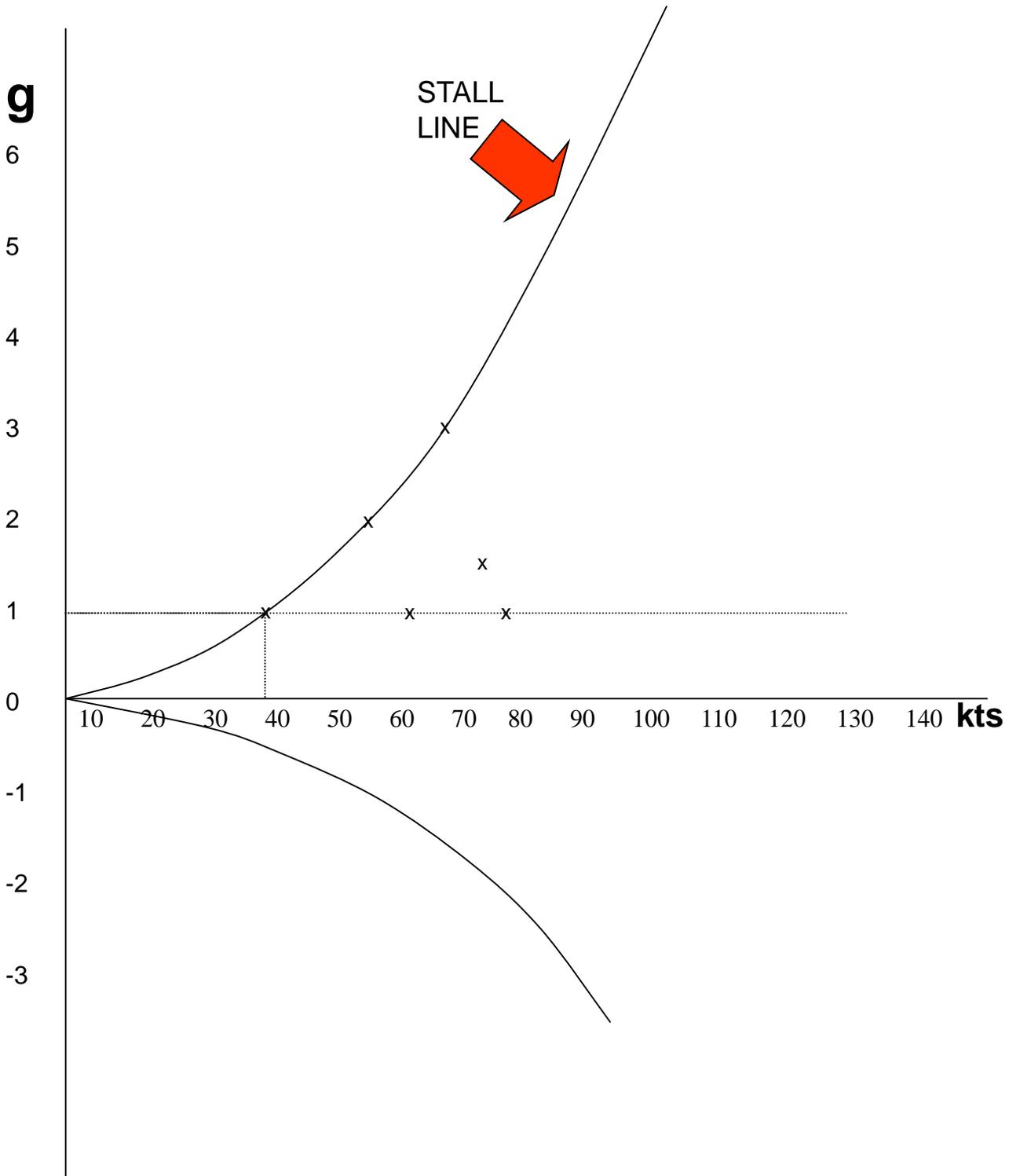


THE FLIGHT ENVELOPE



g

6

5

4

3

2

1

0

-1

-2

-3

STALL
LINE



kts

10

20

30

40

50

60

70

80

90

100

110

120

130

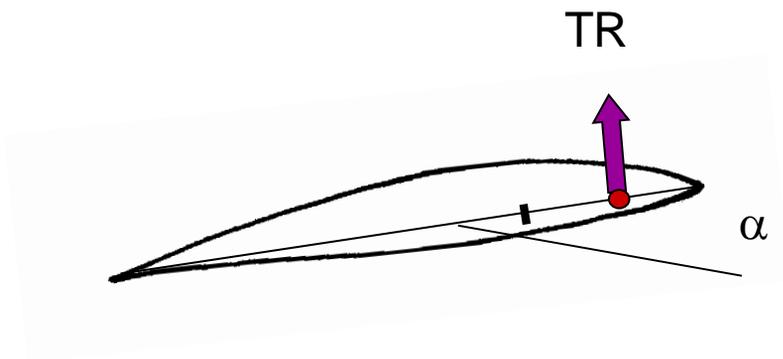
140

x

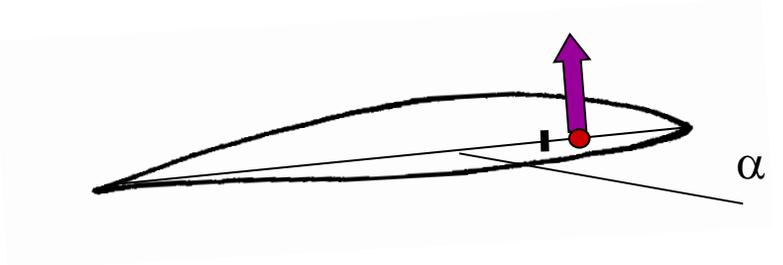
x

x

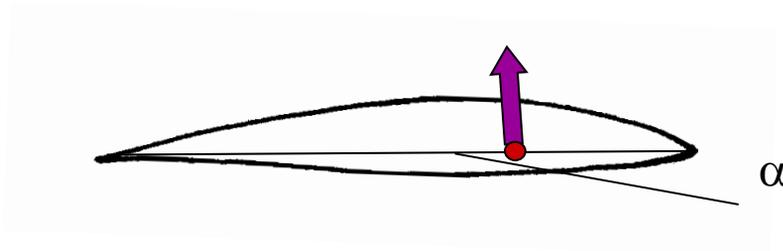
RECAP ON CENTRE OF PRESSURE



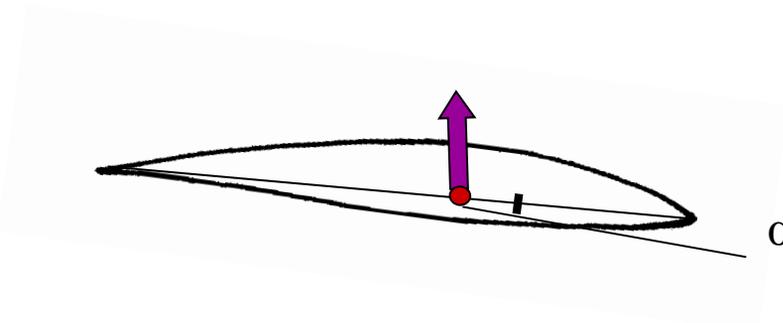
Just above the stall



Slow



Medium



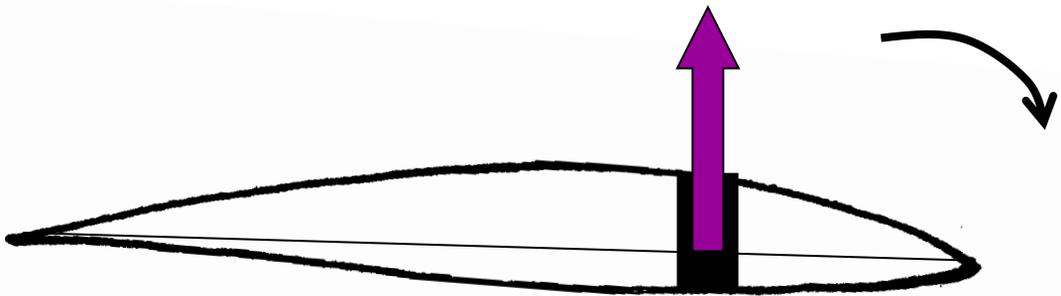
Fast

Normal speed



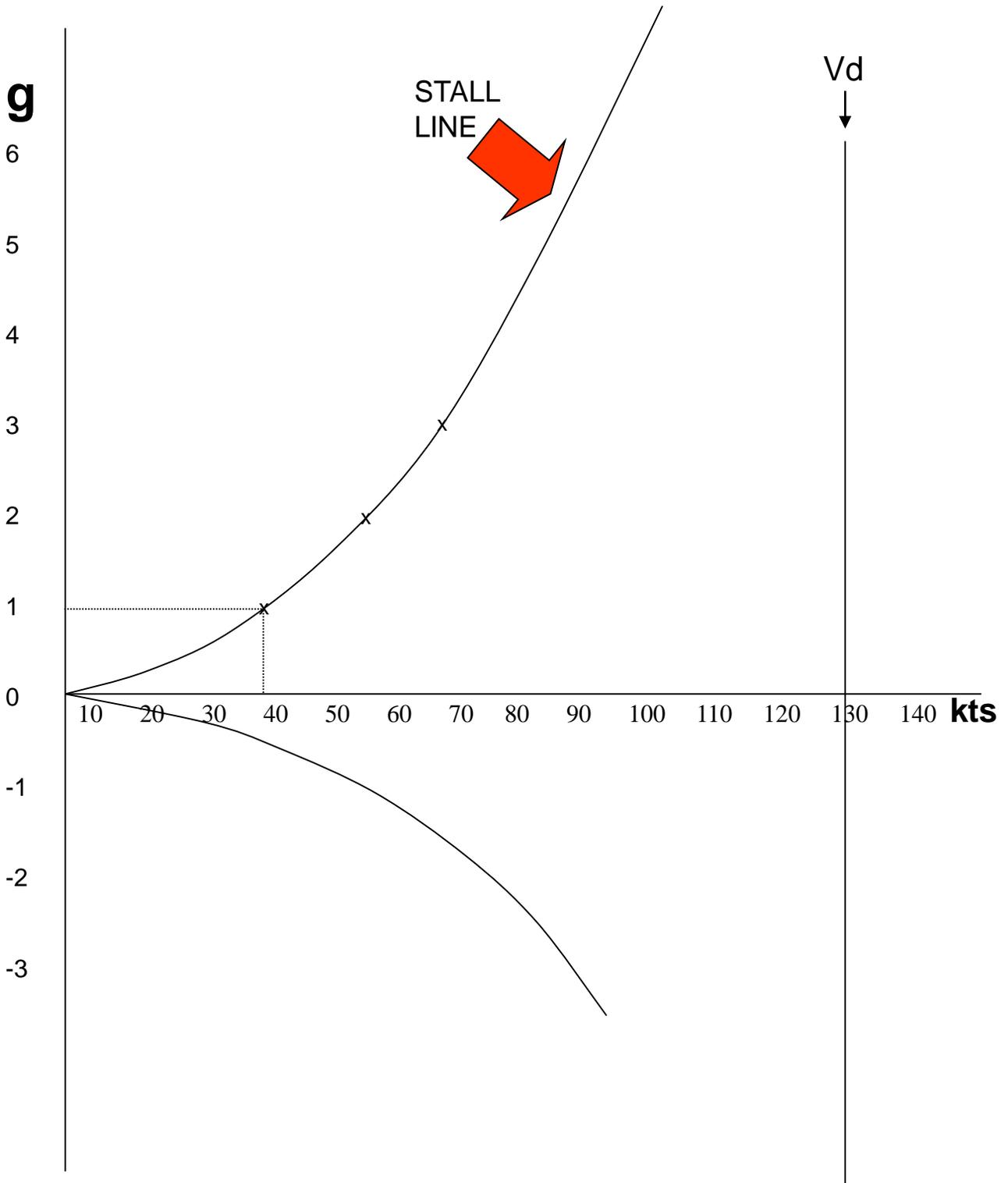
Faster

TWIST



As speed increases C of P moves

- backwards
- as AoA decreases
 - hence wing twisting
 - can reach torsion limit at V_d

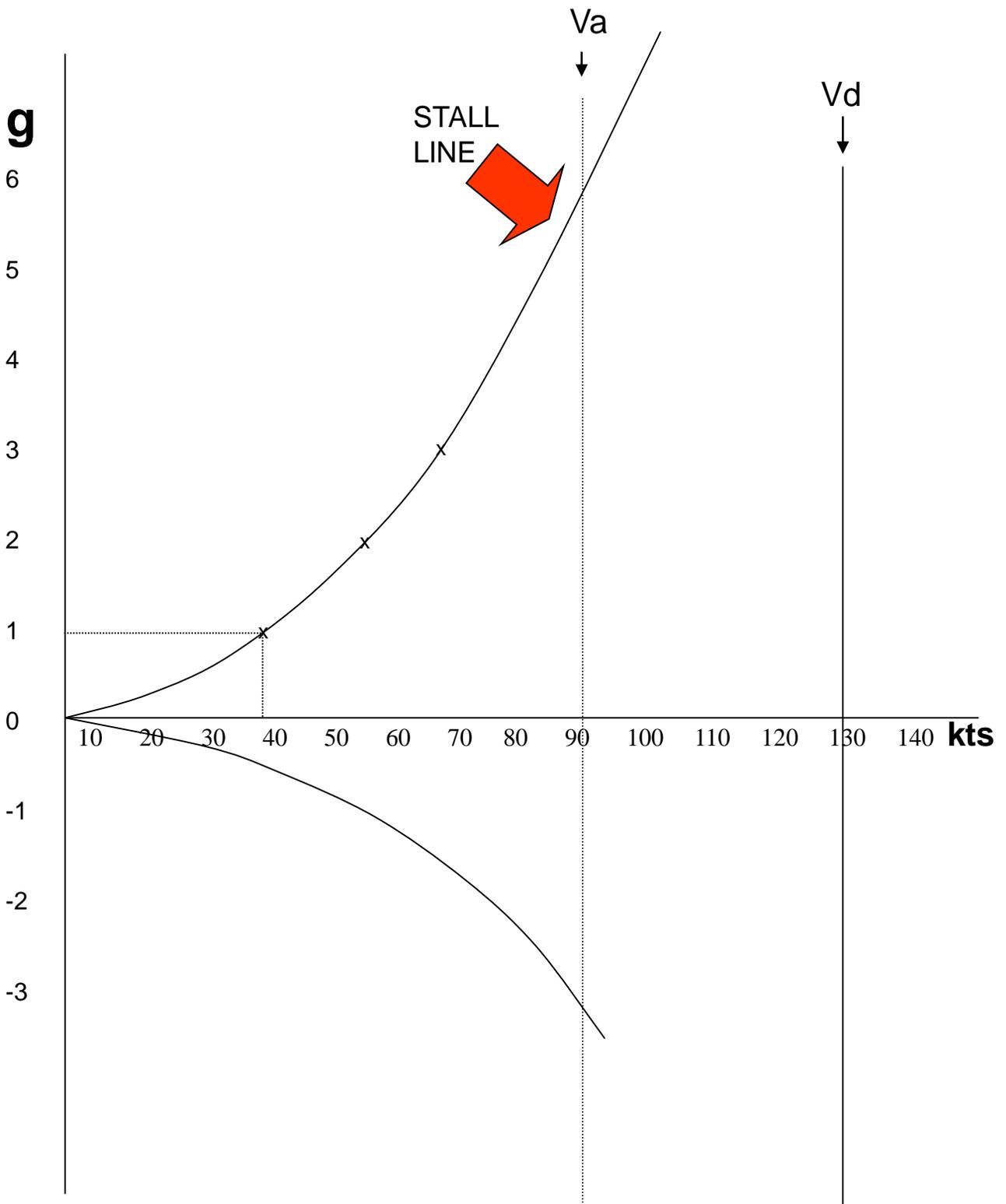


Vd = Design dive speed

As speed increases C of P moves

- backwards
- as AoA decreases
 - hence wing twisting
 - can reach torsion limit at V_d

There is also a max speed for use of full control movement



Va = Max manoeuvring speed

V_A = manoeuvring speed

-full control deflection allowed
(usually of one control only)

-above V_A the permitted deflection
may be reduced to as little as a third

**FLIGHT ENVELOPES NORMALLY REFER
TO USE OF THE ELEVATOR ONLY**

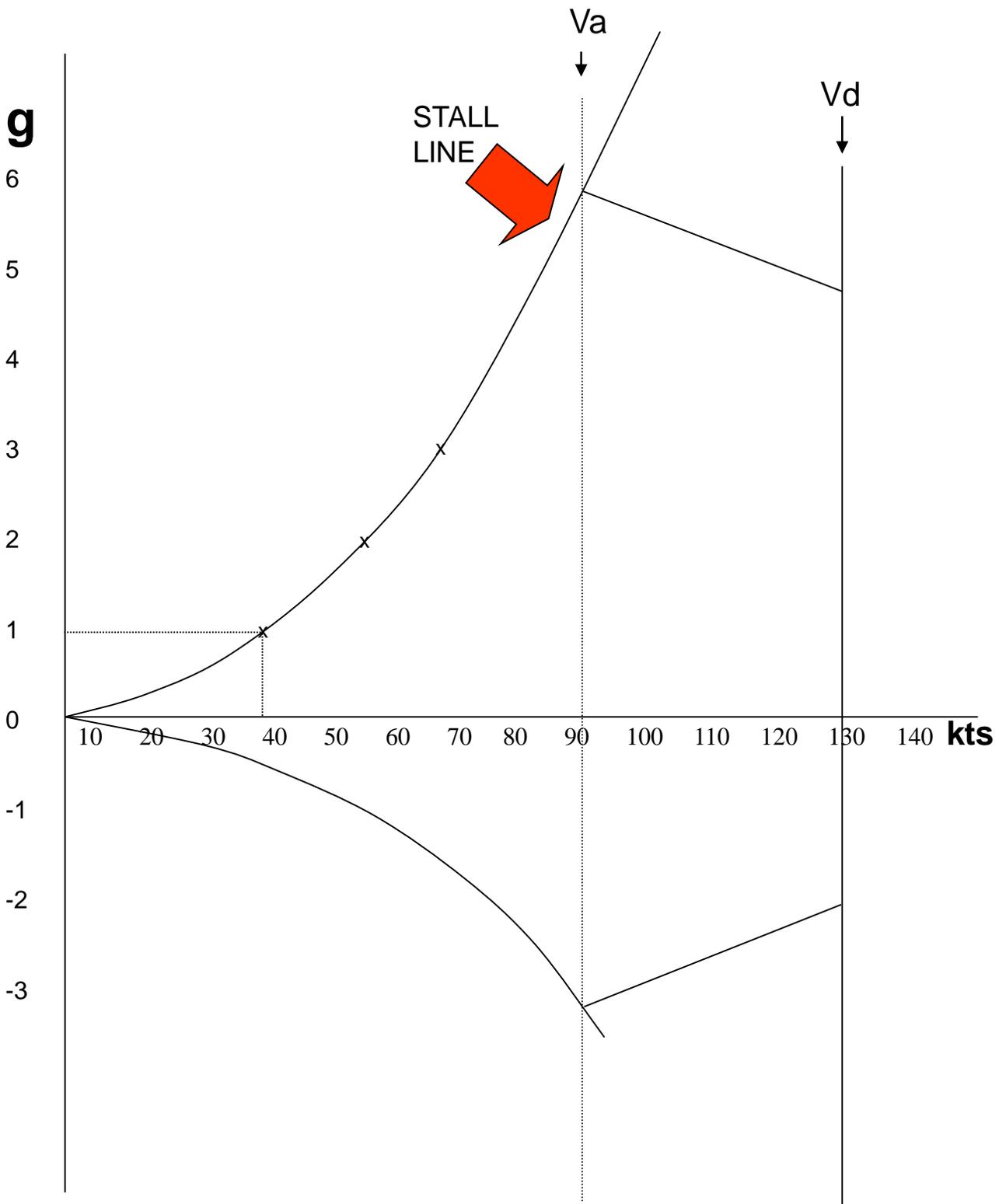
As speed increases C of P moves

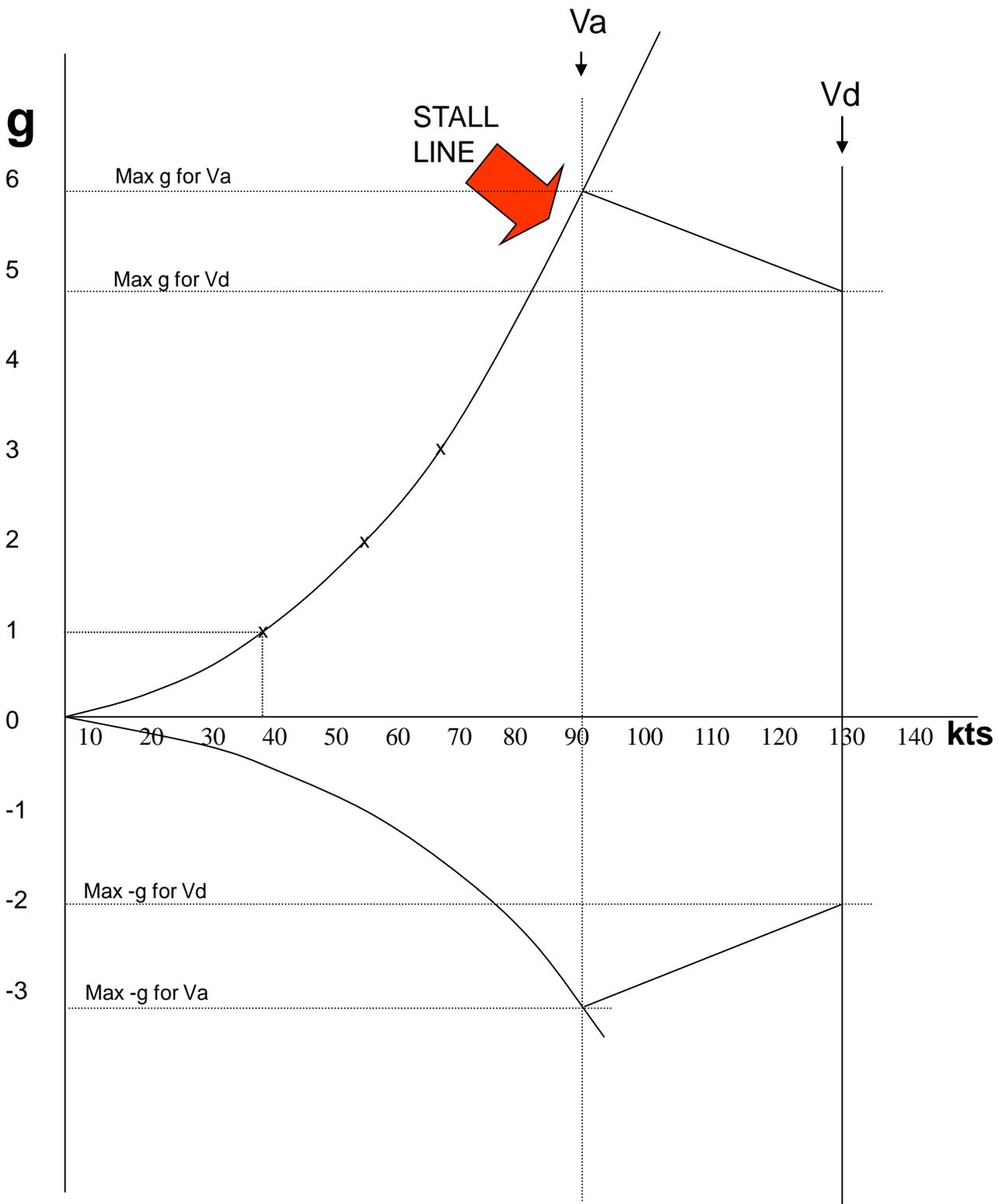
- backwards
- as AoA decreases
 - hence wing twisting
 - can reach torsion limit at V_d

There is also a max speed for use of full control movement (V_a)

Wing twist reduces strength of wing as we go faster

therefore max g allowed decreases as speed is increased





As speed increases C of P moves

- backwards
- as AoA decreases
 - hence wing twisting
 - can reach torsion limit at V_d

There is also a max speed for use of full control movement (V_a)

Wing twist reduces strength of wing as we go faster

(use of ailerons makes it worse)

(and use of airbrakes weakens wing*)

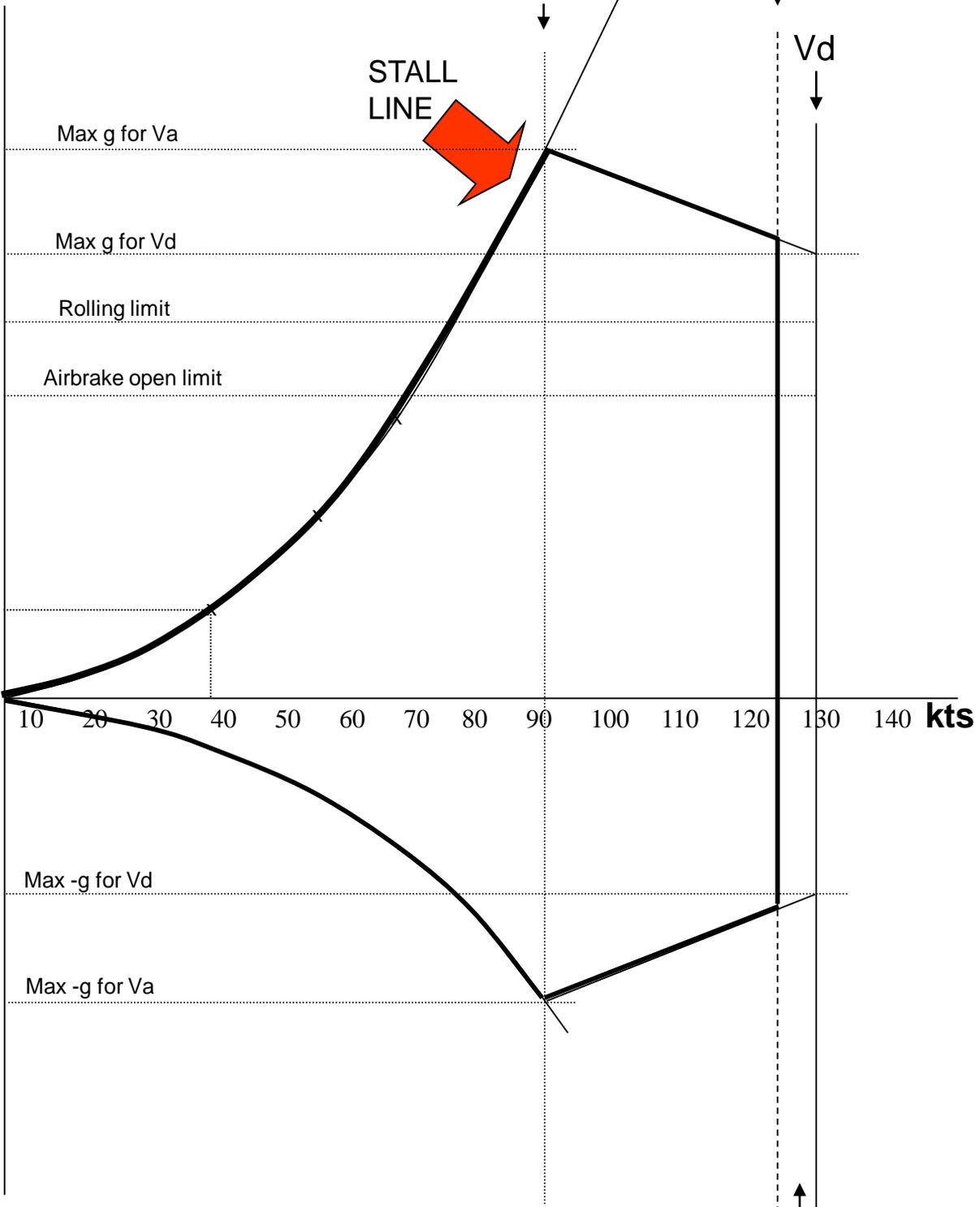
therefore max g allowed decreases as speed is increased

* K21: $3\frac{1}{2}$ g v. $6\frac{1}{2}$ g

Vne = Velocity NEVER exceed

g

6
5
4
3
2
1
0
-1
-2
-3



Va

Vne

Vd

STALL
LINE

Max g for Va

Max g for Vd

Rolling limit

Airbrake open limit

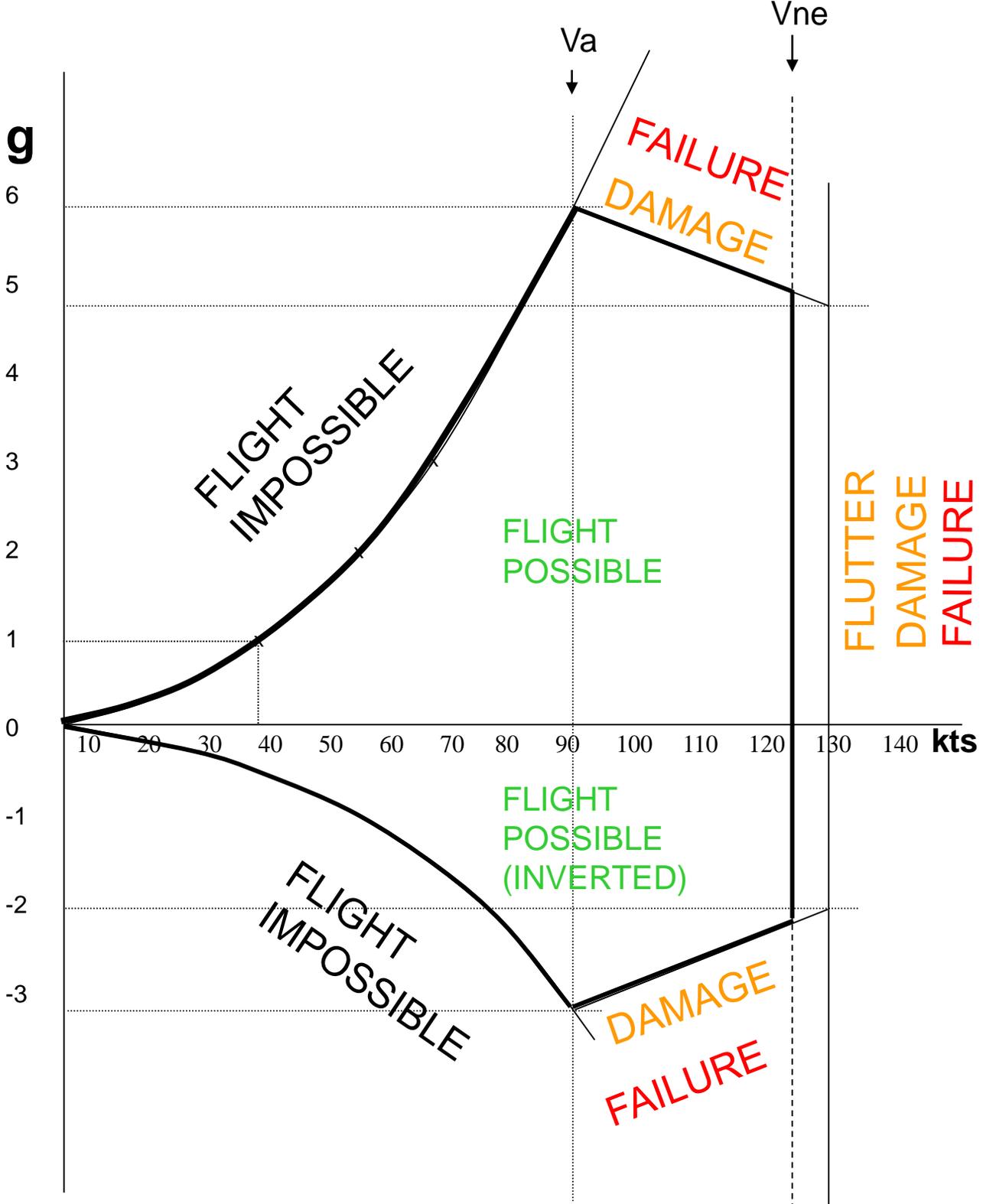
Max -g for Vd

Max -g for Va

kts

Vdf = Demonstrated dive speed

TYPICAL FLIGHT ENVELOPE



TYPICAL FLIGHT ENVELOPE

CENTRE OF PRESSURE

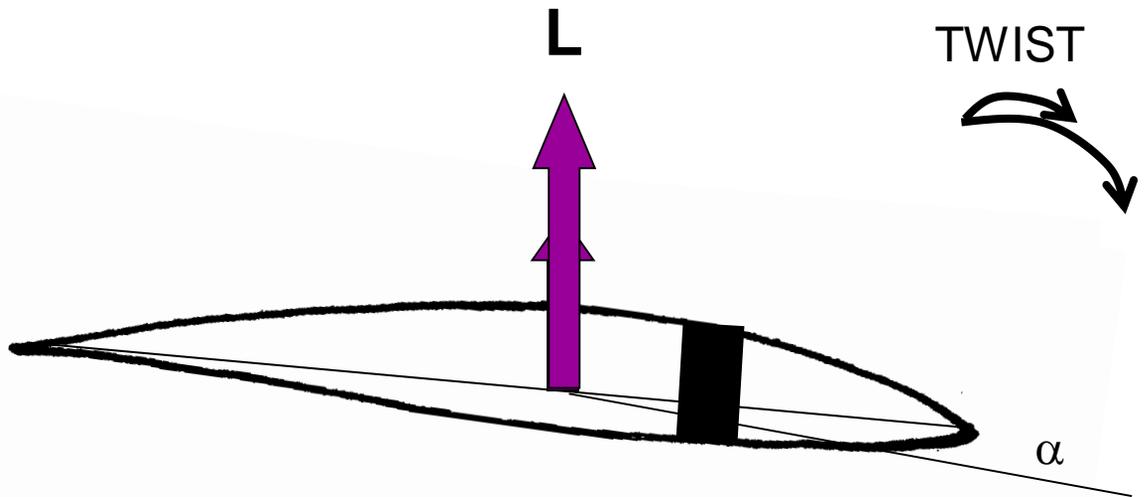
C of P moves

- backwards as AoA decreases (speed increases)
 - hence wing twisting

This leads to

FLUTTER

Flying too fast

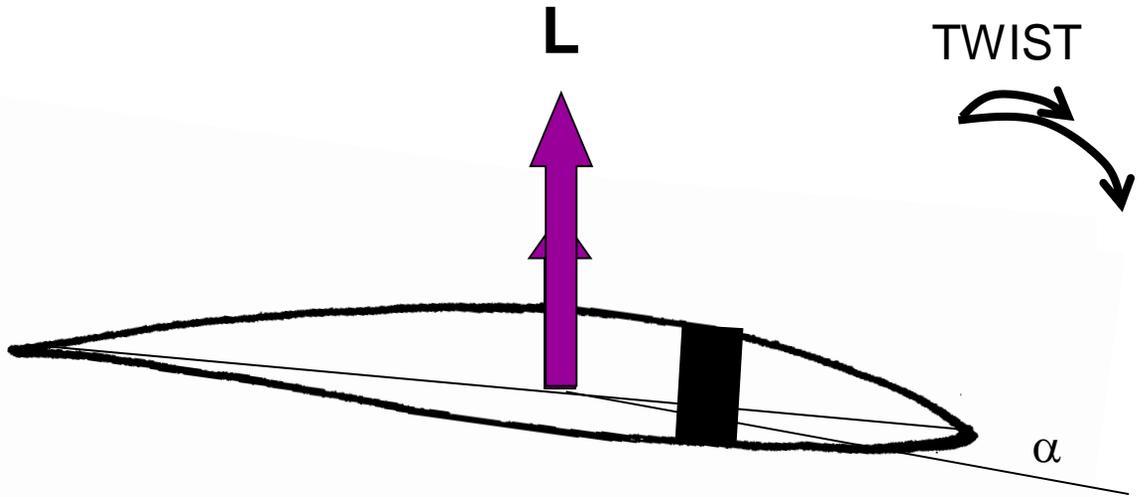


α reduced -> less L

less twist

α increased -> more lift

Flying too fast



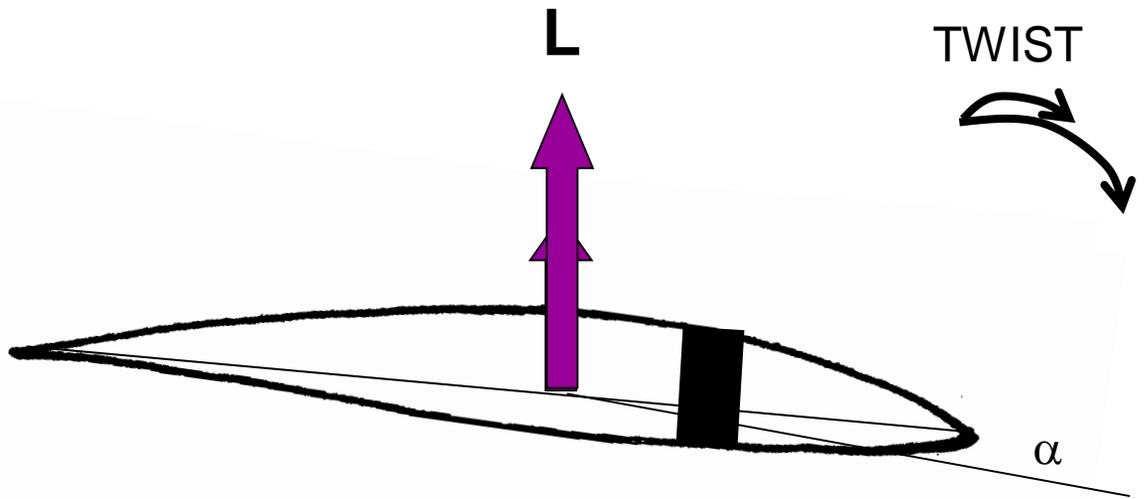
more twist

α reduced -> less L

less twist

α increased -> more lift

Flying too fast



FLUTTER

As you speed up and exceed V_{ne}

-> CoP moves further back

-> more twist

-> lower AoA

-> less lift

-> less twist

-> higher AoA

-> more lift

-> more twist

-> lower AoA

etc

The designer only plans this won't happen up to V_d

SO

if you don't want the wings to break off

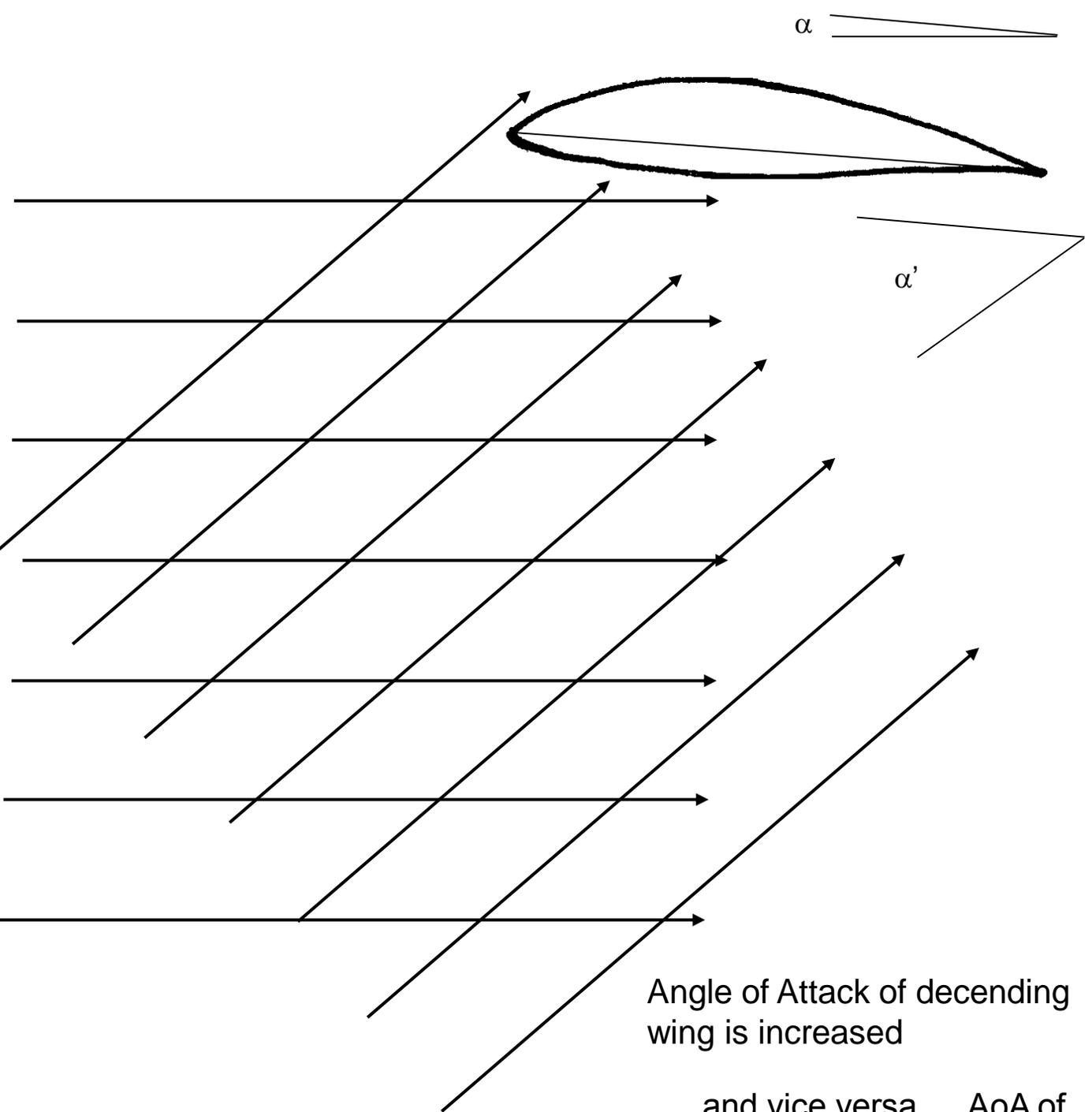
BEWARE V_{ne}

FRIGHTENING VIDEOS !!!

- See YouTube...
- How to break a glider's wing.
<http://www.youtube.com/watch?v=kQI3AWpTWhM>
- Piper PA30 Piper Comanche tail
<http://www.youtube.com/watch?v=qpJBvQXQC2M>

OTHER MODES OF FAILURE $>V_{ne}$

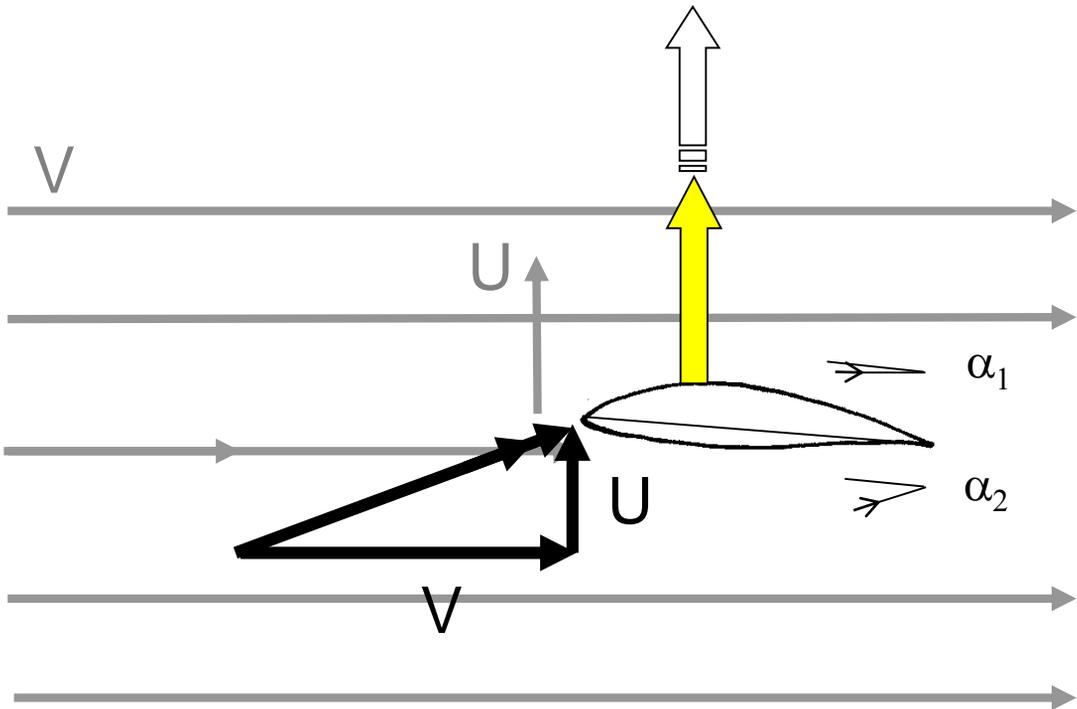
- Tail plane load get too big
- Aileron deflection leads to excessive wing bending because of fuselage inertia and then resonance



Angle of Attack of descending wing is increased

...and vice versa ... AoA of ascending wing is decreased

GUSTS



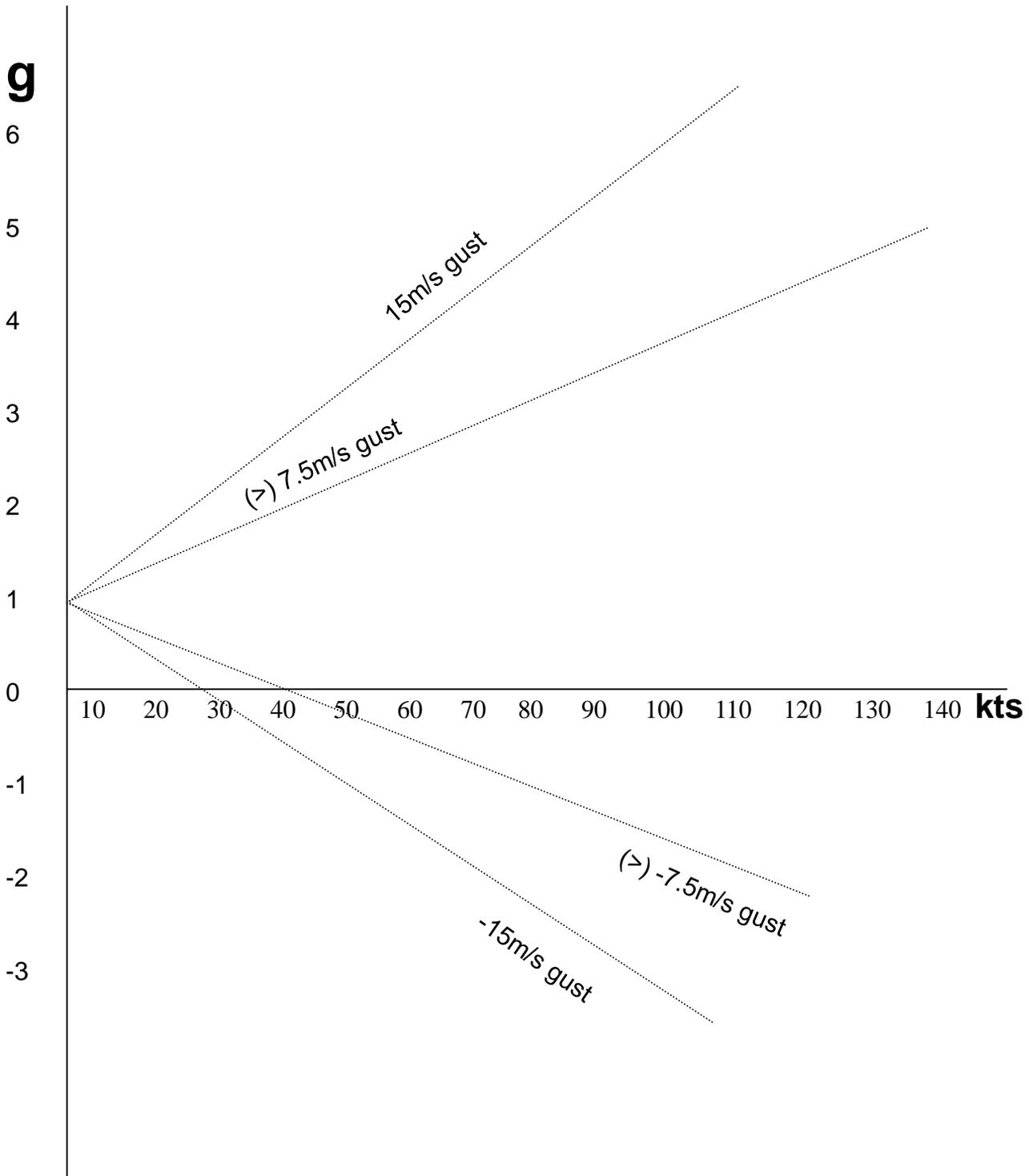
Up-gust effectively increases AoA and results in increased lift (which is the same as increased wing loading)

Lift \propto AoA $\propto U/V$ OR 'the faster you're going the harder you hit it !'

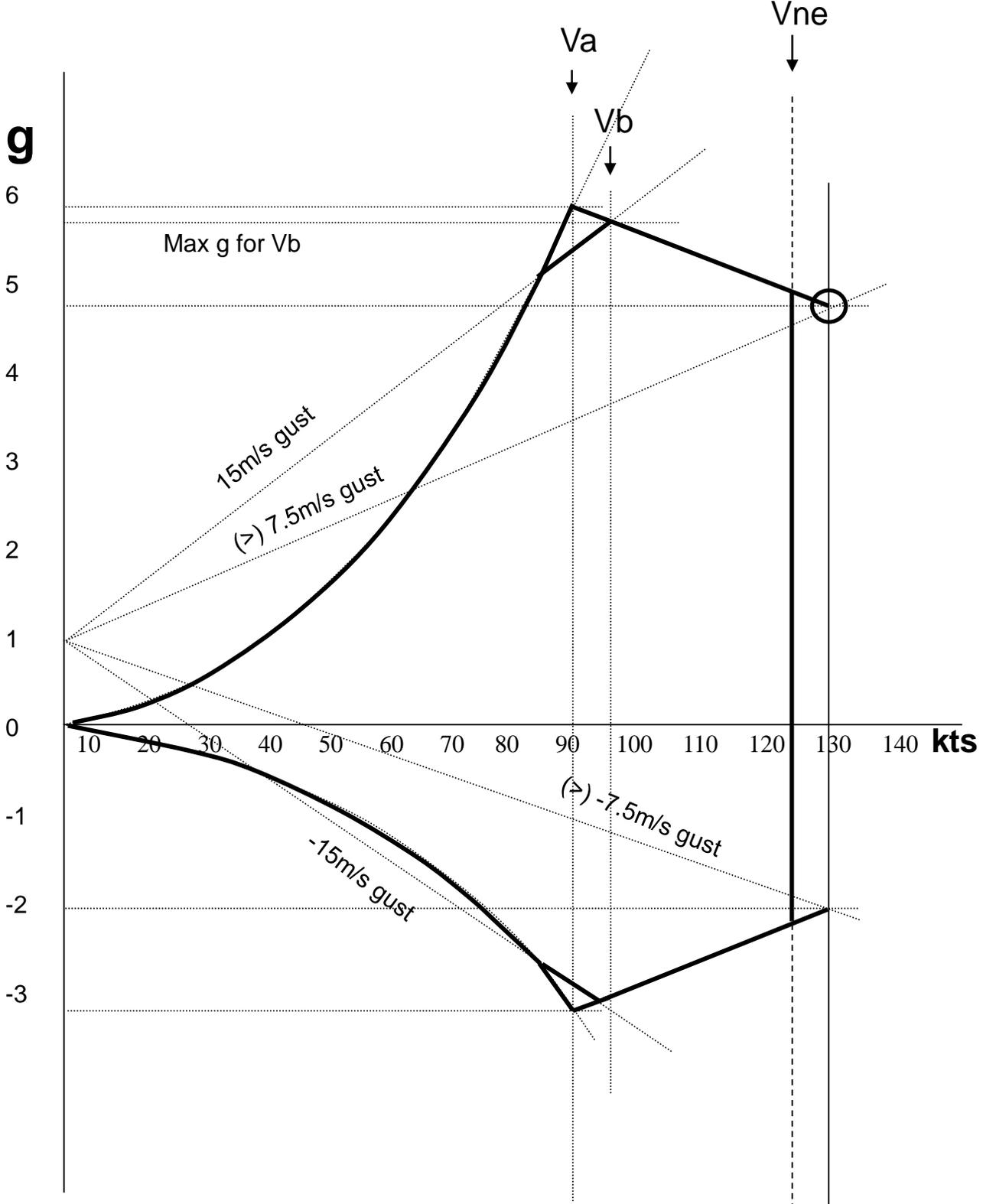
Also Lift $\propto V^2$

$$\therefore \text{Wing loading} \propto (U/V) \times V^2 = UV$$

* Tan angle approx equals angle (in radians) for small angles



GUST LINES



TYPICAL GUST ENVELOPE

V_A = manoeuvring speed

-full control deflection allowed
(usually of one control only)

-above V_A the permitted deflection
may be reduced to as little as a third

V_B = design strong gust speed

The 'rough air speed' placarded
must not exceed V_B

V_B must not be less than V_A

**FLIGHT ENVELOPES NORMALLY REFER
TO USE OF THE ELEVATOR ONLY**

LOADS AND SPEEDS

Limit Load = maximum load expected
in normal flight

Proof Load = limit load x proof factor
(usually =1)

Shall not fail OR deform

Ultimate Load = proof load x 1.5

*Shall not fail (for 3s)
BUT may deform*

failure

V_D = Design dive speed

V_{DF} = Demonstrated dive speed

$$.9V_D < V_{DF} < V_D$$

V_{NE} = Velocity never exceed = $.95V_{DF}$

$$.86V_D < V_{NE} < .95V_D$$

Usually V_{NE} approx = $.9V_D$

Want to become a test pilot?!

FLIGHT ENVELOPE

(and Test Pilot School)

Note that:-

In order not to exceed V_d

the best case scenario allows you to exceed V_{ne} by 15% (actually 16.25%)

but the worst case only allows you to exceed V_{ne} by 5% (5.25%)

- and this is what you have got to assume !!

BUT in relation to V_{df} it **IS** $V_{ne} + 5\%$ (.25) before you become the test pilot.

I don't think so !!!!

THE MORAL IS **DON'T EXCEED V_{ne}**

It is better to PULL G instead (but no airbrakes and not for too long !!)

Ultimate Load factor is 1.5

But the glider may deform and will therefore need inspecting

and don't roll and pull a lot of g at the same time

e.g. spin recovery

K7 main spar failure accident was possibly due to disregard for V_a

FLIGHT ENVELOPE
(and Test Pilot School)
cont....

IAS < TAS – approx 2% per thousand feet
10,000 -> 20% !!!

ASI instrument error (due to pitot/static locations)
- could be five percent
(⇒ CAS [Calc Airspeed])

Manufacturing variations?

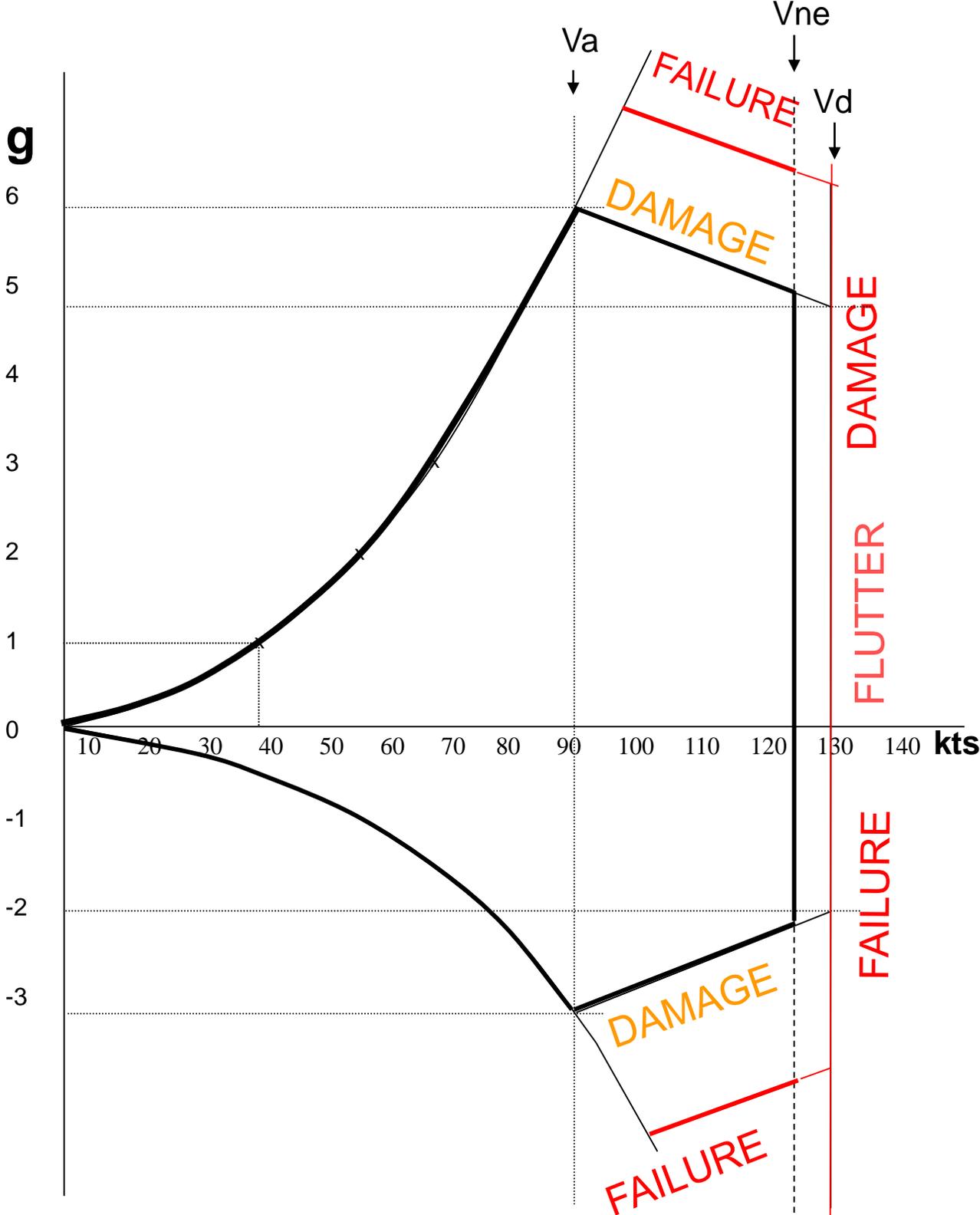
How old is the glider ? !!!!

Do you think it is as strong as when new?

MORAL PART TWO

- if you've got any brains -

DON'T EVEN GO NEAR V_{ne}



TYPICAL FLIGHT ENVELOPE

LIMITATIONS PLACARD

BGA/267/P

B.G.A. No TYPE

CATEGORY: NON AEROBATIC/AEROBATIC

SEMI AEROBATIC/CLOUD FLYING

Auto/Winch Rough Air

SPEED LIMITATIONS (Knots)

Aero Tow VNE

Flaps Gear Down

Max Wt. (Dry) Max Wt. (water)

WEIGHT AND C.G. LIMITATIONS

Empty Wt. Min. Solo Wt.

Max. Solo Wt. Date Weighed

NOTE: Refer to flight Manual for full limitations

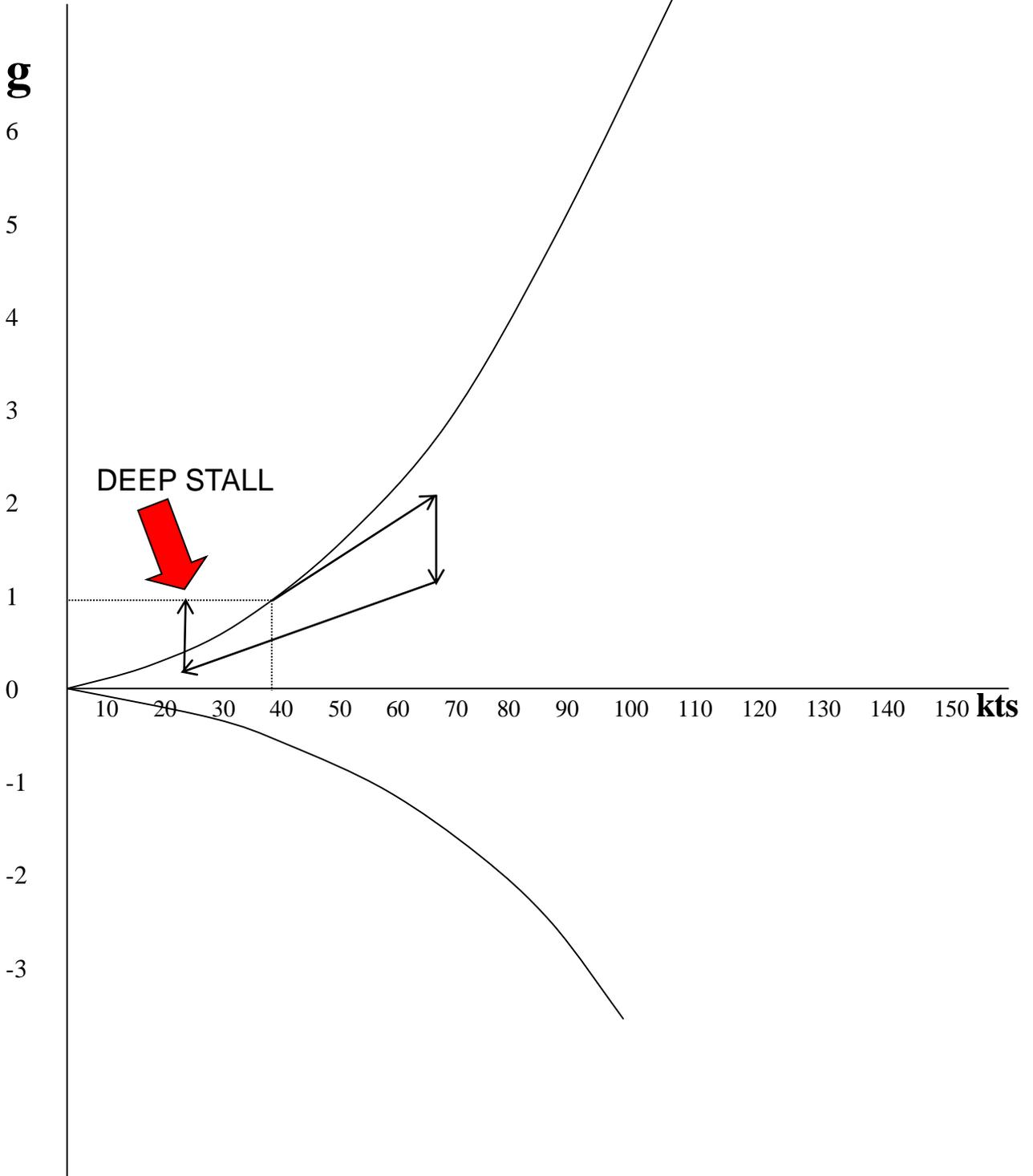
Issued by Dated

NEEDS NEW

WINCH LAUNCHING

and the flight envelope

WINCH LAUNCHING



SPIN OFF A FAILED
WINCH LAUNCH