Docket No. SA-522

Exhibit No. 2-Y

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Excerpts of FAA Advisory Circular 61-23C, Pilot's Handbook of Aeronautical Knowledge
Pages 2-5

(5 Pages)

Figure 1-33.—The load supported by the wings increases as the angle of bank increases. The increase is shown by the relative lengths of the white arrows. Figures below the arrows indicate the increase in load factor. For example, the load factor during a 60° bank is 2.00, and the load supported by the wings is twice the weight of the airplane in level flight.

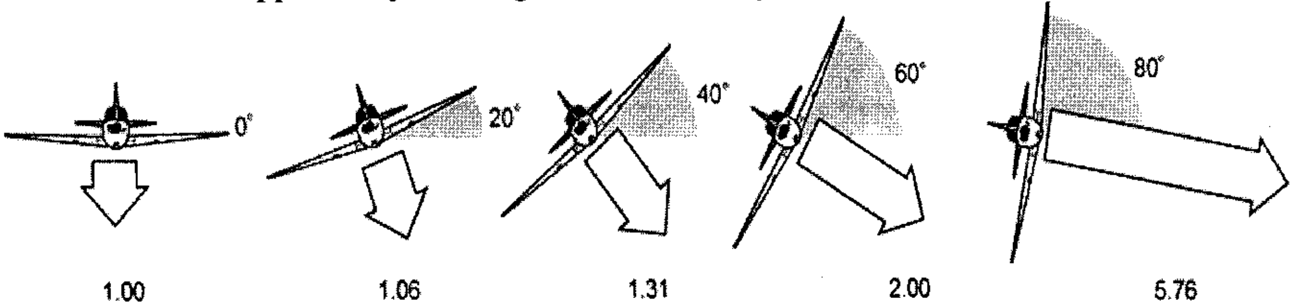
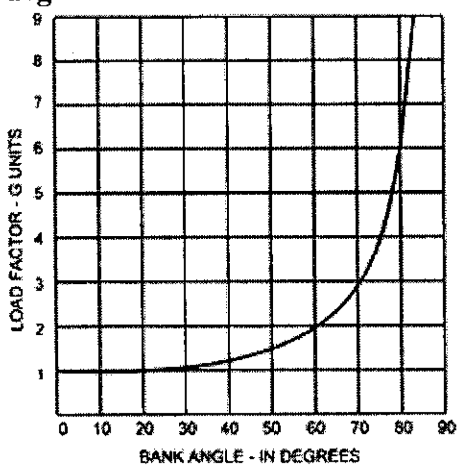


Figure 1-34.—Load factor chart.



At an angle of bank of slightly more than 80°, the load factor exceeds 6, which is the limit load factor of an acrobatic airplane.

The approximate maximum bank for conventional light airplanes is 60° which produces a load factor of 2. An additional 10° of bank will increase the load factor by approximately 1 G, bringing it dangerously close to the point at which structural damage or complete failure may occur in these airplanes. [Figure 1-34]

Effect of Load Factor on Stalling Speed

Any airplane, within the limits of its structure and the strength of the pilot, can be stalled at any airspeed. At a given airspeed, the load factor increases as angle of attack increases, and the wing stalls because the angle of attack has been increased to a certain angle. Therefore, there is a direct relationship between the load factor imposed upon the wing and its stalling characteristics.

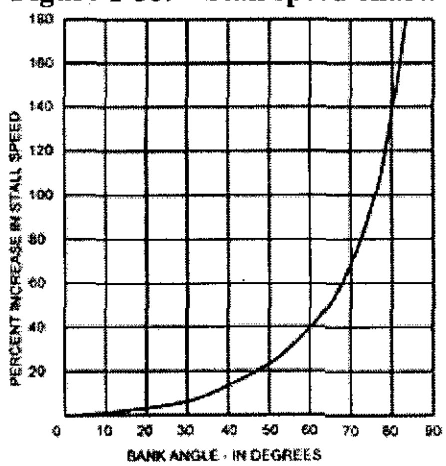
When a sufficiently high angle of attack is reached, the smooth flow of air over an airfoil breaks up and tears away, producing the abrupt change of characteristics and loss of lift which is defined as a stall.

A rule for determining the speed at which a wing will stall is that the stalling speed increases in proportion to the square root of the load factor. To further explain, the load factor produced in a 75° banked turn is 4. Applying the rule, the square root of 4 is 2. This means that an airplane with a normal unaccelerated stalling speed of 50 knots can be stalled at twice that speed or 100 knots, by inducing a load factor of 4. If the airplane were capable of withstanding a load factor of 9, this airplane could be stalled at a speed of 150 knots. [Figure 1-34]

Since the load factor squares as the stalling speed doubles, tremendous loads may be imposed on structures by stalling an airplane at relatively high airspeeds. An airplane which has a normal unaccelerated stalling speed of 50 knots will be subjected to a load factor of 4 G's when forced into an accelerated stall at 100 knots. As seen from this example, it is easy to impose a load beyond the design strength of the conventional airplane.

Reference to the chart in figure 1-35 will show that banking an airplane just over 75° in a steep turn increases the stalling speed by 100 percent. If the normal unaccelerated stalling speed is 45 knots, the pilot must keep the airspeed above 90 knots in a 75° bank to prevent sudden entry into a violent power stall. This same effect will take place in a quick pullup from a dive or maneuver producing load factors above 1 G. Accidents have resulted from sudden, unexpected loss of control, particularly in a steep turn near the ground.

Figure 1-35.—Stall speed chart.



The maximum speed at which an airplane can be safely stalled is the design maneuvering speed. The design maneuvering speed is a valuable reference point for the pilot. When operating below this speed, a damaging positive flight load should not be produced because the airplane should stall before the load becomes excessive. Any combination of flight control usage, including full deflection of the controls, or gust loads created by turbulence should not create an excessive air load if the airplane is operated below maneuvering speed. (Pilots should be cautioned that certain adverse wind shear or gusts may cause excessive loads even at speeds below maneuvering speed.)

Design maneuvering speed can be found in the Pilot's Operating Handbook or on a placard within the cockpit. It can also be determined by multiplying the normal unaccelerated stall speed by the square root of the limit load factor. A rule of thumb that can be used to determine the maneuvering speed is approximately 1.7 times the normal stalling speed.

Thus, an airplane which normally stalls at 35 knots should never be stalled when the airspeed is above 60 knots (35 knots x 1.7 = 59.5 knots).

A knowledge of this must be applied from two points of view by the competent pilot: the danger of inadvertently stalling the airplane by increasing the load factor such as in a steep turn or spiral; and that intentionally stalling an airplane above its design maneuvering speed imposes a tremendous load factor on the structure.

Effect of Speed on Load Factor

The amount of excess load that can be imposed on the wing depends on how fast the airplane is flying. At slow speeds, the maximum available lifting force of the wing is only slightly greater than the amount necessary to support the weight of the airplane. Consequently, the load factor should not become excessive even if the controls are moved abruptly or the airplane encounters severe gusts, as previously stated. The reason for this is that the airplane will stall before the load can become excessive. However, at high speeds, the lifting capacity of the wing is so great that a sudden movement of the elevator controls or a strong gust may increase the load factor beyond safe limits. Because of this relationship between speed and safety, certain "maximum" speeds have been established. Each airplane is restricted in the speed at which it can safely execute maneuvers, withstand abrupt application of the controls, or fly in rough air. This speed is referred to as the design maneuvering speed, which was discussed previously.

Summarizing, at speeds below design maneuvering speed, the airplane should stall before the load factor can become excessive. At speeds above maneuvering speed, the limit load factor for which an airplane is stressed can be exceeded by abrupt or excessive application of the controls or by strong turbulence.

Effect of Flight Maneuvers on Load Factor

Load factors apply to all flight maneuvers. In straight-and-level unaccelerated flight, a load factor of 1G is always present, but certain maneuvers are known to involve relatively high load factors.

- **Turns**—As previously discussed, increased load factors are a characteristic of all banked turns. Load factors become significant both to flight performance and to the load on wing structure as the bank increases beyond approximately 45°.

- **Stalls**—The normal stall entered from straight-and-level flight, or an unaccelerated straight climb, should not produce added load factors beyond the 1G of straight-and-level flight. As the stall occurs, however, this load factor may be reduced toward zero, the factor at which nothing seems to have weight, and the pilot has the feeling of "floating free in space." In the event recovery is made by abruptly moving the elevator control forward, a negative load is created which raises the pilot from the seat. This is a negative wing load and usually is so small that there is little effect on the airplane structure. The pilot should be cautioned, however, to avoid sudden and forceful control movements because of the possibility of exceeding the structural load limits.

During the pullup following stall recovery, however, significant load factors are often encountered. These may be increased by excessively steep diving, high airspeed, and abrupt pullups to level flight. One usually leads to the other, thus increasing the resultant load factor. The abrupt pullup at a high diving speed may easily produce critical loads on structures, and may produce recurrent or secondary stalls by building up the load factor to the point that the speed of the airplane reaches the stalling airspeed during the pullup.

- **Advanced Maneuvers**—Spins, chandelles, lazy eights, and snap maneuvers will not be covered in this handbook. However, before attempting these maneuvers, pilots should be familiar with the airplane being flown, and know whether or not these maneuvers can be safely performed.

***Effect* of Turbulence on Load Factor**

Turbulence in the form of vertical air currents can, under certain conditions, cause severe load stress on an airplane wing.

When an airplane is flying at a high speed with a low angle of attack, and suddenly encounters a vertical current of air moving upward, the relative wind changes to an upward direction as it meets the airfoil. This increases the angle of attack of the wing.

If the air current is well defined and travels at a significant rate of speed upward (15 to 30 feet per second), a sharp vertical gust is produced which will have the same effect on the wing as applying sudden sharp back pressure on the elevator control.

All certificated airplanes are designed to withstand loads imposed by turbulence of considerable intensity. Nevertheless, gust load factors increase with increasing airspeed. Therefore it is wise, in extremely rough air, as in thunderstorm or frontal conditions, to reduce the speed to the design maneuvering speed. As a general rule, when severe turbulence is encountered, the airplane should be flown at the maneuvering speed shown in the FAA-approved Airplane Flight Manual, Pilot's Operating Handbook, or placard in the airplane. This is the speed least likely to result in structural damage to the airplane, even if full control travel is used, and yet allows a sufficient margin of safety above stalling speed in turbulent air.

Placarded "never exceed speeds" are determined for smooth air only. High dive speeds or abrupt maneuvering in gusty air at airspeeds above the maneuvering speed may place damaging stress on the whole structure of an airplane. Stress on the structure means stress on any vital part of the airplane. The most common failures due to load factors involve rib structure within the leading and trailing edges of wings.