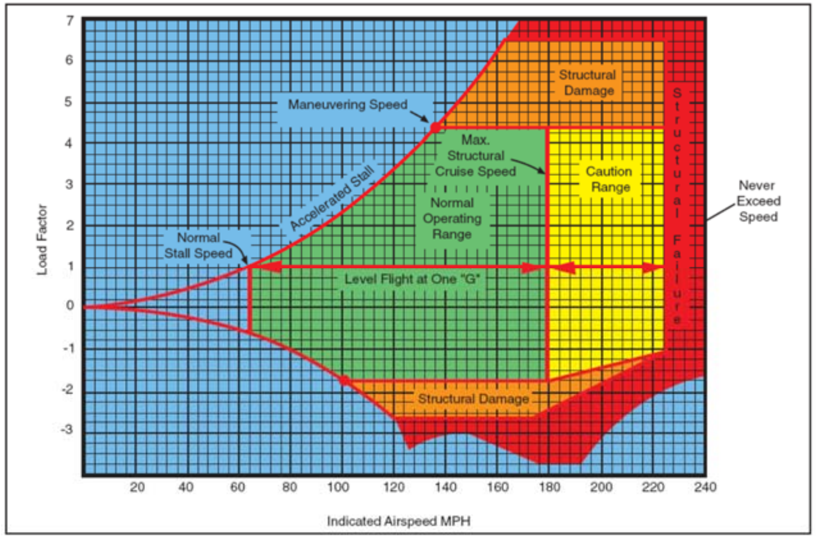
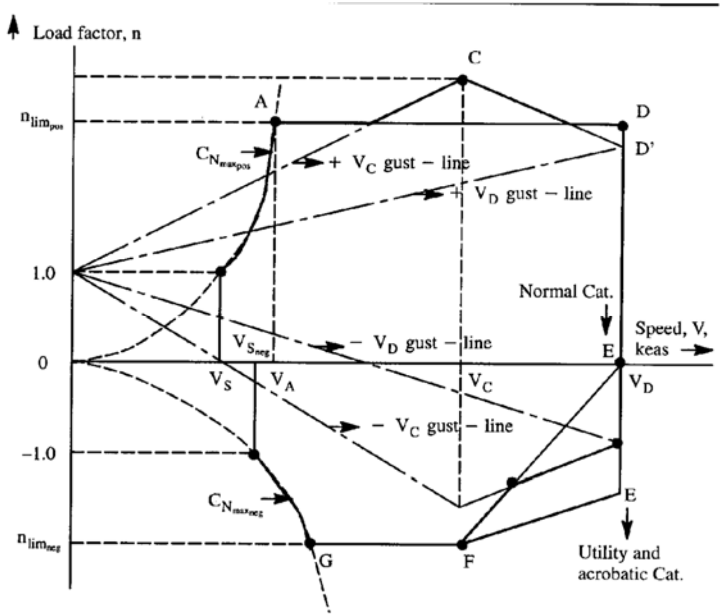
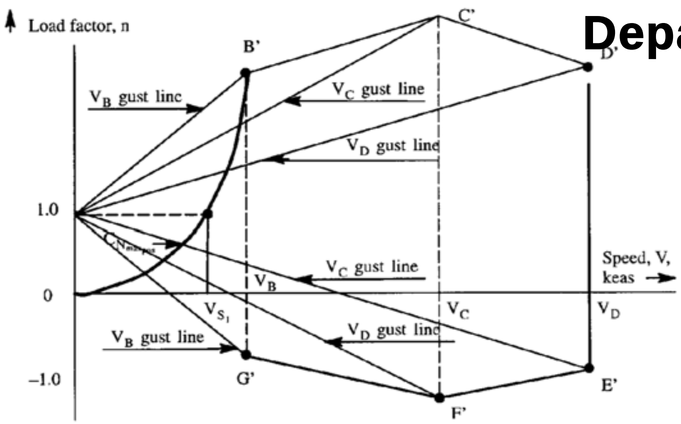




Estructuras Avanzadas

Tema 16

Sergio Esteban Roncero
Departamento de Ingeniería Aeroespacial
Y Mecánica de Fluidos



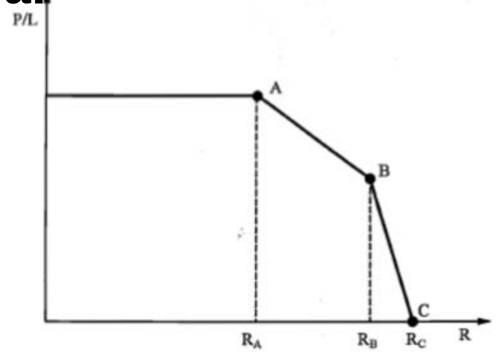
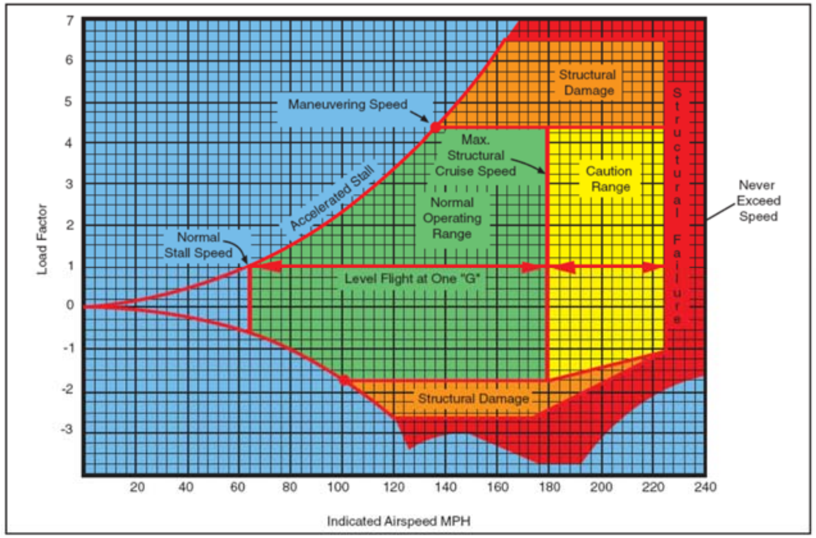


Figura 4.7. Ejemplo de diagrama de Carga de Pago-Alcance (P/L-R) de una aeronave.

V-n diagram – Envolvente de Vuelo - I

- Las características de la envolvente de vuelo depende del tipo de certificación que se le quiere dar al avión:
  - FAR 22 - CS-22 sailplanes and powered sailplanes
  - FAR 23 - CS-23 normal, utility, aerobatic and commuter aeroplanes
  - FAR 25 - CS-25 Large Aeroplanes
- Determina los límites del avión en términos de:
  - Velocidades
  - Alturas
  - Límites estructurales



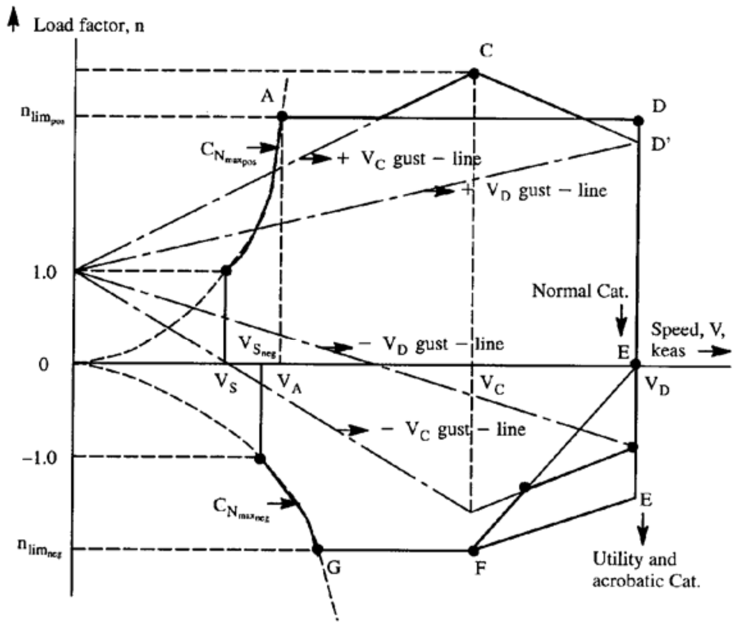


Figure 12.12 V–n Diagram According to FAR 23

V-n diagram – Envolvente de Vuelo - II

- Hay una serie de velocidades que se consideran importantes para la determinación del diagrama V-n:
  - V_S - 1-g stall speed
  - V_A – the design maneuvering speed
  - V_C – the cruising speed
  - V_D – the diving speed
- Estas velocidades determinan la diferentes líneas de la envolvente de vuelo.

Unidades Sistema Imperial

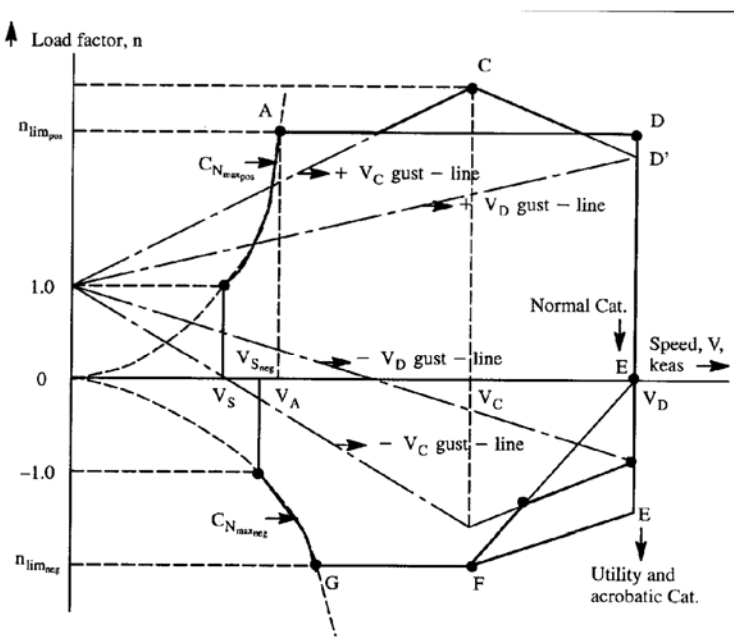


Figure 12.12 V–n Diagram According to FAR 23

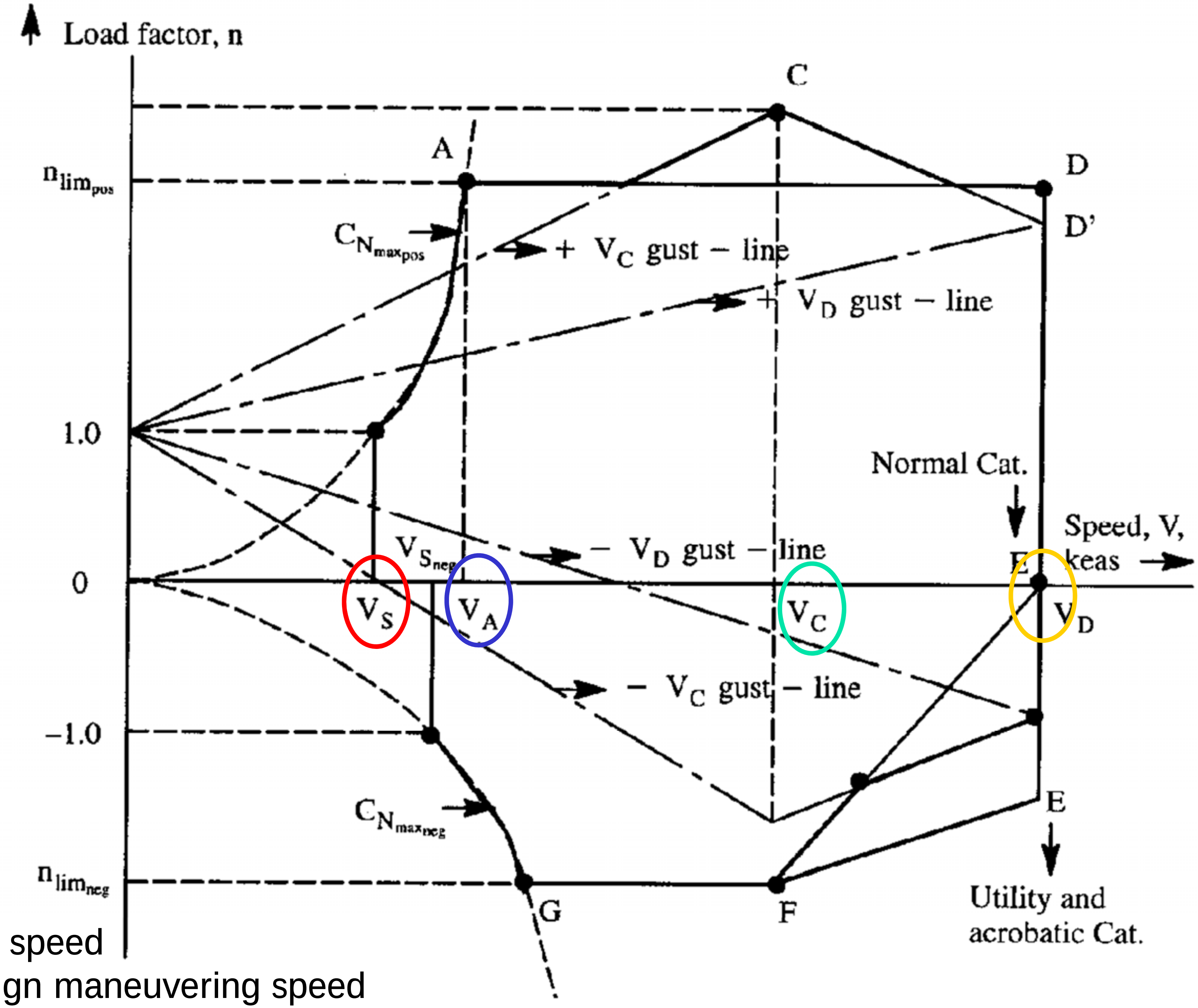


Figure 12.12 V–n Diagram According to FAR 23

V_S - 1-g stall speed
V_A – the design maneuvering speed
V_C – the cruising speed
V_D – the diving speed

V_S - 1-g stall speed

$$C_{N_{max(controllable)}} = \sqrt{\left(C_{L_{max(controllable)}}\right)^2 + \left(C_{D_{at\, C_{L_{max(controllable)}}}}\right)^2}$$

Hipótesis

$$C_{N_{max(controllable)}} = 1{,}1 C_{L_{max(controllable)}}$$

???

$$V_S = \sqrt{\frac{2W_{FDGW}}{\rho C_{N_{max(controllable)}} S}}$$

$$n = \frac{1}{2}\rho V_{S_{n=n}}^2 \frac{C_{N_{max(controllable)}}}{\frac{W_{FDGW}}{S}}$$

$$V_{S_{n=n}} = \sqrt{\frac{2nW_{FDGW}}{\rho C_{N_{max(controllable)}} S}}$$

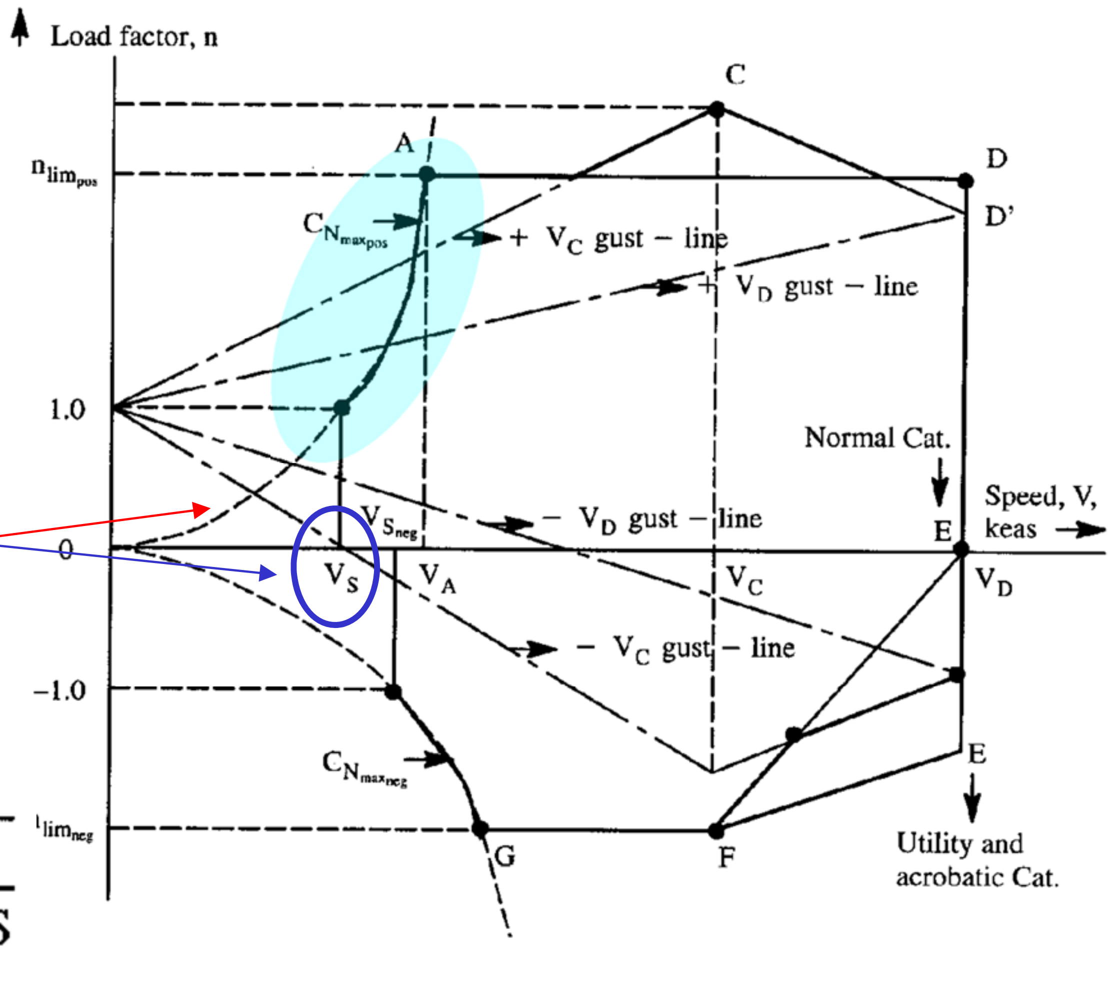


Figure 12.12 V–n Diagram According to FAR 23

V_S - 1-g stall speed

Velocidad de entrada en pérdida

$$V_S = \sqrt{\frac{2W_{FDWG}}{\rho C_{N_{max(controllable)}} S}}$$

Coeficiente de sustentación máximo (condición equilibrio)

$$C_{L_{max(effective)}} = \frac{C_{L_{max}}(n = 1)}{n}$$

C_{Lmax}(n=1) viene determinado por túnel de viento (herramientas de cálculo)

Durante estudio de maniobras de entrada en pérdida suele producirse n=0.9

$$n = 0.9$$

$$C_{N_{max(controllable)}} = 1{,}1 C_{L_{max(controllable)}} \quad \Leftarrow \quad C_{L_{max(effective)}} = \frac{C_{L_{max}}(n = 1)}{n}$$

$$C_{L_{max(controllable)}} \Rightarrow C_{L_{max(effective)}}$$

V_A – the design maneuvering speed

Design maneuvering speed: relización de maniobras

$$V_A \geq V_S\sqrt{n_{lim_{pos}}}$$
$$V_A \leq V_C$$

$$n_{lim_{pos}} \geq 2{,}1 + \frac{24000}{W_{FDGW} + 10000}$$

W_{FDGW} in lbs

$n_{lim_{pos}}$ need not be greater than 3.8

$n_{lim_{pos}}$ = 4.4 for utility category airplanes

$n_{lim_{pos}}$ = 6.0 for acrobatic category airplanes

n impuesto RFP

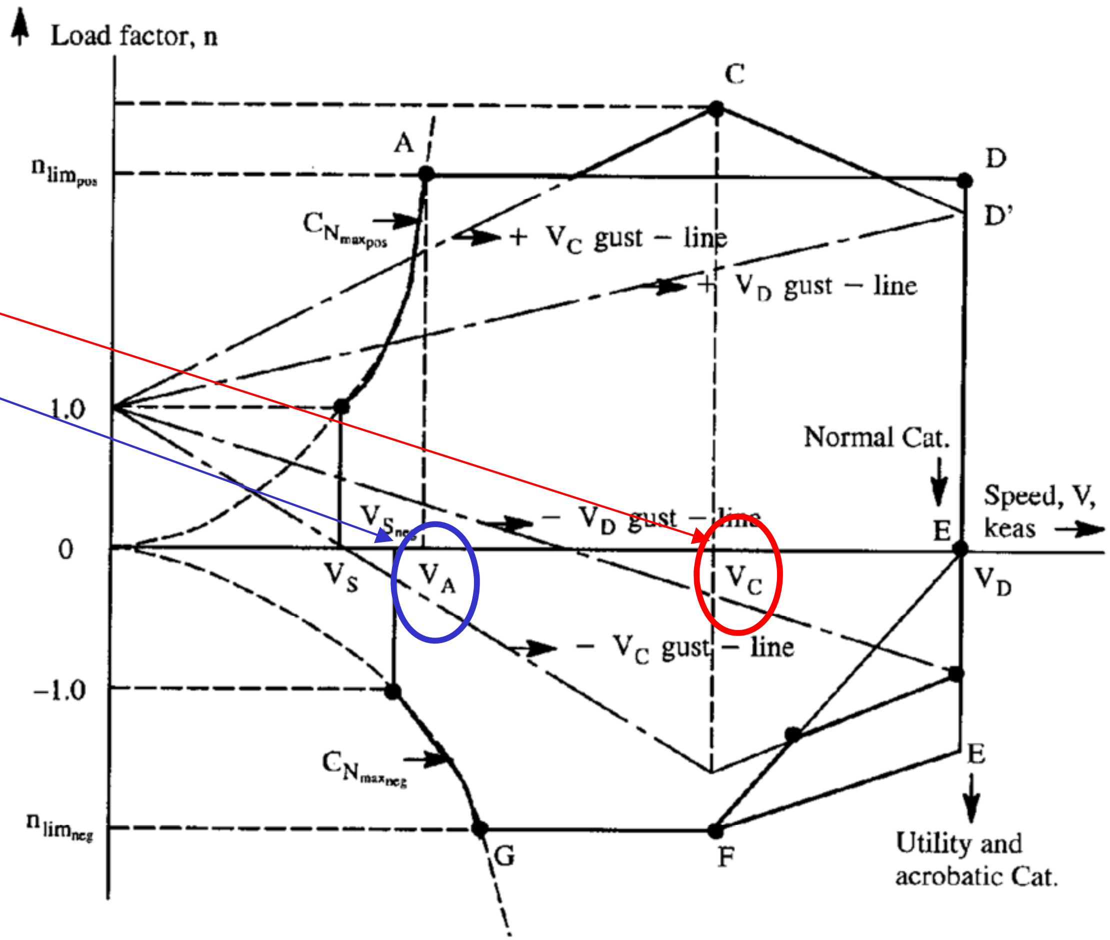


Figure 12.12 V–n Diagram According to FAR 23

V_C – the design cruising speed

$$V_C \geq k_c \sqrt{(W_{FDGW})/S}$$

S in ft^2

V_C en unidades keas
(knots equivalent air speed)
Velocidad calibrada para
efectos de compresibilidad

$$V_C \leq V_H$$

V_H es la velocidad horizontal máxima
obtenida con máximo empuje o potencia

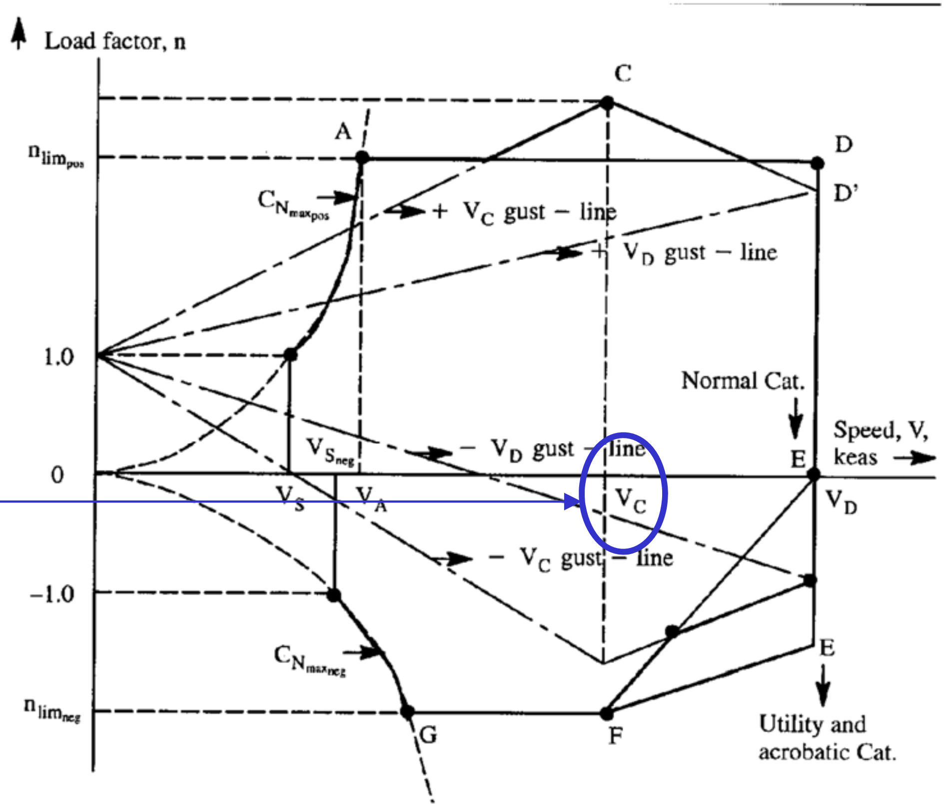


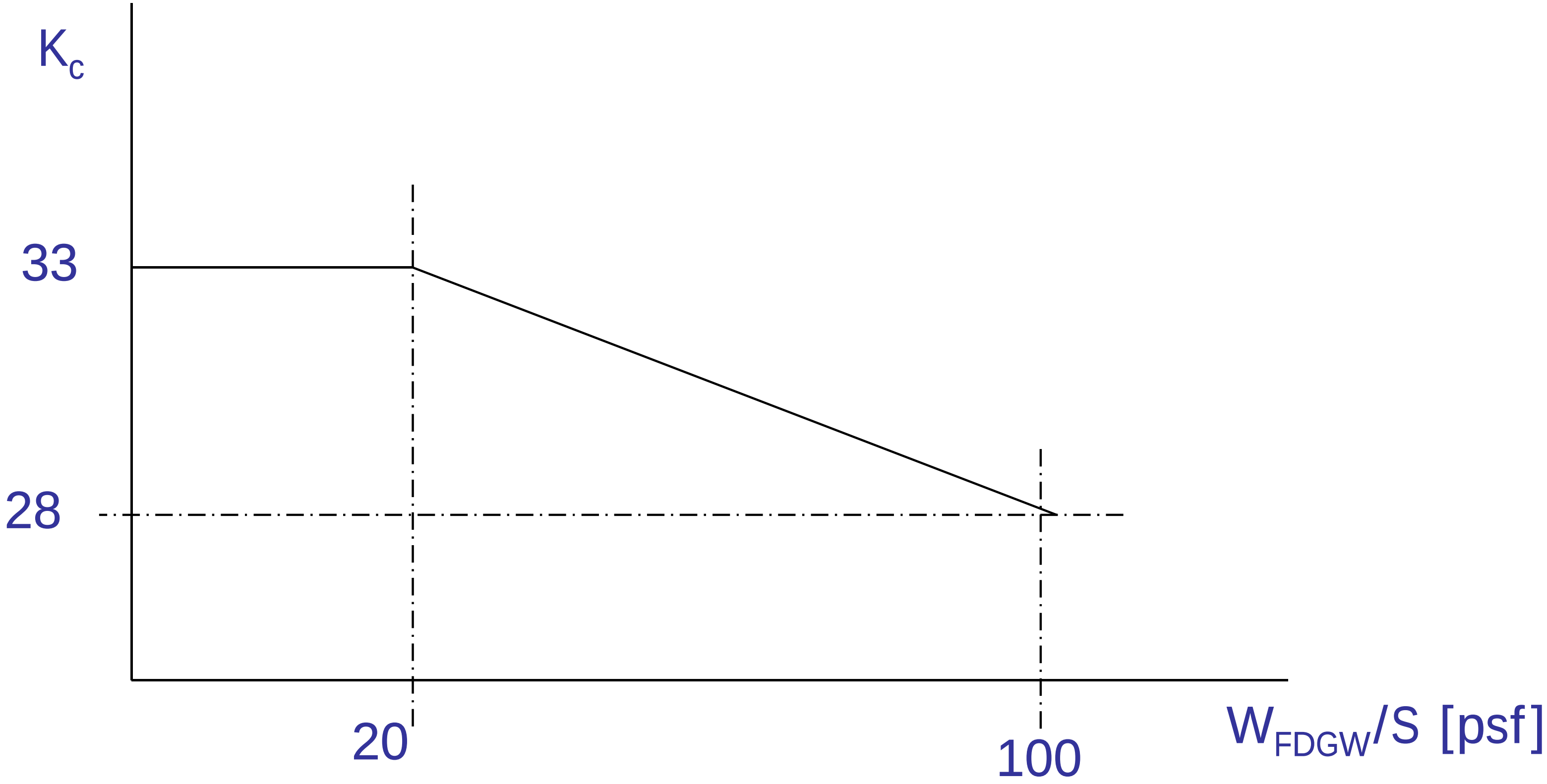
Figure 12.12 V–n Diagram According to FAR 23

k_c varies linearly from 33 to 28.6 as the wing loading varies from 20 to 100 psf, for normal and utility category airplanes

$k_c = 33$ for normal and utility category airplanes with wing loadings up to $W_{FDGW}/S = 20$ psf.

V_C – the design cruising speed

$$V_C \geq k_c \sqrt{(W_{FDGW})/S}$$



k_c varies linearly from 33 to 28.6 as the wing loading varies from 20 to 100 psf, for normal and utility category airplanes

$k_c = 33$ for normal and utility category airplanes with wing loadings up to $W_{FDGW}/S = 20$ psf.

V_D – the diving speed

$$V_D \text{ (or } M_D) \geq 1.25V_c \text{ (or } 1.25M_C)$$

$$V_C \geq k_C\sqrt{(W_{FDGW})/S}$$

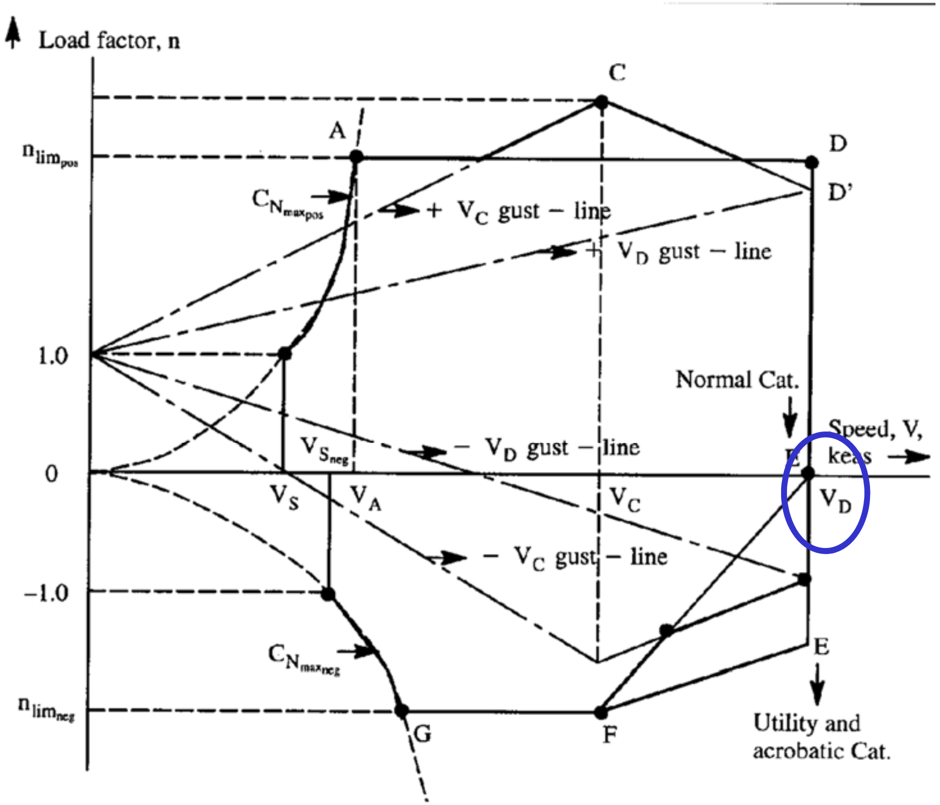


Figure 12.12 V–n Diagram According to FAR 23

The negative 1-g stall speed - $V_{S_{neg}}$

$$V_{S_{neg}} = \sqrt{\frac{2W_{FDGW}}{\varrho C_{N_{max(controllable)_{neg}}} S}}$$

$$C_{N_{max(controllable)_{neg}}} = \sqrt{\left(C_{L_{max(controllable)_{neg}}}\right)^2 + \left(C_{D_{at\, C_{L_{max(controllable)_{neg}}}}}\right)^2}$$

$$C_{N_{max(controllable)_{neg}}} = 1.1 C_{L_{max(controllable)_{neg}}}$$

$$V_{S_{n=n_{neg}}} = \sqrt{2n_{neg}\frac{W_{FDGW}}{\varrho C_{N_{max(controllable)_{neg}}} S}}$$

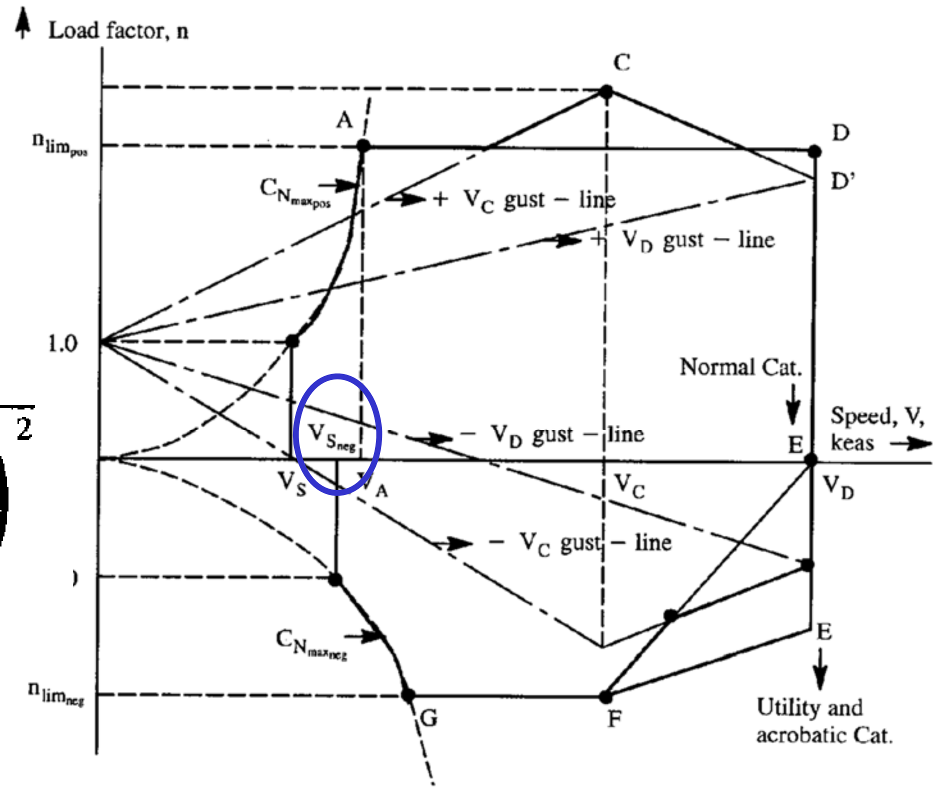
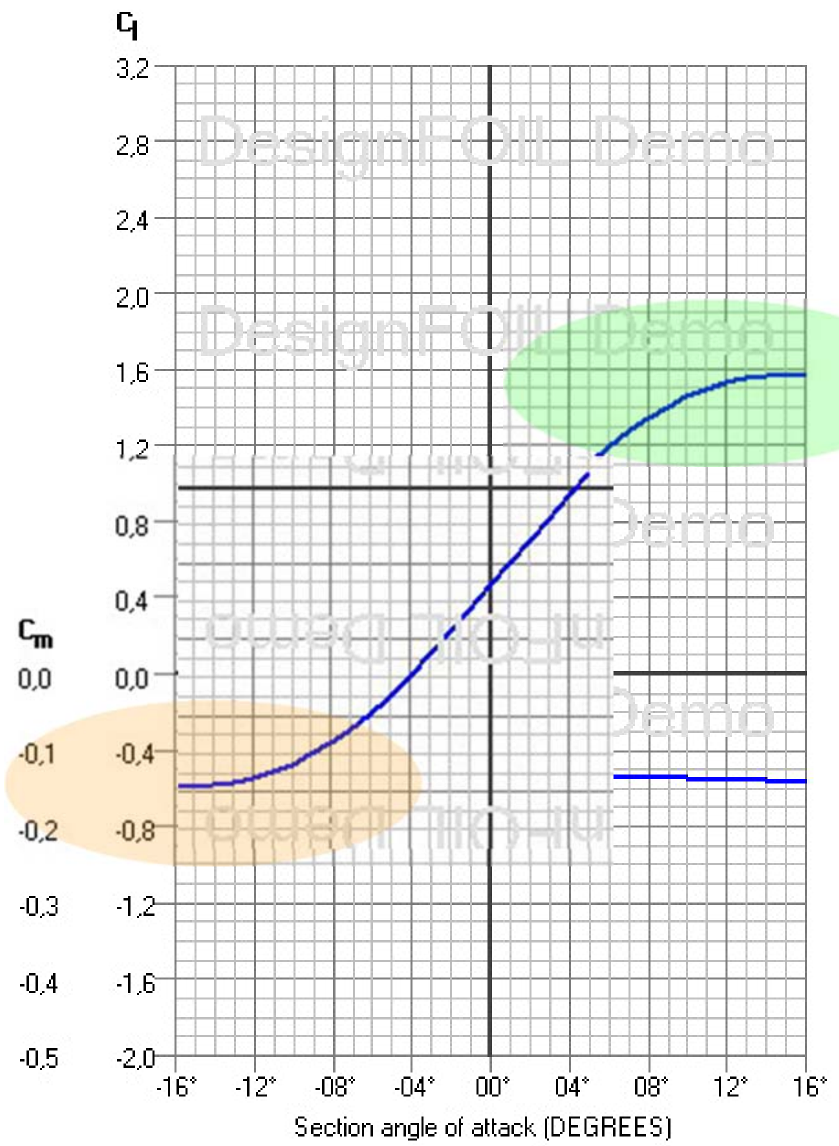


Figure 12.12 V–n Diagram According to FAR 23

The negative 1-g stall speed - $V_{S_{neg}}$

$$C_{L_{max(effective)}} = \frac{C_{L_{max}}(n=1)}{n}$$

$$C_{N_{max(controllable)_{neg}}} = 1.1 C_{L_{max(controllable)_{neg}}}$$



Empleo de herramientas (XFLR5) para invertir ala

Design limit load factors – $n_{lim_{pos}}$ & $n_{lim_{neg}}$

$$n_{lim_{pos}} \geq 2.1 + \frac{24,000}{W_{FDGW} + 10,000}$$

$n_{lim_{pos}}$ need not be greater than 3.8

$n_{lim_{pos}} = 4.4$ for utility category airplanes

$n_{lim_{pos}} = 6.0$ for acrobatic category airplanes

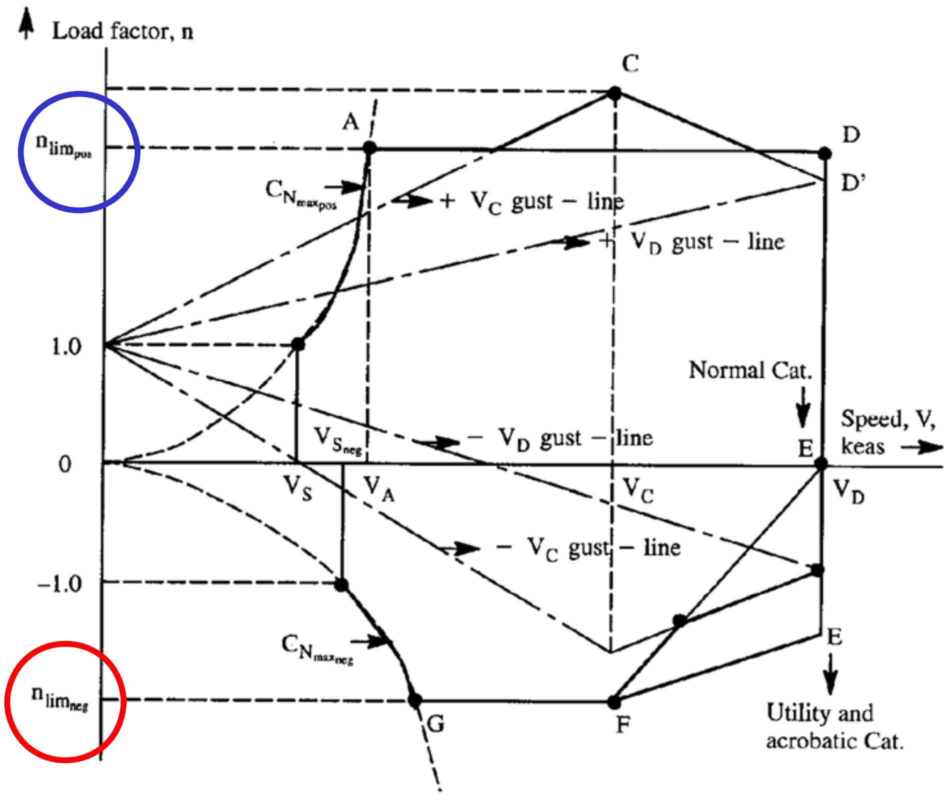


Figure 12.12 V–n Diagram According to FAR 23

$n_{lim_{neg}} \geq 0.4 n_{lim_{pos}}$ for normal and for utility category airplanes

$n_{lim_{neg}} \geq 0.5 n_{lim_{pos}}$ for acrobatic category airplanes

Gust Load Factor Lines

$$n_{lim} = 1 \pm \frac{K_g U_{de} V C_{L_\alpha}}{498(W_{FDGW}/S)}$$

$$K_g = \frac{0.88\,\mu_g}{5.3 + \mu_g} \quad \text{for subsonic airplanes}$$

and

$$K_g = \frac{\mu_g^{1.03}}{6.9 + \mu_g^{1.03}} \quad \text{for supersonic airplanes}$$

$$\mu_g = \frac{2(W_{FDGW}/S)}{\rho\,\bar{c}\,g\,C_{L_\alpha}}$$

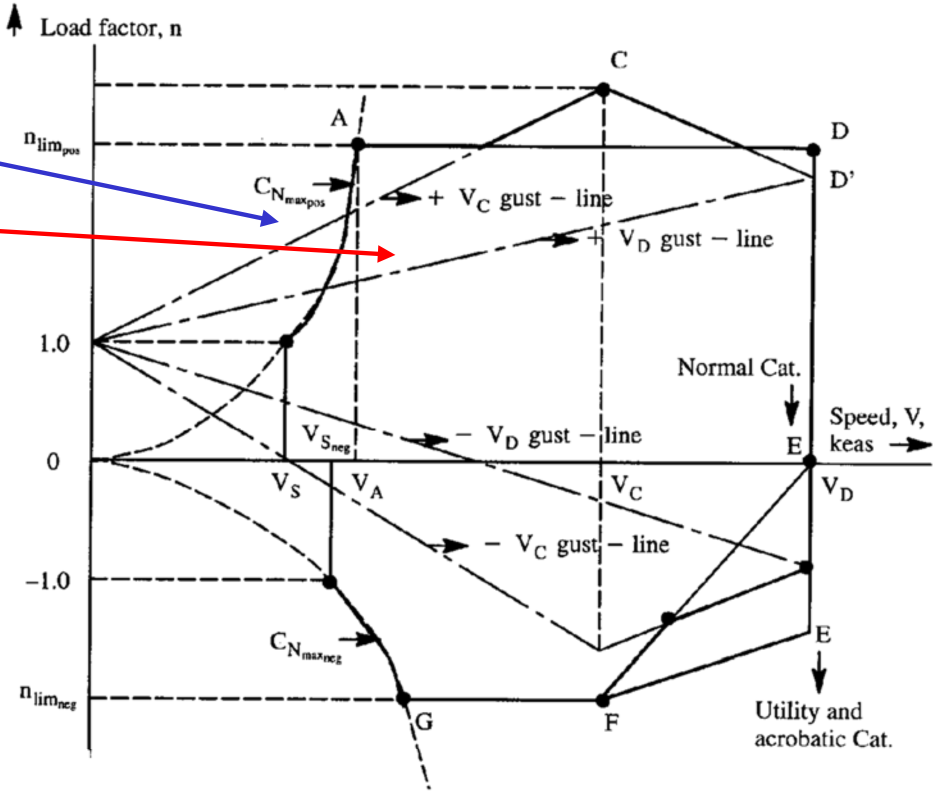


Figure 12.12 V–n Diagram According to FAR 23

C_{L_α} is the airplane lift–curve–slope in 1/rad

U_{de} is the derived gust velocity, which is defined as follows:

For V_C gust lines :

$U_{de} = 50$ fps for altitudes from sea–level to 20,000 ft

$U_{de} = 66.67 - 0.000833\,h$ for altitudes from 20,000 ft to 50,000 ft

For V_D gust lines :

$U_{de} = 25$ fps for altitudes from sea–level to 20,000 ft

$U_{de} = 33.34 - 0.000417\,h$ for altitudes from 20,000 ft to 50,000 ft

V-n FAR 25

The Design Maneuvering Speed, V_A

$$V_A \geq V_{S_1}\sqrt{(n_{lim_{pos}})}$$

The Design Speed for Maximum Gust Intensity, V_B

V_B ????

The Design Cruising Speed, V_C

$$V_C \geq V_B + 43 \text{ keas}$$

The Design Diving Speed, V_D

$$V_D \text{ (or } M_D) \geq 1.25V_c \text{ (or } 1.25M_C)$$

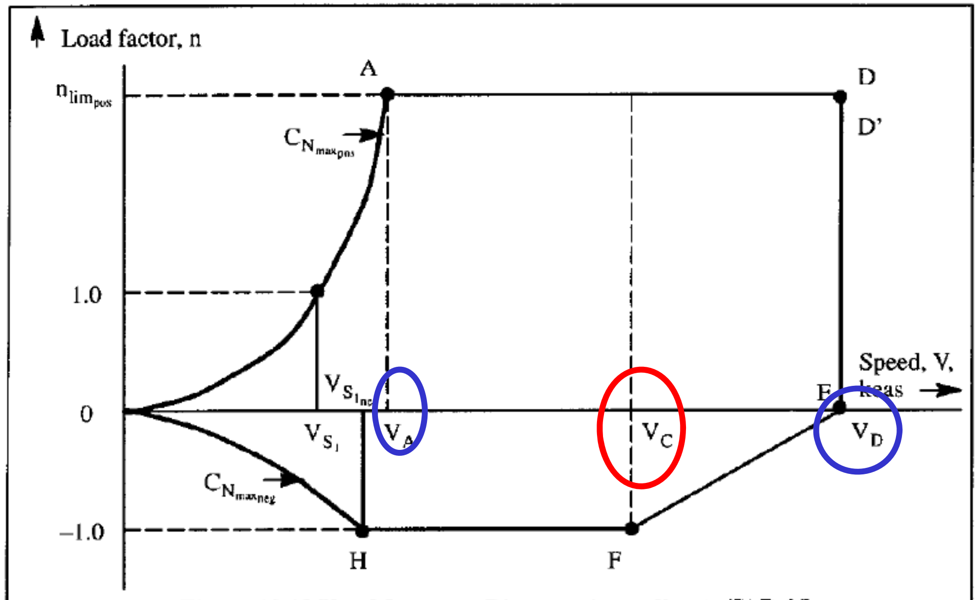


Figure 12.13 V–n Maneuver Diagram According to FAR 25

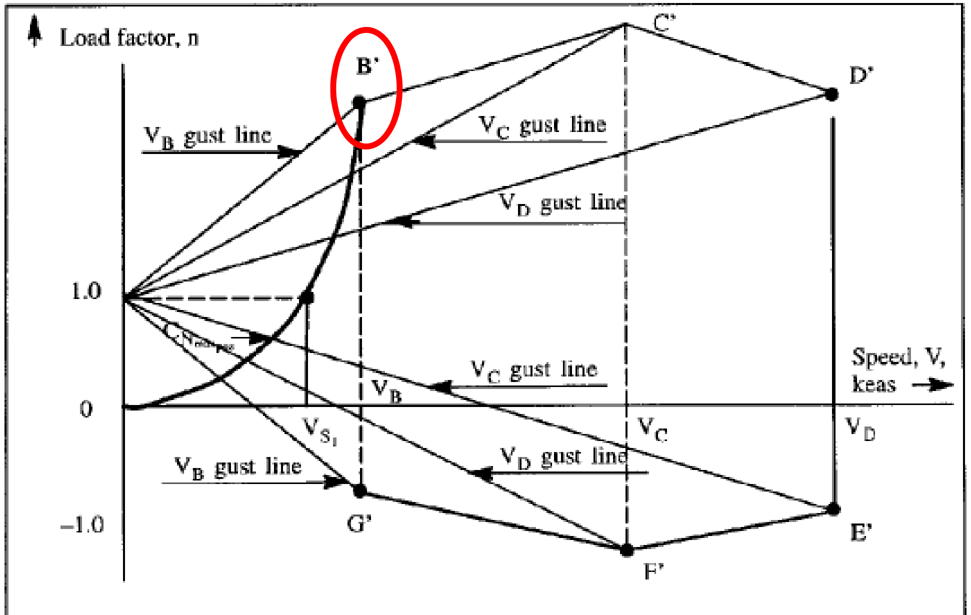


Figure 12.14 V–n Gust Diagram According to FAR 25

V-n – FAR 25

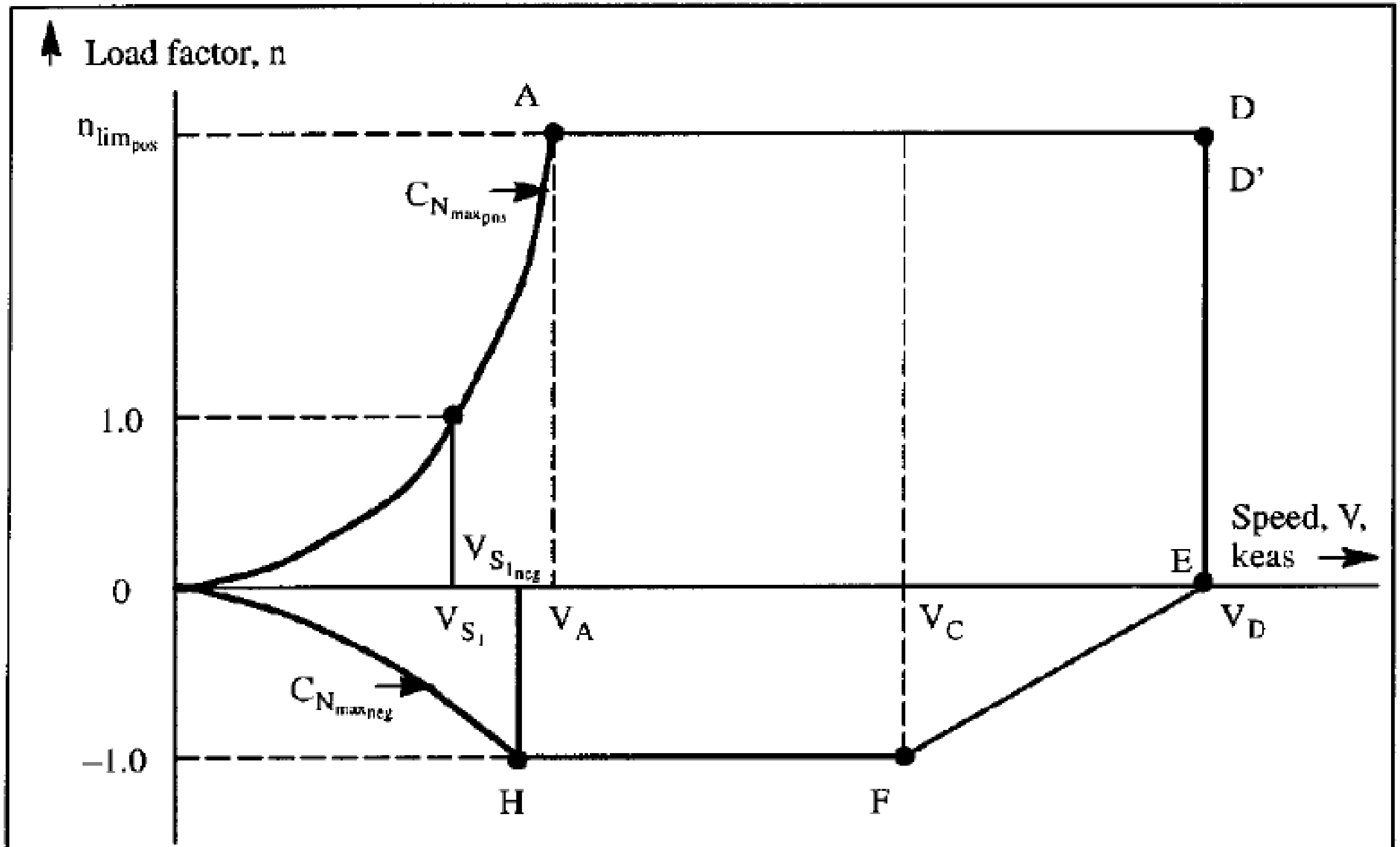


Figure 12.13 V–n Maneuver Diagram According to FAR 25

Design limit load factors – $n_{lim_{pos}}$ & $n_{lim_{neg}}$

$$V_{S_1} = \sqrt{\frac{2W_{FDWG}}{\rho C_{N_{max(controllable)}} S}}$$

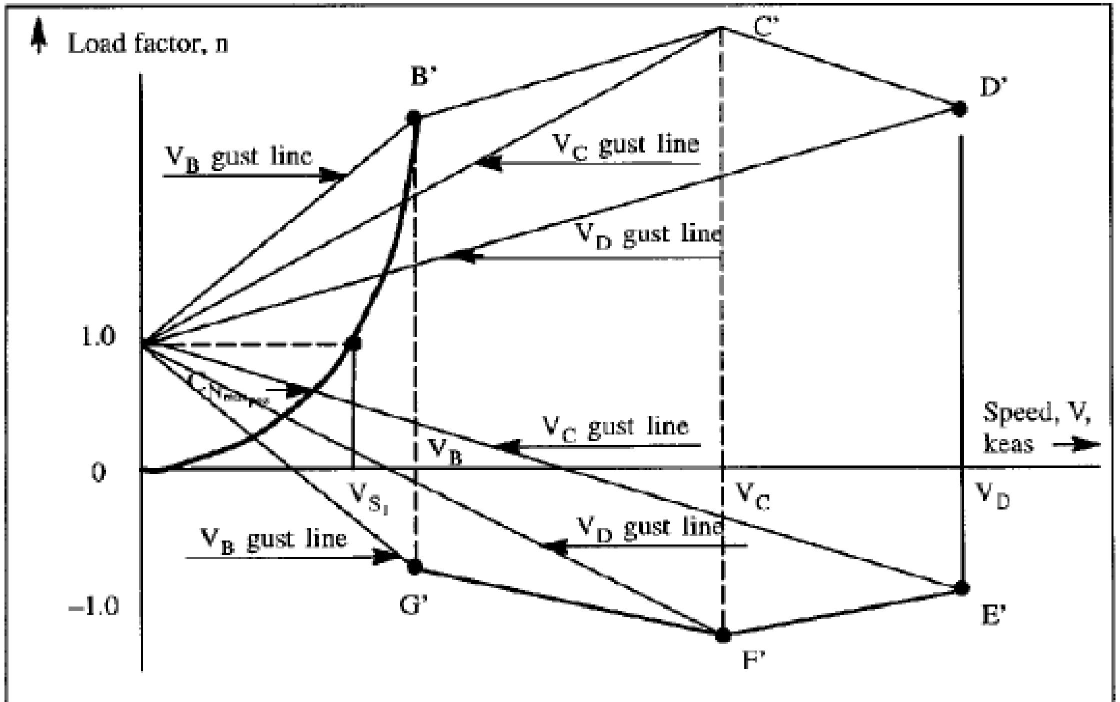


Figure 12.14 V–n Gust Diagram According to FAR 25

$$n_{lim_{pos}} \geq 2.1 + \frac{24,000}{W_{FDGW} + 10,000}$$

$n_{lim_{pos}}$ may not be less than 2.5

$n_{lim_{pos}}$ need not be greater than 3.8 at $W = W_{FDGW}$

$n_{lim_{neg}}$ must be selected by the designer,

$$n_{lim_{neg}} \geq -1.0 \text{ for speeds } \leq V_C$$

$n_{lim_{neg}}$ varies linearly between V_C and V_D

Gust Load Factor Lines – FAR 25

$$n_{lim} = 1 \pm \frac{K_g U_{de} V C_{L_\alpha}}{498(W_{FDGW}/S)}$$

$$K_g = \frac{0.88\,\mu_g}{5.3 + \mu_g} \quad \text{for subsonic airplanes}$$

and

$$K_g = \frac{\mu_g^{1.03}}{6.9 + \mu_g^{1.03}} \quad \text{for supersonic airplanes}$$

$$\mu_g = \frac{2(W_{FDGW}/S)}{\rho\,\bar{c}\,g\,C_{L_\alpha}}$$

C_{L_α} is the airplane lift–curve–slope in 1/rad

U_{de} is the derived gust velocity, which is defined as follows:

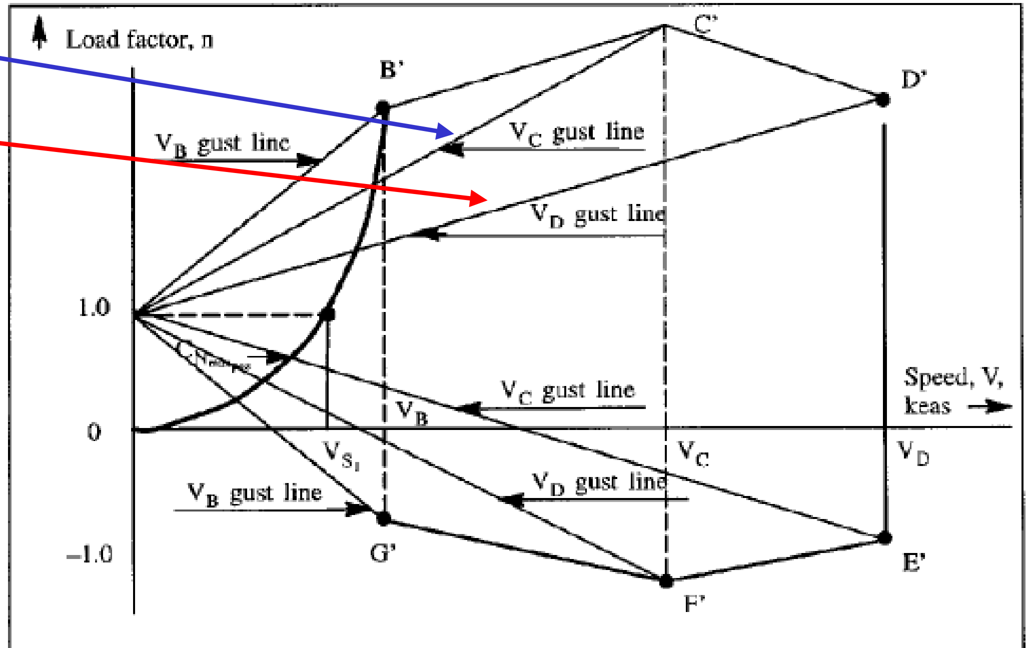


Figure 12.14 V–n Gust Diagram According to FAR 25

For V_B gust lines :

$U_{de} = 66$ fps for altitudes from sea–level to 20,000 ft

$U_{de} = 84.67 - 0.000933\,h$ for altitudes from 20,000 ft to 50,000 ft

For V_C gust lines : $U_{de} = 50$ fps for altitudes from sea–level to 20,000 ft

$U_{de} = 66.67 - 0.000833\,h$ for altitudes from 20,000 ft to 50,000 ft

For V_D gust lines :

$U_{de} = 25$ fps for altitudes from sea–level to 20,000 ft

$U_{de} = 33.34 - 0.000417\,h$ for altitudes from 20,000 ft to 50,000 ft

Military Airplanes

The military gust diagrams are the same as those of FAR 25.

V_H is the maximum level flight speed combination of weight and altitude.

V_L is the maximum design dive speed. Typically: $V_L = 1.25 V_H$.

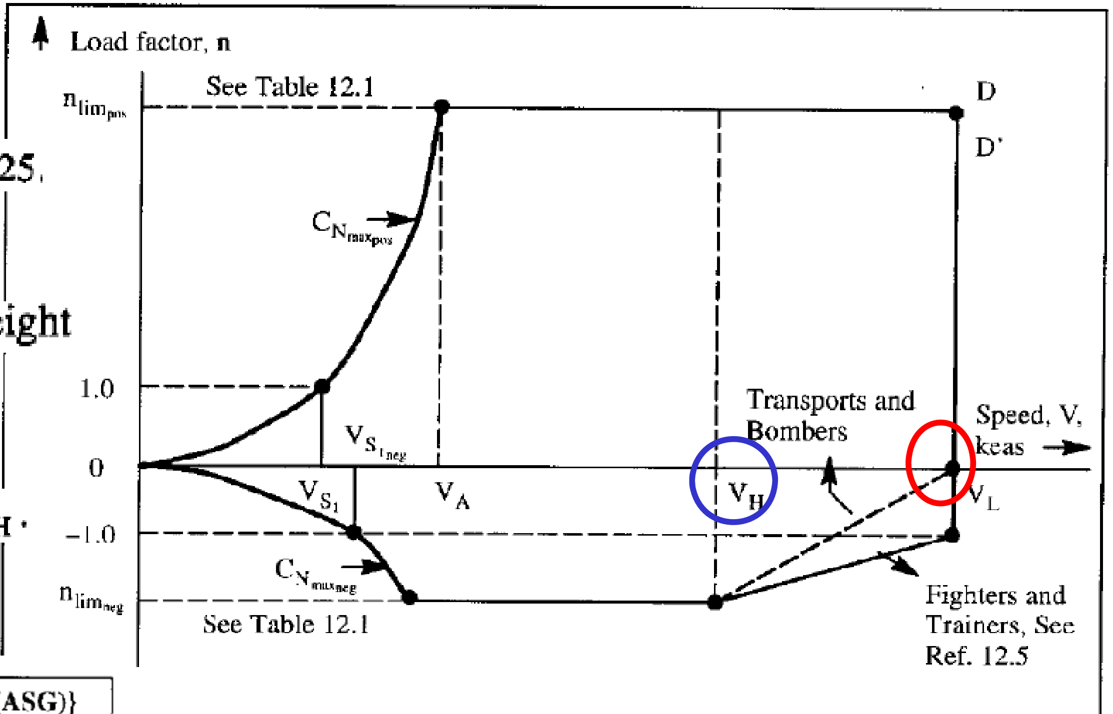
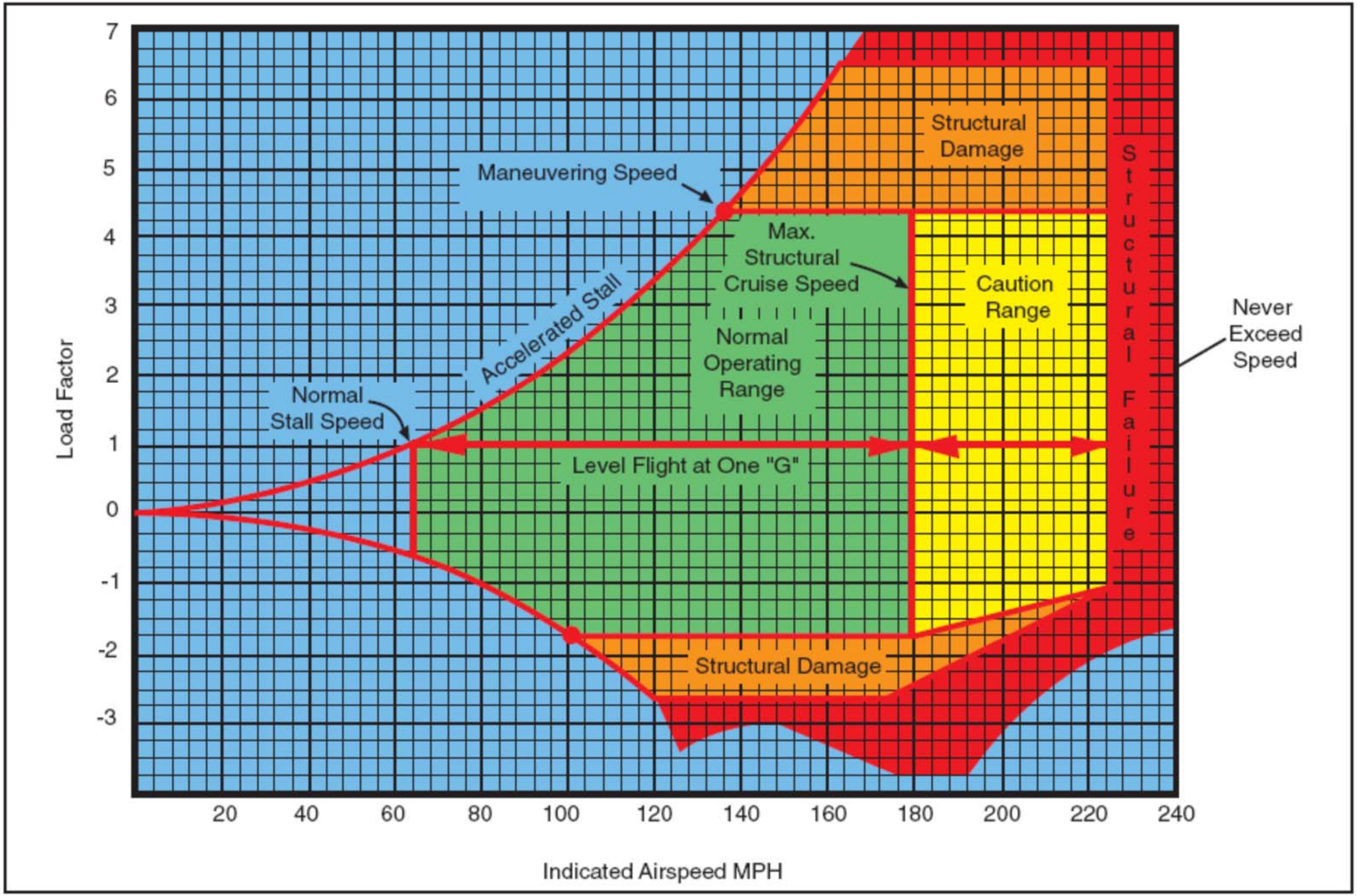


Figure 12.15 V–n Maneuver Diagram for Military Airplanes

Table 12.1 Design Limit Load Factors for Military Airplanes {MIL–A 8861 (ASG)}

Airplane Type		Design Limit Load Factor at Flight Design Gross Weight: W_{FDGW}	
USAF	USN	$n_{lim_{pos}}$	$n_{lim_{neg}}$
Fighter		8.67	–3.00
Attack	Fighter, Attack, Trainer	7.33	–3.00
	Observation	6.00	–3.00
Trainer		5.67	–2.33
Utility	Utility	4.00	–2.00
Small Bomber		3.67	–1.67
Medium Bomber, Assault Transport	Patrol, Weather, Anti–submarine, Reconnaissance	3.00	–1.00
Medium Transport		2.50	–1.00
Heavy Bomber, Heavy Transport		2.00	–1.00


7
6
5
4
3
2
1
0
-1
-2
-3
Load Factor
20
40
60
80
100
120
140
160
180
200
220
240
Indicated Airspeed MPH
Maneuvering Speed
Structural Damage
Max. Structural Cruise Speed
Caution Range
Accelerated Stall
Normal Operating Range
Normal Stall Speed
Level Flight at One "G"
Structural Failure
Never Exceed Speed
Structural Damage

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- Airplane Aerodynamics and Performance, Dr. Jan Roskam and Dr. Chuan-Tau Edward Lan.
- Certification Specifications For Normal, Utility, Aerobatic, and Commuter Category Aeroplanes – CS 23 – European Aviation Safety Agency.