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V-n Diagram

AE460 Aircraft Design

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Lecturer

Introduction

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- V-n diagrams (speed – load factor) defines the strength limitation of an aircraft
  - Every aircraft has their own version
- V-n diagrams are developed during the design process either in the conceptual or very early preliminary design stages
- Four factors affect a V-n Diagram
  - MGTOW
  - Altitude
  - Configuration of aircraft: clean, stores, cruise or landing, etc.
  - Symmetry of loading
- Structural Air Speed Limits, above which may encounter
  - Critical gust
  - Damaging flutter
  - Control/Lift surface reversal
  - Damaging or control-related compressibility effects, i.e. buffets

Development Process Entry Criteria

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- Aircraft has many loading conditions to consider. For this class we are only going to consider air loads on the wing, taking into account maneuver and gust loads.

- Entry Criteria
  - Wing loft complete
  - Aero…
  - Mass Properties completed

- Requirements (most aircraft designs will use one of these or something equivalent)
  - SRD for your aircraft
  - MIL-A-8860: Airplane Strength and Rigidity, General Specification for
  - MIL-A-8861: Airplane Strength and Rigidity Flight Loads
  - 14CFR23 (if applicable)
  - 14CFR25 (if applicable)

- Other Good References
  - Bruhn: Analysis and Design of Flight Vehicle Structures
  - Niu: Airframe Structural Design
  - Raymer: Aircraft Design: *A Conceptual Approach*
  - Roskam: Airplane Aerodynamics and Performance
  - Plenty of other internet sources… Google it.

V-n Diagram[1]

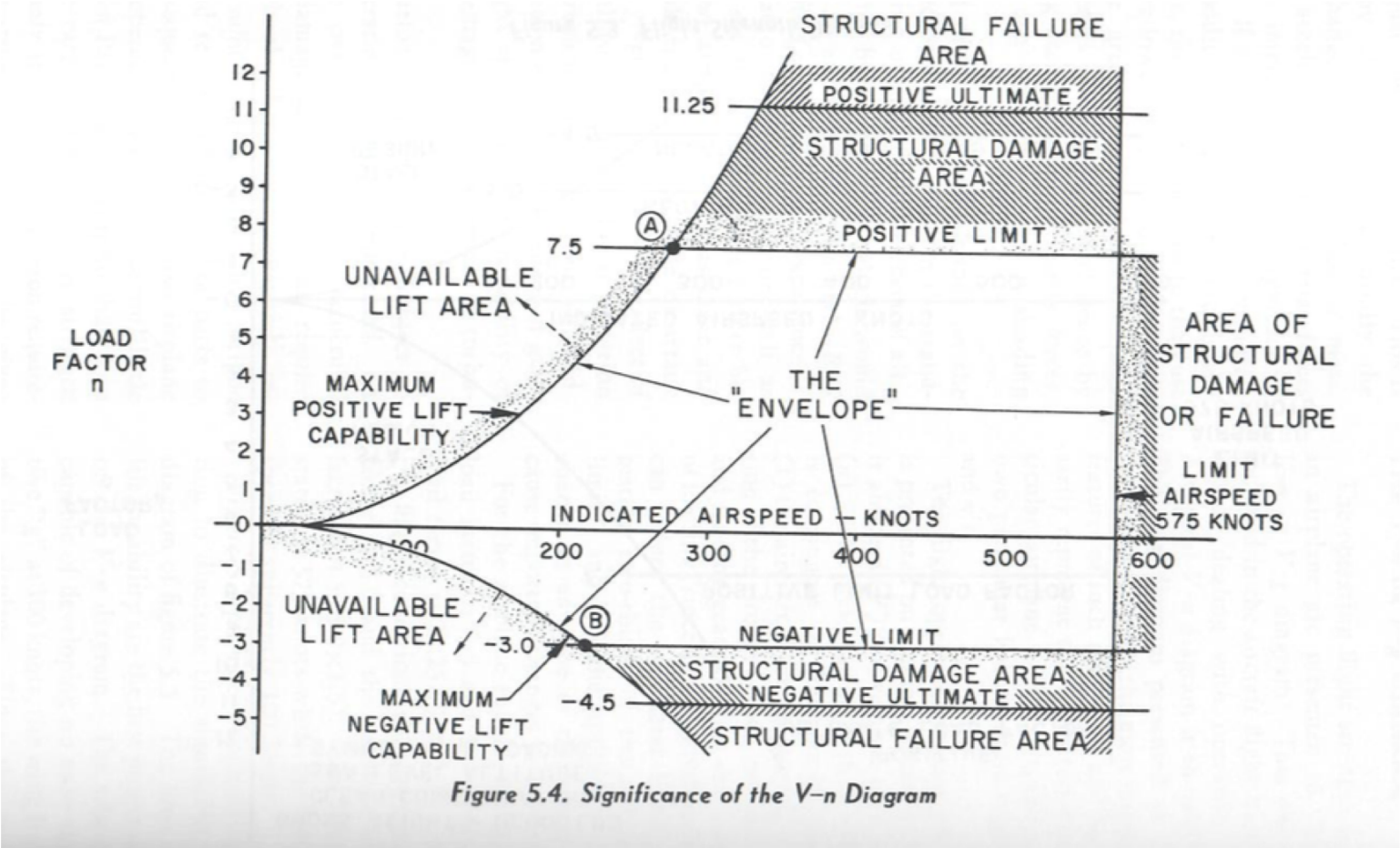

Figure 5.4. Significance of the V–n Diagram

[1]Aerodynamics for Naval Aviators, NAVWEPS 00-80T-80

MIL-A-8861: V-n Diagram

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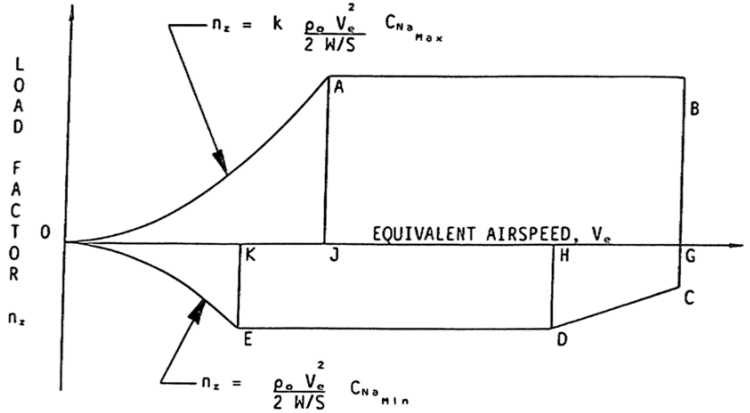
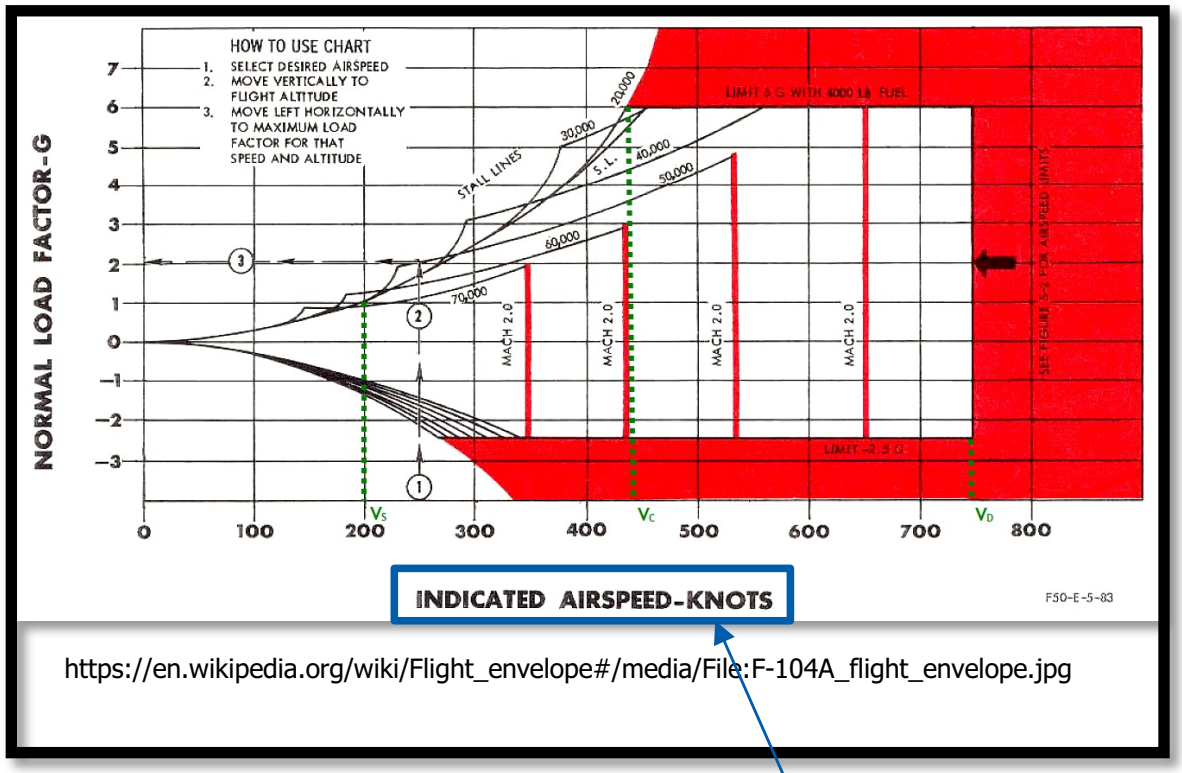


NOTES:

1. JA = GB = value specified in columns 2 and 5, table I.
2. GC = value specified in column 4, table I.
3. HD = KE value specified in columns 3 and 6, table I.
4. OH = v_H as specified in MIL-A-8860 .
5. OG = v_L as specified in MIL-A-8860
6. K = 1.25 for M ≤ 0.6
   = 1.0 for M ≥ 1.0
   = [1.625 - (0.625 M)] for 0.6< M < 1.0

where M is the Mach number corresponding to the speed being considered. K may be determined from applicable wind tunnel and flight test data acceptable to the procuring activity. This determination shall include consideration of abruptness of the maneuver, control surface limitations, Mach number, thrust, center of gravity position, external stores configuration, maximum safe angle of attack as limited by controllability, limiting buffet loads, and other effects which can be shown to have a significant bearing on the maximum attainable airplane normal force coefficient ($C_{N_{a_{max}}}$).

FIGURE 2. V-n diagram for symmetrical flight.



https://en.wikipedia.org/wiki/Flight_envelope#/media/File:F-104A_flight_envelope.jpg

Note: chart is made for IAS vs EAS

Gust Loads

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- Vertical Gusts can cause a rapid increase in AoA
- Use discrete gust formulas (see applicable reference), based on:
  - Altitude
  - Mass Ratio/Gust Alleviation Factor
  - W/S and $C_{L\alpha}$

Reminder: $C_{L\alpha}$ is a f(M, sweep)

- Use MIL-A-8861 Discrete Gust Analysis or equivalent 14CFR25 for SSBJ

Combined V-n Diagram

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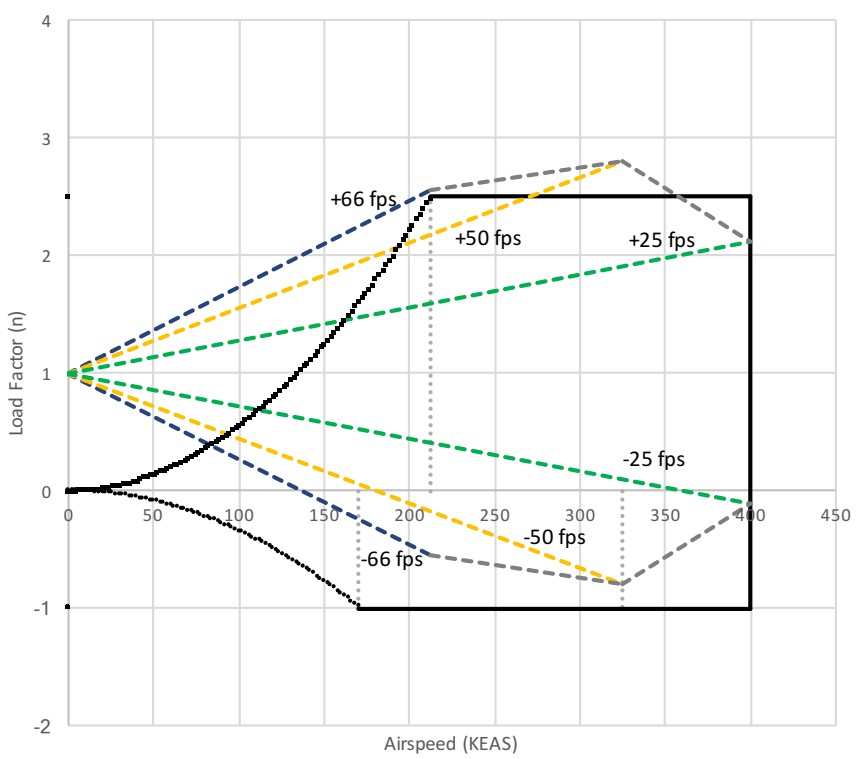

Temperature (T)	483.1	R
Pressure (P)	1454.6	psf
Density (ρ)	0.001755	slug/ft
Speed of Sound (a)	1077.3	ft/s
Aircraft Details		
Altitude (h)	10000	ft
Weight	88000	lb
MTOW	108000	lb
Wing Area	1200	ft^2
Wing Span	98	ft
mac	13	ft
$C_{L\ max}$	1.3	
C_{Lmin}	-1	
$C_{L\ \alpha}$	5.25	rad^{-1}
M_{cr}	0.85	
Vs	81.6	KEAS
V_G	212	KEAS
V_H	325	KEAS
V_L	400	KEAS

Tasking

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- V-n Diagrams for each of the following:
  - lightest weight configuration, at sea level
  - lightest weight configuration, at highest cruise altitude
  - heaviest weight configuration, at sea level
  - heaviest weight configuration, at highest cruise altitude

Thursday

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- Last minute change, no class Thursday.

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