U.S. Department of Commerce — Civil Aeronautics Administration

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Supplement No. 12 — March 26, 1953

SUBJECT: 3.171
Loads

The purpose of this supplement is to make available an optional means whereby the airplane designer may show compliance with §§3.181 through 3.234 of Part 3 by using Appendix A entitled SIMPLIFIED DESIGN CRITERIA FOR AIRPLANES HAVING A DESIGN WEIGHT EQUAL TO OR LESS THAN 6000 POUNDS. The use of the design criteria in Appendix A is restricted to conventional single engine airplanes.

## 3.171-1 DESIGN CRITERIA

The attached page and Appendix A should be retained as part of a series of similar statements that will be issued explaining or implementing CAR 3.

John T. Wallick
for E. S. Hensley
Director, Office of
Aviation Safety

Attachments

DISTRIBUTION: AIR 1, 2, 3, 10, 10A, 11, 13, 14,
40 all tabs, 40D, 40E, 40F-1, 40-1

"§3.171 Loads. (a) Strength requirements are specified in terms of limit and ultimate loads. Limit loads are the maximum loads anticipated in service. Ultimate loads are equal to the limit loads multiplied by the factor of safety. Unless otherwise described, loads specified are limit loads.

(b) Unless otherwise provided, the specified air, ground and water loads shall be placed in equilibrium with inertia forces, considering all items of mass in the airplane. All such loads shall be distributed in a manner conservatively approximating or closely representing actual conditions. If deflections under load would change significantly the distribution of external or internal loads, such redistribution shall be taken into account.

(c) Simplified structural design criteria shall be acceptable if the Administrator finds that they result in design loads not less than those prescribed in §§3.181 through 3.265."

§3.171-1 DESIGN CRITERIA. (CAA policies which apply to §3.171(c)). The Administrator finds that the simplified structural design criteria contained in Appendix A to Civil Aeronautics Manual 3, result in design loads not less than those prescribed in §§3.181 through 3.265.

CIVIL AERONAUTICS MANUAL 3

APPENDIX A

# SIMPLIFIED DESIGN LOAD CRITERIA FOR AIRPLANES HAVING A DESIGN WEIGHT EQUAL TO OR LESS THAN 6000 POUNDS

MARCH
1953

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# APPENDIX A

## SIMPLIFIED DESIGN LOAD CRITERIA FOR AIRPLANES HAVING A DESIGN WEIGHT EQUAL TO OR LESS THAN 6000 POUNDS

1.0 General.

1.1 The design load criteria contained in this Appendix A have been determined by the Administrator under Section 3.171(c) of CAR Part 3 to result in design loads not less than those prescribed in Sections 3.181 through 3.234 of Part 3 of the Civil Air Regulations. The use of these criteria is restricted to conventional single engine airplanes having a design weight equal to or less than 6000 pounds. Careful consideration has been given to the comments and suggestions received and where it was possible to do so, within the limits of Part 3, these comments and suggestions have been incorporated into this appendix.

1.2 It is the option of the designer whether or not he wishes to use this appendix. However, should he elect to use the appendix, he should use it in its entirety as a direct and equivalent substitute for Sections 3.181 through 3.234 of Part 3. Generally speaking, the light plane designer will find that the use of these simplified criteria will substantially reduce the amount of engineering work required to determine the basic design loads for his airplane under present airworthiness standards. In addition, it is easier for him to obtain simultaneous certification of his airplane in more than one category.

2.0 Design Criteria.

2.1 Flight Envelope. The flight envelope used is a combination of the maneuvering and gust envelopes of Part 3. For most designs only the four corners of the V-n diagram need be investigated. Provisions, however, are made for those cases in which the gust load factor at $V_c$ is greater than the manuevering load factor. The basic positive load factors of Part 3 have been retained but it was found necessary to increase the negative load factor of Part 3 from .4 to .5 of the positive value in order to make the criteria for the several categories consistent. In addition, the right hand lower corner has been squared off to reduce the number of design conditions.

2.2 Minimum Design Air Speeds. The minimum design speeds are almost exactly the same as the minimum design speeds now required by Part 3, with the exception of $V_{C\ min}$. It was necessary in this latter case to increase the minimum design speed 0%, 7.5% and 13.5%, for the N. U and A categories respectively, over the Part 3 minimums. $V_{C\ min}$, however, need not exceed $.9V_h$ actually obtained at sea level. $V_{F\ min}$ is equal to 1.4 $V_s$ where $V_s$ was computed using $C_L = 1.35$.

2.3 Control Surface Loads.

2.30 Horizontal Tail. The horizontal tail control surface design loads are determined primarily by the down gust load requirements of Part 3 for the normal category. A study was made of present day airplanes to determine whether or not the up loads on the horizontal tail could be reduced. The magnitude of the loads obtained for the Checked Maneuver Condition (Section 3.216(c) of Part 3) indicated that in some instances it would be unconservative to reduce the up loads below the down loads, therefore the same design curve is used for the up and down loads.

2.31 Vertical Tail. The vertical tail design loads are based on the gust requirements and curve A of Figure 3-3(b), of Part 3. The gust criteria used in developing the vertical tail loading curve is the same as Part 3 gust criteria corrected for an aspect ratio of 2.0. The selection of an aspect ratio = 2.0 is well substantiated by referring to the basic data used in present day design of light airplanes, also by the fact that AR = 2.0 was the minimum in Part 04. The gust alleviation factor, K, was conservatively selected as being equal to 1.2.

2.32 Aileron. The aileron design loads are exactly the same as those given by curve B of Figure 3-3(b) in Part 3.

2.33 Flaps and Tab. Since Part 3 does not contain empirical curves for flap and tab design, these curves were developed for this Appendix by selecting a value of $C_{N_F} = 1.6$ and $V_F = 12.5 \sqrt{n\ w/s}$ for the flap and $C_{N_T} = .80$ and $V_C = 19.5 \sqrt{n\ w/s}$ for the tab. These values of $C_N$ were selected as being reasonable and conservative, based on data from NACA Technical Reports 360, 498, 571, 574 and 633.

2.4 Center of Gravity. Except as noted in Section 5.12 all of the loadings specified in this Appendix are independent of the center of gravity position of the aircraft. A c.g. range is needed, however, to establish operating limitations in accordance with Section 3.778(d) of Part 3 and therefore should be selected by the designer.

3.0 Definitions.

3.1 Except as noted below, the nomenclature and symbols used in this Appendix are the same as the corresponding nomenclature and symbols used in Part 3.

$n_1$ = Airplane Positive Maneuvering Limit Load Factor

$n_2$ = Airplane Negative Maneuvering Limit Load Factor

$n_3$ = Airplane Positive 30 fps Gust Limit Load Factor at $V_C$

$n_4$ = Airplane Negative 30 fps Gust Limit Load Factor at $V_C$

$n_{flap}$ = Airplane Positive Limit Load Factor with Flaps fully Extended at $V_F$

*$V_{F\ min}$ = Minimum Design Flap Speed = $12.5\sqrt{n_1 W/S}$

*$V_{P\ min}$ = Minimum Design Maneuvering Speed = $17.0\sqrt{n_1 W/S}$

*$V_{C\ min}$ = Minimum Design Cruising Speed = $19.5\sqrt{n_1 W/S}$

*$V_{D\ min}$ = Minimum Design Dive Speed = $27.3\sqrt{n_1 W/S}$

*Also see Section 5.3

4.0 Certification in More than one Category. The criteria in this Appendix permit simultaneous certification in more than one category (N, U or A). When certification in more than one category is desired, the design category weights should be selected such that the term "$n_1W$" is constant for all categories or is greater for one desired category than others. The wings and control sufaces (including wing flaps and tabs) need be investigated only for the maximum value of "$n_1W$" or the category corresponding to the maximum design weight in the event "$n_1W$" is constant. If the acrobatic category is one of the categories selected, a special unsymmetrical flight load investigation in accordance with Sections 6.31 and 7.31 should be completed. The wing, wing carry-through and the horizontal tail structure should be checked for this condition. The basic fuselage structure need be investigated only for the highest load factor design category. The local supporting structure for dead weight items need be designed only for the highest load factor imposed when the particular item is installed in the airplane. The engine mount, however, must be substantiated for a higher side load factor when certification in the acrobatic category is desired than is required for certification in the normal and utility categories. The landing gear and the airplane as a whole under landing loads, need only be investigated for the category corresponding to the maximum design weight. These simplifications apply in general to single engine aircraft of conventional type for which experience is available, and the Administrator reserves the right to require additional investigations for aircraft incorporating unusual design features.

5.0 Flight Loads.

5.1 General. The flight loads may be considered independent of altitude and, except for the local supporting structure for dead weight items, only the maximum design weight conditions need be investigated. Values of $n_1$, $n_2$, $n_3$, $n_4$ should be determined from Table 1 and Figures 3 and 4 for the particular maximum design weights appropriate to the category or categories for which approval is desired.

5.10 Values of $n_3$ and $n_4$ corresponding to the minimum flying weight should also be determined using Figures 3 and 4 and if these load factors are greater than the load factors at the design weight, the supporting structure for dead weight items should be substantiated for the resulting higher load factors.

5.11 In all cases the loads and loading conditions specified in Sections 5.2 through 5.4 are the minimum for which strength should be provided in the structure.

5.12 The specified wing and tail loadings are independent of center of gravity range. The designer, however, should select a c.g. range and the basic fuselage structure should be investigated for the most adverse dead weight loading conditions corresponding to the c.g. range selected.

5.2 Airplane Equilibrium. Vertical wing loads may be found directly from vertical airplane loads by multiplying the airplane loads (as determined from Sections 6.2 and 6.3) by a factor of 1.05 for the positive flight conditions and 1.0 for the negative. It should be noted that the vertical wing load is considered to be the wing load vertical to the relative wind. This load, depending on the maximum high angle of attack will have a chordwise component which may be as much as 25% of the vertical wing lead. This chordwise load should be taken into consideration.

5.3 Minimum Design Air Speeds. The minimum design airspeeds may be chosen by the designer except that they should not be less than the minimum speeds found using Figure 1. In addition, $V_{C\ min}$ need not exceed $.9V_h$ actually obtained at sea level for the lowest design weight category for which certification is desired. For purposes of computing these minimum design speeds, $n_1$ should not be less than 3.8.

5.4 Flight Load Factor. The limit flight load factors specified in Table 1, represent the acceleration component in terms of the gravitational constant, g, normal to the assumed longitudinal axes of the airplane, and equal in magnitude and opposite in direction to the airplane inertia load factor at the center of gravity.

6.0 Flight Conditions

6.1 General. The design conditions specified in Sections 6.2 and 6.3 are intended to provide strength for all conditions of speed and load factor on or within the boundary of a V-n diagram for the aircraft similar to the one shown in Figure 2. This V-n diagram should also be used in determining the airplane structural operating limitations as specified in Sections 3.735 through 3.743 and Section 3.748 of Part 3.

6.2 Symmetrical Flight Conditions.

6.20 The airplane should be designed for at least the four Basic Flight Conditions, "A", "D", "E", and "G" as noted on the flight envelope, Figure 2.

6.201 The design limit flight load factors, corresponding to conditions "D" and "E" should be at least as great as those specified in Table 1 and Figure 2 and the design speed for these conditions should be at least equal to the value of $V_D$ found from Figure 1.

6.202 For conditions "A" and "G" the load factors should correspond to those specified in Table 1 and the design speeds should be those computed using these load factors with the maximum static lift coefficient ($C_{N_A}$) determined by the designer. In the absence of more precise computations, these latter conditions may be based on a value of $C_{N_A} = \pm 1.35$. The design speed for condition "A" may be a speed less than $V_{P_{min}}$.



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6.203 Conditions "C" and "F" need be investigated only when $n_3$ W/S or $n_4$ W/S are greater than $n_1$ W/S or $n_2$ W/S respectively, (see Figures 3 and 4).

6.21 When flaps or similar high lift devices intended for use at the relatively low air speeds of approach, landing and take-off are installed, the airplane should be designed for the two flight conditions corresponding to the values of limit flap-down factors specified in Table 1 with the flaps fully extended at not less than the design flap speed $V_{F\,min}$ from Figure 1.

6.3 Unsymmetrical Flight Conditions. The affected structure as noted, should be designed for the unsymmetrical loadings specified in Sections 6.30 through 6.32.

6.30 The aft fuselage to wing attachment should be designed for the critical vertical surface load from Sections 7.30 and 7.31.

6.31 The wing and wing carry-through structure should be designed for 100% of Condition "A" loading on one side of the plane of symmetry and 70% on the opposite side for certification in the normal and utility categories or 60% on the opposite side for certification in the acrobatic category.

6.32 The wing and wing carry-through structure should be designed for the loads resulting from a combination of 75% of the positive maneuvering wing loading on both sides of the plane of symmetry combined with the maximum wing torison resulting from aileron displacement. The effect of aileron displacement on wing torsion at $V_C$ or $V_D$, using the basic airfoil moment coefficient modified over the aileron portion of the span, is computed as follows:

$$C_m = C_{m\,\text{wing basic airfoil}} + .01\,\delta_u \quad \text{(up aileron side)}$$

$$C_m = C_{m\,\text{wing basic airfoil}} - .01\,\delta_d \quad \text{(down aileron side)}$$

$\delta_u$ is the up aileron deflection and $\delta_d$ is the down aileron deflection. The sum of $\delta_u + \delta_d = \Delta$ critical. The method of computing $\Delta$ critical is shown below.



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(1) compute $\Delta_a = \frac{V_p}{V_c} \times \Delta_p$

and $\Delta_b = 0.5 \frac{V_p}{V_d} \times \Delta_p$

where $\Delta_p$ = the maximum total deflection (sum of both aileron deflections) at $V_p$. $V_p$, $V_c$, and $V_d$ are described in Section 5.3.

(2) Determine K from the following formula:

$$K = \frac{(C_m - .01\,\delta_b)V_d^2}{(C_m - .01\,\delta_a)\,V_c^2}$$

Where $\delta_a$ is the down aileron deflection corresponding to $\Delta_a$ and $\delta_b$ is the down aileron deflection corresponding to $\Delta_b$ as computed in step (1).

If K is less than 1.0, $\Delta_a$ is $\Delta$ critical and should be used to determine $\delta_u$ and $\delta_d$. In this case $V_c$ is the critical speed to be used in computing the wing torsion loads over the aileron span.

If K is equal to or greater than 1.0, $\Delta_b$ is $\Delta$ critical and should be used to determine $\delta_u$ and $\delta_d$. In this case $V_d$ is the critical speed to be used in computing the wing torsion loads over the aileron span.

6.4 Supplementary Conditions. At least the conditions specified in Sections 6.41 and 6.42 should be investigated.

6.40 Special Conditions for Rear Lift Truss. In lieu of an investigation of condition G, Figure 2, the special condition specified in Section 3.194 of Part 3 may be investigated. In such event and if certification in more than one category (see Section 4.0) is desired, the value of W/S used in the formula appearing in Section 3.194 of Part 3 should be that for the category corresponding to the Maximum gross weight.

6.41 Engine Torque Effects. Engine mounts and their supporting structure should be designed for the maximum limit torque corresponding to METO power and propeller speed, acting simultaneously with the limit loads resulting from the maximum positive maneuvering flight load factor $n_1$. The limit torque should be obtained by multiplying the mean torque by a factor of 1.33 in the case of engines having five or more cylinders. For 4, 3, and 2 cylinder engines the factor should be 2, 3, and 4 respectively.

6.42 Side Load on Engine Mount. Engine mounts and their supporting structure should be designed for the loads resulting from a lateral limit load factor not less than 1.47 for N & U categories and 2.0 for the acrobatic category.

7.0 Control Surface Loads

7.1 General. Control surface loads should be determined using the criteria of Section 7.2 and within the simplified loadings of Section 7.3.

7.2 Pilot Effort. In the control surface loading conditions described in Sections 7.3 through 7.5, the airloads on the movable surfaces and the corresponding deflections need not exceed those which could be obtained in flight by employing the maximum pilot control forces specified in Figure 3-11 of Part 3. In cases where the surface loads are limited on the basis of maximum pilot effort, the tabs should either be considered to be deflected to their maximum travel in the direction which would assist the pilot or the deflection should correspond to the maximum expected degree of "out of trim" at the speed for the condition under consideration. The tab load, however, need not exceed the value specified in Table 2.

7.3 Surface Loading Conditions.

7.30 Simplified limit surface loadings and distributions for the horizontal tail, vertical tail, aileron, wing flaps and trim tabs are specified in Table 2 and Figures 5 and 6. Where more than one distribution is given, each distribution should be investigated.

7.31 When certification in the Acrobatic category is desired the horizontal tail shall be investigated for an unsymmetrical load of 100% $\bar{w}$ on one side of the airplane center line and 50% on the other side of the airplane center line.

7.4 Outboard Fins. See Section 3.221 of Part 3.

7.5 Special Devices. See Section 3.225 of Part 3.

8.0 Control System Loads

8.1 Primary Flight Controls and Systems.

8.10 Flight control systems and supporting structures should be designed for loads corresponding to 125 percent of the computed hinge moments of the movable control surface in the conditions prescribed in Section 7.0 subject to the following maxima and minima:

8.101 The system limit loads need not exceed those which could be produced by the pilot and automatic devices operating the controls.

8.102 The loads should in any case be sufficient to provide a rugged system for service use, including consideration of jamming, ground gusts, taxying tail to wind, control inertia, and friction.

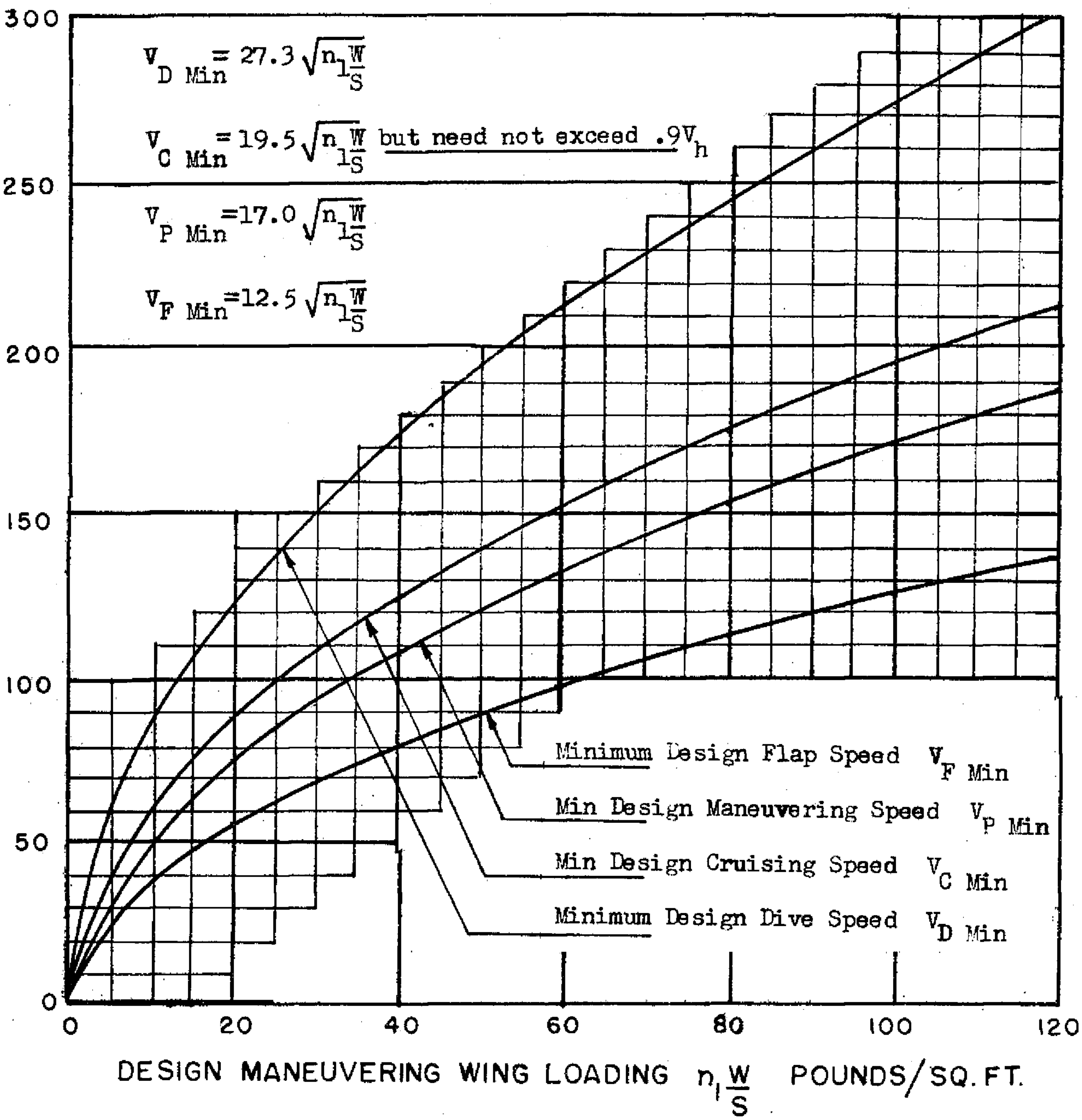
8.11 Acceptable maximum and minimum pilot loads for elevator, aileron, and rudder controls are as shown in Figure 3-11 of Part 3. These pilot loads should be assumed to act at the appropriate control grips or pads in a manner simulating flight conditions and to be reacted at the attachments of the control system to the control surface horn.

8.2 Dual controls. When dual controls are provided the systems should be designed for the pilots operating in opposition, using individual pilot loads equal to 75 percent of those obtained in accordance with Section 8.1 except that the individual pilot loads should not be less than the minimum loads shown in Figure 3-11, of Part 3.

8.3 Ground Gust Conditions. See Section 3.233 of Part 3.

8.4 Secondary Controls and Systems. See Section 3.234 of Part 3.

**FIGURE I**
**MINIMUM DESIGN AIR SPEEDS**



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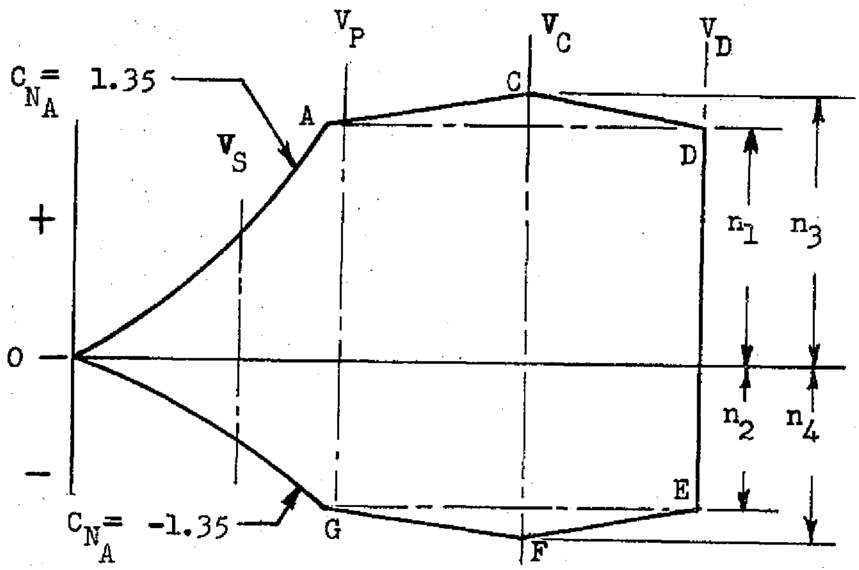
(V - n) Diagram (Flight Envelope)




Notes: -

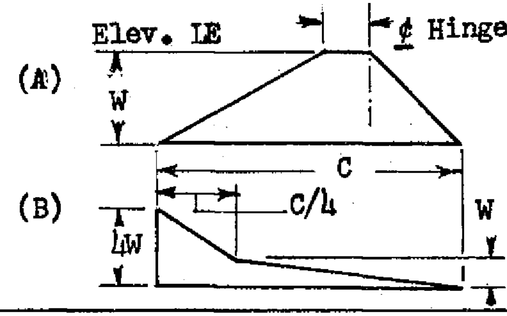
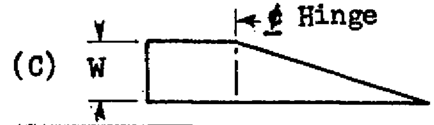
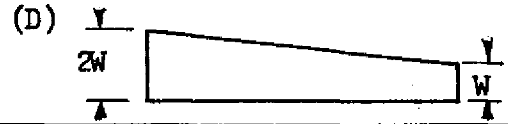
1. Conditions "C" or "F" need be investigated only when $n_3 \frac{W}{S}$ or $n_4 \frac{W}{S}$ are greater than $n_1 \frac{W}{S}$ or $n_2 \frac{W}{S}$, respectively.
2. Condition "G" need not be investigated, when the supplementary condition specified in CAR 3.194 is investigated.

TABLE 1

| LIMIT FLIGHT LOAD FACTORS | | | | | |
|---|---|---|---|---|---|
| | | | N | U | A |
| FLIGHT Load Factors | Flaps up | $n_1$ | 3.8* | 4.4 | 6.0 |
| | | $n_2$ | $-0.5n_1$ | | |
| | | $n_3$ | Find $n_3$ from Fig. 3 | | |
| | | $n_4$ | Find $n_4$ from Fig. 4 | | |
| | Flaps Down | $n_{flap}$ | $0.5n_1$ | | |
| | | $n_{flap}$ | Zero** | | |

*3.5 for Spin-Proof Airplanes
** Vertical Wing Load may Be Assumed Equal to Zero and Only the Flap Portion of the Wing Need Be Checked for this Condition.

TABLE 2

| AVERAGE LIMIT CONTROL SURFACE LOADING | | | |
|---|---|---|---|
| SURFACE | DIRECTION OF LOADING | MAGNITUDE OF LOADING | CHORDWISE DISTRIBUTION |
| HORIZONTAL TAIL I | a) Up and Down | Figure 5 Curve (2) |  |
| | b) Unsymmetrical loading (Up and Down) | 100% $\bar{W}$ on one side airplane ¢. 65% $\bar{W}$ on other side of airplane ¢ for N and U categories. For A category see 7.3 | |
| VERTICAL TAIL II | a) Right and Left | Figure 5 Curve (1) | Same as (A) above |
| | b) Right and Left | Figure 5 Curve (1) | Same as (B) above |
| AILERON III | a) Up and Down | Figure 6 Curve (5) |  |
| WING FLAP IV | a) Up | Figure 6 Curve (4) |  |
| | b) Down | .25 x Up Load (a) | |
| TRIM TAB V | a) Up and Down | Figure 6 Curve (3) | Same as (D) above |

NOTE: The surface loadings I, II, III, and V above are based on speeds $V_p$ min and $V_c$ min. The loading of IV is based on $V_f$ min. If values of speeds greater than these minimums are selected for design the appropriate surface loadings shall be multiplied by the ratio $\left[\frac{V_{selected}}{V_{minimum}}\right]^2$. For conditions I, II, III and V the multiplying factor used shall be the higher of $\left[\frac{V_p \text{ sel.}}{V_p \text{ min.}}\right]^2$ or $\left[\frac{V_c \text{ sel.}}{V_c \text{ min.}}\right]^2$

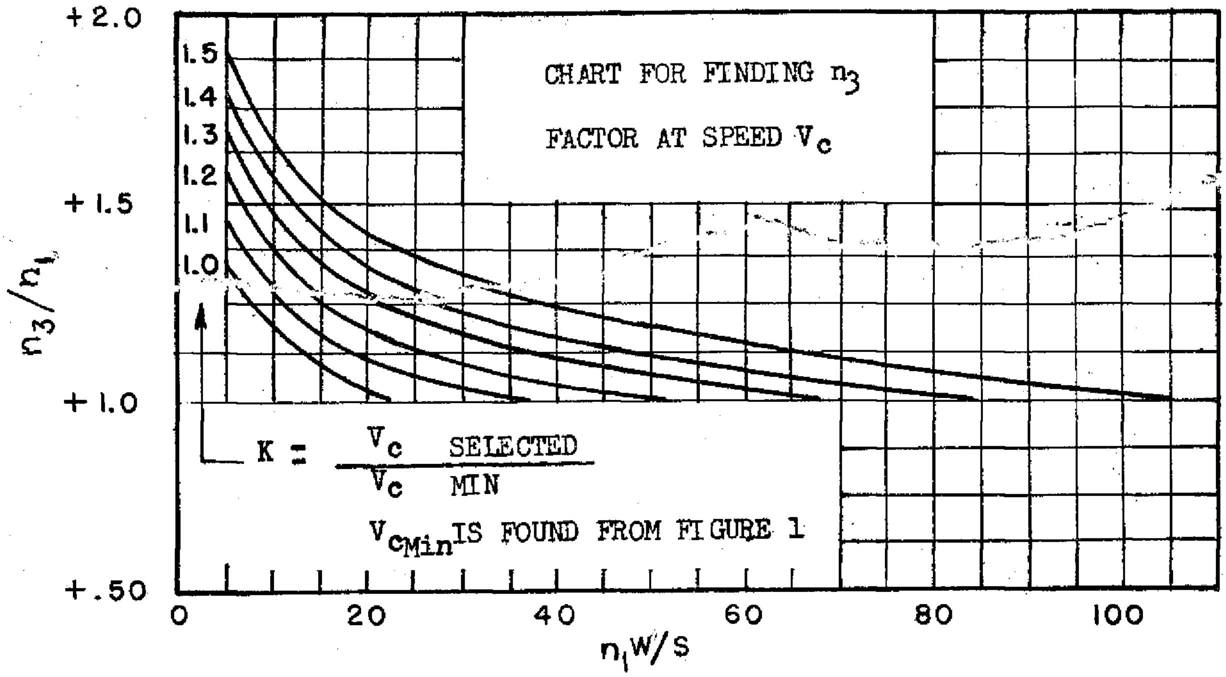



FIGURE 3

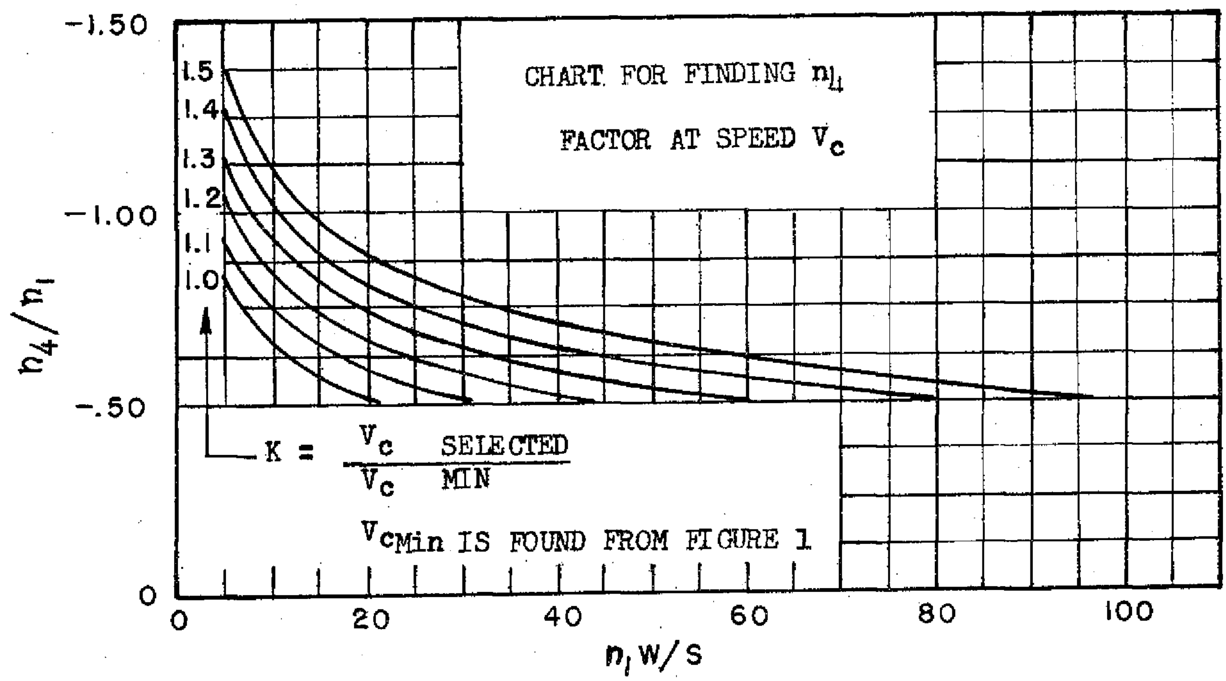
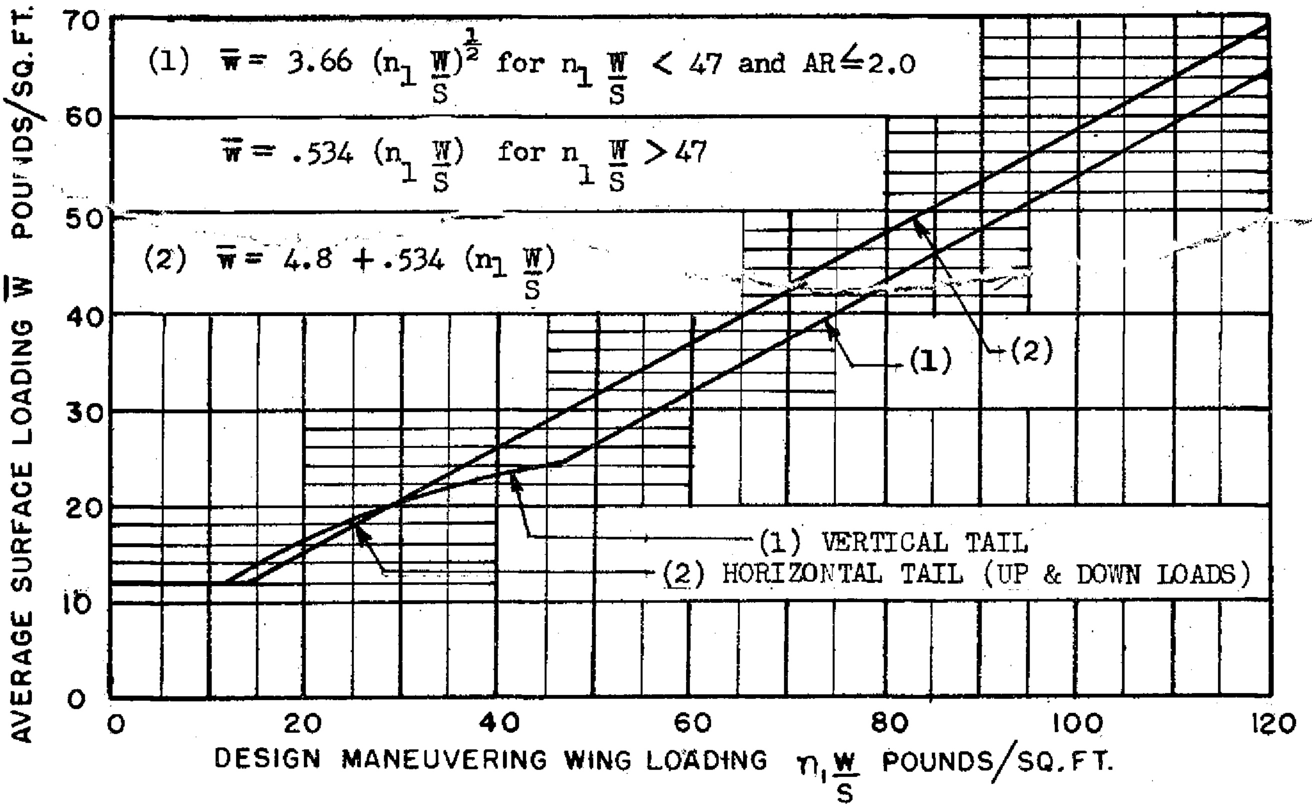



FIGURE 4

## FIGURE 5 AVERAGE LIMIT CONTROL SURFACE LOADING




## FIGURE 6 AVERAGE LIMIT CONTROL SURFACE LOADING