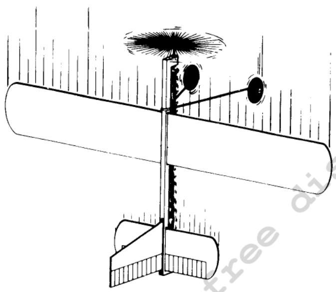
DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration

VFR PILOT EXAM-O-GRAM* NO. 57

FLIGHT IN THE REGION OF REVERSED COMMAND IN RELATION TO TAKEOFFS AND LANDINGS



REGION OF REVERSED COMMAND - or - BACK SIDE OF THE POWER CURVE

The aeronautical knowledge requirements, set forth in Federal Aviation Regulations for pilot certification, place emphasis on basic aerodynamics and principles of flight. Consequently, FAA written tests contain test items relating to these subject areas.

This Exam-O-Gram deals with a rather complex and often misunderstood subject as it relates principally to propeller driven airplanes. Modern aerodynamics manuals refer to this as the "Region of Reversed Command," and devote one or more chapters to explaining its meaning. It is the intent of this Exam-O-Gram, to explain in layman's language and through the use of simple illustrations, flight in the regions of normal and reversed command, without the use of mathematical formulas, symbols, or equations. These few pages, though perhaps an oversimplification of a complicated subject, should serve as a stimulus for further study.

The following brief definitions of terms used in the text are presented to refresh the reader's memory:

PARASITE DRAG -- the drag not directly associated with lift (form and skin friction) and which predominates in the region of high-speed flight. NOTE: An increase in the parasite area of an airplane may be brought about by the deflections of flaps or extension of the landing gear.

INDUCED DRAG -- the drag caused by lift.

TOTAL DRAG -- the sum of the parasite and induced drags.

EQUILIBRIUM -- a state of balance or equality between opposing forces. An airplane is in a state of equilibrium when the sum of all forces and the sum of all moments acting on it are equal to zero.

BRAKE HORSEPOWER -- the power output of the reciprocating engine is determined by attaching a brake or load device to the output shaft. Hence, the term brake horsepower (BHP) is used to denote engine power.

POWER REQUIRED -- the aerodynamic properties of the airplane generally determine the power requirements at various conditions of flight, while the powerplant capabilities generally determine the power available at various conditions of flight. When the airplane is in steady level flight the condition of equilibrium must prevail. An unaccelerated condition of flight is achieved when lift equals weight, and the powerplant is set for a thrust equal to the airplane drag.

POWER REQUIRED CURVE -- the power required to achieve equilibrium in constant-altitude flight at various airspeeds. The power required curve illustrates the fact that at low airspeeds near the stall or minimum control speed, the power setting required for steady level flight is quite high.

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WHAT DOES "FLIGHT IN THE REGION OF NORMAL COMMAND" MEAN? Flight in the region of normal command means that while holding a constant altitude, a higher airspeed requires a higher power setting and a lower airspeed requires a lower power setting. The majority of all airplane flying (climb, cruise, and maneuvers) is conducted in the region of normal command.

WHAT DOES "FLIGHT IN THE REGION OF REVERSED COMMAND" MEAN? Flight in the region of reversed command means that a higher airspeed requires a lower power setting and a lower airspeed requires a higher power setting to hold altitude. It does not imply that a decrease in power will result in higher airspeed, or that an increase in power will produce lower airspeed. The region of reversed command is encountered in the low speed phases of flight. Flight speeds below the speed for maximum endurance (lowest point on the power curve) require higher power settings with a decrease in airspeed. Since the need to increase the required power setting with decreased speed is contrary to the normal command of flight, the regime of flight speeds between the speed for minimum required power setting and the stall speed (or minimum control speed) is termed the region of reversed command. In the region of reversed command, a decrease in airspeed must be accompanied by an increased power setting in order to maintain steady flight. Simply stated — it takes a lot of power to fly at very slow airspeeds.

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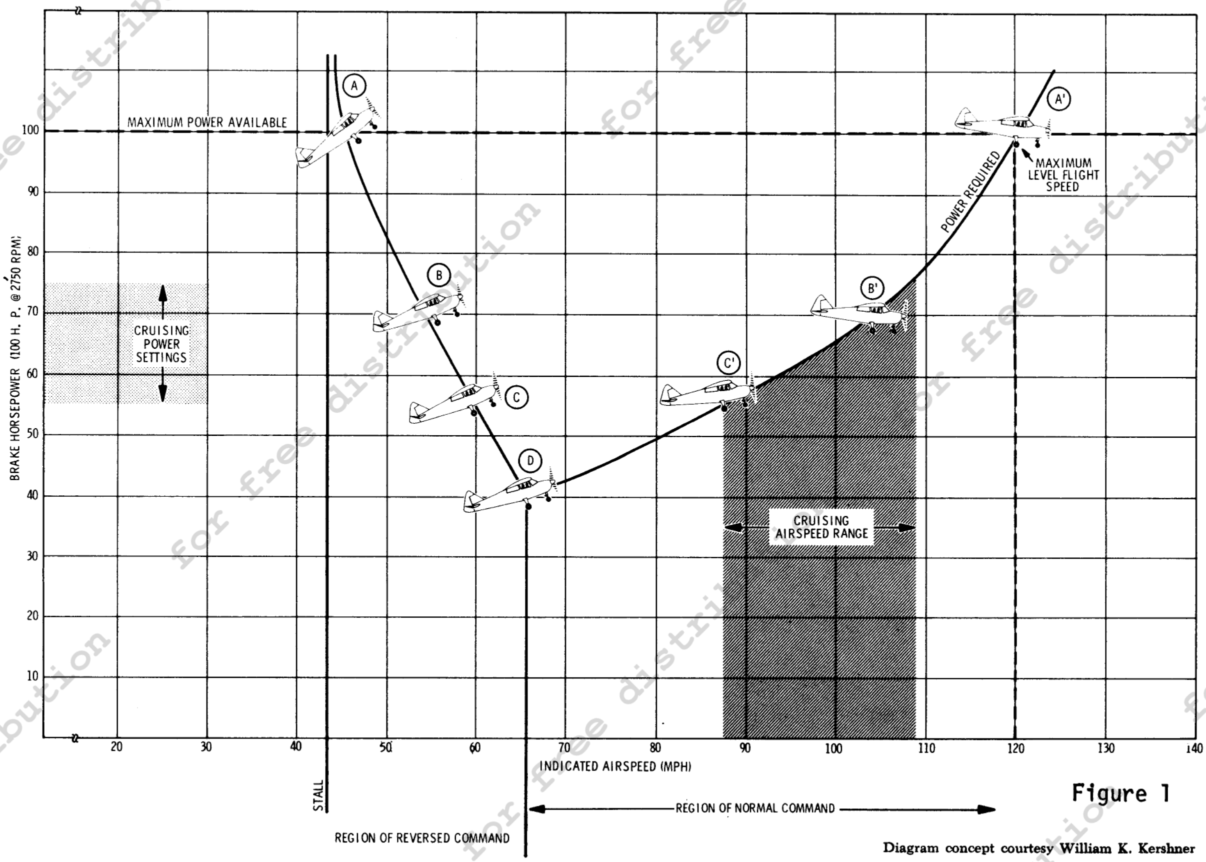

Figure 1

Diagram concept courtesy William K. Kershner

A LIGHT AIRPLANE IN A CLEAN CONFIGURATION AT SEA LEVEL

In order to chart the performance of a light airplane in the available space on the diagram above, it was necessary to somewhat distort the lower portion of the power required curve. This diagram illustrates that high power settings are required to fly fast or very slow. For example:

Airplane Position A — requires full power to hold altitude at 45 MPH. At position A' the airplane is flying with full power to attain maximum level flight speed. Any attempt to increase the airspeed at position A' will result in a loss of altitude.

Position B — requires 70 HP to maintain altitude at 55 MPH. Using the same power setting (70 HP) at position B' the airplane will maintain steady level flight while holding altitude and maintaining 104 MPH.

Position C — 55 HP is required to maintain altitude at approximately 58 MPH. With the same power setting the airplane will attain a speed of 87 MPH at position C'. At position C', if the angle of attack is increased the airplane will climb and fly slower -or- if the angle of attack is reduced the airplane will lose altitude and fly faster than 87 MPH. NOTE: Increasing or decreasing the angle of attack at positions A' and B' would produce similar results.

Position D — the aircraft is maintaining altitude at the lowest power (40 HP) and airspeed combination. Increasing the angle of attack at this point will not produce a climb — but a loss of altitude. Also, any reduction in the angle of attack will result in a loss of altitude.

WHAT DOES THE SPEED OF AIRPLANE D ON THE POWER REQUIRED CURVE REPRESENT? The Best Endurance Speed.— It is the lowest point on the curve. Since this is the lowest brake horsepower which will sustain level flight, it also will be the lowest fuel flow — hence, best endurance.

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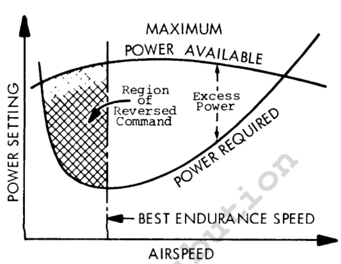

Figure 2

The illustration to the left shows the "maximum power available" as a curved line. Lower power settings such as cruise power would also appear in a similar curve. The bottom of the power required curve is more realistic in this illustration than the one shown above.

WHY IS THE POWER AVAILABLE A CURVED LINE? If the engine produces full power at the rated RPM in level flight, at other airspeeds lower than maximum the engine does not turn up its rated RPM, but gradually loses RPM, even though full throttle is being used. This can be demonstrated in a fixed-pitch propeller equipped airplane by raising the nose above cruising level flight attitude and noting a decrease in RPM. (cont'd)

Power at high altitudes — the power produced by the unsupercharged aircraft engine also decreases with altitude, because weight of the charge of air and the oxygen content necessary for combustion decreases. Even if it is possible to prolong sea-level power to some greater altitude by supercharging, or some other method of power boosting, the power will inevitably decline when the boosting method reaches an altitude at which it can no longer maintain a set power.

The propeller suffers a gradual loss of efficiency for a given rated engine horsepower at both ends of the speed range, and therefore a gradual loss of thrust. For this reason, the Maximum Power Available Curve is just that, a curve — not a straight line.

NOTE: See Figure 2 on page 2. If the power available is greater than the power required, the difference is "excess horsepower" which can be used for climb. Where the power available and power required curves cross, there is no excess power, and therefore no ability to climb at that airspeed.

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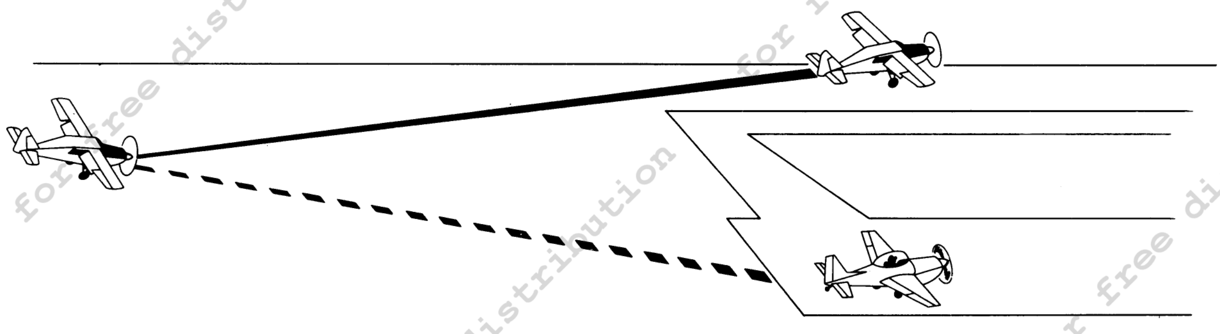
WHEN WOULD AN AIRPLANE BE OPERATING IN THE REGION OF REVERSED COMMAND? An airplane performing a low airspeed, high-pitch attitude power approach for a short field landing is an example of operating in this flight regime. Imagine what might happen if the pilot closed the throttle to idle position during this approach. Then by using a lot of power to correct this mistake it might be possible for the pilot to reduce or stop the resulting rapid rate of descent, but without further use of power the airplane would probably stall or be incapable of flaring for the landing. Merely lowering the nose of the airplane to regain flying speed in this situation, without the use of power, would result in a rapid sink rate and a great loss of altitude.

Airplane pilots must give particular attention to precise control of airspeed when operating in the low flight speeds of the region of reversed command. Now consider the use of wing flaps on airplane performance at low flight speeds with emphasis on climb performance. Some airplanes that have the capability of maintaining altitude in level flight with full flaps are incapable of climbing with full flaps extended. Drag is so great in this configuration that when the nose of the airplane is raised to establish a climb, there is a rapid decay in airspeed. Since the majority of pilot caused airplane accidents occur during takeoffs and landings, the remainder of this Exam-O-Gram is devoted to these phases of flight.

HOW DOES THE USE OF FULL FLAPS AFFECT STALL SPEED? An airplane in a clean configuration will stall at a higher airspeed than it will with the flaps fully extended. This means that if the flaps are rapidly or prematurely retracted, while the airplane is being flown with insufficient airspeed, lift may not be great enough to support the airplane in the clean configuration, and it will sink or stall. On a go-around with full power a safe airspeed must be maintained as the flaps are slowly retracted — in small increments.

SHOULD WING FLAPS BE USED FOR TAKEOFF? Certain Airplane Owner's Manuals do recommend the use of partial wing flaps (10°-20°) to reduce the ground run on short or soft field takeoffs. The use of full flaps on takeoff, however, is not recommended because of the great amount of drag they produce. A go-around with full flaps extended is a situation similar to the full flap takeoff.



A GO-AROUND WITH FULL FLAPS

Figure 3

In the illustration above, suppose the pilot of the airplane on the landing approach applies full throttle for a go-around because another airplane is on the runway, but due to a burned-out flap motor fuse, is unable to retract the fully extended flaps. Assume also that he is operating his airplane at near maximum certificated gross weight, or at an airport having a high elevation or high density altitude. Any one or a combination of these situations plus the tremendous drag of the flaps will require considerable pilot skill if the airplane is to gain enough altitude to circle the airport and land. Any misuse of the controls, such as overcontrolling or banking too steeply while operating in the "Region of Reversed Command," may cause the airplane to stall.

With a margin of only a few MPH between climbing, holding altitude, and descending, the airplane may cease its slow rate of climb and start descending or even stall, while the occupants are distracted in their attempt to identify or correct the cause of the malfunction. (cont'd)

Actual failure of the electric flap motor would require operating in this high drag configuration until the airplane lands.

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Most Airplane Owner's Manuals of present-day trainers state that full flaps are not recommended at any time for takeoff. In recent years an average of ten serious accidents have occurred each year as a result of pilots attempting to take off with full flaps extended.

Accident Report Summaries all recite much the same story as the excerpts which follow: "A solo student performing touch-and-go landings in an airplane attempted a takeoff with full flaps. He lost control of the airplane, closed the throttle, and the airplane flipped over on its back. He stated that his instructor had never demonstrated how the aircraft would react or respond when full flaps were used for takeoff. A low time student in a new and strange situation set the stage for this accident."

"A 200 hour private pilot with a passenger attempted to take off with full flaps. The airplane climbed to 150 feet, stalled and rotated one-half turn to the left and struck the ground nosedown in a near vertical attitude at impact."

"A commercial pilot with a passenger attempted to take off with full flaps. The airplane, which was 15 pounds over gross weight, staggered into the air to a height of about 30 feet. Power was reduced and the airplane descended at a steep angle with no flare for touchdown. The nosewheel collapsed on impact."

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<u>The slow rate of climb or inability to climb to traffic pattern altitude with full flaps presents the greatest problem!</u> Good pilot technique is necessary to obtain a slow rate of climb under ideal conditions. Climb performance is even more critical at high altitudes, higher weights, or high temperatures.

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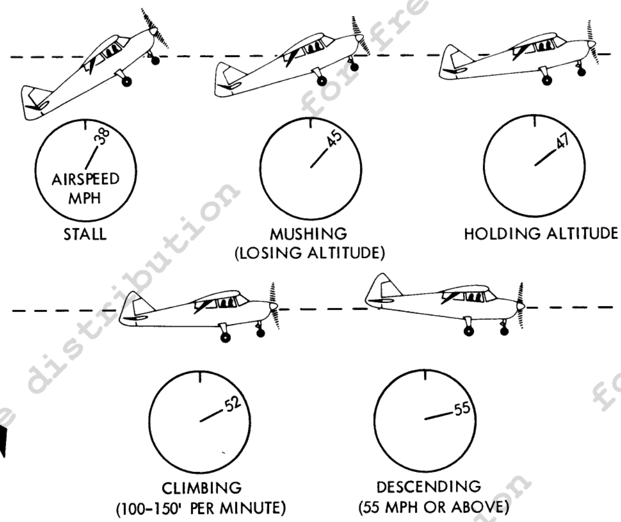

NOTE: Indicated airspeeds may be unreliable near the stall or in steep pitch attitudes. The airplanes and indicated airspeeds shown in this illustration are fictitious.

ATTEMPTING TO CLIMB (FULL THROTTLE) WITH FULL FLAPS EXTENDED

Operation in the region of reversed command does not imply that great control difficulty and dangerous conditions exist. For many aircraft, normal approach speeds are well within the region of reversed command. However, flight in the region of reversed command does amplify any errors of basic flying technique. Hence, proper flying technique and precise control of airplane are most necessary in the region of reversed command.

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