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# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 827

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## CHARTS FOR THE MINIMUM-WEIGHT DESIGN OF 24S-T ALUMINUM-ALLOY FLAT COMPRESSION PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS

By EVAN H. SCHUETTE

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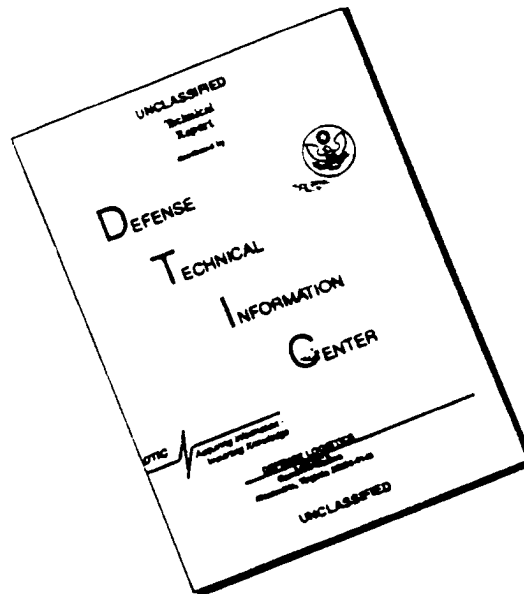
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## AERONAUTIC SYMBOLS

### 1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Abbreviation	Unit	Abbreviation
Length.....	$l$	meter.....	m	foot (or mile).....	ft (or mi)
Time.....	$t$	second.....	s	second (or hour).....	sec (or hr)
Force.....	$F$	weight of 1 kilogram.....	kg	weight of 1 pound.....	lb
Power.....	$P$	horsepower (metric).....		horsepower.....	hp
Speed.....	$V$	kilometers per hour.....	kph	miles per hour.....	mph
		meters per second.....	mps	feet per second.....	fps

### 2. GENERAL SYMBOLS

$W$	Weight = $mg$	$\nu$	Kinematic viscosity
$g$	Standard acceleration of gravity = $9.80665 \text{ m/s}^2$ or $32.1740 \text{ ft/sec}^2$	$\rho$	Density (mass per unit volume)
$m$	Mass = $\frac{W}{g}$		Standard density of dry air, $0.12497 \text{ kg-m}^{-3}$ at $15^\circ \text{ C}$ and $760 \text{ mm}$ ; or $0.002378 \text{ lb-ft}^{-3} \text{ sec}^2$
$I$	Moment of inertia = $mk^2$ . (Indicate axis of radius of gyration $k$ by proper subscript.)		Specific weight of "standard" air, $1.2255 \text{ kg/m}^3$ or $0.07651 \text{ lb/cu ft}$
$\mu$	Coefficient of viscosity		

### 3. AERODYNAMIC SYMBOLS

$S$	Area	$i_w$	Angle of setting of wings (relative to thrust line)
$S_w$	Area of wing	$i_s$	Angle of stabilizer setting (relative to thrust line)
$G$	Gap	$Q$	Resultant moment
$b$	Span	$\Omega$	Resultant angular velocity
$c$	Chord	$R$	Reynolds number, $\rho \frac{Vl}{\mu}$ where $l$ is a linear dimen- sion (e.g., for an airfoil of $1.0 \text{ ft}$ chord, $100 \text{ mph}$ , standard pressure at $15^\circ \text{ C}$ , the corresponding Reynolds number is $935,400$ ; or for an airfoil of $1.0 \text{ m}$ chord, $100 \text{ mps}$ , the corresponding Reynolds number is $6,865,000$ )
$A$	Aspect ratio, $\frac{b^2}{S}$	$\alpha$	Angle of attack
$V$	True air speed	$\epsilon$	Angle of downwash
$q$	Dynamic pressure, $\frac{1}{2}\rho V^2$	$\alpha_0$	Angle of attack, infinite aspect ratio
$L$	Lift, absolute coefficient $C_L = \frac{L}{qS}$	$\alpha_i$	Angle of attack, induced
$D$	Drag, absolute coefficient $C_D = \frac{D}{qS}$	$\alpha_a$	Angle of attack, absolute (measured from zero- lift position)
$D_0$	Profile drag, absolute coefficient $C_{D_0} = \frac{D_0}{qS}$	$\gamma$	Flight-path angle
$D_i$	Induced drag, absolute coefficient $C_{D_i} = \frac{D_i}{qS}$		
$D_p$	Parasite drag, absolute coefficient $C_{D_p} = \frac{D_p}{q}$		
$C$	Cross-wind force, absolute coefficient $C_c = \frac{C}{qS}$		

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ALUMINUM-ALLOY FLAT COMPRESSION PANELS  
WITH LONGITUDINAL Z-SECTION STIFFENERS**

By **EVAN H. SCHUETTE**

**Langley Memorial Aeronautical Laboratory  
Langley Field, Va.**

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## REPORT No. 827

# CHARTS FOR THE MINIMUM-WEIGHT DESIGN OF 24S-T ALUMINUM-ALLOY FLAT COMPRESSION PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS

By EVAN H. SCHUETTE

### SUMMARY

*Design charts are developed for 24S-T aluminum-alloy flat compression panels with longitudinal Z-section stiffeners. These charts make possible the design of the lightest panels of this type for a wide range of design requirements. Examples of the use of the charts are given and it is pointed out on the basis of these examples that, over a wide range of design conditions, the maintenance of buckle-free surfaces does not conflict with the achievement of high structural efficiency. The achievement of the maximum possible structural efficiency with 24S-T aluminum-alloy panels, however, requires closer stiffener spacings than those now in common use.*

### INTRODUCTION

In a longitudinally stiffened compression panel, in which all the material is active in carrying load, the requirement of minimum weight is tantamount to that of carrying the load at the highest possible average stress. The average stress developed by such a panel under the loading conditions imposed is thus a direct measure of the structural efficiency of the panel. If longitudinally stiffened compression panels are to be designed for high structural efficiency without a large number of cut-and-try computations, it is desirable that design charts be prepared to indicate the average stress attainable under various loading conditions. The preparation of such charts requires that a suitable design parameter in which the important loading conditions are incorporated be found.

It has been found that a suitable parameter for longitudinally stiffened compression panels in the design of which the transverse stiffness can be neglected is  $\frac{P_t}{L\sqrt{c}}$ , where  $P_t$  is the compressive load per inch of panel width,  $L$  is the panel length, or distance between supporting ribs, and  $c$  is the coefficient of end fixity at the ribs. The quantity  $P_t$ , which is essentially independent of the distribution of material in the compression panel, can be estimated for a wing panel from the bending moment on the wing and the thickness and chord of the wing. The length  $L$  may be fixed by the presence of such installations as fuel tanks or armament or may be arbitrarily assigned for the purpose of arriving at a trial design.

In reference 1 buckling stresses were plotted against the parameter  $\frac{P_t}{L\sqrt{c}}$ , with slightly different notation, to form the basis of a theoretical study of the efficiencies of various

types of stiffening elements. In the present paper the same parameter has been used as a basis for the preparation of design charts from extensive test data on 24S-T aluminum-alloy flat compression panels with longitudinal Z-section stiffeners; the data were obtained from reference 2 and from additional tests completed since publication of reference 2. These charts make possible the choice of the lightest panels of this type to conform to a wide range of design conditions. An appendix is presented in which the procedure followed in preparing the charts from test data is described and the method for obtaining  $\frac{P_t}{L\sqrt{c}}$  as a natural parameter against which the average stress may be plotted to obtain a direct measure of structural efficiency is developed.

### SYMBOLS AND DEFINITIONS

The symbols used for the principal panel cross-sectional dimensions are indicated in figure 1. In addition, the following symbols are used:

- $A_t$  cross-sectional area per inch of panel width, or equivalent thickness of panel, inches
- $L$  length of panel, inches
- $P_t$  compressive load per inch of panel width, kips per inch
- $E_c$  modulus of elasticity in compression, ksi
- $c$  coefficient of end fixity as used in Euler column formula
- $k$  coefficient in formula for local-buckling stress
- $\rho$  radius of gyration of panel cross section, inches
- $\tau$  nondimensional coefficient that takes into account reduction in effective modulus of elasticity when panel fails as a column beyond the elastic range
- $\sigma_{cr}$  critical stress, or stress for local buckling, ksi
- $\bar{\sigma}_c$  average stress at column failure, ksi
- $\bar{\sigma}_{max}$  average stress at local failure, ksi
- $\bar{\sigma}_f$  average stress at failure for any panel, ksi

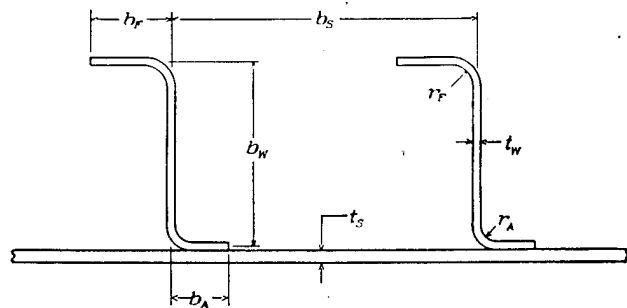


FIGURE 1.—Symbols for panel dimensions.

The average stress at which any particular panel fails,  $\bar{\sigma}_f$ , may be a local-failure stress, a column-failure stress, or the stress for a type of failure intermediate to these two. Failure by twisting of the stiffeners is included as a form of local failure. Because the design charts are based on actual test data, it is not necessary to make any distinction between local and twisting failure. Such a distinction, moreover, would be at best an arbitrary one, as the two types of failure are interrelated in the case of stiffened panels.

It should be noted that the local-failure stress  $\bar{\sigma}_{max}$ , which represents the maximum value of average stress that can be achieved in a given cross section as the panel length is reduced, is an average stress at failure and is not to be confused with the stress for local buckling  $\sigma_{cr}$ , which does not necessarily imply failure. The term "local buckling" as used herein includes both buckling of the skin and buckling of the stiffeners, because neither of these elements can buckle without exerting moments on, and thus causing deformation of, the other element.

### DESIGN CHARTS

Design charts for 24S-T aluminum-alloy flat compression panels with longitudinal Z-section stiffeners are presented in figures 2 to 5. The procedure used in the preparation of these charts from test data is described in the appendix. Values of  $A_i/t_s$ , necessary for arriving at a final design, are given in tables 1 to 3 for a wide range of dimension ratios.

In order to show the maximum stresses attainable by the use of panels of the type to which the charts apply, envelopes are indicated by the dashed lines for each value of the ratio  $b_s/t_s$  in figures 2 to 5. These envelopes have been combined (fig. 6) to give the over-all envelopes for the four values of the ratio  $t_w/t_s$ . The values of  $b_s/t_s$  and  $b_w/t_w$  needed in order that a panel will develop the stress indicated by an envelope are also given in figure 6.

The design parameter  $\frac{P_i}{L/\sqrt{c}}$ , against which stress is plotted in figures 2 to 6, comprises the principal design conditions: the compressive load per inch of panel width; the length of panel, or distance between supporting ribs; and the coefficient of end fixity. The most efficient (lightest) panel for a given combination of these conditions is that panel which will develop the highest average stress for the particular value of  $\frac{P_i}{L/\sqrt{c}}$ .

**Discussion of charts.**—The charts include a wide range of panel proportions. All the charts have been drawn for a value of  $\frac{b_r}{b_w} = 0.4$ ; it is shown in the appendix (figs. 17 to 20), however, that curves for  $\frac{b_r}{b_w} = 0.3$  and 0.5 would be in close agreement with the curves for  $\frac{b_r}{b_w} = 0.4$ . The curves of figures 2 to 5 may therefore be applied with reasonable accuracy for any value of  $b_r/b_w$  between 0.3 and 0.5. The available test data seem to indicate, moreover, that the most efficient use of material will be realized if a proportion in this range is selected. (See appendix.)

The short horizontal lines that intersect the curves of figures 2 to 5 indicate, for each panel cross section having appreciable local buckling, the stress at which this buckling occurs. In this report this stress is taken as that at which the compressive strain on one side of the skin or the stiffener web begins to be reduced with increasing load. This definition of buckling is convenient for structural testing; from the standpoint of aerodynamic smoothness, appreciable buckling probably takes place at stresses somewhat lower than those indicated on the charts. It will be noted that for some of the lower values of  $b_s/t_s$  and  $b_w/t_w$  no buckling stress is shown. In these cases, there will undoubtedly be some buckling but presumably it will occur at a stress coincident with or only very slightly below the failure stress.

It is pointed out that for  $\frac{t_w}{t_s} = 0.79$  and 1.00 (figs. 4 and 5), the curves for values of  $\frac{b_s}{t_s} = 25$  and 30 have been obtained entirely by extrapolation. These curves should therefore be used with a certain degree of caution. A few check tests made since the preparation of the charts, however, indicate that the curves will in no case be more than 6 percent unconservative. In all the other curves, it is believed that any unconservatism that may be present is of much smaller magnitude.

**Discussion of tests and test panels.**—In order that the design charts may be properly used, it is necessary to know something of the test panels and the test results on which the design charts are based. The details of these tests are described in reference 2; some of the pertinent information regarding the tests follows:

The test panels consisted of six stiffeners and five bays. The panels were tested flat-ended and without edge support. A fixity coefficient of 3.75 was used in reducing the test data for application to an effective pin-ended length. The average compressive yield strength for the material of which the test panels were constructed was about 44 ksi; the minimum yield strength, about 41 ksi; and the maximum yield strength, about 46.5 ksi. The rivets were countersunk and were driven by the NACA method of inserting a flat-head rivet from the stiffener side of the hole, upsetting the rivet shank into the countersunk cavity, and milling off the protruding portion of the upset shank. The rivets were A17S-T (AN442AD) and were of the sizes and spacings indicated by the following table:

$\frac{t_w}{t_s}$	Rivet spacing $\frac{t_s}{t_s}$	Rivet diameter $\frac{t_s}{t_s}$
0.51	10.0	1.50
.63	12.3	1.84
.79	12.3	1.93
1.00	11.7	1.95

Because the compressive strength of stiffened panels may be affected by the size and spacing of the rivets used to attach stiffeners to skin (reference 3), the rivet attachment must be equivalent to that indicated by the foregoing table in order to be sure of realizing the strengths indicated by the design charts.

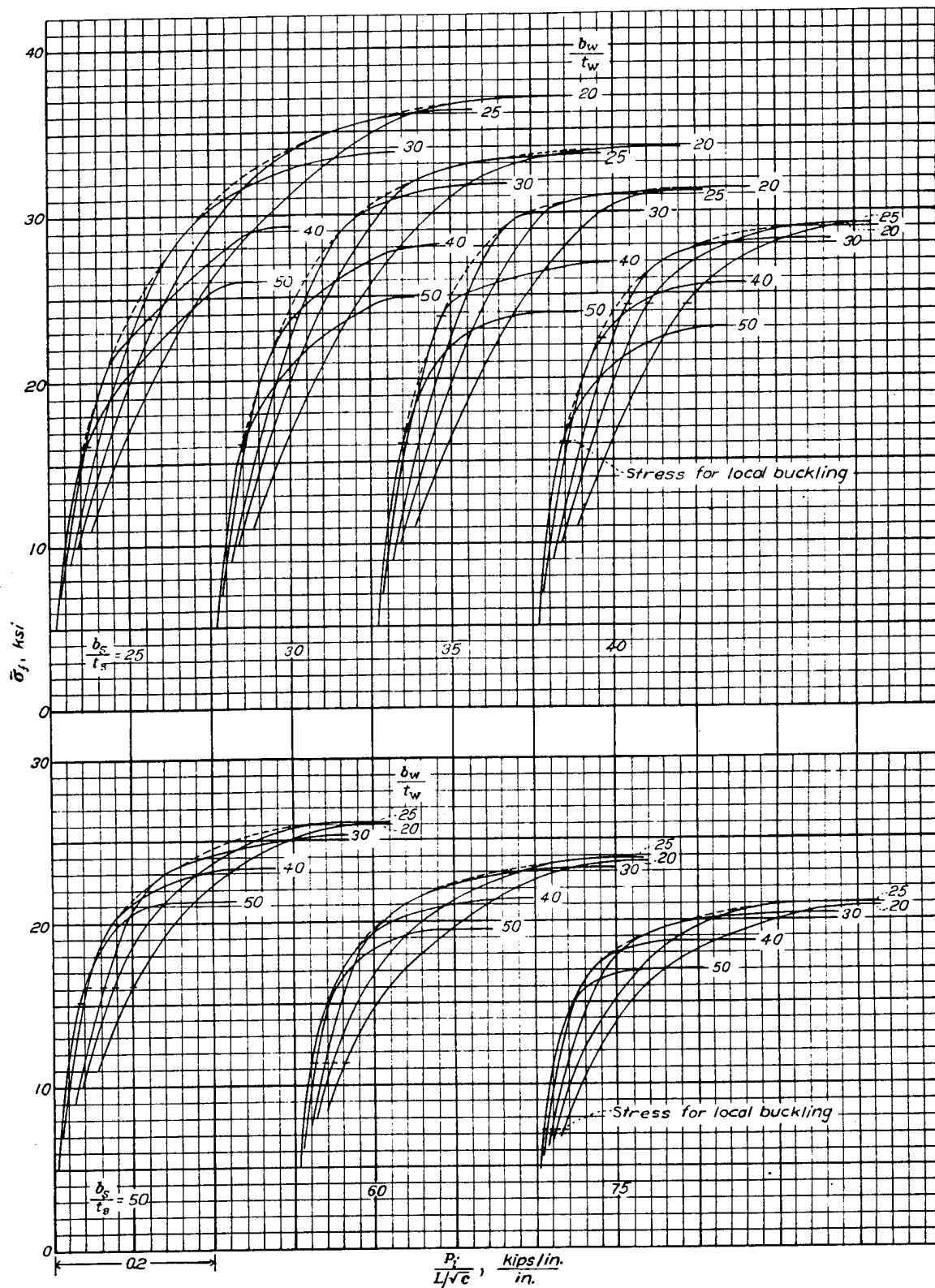


FIGURE 2.—Design chart for 24S-T aluminum-alloy flat panels with Z-section stiffeners;  $\frac{t_w}{t_s} = 0.51$  ( $\frac{b_A}{t_w} = 11.4$ ;  $\frac{r_A}{t_w} = 3$ ;  $\frac{r_F}{t_w} = 4$ ; and  $\frac{b_F}{b_w} = 0.3$  to  $0.5$ ).

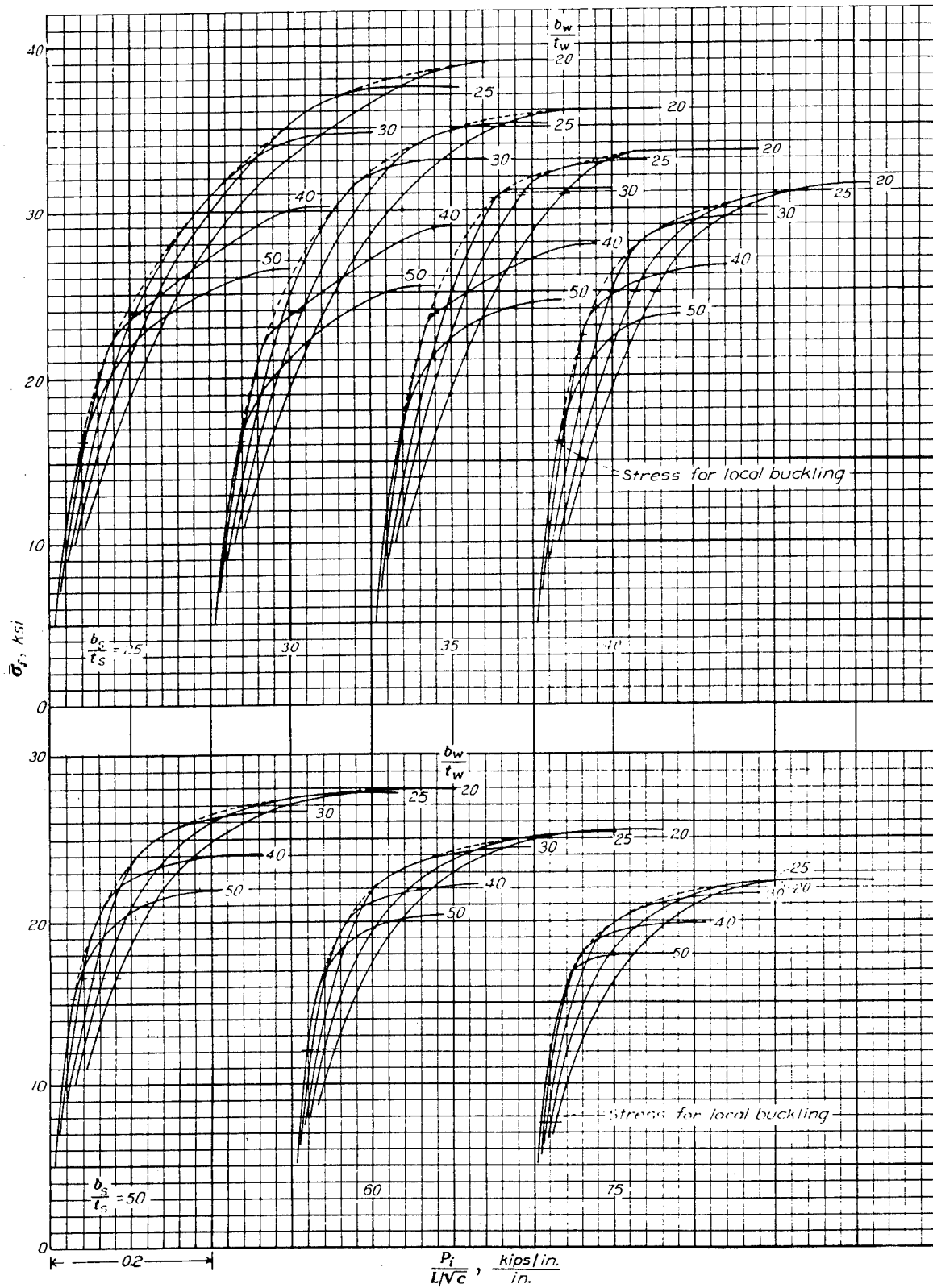


FIGURE 3.—Design chart for 24S-T aluminum-alloy flat panels with Z-section stiffeners:  $\frac{t_w}{t_s} = 0.63$  ( $\frac{b_s}{t_s} = 10.9$ ;  $\frac{r_A}{t_w} = 3$ ;  $\frac{r_P}{t_w} = 4$ ; and  $\frac{h_P}{b_w} = 0.3$  to  $0.5$ ).

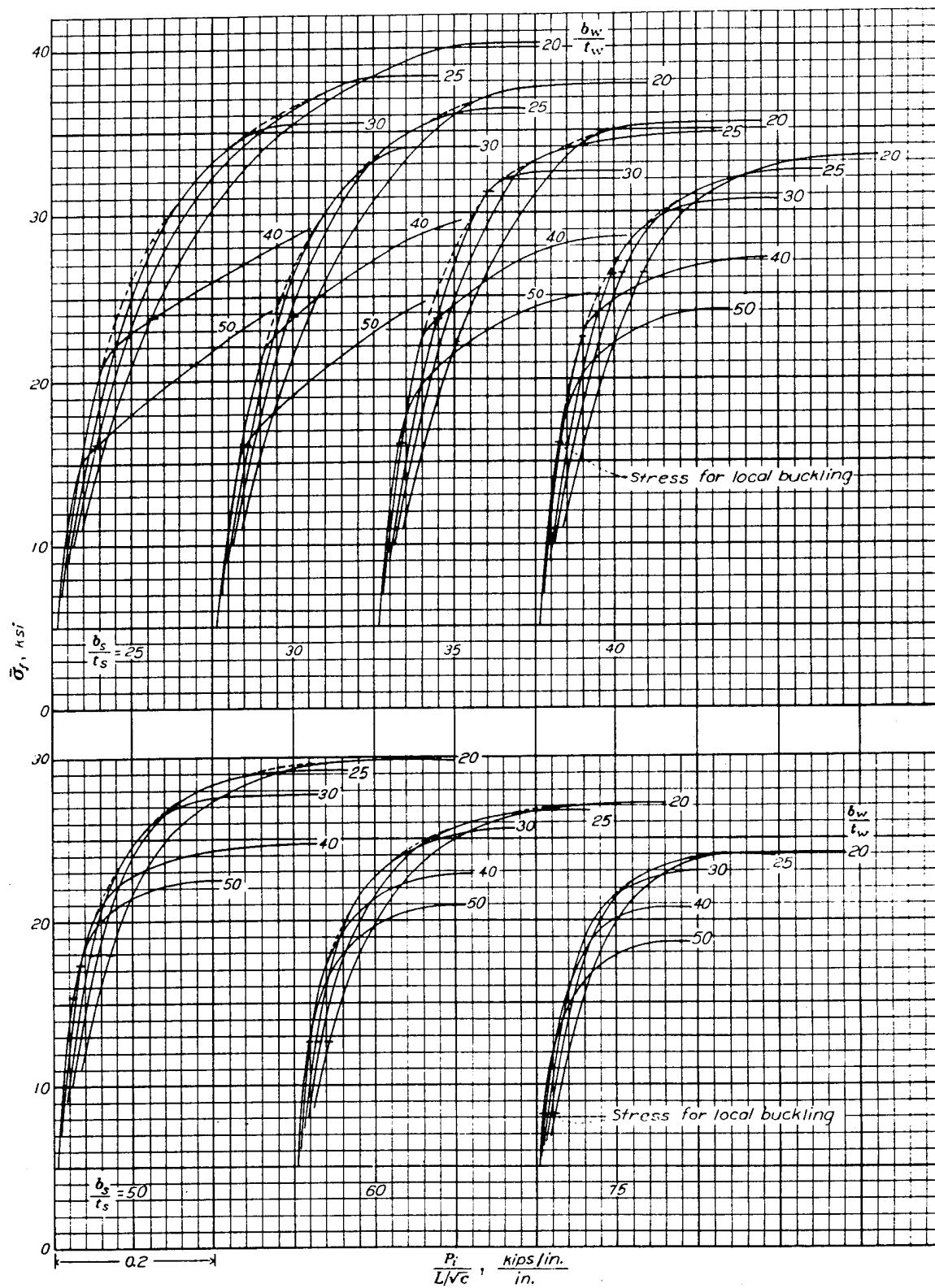


FIGURE 4.—Design chart for 24S-T aluminum-alloy flat panels with Z-section stiffeners:  $\frac{t_w}{t_s} = 0.70$  ( $\frac{b_s}{t_s} = 9.8$ ;  $\frac{r_s}{t_w} = 3$ ;  $\frac{r_p}{t_w} = 4$ ; and  $\frac{b_p}{b_w} = 0.3$  to  $0.5$ ).

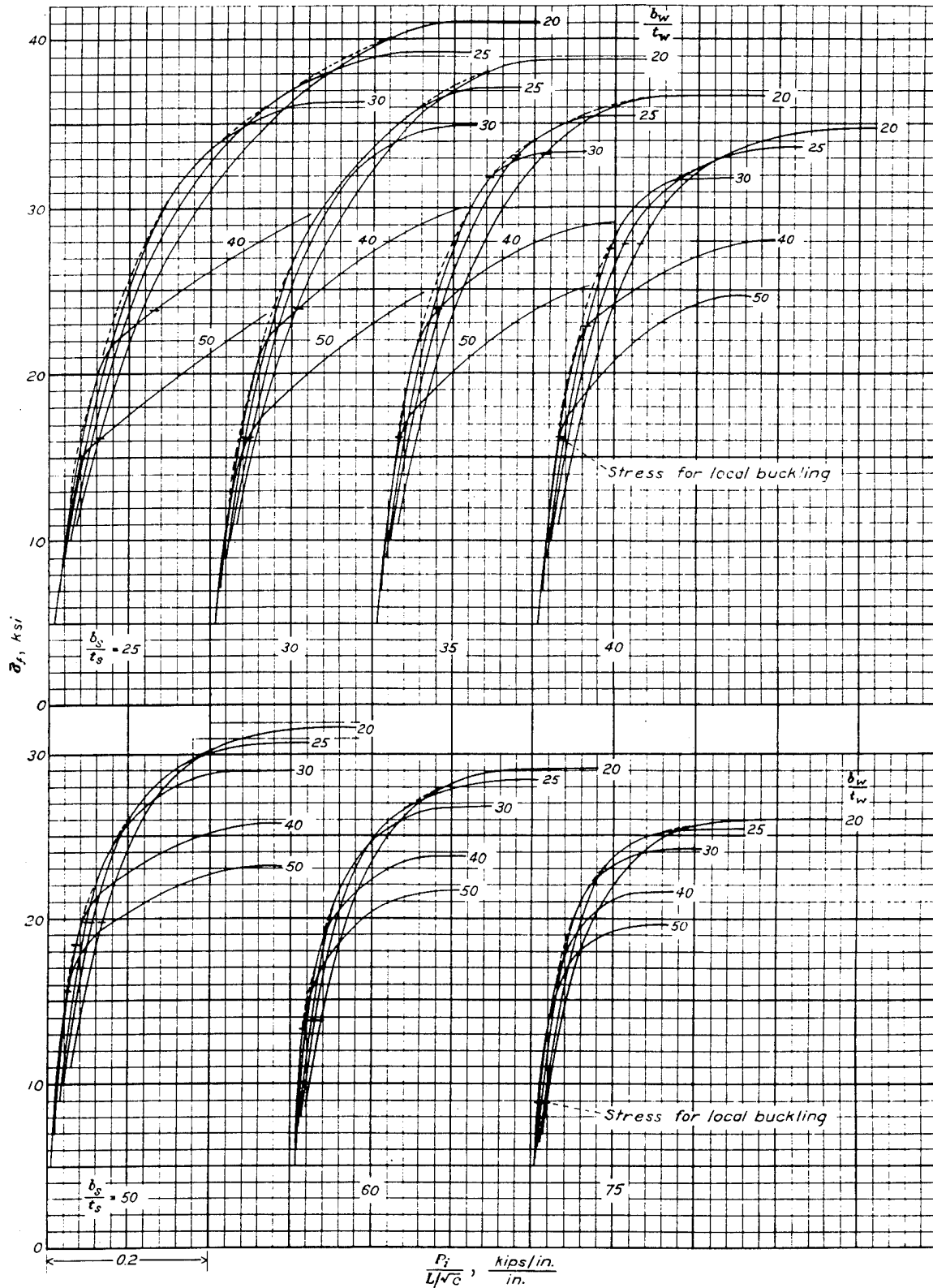


FIGURE 5.—Design chart for 24S-T aluminum-alloy flat panels with Z-section stiffeners;  $\frac{t_w}{t_s} = 1.00$  ( $\frac{b_s}{t_s} = 8.6$ ;  $\frac{r_s}{t_s} = 3$ ;  $\frac{r_w}{t_w} = 4$ ; and  $\frac{b_w}{h_w} = 0.3$  to  $0.5$ ).

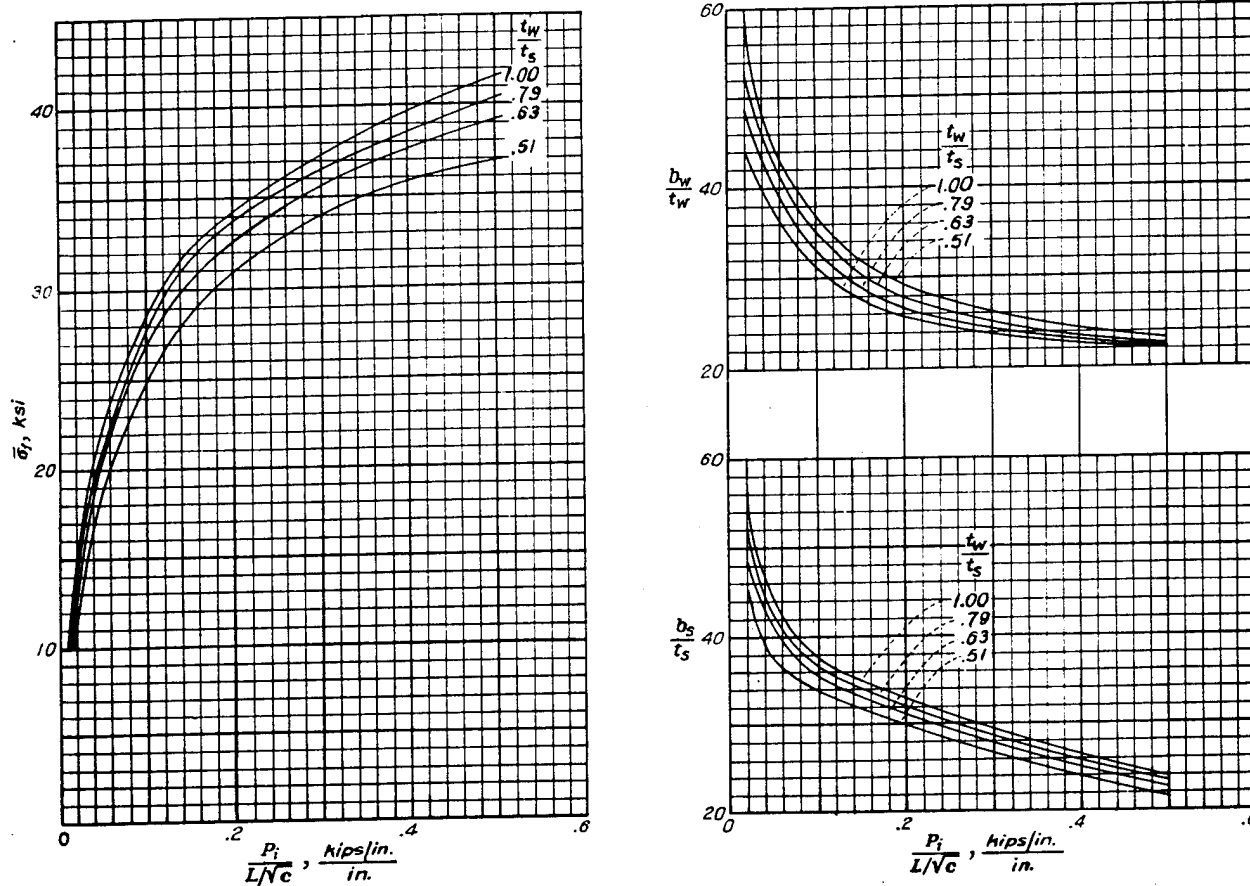


FIGURE 6.—Highest values of average stress at failure for 24S-T aluminum-alloy flat panels with Z-section stiffeners, with values of  $b_s/t_s$  and  $b_w/t_w$  needed to realize these stresses.

USE OF DESIGN CHARTS AND EXAMPLES

If sheet material could be obtained in any desired thickness and if no special limitations were put on the design, it would be sufficient merely to find those proportions that would give the highest stress for the given value of  $\frac{P_f}{L\sqrt{c}}$ . Because

certain limitations are usually imposed, however, the structure that represents the best compromise of all the requirements must be chosen.

The usual gages in which aluminum-alloy sheet is manufactured are such that if the four ratios of  $t_w/t_s$  in figures 2 to 6 are applied consecutively to a particular skin gage, the four stiffener gages that result will generally be consecutive standard gages. Interpolation between the curves of two consecutive charts (figs. 2 and 3, 3 and 4, etc.) is therefore unnecessary for most practical purposes.

The particular procedure to be used in obtaining a design from the charts will depend on the nature of the results desired. Three possible methods are discussed, and examples are given of designs obtained for a given load intensity and three different lengths by each of the methods.

The distinguishing features of each method are

Ideal design:

The method for obtaining the ideal design gives the lightest panel that could be obtained if the designer were not restricted to the use of standard sheet gages. The design is obtained by use of the over-all envelopes of figure 6 only.

Short method:

The short design method provides, without lengthy computation, a near approach to the lightest panel that can be obtained by use of standard sheet gages. The design is obtained by use of the envelopes for given values of  $b_s/t_s$  that appear as dashed lines in figures 2 to 5.

Maximum efficiency:

The method of designing for maximum structural efficiency gives the lightest panel that can be obtained by use of standard sheet gages. The design is obtained through a complete study of the individual solid curves in figures 2 to 5. The method is somewhat lengthy; examples have been worked out by its use, however, to serve as a check on the short method, so that that method can be used with confidence.

Each of the three methods is given as a series of steps for reaching the final designs. In the method for obtaining the ideal design, the detailed computations for the four values of  $t_w/t_s$  included in figure 6 are given for  $L=10, 20,$  and  $30$  inches with  $P_t=3.0$  kips per inch and  $c=1$ . In the other two methods, the detailed computations are given only for  $L=20$  inches and  $\frac{t_w}{t_s}=0.79$ , again with  $P_t=3.0$  kips per inch and  $c=1$ ; final results are given, however, for the complete set of examples considered in the discussion of the first method. It is assumed in all cases that a skin thickness of  $0.064$  inch is necessary in order to comply with other design requirements. A value of  $b_f/b_w$  of  $0.4$  is used throughout. In arriving at the final designs, no values of the dimension ratios outside of the ranges covered by the charts are given consideration.

**Method for obtaining the ideal design.**—The ideal-design method consists of picking from figure 6 the optimum proportions and the stress and computing from these the actual panel dimensions.

The values and computed quantities for the conditions previously mentioned are given in table 4 and are referenced to the steps in the following procedure:

$$(1) \text{ Compute } \frac{P_t}{L/\sqrt{c}}$$

(2) From the curves of figure 6 pick off for each value of  $t_w/t_s$  the values of  $b_s/t_s$ ,  $b_w/t_w$ , and  $\bar{\sigma}_f$  corresponding to the value of  $\frac{P_t}{L/\sqrt{c}}$ .

(3) Pick from table 2 the values of  $A_t/t_s$  for the ratios determined in step 2. (If  $\frac{b_f}{b_w}=0.3$  or  $0.5$  is used, table 1 or table 3, respectively, should be used instead of table 2.)

(4) Compute

$$t_s = \frac{P_t}{\bar{\sigma}_f A_t}$$

This formula is based on the equality

$$P_t = \bar{\sigma}_f A_t$$

(5) Compute

$$t_w = \frac{t_w}{t_s} t_s$$

$$b_s = \frac{b_s}{t_s} t_s$$

$$b_w = \frac{b_w}{t_w} t_w$$

This procedure results in four designs for each length, corresponding to the four values of  $t_w/t_s$ , for the given conditions. (See table 4.) The values marked with footnote *a* in table 4 represent those chosen as approaching most closely the desired condition of  $t_s=0.064$  inch; these values therefore give an indication of the proportions needed in a practical design to meet the design requirements most efficiently.

The resulting designs are shown as the ideal designs at the tops of figures 7 to 9, along with bar graphs of the average stress at failure and the buckling stress. The buckling stress for each design was obtained by interpolation from the short horizontal lines for buckling in figures 2 to 5. In some cases in which failure is by column action, the buckling stress shown by figures 2 to 5 will be greater than the failure stress for the designs obtained. Whenever this difference occurred in the present examples, the buckling stress is shown equal to the failure stress.

**Short method for obtaining a practical design.**—The short method consists of picking the optimum value of  $b_w/t_w$  and the corresponding stress for each value of  $b_s/t_s$  from the individual envelopes of figures 2 to 5 and computing from these values the actual panel dimensions. Panel designs that employ standard sheet gages are then selected from the various designs obtained.

The values and computed quantities for  $L=20$  inches and  $\frac{t_w}{t_s}=0.79$  are given in table 5 and are referenced to the steps in the following procedure:

$$(1) \text{ Compute } \frac{P_t}{L/\sqrt{c}}$$

(2) From the curves for a particular value of  $t_w/t_s$  (in this example, fig. 4 for  $\frac{t_w}{t_s}=0.79$  is used) pick off for each value of  $b_s/t_s$  the values of  $b_w/t_w$  (by interpolation along the dashed envelope) and  $\bar{\sigma}_f$  (from the envelope) corresponding to the value of  $\frac{P_t}{L/\sqrt{c}}$ .

(3) Pick from table 2 the values of  $A_t/t_s$  for the ratios determined in step 2.

(4) Compute

$$t_s = \frac{P_t}{\bar{\sigma}_f A_t}$$

(5) Plot  $b_w/t_w$ ,  $t_s$ , and  $\bar{\sigma}_f$  against  $b_s/t_s$  for the particular value of  $t_w/t_s$ . (The plot for the example being considered is shown in fig. 10.) Tabulate the values of  $b_s/t_s$ ,  $b_w/t_w$ , and  $\bar{\sigma}_f$  corresponding to the point where  $t_s$  equals the specified value.

(6) Check computations by picking from table 2 the value of  $A_t/t_s$  corresponding to the ratios tabulated in step 5. If all computations and plots are correct,

$$P_t = \bar{\sigma}_f \frac{A_t}{t_s} t_s$$

(7) Compute

$$t_w = \frac{t_w}{t_s} t_s$$

$$b_s = \frac{b_s}{t_s} t_s$$

$$b_w = \frac{b_w}{t_w} t_w$$

(8) Repeat steps 2 to 7 for other values of  $t_w/t_s$ .

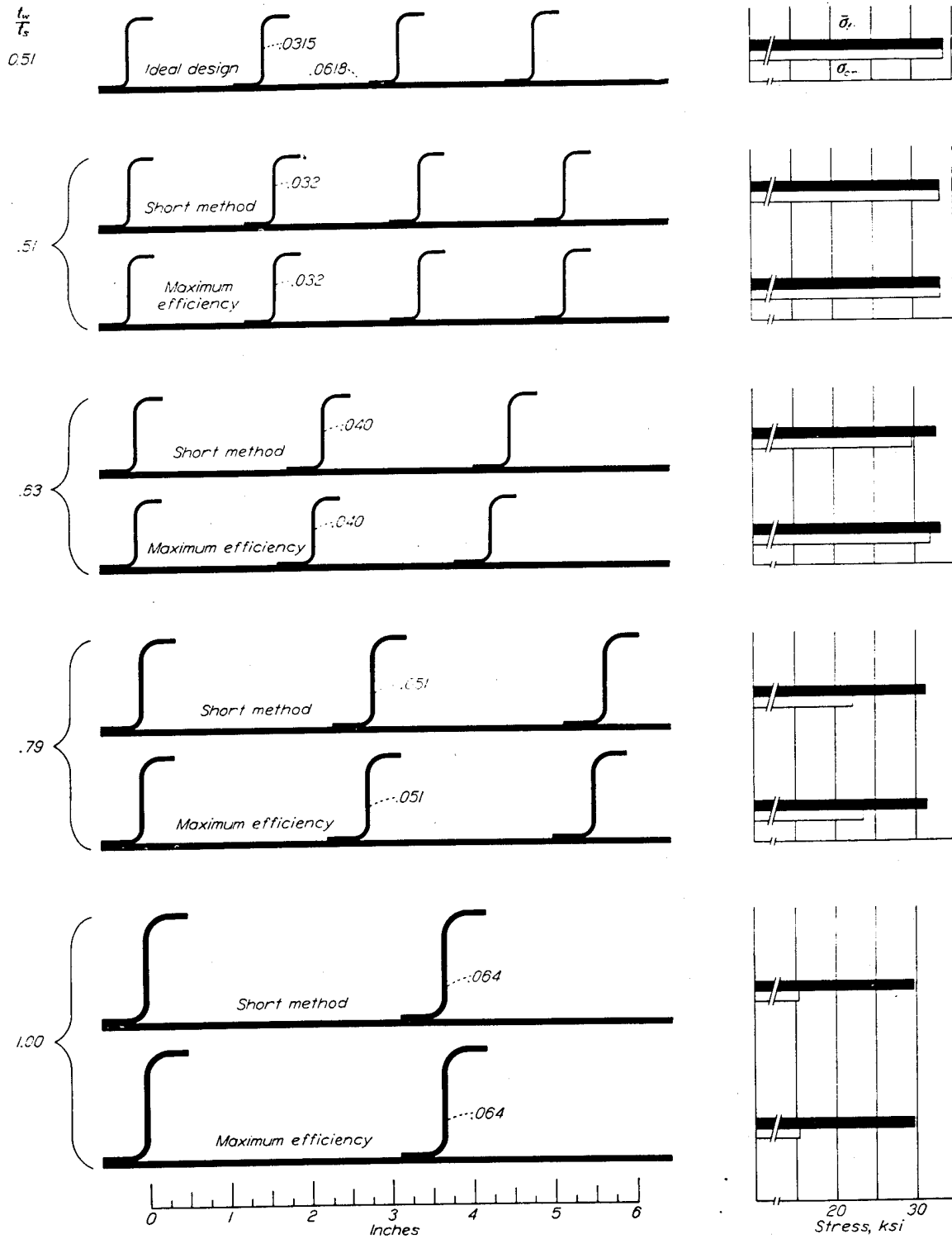


FIGURE 7.—Designs of 24S-T aluminum-alloy panels 10 inches long with  $P_c=3.0$  kips per inch,  $c=1$ , and  $t_s=0.064$  inch.

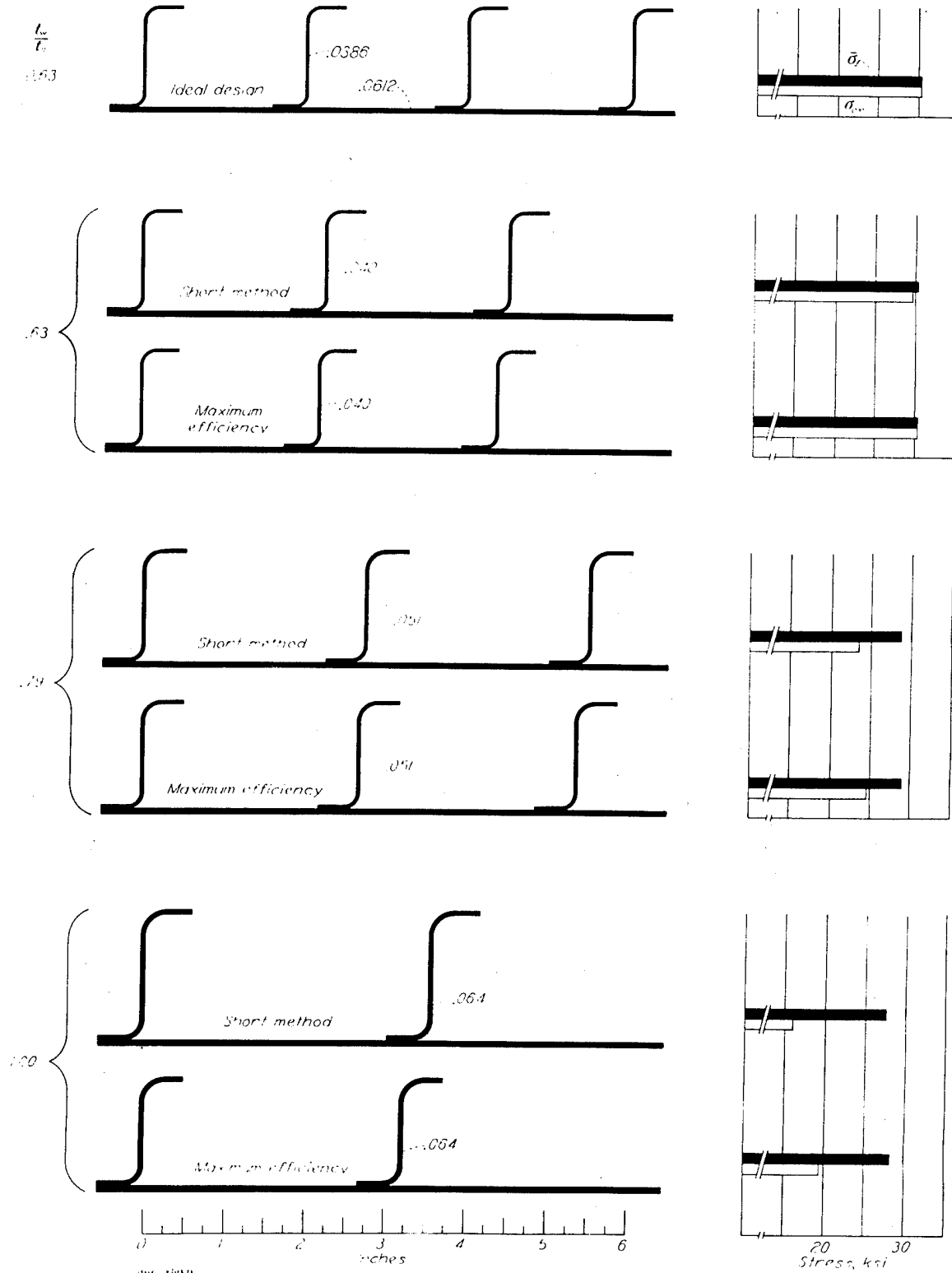


FIGURE 8.—Designs of 24S-T aluminum-alloy panels 20 inches long with  $P_1=3.0$  kips per inch,  $c=1$ , and  $t_s=0.064$  inch.

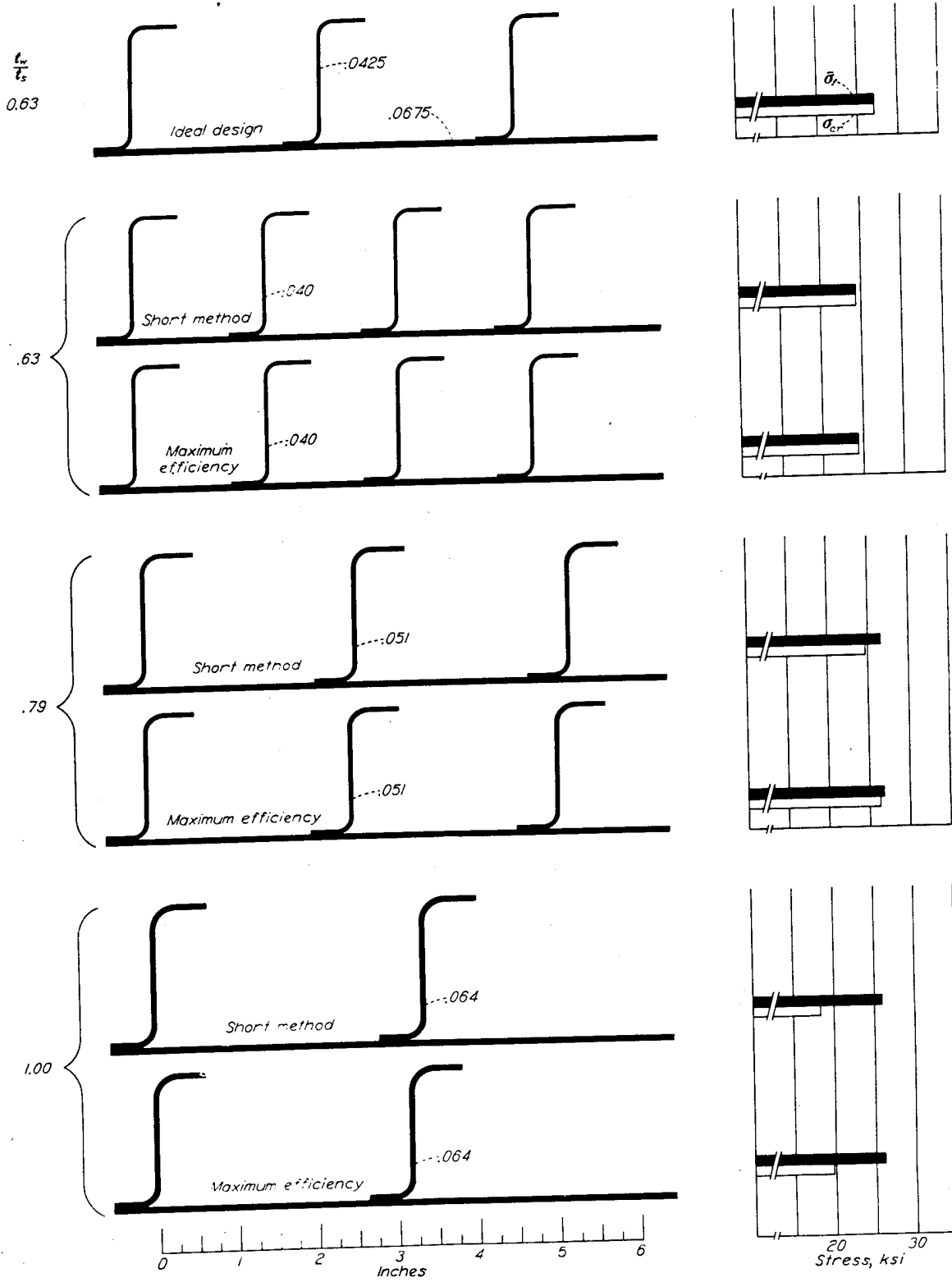


FIGURE 9.—Designs of 24S-T aluminum-alloy panels 30 inches long with  $P_s=3.0$  kips per inch,  $c=1$ , and  $l_s=0.064$  inch.

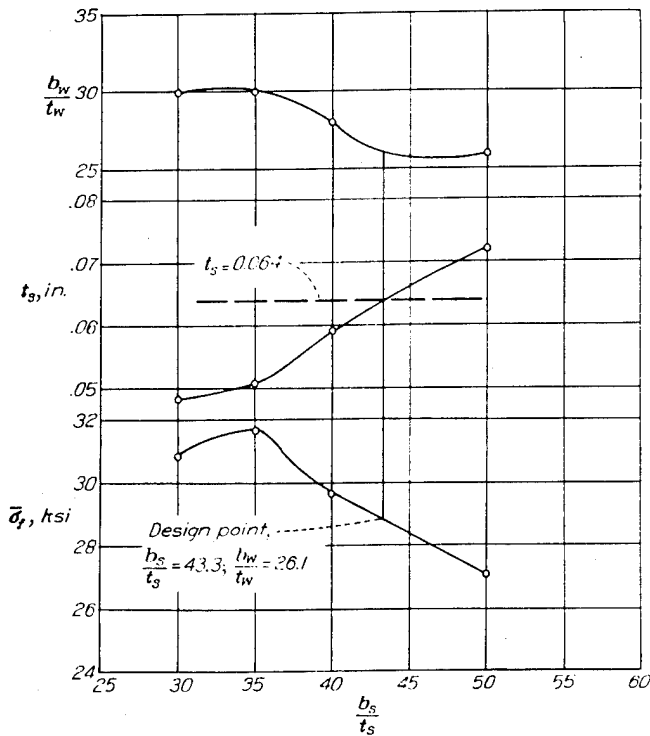


FIGURE 10. Plot for obtaining practical design by short method.  $P_i = 3.0$  kips per inch;  $L = 20$  inches;  $c = 1$ ;  $t_s = 0.064$  inch;  $\frac{t_w}{t_s} = 0.79$ .

Like that for the ideal design, this procedure results, for each length considered, in one design for each value of  $t_w/t_s$ . It may not always be possible to find satisfactory designs under the conditions imposed for all values of  $t_w/t_s$ . (Note that no designs are given in figs. 8 and 9 for  $\frac{t_w}{t_s} = 0.51$ .) All the designs resulting from the use of the short method utilize standard sheet gages and meet the requirement that  $t_s = 0.064$  inch. The choice of design now depends on arriving at a suitable compromise between high stress and wide stiffener spacing. If the prevention of buckling under load is considered important, then the buckling stress must also be taken into account in making a choice.

The designs obtained by carrying out the foregoing procedure for the several values of  $L$  and  $t_w/t_s$  are shown as the short-method designs in figures 7 to 9 along with bar graphs of the average stress at failure and the buckling stress.

**Method of designing for maximum structural efficiency.**

The maximum-efficiency method consists of computing the thickness required as  $b_s/t_s$  is varied for each value of  $b_w/t_w$  and selecting the designs for which the skin gage is equal to that desired. The procedure results in a series of possible designs for each value of  $t_w/t_s$ , from which those designs that provide the highest average stress at failure can be selected.

The values and computed quantities for  $L = 20$  inches and  $\frac{t_w}{t_s} = 0.79$  are given in table 6 and are referenced to the steps in the following procedure:

- (1) Compute  $\frac{P_i}{L/\sqrt{c}}$
- (2) From the curves for a particular value of  $t_w/t_s$  (in this example, fig. 4 for  $\frac{t_w}{t_s} = 0.79$  is used) pick off for each value of  $b_w/t_w$  and  $b_s/t_s$  the value of  $\bar{\sigma}_f$  corresponding to the value of  $\frac{P_i}{L/\sqrt{c}}$
- (3) Pick from table 2 the values of  $A_i/t_s$  corresponding to the ratios used in step 2.
- (4) Compute

$$t_s = \frac{P_i}{\bar{\sigma}_f A_i}$$

(5) Plot  $t_s$  and  $\bar{\sigma}_f$  against  $b_s/t_s$  for each value of  $b_w/t_w$  and  $t_w/t_s$ . Plot the particular value of  $b_w/t_w$  at the value of  $b_s/t_s$  for which  $t_s$  equals the specified value and mark the value of stress at that value of  $b_s/t_s$ . The plots of this step for the example under consideration are given in figure 11 as the short lines for the several values of  $b_w/t_w$  indicated. In order to avoid unnecessary confusion, only short portions of the curves, except the curve for  $\frac{b_w}{t_w} = 20$ , are shown.

(6) After step 5 has been completed for all the values of  $b_w/t_w$ , draw curves of stress and of  $b_w/t_w$  against  $b_s/t_s$  through the points determined in step 5 (heavy curves in fig. 11).

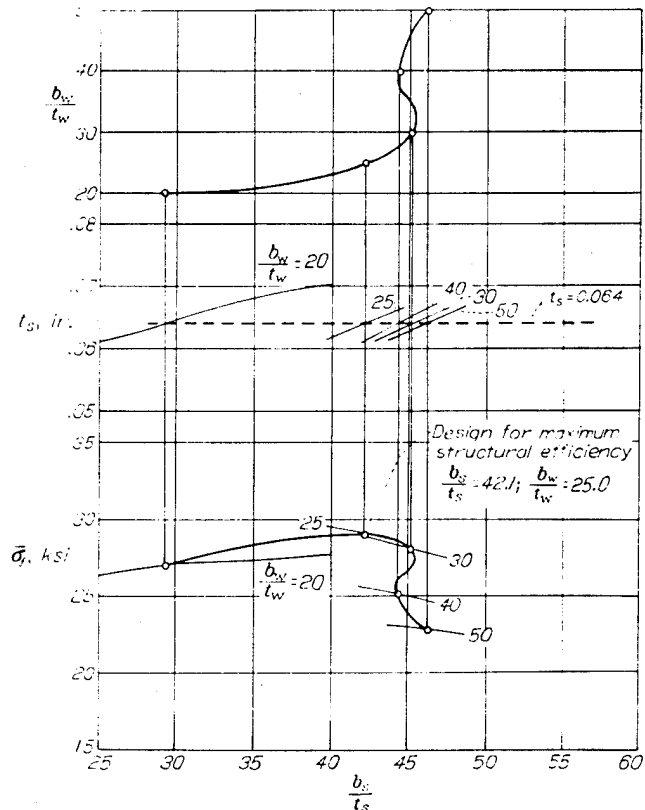


FIGURE 11. Plot for obtaining design for maximum structural efficiency.  $P_i = 3.0$  kips per inch;  $L = 20$  inches;  $c = 1$ ;  $t_s = 0.064$  inch;  $\frac{t_w}{t_s} = 0.79$ .

(7) Each of the curves drawn in step 6 represents a series of designs, all of which have the required value of  $t_s$  (in this case, 0.064 in.). The maximum point on the curve of  $\bar{\sigma}_f$  indicates the design for maximum structural efficiency for the particular value of  $t_w/t_s$ . Note this maximum value of  $\bar{\sigma}_f$ , the value of  $b_s/t_s$  at which it is reached, and the value of  $b_w/t_w$ , which can be picked from the curve of  $b_w/t_w$  against  $b_s/t_s$ .

(8) Check computations by picking from table 2 the value of  $A_i t_s$  corresponding to the ratios selected for maximum structural efficiency in step 7. If all computations and plots are correct,

$$P_i = \bar{\sigma}_f \frac{A_i}{t_s} t_s$$

(9) Compute

$$t_w = \frac{t_w}{t_s} t_s$$

$$b_s = \frac{b_s}{t_s} t_s$$

$$b_w = \frac{b_w}{t_w} t_w$$

(10) Repeat steps 2 to 9 for other values of  $t_w/t_s$ .

This procedure results, for each length considered, in one design for each value of  $t_w/t_s$ . The choice of a design depends on arriving at a suitable compromise between high stress and wide stiffener spacing, with possible consideration for the buckling stress.

The designs obtained by carrying out the foregoing procedure for the several values of  $L$  and  $t_w/t_s$  are shown as the maximum-efficiency designs in figures 7 to 9 along with bar graphs of the average stress at failure and the buckling stress.

DISCUSSION

Figures 7 to 9 provide a visual comparison of the designs that result from use of the three methods presented. The short method of design gives in every case an average stress at failure very close to that obtained by designing on the basis of maximum structural efficiency; the buckling stress, however, is in some cases somewhat lower than that for the maximum-efficiency panel.

Whether the design obtained by the short method or the design for maximum efficiency is selected, the best design for  $P_i=3.0$  kips per inch, on the basis of stress, is obtained at  $L=10$  inches with  $\frac{t_w}{t_s}=0.51$ , at  $L=20$  inches with  $\frac{t_w}{t_s}=0.63$ , and at  $L=30$  inches with  $\frac{t_w}{t_s}=0.79$ . In figure 6, however, the highest envelope, which gives the lightest design, is that for  $\frac{t_w}{t_s}=1.00$ . This apparent contradiction results from the

fact that in working out the examples a skin thickness of 0.064 inch was specified. In order to reach the curve for  $\frac{t_w}{t_s}=1.00$  (fig. 6), a study of table 4 shows that the skin thickness would have to be 0.034 inch at  $L=10$  inches, 0.041 inch at 20 inches, and 0.046 inch at 30 inches. Moreover, the stiffener spacings for designs having such small skin thicknesses are very small. (See table 4.) Because of limitations on skin gages and stiffener spacings, therefore, it is frequently not possible to reach the envelope values of stress and hence the lowest possible weight.

Figures 7 to 9 show that the best panel (that with highest  $\bar{\sigma}_f$ ) obtained at each length by the maximum-efficiency method does not buckle until failure or very close to failure. The best panel designed by the short method, although it may not have quite so high an average stress at failure as the maximum-efficiency panel, also does not buckle until very close to failure. This condition has been found to hold true over a wide range of design requirements. It is therefore evident that over a wide range of conditions the maintenance of buckle-free surfaces does not conflict with the achievement of high structural efficiency. The simultaneous achievement of both these ends by use of 24S-T aluminum-alloy panels, however, apparently requires closer stiffener spacings than those now in common use. For example, the maximum-efficiency designs for  $P_i=3.0$  kips per inch and  $t_s=0.064$  inch have the following spacings for the three lengths:

$L$ (in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$ (in.)
10	23.0	1.79
20	42.1	2.69
30	39.0	2.56

CONCLUDING REMARKS

Charts are presented for the minimum-weight design of 24S-T aluminum-alloy flat compression panels with longitudinal Z-section stiffeners. From examples based on the use of these charts, it is concluded that, over a wide range of design conditions, the maintenance of buckle-free surfaces on longitudinally stiffened compression panels does not conflict with the achievement of high structural efficiency. The achievement of the maximum possible structural efficiency with 24S-T aluminum-alloy panels, however, requires closer stiffener spacings than those now in common use.

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(7) Each of the curves drawn in step 6 represents a series of designs, all of which have the required value of  $t_s$  (in this case, 0.064 in.). The maximum point on the curve of  $\bar{\sigma}_f$  indicates the design for maximum structural efficiency for the particular value of  $t_w/t_s$ . Note this maximum value of  $\bar{\sigma}_f$ , the value of  $b_s/t_s$  at which it is reached, and the value of  $b_w/t_w$ , which can be picked from the curve of  $b_w/t_w$  against  $b_s/t_s$ .

(8) Check computations by picking from table 2 the value of  $A_i/t_s$  corresponding to the ratios selected for maximum structural efficiency in step 7. If all computations and plots are correct,

$$P_i = \bar{\sigma}_f A_i t_s$$

(9) Compute

$$t_w = \frac{t_w}{t_s} t_s$$

$$b_s = \frac{b_s}{t_s} t_s$$

$$b_w = \frac{b_w}{t_w} t_w$$

(10) Repeat steps 2 to 9 for other values of  $t_w/t_s$ .

This procedure results, for each length considered, in one design for each value of  $t_w/t_s$ . The choice of a design depends on arriving at a suitable compromise between high stress and wide stiffener spacing, with possible consideration for the buckling stress.

The designs obtained by carrying out the foregoing procedure for the several values of  $L$  and  $t_w/t_s$  are shown as the maximum-efficiency designs in figures 7 to 9 along with bar graphs of the average stress at failure and the buckling stress.

DISCUSSION

Figures 7 to 9 provide a visual comparison of the designs that result from use of the three methods presented. The short method of design gives in every case an average stress at failure very close to that obtained by designing on the basis of maximum structural efficiency; the buckling stress, however, is in some cases somewhat lower than that for the maximum-efficiency panel.

Whether the design obtained by the short method or the design for maximum efficiency is selected, the best design for  $P_i=3.0$  kips per inch, on the basis of stress, is obtained at  $L=10$  inches with  $t_w/t_s = 0.51$ , at  $L=20$  inches with  $t_w/t_s = 0.63$ , and at  $L=30$  inches with  $t_w/t_s = 0.79$ . In figure 6, however, the highest envelope, which gives the lightest design, is that for  $t_w/t_s = 1.00$ . This apparent contradiction results from the

fact that in working out the examples a skin thickness of 0.064 inch was specified. In order to reach the curve for  $t_w/t_s = 1.00$  (fig. 6), a study of table 4 shows that the skin thickness would have to be 0.034 inch at  $L=10$  inches, 0.041 inch at 20 inches, and 0.046 inch at 30 inches. Moreover, the stiffener spacings for designs having such small skin thicknesses are very small. (See table 4.) Because of limitations on skin gages and stiffener spacings, therefore, it is frequently not possible to reach the envelope values of stress and hence the lowest possible weight.

Figures 7 to 9 show that the best panel (that with highest  $\bar{\sigma}_f$ ) obtained at each length by the maximum-efficiency method does not buckle until failure or very close to failure. The best panel designed by the short method, although it may not have quite so high an average stress at failure as the maximum-efficiency panel, also does not buckle until very close to failure. This condition has been found to hold true over a wide range of design requirements. It is therefore evident that over a wide range of conditions the maintenance of buckle-free surfaces does not conflict with the achievement of high structural efficiency. The simultaneous achievement of both these ends by use of 24S-T aluminum-alloy panels, however, apparently requires closer stiffener spacings than those now in common use. For example, the maximum-efficiency designs for  $P_i=3.0$  kips per inch and  $t_s=0.064$  inch have the following spacings for the three lengths:

$L$ (in.)	$b_s$ $t_s$	$b_w$ (in.)
10	23.0	1.79
20	12.1	2.69
30	50.0	2.56

CONCLUDING REMARKS

Charts are presented for the minimum-weight design of 24S-T aluminum-alloy flat compression panels with longitudinal Z-section stiffeners. From examples based on the use of these charts, it is concluded that, over a wide range of design conditions, the maintenance of buckle-free surfaces on longitudinally stiffened compression panels does not conflict with the achievement of high structural efficiency. The achievement of the maximum possible structural efficiency with 24S-T aluminum-alloy panels, however, requires closer stiffener spacings than those now in common use.

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as a guide in fairing the curves, and the curves will be shown to be reasonably accurate for any value of  $b_F/b_w$  between 0.3 and 0.5.

**Determination of stress for local buckling  $\sigma_{cr}$ .**—If the panel did not buckle locally before failure, the theoretical results thus far presented, used in conjunction with values of  $\bar{\sigma}_{max}$ , would be sufficient to construct a design curve of  $\bar{\sigma}_t$  against  $\frac{P_t}{L/\sqrt{c}}$  for any panel. A typical curve for panels

that do not buckle before failure is shown in figure 13. Unless the width-thickness ratios of the various plate elements of the panel are small or the panel is relatively long, however, there will generally be some local buckling before failure. When this buckling takes place, the cross-sectional moment of inertia of the panel is reduced by the presence of ineffective areas; the original curve of column strength therefore no longer applies and the point at which buckling takes place must be connected with the line for local failure by means of a reduced curve. A typical curve, adjusted for the effects of local buckling, is shown in figure 14.

The foregoing discussion shows that it is necessary to know the stress at which buckling takes place. Data on buckling stresses from reference 2 plus additional data now available are therefore plotted in figure 15 for  $\frac{b_F}{b_w} = 0.4$ . Because the measured value of  $b/t$  for the element (skin or stiffener web) that first showed buckling in a test panel was never in exact agreement with the specified nominal value, the observed buckling stresses from reference 2 were corrected for use in figure 15 according to the following formula:

$$(\sigma_{cr})_{corrected} = (\sigma_{cr})_{observed} \left( \frac{b/t}{b/t} \right)^2_{measured} \left( \frac{b/t}{b/t} \right)^2_{nominal}$$

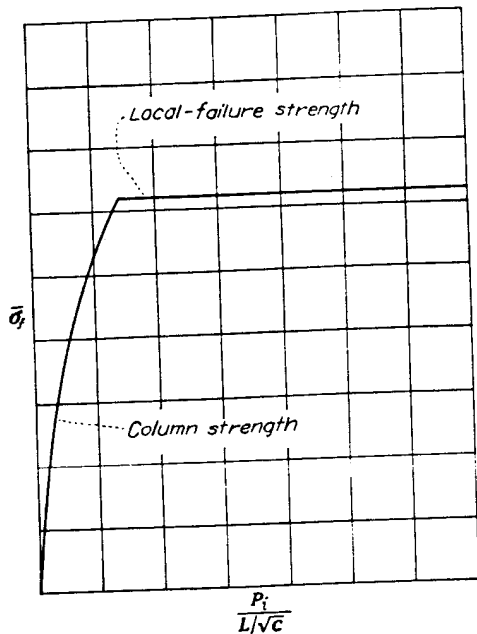


FIGURE 13.—Typical design curve for panels that do not buckle.

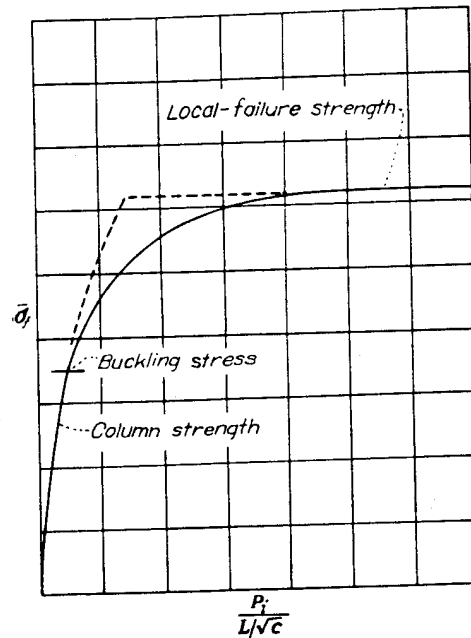


FIGURE 14.—Typical design curve for panels that buckle.

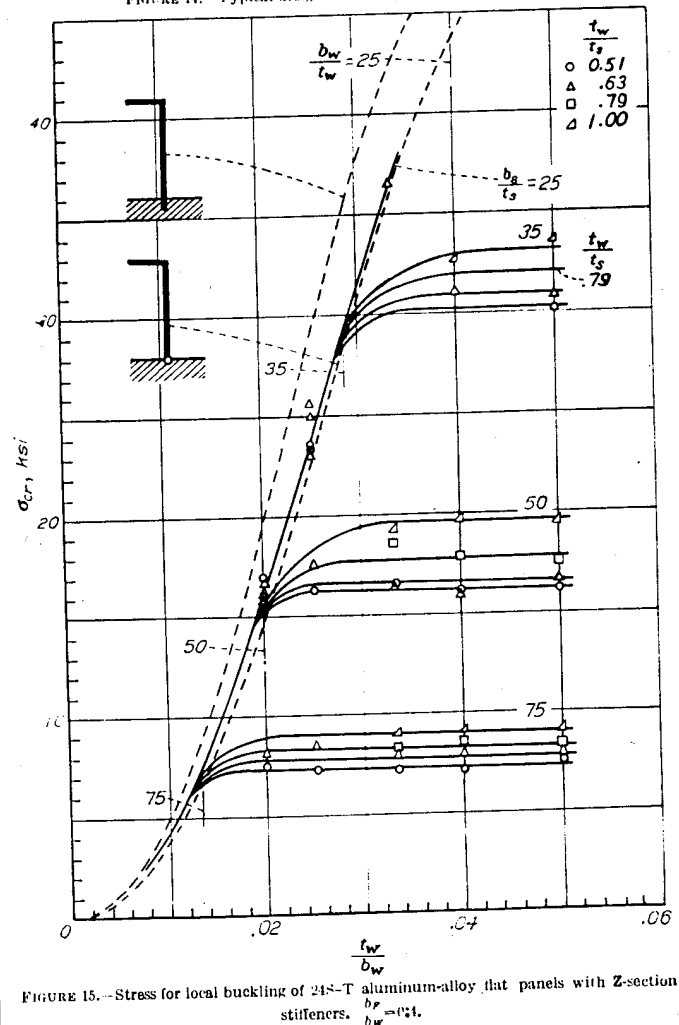


FIGURE 15.—Stress for local buckling of 24S-T aluminum-alloy flat panels with Z-section stiffeners.  $\frac{b_F}{b_w} = 0.4$ .

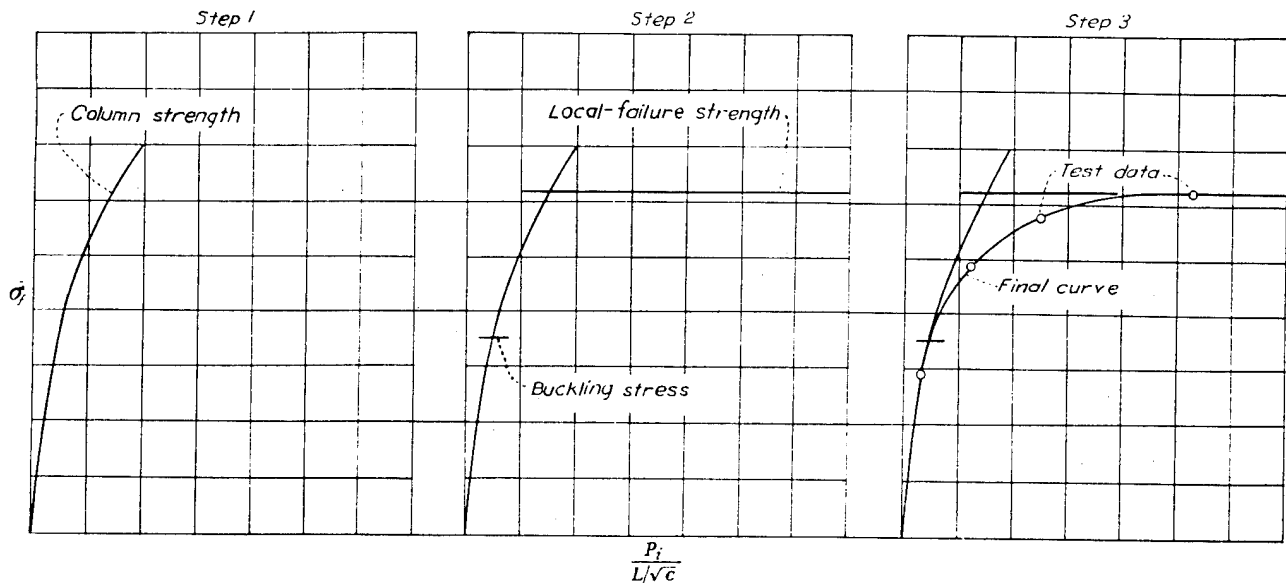


FIGURE 16.—Illustration of procedure used in preparation of design charts.

where the value of  $b/t$  is that for the web of the stiffener or for the skin between stiffeners, depending on which of these elements first gave evidence of buckling. This correction formula is based on the fact that, other factors being equal, the critical stress is inversely proportional to the square of the width-thickness ratio. No account is taken herein of the fact that this relationship is not entirely true for stresses beyond the elastic range; it is assumed that neglecting this fact will have no significant effect because the total correction is relatively small.

The method used in fairing curves through the test points in figure 15 is as follows:

For the horizontal portions of the curves on the right-hand side of figure 15, the skin is primarily responsible for the buckling; the ordinates for the curves in this region are determined by drawing average lines through the test points. As the value of  $t_w/b_w$  is reduced, however, the responsibility for the buckling shifts to the stiffeners and there is a reduction in  $\sigma_{cr}$ . In the absence of adequate test data for low values of  $t_w/b_w$ , certain theoretical considerations are used for determining the values of  $\sigma_{cr}$  in this region.

It is possible to describe certain limiting conditions that determine curves between which the correct curves must lie. As the value of  $t_w/b_w$  approaches zero, with all other dimension ratios held constant, the skin tends to become infinitely stiff by comparison with the stiffener and the stiffener approaches a condition of complete fixity at the edge where it is attached to the skin. This condition of complete fixity represents the upper limit of buckling stress. The value of  $k$ , the coefficient in the formula for local-buckling stress (reference 4), when applied to the stiffener web may be taken for this condition as the geometric mean of the value of  $k$  for the web of a Z-section column with  $b_r/b_w = 0.4$  (about 3.77, see reference 4) and the value of  $k$  for a flat plate fixed at both edges (about 6.98, see reference 5). This value of  $k$  is  $\sqrt{3.77 \times 6.98}$ , or 5.13. The upper dashed curve in figure 15

gives  $\sigma_{cr}$  for  $k=5.13$ . The use of the geometric mean of values of  $k$  to obtain the critical stress for a plate with different restraints along the two unloaded edges is discussed and justified for practical use in reference 5.

When  $b_w = b_s$ , it is a reasonable and probably conservative assumption to consider the stiffener hinged at the edge where it is attached to the skin. This hinged condition represents the lower limit of buckling stress. The value of  $k$  for the web of the stiffener may be taken for this condition as the geometric mean of 3.77 for the simple Z-section and the value for a flat plate hinged at both edges (4.00, see reference 5) or  $k = \sqrt{3.77 \times 4.00} = 3.88$ . The lower dashed curve in figure 15 gives  $\sigma_{cr}$  for  $k = 3.88$ . In the preparation of the two dashed curves, the effect of reduction in the modulus of elasticity for stresses beyond the elastic range was determined from results of tests of 24S T aluminum-alloy columns of Z-, channel, and H-section that develop local instability.

The solid curve on the left-hand side of figure 15 is drawn in to give a gradual transition from the lower dashed curve in the region where  $b_w/b_s \approx t_w/t_s$  toward the upper dashed curve as  $t_w/b_w$  approaches zero. In the region where  $b_w/b_s \approx t_w/t_s$  the curves are fairing into the horizontal lines drawn through the test points. A single curve was considered sufficient for all values of  $t_w/t_s$  for the left-hand portion of figure 15, because the few test points that were available in this region indicated that the individual curves would be so close together as to be almost indistinguishable.

The curves of figure 15, like those of figure 12, were cross-plotted to give buckling stresses for the intermediate values of  $b_s/t_s$  that appear in figures 2 to 5.

**Preparation of final curves.** The procedure used in the preparation of the final curves of figures 2 to 5 is illustrated in figure 16. An outline of this procedure is as follows:

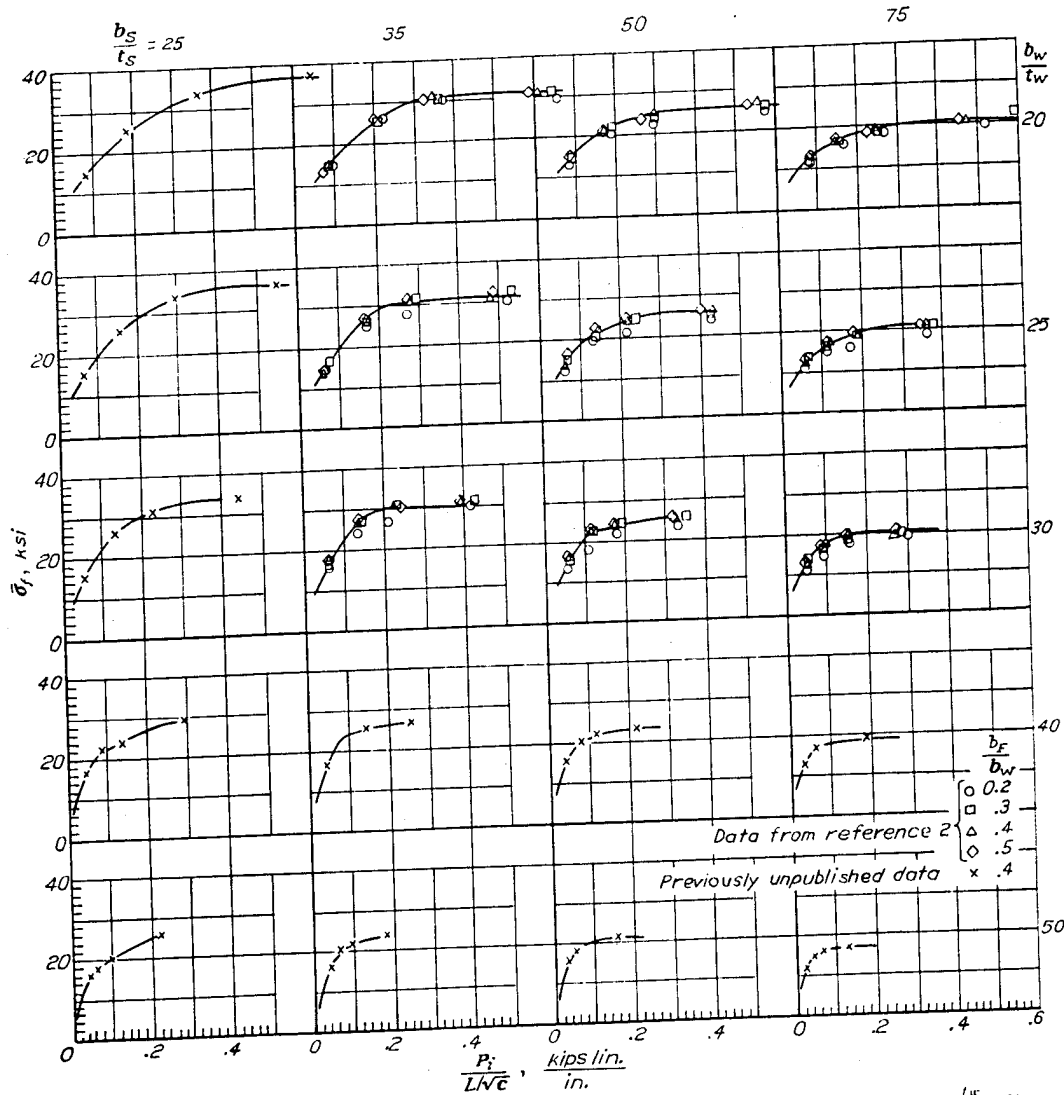


FIGURE 17. Comparison of test data with design curves for 24S-T aluminum-alloy flat panels with Z-section stiffeners.  $t_w/t_s = 0.51$ .

(1) Draw curve for column strength corresponding to the value of  $\rho \cdot A_i$  for the panel cross section. For the curves of this report, the column curve for 24S T aluminum alloy was obtained from equations (5) and (6) and table I, all of reference 6.

(2) Plot the values of stress for local buckling and for local failure of panel obtained from the cross plots of the curves in figures 12 and 15.

(3) Plot available test data and fair curves between buckling stress and local-failure stress. This fairing was done first for those curves for which test data were available; the remaining curves were then faired in a manner consistent with the curves already established.

In a few cases (low  $b_s/t_s$  with high  $b_w/t_w$ ) the test data indicated that the curves did not follow the smooth transition between column and local failure indicated by figure 16. Instead the curves tended to bend over sharply, in some cases even below the buckling stress given by figure 15, and to follow very nearly a straight line up to the average stress for local failure. No explanation is offered for this phenom-

enon; the available test data were used as the sole guide for fairing the curves in these cases.

**Correlation between design curves and test data.**—The test data of reference 2 as well as the additional data made available since the publication of reference 2 are plotted against the parameter  $\frac{P_i}{L_j^2 \cdot E}$  in figures 17 to 20. Appropriate curves taken from figures 2 to 5 are also drawn in these figures and good agreement between the final design curves and the test data for  $\frac{b_F}{b_W} = 0.4$  exists throughout the range of the data. In order to make it possible, if desired, to check the correlation on a larger-scale plot, the test data for  $\frac{b_F}{b_W} = 0.3, 0.4,$  and  $0.5$  are given in table 7 in a form suitable for plotting directly on the design charts (figs. 2 to 5). Table 7 and figures 17 to 20 also make it possible to determine in which regions the design charts are substantiated by test data and in which regions they were obtained by interpolation or extrapolation.

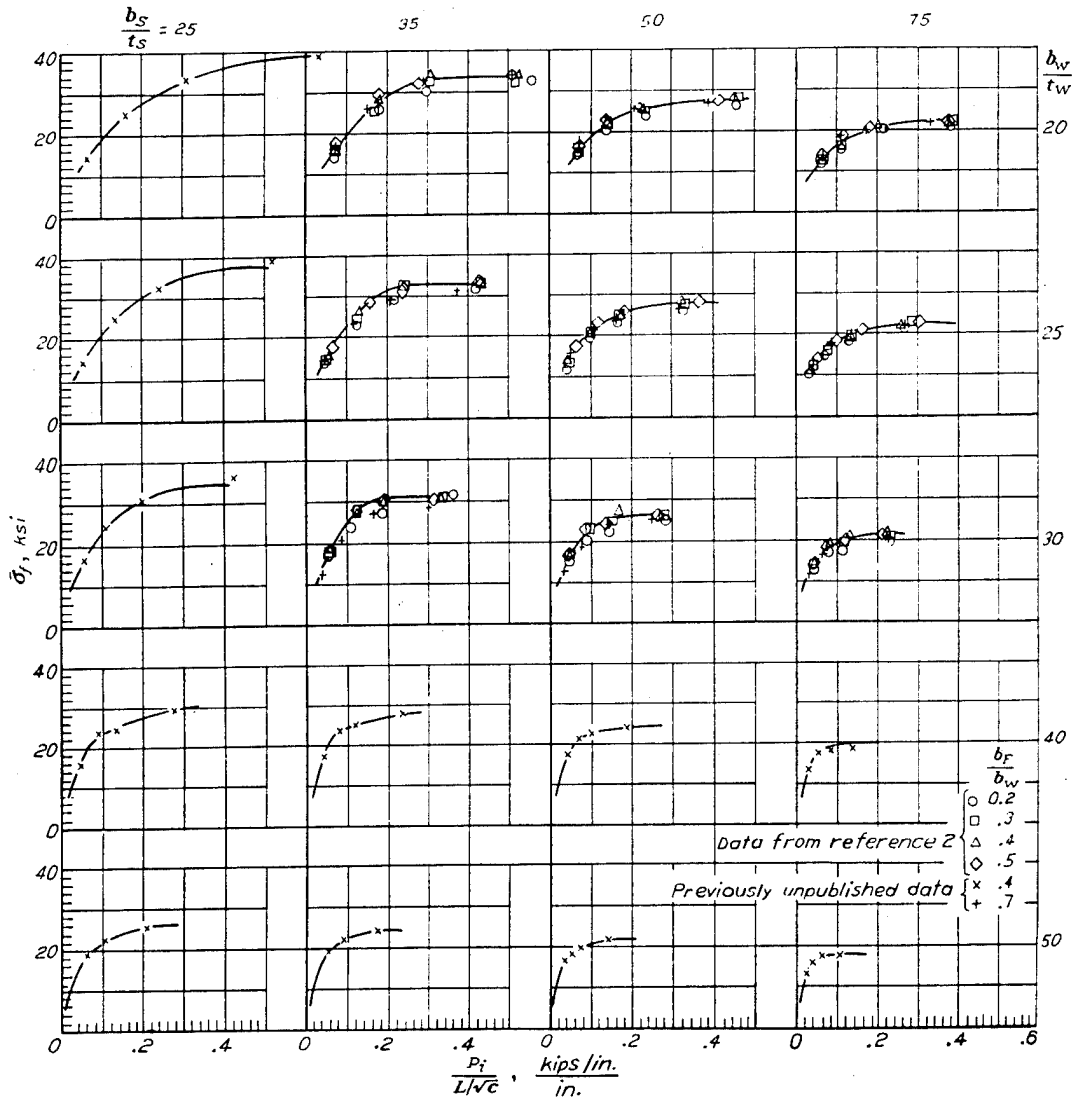


FIGURE 18.—Comparison of test data with design curves for 24S-T aluminum-alloy flat panels with Z-section stiffeners.  $\frac{t_w}{t_s} = 0.63$ .

Figures 17 to 20 indicate that there would be little difference in the curves for  $\frac{b_F}{b_W} = 0.3, 0.4,$  and  $0.5$  but that the curves for  $\frac{b_F}{b_W} = 0.2$  and probably  $0.7$  would be lower than those for  $\frac{b_F}{b_W} = 0.4$ . The most efficient use of material will therefore be realized if a value of  $\frac{b_F}{b_W}$  between  $0.3$  and  $0.5$  is used. It is for this range that the design charts are intended to be used, although they are based on the specific data for  $\frac{b_F}{b_W} = 0.4$ .

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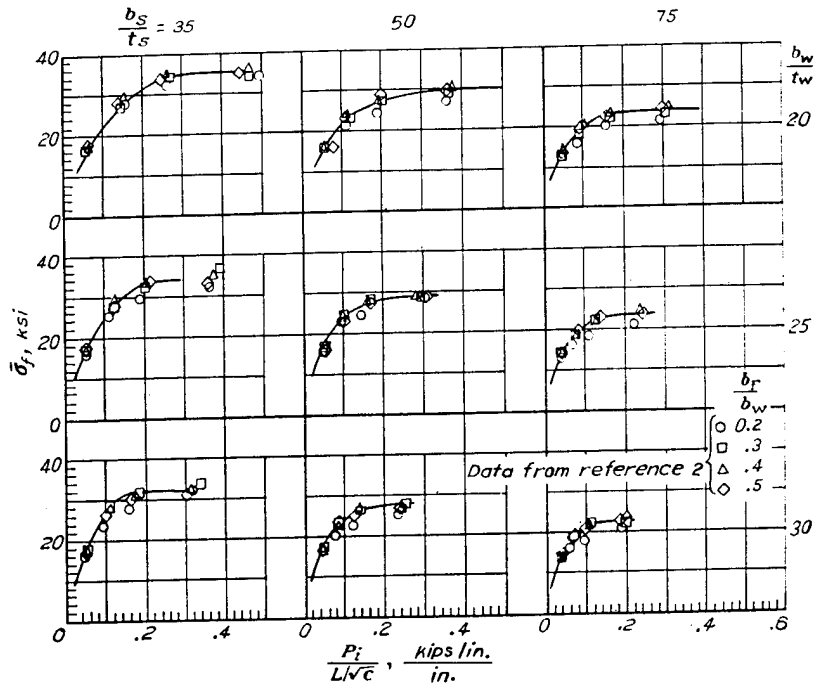


FIGURE 19.—Comparison of test data with design curves for 24S-T aluminum-alloy flat panels with Z-section stiffeners.  $\frac{t_w}{t_s} = 0.79$ .

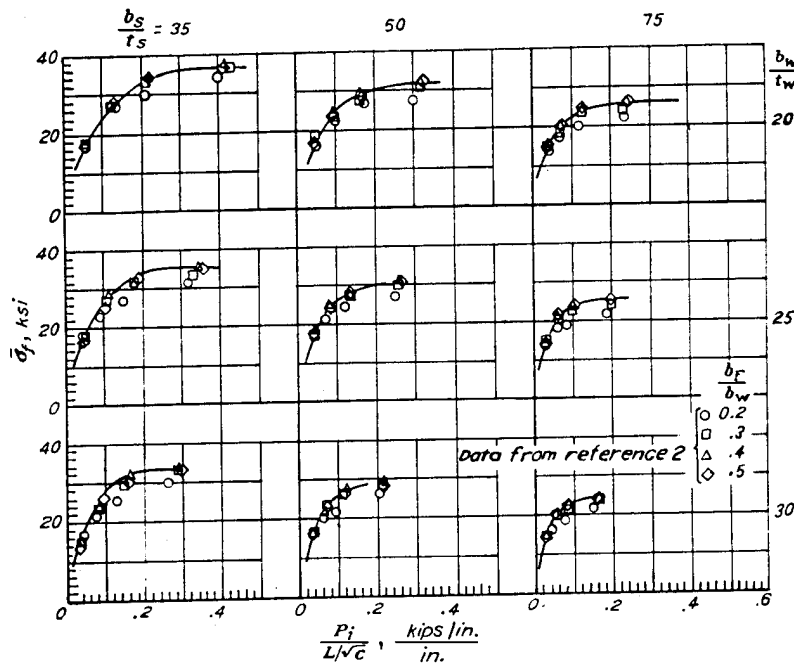


FIGURE 20.—Comparison of test data with design curves for 24S-T aluminum-alloy flat panels with Z-section stiffeners.  $\frac{t_w}{t_s} = 1.00$ .

TABLE I  
VALUES OF  $U_{ts}$  FOR FLAT PANELS WITH Z-SECTION STIFFENERS.  $b_F/b_W = 0.3$ .

$$\left[ A_{ts} = 1 + \frac{b_W}{t_W} \left( 1 + \frac{b_F}{b_W} \right) + \frac{b_W}{t_W} \left( 2 - \frac{\pi}{2} \right) \left( \frac{t_W}{t_S} + \frac{t_F}{t_W} + 1 \right) \left( \frac{t_W}{t_S} \right) \right]$$

$b_S/t_S$	$b_W/t_W$	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
$t_W/t_S = 0.51$																						
25	1.353	1.367	1.380	1.394	1.407	1.421	1.435	1.448	1.462	1.475	1.489	1.506	1.533	1.570	1.597	1.624	1.651	1.678	1.705	1.732	1.759	1.789
26	1.340	1.353	1.366	1.379	1.392	1.405	1.418	1.431	1.444	1.457	1.470	1.496	1.522	1.558	1.574	1.600	1.626	1.652	1.678	1.704	1.730	1.760
27	1.327	1.340	1.352	1.365	1.377	1.390	1.402	1.415	1.427	1.440	1.452	1.477	1.502	1.538	1.553	1.578	1.603	1.628	1.653	1.678	1.703	1.733
28	1.316	1.328	1.340	1.352	1.364	1.376	1.388	1.400	1.412	1.424	1.436	1.460	1.485	1.509	1.533	1.557	1.581	1.605	1.629	1.654	1.678	1.708
29	1.305	1.316	1.328	1.340	1.351	1.363	1.375	1.386	1.398	1.410	1.421	1.445	1.468	1.491	1.514	1.538	1.561	1.584	1.608	1.631	1.654	1.684
30	1.294	1.306	1.317	1.328	1.340	1.351	1.362	1.373	1.385	1.396	1.407	1.430	1.452	1.475	1.497	1.520	1.542	1.565	1.587	1.610	1.633	1.663
31	1.285	1.296	1.307	1.318	1.329	1.340	1.350	1.361	1.372	1.383	1.394	1.416	1.438	1.459	1.481	1.503	1.525	1.547	1.569	1.590	1.612	1.642
32	1.276	1.287	1.297	1.308	1.318	1.329	1.339	1.350	1.361	1.371	1.382	1.403	1.424	1.445	1.466	1.487	1.509	1.530	1.551	1.572	1.593	1.623
33	1.268	1.278	1.288	1.298	1.309	1.319	1.329	1.339	1.350	1.360	1.370	1.391	1.411	1.432	1.452	1.473	1.493	1.514	1.534	1.555	1.575	1.605
34	1.260	1.270	1.280	1.290	1.300	1.310	1.320	1.329	1.339	1.349	1.359	1.379	1.399	1.419	1.439	1.459	1.479	1.498	1.518	1.538	1.558	1.588
35	1.252	1.262	1.272	1.281	1.291	1.301	1.310	1.320	1.330	1.339	1.349	1.368	1.388	1.407	1.426	1.446	1.465	1.484	1.504	1.523	1.542	1.572
36	1.245	1.255	1.264	1.274	1.283	1.292	1.302	1.311	1.321	1.330	1.339	1.358	1.377	1.396	1.414	1.433	1.452	1.471	1.490	1.508	1.527	1.557
37	1.239	1.248	1.257	1.266	1.275	1.284	1.293	1.302	1.312	1.321	1.330	1.348	1.367	1.385	1.403	1.422	1.440	1.458	1.476	1.495	1.513	1.543
38	1.232	1.241	1.250	1.259	1.268	1.277	1.286	1.295	1.304	1.313	1.321	1.339	1.357	1.375	1.393	1.410	1.428	1.446	1.464	1.482	1.500	1.530
39	1.227	1.235	1.244	1.253	1.261	1.270	1.279	1.287	1.296	1.305	1.313	1.331	1.348	1.365	1.383	1.400	1.417	1.435	1.452	1.469	1.487	1.517
40	1.221	1.229	1.238	1.246	1.255	1.263	1.272	1.280	1.288	1.297	1.305	1.322	1.339	1.356	1.373	1.390	1.407	1.424	1.441	1.458	1.474	1.504
42	1.210	1.218	1.226	1.234	1.243	1.251	1.259	1.267	1.275	1.283	1.291	1.307	1.323	1.339	1.355	1.371	1.387	1.404	1.420	1.436	1.452	1.482
44	1.201	1.208	1.216	1.224	1.232	1.239	1.247	1.255	1.262	1.270	1.278	1.293	1.308	1.324	1.339	1.354	1.370	1.385	1.401	1.416	1.431	1.461
46	1.192	1.199	1.207	1.214	1.221	1.229	1.236	1.244	1.251	1.258	1.266	1.280	1.295	1.310	1.324	1.338	1.353	1.368	1.383	1.398	1.413	1.443
48	1.184	1.191	1.198	1.205	1.212	1.219	1.226	1.233	1.240	1.247	1.254	1.269	1.283	1.297	1.311	1.325	1.339	1.353	1.367	1.381	1.395	1.425
50	1.177	1.183	1.190	1.197	1.204	1.211	1.217	1.224	1.231	1.238	1.244	1.259	1.271	1.285	1.298	1.312	1.325	1.339	1.353	1.366	1.380	1.410
52	1.170	1.176	1.183	1.189	1.196	1.202	1.209	1.215	1.222	1.228	1.235	1.248	1.261	1.274	1.287	1.300	1.313	1.326	1.339	1.352	1.365	1.395
54	1.164	1.170	1.176	1.182	1.189	1.195	1.201	1.207	1.214	1.220	1.226	1.239	1.251	1.264	1.276	1.289	1.301	1.314	1.326	1.339	1.351	1.381
56	1.158	1.164	1.170	1.176	1.182	1.188	1.194	1.200	1.206	1.212	1.218	1.230	1.242	1.254	1.266	1.279	1.291	1.303	1.315	1.327	1.339	1.369
58	1.152	1.158	1.164	1.170	1.176	1.181	1.187	1.193	1.199	1.205	1.211	1.222	1.234	1.246	1.257	1.269	1.281	1.292	1.304	1.316	1.327	1.357
60	1.147	1.153	1.159	1.164	1.170	1.175	1.181	1.187	1.192	1.198	1.204	1.215	1.226	1.237	1.249	1.260	1.271	1.282	1.294	1.305	1.316	1.346
65	1.136	1.141	1.146	1.152	1.157	1.162	1.167	1.172	1.178	1.183	1.188	1.198	1.209	1.219	1.230	1.240	1.250	1.261	1.271	1.282	1.292	1.322
70	1.126	1.131	1.136	1.141	1.146	1.150	1.155	1.160	1.165	1.170	1.175	1.184	1.194	1.203	1.213	1.223	1.232	1.242	1.252	1.261	1.271	1.301
75	1.118	1.122	1.127	1.131	1.136	1.140	1.145	1.149	1.154	1.158	1.163	1.172	1.181	1.190	1.199	1.208	1.217	1.226	1.235	1.244	1.253	1.283
$t_W/t_S = 0.73$																						
25	1.531	1.552	1.573	1.593	1.614	1.635	1.655	1.676	1.696	1.717	1.738	1.779	1.820	1.862	1.903	1.944	1.985	2.027	2.068	2.109	2.151	2.196
26	1.511	1.531	1.551	1.570	1.590	1.610	1.630	1.650	1.670	1.690	1.709	1.749	1.789	1.828	1.868	1.908	1.948	1.987	2.027	2.067	2.107	2.152
27	1.492	1.511	1.530	1.549	1.568	1.588	1.607	1.626	1.645	1.664	1.683	1.721	1.760	1.798	1.836	1.874	1.912	1.951	1.989	2.027	2.065	2.110
28	1.474	1.493	1.511	1.530	1.548	1.567	1.585	1.603	1.622	1.640	1.659	1.696	1.732	1.769	1.806	1.843	1.880	1.917	1.954	1.990	2.027	2.072
29	1.458	1.476	1.494	1.511	1.529	1.547	1.565	1.583	1.600	1.618	1.636	1.672	1.707	1.743	1.778	1.814	1.849	1.885	1.921	1.956	1.992	2.037
30	1.443	1.460	1.477	1.494	1.512	1.529	1.546	1.563	1.580	1.598	1.615	1.649	1.684	1.718	1.752	1.787	1.821	1.856	1.890	1.924	1.959	2.004
31	1.428	1.445	1.462	1.478	1.495	1.512	1.528	1.545	1.562	1.578	1.595	1.628	1.662	1.695	1.728	1.761	1.795	1.828	1.861	1.895	1.928	1.973
32	1.413	1.431	1.447	1.463	1.480	1.496	1.512	1.528	1.544	1.560	1.576	1.609	1.641	1.673	1.705	1.738	1.770	1.802	1.834	1.867	1.900	1.945
33	1.403	1.418	1.434	1.449	1.465	1.481	1.496	1.512	1.528	1.543	1.559	1.590	1.621	1.653	1.684	1.715	1.747	1.778	1.809	1.840	1.872	1.917
34	1.391	1.406	1.421	1.436	1.451	1.467	1.482	1.497	1.512	1.527	1.542	1.573	1.603	1.634	1.664	1.694	1.725	1.755	1.785	1.816	1.846	1.891
35	1.380	1.394	1.409	1.424	1.438	1.453	1.468	1.483	1.497	1.512	1.527	1.556	1.586	1.615	1.645	1.674	1.704	1.733	1.763	1.792	1.822	1.867
36	1.369	1.383	1.398	1.412	1.426	1.441	1.455	1.469	1.484	1.498	1.512	1.541	1.570	1.598	1.627	1.656	1.684	1.713	1.742	1.770	1.799	1.844
37	1.359	1.373	1.387	1.401	1.415	1.429	1.443	1.457	1.471	1.485	1.498	1.526	1.554	1.582	1.610	1.638	1.666	1.694	1.722	1.750	1.779	1.824
38	1.350	1.363	1.377	1.390	1.404	1.417	1.431	1.445	1.458	1.472	1.485	1.513	1.540	1.567	1.594	1.621	1.648	1.675	1.703	1.730	1.757	1.802
39	1.341	1.354	1.367	1.380	1.394	1.407	1.420	1.433	1.446	1.460	1.473	1.499	1.526	1.552	1.579	1.605	1.632	1.658	1.685	1.711	1.738	1.783
40	1.332	1.345	1.358	1.371	1.384	1.397	1.409	1.422	1.435	1.448	1.461	1.487	1.513	1.538	1.564	1.590	1.616	1.642	1.667	1.693	1.719	1.764
42	1.316	1.329	1.341	1.353	1.365	1.378	1.390	1.402	1.415	1.427	1.439	1.464	1.488	1.513	1.537							

TABLE 1--Concluded

VALUES OF  $A_c/t_s$  FOR FLAT PANELS WITH Z-SECTION STIFFENERS.  $b_F/b_W = 0.3$  - Concluded.

$b_s/t_s$	$b_W/t_W$	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
$t_W/t_s = 0.79$																						
25	1.808	1.840	1.873	1.905	1.938	1.970	2.003	2.035	2.068	2.100	2.133	2.167	2.202	2.237	2.272	2.307	2.342	2.377	2.412	2.447	2.482	2.517
26	1.777	1.808	1.839	1.871	1.902	1.933	1.964	1.995	2.027	2.058	2.090	2.121	2.154	2.187	2.220	2.253	2.287	2.320	2.353	2.387	2.420	2.454
27	1.748	1.778	1.808	1.838	1.868	1.898	1.928	1.958	1.989	2.019	2.049	2.079	2.109	2.139	2.169	2.199	2.229	2.259	2.289	2.319	2.349	2.379
28	1.721	1.750	1.779	1.808	1.837	1.866	1.895	1.924	1.953	1.982	2.011	2.040	2.069	2.098	2.127	2.156	2.185	2.214	2.243	2.272	2.301	2.330
29	1.697	1.725	1.752	1.780	1.808	1.836	1.864	1.892	1.920	1.948	1.976	2.004	2.032	2.060	2.088	2.116	2.144	2.172	2.200	2.228	2.256	2.284
30	1.673	1.700	1.727	1.754	1.781	1.809	1.836	1.863	1.890	1.917	1.944	1.971	1.998	2.025	2.052	2.079	2.106	2.133	2.160	2.187	2.214	2.241
31	1.652	1.678	1.704	1.730	1.756	1.782	1.809	1.835	1.861	1.887	1.913	1.939	1.965	1.991	2.017	2.043	2.069	2.095	2.121	2.147	2.173	2.199
32	1.631	1.657	1.682	1.707	1.733	1.758	1.783	1.809	1.834	1.859	1.885	1.910	1.935	1.960	1.985	2.010	2.035	2.060	2.085	2.110	2.135	2.160
33	1.612	1.637	1.661	1.686	1.710	1.735	1.760	1.784	1.809	1.833	1.858	1.907	1.956	2.005	2.054	2.103	2.152	2.201	2.250	2.299	2.348	2.397
34	1.594	1.618	1.641	1.666	1.690	1.713	1.737	1.761	1.785	1.809	1.833	1.880	1.928	1.976	2.024	2.071	2.119	2.167	2.215	2.262	2.310	2.358
35	1.577	1.600	1.623	1.647	1.670	1.693	1.716	1.739	1.763	1.786	1.809	1.855	1.902	1.948	1.994	2.041	2.087	2.133	2.179	2.225	2.271	2.317
36	1.561	1.584	1.606	1.629	1.651	1.674	1.696	1.719	1.741	1.764	1.786	1.832	1.877	1.922	1.967	2.012	2.057	2.102	2.147	2.192	2.237	2.282
37	1.546	1.568	1.590	1.612	1.634	1.656	1.677	1.699	1.721	1.743	1.765	1.809	1.853	1.897	1.941	1.984	2.028	2.072	2.116	2.160	2.204	2.248
38	1.532	1.553	1.574	1.596	1.617	1.638	1.660	1.681	1.702	1.724	1.745	1.788	1.830	1.873	1.916	1.959	2.001	2.044	2.087	2.129	2.172	2.215
39	1.518	1.539	1.560	1.580	1.601	1.622	1.643	1.664	1.684	1.705	1.726	1.768	1.809	1.851	1.892	1.934	1.975	2.017	2.059	2.100	2.142	2.183
40	1.505	1.525	1.546	1.566	1.586	1.606	1.627	1.647	1.667	1.688	1.708	1.748	1.789	1.830	1.870	1.911	1.951	1.992	2.032	2.072	2.112	2.152
42	1.481	1.500	1.520	1.539	1.558	1.578	1.597	1.616	1.635	1.655	1.674	1.713	1.751	1.790	1.829	1.867	1.906	1.945	1.983	2.022	2.060	2.099
44	1.459	1.478	1.496	1.514	1.533	1.551	1.570	1.588	1.607	1.625	1.643	1.680	1.717	1.754	1.791	1.828	1.865	1.902	1.938	1.975	2.012	2.049
46	1.439	1.457	1.474	1.492	1.510	1.527	1.545	1.563	1.580	1.598	1.615	1.651	1.686	1.721	1.757	1.792	1.827	1.862	1.898	1.933	1.968	2.003
48	1.421	1.438	1.455	1.472	1.488	1.505	1.522	1.539	1.556	1.573	1.590	1.624	1.657	1.691	1.725	1.759	1.793	1.826	1.860	1.894	1.928	1.962
50	1.404	1.420	1.436	1.453	1.469	1.485	1.501	1.518	1.534	1.550	1.566	1.599	1.631	1.664	1.696	1.729	1.761	1.793	1.826	1.858	1.891	1.924
52	1.388	1.404	1.420	1.435	1.451	1.466	1.482	1.498	1.513	1.529	1.544	1.576	1.607	1.638	1.669	1.700	1.732	1.763	1.794	1.825	1.857	1.889
54	1.374	1.389	1.404	1.419	1.434	1.449	1.464	1.479	1.494	1.509	1.524	1.554	1.584	1.614	1.644	1.675	1.705	1.735	1.765	1.795	1.825	1.855
56	1.361	1.375	1.390	1.404	1.419	1.433	1.448	1.462	1.477	1.491	1.506	1.535	1.564	1.593	1.621	1.650	1.679	1.708	1.737	1.766	1.795	1.824
58	1.348	1.362	1.376	1.390	1.404	1.418	1.432	1.446	1.460	1.474	1.488	1.516	1.544	1.572	1.600	1.628	1.656	1.684	1.712	1.740	1.768	1.796
60	1.337	1.350	1.364	1.377	1.391	1.404	1.418	1.431	1.445	1.458	1.472	1.499	1.526	1.553	1.580	1.607	1.634	1.661	1.688	1.715	1.742	1.769
65	1.311	1.323	1.336	1.348	1.361	1.373	1.386	1.398	1.411	1.423	1.436	1.461	1.485	1.510	1.535	1.560	1.585	1.610	1.635	1.660	1.685	1.710
70	1.289	1.300	1.312	1.323	1.335	1.347	1.358	1.370	1.381	1.393	1.404	1.428	1.451	1.474	1.497	1.520	1.544	1.567	1.590	1.613	1.636	1.659
75	1.269	1.280	1.291	1.302	1.313	1.323	1.334	1.345	1.356	1.367	1.377	1.399	1.421	1.442	1.464	1.486	1.507	1.529	1.551	1.572	1.594	1.615
$t_W/t_s = 1.00$																						
25	2.247	2.299	2.351	2.403	2.455	2.506	2.559	2.611	2.663	2.715	2.767	2.871	2.975	3.079	3.183	3.287	3.391	3.495	3.599	3.703	3.807	3.911
26	2.199	2.249	2.299	2.349	2.399	2.449	2.499	2.549	2.599	2.649	2.699	2.799	2.899	2.999	3.099	3.199	3.299	3.399	3.499	3.599	3.699	3.799
27	2.154	2.202	2.251	2.299	2.347	2.395	2.443	2.491	2.539	2.588	2.636	2.732	2.828	2.925	3.021	3.117	3.213	3.310	3.406	3.502	3.598	3.694
28	2.113	2.160	2.206	2.252	2.299	2.345	2.392	2.438	2.485	2.531	2.577	2.670	2.763	2.856	2.949	3.042	3.135	3.227	3.320	3.413	3.506	3.599
29	2.075	2.120	2.164	2.209	2.254	2.299	2.344	2.389	2.433	2.478	2.523	2.613	2.702	2.792	2.882	2.971	3.061	3.151	3.240	3.330	3.420	3.509
30	2.039	2.082	2.126	2.169	2.212	2.256	2.299	2.342	2.386	2.429	2.472	2.559	2.646	2.732	2.819	2.906	2.992	3.079	3.166	3.252	3.339	3.426
31	2.005	2.047	2.089	2.131	2.173	2.215	2.257	2.299	2.341	2.383	2.425	2.509	2.592	2.676	2.760	2.844	2.928	3.012	3.096	3.180	3.263	3.347
32	1.971	2.015	2.055	2.096	2.136	2.177	2.218	2.258	2.299	2.340	2.380	2.461	2.543	2.624	2.705	2.786	2.868	2.949	3.030	3.111	3.193	3.274
33	1.944	1.984	2.023	2.063	2.102	2.141	2.181	2.220	2.259	2.299	2.338	2.417	2.496	2.575	2.654	2.732	2.811	2.890	2.969	3.048	3.126	3.205
34	1.917	1.955	1.993	2.031	2.070	2.108	2.146	2.184	2.223	2.261	2.299	2.376	2.452	2.528	2.605	2.681	2.758	2.834	2.911	2.987	3.064	3.141
35	1.890	1.928	1.965	2.002	2.039	2.076	2.113	2.150	2.188	2.225	2.262	2.336	2.410	2.485	2.559	2.633	2.708	2.782	2.856	2.930	3.005	3.079
36	1.866	1.902	1.938	1.974	2.010	2.046	2.082	2.119	2.155	2.191	2.227	2.299	2.371	2.444	2.516	2.588	2.660	2.732	2.805	2.877	2.949	3.021
37	1.842	1.877	1.913	1.948	1.983	2.018	2.053	2.088	2.123	2.159	2.194	2.264	2.334	2.405	2.475	2.545	2.615	2.686	2.756	2.826	2.896	2.966
38	1.820	1.854	1.889	1.923	1.957	1.991	2.025	2.060	2.094	2.128	2.162	2.231	2.299	2.368	2.436	2.504	2.573	2.641	2.710	2.778	2.847	2.915
39	1.799	1.832	1.866	1.899	1.932	1.966	1.999	2.033	2.066	2.099	2.133	2.199	2.266	2.333	2.399	2.466	2.533	2.599	2.666	2.733	2.799	2.866
40	1.779	1.812	1.844	1.877	1.909	1.942	1.974	2.007	2.039	2.072	2.104	2.169	2.234	2.299	2.364	2.429	2.494	2.559	2.624	2.689	2.754	2.819
42	1.742	1.773	1.804	1.835	1.866	1.897	1.928	1.959	1.990	2.021	2.052	2.114	2.175	2.237	2.299	2.361	2.423	2.485	2.547	2.609	2.671	2.733
44	1																					

TABLE 2  
VALUES OF  $A_s/t_s$  FOR FLAT PANELS WITH Z-SECTION STIFFENERS.  $b_F/b_W = 0.4$

$$\left[ A_s/t_s = 1 + \frac{b_W \left( 1 + \frac{b_F}{b_W} \right) + \frac{b_s}{t_s} - \left( 2 - \frac{\pi}{2} \right) \left( \frac{t_s}{t_w} + \frac{t_F}{t_w} + 1 \right)}{b_s/t_s} \left( \frac{t_w}{t_s} \right)^2 \right]$$

$b_s/t_s$	$b_W/t_W$	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
$t_w/t_s = 0.51$																						
25	1.374	1.389	1.403	1.418	1.432	1.447	1.462	1.476	1.491	1.505	1.520	1.534	1.549	1.578	1.607	1.636	1.665	1.695	1.724	1.753	1.782	1.811
26	1.390	1.374	1.388	1.402	1.416	1.430	1.444	1.458	1.472	1.486	1.500	1.528	1.556	1.584	1.612	1.640	1.668	1.696	1.724	1.752	1.780	1.808
27	1.346	1.360	1.373	1.387	1.400	1.414	1.427	1.441	1.454	1.468	1.481	1.508	1.535	1.562	1.589	1.616	1.643	1.670	1.697	1.724	1.751	1.778
28	1.334	1.347	1.360	1.373	1.386	1.399	1.412	1.425	1.438	1.451	1.464	1.490	1.516	1.542	1.568	1.594	1.620	1.646	1.672	1.698	1.724	1.750
29	1.323	1.335	1.348	1.360	1.373	1.385	1.398	1.410	1.423	1.436	1.448	1.473	1.498	1.523	1.549	1.574	1.599	1.624	1.649	1.674	1.699	1.724
30	1.312	1.324	1.336	1.348	1.360	1.373	1.385	1.397	1.409	1.421	1.433	1.457	1.482	1.506	1.530	1.555	1.579	1.603	1.627	1.652	1.676	1.700
31	1.302	1.313	1.325	1.337	1.349	1.360	1.372	1.384	1.396	1.407	1.419	1.443	1.466	1.490	1.513	1.537	1.560	1.584	1.607	1.631	1.654	1.678
32	1.292	1.304	1.315	1.326	1.338	1.349	1.361	1.372	1.383	1.395	1.406	1.429	1.452	1.474	1.497	1.520	1.543	1.565	1.588	1.611	1.634	1.657
33	1.283	1.294	1.306	1.317	1.328	1.339	1.350	1.361	1.372	1.383	1.394	1.416	1.438	1.460	1.482	1.504	1.526	1.548	1.570	1.592	1.614	1.636
34	1.275	1.286	1.297	1.307	1.318	1.329	1.339	1.350	1.361	1.372	1.382	1.404	1.425	1.446	1.468	1.489	1.511	1.532	1.554	1.575	1.596	1.617
35	1.267	1.278	1.288	1.298	1.309	1.319	1.330	1.340	1.350	1.361	1.371	1.392	1.413	1.434	1.455	1.475	1.496	1.517	1.538	1.559	1.579	1.600
36	1.260	1.270	1.280	1.290	1.300	1.310	1.321	1.331	1.341	1.351	1.361	1.381	1.401	1.422	1.442	1.462	1.482	1.503	1.523	1.543	1.563	1.583
37	1.253	1.263	1.272	1.282	1.292	1.302	1.312	1.322	1.332	1.341	1.351	1.371	1.391	1.410	1.430	1.450	1.469	1.489	1.509	1.528	1.548	1.568
38	1.246	1.256	1.265	1.275	1.285	1.294	1.304	1.313	1.323	1.332	1.342	1.361	1.380	1.399	1.419	1.438	1.457	1.476	1.495	1.514	1.534	1.553
39	1.240	1.249	1.259	1.268	1.277	1.287	1.296	1.305	1.315	1.324	1.333	1.352	1.371	1.389	1.408	1.427	1.445	1.464	1.483	1.501	1.520	1.539
40	1.234	1.243	1.252	1.261	1.270	1.279	1.288	1.298	1.307	1.316	1.325	1.343	1.361	1.380	1.398	1.416	1.434	1.452	1.471	1.489	1.507	1.525
42	1.223	1.231	1.240	1.249	1.257	1.266	1.275	1.283	1.292	1.301	1.309	1.327	1.344	1.361	1.379	1.396	1.413	1.431	1.448	1.465	1.483	1.501
44	1.213	1.221	1.229	1.237	1.246	1.254	1.262	1.271	1.279	1.287	1.295	1.312	1.328	1.345	1.362	1.378	1.395	1.411	1.428	1.444	1.461	1.478
46	1.203	1.211	1.219	1.227	1.235	1.243	1.251	1.259	1.267	1.275	1.283	1.298	1.314	1.330	1.346	1.362	1.377	1.393	1.409	1.425	1.441	1.457
48	1.195	1.202	1.210	1.218	1.225	1.233	1.240	1.248	1.256	1.263	1.271	1.286	1.301	1.316	1.331	1.347	1.362	1.377	1.392	1.407	1.422	1.437
50	1.187	1.194	1.202	1.209	1.216	1.224	1.231	1.238	1.245	1.253	1.260	1.274	1.289	1.304	1.318	1.333	1.347	1.362	1.376	1.391	1.406	1.421
52	1.180	1.187	1.194	1.201	1.208	1.215	1.222	1.229	1.236	1.243	1.250	1.264	1.278	1.292	1.306	1.320	1.334	1.348	1.362	1.376	1.390	1.404
54	1.173	1.180	1.187	1.193	1.200	1.207	1.214	1.220	1.227	1.234	1.241	1.254	1.268	1.281	1.295	1.308	1.322	1.335	1.349	1.362	1.376	1.390
56	1.167	1.174	1.180	1.187	1.193	1.200	1.206	1.213	1.219	1.226	1.232	1.245	1.258	1.271	1.284	1.297	1.310	1.323	1.336	1.349	1.362	1.376
58	1.161	1.168	1.174	1.180	1.186	1.193	1.199	1.205	1.212	1.218	1.224	1.237	1.249	1.262	1.274	1.287	1.299	1.312	1.324	1.337	1.350	1.363
60	1.156	1.162	1.168	1.174	1.180	1.186	1.192	1.198	1.204	1.211	1.217	1.229	1.241	1.253	1.265	1.277	1.289	1.302	1.314	1.326	1.338	1.351
65	1.144	1.150	1.155	1.161	1.166	1.172	1.178	1.183	1.189	1.194	1.200	1.211	1.222	1.234	1.245	1.256	1.267	1.278	1.290	1.301	1.312	1.323
70	1.134	1.139	1.144	1.149	1.154	1.160	1.165	1.170	1.175	1.180	1.186	1.196	1.206	1.217	1.227	1.238	1.248	1.258	1.269	1.279	1.290	1.300
75	1.125	1.130	1.134	1.139	1.144	1.149	1.154	1.159	1.164	1.168	1.173	1.183	1.193	1.202	1.212	1.222	1.232	1.241	1.251	1.261	1.270	1.280
$t_w/t_s = 0.53$																						
25	1.563	1.585	1.608	1.630	1.652	1.674	1.696	1.719	1.741	1.763	1.785	1.830	1.874	1.919	1.963	2.008	2.052	2.097	2.141	2.186	2.230	2.274
26	1.541	1.563	1.584	1.606	1.627	1.648	1.670	1.691	1.712	1.734	1.755	1.798	1.841	1.883	1.926	1.969	2.012	2.054	2.097	2.140	2.183	2.226
27	1.521	1.542	1.563	1.583	1.604	1.624	1.645	1.665	1.686	1.707	1.727	1.768	1.810	1.851	1.892	1.933	1.974	2.015	2.057	2.098	2.139	2.180
28	1.503	1.523	1.542	1.562	1.582	1.602	1.622	1.642	1.662	1.681	1.701	1.741	1.781	1.820	1.860	1.900	1.939	1.979	2.019	2.059	2.098	2.138
29	1.485	1.505	1.524	1.543	1.562	1.581	1.600	1.620	1.639	1.658	1.677	1.715	1.754	1.792	1.830	1.869	1.907	1.945	1.984	2.022	2.060	2.098
30	1.469	1.488	1.506	1.525	1.543	1.562	1.580	1.599	1.617	1.636	1.654	1.692	1.729	1.766	1.803	1.840	1.877	1.914	1.951	1.988	2.025	2.062
31	1.454	1.472	1.490	1.508	1.526	1.544	1.562	1.580	1.598	1.615	1.633	1.669	1.705	1.741	1.777	1.813	1.848	1.884	1.920	1.956	1.992	2.028
32	1.440	1.457	1.475	1.492	1.509	1.527	1.544	1.561	1.579	1.596	1.614	1.648	1.683	1.718	1.753	1.787	1.822	1.857	1.891	1.926	1.961	2.000
33	1.427	1.443	1.460	1.477	1.494	1.511	1.528	1.544	1.561	1.578	1.595	1.629	1.662	1.696	1.730	1.763	1.797	1.831	1.864	1.898	1.932	1.970
34	1.414	1.430	1.447	1.463	1.479	1.496	1.512	1.528	1.545	1.561	1.577	1.610	1.643	1.676	1.708	1.741	1.774	1.806	1.839	1.872	1.904	1.940
35	1.402	1.418	1.434	1.450	1.466	1.482	1.497	1.513	1.530	1.545	1.561	1.593	1.624	1.656	1.688	1.720	1.752	1.783	1.815	1.847	1.879	1.911
36	1.391	1.406	1.422	1.437	1.453	1.468	1.484	1.499	1.515	1.530	1.545	1.576	1.607	1.638	1.669	1.700	1.731	1.762	1.792	1.823	1.854	1.885
37	1.380	1.395	1.411	1.426	1.441	1.456	1.471	1.486	1.501	1.516	1.531	1.561	1.591	1.621	1.651	1.681	1.711	1.741	1.771	1.801	1.831	1.861
38	1.370	1.385	1.400	1.414	1.429	1.444	1.458	1.473	1.487	1.502	1.517	1.546	1.575	1.604	1.634	1.663	1.692	1.721	1.751	1.780	1.809	1.838
39	1.361	1.375	1.389	1.404	1.418	1.432	1.446	1.461	1.475	1.489	1.503	1.532	1.560	1.589	1.617	1.646	1.674	1.703	1.731	1.760	1.788	1.817
40	1.352	1.366	1.380	1.394	1.408	1.421	1.435	1.449	1.463	1.477	1.491	1.519	1.546	1.574	1.602	1.630	1.658	1.685	1.713	1.741	1.769	1.797
42	1.335	1.348	1.362	1.375	1.388	1.401	1.415	1.428	1.441	1.454	1.467	1.494	1.520	1.547	1.5							

TABLE 2—Concluded

VALUES OF  $A_{ij}/t_s$  FOR FLAT PANELS WITH Z-SECTION STIFFENERS.  $b_r/b_w = 0.4$ —Concluded.

$b_s/t_s$	$b_w/t_w$	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
$t_w/t_s = 0.75$																						
25	1.858	1.893	1.928	1.963	1.998	2.033	2.068	2.103	2.138	2.172	2.207	2.242	2.277	2.311	2.345	2.380	2.414	2.448	2.483	2.517	2.552	2.586
26	1.825	1.859	1.892	1.926	1.959	1.992	2.025	2.058	2.091	2.124	2.157	2.190	2.223	2.256	2.289	2.322	2.355	2.388	2.421	2.454	2.487	2.520
27	1.791	1.824	1.857	1.890	1.923	1.956	1.989	2.021	2.053	2.085	2.118	2.150	2.182	2.214	2.246	2.278	2.310	2.342	2.374	2.406	2.438	2.470
28	1.756	1.789	1.822	1.855	1.888	1.921	1.953	1.984	2.015	2.046	2.077	2.108	2.139	2.170	2.201	2.232	2.262	2.292	2.322	2.352	2.382	2.412
29	1.740	1.770	1.800	1.830	1.860	1.890	1.920	1.950	1.981	2.011	2.041	2.071	2.101	2.131	2.161	2.191	2.221	2.251	2.281	2.311	2.341	2.371
30	1.715	1.744	1.773	1.802	1.831	1.861	1.890	1.919	1.948	1.977	2.006	2.035	2.064	2.093	2.122	2.151	2.180	2.209	2.238	2.267	2.296	2.325
31	1.692	1.720	1.748	1.776	1.805	1.833	1.861	1.889	1.917	1.945	1.973	2.001	2.029	2.057	2.085	2.113	2.141	2.169	2.197	2.225	2.253	2.281
32	1.670	1.698	1.725	1.752	1.779	1.807	1.834	1.861	1.889	1.916	1.943	1.970	1.997	2.024	2.051	2.078	2.105	2.132	2.159	2.186	2.213	2.240
33	1.650	1.676	1.703	1.729	1.756	1.782	1.809	1.835	1.862	1.888	1.915	1.942	1.968	1.995	2.021	2.047	2.073	2.100	2.126	2.152	2.178	2.204
34	1.631	1.657	1.683	1.708	1.734	1.759	1.785	1.811	1.836	1.862	1.888	1.913	1.939	1.964	1.990	2.015	2.041	2.066	2.092	2.117	2.142	2.167
35	1.613	1.638	1.663	1.688	1.713	1.738	1.763	1.788	1.812	1.837	1.862	1.887	1.912	1.936	1.961	1.985	2.010	2.034	2.058	2.082	2.106	2.130
36	1.596	1.620	1.644	1.669	1.693	1.717	1.741	1.766	1.790	1.814	1.838	1.862	1.887	1.911	1.935	1.959	1.983	2.007	2.031	2.055	2.079	2.103
37	1.580	1.603	1.627	1.650	1.674	1.698	1.721	1.745	1.769	1.792	1.816	1.840	1.863	1.887	1.910	1.934	1.957	1.981	2.004	2.028	2.051	2.075
38	1.561	1.585	1.610	1.633	1.656	1.679	1.702	1.725	1.748	1.771	1.794	1.818	1.841	1.864	1.887	1.910	1.933	1.956	1.979	2.002	2.025	2.048
39	1.550	1.572	1.595	1.617	1.640	1.662	1.684	1.707	1.729	1.752	1.774	1.797	1.819	1.841	1.863	1.885	1.907	1.929	1.951	1.973	1.995	2.017
40	1.536	1.558	1.580	1.602	1.624	1.645	1.667	1.689	1.711	1.733	1.755	1.778	1.800	1.822	1.844	1.866	1.888	1.910	1.932	1.954	1.976	1.998
42	1.511	1.531	1.552	1.573	1.594	1.615	1.635	1.656	1.677	1.698	1.719	1.740	1.761	1.782	1.803	1.824	1.845	1.865	1.886	1.907	1.927	1.948
44	1.487	1.507	1.527	1.547	1.567	1.587	1.607	1.626	1.646	1.666	1.686	1.706	1.725	1.745	1.765	1.785	1.805	1.824	1.844	1.863	1.883	1.902
46	1.466	1.485	1.504	1.523	1.542	1.561	1.580	1.599	1.618	1.637	1.656	1.674	1.693	1.712	1.730	1.749	1.768	1.787	1.806	1.824	1.843	1.861
48	1.447	1.465	1.483	1.501	1.519	1.537	1.555	1.573	1.591	1.609	1.627	1.645	1.663	1.681	1.699	1.717	1.735	1.753	1.771	1.789	1.807	1.825
50	1.429	1.446	1.464	1.481	1.499	1.516	1.534	1.551	1.569	1.586	1.604	1.621	1.639	1.657	1.674	1.692	1.710	1.727	1.745	1.762	1.780	1.797
52	1.412	1.429	1.446	1.463	1.480	1.496	1.513	1.530	1.547	1.564	1.580	1.601	1.618	1.634	1.651	1.668	1.684	1.701	1.717	1.734	1.751	1.768
54	1.397	1.413	1.430	1.446	1.462	1.478	1.494	1.510	1.527	1.543	1.559	1.575	1.591	1.607	1.623	1.639	1.655	1.671	1.687	1.703	1.719	1.735
56	1.383	1.399	1.414	1.430	1.445	1.461	1.477	1.492	1.508	1.523	1.539	1.554	1.570	1.585	1.601	1.616	1.631	1.646	1.661	1.676	1.691	1.706
58	1.370	1.385	1.400	1.415	1.430	1.445	1.460	1.475	1.490	1.505	1.520	1.535	1.550	1.565	1.580	1.595	1.610	1.625	1.640	1.655	1.670	1.685
60	1.357	1.372	1.387	1.401	1.416	1.430	1.445	1.459	1.474	1.489	1.503	1.518	1.532	1.547	1.561	1.576	1.590	1.605	1.620	1.634	1.649	1.663
65	1.330	1.343	1.357	1.370	1.384	1.397	1.411	1.424	1.438	1.451	1.464	1.479	1.491	1.518	1.545	1.572	1.599	1.626	1.653	1.679	1.706	1.733
70	1.306	1.319	1.331	1.344	1.356	1.369	1.381	1.394	1.406	1.419	1.431	1.456	1.481	1.506	1.531	1.556	1.581	1.606	1.631	1.656	1.681	1.706
75	1.286	1.298	1.309	1.321	1.333	1.344	1.356	1.368	1.379	1.391	1.402	1.426	1.449	1.472	1.496	1.519	1.542	1.566	1.589	1.612	1.635	1.658
$t_w/t_s = 1.00$																						
25	2.327	2.383	2.439	2.495	2.551	2.607	2.663	2.719	2.775	2.831	2.887	2.943	3.000	3.111	3.223	3.335	3.447	3.559	3.761	3.783	3.805	4.007
26	2.276	2.330	2.383	2.437	2.491	2.545	2.599	2.653	2.706	2.760	2.814	2.868	2.922	3.030	3.137	3.245	3.353	3.460	3.568	3.676	3.783	3.891
27	2.228	2.280	2.332	2.384	2.436	2.488	2.540	2.591	2.643	2.695	2.747	2.799	2.851	2.954	3.058	3.162	3.265	3.369	3.473	3.577	3.680	3.784
28	2.185	2.235	2.285	2.335	2.385	2.435	2.485	2.535	2.585	2.635	2.685	2.735	2.785	2.885	2.985	3.085	3.185	3.285	3.385	3.485	3.585	3.685
29	2.144	2.192	2.240	2.288	2.337	2.385	2.433	2.482	2.530	2.578	2.626	2.674	2.722	2.820	2.916	3.013	3.109	3.206	3.302	3.399	3.495	3.592
30	2.100	2.152	2.200	2.246	2.292	2.339	2.386	2.432	2.478	2.526	2.572	2.618	2.666	2.759	2.852	2.946	3.039	3.132	3.226	3.319	3.412	3.506
31	2.070	2.115	2.160	2.205	2.251	2.296	2.341	2.386	2.432	2.476	2.522	2.567	2.612	2.702	2.792	2.883	2.973	3.063	3.154	3.244	3.334	3.425
32	2.036	2.080	2.124	2.168	2.211	2.255	2.299	2.343	2.386	2.430	2.473	2.516	2.560	2.649	2.736	2.824	2.911	2.999	3.086	3.174	3.261	3.349
33	2.005	2.048	2.090	2.132	2.175	2.217	2.260	2.302	2.344	2.387	2.429	2.471	2.514	2.599	2.684	2.769	2.854	2.939	3.023	3.108	3.193	3.278
34	1.975	2.017	2.058	2.099	2.140	2.181	2.223	2.264	2.305	2.346	2.387	2.428	2.470	2.552	2.634	2.717	2.799	2.881	2.964	3.046	3.128	3.211
35	1.948	1.988	2.028	2.068	2.108	2.148	2.188	2.228	2.268	2.308	2.348	2.388	2.428	2.508	2.588	2.668	2.748	2.828	2.908	2.988	3.068	3.148
36	1.921	1.960	1.999	2.038	2.077	2.116	2.155	2.194	2.232	2.271	2.310	2.348	2.386	2.466	2.544	2.621	2.699	2.777	2.855	2.932	3.010	3.088
37	1.896	1.934	1.972	2.010	2.048	2.086	2.123	2.161	2.199	2.237	2.275	2.313	2.350	2.426	2.502	2.578	2.653	2.729	2.805	2.880	2.956	3.032
38	1.873	1.910	1.946	1.983	2.020	2.057	2.094	2.131	2.168	2.204	2.241	2.278	2.315	2.389	2.462	2.536	2.610	2.683	2.757	2.831	2.904	2.978
39	1.850	1.886	1.922	1.958	1.994	2.030	2.066	2.102	2.138	2.174	2.209	2.245	2.281	2.353	2.425	2.497	2.569	2.640	2.712	2.784	2.856	2.927
40	1.829	1.864	1.899	1.934	1.969	2.004	2.039	2.074	2.109	2.144	2.179	2.214	2.249	2.319	2.389	2.459	2.529	2.599	2.669	2.739	2.809	2.879
42	1.790	1.823	1.856	1.890	1.923	1.956	1.990	2.023	2.056	2.090	2.123	2.156	2.190	2.256	2.323	2.390	2.456	2.523	2.590	2.656	2.723	2.790
44																						

TABLE 3  
VALUES OF  $A_{ts}$  FOR FLAT PANELS WITH Z-SECTION STIFFENERS.  $\frac{b_F}{b_W} = 0.5$

$$\left[ A_{ts} = 1 + \frac{b_W}{t_W} \left( 1 + \frac{b_F}{b_W} \right) + \frac{b_W}{t_W} \left( \frac{t_W}{2} \right) \left( \frac{t_W}{t_W} + \frac{t_W}{t_W} - 1 \right) \left( \frac{t_W}{t_S} \right)^2 \right]$$

$t_W/t_S$	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
$t_W/t_S = 0.51$																					
25	1.395	1.411	1.426	1.442	1.457	1.473	1.489	1.504	1.520	1.535	1.551	1.582	1.613	1.645	1.676	1.707	1.738	1.769	1.801	1.832	1.863
26	1.381	1.395	1.410	1.425	1.440	1.455	1.470	1.485	1.500	1.515	1.530	1.560	1.590	1.620	1.651	1.681	1.710	1.740	1.770	1.800	1.830
27	1.366	1.380	1.395	1.409	1.424	1.438	1.452	1.467	1.481	1.496	1.510	1.539	1.568	1.597	1.626	1.655	1.684	1.712	1.741	1.770	1.799
28	1.353	1.367	1.381	1.394	1.408	1.422	1.436	1.450	1.464	1.478	1.492	1.520	1.548	1.575	1.603	1.631	1.659	1.687	1.715	1.743	1.771
29	1.340	1.354	1.367	1.381	1.394	1.408	1.421	1.435	1.448	1.462	1.475	1.502	1.529	1.556	1.583	1.610	1.636	1.663	1.690	1.717	1.744
30	1.329	1.342	1.355	1.368	1.381	1.394	1.407	1.420	1.433	1.446	1.459	1.485	1.511	1.537	1.563	1.589	1.615	1.641	1.667	1.693	1.719
31	1.319	1.331	1.344	1.356	1.369	1.381	1.394	1.407	1.419	1.432	1.444	1.470	1.495	1.520	1.545	1.570	1.595	1.621	1.646	1.671	1.696
32	1.309	1.321	1.333	1.345	1.357	1.370	1.382	1.394	1.406	1.418	1.430	1.455	1.479	1.504	1.528	1.552	1.577	1.601	1.626	1.650	1.674
33	1.299	1.311	1.323	1.335	1.347	1.358	1.370	1.382	1.394	1.406	1.417	1.441	1.465	1.488	1.512	1.536	1.559	1.583	1.607	1.630	1.654
34	1.291	1.302	1.313	1.325	1.336	1.348	1.359	1.371	1.382	1.394	1.405	1.428	1.451	1.474	1.497	1.520	1.543	1.566	1.589	1.612	1.635
35	1.282	1.293	1.304	1.316	1.327	1.338	1.349	1.360	1.371	1.382	1.394	1.416	1.438	1.460	1.483	1.505	1.527	1.550	1.572	1.594	1.616
36	1.274	1.285	1.296	1.307	1.318	1.328	1.339	1.350	1.361	1.372	1.383	1.404	1.426	1.448	1.469	1.491	1.513	1.534	1.556	1.578	1.599
37	1.267	1.277	1.288	1.298	1.309	1.320	1.330	1.341	1.351	1.362	1.372	1.393	1.414	1.435	1.457	1.478	1.499	1.520	1.541	1.562	1.583
38	1.260	1.270	1.280	1.291	1.301	1.311	1.321	1.332	1.342	1.352	1.363	1.383	1.404	1.424	1.445	1.465	1.486	1.506	1.527	1.547	1.568
39	1.253	1.263	1.273	1.283	1.293	1.303	1.313	1.323	1.333	1.343	1.353	1.373	1.393	1.413	1.433	1.453	1.473	1.493	1.513	1.533	1.553
40	1.247	1.257	1.266	1.276	1.286	1.296	1.305	1.315	1.325	1.335	1.344	1.364	1.383	1.403	1.422	1.442	1.461	1.481	1.500	1.520	1.539
42	1.235	1.244	1.254	1.263	1.272	1.282	1.291	1.300	1.309	1.319	1.328	1.347	1.365	1.384	1.402	1.421	1.439	1.458	1.477	1.495	1.514
44	1.221	1.229	1.237	1.245	1.253	1.261	1.269	1.277	1.285	1.293	1.301	1.319	1.336	1.354	1.371	1.389	1.407	1.424	1.442	1.459	1.477
46	1.215	1.223	1.230	1.238	1.245	1.252	1.259	1.266	1.273	1.280	1.287	1.304	1.321	1.338	1.354	1.371	1.388	1.404	1.421	1.438	1.454
48	1.206	1.214	1.222	1.229	1.236	1.243	1.250	1.257	1.264	1.271	1.278	1.295	1.311	1.327	1.343	1.359	1.374	1.390	1.406	1.421	1.437
50	1.197	1.205	1.212	1.220	1.227	1.234	1.241	1.248	1.255	1.262	1.269	1.286	1.302	1.317	1.332	1.348	1.363	1.378	1.393	1.408	1.423
52	1.191	1.197	1.205	1.212	1.220	1.227	1.235	1.242	1.250	1.257	1.265	1.280	1.295	1.310	1.325	1.340	1.355	1.370	1.385	1.400	1.415
54	1.183	1.190	1.197	1.205	1.212	1.219	1.226	1.233	1.241	1.248	1.255	1.270	1.283	1.298	1.313	1.327	1.342	1.356	1.371	1.385	1.400
56	1.176	1.183	1.190	1.197	1.204	1.211	1.218	1.225	1.232	1.239	1.246	1.260	1.273	1.288	1.302	1.316	1.330	1.344	1.357	1.371	1.385
58	1.170	1.177	1.184	1.190	1.197	1.204	1.211	1.217	1.224	1.231	1.237	1.251	1.263	1.278	1.291	1.305	1.318	1.332	1.345	1.359	1.372
60	1.165	1.171	1.178	1.184	1.191	1.197	1.204	1.210	1.217	1.223	1.230	1.243	1.256	1.269	1.282	1.295	1.308	1.321	1.334	1.347	1.360
65	1.152	1.158	1.164	1.170	1.176	1.182	1.188	1.194	1.200	1.206	1.212	1.224	1.236	1.248	1.260	1.272	1.284	1.296	1.308	1.320	1.332
70	1.141	1.147	1.152	1.158	1.163	1.169	1.175	1.180	1.186	1.191	1.197	1.208	1.219	1.230	1.241	1.253	1.264	1.275	1.286	1.297	1.308
75	1.132	1.137	1.142	1.147	1.152	1.158	1.163	1.168	1.173	1.178	1.184	1.191	1.204	1.215	1.226	1.236	1.246	1.256	1.267	1.277	1.288
$t_W/t_S = 0.53$																					
25	1.595	1.619	1.642	1.666	1.690	1.714	1.738	1.762	1.785	1.809	1.833	1.881	1.928	1.976	2.024	2.071	2.119	2.166	2.214	2.262	2.309
26	1.572	1.595	1.618	1.641	1.664	1.686	1.709	1.732	1.755	1.778	1.810	1.847	1.893	1.938	1.984	2.030	2.076	2.122	2.167	2.213	2.259
27	1.551	1.573	1.595	1.617	1.639	1.661	1.683	1.705	1.727	1.749	1.771	1.815	1.860	1.904	1.948	1.992	2.036	2.080	2.124	2.168	2.212
28	1.531	1.552	1.574	1.595	1.616	1.637	1.659	1.680	1.701	1.722	1.744	1.786	1.829	1.871	1.914	1.956	1.999	2.042	2.084	2.127	2.169
29	1.513	1.533	1.554	1.574	1.595	1.615	1.636	1.657	1.677	1.698	1.718	1.759	1.800	1.841	1.882	1.923	1.964	2.006	2.047	2.088	2.129
30	1.496	1.516	1.535	1.555	1.575	1.595	1.615	1.635	1.654	1.674	1.694	1.734	1.774	1.813	1.853	1.893	1.932	1.972	2.012	2.051	2.091
31	1.480	1.499	1.518	1.537	1.557	1.576	1.595	1.614	1.633	1.653	1.672	1.710	1.749	1.787	1.825	1.864	1.902	1.941	1.979	2.018	2.056
32	1.465	1.483	1.502	1.521	1.539	1.558	1.576	1.595	1.614	1.632	1.651	1.688	1.725	1.762	1.800	1.837	1.874	1.911	1.949	1.986	2.023
33	1.451	1.469	1.487	1.505	1.523	1.541	1.559	1.577	1.595	1.613	1.631	1.667	1.703	1.739	1.775	1.811	1.848	1.884	1.920	1.956	1.992
34	1.437	1.455	1.472	1.490	1.507	1.525	1.542	1.560	1.578	1.595	1.613	1.648	1.683	1.718	1.753	1.788	1.823	1.858	1.893	1.928	1.963
35	1.425	1.442	1.459	1.476	1.493	1.510	1.527	1.544	1.561	1.578	1.595	1.629	1.663	1.697	1.731	1.765	1.799	1.833	1.867	1.901	1.935
36	1.413	1.430	1.446	1.463	1.479	1.496	1.512	1.529	1.545	1.562	1.578	1.612	1.645	1.678	1.711	1.744	1.777	1.810	1.843	1.876	1.909
37	1.402	1.418	1.434	1.450	1.466	1.482	1.498	1.515	1.531	1.547	1.563	1.595	1.627	1.659	1.692	1.724	1.756	1.788	1.820	1.853	1.885
38	1.391	1.407	1.423	1.438	1.454	1.470	1.485	1.501	1.517	1.532	1.548	1.579	1.611	1.642	1.673	1.705	1.736	1.767	1.799	1.830	1.861
39	1.381	1.397	1.412	1.427	1.442	1.458	1.473	1.488	1.503	1.519	1.534	1.565	1.595	1.626	1.656	1.687	1.717	1.748	1.778	1.809	1.839
40	1.372	1.387	1.402	1.416	1.431	1.446	1.461	1.476	1.491	1.506	1.521	1.550	1.580	1.610	1.640	1.669	1.699	1.729	1.759	1.789	1.818
42	1.354	1.368	1.382	1.397	1.411	1.425	1.439	1.453	1.468	1.482	1.496	1.521	1.553	1.584	1.609	1.638	1.666	1.694	1.723	1.751	1.779
44	1.338	1.352	1.365	1.379	1.392	1.406	1.419	1.433	1.446	1.460	1.473	1.500	1.531	1.562	1.592	1.620	1.648	1.676	1.704	1.731	1.759
46	1.323	1.336	1.349	1.362	1.375	1.388	1.401	1.414	1.427	1.440	1.453	1.479	1.509	1.539	1.568	1.596					

TABLE 3—Concluded

VALUES OF  $A_e/b_s$  FOR FLAT PANELS WITH Z-SECTION STIFFENERS,  $b_w/b_s = 0.5$ —Concluded.

$b_w/b_s$	$b_w/b_s$	$t_w/t_s = 0.70$																			
		20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48
25	1.908	1.915	1.983	2.020	2.058	2.095	2.133	2.170	2.207	2.245	2.282	2.357	2.432	2.507	2.582	2.657	2.732	2.807	2.881	2.956	3.031
26	1.873	1.909	1.915	1.981	2.017	2.053	2.089	2.125	2.161	2.197	2.233	2.305	2.377	2.449	2.521	2.593	2.665	2.737	2.809	2.881	2.953
27	1.841	1.875	1.910	1.945	1.979	2.014	2.049	2.083	2.118	2.153	2.187	2.257	2.326	2.395	2.465	2.534	2.603	2.673	2.742	2.811	2.881
28	1.811	1.844	1.877	1.911	1.944	1.978	2.011	2.045	2.078	2.111	2.145	2.212	2.279	2.346	2.412	2.479	2.546	2.613	2.680	2.747	2.814
29	1.783	1.815	1.847	1.879	1.912	1.944	1.976	2.009	2.041	2.073	2.105	2.170	2.235	2.299	2.364	2.428	2.493	2.557	2.622	2.686	2.751
30	1.756	1.788	1.819	1.850	1.881	1.913	1.944	1.975	2.006	2.037	2.069	2.131	2.193	2.256	2.318	2.381	2.443	2.505	2.568	2.630	2.693
31	1.732	1.762	1.793	1.823	1.853	1.883	1.913	1.943	1.974	2.004	2.034	2.095	2.155	2.215	2.276	2.336	2.396	2.457	2.517	2.578	2.638
32	1.709	1.738	1.768	1.797	1.826	1.855	1.885	1.914	1.943	1.973	2.002	2.060	2.119	2.177	2.236	2.294	2.353	2.411	2.470	2.528	2.587
33	1.688	1.716	1.744	1.773	1.801	1.829	1.858	1.886	1.915	1.943	1.971	2.028	2.085	2.142	2.198	2.255	2.312	2.369	2.425	2.482	2.539
34	1.668	1.695	1.723	1.750	1.778	1.805	1.833	1.860	1.888	1.915	1.943	1.998	2.053	2.108	2.163	2.218	2.273	2.328	2.383	2.438	2.494
35	1.648	1.675	1.702	1.729	1.755	1.782	1.809	1.836	1.862	1.889	1.916	1.969	2.023	2.076	2.130	2.183	2.237	2.290	2.344	2.397	2.451
36	1.630	1.656	1.682	1.708	1.734	1.760	1.786	1.812	1.838	1.864	1.890	1.942	1.994	2.047	2.099	2.151	2.203	2.255	2.307	2.359	2.411
37	1.614	1.639	1.664	1.689	1.715	1.740	1.765	1.790	1.816	1.841	1.866	1.917	1.968	2.018	2.069	2.119	2.170	2.221	2.271	2.322	2.372
38	1.597	1.622	1.647	1.671	1.696	1.720	1.745	1.770	1.794	1.819	1.844	1.893	1.942	1.991	2.041	2.090	2.139	2.189	2.238	2.287	2.336
39	1.582	1.606	1.630	1.654	1.678	1.702	1.726	1.750	1.774	1.798	1.822	1.870	1.918	1.966	2.014	2.062	2.110	2.158	2.206	2.254	2.302
40	1.567	1.591	1.614	1.638	1.661	1.684	1.708	1.731	1.755	1.778	1.801	1.848	1.895	1.942	1.989	2.035	2.082	2.129	2.176	2.223	2.270
42	1.540	1.563	1.585	1.607	1.630	1.652	1.674	1.696	1.719	1.741	1.763	1.808	1.852	1.897	1.942	1.986	2.031	2.075	2.120	2.165	2.209
44	1.516	1.537	1.558	1.580	1.601	1.622	1.643	1.665	1.686	1.707	1.729	1.771	1.814	1.856	1.899	1.941	1.984	2.026	2.069	2.112	2.154
46	1.493	1.514	1.534	1.554	1.575	1.595	1.615	1.636	1.656	1.677	1.697	1.738	1.778	1.819	1.860	1.900	1.941	1.982	2.023	2.063	2.104
48	1.473	1.492	1.512	1.531	1.551	1.570	1.590	1.609	1.629	1.648	1.668	1.707	1.746	1.785	1.824	1.863	1.902	1.941	1.980	2.019	2.058
50	1.454	1.473	1.491	1.510	1.529	1.548	1.566	1.585	1.604	1.622	1.641	1.679	1.716	1.753	1.791	1.828	1.866	1.903	1.941	1.978	2.016
52	1.436	1.454	1.472	1.490	1.508	1.526	1.544	1.562	1.580	1.598	1.616	1.652	1.688	1.724	1.760	1.796	1.831	1.869	1.905	1.941	1.977
54	1.420	1.438	1.455	1.472	1.490	1.507	1.524	1.542	1.559	1.576	1.594	1.628	1.663	1.698	1.732	1.767	1.802	1.836	1.871	1.906	1.940
56	1.405	1.422	1.439	1.455	1.472	1.489	1.506	1.522	1.539	1.556	1.572	1.605	1.639	1.673	1.706	1.740	1.773	1.806	1.840	1.873	1.907
58	1.391	1.407	1.424	1.440	1.456	1.472	1.488	1.504	1.520	1.537	1.553	1.585	1.617	1.650	1.682	1.714	1.746	1.779	1.811	1.843	1.875
60	1.378	1.394	1.409	1.425	1.441	1.456	1.472	1.487	1.503	1.519	1.534	1.565	1.597	1.628	1.659	1.690	1.722	1.753	1.784	1.815	1.846
65	1.349	1.364	1.378	1.392	1.407	1.421	1.436	1.450	1.464	1.479	1.493	1.522	1.551	1.580	1.608	1.637	1.666	1.695	1.724	1.752	1.781
70	1.324	1.338	1.351	1.364	1.378	1.391	1.404	1.418	1.431	1.445	1.458	1.485	1.511	1.538	1.565	1.592	1.618	1.645	1.672	1.699	1.725
75	1.303	1.315	1.328	1.340	1.353	1.365	1.377	1.390	1.402	1.415	1.427	1.452	1.477	1.502	1.527	1.552	1.577	1.602	1.627	1.652	1.677
$t_w/t_s = 1.00$																					
25	2.407	2.467	2.527	2.587	2.647	2.707	2.767	2.827	2.887	2.947	3.007	3.127	3.247	3.367	3.487	3.607	3.727	3.847	3.967	4.087	4.207
26	2.353	2.410	2.468	2.526	2.583	2.641	2.699	2.756	2.814	2.872	2.930	3.045	3.160	3.275	3.391	3.506	3.622	3.737	3.853	3.968	4.083
27	2.302	2.358	2.414	2.469	2.525	2.580	2.636	2.691	2.747	2.802	2.858	2.969	3.080	3.191	3.302	3.414	3.525	3.636	3.747	3.858	3.969
28	2.256	2.310	2.363	2.417	2.470	2.523	2.577	2.631	2.685	2.738	2.792	2.899	3.006	3.113	3.220	3.327	3.435	3.542	3.649	3.756	3.863
29	2.213	2.264	2.316	2.368	2.420	2.471	2.523	2.575	2.628	2.678	2.730	2.833	2.937	3.040	3.144	3.247	3.351	3.454	3.558	3.661	3.764
30	2.172	2.222	2.272	2.322	2.372	2.422	2.472	2.522	2.572	2.622	2.672	2.772	2.872	2.972	3.072	3.172	3.272	3.372	3.472	3.572	3.672
31	2.134	2.183	2.231	2.280	2.328	2.376	2.425	2.473	2.522	2.570	2.618	2.715	2.812	2.909	3.005	3.102	3.199	3.296	3.392	3.489	3.586
32	2.099	2.146	2.193	2.240	2.286	2.333	2.380	2.427	2.474	2.521	2.568	2.661	2.755	2.849	2.943	3.036	3.130	3.224	3.318	3.411	3.505
33	2.066	2.111	2.157	2.202	2.248	2.293	2.338	2.384	2.429	2.475	2.520	2.611	2.702	2.793	2.884	2.975	3.066	3.157	3.248	3.339	3.429
34	2.034	2.078	2.123	2.168	2.211	2.254	2.299	2.343	2.387	2.431	2.475	2.564	2.652	2.740	2.828	2.917	3.005	3.093	3.181	3.270	3.358
35	2.005	2.048	2.090	2.133	2.176	2.219	2.262	2.305	2.348	2.390	2.433	2.519	2.605	2.690	2.776	2.862	2.948	3.033	3.119	3.205	3.290
36	1.977	2.019	2.060	2.102	2.144	2.185	2.227	2.269	2.310	2.352	2.394	2.477	2.560	2.644	2.727	2.810	2.894	2.977	3.060	3.144	3.227
37	1.950	1.991	2.032	2.072	2.113	2.153	2.194	2.234	2.275	2.315	2.356	2.437	2.518	2.599	2.680	2.761	2.842	2.923	3.005	3.086	3.167
38	1.925	1.965	2.004	2.044	2.083	2.123	2.162	2.202	2.241	2.281	2.320	2.399	2.478	2.557	2.636	2.715	2.794	2.873	2.952	3.031	3.110
39	1.902	1.940	1.979	2.017	2.055	2.094	2.133	2.171	2.209	2.248	2.286	2.363	2.440	2.517	2.594	2.671	2.748	2.825	2.902	2.979	3.056
40	1.879	1.917	1.954	1.992	2.029	2.067	2.104	2.142	2.179	2.217	2.254	2.329	2.404	2.479	2.554	2.629	2.704	2.779	2.854	2.929	3.004
42	1.837	1.873	1.909	1.944	1.980	2.016	2.052	2.087	2.123	2.159	2.195	2.266	2.337	2.409	2.480	2.552	2.623	2.695	2.766	2.837	2.909
44	1.799	1.833	1.867	1.901	1.936	1.970	2.004	2.038	2.072	2.106	2.140	2.208	2.277	2.345	2.413	2.481	2.549	2.617	2.686	2.754	2.822
46	1.764	1.797	1.830	1.862	1.895	1.928	1.960	1.993	2.025	2.058	2.091	2.156	2.221	2.286	2.351	2.417	2.482	2.547	2.612	2.678	2.743
48	1.733	1.764	1.795	1.826	1.858	1.889	1.920	1.951	1.983	2.014	2.045	2.108	2.170	2.233	2.295	2.358	2.420	2.483	2.545	2.608	2.670
50	1.703	1.733	1.763	1.793	1.823	1.853	1.883	1.913	1.943	1.973	2.003	2.063	2.123	2.183	2.243	2.303	2.363	2.423	2.483	2.543	2.603
52	1.676	1.705	1.734	1.763	1.792	1.821	1.849	1.878	1.907	1.936	1.965	2.022	2.080	2.138	2.196	2.253	2.311	2.369	2.426	2.484	2.542
54	1.651	1.679	1.707	1.735	1.762	1.790	1.818	1.846	1.873	1.901	1.929	1.985	2.040	2.096	2.151	2.207	2.262	2.318	2.374	2.429	2.485
56	1.628	1.655	1.682	1.708	1.735	1.762	1.789	1.815	1.842	1.869	1.896	1.949	2.003	2.057	2.110	2.164	2.217	2.271	2.324	2.378	2.432
58	1.606	1.632	1.658	1.684	1.710	1.736	1.761	1.787	1.												

TABLE 4  
VALUES AND COMPUTATIONS FOR OBTAINING IDEAL DESIGN  
[ $P_1=3.0$  kips/in.;  $e=1$ ]

L (in.)	Step 1	Step 2			Step 3	Step 4	Step 5			
	$\frac{P_1}{L\sqrt{e}}$ (kips/in.)	$\frac{t_w}{t_s}$	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_1}{t_s}$	$\frac{t_w}{t_s}$	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	
10	0.30	0.51	27	26	* 31.0	1.427	* 0.0618	* 0.0315	* 1.67	* 0.82
	.63	.28	25	25	35.6	1.602	.0526	.0331	1.17	.83
	.79	.29	21	21	36.7	1.800	.0110	.0318	1.28	.83
	1.00	.29	21	21	37.4	2.337	.0343	.0343	1.00	.82
20	.15	.51	32	32	28.7	1.429	.0732	.0373	2.31	1.19
	.63	.33	31	31	* 30.4	1.612	* .0612	* .0386	* 2.02	* 1.20
	.79	.31	29	29	31.6	1.862	.0510	.0403	1.73	1.17
	1.00	.35	28	28	32.2	2.268	.0411	.0411	1.44	1.15
30	.10	.51	34	37	25.0	1.457	.0824	.0421	2.80	1.56
	.63	.35	35	35	* 27.1	1.640	* .0675	* .0425	* 2.36	* 1.49
	.79	.37	33	33	27.8	1.886	.0572	.0452	2.12	1.49
	1.00	.38	31	31	28.6	2.278	.0461	.0461	1.75	1.43

\* Values indicating designs that approach requirement of  $t_s=0.064$  in.

TABLE 5  
VALUES AND COMPUTATIONS FOR OBTAINING PRACTICAL DESIGN BY SHORT METHOD

[ $P_1=3.0$  kips/in.;  $L=20$  in.;  $e=1$ ;  $t_s=0.064$  in.;  $\frac{t_w}{t_s}=0.79$ ]

Step 1	Step 2			Step 3	Step 4	Step 5			Step 6		Step 7		$\sigma_{cr}$ (ksi)	
$\frac{P_1}{L\sqrt{e}}$ (kips/in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_1}{t_s}$	$\frac{t_s}{t_s}$ (in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_1}{t_s}$	$\frac{P_1}{t_s}$ (kips/in.)	$\frac{t_w}{t_s}$ (in.)	$\frac{b_s}{t_s}$ (in.)		$\frac{b_w}{t_s}$ (in.)
0.15	30	30	30.9	2.096	0.0484	43.3	26.1	28.8	1.619	2.98	0.051	2.77	1.33	23.5
	35	30	31.7	1.862	.0508									
	40	28	29.7	1.711	.0590									
	50	26	27.1	1.531	.0722									

TABLE 6

VALUES AND COMPUTATIONS FOR OBTAINING DESIGN FOR MAXIMUM STRUCTURAL EFFICIENCY

[ $P_1=3.0$  kips/in.;  $L=20$  in.;  $e=1$ ;  $t_s=0.064$  in.;  $\frac{t_w}{t_s}=0.79$ ]

Step 1	Step 2			Step 3	Step 4	Step 7			Step 8		Step 9		$\sigma_{cr}$ (ksi)	
$\frac{P_1}{L\sqrt{e}}$ (kips/in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_1}{t_s}$	$\frac{t_s}{t_s}$ (in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_1}{t_s}$	$\frac{P_1}{t_s}$ (kips/in.)	$\frac{t_w}{t_s}$ (in.)	$\frac{b_s}{t_s}$ (in.)		$\frac{b_w}{t_s}$ (in.)
0.15	20	25	26.4	1.858	0.0612	42.1	25.0	29.0	1.612	2.99	0.051	2.69	1.27	24.6
		30	27.1	1.715	.0646									
		35	27.3	1.613	.0682									
		40	27.8	1.536	.0702									
	25	30	29.9	1.861	.0549									
		35	30.2	1.738	.0572									
		40	29.5	1.645	.0618									
		50	27.1	1.516	.0730									
	30	35	31.7	1.862	.0508									
		40	29.6	1.755	.0578									
		50	26.9	1.604	.0696									
		60	24.5	1.503	.0814									
40	35	26.2	2.112	.0542										
	40	25.8	1.973	.0589										
	50	23.8	1.778	.0709										
	60	22.6	1.649	.0805										
50	35	23.2	2.362	.0547										
	40	23.4	2.192	.0584										
	50	22.3	1.953	.0688										
	60	20.7	1.794	.0812										

TABLE 7

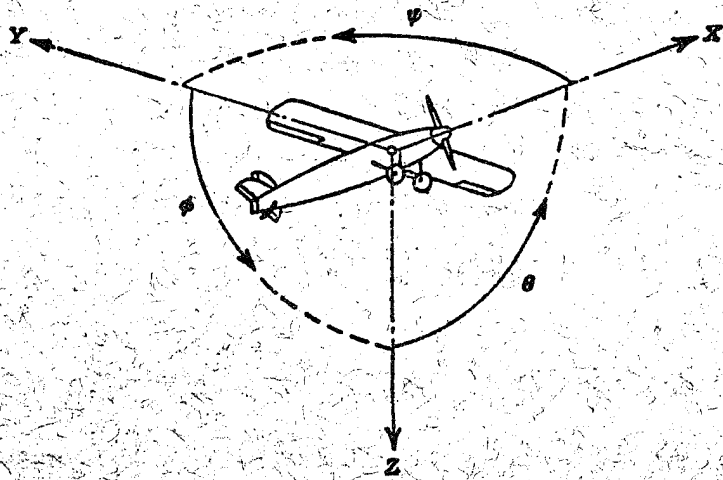
TEST DATA ON WHICH DESIGN CHARTS ARE BASED FOR 24S-T ALUMINUM-ALLOY FLAT PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS

$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\frac{b_r}{b_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_c}{L/\sqrt{c}}$ (kips/in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\frac{b_r}{b_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_c}{L/\sqrt{c}}$ (kips/in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\frac{b_r}{b_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_c}{L/\sqrt{c}}$ (kips/in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\frac{b_r}{b_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_c}{L/\sqrt{c}}$ (kips/in.)	
																				$t_w = 0.51$
25	20	0.4	37.0	0.646	50	25	0.3	25.2	0.430	25	20	0.4	38.9	0.626	50	25	0.3	27.4	0.329	
			33.7	.365				24.7	.241				33.4	.307				25.0	.171	
			25.2	.188				20.8	.140				24.9	.159				20.6	.099	
			14.8	.082				15.2	.070				14.3	.065				13.5	.047	
	25	.4	.4	36.3	.550	30	.4	.4	25.9	.431	30	.4	.4	38.9	.517	30	.4	.4	28.0	.323
				33.8	.298				24.0	.217				32.4	.242				25.0	.168
				26.0	.159				22.2	.144				24.8	.132				20.4	.094
				15.6	.066				13.6	.061				14.2	.054				13.5	.044
	30	.4	.4	33.8	.442	30	.5	.5	26.5	.403	30	.4	.4	36.3	.420	30	.5	.5	28.0	.365
				31.3	.227				24.9	.217				30.9	.199				26.2	.183
				26.0	.131				22.8	.140				24.6	.113				23.0	.117
				15.4	.056				15.9	.069				16.6	.055				17.2	.073
40	.4	.4	29.3	.295	30	.3	.3	25.6	.355	40	.4	.4	29.4	.275	30	.3	.3	26.0	.279	
			23.9	.137				24.3	.192				24.2	.131				24.9	.152	
			22.5	.090				22.6	.123				23.5	.088				22.9	.087	
			16.8	.048				15.7	.061				16.6	.042				16.3	.049	
50	.4	.4	25.9	.222	30	.4	.4	25.0	.323	50	.4	.4	25.2	.210	30	.4	.4	25.8	.266	
			20.5	.101				23.8	.176				22.1	.104				26.9	.167	
			17.7	.061				22.6	.117				18.7	.061				23.2	.095	
			16.4	.049				16.4	.060				15.4	----				16.2	.048	
35	20	.3	31.5	.644	75	20	.3	25.5	.321	35	20	.3	32.0	.516	75	20	.3	26.2	.261	
			30.6	.358				24.4	.174				32.8	.304				24.0	.135	
			25.6	.211				23.0	.116				25.4	.168				22.3	.088	
			14.9	.088				16.5	.059				15.6	.072				17.1	.049	
	.4	.4	.4	31.2	.611	40	.4	.4	23.3	.219	40	.4	.4	33.5	.524	40	.4	.4	23.8	.187
				31.2	.347				22.2	.118				34.0	.306				22.4	.101
				23.8	.203				20.2	.078				28.3	.179				21.4	.067
				15.2	.086				15.7	.041				15.4	.069				17.4	.040
	.5	.5	.5	31.4	.587	50	.4	.4	21.3	.159	50	.4	.4	33.5	.506	50	.4	.4	21.5	.141
				30.3	.325				19.1	.080				32.0	.275				19.6	.071
				26.4	.202				18.0	.054				29.4	.178				17.9	.046
				13.4	.073				15.6	.037				17.7	.075				16.9	.037
25	.3	.3	32.5	.533	75	20	.3	22.4	.591	25	.3	.3	33.1	.430	75	20	.3	22.0	.281	
			31.7	.295				18.4	.252				32.4	.243				20.2	.206	
			26.6	.171				16.5	.158				24.7	.127				15.8	.110	
			16.8	.078				12.2	.084				14.4	.053				13.0	.065	
.4	.4	.4	30.9	.477	40	.4	.4	20.5	.471	40	.4	.4	33.8	.419	40	.4	.4	22.7	.374	
			31.2	.278				19.2	.245				32.4	.235				21.3	.200	
			26.9	.169				16.7	.149				26.1	.130				17.2	.113	
			13.4	.060				12.0	.078				15.1	.055				12.5	.059	
.5	.5	.5	32.3	.486	50	.5	.5	21.2	.454	50	.5	.5	32.5	.429	50	.5	.5	22.4	.372	
			31.4	.271				18.6	.227				30.9	.238				20.5	.181	
			27.0	.163				17.2	.148				28.2	.158				18.5	.114	
			14.4	.062				13.3	.085				17.4	.068				13.9	.064	
30	.3	.3	31.4	.427	25	.3	.3	21.0	.378	30	.3	.3	30.7	.335	25	.3	.3	22.7	.281	
			30.7	.235				18.6	.191				29.9	.186				19.2	.134	
			27.0	.145				16.5	.118				27.9	.122				15.6	.076	
			16.8	.064				13.7	.069				17.9	.055				12.1	.043	
.4	.4	.4	30.7	.391	40	.4	.4	21.0	.360	40	.4	.4	30.7	.329	40	.4	.4	22.1	.257	
			31.0	.227				19.4	.189				31.4	.193				19.6	.132	
			27.4	.141				17.5	.121				28.1	.121				16.4	.076	
			17.4	.064				12.2	.059				16.5	.057				11.3	.038	
.5	.5	.5	31.1	.392	50	.5	.5	20.9	.343	50	.5	.5	30.4	.314	50	.5	.5	22.7	.304	
			30.3	.242				19.4	.182				29.1	.173				20.9	.161	
			27.5	.138				17.6	.115				27.6	.115				18.1	.097	
			17.5	.062				12.8	.061				18.0	.054				13.8	.053	
40	.4	.4	26.5	.252	30	.3	.3	19.9	.289	40	.4	.4	27.8	.235	30	.3	.3	20.6	.226	
			25.6	.142				18.8	.155				24.9	.118				19.6	.121	
			23.6	.091				16.4	.094				23.8	.080				18.6	.081	
			16.8	.046				13.6	.055				16.9	.042				13.8	.043	
50	.4	.4	23.9	.183	40	.4	.4	19.1	.268	50	.4	.4	24.0	.173	40	.4	.4	21.2	.219	
			21.8	.079				18.8	.156				21.9	.089				21.0	.128	
			20.8	.065				17.7	.098				19.2	.054				18.8	.079	
			16.0	.042				13.4	.053				14.4	----				14.1	.042	
50	20	.3	26.2	.577	50	.5	.5	20.6	.272	50	20	.3	28.2	.450	50	.5	.5	21.0	.207	
			24.0	.300				19.8	.148				25.0	.233				20.2	.121	
			21.9	.193				17.0	.089				21.8	.144				18.0	.075	
			15.0	.092				13.2	.049				15.1	.071				14.2	.040	
.4	.4	.4	26.7	.557	40	.4	.4	19.2	.186	40	.4	.4	28.3	.447	40	.4	.4	18.6	.138	
			25.1	.297				17.9	.100				25.8	.230				18.2	.081	
			21.2	.177				16.8	.065				22.2	.140				17.5	.053	
			14.6	.087				12.8	.035				14.5	.065				13.4	.029	
.5	.5	.5	26.3	.531	50	.4	.4	17.0	.129	50	.5	.5	27.4	.410	50	.4	.4	17.7	.105	
			23.7	.266				16.2	.070				25.5	.216				17.5	.061	
			21.1	.170				14.9	.046				22.9	.137				16.0	.039	
			15.0	.086				11.7	.025				16.3	.069				13.1	.024	

TABLE 7—Concluded

TEST DATA ON WHICH DESIGN CHARTS ARE BASED FOR 24S-T ALUMINUM-ALLOY FLAT PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS—Concluded

$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\frac{b_f}{b_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_f}{L\sqrt{c}}$ (kips/in. in.)	$\frac{t_w}{t_s}=0.75$				$\frac{t_w}{t_s}=1.00$															
					$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\frac{b_f}{b_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_f}{L\sqrt{c}}$ (kips/in. in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\frac{b_f}{b_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_f}{L\sqrt{c}}$ (kips/in. in.)										
35	20	0.3	34.5	0.470	50	25	0.4	23.3	0.092	35	20	0.3	36.3	0.430	50	25	0.4	21.5	0.083					
			34.4	.270				17.0	.048				32.8	.215				18.0	.046					
		26.9	.148	.5		28.5	.309	26.8	.123			.5	30.8	.270										
		16.5	.063			27.4	.169	17.6	.059				27.9	.139										
		.4	35.7	.472		30	.3	23.5	.102			.4	36.7	.418										
			34.6	.265				17.2	.053				33.7	.222		23.9	.081							
	29.7		.157	.5	27.8		.250	.5	27.3		.122													
	16.8		.062		26.6		.137		17.5		.057		17.5	.041										
	.5		34.8	.449	75		.3		23.6		.084		.5	36.1	.414									
			33.7	.249					17.6		.041			34.1	.223	23.3	.070							
		27.7	.141	.4		27.6	.238		.4		28.0	.130												
		17.6	.065			26.6	.134				17.2	.057		16.6	.037									
25		.3	37.0	.394		25	.3	22.6		.079	25	.3		33.5	.333	30	.3	28.2	.213					
			32.6	.202				17.2		.043				31.7	.180			25.9	.112					
	.4	28.2	.126	.5	26.9		.234	.4		27.3		.108	.5	28.1	.052		.5	28.1	.216					
		17.6	.056		25.0		.122			18.1		.052		26.3	.117									
	.5	35.2	.374	20	.3		23.7		.081	.5		35.4		.347	75		.3	20	.3	24.0	.235			
		33.3	.204				16.5		.040			31.8		.177						22.7	.070			
.4		29.3	.123		.4	22.9	.306		.4		28.7	.112		.5		.5	20	.3	24.0	.235				
		17.1	.052			21.7	.167				16.4	.047							23.2	.129				
.5		33.2	.357		25	.3	17.4	.092			.5	35.3	.358			25	.3	20	.3	24.0	.235			
		33.8	.213				12.7	.049				33.1	.190							14.6	.041			
	.4	17.7	.056	.4		24.7	.313	.4		25.3		.103	.5		.5		20	.3	25.9	.245				
		33.8	.340			23.1	.108			16.8		.048							23.8	.128				
	30	.3	32.0	.181		30	.3		20.4	.106		30		.3	33.1		.290	25	.3	20.1	.076			
			28.5	.110					14.2	.052					29.4		.149			14.3	.039			
.4		18.6	.052	.5	24.2		.298		.4	23.6	.084			.5	.5	20	.3		26.1	.250				
		32.5	.313		22.3		.157			15.0	.037								24.7	.129				
.5		31.7	.173	25	.3		19.4	.094		.5	33.3		.291		25	.3	20		.3	24.2	.200			
		28.2	.107				13.3	.046			31.6		.163							22.4	.101			
	.4	17.5	.048		.4	22.2	.125	.4			23.8	.083	.5			.5	20	.3	24.2	.200				
		31.2	.302			19.3	.077				15.1	.038							22.4	.101				
	50	20	.3		27.2	.205	50		20		.3	32.7		.300		50	20	.3	20	.3	20.7	.066		
					23.4	.123						13.8		.040							30.1	.160	14.7	.033
.4		16.2	.061	.5	24.4	.236			.4	26.0	.095	.5		.5	20		.3	25.8	.199					
		29.6	.374		22.6	.125				13.5	.036							24.1	.106					
.5		27.2	.194	30	.3	19.5		.075		.5	32.0		.320	30	.3		20	.3	25.5	.199				
		23.2	.115			13.4		.037			27.8		.165						14.3	.033				
	.4	16.4	.059		.4	22.9	.242	.4			23.2		.096		.5	.5	20	.3	25.5	.199				
		29.7	.365			19.9	.077				18.5		.051						20.7	.066				
	.5	28.5	.201		25	.3	14.4		.035		.5	31.6	.322			25	.3	20	.3	24.1	.106			
		23.1	.112				.4		24.4			.236	.4							29.1	.167	.5	.5	20
.4		16.4	.082	.4		22.9			.199	.4		24.1		.096			.5	.5	20	.3	24.2			
		29.7	.365			22.3	.109		16.7			.048		22.4							.101			
25		.3	28.9	.295		25	.3	21.6	.102			.5		32.0	.326			30	.3	20	.3		25.9	.245
			28.2	.165				19.2	.066					28.2	.164								14.5	.028
	.4	16.9	.049	.4	14.4		.035	.4	23.2		.062			.5	.5	20			.3	24.2	.200			
		29.2	.277		23.6		.198		16.5		.049		24.2							.200				
	.5	27.8	.158	25	.3		21.6		.102	.5	31.6		.322		25	.3	20		.3	25.8	.199			
		24.4	.100				19.7		.067		29.1		.167							14.1	.032			
.4		16.9	.049		.4	14.0	.033		.4		24.1	.096	.5			.5	20	.3	24.8	.086				
		29.2	.277			22.5	.182				17.2	.042							20.8	.056				
.5		27.8	.158		25	.3	20.9	.095			.4	24.3		.084		25	.3	20	.3	24.0	.163			
		24.4	.100				18.9	.061				27.1		.134						20.2	.055			
	.4	16.9	.049	.4		14.8	.037	.4		17.2		.042		.5	.5		20	.3	22.4	.101				
		29.2	.277			22.9	.137			18.5		.051							20.7	.066				
	.5	27.8	.158	25		.3	14.8		.037	.4		31.0	.262		25		.3	20	.3	24.0	.163			
		24.4	.100				14.8		.037			27.7	.138							14.1	.027			



Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	Rolling	L	Y → Z	Roll	φ	u	p
Lateral	Y	Y	Pitching	M	Z → X	Pitch	θ	v	q
Normal	Z	Z	Yawing	N	X → Y	Yaw	ψ	w	r

Absolute coefficients of moment

$$C_l = \frac{L}{qbS}$$

(rolling)

$$C_m = \frac{M}{qcS}$$

(pitching)

$$C_n = \frac{N}{qbS}$$

(yawing)

Angle of set of control surface (relative to neutral position), δ. - (Indicate surface by proper subscript.)

#### 4. PROPELLER SYMBOLS

$D$  Diameter

$p$  Geometric pitch

$p/D$  Pitch ratio

$V'$  Inflow velocity

$V_s$  Slipstream velocity

$T$  Thrust, absolute coefficient  $C_T = \frac{T}{\rho n^3 D^4}$

$Q$  Torque, absolute coefficient  $C_Q = \frac{Q}{\rho n^3 D^5}$

$P$  Power, absolute coefficient  $C_P = \frac{P}{\rho n^3 D^5}$

$C_s$  Speed-power coefficient =  $\sqrt{\frac{\rho V_s^5}{P n^3}}$

$\eta$  Efficiency

$n$  Revolutions per second, rps

$\phi$  Effective helix angle =  $\tan^{-1} \left( \frac{V}{2\pi r n} \right)$

#### 5. NUMERICAL RELATIONS

1 hp = 76.04 kg-m/s = 550 ft-lb/sec

1 metric horsepower = 0.9863 hp

1 mph = 0.4470 mps

1 mps = 2.2369 mph

1 lb = 0.4536 kg

1 kg = 2.2046 lb

1 mi = 1,609.35 m = 5,280 ft

1 m = 3.2808 ft