½	½	½	½
					10	0	0	1	1	1	1	1	1	1	1	1	1
		.9	20	.1	0	F	1	1	1	1	1	0	0	0	0	0	0
					1	F	1	1	1	1	1	0	0	0	0	0	0
					5	F	1	1	1	F	1	1	1	0	0	0	½
					10	0	1	1	1	1	1	1	1	1	1	1	1
				.9	0	1	1	1	1	1	1	0	0	0	0	0	0
					1	1	1	1	1	1	1	0	0	0	0	0	0
					5	½	1	1	1	1	1	1	½	0	½	0	½
					10	0	1	1	1	1	1	1	1	1	1	1	1
			80	.1	0	0	0	0	0	1	1	0	½	0	½	0	½
					1	0	0	0	0	1	1	0	½	0	½	0	½
					5	0	0	0	½	1	1	0	1	0	1	0	1
					10	0	0	0	1	1	1	½	1	1	1	1	1
				.9	0	0	0	0	½	1	1	0	½	0	½	0	½
					1	0	0	0	½	1	1	0	½	0	½	0	½
					5	0	0	0	½	1	1	½	½	½	½	½	½
					10	0	0	0	1	1	1	½	½	1	1	1	1

F - denotes F_s values did not vary with respect to k_r.

TABLE 4 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Outside, Rings Inside.

					Z=	1	10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
1.5	10	.1	20	.1	0	0	0	1	1	0	0	0	0	0	0	0	0
					1	0	0	1	1	0	½	0	0	0	1	0	½
					5	0	0	F	1	1	1	1	1	½	1	1	1
					10	0	0	F	F	1	1	1	1	F	1	F	1
				.9	0	0	0	1	1	0	½	0	½	0	½	0	½
					1	0	0	1	1	0	½	0	½	0	½	0	½
					5	0	0	F	1	1	1	1	1	1	1	1	1
					10	0	0	F	1	1	1	1	1	1	1	1	1
			80	.1	0	0	0	1	1	0	1	0	1	0	1	0	1
					1	0	0	1	1	0	1	1	1	½	1	½	1
					5	0	0	1	1	0	1	1	1	1	1	1	1
					10	0	0	1	1	1	1	1	1	1	1	1	1
				.9	0	0	0	1	1	0	½	½	½	½	½	½	½
					1	0	0	1	1	½	½	½	½	½	1	½	1
					5	0	0	1	1	½	½	1	1	1	1	1	1
					10	0	0	F	1	1	1	1	1	1	1	1	1
		.9	20	.1	0	0	0	1	1	0	1	0	1	0	0	0	0
					1	0	0	1	1	1	1	0	1	0	1	0	1
					5	0	0	1	1	1	1	1	1	1	1	1	1
					10	0	0	1	1	1	1	1	1	F	1	F	1
				.9	0	0	0	1	1	½	½	0	½	0	½	0	½
					1	0	0	1	1	1	½	½	½	½	½	½	½
					5	0	0	1	1	1	1	1	1	1	1	1	1
					10	0	0	1	1	1	1	1	1	F	1	F	1
			80	.1	0	0	0	0	1	0	1	0	1	0	1	0	1
					1	0	0	0	1	0	1	0	1	1	1	½	1
					5	0	0	1	1	1	1	1	1	1	1	1	1
					10	0	0	1	1	1	1	1	1	1	1	1	1
				.9	0	0	0	½	1	½	½	½	½	½	1	½	1
					1	0	0	1	1	½	½	½	½	½	1	½	1
					5	0	0	1	1	1	1	1	1	1	1	1	1
					10	0	0	0	1	1	1	1	1	1	1	1	1

F - denotes F_s values did not vary with respect to k_r.

TABLE 5 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Outside, Rings Inside.

					Z	Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
1.5	30	.1	20	.1	0	1	1	1	1	1	1	0	0	0	0	0	0
					1	1	1	1	1	1	1	0	0	0	0	0	0
					5	1	1	1	1	F	1	1	1	0	1	1	1
					10	1	1	1	1	1	1	1	1	1	1	1	1
				.9	0	1	1	1	1	1	1	0	0	0	0	0	0
					1	1	1	1	1	1	1	0	½	0	½	0	½
					5	1	1	1	1	1	1	1	1	½	½	½	½
					10	1	1	1	1	1	1	1	1	1	1	1	1
			80	.1	0	0	0	0	0	1	1	0	½	0	0	0	½
					1	0	0	0	0	1	1	0	½	0	½	0	½
					5	0	0	0	0	1	1	0	1	0	1	0	1
					10	0	0	1	0	1	1	1	1	1	1	1	1
				.9	0	0	0	0	½	1	1	0	½	0	½	0	½
					1	0	0	0	½	1	1	0	½	0	½	0	½
					5	0	0	0	½	1	1	½	½	½	½	½	½
					10	0	0	0	½	1	1	1	½	1	1	1	1
		.9	20	.1	0	1	1	1	1	F	1	0	0	0	0	0	0
					1	1	1	1	1	F	1	0	0	0	0	0	0
					5	1	1	1	1	F	F	½	0	0	1	1	1
					10	1	1	1	1	1	F	1	1	1	1	1	1
				.9	0	1	1	1	1	F	1	0	0	0	0	0	0
					1	1	1	1	1	F	1	0	0	0	0	0	0
					5	1	1	1	1	F	1	0	½	½	½	1	½
					10	1	1	1	1	1	1	1	1	1	1	1	1
			80	.1	0	0	0	0	0	F	1	0	1	0	½	0	1
					1	0	0	0	0	F	1	0	1	0	½	0	1
					5	0	0	0	0	F	1	1	1	0	1	0	1
					10	0	0	0	0	1	1	1	1	1	1	1	1
				.9	0	0	0	0	0	1	1	½	½	0	½	0	½
					1	0	0	0	0	1	1	½	½	0	½	½	½
					5	0	0	0	0	F	1	1	1	½	½	½	½
					10	0	0	0	0	1	1	1	1	1	1	1	1

F - denotes F_s values did not vary with respect to k_r.

TABLE 6 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Outside, Rings Inside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$	Z=1	10	10^2	10^3	10^4	10^5
.5	10	.1	20	.1	0	0	0	.10	.08	.08	.08
					1	0	0	.05	.03	.04	.03
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.08	.06	.06	.06
					1	0	0	.06	.03	.04	.04
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.05	.04	.04	.04
					1	0	0	.03	.01	.02	.02
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.04	.04	.04	.04
					1	0	0	.02	.01	.01	.02
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
		.9	20	.1	0	0	0	.06	.11	.11	.11
					1	0	0	.02	.03	.05	.05
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.05	.06	.07	.07
					1	0	0	.03	.04	.05	.05
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.05	.04	.04	.04
					1	0	0	.04	.02	.02	.02
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.04	.04	.04	.04
					1	0	0	.04	.02	.02	.02
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0

TABLE 7 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Outside, Rings Inside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
.5	30	.1	20	.1	0	0	0	0	.21	.20	.20
					1	0	0	0	.11	.1	.08
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.14	.13	.13
					1	0	0	0	.10	.11	.10
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.03	.08	.06	.06
					1	0	0	0	.07	.05	.05
					5	0	0	0	.03	.0	.0
					10	0	0	0	0	0	0
				.9	0	0	0	.03	.05	.04	.04
					1	0	0	.01	.07	.05	.05
					5	0	0	0	.03	.02	.02
					10	0	0	0	0	0	0
		.9	20	.1	0	0	0	0	.18	.27	.28
					1	0	0	0	.06	.09	.10
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.17	.18	.18
					1	0	0	0	.11	.11	.10
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	0	.08	.08	.08
					1	0	0	0	.05	.07	.07
					5	0	0	0	0	.02	.02
					10	0	0	0	0	0	0
				.9	0	0	0	0	.04	.06	.06
					1	0	0	0	.04	.06	.06
					5	0	0	0	0	.02	.02
					10	0	0	0	0	0	0

TABLE 8 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Outside, Rings Inside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
1.5	10	.1	20	.1	0	0	0	.07	.10	.11	.11
					1	0	0	.03	.04	.04	.05
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.06	.08	.07	.07
					1	0	0	.04	.05	.05	.05
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.06	.04	.04	.04
					1	.01	0	.05	.02	.03	.03
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.06	.04	.04	.04
					1	.01	0	.07	.02	.01	.08
					5	0	0	.03	0	0	0
					10	0	0	0	0	0	0
		.9	20	.1	0	0	0	0	.13	.12	.12
					1	0	0	0	.06	.04	.05
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.08	.08	.08
					1	0	0	0	.06	.05	.05
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.04	.04	.04	.04
					1	.01	0	.02	.03	.02	.02
					5	0	0	0	0	0	0
					10	.01	0	0	0	0	0
				.9	0	.03	0	.04	.05	.04	.04
					1	.02	0	.02	.03	.08	.07
					5	.02	0	0	0	0	0
					10	.02	0	0	0	0	0

TABLE 9 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency.
Stringers Outside, Rings Inside.

$\bar{s}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
1.5	30	.1	20	.1	0	0	0	0	.23	.26	.28
					1	0	0	0	.13	.13	.11
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.21	.18	.18
					1	0	0	0	.16	.12	.14
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	0	.06	.08	.09
					1	0	0	0	.05	.07	.07
					5	0	0	0	0		.02
					10	0	0	0	0	0	0
				.9	0	0	0	0	.05	.06	.06
					1	0	0	0	.06	.08	.07
					5	0	0	0	.03	.03	.03
					10	0	0	0	0	0	0
		.9	20	.1	0	0	0	0	.16	.42	.40
					1	0	0	0	.07	.15	.14
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.15	.25	.24
					1	0	0	0	.10	.11	.13
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	0	.11	.10	.09
					1	0	0	0	.12	.08	.08
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.10	.06	.06
					1	0	0	0	.07	.06	.07
					5	0	0	0	0	0	.02
					10	0	0	0	0	0	0

TABLE 10 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Inside, Rings Inside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
.5	10	.1	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	½	1	½	1	1	1	1	1
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	½	0	½	0	½
					5	0	0	0	½	0	½	0	½	0	½	0	½
					10	0	0	0	½	½	1	1	½	½	½	½	½
			80	.1	0	0	F	0	1	0	0	0	0	0	½	0	0
					1	0	F	0	1	0	0	0	½	0	0	0	0
					5	0	F	0	1	0	½	0	½	0	0	0	0
					10	0	F	1	1	0	1	0	0	0	0	0	0
				.9	0	0	0	½	½	0	½	0	½	0	½	0	½
					1	0	0	0	½	0	½	0	½	0	½	0	½
					5	0	0	0	1	0	½	0	½	0	½	0	½
					10	0	0	½	1	0	½	0	½	0	½	0	½
		.9	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	½	0	½
					10	0	0	0	0	0	½	0	½	0	½	0	½
			80	.1	0	0	0	0	1	0	0	0	0	0	0	0	0
					1	0	0	0	1	0	0	0	0	0	0	0	0
					5	0	0	0	1	0	0	0	½	0	0	0	0
					10	0	0	0	1	0	0	0	1	0	1	0	1
				.9	0	0	0	0	½	0	½	0	½	0	½	0	½
					1	0	0	0	½	0	½	0	½	0	½	0	½
					5	0	0	0	½	0	½	0	½	0	½	0	½
					10	0	0	¼	½	0	½	0	½	0	½	0	½

F - denotes F_s values did not vary with respect to k_r.

TABLE 11 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Inside, Rings Inside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
.5	30	.1	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	½	0	0	0	0	0	½
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	½	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	½	0	½	0	½	0	½	0	½
					1	0	0	0	½	0	½	0	½	0	½	0	½
					5	0	0	0	½	0	½	0	½	0	½	0	½
					10	0	0	0	½	0	½	0	½	0	½	0	½
		.9	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	½	0	0	0	0	0	0
					10	0	0	0	0	0	½	0	½	0	½	0	½

TABLE 12 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Inside, Rings Inside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
1.5	10	.1	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	½	0	½	0	½	0	½
			80	.1	0	0	0	0	1	0	0	0	0	0	0	0	0
					1	0	0	0	1	0	0	0	0	0	0	0	0
					5	0	0	0	1	0	0	0	0	0	0	0	0
					10	0	0	0	1	0	0	0	½	0	½	0	½
				.9	0	0	0	0	½	0	½	0	½	0	½	0	½
					1	0	0	0	½	0	½	0	½	0	½	0	½
					5	0	0	0	½	0	½	0	0	0	½	0	½
					10	0	0	0	½	0	½	0	½	0	½	0	½
		.9	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	½	0	½	0	½	0	½	0	½
					1	0	0	0	½	0	½	0	½	0	½	0	½
					5	0	0	0	½	0	½	0	½	0	½	0	½
					10	0	0	0	½	0	½	0	½	0	½	0	½

TABLE 13 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency.
Stringers Inside, Rings Inside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
1.5	30	.1	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	½	0	½	0	½	0	½
		.9	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 14 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency.
Stringers Inside, Rings Inside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
.5	10	.1	20	.1	0	0	.03	.16	.17	.16	.16
					1	0	.01	.11	.12	.10	.11
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	.03	.13	.12	.12	.12
					1	0	.02	.11	.08	.09	.10
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	.03	.10	.09	.08	.08
					1	0	.02	.10	.08	.07	.07
					5	0	0	.06	.04	.04	.04
					10	0	0	0	0	0	0
				.9	0	0	.03	.09	.06	.06	.05
					1	0	.01	.08	.04	.04	.04
					5	0	0	.04	.04	.04	.04
					10	0	0	0	.01	.01	.01
		.9	20	.1	0	0	0	.14	.22	.19	.19
					1	0	0	.10	.11	.13	.13
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.13	.14	.16	.16
					1	0	.01	.10	.11	.11	.12
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	.03	.10	.11	.10	.10
					1	0	.02	.09	.10	.08	.08
					5	0	0	.06	.06	.06	.06
					10	0	0	.03	.02	.02	.02
				.9	0	0	.03	.09	.07	.08	.08
					1	0	.02	.06	.06	.07	.07
					5	0	0	.06	.05	.05	.05
					10	0	0	.04	.02	.03	.03

TABLE 15 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Inside, Rings Inside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
.5	30	.1	20	.1	0	0	0	.06	.29	.26	.25
					1	0	0	.03	.10	.14	.15
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.07	.18	.20	.20
					1	0	0	.05	.12	.16	.15
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.08	.14	.14	.14
					1	0	0	.07	.13	.12	.12
					5	0	0	.05	.09	.08	.08
					10	0	0	.02	.05	.04	.04
				.9	0	0	0	.06	.12	.11	.11
					1	0	.01	.06	.11	.10	.10
					5	0	0	.05	.09	.08	.08
					10	0	0	.03	.06	.04	.05
		.9	20	.1	0	0	0	0	.28	.29	.28
					1	0	0	0	.16	.14	.16
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.03	.26	.23	.24
					1	0	0	.02	.19	.16	.17
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.06	.15	.17	.18
					1	0	0	.05	.11	.16	.16
					5	0	0	.04	.08	.11	.11
					10	0	0	.02	.04	.05	.05
				.9	0	0	0	.06	.11	.14	.13
					1	0	0	.05	.10	.13	.12
					5	0	0	.04	.08	.09	.10
					10	0	0	0	.06	.06	.07

TABLE 16 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Inside, Rings Inside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
1.5	10	.1	20	.1	0	0	.03	.21	.25	.27	.27
					1	0	.02	.16	.17	.20	.19
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	.04	.18	.19	.21	.21
					1	0	.03	.16	.16	.17	.17
					5	0	0	.06	.06	.06	.06
					10	0	0	0	0	0	0
			80	.1	0	0	.04	.15	.16	.14	.14
					1	.02	.02	.14	.15	.13	.13
					5	0	.03	.10	.09	.10	.10
					10	.02	.01	.05	.04	.03	.05
				.9	0	.03	.04	.12	.10	.11	.11
					1	.01	.03	.11	.09	.10	.10
					5	0	.03	.09	.06	.08	.08
					10	.01	.01	.06	.04	.04	.05
		.9	20	.1	0	0	0	.19	.32	.33	.33
					1	0	0	.08	.25	.23	.23
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	.03	.18	.27	.25	.26
					1	0	.02	.15	.23	.22	.21
					5	0	0	.07	.07	.08	.08
					10	0	0	0	0	0	0
			80	.1	0	.03	.04	.15	.16	.18	.18
					1	.02	.03	.14	.15	.16	.17
					5	.03	.03	.11	.11	.12	.12
					10	.02	.02	.07	.07	.08	.07
				.9	0	.03	.04	.13	.14	.14	.14
					1	.02	.04	.12	.13	.13	.15
					5	.03	.04	.10	.11	.11	.11
					10	.02	.03	.07	.08	.07	.08

TABLE 17 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Inside, Rings Inside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
1.5	30	.1	20	.1	0	0	0	.04	.42	.42	.40
					1	0	0	.02	.28	.24	.25
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.07	.36	.31	.32
					1	0	0	.05	.29	.25	.25
					5	0	0	0	.05	.07	.07
					10	0	0	0	0	0	0
			80	.1	0	0	0	.09	.19	.24	.24
					1	0	.01	.08	.17	.23	.21
					5	0	0	.07	.13	.17	.16
					10	0	0	.04	.08	.09	.10
				.9	0	0	.03	.08	.16	.19	.19
					1	0	.02	.08	.15	.18	.17
					5	0	0	.07	.13	.13	.14
					10	0	.01	.05	.10	.01	.10
		.9	20	.1	0	0	0	0	.39	.40	.46
					1	0	0	0	.26	.28	.28
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.36	.37	.38
					1	0	0	0	.29	.30	.29
					5	0	0	0	.07	.06	.06
					10	0	0	0	0	0	0
			80	.1	0	0	0	.08	.34	.29	.29
					1	0	0	.07	.32	.27	.27
					5	0	0	.06	.25	.21	.19
					10	0	0	.04	.14	.12	.13
				.9	0	0	.03	.08	.28	.24	.22
					1	.01	.02	.07	.26	.23	.22
					5	0	0	.07	.20	.16	.18
					10	.01	.02	.05	.10	.13	.13

TABLE 18 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Outside, Rings Outside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
.5	10	.1	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
.5	30				1	0	0	0	0	0	0	0	0	0	0	0	0
1.5	10				5	0	0	0	0	0	0	0	0	0	0	0	0
1.5	30				10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
		.9	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 19 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Outside, Rings Outside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
.5	10	.1	20	.1	0	0	0	.18	.13	.12	.12
					1	0	0	.12	.08	.08	.08
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.08	.06	.07	.07
					1	0	0	.06	.05	.05	.05
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.02	.02	.03	.03
					1	0	0	.04	.04	.04	.04
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.01	.02	.02	.02
					1	0	0	.04	.04	.04	.04
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
		.9	20	.1	0	0	0	.15	.17	.20	.18
					1	0	0	.11	.12	.11	.11
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.18	.09	.09	.09
					1	0	0	.15	.06	.07	.07
					5	0	0	.04	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.15	.04	.03	.03
					1	0	0	.13	.04	.04	.04
					5	0	0	.09	0	0	0
					10	0	0	.03	0	0	0
				.9	0	0	0	.08	.02	.02	.02
					1	0	0	.08	.04	.04	.04
					5	0	0	.06	0	0	0
					10	0	0	.03	0	0	0

TABLE 20 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Outside, Rings Outside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
.5	30	.1	20	.1	0	0	0	.03	.27	.34	.34
					1	0	0	0	.16	.16	.16
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.03	.29	.28	.28
					1	0	0	0	.16	.19	.19
					5	0	0	0	.04	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.03	.07	.08	.09
					1	0	0	.03	.07	.08	.08
					5	0	0	0	.03	.04	.04
					10	0	0	0	0	0	0
				.9	0	0	0	.03	.05	.06	.05
					1	0	0	.03	.04	.05	.05
					5	0	0	0	.03	.04	.03
					10	0	0	0	0	0	0
		.9	20	.1	0	0	0	0	.22	.32	.34
					1	0	0	0	.13	.13	.13
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.24	.30	.31
					1	0	0	0	.19	.19	.19
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	0	.14	.11	.11
					1	0	0	0	.13	.10	.10
					5	0	0	0	.09	.06	.06
					10	0	0	0	.04	0	0
				.9	0	0	0	0	.10	.06	.06
					1	0	0	0	.10	.06	.06
					5	0	0	0	.07	.04	.04
					10	0	0	0	.05	0	0

TABLE 21 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Outside, Rings Outside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
1.5	10	.1	20	.1	0	0	0	.32	.17	.21	.22
					1	0	0	.28	.13	.16	.16
					5	0	0	.12	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.40	.14	.13	.13
					1	0	0	.37	.14	.09	.10
					5	0	0	.22	0	0	0
					10	0	0	.17	0	0	0
			80	.1	0	0	0	.26	.06	.04	.04
					1	0	0	.24	.06	.04	.04
					5	0	0	.24	0	0	0
					10	0	0	.18	0	0	0
				.9	0	0	0	.17	.04	.03	.02
					1	0	0	.19	.04	.04	.04
					5	0	0	.19	0	0	0
					10	0	0	.19	0	0	0
		.9	20	.1	0	0	0	.17	.21	.21	.21
					1	0	0	.13	.16	.13	.13
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.23	.11	.10	.09
					1	0	0	.24	.08	.07	.07
					5	0	0	.13	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	.02	0	.13	.03	.03	.03
					1	.03	0	.12	.04	.04	.04
					5	.03	0	.07	0	0	0
					10	.03	0	0	0	0	0
				.9	0	.02	0	.07	.02	.02	.02
					1	.03	0	.07	.04	.04	.04
					5	.03	0	.04	0	0	0
					10	.03	0	0	0	0	0

TABLE 22 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Outside, Rings Outside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
1.5	30	.1	20	.1	0	0	0	0	.36	.49	.53
					1	0	0	0	.26	.26	.26
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.38	.25	.24
					1	0	0	0	.34	.3	.29
					5	0	0	0	.07	.09	.10
					10	0	0	0	0	0	0
			80	.1	0	0	0	0	.24	.17	.15
					1	0	0	0	.22	.15	.14
					5	0	0	0	.17	.10	.10
					10	0	0	0	.12	.03	.04
				.9	0	0	0	0	.12	.08	.09
					1	0	0	0	.12	.08	.08
					5	0	0	0	.10	.06	.06
					10	0	0	0	.07	.03	.03
		.9	20	.1	0	0	0	0	.27	.47	.53
					1	0	0	0	.19	.22	.22
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.31	.29	.29
					1	0	0	0	.26	.30	.29
					5	0	0	0	0	.05	.06
					10	0	0	0	0	0	0
			80	.1	0	0	0	0	.13	.13	.14
					1	0	0	0	.11	.12	.12
					5	0	0	0	.06	.06	.06
					10	0	0	0	0	0	0
				.9	0	0	0	0	.12	.06	.06
					1	0	0	0	.11	.06	.06
					5	0	0	0	.08	.04	.04
					10	0	0	0	.03	0	0

TABLE 23 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Inside, Rings Outside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
.5	10	.1	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	F	0	F	0	F	0	F	0	F	0	F
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	F	0	F	0	F	0	F	0	F	0	F
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
		.9	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	F	0	F	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	F	0	F	0	F	0	F	0	F	0	F
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 24 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Inside, Rings Outside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
.5	30	.1	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
		.9	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	½	0	0	0	0	0	0	0	0	0	0
				.9	0	0	½	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	½	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 25 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Inside, Rings Outside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
1.5	10	.1	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	F	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	F	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
		.9	20	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 26 - Amount of Bottom Flange Material k_r for Maximum Structural Efficiency. Stringers Inside, Rings Outside.

						Z=1		10		10^2		10^3		10^4		10^5	
$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{P}$ \ $\bar{R}$	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5
1.5	30	.1	20	.1	0	0	1	0	0	0	0	0	0	0	0	0	0
					1	0	1	0	0	0	0	0	0	0	0	0	0
					5	0	1	0	0	0	0	0	0	0	0	0	0
					10	0	1	0	0	0	0	0	0	0	0	0	0
				.9	0	½	1	0	0	0	0	0	0	0	0	0	0
					1	½	1	0	0	0	0	0	0	0	0	0	0
					5	½	1	0	0	0	0	0	0	0	0	0	0
					10	½	1	0	0	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
		.9	20	.1	0	1	1	1	1	0	0	0	0	0	0	0	0
					1	1	1	1	1	0	0	0	0	0	0	0	0
					5	1	1	1	1	0	0	0	0	0	0	0	0
					10	1	1	1	1	0	0	0	0	0	0	0	0
				.9	0	1	1	1	1	0	0	0	0	0	0	0	0
					1	1	1	1	1	0	0	0	0	0	0	0	0
					5	1	1	1	1	0	0	0	0	0	0	0	0
					10	1	1	1	1	0	0	0	0	0	0	0	0
			80	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0
				.9	0	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0	0
					5	0	0	0	0	0	0	0	0	0	0	0	0
					10	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 27 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Inside, Rings Outside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
.5	10	.1	20	.1	0	0	.02	.29	.25	.27	.26
					1	0	0	.24	.19	.20	.21
					5	0	0	.04	.03	0	0
					10	0	0	0	0	0	0
				.9	0	0	.03	.30	.25	.24	.23
					1	0	.03	.28	.21	.20	.20
					5	0	0	.15	.11	.09	.09
					10	0	0	0	0	0	0
			80	.1	0	0	.02	.08	.11	.12	.12
					1	0	.03	.08	.10	.11	.11
					5	0	0	.05	.08	.08	.08
					10	0	0	0	.04	.04	.04
				.9	0	0	.02	.04	.06	.06	.06
					1	0	.03	.05	.06	.06	.06
					5	0	0	.04	.05	.05	.05
					10	0	0	0	.03	.03	.03
		.9	20	.1	0	0	0	.24	.31	.30	.31
					1	0	0	.18	.20	.23	.22
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.27	.27	.28	.27
					1	0	0	.23	.24	.23	.24
					5	0	0	.11	.12	.10	.11
					10	0	0	0	0	0	0
			80	.1	0	0	.02	.23	.15	.15	.15
					1	0	.03	.22	.13	.15	.14
					5	0	0	.18	.11	.11	.11
					10	0	0	.13	.07	.07	.07
				.9	0	0	.02	.21	.12	.11	.11
					1	0	.03	.20	.11	.11	.11
					5	0	0	.18	.10	.09	.09
					10	0	0	.14	.07	.07	.07

TABLE 28 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Inside, Rings Outside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
.5	30	.1	20	.1	0	0	0	.06	.34	.31	.33
					1	0	0	.03	.14	.18	.19
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.11	.28	.29	.30
					1	0	0	.08	.20	.24	.24
					5	0	0	0	.06	.06	.06
					10	0	0	0	0	0	0
			80	.1	0	0	0	.14	.29	.26	.24
					1	0	0	.13	.28	.23	.23
					5	0	0	.10	.20	.17	.18
					10	0	0	.06	.12	.12	.12
				.9	0	0	0	.10	.14	.20	.19
					1	0	0	.12	.14	.19	.19
					5	0	0	.11	.12	.16	.16
					10	0	0	.08	.10	.13	.13
		.9	20	.1	0	0	0	0	.30	.31	.32
					1	0	0	0	.16	.15	.16
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.02	.32	.32	.32
					1	0	0	0	.23	.21	.22
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
			80	.1	0	0	0	.09	.23	.30	.28
					1	0	0	.08	.22	.28	.26
					5	0	0	.06	.17	.19	.20
					10	0	0	.03	.12	.13	.13
				.9	0	0	0	.09	.25	.26	.25
					1	0	0	.09	.24	.26	.25
					5	0	0	.08	.21	.22	.21
					10	0	0	.06	.18	.17	.17

TABLE 29 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Inside, Rings Outside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
1.5	10	.1	20	.1	0	0	0	.42	.44	.46	.46
					1	0	0	.35	.38	.40	.38
					5	0	0	.14	.15	.14	.13
					10	0	0	0	0	0	0
				.9	0	0	.03	.45	.47	.46	.45
					1	0	.03	.42	.43	.42	.4
					5	0	0	.28	.25	.25	.25
					10	0	0	.14	.07	.10	.10
			80	.1	0	.01	.05	.45	.31	.30	.25
					1	0	.04	.42	.30	.28	.29
					5	0	.04	.37	.26	.23	.24
					10	0	0	.25	.2	.18	.18
				.9	0	.01	.03	.29	.16	.15	.14
					1	.03	.03	.29	.16	.14	.14
					5	0	.03	.26	.14	.12	.12
					10	0	.03	.23	.11	.10	.10
		.9	20	.1	0	0	0	.31	.51	.48	.52
					1	0	0	.25	.42	.42	.38
					5	0	0	.03	.05	.08	.08
					10	0	0	0	0	0	0
				.9	0	0	0	.36	.49	.46	.46
					1	0	0	.34	.36	.42	.42
					5	0	0	.20	.22	.23	.22
					10	0	0	.06	.07	.08	.08
			80	.1	0	.02	.04	.39	.42	.35	.34
					1	.03	.04	.38	.41	.33	.33
					5	0	.04	.33	.35	.28	.28
					10	0	.03	.27	.29	.23	.23
				.9	0	.03	.05	.34	.22	.25	.22
					1	.03	.05	.35	.22	.25	.26
					5	.03	.04	.30	.20	.23	.23
					10	.03	.04	.28	.17	.20	.20

TABLE 30 - Ring Area Parameter $\bar{R}$ for Maximum Structural Efficiency. Stringers Inside, Rings Outside.

$\bar{S}$	h_s/t	γ_s	h_r/t	γ_r	$\bar{p}$	Z=1	10	10^2	10^3	10^4	10^5
1.5	30	.1	20	.1	0	0	0	0	.51	.53	.49
					1	0	0	0	.35	.32	.33
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	.05	.49	.45	.46
					1	0	0	.04	.40	.38	.38
					5	0	0	0	.08	.14	.14
					10	0	0	0	0	0	0
			80	.1	0	0	0	.16	.41	.44	.45
					1	0	0	.15	.40	.42	.43
					5	0	0	.12	.35	.37	.37
					10	0	0	.09	.28	.30	.28
				.9	0	0	.02	.18	.44	.39	.41
					1	0	0	.17	.43	.39	.40
					5	0	0	.15	.40	.36	.37
					10	0	0	.13	.35	.32	.33
		.9	20	.1	0	0	0	0	.44	.46	.40
					1	0	0	0	.27	.28	.27
					5	0	0	0	0	0	0
					10	0	0	0	0	0	0
				.9	0	0	0	0	.45	.46	.46
					1	0	0	0	.36	.37	.35
					5	0	0	0	.08	.06	.06
					10	0	0	0	0	0	0
			80	.1	0	0	0	.09	.55	.51	.48
					1	0	0	.08	.53	.45	.47
					5	0	0	.06	.32	.35	.37
					10	0	0	.04	.19	.28	.29
				.9	0	0	0	.12	.36	.47	.46
					1	0	0	.12	.35	.45	.45
					5	0	0	.11	.32	.43	.40
					10	0	0	.09	.28	.38	.35

Table 31. - Expressions For Optimum Value of Stiffener Area Parameter

Area Parameter	$Z < 1000$	$Z \geq 1000$
Stringers Outside, No Rings		
$\bar{S} =$	$.65 - .098(\log_{10} Z) - .038 \sqrt{\bar{P}}$	$.44 - .062(\log_{10} Z) + .017 \sqrt{\bar{P}}$
Stringers Inside, No Rings		
$\bar{S} =$	$.63 - .14(\log_{10} Z) - .019 \sqrt{\bar{P}}$	$.15 - .022(\log_{10} Z) + .043 \sqrt{\bar{P}}$
Stringers Outside, Rings Inside		
$\bar{R} =$	$.010 + .012(\log_{10} Z) - .01 \sqrt{\bar{P}}$	$.088 + .0025(\log_{10} Z) - .035 \sqrt{\bar{P}}$
Stringers Inside, Rings Inside		
$\bar{R} =$	$.024 + .038(\log_{10} Z) - .022 \sqrt{\bar{P}}$	$.20 + .00076(\log_{10} Z) - .060 \sqrt{\bar{P}}$
Stringers Outside, Rings Outside		
$\bar{R} =$	$.019 + .027(\log_{10} Z) - .017 \sqrt{\bar{P}}$	$.16 - .0013(\log_{10} Z) - .050 \sqrt{\bar{P}}$
Stringers Inside, Rings Outside		
$\bar{R} =$	$.025 + .073(\log_{10} Z) - .030 \sqrt{\bar{P}}$	$.33 + .001(\log_{10} Z) - .078 \sqrt{\bar{P}}$

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