Level 4 Study Notes

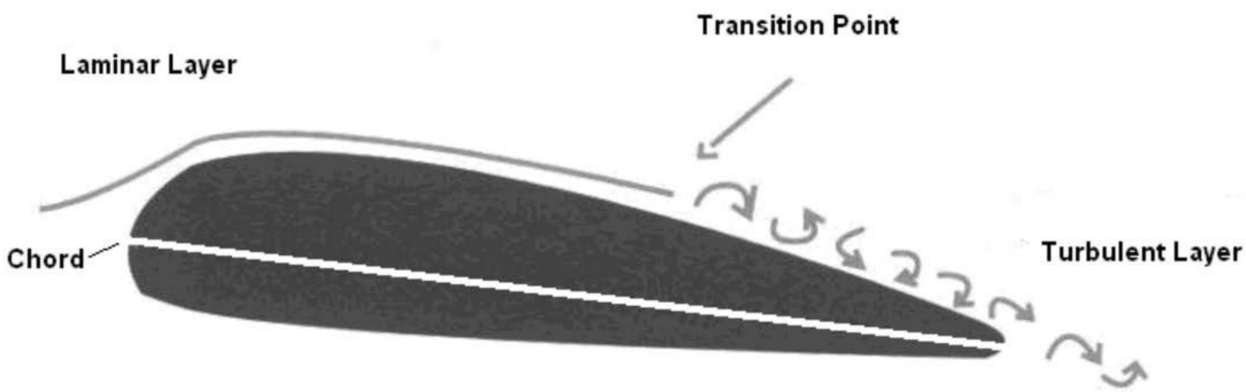
EO M431.01 – EXPLAIN FEATURES OF WING DESIGN

AIRFOILS:

Chord:

An imaginary straight line joining the leading and trailing edges of the wing. The mean aerodynamic chord (MAC) is the average chord of the wing.

The shape and design of the wing is directly influenced by the intended purpose of the aircraft. Aircraft designed to fly slowly typically have thick airfoils, while aircraft designed to fly fast have thin airfoils.



The very thin layer of air lying over the surface of the wing is called the boundary layer. At the front of the wing, the boundary layer flows smoothly over the surface and this area is called the laminar layer. As the air flows further along the wing, it slows down due to skin friction, the layer becomes thicker, and it becomes turbulent.

The turbulent area is called the turbulent layer.

The transition point between the laminar and turbulent areas tends to move forward as airspeed and the angle of attack increase.

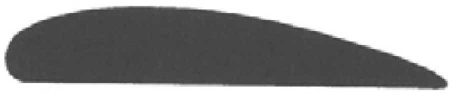
Level 4 Study Notes

Conventional Airfoils:

Conventional airfoils generally are the thickest at 25 percent of the chord and can be found in a variety of shapes and designs.

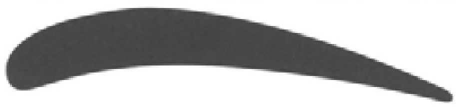
- Low camber
- Low drag
- High speed
- Thin wing section

- Race planes
- Fighters
- Interceptors



- Deep camber
- High lift
- Low speed
- Thick wing section

- Transports
- Freighters
- Bombers



- Deep camber
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- Low speed
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- Freighters
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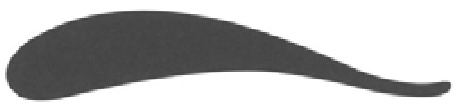
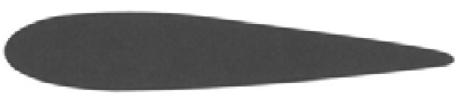


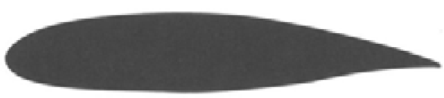
- Low lift
- High drag
- Reflex trailing edge wing section

- Very little movement of centre of pressure
- Good stability



- Symmetrical wing section (cambered top and bottom)

- Very little movement of centre of pressure
- Good stability

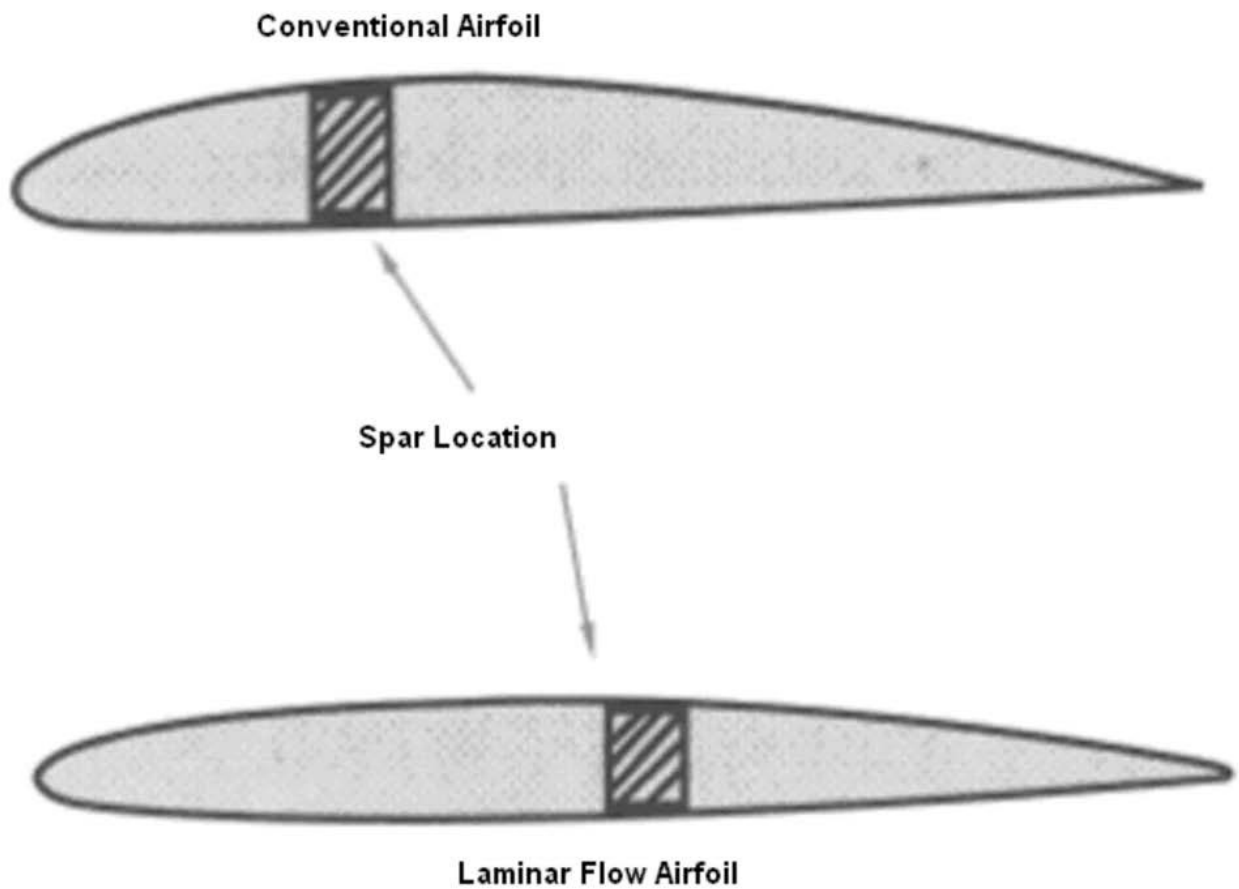


- GA(W)-1 airfoil
- Thicker for better structure and lower weight
- Good stall characteristics

- Camber is maintained farther rearward which increases lifting capability over more of the airfoil and decreases drag

Laminar Flow Airfoils:

Laminar flow airfoils have their thickest point at 50 percent of the chord, a leading edge that is more pointed and upper and lower surfaces that are nearly symmetrical. Originally developed to make aircraft fly faster, they can be found on many different aircraft types.



Level 4 Study Notes

Planform:

The shape of the wing as seen from directly above is called the planform. The three general wing shapes are:

- rectangular,
- elliptical (rounded), and
- delta (swept).
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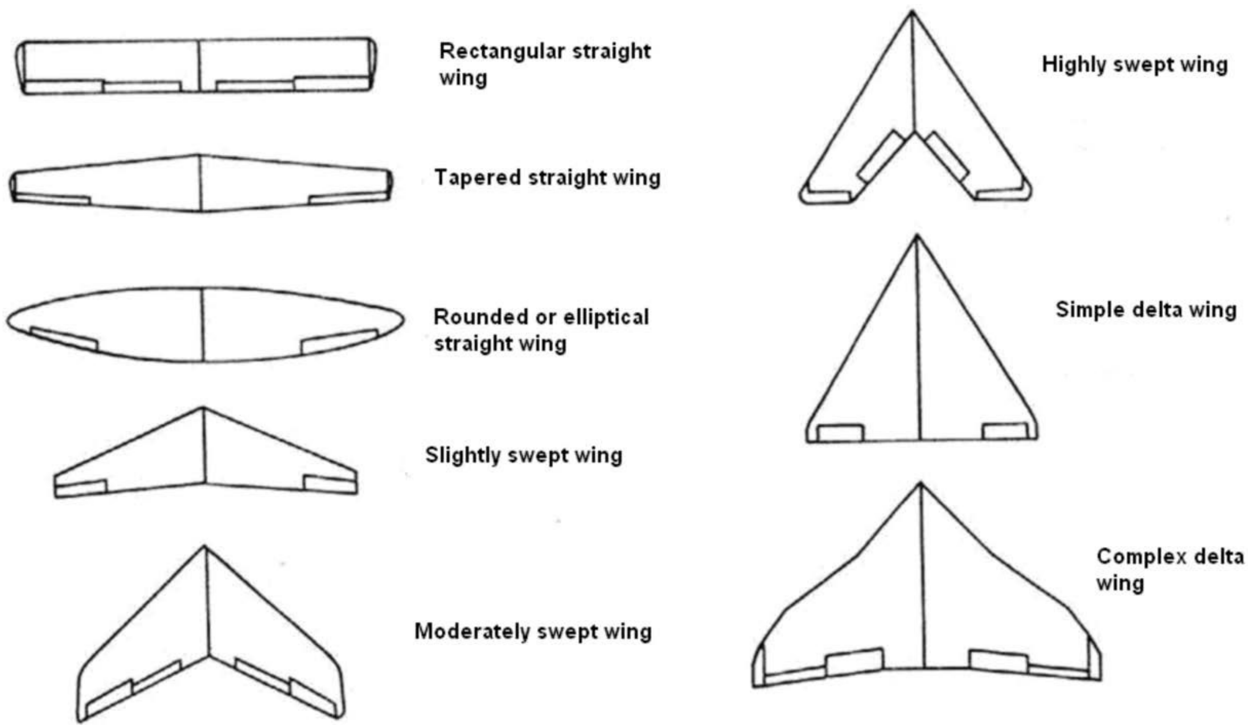


Aspect ratio.

The relationship between the length of the wing and its width (chord). It is calculated by dividing the span by the average chord.

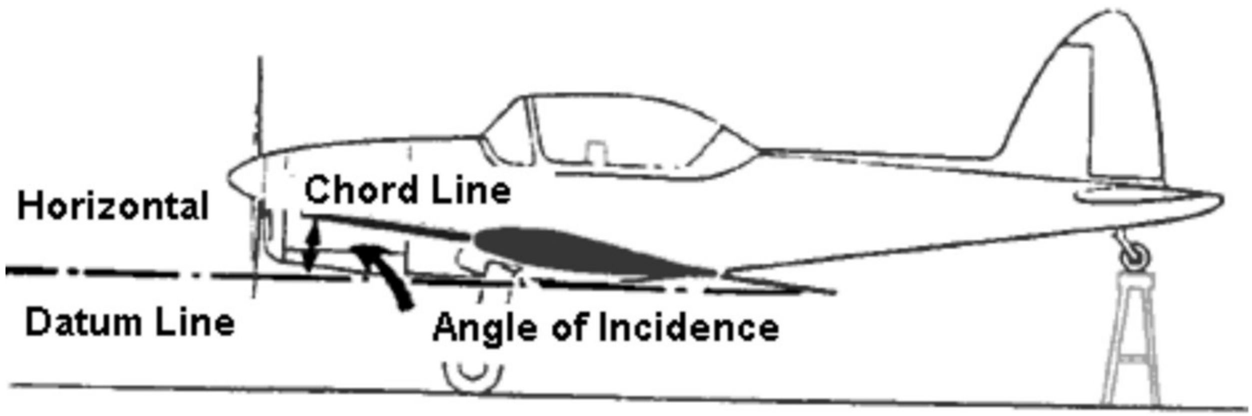
A wing with a **high aspect ratio** generates **more lift** with **less induced drag** than a wing with the same wing area and a low aspect ratio. High aspect ratio wings are commonly found on gliders.

Angle of Incidence:

The angle of incidence is the angle at which the wing is permanently inclined to the longitudinal axis of the aircraft.

The angle of incidence affects the following items:

- flight visibility,
- takeoff and landing characteristics, and
- amount of drag in level flight.

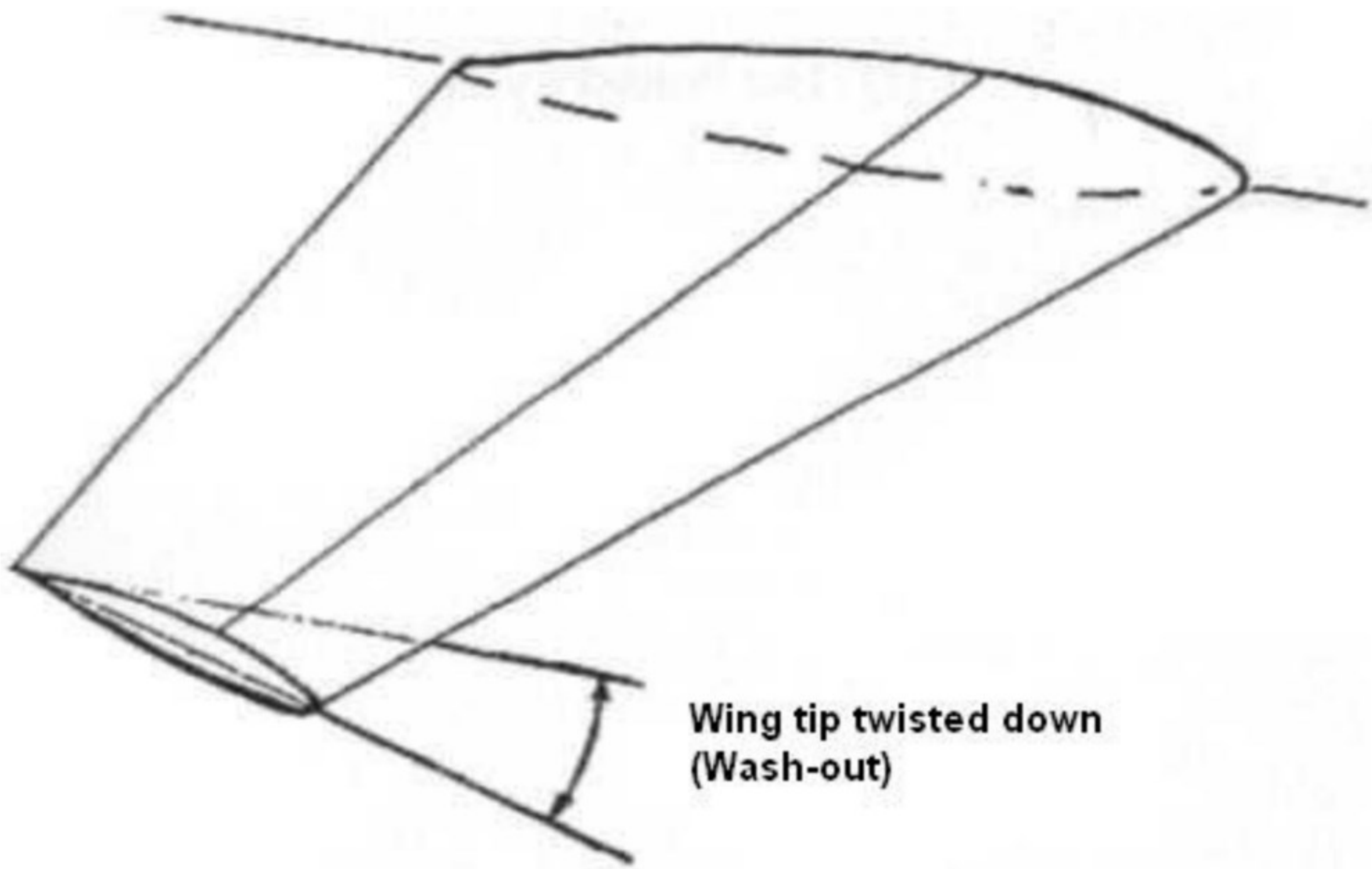


Wash-Out and Wash-In:

To reduce the tendency of the wing to stall suddenly, the wing can be designed so that the angle of incidence at the wing tip is different than the angle of incidence at the wing root.

The twist in the wing causes the tip and root to stall at slightly different angles of attack and improves the stall characteristics. If the wing root stalls before the wing tip, the ailerons, located closer to the wing tip, can still be effective during the early part of the stall.

Decreasing the angle of incidence at the wing tip is called wash-out and increasing the angle is called wash-in.



HIGH-LIFT DEVICES:

The efficiency of a wing can be improved by either increasing the amount of lift generated, or by decreasing the amount of induced drag created. High-lift devices can be used individually or in various combinations to create a very efficient wing.

Although great gains in efficiency can be realized by adding these devices to a wing, there are penalties to pay, such as increased weight and increased mechanical complexity.

Wing Tip Design:

Induced drag can be reduced by limiting the formation of wing tip vortices. This is done by preventing air from spilling over the wing tip by modifying the wing tips in one of the following ways:

- installing wing tip fuel tanks,
- using wing tip plates or winglets, and
- drooping the wing tips.

Wing Fences:

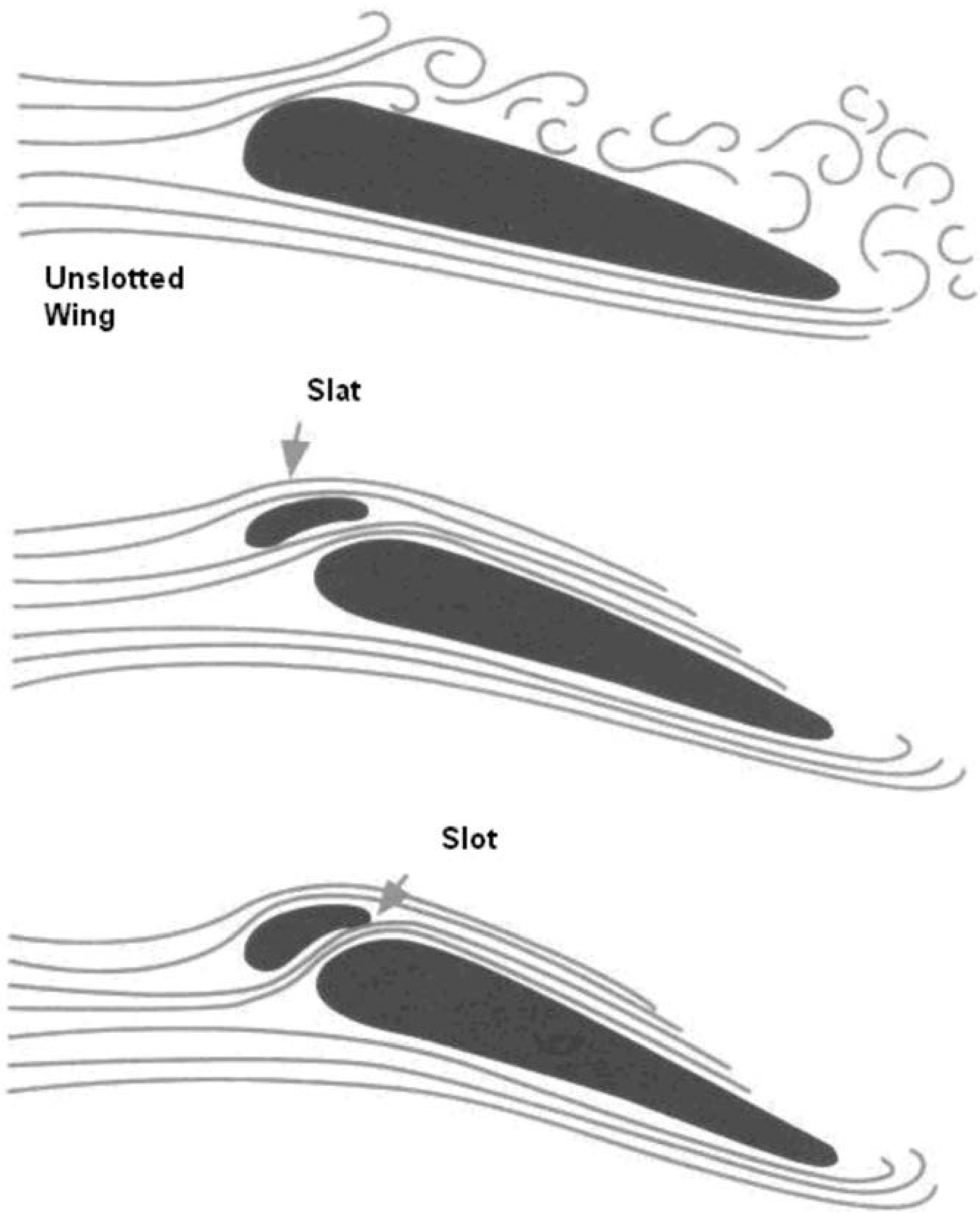
Wing fences are vertical surfaces attached to the upper surface of the wing. They act as guides and control the direction of airflow over the wing, especially at high angles of attack. This improves low-speed handling and stall characteristics.

Slats:

Auxiliary airfoils that automatically move out in front of the leading edge at high angles of attack are known as slats. The resulting opening changes the airflow over the leading edge, smoothing out eddies that form on the top of the wing.

Slots

Slots affect the airflow in the same way as slats, except that they are passageways built into the wing. Slots can either be full- or partial-span.



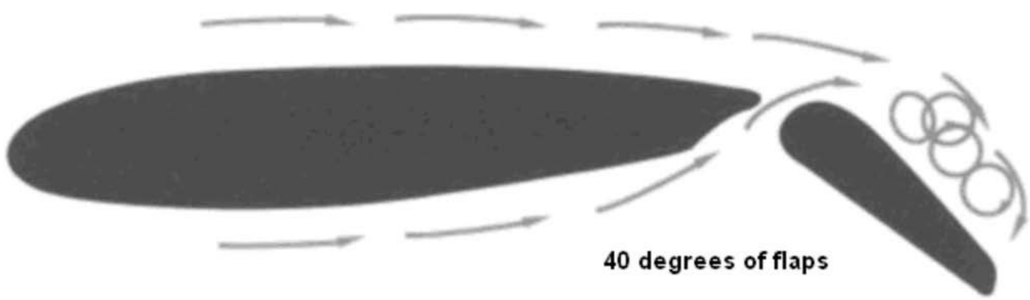
Flaps:

The most common high-lift device found on a wing is the flap. Located at the trailing edge, their primary purpose is to increase lift by changing the camber of the wing. Some styles of flaps also increase the effective wing area. The increased lift causes a lower stall speed and allows the aircraft to approach at a slower airspeed.

With a small amount of flap deflection, the amount of extra lift produced is greater than the amount of extra drag. As the amount of deflection increases, the amount of extra drag catches up to and passes the amount of extra lift being generated. The extra drag produced can be used to improve landing capabilities by slowing the aircraft down and creating a steeper approach angle (useful in approaching a runway with obstacles near the threshold).

Generally, the amount of drag produced by flaps reduces acceleration to the point where flaps should not be deployed during takeoff (as is the case with plain and split flaps). Slotted, Zap, and Fowler flaps produce more lift than drag at small amounts of deflection (5–15 degrees) and are usually recommended for takeoff.

10 degrees of flaps



40 degrees of flaps

SPOILERS:

Spoilers are devices on a wing that are used to decrease the lift and increase the drag being produced. They work by being extended up from the top surface of the wing and disrupting the airflow. Spoilers are found on almost all types of gliders and are used to increase the rate of descent during the landing approach.

Spoilers can also be used to supplement aileron control or replace ailerons completely. A deployed spoiler has the same effect as an up-going aileron, causing the aircraft to bank to that side.

SPEED BRAKES:

Speed (dive) brakes are devices that are extended into the airflow, creating drag, with minimal effect on the lift being produced. Speed brakes allow aircraft to slow down without reducing thrust, and to control approach angles.

Speed brakes may be plates that extend out of a wing or hinged doors that open out from the fuselage.

Spoilers and Dive Brakes Closed

Spoilers and Dive Brakes Open

EO M431.02 – DESCRIBE FLIGHT INSTRUMENTS

PITOT STATIC SYSTEM:

Instruments connected to the pitot static system work on air pressure. There are two types of air pressure in the pitot static system:

- pitot pressure, and
- static pressure.

Pitot pressure:

The increase in air pressure caused by the forward motion of the aircraft through the air.

Static pressure:

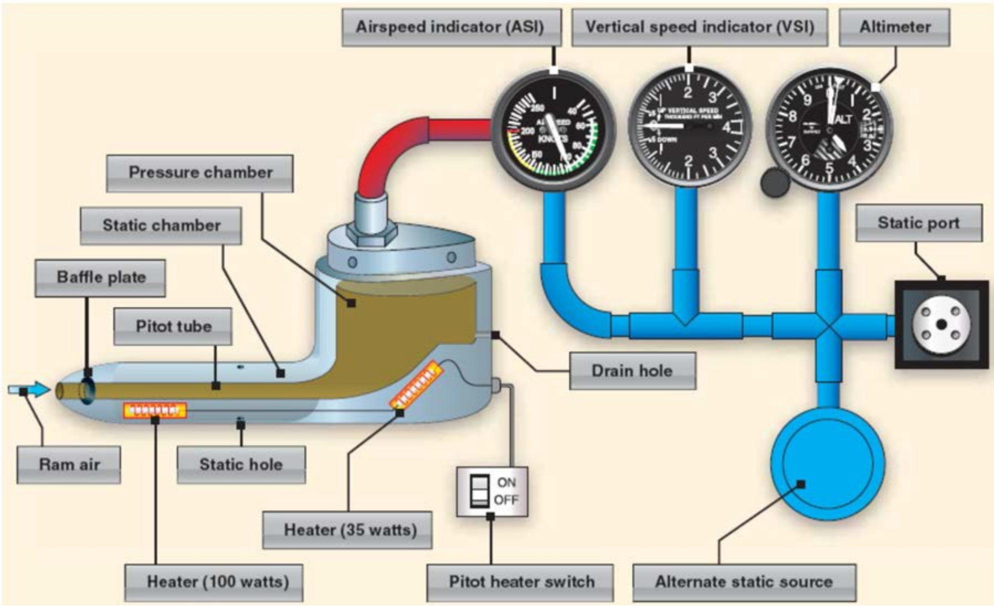
The atmospheric pressure outside the aircraft, not affected by turbulence or motion.

The airspeed indicator (ASI) is connected to both the pitot pressure source (usually a tube attached to the nose or wing) and the static pressure port(s) (usually a small vent on the side of the aircraft).

The altimeter and the vertical speed indicator (VSI) are connected only to the static pressure port.

Both the pitot tube and static pressure ports should be carefully checked during the walk-around inspection prior to flight to ensure they are not blocked. A blockage will cause an instrument to provide an incorrect reading.

During flight, it is possible for the pitot tube to become blocked by ice. Aircraft that are designed to be flown under instrument flight rules (IFR) will have a pitot heater to prevent ice buildup in the pitot tube.



AIRSPEED INDICATOR (ASI)

The ASI is connected to both the pitot pressure source and static pressure port(s) and displays the difference between the two pressures as the speed of the aircraft moving through the air (not over the ground).

ASI Markings

The ASI has colour-coded markings to indicate operating ranges and speeds.

- **Red.** A red line indicates the never exceed speed (V_{NE}).
- **Yellow.** A yellow arc starts at the maximum structural cruise (V_{NO}) and extends to the V_{NE}. This area is typically known as the caution range.
- **Green.** The normal operating range. It starts at the power-off stalling speed (V_{SL}) and extends to the V_{NO}.
- **White.** The range in which fully extended flaps may be used. It starts at the power-off stalling speed with flaps and gear extended (V_{SO}) and extends to the maximum flaps extended speed (V_{FE}).

Level 4 Study Notes

ASI Errors:

Density error:

The ASI is calibrated for normal sea level pressure of 29.92 inches of mercury (Hg) at a temperature of 15 degrees Celsius. Temperature and pressure normally decrease with an increase in altitude, decreasing the density of the air and causing the ASI to read less than the true airspeed.

Position error.

Results from the position of the pitot pressure source. Eddies formed by air moving over the aircraft and the angle of the pitot source to the airflow cause position error.

Lag error.

A mechanical error that is the result of friction between the working parts of the instrument. This error is responsible for a slight delay between a change in airspeed occurring and the change being shown on the instrument.

Icing error.

The error caused by a complete or partial blockage of the pitot pressure by ice. This error can be prevented or corrected by turning on the pitot heat (if equipped) or descending to a lower altitude where the outside air temperature (OAT) is higher.

Water error.

Water in the system can cause higher or lower than normal readings and may block the system completely. Water can be kept out of the system by covering the pitot source when the aircraft is parked. This will also keep dirt and insects from entering the system.

Airspeed Definitions:

Indicated airspeed (IAS).

The uncorrected airspeed read from the instrument dial.

Calibrated airspeed (CAS).

The IAS corrected for instrument (lag) error and installation (position) error.

Equivalent airspeed (EAS).

The CAS corrected for the compressibility factor. This is very significant to aircraft operating above 10 000 feet and 250 knots (kt).

True airspeed (TAS).

The CAS (or EAS) corrected for density (pressure and temperature).

ALTIMETER

The altimeter is connected only to the static pressure port(s) and measures the pressure of the outside air. A sealed aneroid capsule inside the instrument case expands or contracts due to changes in the static pressure.

The expansion or contraction is mechanically linked to the indicator's needles and causes them to rotate around the dial to show the altitude.

Level 4 Study Notes

Altimeter Errors

Pressure error.

Barometric pressure varies from place to place and this error is corrected by using an altimeter setting obtained from the nearest aviation facility (flight service station, control tower, etc).

All aircraft flying in the same area should be using the same altimeter setting.

Abnormally high pressure.

Cold, dry air masses are capable of producing barometric pressures in excess of 31.00 inches of Hg (the limit of the altimeter setting scale in most altimeters). In this case, the actual altitude will be higher than the altitude indicated on the altimeter.

Abnormally cold temperature.

Altimeters are calibrated for the standard atmosphere (15 degrees Celsius at sea level) and any deviation from that will cause an error. Extremely low temperatures may cause as much as 20 percent error in the altimeter, causing the altimeter to read higher than the actual altitude.

Mountain effect error.

Increased wind speed through mountain passes or in mountain waves may cause a localized area of low pressure. Temperatures may also be affected, compounding the altimeter error.

Altitude Definitions:

Indicated altitude.

The altitude displayed on the altimeter when it is set to the current barometric pressure.

Pressure altitude.

The altitude displayed on the altimeter when it is set to the standard barometric pressure (29.92 inches of Hg).

Density altitude.

The pressure altitude corrected for temperature.

Absolute altitude.

The actual height above the Earth's surface (the altimeter set to field level pressure).

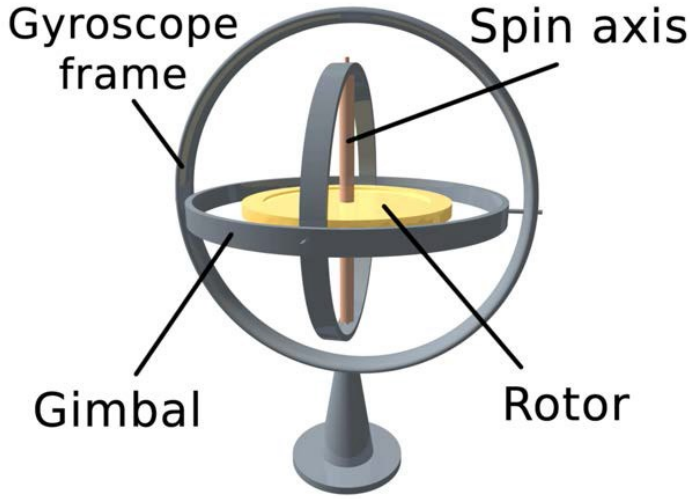
VERTICAL SPEED INDICATOR (VSI)

The VSI is connected only to the static pressure port(s). The rate of change of the static pressure is transmitted to the needle to indicate if the altitude is increasing or decreasing.

Even though the VSI will quickly indicate a climb or descent, it may take several seconds before the correct rate of descent is displayed. This delay is known as lag. An instantaneous VSI has a complicated system of pistons and cylinders instead of the simpler aneroid capsule found in most VSIs and does not experience lag.

THE GYROSCOPE

The gyroscope is a spinning wheel (rotor) in a universal mounting (gimbal) that allows its axle to be pointed in any direction.



Gyroscopic Inertia

Also known as rigidity in space, gyroscopic inertia is the tendency of a rotating object to remain in its plane of rotation. This allows the spinning rotor to remain in place regardless of how the gimbal is moved around it.

Precession

Precession is the tendency of a rotating body, when a force is applied perpendicular to its plane of rotation, to turn in the direction of its rotation 90 degrees to its axis and take up a new plane of rotation parallel to the force applied.

Power Sources

To work properly the rotor must be kept spinning at a constant speed. The gyroscopic instruments may be powered by one or more power source.

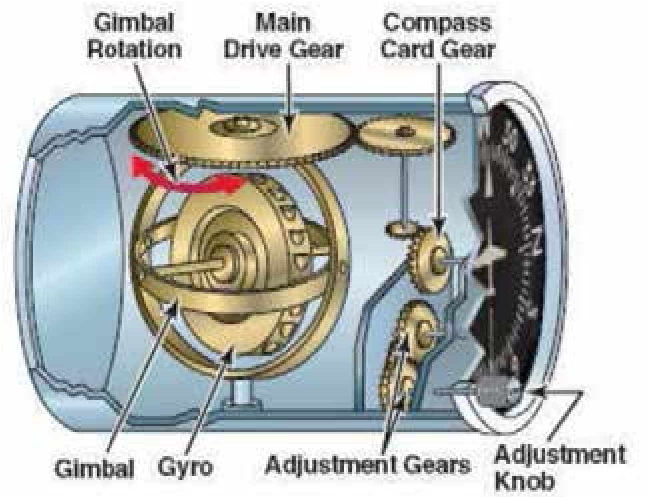
- **Engine driven vacuum system.** A vacuum pump powered by the engine. It does not work if the engine is not running (eg, prior to startup, following an engine failure). A variation of this system is an engine driven air pump that uses positive air pressure to spin the rotor.
- **Venturi driven vacuum system.** A venturi tube on the outside of the aircraft creates a vacuum to spin the rotor. Simple to install, it has no moving parts that could fail, but depends on the airspeed of the aircraft and the tube causes additional drag.
- **Electrically driven gyroscopes.** The rotor is spun by an electric motor allowing the gyroscope to work at high altitudes where vacuum systems are ineffective.

Care of Gyroscopic Instruments

Gyroscopic instruments are precision instruments and need to be cared for properly to prevent premature failure and damage. The air used to spin the rotor (vacuum or positive pressure) must be filtered to prevent dust and dirt from contaminating the system. The instruments need to be handled gently during installation and removal.

Some gyroscopes must also be locked (caged) prior to aerobatics. Venturi driven systems are also susceptible to ice blockages.

HEADING INDICATOR (HI):



The HI (directional gyro [DG]) is steady and accurate as it is not afflicted with any of the errors that apply to magnetic compasses (eg, northerly turning error, acceleration and deceleration errors). It remains constant without swinging or oscillating and provides accurate readings even in rough air.

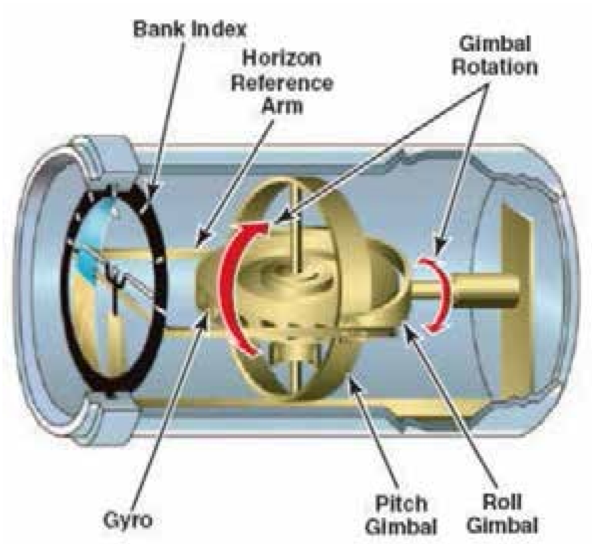
Vacuum driven HIs may take up to five minutes for the rotor to reach operating speed and should not be used during this period. Venturi driven HIs can not be used while taxiing or during takeoff. Once the rotor is spinning at the correct speed, the HI needs to be set to the current heading (by referencing the magnetic compass or runway heading).

Friction in the gyroscope causes a small amount of precession and will cause the reading to drift approximately three degrees over a period of 15 minutes. It is also subject to apparent precession. The rotation of the Earth gives the gyroscope an apparent motion relative to the Earth.

This error varies with latitude. Apparent precession is zero at the equator and 15 degrees per hour at the poles.

Precession errors are easily corrected by resetting the HI to the current heading (by referencing the magnetic compass during straight and level flight) every 15 minutes.

ATTITUDE INDICATOR (AI)



The AI (artificial horizon or gyro horizon) is designed to provide an artificial horizon for the pilot during periods of poor visibility (eg, fog, clouds, rain, snow). The artificial horizon provides attitude information to the pilot (pitch and bank).

During acceleration or deceleration, precession will cause a slight indication of a climb or descent, respectively.

TURN AND SLIP INDICATOR

TURN CO-ORDINATOR

The turn and slip indicator (turn and bank) is a combination of two instruments and is also known as the needle and ball. The direction and rate of turn is indicated by the needle. The needle is controlled by a gyroscope. The ball is controlled by gravity. During a properly executed turn, centripetal and centrifugal forces are balanced with gravity and the ball stays in the centre. During a slipping turn there is not enough centrifugal force and the gravity will pull the ball in the direction of the turn. During a skidding turn there is not enough centripetal force and the ball is pulled in the opposite direction of the turn.

The turn and slip indicator will also indicate if a wing is low during straight flight. If the needle is centred but the ball is not, then the wing on the side that the ball has moved to is low.

The turn co-ordinator is an updated version of the turn and slip indicator and is able to display the rate of roll as well as the rate of turn.

ANGLE OF ATTACK (AOA) INDICATOR

An aircraft will stall at different airspeeds depending on factors such as weight, load factor, and configuration. A stall will occur if the critical angle of attack is exceeded. The AOA indicator displays the relationship between the chord line of the wing and the relative airflow. Many indicators also have colour-coded ranges to alert the pilot that the critical AOA is being approached.

MACH INDICATOR

The Mach indicator displays the ratio of its airspeed to the local speed of sound. The Mach number is calculated by dividing the airspeed by the speed of sound. A Mach number of one means that the aircraft is travelling at the speed of sound. The Mach indicator measures and correlates static and dynamic pressures.

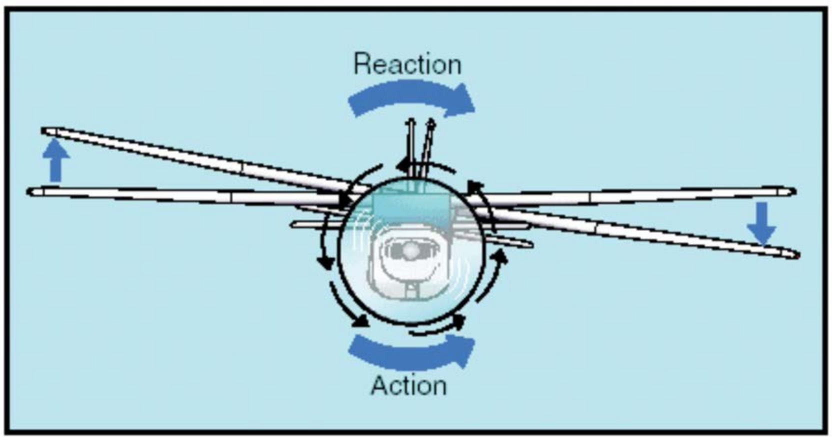
LEFT TURNING TENDENCIES

Most airplane engines turn the propeller in a clockwise direction (as seen from the pilot's seat). As a result of four different factors, this produces a tendency for the airplane to turn left. These tendencies must be factored into the design of the airplane or corrected by the pilot.

Torque

Newton's Third Law of Motion states that every action has an equal and opposite reaction. This means that the clockwise rotation of the propeller is counteracted by a counter-clockwise rotation of the airplane. This reaction tends to force the left wing downwards, producing a tendency to turn left.

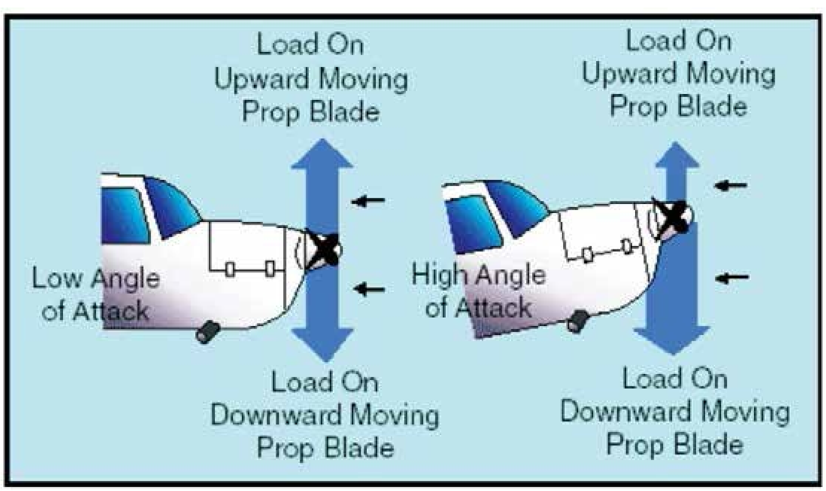
To correct this, airplanes can be designed with a right turning tendency, typically by having a slightly greater angle of incidence on the left wing. During takeoff (when the engine is usually running at full power) additional corrections must be applied by the pilot (rudder and / or ailerons) because of the increased amount of torque.



Asymmetric Thrust

At high angles of attack and high power settings (eg, takeoff) the blade of the propeller that is travelling down (the blade on the right) has a greater angle of attack than the blade that is travelling up. This creates more thrust from the right side of the propeller and creates a tendency for the aircraft to yaw or turn left.

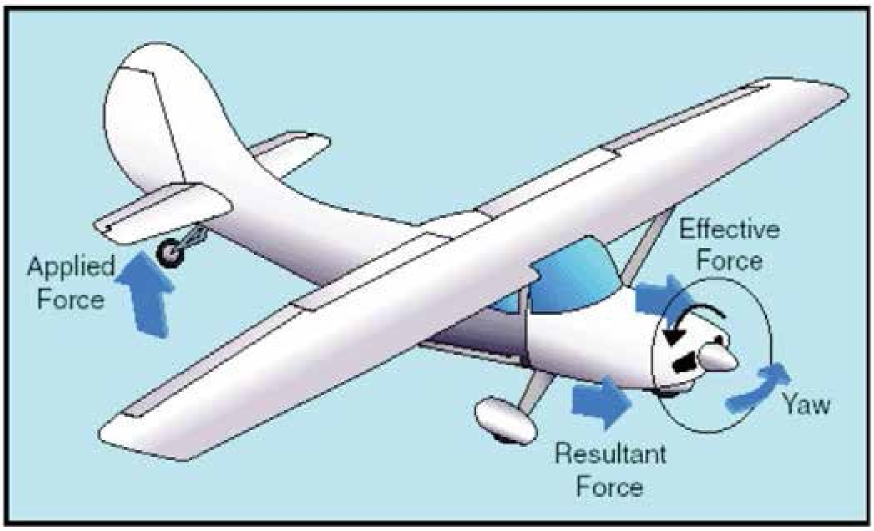
To correct for asymmetric thrust (also known as P Factor), the pilot uses right rudder.



Precession

The spinning propeller acts like a gyroscope and tends to stay in the same plane of rotation, and resists any change to the plane. When a perpendicular force is applied to change the plane, a resultant force called precession is the result.

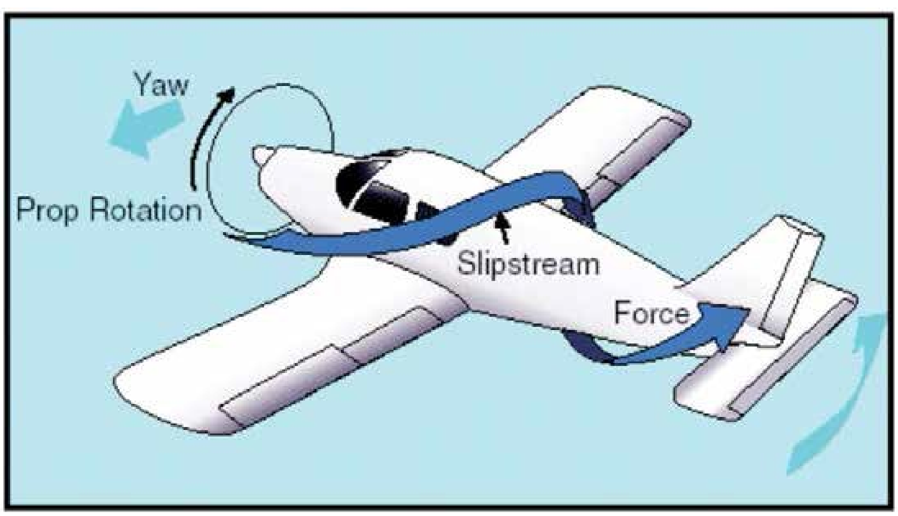
The force of precession is ahead of the plane of rotation and 90 degrees to the original applied force. Precession occurs in airplanes when the tail is lifted or lowered (eg, takeoff in a tailwheel aircraft). To correct for precession, the pilot uses right rudder.



Slipstream

The air being pushed backwards by the propeller has a corkscrew motion and is called the slipstream. This causes more pressure on the left side of the fuselage and tail, and results in a tendency for the airplane to turn left.

The effects of the slipstream can be corrected by having the engine thrust line offset to the right, and / or by offsetting the vertical fin. When the airspeed of the airplane is low (eg, takeoff) the pilot may have to apply right rudder.



Level 4 Study Notes

CLIMBS

During level flight at a constant airspeed, the engine produces thrust equal to drag, and the wings produce lift equal to weight. A pilot can initiate a climb by increasing the angle of attack (eg, pulling back on the stick) to produce more lift. The aircraft will climb but the airspeed will decrease. in airspeed). If the angle of attack is not changed, the increased airspeed will create additional lift and theairplane will climb.

Once the climb is established, the aircraft is again in equilibrium. The attitude of the aircraft creates a rearward component of weight. In this state, thrust must equal drag plus the rearward component of weight and lift must equal weight, less its rearward component.

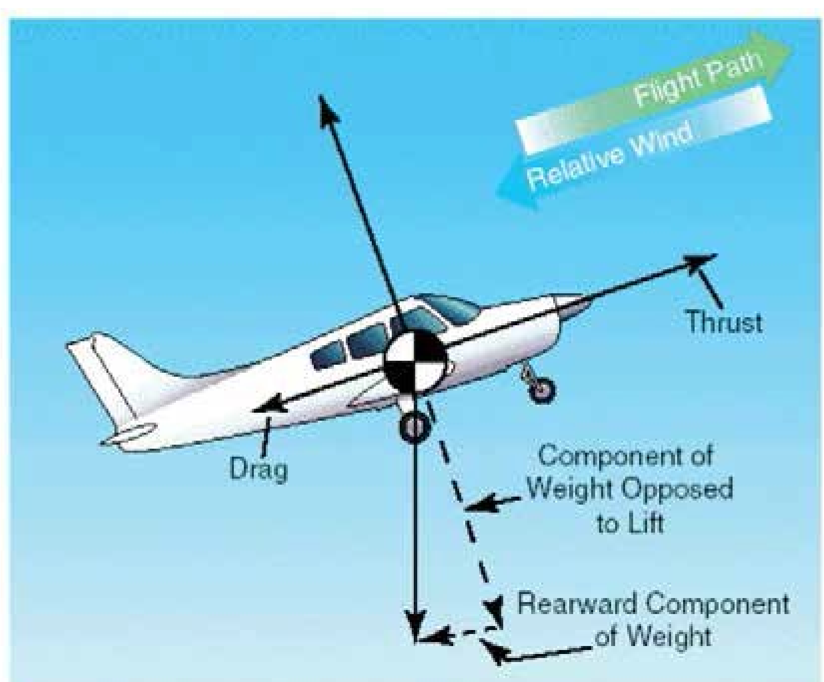
The extra power available from the engine to overcome the rearward component of weight determines the aircraft's ability to climb. As the altitude of the airplane increases, the air becomes less dense, and the available power of the engine decreases. The climb angle is reduced and further climbing eventually becomes impossible.

The altitude at which this occurs is the absolute ceiling of the airplane.

Best rate of climb (V_Y). The rate of climb that gains the most altitude in the least amount of time. It is normally used during takeoff after all obstacles have been cleared.

Best angle of climb (V_X). The angle of climb that gains the most altitude in a given distance. It is used during takeoff to clear obstacles at the departure end of the runway.

Normal climb (cruise climb). The rate of climb recommended for prolonged climbs. It provides better cooling, visibility, and control compared to V_Y.



GLIDES

During a glide, the engine is producing minimal power and the airplane is influenced by gravity. In this state, equilibrium is achieved by balancing lift, weight, and drag.

To increase airspeed, the angle of the glide must be increased. Reducing airspeed creates a shallower glide, until the point of a stall.

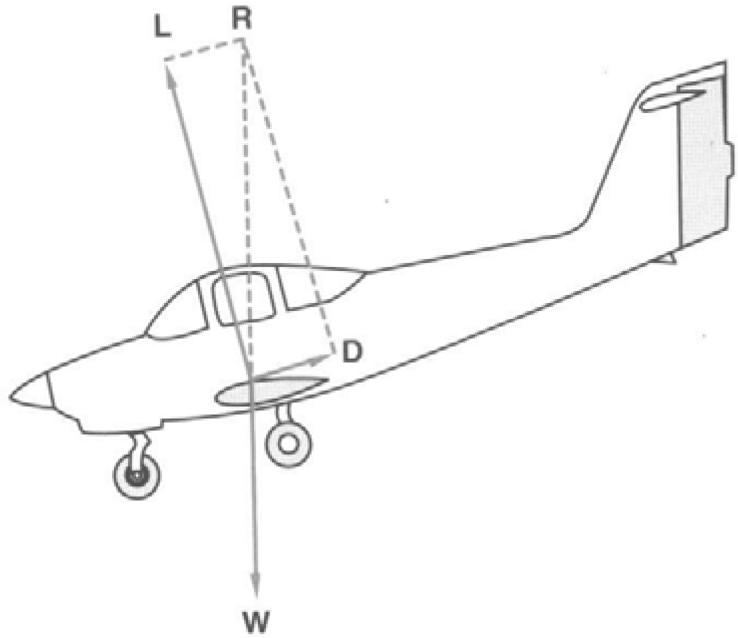
A windmilling propeller (the propeller is being spun by the relative wind, not the power of the engine) can reduce the gliding distance by approximately 20 percent. Although getting the propeller to stop can increase the gliding range, it is difficult to perform. Additionally, the chances of restarting the engine are improved if the propeller is windmilling.

Best glide speed for range (maximum lift / drag).

The airspeed which allows the aircraft to glide the farthest distance for altitude lost.

Best glide speed for endurance (minimum sink).

The airspeed which allows the aircraft to remain in the air for the longest period of time.



TURNS

In straight and level flight, the lift created by the wings is acting perpendicular to the wing span (vertically). To turn the aircraft, the pilot uses the ailerons to bank the aircraft in the direction of the desired turn. The lift is acting perpendicular to the wing span, but has both a horizontal and vertical component. It is the horizontal component of the lift (known as the centripetal force) that makes the aircraft turn. The opposing force (known as the centrifugal force) pulls the aircraft to the outside of the turn.

To maintain a constant altitude, the vertical component of lift must remain equal to the weight of the aircraft.

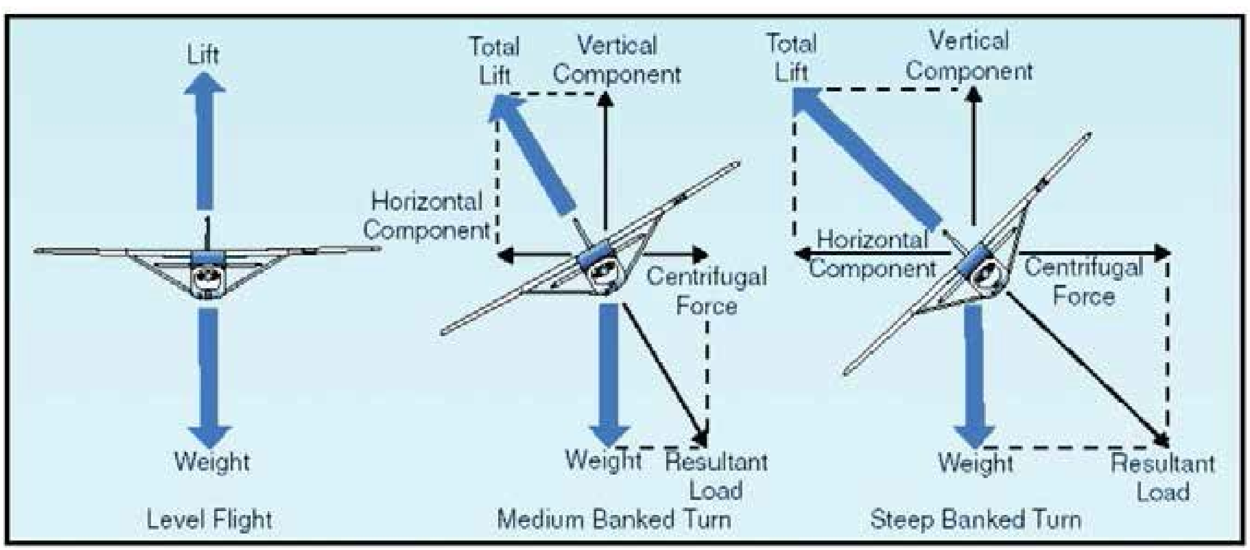
This can be accomplished by increasing the angle of attack or the airspeed (by adding power). If the angle of attack is increased, additional power must be added to maintain the desired airspeed. The steeper the angle of bank, the more the angle of attack and power must be increased to maintain altitude.

At any given airspeed, a steeper angle of bank produces:

- a higher rate of turn,
- a lower radius of turn,
- a higher stalling speed, and
- a higher load factor (G load).
- At any given angle of bank, a higher airspeed produces:
- a lower rate of turn, and
- a larger radius of turn.

Load Factors in Turns

Turns increase the load factor. The steeper the angle of bank, the higher the load factor is. For example, a 60- degree bank produces a load factor of two. This means an aircraft that weighs 2 500 kg will have an equivalent weight of 5 000 kg. Very steep turns can produce very high load factors and may lead to structural failure.



Level 4 Study Notes

STALLS

At low angles of attack, the air flows smoothly over the wing. As the angle of attack increases, the separation point between the laminar area and the turbulent area moves forward. At the critical angle of attack (determined by the design of the airfoil) the laminar flow separates from the wing and a large loss of lift (called a stall) occurs.

Symptoms of a Stall

As a stall is approached, there is usually a light buffeting of the airframe and controls. Lateral control of the aircraft is reduced as the ailerons lose their effectiveness in the separated airflow.

When the stall is reached, lift is lost and the nose of the airplane drops.

A stall occurs gradually on most airplanes, giving the pilot time to recognize and react to the symptoms. If there is wash-out designed in the wing, the wing root will stall first and the ailerons will still be effective in the early stages of the stall.

Factors Affecting Stalls

- **Weight.** Increasing the weight of an airplane increases the indicated airspeed at which it will stall.
- **Centre of gravity.** Moving the centre of gravity forward increases the indicated airspeed at which the airplane will stall. Moving the centre of gravity rearward decreases the indicated airspeed at which it will stall. Moving the centre of gravity beyond the design limits will affect handling, stability, stall characteristics, and stall recovery.
- **Turbulence.** An upward gust increases the angle of attack of the wing and could cause the airplane to exceed the critical angle at a lower airspeed than would be expected in calm air.
- **Turns.** As the angle of bank in a turn is increased, the load factor and stalling speed increase. The stall speed in a turn can be calculated by multiplying the normal stall speed by the square root of the load factor.
- **Flaps.** Increase the lift produced by the wing and lower the indicated airspeed at which the airplane will stall.
- **Snow, frost and ice.** Accumulations on the wing (including dirt and bugs) disrupt the airflow and add additional weight (especially accumulations of ice) causing an increase in the airspeed at which the airplane will stall and a lower critical angle of attack.
- **Heavy rain.** Increases the airspeed at which an airplane will stall as the water forms a film over the surface of the wing. Raindrops create craters and waves in the film, reducing lift and increasing drag, much like frost does.

Stall Recovery

To recover from the stall, the wing has to produce sufficient lift. In general, the stall recovery for most light aircraft involves reducing the angle of attack (below the critical angle of attack).

Applying power to increase the airspeed may also be part of the recovery process.
The pilot operating handbook (POH) for most light aircraft lists the following steps to recover from a stall:

1. Reduce the angle of attack by moving the control column forward.
2. Apply power to increase the airspeed.
3. Return to level flight.

Level 4 Study Notes

SPINS

A spin may develop after a stall if one wing becomes disturbed and produces a different amount of lift. This may happen as a result of using ailerons, applying rudder to produce yaw, entering a stall in a banked attitude, or movement of a wing by turbulent air.

When one wing drops, it has a larger angle of attack and produces less lift (as it has already stalled) compared to the wing that is moving up which has a smaller angle of attack. This difference accelerates the rolling motion and autorotation sets in.

Stages of a Spin

A spin has three stages:

1. incipient,
2. developed, and
3. recovery.

The incipient stage occurs from the time the airplane stalls and rotation starts until the spin axis becomes vertical or nearly vertical.

In the developed stage, the angles and motions of the airplane are stabilized and the flight path is nearly vertical. During this stage the airspeed has stabilized.

Spin characteristics are different for different aircraft so the technique for recovery from the specific POH must be followed. In the absence of recommendations from the manufacturer, most light airplanes can be brought out of a spin by following these steps:

1. Decrease power to idle and neutralize ailerons.
2. Apply full rudder in the opposite direction of the rotation.
3. Move the control column forward to reduce the angle of attack and unstall the wings.
4. When rotation stops, neutralize the rudder, level the wings, and ease out of the dive.

SPIRALS

A spiral is a steep descending turn in which the aircraft rapidly loses altitude while the airspeed rapidly increases.

The characteristics of a spiral include:

- excessive angle of bank,
- rapidly increasing airspeed, and
- rapidly increasing rate of descent.

The recovery process for a spiral is as follows:

1. Decrease power to idle and level the wings simultaneously with coordinated use of rudder and ailerons.
2. Ease out of the dive.
3. Apply power as required to maintain altitude.

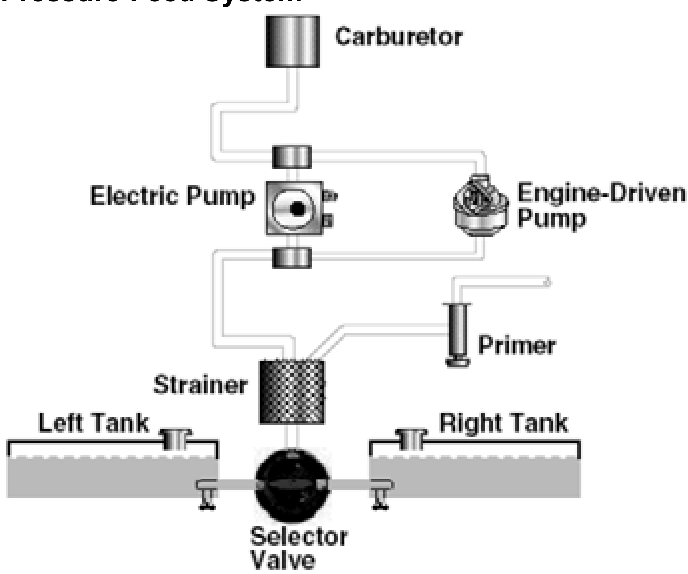
EO M432.01 – DESCRIBE FUEL SYSTEMS

THE FUEL SYSTEM

An aircraft fuel system stores and delivers the proper amount of fuel for all phases of flight, including:
- normal flight,
- violent manoeuvres,
- sudden acceleration,
- and sudden deceleration.

Fuel systems include the following parts:
- fuel tanks,
- a fuel selector valve,
- fuel lines and filters,
- a fuel quantity gauge, and
- fuel primer.

Pressure-Feed System

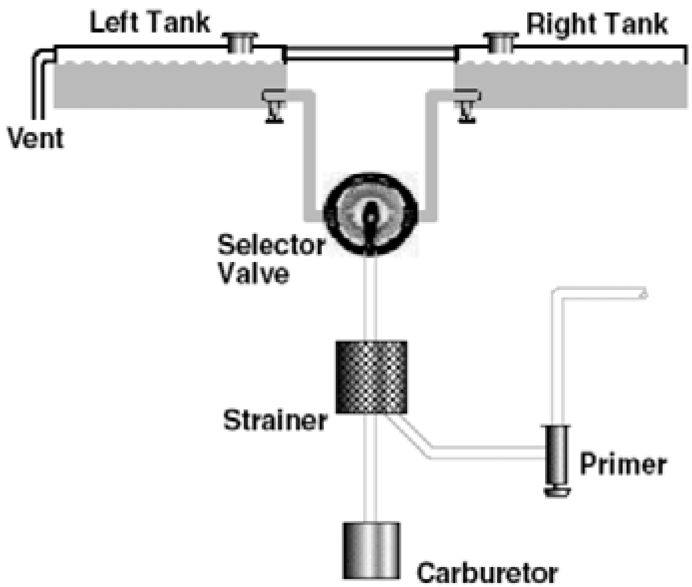


Aircraft with low-wing configurations and large aircraft with a large volume of fuel movement use an enginedriven fuel pump to provide the pressure to keep fuel flowing.

This system includes:
- the basic pump,
- auxiliary electric pumps for emergency situations,
- a booster pump to create the pressure required to start the fuel flowing before the engine is running,
- the pressure gauge mounted on the cockpit panel used to read the pressure of fuel entering the carburetor.

Gravity-Feed System

High-wing, low-powered light aircraft use the gravity-feed system. The bottom of the fuel tank in the wing must be high enough to provide pressure for the fuel to travel past the fuel selector to the carburetor.



Fuel Selector Valve

The fuel selector valve is used by the pilot to select the desired fuel tank to draw fuel. The selector valve may also be used to shut off the flow of fuel from the tanks.

FUEL

Aviation fuel has been specially formulated for use in aircraft. It is available in several different types / grades.

The approved fuel types are specified in the pilot operating handbook.

Fuel Types

Fuel used in modern high compression engines must burn slowly and expand evenly rather than explode quickly (detonation). High octane fuels meet this requirement. The octane rating of fuels is calculated by the ratio of octane and heptane.

- **Octane.** A substance which possesses minimum detonating qualities.
- **Heptane.** A substance which possesses maximum detonating qualities.

`Higher octane fuels are treated with sulphuric acid, lye, etc, used to remove the gum, acid, and other impurities.

Octane numbers can only go as high as 100. Beyond this, the performance number is the anti-knock value of the fuel for octane numbers above 100. Fuel grades are expressed by two performance numbers the first number indicates octane rating at lean mixture conditions, and the second number indicates octane rating at rich mixture condition.

FUEL TYPE AND GRADE	COLOR OF FUEL	EQUIPMENT COLOR
AVGAS 80	RED	80 AVGAS
AVGAS 100	GREEN	100 AVGAS
AVGAS 100LL	BLUE	100LL AVGAS
JET A	COLORLESS OR STRAW	JET A

CARBURETORS

The heat energy in an internal combustion engine is developed from the burning of a mixture of gasoline and air. The carburetor measures the correct quantity of gasoline, vaporizes fuel, mixes it with the air in the required proportion and delivers the mixture to the cylinder when the combustion occurs.

An engine will run hotter with a lean mixture than a rich mixture as the lean mixture will burn slower and the cylinder walls are exposed to high heat for a longer time. A rich mixture burns quickly exposing the cylinder walls to high temperatures for a shorter time and the additional fuel in the fuel / air mix cools the engine.

The carburetor involves numerous complex devices to control the mixture ratio. Two types of carburetors used, include float carburetor, or pressure carburetor.

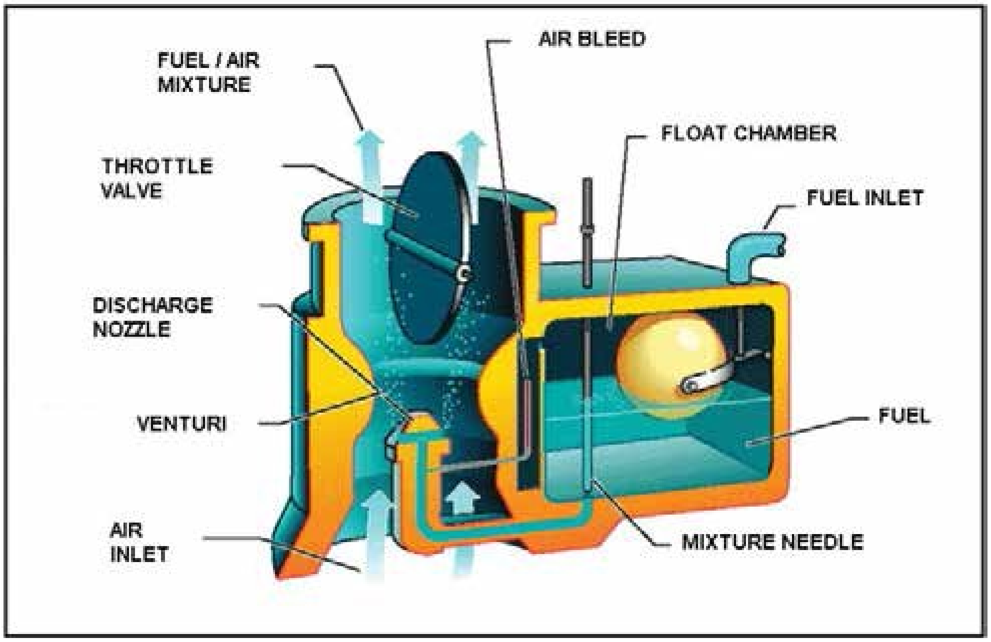
Float Carburetor

Fuel flows through the fuel lines, enters the carburetor at the float valve and into the float chamber. A needle attached to the float, resting on the fuel within the chamber, opens and closes an opening at the bottom of the carburetor bowl. The float chamber is vented so the atmospheric and chamber pressure equalizes as the aircraft climbs and descends.

Air flows through an air filter usually located at an air intake in the front part of the engine cowling. The filtered air flows into the carburetor through a venturi (narrow throat in the carburetor).

The air speed increases, creating a low pressure area which draws fuel at atmospheric pressure.

The air and vaporized fuel is regulated, in volume, by the throttle valve, enters the intake manifold and is distributed to the individual cylinders. The pilot is able to control the amount of fuel / air mixture from within the cockpit using the throttle control.



Mixture Control

As altitude increases, the density of the air decreases and a given volume of air weighs less. The proportion of air by weight to that of fuel will become less although the volume remains the same. The mixture at higher altitude becomes over-rich causing fuel waste and loss of power.

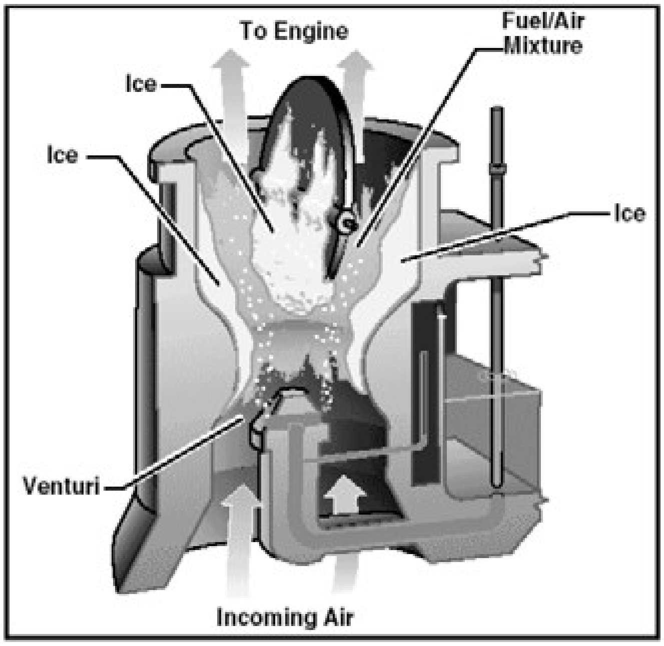
A mixture control is fitted to the carburetor that adjusts the amount of fuel being drawn from the nozzle, restoring the proper fuel / air mix.

The general rules when using a manual mixture control are:

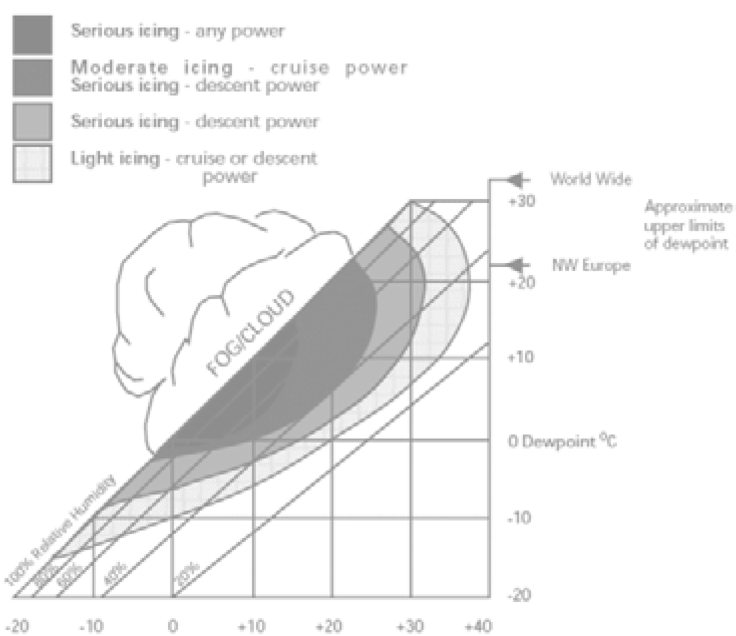
- **rich** mixtures—high power settings, and
- **leaner** mixtures—cruise power settings.

Carburetor Icing

With temperatures ranging from minus 5 degrees Celsius to plus 30 degrees Celsius and under certain moist atmospheric conditions, ice can form in the induction system closing off the flow of fuel to the engine. Ice can form on various surfaces of the carburetor especially on the throttle.



Carburetor Icing Chart



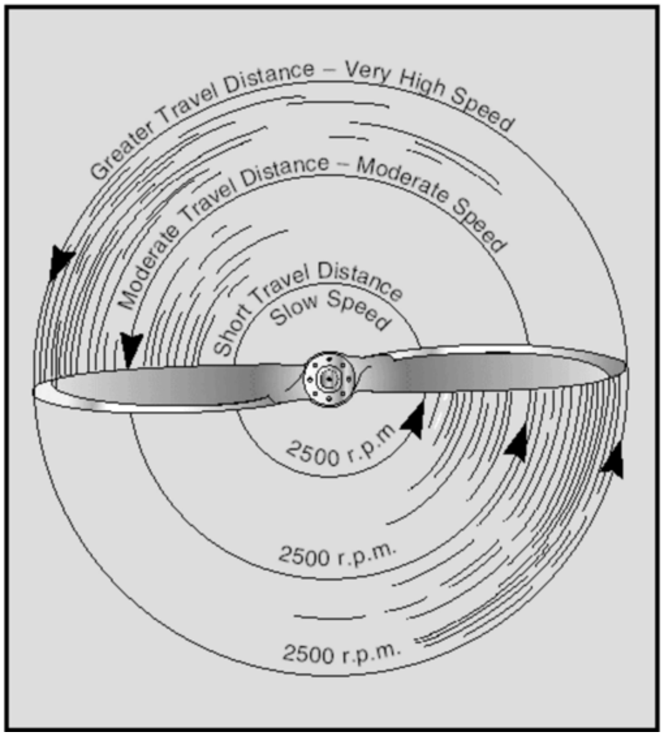
EO M432.02 – DESCRIBE PROPELLER SYSTEMS

The propeller provides the necessary thrust to pull, or in some cases push, the airplane through the air. The engine power rotates the propeller that generates thrust very similar to the manner in which a wing produces lift.

The propeller is a rotating airfoil designed to push air backward as it moves forward along a corkscrew (helical) path. It meets the air at an angle of attack as it rotates, producing thrust (lift) and torque (drag).

A typical propeller is twisted so the blade angles and tapers from the hub to the tip. The highest angle of incidence (pitch) is at the hub and the smallest pitch is at the tip.

By means of the variation in airfoil sections and the angle of attack, uniform thrust is maintained throughout most of the diameter of the propeller.



Pitch. The distance in feet a propeller travels forward in one revolution. Propeller pitch is the difference between theoretical pitch (geometric pitch) and practical pitch (effective pitch).

Theoretical pitch. The distance travelled forward in one revolution if the propeller was working in a perfect fluid. This depends on the blade angle and diameter of the propeller.

Practical pitch. The distance the propeller travels in air in one revolution. The forward motion is less than theoretical pitch.

The angle of the blade, like the angle of incidence of a wing, governs the pitch. The propeller set in coarse pitch will travel a greater distance with each revolution. The aircraft will move forward at greater speed for a given rpm.

The propeller set in fine pitch will have less torque (drag) and will revolve at a higher speed around its axis. The engine will produce greater power. A fine pitch propeller will be good for taking off and climbing but a coarse pitch propeller will develop high cruise speed with comparatively low engine rpm giving good fuel economy.

FIXED PITCH PROPELLERS

Fixed pitch propeller.

- The blade angle can not be adjusted by the pilot and is used on most training aircraft.
- The blade angle is set by the manufacturer to provide the best compromise for all flight conditions.
-

VARIABLE PITCH PROPELLERS

- **Adjustable pitch propeller.** The blade angle can be changed on the ground to adjust for the varying flight situations such as changed takeoff and climb needs.

- **Controllable pitch propeller.** The blade angles can be adjusted by the pilot during flight. The propeller set in a fine pitch for takeoff allows the engine to develop maximum power. The propeller is then adjusted to a coarse pitch to accelerate at a rapid rate to the desired cruise speed.
- **Constant speed propeller.** The blade angles automatically adjust themselves to maintain a constant rpm as set by the pilot.
  The mechanism for adjusting the pitch of the propeller includes:
  - mechanical,
  - hydraulic, and
  - electrical.
- **Mechanical variable pitch propeller.** The pilot adjusts this type of propeller by a control on the instrument panel. The control is directly linked to the propeller which has stop sets to govern the blade angle and travel.
- **Hydraulic variable pitch propellers.** A hydraulically operated cylinder pushes or pulls on a cam connected to gears on the propeller blade. The mechanism can be a counterweight or hydromatic.

  The counterweight relies on oil pressure to move the cylinder that twists the blades of a controllable pitch propeller toward fine pitch. The control is adjusted by the pilot in the cockpit.

  A constant pitch propeller uses the oil pressure and counterweight principle to twist the blades to the proper pitch angle to maintain a constant rpm. The pilot uses the throttle and propeller control located in the cockpit. The throttle controls the power output of the engine and the propeller control regulates the rpm of both the propeller and the engine.

  A powerful force called centrifugal twisting moment turns the blades toward the fine pitch position of a hydromatic constant speed propeller. The natural force eliminates the use of counterweights. Oil enters the piston chamber under high pressure which moves the piston aft and the blades move into coarse pitch. When the oil enters into the piston chamber under engine pressure, the blades move to fine pitch. If oil pressure is lost during flight, the propeller will automatically go into fine pitch

- **Electric variable pitch propellers.** An electrical motor turns the blades through a gear speed reducer and bevel gears for an electrical variable pitch propeller. Flyweights open and close electric circuits. One circuit causes a right-hand rotation of the motor and another causes a left-hand rotation. The rotation of the motor will adjust the blades toward a fine or coarse pitch as required. The pilot can set a two-way switch to either manual or automatic operation.

EO M432.03 – DESCRIBE ENGINE INSTRUMENTS

Oil pressure and oil temperature gauges.

One of the principle engine instruments is the oil pressure gauge. It is usually positioned beside the oil temperature and fuel gauges. The instrument is calibrated in pounds per square inch (psi) and indicates the oil pressure supplied by the oil pump to lubricate the engine.

The gauge should be checked immediately after the engine has been started. As the oil warms, the reading should adjust to operational pressure. This may take up to 15 minutes. If the pressure remains high, the engine is not getting proper lubrication. High oil pressure pushes oil into the combustion chamber where it burns causing a smoky exhaust and badly carbonized piston heads, valve seats, cylinder heads and more.

Low oil pressure causes more serious problems as no film of oil goes between the working surfaces of the engine. Metal against metal rubbing causes main bearings to wear out.

The oil temperature gauge records the temperature of the oil in degrees Fahrenheit or Celsius. As the oil warms during start-up, the pressure should read high and the temperature low. Both instruments should approach their normal readings as the oil warms.

Oil Pressure Gauge

Oil Temperature Gauge

Cylinder head temperature gauge.

The cylinder head temperature gauge shows the temperature of one or all engine cylinder heads. This reading shows the pilot the effectiveness of the engine cooling system. Extremely high cylinder head temperatures indicate an immediate sign of engine overload which can result in detonation, pre-ignition, and eventual engine failure.

Tachometer.

The tachometer shows the speed at which the engine crankshaft is turning in hundreds of revolutions per minute (rpm). The tachometer records the engine hours of operation. The more common types of tachometer, are mechanical including centrifugal, or magnetic and electrical, which include direct current, or alternating current.

An aircraft with a fixed pitch propeller will only have a tachometer to read the engine power produced. It records the rpm at which the engine cranks and the propeller turns.

An aircraft with a controllable pitch or a constant speed propeller uses two gauges. The tachometer shows the rpm settings as controlled by the propeller control. The manifold pressure gauge shows the power produced by the engine.

The tachometer is marked with colour-coded arcs to indicate the proper range of engine operation, including:

- green indicating normal range of operation;
- yellow indicating the caution range and possible problems; and
- red indicating the maximum limit.

Manifold pressure gauge

The manifold pressure gauge also has colour-coded arcs displayed on the gauge to indicate the normal operating range and operation limits. The gauge indicates in inches of mercury the fuel / air pressure in the engine intake manifold at the point between the carburetor and the cylinders.

With an aircraft fitted with a constant speed propeller, the rpm setting will remain constant. The manifold pressure gauge is the only instrument to show any fluctuations in the engine power output. A reduction in manifold pressure can indicate carburetor icing.

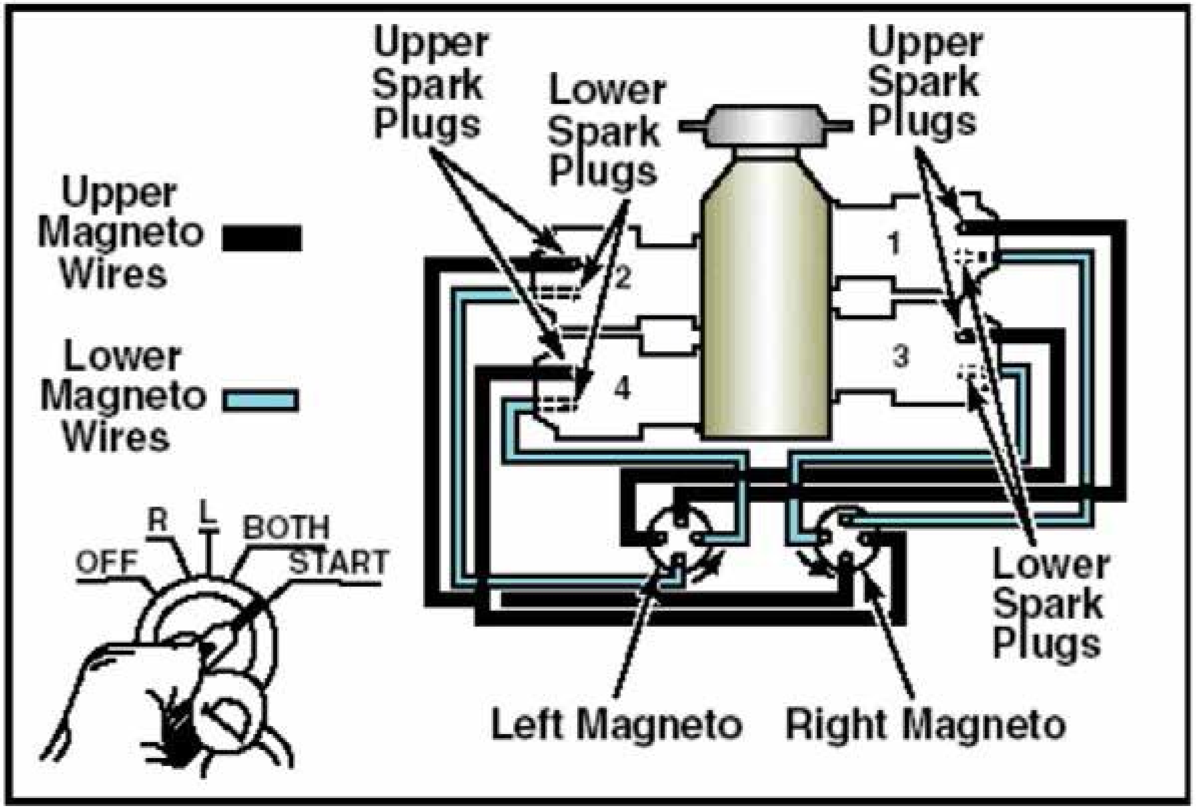
When the engine is not running, the reading on the manifold pressure gauge will be of the existing atmospheric pressure.

Excessive manifold pressure raises the compression pressure causing high stress on the pistons and cylinder assemblies. It also produces excessive temperature which may cause scoring on the pistons, sticking rings, and burned out valves.

EO C432.01 – DESCRIBE IGNITION AND ELECTRICAL SYSTEMS

Ignition system.

Level 4 Study Notes



The ignition system provides an electrical spark to ignite the fuel / air mixture in each cylinder. The system usually consists of:

- two magnetos,
- two spark plugs per cylinder,
- ignition leads, and
- a magneto switch (on the instrument panel).

The magneto is an engine-driven generator which produces an electrical current without using an external current. It combines all elements of the ignition system, including:

- generating a low tension current;
- transforming the low tension current to high tension; and
- distributing the current to the individual spark plugs and causing them to fire.

When the magneto switch is off, the system is grounded and the electrical charge does not flow through the magneto and a spark is not produced. When the switch is on, the system is not grounded and the electrical charge flows through the magneto and a spark can be produced.

Dual ignition systems include two spark plugs in each cylinder, and two magnetos.

One spark plug in each cylinder is fired by one magneto. The other magneto fires the second spark plug in each cylinder. This dual ignition system provides improved:

- **Safety.** If one system fails, the engine will still operate.
- **Performance.** Improved combustion of the fuel / air mixture increases the power output and gives better engine performance.

The magneto switch allows the pilot to select either one or both magneto systems. The engine should always be operated on both magneto systems during takeoff and normal flight.

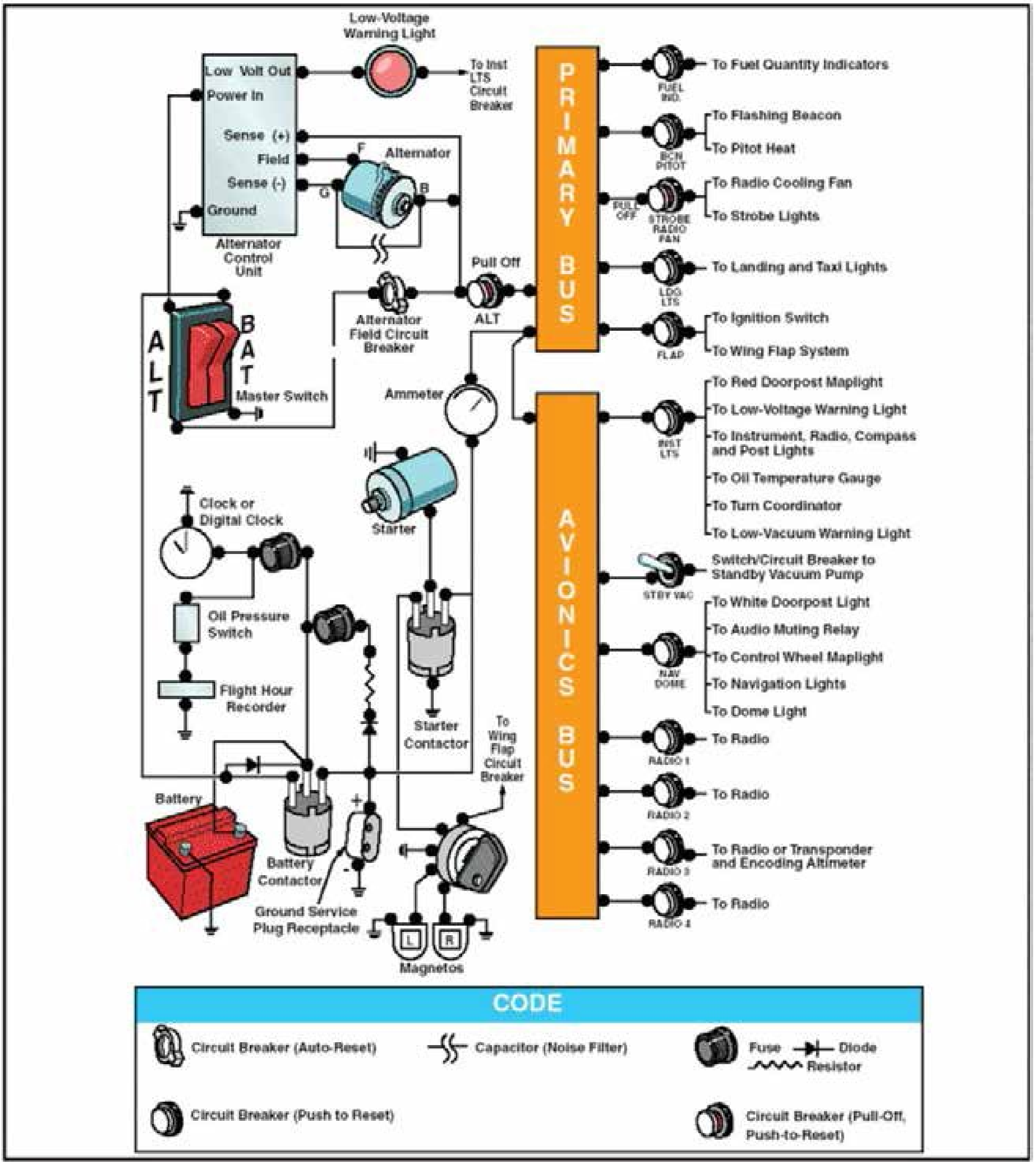
Correctly set ignition timing allows the magneto to fire at the right time. If the spark plug fires too early, poor engine performance may occur, including:

- loss of power, and
- overheating which can lead to:
- detonation,
- pre-ignition,
- piston burning,
- scored cylinders, and
- broken rings.

The wires in the ignition system are shielded (a metal covering which is grounded). Shielding prevents the ignition current from interfering with the radio, whole ignition system, magnetos, plugs, and wiring.

Electrical system

Level 4 Study Notes



The electrical system includes everything that operates electrically except the magnetos. There is ***no connection from the aircraft's electrical system to the ignition system***.

The basic electrical system includes:

- a storage battery,
- master switch and battery solenoid,
- starter motor and solenoid,
- generator (or alternator),
- voltage regulator,
- bus bar, and
- circuit breakers.
-

The electrical system is either a 12- or 24-volt system and is direct current. The battery solenoid activated by the master switch completes the circuit between the electrical energy from the storage battery and the electrical system. The most important action by a pilot is to have the battery fully charged for the electrical components to function satisfactorily.

The starter switch activates the starter solenoid which allows current to enter and drive the starter motor. The engine drives the generator or alternator for the purpose of providing current to the electrical system, and recharging the battery.

The voltage regulator is used to prevent the generator or alternator from overloading the system, and the battery from becoming overcharged.

The current produced by the generator or alternator and battery is received by the bus bar which passes the current through the various circuit breakers and branches out to the various electrical circuits.

Circuit breakers or other fuses protect all electrical circuits from damage from excess voltage or current, and short-circuits. Most circuit breakers have a push button to reset. If the circuit breaker continues to fail, there may be malfunction in the component that could cause an electrical fire.
The pilot monitors the electrical system in the cockpit using:

- an ammeter,
- a voltmeter, and / or
- a warning light.

The ammeter measures in amperes the rate of flow of the electrical current being produced and when power is being used by the battery.

The voltmeter indicates the voltage in the electrical system.

The generator warning light shows when the generator is not working.

All contacts between the battery, voltage regulator, and the alternator or generator need to be clean and secure.

Battery water level should be checked regularly and an aged battery that is no longer working properly should immediately be replaced.

EO M436.01 – EXPLAIN WINDS

SURFACE WINDS

Wind is a major factor in flight planning and flight characteristics. Pilots must constantly be aware of the direction and speed of wind during the flight, especially when close to the ground during takeoff and landing.

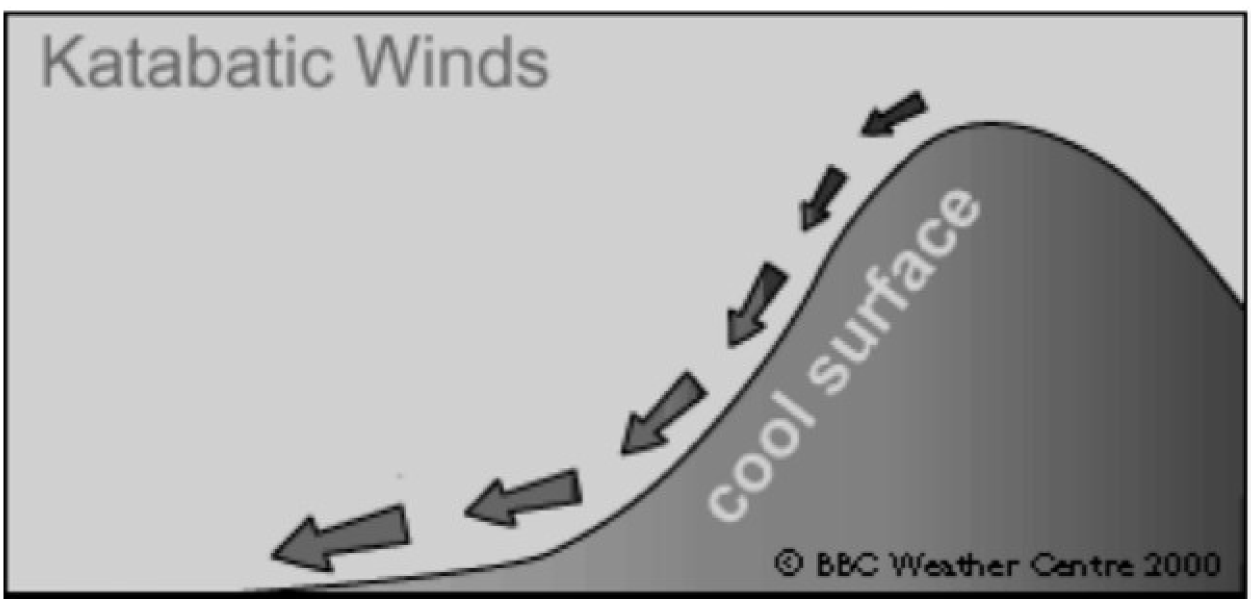
Surface friction plays an important role in the speed and direction of surface winds. The friction between the air and the ground slows the air down causing a lower wind speed than would be expected from the pressure gradient. The friction also changes the direction causing the wind to blow across the isobars toward the centre of a low pressure area and away from the centre of a high pressure area.

The effect of surface friction usually does not extend more than a couple of thousand feet into the air. At 3 000 feet above the ground, the wind blows parallel to the isobars with a speed proportional to the pressure gradient.

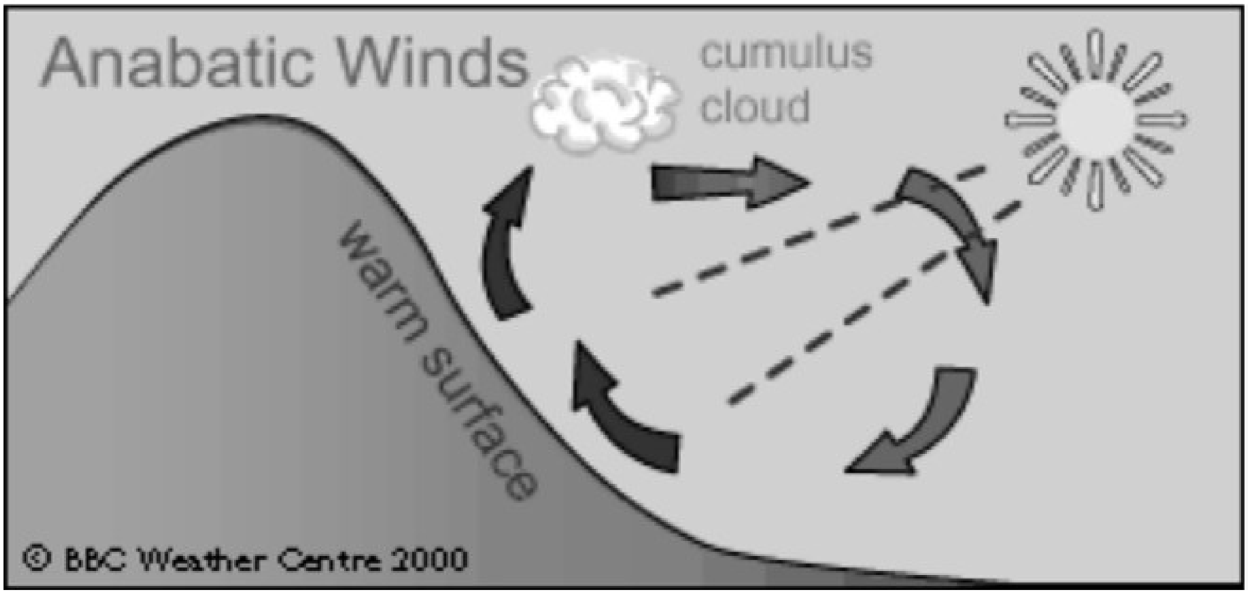
Hills and valleys substantially distort the airflow associated with the prevailing pressure system and the pressure gradient. Katabatic and anabatic winds and mountain waves are examples of wind phenomena in mountainous areas.

Katabatic and Anabatic Winds

At night, the sides of hills cool by radiation. The air in contact with them becomes cooler and denser, and blows down the slope into the valley. A katabatic wind is the term for down slope winds flowing from high elevations down the slopes to valleys below. If the slopes are covered with ice and snow, the katabatic wind can also carry the cold dense air into the warmer valleys during the day.



Anabatic wind occurs during the day when the slopes of hills, not covered by snow, are warmed. The air in contact with them becomes warmer and less dense, therefore flowing up the slope.



Mountain Waves

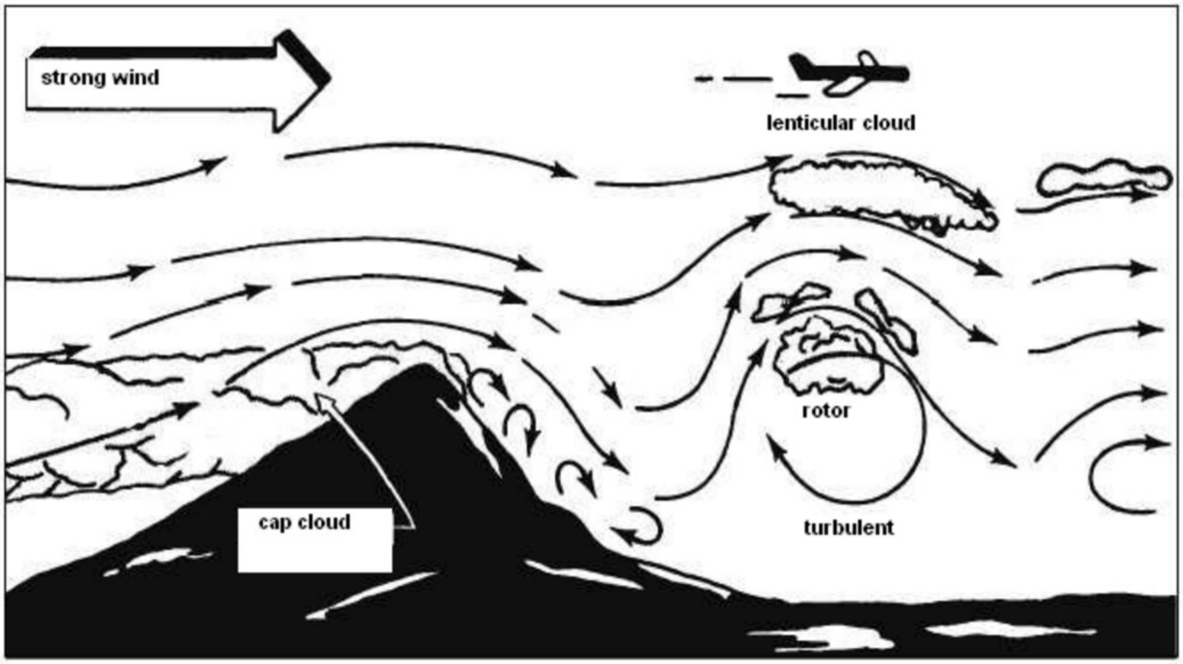
Air flowing across a mountain range usually rises smoothly up the slope of the range. Once over the top, it pours down the other side with considerable force, bouncing up and down, creating eddies and turbulence. It also creates powerful vertical waves that may extend for great distances downwind of the mountain range. This phenomenon is known as a mountain wave. The most severe mountain wave conditions are created in strong airflows that are blowing at right angles to the mountain range in very unstable air.

If the air mass has high moisture content, clouds of a very distinctive appearance will develop, thereby serving as a warning to pilots. Orographic lift causes a cap cloud to form along the top of the ridge. Lenticular (lensshaped) clouds form in the wave crests aloft and lie in bands that may extend well above 40 000 feet. Rotor clouds resemble a long line of stratocumulus clouds and form in the rolling eddies downstream.

Mountain waves may cause many dangers to aircraft, such as:

- common downdrafts of 2 000 feet per minute along the downward slope;
- extremely severe turbulence in the air layer between the ground and the tops of the rotor clouds;
- severe wind shear due to wind speed variation between the crests and troughs of the waves;
- severe icing due to large supercooled droplets sustained in the strong vertical currents; and
- an altimeter error of more than 3 000 feet on the high side due to the increase in wind speed and accompanying decrease in pressure.

Level 4 Study Notes



Gusts

A gust is a rapid and irregular change of wind speed and may be associated with a rapid change in wind direction. Gusts are caused by mechanical turbulence that results from friction between the air and the ground and by the unequal heating of the earth's surface, particularly during hot summer afternoons.

Squalls

A squall is a sudden increase in the strength of the wind of longer duration than a gust and like a gust, may be accompanied by a rapid change of wind direction. Squalls may be caused by the passage of a fast moving cold front or thunderstorm.

JET STREAMS

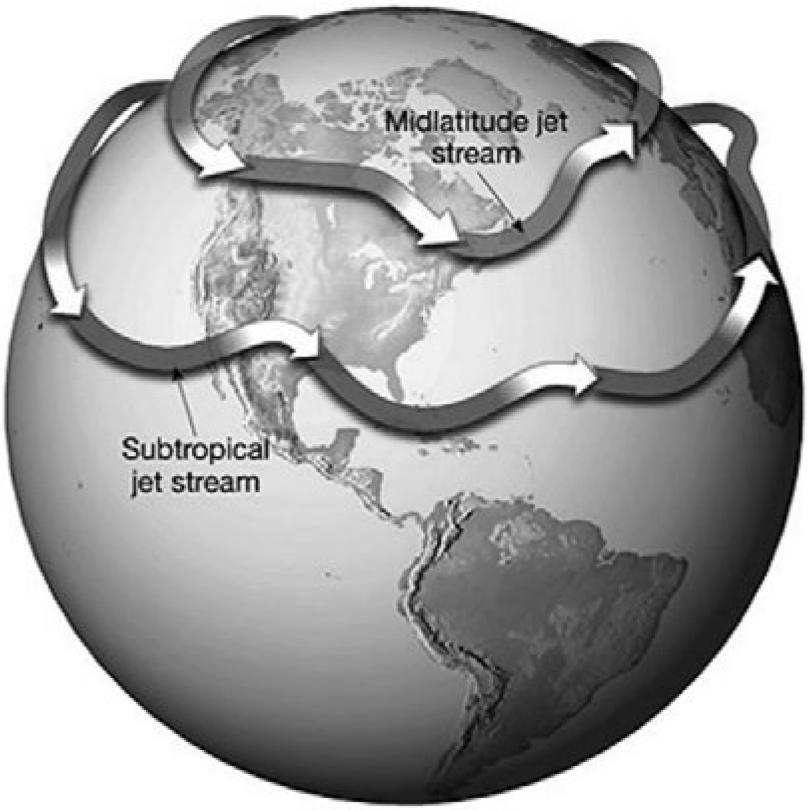
Jet streams are narrow bands of exceedingly high speed winds that exist in the higher levels of the atmosphere at altitudes ranging from 20 000 to 40 000 feet or more. They flow from west to east and are usually 300 nautical miles wide and 3 000 to 7 000 feet thick. Winds in the central core of a jet stream are generally between 100 and 150 knots, although they may reach speeds as great as 250 knots.

The northern hemisphere has two such streams: the mid-latitude (polar) jet, which is the one usually affecting weather in North America, Europe and Asia, and the subtropical jet.

When the mid-latitude jet is farther north, in Canada, the weather to its south tends to be mild or at least less cold. When the stream swings south well within the United States (U.S.), especially in winter, very cold, often harsh weather prevails at the surface on the northern side.

Knowing the location of a jet stream is important when planning long range flights at high altitudes. For example, on an eastbound flight a pilot would want to take advantage of the excellent tail winds a jet stream would provide. On a westbound flight they would want to avoid the winds.

Level 4 Study Notes



Clear Air Turbulence (CAT)

CAT is a bumpy, turbulent condition that occurs in a cloudless sky. It occurs at high altitudes, usually above 15 000 feet and is more severe near 30 000 feet. The most probable place to expect CAT is just above the central core of a jet stream.

CAT is almost impossible to forecast and can be severe enough to be a hazard to modern high-performance airplanes. Therefore, knowledge of areas in which CAT is most likely to occur is important for pilots to help minimize encounters with it.

EO M436.02 – DESCRIBE AIR MASSES AND FRONTS

WEATHER IN AN AIR MASS

There are three main factors that determine the weather in an air mass:
- moisture content,
- the cooling process, and
- the stability of the air.

Moisture Content

Continental air masses are very dry and little cloud develops. The high moisture content in maritime air may cause cloud, precipitation, and fog.

The Cooling Process

Even if the air is moist, condensation and cloud formation only occur if the temperature is lowered to the dewpoint. The cooling processes that contribute to condensation and the formation of clouds are:

- contact with a surface cooling by radiation,
- advection over a colder surface, and
- expansion brought about by lifting.

Cloud formation within an air mass is not uniform. For example, clouds may form in an area where the air is undergoing orographic lift even though the rest of the air mass is clear.

The Stability of the Air

In stable air, stratus cloud and poor visibility are common, whereas in unstable air, cumulus cloud and good visibility are common.

Characteristics of Cold Air Masses and Warm Air Masses

Cold air masses (eg, arctic and polar air masses) will typically have the following characteristics:

- instability,
- turbulence,
- good visibility,
- cumuliform clouds, and
- precipitation in the form of showers, hail, and thunderstorms.

Warm air masses (eg, tropical air masses) will typically have the following characteristics:

- stability,
- smooth air,
- poor visibility,
- stratiform clouds and fog, and
- precipitation in the form of drizzle.

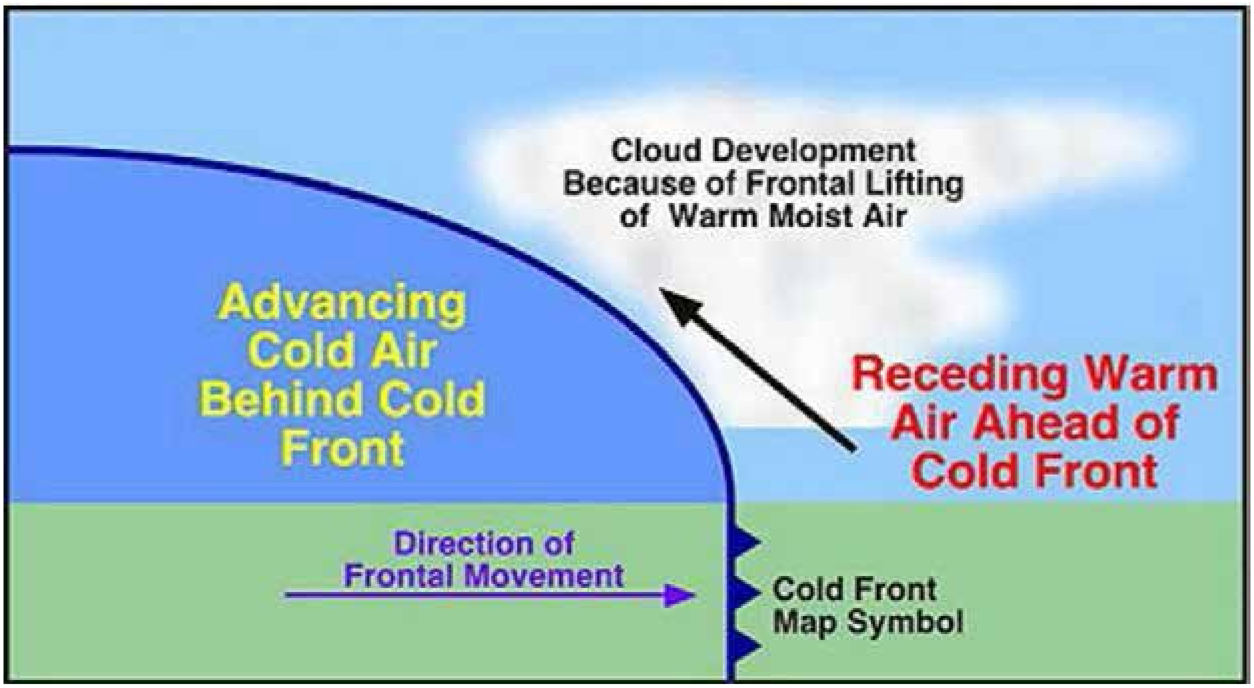
Level 4 Study Notes

FRONTS

A front is the transition zone between two air masses. The interaction of air masses along their frontal zones is responsible for weather changes.

COLD FRONT

A cold front is the part of a frontal system along which cold air is advancing.



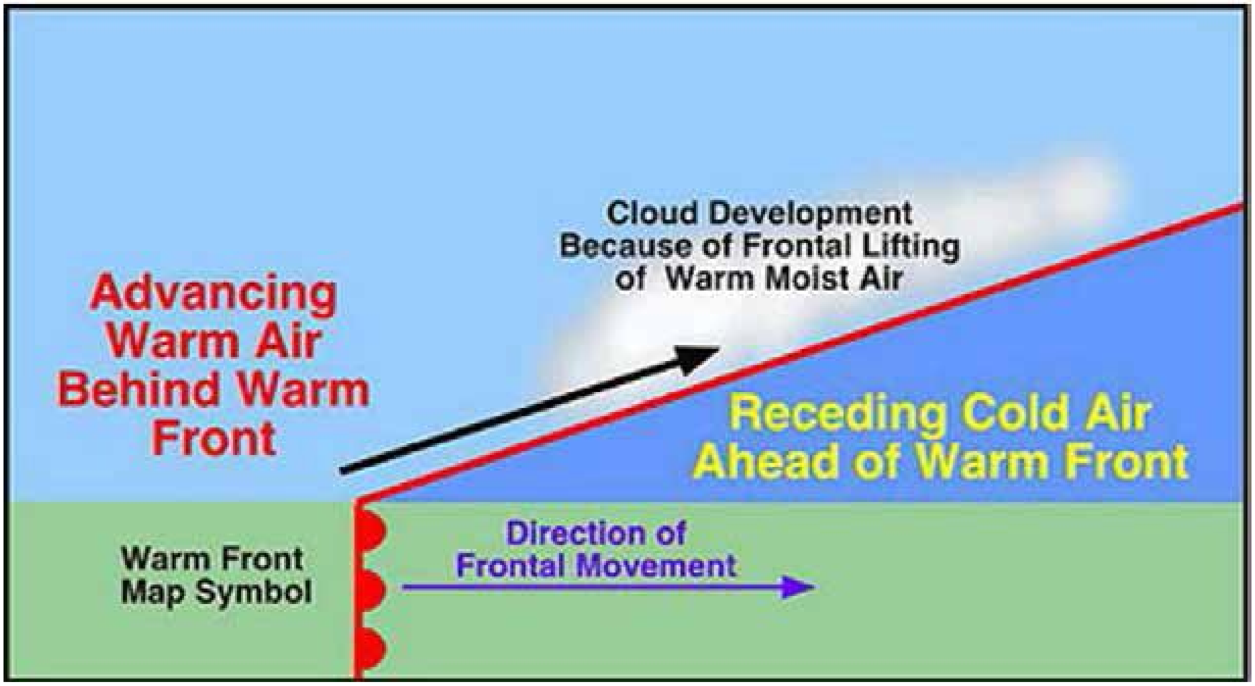
When a mass of cold air overtakes a mass of warm air, the cold air, being denser, stays on the surface and undercuts the warm air violently. The slope of the advancing cold front is quite steep as surface friction slows the air at the surface, allowing the upper air to catch up. The rapid ascent of warm air gives rise to a relatively narrow band (only about 50 nautical miles) of cumuliform cloud that frequently builds up into violent thunderstorms.

The severity of the weather depends on the moisture content and stability of the warm air mass that the cold air mass is undercutting and the speed of the advancing cold front. If the warm air is very moist and unstable, towering cumulus clouds and thunderstorms are likely to develop, bringing heavy showers in the form of rain, snow, or hail. A slower moving cold front advancing on more stable and drier air will produce stratus or altocumulus clouds with light or no precipitation.
A squall line, a continuous line of thunderstorms, sometimes develops ahead of a fast moving cold front. Theweather brought about by a squall line is extremely violent, including rapid shifts in wind, heavy rain or hail, and thunder and lightning. Pilots should avoid squall lines at all costs.

A sharp fall in temperature, a rise in pressure, and rapid clearing usually occur with the passage of the cold front.

WARM FRONT

A warm front is the part of a frontal system along which cold air is retreating.



As a mass of warm air advances on a retreating mass of cold air, the warm air, being lighter, ascends over the cold air in a long gentle slope. As a result of this long gentle slope and the relatively slow speed of warm fronts, the cloud formation associated with them may extend for 500 or more nautical miles in advance. If the warm air is moist and stable, these clouds develop in a distinctive sequence:

1. cirrus,
2. cirrostratus,
3. altostratus,
4. nimbostratus, and
5. stratus.

The clouds indicating the passing of a warm front can easily be remembered using the mnemonic "C-CANS".

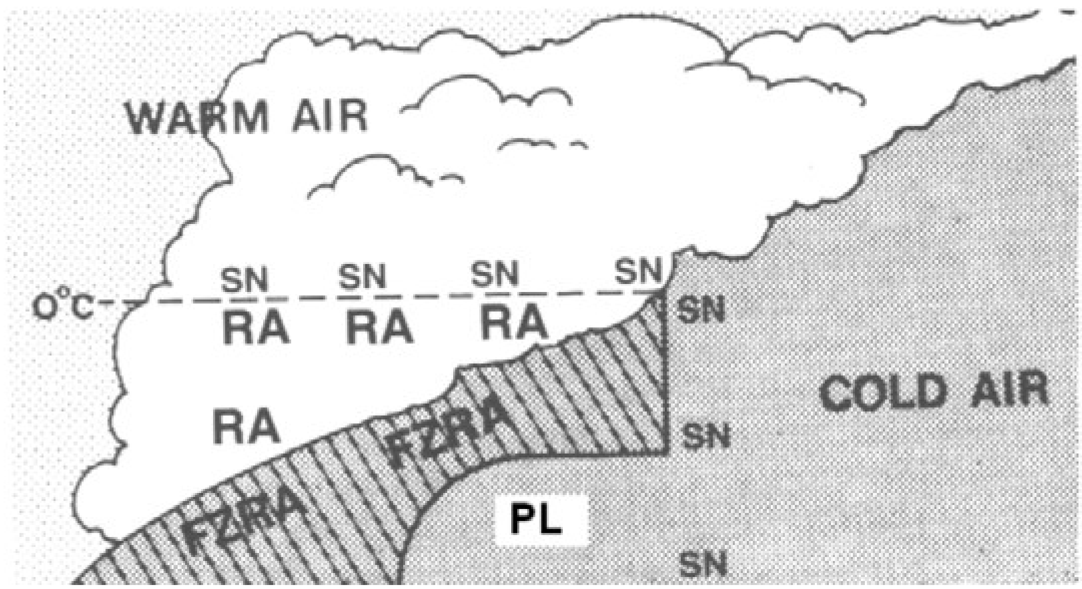
If the warm air is moist and unstable, cumulonimbus and thunderstorms may be embedded in the stratiform layers, bringing heavy showers.

Warm fronts bring low ceilings and restricted visibility for a considerable length of time due to their slow movement.

Level 4 Study Notes

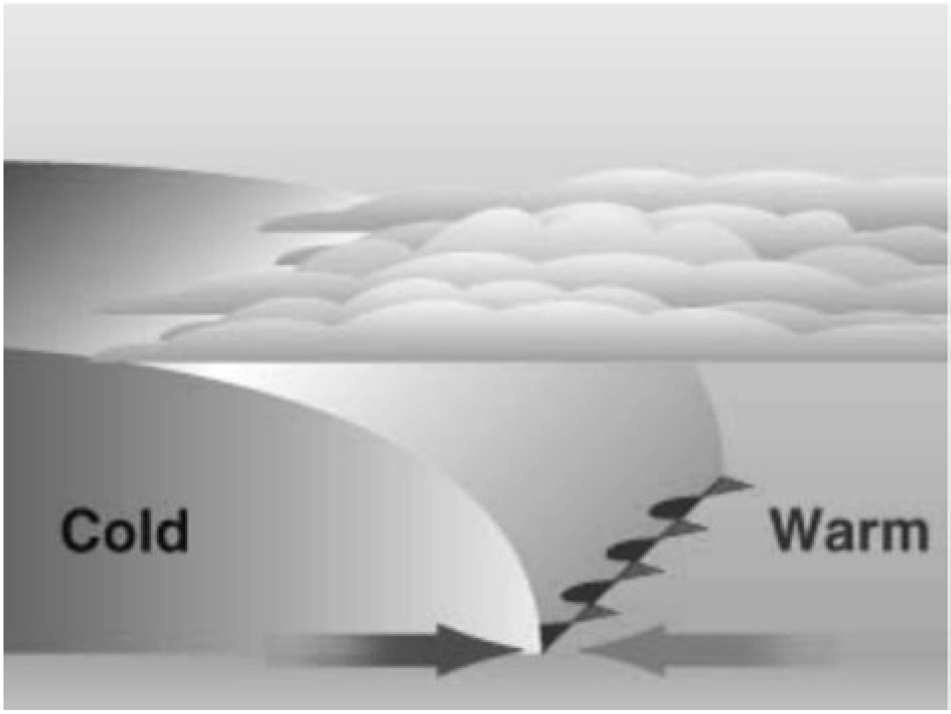
In winter, when temperatures in the cold air are below freezing and temperatures in the lower levels of the warm air are above freezing, snow and freezing rain can be expected. Snow (SN) falls from the part of the warm air cloud that is high and therefore below freezing. Rain (RA) falls from the lower warm air cloud but becomes supercooled as it falls through the cold air mass. This creates freezing rain (FZRA) and ice pellets (PL). Therefore, icing is a problem associated with warm fronts in winter.

The passing of the warm front is marked by a rise of temperature due to the entry of the warm air, and the sky becoming relatively clear.



STATIONARY FRONT

A stationary front is the part of a front along which the colder air is neither advancing nor retreating.



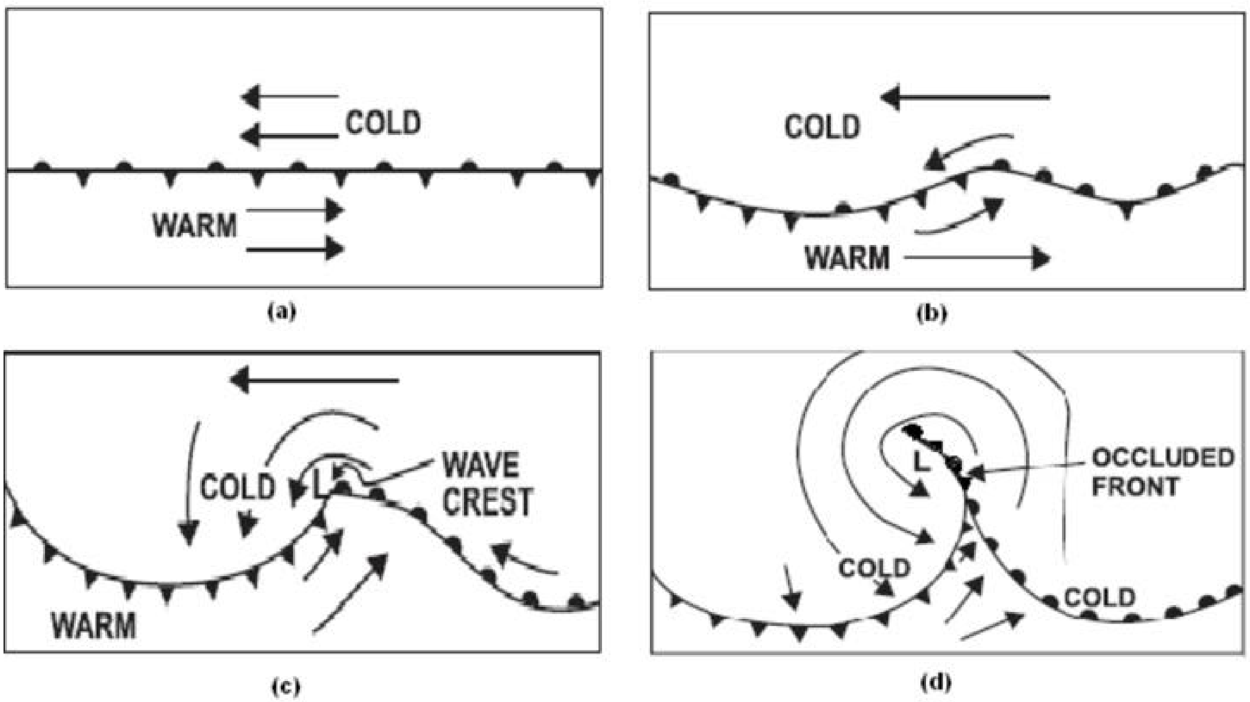
A stationary front occurs when the front does not move because the opposing air masses are of equal pressure. The weather conditions are similar to those associated with a warm front, (low cloud, and continuous rain or drizzle) although generally less intense and not so extensive. Usually a stationary front will weaken and eventually dissipate. Sometimes, however, it will begin to move after several days, becoming either a cold front or a warm front.

Level 4 Study Notes

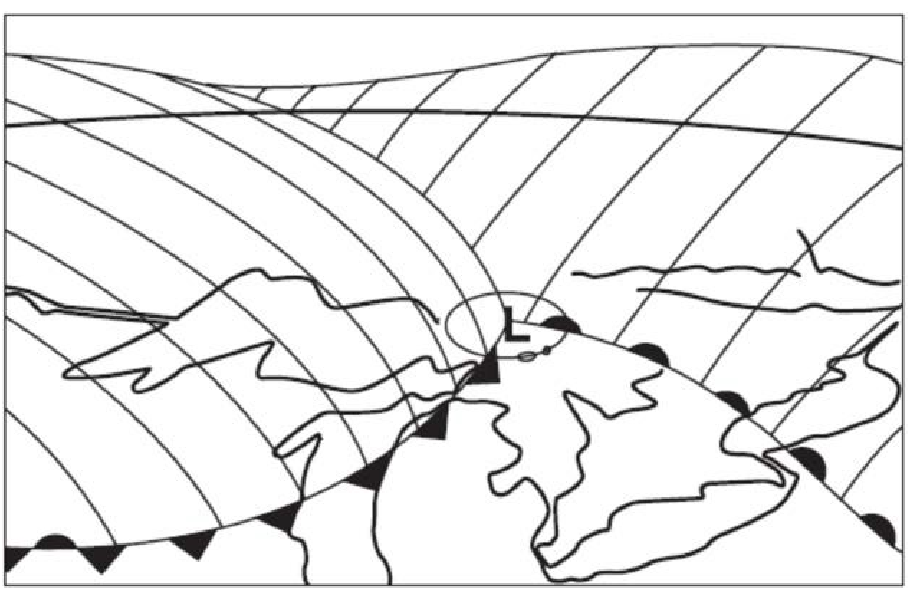
OCCLUDED FRONTS

A wave-like disturbance sometimes forms on a stationary front. This can develop into a small low known as a depression. As the depression forms, one section of the front begins to move as a warm front and the other section as a cold front. Over time, under certain atmospheric conditions, the cold front gradually overtakes the warm front and lifts the warm air entirely from the ground forming a single occluded front. Basically, the cold air catches up with itself as it flows around the low pressure area.

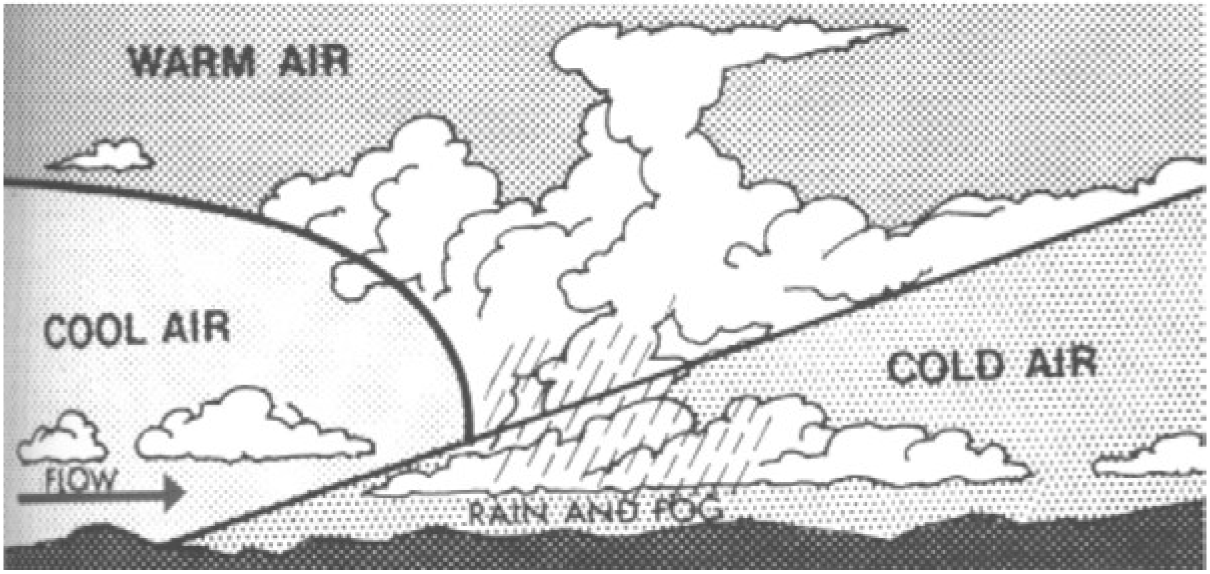
Occluded Front Formation



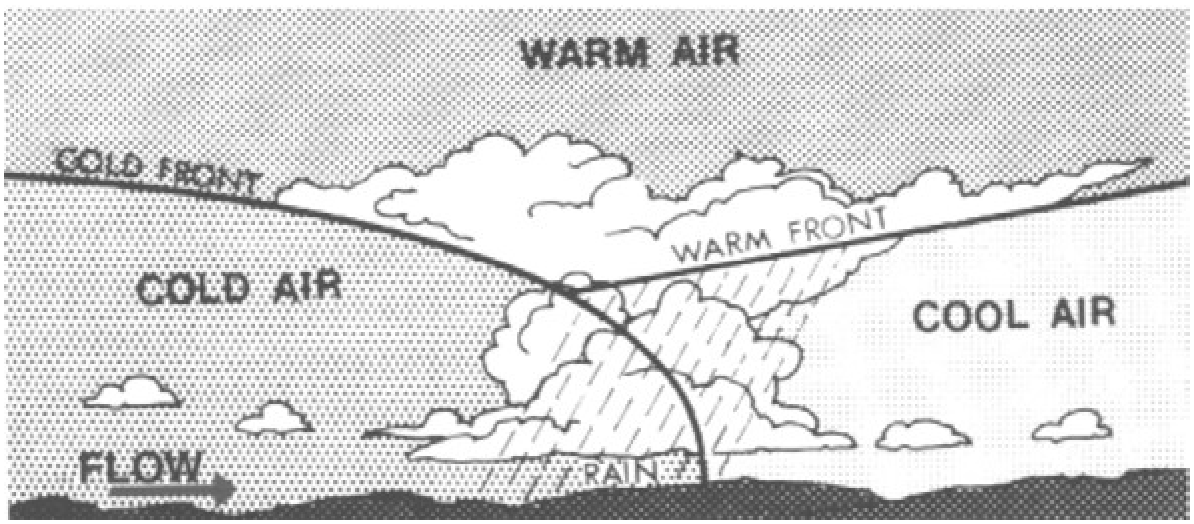
Frontal Depression



If the cold air is not as cold as the air it is overtaking (cool air advancing on cold air), the front is known as a warm occlusion.



If the cold air is colder than the air it is overtaking (cold air advancing on cool air), the front is known as a cold occlusion.



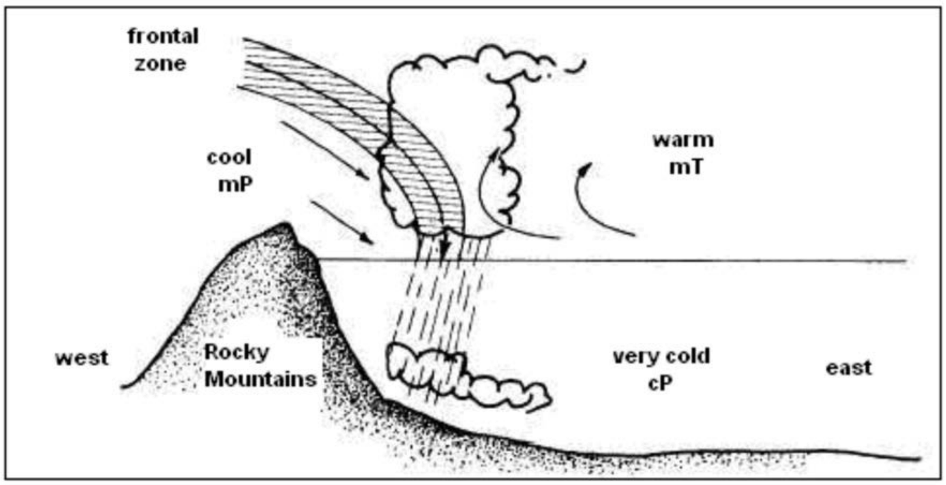
In both warm occlusions and cold occlusions, three air masses are present: a cool air mass, a cold air mass, and a warm air mass lying wedge-shaped over the colder air. The wedge-shaped mass of warm air is known as a trowal.

Both warm occlusions and cold occlusions have much the same characteristic as warm fronts, with low cloud and continuous rain. If the warm air is unstable, cumulonimbus clouds may develop; they are more likely to occur and bring about heavy turbulence, lightning, and icing in a cold occlusion.

UPPER FRONTS

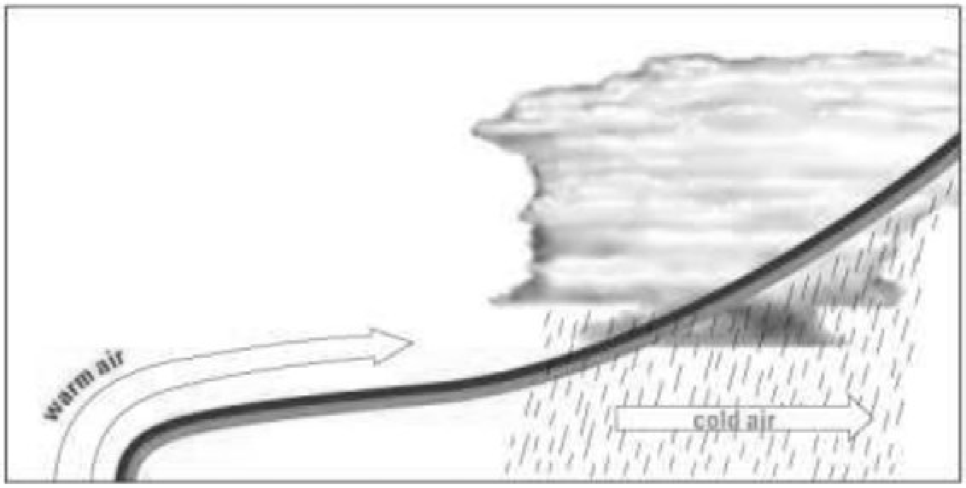
An upper cold front can form in two ways:

- A cold front advancing across the country may encounter a shallow layer of colder air resting on the surface. The cold front will then leave the ground and ride up over the colder, heavier air.
- The structure of the advancing cold front is such that the cold air forms a shallow layer for some distance along the ground in advance of the main body of cold air. This causes the frontal surface of the main mass of cold air to be very steep. The line along which the frontal surface steepens is also known as an upper cold front.



An upper warm front can form in two ways:

- An advancing warm front rides up over a layer of cold air trapped on the ground. A change of air mass is not experienced on the ground because the front passes overhead.
- The surface of the cold air that is retreating ahead of an advancing warm front is almost flat for some distance ahead of the surface front and then steepens abruptly. The line along which the surface of the retreating cold air steepens sharply is also called an upper warm front.



EO C436.02 – DESCRIBE SEVERE WEATHER CONDITONS

THUNDERSTORMS

Formation

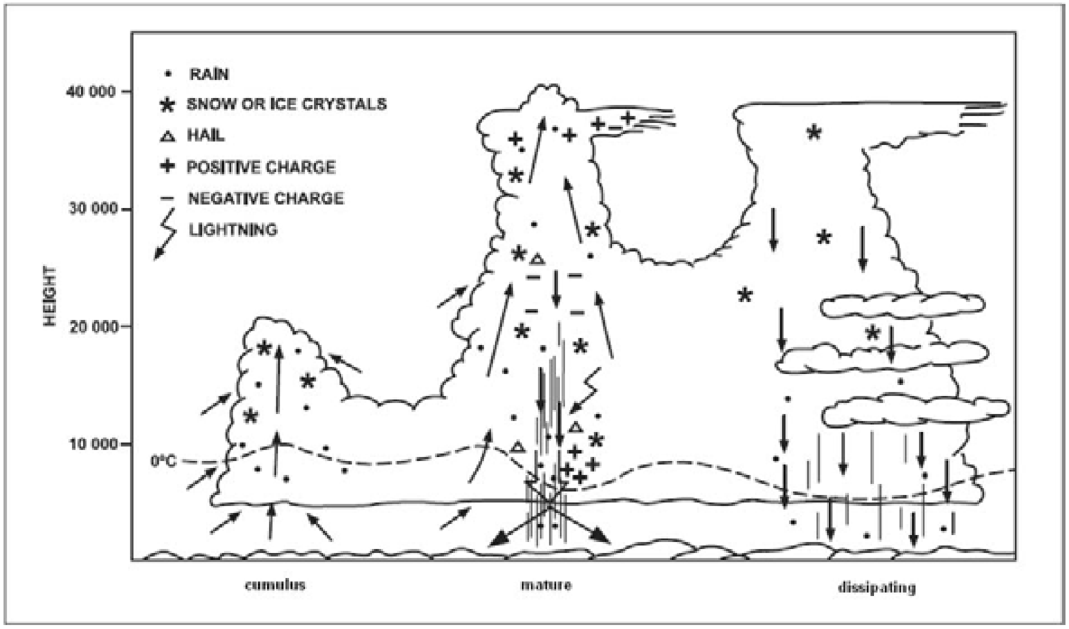
The requirements for the formation of a thunderstorm are the following: unstable air, high moisture content, and some form of lifting agent.

The intensity of these conditions is the difference between a harmless cumulus cloud and a violent thunderstorm. Such unstable atmospheric conditions may be brought about when air is heated from below (convection), forced to ascend the side of a mountain (orographic lift), or lifted over a frontal surface (frontal lift).

There are three distinct stages of a thunderstorm:

1. cumulus,
2. mature, and
3. dissipating.

Level 4 Study Notes



Every thunderstorm begins as a cumulus cloud. Strong updrafts, due to the unstable air and lifting agent cause the cloud to build rapidly into a towering cumulus and then cumulonimbus cloud. There is usually no precipitation in this stage as the water droplets and ice crystals are kept suspended in the cloud by the strong updrafts.

In the mature stage, the cumulonimbus cloud may reach heights up to 60 000 feet, with updrafts of 6 000 feet per minute and downdrafts of 2 000 feet per minute. Precipitation, violent turbulence, and thunder and lightning are all associated with thunderstorms in their mature stage.

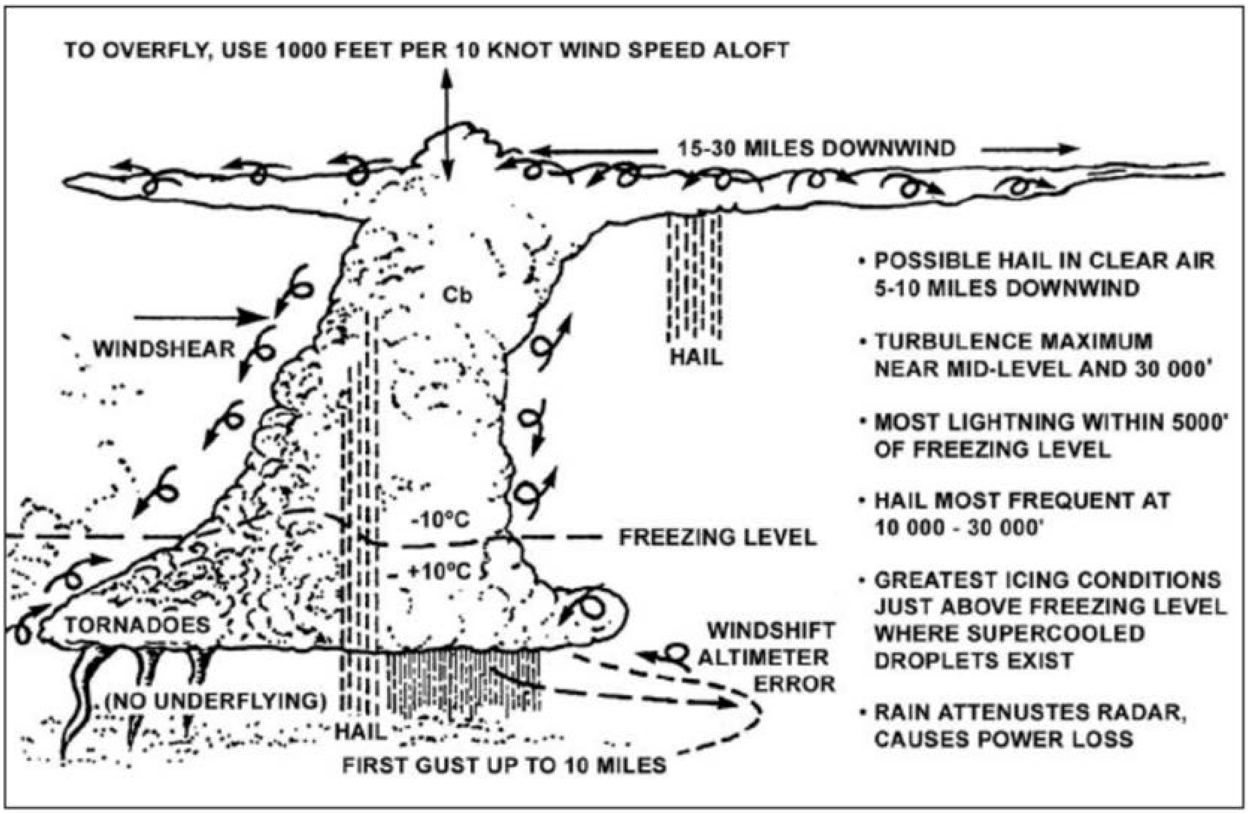
The precipitation tends to cool the lower region of the cloud causing the thunderstorm cell to dissipate. The downdrafts spread throughout the whole cell except for a small portion at the top where updrafts still occur. The rainfall gradually ceases and the top of the cell spreads out into an anvil shape.

Level 4 Study Notes

Dangers

The dangers of flying in or close to a thunderstorm are:

- severe turbulence,
- lightning,
- hail,
- icing,
- unreliable altimeter readings due to rapid changes in pressure,
- strong wind gusts, and
- heavy rain.



Avoidance

Stay at least five miles away from a thunderstorm. When flying around a thunderstorm, fly to the right side of it as the wind is circulating counter-clockwise around the low pressure area. Never fly through a thunderstorm in a light aircraft.

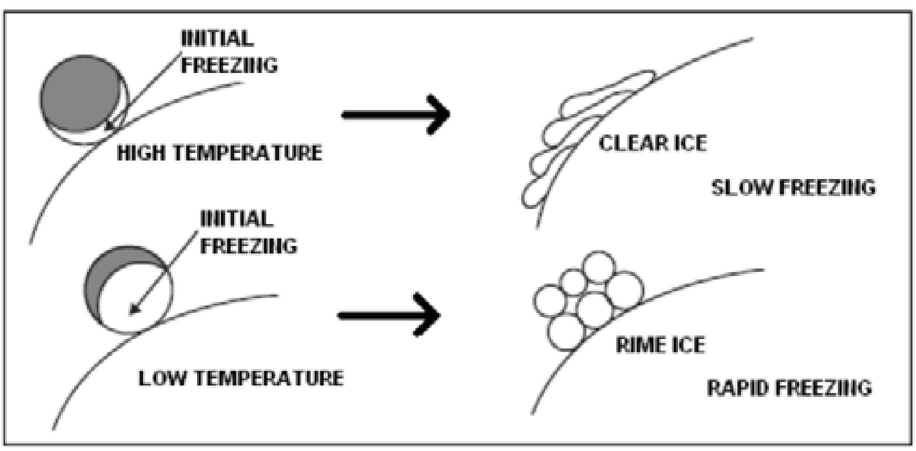
ICING

When an airplane flies at an altitude where the outside air temperature is at or below freezing and strikes a supercooled water droplet, the droplet will freeze and adhere to the airplane. This can occur in cloud, freezing rain, or freezing drizzle. Icing can also occur in clear air through sublimation.

Types of Icing

There are three main types of icing:

- clear ice,
- rime ice, and
- frost.



Clear ice is a heavy coating of glassy ice which forms when flying in dense cloud or freezing rain. It forms when only a small part of the supercooled water droplet freezes on impact, with the rest of the droplet spreading out and freezing slowly. Clear ice is the most dangerous form of icing because of the following:

- loss of lift due to the altered camber of the wing,
- increase in drag due to the enlarged profile area of the wings,
- increase in weight due to the large mass of ice, and
- the vibration caused by the unequal loading on the wings and propeller blades.

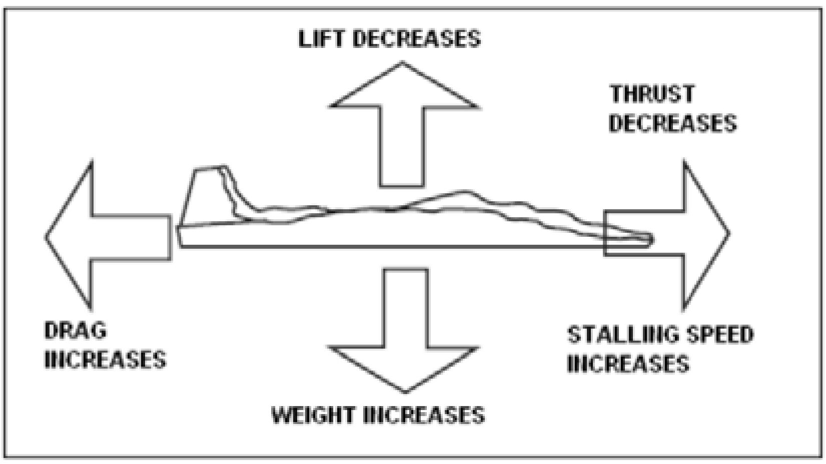
Rime ice is an opaque (milky white) deposit of ice. Rime ice forms when the aircraft skin is at a temperature below zero degrees Celsius, causing the water droplet to freeze completely on contact. Although rime ice is light, it is dangerous due to the aerodynamic alteration of the wing camber and the interference it causes with the carburetor and pitot static system.

Frost is a white semi-crystalline form of icing which forms in clear air by the process of sublimation. It generally forms on two occasions:

- when a cold aircraft enters warmer and damper air during a steep descent; and
- when an aircraft parked outside on a clear cold night cools by radiation to a temperature below that of the surrounding air.

Frost should be removed before takeoff as it will reduce lift and increase the stall speed of the aircraft.

Effects of Icing

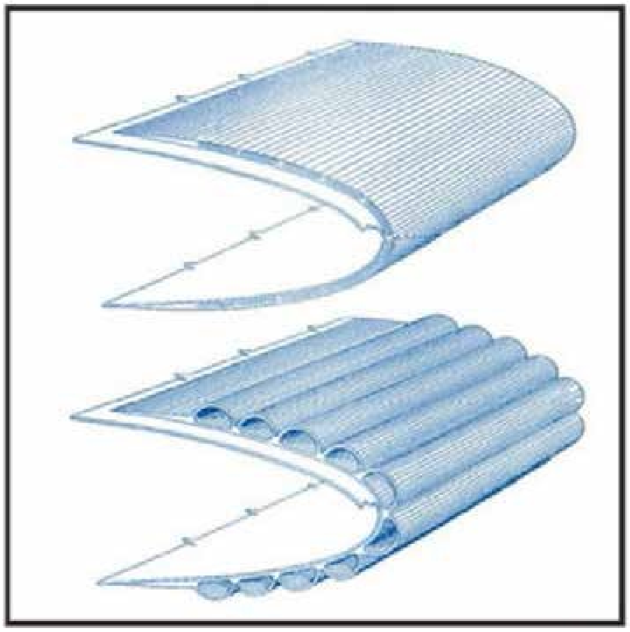


Protection From Icing

Many modern airplanes are fitted with various systems designed to prevent ice from forming or to remove ice after it has formed. Three of these systems are:

- fluids,
- rubber boots, and
- heating devices.

Fluids with a low freezing point are released over the blades of the propellers and the surfaces of the wings to prevent icing.



Heating vulnerable areas with hot air from the engine or special heaters prevents the buildup of ice.

TYPES OF TURBULENCE

Turbulence is an irregular motion of the air resulting from eddies and vertical currents. It is one of the most unpredictable of all the weather phenomena.

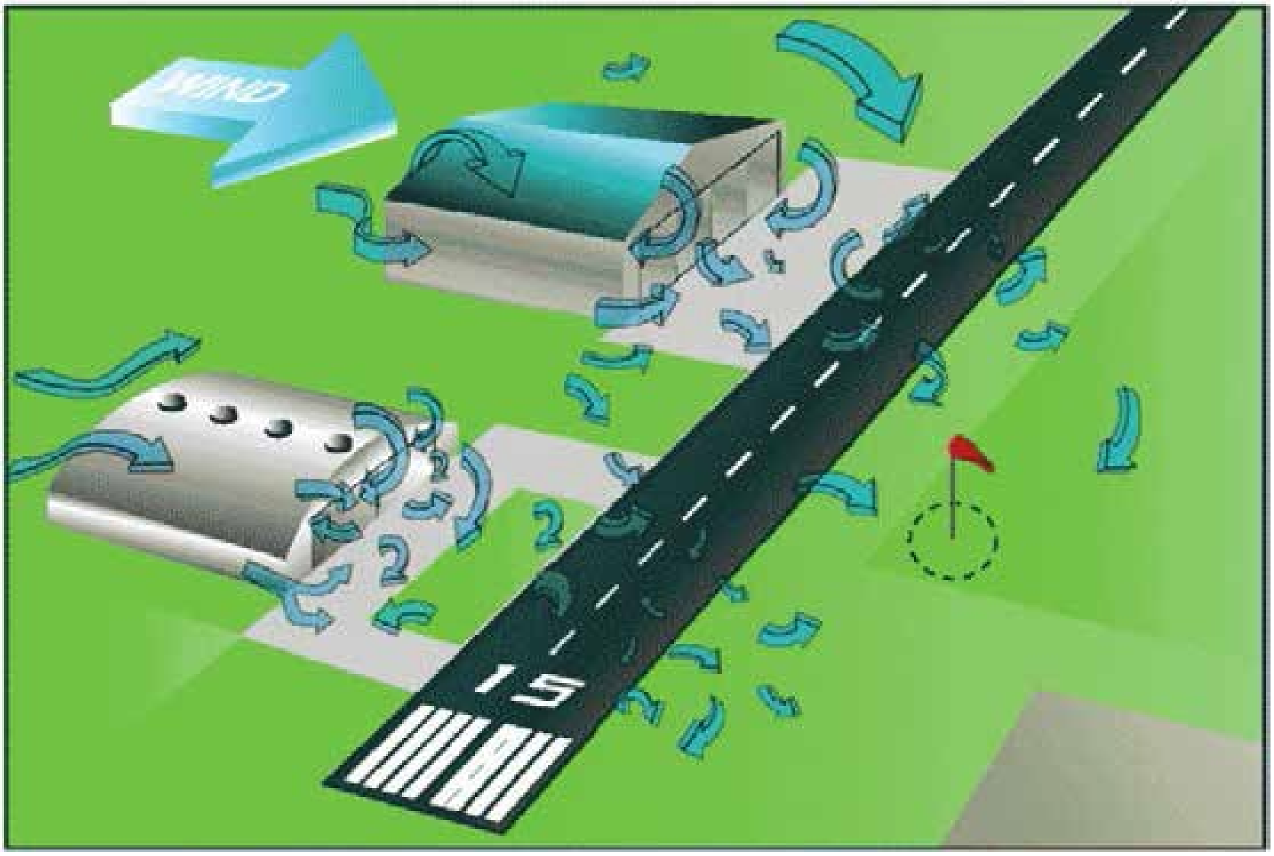
There are four types of turbulence:

- mechanical turbulence,
- thermal turbulence,
- frontal turbulence, and
- wind shear.

Mechanical Turbulence

Mechanical turbulence is caused by friction between the air and the ground. The intensity of mechanical turbulence depends on the strength of the surface wind, the nature of the terrain, and the stability of the air.

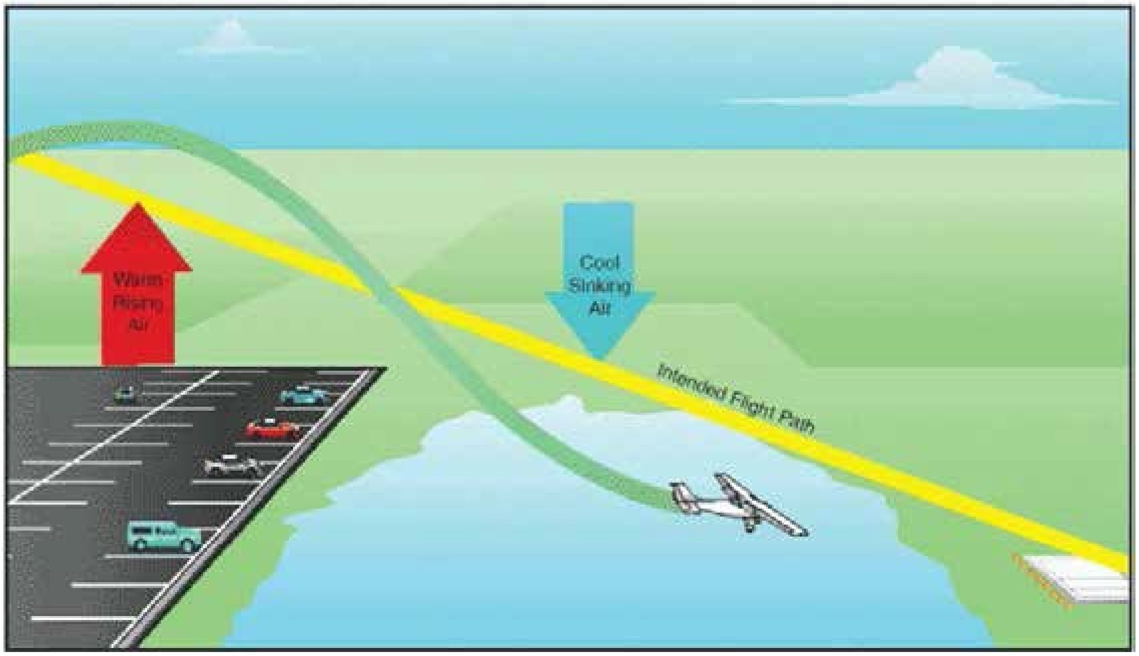
Strong winds, rough terrain, and very unstable air create greater turbulence. Mountain waves produce some of the most severe mechanical turbulence.



Thermal Turbulence

Thermal turbulence is caused by the uneven heating of the ground. Certain surfaces, such as plowed fields and pavement, are heated more rapidly than others, such as grass-covered fields and water. This causes isolated convective currents that are responsible for bumpy conditions as an airplane flies in and out of them. These convective currents can have a pronounced effect of the flight path of an airplane approaching a landing area, causing it to either overshoot or undershoot.

Rising convective currents are commonly referred to as "thermals" or "lift". Glider pilots use their knowledge of the terrain to find thermals and soar for extended periods of time. They also learn to recognize and avoid sinking convective currents (commonly known as "sink").



Frontal Turbulence

Frontal turbulence is caused by the lifting of warm air by the sloping frontal surface and the friction between the two opposing air masses. This turbulence is strongest in cold fronts, especially when the warm air is moist and unstable.

Wind Shear

Wind shear is caused when there are significant changes in wind speed and direction with height.

EO C436.03 – ANALYZE WEATHER INFORMATION

METARs

METAR is the name given to the international meteorological code used in aviation routine weather reports.

These reports describe the existing weather conditions at a specific time and location. In other words, the METAR is a snapshot of the current weather; it is not a forecast.

Frequency of Reports

METARS are normally issued every hour, on the hour as weather does not normally change much in this brief period of time. METARs are only valid at the time that they are issued, not for the hour between reports.

Special Weather Reports (SPECI)

There are times when the weather changes drastically in a short period of time. When this happens a SPECI is issued. SPECIs use the same code as a METAR, but start with SPECI.

Where METARs are Available

METARs can be found at several locations. The three most common locations are:

- NAV CANADA's aviation weather website,
- a Flight Services Station (FSS), and
- a Flight Information Centre (FIC) (normally accessed by phone).

SAMPLE METARs AND SPECIs

METAR CYHZ 111700Z 28009G16KT 15SM FEW250 00/M11 A2990 RMK CS0 SLP134=
METAR CYHZ 111800Z 29015KT 15SM FEW250 01/M10 A2989 RMK CI0 SLP128=
METAR CYHZ 111900Z 30008KT 15SM FEW250 02/M12 A2987 RMK CI0 SLP123=
SPECI CYYJ 111744Z CCA 23019G24KT 20SM -SHRA BKN014 BKN030 BKN120 09/07 RMK SC5SC1AC1=
SPECI CYYJ 111744Z 23019G24KT 20SM -RA BKN014 BKN030 BKN120 09/07 RMK SC5SC1AC1=

METAR is a code used in aviation weather reporting. This code is based on the World Meteorological Organization's (WMO) standards and conventions. A METAR is organized into sections with each section always in the same order.

Report Type
The report name is in the first line of the text. The name will show as either METAR or SPECI.

Location Indicator

Each weather reporting station in Canada is assigned a four-letter identifier, starting with the letter C. The second letter indicates the type of station and the last two letters identify the specific reporting station.

For example, CYOW is the reporting station at Ottawa / MacDonald-Cartier International Airport. The C means the station is Canadian, the Y means the station is co-located with an airport, and OW is the airport identifier.

Date and Time of Observation

The date and time of the observation are given as a six-digit grouping, based on Coordinated Universal Time (UTC / ZULU / Z). The first two digits signify the day of the current month, while the last four digits signify the time of the day. The official time of the observation is given for all METAR reports that do not deviate more than 10 minutes from the top of the hour. SPECIs will have the time reported to the exact minute.

For example, a METAR will show as 091000Z which means that the observation was taken on the ninth day of the month at 1000 hours UTC (or within 10 minutes of that hour).

For example, a SPECI will show as 091036Z, which means that a significant change in weather was observed on the ninth day of the month at 1036 hours UTC.

Report Modifier

This field may contain two possible codes: AUTO or CC* (where * is a letter from A–Z which represents corrections). AUTO indicates that the report is primarily based on observations from an automated weather observation station (AWOS). CC* is used to indicate corrected reports, where the first correction is CCA, the second is CCB, and so on. Both AUTO and CC* may be found in the same report.

Wind

This group reports the two-minute average wind direction and speed. Direction is always three digits, given in degrees true but rounded off to the nearest 10 degrees. Speed is normally two digits, and is given in knots (nautical miles per hour or kt). A reading of 00000KT indicates calm winds.

For example, 35016KT means winds are from 350 degrees true (rounded off) at 16 knots. If gust conditions exist, the direction and speed will be followed by a G and the maximum gust strength. A gust must be five knots stronger than the 10-minute average wind speed.
For example, 35016G25KT means winds are from 350 degrees true at 16 knots gusting to 25 knots.

Prevailing Visibility

Prevailing visibility is the average visibility at the reporting station. The prevailing visibility is reported in statute miles (SM) or fractions of a statute mile.

For example, 3SM means the prevailing visibility is 3 statute miles.

Runway Visual Range

This is only included if the prevailing visibility is less than 1 SM, or the runway visual range is less than 6 000 feet. This group will start with an R, then the runway number (eg, 06) and position (eg, L for left, R for right, C for centre), followed by the runway visual range in hundreds of feet. This is based on a 10-minute average. The runway visual range trend is indicated if there is a distinct upward or downward trend from the first to the second five-minute part-period. If the runway visual range changes by 300 feet or more it is indicated as /U for an upward trend or /D for a downward trend. No distinct change is indicated as /N. If it is not possible to determine the trend it will be left blank.

For example, R06L/4000FT/D means the runway visual range for runway 06 left is 4 000 feet with a downward trend.

Present Weather

This group indicates the current weather phenomena at the reporting station. This may include precipitation, obscuration, or other phenomena.

Each phenomenon is represented by a code, which may be two to nine characters in length. Each code may include one or both of the following prefixes:

- **Intensity.** (-) indicates light, (+) indicates heavy, and no symbol indicates moderate.
- **Proximity.** Used primarily with precipitation or tornadoes. VC will precede certain phenomena, meaning that they are in the vicinity (5 SM) of the station, but not actually at the station.

For example, VCFZRABLSN+SNVA means in the vicinity of the airport there is freezing rain, blowing snow, heavy snow, and volcanic ash.

Sky Conditions

This group reports the sky condition for layers aloft. The group will include how much of the sky is covered, measured in oktas (eighths of the sky) and the height of the clouds in hundreds of feet above ground level (AGL). The sky cover is represented by the following abbreviations:

- **SKC.** Sky clear, no cloud present.
- **FEW.** Few, greater than zero to two-eighths cloud cover.
- **SCT.** Scattered, three-eighths to four-eighths cloud cover.
- **BKN.** Broken, five-eighths to less than eight-eighths cloud cover.
- **OVC.** Overcast, eight-eighths cloud cover.
- **CLR.** Clear, clear below 10 000 feet AGL.

Cloud height is represented by a three-digit number, which when multiplied by one hundred equals the actual height AGL. There will be one entry for every layer of cloud.
For example, SCT025 means scattered cloud at 2 500 feet AGL.

Temperature and Dewpoint

This group reports the air temperature and dewpoint temperature, rounded to the nearest whole degree Celsius. A negative value will be preceded by an M. A forward slash (/) will separate the two values.

For example, M05/M08 means the temperature is minus five degrees Celsius and the dewpoint is minus eight degrees Celsius.

Altimeter Setting

This group reports the altimeter setting at the reporting station in inches of mercury. The group starts with an A followed by four digits, which directly relate to the actual value of the altimeter setting. Place a decimal after the second digit in order to read this group.

For example, A3006 means the altimeter setting is 30.06 inches of mercury.

Recent Weather

This group reports recent weather of operational significance. The group indicator RE follows without a space, by the appropriate abbreviation(s) for weather observed during the period since the last METAR or SPECI, but not observed at the time of observation.

For example, RE+PL means although not observed now, there were heavy ice pellets recently reported.

Wind Shear

This group reports low level wind shear (within 1 600 feet AGL) along the takeoff or approach path of the designated runway. The two-number runway identifier is used, to which the letters L, C, or R may be appended. If the existence of wind shear applies to all runways, WS ALL RWY is used.

Remarks

This group will usually include cloud types in each layer as well as opacity, general weather remarks, and sea level pressure measured in hectopascals (hPa). The sea level pressure will always be the last entry in a METAR, prefaced by SLP. Sea level pressure is translated by placing the decimal point between the last two digits and either adding a 9 or a 10 in front of the value given. The goal is to make the number as close to 1 000 as possible.

For example, SLP123 means sea level pressure is 1012.3 hPa.

For example, SLP998 means sea level pressure is 999.8 hPa.

TAFs

TAF is the name given to the international meteorological code for an aerodrome forecast. These forecasts describe the expected weather conditions that will affect takeoff and landing at the aerodrome.

Issue and Validity

TAFs are prepared for approximately 180 aerodromes across Canada. They are limited to aerodromes for which METAR and SPECI reports are available. TAFs are generally prepared four times daily with periods of coverage from 12–24 hours. A TAF is valid from the time of issue until it is amended or until the next scheduled TAF is issued.

Where TAFs are Available

TAFs can be found at several locations. The three most common locations are:

- NAV CANADA's aviation weather website,
- a Flight Services Station (FSS), and
- a Flight Information Centre (FIC) (normally accessed by phone).

TERMINOLOGY USED IN TAFs

SAMPLE TAFs

TAF CYHZ 201738Z 2018/2118 25008KT P6SM OVC015
TEMPO 2018/2020 OVC025
FM202000 24010KT P6SM OVC025 TEMPO 2020/2022 OVC020
FM202200 23012KT P6SM BKN030
FM210200 23010KT P6SM SCT030
RMK NXT FCST BY 202100Z=
TAF CYVR 201739Z 2018/2124 10012G22KT P6SM -RA SCT025
OVC050 TEMPO 2021/2103 5SM -RA BR BKN020
BECMG 2021/2022 14012G22KT
BECMG 2101/2102 28020G30KT
FM210300 28020G30KT P6SM FEW030 SCT060
BECMG 2103/2104 26012KT
FM210800 11005KT P6SM -SHRA BKN030
BECMG 2110/2112 14010G20KT
FM211600 12012G22KT 5SM -RA BR SCT008 BKN012
RMK NXT FCST BY 202100Z=
TAF CYYG 201738Z 2018/2106 25012KT P6SM FEW009 OVC015
TEMPO 2018/2020 6SM -SHSN BKN009
FM202300 24012KT P6SM BKN025 TEMPO 2023/2102 BKN020
FM210200 26008KT P6SM SCT025 TEMPO 2102/2106 BKN025
RMK NXT FCST BY 210000Z=
TAF CYOW 201738Z 2018/2118 34012KT P6SM BKN040
FM202200 31005KT P6SM FEW050 SCT100
FM211600 31012KT P6SM BKN030
RMK NXT FCST BY 202100Z=

A TAF is organized into sections with each section always in the same order.

Report Type

The code name TAF is given in the first line of text. It may be followed by “AMD” for amended or corrected forecasts.

Location Indicator

A four-letter International Civil Aviation Organization (ICAO) location indicator is used, as in the METAR.

Date and Time of Origin

As with the METAR format, the day of the month and time (UTC) of origin are included in all forecasts. TAFs are issued approximately 30 minutes before the validity period. Some forecasts have update cycles as frequent as every three hours; however, the next issue time will always be indicated in the remarks group.

Period of Validity

The period of validity for the TAF is indicated by two four-digit date / time groups. The first four-digit group indicates the start date and time of the TAF, and the second four-digit group indicates the end date and time of the TAF. The maximum validity period for a TAF is 30 hours; however, some TAFs have staggered issue times and more frequent update cycles, which will affect their periods of validity.

Wind

The forecasted wind direction and speed are encoded as in a METAR.

Low-Level Wind Shear

This group is used if the forecaster has strong evidence to expect significant, non-convective wind shear that could adversely affect aircraft operation within 1 500 feet AGL over the aerodrome. The coded grouping begins with the letters WS followed by a three-digit grouping indicating the height in hundreds of feet AGL of the shear zone. A slash followed by a five-digit group indicates the wind speed and direction at that height.

For example, WS 015/20015KT means wind shear is forecast at 1 500 feet AGL over the aerodrome. The wind will be from 200 degrees true at 15 knots
.

Prevailing Visibility

The prevailing visibility is encoded as in a METAR, except that visibility greater than six statute miles will be indicated by the code P6SM.

For example, 3/4SM means the visibility is forecast to be 3/4 statute mile.

Significant Weather

Significant weather is encoded with the same codes as present weather in METARs. Intensity and proximity qualifiers, descriptors, precipitation, and obscuration are included as required.

For example, -RA BR means light rain and mist.

Sky Condition

Sky condition is encoded as in a METAR. Possible codes for sky cover amounts are SKC, FEW, SCT, BKN, OVC, CLR, and VV. A vertical visibility (VV) is reported in hundreds of feet when the sky is obscured. Forecast cloud type is not identified except in the case of cumulonimbus layers.

For example, BKN040CB means broken cumulonimbus cloud at 4 000 feet.

Change Groups

There are four change groups:

- FM (from),
- BECMG (becoming),
- TEMPO (temporarily), and
- PROB (probability).

FM. Indicates the weather is forecast to change permanently and rapidly. All forecast conditions given before this group are superseded by the conditions indicated after the group. In other words, a complete forecast will follow and all elements must be indicated, including those for which no change is forecast. The time group represents hours and minutes in UTC.

For example, FM280945 means from the 28th day of the month at 0945Z.

BECMG. Used when a permanent change in a few weather elements is forecast to occur gradually, with conditions evolving over a period of time (normally one to two hours, but not more than four hours). Normally only those elements for which a change is forecast to occur will follow BECMG. Any forecast weather element not indicated as part of the BECMG group remains the same as the period prior to the change.

The start and stop time of the change period is indicated by two four-digit date / time groups following BECMG.

The first two digits of each group indicate the date, while the last two digits of each group indicate the time in whole UTC hours.

For example, BECMG 2808/2809 OVC030 means a change towards overcast sky conditions at 3 000 ft AGL occurring gradually between 0800Z and 0900Z on the 28th day of the month
.

TEMPO. Used when a temporary fluctuation in some or all of the weather elements is forecast to occur during a specified period. When an element is not indicated after TEMPO, it is the same as the period prior to the change. The time period is indicated the same as with BECMG.

For example, TEMPO 2812/2815 1SM RA BR means temporarily between 1200Z and 1500Z on the 28th day of the month, visibility is forecast to be one statute mile with rain and mist.

PROB. Used to indicate a 30 or 40 percent probability of changing conditions that would constitute a hazard to aviation, such as thunderstorms, freezing precipitation, and low-level wind shear. The time period is indicated the same as with BECMG and TEMPO.

For example, PROB30 2817/2821 1/2SM +TSRAGR means there is a 30 percent probability between 1700Z and 2100Z on the 28th day of the month that visibility will be 1/2 statute mile with heavy thunderstorms, rain, and hail.

Remarks
Remarks will be prefaced by the abbreviation RMK. Remarks may include such information as when a TAFis based on observations taken by an Automated Weather Observation System (AWOS), and when there aresignificant discrepancies between the AWOS and a TAF. Remarks will indicate the issue date and time (UTC)of the next regular TAF.

FDs

SAMPLE FDS

STN YNA - NATASHQUAN. QUEBEC	for use	3000	6000	9000	12000	18000
FDCN01 CWAO FCST BASED ON 271200 DATA **VALID 271800**	**17-21**	2130	2129+05	2131+03	2140-03	2158-11
FDCN02 CWAO FCST BASED ON 271200 DATA **VALID 280000**	**21-06**	1916	1917+06	2023+03	2130-02	2152-11
FDCN03 CWAO FCST BASED ON 271200 DATA **VALID 281200**	**06-17**	1635	1633+05	1929+03	1936+00	1838-11

STN YQI - YARMOUTH. NS	for use	3000	6000	9000	12000	18000
FDCN01 CWAO FCST BASED ON 271200 DATA **VALID 271800**	**17-21**	1616	1919+10	1936+05	1934+00	2043-10
FDCN02 CWAO FCST BASED ON 271200 DATA **VALID 280000**	**21-06**	1842	1843+11	1843+06	1842+00	1842-10
FDCN03 CWAO FCST BASED ON 271200 DATA **VALID 281200**	**06-17**	1451	1551+10	1537+04	1651+00	1865-08

STN YQI - YARMOUTH. NS	for use	24000	30000	34000	39000	45000	53000
FDCN01 KWBC DATA BASED ON 271200Z **VALID 271800Z**	**1700-2100Z.**	2145-24	225139	225248	206558	215363	213964
FDCN02 KWBC DATA BASED ON 271200Z **VALID 280000Z**	**2100-0600Z.**	2043-23	215140	215149	214558	215062	213864
FDCN03 KWBC DATA BASED ON 271200Z **VALID 281200Z**	**0600-1700Z.**	1855-23	195738	205047	226656	216062	204264

An FD is an forecast of upper wind conditions and temperatures at selected levels. Wind direction is given in degrees true to the nearest ten degrees and wind speed is in knots.

When the forecast speed is less than five knots, the code group is 9900, which reads light and variable. Encoded wind speeds from 100–199 knots have 50 added to the direction code and 100 subtracted from the speed. Wind speeds that have had 50 added to the direction can be recognized when figures from 51–86 appear in the code. Since no such directions exist (eg, 510 degrees to 860 degrees), obviously they represent directions from 010 degrees to 360 degrees. Should the forecast wind speed be 200 knots or greater, the wind group is coded as 199 knots.

For example, 7799 is decoded as 270 degrees at 199 knots or greater.

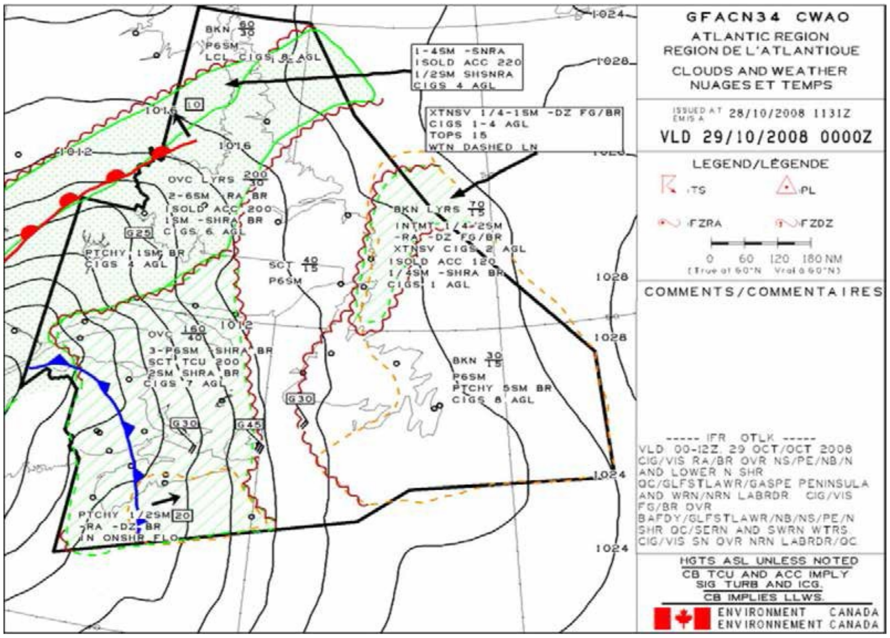
Examples of decoding FD winds and temperatures are as follows (the third and fourth examples are for altitudes above 24 000 feet):

EXAMPLE	DECODED
9900+00	Wind light and variable. Temperature zero degrees Celsius.
2523	Wind 250 degrees true at 23 knots.
791159	Wind 290 degrees true (79 - 50 = 29) at 111 knots (11 + 100 = 111). Temperature minus 59 degrees Celsius.
859950	Wind 350 degrees true (85 - 50 = 35) at 199 knots or greater, temperature minus 50 degrees Celsius.

FDs can be found at several locations. The three most common locations are:

- NAV CANADA's aviation weather website,
- a Flight Services Station (FSS), and
- a Flight Information Centre (FIC) (normally accessed by phone).

GFAs



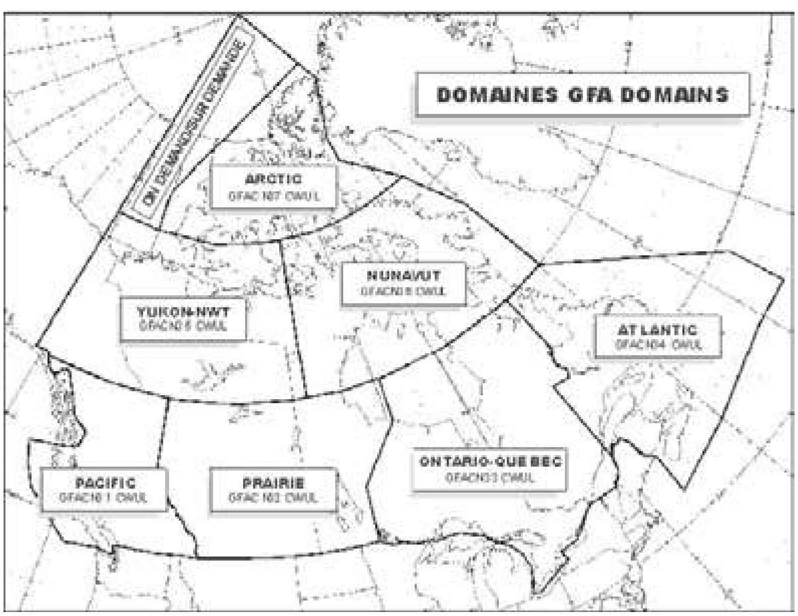
A GFA consists of a series of weather charts, each depicting the most probable meteorological conditions expected to occur below 24 000 feet, over a given area at a specified time.

Issue and Validity

GFA charts are issued four times daily, approximately 30 minutes before the beginning of the forecast period. GFAs are issued at approximately 2330, 0530, 1130, and 1730 UTC and are valid at 0000, 0600, 1200, and 1800 UTC respectively.

Coverage Area

There are seven distinct GFA areas covering the entire Canadian Domestic Airspace.



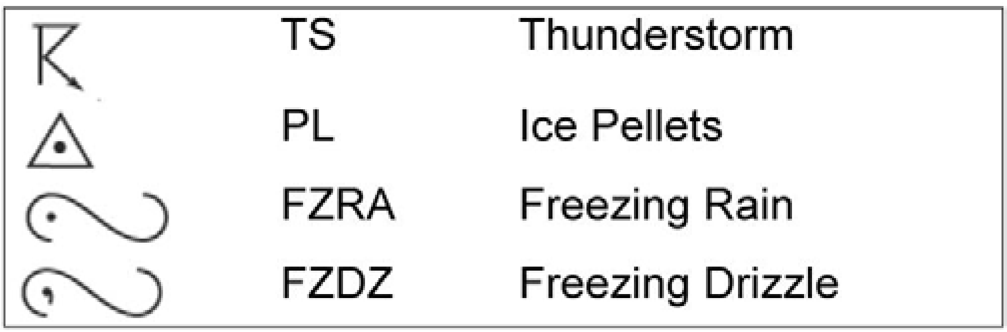
Units of Measure

Speeds in a GFA are expressed in knots (kt). Horizontal visibility is measured in statute miles (SM).

Times are stated in Co-ordinated Universal Time (UTC). A nautical-mile (NM) scale bar is included to assist in determining approximate distances on the chart. All heights are measured in hundreds of feet above sea level (ASL) unless otherwise noted.

Abbreviations and Symbols

Only standard meteorological abbreviations are used in a GFA. Figure 3 is a list of common weather symbolsthat may be found in a GFA.



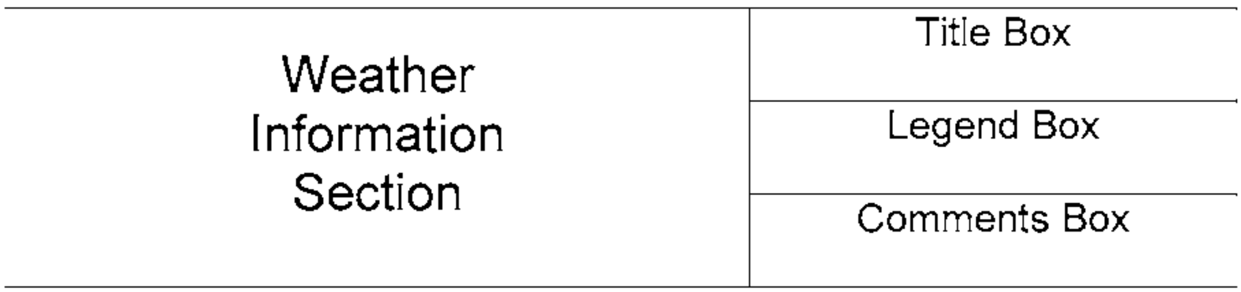
Where GFAs are Available

GFAs can be found at several locations. The three most common locations are:

- NAV CANADA's aviation weather website,
- a Flight Services Station (FSS), and
- a Flight Information Centre (FIC) (normally accessed by phone).

GFA CLOUDS AND WEATHER CHART LAYOUT

Each GFA chart is divided into four parts: title box, legend box, comments box, and weather information section.



Title Box

The title box includes the chart name, issuing office four-letter identification, name of the GFA region, chart type, the date and time of issue, and the validity period.

Legend Box

The legend box includes weather symbols that may be used in the weather information part of the GFA chart. It also includes a nautical-mile scale bar to facilitate determining distances.

Comments Box

The comments box provides information that the weather forecaster considers important (eg, formation or dissipation of fog, increasing or decreasing visibility). It is also used to describe elements that are difficult to render pictorially or, if added to the depiction, would cause the chart to become cluttered (eg, light icing). The following standard phrases are also included in the comments box:

- HGTS ASL UNLESS NOTED,
- CB TCU AND ACC IMPLY SIG TURB AND ICG, and
- CB IMPLIES LLWS.

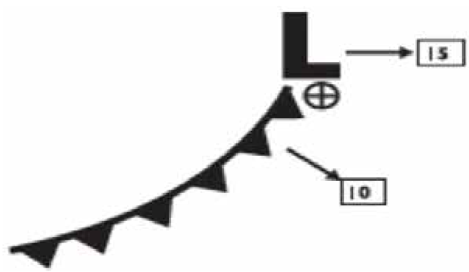
The comments box of the 12-hour GFA Clouds and Weather Chart also includes an Instrument Flight Rules (IFR) outlook for an additional 12-hour period in the lower section of the box. The IFR outlook is always general in nature, indicating the main areas where IFR weather is expected, the cause for the IFR weather, and any associated weather hazards.

Weather Information Section

The weather information section of the chart depicts a forecast of the clouds and weather conditions.

Synoptic features. The motion of synoptic features, when the speed of movement is forecast to be five knots or more, will be indicated by an arrow and a speed value. For speeds less than five knots, the letters QS (quasistationary) are used.

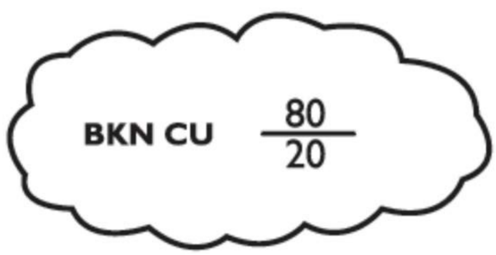
For example, a low pressure centre moving eastwards at 15 knots with an associated cold front moving southeast at 10 knots would be indicated as follows:



Clouds. The bases and tops of forecast clouds between the surface and 24 000 feet ASL will be indicated. The tops of convective clouds (eg, TCU, ACC, CB) are indicated, even if they extend above 24 000 feet ASL. Cirrus clouds are not depicted on the chart. The cloud type will be indicated if considered significant, however, convective clouds such as CU, TCU, ACC, and CB will always be stated when forecast to be present.

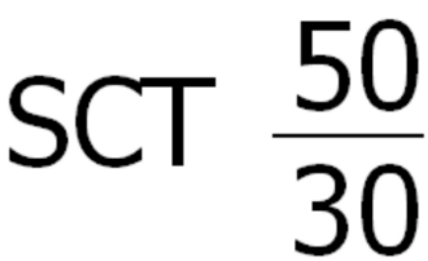
A scalloped border encloses organized areas of clouds where the sky condition is either broken (BKN) or overcast (OVC).

For example, an organized area of broken cumulus clouds based at 2 000 feet ASL with tops at 8 000 feet ASL would be indicated as follows:



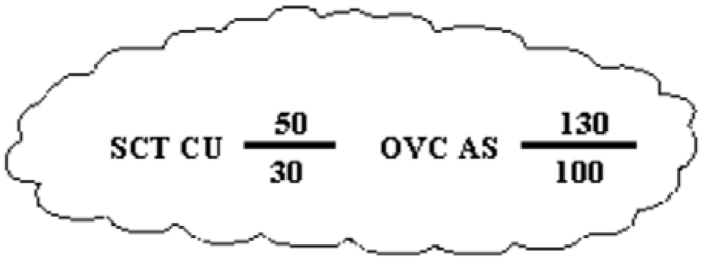
In areas where organized clouds are not forecast and the visibility is expected to be greater than six statute miles a scalloped border is not used.

For example, unorganized scattered clouds based at 3 000 feet ASL with tops at 5 000 feet ASL would be indicated as follows:



When multiple cloud layers are forecast, the bases and tops of each layer are indicated.

For example, a scattered layer of cumulus cloud based at 3 000 feet ASL with tops at 5 000 feet ASL and a higher overcast layer of altostratus cloud based at 10 000 feet ASL with tops at 13 000 feet ASL would be indicated as follows:



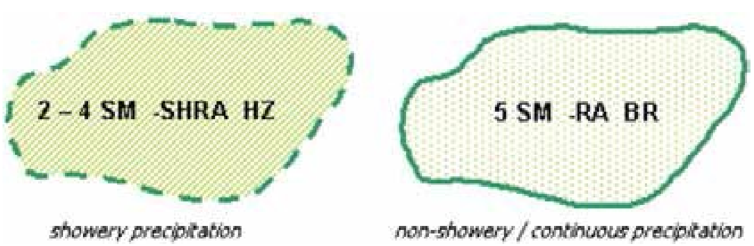
Surface-based layers. The abbreviation OBSCD (obscured) is used to describe surface-based layers. The vertical visibility in surface-based layers is measured in hundreds of feet AGL.

For example, local obscured ceilings with a vertical visibility between 300 and 500 feet AGL would be indicated as: LCL OBSCD CIG 3 - 5 AGL.

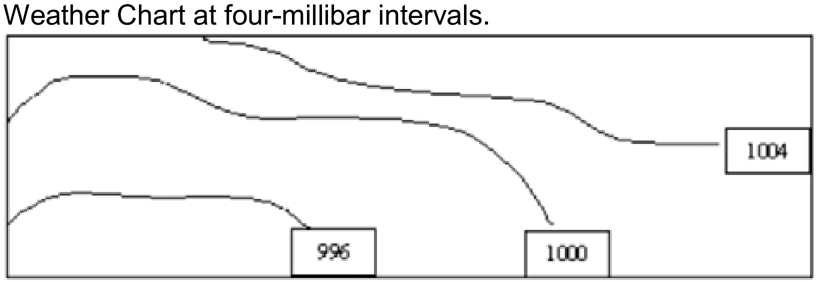
Visibility. The forecast visibility is measured in statute miles. When the visibility is expected to be greater than six statute miles, it is indicated as P6SM.

For example, a forecast visibility that is expected to vary between two and four statute miles with light rain showers would be indicated as: 2 - 4 SM - SHRA.

Weather and obstructions to vision. Forecast weather is always included immediately after the visibility. Obstructions to vision are only mentioned when the visibility is forecast to be six statute miles or less (eg, 2 - 4SM - RA BR). Areas of showery or intermittent precipitation are shown as hatched areas enclosed by a dashed green line. Areas of continuous precipitation are shown as stippled areas enclosed by a solid green line. Areas of obstruction to vision not associated with precipitation, where visibility is six statute miles or less, are enclosed by a dashed orange line. Areas of freezing precipitation are depicted in red and enclosed by a solid red line.



Isobars. Lines joining points of equal surface pressure. They are included in the GFA Clouds and Weather Chart at four-millibar intervals.



Surface winds. The speed and direction of forecast surface winds with a sustained speed of at least 20 knots are indicated by wind barbs and an associated wind speed value. Wind gusts are indicated by the letter G, followed by the peak gust speed in knots.

For example, surface winds forecast to be from the west (270 degrees true) with a speed of 25 knots and a peak gust speed of 35 knots would be indicated as:

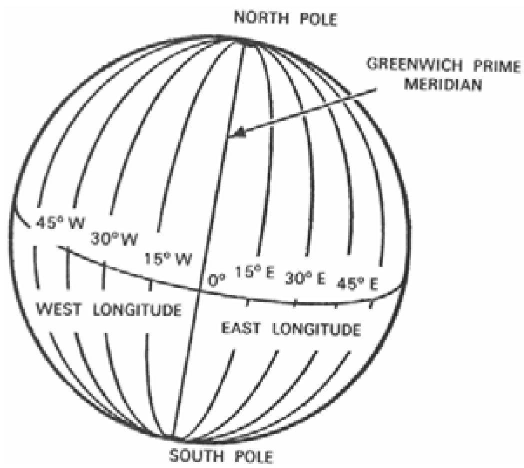
Level 4 Study Notes

EO M437.01 – DEFINE AIR NAVIGATION TERMS

MERIDIANS OF LONGITUDE

Meridians of longitude. Semicircles joining the true / geographic poles of the Earth. Longitude is measured from 0–180 degrees east and west of the prime meridian. The prime meridian is the meridian which passes through Greenwich, England and is numbered zero degrees. The meridian on the opposite side of the Earth to the prime meridian is the 180th and is called the international date line (the time changes a day).

Longitude is measured in degrees (°), minutes ('), and seconds ("). There are 60 minutes in a degree and 60 seconds in a minute.

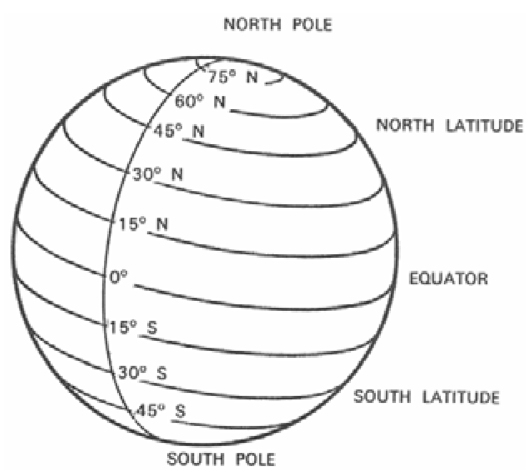


PARALLELS OF LATITUDE

Parallels of latitude. Circles on the Earth's surface that lie parallel to the equator.

Equator. An imaginary line on the surface of the Earth equidistant from the poles.

Latitude is measured from 0–90 degrees north and south of the equator, which is numbered zero degrees. Like longitude, latitude is measured in degrees, minutes, and seconds.



GEOGRAPHICAL CO-ORDINATES

Geographical co-ordinates. The intersection of lines of latitude and longitude. Geographical co-ordinates mark the position of places (eg, cities, towns, airports) on a chart.

On a chart, there are black lines representing longitude and latitude, every 30 minutes. Small marks represent 1 minute. There are slightly larger marks for 5 minute and 10 minute increments.

Co-ordinates express latitude first, in degrees north or south of the equator and longitude second, in degrees east or west of the prime meridian. For example, the geographical coordinates of the military airport at Trenton, Ont. are 44°07' N, 77°32' W.

THE RELATIONSHIP BETWEEN TIME AND LONGITUDE

The Earth rotates about its axis as it revolves in an elliptical orbit around the Sun. This creates the illusion that the Sun is revolving around the Earth. The time between one apparent passage of the Sun over a meridian of longitude is called an apparent solar day and varies throughout the year. To provide a convenient method of measuring time, it has been averaged to a mean solar day, divided into 24 hours. During the mean solar day, the Sun is assumed to travel once around the Earth, thereby travelling through 360 degrees of longitude.Hence, mean time can be expressed in terms of longitude and vice versa.

For example:

- 24 hours = 360 degrees of longitude
- 1 hour = 15 degrees of longitude
- 1 minute = 15 minutes of longitude
- 1 second = 15 seconds of longitude
- 360 degrees of longitude = 24 hours
- 1 degree of longitude = 4 minutes
- 1 minute of longitude = 4 seconds
- 1 second of longitude = 1/15 second

Local mean time (LMT). The mean time on any particular meridian.

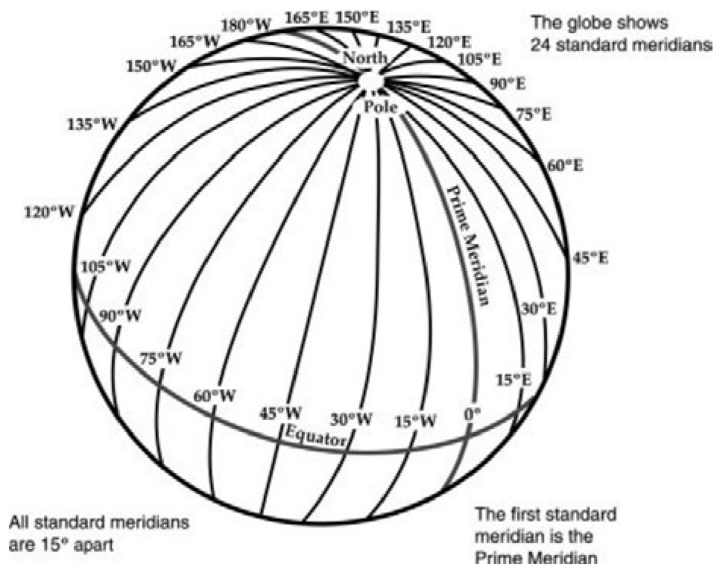
Co-ordinated universal time (UTC). An atomically measured global standard time, calculated from midnight on the zero meridian. UTC is also referred to as Zulu (Z) time.

UTC is the LMT for the prime meridian.

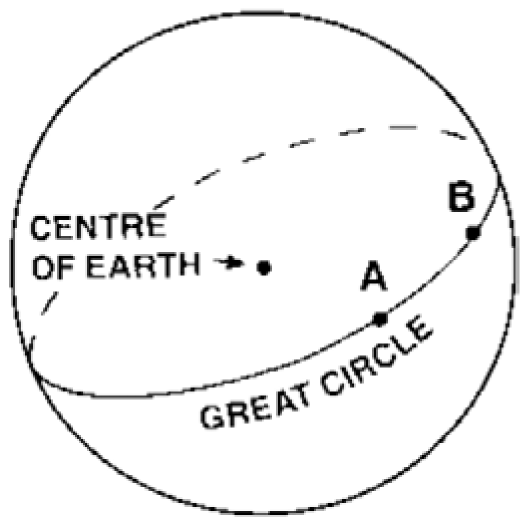
The LMT of any place east of the prime meridian is ahead of UTC. For example, 1200 hours LMT in Cairo is 1000Z.

The LMT of any place west of the prime meridian is behind UTC. For example, 1200 hours LMT in Halifax is 1600Z.

The world is divided into 24 time zones, each 15 degrees of longitude (one hour) wide. When travelling westward into a new time zone, time is turned back one hour. When travelling eastward into a new time zone, time is turned ahead one hour.



GREAT CIRCLES



Great circle. A circle on the surface of a sphere that passes through the centre of the sphere, cutting it into two equal parts

The equator is a great circle. The meridians of longitude are semi-great circles as they run from pole to pole and do not completely encircle the Earth.

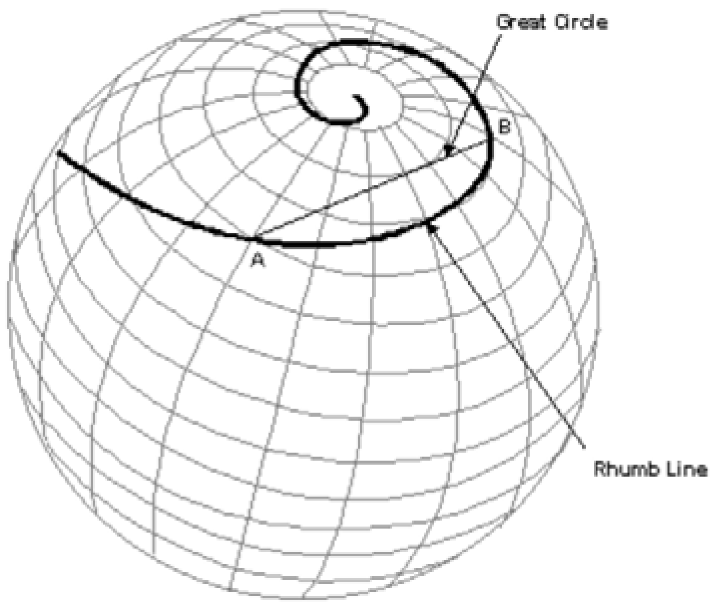
Only one great circle can be drawn through two places that are not diametrically opposite each other. Theshortest distance between these two points is the shorter arc of the great circle joining them. Therefore, mostlong-distance flights are flown over great circle routes.

A great circle does not cross the meridians it meets at the same angle. Therefore, the heading must be changedat frequent intervals to enable the airplane to maintain a great circle route.

Rhumb line. A curved line on the surface of the Earth, cutting all the meridians it meets at the same angle.

All parallels of latitude are rhumb lines. The meridians of longitude and the equator are rhumb lines as well as great circles.

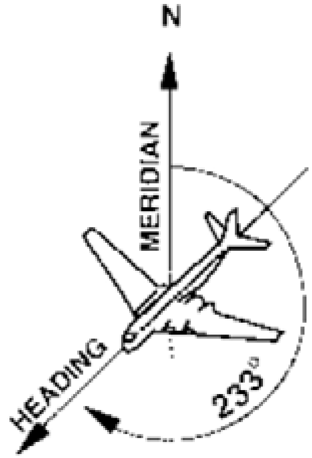
When two places are not situated on the equator or on the same meridian of longitude, the distance measured along the rhumb lines joining them will not be the shortest distance between them. The advantage of the rhumb line route is that the direction is constant, allowing a navigator to follow a constant heading.



The great circle is a straight line and the Rhumb line is a spiral curve

HEADINGS AND BEARINGS

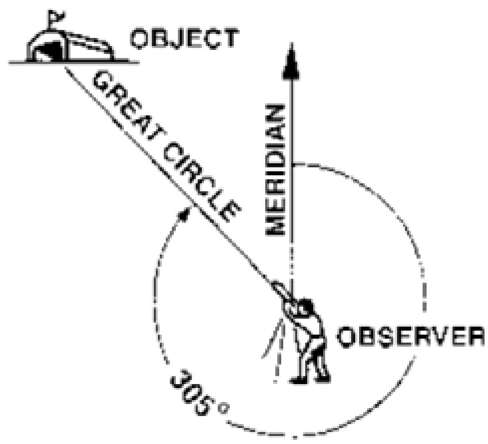
Direction is measured in degrees clockwise from north, which is zero degrees (or 360 degrees). East is 90 degrees, south is 180 degrees, and west is 270 degrees.



True heading. The angle between the meridian of longitude over which an airplane is flying and the line representing the direction the airplane's nose is pointing, measured clockwise from the meridian.

The direction of any point on the surface of the Earth from an observer is known by measuring the bearing.

Bearing. The angle between the meridian of longitude passing through the observer and the great circle that joins the observer to the object, measured clockwise from the meridian. Headings and bearings are found using a compass.



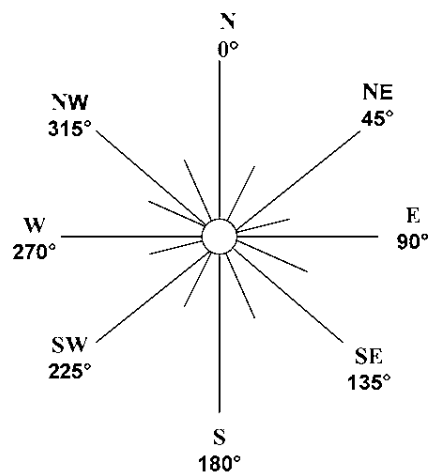
EO M437.02 – DESCRIBE THE MAGNETIC COMPASS

THE EARTH'S MAGNETISM

The Earth is a giant magnet that has a north and south pole. There are lines of force generated by currents of molten iron that flow within the Earth. The lines of force flow between the poles, creating a magnetic field that surrounds the Earth. The compass needle is affected by the lines of force, causing the magnetic needle to point to magnetic north.

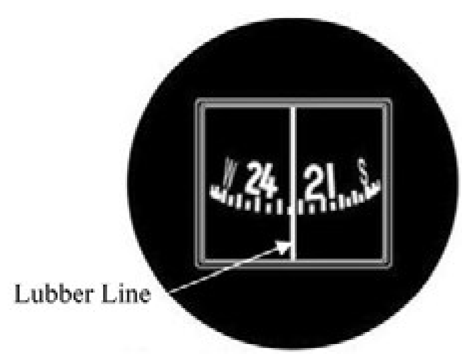
Points of a Compass Rose

The main cardinal points are north, south, east, and west. The inter-cardinal points are northeast, southeast,southwest, and northwest.



MAIN PARTS OF THE MAGNETIC COMPASS

Lubber line.
The lubber line is a painted white line that indicates the direction the airplane is heading. It is in line with or parallel to the longitudinal axis of the airplane. It is at this location that the compass card is read.



Compass card.

The compass card contains the numbers. It is attached to the pivot and moves within the compass bowl. The compass card is read at the lubber line through a window.

Compass bowl.
The compass bowl encompasses the entire compass assembly, including the liquid. The compass bowl is made of brass which is a non-magnetic material.

Pivot.
The pivot allows the compass card to rotate freely.

Magnetic needle.
The magnetic needle always points to magnetic north.

Liquid.
The compass bowl is filled with liquid to lubricate the pivot, reduce the weight of the compass card and magnets, and limit movement that may be caused by turbulence. The liquid is either alcohol or white kerosene because they are transparent and have a low freezing point and a high boiling point.

VARIATION

True north and magnetic north do not have the same location. The two poles can be located far apart because magnetic north is continuously moving at a very slow rate. This is a significant concern for navigation because geographical coordinates are based on true or geographic north whereas a magnetic compass points to magnetic north.

Variation. Variation is the angle between true north and magnetic north. It is also known as magnetic declination. This angle is taken into consideration during flight planning.

Agonic lines. Agonic lines join places of zero magnetic variation. This is to say that both the true north and magnetic north lie in a straight line relative to these places.

Isogonic lines. Isogonic lines join places of equal magnetic variation. If an observer were to move along this invisible line, the angle between true and magnetic north would remain the same.

Deviation

The magnetic compass is affected by anything metal that is in close proximity to it. When mounted in an aircraft, it is affected by the surrounding metal in the aircraft's frame and engine, as well as electrical equipment. The compass does not point to magnetic north, but is deflected slightly by the magnetic fields associated with the surrounding metal. The direction that the magnetic needle will point when affected by the running engine and working electrical equipment is unique to the aircraft. It is referred to as compass north. The angle between magnetic north and compass north is deviation.

Since deviation cannot be eliminated, the amount of deviation on a given heading is determined so that a pilot can compensate for this compass error. This occurs by swinging the compass. The aircraft is lined up on a known magnetic heading with its engine running and all electrical equipment working. The direction is read from the compass and compared to the known magnetic heading. After this is taken on many headings, a compass correction card is prepared and placed in the aircraft.

When the magnetic heading is between the headings listed on the compass correction card, interpolate (estimate) the amount of deviation by using the two nearest magnetic headings that are listed.

Magnetic Dip

The magnetic lines of force of the Earth's magnetic field are horizontal at the equator, but bend down into the poles. This causes the north-seeking end of the needle to dip towards the ground. This error is more pronounced the closer the compass is to the poles. Magnetic dip can be reduced, but not eliminated, by the design of the compass.

Northerly Turning Error

During a turn, centripetal and centrifugal forces combine with the inertial influence of the liquid in the compass bowl to affect the movement of the compass needle. This error is most apparent on north and south headings. The amount of the error is greatest over the poles and the least over the equator.

Acceleration and Deceleration Errors

Acceleration or deceleration of the aircraft affects the magnetic compass and the inertia causes a turning moment when the aircraft is on an east or west heading. Once the airspeed has stabilized, the compass will again read correctly.

EO C437.02 – USE A VISUAL FLIGHT RULES (VFR) NAVIGATION CHART (VNC)

Types of projections.

Earth is a sphere, so its surface cannot be represented accurately on a flat plane. Therefore, a map shows a portion of the Earth's surface with some distortion. There are four basic elements in map construction:

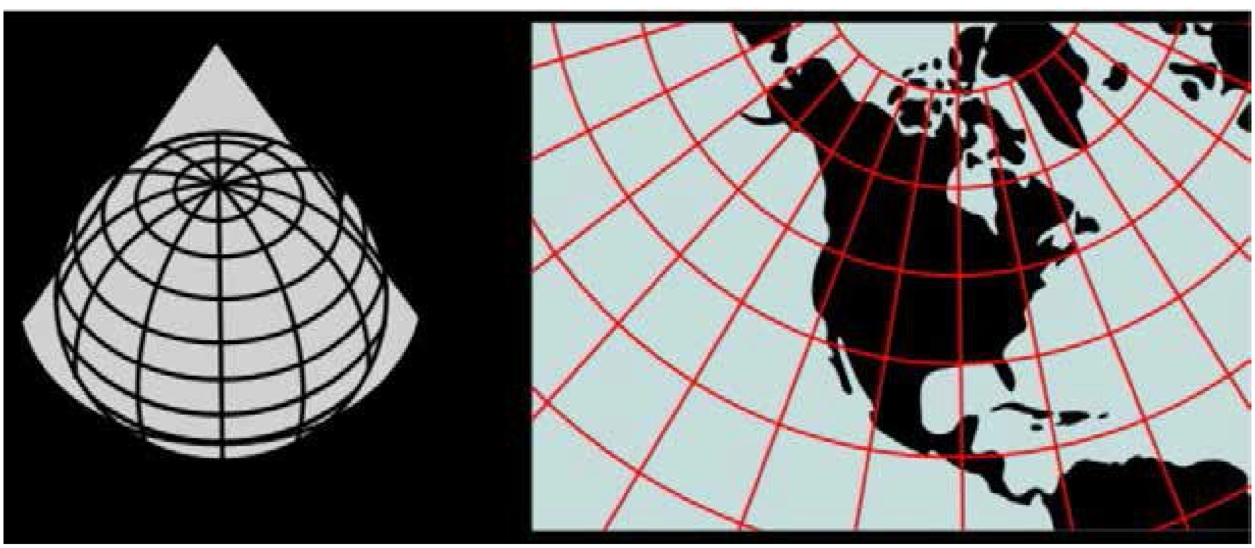
- areas,
- shapes,
- bearings, and
- distances.

Depending on the particular purpose of the map, one or more of these elements is preserved with minimal distortion, with the most distortion in the remaining elements.

The two principal types of chart projections used in air navigation charts are:

- the Lambert Conformal Conic Projection, and
- the Transverse Mercator Projection.

THE LAMBERT CONFORMAL CONIC PROJECTION



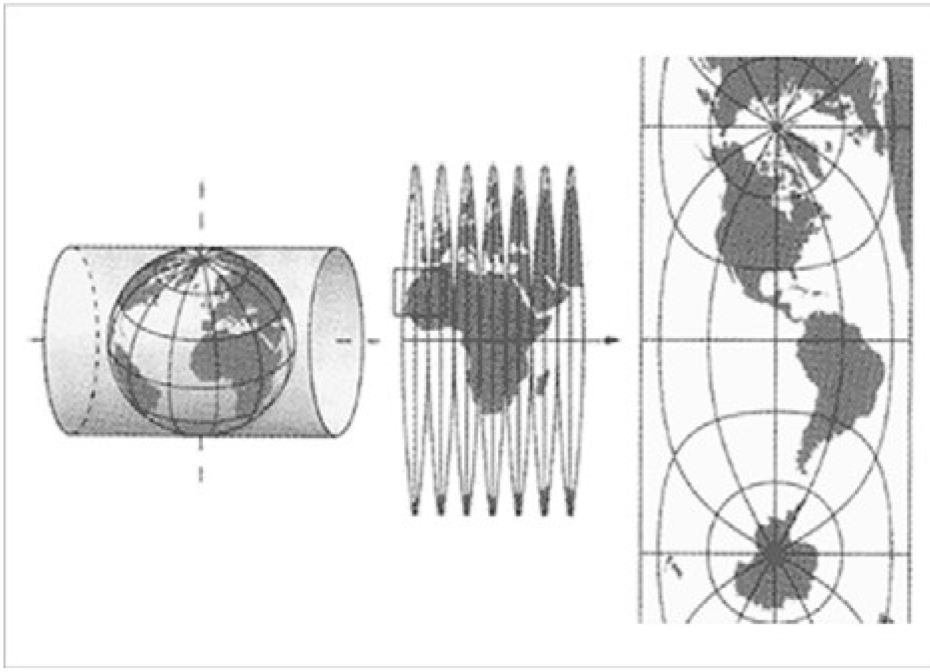
The properties of the Lambert Conformal Conic Projection are:

- Meridians of longitude are slight curves or straight lines converging toward the nearer pole.
- Parallels of latitude are curves which are concave toward the nearer pole.
- The scale of distance is uniform throughout the entire chart.
- A straight line drawn between any two points on the chart represents an arc of a great circle.

VNCs and World Aeronautical Charts (WACs) are examples of Lambert Conformal Conic Projections.

The Transverse Mercator Projection.

Applies the Mercator technique by rotating the cylinder 90 degrees so the point of tangency is a meridian of longitude rather than the equator. This projection is accurate in depicting scale, especially on charts covering a relatively small geographical area. The VFR Terminal Area (VTA) Charts are examples of Transverse Mercator Projections.



VFR NAVIGATION CHART (VNC)

VNCs are designed primarily for visual navigation at low altitudes and slow speeds. Each chart is identified by the name of a principal landmark on the chart (eg, Toronto, Winnipeg, Gander). The scale of the chart is 1 :500 000 or about one inch to eight miles.

WORLD AERONAUTICAL CHART (WAC)

WACs are designed primarily for visual navigation at higher altitudes and greater speeds. Each chart depicts a sizeable portion of the country's geographical area—eighteen charts cover Canada. Each chart is identified by a letter and a number. For example, E17 covers the area from Marathon, Ont., west to Brandon, Man., and from the 48th parallel north to Thompson, Man. The scale of the chart is 1 : 1 000 000 or about one inch to 16 miles.

VFR TERMINAL AREA (VTA) CHART

VTA Charts are large scale charts (1 : 250 000) published for airports where there is a high volume of air traffic and where there is usually a mix of controlled airspace. Radio communication information and other information that is necessary for conducting flight through the area are given on the chart.

ENROUTE CHART

Enroute Charts provide information for radio navigation over designated airways systems. Enroute Charts do not portray any cities, towns, or topographical features. They depict all radio navigation aids, including airways, beacons, reporting points, and communication frequencies. Examples of Enroute Charts are Enroute Low Altitude Charts, Enroute High Altitude Charts, and Terminal Area Charts.