Lesson 5
Buffet Boundaries
VMO/MMO Limits

General

High speed jet aircraft may suffer both high and low speed stall buffet. The high speed buffet is caused by flow separation from the wings as occurs behind a shockwave at high altitudes and/or Mach numbers. The low speed buffet is caused by the same airflow separation as the aircraft approaches the stall angle of attack. High speed aircraft flight manuals will have published in them at least 3 graphs called "Initial Buffet Boundary Charts". One is for level flight and nil turbulence (ie: 1G manoeuvres), one for 40 degree bank angles/moderate turbulence (ie: 1.3G manoeuvres), and one for 50 degree bank angles/heavy turbulence (ie: 1.6G manoeuvres).

As you are probably aware, low speed stall speeds are increased as angle of bank increases. The same is true as the degree if turbulence increases, effectively the aircraft weighs more in both cases (eg: 30% more in the case of moderate turbulence or 40 degree bank angles). Increased aircraft weight on it's own also increases the low speed stall speed.

The buffet boundary tables are in Flight Manual for aircrew guidance in selecting a suitable flight level, given the atmospheric conditions forecast, or actually experienced. The turbulence penetration speeds are also displayed, along with maximum normal operation speeds as indicated airspeed (abbreviated VMO) up to maximum VMO, and as a Mach number (abbreviated MMO) for flight levels above this.

The Buffet Boundary charts in detail

Flight manual pages cover nil turbulence and level flight, moderate turbulence or 40 degree bank angle = 1.3G, and heavy turbulence or 50 degree bank angle = 1.6G . Along the graphs vertical axis is the pressure altitude scale (FL), and along the bottom are the indicated airspeed values. The curved lines represent the aircraft weight in kgs x 1000. You may be asked in the ATPL exam to identify the values of low speed aerodynamic buffet, and high speed aerodynamic buffet.
Example:
What is the low and high speed buffet speeds expressed as an IAS if the aircraft gross weight is 80, 000 kg, and the aircraft is at FL310, assuming MODERATE turbulence ? Refer to Figure Buffet 1 below.

A line drawn across at FL310 intersects the low speed buffet curve at a speed of 202 kt IAS, and high speed buffet line at 325 kt IAS. The spread between the buffet speeds is a comforting 123 kt.

For the same weight and conditions at the higher altitude of FL350, the speeds are approx 212 kt and 290 kt. A 78 kt margin between the speeds.

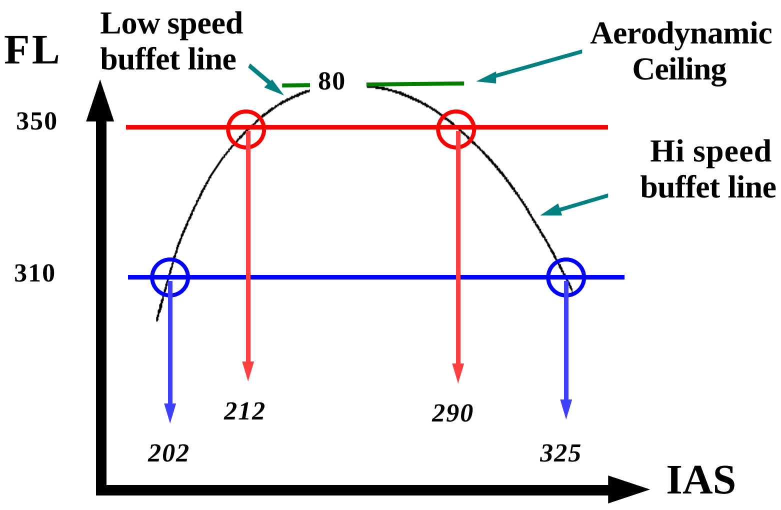


Fig Buffet 1. Nil turbulence buffet speeds.

At high levels, manoeuvre margin between Hi and Low speed stall decreases.

Effect of turbulence

Increased turbulence or bank angles bring the high and low speed stall buffet values closer together, and the manoeuvre margin is therefore reduced. Using the previous example at FL310, aircraft GW 80, 000 kg, compare the values shown below in moderate and **heavy turbulence**.

Nil Turb	Mod Turb	Heavy Turb
Low 205/Hi 325	Low 247/Hi 310	Outside limits

In the case of the heavy turbulence, flying at FL310 put's you outside the manoeuvre margins, something you can NOT afford to let happen, and the aircraft will be suffering a combination of both low and high speed stall at the same time. The area in the top corner of the buffet boundary curves is called "COFFIN CORNER", for a good reason. Jet aircraft are, generally speaking more fuel efficient at higher altitudes, so high altitude is best for minimising fuel burn, and therefore increasing the range with a given quantity of fuel. The altitude capability of the aircraft is in consideration of the engine cruise thrust limits, keeping the engine turbines within their cruise limit temperatures. We must consider also whether such a high altitude is safely within the buffet limits, given the forecast or actual degree of turbulence.

Same FL, increased turbulence/bank angle reduces manoeuvre margins.

THE VMO NEEDLE

This is sometimes referred to as the “BARBERS POLE”, as it has red and white diagonal stripes on it. Refer to Fig Buffet 2.

It denotes the maximum operating IAS up to which the aircraft may be safely operated (abbreviated VMO).

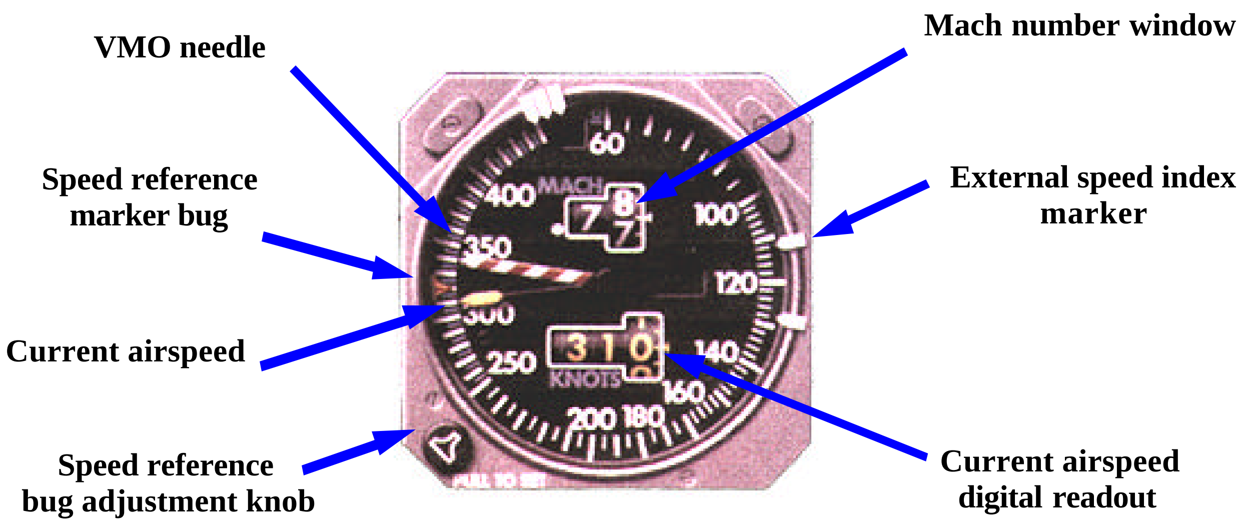


Fig: Buffet 2. Typical combination airspeed/Mach indicator

VMO is an airspeed value something less than VNE, which is the RED LINE limit of forward airspeed. The difference between VMO and VNE is to allow a safety buffer in case of inadvertent exceedance of the VMO value. Should VMO be exceeded, an audible alarm will sound in the cockpit, the volume of which is enough to wake the dead. This alarm cannot be inhibited by the crew and will continue to sound until the aircraft has been slowed to below the VMO limit. The “Limitations” section of the aircraft operating manual (AOM) will specify a VMO limit speed for that model of aircraft., and also as a dashed line on the buffet boundary graphs.

Another limit speed specified in the Operating Manual is that of “Maximum Mach Operating Speed” (abbreviated MMO). This speed is something less than MNE, which is the “NEVER EXCEED MACH NUMBER”. The buffer between MMO and MNE is again to allow a safety speed buffer.

The Mach number window is covered by a flag when the Mach display is unusable, or CADC data unreliable.

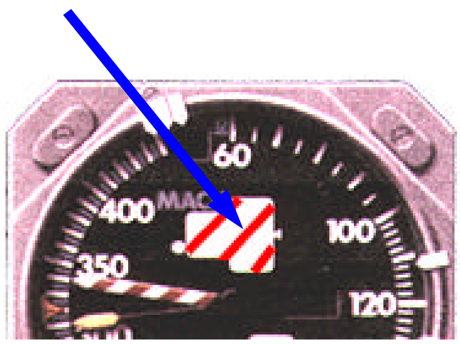


Fig Buffet 3. CADC unreliable.

As an example VMO/MMO specified by the manufacturer of an aircraft might be 330 IAS/M 0.75. This gives a VMO/MMO changeover level of FL225 (ie: 22, 500 ft pressure altitude). Refer to Fig Buffet 4. Check it out on your prayer wheel !

At sea level and upon initial climbout the VMO needle will, in this case remain fixed,as if glued to the face of the ASI instrument at the 330 IAS marker.That will remain the case until FL225, at which point the needle will fall anti-clockwise, due to the fact that after passing FL225, it will conform to the MMO limit of M 0.75.

Remember from an earlier section of these notes, that if an aircraft climbs at a fixed Mach number (M 0.75 in this case), then the value of IAS falls in value with altitude gained !

The behaviour of the VMO needle upon climbing, in the above example would be a steady reading of 330 IAS up to VMO/MMO changeover level (FL225 in this case), after which the needle would count back anti-clockwise, showing continuously decreasing IAS values. This is a popular question type in the ATPL examination.

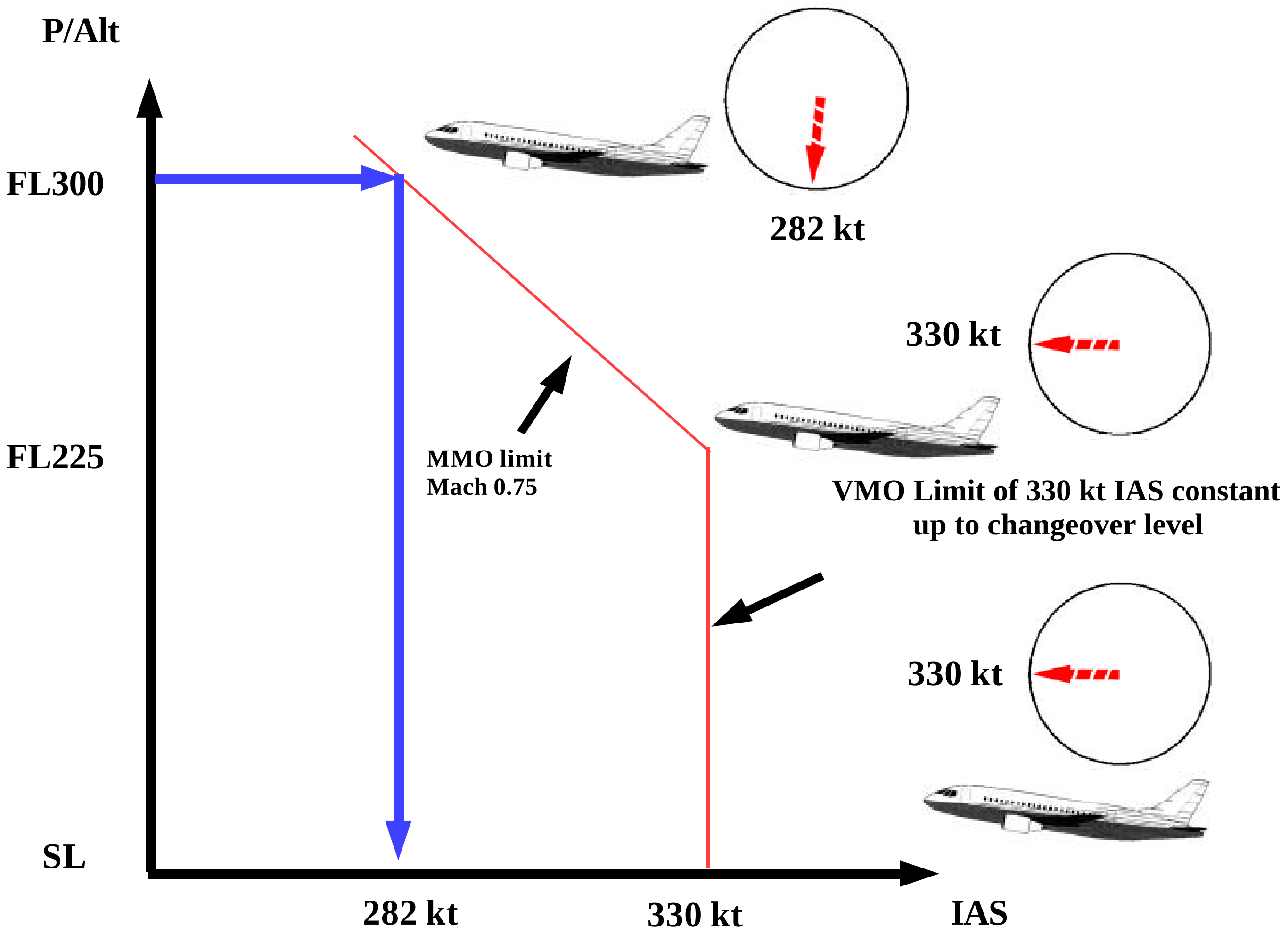
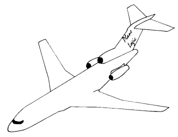


Fig: Buffet 4. VMO/MMO ... Fixed VMO value.



Some aircraft such as the B727 and Fokker F28 have a variable VMO value dependant on pressure altitude.
Refer to extract from B727 manual and Fig Buffet 5.

In this case, the behavior of the VMO needle with altitude gained from sea level would be a rising value up to VMO/MMO changeover, thereafter the needle would move anti-clockwise to lower and lower IAS values.

If the aircraft type is not mentioned in a question involving movement of the VMO needle with altitude gained, assume a fixed VMO limit.

Pressure Alt	**Max IAS (VMO)**	**Max Mach (MMO)**
SL	**350**	
5000	**353**	
10000	**355**	
15000	**359**	
20000	**365**	
25000	**370**	
30000	**347**	**0.902**
35000	**311**	**0.902**
40000	**277**	**0.902**

B727 manual extract. Max operating speeds. Changeover at approximately 26, 600 ft.

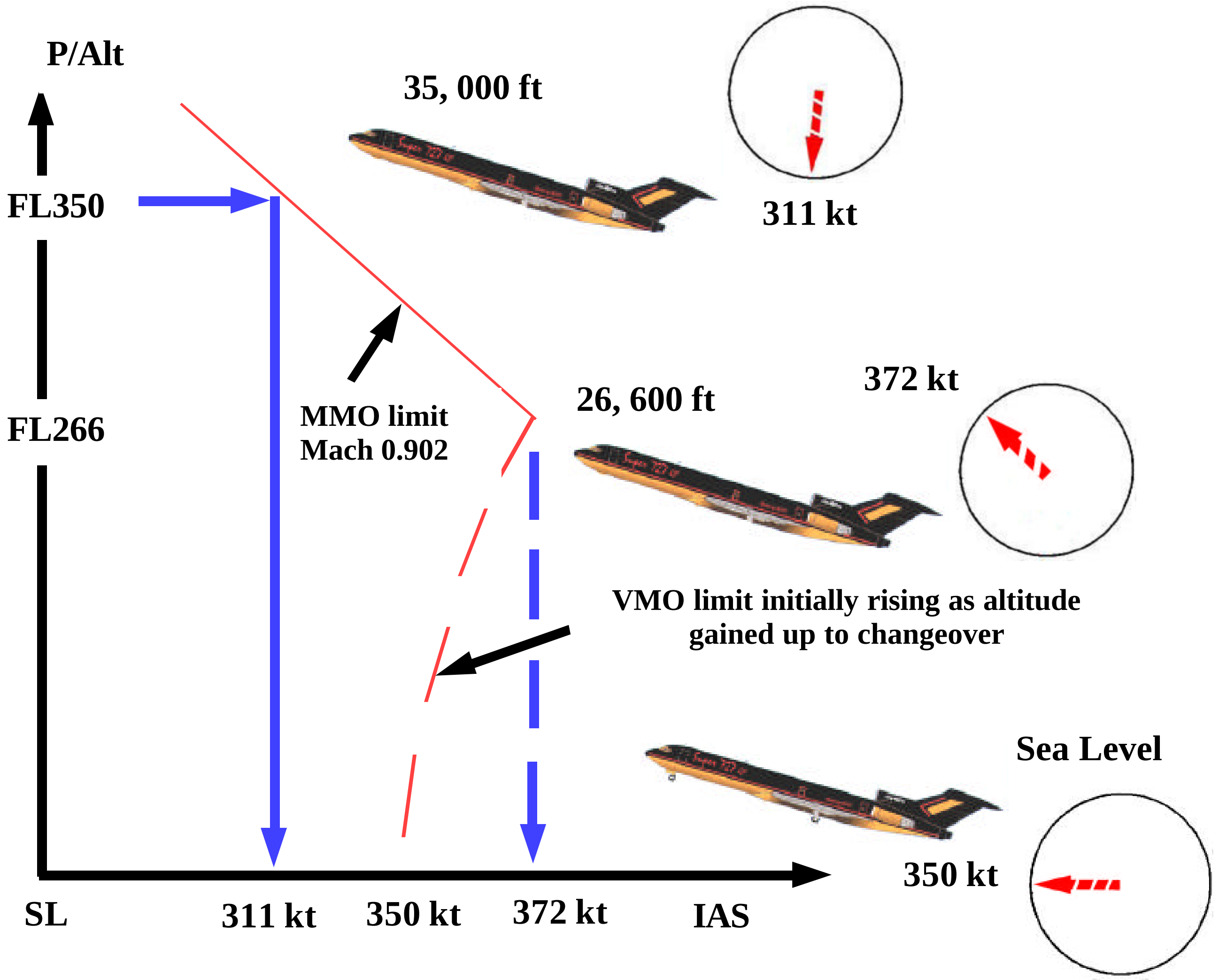


Fig Buffet 5. B727-200 VMO/MMO changeover profile - variable VMO limit.

End of Buffet Boundary and VMO/MMO training texts.
There are no assignments for the Buffet section !