

Estructuras Avanzadas

Tema 16

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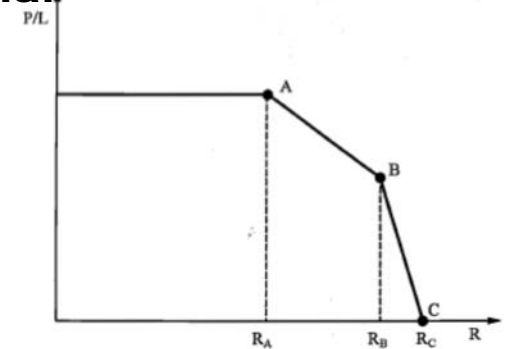
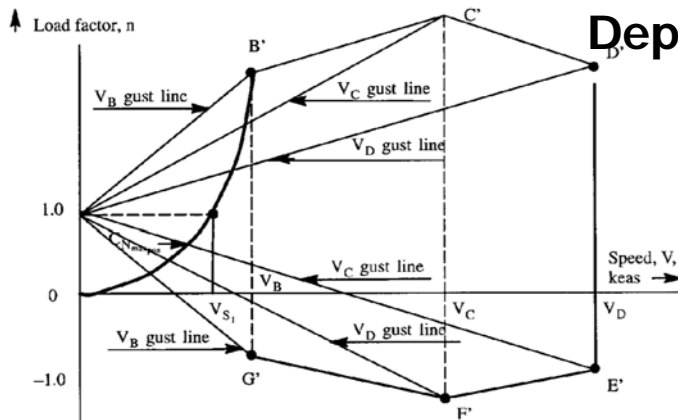


Figura 4.7. Ejemplo de diagrama de Carga de Pago-Alcance (P/L-R) de una aeronave.

V-n diagram – Envolverte de Vuelo - I

- Las características de la envolverte 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

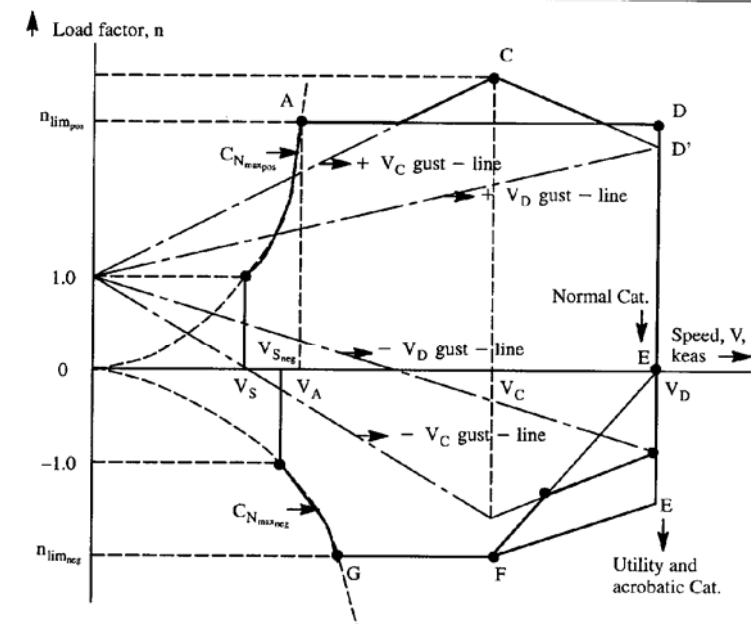
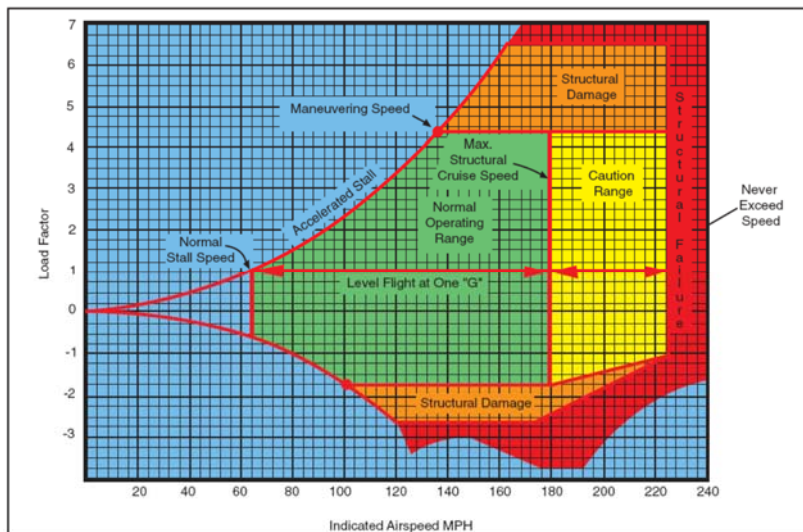


Figure 12.12 V-n Diagram According to FAR 23

V-n diagram – Envolverte 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 envolverte de vuelo.

Unidades Sistema Imperial

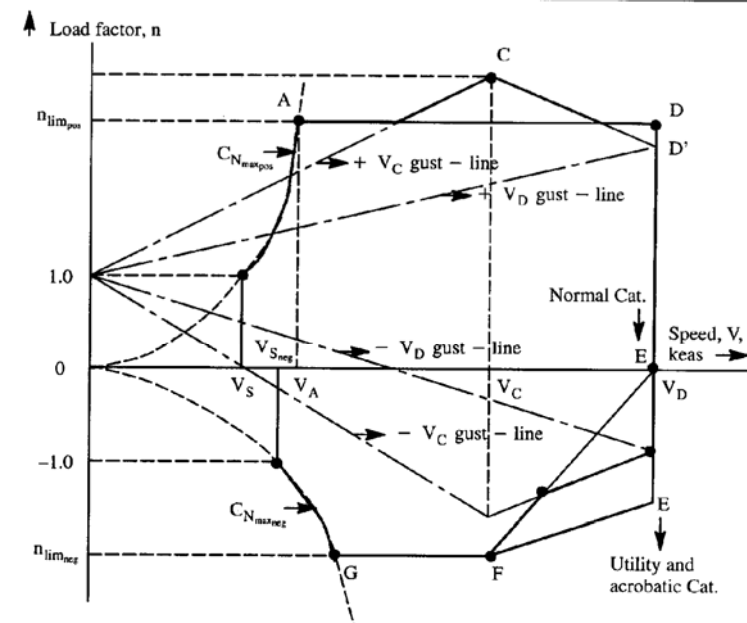
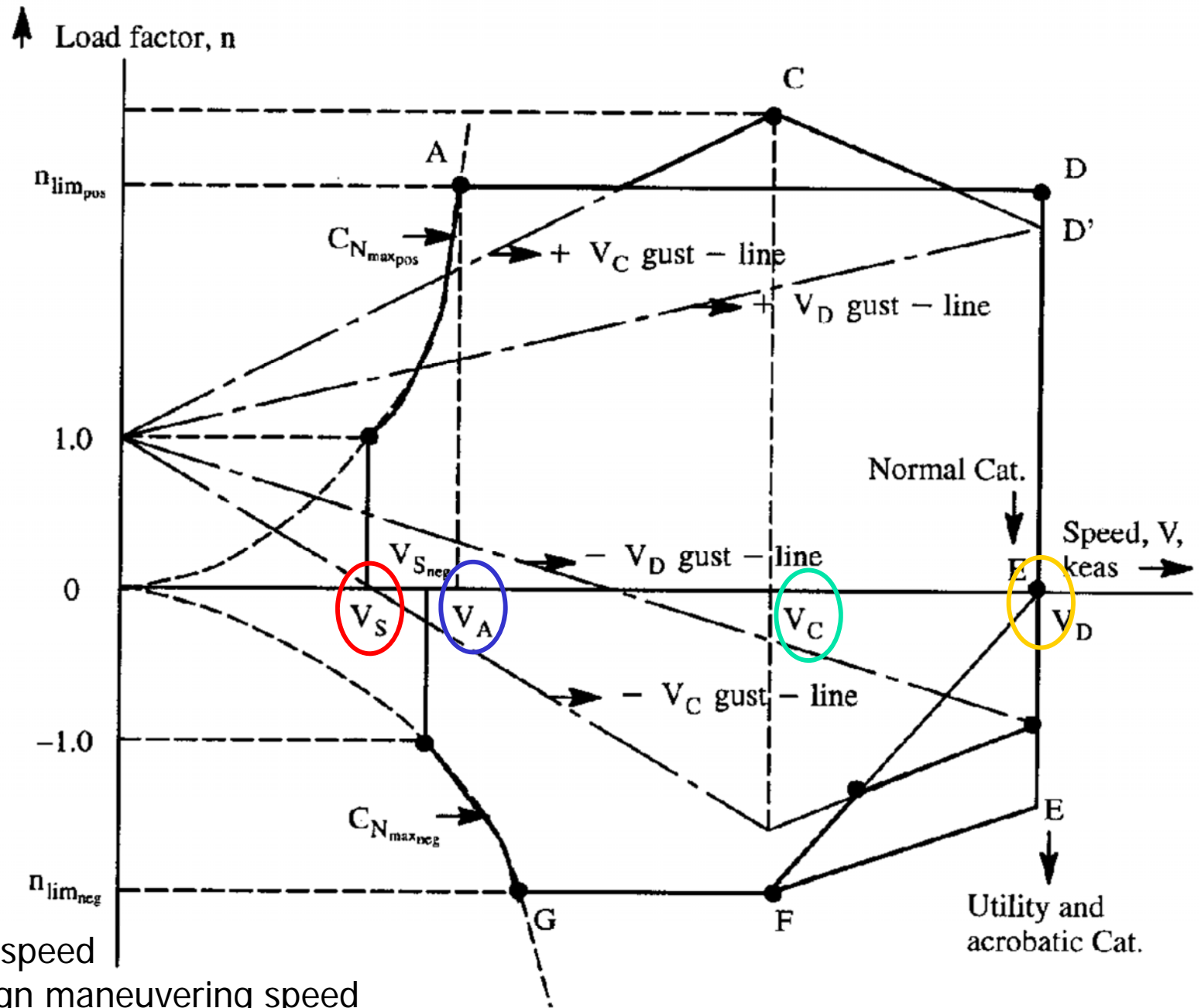
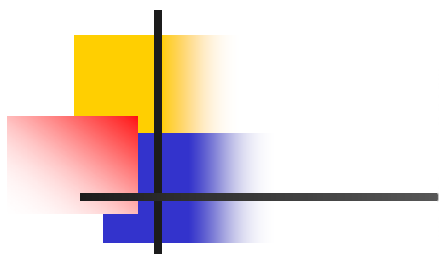


Figure 12.12 V-n Diagram According to FAR 23



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

Figure 12.12 V-n Diagram According to FAR 23

V_S - 1-g stall speed

$$C_{N_{max(rollable)}} = \sqrt{(C_{L_{max(rollable)}})^2 + (C_{D_{at C_{L_{max(rollable)}}})}^2}$$

Hipótesis

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

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

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

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

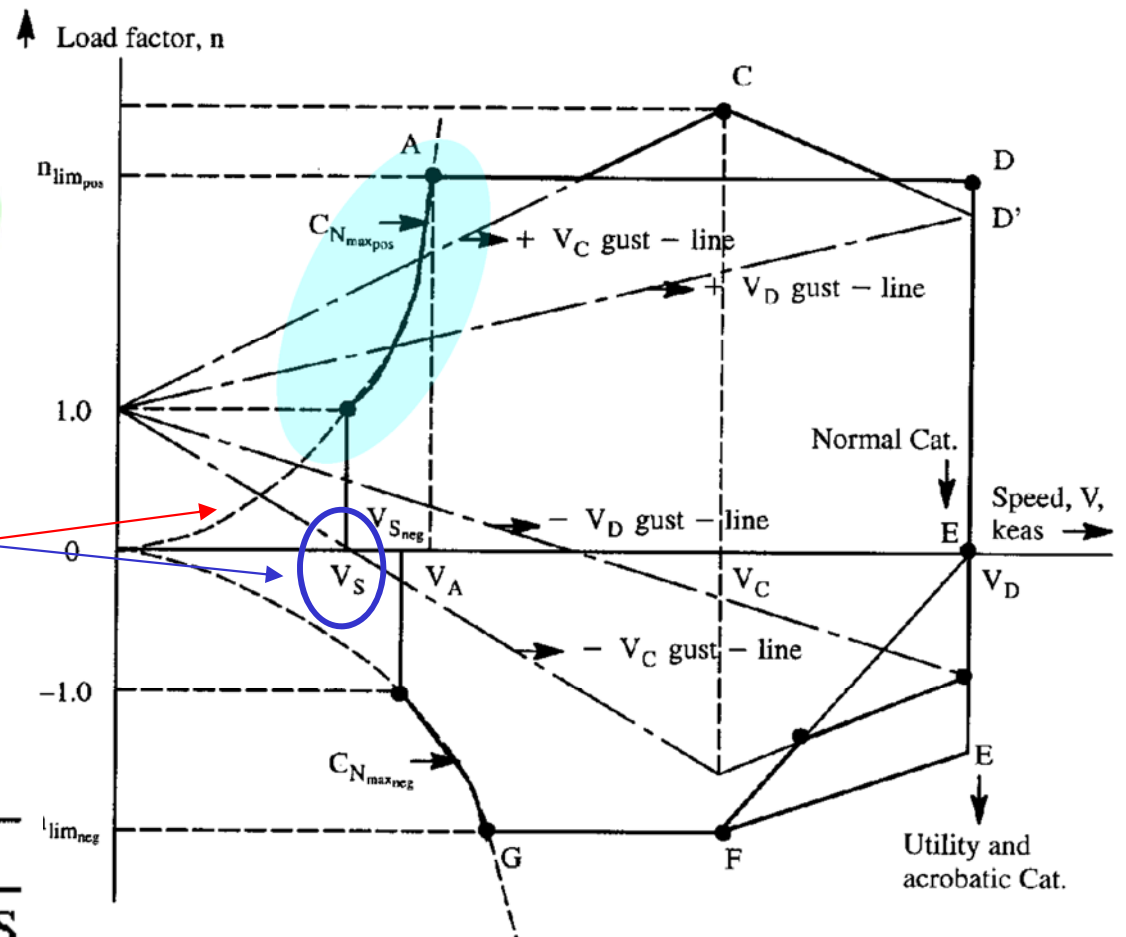


Figure 12.12 V-n Diagram According to FAR 23

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)

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

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

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

$$n = 0.9$$

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

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

V_A – the design maneuvering speed

Design maneuvering speed: realización 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

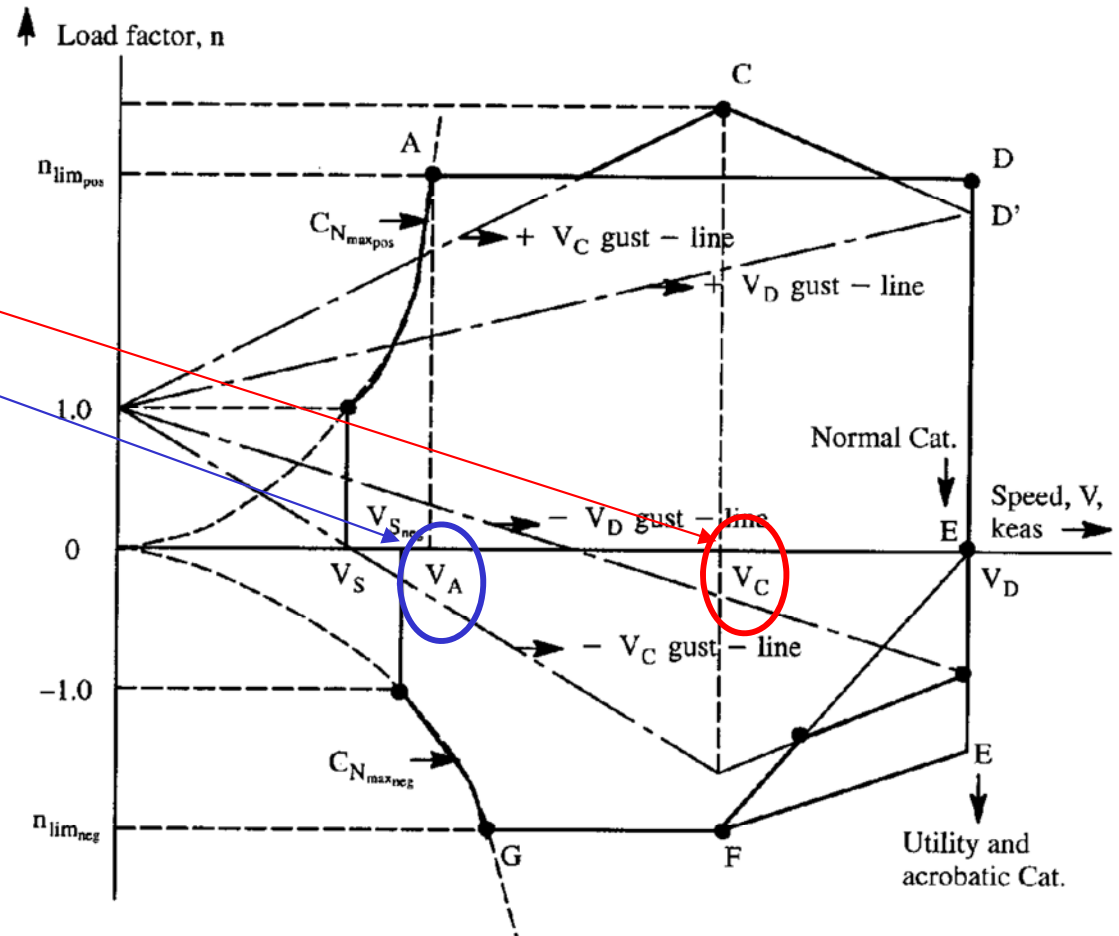


Figure 12.12 V-n Diagram According to FAR 23

V_C – the design cruising speed

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

S in ft²

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

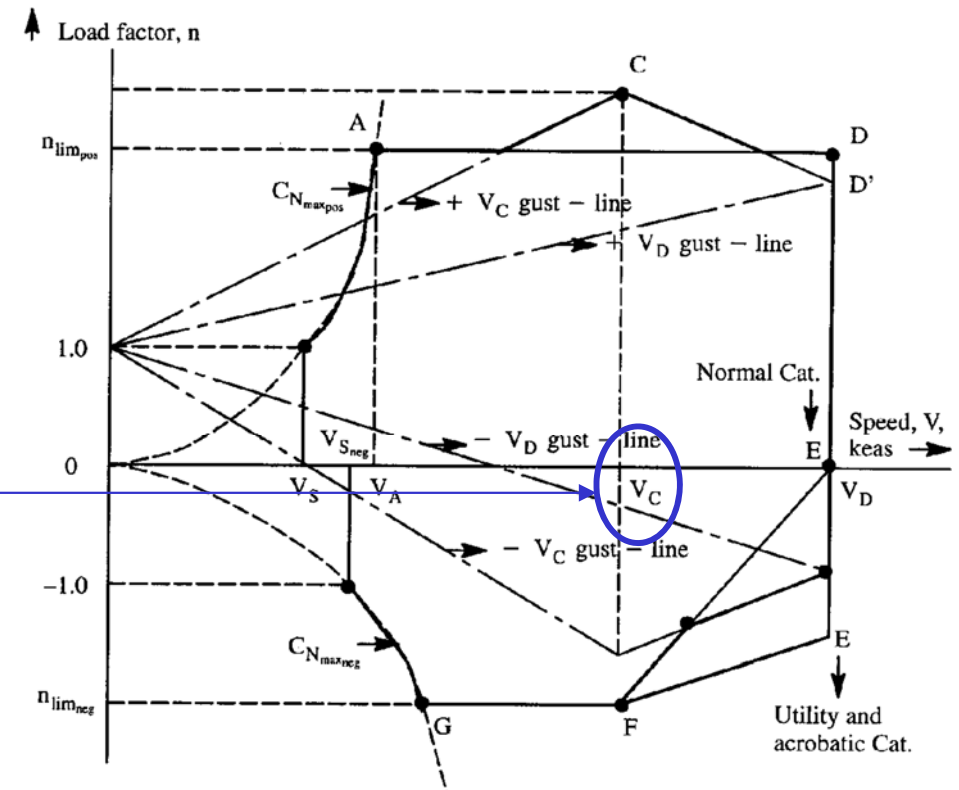


Figure 12.12 V-n Diagram According to FAR 23

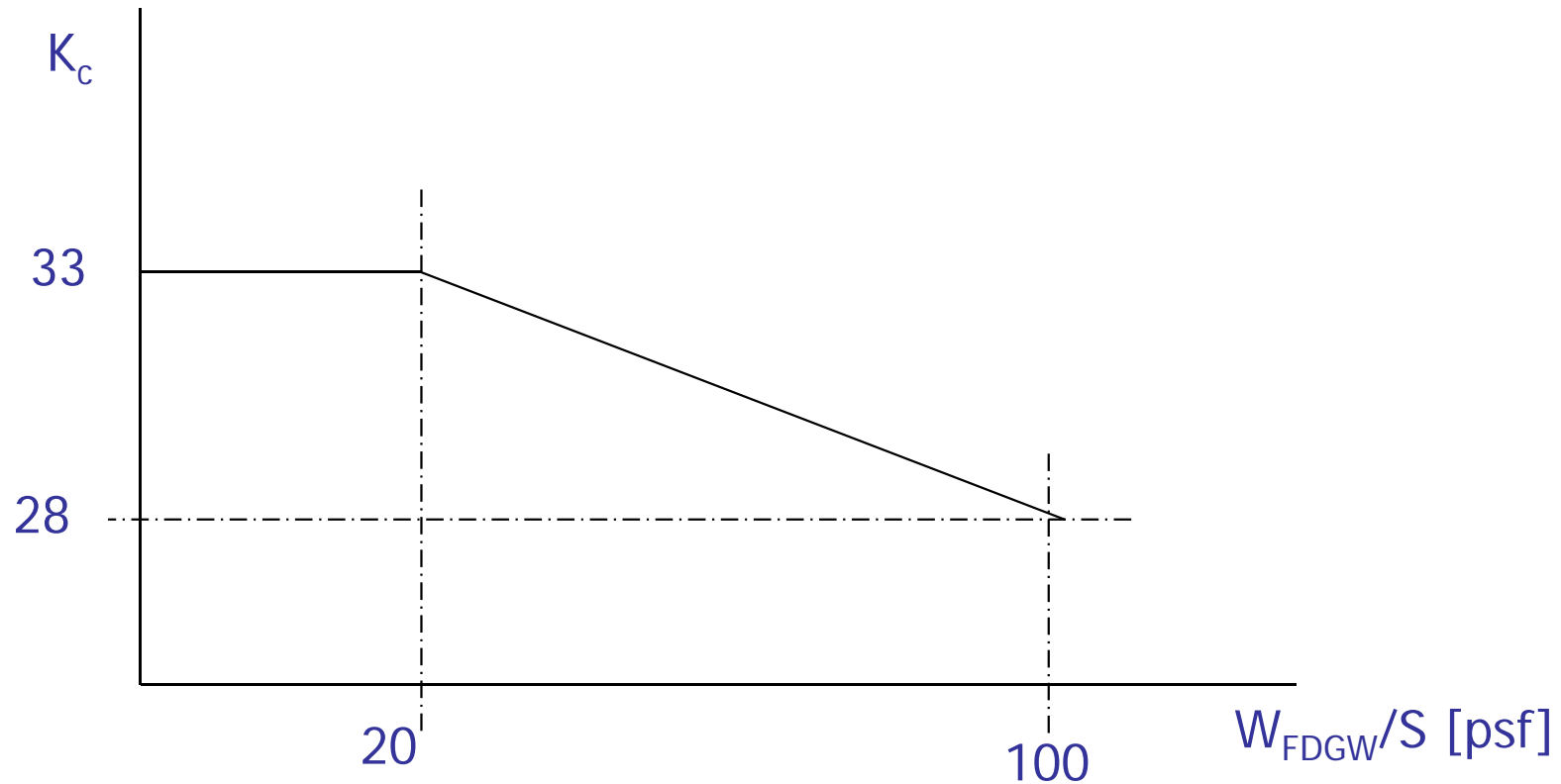
k_C varies linearly from 33 to 28.6 as the wing loading varies from 20 to 100 psf,
for normal and utility category airplanes

$k_C = 33$ for normal and utility category airplanes with wing loadings up to

$$W_{FDGW}/S = 20 \text{ psf.}$$

V_C – the design cruising speed

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



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$k_C = 33$ for normal and utility category airplanes with wing loadings up to

$W_{FDGW}/S = 20$ psf.

V_D – the diving speed

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

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

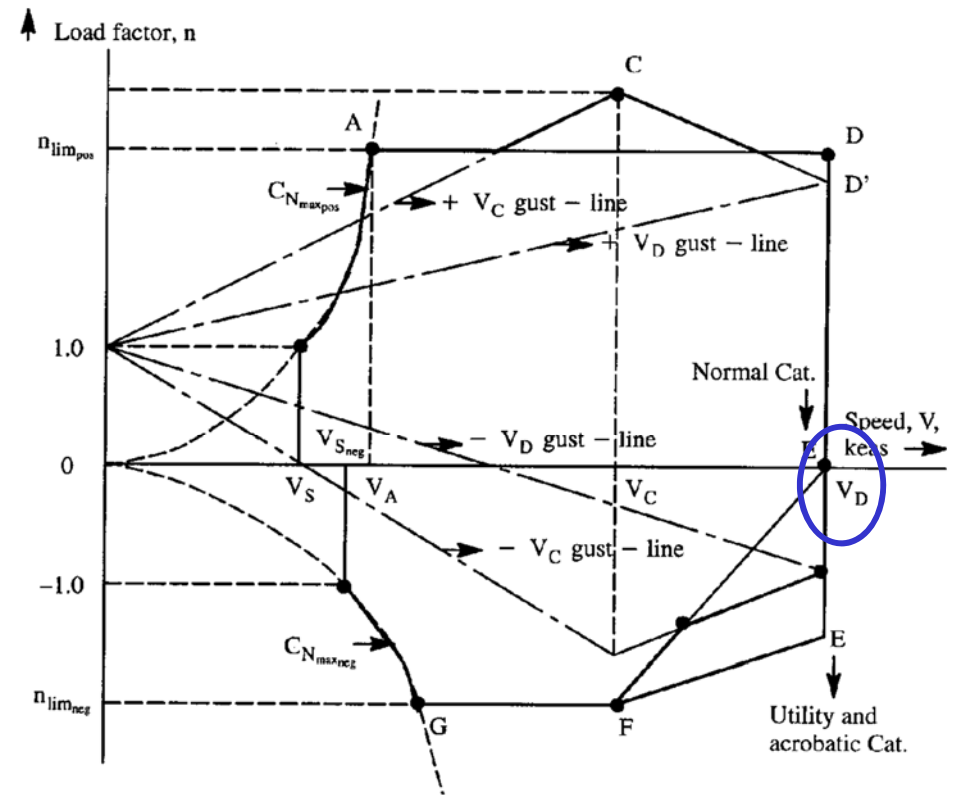


Figure 12.12 V-n Diagram According to FAR 23

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

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

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

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

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

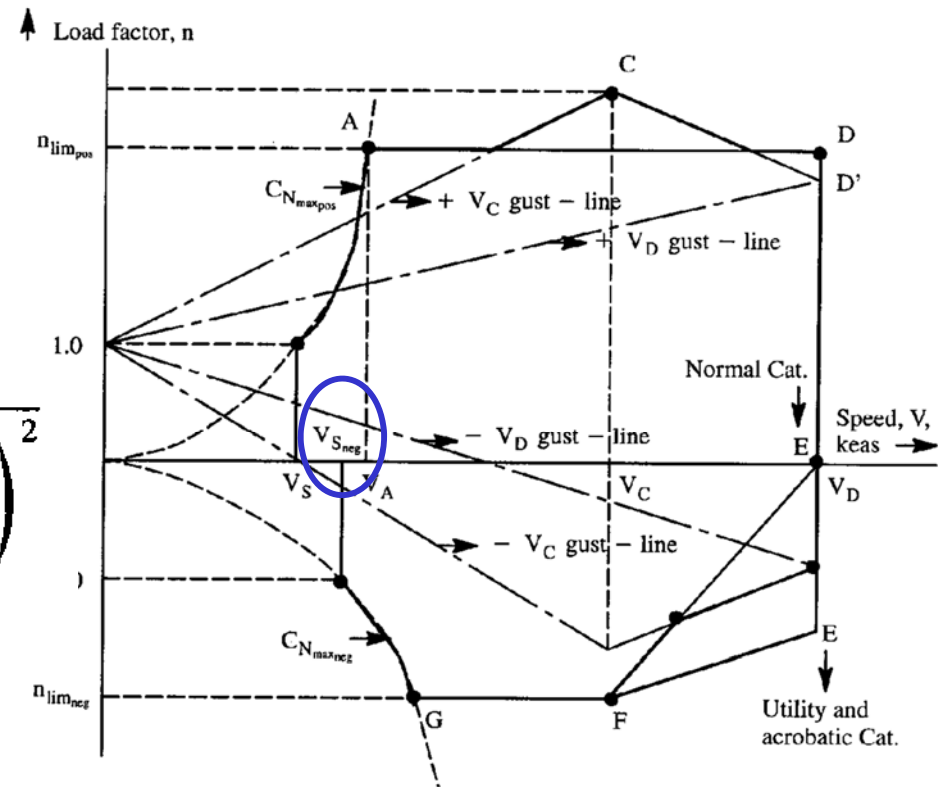
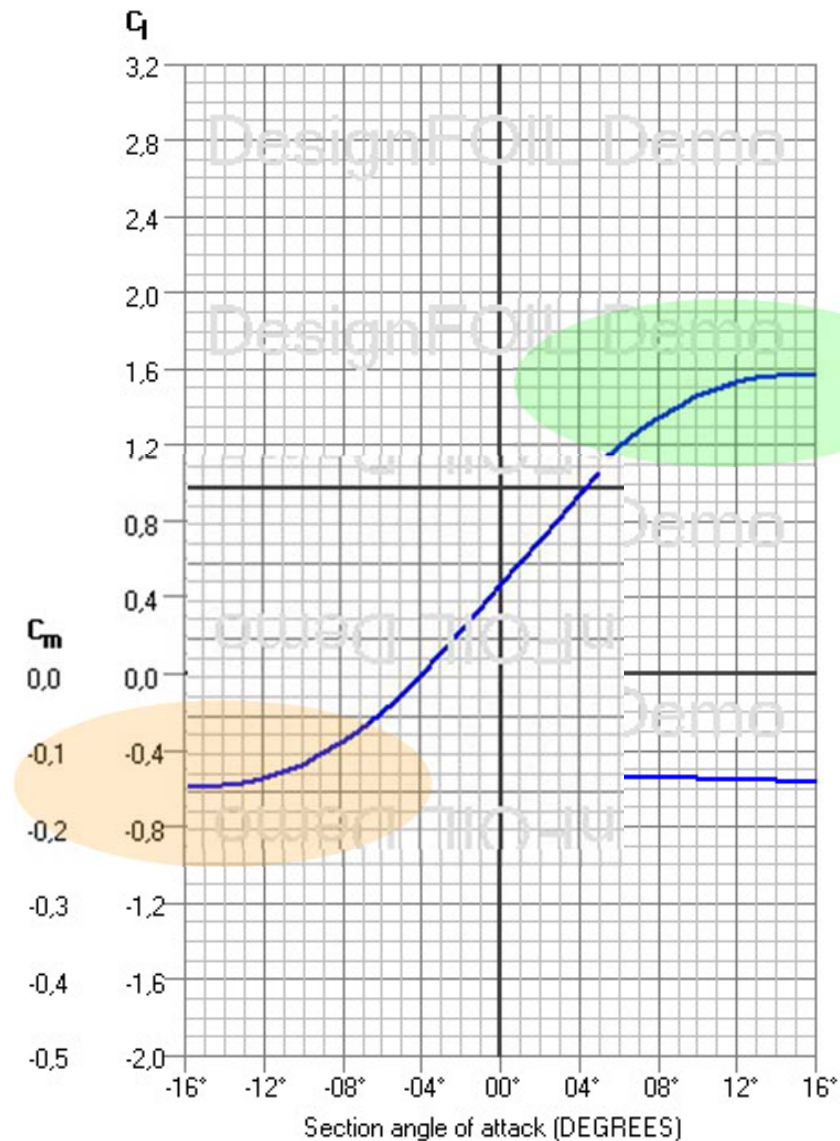


Figure 12.12 V-n Diagram According to FAR 23

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

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

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



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

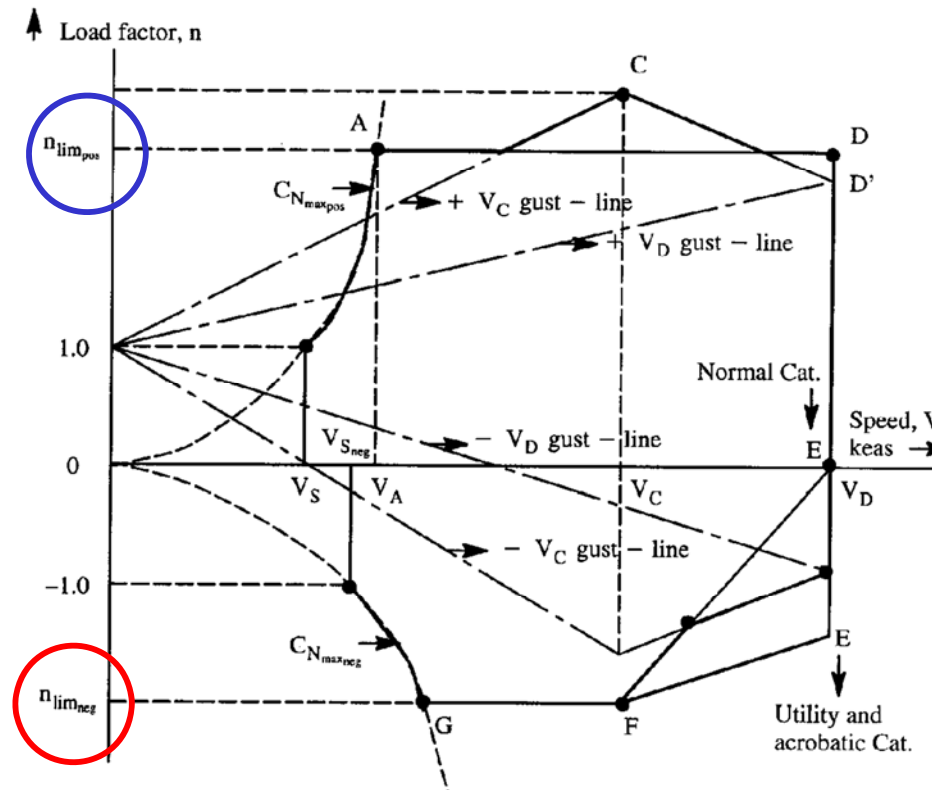


Figure 12.12 V-n Diagram According to FAR 23

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

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

Gust Load Factor Lines

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

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

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

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

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

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

For V_C gust lines : $U_{de} = 50 \text{ fps}$ 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 :

$U_{de} = 25 \text{ fps}$ 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

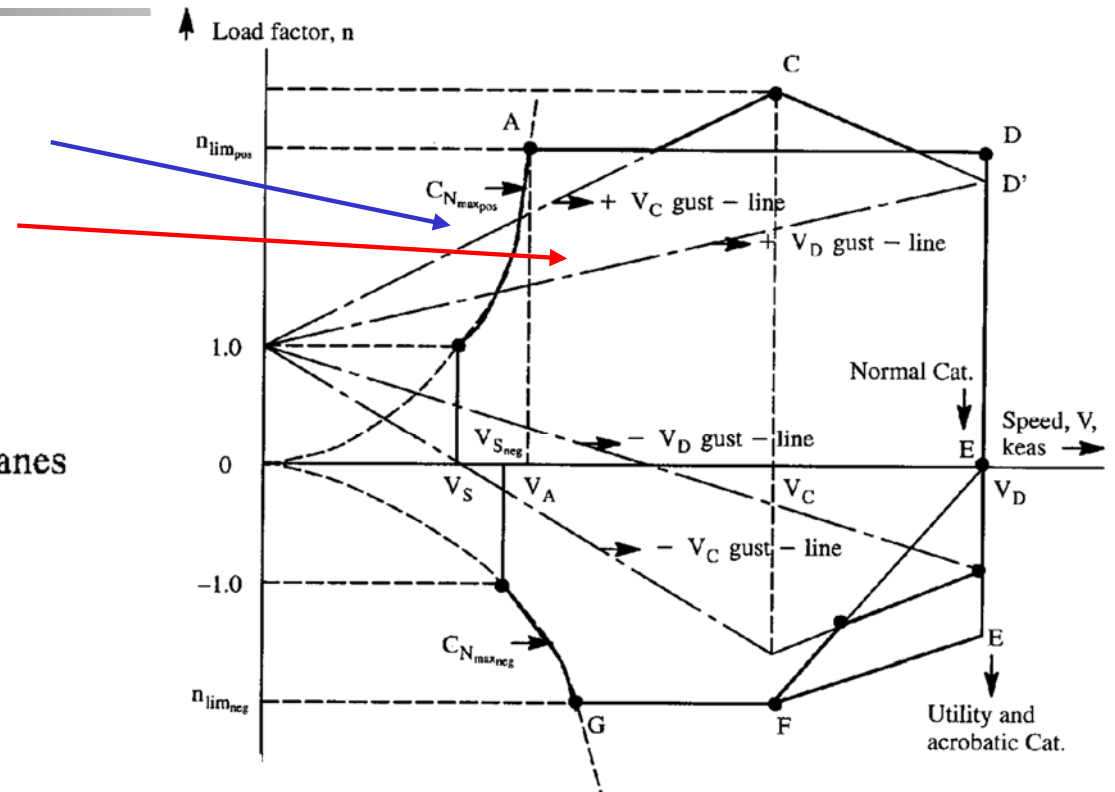


Figure 12.12 V-n Diagram According to FAR 23

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

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

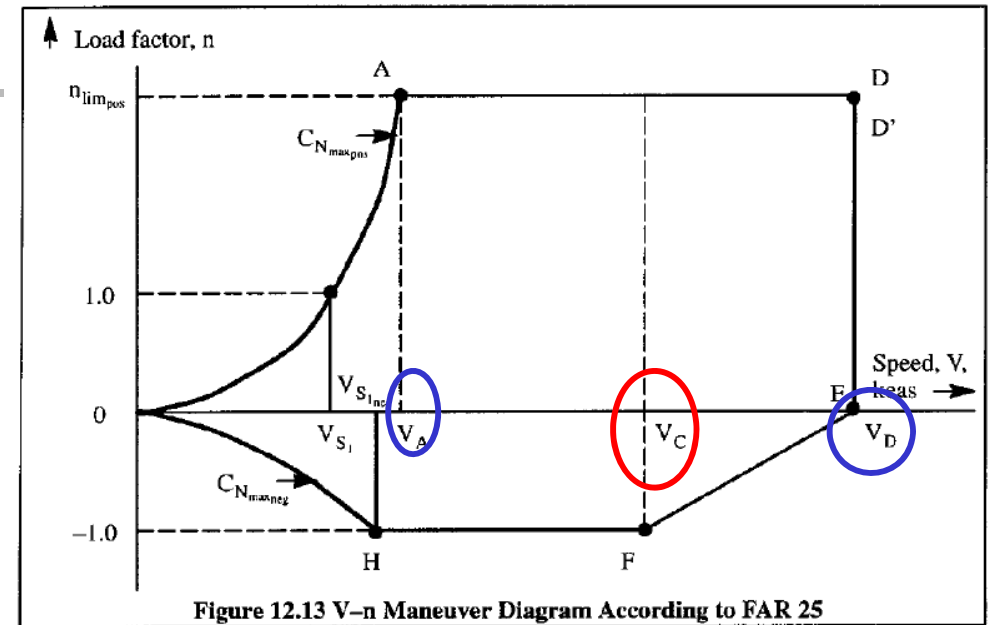


Figure 12.13 V-n Maneuver Diagram According to FAR 25

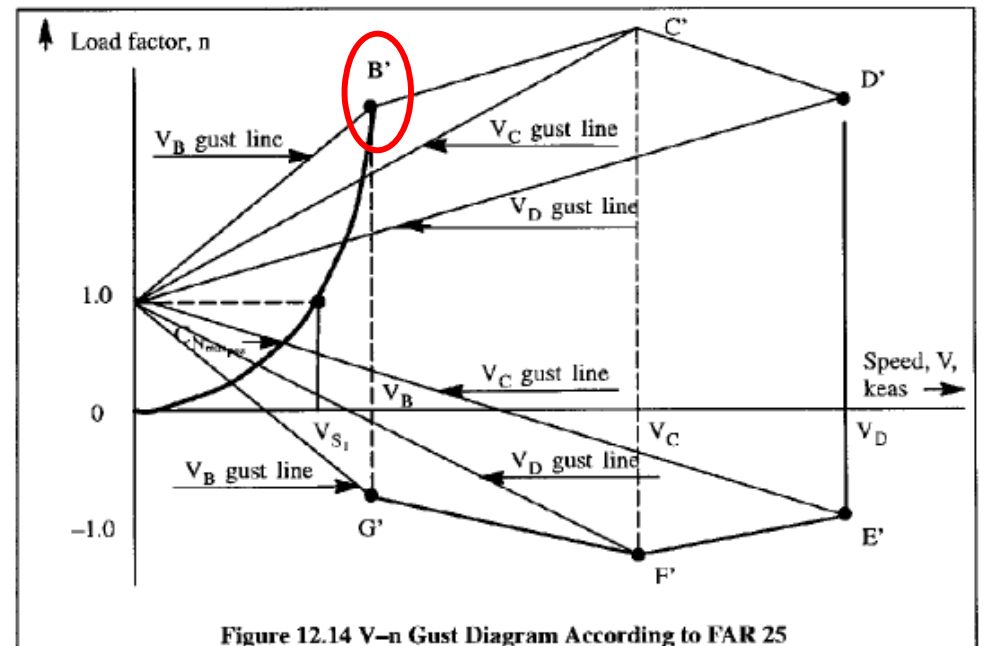


Figure 12.14 V-n Gust Diagram According to FAR 25

V-n – FAR 25

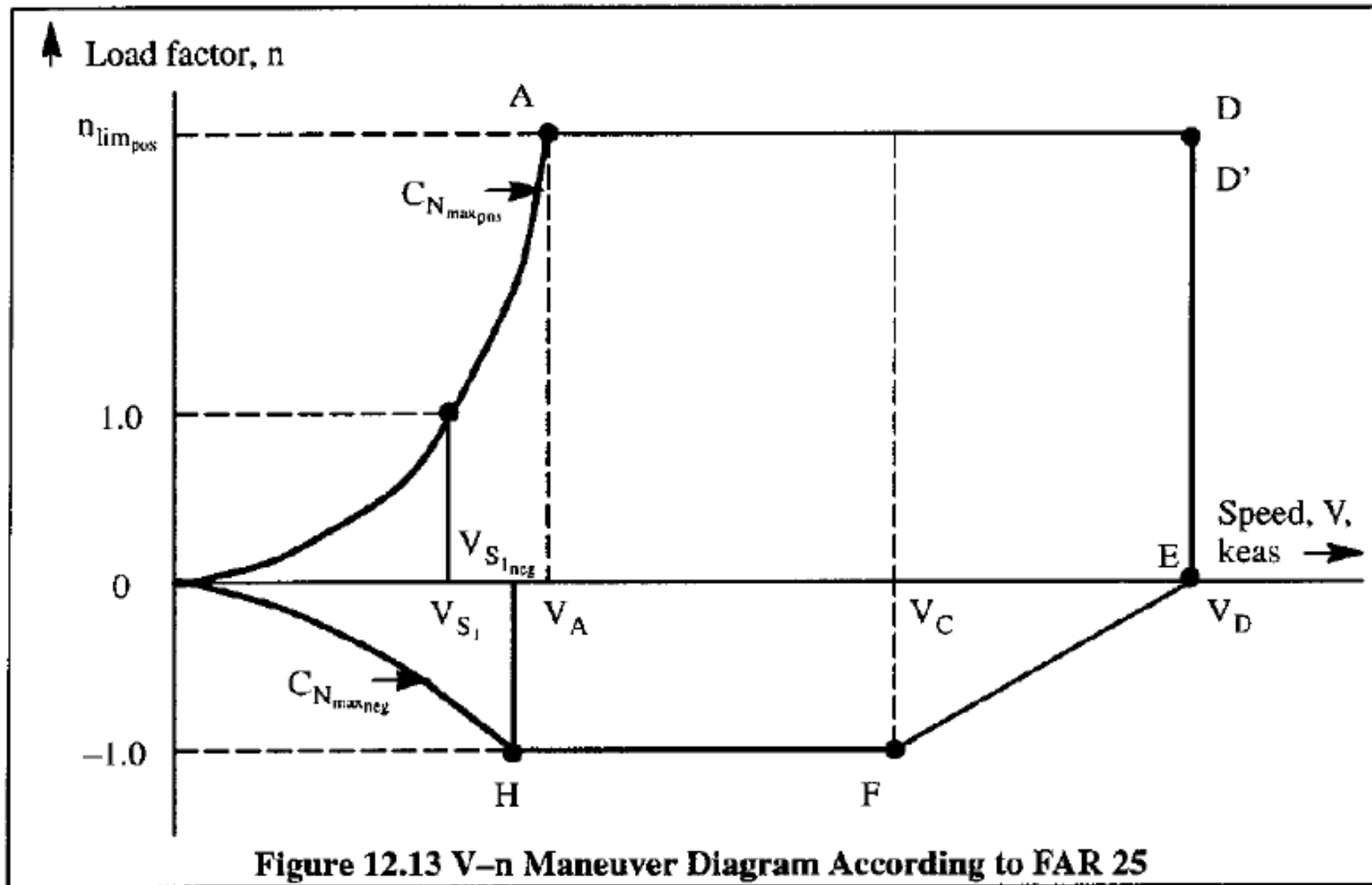


Figure 12.13 V-n Maneuver Diagram According to FAR 25

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

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

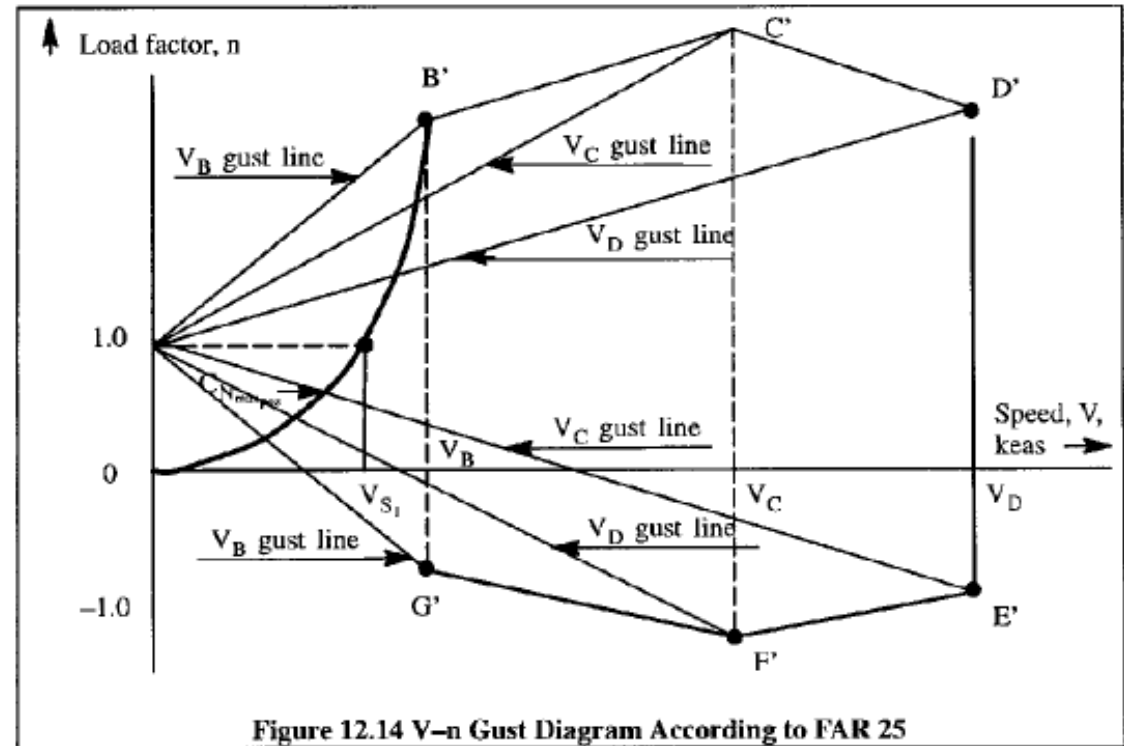


Figure 12.14 V-n Gust Diagram According to FAR 25

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

$n_{lim_{pos}}$ 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

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

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

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

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

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

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

For V_B gust lines :

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

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

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

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

For V_D gust lines :

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

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

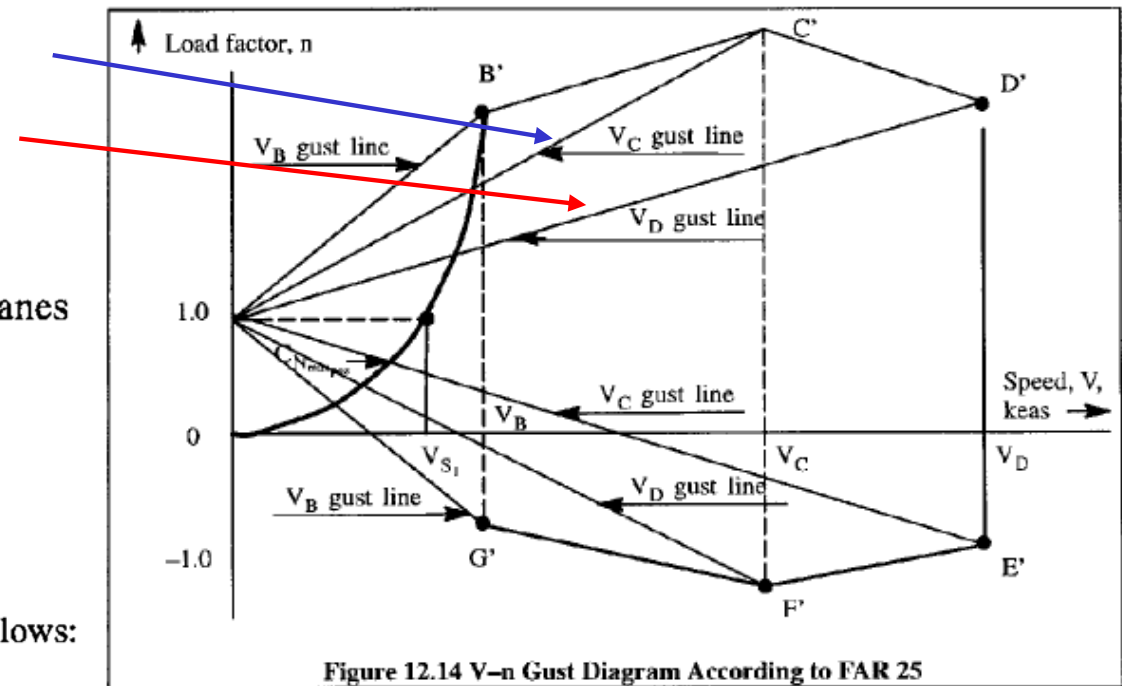


Figure 12.14 V-n Gust Diagram According to FAR 25

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: $V_L = 1.25V_H$.

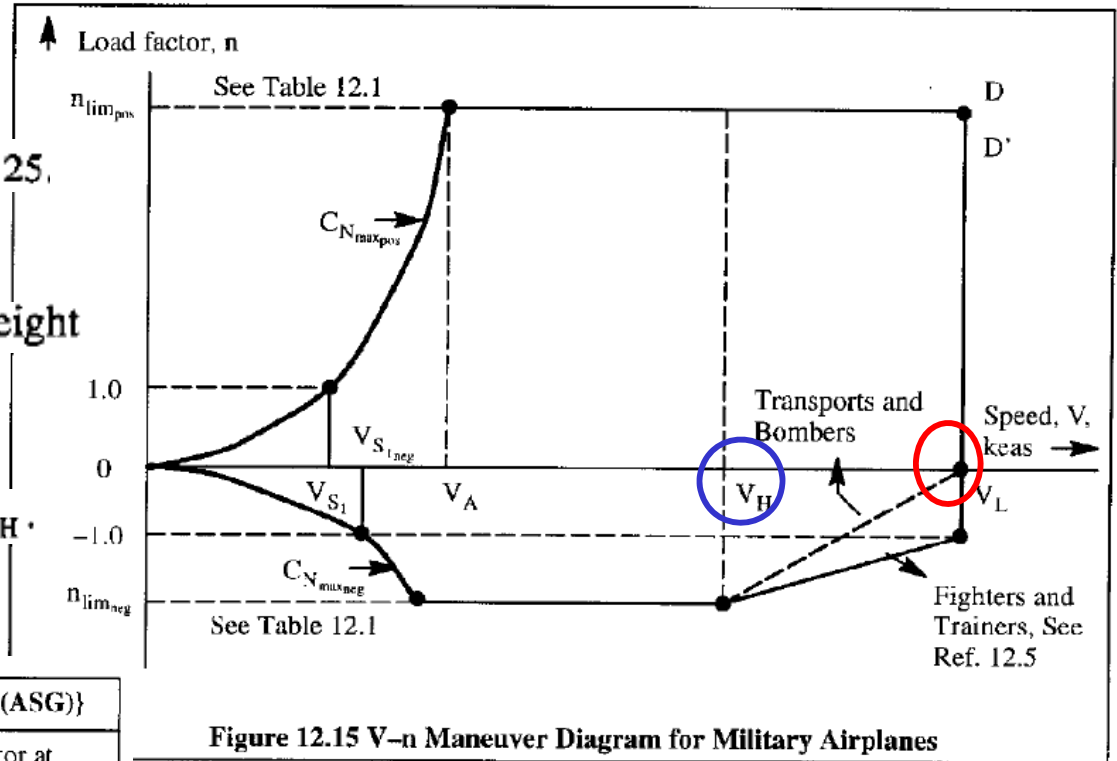
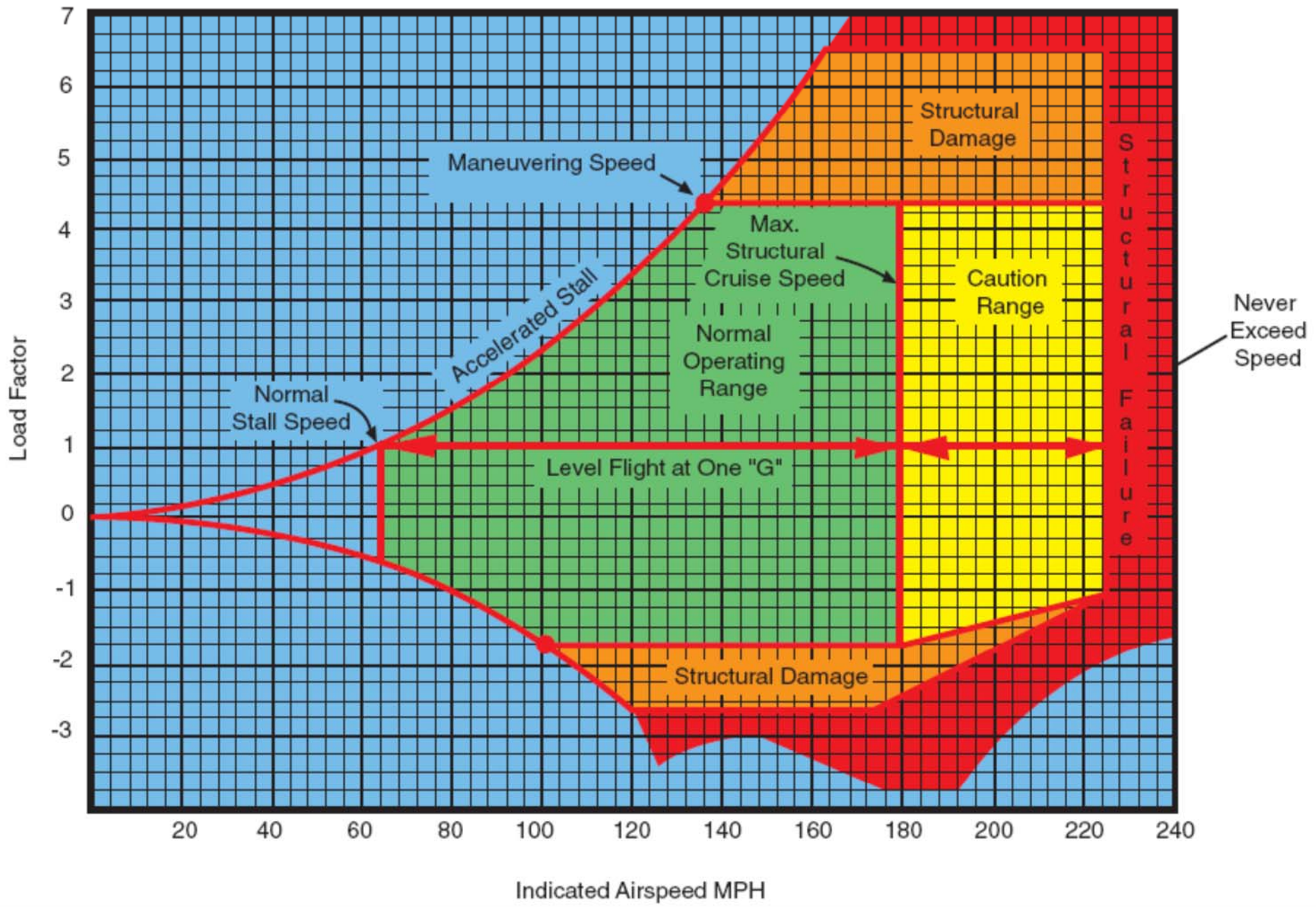


Figure 12.15 V-n Maneuver Diagram for Military Airplanes

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





Bibliografía

- Aircraft Performance and Design – John D. Anderson.
- 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.