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TECHNICAL NOTE

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DIRECT-READING DESIGN CHARTS FOR 24S-T ALUMINUM-ALLOY
FLAT COMPRESSION PANELS HAVING LONGITUDINAL
STRAIGHT-WEB Y-SECTION STIFFENERS

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SUMMARY

Direct-reading design charts are presented for 24S-T aluminum-alloy flat compression panels having longitudinal straight-web Y-section stiffeners. These charts make possible the direct determination of the stress and all the panel proportions required to carry a given intensity of loading with a given skin thickness and effective length of panel.

INTRODUCTION

Design charts for wing compression panels have been presented in several different forms. (See references 1 and 2.) In reference 3, a form was developed which permitted the direct selection of proportions for given values of the principal design conditions - intensity of loading, skin thickness, and effective length of panel. This form also made possible the ready determination of the proportions having minimum weight to meet these conditions. The charts presented in reference 3 covered 75S-T aluminum-alloy flat compression panels having longitudinal straight-web Y-section stiffeners. Similar charts for 24S-T aluminum-alloy panels with formed Z-section stiffeners are presented in reference 4 and direct-reading design charts for 24S-T aluminum-alloy Y-stiffened panels are presented herein.

SYMBOLS

The symbols used for the panel dimensions are given in figure 1. In addition, the following symbols are used:

- c coefficient of end fixity as used in Euler column formula
- d rivet diameter, inches
- L length of panel, inches
- p rivet pitch, inches

- P_1 compressive load per inch of panel width, kips per inch
- r all fillet radii, inches
- \bar{t} cross-sectional area per inch of panel width, expressed as an equivalent or average thickness, inches
- ρ radius of gyration, inches
- $\bar{\sigma}_F$ average stress at failing load, ksi
- σ_{CR} stress for local buckling of sheet, ksi
- σ_{CY} compressive yield stress, ksi

DIRECT-READING DESIGN CHARTS

Direct-reading design charts for 24S-T aluminum-alloy flat compression panels with longitudinal straight-web Y-section stiffeners having the properties and proportions given in tables 1 to 6 are presented in two forms in figures 2 to 11. In the first form (figs. 2 to 6), the design conditions of intensity of loading, effective length of panel, and skin thickness are incorporated in the ordinate P_1/t_S and the abscissa $\frac{P_1}{L/\sqrt{C}}$. This form, having the design conditions incorporated in the ordinate and abscissa, is the more useful for most design purposes because the curves are more widely spaced and interpolation is more straightforward. In the second (alternate) form (figs. 7 to 11), the average stress at failure $\bar{\sigma}_F$ is plotted against P_1/t_S as was done in the summary plots of reference 5. This alternate form, having the stress - an inverse measure of weight for a given load - as ordinate, is the more useful for making generalizations and comparisons of structural efficiency because it shows how nearly the stress actually carried approaches the upper limit corresponding to the stress that would be achieved by a pure shell construction if a pure shell could carry the load without failure. This upper limit of stress is represented by the lines for $\bar{\sigma}_F = \frac{P_1}{t_S}$ (infinite stiffener spacing) in figures 7 to 11.

Values of the ratios of stiffener thickness to skin thickness t_W/t_S , average spacing of rivet lines to skin thickness S/t_S (because there are two rivet lines associated with each Y-section, the stiffener spacing equals 2S), and height of stiffener to stiffener thickness H/t_W , which will satisfy the design conditions, may be found directly from these charts, and the corresponding section properties \bar{t}/t_S , \bar{h}/t_S , and ρ/t_S may be found from tables 2 to 6. In the first form of design chart (figs. 2 to 6) dashed lines are used to indicate values of average

stress at failure $\bar{\sigma}_f$; whereas, on the alternate form of design chart (figs. 7 to 11) dashed lines are used to indicate values of $\frac{P_1}{L/\sqrt{c}}$. In both forms the value of $\bar{\sigma}_f$ corresponding to the point at which each curve is cut by a short heavy line is the value of the stress for local buckling σ_{cr} for the proportions represented by the curve. For example, the value of σ_{cr} for $\frac{H}{t_w} = 33.8$ and $\frac{S}{t_s} = 16.2$ in figure 2 is approximately 41.3 ksi. (Only a very short panel of these proportions would buckle before failure - one having a value of $\frac{P_1}{L/\sqrt{c}} \geq 0.60$.)

If the value of σ_{cr} is so low that the short heavy line would fall outside the boundaries of the chart, a numerical value of σ_{cr} is given and is associated with the proper proportions by a leader to the curve. The panel proportions which have minimum weight are indicated on both forms of these charts by the use of colors as follows:

- (1) If the proportions correspond to a blue region, they are the proportions which give the lightest possible 24S-T Y-stiffened panel which will meet the design conditions
- (2) If the proportions correspond to a red region, they are the lightest possible at the ratio of stiffener thickness to skin thickness given by that particular chart, but some other thickness ratio would give a lighter design
- (3) If the proportions correspond to a white region, the proportions meet the design conditions, but they are not the lightest which will meet the conditions

Because in many cases the proportions may be varied somewhat from those indicated by the red and blue regions with little change in the value of the stress that can be carried, too much importance should not be attached to the exact proportions indicated by the colors to have minimum weight. In any particular case for which a deviation from the minimum-weight proportions is made, however, caution dictates that the weight penalty associated with this deviation be determined.

The direct-reading design charts presented herein were developed in the manner described in reference 3 from the test data and resulting curves given in reference 5.

USE OF THE DIRECT-READING DESIGN CHARTS

The manner of using the direct-reading design charts depends in some measure on the desired degree of precision of interpolation among the curves. For many purposes, interpolation by inspection is of adequate accuracy, and the use of the charts requires only the calculation

of the values of the design parameters P_1/t_S and $\frac{P_1}{L/\sqrt{c}}$ to permit the desired proportions to be read directly from the curves. The proportions for minimum weight, moreover, may be found directly as those corresponding to the blue region on the curves.

If more accurate interpolation is desired, a plot can readily be made of H/t_W , $\bar{\sigma}_F$, and σ_{cr} against S/t_S at the given values of P_1/t_S and $\frac{P_1}{L/\sqrt{c}}$ and the proportions can be picked from it. (This plot is similar to that which results from the use of the minimum-weight design procedure with the previously available design charts as illustrated in reference 2.) On a plot of this type, the proportions for minimum weight correspond to those associated with the highest value of $\bar{\sigma}_F$.

As a check on the accuracy of interpolation, the cross-sectional area per inch of width of the design may be determined from the values of \bar{t}/t_S given in tables 2 to 6 and the value of the intensity of loading P_1 that can be carried on this cross-sectional area per inch at the value of $\bar{\sigma}_F$ given by the charts may then be compared with the design value of P_1 .

ILLUSTRATIVE EXAMPLE

In order to illustrate the use of the direct-reading design charts and the simplicity of the computations associated with them, a panel will be designed for minimum weight to meet the same principal design conditions used to illustrate the design procedures in reference 2, namely:

1. Intensity of loading $P_1 = 3.0$ kips per inch
2. Skin thickness $t_S = 0.064$ inch
3. Effective length $L/\sqrt{c} = 20$ inches

As was pointed out in reference 5, an intensity of loading as small as 3.0 kips per inch may require a stiffener thickness smaller than can be successfully extruded. The value of P_1 of 3.0 kips per inch is retained for the example, however, in order to provide a ready comparison with the examples of reference 2.

First the values of P_1/t_S and $\frac{P_1}{L/\sqrt{c}}$ are calculated

$$\frac{P_1}{t_S} = \frac{3.0}{0.064}$$

$$= 46.9 \text{ ksi}$$

$$\frac{P_1}{L/\sqrt{c}} = \frac{3.0}{20/\sqrt{1}}$$

$$= 0.15 \text{ ksi}$$

Then a trial value of t_W/t_S is assumed (for the example $\frac{t_W}{t_S} = 0.51$ will be used). In the chart for this value of t_W/t_S (fig. 3) the points corresponding to the design values of P_1/t_S and $\frac{P_1}{L/\sqrt{c}}$ lie above the red line at $\frac{H}{t_W} \leq 44.6$ (or $\frac{b_W}{t_W} \leq 24$), below the red line at $\frac{H}{t_W} \geq 55.3$ (or $\frac{b_W}{t_W} \geq 30$), and very nearly on the red line at $\frac{H}{t_W} = 49.9$ (or $\frac{b_W}{t_W} = 27$).

Accordingly, the value of H/t_W for minimum weight for $\frac{t_W}{t_S} = 0.51$ lies between 44.6 and 55.3, and because the values are established by red lines, not blue lines, some value of t_W/t_S other than 0.51 will give less weight. Inspection of the charts for other values of t_W/t_S reveals that at the given design values of P_1/t_S and $\frac{P_1}{L/\sqrt{c}}$ the blue region lies between $\frac{H}{t_W} = 55.3$ and $\frac{H}{t_W} = 60.7$ on the chart for $\frac{t_W}{t_S} = 0.40$. By interpolation, the panel proportions corresponding to this blue region are found to be $\frac{H}{t_W} \approx 60.5$ ($\frac{b_W}{t_W} \approx 33$) and $\frac{s}{t_S} \approx 27.0$ ($\frac{b_S}{t_S} \approx 38.0$), and for these proportions $\bar{\sigma}_F \approx 31.3 \text{ ksi}$ and $\sigma_{cr} \approx 31.3 \text{ ksi}$, which are the values for

minimum weight. The actual panel dimensions can be calculated from these proportions as

$$t_W = \frac{t_W}{t_S} t_S$$

$$= 0.40(0.064)$$

$$\approx 0.025 \text{ inch}$$

$$H = \frac{H}{t_W} t_W$$

$$= 60.5(0.025)$$

$$= 1.51 \text{ inches}$$

$$S = \frac{S}{t_S} t_S$$

$$= 27.0(0.064)$$

$$= 1.73 \text{ inches}$$

and the section properties can be determined from table 2 as

$$\bar{h} = \frac{\bar{h}}{t_S} t_S$$

$$= 4.90(0.064)$$

$$= 0.314 \text{ inch}$$

$$\rho = \frac{\rho}{t_S} t_S$$

$$= 8.13(0.064)$$

$$= 0.521 \text{ inch}$$

In order to illustrate the use of the direct-reading design charts when more accuracy than that corresponding to interpolation by inspection is desired, a plot has been made (fig. 12) of the values of $\bar{\sigma}_F$, σ_{cr} ,

and H/t_W given by the charts at the design values of P_1/t_S and $\frac{P_1}{L/\sqrt{C}}$.

The proportions which give the highest value of $\bar{\sigma}_F$ can be readily selected from a plot of this kind. (For the example these proportions are so nearly the same as were obtained by inspection that the values will not be repeated; however, the flatness of the curve of $\bar{\sigma}_F$ against S/t_S in figure 12 shows that, for a fairly wide range of proportions for this particular design, the stress that could be carried would be substantially the same as that for minimum weight.)

As a check on the accuracy of interpolation, the magnitude of \bar{t}/t_S for these proportions can be determined from table 2 and multiplied by the values of t_S and $\bar{\sigma}_F$ for the design. This product should be equal to the design value of P_1 . For the example

$$\bar{\sigma}_F = 31.3 \text{ ksi}$$

$$\frac{\bar{t}}{t_S} = 1.500$$

and

$$\begin{aligned} P_1 &= \bar{\sigma}_F \bar{t} \\ &= \bar{\sigma}_F \frac{\bar{t}}{t_S} t_S \\ &= 31.3(1.500)(0.064) \\ &= 3.0 \text{ kips per inch} \end{aligned}$$

which agrees with the design value of P_1 originally assumed.

Langley Aeronautical Laboratory
 National Advisory Committee for Aeronautics
 Langley Field, Va., July 30, 1948

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1. Langhaar, Henry L.: Design of Hat-Type Plate-Stringer Combinations. Auto. and Aviation Ind., vol. 91, no. 11, Dec. 1, 1944, pp. 28-32 and 103-104.
2. Schuette, Evan H.: Charts for the Minimum-Weight Design of 24S-T Aluminum-Alloy Flat Compression Panels with Longitudinal Z-Section Stiffeners. NACA Rep. No. 827, 1945.
3. Dow, Norris F., and Hickman, William A.: Direct-Reading Design Charts for 75S-T Aluminum-Alloy Flat Compression Panels Having Longitudinal Straight-Web Y-Section Stiffeners. NACA TN No. 1640, 1948.
4. Dow, Norris F., and Keevil, Albert S., Jr.: Direct-Reading Design Charts for 24S-T Aluminum-Alloy Flat Compression Panels Having Longitudinal Formed Z-Section Stiffeners. NACA TN No. 1778, 1949.
5. Dow, Norris F., and Hickman, William A.: Design Charts for Flat Compression Panels Having Longitudinal Extruded Y-Section Stiffeners and Comparison with Panels Having Formed Z-Section Stiffeners. NACA TN No. 1389, 1947.

TABLE 1.-- MATERIAL PROPERTIES AND PROPORTIONS OF
 24S-T ALUMINUM-ALLOY PANELS HAVING EXTRUDED
 STRAIGHT-WEB Y-SECTION STIFFENERS

[For details of stiffener proportions and diameter and pitch of rivets, see tables 2 to 6; for panel dimensions, see fig. 1]

Material properties		
	Aluminum alloy	σ_{cy} (ksi)
Sheet	24S-T	44.0
Stiffeners	24S-T	42.3
Proportions		
$\frac{b_W}{t_W} = 0.56 \frac{H}{t_W} - 0.89$		
$\frac{H}{t_W} = 1.79 \frac{b_W}{t_W} + 1.6$		
$\frac{b_S}{t_S} = \frac{2S}{t_S} - \left(0.58 \frac{H}{t_W} + 3.7 \right) \frac{t_W}{t_S}$		
$\frac{S}{t_S} = 0.5 \frac{b_S}{t_S} + \left(0.52 \frac{b_W}{t_W} + 2.3 \right) \frac{t_W}{t_S}$		



TABLE 2.- Y-PANEL PROPERTIES $\frac{b_A}{b_S} = 0.40$; $\frac{b_B}{b_S} = 9.3$; $\frac{b_C}{b_S} = 1.04$; $\frac{t_C}{t_S} = 1.06$; $\frac{b_D}{b_S} = 0.94$; $\frac{t_D}{t_S} = 2.13$; $\frac{b_E}{b_S} = 0.69$; $\frac{t_E}{t_S} = 1$; $\frac{d}{t_S} = 1.5$; $\frac{t_S}{t_S} = 4.6$

Table with columns for Y-axis (18-33) and X-axis (23-84). Rows are grouped by Y-axis labels: 18-33, 34-62, 63-84. Each cell contains numerical data points.



TABLE 4.- Y-PANEL PROPERTIES $\frac{b}{c} = 0.63; \frac{d}{c} = 9.3; \frac{b_1}{b} = 1.04; \frac{c_1}{c} = 1.06; \frac{d_1}{d} = 0.94; \frac{t}{c} = 2.13; \frac{d_2}{d} = 0.69; \frac{r}{c} = 1; \frac{d}{c_s} = 1.8; \frac{r}{c_s} = 6.1$

Table with columns for Y-axis (18-33) and X-axis (23-84). Rows are grouped by 'h/c' (18-33, 34-62, 63-84) and 'h/b' (18-33, 34-62, 63-84). Each cell contains numerical values representing panel properties.



TABLE 6.- Y-PANEL PROPERTIES $\frac{c_w}{c_s} = 1.00$; $\frac{b_A}{c_w} = 9.3$; $\frac{b_y}{c_w} = 1.04$; $\frac{b_L}{c_w} = 1.06$; $\frac{b_T}{c_w} = 0.94$; $\frac{b_P}{c_w} = 2.13$; $\frac{b_F}{c_w} = 0.69$; $\frac{r}{c_w} = 1$; $\frac{d}{c_s} = 2.4$; $\frac{e}{c_s} = 7.8$

Table with 33 columns (18-33) and 14 rows of property values (18-33). The table is divided into sections for T, H, and P. Each section has a vertical label on the left side of the data rows.

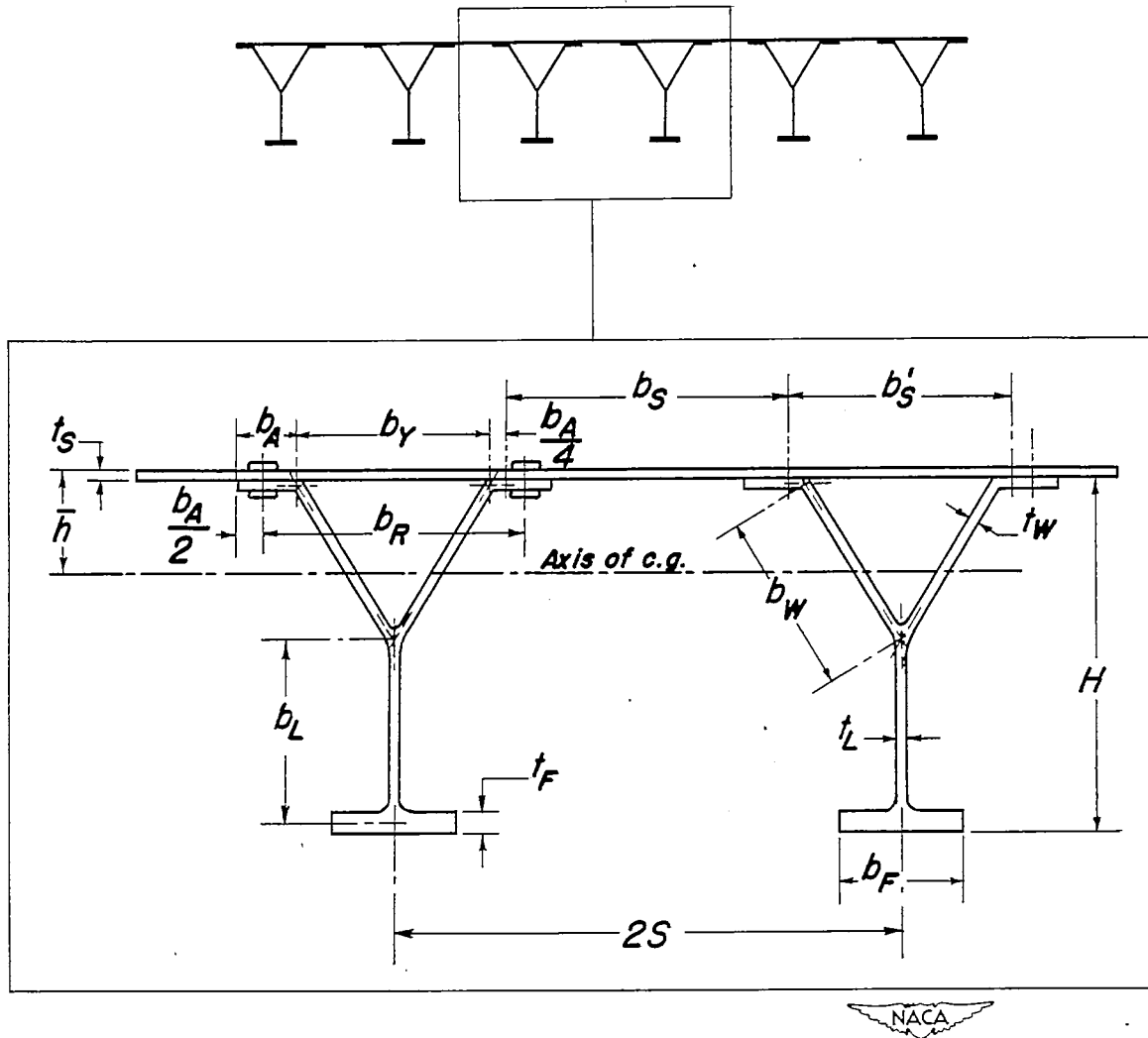


Figure 1. - Symbols for panel dimensions.

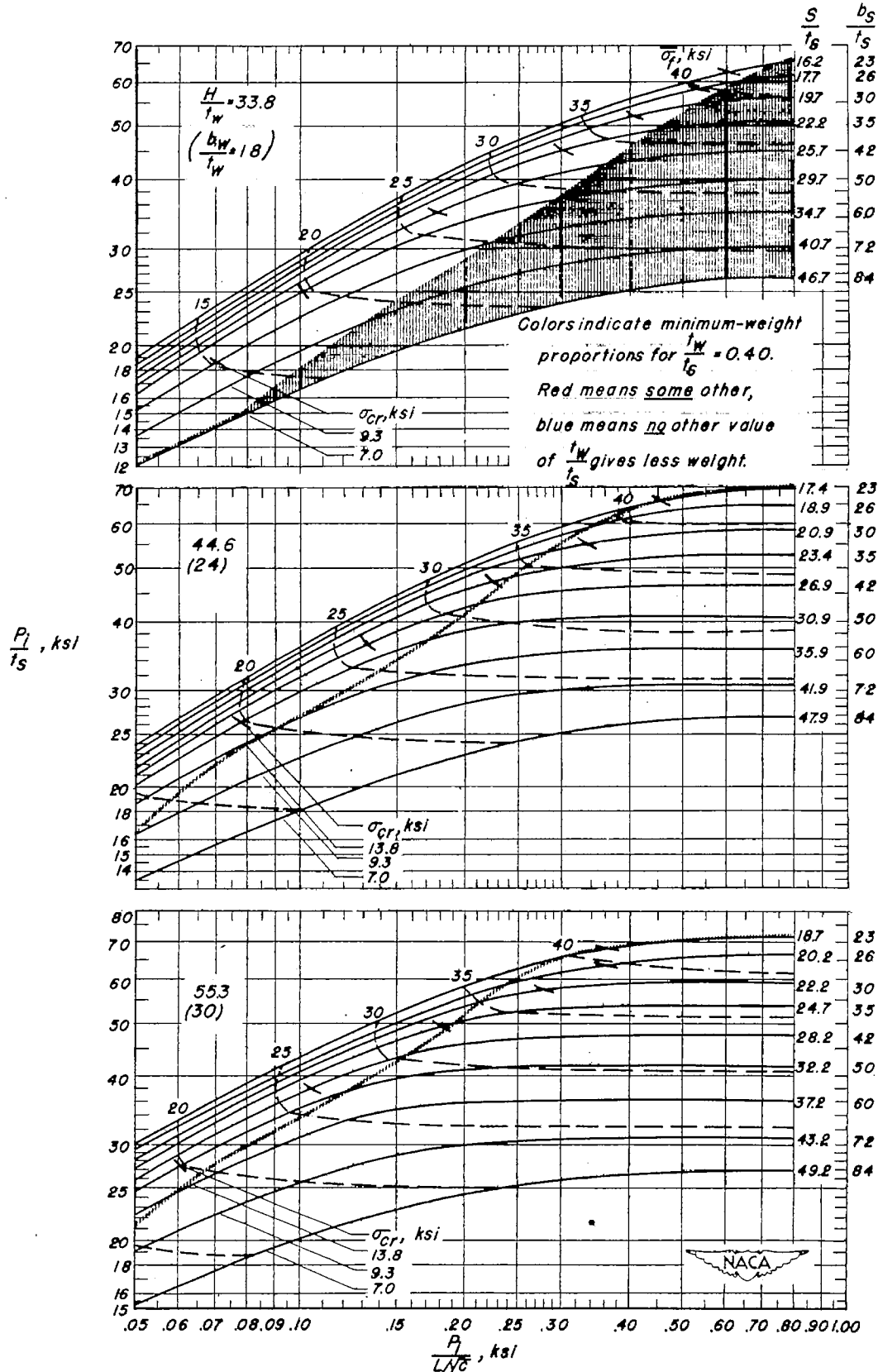


Figure 2.—Direct-reading design chart for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners, $t_w/t_b = 0.40$.

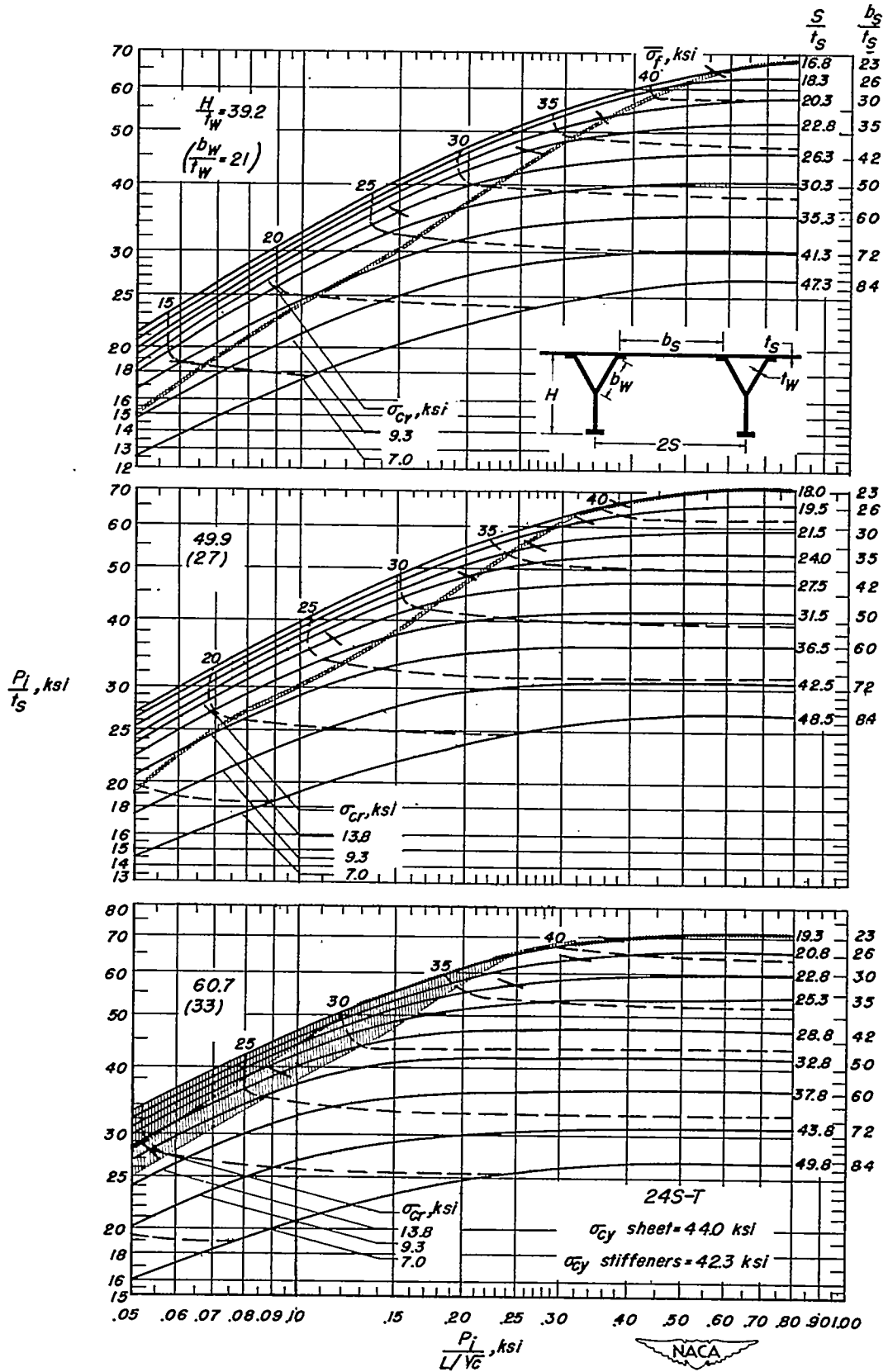


Figure 2.-Concluded. $\frac{t_w}{t_s} = 0.40$.



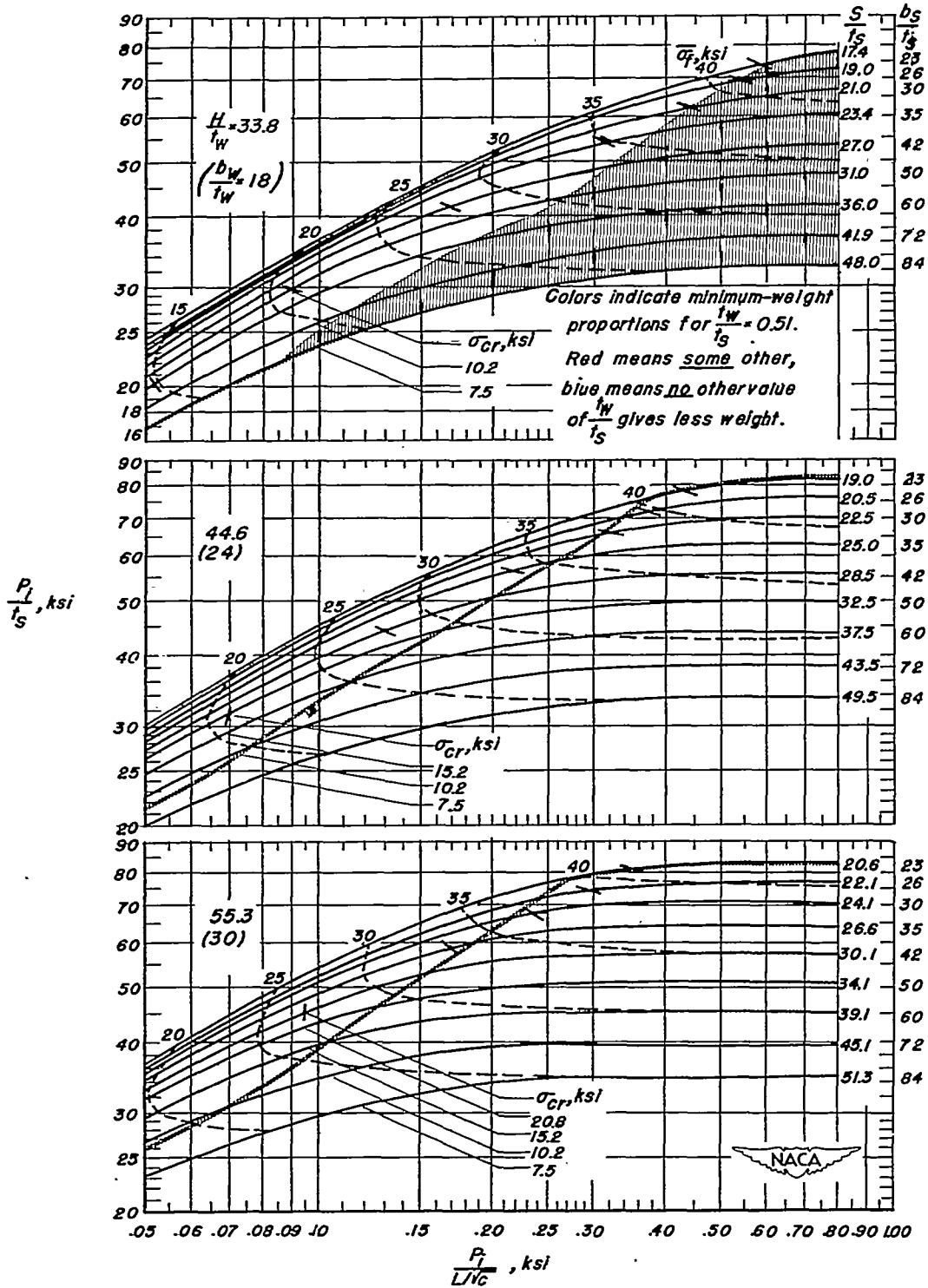


Figure 3.—Direct-reading design chart for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners $\frac{t_w}{t_s} = 0.51$.

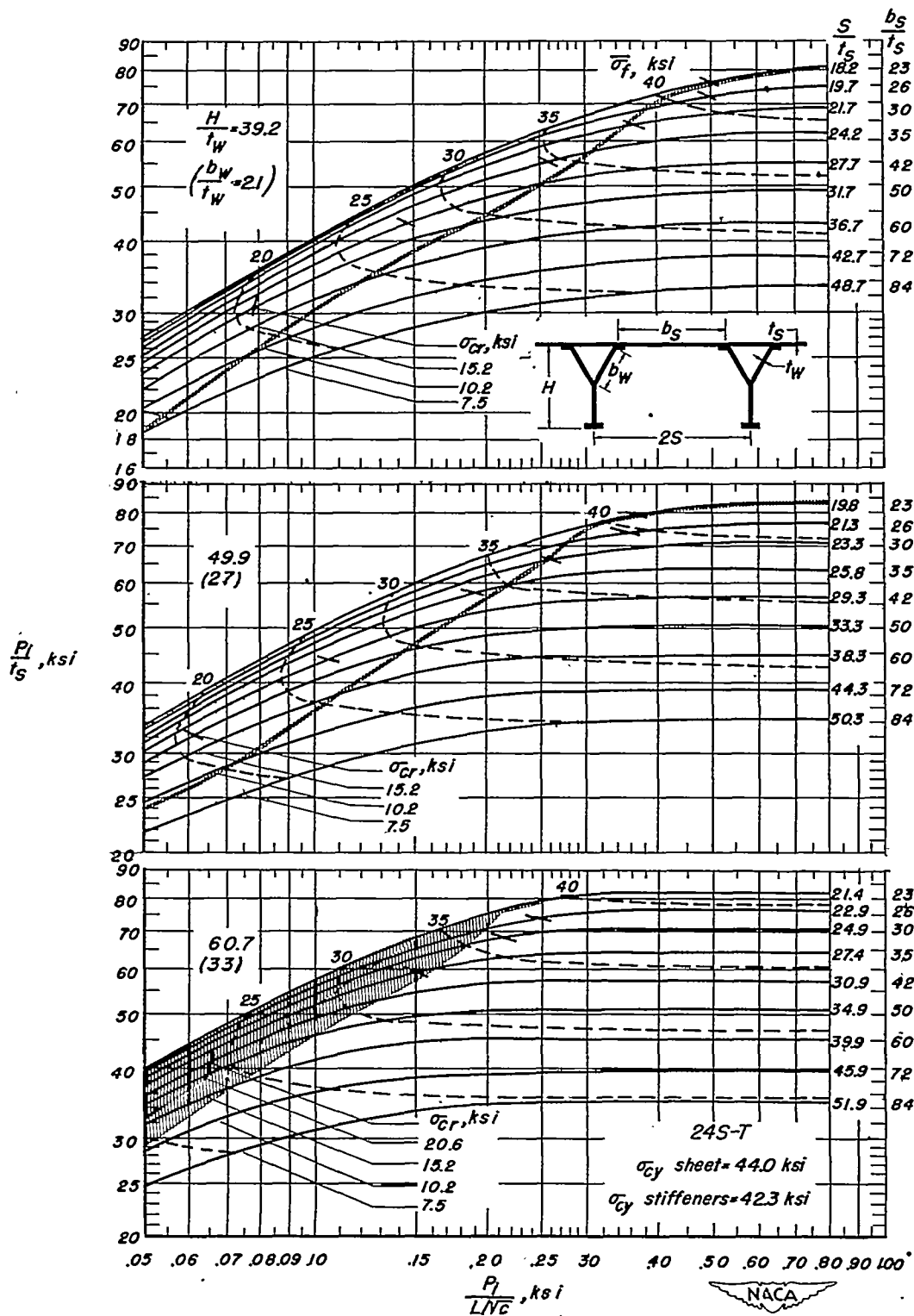
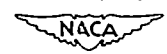


Figure 3.—Concluded, $t_w/t_s = 0.51$.



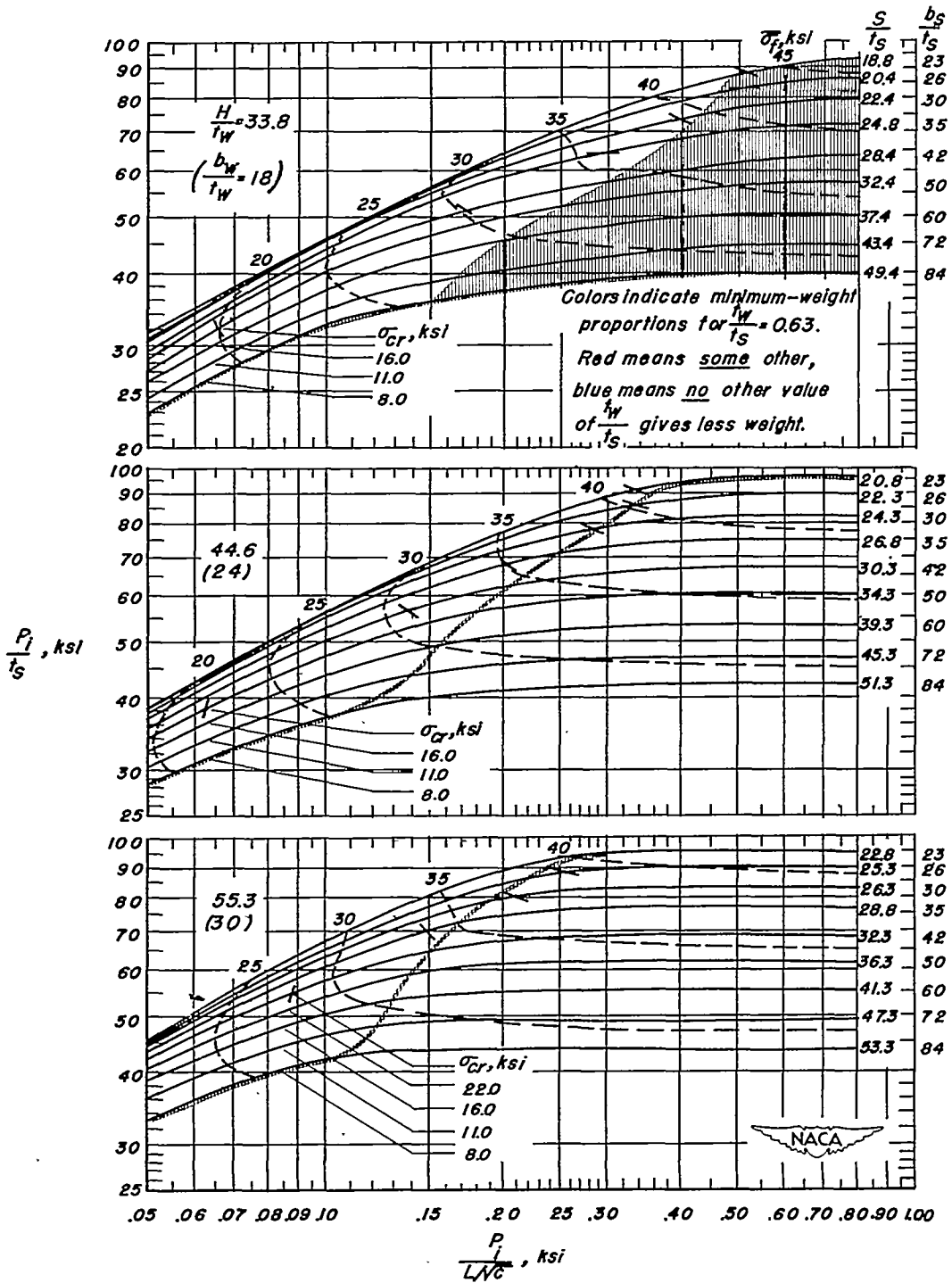


Figure 4.—Direct-reading design chart for flat compression panels of 245-T aluminum alloy with straight-web Y-section stiffeners $t_w/t_s = 0.63$.

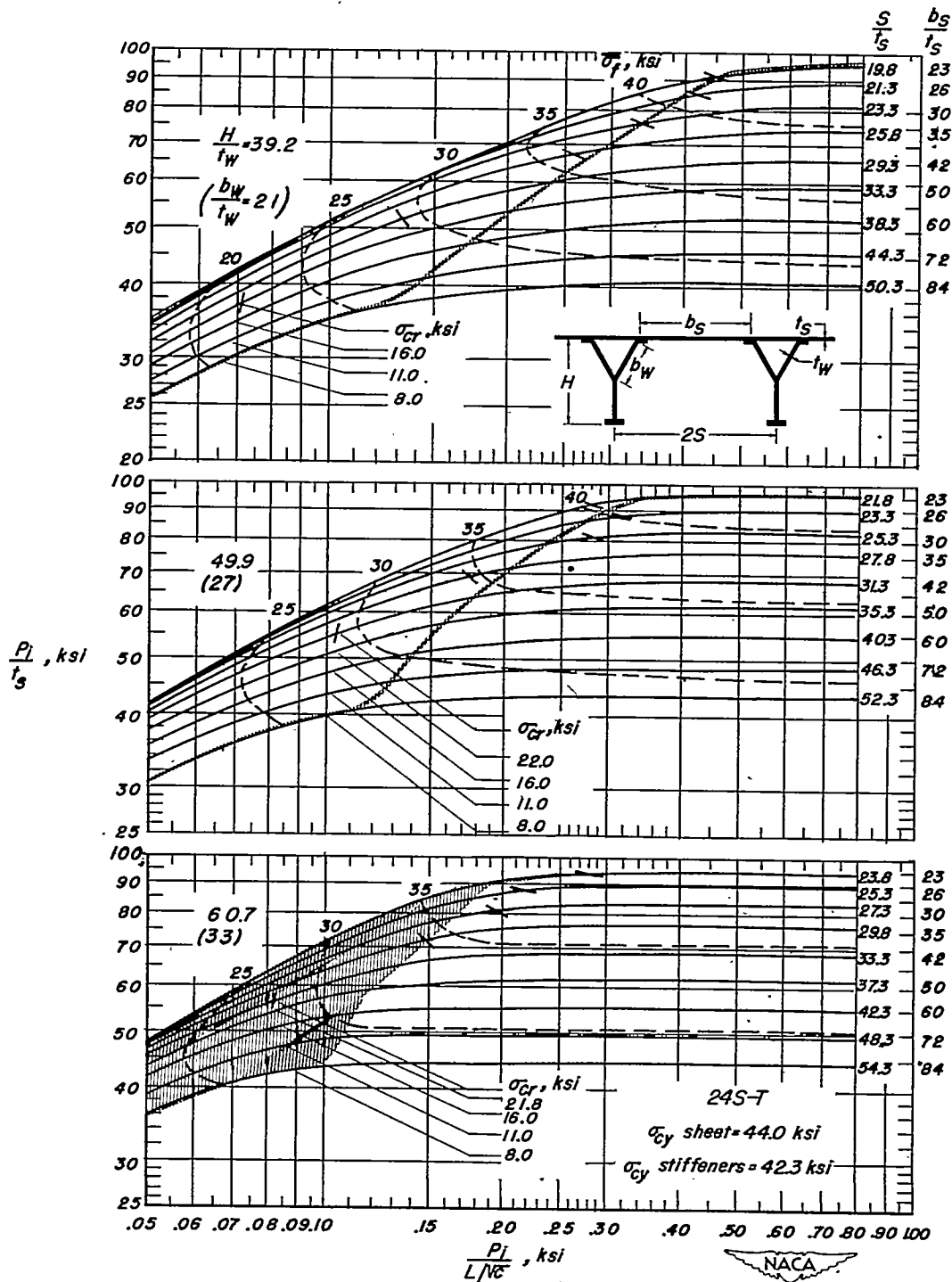


Figure 4.—Concluded, $\frac{t_w}{t_s} = 0.63$.



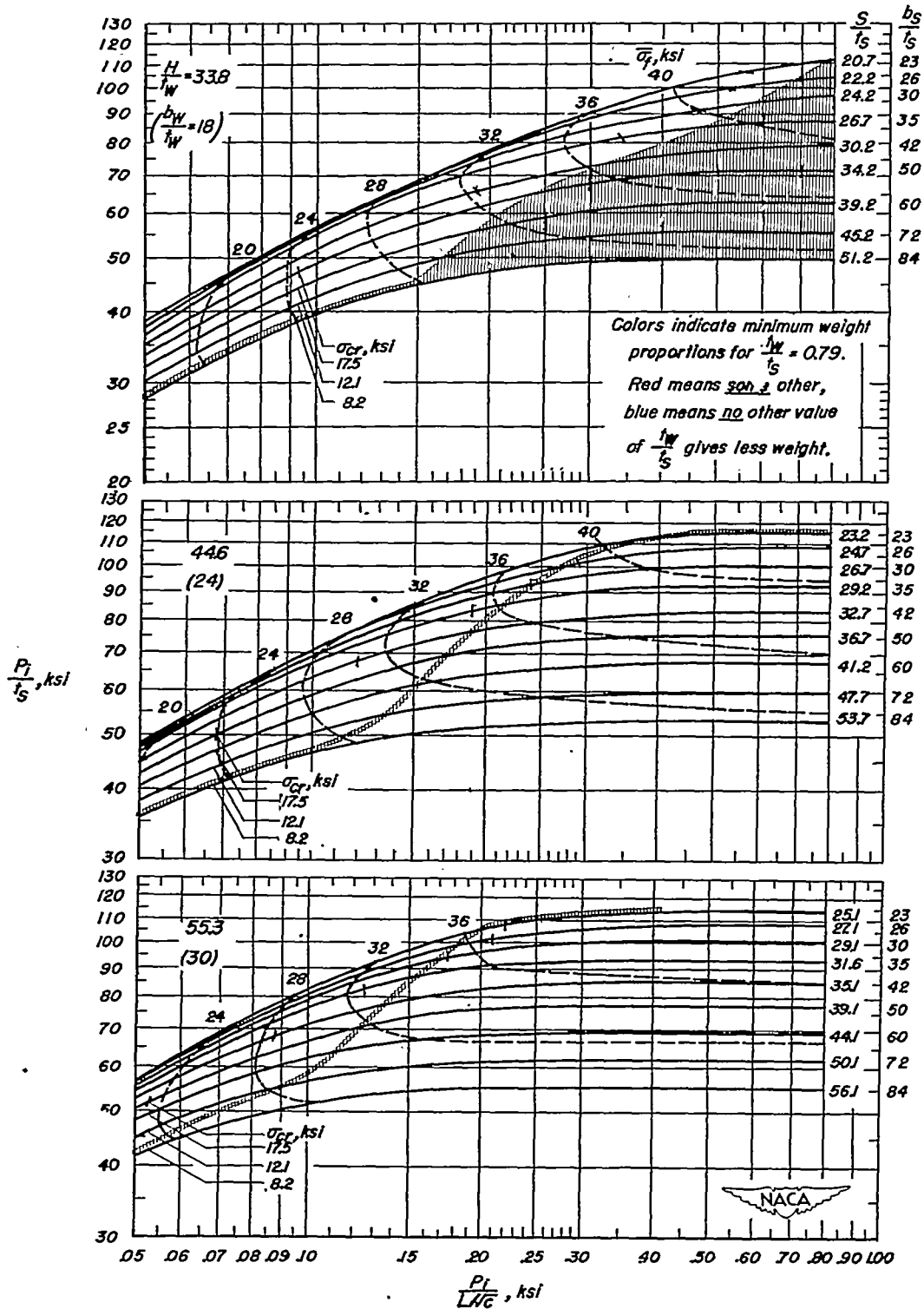


Figure 5.— Direct-reading design chart for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners. $\frac{t_w}{t_s} = 0.79$.

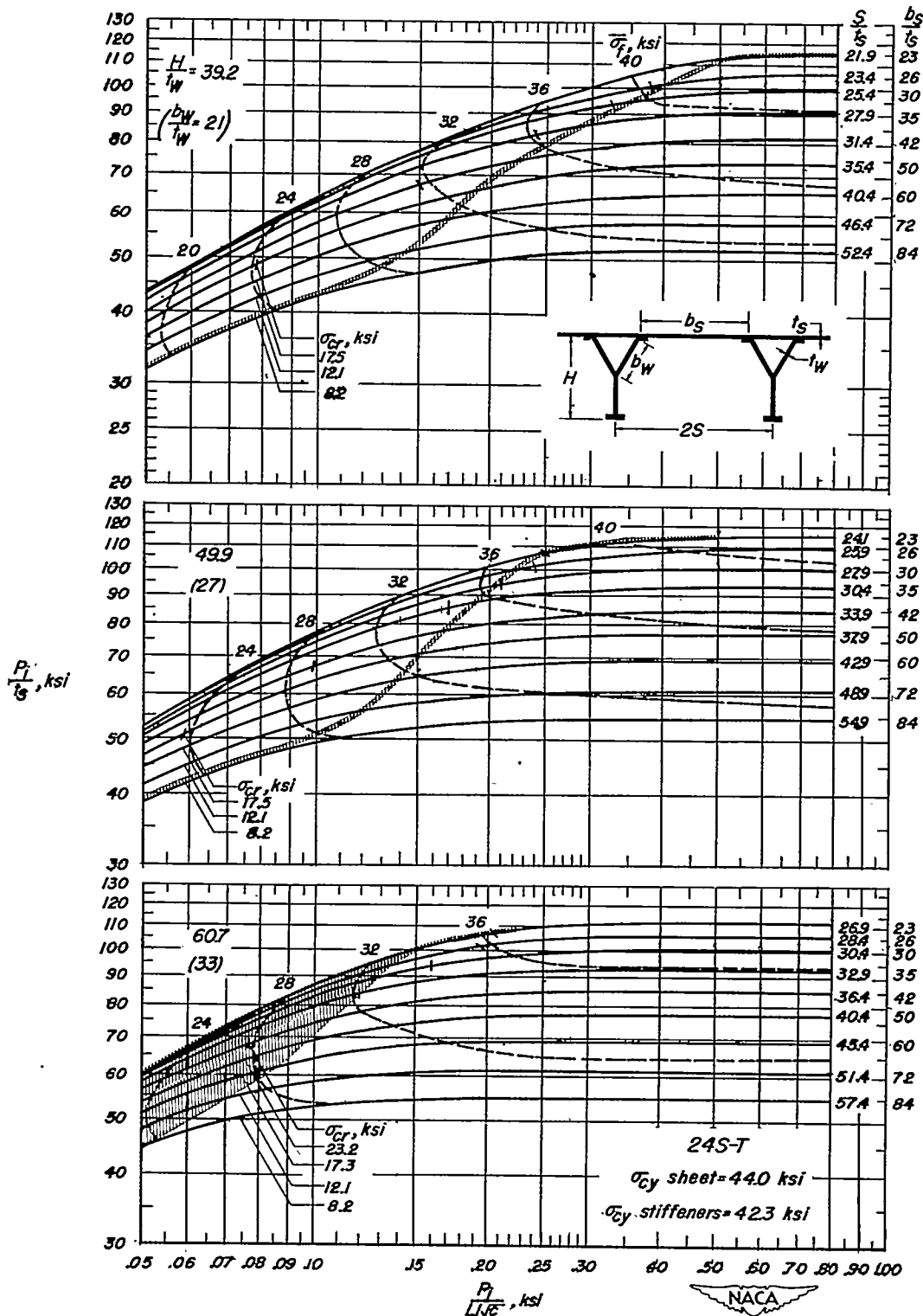


Figure 5.-Concluded. $\frac{t_w}{t_s} = 0.79$.

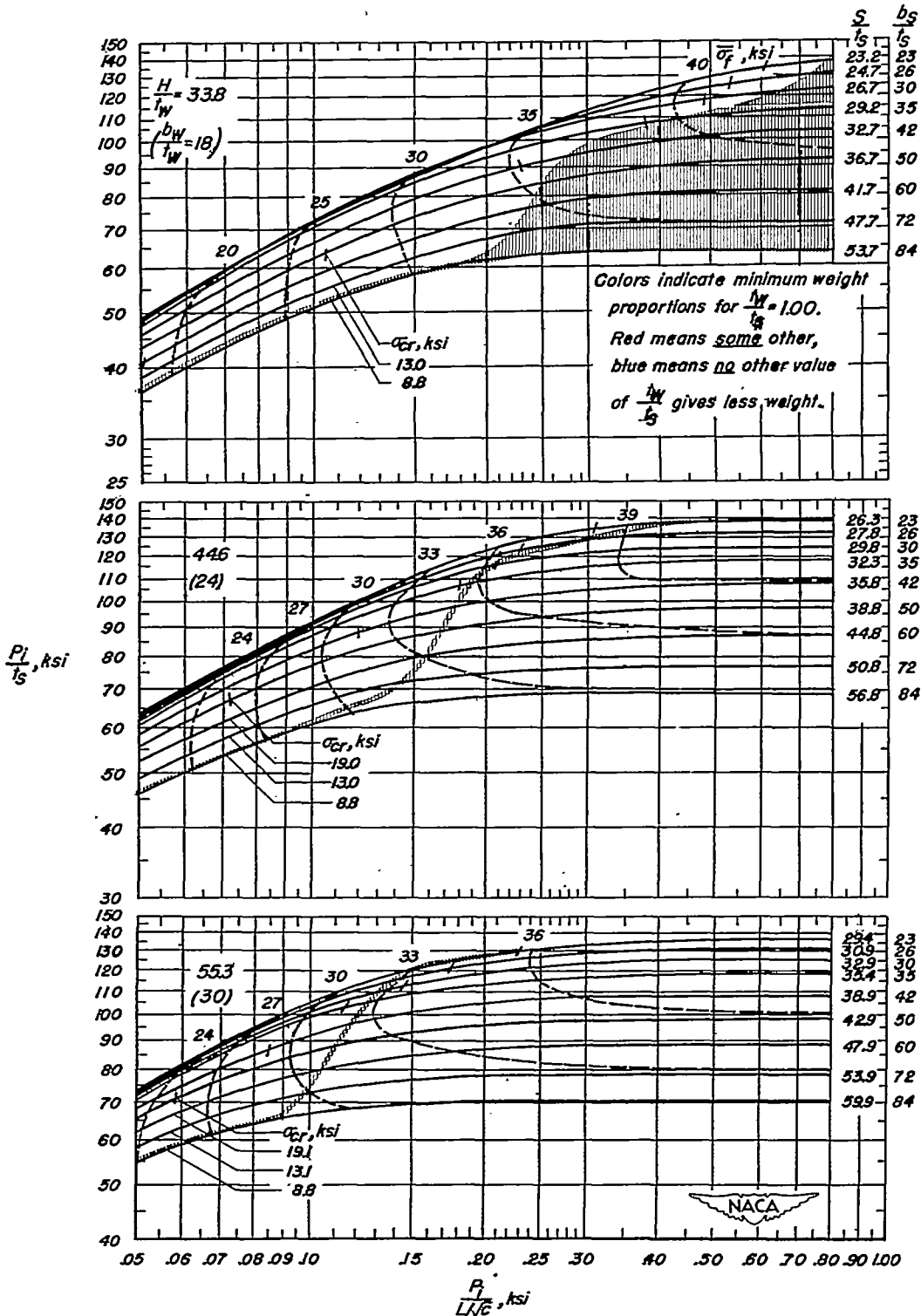
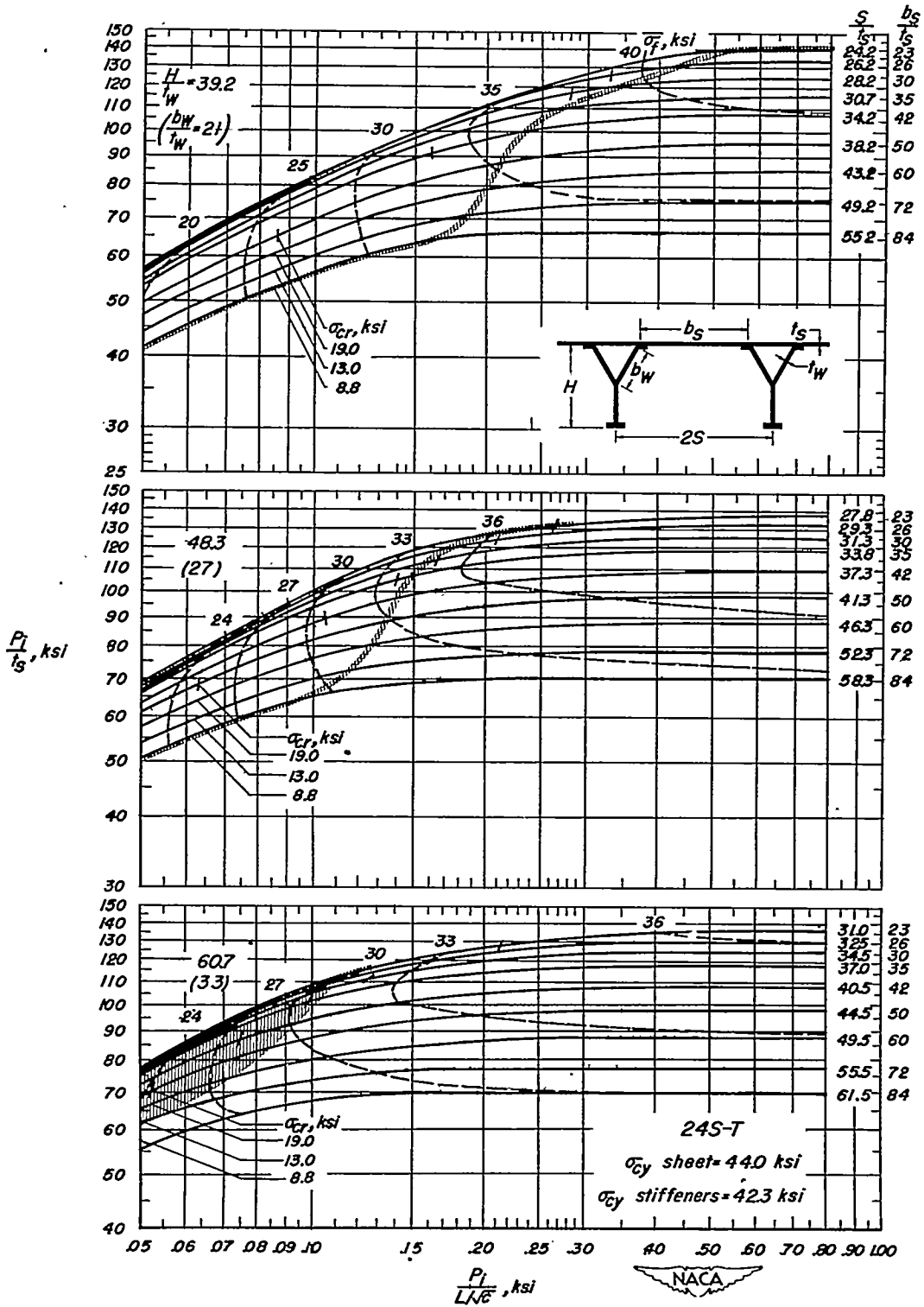


Figure 6.—Direct-reading design chart for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners, $\frac{H}{t_w} = 1.00$.



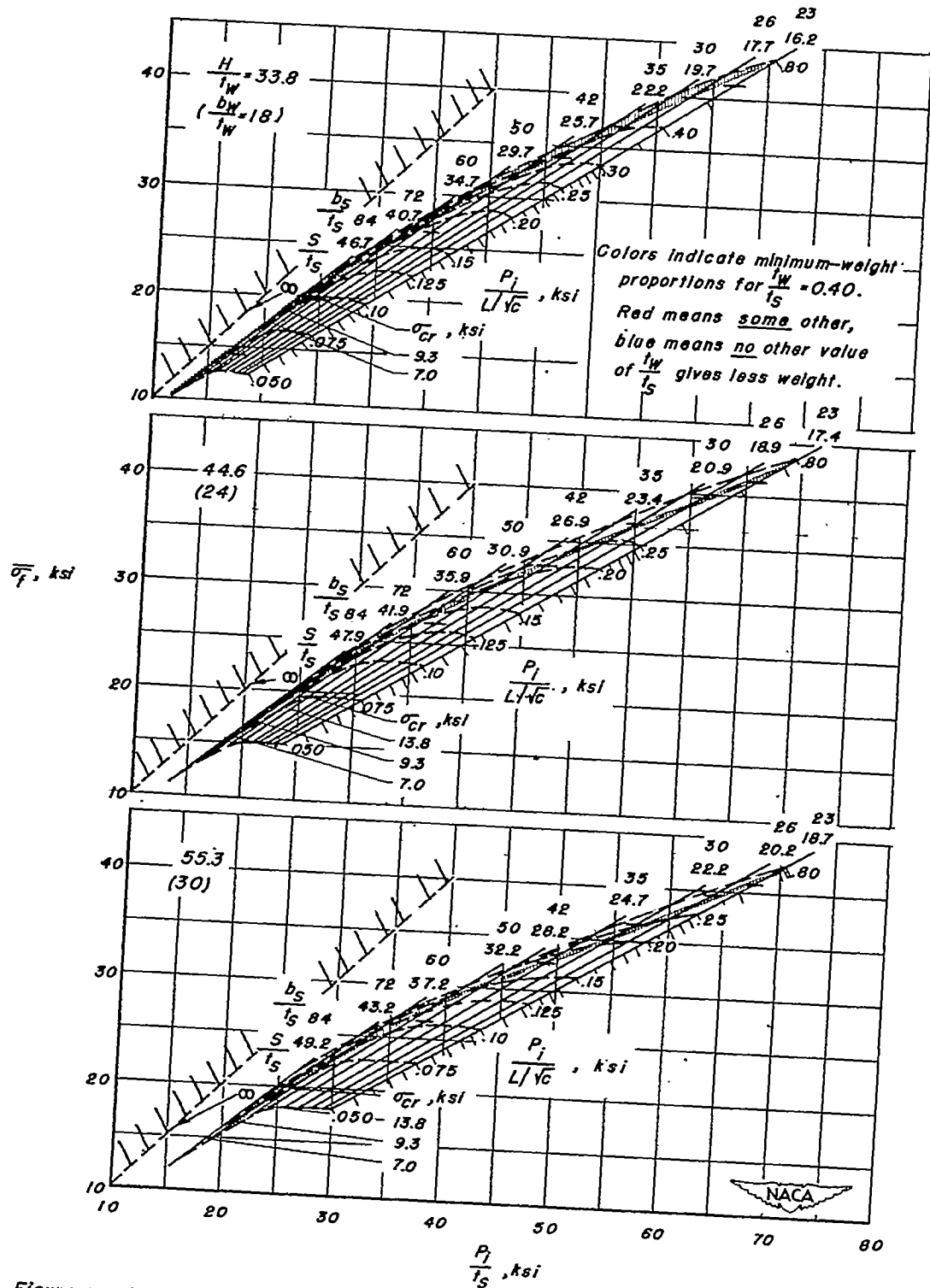


Figure 7.—Direct-reading design chart (alternate form) for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners, $\frac{I_w}{I_s} = 0.40$.

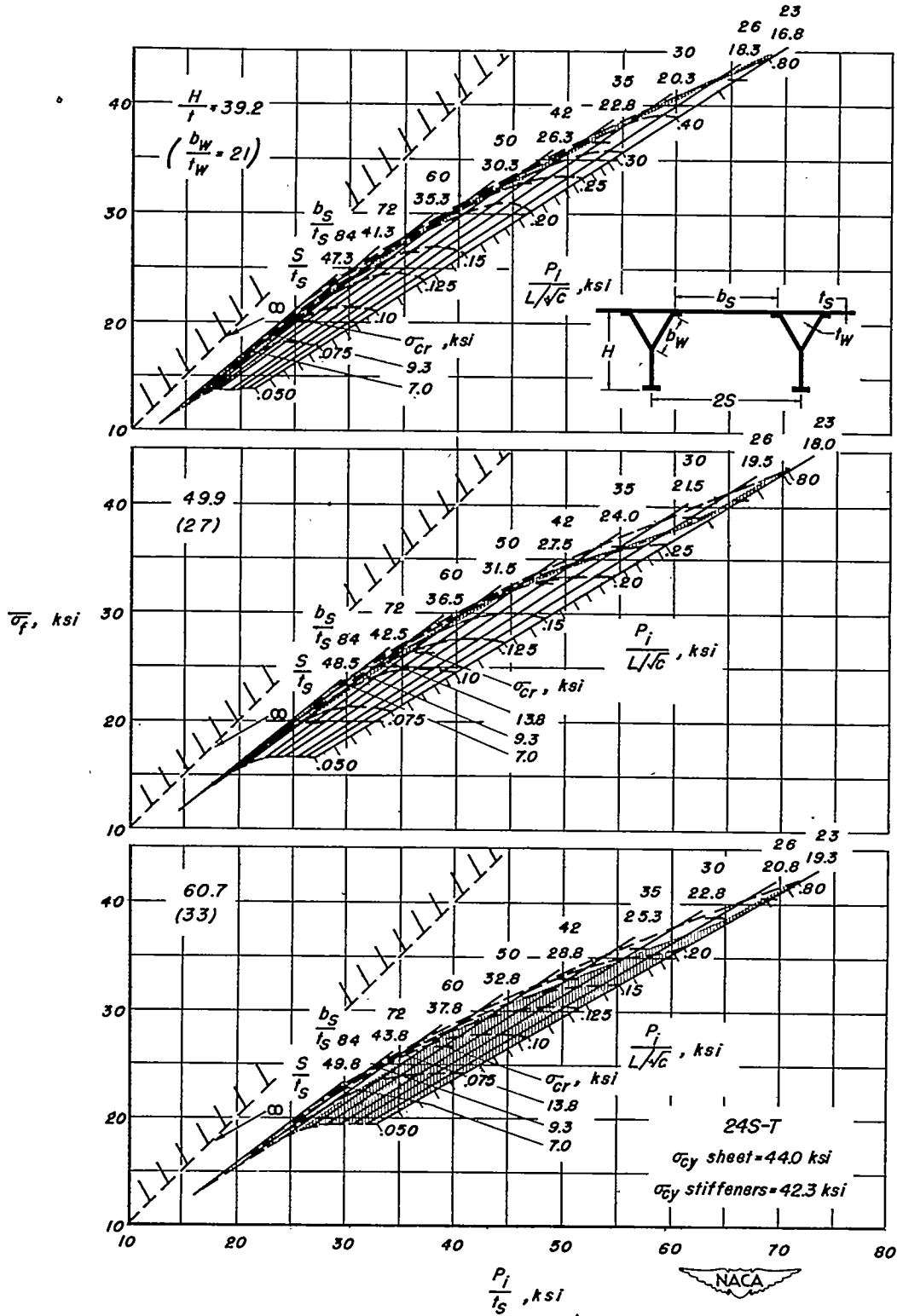


Figure 7.—Concluded, $\frac{t_w}{t_s} = 0.40$.

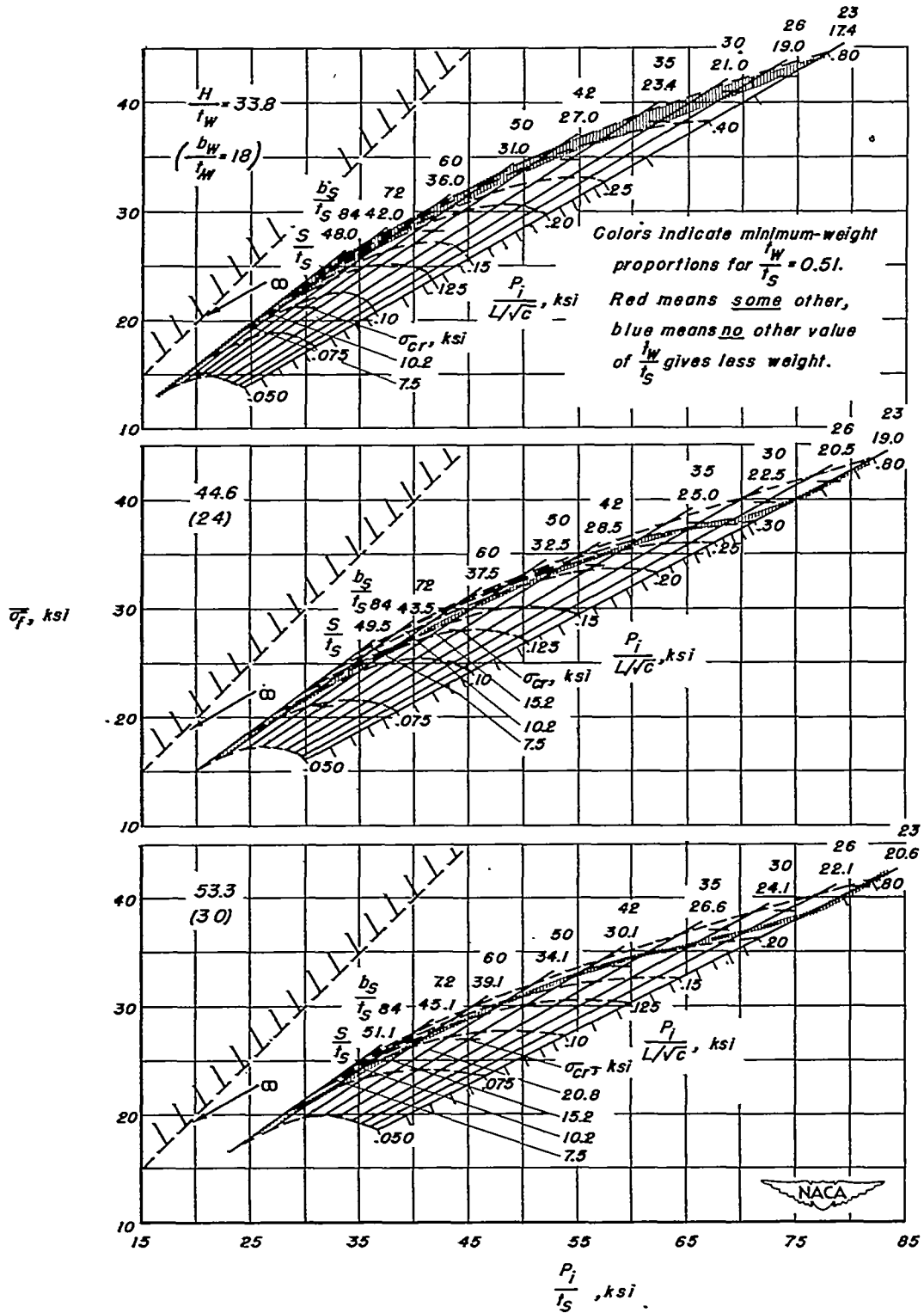


Figure 8.—Direct-reading design chart (alternate form) for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners. $\frac{I_w}{I_s} = 0.51$.

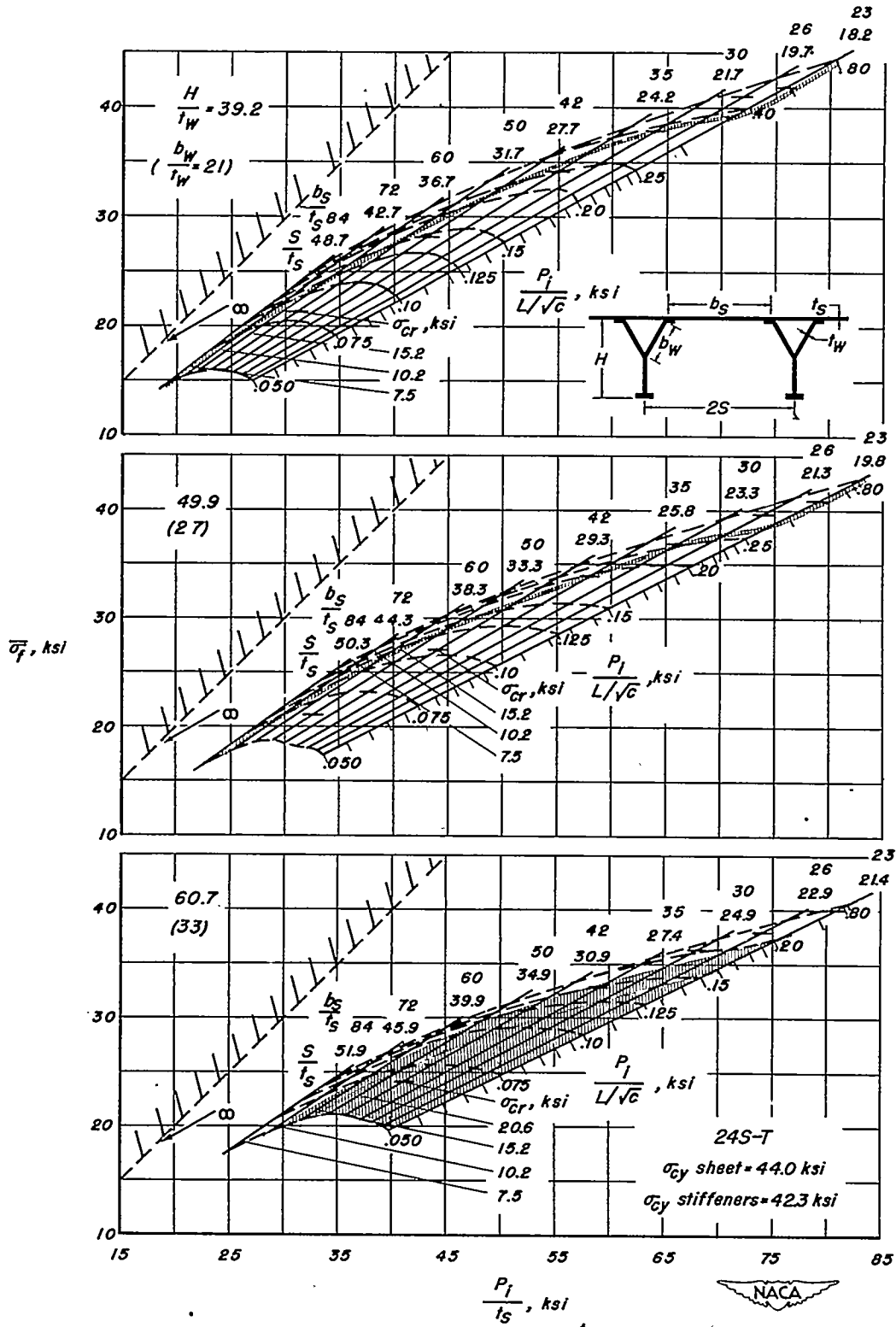


Figure 8, -Concluded, $\frac{t_w}{t_s} = 0.51$.



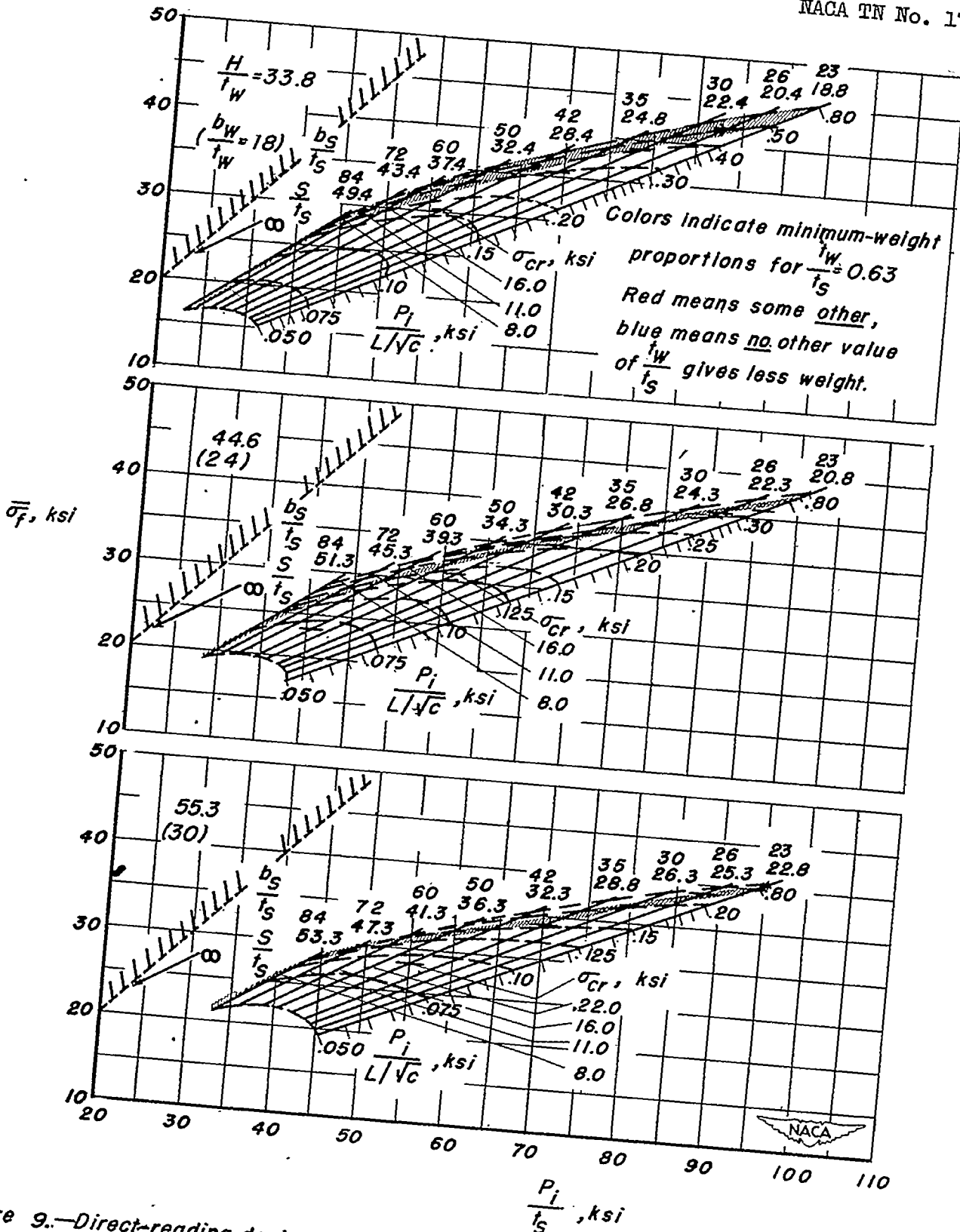


Figure 9.—Direct-reading design chart (alternate form) for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners. $\frac{t_w}{t_s} = 0.63$.

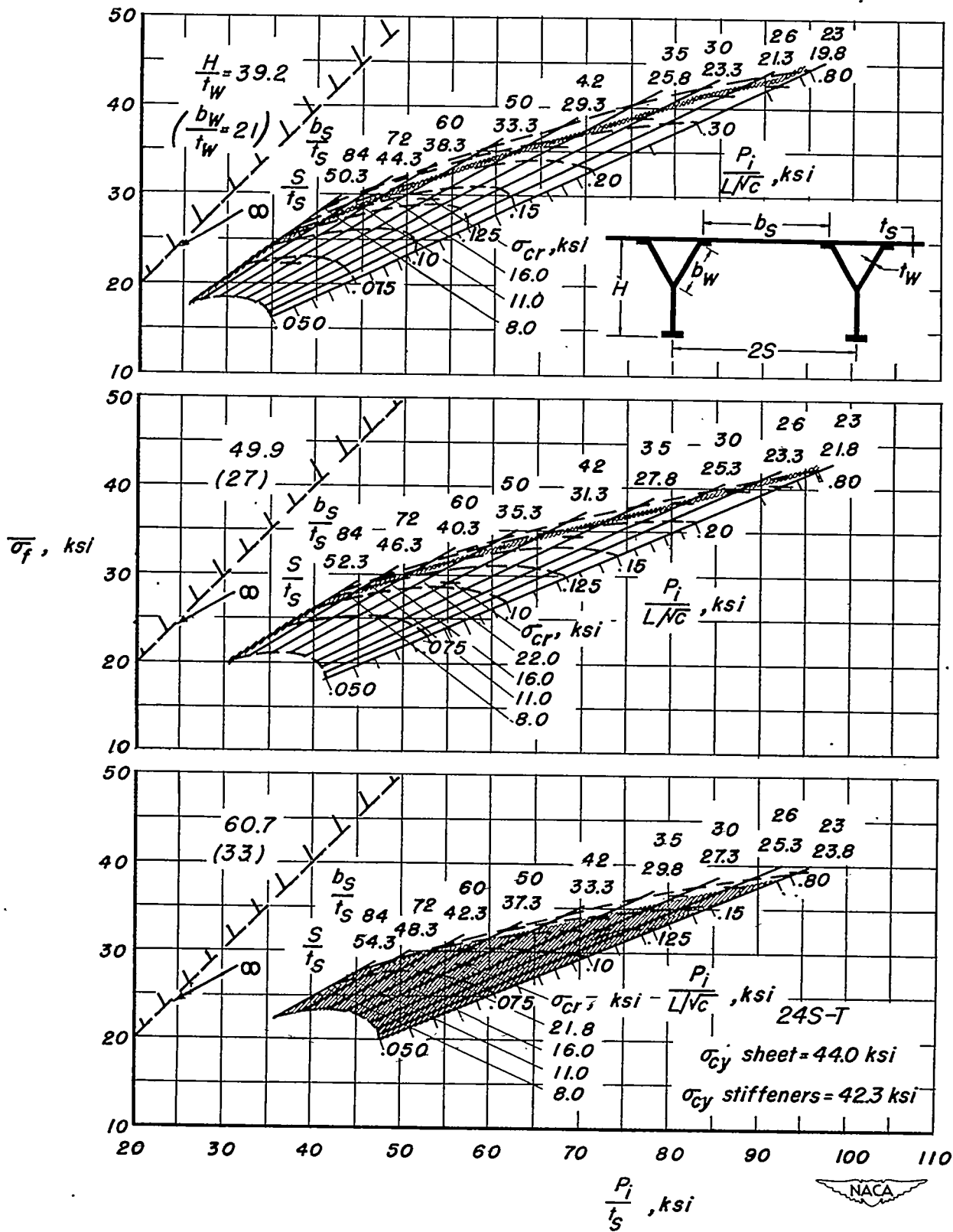


Figure 9.—Concluded. $t_w/t_s = 0.63$.



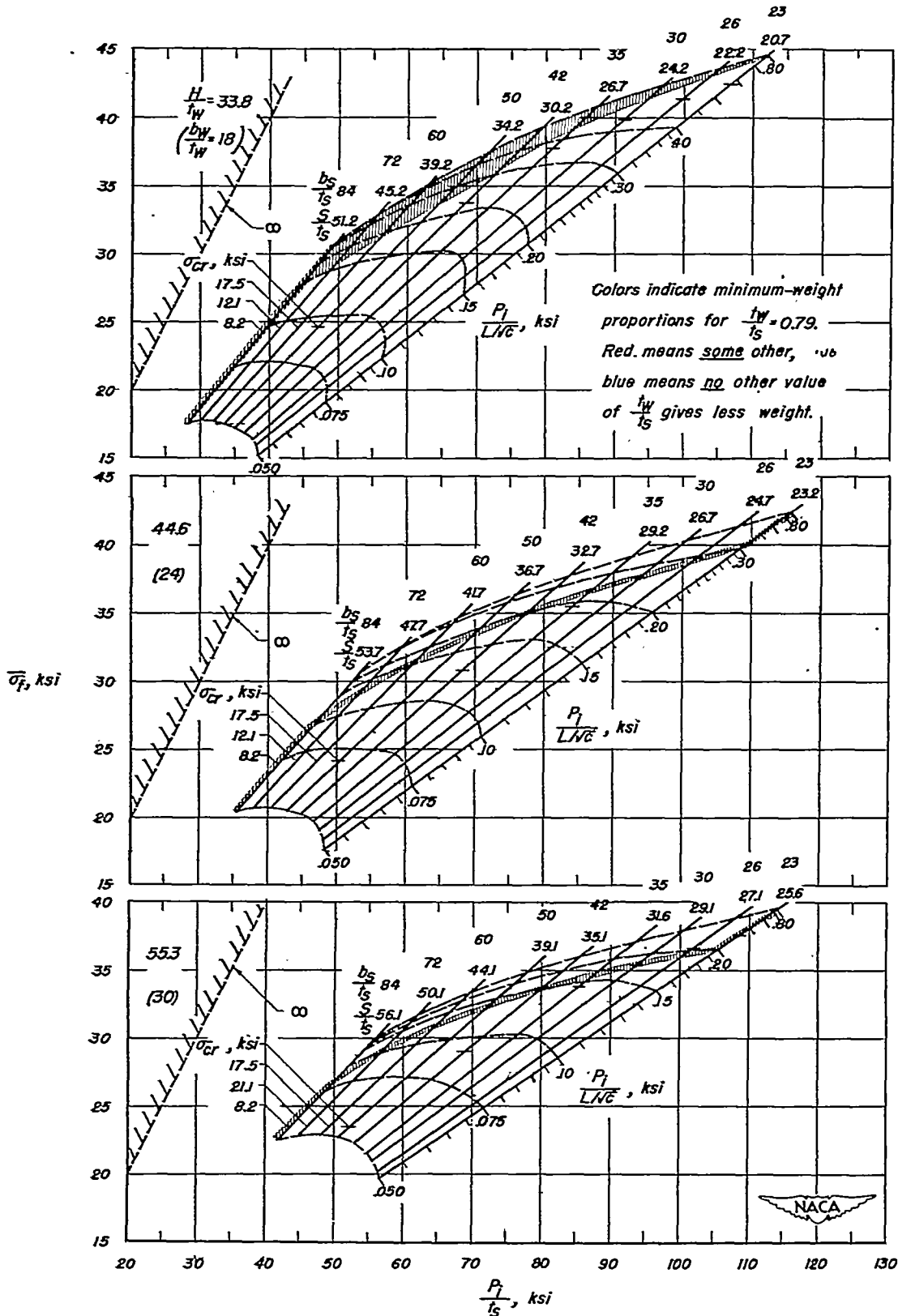


Figure 10.—Direct-reading design chart (alternate form) for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners. $\frac{t_w}{l_s} = 0.79$.

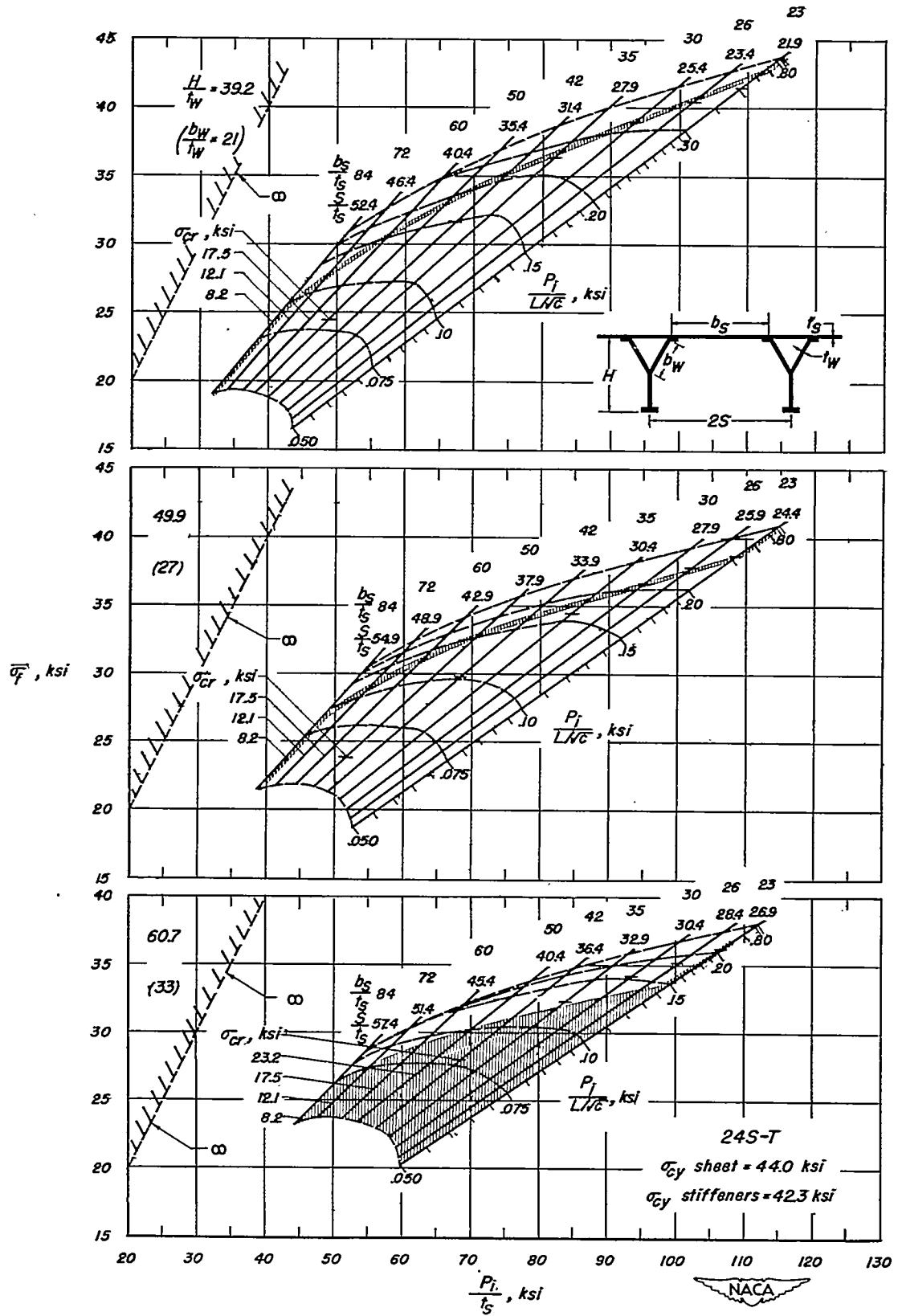


Figure 10.-Concluded. $t_w/t_s = 0.79$.

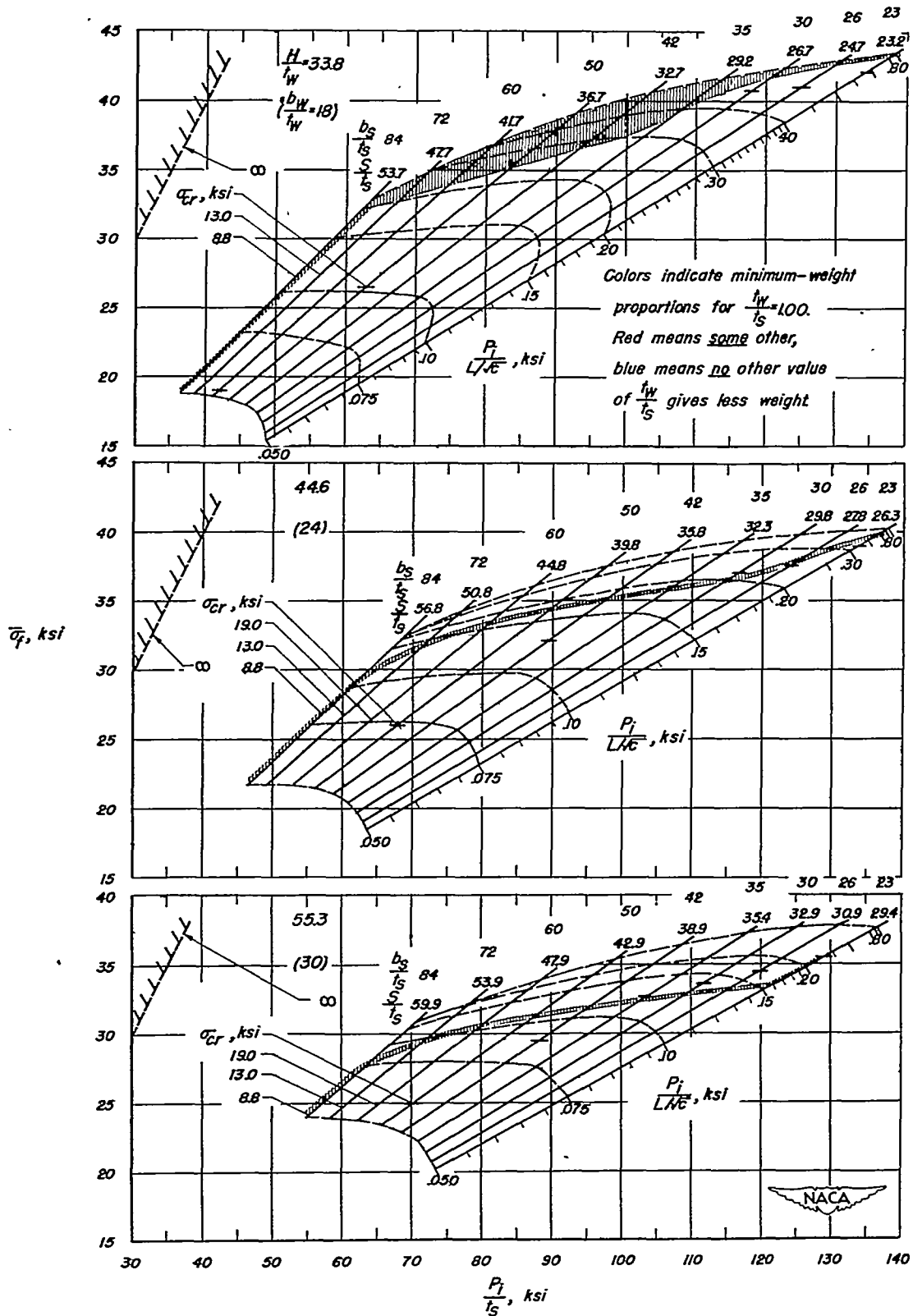


Figure 11.—Direct-reading design chart (alternate form) for flat compression panels of 24S-T aluminum alloy with straight-web Y-section stiffeners, $\frac{t_w}{t_s} = 100$.

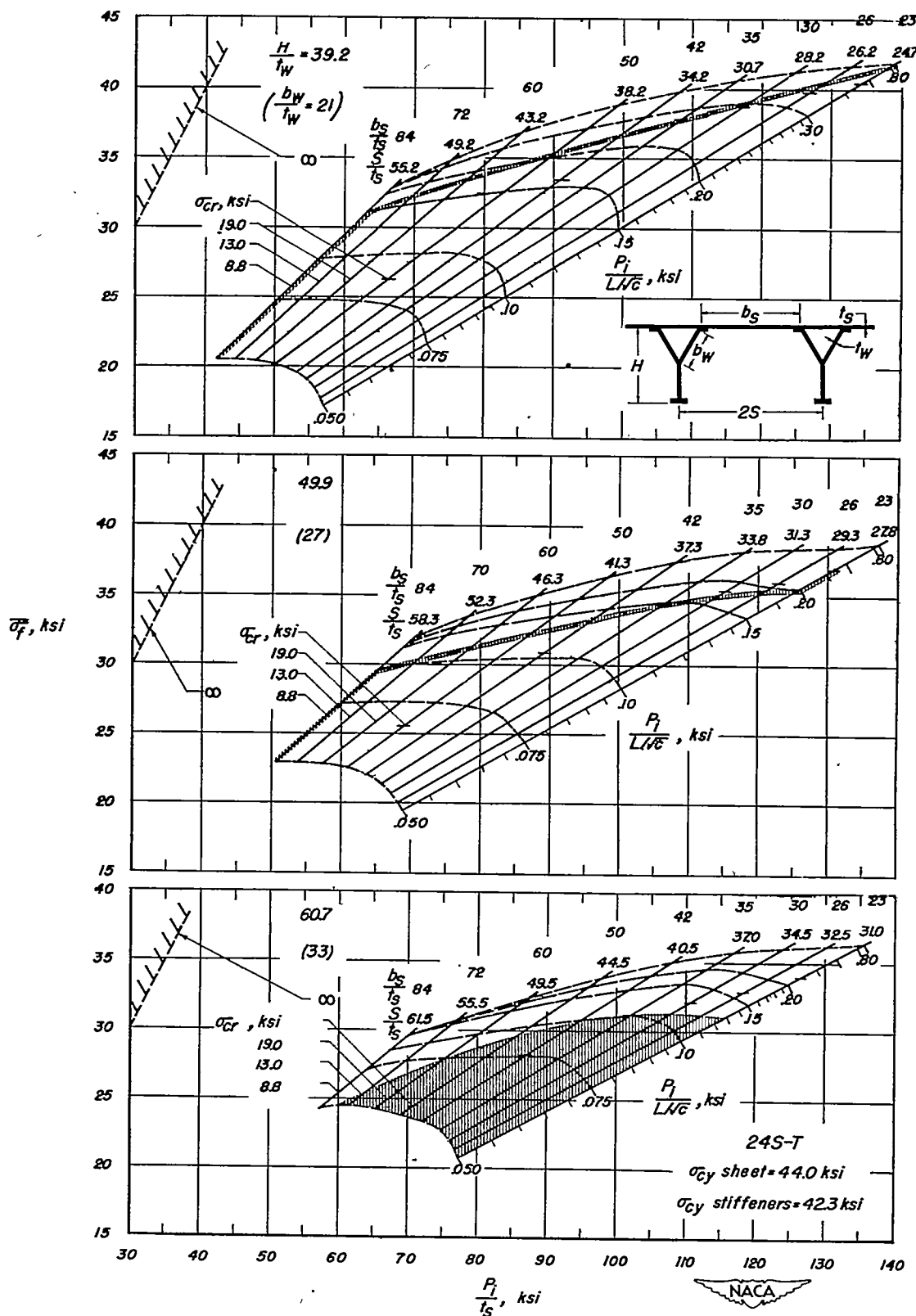


Figure 11.-Concluded, $t_w/t_s = 1.00$.

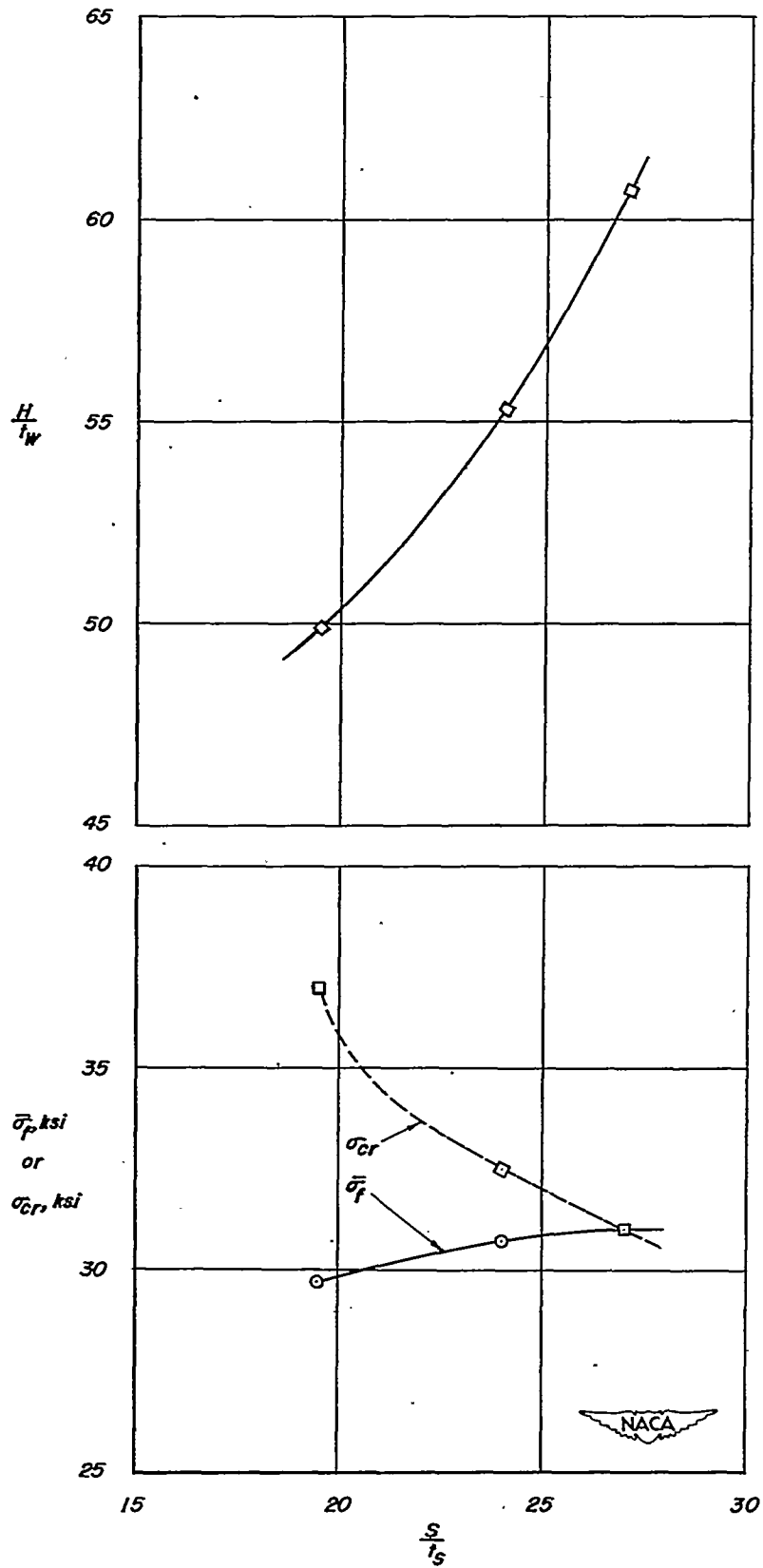


Figure 12.- Plot for obtaining design from design charts.