... Imperial Oil establishes fuel storage facilities for the new polar air-route to Europe

Frobisher Bay on bleak Baffin Island is one of North America's most northerly civilian airports. As a refueling point for west coast aircraft flying to Europe it is strategically located at a point almost exactly midway between the western portion of the North American Continent and continental Europe.

Imperial Oil, which has more than three decades of experience in supplying fuel to Arctic regions, took on the task of building storage tanks and elaborate refueling facilities at Frobisher Bay.

Construction commenced in the last few remaining days of August 1957. Imperial flew in welders, steel men and laborers in addition to the Eskimos who worked as casual laborers helping lay pipe lines.

On September 13, only 15 days after construction began, the 96,000 barrel main storage tank was finished. The same day, the tanker Imperial Surma sailed into the bay and commenced discharging her two million gallon cargo of fuel.

The Frobisher Bay installation was the fastest, closest-timed construction job in the history of Imperial Oil, and it exemplifies the way in which Imperial is equipped to meet the challenges of the Air Age with ever finer products and service.
Qualifying for his Commercial Pilot's License, he became one of that famed band of doughty men, Canada's bush pilot brood, whose record of skill and resourcefulness became known and respected the world over. Sandy's activities, which included aerial photographic survey, forestry patrols, freighting and transportation, took him over countless thousands of miles of bush country in Northern Manitoba, Saskatchewan, the North-West Territories and the bleak, barren wastes of the Arctic. In 1931, he flew the first official air mail flight from Chesterfield Inlet to Fort Churchill.

Returning East, he spent several years on charter and sales demonstration piloting in Ontario, Quebec and the U.S.A. He became Vice-President of Aviation Service Corporation Ltd. in 1937. During 1939 and '40, while associated with Adam Craigon, Aeronautical Engineer, in test and experimental flying activities, he gained much valuable experience in aeronautical research.

As an author, Mr. MacDonald has published over half a million words on aviation subjects in more than a score of magazines and newspapers in Canada, the U.S.A. and England.

He is a Member of the Institute of the Aeronautical Sciences.

In 1939 he was made a Director of P & H Aircraft Company Limited and when war broke out assumed an active post as Chief Ground School Instructor in that Company's flying school. In this capacity, he graduated over 35 per cent of the elementary flying instructors engaged in the British Commonwealth Air Training Plan in ground school subjects.

In June, 1941, he was appointed Chief Air Navigation Instructor at No. 20 Elementary Flying Training School, Oshawa, where he organized the first practical Navigation Flight to be established in any elementary flying training school in Canada—to borrow his own expression, "To try to keep the boys off the railway tracks and on their instrument panels."

At 45, veteran of World War Number One, Mr. MacDonald was later engaged on war service flying duties as a Transatlantic Ferry Pilot with the Royal Air Force Ferry Command.

John M. Calder.
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EDUCATION (by grade and prov.).................................................................AGE........

Royal Canadian Air Force
from

THE GROUND UP

by SANDY A. F. MacDONALD

Associate Editor—J. E. WATTS

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OFFICIALLY

THE AIR INDUSTRIES AND

APPROVED BY

TRANSPORT ASSOCIATION
The Avro Arrow is shown in flight during test manoeuvres over Ontario.

The Arrow weapon system is a bomber-destroyer having supersonic mission capabilities.

AN ARROW IN THE SKY

Since its first flight on March 25th, the Avro Arrow has been meeting the vigorous demands of its extensive flight test program. Proceeding according to plan, the Arrow flew faster than sound on its third flight, and more than 1,000 miles per hour on its seventh flight.
From The Ground Up . . .

Among other things, one of the problems a pilot should tackle is learning to fly. Countless deluded young men, yearning for a career in aviation, have the sadly mistaken idea that that is all there is to it. A few hundred hours of patient application, the acquired ability to handle a ship with skill and ease—and presto! . . . wings and gold braid . . . and the Airlines only too grateful for the privilege of granting one a commission! To those misguided young men I say, "Son, go back to the farm before God changes his mind." There is no easy way.

Ability to fly is a step in the right direction—but the most elementary one in our whole curriculum. In a few years Junior will learn to fly before he graduates from high school. Countless millions will line up once every year all over the world to renew their pilot's certificates—much the same as motorists do to-day. There is no pay-off on arts or crafts which are the common accomplishment of the masses. A transport pilot is, and always will be, however, a highly sought, highly paid individual specialist—because he is a master craftsman in his trade.

"Well," you ask, "what has he got that I haven't got?" That's exactly what I propose to tell you in these pages. "Weather sense", for one thing, a knowledge of line squalls and thunderstorms and icing conditions—of stable and unstable air masses—of cold fronts, and dewpoint, and all the odds and ends that go to make up the science of meteorology.

He is an expert navigator, and understands how to plot headings and bearings. He has an expert knowledge of wind and drift problems. He is thoroughly conversant with such things as Azimuth, Isoconic lines, and Great Circle Tracks. And right here, let us definitely emphasize that the latter in no way refer to those affairs that railway trains run to and fro on. The bird who specializes in following railway lines around from place to place is not a navigator, but an opportunist. When the tracks go in a tunnel, he is lost and has to go home. His only means of getting a ship across open water is a matter of pure good fortune—if there happens to be a ferry boat going his way!

A transport pilot knows his ship and his engine. Their airworthiness is a matter on which the lives of his passengers depend as much as on his own skill and knowledge—so he conscientiously superintends their service and maintenance. He understands fuel-air ratio, and all that sort of thing, and knows how to get the last ounce of power and the most miles out of a given volume of gasoline. He is familiar with all the invisible forces and couples that act on an airplane in flight and he knows when his ship has been subjected to any abnormal stresses that may lead to a structural strain.

In other words, he is the type of skipper one flies behind with utmost confidence—based on assurance that he not only rates officially a Grade A Pilot and Navigator, but is a thorough technician as well, completely versed in every last-minute detail of his profession BOTH ON THE GROUND AND IN THE AIR.

"But", you may point out, "I have no ambition to become an airline captain. I am only interested in learning to fly as a private pilot. Is it necessary that I should learn all this technical stuff as well?"

Suppose I answer that by asking you a question in turn. Is your own life not every bit as precious to you as the lives of its passengers are to an airline company?

An airplane moves in a medium known as the atmosphere. This layer of air surrounding the earth for a depth of several miles is a turbulent region of shifting winds, cross currents, storms, gusts and squalls. Invisible giants, the Polar and Equatorial Air Masses, forever in conflict, make this atmosphere of ours a perpetual proving ground for the science of air navigation—by frequent blanketing of entire areas with dense drop-curtains of cloud, fog, rain, or snow.

An airplane moves in three-dimensional space, which involves three-fold problems in its control. It lacks buoyancy, is heavier than air, and hence is dependent on the power from its engine to sustain it in flight. A forced landing is not necessarily a hazardous, but under no circumstances, a desirable undertaking. Reliability is therefore a matter of vastly greater importance in the air than on land or sea. And reliability refers not only to the mechanical perfection of the airplane and its engine, but to the knowledge, judgment, and all-round proficiency that rides in the control cabin.

Time was, two wars ago as we measure time nowadays, when an older generation—my own—learned to fly by the seat of its pants. We flew by what is known as "feal." It frequently happened that the ships we flew, being inanimate objects, did not always feel as we felt. The arrangement was a hair-hazard one, and frequently when we accidentally strayed into a cloud, the only "feal" that most of us had was a feeling of utter hopelessness. All too many of us emerged out of clouds minus our wings, or ended our innocent young lives "spinning in" out of fog.

There was, of course, a certain romance attached to
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flying in those days. We were gentlemen adventurers pitting our wits against the unknown. The "unknown" in this case included practically everything that had to do with the ships, the engines and the conditions under which we flew. A compass, had you asked us, was an affair filled with a precious fluid known as alcohol. Other than that, it was a gadget as meaningless as most of the others that littered our instrument panels with misinformation. There was no great point in fussing over mechanical details in those days anyway. The crates we flew were so unreliable they let you down every few hundred miles in any event. It was a hit and miss, happy go lucky era of aviation—but it was not getting anywhere particularly—except to plant a firm conviction in the public mind that flying was the shortest distance between here and the hereafter.

Time marches on, and aviation has since swept ahead with giant strides of progress. Many a private owner to-day will casually climb aboard his sliver plane to start off on a flight that to the Early Birds would have seemed an epic undertaking. He is equipped with information and knowledge that two decades of experimental trial and error, of toil and effort and human sacrifice have placed at his disposal.

Those of us who can count the years we've held a pilot's certificate in multiples of ten, can boast of bearing the scars of many a Near Thing. For we had to get our experience the hard way! To-day the Ground School has become an international institution where those who want to fly the scientifically sure way, may learn the things they should know the only sound and thorough way—FROM THE GROUND UP.

There are two ways of doing anything, a right way and a wrong way. With the exception of a certain transatlantic episode which amused the world once upon a time, the wrong way in aviation is generally the quick and certain way to keep from growing old. Here, let me introduce a couple of characters whom you will run across from time to time in the chaps that follow. They personify the right and wrong way in aviation, and can usually be located around any flying field at the top and bottom of affairs respectively. First, meet Captain Wise—clean shaved, well groomed, a smartly uniformed individual. Though quiet-mannered, he is anything but lacking in self-assurance. He is moderate in his habits, keen, thorough, punctual, and as fit as a fiddle. He is young in years, but a veteran in experience. Like the aeroplane he flies—geared up to the swift tempo of the times—he typifies the Spirit of the Modern Age. He can always be depended on to come through, because, like a racing thoroughbred—he has never learned how to lose!

Ferdinand Fumble, on the other hand, is as casual about his appearance as he is about his habits. The only place he is ever known to arrive at on time is the airport lunch counter. Around the hangars, the boys have nicknamed him "Flatspin". One of his favourite forms of amusement is "shooting up houses". He thinks flying is no end of fun, provided you don't take it too seriously. Study? Ground School? "Nuts," he exclaims, "that's the sissy way to learn these things." His idea of a real two-listed career is his own long record of crashes. His favourite brand of topic is about the time he cracked-up the Jittercraft, trying to turn back in with a missing engine... and so on, and et cetera, ad infinitum.

**CAPTAIN WISE**

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**FLATSPIN FUMBLE**

**AIRMANSHIP**

Airmanship is proficiency in the knowledge of handling and operating aircraft on the ground and in the air.

"Flatspin" Fumble leaves the ground end of it entirely to the mechanics. "That's their pigeon," he concludes.

Captain Wise, on the other hand, carefully and systematically supervises the inspection, maintenance, and servicing of his ship. "Air Engineers are, on the whole," he observes, "more precise, painstaking and conscientious about their work than the average pilot.
is. They are, after all however, only human beings and as such are not immortal and infallible. They could forget to clean the filter for instance, or fit a split-pin, or ground the ship while refuelling. It pays a pilot to check every detail before starting a ship from the line."

RESPONSIBILITY OF THE PILOT
A pilot's responsibility does not cease when he has landed, but a thorough knowledge of the proper care of the airframe and engine constitutes one of the most important of his flying qualifications. The inspection of an airplane is best performed under the supervision of the pilot who flies it for the following reasons:

1. He has a personal appreciation of the importance of finding any fault before going into the air.
2. He knows whether any fault developed during his last flight.
3. He knows what special stresses his ship has been subjected to during flight or in landing and he therefore knows where to look for possible trouble.

PILOT'S INSPECTION PRIOR TO FLIGHT
1. Check the tires for proper inflation (for planes). Remove float covers and inspect floats for water. Pump out bilge pump if necessary (seaplanes).
2. See that all controls move freely when locking devices (if fitted) have been removed.
3. All engine controls must move smoothly, but with sufficient friction to prevent their "creeping".
4. Check fuel and oil. If there is any doubt in your mind as to the accuracy of the gauges, look in the tanks.
5. Check fuel supply system. Make sure that all cocks are fully open and there are no drips.
6. Secure safety belts or harness in unoccupied seats, to prevent fouling the controls.
7. See that ballast (if carried) is secured and disposable load does not upset the trim, or cannot shift in flight.
8. See that there are no loose articles which might foul the controls, or cause distracting noises.
9. Check the fire-fighting equipment.
10. Medical Kit on board and accessible (commercial aircraft).

11. Following documents on board (mandatory): Certificate of Registration—Certificate of Airworthiness—Journey and Aircraft Log Book (Can.)—Radio Equipment License (Can.)—License or Permit for each crew member (Can.)—Aircraft Operating Limitations Data (U.S.).

PILOT'S ENGINE INSPECTION
1. Check for security of parts.
2. Check for leakage of oil or fuel.
3. Check cowling for cracks and fasteners for security.
4. Check exhaust stacks for cracks and studs for tightness.
5. Check spark plug terminals for security and cleanliness.
6. Drain some fuel to check for sediment or water.
7. Check engine mount for security.

STARTING PRECAUTIONS
Modern aircraft engines are practically all fitted with starters. However, because of a weak battery, defective starter, or for other reasons, it is sometimes necessary to start an engine by swinging the propeller by hand.

1. Place aircraft so that dust will not be blown into hangars or on to other planes. In a strong wind, a light plane should be faced into wind for run-up, but not where it will blow dust on to other planes.

2. If propeller is to be swung by hand, the ground in front of the machine must provide a good solid foothold for the mechanic swinging the prop. If it should become soggy or slippery while swinging, the ship should be moved.

3. Only experienced personnel should be permitted to swing a propeller by hand, or to handle the controls in the cockpit. The person swinging must not have any loose articles hanging around his neck.

4. Chocks should be placed in front of the wheels, or parking brakes, if fitted, tightly applied.

5. Except for the starting swing, the propeller must not be touched unless in the "off" position. Even with the switches "off", THE PROPPELLER MUST ALWAYS BE HANDLED AS ON "CONTACT". (Many serious accidents have occurred due to short circuits in the wiring system, defective switches, etc.)

6. If a starter is fitted, the propeller should be pulled through several times by hand. This is to release any accumulation of oil in the combustion chambers. Also to assist in partially priming the engine. (Be sure the switches are OFF before pulling through.) The propeller must not be motored over on "Contact" until the pilot has had an "All clear" from a ground crew mechanic.

7. ALL ORDERS MUST BE REPEATED.

STARTING ROUTINE—SWINGING BY HAND
(Primary Trainer Type Aircraft)

<table>
<thead>
<tr>
<th>SEQUENCE OF ACTION</th>
<th>ACTION BY PILOT</th>
<th>ACTION BY MECHANIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Turn on gas. &quot;Gas on. Switches off.&quot; (Thumbs down.)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pump throttle or priming pump, if fitted, as required. &quot;Gas on. Switches off.&quot; (Thumbs down.)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&quot;Throttle set. Contact.&quot; (Thumbs up.)</td>
<td>&quot;Throttle set. Contact.&quot; (Thumbs up.)</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Throttle set. Contact.&quot; (Thumbs up.)</td>
<td>Swings propeller</td>
</tr>
<tr>
<td>5</td>
<td>If engine starts, Check oil pressure.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>If engine fails to start, &quot;Switches off.&quot; (Thumbs down.)</td>
<td>&quot;Switches off.&quot; (Thumbs down.)</td>
</tr>
<tr>
<td>7</td>
<td>If overpriming is suspected, &quot;Switches off. Throttle open.&quot; (Thumbs down.)</td>
<td>&quot;Switches off. Throttle open.&quot; (Thumbs down.)</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Repeat above drill until engine starts.

NOTE: The "Thumbs up" or "Thumbs down" signals are to indicate "Contact" or "Switches off" respectively in case the noise of other engines running-up nearby makes hearing difficult.

Backfire. If a backfire occurs in the carburetor when an engine starts, open the throttle. This will suck the fire into the engine where it will do no harm.
STARTING ROUTINE—SEAPLANES

In starting a seaplane moored to a dock or beached on a shoreline, the starting routine is the same as tabled above—except that the crewman must stand on the float back of the propeller, and swing it from behind.

When starting at a buoy a line should be passed loosely around one of the undercarriage struts and not slipped until the pilot is satisfied that his engine will continue to run.

GROUND CONTROL SIGNALS TO AIRCRAFT

RUNNING UP THE ENGINE

An aero engine should be run up SLOWLY.

1. Check oil pressure and temperature. If oil pressure fails to rise within a few seconds, or temperature appears abnormal, switch off immediately and investigate.

2. Check the rpm at full throttle. Cut the switches one at a time to test each individual magneto, by moving the switch from BOTH to RIGHT, to BOTH, to LEFT, and back to BOTH. (You return to BOTH each time to allow the engine to regain its normal rpm and to clear the inoperative set of plugs in case they may have fouled with oil while their magneto switch was off). Move the switches to OFF momentarily to check for malfunctioning of the switch or ground connections. (If engine continues to fire, shut off fuel and check magneto ground lead).

CAUTION: Conduct these checks as quickly as possible to prevent backfiring when the ignition is switched on.

3. If the engine is fitted with a controllable or constant speed propeller, test its operation by moving the lever to “Coarse Pitch” or “Decrease RPM”. See that the required drop in r.p.m. occurs. Return lever to “Fine Pitch” or “Increase RPM” after the test.

4. Test operation of the carburetor heat control by selecting “Warm Air”. If the control is working satisfactorily, a drop in power will be noted.

5. Idle the engine for a few moments to check the idling speed at proper working temperature.

6. See that the choke is closed—mixture control full rich—and propeller in fine pitch (if controllable).

During the running up, the pilot should check and listen intensively for any signs of engine trouble. A minor adjustment on the ground may forestall a serious situation due to engine failure on take-off or in flight.

NEVER ATTEMPT TO TAKE-OFF WITH A COLD ENGINE.

OPERATION OF THE ENGINE

The “Normal r.p.m.” stated by the engine manufacturer should never be exceeded for more than 5 minutes—and then only when absolutely essential.

The “Maximum Permissible r.p.m.” should never be exceeded more than momentarily in emergencies.

The best cruising r.p.m. is where the motor runs the smoothest at approximately three-quarter throttle (or where the propeller load curve intersects the engine power curve, if these curves are available for the engine you are using).

With supercharged engines, the “Maximum Permissible Boost” must never be exceeded.

Boost pressures greater than “Rated Boost” are only permissible for 5 minutes at a time.
The life and efficiency of an aero engine depend to an appreciable extent on the use or abuse the motor suffers at the hands of the pilot. “Flatspin” Fumbles’s slam-bang, push-and-pull technique in the handling of the throttle puts engines on the old-age pension list before their time. 

**ABOVE ALL NEVER SWITCH OFF AN OVER-HEATED ENGINE.** After taxiing in, allow it to idle a sufficient time to cool. A lot of residual heat has to be dissipated.

If the engine is fitted with Idle Cut-off, this should always be used to stop the engine.

**REFUELING**

Always ground the aircraft or hose nozzle when refuelling from pumps, owing to danger of fire from static electricity.

Gasoline of the octane rating specified by the engine maker **ONLY** should be used. (IMPORTANT)

Gas tanks should be filled immediately after flying to prevent moisture in the gas due to condensation in the empty tank.

Do not completely fill tanks with cold fuel if aircraft is to be stored in a warm hangar. Aviation gas will expand about 0.5% in volume for a 10°F. rise in temperature.

Never pump gas from the bottom of a drum which has just been moved around. Let the drum stand stationary for some time to allow any water or dirt to settle to the bottom. Unless a more efficient filter is available, refuelling from drums should always be done through a chamois leather and funnel.

Oil of the S.A.E. number or grade specified by the engine manufacturer for the particular engine operating conditions **ONLY** should be used.

Oil should **ONLY** be changed in accordance with the recommendation of the engine manufacturer.

The oil tank should never be filled to the top. Leave room for the expansion of the oil when it gets hot.

**COCKPIT CHECK PRIOR TO TAKE-OFF** (Elementary Trainer Type Aircraft)

1. Run up the engine, as outlined above.
2. Check all instruments.
3. If Controllable or Constant Speed Propeller is fitted, check operation in Coarse Pitch. The R.P.M. should decrease when Coarse Pitch is selected, and recover to normal when propeller is returned to Fine Pitch. (If a Manifold Pressure Gauge is fitted, you will notice a slight increase in manifold pressure with the decrease in R.P.M.)
4. Set Altimeter to correct barometric reading on Barometric Scale. If Altimeter is not fitted with a Barometric Scale, set the correct elevation of the airport above sea level. (You will find this printed on the map.)
5. Wind the clock. Set correct time.
6. Uncaque the Directional Gyro (if fitted). Set to match heading on Magnetic Compass.
7. Trimming Tabs to correct positions for take-off.
8. Flaps to recommended position for take-off.
9. Propeller in Fine Pitch (if applicable).
10. Carburetor Cold Air. This is essential to obtain full power for take-off. If carburetor icing conditions are indicated, select warm air after taking off.
11. Doors, or canopy top, closed and secured.

The Cockpit Check should be made **deliberately without haste.** A definite sequence should be followed, moving clockwise around the cockpit. Touch each control with your hand and name it aloud, e.g.: “Trim Tabs — Flaps — Fine Pitch”, etc. etc. With more advanced types the Cockpit Check becomes more and more involved, including cowl gills, booster pumps, automatic mixture controls, etc. etc. The Cockpit Check for some large transport aircraft requires several typewritten pages to list. Form the habit of being thorough and systematic about your Cockpit Check from the beginning and you will make it easy for yourself as you progress to more advanced types later on.

**Visual Flight Rules**

“VFR”—VISUAL FLIGHT RULES, means flying by means of visual reference to the ground.

“IFR”—INSTRUMENT FLIGHT RULES, means flying by means of visual reference to the instruments in the cockpit.

It is the responsibility of the pilot in command of an aircraft to determine whether a flight will be conducted in accordance with Visual or Instrument Flight Rules.

Visual Flight Rules only are dealt with in this manual.

**Night**

**NIGHT** is the period between the end of Evening Civil Twilight and the beginning of Morning Civil Twilight (when the sun is 6° below the horizon, as defined in the Air Almanac) in Canada, it is further defined as not less than one half hour after sunset and one half hour before sunrise.

An aircraft operated at night within Control Areas or Control Zones will be flown in accordance with Instrument Flight Rules (unless otherwise authorized by Air Traffic Control). **AERODROME PROCEDURE**

Taxi slowly, clear of the take-off zone. Always turn to the left. Single-engined aircraft which are particularly blind on the ground should taxi zig-zag fashion.

Always taxi down-wind to the extreme end of the field or runway to take-off. There may come a day when that few hundred feet you are tempted to save would be worth a thousand dollars a foot to you. Captain Wise’s tip on seaplane technique is worth remembering. “When taking off towards a shoreline,” he advises, “taxi out until your judgment tells you that you have allowed yourself a safe margin to clear the shoreline—then go back double that distance and take off!”

Turn 45° out of wind before taking off to see that no ships are immediately approaching to land. Make a final check of the instruments and everything in the cockpit again, stabilizer properly trimmed for take-off, etc.—turn and take-off into wind.

At airports where the air traffic is regulated by a Control Tower—if your aircraft is not fitted with radio—do your engine run-up and cockpit check on the apron before taxiing to the runway. (The APRON is a surfaced area in front of the hangars, which old timers refer to affectionately as the “Tarmac”.) When ready for take-off, taxi to a position on the taxi strip approximately 100 feet from the boundary line of the runway in use. Place your aircraft in such a position that you have a clear view of the Control Tower. Wait for the steady green light signal to proceed onto the runway, and take off. At night switch on your landing light to let the Tower know you are waiting for a signal.

**Steady Green Light**—Clear to take off.
Flashing Green Light—Clear to taxi, but do not take off.
Steady Red Light (or Red Flare)—Stop. Do not taxi.
Flashing Red Light—Taxi clear of the landing area in use.
Flashing White Light—Return to the ramp or hangar.
Flashing Red and Green Light—Danger. Be on alert.
Note: This signal has been discontinued in Canada.
Blinking Runway Lights—Taxi clear of runway immediately.
Take off towards the left side of the runway or take off area, but keep to right of any aircraft taking off ahead of you.

If your aircraft is radio equipped, taxi instructions will be given you verbally by the Tower. Taxi to a position on the taxi strip approximately 100 feet from the boundary of the runway in use to do your engine run-up and cockpit check. Turn at an angle of about 45° to the taxi strip to do your engine run-up in case there may be another aircraft behind you. When you have made your cockpit check, request a take-off clearance from the Tower. Radio equipped aircraft on a traffic controlled airport use the centre line of the runway for take-off and landing. (Radio traffic procedures are described in the Chapter on Radio.)

Always turn left after take-off, unless otherwise authorized by the Tower.

Airport Runways
Airport runways are numbered to correspond to their magnetic bearings. For convenience, the last digit of the number is omitted. Thus, Runway "09" would be the runway which runs from west to east. (90° Magnetic.) The same Runway in the opposite direction, east to west, would be numbered "27" (270° Magnetic). The Runway numbers are taken to the nearest 10° Magnetic. Hence, a Runway which lies 18° Magnetic would be considered as 20° Magnetic, and numbered "02":

**TAKE-OFF LIMITATIONS**
(Altitude and Temperature)
The higher an airport is located above sea level, the longer the take-off and landing run of your airplane will be, and the poorer its rate-of-climb.
High temperature has exactly the same effect.
This is because you get thin air at high altitude and in hot weather. Thin air reduces lift. The rarefied air at high altitude also lowers the efficiency of the engine and propeller and lessens the plane's rate-of-climb. Fig. A illustrates how the elevation of the field above sea level increases the length of the take-off run.
Also remember that long grass, sand, mud, glassy water, or soft snow can easily double the take-off run of

landplanes, seaplanes or skiplanes respectively, as the case may be.

**AIR REGULATIONS**
Air Regulations are undergoing constant change and revision. To date, no attempt has been made to establish an internationally uniform code. For these reasons, only a limited amount of information regarding Air Regulations will be found in this manual. However, a knowledge of the current Air Regulations of the country or countries in which he may be flying IS THE MOST IMPORTANT OF ALL THE KNOWLEDGE WHICH A PILOT MUST HAVE IN HIS POSSESSION.

**RULES OF THE AIR**
Air Traffic regulations are subject to constant revision. The few basic rules outlined below do not by any means attempt to cover the entire subject. It is vitally important that pilots keep themselves fully informed on current Air Traffic matters by reference to the Circulars issued regularly by the Department of Transport in Canada and the Civil Aeronautics Authority in the U.S.A.
Aircraft meeting head-on both alter course to the right.
An aircraft overtaking another turns out to pass on the right. (This is the only air traffic rule which differs from motor traffic regulations.)
When two aircraft are on courses which cross, the one on the right has the right-of-way.
An aircraft giving another the right-of-way must do so by altering course to the right—but not by diving or climbing.
Based on their ability to maneuver, aircraft have priority for the right-of-way in the following order:

1. Fixed or free balloons.
2. Gliders.
3. Airships.
4. Fixed or Rotary wing Airplanes.
Aircraft in distress have top priority for landing.
An aircraft towing another has priority over other aircraft having mechanical power.
Over cities, towns, congested areas, or open air assemblies, the minimum altitude is "sufficient height to permit an emergency landing without damage to persons or property on the ground"—but in any case, not less than 1000 feet.
Within Control Zones and Elsewhere—500 feet. Seaplanes over water—300 feet.
(Minimum altitude for aircraft "on instruments"—1000 feet).
No aircraft may be flown over a jail or penitentiary in Canada without permission from the Minister of Transport. (This regulation does not apply in the United States, unless the penitentiary is located within a prohibited area.)
If two aircraft are approaching to land at the same
time, the ship flying at the greater height is responsible for avoiding the lower one.

An airplane on Final Approach maintaining a straight approach for a landing has the right-of-way over other aircraft approaching to land (except aircraft in distress, which have the landing right-of-way over all others).

AEROBATICS

In Canada, no aerobatics are permitted over cities, towns, or over a civil airway. Aerobatics or air exhibitions may be permitted over open air assemblies with the written authorization of the Minister of Transport. In the United States, no aerobatics are permitted over cities, towns, or open air assemblies. Over civil airways or within control zones, aerobatics may be permitted by a Certificate of Waiver. At air shows, aerobatics will not be permitted at an altitude of less than 1500 feet except by Certificate of Waiver. In any event, in either Canada or the U.S.A., the performance of aerobatics must not in any way constitute a hazard to air traffic.

AIRWAYS

AIRWAYS are routes between points along which aircraft can navigate by following radio “beams” or “radials”. They are 10 miles wide. The older type of Airways, which are rapidly becoming obsolete, are composed of chains of low/medium frequency radio range stations, located approximately 95 to 150 miles apart, whose low frequency beams lie along the centre line of the airways.

Airways are designated by numbers and colours. When two Airways intersect, aircraft flying along the airway which has the right-of-way will not alter height. Those on the other airway will cross at a height 500 feet higher than the level at which they are flying.

The order of priority for the right-of-way is as follows:

1. Green Airways
2. Amber Airways
3. Red Airways
4. Blue Airways

The Airways described are indicated on maps as follows: Controlled Airways by blue-grey tinted areas, and their boundaries by magenta lines. Uncontrolled Airways by magenta boundary lines only. Aircraft are required to fly to the RIGHT of the centre line of the Airway.

A new system of Airways has been established in America. The new Airways are called “VOR” or “VICTOR AIRWAYS”. These Airways are followed by reference to “Courses” or “Radials” projected by chains of VHF Omirange Stations located approximately 100 miles apart along the Airways. They are designated by the letter “V” and numbers, e.g.: “V52”. Controlled Victor Airways are indicated on maps by a single blue line and a blue-grey tinted area 10 miles wide. Uncontrolled Victor Airways by the blue line only. When flying along Victor Airways, fly down the centre line of the airway.

NOTE: See “Change in U.S. Cruising Altitudes” at the end of this Chapter.

When flying along Green, Red or Victor even numbered Airways:

- Fly Eastbound at odd heights (3000 — 5000 feet, etc. Above Sea Level).
- Fly Westbound at even heights (2000 — 4000 feet, etc. Above Sea Level).

When flying along Amber, Blue or Victor odd numbered Airways:

- Fly Northbound at odd heights (3000 — 5000 feet, etc. Above Sea Level).
- Fly Southbound at even heights (2000 — 4000 feet, etc. Above Sea Level).

When crossing an Airway (other than at an intersection) cross it at an angle of not less than 45°.

When flying OFF a designated Airway:

- Fly NORTHEAST (0° to 89° Mag.) at odd heights (3000 — 5000 feet, etc. Above Sea Level).
- Fly SOUTHEAST (90° to 179° Mag.) at odd heights plus 500 feet (1500 — 3500 feet, etc. Above Sea Level).
- Fly SOUTHWEST (180° to 269°) at even heights (2000 — 4000 feet, etc. Above Sea Level).
- Fly NORTHWEST (270° to 359°) at even heights plus 500 feet (2500 — 4500 feet, etc. Above Sea Level).

A CONTROL AREA is an area in which air traffic is controlled by Air Traffic Control Centres located along the airways. Control Areas are usually designated Airways approximately 10 miles wide and are shown on aeronautical charts by blue-grey tinted areas. Within Control Areas air traffic control does not extend below 700 feet above the surface.

CONTROL AREA EXTENSION. A term applied to a Control Area which does not form a segment of a designated Airway.

CONTROL CENTRE. A station located within a Control Area which provides supervision of air traffic within the Area.

CONTROL TOWER. A station which exercises control over traffic arriving at, departing from, or flying in the vicinity of an airport, and control over all ground traffic in the area.

A CONTROL ZONE is an area, usually a circle which may be 5 miles (within a Control Area) to 25 miles (outside a Control Area) in radius, and within which air traffic is controlled by an Airport Traffic Controller from an airport located within the area. Control Zones are indicated by magenta circles printed on aeronautical charts.

A FLIGHT INFORMATION REGION is an area in which an Area Control Centre will provide flight information service to aircraft and warn search and rescue organizations when aircraft become overdue. Flight Information Regions include the 700-foot space which lies below Control Areas.

"ELSEWHERE" is any area outside the boundaries of a Control Zone, Control Area or Flight Information Region. The weather minimums specified for flight information regions apply elsewhere.
WEATHER MINIMA FOR VFR FLIGHT

<table>
<thead>
<tr>
<th>Visibility</th>
<th>Vertical above cloud (U.S.)</th>
<th>Horizontal (U.S.)</th>
<th>Vertical above cloud (Can.)</th>
<th>Horizontal (Can.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td>3 miles</td>
<td>1000' vertically above</td>
<td>500' vertically below</td>
<td>2000' horizontally</td>
</tr>
<tr>
<td>Distance from cloud (U.S.)</td>
<td>1000' vertically above</td>
<td>500' vertically below</td>
<td>2000' horizontally</td>
<td>1 mile horizontally</td>
</tr>
<tr>
<td>Height above surface (Can.)</td>
<td>500' vertically</td>
<td>1 mile horizontally</td>
<td>1000' vertically</td>
<td></td>
</tr>
<tr>
<td>Ceiling (U.S.)</td>
<td>1000'</td>
<td>500' vertically below</td>
<td>2000' horizontally</td>
<td>1 mile horizontally</td>
</tr>
</tbody>
</table>

Within Control Areas ("On Airways")

Below 700' above surface Control Areas do not extend below 700'. Therefore: clear of cloud

Elsewhere ("Off Airways")

Visibility 1 mile
Distance from cloud (U.S.) 1000' vertically above
At or above 700' above surface

The following ceiling and visibility minimums apply:
1. Aircraft without radio—300' and 1 mile. (Within sight of the Control Tower at all times).
2. Aircraft with receiver only—300' and 1 mile.
3. Aircraft with 2-way radio (functioning)—500' and 3 miles or 600' and 2 miles or 700' and 1 mile.
4. Helicopters—500' and 1 mile.

Along certain airways where obstructions exist, minimum altitudes are prescribed. These are shown on I.C.A.O. maps alongside the airway boundaries. They are not intended to indicate the height to fly—but the minimum height, below which you must not fly.

AERONAUTICAL ADVISORY STATIONS have been set up at many landing fields in the United States, not served by Airport Traffic Control, to give information to private pilots on such matters as condition of runways, types of fuel available, wind conditions, weather information, etc. They are not permitted to issue traffic instructions. They may be contacted on the "private flyer's frequency" (UNICOM) —122.8 mc. and will reply on this same channel.

In 1954, similar stations were authorized to be established in Canada, where they are designated as PRIVATE ADVISORY STATIONS. Their functions are identical to the U.S. Aeronautical Advisory Stations described above, and they also operate on the UNICOM frequency —122.8 mc.

Complete and detailed information regarding Airways, Control Zones, Control Areas, etc., etc., will be found in the Designated Airspace Handbook, published quarterly by the Department of Transport in Canada, and the Flight Information Manual published by the Civil Aeronautics Administration in the United States.

CONTROLLED V.F.R.

In Canada, visual contact flights along airways at or above 9500 feet above sea level east of the Rockies, or 12,500 feet above sea level west of the Rockies (that is, the 114th Meridian W.) will be by controlled VFR.

Controlled VFR does not apply along segments of airways in Canada which are controlled by U.S. ARTC (Air Route Traffic Control) Centres.

Controlled VFR permits flying only in weather that is "VFR" along airways—that is, with visual reference to the ground, 500 feet vertically and 1 mile horizontally clear of cloud, and with visibility of at least 3 miles. In practically all other respects, the same traffic clearances and procedures which govern flying under instrument flying conditions (IFR) apply to Controlled VFR. The airspace along the airways in which Controlled VFR is mandatory is known as a BLOCK AIRSPACE. (It doesn’t extend above 23,000 feet, so if you happen to be the proud possessor of a private jet airliner, once you’ve climbed above this altitude, you’re as free as the birds.)

To be qualified to fly Controlled VFR, a private or commercial pilot without an instrument rating must pass an examination to obtain a special endorsement to his license. This will read "VALID FOR BLOCK AIRSPACE". The examination requirements are outlined in the Examination Guide.

Flatspin Fumble’s reaction to all this when the Air Navigation Order first became effective was, “Holy cats—how complicated can it get! If you’re flying...
VFR, all you have to do is look out the window and you can see anything that's coming your way—so why all the rigmarole?" Captain Wise reminded him that it's common practice nowadays for the airlines to fly instrument flight rules most of the time regardless of the weather, and they may not be looking out the window at the time you happen along. Furthermore, if Flatspin consulted his own conscience, he would have to admit that he, like a lot of others of his irresponsible breed, have been guilty on many occasions of sneaking along an airway when the visibility was anything but VFR. With modern high speed airplanes the rate of closing between two approaching aircraft can be in excess of 500 miles an hour—or 8 miles a minute. This means that with 3 miles visibility, a 200 mile-an-hour airplane approaching a 300 mile-an-hour airplane would have 22 seconds to alter course. But lag in vision, pilot reaction, and aircraft response to control movement (averaging 15 seconds) would reduce this time to 7 seconds. The object of Controlled VFR, like IFR, is to prevent collision by controlled separation of the movement of all aircraft within control areas by an Air Traffic Control Centre.

PROCEDURES

Pilot's License: Must be properly endorsed "VALID FOR BLOCK AIRSPACE".

Radio: Functioning two-way radio capable of transmitting and receiving on frequencies appropriate to the route to be flown.

Pre-Flight Precautions: Check the Canada Air Pilot Radio Facility Charts for distances between reporting points along your route. They are shown along the airways thus: 100S - 87N (100 statute, 87 nautical miles). Take your computer. (When you file a position report on passing a reporting point, you have to state your estimated time of arrival at the next reporting point. This means you have to compute ground speeds and E.T.A.'s as you go.)

Flight Plan: A VFR Flight Plan must be filed. In addition to the information given in a regular VFR Flight Plan, it will state the desired altitude to be flown and the route. e.g.:

Flight Altitude: 12,000/VFR.
Route: RED 1.

Clearance: An ATC Clearance of the flight plan is not necessary prior to departure. Take off, and remain tuned to the Tower until cleared from the tower frequency. Climb towards the desired altitude. Approximately 1000 ft. below the base of the Block Airspace (8500 ft. or 11,500 ft. as the case may be) file a POSITION REPORT and request a clearance to enter the Block Airspace. e.g.:

"Montreal Centre—This is Otter Delta Oscar Golf—over Montreal at three five*.—Eight thousand five hundred VFR—requesting ten thousand controlled VFR to Ottawa via Victor three zero zero*."

*Meaning the time is 35 minutes past the hour.
*Means Victory Airway 300.

Note: All clearance reports you make are to the Air Traffic Control Centre (ATC) but may be made through a Communications Facility such as a Tower, Radio Range or Omni Range Station, etc. The Communications Facility relays your message to ATC and issues the clearance to you.

The Air Traffic Centre will clear you to a specific point. This may be your destination airport, radio or omni range or some radio or visual reporting point on route. The location to which you are cleared is known as a CLEARANCE LIMIT. e.g.:

"ATC clears Otter Delta Oscar Golf to Ottawa Range via Victor three zero zero.—Climb to and maintain ten thousand."

You must maintain (with precision) the altitude assigned, and must not deviate from the clearance in any way without advising ATC.

Should you arrive at the Clearance Limit without clearance beyond, or holding instructions, you must immediately request further clearance and meanwhile HOLD at the assigned altitude. The reason for this is that another airplane may be flying at your altitude beyond this point. (If you do not wish to hold, however, you may leave the Block Airspace and advise ATC.)

Position Reports: You are required to make Position Reports en route when passing all compulsory reporting points or when requested by ATC. A pilot on a Controlled VFR Flight Plan must maintain a continuous listening watch on the appropriate radio frequency at all times.

A POSITION REPORT is a report from an aircraft en route to ATC, made upon passing a Reporting Point. It states your identification, position, time of passing the Reporting Point, your altitude, your Flight Plan (type), your estimated time of arrival at the next reporting point, and the name of the reporting point beyond (to identify the route).

A REPORTING POINT is a geographical location in relation to which the position of an aircraft is reported. Compulsory Reporting points are shown on Radio Facility Charts as solid triangles ▲, non compulsory Reporting Points as outline triangles △. Reporting Points are usually radio range stations and the position report should be filed with the communications station associated with the radio range.

A Flight Plan may not be changed en route without authority from an ATC Centre. If you should desire to make a change in altitude, route or destination, obtain an amended clearance from ATC.

EMERGENCY

If instrument weather conditions are encountered, do not climb or descend but LEAVE THE AIRWAY IMMEDIATELY. Advise ATC as soon as possible of your action. (Remember that you can call any communications station along your route to request a report on weather conditions ahead.)

In the event of radio failure, maintain your last assigned altitude and LEAVE THE AIRWAY IMMEDIATELY. Report your action as soon as possible after landing.

When you are clear of the airway:

(i) Proceed, remaining well clear of the airway,

or

(ii) Descend below the block airspace and return to the airway—provided in either case the weather conditions you are flying in are VFR.

In the event of engine failure or any other cause necessitating an immediate descent, advise ATC immediately (using your emergency frequency (121.5 mc.) if necessary).
**Holding:** If you reach a Clearance Limit with no clearance to proceed beyond, or it becomes necessary for ATC to stop you from proceeding beyond a particular point, you will be required to HOLD. Since you are maintaining visual reference to the ground, a precise HOLDING PATTERN is not absolutely necessary, but it is no more difficult to fly than aimless circling around, and will be good practice in a procedure that you will need later on if you obtain your instrument rating.

The standard form of holding pattern is the elliptical, or “race track” pattern. It is illustrated and explained in Fig. D. The holding fix may be a radio range station, marker beacon, intersection of radio range beams, non-directional radio beacon (formerly known in Canada as “Compass Locator”) or any facility which can be definitely identified by a radio signal when you are directly overhead. Do not leave the holding pattern until cleared by ATC to do so.

![Fig. D. Standard Holding Pattern.](image)

**PROCEDURE WHEN APPROACHING TO LAND**

The TRAFFIC PATTERN (Fig. 1) is an imaginary rectangle oriented to the direction of the runway into wind. (A) Approach the field at 2000 feet, entering the Traffic Pattern at a tangent. Circle the field left handed, letting down to 1500 feet. Observe the Control Tower and windsock at (B) Turn on to the Cross Wind Leg at (C), letting down to 1000 feet. Join the Downwind (Initial Approach) Leg at (D) Close the throttle to test warning devices and let down the undercarriage (if applicable) at (E) Turn cross-wind on the Base Leg at (F) at a distance of not less than 3000 feet below the end of the runway in use. Turn on to the Final Approach Leg at (G) Lower flaps. Move propeller into fine pitch. Land straight ahead down the runway in use.

When approaching a strange field, enter the airport zone throttled back to slow speed and letting down in a gradual descent. Never dive into the area from a height or out of clouds.

Always plan your approach to land into wind, unless otherwise instructed by the Tower.

Wind Direction is indicated by several methods. Fig. E. Left: The WINDSOCK: the old reliable good Samaritan to homecoming airmen since World War I, and the traditional symbol of flying fields the world over. Captain Wise cautions you not to forget that the wind ALWAYS blows in the big end and out the small end. Right: the TETRAHEDRON as defined by Flatspin Fumble, a gimmick designed to satisfy the modern mania for change. Just so it would be different from the windsock, they designed it like an arrow whose SMALL END points into wind.

![Fig. E. Wind Direction Indicators.](image)

The Segmented Circle Marker, Fig. F, indicates the runways or landing strips, and the traffic pattern direction.

![Fig. F. Segmented Circle Marker.](image)

When you enter the Traffic Pattern, check the condition of the field, or runways, and the taxi pattern to be followed after landing.

On the Downwind Leg watch the Control Tower for light signals.

- **Steady Green Light** — Clear to land.
- **Steady Red Light or Red Flare** — Do not land — continue in circuit. Avoid making sharp turns, climbing or diving after you receive this signal.
- **Flashing Green Light** — Recall signal. Return for landing (usually to recall an aircraft which has taken off) This will be followed by a steady green light when the approach path and landing area is clear.
- **Alternating Red and Green Light** — Danger — Be on alert. This signal may be used to warn you of such hazards as danger of collision, obstructions, soft field, ice on runways, mechanical failure of your undercarriage, etc. The Danger Signal is not a Prohibitive Signal and will be followed by a red or green light as circumstances warrant.

**Note:** This signal has been discontinued in Canada.

**Flashing Red Light.** — Airport unsafe. Do not land.
By day, the pilot should acknowledge all light signals from the Tower by moving the ailerons or rudder, at night, by blinking the landing light. Do not acknowledge by blinking the navigation lights, since this is an URGENCY signal.

When cleared to land by a green light signal, come in on a straight glide or power approach for a distance of not less than 3000 feet. Do not S-turn. Continue to watch the Tower on final approach for further signals.

After landing, clear the runway as quickly as possible by taxiing ahead to the nearest intersection or taxi strip. If you have landed beyond a turn-off point, proceed to the end of the runway, turn off and wait for permission to taxi back to an intersection. Do not turn and taxi back against the direction of landing traffic, however, unless instructed to do so by the Tower. Note: All runways, except the runway in use, may be considered as taxi strips.

If the field has no Air Traffic Control Tower, after landing turn left 90° and watch for aircraft landing before taxiing in.

Runways are marked by white or amber lights. When required for take-off or landing, only the runway in use is lighted. When, however, a runway is required for taxiing, that particular runway (but not the approach lights leading to it) may be lighted until the taxiing aircraft has cleared.

Taxiways are usually marked by blue lights.

Favorable approaches may be indicated by green lights. When, however, the approach lights are mounted on posts to indicate a line of approach, they are red or amber.

If an airport (without lighted runways) is not flood-lighted, the landing area may be indicated by:

(a) A line of white lights with green lights at one end and red lights at the other end. Landings are made from the direction of the green lights towards the red lights.

The green lights at the approach end are referred to as "Threshold Lights".

(b) A long T. Landings are made parallel to the long arm of the T and must not overshoot the cross arm.

A night beacon flashing by day, a stationary flashing red light on the control tower at night, or blinking the lights outlining the traffic direction indicator means "Visual flying suspended."

Blinking the runway lights means "Clear the runway immediately."

A flashing amber light on the control tower means "Right hand circuits in the traffic pattern."

Black smoke bombs bursting by day or white lights or stars bursting by night means "Land immediately."

Orange smoke bombs bursting by day or orange lights or stars bursting by night means "Alter course." (You are flying over a prohibited area.)

**RUNNING LIGHTS**

**SINGLE-ENGINE AIRCRAFT**

*Port (left) wing tip: RED light visible for 3 miles from dead ahead through an angle of 110°. Starboard (right) wing tip: GREEN light visible for 3 miles from dead ahead through an angle of 110°. Tail: WHITE light visible for 3 miles to rear through an angle of 140°.*
Airmanship

Running Lights (also referred to as Position Lights or Navigation Lights) must be displayed on a landing area, under way on water, and in flight at night. Aircraft carrying passengers at night must be equipped with running lights, landing light(s), flares, spare fuses, and, if over 12,000 lbs. gross weight, an anti-collision flashing beacon.

Aircraft moored or at anchor at night must carry one white light visible all around the horizon. Seaplanes under way and under control must carry a white light forward visible for 3 miles through an angle of 220° ahead.

Most airline and many non scheduled aircraft are fitted with flashing navigation lights. At the time this is written, there is no ruling on this requirement—which is therefore entirely optional.

DISTRESS SIGNALS

From aircraft in flight

DISTRESS, meaning “I am threatened with grave and immediate danger.” A succession of red lights fired at short intervals, SOS flashed with signal apparatus, or a series of flashes of the navigation lights.

URGENCY, meaning “I am compelled to land.” A succession of white lights by day, or a series of flashes of the navigation lights by night.

SAFETY, meaning “I have an urgent message to transmit.” A succession of green lights, or a succession of green flashes with signal apparatus.

The landing light turned on means “I request a clearance to land.”

See also — “DISTRESS — URGENCY — SAFETY” in the Chapter on Radio.

FORCED LANDING

A seasoned pilot will seldom get caught with engine failure without having a forced landing area already selected in his mind. He forms the habit of picking suitable fields as he goes, and constantly checking the wind. As a result, if his engine unexpectedly quits, he immediately knows of a suitable field and is free to concentrate entirely on his approach.

The requirements of a good forced landing ground are:

1. Firm surface, reasonably smooth, with sufficient space to effect a landing into wind. Pasture land is okay because the short grass cannot hide holes, ditches, boulders, or other hazards. Avoid ploughed fields.

2. Approach clear of obstacles such as trees, telegraph wires, high tension lines, houses, etc. Avoid fields immediately alongside highways or railway lines because of wires.

3. Clear take-off.

In winter, if on wheels, it is better to attempt a forced landing on a highway comparatively free of traffic than a deep snow covered field.

Similarly, if forced to fly over very rough bush country on wheels, it is wise to keep within gliding distance of a highway as a possible emergency landing place. If no such highway exists, by all means pancake into a lake close in to a shoreline, or into muskeg, rather than risk crashing through timber.

Flying seaplanes over land was at one time considered a highly hazardous undertaking. Experimental landings, however, have proved conclusively that a seaplane can be landed in a restricted field with less risk of damage than the average landplane. A pilot should have no hesitation about flying a seaplane overland when necessary, provided good level country lies below, such as would be considered reasonably safe for landplanes.

FORCED LANDING SEQUENCE

ONCE A PILOT HAS MADE UP HIS MIND TO EXECUTE A FORCED LANDING, HE MUST STICK TO HIS DECISION, EVEN THOUGH THE ENGINE DOES PICK UP AGAIN AS HE NEARS THE GROUND. Should the engine pick up on the line of approach and the pilot decide to carry on, it may completely fail again a few moments later when he is no longer in a position to reach a field.

Immediately the engine fails:

1. Reduce speed to gliding speed and set stabilizer — any excess speed can be utilized to gain height.

2. Select a suitable field, check direction of wind, and glide to lee side of field.

3. Look around for the cause of the engine failure. If it cannot be found and rectified, close the throttle, shut off the switches and gas supply, open sliding windshields and emergency exits. Lower the flaps to the desired position for landing, and unless the field is too small for a successful landing to be assured, lower the undercarriage.

4. At leeward side of field, glide cross wind and look for any obstacles in the field. Decide on landing path.

5. Note drift, which will indicate strength of wind, and lose height by turning—always towards the field — until aircraft is in a position at about 1,000 feet, from which a cross wind approach can be carried out. Turn at about 500 feet in to the selected landing line and land into wind.

6. Tend to overshoot, and when certain of clearing all obstructions on the leeward boundary of the field, sideslip off the surplus height. Aim to land well into the field. It is better to overshoot and hit the far fence at low speed than to undershoot and hit the near fence at flying speed.

If it becomes necessary to stretch the glide to reach a certain field, do not lower the undercarriage or flaps until absolutely necessary, as these increase the drag and steepen the glide.

If the field is hopelessly small or rough for a safe landing, retract the undercarriage and make a “belly” landing.
Engine Failure on Take-off

If an engine fails immediately after take-off, land straight ahead—do not attempt to turn back into the field. Some instructors stretch this statement to ridiculous lengths and say that you should glide straight ahead no matter what may lie in your path—even if it means ploughing into a brick wall head-on. It would be mighty interesting to see one of these gentlemen caught with a dead engine and a brick wall staring him in the face sometime! Obviously, a good pilot caught in circumstances such as that would attempt to veer somehow and sidestep in on one wing rather than adhere to a rule which would dictate a head-on collision.

PRECAUTIONARY LANDING

A Precautionary Landing is one made with the engine and aircraft functioning normally but when landing is made compulsory due to shortage of fuel, being lost, bad weather, darkness, etc.

In the selection of a field, the same requirements as outlined in SELECTION OF A FIELD above should be sought for by the pilot.

Having chosen the field, fly over it at least once at low altitude, preferably to one side of the proposed landing path, to check the size and surface of the field, and the suitability of the approaches.

After the preliminary inspection, get into position for a normal engine-assisted approach and landing. Select the flaps down to landing position, if applicable. Approach with as low forward speed as possible (with, however, a safe margin above stalling speed) and aim to touch down as close to the near boundary as is practical. The aim is to reduce the landing run to the minimum.

If the field is very small, switch off the engine after touching down.

PROCEDURE AFTER FORCED LANDING

If the forced landing is due to engine failure, examine the tanks to see if there is gas and oil. Check the high tension leads to the plugs to see that they are intact. Examine the filters for dirt. Do not attempt to repair the trouble, if you have located it, unless you are experienced and qualified to do so.

If the failure is repaired, a thorough test of engine performance must be made before attempting to take-off.

If no self-starter is fitted, and it is necessary to get an inexperienced person to assist in swinging the prop., see that he is made familiar with propeller swinging routine before attempting to start the engine.

NEVER, UNDER ANY CIRCUMSTANCES, HAVE AN INEXPERIENCED PERSON HANDLE THE THROTTLE OR SWITCHES. THE PILOT ONLY MUST OPERATE THESE WHEN STARTING AN ENGINE.

If the trouble cannot be repaired, and it is necessary to obtain assistance, be sure to have the following information ready to transmit over the long distance telephone or wire:

1. Type of aircraft and engine model number.
2. Exact location of the field in which the forced landing was made, and the nearest village or town.
3. Reason for the forced landing, and cause, if it can be ascertained.
4. Whether gas or oil is required for the return trip.
5. Any parts, special tools, or materials required to make the necessary repairs.
6. Whether the forced landing field is suitable for take-off.
7. The type of ship that may safely land and take-off from the field.
8. The telephone number at which you may be reached.

PICKETING AIRCRAFT IN THE OPEN

1. Picket plane behind a barn, haystack or similar shelter if available.
2. Head plane into wind.
3. Lash controls in neutral. Secure ailerons by chocks (see Fig. 2)
4. Lock brakes, if fitted, and place chocks at both front and rear of wheels.
5. Peg down with ropes and stakes. If ground is frozen, ropes can be secured by freezing to ground with snow and water.
6. Cover engine with improvised engine cover (piece of tarpaulin, or canvas, etc.) Also cockpit, if open type.
7. In excessive cold weather, drain oil.

![Diagram of Picketing an Aircraft in the Open](Image)
If sheltered area is not available, re-picket airplane whenever there is a change of wind.

**ACTION IN THE EVENT OF FIRE**

**Single Engine Aircraft**
1. Turn off gas.
2. Open throttle fully (to get rid of gas in fuel lines).
3. Switch off when engine ceases firing but not before.
4. Sideslip to keep flames from fuselage and fumes from pilot.
5. Operate fire extinguisher.
6. When the fire ceases, do not continue — land in nearest suitable field and investigate cause of fire.

**Twin-Engine Aircraft**
1. Turn off fuel to burning engine.
2. Open throttle fully on this engine.
3. Switch off when the engine ceases firing.
4. Keep straight course and reduce speed to minimum required for maintaining height.
5. When fire subsides, throttle back sound engine and land immediately in nearest suitable field. Do not sideslip as flames may spread to tanks or fuselage.

**ENGINE FAILURE**
A few of the common causes of engine failure which can be put right in the air are the following:
1. Gas cock accidentally knocked closed.
2. Failure to switch over to full fuel tank when the one in use runs dry.
3. Switches accidentally knocked off.
4. Mixture control or choke inadvertently open.
5. Failure of fuel supply from the tank in use.
6. Carburetor icing.

**LOW FLYING**
Remember the one about the dear old lady who cautioned her son to "Always fly LOW and SLOW"? There is one occasion on which her counsel turns out to be good sound airmanship after all. That is when a pilot is forced to fly low in thick weather. Under these conditions the following precautions should be observed:

- Reduce speed because of the limited visibility — but keep a safe margin in case it is necessary to turn fast to avoid a collision. Always keep one hand on the throttle, ready for any sudden emergency.
- Keep more than a customary sharp look-out both ahead and on either side.

Remember that it is easy to overestimate actual airspeed when flying low downwind, because of the apparent high ground speed, and a pilot has therefore a tendency to stall after turning down wind.

It should be noted that the tendency to stall when flying downwind is due to an optical illusion on the part of the pilot. The actual stalling speed of an airplane is the same whether flying up-wind or downwind.

When forced to fly low, detour around any towns or cities that lie along your route.

Flying low in thick weather should only be resorted to, of course, in an emergency, or when authorized to proceed with conditions below VFR minimums by an Air Traffic Controller.

**GUST CONDITIONS**
A gust or bump increases the load on the wings. The speed of the airplane should therefore be reduced when flying in gusty air.

In approaching to land, on the other hand, a little higher speed should be maintained to assure positive control.

A light airplane making a landing in gusty wind should make a WHEEL LANDING. With this type of landing, the airplane makes contact with the ground while still maintaining flying speed. There is no critical period between positive air control and positive ground control. If the tail is held high until all forward speed has been lost, there is no tendency for a gust to lift the plane back into the air.

**COLLISION HAZARD**
With the progressive increase in both speeds and traffic density, risk of collision becomes an increasingly serious hazard. A pilot in a high speed executive transport airplane who observes a jet ½ mile distant on a 90° converging track HAS APPROXIMATELY 7 SECONDS TO TAKE EVASIVE ACTION.

When another airplane is approaching your track at any angle, and there is no apparent change in the relative position at which you first saw it, YOU ARE ON A COLLISION COURSE. Take evasive action immediately.

Observe the traffic rules governing altitude to fly both on and off airways rigidly. If visibility drops below VFR minimums, and you are not qualified to file an IFR flight plan, DO NOT PROCEED. Land or turn back.

**AIR ENDURANCE**
The Maximum time an aircraft can continue to fly under given conditions without refuelling.

**RANGE**
The maximum distance an aircraft can fly in still air in standard atmosphere without refuelling.

**RADIUS OF ACTION**
The distance an aircraft can fly and return under given conditions without refuelling (less 45 minutes reserve).

**LOADS**
A pilot is responsible for the safe loading of his ship. An airplane may be overloaded to the extent that the take-off run is greater than the available runway. The Total Gross Weight Authorized for any particular aircraft type must never be exceeded. A pilot must therefore be capable of estimating the proper ratio of gasoline, oil and pay load permissible for a flight of any given duration. The following data will be found helpful in this regard:

**WEIGHTS**
- **Weight Empty:** The weight of the airframe and engine with all standard equipment installed.
- **Extra Equipment:** Any and all additional instruments, generators, radio equipment, etc. installed but not included as "standard equipment", the weight of which must be deducted from the pay load.
- **Basic Weight:** The weight of the aircraft with all special equipment included is sometimes referred to as the Basic Weight.
- **Disposable Load:** All load which is removable, that is, which is not permanently part of the airplane. It includes the gasoline and oil, pilot, crew, passengers, baggage, freight, etc.
- **Pay Load:** The load available as passengers, baggage, freight, etc., after the weight of pilot, crew, gas and oil have been deducted from the disposable load.
- **Gross Weight:** The all-up weight of the airplane fully loaded.
Example: Typical Light Airplane

Basic Weight 993 lb.
Consisting of:
Weight Empty 973 lb.
Extra Equipment 20 lb.
Disposable Load 607 lb.
Consisting of:
Pilot, 165 lb.; Gas, 146 lb.; Oil, 15 lb.
Authorized Gross Weight 1,600 lb.

FACTORS
The pilot's weight (Canada) is assumed for all practical purposes to be 165 lbs. Male passengers: 165 lbs. Female passengers: 143 lbs. Children: 77 lbs. Infants: 22 lbs. In the United States, 170 lbs. per person, passengers and crew.


FUEL CONSUMPTION
The Specific Fuel Consumption of aero engines at full take-off power varies from around .57 to .66 lbs. per Brake Horse Power per Hour. This represents approximately 8 to 9 gallons per 100 H.P. per Hour.

Cruising consumption varies with the percent of power used, altitude, mixture, and a number of other variable factors. Cruising at 55% to 60% of power, .55 lbs. per B.H.P. per Hr. (of the cruising power used, that is) might be assumed a reasonable average cruising consumption for light engines up to 200 H.P. with fixed pitch propellers—including take-off, cross country cruising and descent.

To find the cruising consumption of an engine of, say, 100 H.P., cruising at 60% of power:

Factors: Cruising consumption—.55 lbs. per B.H.P. per Hr.

Power used—60% of 100 H.P. = 60 H.P.
Then .55 x 60 = 33 lbs. per hour.
Or 33 ÷ 7.2 = 4.6 gals. per hour.

Supercharged engines with constant speed propellers, automatic mixture control and other devices for improving cruising consumption would average closer to .50 lbs. per B.H.P. per hr.

Using 100 Octane gasoline, some large modern aero engines consume as little as 0.375 lbs. of gasoline per B.H.P. per hour.

More specific cruising consumption figures for any particular engine should be obtained by consulting the manufacturer's handbook which is furnished with the engine.

COMPUTING THE LOAD

PROBLEM: To find the maximum payload that can be transported a given distance and the amount of fuel required.

EXAMPLE: A de Havilland Beaver seaplane is required to transport a maximum load of freight a distance of 350 miles. The ship is fitted with a Wasp Junior engine, 450 h.p. The estimated ground speed is 124 m.p.h., cruising at 240 H.P. (approximately 53% of power). The disposable load is 1836 lbs. Fuel capacity is 72 Imp. gals. Oil capacity is 5 Imp. gals.

SOLUTION:
Engine consumption: 240 x .50 = 120 lbs. per hr.
Time to fly 350 miles: 350 ÷ 120 = 169 minutes.
Plus 45 minutes reserve: 169 + 45 = 214 minutes.

AMOUNT OF FUEL REQUIRED
(at 120 lbs./hr.) 120 ÷ 60 = 2.0 = 214 lbs.

If the cruising consumption of the engine in gals. per hr. is definitely known, an alternative method of computing the weight of fuel is as follows:

(at 16.7 gal./hr.) 16.7 ÷ 10 = 169 gals.
or 59.5 ÷ 7.3 = 82.4 lbs.

Therefore: Disposable Load 1836 lbs.
Less: Fuel 428 lb.
Oil (5 x 9) 45 lb.
Pilot 165 lb.

MAXIMUM PAYLOAD PERMISSIBLE 1198 lbs.

FLOAT BUOYANCY
The maximum permissible gross weight of a seaplane is governed by the buoyancy of the floats. The buoyancy of a seaplane float is equal to the weight of water displaced by the immersed part of the float. This is equal to the weight the float will support without sinking beyond a predetermined level (draught line).

The buoyancy of a seaplane float is designated by its model number. A "4580" float has a buoyancy of 4580 lbs.

Civil Air Regulations require an 80% reserve float buoyancy. This means that the buoyancy of the floats must equal 1.8 times the weight of the airplane.

To find the maximum gross weight of a seaplane fitted with, say, 7170 model floats:

(i) Multiply the float buoyancy by 2.
(ii) Divided by 1.8.

EXAMPLE: 7170 x 2 = 14340 lbs.
1.8

WEIGHT AND BALANCE
The position of the Centre of Gravity affects the stability of the aircraft. If it is too far forward, the airplane will be nose heavy, if too far aft, tail heavy. An airplane whose centre of gravity is too far aft may be dangerously unstable, and will possess abnormal stall and spin characteristics. Recovery may be difficult. It is the pilot's responsibility when loading an airplane to see that the C.G. lies within the recommended limits.

On some types of large modern aircraft certain items of expendable load will affect the C.G. during flight and when landing. It is necessary for transport pilots flying such types to be able to calculate the C.G. position during flight and to trim the aircraft by rearranging the disposable load—particularly before landing. Such computer calculation is beyond the scope of this book, but an elementary discussion on the method of calculating AIRPLANE BALANCE will be found in "Weight and Balance". (Theory of Flight).
The following is a typical C.G. calculation example:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight</th>
<th>Moment</th>
<th>Arm</th>
<th>Balance Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Landplane</td>
<td>2,800</td>
<td>5.4</td>
<td>-15,110</td>
<td></td>
</tr>
<tr>
<td>Pilot</td>
<td>170</td>
<td>7.0</td>
<td>1,190</td>
<td></td>
</tr>
<tr>
<td>Fuel (Front tank, 26.5 Imp. Gal.)</td>
<td>191</td>
<td>4.5</td>
<td>859</td>
<td></td>
</tr>
<tr>
<td>(Centre tank, 26.5 Imp. Gal.)</td>
<td>191</td>
<td>-19.6</td>
<td>-3,740</td>
<td></td>
</tr>
<tr>
<td>Oil (5.2 Imp. Gal.)</td>
<td>47</td>
<td>37</td>
<td>1,739</td>
<td></td>
</tr>
<tr>
<td>Front Passenger Seat</td>
<td>8.5</td>
<td>5</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Front Passenger</td>
<td>170</td>
<td>7</td>
<td>1,190</td>
<td></td>
</tr>
<tr>
<td>Centre Passenger Seat</td>
<td>8.5</td>
<td>31</td>
<td>264</td>
<td></td>
</tr>
<tr>
<td>Centre Passenger</td>
<td>170</td>
<td>-29</td>
<td>-4,930</td>
<td></td>
</tr>
<tr>
<td>Radio</td>
<td>53</td>
<td>-83</td>
<td>4,400</td>
<td></td>
</tr>
<tr>
<td>Trailing Antenna</td>
<td>9.4</td>
<td>-56</td>
<td>-526</td>
<td></td>
</tr>
<tr>
<td>Emergency stowage</td>
<td>75</td>
<td>-92</td>
<td>-6,900</td>
<td></td>
</tr>
<tr>
<td>Baggage</td>
<td>150</td>
<td>-32</td>
<td>-4,800</td>
<td></td>
</tr>
<tr>
<td>Cargo</td>
<td>250</td>
<td>-53</td>
<td>-13,250</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>4,293.4</td>
<td>-19,227</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hence Basic Balance Moment + Load Moments

\[
\text{Total Weight} \quad = \quad -19,227 \\
\frac{4,293.4}{4,293.4} \quad = \quad -4.5 \text{ inches} - \text{which is the distance of the loaded aircraft's C.G. behind the vertical datum.}
\]

PROCEDURE WHEN STARTING ON A CROSS COUNTRY FLIGHT

1. Obtain up-to-date aeronautical charts appropriate to the route you plan to fly.
2. Study the Weather Map for wind circulation, frontal activity, and the weather over the whole general area in which you intend to fly. (This knowledge will be valuable in case you have to alter your flight to an alternate destination.) Check the Terminal, Area, and Winds Aloft Forecasts, Hourly Weather Sequences along your route.
3. Study the route, plot the Heading to steer by Compass, and the Ground Speed for each leg. Prepare the map, as detailed in the Chapter on Air Navigation — "Preparation for a Flight".
4. Compute the safe range of your plane.
5. Select refuelling points.
6. Check suitability of airports, runway patterns, and field conditions.
7. Note time of sunrise and sunset (VFR).
8. Check radio facilities which are available en route, and the frequencies on which they operate.
10. Be sure you are familiar with pertinent flight information, such as Air Navigation Radio Aids—Airway Lighting Aids—Good Operating Practices—Air Traffic Control Procedures—Radio Telephone Procedures and Techniques—Search and Rescue—Weather Bureau information available.
11. Check Caution, Restricted and Prohibited areas—Air Defence Identification Zones (ADIZ) and Security Identification Zones (SIZ).
12. Fold maps correctly and place in proper sequence in the cockpit. Be sure to carry other maps adjacent to your line of flight. You may need them badly in case you have to fly around bad weather or become temporarily lost.
13. Be sure that you are properly licensed and qualified for the particular type of plane you're flying, and the nature of the flight you are about to undertake.
14. See that aircraft is properly signed out. Mandatory certificates and manuals on board. Licenses and/or permits carried by members of the crew.
15. Fuel of proper grade on board, sufficient for the flight plus 45 minutes reserve.
16. Check the Load (all-up weight must not exceed the authorized limit) and the distribution of the load (to insure that Centre of Gravity is within safe limits).
17. Check the Temperature, and the Elevation of the field. Be sure that runway lengths are adequate if high temperature or high altitude conditions prevail.
18. Regardless of the weather along your route, whether or not it is compulsory, to do so, FILE A FLIGHT PLAN with ATC (Air Traffic Control). This will ensure that Search and Rescue planes will be out to aid you in case you fail to reach your destination. A VFR Flight Plan should contain the following information:

**Flight Plan**

(i) Aircraft identification.
(ii) Type (and colour).
(iii) Point of departure.
(iv) Flight altitude and Route to be followed.
(v) Point of first intended landing.
(vi) Time of departure.
(vii) True airspeed.
(viii) Estimated elapsed time.
(ix) Radio frequencies.
(x) Pilot's name.
(xi) Remarks.

*This is not compulsory, but strongly recommended by Air Traffic Control for search and rescue reasons. Odd or even altitudes appropriate to the direction of flight are, however, mandatory.*

The specification of an Alternate Airport—Approach Aids to be used—Number of persons on board—and Fuel on board (in hours + minutes) must be included in an IFR Flight Plan, but are not required in a VFR Flight Plan. (Note: In an IFR Flight Plan the true airspeed must be stated in KNOTS.)

19. If flight to be made over bush country or isolated area see that proper emergency equipment is placed aboard.

If the flight is to be across the Canadian-United States border, you must clear customs outward from a Customs Port of Entry. Your first landing must be at a Customs Port of Entry on the other side of the international border to clear customs inward. Regulations require that you must notify the customs authorities of your Expected Time of Arrival in advance. Upon landing, you must not leave your aircraft until the customs and immigration officers arrive at the airport to clear you.

If you add "ADVISE CUSTOMS" to your Flight Plan, A.T.C. will automatically notify the customs authorities of your Expected Time of Arrival. This saves you the inconvenience of sending a wire or making a long distance phone call. The Flight Plan must contain the name and nationality of each passenger aboard the aircraft.

CROSS COUNTRY PROCEDURE IN-FLIGHT

1. Pilot's inspection before flight. Engine starting and run-up. Cockpit check. Aerodrome procedure, etc.
2. Take off, note time of departure. Turn on to desired compass heading. Climb to selected altitude. Adjust power and mixture in accordance with the manufacturer’s operating instructions during climb and cruise. Check all instruments during climb.

3. Check distance, time and rate of speed by D.R. navigation as detailed in the Chapter on Air Navigation, or by radio aids as detailed in the Chapter on Radio. Make course corrections and revise expected time of arrival as necessary.

4. Avoid thunderstorms and turbulent air, if possible. Take appropriate action if unavoidable.

5. Check the weather as you go by radio or observation.

6. Apply carburetor heat, windshield defroster, wing de-icers when necessary.

7. Observe air traffic rules, especially those dealing with ceiling and distance from cloud, visibility, cruising altitudes both on and off airways, weather minimums in Control Zones and Control Areas.

8. Keep a constant lookout for other aircraft.


10. Observe wind and weather changes.

11. Report to communications stations en route any unusual weather conditions encountered, or observed, as an aid to other pilots. Reports so transmitted by pilots on route are referred to as PIREPS.

12. Fly around bad weather if possible. If this is impractical . . . turn back—repeat—turn back.

13. Check your flight and engine instruments frequently. Be sure you understand “altimeter setting” and altimeter errors thoroughly.

14. Report time over intermediate stations en route. This is good practice if you intend to acquire an instrument rating later on, and it provides Search and Rescue Service with a clue as to your whereabouts if you fail to arrive at your destination.

15. On approach to destination, contact Control Tower, if the field has one.

16. Observe segmented circle marker, wind tee or windsock, and note direction of traffic.

17. Follow instructions from the Control Tower (when available). Observe standard procedure when entering Traffic Pattern. Keep a sharp lookout for other aircraft. Be ready to pull up and go around if necessary.

18. Be thoroughly familiar with traffic control light signals as they apply to traffic both on the ground and in the air.

19. Clear the active runway as quickly as possible.

CROSS COUNTRY POST-FLIGHT PROCEDURE

1. Taxi with utmost caution to parking area or gas pit.

2. CLOSE YOUR FLIGHT PLAN by filing an ARRIVAL REPORT with ATC. If Air Traffic Control fails to receive an Arrival Report within a reasonable time, you will be assumed lost and a costly Search and Rescue operation begun.

3. Refuel the tanks and service your aircraft.

4. Tie-down securely if hangar storage not available. Put wing covers and engine covers on if aircraft stored in open in cold climate.

ADIZ

The Defence Authorities of both the United States and Canada have established a number of Air Defence Identification Zones (ADIZ) for the security control of air traffic. It is imperative that pilots must acquaint themselves with the locations and boundaries of these zones. This information may be obtained from aeronautical charts, radio facility charts, "Flight Information Manual" (U.S.), "Canada Air Pilot" or "Designated Airspace Handbook" (Can.).

No aircraft may be flown into an ADIZ unless it is equipped with functioning two-way radio.

In Canada, no aircraft may enter or fly within an ADIZ unless it has filed a flight plan. In the United States, a flight plan is only required if the direction of flight is TOWARDS the centre of the Defence Zone—or in the case of the Canadian and Mexican borders, if the flight is INTO the United States.

Pilots flying on instruments will file an IFR Flight Plan.

Pilots flying "contact" will file a "DVFR" (Defence Visual Flight Rules) Flight Plan, which is the same as a VFR Flight Plan, except that it is compulsory. In filing a DVFR Flight Plan, the abbreviation "DVFR" will be inserted before (iv) The Flight Altitude, in the Flight Plan.

The Flight Plan must be filed in person or by phone. C.A.A. facilities in the U.S. will accept collect phone calls to file a DVFR Flight Plan provided you use the prefix "SECURITY PILOT" before your own name when placing the call.

A DVFR Flight Plan is not required to fly over domestic ADIZ's if the aircraft maintains an altitude below 3,000 ft. above the ground. A DVFR Flight Plan is, however, required without exception when flying over the coastal or international boundary zones.

Before entering an ADIZ, a pilot on a DVFR Flight Plan must report to a C.A.A. or D.O.T. radio communication station either:

1. The estimated time, position and altitude at which he will penetrate the ADIZ; or

2. The time, position and altitude when he passed the last reporting point before penetrating the ADIZ, and his estimated time over the next reporting point.

Pilots must file an IFR or DVFR Flight Plan when entering either the United States or Canada across an international boundary ADIZ. They should check with the first airport of landing across the border for full information regarding the "Security Control of Traffic Regulations"—Part 620 of the Civil Air Regulations in the U.S.A.—NOTAM 30/56 in Canada.

SIZ

The security rules for the identification of aircraft within ADIZ's do not apply to aircraft flying below 3,000 feet—since aircraft can be readily identified by ground observers at low altitudes. Security Identification Zones (SIZ) have, however, been established in certain areas within which aircraft flying at or below 3,000 feet SOUTHBOUND must comply with the rules which apply to ADIZ's above 3,000 feet. When penetrating a SIZ in a southerly direction, the DVFR Flight Plan must be filed at least 15 minutes before penetration.

MOVING AIRCRAFT IN AND OUT OF HANGARS

Maneuvering airplanes in and out of hangars requires considerable judgement, acquired only by practice. The pilot, or air engineer in charge of the ground crew should supervise the storage or removal of aircraft from hangars. Considerable damage can be done by lifting, pushing or pulling airplanes at other than designated handling points. A mechanic should be stationed at each wing tip while the plane is being maneuvered around other machines.
MOVING AIRCRAFT OVER BAD GROUND

The ground must be carefully inspected by the pilot or a thoroughly qualified person. A "dolly" should be used under the tail. If this is not available, the tail should be lifted over rough ground. The tail must be lifted only at the point marked "Lift here" by the manufacturer—usually under a vertical fuselage member.

If the tail has to be carried some distance, a man may hang on the propeller boss to help balance the weight, but he must hold himself in readiness to leap clear in case the plane should accidentally overturn.

In soft ground it may be necessary to lay a track of planks. In bush country, a "cordonoy" road of poles will serve the same purpose.

CARE OF THE AIRPLANE

CLEANLINESS: Use soap and water only. Never use gasoline on fabric. Remove mud with water. See that drain grommets in wings are not clogged.

Metal airplanes are susceptible to corrosion and must be kept scrupulously clean to prevent corrosion. Cleaning agents which do not contain abrasive compounds should be used. Wax applied to metal surfaces prevents oxidation and reduces the amount of cleaning and polishing required.

EXHAUST HEATERS. Cabin heaters which obtain heat from the exhaust system should be inspected at frequent intervals for leaks which might allow carbon monoxide fumes to enter the cabin.

IMPORTANCE OF CLEANLINESS: Dirt covers defects, making them more difficult to detect. Dirt also increases skin friction, detracting from the performance of the aircraft. Dust in fuselage increases weight and adds to fire hazard.

CONVERSION FACTORS

To convert:

Imp. gals. to U.S. gals.: Multiply by 1.20
U.S. gals. to Imp. gals.: Multiply by .833

Inches Hg. to Millibars: Multiply by .339
Millibars to Inches Hg.: Multiply by .0295

Fahrenheit to Centigrade: \((F - 32) \times \frac{5}{9}\)
Centigrade to Fahrenheit: \(9.5 \times C + 32\)

"Inches Hg." means Inches of Mercury.

BUSH SENSE

Canada's vast Northland offers a challenge to the spirit of youth which few other lands the world over can rival. To the Sportsman Pilot it spells romance—the thrill of the great outdoors, the lure of unfished waters, the zest of virgin forest hunting areas. To the Commercial Pilot, its mining, forest and fur industries offer rare and profitable opportunity.

Flying in the trackless wilderness can be just as safe and practicable as flying the organized airways. Plain, ordinary airmanship—a knowledge of the basic laws, and proper provision for essential needs, are the secrets of the bush pilot's much publicized "sixth sense". Bush sense is, after all, just reasonable proficiency in the handling of seaplanes and skiplanes, plus some fundamental knowledge of the woods.

Turbulence. Temperature variations between large areas of rock and water in the North country cause turbulence more pronounced than in more settled areas. Shore-line bumps can be sudden and violent. A seaplane approach over a shore-line should be made in a straight line and with a margin of surplus speed.

Shore-line bumps also present hazards to take-off. In a strong wind, a very severe down-current of air may be encountered in taking off towards a steep shore-line. Always allow yourself plenty of room when taking off towards a steep rising shore.

Glassy Water. One of the most difficult conditions a bush pilot has to contend with is glassy water. When water is glassy, its surface is practically invisible from above.

1. Try to land alongside a weedbed if one exists within reasonable distance of the landing area. If necessary, land in the weeds. Wild rice is not heavy enough to turn a seaplane over.

2. Land in close to a shore-line, using the shore-line as a guide to the height of the surface of the water. Before doing so "drag" the shore-line at low altitude to look for reefs and shoals.

3. Fly the aircraft on by instruments. Make a straight approach down from 300 or 400 feet. Maintain sufficient back pressure on the control column to keep the nose high (to prevent the floats or hull from "digging in" and turning you over). Maintain sufficient power for safe forward speed above the stall, allowing the aircraft to slowly "mush" or "sink". When you make contact with the water, close the throttle and ease the control column forward gently to prevent the ship from bouncing out of the water.

This method of approach and landing on glassy water should be practiced under normal landing conditions at every possible opportunity.

If caught with a dead engine over glassy water and beyond gliding distance of a shore-line or weed bed, do not hesitate to throw the cushions or any moveable equipment overboard to make ripples on the water to land by.

Rough Water. Do not attempt "step" landings on rough water. Land SLOW. If gusty weather has necessitated coming in fast, hold off until all surplus speed has been lost. Waves, like sheep, travel in flocks. In very rough water, comparative calm patches can sometimes be found by looking ahead.

Entering a Strange Area. When landing in a strange area, circle the vicinity low several times to look for rocks, reefs or floating timber. If you are not sure of their location when about to take-off, taxi slowly down wind over the area you intend to use on take-off.

The Wind Direction for landing on water can be observed by noting the calm space which always
exists on the lee side of the shore-line over which the wind is blowing.

Taxying. Taxi either very slowly or very fast (up on the step). Taxi speeds in between are critical as they will cause spray to strike the tips of the propellers, causing serious damage, and will also overheat the engine.

Do not approach a dock or rocky shore down-wind in a high wind, head-on. Allow the aircraft to weather-cock and sail it in tail first, using bursts of engine if necessary to steer it.

Taking Off. A take-off from a very restricted area can be assisted by having persons on the shore hold the tail by a rope until the engine is rev'd up — and then cut it loose.

Another method is to get the plane up on the step down wind and then "skid" around into wind in a wide circle. This maneuver is more applicable to flying boats than seaplanes because of their lower centre of gravity.

A take-off from glassy water can be assisted by taxying over the area to make ripples, or having a boat do so.

Immediately after taking off in very cold weather, move the controls to prevent spray from freezing on the control hinges.

**SKIPLANES**

Unbroken Snow. An unbroken snow surface, particularly with an overcast condition, is sometimes as difficult to judge as glassy water. A high wind may cause drifting snow for a height of three or four feet above the surface, similar to a ground fog. If in doubt as to snow surface conditions, fly the aircraft on, using the same method as detailed for glassy water, above.

Soft Snow. If snow conditions are soft, sweep a runway, or make one by taxying up and down with the aircraft lightly loaded before attempting to take off with full load.

When taxying in loose snow, make good wide turns to avoid too much torsional strain on the undercarriage.

If the snow is sticky, oil the skis before taking off. One simple method of doing this is to freeze a couple of bags to the ice. Saturate these with coal oil and taxi over them when about to take off.

Ice on Wings. Make sure that all surfaces are free from moisture, frost, ice or snow before attempting to take off. Even a light coating of frost can destroy the lift of the wings sufficiently to prevent a take-off.

Picketting in the Open. Skiplanes can be picketed by freezing the ends of the wing and tail mooring lines into the ice. (Dig a channel in the ice through which the mooring lines can be passed and frozen in)

When picketting overnight, block the skis up off the ice, or place a mat of evergreen under them. Skis become warm from taxying, may melt the ice under neath, and by morning become frozen in.

If the ice has become soft and honeycombed, it may be necessary to move the aircraft several times during the night. The weight of the aircraft generates heat and it may commence to thaw its way through the soft ice.

Landing on Glare Ice. Unless the aircraft is fitted with a steerable tail ski or some other form of anti ground-looping device, allow yourself as much room as possible in all directions when landing on glare ice.

Wet and Slushy Snow is similar to mud. With this condition, therefore, always land with the tail well down. In the Spring when there is some doubt as to ice conditions on a lake, land out in the middle. The ice is always thickest there (unless there is a current).

**EQUIPMENT**

The following minimum equipment should be carried by aircraft operating over remote areas in bush country:

**Seaplanes**

1 small light-weight folding anchor.
2 wing lines (about 30' long).
1 line (about 50' long) for anchoring, or for tying the tail to a tree or rock when beached on a shore.
1 paddle.
1 bilge pump (for pumping out the floats or hull).
1 engine cover.
1 float repair kit.

A gallon pail is not a necessity, but comes in handy. It can be used to store some of the emergency kit, for carrying water, as a drogue (sea anchor) or as an anchor (by filling it with stones).

**Skiplanes**

1 snow shovel.
2 wing lines (about 15' is ample).
1 line (about 50' long).
1 engine heating tent. This fits completely over the nose and reaches to the ground. It is designed to house a stove for preheating the engine in sub zero weather which is too severe for oil dilution to be effective (below -20 F).
1 blowpot, or some other form of stove, for preheating the engine and lubricating oil.
1 scraper. For removing frost or ice from the windshield.
1 set of wing covers.
A tent. (If engine or wing covers are carried they may be used to improvise a tent.)

**All Bush Aircraft**

1 fuel funnel and chamois.
1 oil can.

Engine and airframe tools and spares sufficient to affect at least minor repairs.

Most bush pilots carry a small portable semi-rotary pump for refuelling out of gas drums.

**EMERGENCY EQUIPMENT**

At least 5 lbs. of concentrated food per person.
Matches in four separate waterproof containers. (One should be carried on the person of the pilot).
Three-quarter size axe with 26” handle. 
Clasp knife, with splicing attachment.
Flash light.
Snowshoes.

If you become lost in smoke haze, rain fog or snow, do not fly aimlessly, use your fuel supply. Land immediately, tie up and wait until conditions improve sufficiently to enable you to go up and pick up your bearings.

If you have landed with trouble sufficiently serious to preclude all hope of getting away, REMAIN WITH YOUR AIRCRAFT. An airplane is a comparatively easy object for search and rescue planes to spot, but a human being in a forest is an almost impossible objective. Remain with your aircraft, reserve your energy and conserve your food supply. Have a smudge fire ready to light to assist search planes in locating you.


**GROUND-AIR EMERGENCY SIGNALS**

**To Attract Attention**

1. Make a smudge fire by pouring oil on rags or using green grass, brush wood, or anything to produce heavy smoke.
2. Make large SOS in open ground. In snow, outline with boughs or moss.
3. Make trails in virgin snow. These can be readily seen from search aircraft.
4. Lay your cowlings out so they shine in the sun.
5. Keep your aircraft clear of snow or brush.
6. Using radio, call at 15 and 45 minutes past the hour (weather broadcast times). Save your battery as much as possible.
7. Point the flashlight at approaching aircraft and flash SOS.

**RADAR ADVISORY SERVICE**

Radar Weather Advisory Service is available in the United States. To provide information with regard to storm areas and, at pilot’s request, suggestions as to safest route of flight around or through the storm areas. To obtain the service, call “STARGAZER” on 133.2 mc. (or 121.5 mc.). “Stargazer” is a special call sign that automatically indicates you are requesting radar weather advisory service. State your aircraft identification, position, heading, and your flight plan (type) e.g.:

“STARGAZER—THIS IS CESSNA NOVEMBER THREE THREE ZERO—ONE MILE SOUTH OF VICKERSBURG—HEADING ZERO NINE TWO—VFR—OVER.”

The Radar facility will reply, giving the name of the radar site, information concerning the storm area, suggested route to follow, etc. If for any reason the service cannot be furnished, the reply will be “UNABLE”.

Radar Advisory Service is available in Canada to all aircraft lost, requiring navigation assistance, weather advice, or in distress—if within range of a radar station. To request Radar Advisory Service in Canada, call “RADAR ADVISORY” on 122.2 mc. The following information may be requested:

1. Track and groundspeed checks.
2. Position of aircraft (in latitude and longitude, or geographical reference, or distance and direction from a known point.)
3. Direction to steer to the nearest aerodrome, or other known point.
4. Position of storms or heavy cloud in reference to the aircraft.

Note: Speeds and distances will be given in knots and nautical miles.

Direction will be given in degrees magnetic.

If Advisory Service cannot be furnished for any reason, Station will reply “UNABLE”.

When requesting service, climb to best possible altitude. This will improve your chances of being picked up by radar station.

A pilot who is lost or in distress and unable to transmit radio messages will adopt the following procedure:

A. If his Radio Receiver is Working. Fly a triangular pattern to the RIGHT. Hold each heading for 2 minutes. (Jet aircraft will fly two 2-minute legs and one 1-minute leg.) Repeat the triangular pattern twice. Resume original heading—repeating triangular pattern at 20-minute intervals.

B. If he has No Radio operating. Fly the triangular pattern as above, but to the LEFT.

An aircraft may be seen as a “blip” on a radar scope, but cannot be individually identified. By flying the pre-arranged pattern, the radar facility will be able to identify the “blip” that is the aircraft in need of help.

An aircraft lost or in need of assistance (“B” above) will be intercepted by a search and rescue plane and led to the nearest landing field. (Subject, of course, to availability of search and rescue aircraft.)

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![Fig. C. Triangular Pattern for Aircraft lost or requiring assistance. If radio receiver is operating, fly pattern to the RIGHT or CLOCKWISE. If no radio operating, fly pattern to the LEFT or ANTI-CLOCKWISE.](image-url)
THE APPLICATION OF AIRMANSHIP

The application of airmanship means putting into practical use all the detailed information on flying and technical matters a pilot has acquired in the course of his career. It is, in other words sound judgment based upon a thorough knowledge of the subjects which will be dealt with in the Chapters that follow.

The following incident will illustrate what is meant by the application of Airmanship:

Captain Wise was down in a field one day with a light airplane which had developed engine trouble—when he noted a violent line squall approaching. The storm was coming up fast and there was no time to look around for ropes or stakes to picket the aircraft down. Turning the propeller horizontal, he rolled the machine over on its back.

In this secure, if undignified position the little ship survived the storm undamaged. At a nearby airport, two similar types which were picketed with their tail to the storm, were wrecked. The terrific down-load on the wings crumpled the wing-bracing struts, causing the entire wing structures to collapse!

CHANGE IN U.S. CRUISING ALTITUDES

Just as this Edition was about to go to press, the following change in C.A.R. Part 60.32 was announced:

Effective August 1958, the following cruising altitudes within the United States will be observed:

"On Airways"

Above 3000 ft. but below 29,000 ft.

0°-179°: VFR — Fly odd thousands plus 500 ft.
IFR — As authorized by ATC.

180°-359°: VFR — Fly even thousands plus 500 ft.
IFR — As authorized by ATC.

Above 29,000 ft.

0°-179°: VFR — At 4000 ft. intervals (30,000: 34,000 etc.)
180°-359°: VFR — At 4000 ft. intervals (32,000: 36,000 etc.)

Note: Altitudes for VFR apply to "VFR on top".

"Off Airways"

Below 29,000 ft.

0°-179°: IFR — Odd thousands.
180°-359°: IFR — Even thousands.

Above 29,000 ft.

0°-179°: IFR — At 4000 ft. intervals (29,000: 33,000 etc.)
180°-359°: IFR — At 4000 ft. intervals (31,000: 35,000 etc.)

Note: VFR Altitudes "Off Airways" same as "On Airways".
Theory of Flight

The Atmosphere

Air is a gaseous fluid. As such it has density, that is, weight per unit volume. A cubic foot of air weighs approximately 0.08 lbs. By way of comparison, a cubic foot of water weighs 62½ lbs.

Newton's Laws of Motion

Air possesses inertia and therefore obeys Newton’s three Laws of Motion:

1. Air will still remain still. When in motion it will remain in motion and will resist any change in speed or direction.
2. To alter the state of rest or uniform motion of air, a force must be applied. The more sudden the change of speed or direction—and the greater the mass of air—the greater will be the force required.
3. The application of such a force will cause an equal and opposite reaction.

Air has pressure. The weight of the air above any surface will exert a force or pressure on that surface. The average Sea Level Pressure of air is 14.7 lbs. per sq. inch. This pressure diminishes with height. At 20,000 ft. it is 6.75 lbs. per sq. in.

Air has viscosity. This means the tendency of one layer to stick to and move with the layer next to it. It is owing to viscosity that eddies are formed when air is disturbed by a body passing through it. These eddies are responsible for many of the phenomena of flight.

Standard Atmosphere

A pressure of 14.69 lbs. per sq. in. (29.92 ins. of mercury) at a density of .077 lbs. per cu. ft. at a temperature of 59°F. at Sea Level is Standard Atmosphere. Airplane and engine performance data is always reduced to standard atmosphere for comparative purposes.

THEORY OF FLIGHT

According to the definitions cited in Air Regulations, a boy flying a kite could be construed to be a pilot in charge of an aircraft! Ponder the idea a moment and it may not appear quite as absurd as it seems at first glance.

A kite is an inclined plane, the weight of which is supported in the air by the reaction of the wind flowing against it. If we substitute for the string, which holds the kite against the wind, the engine and propeller of an aircraft, which drag the wings forward against the airflow, we will see that Flatspin Fumble’s impious reference to all manner of aircraft as “kites” is not without some validity. (In Flatspin’s hands, the analogy between the aircraft and the kite is still more pronounced—but then, that’s beside the point.)

The wings of an airplane are so designed that when moved through the air horizontally, the force exerted on them produces a REACTION as nearly vertical as possible. It is this reaction that lifts the weight of the airplane.

Airfoils

It is found that the most suitable shape for producing a Reaction as vertical as possible is a curved or cambered shape. This shape is known as an AIRFOIL SECTION.

In Fig. 1, an airfoil is shown as being pushed through the air. By the method of mechanics known as

![Fig. 1. Forces acting on an Airfoil](image)
the "Resolution of Forces" the resultant Reaction (OR can be resolved from two components. The vertical component (OL) is the LIFT, and is used to support the weight of the airplane. The horizontal component (OD) is the DRAG. The Drag is a force directly opposed to the motion of the airfoil and as the work of overcoming it is performed by the engine, it is desirable to have it as small as possible.

The Airflow Around an Airfoil

What, then, causes this Lift, you may ask. If an airfoil is pushed through the air at an angle, the relative wind meeting the airfoil will be "piled up", or compressed, against the underside, and its speed, or velocity, will be reduced. This causes an area of increased pressure on the underside.

The air flowing over the top will be forced to follow the curvature, or camber, of the top surface, and will have a greater distance to travel. Its velocity will therefore be increased.

BERNOULLI'S THEOREM states that as the velocity (Kinetic Energy) of a body is increased, the pressure (Pressure Energy) is decreased proportionally, and vice versa.

Hence the increased velocity will cause an area of decreased pressure over the top surface.

As the area of decreased pressure over the top surface is greater than the increased pressure below, the top surface of the wing is credited with providing more of the total lifting force.

Lift and Drag Curves

As the amount of Lift varies with the Angle of Attack, so too does the Drag—hence Drag is the price we pay for Lift. Thus, although it is desirable to obtain as much lift as possible from a wing, this cannot be done without increasing the drag. It is therefore necessary to find the best compromise.

The lift and drag of an airfoil depend not only on the Angle of Attack, but also upon:

- The shape of the airfoil.
- The plan area of the airfoil (or wing area) — S.
- The square of the velocity (or airspeed) — $V^2$.
- The density of the air — $p$.

Hence the lift of an airfoil can be expressed as a formula by: $C_l \cdot \frac{1}{2} p V^2 S$

And the drag by: $C_d \cdot \frac{1}{2} p V^2 S$

The symbols $C_l$ and $C_d$ represent the LIFT COEFFICIENT and DRAG COEFFICIENT respectively. They depend on the shape of the airfoil and will alter with changes in the Angle of Attack.

The LIFT-DRAG RATIO is used to express the relation between lift and drag and is obtained by dividing the Lift Coefficient by the Drag Coefficient. $\frac{C_l}{C_d}$. 

wind as it is moved forward is called the ANGLE OF ATTACK (Symbol $\theta$).

As the Angle of Attack is increased, the pressure areas increase up to a point (the stalling angle). Beyond this angle, they decrease. (Fig 4).

If we consider all the distributed pressure to be equivalent to a single force, this force will act through a straight line. The point where this line cuts the chord of an airfoil is called the CENTRE OF PRESSURE.

Thus, it will be seen that as the Angle of Attack of an airfoil is increased up to the point of stall, the Centre of Pressure will move forward. Beyond this point, it will move back. The movement of the Centre of Pressure causes an airplane to be unstable.

![Fig. 4. Change of Pressure Distribution with Angle of Attack](image-url)
The characteristics of any particular airfoil section can conveniently be represented by curves on a graph showing the amount of lift and drag obtained at various Angles of Attack, the Lift-Drag Ratio, and the movement of the Centre of Pressure. (Fig. 5).

![Graph showing Lift, Drag, Lift-Drag Ratio, and Centre of Pressure](image)

Notice that the Lift Curve (\(C_L\)) reaches its maximum for this particular wing section at 18° Angle of Attack, and then rapidly decreases. 18° is therefore the stalling angle.

The Drag Curve (\(C_D\)) increases very rapidly from 14° Angle of Attack—completely overcoming the lift at 22° Angle of Attack.

The Lift-Drag Ratio (\(L/D\)) reaches its maximum at 0° Angle of Attack, meaning that at this angle we obtain the most lift for the least amount of drag. A designer would therefore choose this as his Angle of Incidence (the angle at which the wing is permanently set when the ship is in flying position).

The C.P. moves gradually forward till 12° Angle of Attack is reached, and from 18° commences to move back.

**Drag**

Drag is resistance to forward motion through the air and is of three distinct types:

1. PROFILE DRAG. The diversion of the airstream and the energy required to push it over the cambered surface of the wing causes a form of drag directly associated with lift. This is called Profile Drag.

2. PARASITE DRAG. Skin friction, or the tendency of air flowing round a body to cling to its surface causes drag on the undercarriage, struts, frontal area of the engine, and other parts which contribute no useful lift. This is called Parasite Drag.

3. INDUCED DRAG. As the decreased pressure over the top of a wing is less than the atmospheric pressure around it, the air flowing over the top surface of the wing tends to flow inward.

The air flowing over the lower surface, due to the lower pressure around it, tends to flow outward.

When the two airflows unite at the trailing edge, they are flowing contra-wise. Eddies or vortices are formed which tend to unite into one large eddy at each wing tip. These are called WING-TIP VORTEXES, and contribute to Induced Drag.

In order to support the weight of an airplane, a large amount of air must be displaced downward. This displaced air must have somewhere to go, and tends to flow spanwise outwards, as explained above. It is seeking to escape around the wing tips and flow into the low pressure area created over the upper surface of the wing. It will be obvious that the HEAVIER the airplane, the HIGHER the span loading on the wing, the more air it will displace downward—therefore the greater will be the circulation of air, and the greater will be the magnitude of the Wing Tip Vortex created.

![Airflow over the Top Surface](image)

Boundary Layer

The Boundary Layer is an extremely thin sheet of air over the surface of a wing.

Due to the forward motion of the wing through the air, the Boundary Layer commences to flow in conformity to the shape of the airfoil, and is known as the Laminar Layer.

Laminar Layer.

However, as the Laminar Layer approaches the centre of the wing it begins to lose its velocity and at a point known as the Transition Point, or Laminar Separation Point it develops into the Turbulent Layer. (Fig. 9).

The turbulence is caused by other immediately adjacent layers taking on different velocities and causing friction. This friction consumes part of the energy of the original acceleration over the leading edge, the remaining energy being insufficient to complete the desirable deceleration over the trailing edge.

The force required over the boundary layer contributes to Profile Drag.
forces Acting on an Aircraft
The four forces acting on an airplane in flight are:
1. THRUST. The force exerted by the engine and its propeller which pulls or pushes the airplane forward.
2. DRAG. The resistance to forward motion directly opposed to Thrust.
3. LIFT. The force upward which sustains the airplane in flight.
4. WEIGHT. The downward force due to gravity, directly opposed to Lift.

When Thrust and Drag are equal and opposite, the airplane is said to be in EQUILIBRIUM. That is to say, it will continue to move forward at the same uniform rate of speed. (Note that equilibrium refers to steady motion, not a state of rest.)

If Thrust is greater than Drag, the airplane will accelerate or gain speed.
If Drag is greater than Thrust, the airplane will decelerate or lose speed.

Similarly, when Lift and Weight are equal and opposite, the airplane will be in Equilibrium.
If Lift is greater than Weight, the airplane will climb.
If Weight is greater than Lift, the airplane will sink.

Couples
When two forces are equal and opposite, and parallel, but do not pass through the same point, they are said to form a Couple.
A Couple will cause a Turning Moment about a given axis.

Weight and Balance
The airplane's Basic Weight and its Centre of Gravity are determined by weighing the airplane. The BASIC WEIGHT is the weight without crew, fuel, oil, or any items of removable equipment. These items, when subsequently added, will alter the C.G. position, which must therefore be re-determined.

To calculate BALANCE, a suitable BALANCE DATUM (or vertical line) is selected. This is sometimes the nose of the airplane, but may be any other convenient point.

The BALANCE MOMENT of the Basic airplane is found by multiplying the Weight of the airplane (W) in lbs. (Fig. 13) by the MOMENT ARM (distance) in inches (D) from the Balance Datum to the C.G. (O). The balance moment is, therefore, expressed in Inch-Pounds.

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Fig. 9. Laminar and Turbulent Layer.

Fig. 10. Effect of a Couple.

Fig. 11. Forces acting on an Airplane in flight.

Fig. 12. The Axes of an Airplane.

Fig. 13. Balance.
If loads are forward of the C.G. Datum their Moment Arms are Positive (+). Loads behind the C.G. Datum have Negative (−) Moment Arms. The Total Balance Moment is the algebraic sum.

The C.G. is found by dividing the Total Balance Moment (in Inch-Pounds) by the Total Weight (in Lbs.) and is expressed in inches forward (+) or aft (−) of the Datum Line.

The Balance Moment of any Item of Load subsequently added to the basic airplane is found by multiplying the Weight of the item by the Moment Arm (or distance d) from the Balance Datum to the C.G. of the item (a) Fig. 13.

To find the new C.G. after adding Items A, B, and C (Fig. 13).

\[ A (\text{lbs.}) \times \text{Moment Arm ("')} = \text{Balance Moment (in lbs.)} \]
\[ B (\text{lbs.}) \times \text{Moment Arm ("')} = \text{Balance Moment (in lbs.)} \]
\[ C (\text{lbs.}) \times \text{Moment Arm ("')} = \text{Balance Moment (in lbs.)} \]
\[ \text{Total lbs.} + \text{Basic Airplane Wt.} = \text{New Gross Wt. (W)} = \text{New Balance Moment (K)} \]
\[ K + W = \text{New C.G.} \]

The C.G. position may be expressed in inches from the Balance Datum, or in per cent of the MEAN AERO-DYNAMIC CHORD (M.A.C.). The M.A.C. is a line and oft distance representing the average chord of the wing. If the calculated C.G. is within the recommended limits, the airplane is loaded properly (Fig. 14).

**Fig. 14. Mean Aerodynamic Chord.**

**The Planes of Reference**

The plane in which the airplane moves around the Longitudinal, or "X" Axis, is called the ROLLING PLANE.

The plane in which the airplane moves around the Lateral, or "Y" Axis, is called the PITCHING or LOOPING PLANE.

The plane in which the airplane moves around the Normal, or "Z" Axis, is called the YAWING PLANE.

**Slipstream**

The air pushed backward by a revolving propeller has a corkscrew motion. This causes an increased pressure on one side of the tail unit, and a decreased pressure on the other side. The tail is consequently pushed sideways from the high pressure side towards the low—causing the airplane to yaw. The condition is corrected by offsetting the fin, cambering one side of the fin, or fitting trimming tabs.

![Fig. 15. Slipstream.](image)

**Torque**

Torque is the resistance of the propeller to its motion through the air due to the drag of the blades. The effect of torque is to tend to rotate the airplane in a direction opposite to the rotation of the propeller. Flatspin Fumble insists that it is "torque" which causes his littercraft DeLux to groundloop. It will be seen from the above, however, that torque causes a roll, not a yaw. Torque is corrected—not by offsetting the fin, as Flatspin and many others suppose—but by "wash out" and "wash in" of the wings, that is, decreasing or increasing the incidence respectively.

The wash-in and wash-out on the wings causes more drag on one side than the other, which results in a tendency to swing on take-off and during the initial climb. Thus, although Torque is not primarily the cause of a yaw, the means adopted to cure it do definitely contribute towards a tendency to swing on take-off.

**Gyroscopic Action**

Gyroscopic Action is due to the rotating mass of the engine and propeller, causing the airplane to drop its nose on a right-hand turn if the propeller is rotating clockwise (as seen from the pilot's seat) or raise its nose on a left-hand turn. This is due to Gyroscopic Precession.

If a heavy body is rotating about an axis (the axis of rotation) and this is turned about another axis (the turning axis), the body will tend to turn about an axis at right angles to them both. This phenomenon is known as Gyroscopic Precession.

A simple illustration is as follows: Imagine a bicycle wheel spinning rapidly on a broomhandle. Attempt to turn the broomhandle either to the right or left, and one end will automatically raise in your hand while the other will drop.

![Fig. 16. Gyroscopic Action.](image)

**Aileron Drag**

In banking to make an airplane turn, one aileron is depressed and the other is raised. The downgoing aileron, being depressed into the compressed airstream on the underside of the wing, causes drag. The upgoing aileron, moving up into a more streamlined position, causes less drag. The drag on the downgoing aileron is known as Aileron Drag and tends to cause a yaw in the opposite direction to which the bank is applied.

**Frieze and Differential Ailerons**

Both Frieze and Differential Ailerons have been designed to overcome aileron drag.

![Fig. 17. Differential Ailerons.](image)
Balanced Controls

Controls are sometimes dynamically balanced to assist the pilot to move them. Several of the various means by which an aerodynamic reaction is used to serve this purpose are illustrated in Fig. 19.

Mass, or Static Balance, is used mainly to counteract flutter and consists of placing a weight ahead of the control surface, to balance the overhanging mass of the control.

Slotted Wings

Slats are auxiliary airfoils fitted to the leading edge of the wing. At high angles of attack they automatically move out ahead of the wing. The angle of attack of the slat being less than that of the mainplane, there is a smooth airflow over the slat which tends to smooth out the eddies forming over the wing. Slats are usually fitted to the leading edge near the wing tips to improve lateral control.

Slots are passageways built into the wing a short distance from the leading edge in such a way that at high angles of attack the air flows through the slot and over the wing, tending to smear out the turbulence due to eddies.

Flaps

Plain and Split Flaps are fitted essentially for steepening the glide and reducing the landing speed.

It is true that they increase the lift of a wing, but at the same time, they greatly increase the drag. For all practical purposes they are of value only in approach and landing. They should not normally be employed for take-off because the extra drag reduces acceleration to full speed and consequent maximum rate of climb.

Slotted Flaps, on the other hand, including such types as Fowler and Zap, produce lift in excess of drag and their partial use is therefore recommended for take-off. This is only true up to a limited Angle of Attack—beyond which the drag becomes greater than the lift (See "Lift and Drag Curves"). Excessive use of the Flaps in landing may cause buffetting over the tail. It is therefore important that the flap settings recommended for the particular aircraft you are flying be strictly adhered to, both for take-off and landing.

In most types of aircraft, change of flap setting produces a change of trim, and the aircraft is apt to lose considerable height when the flaps are raised. They therefore be raised cautiously at low altitude.

Most airplanes are placarded to show a maximum speed above which the flaps must not be lowered. This is because flaps are not designed to withstand the loads imposed by high speeds. Structural failure may result from severe strain if the flaps are selected "down" at higher than the specified speed.

There are two distinct methods of flap technique in vogue. One is a fast nose-down, dive approach. This produces a very steep rate of descent, but the aircraft will "float" some distance after flattening out until the
surplus speed is lost. The other is a slow-speed, nose-high, "mushing down" approach. By this method a ship can be landed in a very short space. If a little speed is not gained just before flattening out, however, it is apt to produce a heavy landing.

When the flaps have been lowered for a landing, they should not ordinarily be raised until the airplane is on the ground. If a landing has been missed, the flaps should not be raised until the power has been applied and the airplane has regained normal climbing speed.

**Dihedral**

The Dihedral Angle is the angle that each plane makes with the horizontal (Fig. 23). The purpose of Dihedral is to improve lateral stability. If a disturbance causes one wing to drop, the unbalanced force (Fig. 23) produces a sideslip in the direction of the downgoing wing. This wing then meets the relative airflow at a high angle, obtains more lift, and is restored to normal flying position.

Since Dihedral inclines the wing to the horizontal, so too will the Lift Reaction of the wing be inclined to the vertical (Fig. 23). Hence an excessive amount of Dihedral will produce a loss of lift.

The upgoing wing will have a relative downward wind, hence a decreased Angle of Attack, therefore, increased lift, and will rise more rapidly (Fig 25).

The effect is to accelerate the rolling moment in the direction in which it first started. This is AUTOROTATION.

Any attempt to correct Autorotation with aileron will only aggravate the roll. If the aileron on the downgoing wing is moved downward to bring the wing up, it will meet the airflow at a high Angle of Attack and will therefore become more stalled than the wing itself. The upgoing aileron, on the other hand, will be uninstalled and will have increased lift.

If the aircraft is in stalled, or near stalled condition, the pilot should correct by use of rudder, not aileron.

**Spinning**

Spinning results from a Yawing Couple applied when an aircraft is stalled—by application of rudder, aileron drag, or misuse of the controls. (The weight of the aircraft is borne chiefly by the drag of the wings. The lift is negligible since the Angle of Attack may be as high as 30°.)

When an aircraft has commenced to spin, the inner wing is descending almost vertically. Hence it meets the air at a high Angle of Attack and, being stalled, has very little Lift.

The outer wing is descending in a spiral round the spinning axis—meets the airflow at a lesser Angle of Attack and hence has more lift than the inner wing.

The result is a Couple which gives the aircraft a turning moment about the spinning axis.

(The drag on the outer wing is less than the inner. The resulting Couple in the yawing plane however is balanced by the resistance of the keel surface.)

**Forces Acting in a Turn**

To make an airplane turn, a force must be applied towards the centre of the turn. This is known as CENTRIPETAL FORCE. The force is not balanced as the airplane is not in equilibrium, but accelerating. In order to apply Centripetal Force, the pilot banks the airplane, thus causing the Reaction to be inclined to the vertical in a horizontal direction. (Fig. 26).
OW represents the weight of the airplane. OL is the reaction inclined at an angle α. The vertical component OA balances the weight of the airplane while the horizontal OC provides the necessary Centripetal Force.

Loading in Turns

By the LOADING of an airplane, is meant its WEIGHT. This is not constant, but may be increased by ACCELERATION. A steep turn may impose an increase in the loading as high as ten times the normal load. With some types of light airplanes, a bank of 60° or over can lead to a possibility of structural failure.

Stalling Speed in Turns

An increased load factor corresponds to an increased stalling speed. The increased stalling speed is found by multiplying the normal stalling speed by the square root of the load factor being imposed. Typical load factor values and their square roots are shown in the following table:

<table>
<thead>
<tr>
<th>Degree of Bank</th>
<th>Load Factor</th>
<th>Square Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°</td>
<td>1.04</td>
<td>1.02</td>
</tr>
<tr>
<td>20°</td>
<td>1.06</td>
<td>1.03</td>
</tr>
<tr>
<td>30°</td>
<td>1.15</td>
<td>1.07</td>
</tr>
<tr>
<td>40°</td>
<td>1.31</td>
<td>1.14</td>
</tr>
<tr>
<td>45°</td>
<td>1.41</td>
<td>1.19</td>
</tr>
<tr>
<td>50°</td>
<td>1.56</td>
<td>1.25</td>
</tr>
<tr>
<td>60°</td>
<td>2.00</td>
<td>1.41</td>
</tr>
<tr>
<td>70°</td>
<td>2.92</td>
<td>1.71</td>
</tr>
<tr>
<td>75°</td>
<td>3.86</td>
<td>1.96</td>
</tr>
</tbody>
</table>

Suppose an airplane has a normal stalling speed of 45 knots. What is its stalling speed in a 60° banked turn?

The square root of the load factor in a 60° banked turn is 1.41.

\[1.41 \times 45 = 63.45 \text{ knots.}\]

Airspeed Limitations

Loads greater than the weight of the airplane are produced by certain maneuvers and by gust conditions. The amount of excess load which can be imposed on the wings depends upon the speed at which the airplane is flying. At slow speed, the lift of the wings is only slightly greater than required to support the weight of the airplane. An additional load imposed by abrupt maneuvers or severe gusts will therefore not become excessive. At high speed, the lift of the wings is so great that an additional load may exceed the safe limits. For this reason, certain "maximum" speeds are established by the manufacturer of each particular airplane and specified in the Flight Manual.

THE NEVER EXCEED SPEED (or MAXIMUM PERMISSIBLE DIVE SPEED). The maximum speed at which the airplane can be safely operated in smooth air. A higher speed may result in structural failure, flutter, or loss of control. If you ever find yourself over the Never Exceed Speed inadvertently, throttle back and execute pull-outs with slow and firm pressure on the controls.

MAX. NORMAL OPERATING SPEED. The greatest safe speed for normal operating maneuvers in moderately rough air. Warning: Do not EVER exceed this speed intentionally with severe gust conditions prevailing.

MANEUVERING SPEED. The maximum safe speed for abrupt maneuvers or when flying in very rough air. Maneuvers which involve an approach to a stall, or full use of rudder or aileron control, should never be attempted above this speed. If the Maneuvering Speed is not known, it can be computed as 70% greater than the normal stalling speed — or stalling speed \(\times 1.7\).

e.g.: Stalling speed 63 kts. \(\times 1.7 = \text{maneuvering speed 107 kts.}\)

MAX. FLAPS DOWN SPEED. The maximum speed at which the aircraft may be flown with the flaps lowered. A speed in excess of this value may lead to a structural failure of the flaps.

Acceleration

When the engine is opened up the aircraft will commence to climb. This is because the increased velocity will provide more lift. The increased lift will cause the aircraft to "mush upward". This reduces the Angle of Attack until a new condition of equilibrium is attained \((L=W)\) in which the flight path will be slightly inclined to the horizontal.

To regain level flight at increased speed, the pilot must push the control column forward to reduce the Angle of Attack.

Climbing

During a climb the Thrust, in addition to overcoming the Drag, has to do part of the work of lifting the aircraft. This rate of lifting is limited by the extra power available. During a climb the airplane is in equilibrium.

![Fig. 29. Forces in a Climb.](image)

Every airplane has a BEST RATE OF CLIMB. This is the rate of climb which will gain the most altitude in the least time. For every airplane there is an airspeed at a given power setting which will give the best rate of climb.

The BEST ANGLE OF CLIMB is the angle which will gain the most altitude in a given distance. It is valuable in climbing out of restricted areas over obstacles. The airspeed for the steepest angle of climb is somewhat lower than the speed at which the best rate of climb is obtained.

Every pilot should determine the Best-Rate-of-Climb Speed and Best-Angle-of-Climb Speed for the particular airplane he is flying.

The rate of climb is not affected by the wind, since it is a vertical measurement of airplane performance and is not in any way related to groundspeed. The angle of climb, on the other hand, is appreciably affected by the wind. When climbing into wind, the airplane moves over the ground at a lower speed and hence takes longer to cover a given forward distance. The stronger the wind, the slower the forward speed, and hence the steeper the Angle of Climb.

Normal Climb is usually 6 to 12 mph (5 to 10 kts) faster than the best rate of climb speed to provide better engine cooling and easier control.

Gilding

In gliding there is no Thrust from the engine, so Gravity must provide the necessary power. The flight
path is inclined downward so that Weight has a component in the direction of flight. The pilot must adjust his gliding angle so that this inclined component of Weight will push the aircraft through the air with sufficient speed to maintain flight. (Fig. 30).

R represents the Total Reaction, i.e., Resultant of Lift and Drag. This is equal and opposite to W.

![Fig. 30. Forces in a Glide.]

Gliding Angle

If the pilot attempts to glide at an Angle of Attack either greater or less than that which gives the best L/D ratio, then in each case the path of descent will be steeper.

Flatspin Fumble still can't understand why he smeared his Jitterbug DeLux over Farmer Brown's fence when he essayed his last forced landing. To quote Flatspin, he was "stretching his glide to the limit". Actually, Fumble had plenty of height to start with and if he had "stretched" his glide a little less, he'd have got in with room to spare.

Hazards of Wing Tip Vortex

In "Drag" (INDUCED DRAG), the theory of Wing Tip Vortex is discussed. The wing tip vortex in the wake of a heavy aircraft under certain conditions can be EXTREMELY VIOLENT. Turbulence sufficiently severe to tear the wings off a light airplane can be encountered in the wake of (a) a large heavy aircraft, or (b) a relatively small heavy aircraft, such as a jet fighter.

The risk of structural failure occurs when the light plane enters the churning vortex at an angle of 90° (left in Fig. X). A violent roll and complete loss of control may occur when the light plane flies into the vortex from directly astern (right in Fig. X).

The vertical gusts encountered when crossing laterally through the vortex can impose structural loads as high as 10 G's on a small airplane flying at a high angle of attack. The combined effect of an up-gust immediately followed by a down-gust has been estimated as high as 80-feet-per-second. Most small planes are designed to withstand vertical gusts of 30-feet-per-second at their normal operating speeds.

Severe vortex turbulence may exist as long as 30 to 40 seconds (1 to 3 miles) behind the passage of the heavy transport or jet aircraft which caused it.

DO NOT follow a large transport type aircraft, especially on landing in calm air. If circumstances require you must follow one on landing, stay at least 60 seconds behind him. Keep your glide path well above that of the heavy aircraft, and land down the runway well ahead of the point where he touched down.

DO NOT cross behind other aircraft, especially those flown at slow speed.

There is little difference between the wakes of large propeller driven airplanes and those of heavy jet planes. AVOID THE AREA immediately behind and below the flight paths of both.

![Fig. X. Hazards of Wing Tip Vortex.]

Mach Number

The MACH NUMBER (pronounced "Mock") is the ratio of the speed of a body to the speed of sound in the air surrounding the body. (The SPEED OF SOUND is 1120 feet per sec. in air at a temperature of 15°C, but varies with temperature, pressure and density). An aircraft flying at a Mach Number of .85 would be travelling at 85% of the speed of sound.

The Mach Number is found by dividing the air speed by the speed of sound at any particular altitude condition.

A Mach Number of 1 equals 761 m.p.h. at sea level. At 40,000 feet, a Mach Number of 1 equals 663 m.p.h.

FLIGHT INSTRUMENTS

The Altimeter

![Fig. 31. Pioneer Altimeter. Fig. 32. Pioneer Sensitive Altimeter.]

This instrument is a special form of aneroid barometer (a barometer without liquid) which measures the pressure of the atmosphere. The atmospheric pressure at any point is due to the weight of the overlying air above, which decreases as the height above sea level increases. Hence, the instrument can be calibrated to read in terms of height. Under STANDARD AIR CONDITIONS at a temperature of 59°F, the weight of a column of air—one square inch in area—is 14.7 lbs. at sea level, and exerts a pressure of 14.7 lbs. per sq. in. This pressure is recorded on a barometer as 29.92 inches of mercury and by an altimeter as 0 feet. At 10,000 feet the weight of the one square inch air column has decreased to 10.11 lbs., the corresponding barometric pressure to 20.58 inches, and the altimeter records 10,000 feet. Note that as the Altitude increases, the Barometric Pressure decreases.

The basic component in the Altimeter is a small corrugated expansion box, or diaphragm, located inside the case. Atmospheric pressure admitted to the case causes this box to expand and contract. This movement actuates gears and levers which in turn rotate a hand on the face of a dial calibrated in hundreds and thousands of feet. (Fig. 31.)

The SENSITIVE ALTIMETER is similar in principle
to the ordinary Alimeter, except that it has a multiple diaphragm which is designed to react to the slightest variation in atmospheric pressure. The expansion and contraction of the multiple expansion boxes transmits motion direct to a large hand, which records altitude changes in hundreds of feet. After the rate of motion has been decreased by a reduction gear, motion is transmitted to a smaller hand, which records altitude in thousands of feet. Similarly, through further reduction gears, a third still smaller hand records altitude in units of ten thousand feet. (Fig. 32.)

Alimeter Errors

1. Pressure. The heights at which aircraft are required to fly for air navigation purposes are Indicated Heights Above Sea Level. Since the barometric pressure varies from place to place, an altimeter set to indicate height above sea level at its point of departure may give an erroneous indication after it has flown some distance towards its destination. To correct for this, practically all modern Alimeters are fitted with a BAROMETRIC SCALE, calibrated in inches of mercury. The ALIMETER SETTING, which is given in inches, may be obtained from Towers and Radio Range Stations in any particular locality over which the aircraft is operating.

In Fig. 31, an Alimeter Setting of 30 inches has been set on the Barometric Scale. In Fig. 32, the Alimeter Setting is 29.92 inches.

When the Alimeter Setting is set on the Barometric Scale, the Alimeter will register the Indicated Height Above Sea Level. When you land at an airport from which the Alimeter Setting was obtained by radio, your altimeter will record the altitude of the field above sea level.

Because of the impossibility of obtaining corrected Alimeter Settings from time to time over Trans-oceanic routes and some continental areas where radio communications are non-existent, flights over these routes are flown at Pressure Altitude.

PRESSURE ALTITUDE is the height above sea level corresponding to a given barometric pressure under Standard Air conditions. When the Barometric Scale is set to read 29.92, the height recorded by the Alimeter is Pressure Altitude.

The altitude in this case is referred to as the FLIGHT LEVEL at which the aircraft is flying. In reporting the Flight Level, the last two digits of the altitude are omitted. e.g.: An aircraft flying at a pressure altitude of 15,000 ft. would report his height as "FLIGHT LEVEL 150".

FIELD LEVEL PRESSURE is the actual barometric pressure (not corrected to sea level) at any particular airport. If a pilot obtains the Field Level Pressure by radio from an airport he is approaching, and sets it on his Barometric Scale, his Alimeter will register 0 feet when he lands.

CAUTION: When an aircraft is flying from an area of HIGH Pressure into an area of LOW Pressure, if a corrected Alimeter Setting has not been obtained by radio, The Alimeter will read High, "From High to Low — watch out below!"

In the northern hemisphere a drift to right, or starboard, indicates that an aircraft is flying towards an area of low pressure. A glance at the wind circulation around a low pressure area — Fig. 7 ("Meteorology") — will indicate why this is so. Continued drift to starboard over a long period should act as a warning that an uncorrected altimeter may be reading high.

2. Temperature. Due to continual heating and cooling, the atmosphere at any given point seldom remains at the temperature of Standard Air. Cooling causes air to sink. The air above the point where the cooling occurred will therefore weigh less, and the Alimeter—designed to convert standard barometric pressure to feet—will indicate too high.

Changes in temperature may cause your altimeter to register an Indicated Altitude as much as 2500 feet above or below your True Altitude.

If the Actual Temperature of the air column in which the airplane is flying is colder than Standard Air, the True Altitude of the airplane above sea level will be lower than the Indicated Altitude. If the Actual Temperature is warmer than Standard Air, the True Altitude will be higher.

Since all alimeters in the same area are equally affected by Temperature Error, air traffic regulations require you to fly only at Indicated Altitude. However, it is important, particularly in mountainous country, for a pilot to be able to calculate his True Altitude above sea level.

All computers currently in use are fitted with a sliding scale for correcting temperature error and converting indicated altitude to true altitude. However, the correction is based on the PRESSURE ALTITUDE rather than the indicated Altitude. To obtain the altitude at which you are flying, subtract the Temperature Error from the Pressure Altitude.

The Radio Alimeter

The RADIO ALIMETER indicates the actual height of the aircraft above the earth, or above any object on the earth over which the aircraft is passing. The principle is extremely simple. A radio transmitter in the aircraft sends a signal towards the earth whose frequency changes at a definite rate with respect to time. This signal is reflected by the earth and returns as an ECHO after a time interval equal to twice the height divided by the velocity of the signal. During this interval, the frequency of the transmitter has changed, and now differs from that of the echo by the rate of change of frequency X the time of transit. The reflected wave is combined with some of the outgoing wave in the plane receiver, and the difference, or "beat" frequency, is measured by a Frequency Meter. Since the reading of the meter is that of the "beat" frequency, it is proportional to the time delay of the echo — hence to the height — and can thus be calibrated in feet.

Radio waves or signals are reflected best from smooth salt water or smooth ground — less perfectly from rough water and wooded areas.

The Airspeed Indicator

Fig. 33. Pioneer Airspeed Indicator.

Fig. 34. Pioneer Vertical Speed Indicator.
The AIRSPEED INDICATOR tells the pilot the speed at which he is travelling through the air (not over the ground). The dial is calibrated in miles per hour, or knots (Fig. 33).

The Airspeed Indicator system comprises a PRESSURE HEAD connected by tubes to the instrument which is mounted on the instrument panel. The pressure head is mounted clear of the slipstream in a position as free as possible from air disturbances. It consists of two tubes. One, the PITOT TUBE, is open at the end. The pressure which enters this tube is Dynamic Pressure, due to the forward speed of the airplane. The other, the STATIC PRESSURE TUBE is closed at the end and has small holes drilled in it. The pressure in this tube is Static Pressure, that is, the pressure of the surrounding still air. In some types of instruments the static tube has a plate mounted in front of the holes, and in others it is connected to a venturi tube. In these cases, the purpose is to obtain a decreased pressure in the tube.

The two tubes are led to opposite sides of a DIAPHRAGM installed in the case of the instrument (Fig. 35). The difference between the two different pressures causes a movement of the diaphragm. This movement is transmitted through a system of links and levers to a hand, which rotates around a dial calibrated in miles per hour.

Another type has a CAPSULE, or thin corrugated metal expansion box. The pitot tube is led to the interior of this box and the static pressure tube to the inside of the instrument case. The changes in dynamic pressure inside the box cause it to expand or contract. This movement, through a system of linkage, rotates the hand on the face of the dial.

Air Speed Indicator Errors

The Air Speed Indicator is affected by several errors which must be corrected or allowed for. These are:

![Fig. 15. Principle of the Air Speed Indicator.]

1. Density: The density of the air depends on atmospheric pressure and temperature. These are variable factors. Consequently a standard value for density has to be assumed in order that the Air Speed Indicator may be calibrated.

The standard for calibrating Air Speed Indicators is normal sea level pressure, 29.92 inches of mercury, at a temperature of 59°F.

A rough correction may be made by adding 2% to the Indicated Airspeed for every 1,000 ft. above sea level. Example: Indicated Airspeed at 10,000 ft. — 130 knots.

Correction: 10 × 2% = 20%
20% of 130 kts. = 26 kts.
:. True Airspeed = 130 + 26 = 156 kts.

More accurate corrections, allowing for the actual temperature and pressure, can be obtained with the Dalton Computer or other suitable disk type computers.

2. Position Error. This is due to eddies set up in the neighborhood of the wings, struts, etc., and is reduced by placing the pressure Head as far away from the leading edge of the wing as is practicable.

3. Lag: This is a mechanical error due to the friction of the working parts of the instrument.

4. Icing: Ice formation, blocking the openings of the Pitot and Static Pressure Tubes, has been a source of considerable trouble with Air Speed Indicators in the past. This has been largely eliminated in present day instruments by the adoption of electrically heated Pressure Heads.

5. Water: Water in the Pressure Head can cause very erratic air speed indications. The errors may be high or low, depending on whether the water is in the dynamic or static tubes. Sufficient water in the Dynamic Tube to block it off, for instance, would convert the Air Speed Indicator into an Altimeter — and the indicated air speed would vary with changes in height. The Pressure Head should be covered when an airplane is standing in the open to prevent water getting in.

The Vertical Speed Indicator

The VERTICAL SPEED or RATE-OF-CLIMB INDICATOR shows the rate, in feet per minute, at which the aircraft is ascending or descending. The principle is based on the change in barometric pressure which occurs with any change of height.

Atmospheric pressure is led from the pitot static tube directly into a corrugated expansion box or diaphragm, contained within the case of the instrument. From there it is permitted to "leak" at a relatively slow rate through a Capillary Tube into the case of the instrument. The difference between the quick change in pressure which occurs within the diaphragm and the relatively slow rate at which this pressure is equalized within the case, causes the box to expand or contract. This movement is amplified and transmitted by linkage to the pointer on the dial of the instrument. (Fig. 34.)

When the aircraft loses altitude, pressure within the diaphragm increases almost immediately, while pressure within the case changes slowly. The diaphragm therefore expands, and the pointer indicates DOWN in feet per min.

When the aircraft gains altitude, the process is reversed, and the pointer indicates UP.

When the aircraft remains level, the pressures equalize, and the pointer indicates O.

Note that the Vertical Speed Indicator registers the rate of climb or descent, not the attitude of the airplane. An aircraft may gain height in a vertical up-current of air when it is flying perfectly level. The Vertical Speed Indicator should be closely co-ordinated with the Altimeter and Air Speed Indicator. Corrections for altitude gained or lost in cruising flight should be made by nose- ing the airplane up or down — by use of the elevators. Intentional change in altitude should be made by increasing or decreasing power at a given airspeed — by use of the throttle.

THE GYROSCOPE

The Gyroscope is a rotor, or spinning wheel, rotating at high speed in a universal mounting, called a gimbal, (Fig. 36) so its axle can be pointed in any direction.

The peculiar actions of a Gyroscope, though they may appear to defy physical laws, actually depend entirely upon Sir Isaac Newton's Laws of Motion.

All of the practical applications of the gyroscope are based upon two fundamental characteristics.
namely, Gyroscopic Inertia (or Rigidity in Space) and Precession.

Gyroscopic Inertia is the tendency of any rotating body, if undisturbed, to maintain its plane of rotation. When the rotor in Fig. 36 is spinning about its axis A-B, the direction of this axis will remain fixed in space, regardless of how the base of the gyroscope is moved around it.

Precise insulation of this type of gyroscope is obtained by a wheel, or rotor, free to rotate in a supporting ring about the axis A-B. The supporting ring is free to rotate in the outer ring about the axis C-D, at right angles to the rotation axis of the rotor. The outer ring is free to rotate about the vertical axis E-F on the pivot bearing at F.

Precession is the tendency of a rotating body, if a force is applied to it, to turn about an axis at right angles to the axis about which the force was applied. The following is a simple illustration: Imagine a bicycle wheel spinning rapidly on a broomhandle which is held horizontally in your hands. Attempt to push either end forward and one end will automatically raise in your hand while the other will drop. A push applied in the direction of the arrow at G (Fig. 36) would cause the rotor in its supporting ring to tend to rotate around the axis C-D.

The Directional Gyro

The DIRECTIONAL GYRO is an instrument designed to indicate the Heading of the aircraft and to enable the pilot to steer it.

The basic mechanical principle revolves around a Gyro Wheel or Rotor Mounted vertically and spinning about its horizontal axis at approximately 12,000 r.p.m. The force required to spin the Rotor is provided by suction from a venturi tube or vacuum pump and by jets of air discharged through a nozzle against paddles on the gyro wheel, which also serve to keep the gyro upright.

The spinning gyro wheel is universally mounted in a Gymsal Ring, free to turn about any axis. The Compass Card, which the pilot reads through a rectangular window on the face of the instrument (Fig. 37) is mounted on the Gymsal Ring and therefore moves with it.

When spinning, the gyro obeys a fundamental gyroscopic principle, "rigidity in space". Thus, the Rotor and Gymsal Ring, and the Compass Card attached to them remain fixed, while the airplane moves around them.

The Compass Card is read against a Lubber Line, the same as a Magnetic Compass. As in the case of the Compass, the figures are printed with the "0" left off — "1" for "10", "35" for "350", etc.

Pushing the CAGING KNOB (Fig. 37) In, "cages" or locks the gyro system upright. When the Caging Knob is pushed in, turning the knob—by means of a synchronizing gear—enables the Compass Card to be turned to any desired Heading. The Gyro is not, of its own accord, North Seeking.

Pulling the Caging Knob Out releases the locking mechanism, and leaves the gyro horizontal and free to indicate changes in direction.

The Magnetic Compass, as we discuss in "Vagaries of the Compass", is afflicted with many vagaries, including northerly turning error, acceleration and deceleration errors.

The Directional Gyro remains constant without swinging or oscillating, and provides a means of accurate steering even in rough air. Precise turns can be made and stopped at any desired heading, as the instrument responds instantly without log.

From all of which it might appear that the Magnetic Compass has had its day. Such would indeed be the case were it not for the fact that the Directional Gyro has a pet little "Gremlin" of its own, and must from time to time be reset—using the magnetic Compass as a reference!

Precession Error. Frictional forces in the gyro system cause it to precess. This precession causes a "creep" or "drift" in the reading on the card, amounting to approximately 3 degrees in 15 minutes.

To correct for Precession:
(1) Hold the aircraft straight and level to insure that the magnetic compass is free from error.
(2) Push the caging Knob IN. ("Cage").
(3) Turn the directional gyro card to the correct heading as read off the magnetic compass.
(4) Pull the caging knob OUT. ("Uncage").

Limitations of the Directional Gyro. The gyro requires 3 inches of mercury vacuum to operate. It should not be used for take-off until it has run for 5 minutes. This time is required to get up to operating speed. (If the gyro is operated by a venturi tube instead of a vacuum pump, it cannot be used for take-off at all.)

The gyro will not function in climbs, glides or banks exceeding 55 degrees. If these limits are to be exceeded — or during aerobatics — the gyro should be caged.
The Gyroscopic Compass

The GYROSCOPIC COMPASS combines the functions of both the Directional Gyro and the Magnetic Compass.

It provides stable compass headings in rough air. It is north-seeking like a Magnetic Compass, but is free from northerly turning error and oscillation.

It does not "drift" nor require resetting like the Directional Gyro does.

The system is light in weight and takes up little space in the airplane. The Gyroscopic Compass consists of a Flux Valve, Gyroscopic and Amplifier.

The Flux Valve is composed of a core and exciting coils through which an alternating current flows. The element is pendulously mounted inside its case, which is usually installed in a wing tip—remote from local magnetic disturbances in the aircraft. The Flux Valve senses the direction of the earth's magnetic lines of force and transmits this information electrically to the Gyroscopic Compass.

The Gyroscopic Compass contains a gyroscope which indicates changes in the heading of the aircraft. It is basically the same instrument as the Directional Gyro described above.

The Amplifier amplifies the phase of the signals from the Flux Valve.

Fundamentally, the Gyroscopic Compass is a Directional Gyro with a magnetic "sense"—Directional Glyro SYNchronized with the earth's magnetic meridians by means of the Flux Valve. It is, in effect, a gyro-stabilized compass—hence the name, "Gyroscopic Compass".

The dial of the Gyroscopic Compass is shown in Fig. G. The moveable pointer points to the magnetic heading of the aircraft. The Course Indicator (parallel lines) can be set to any desired heading for easy reference.

At the upper right of the dial is a small round window in which a dot and cross appear alternately, indicating that the gyro is synchronized with the earth's magnetic lines of force. If one or the other predominates, turn the knob towards either the dot or cross as required, until both appear with equal regularity. The gyroscopic compass is then synchronized.

Operation: (i) Switch on the electrical supply.
   (ii) Push in and turn the knob at lower left to synchronize the Gyroscopic—
        that is, line it up with magnetic north initially.
   (iii) Turn the knob, (without pushing in) to set the Course Indicator to the desired heading.

Some Gyrosyns are fitted with a dual switch. In one position, the complete system is in operation. In the other position, the Flux Valve is shut off and the instrument operates as a free Directional Gyro. This feature is for use in high polar latitudes or under any other circumstances where magnetic indications are unreliable.

The Artificial (or Gyro) Horizon

The ARTIFICIAL HORIZON, as the name implies, provides the pilot with a "mechanical" horizon as a means of reference when the natural horizon cannot be seen because of cloud, fog, rain or limited visibility.

The natural horizon is represented by a Horizon Bar on the face of the instrument (Fig. 38.) The attitude of the aircraft in relation to the horizon is indicated by a Miniature Airplane. A pointer at the top indicates degrees of bank on an Index scale graduated from 0° to 90° right or left.

In the Artificial Horizon the gyro wheel is mounted horizontally and spins about its vertical axis. It is mounted in a universal gimbals ring system, free about either the pitching or rolling axes of the aircraft and is therefore able to remain spinning in a horizontal plane parallel to the True Horizon, regardless of the rolling or pitching movements of the aircraft around it.

The gyro wheel is actuated by suction, similar to the Directional Gyro, and jets of air which strike the blades of the Rotor, causing it to spin. Pendulous valves and ports attached to the rotor assist in keeping its axis vertical.

The Horizon Bar is attached by a pivoted arm to the gimbals ring. When the aircraft is flying level, the Miniature Airplane is lined up level with the Horizon Bar.

When the aircraft noses up, the gyro wheel remains horizontal. A relative down force is exerted on the pivoted arm to which the horizon bar is attached, causing the Horizon Bar to sink below the Miniature Airplane.

In the case of a nose down condition, the reverse action takes place.

The Artificial Horizon may be thought of and used in either of two ways:

1. Some like to consider it as a window through the instrument panel and through the fog or clouds—in which case the horizon bar is where the natural horizon would be.
2. Others like to fly the miniature airplane with respect to the horizon bar.

When the aircraft noses up, the miniature airplane rises above the horizon bar, indicating a nose high condition.

When the aircraft noses down, the miniature airplane sinks below the horizon bar, indicating a nose down condition.

When the aircraft banks, the miniature airplane banks on the horizon bar and the pointer indicates the degree of bank on the index scale.

When it is necessary to fly the aircraft slightly nose up or down, according to altitude, power and load, the miniature airplane can be adjusted to match the horizon bar by means of a knob at the bottom of the case.

Limitations of the Gyro Horizon. The gyro requires 3 inches of mercury vacuum to operate, and 5 minutes to get up to operational speed.

The gyro horizon permits dives or climbs up to 70 degrees and banks up to 90 degrees (vertical). If these limits are to be exceeded—or during aerobatics—the gyro should be caged. The caging knob is shown at the lower right in Fig. 38.
The Bank and Turn Indicator

The BANK AND TURN INDICATOR combines two instruments in one. The needle shows the rate at which the plane turns or rotates about its normal (or "z") axis. The ball indicates the lateral level of the wings and, in a turn, the correct amount of bank for the turn.

The ball is controlled by gravity and centrifugal force.

The turn needle is actuated by a gyro wheel operated by the suction from a venturi tube or vacuum pump which draws air out of the case. Free air entering through a nozzle impinges on the paddles of the gyro wheel, causing it to rotate at approximately 3,000 r.p.m. The gyro wheel is mounted vertically and rotates about its horizontal axis.

The basic principle which governs the operation of the turn needle is "Gyroscopic Precession". The spinning gyro wheel, or rotor, is mounted in a gymbal ring. When the aircraft turns to the right or left, the gyro wheel "Precesses" about its turning axis, and "rolls" the gymbal ring. The rolling motion of the gymbal ring in turn rotates the turn needle on the face of the instrument. A spring returns the needle to zero when the airplane ceases to turn.

The turn indicator indicates the rate of the turn, not the amount of the turn. Thus a "rate one" turn will give a rate of turn of 3° per second—or 360° in two minutes.

The instrument is usually calibrated to indicate a Rate One Turn when the turn needle is centred on one of the Indexes seen either side of the Centre Index (Fig. 39).

In straight and level flight, the ball and needle are both centred. (Fig. 40).

In a correctly banked turn, the needle indicates the rate of the turn. The forces acting on the ball cause it to remain centred. (Fig. 41.)

If one wing is permitted to drop, the ball will roll towards the side of the low wing. The needle in Fig. 42 shows the airplane to be flying straight, but the ball indicates it to be right wing low.

If the aircraft is not sufficiently banked in a turn, a skid towards the outside of the turn will occur. In Fig. 43, the needle indicates a left turn, the ball a right skid outswards.

When the airplane is overbanked in a turn, it will sideslip inwards. The needle in Fig. 44 indicates a left turn, the ball a sideslip inwards.
"Man lives at the base of an invisible ocean of air termed the atmosphere."— Pick.

This atmosphere is forever in a state of commotion and physical change, giving rise to weather conditions which vary throughout the range of an extremely vast scale. The airman not only lives at the base of this sea of air, but navigates through it. The weather, therefore, is a matter of vital concern to him—particularly conditions such as fog, ice formation, thunderstorms, and line squalls, which present unusual hazards to flying.

Unfavorable weather has, during the development of aviation, taken a heavy toll in the percentage of air fatalities due to this cause. In order to minimize the hazards to air navigation being constantly manufactured in the "weather factory", a vast world-wide meteorological organization has been built up, to collect, analyze and broadcast information relative to the ever changing phenomena of the upper air.

The pilot can today avail himself of last minute weather reports and forecasts along all the regularly established air routes. In addition, he can secure much valuable weather data with reference to areas located off the organized airways. He must, however, possess sufficient "weather sense" to be able to size up and deal with sudden changing conditions which may be encountered at any stage along his route. The few brief notes which follow are intended to cover the highlights of this subject only. The student of aviation will be well advised, however, to include meteorology among the subjects marked for further detailed study from some of the excellent manuals which are available on the subject.

THE ATMOSPHERE

The Atmosphere consists of four distinct gaseous layers surrounding the Earth for a depth of at least 1000 miles. Air, which is the material of which the atmosphere is composed, is a mixture (not a chemical compound) of gases. At altitudes up to 50 miles the atmosphere consists of approximately 80% Nitrogen and 19% Oxygen. The remainder is made up of Argon, Carbon Dioxide, several other gases, and Water Vapor. Water Vapor acts as an independent gas mixed with the air.

The lower layer of the Atmosphere contains an enormous number of microscopic impurities such as dust, smoke and hygroscopic gases.

The upper layers of the Atmosphere do not contain dust particles or impurities for the Sun's light to reflect off, and for this reason appear deep cobalt blue to black in colour.

The weight of the Atmosphere is approximately one millionth the weight of the earth. A square inch column of air weighs approximately 14.7 lbs. at sea level.
The characteristics of the Atmosphere vary with time of day, season of year and latitude. Consequently only average values are referred to in this manual.

Characteristics of the Atmosphere

THE TROPOSPHERE. This is the lowest layer of the Atmosphere, whose height varies in different parts of the world from roughly 28,000 feet above sea level at the Poles to 54,000 feet at the Equator. Within the Troposphere the Temperature, Density and Temperature all decrease rapidly with height. The point where the Temperature ceases to drop and remains constant at —67°F. is known as the TROPOPAUSE.

THE STRATOSPHERE. This layer lies between 6 and 65 miles, approximately, above the Earth. Within the Stratosphere the Pressure continues to decrease, but more slowly. The Temperature remains constant at —67°F. up to a height of roughly 23 miles. From this point it again commences to rise to a maximum of 170°F. at 30 miles and remains constant to a height of 40 miles, the approximate height of the Stratosphere.

The rise in temperature is due to the presence of a layer of ozone (sometimes called the Ozonosphere) which absorbs more of the sun's radiation.

THE IONOSPHERE lies roughly between 40 miles and 400 miles above the Earth. Within this layer the Temperature falls to —28°F. at 55 miles altitude and then commences to rise. At 400 miles it reaches 4000°F. This does not mean that an airplane, if it were possible to fly at this height, would experience a temperature of 4000°F by contact with the atmosphere. The temperature in these rarefied layers is based on the "kinetic" theory of gases. The only heat the airplane would experience would be what it would receive from the radiation of the sun. The Ionosphere is the layer which reflects low and medium frequency radio waves back to the earth. Very high frequency waves, however, penetrate this layer.

THE EXOSPHERE lies on the fringe of interplanetary space. Here the Temperature remains constant at 4000°F. and the Pressure drops to little more than a vacuum.

Standard Atmosphere

The decrease of Pressure, Density and Temperature which occurs in the lower layers of the atmosphere is not constant but varies with local conditions. However, for aeronautical purposes, it is necessary to have a "standard" atmosphere. The STANDARD ATMOSPHERE for the Continent of North America, based on summer and winter averages at Latitude 40° is shown in the following table:

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Pressure in inches of Mercury</th>
<th>Temperature in degrees Fahrenheit</th>
<th>Density in kilograms per cubic meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level</td>
<td>29.92</td>
<td>+58</td>
<td>1.22</td>
</tr>
<tr>
<td>5,000 ft.</td>
<td>24.89</td>
<td>+41.2</td>
<td>1.06</td>
</tr>
<tr>
<td>10,000 ft.</td>
<td>20.58</td>
<td>+3.4</td>
<td>.905</td>
</tr>
<tr>
<td>15,000 ft.</td>
<td>16.88</td>
<td>—6.5</td>
<td>.771</td>
</tr>
<tr>
<td>20,000 ft.</td>
<td>13.75</td>
<td>—12.3</td>
<td>.653</td>
</tr>
<tr>
<td>30,000 ft.</td>
<td>8.88</td>
<td>—47.9</td>
<td>.458</td>
</tr>
<tr>
<td>40,000 ft.</td>
<td>5.54</td>
<td>—67.0</td>
<td>.300</td>
</tr>
<tr>
<td>50,000 ft.</td>
<td>3.44</td>
<td>—67.0</td>
<td>.186</td>
</tr>
</tbody>
</table>

Note: Standard Atmosphere is sometimes referred to as "I.C.A.N." Air.

HUMIDITY

Of all the elements which compose the lower atmosphere Water Vapor is the most variable. Although it forms but a small proportion of the total mass of air at any time, its effects from a flying point of view are of great importance. Moisture exists in the atmosphere in two forms:

1. WATER VAPOR. An Invisible gas.
2. VISIBLE MOISTURE. Composed of water drops or ice crystals.

The process of changing from the form of Water Vapor into Visible Water Drops is called CONDENSATION.

The amount of water vapor that a given volume of air can contain is governed by the temperature. Warm air can hold more moisture than cold air. When a mass of air contains the maximum amount of water vapor it can hold at a given temperature, it is said to be SATURATED. If the temperature falls any lower after the air is saturated, some of the invisible water vapor will condense out in the form of visible water droplets. These form clouds, fog or dew. If the temperature is below freezing when condensation occurs, the water vapor condenses into ice crystals or frost.

The temperature at which unsaturated air must be cooled at constant pressure to become saturated (without the addition or removal of any water vapor) is called the DEWPOINT.

When the spread between the temperature and dewpoint is very small, the air can be said to be highly saturated and a slight drop in temperature may cause condensation in the form of clouds, fog, or precipitation.

THE RELATIVE HUMIDITY is the ratio of the actual water vapor present in the air to the amount which the same volume of air would hold if it were saturated (at the same atmospheric pressure and temperature). Saturated air has 100% Relative Humidity. Completely dry air has 0% Relative Humidity.

When a given mass of air is heated and no new water vapor is added, the Relative Humidity of air decreases. If the mass of air is cooled, the Relative Humidity increases. If cooling continues long enough, the Relative Humidity will reach 100% and the air will be saturated.

Hence, the smaller the spread between Temperature and Dewpoint, the higher will be the Relative Humidity.

Fog or low clouds are likely to form when the temperature is within 4° of the dewpoint.

ABSOLUTE HUMIDITY expresses the weight of water vapor per unit volume of air. It is usually stated in grains of water vapor per cubic foot of air. (A grain is 1/7000th part of a lb. of water.)

VAPOR TRAILS ("CONTRAIRLS")

The white vapor trails you see high up in the blue in this new jet age of supersonic speeds, owe their origin to two different causes.

1. EXHAUST TRAILS. When the hydrogen and carbon in aviation fuel is burned, the carbon produces a colorless gas, and the hydrogen produces water vapor — both of which are invisible. The latter product of combustion, which comes out of the exhaust, will remain invisible as long as the humidity of the surrounding air has not reached its saturation point. As stated in the section above, warm air can contain much more invisible water vapor than cold air before it becomes saturated. In the extreme low temperatures encountered at very high altitudes, the cold air is incapable of
absorbing the excess water vapor coming out of the exhaust. The latter therefore condenses into a visible cloud of water droplets or ice crystals. This is known as an EXHAUST TRAIL.

2. WING TIP TRAILS. As we learned in Theory of Flight ("Drag" vortex), in the form of eddies rotating with a corkscrew motion, come off the tips of an airplane wing in flight. These rapidly rotating vortices have considerable centrifugal force acting outwards, which causes a rarefaction and therefore an expansion of the air in the middle of the vortex. Air which expands, cools. If the vortex is strong enough, and the humidity of the air high enough, this cooling will cause condensation. The white cloud-like trails which form off the wing tips are known as WING TIP TRAILS.

IMPURITIES

The Atmosphere contains a vast quantity of impurities, such as fine dust from deserts, smoke from industrial regions, salts from the oceans and hygroscopic gases. Since these originate from the Earth they exist only in the lower layers of the atmosphere. They act as CONDENSATION NUCLEI on which the condensation of water vapor takes place when air is cooled below its saturation temperature (Dewpoint).

TEMPERATURE

The source of energy which warms the Earth's surface, evaporates moisture into the atmosphere, and causes the movement of air which we call wind, is the Sun. The lower Atmosphere absorbs very little of the heat radiated by the Sun. Most of the Sun's heat is absorbed by the Earth and about half of it is reflected back into the atmosphere by RADIATION. This is important, for it means that the lower layers of the atmosphere are heated from below and not from above.

Land surfaces absorb more heat from the Sun than water surfaces, and radiate it more readily. Therefore land surfaces warm up more during the day and cool more rapidly at night than water. For the same reason, the land is warmer than the sea in Summer and cooler in Winter.

Lapse Rate

The OBSERVED LAPSE RATE is the rate at which the temperature of the lower atmosphere decreases with height.

The normal lapse is 3.5°F per 1000 feet.

The ADIABATIC LAPSE RATE is the rate at which the temperature of a mass of air changes, due to expansion or compression — when no heat from any outside source is added to it or taken away from it.

When air rises, it expands and cools—adiabatically. The Adiabatic Lapse Rate of dry air is 5.4°F per 1000 feet.

The Adiabatic Lapse Rate of moist air is approximately 2°F or 3°F per 1000 feet.

If a mass of rising air (cooling adiabatically) is still warmer than the air around it, it is UNSTABLE. (Fig. 1). If disturbed, it will tend to rise further. Unstable air gives rise to cloud and rain formation, turbulence and sometimes thunderstorms.

If a mass of air is cooler than the air around it, it is STABLE. (Fig. 2). If disturbed, it will tend to sink back to its original level. Stable air means stable weather conditions.

An air mass whose temperature is the same as the surrounding air (that is, its adiabatic lapse rate is the same as the observed temperature lapse rate) is said to be in NEUTRAL EQUILIBRIUM. It will neither rise nor sink. Fig. 3.

<table>
<thead>
<tr>
<th>UNSTABLE</th>
<th>STABLE</th>
<th>EQUILIBRIUM</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Fig. 1" /></td>
<td><img src="image2" alt="Fig. 2" /></td>
<td><img src="image3" alt="Fig. 3" /></td>
</tr>
</tbody>
</table>

In the above we have considered the case masses, or lumps of air which have, for any reason, been displaced upwards. If a layer of air becomes either heated from below or cooled from above, it will have a steep temperature lapse rate. It will therefore be UNSTABLE. Flying conditions in such a layer will be rough, with heap type clouds such as cumulus or cumulonimbus and frequently showers or thunderstorms.

A layer of air which has a small temperature lapse rate will be STABLE. There will be little tendency for vertical currents to develop. Cloud formation will be of the layer type, such as stratus, and flying conditions will be smooth.

Temperature Scales

The scales commonly used in meteorology to measure the temperature are the Centigrade, Fahrenheit, and Absolute Scales.

The CENTIGRADE SCALE has a freezing point of 0°C and a boiling point of 100°C.

The FAHRENHEIT SCALE has a freezing point of 32°F and a boiling point of 212°F.

The ABSOLUTE CENTIGRADE SCALE assumes an absolute zero of -273°C. The Absolute Temperature can be found by adding 273 to the Centigrade Temperature, e.g. +10°C = 283° Absolute. -10°C = -263° Absolute.

INVERSION

Normally, the temperature of the atmosphere decreases with height. However, this is not invariably the case. Sometimes warmer air may be found at higher altitude. Such a reversal of normal conditions is known as an INVERSION. It can occur on a clear night when the cold ground cools the air above it in the lower levels, or when warm air is lifted above colder air over a frontal surface (which will be explained in "The Polar Front", further along).

DENSITY

The DENSITY of air means its mass per unit of volume. Cold air is dense because the molecules which compose it are still, and are packed closely together.
Warm air is less dense because the molecules which compose it are moving rapidly about. Hence, they take up more space, and consequently there are less molecules in a given volume. Since cold air is denser it is therefore heavier and tends to sink due to the force of gravity. Warm air, being lighter, is pushed up by the denser cold air and tends to rise.

**PRESSURE**

The PRESSURE of the atmosphere at any point is due to the weight of overlying air. Pressure at the surface of the Earth is usually measured by the Mercury Barometer and is expressed in inches of Mercury (written "Hg"). A measurement so expressed really means the length of a column of mercury, the weight of which will balance a column of air extending from the ground to the top of the atmosphere (Fig 4).

Pressure, however, is a force and in meteorological work it is common to employ a unit, the MILLIBAR to measure it. A Millibar is a pressure exerted on an area of 1 square centimeter by a force of 1000 Dynes.

A pressure expressed as 30 inches of Mercury (30”Hg) is equivalent to 1015.9 millibars.

If some of the air were removed from a room, the pressure would be reduced and the pressure outside would force air in through the doors and wind-ways until the room was again filled with the normal amount of air. Similarly, if over some area, some of the air were removed, the pressure over that area would be reduced, and the pressure of the air in the surrounding areas would force air into the region of deficient pressure.

Such areas of deficient or low pressure are known to exist, but for the following reason the air does not flow directly into them. Anything moving above the surface of the Earth will continue to move in a straight line if no force acts on it, but the Earth in its rotation moves under the moving body. The moving body is therefore, apparently deflected to the right in the Northern Hemisphere. This is known as FENNELL'S LAW. The apparent deflecting force is called CORIOLIS FORCE. (Fig 5).

Hence, the wind does not blow straight into an area of Low Pressure from all sides but is deflected to the right and blows round the area of low pressure anti-clockwise in the Northern Hemisphere.

It is the same force which causes water to swirl anti-clockwise in a wash basin when the plug has been removed.

**WIND CIRCULATION**

The movement of air from the high towards the low pressure areas is called Wind. Thus it will be seen that the Winds of the Earth are controlled by Pressure - and affected by the Earth's rotation, on its axis. Temperature Conditions in turn, are responsible for the differences in pressure.

Warm air rises until it reaches a great height, when it flows over into the surrounding regions. The weight of a column of rising warm air therefore becomes less and its pressure decreases - thus creating an area of Low Pressure. Cold air sinks, and air from the upper levels of the surrounding atmosphere flows in on top of it. This increases the weight of the column of sinking cold air, increasing its pressure, and thus creating an area of High Pressure.

The Poles are areas of High Pressure. The Equator is an area of Low Pressure. An intermediate belt of High Pressure lies about Latitude 30° North and 30° South of the Equator. An intermediate belt of Low Pressure lies about Latitude 60° North and 60° South of the Equator.

The so-called permanent wind systems of the Earth are the result of this general distribution of pressure. Fig. 6 illustrates the Prevailing Winds of the globe. The figure will be self-explanatory if it is kept in mind that the wind moves from the High towards the Low Pressure Areas and is diverted to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Since there is a constant horizontal flow of air from the High to the Low Pressure areas on the surface of the Earth, it will be obvious that there must be a corresponding vertical circulation - since this moving air must come from somewhere and have somewhere to go. The vertical flow of rising and descending air circulation is shown on Fig. 6.
causing a DOWN-DRAFT. If the wind velocity is strong, EDDIES may form, causing gustiness or turbulence, particularly on the leeward side.

Veering and Bucking

The wind VEERS when it changes direction clockwise. Example: The surface wind is blowing from 270°. At 2000 feet it is blowing from 260°. It has changed in a right-hand, or clockwise direction.

The wind BACKS when it changes direction anti-clockwise. Example: Wind direction at 2000 feet, 90°. Wind at 3000 feet, 85°. It is changing in a left-hand, or anti-clockwise direction.

Isobars

If the observed readings from the barometer (reduced to sea level) from a number of places are put on a map, and arrows are put in to represent the direction of the wind, we have a weather map which at first looks like a disordered collection of figures. We may make it clearer by drawing lines through places of equal barometric pressure. Such lines are called ISOBARS. When the Isobars are drawn in, we can readily see that they form themselves into distinct areas of high and low pressure. We can also see that the winds circulate anti-clockwise inwards around the Low Pressure Areas and clockwise outwards around the High Pressure Areas.

The force of friction which causes the wind to blow inwards towards the centre of the Lows and outwards from the centre of the Highs is not present in the upper levels (above 2000 feet). Above this height the wind blows practically along the Isobars.

The Isobars are as Contour Lines on a map, the high pressure corresponding to hills and the low pressure to vallies. The steepness of a gradient on a map is measured by the distance between the Contour Lines. The steepness of the PRESSURE GRADIENT is measured by the nearness of the Isobars.

The steeper the Pressure Gradient, the greater the force of the wind.

If we put down on a map beside the barometer readings and wind arrows the state of the weather, we shall see that in the High Pressure Areas it is usually fine and clear, probably cooler, while in the Low Pressure Areas it is generally rainy and cloudy on the east side, and probably fine on the west side. The weather, in fact, is intimately connected with the shape of the Isobars.

LOW PRESSURE AREAS

Areas of Low Pressure are called CYCLONES, DEPRESSIONS, or simply LOWS.

A Depression may cover a small region, such as a county, or it may extend across half the continent.

Fig. 6. Wind Circulation.

Local Winds

The constant wind changes experienced, particularly in the intermediate Latitudes, are due mainly to the formation and movement of local high and low pressure areas which travel, generally speaking, from west towards east, and which carry their own wind and weather systems with them.

Other examples of local winds are: Land and Sea Breezes, caused by the differences in temperature over land and water. The Sea (or Lake) Breeze occurs during the day when the land area becomes warmer and its pressure lower than the water area. The Land Breeze blows at night when the land becomes cooler and the wind blows towards the warm, low pressure area over the water. Mountain Breezes are caused by the cooler air over mountains gravitating down towards the warmer valleys at night. These are called KATABATIC WINDS. Valley Breezes are winds that blow up the valleys when the sun warms the ground. These are known as ANABATIC WINDS.

Gustiness is caused by eddies in the air set up by obstacles in the path of the wind. Also by surface heating, particularly on hot summer afternoons.

Diurnal (Daily) Variation of Wind is caused by strong surface heating during the day which causes turbulence in the lower levels. This turbulence brings down air from higher levels which is moving faster and increases the surface wind. At night there is less turbulence and the surface winds become lighter.

Up-Drags and Down-Drags. Wind flowing over a mountain or other obstacle will be diverted upward on the windward side, causing an UP-DRAFT, and its velocity will be increased. The rough mountain terrain will cause the flow of air to become turbulent, like water flowing over a rough stream bed. On the leeward side of mountains or obstacles such as buildings, high shore lines, etc., the wind will flow downward.
Some are much deeper than others. A deep Depression is one where the barometer is very low in the centre and the Isobars are rather close together. A shallow Depression is low in the centre, but not much lower than the surrounding areas.

Depressions seldom stay long in one place but move in an easterly direction. Their average rate of movement is 500 miles a day in Summer, and 700 miles a day in Winter. Their drift is generally to north-east or south-east. It is very unusual that there is an exception to this rule.

Secondary Depression

This is a smaller disturbance of a cyclonic nature which forms within the area dominated by the main depression. The Secondary centre revolves around the main centre in an anti-clockwise direction. Secondaries are frequently associated with thunder storms in summer and gales or heavy precipitation in winter.

Trough of Low Pressure

These were formerly called V-shaped Depressions, the Isobars being in the form of a V, or trough. The passage of the Trough across the country is associated with a very severe squall, called a LINE SQUALL. This squall is a very rapid freshening of the wind to probably 50 or 60 m.p.h. or even more. The increase in velocity is accompanied by a sudden veer to north or north-west, heavy precipitation, and usually thunder. Along the trough line and travelling broadside to it is a dark line of very turbulent clouds in a roller formation.

Col

A COL is a neutral region between two Highs and two Lows. Weather conditions are generally very unstable and liable to rather sudden changes. As a rule, thundery conditions in summer, and fog in winter are likely to occur.

HIGH PRESSURE AREAS

An ANTI-CYCLONE, or HIGH is an area of relatively high pressure, higher than the surrounding regions, with the highest pressure in the centre and decreasing towards the outside. The accompanying clockwise direction around the centre, blowing outwards into the Lows.

Highs move much more slowly across the country than Depressions and occasionally remain almost stationary for days at a time.

Ridge of High Pressure

An anti-cyclical Ridge is a neck or ridge of high pressure with low pressure lying on either side. The weather in a Ridge is generally fine to fair, but does not persist for more than a day or two at most.

Visibility

VISIBILITY means the distance at which prominent objects may be seen and identified by day, and prominent lighted objects by night.

FLIGHT VISIBILITY is the average range of visibility forward from the cockpit of an airplane in flight.

GROUND VISIBILITY is the visibility at an aerodrome, as reported by an accredited observer.

CLOUDS

The International System classifies clouds into four families, characterized by their form and appearance, and the general relationship between the form of clouds and their height.

1. High Clouds (Mean base, 20,000 ft.):

   Cirrus (Ci). Very high. Thin, wavy sprays of white clouds, made up of slender, delicate curling wisps or fibres. Sometimes takes the form of feathers or ribbons, or delicate fibrous bands. Composed of ice crystals. Often called "cats' whiskers" or "mares tails".

   Cirrus is frequently one of the first signs of the approach of a depression or of bad weather.

   Cirrostratus (Cs)—Very thin high sheet cloud. Cirrostratus is frequently an indication of a warm front or occlusion and therefore of deteriorating weather.

   Cirrostratus is characteristic of future weather developments. Cirrostratus
Castellatus (Acc) is Altocumulus with a turreted appearance.

Altrostratus (As) — Medium high uniform sheet cloud. The presence of Altrostratus indicates the near approach of a warm front. The base of the cloud slopes downward towards the warm front. Some light rain or snow may fall from thick Altrostratus. Icing may occur in this cloud.

3. Low Clouds (Mean tops 6500 ft.—Base, close to ground):

Stratocumulus (Sc) — Globular masses or rolls. This cloud type has little value as an indication of future weather conditions. Icing may occur when the temperature of the cloud is between 0°C, and —7°C.

Stratus (St) — Low uniform cloud sheet.

Greatest abundance during the warm part of the day.

If Cumulus builds up into very high towering masses it is apt to develop into Cumulonimbus and showers or thunderstorms may be expected. Rough air will be encountered underneath the cloud. Heavy icing may occur in Cumulus between 0°C, and —15°C.

Note: Heavy Cumulus is designated Cu+.

Cumulonimbus (Cb) — Great towering masses of rain cloud. Cumulonimbus has little value as an indication of future weather conditions, but a line of Cumulonimbus is often an indication of a cold front. The cloud should be avoided on account of its violent bumpiness, the danger of heavy icing, and violent electrical activity.

4. Convection Clouds (Mean base, 1600 ft.)

Cumulus (Cu.) — Medium high. Thick, rounded, lumpy clouds which resemble cotton balls. Usually have flat bases. Cast dense shadows and appear in
2. Scattered: When 1/10th to 5/10ths is covered by clouds.
3. Broken: When more than 5/10ths but not more than 9/10ths of the sky is covered.
4. Overcast: When more than 9/10ths of the sky is covered.
5. Obscured: When more than 5/10ths of the sky is hidden by an "obscurating medium", such as rain, snow, hail, fog, haze, dust, smoke, etc.

**FORMATION OF CLOUDS AND RAIN**

Both clouds and rain are formed by warm, moisture-laden air rising and cooling to the point where condensation occurs. This is known as the DEWPOINT. The Dewpoint is the temperature below which the moisture in the air, existing in the form of invisible water vapour, changes into visible water drops. This is also the process known as CONDENSATION.

These visible water drops, minute in size, present the appearance known as clouds.

Further cooling of the air causes more condensation, which deposits more water on the drops. These increase in size until eventually they become too heavy for the rising currents of air to support. They then fall in the form of rain.

Broadly speaking, the methods of formation of clouds and rain may be classified as follows:

**OROGRAPHY**—Wind blowing against a range of hills or mountains is forced upward and cools until condensation occurs. A long bank of cloud forms on the windward side and the upper part of the hills or mountains from which OROGRAPHIC rain may fall. Due to the fact that the rising ground is always in the same place, orographic clouds and rain are typically persistent and usually widespread.

**CONVECTION**—Warm air rises. Owing to the heating of the ground by the sun, rising currents of air occur. The upward (or downward) movement of air is known as CONVECTION. As convection currents of air rise, they expand. The expansion is accompanied by cooling. The cooling produces condensation, and a cumulus cloud forms at the top of each rising column of air. Further ascent and cooling cause rain—frequently heavy rain accompanied by thunderstorms.

**FRONTAL**—When a mass of warm air is advancing on a colder mass, the warm air rises over the cold air on a long gradual slope. This slope is called a Warm Front. The ascent of the warm air causes cooling, and clouds are formed, ranging from high Cirrus through Altostratus down to low Nimbostratus from which continuous steady rain may fall over a wide area.

When a mass of cold air is advancing on a mass of warm air, the cold air undercut the warm air and forces the latter to rise. The slope of the advancing wedge of cold air is called a Cold Front. The clouds which form along the front are heavy Cumulus or Cumulonimbus. Heavy rain, thunderstorms, turbulence and icing are associated with the latter.

In the case of Warm and Cold Occluded Fronts (which will be described in "The Polar Front") the clouds which form are very similar to those of the warm front described above, except that Cumulus or Cumulonimbus may also be present. Violent turbulence, lightning and icing conditions are apt to be associated with the latter.

**TURBULENCE**—When a strong wind blows over a rough surface, or when uneven surface heating occurs, TURBULENCE, in other words Edy Motion, is set up. This motion consists of irregular up and down currents. The air in the upward current cools, and if sufficient moisture is available, and the turbulence is vigorous, condensation may take place in the upper part of the turbulent layer. This results in a layer type cloud such as Straus or Stratocumulus, the latter being accompanied by rain, light drizzle, or perhaps showers.

**HAIL**

Observations have revealed the fact that water drops, certainly in the liquid form, can exist with temperatures as low as —38°C. It is clear, then, that small drops can be supercooled a long way without freezing.

Most big clouds formed as a result of an upward current of air are divisible into three well defined regions.

First there is the lowest layer where the cloud particles are in the form of water drops.

Next there is the region where the cloud particles are still water drops but are super-cooled.

Third there is the highest region of the cloud where the drops are frozen into ice crystals — this usually being called the "snow region".

There is no sharp dividing line between the snow and supercooled water regions. For some distance the ice crystals and supercooled water drops are co-existing. When a supercooled water drop collides with an ice crystal it at once freezes on the latter, imprisoning a little air which causes it to freeze in the form of soft ice. Falling through the supercooled region, more soft ice is deposited on it, increasing its size. The ball of soft ice so formed then falls through the water region. Water freezes on it in the form of hard, transparent ice. Finally the ball falls out of the base of the cloud as a hailstone—with a hard, transparent layer of ice covering a soft, white core.

Sometimes gusts carry hailstones back up to the top of the cloud, in which case the whole process is repeated, perhaps several times. In this way, very large hailstones are formed.

The vertical gusts which produce very large hailstones may have velocities in excess of 100 mph.

The conditions which produce hail are very similar to those in which thunderstorms originate. Hence hail is sometimes encountered in a cumulonimbus thundercloud.
Snow Pellets (Soft Hail)

If the water region lying below the supersaturated region of the cloud is not of great depth, the hailstone does not acquire the hard, transparent covering and arrives at the ground as the original soft, white ice. It then is known as a snow pellet or "soft hail".

Snow

In the formation of snow, the invisible water vapour in the air condenses directly into ice crystals, without passing through any intermediate water stage. Snow flakes are formed of an agglomeration of ice crystals.

Ice Pellets (Sleet)

Ice Pellets are formed by the freezing of raindrops. They are hard transparent globular grains of ice about the size of raindrops. They generally rebound when striking the ground.

Fog

To form a water drop in the atmosphere (the basis of fog formation) there must be present some nucleus on which the water may form. It was formerly thought that dust formed the nuclei for condensation, but it is now believed that particles of some hygroscopic substance such as salt, sulphur trioxide, etc., perform this function.

Fogs are due to the condensation of the water vapour in the atmosphere upon nuclei existing in that atmosphere. The condensation is due to cooling of the air below its dew point.

Smoke and dust in the air over large cities produce the "pea soup" fogs characteristic of London and other large industrial centres. The carbon and dust particles cause such fogs to be dark. Otherwise, when composed of water drops only, fogs are white in colour.

Fog is usually dissipated by sunlight filtering down through the fog or stratus layer. This results in heating from below.

RADIATION FOG is formed on calm clear nights when the cold ground cools the moist air above.

ADVECTION FOG is caused by the drifting of warm damp air over a colder land or sea surface.

UPSLOPE FOG is caused by the cooling of air due to expansion as it moves up a slope.

STEAM FOG forms when cold air passes over a warm water surface.

Haze

Haze is composed of very small water droplets, dust or salt particles so minute that they cannot be felt or individually seen with the unaided eye. Haze produces a uniform veil that subdues visibility. Against a dark background it has a bluish tinge. Against a bright background it has a dirty yellow or orange hue.

Freezing Rain

Rain which falls in the form of water drops but freezes on impact with objects in the open.

Thunderstorm

The conditions necessary for the formation of a thunderstorm are:

(i) An adequate supply of moisture in the atmosphere. This is supplied through evaporation from the surface of ponds, lakes, rivers, etc.

(ii) A steep temperature lapse rate—that is, a considerable drop in temperature with increasing height.

Thunderstorms are associated with cumulonimbus clouds, with strong up-gusts, frequently accompanied by hail.

Lightning flashes are evidence of the vast quantity of electrical energy released in a thunderstorm. The lightning is due to the separation of positive and negative charges in a cloud, the flash being the discharge between them. A distinction is sometimes made between "forked" lightning and "sheet" lightning. Forked lightning may be described as that in which the flash is actually visible. Sheet lightning is an illumination of the clouds caused by a distant lightning flash which cannot be seen.

Thunder is the noise which accompanies a lightning flash. It is attributed to the vibration set up by the sudden heating and expansion of the air along the path of the lightning flash.

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

(i) The violence of vertical currents encountered (in some cases sufficient to cause structural failure).

(ii) Limited visibility.

(iii) Possibility of static electricity building up in the airframe.

(iv) Danger of hail, lightning and icing conditions.

Because of the severe hazards enumerated above, attempting to fly through a thunderstorm is asking for trouble. If, however, circumstances make it a "must", go straight through the front—not across it. Unless hills or mountains dictate otherwise, go under the storm. It will be rough, but not as rough as flying through it.

If forced to fly around a thunderstorm, it is better to fly around the right side of it. The wind circulates anti-clockwise and you will get more favorable winds.

Do not attempt to go through a narrow "clear space" between two thunderstorms. The turbulence there may be more severe than through the storms themselves.
If the clear space is a mile or more in width, however, it may be safe to attempt to fly through the centre.

St. Elmo's Lights

If a plane flies through clouds in which positive charges have been separated from negative charges, it may pick up some of the cloud's overload of positive charges. Weird flames may appear along the wings and around the propeller tips. These are called ST. ELMO'S LIGHTS. They are awe-inspiring, but harmless. If the plane flies in the vicinity of a cloud where negative charges are concentrated, its positive overload may discharge into the cloud. In this case, it is the airplane which strikes the cloud with lightning!

Icing

Ice accretion on aircraft is caused by supercooled water drops impinging on the leading edge of the moving plane, and freezing. Hence dangerous icing conditions are encountered only in clouds, freezing rain or freezing drizzle, or in rain or drizzle when flying in temperatures below freezing (32°F to 15°F or 0°C to −10°C). Ice accretion may occur in any type of cloud (except cirrus) but only when the temperature in the cloud lies at or below freezing.

The cloud in which icing most frequently occurs in winter is stratocumulus, but the heaviest deposits are encountered in cumulus and cumulonimbus.

The smaller the water drop, the less distance it will spread back over the wing before freezing—hence the more dangerous types of icing are encountered in dense clouds, composed of heavy accumulations of large drops, and in rain.

(Note: Carburetor icing may occur in clear air at higher than freezing temperatures. This subject is dealt with in the Chapter on Engines.)

The four main types of ice accretion, in the order of their hazard to flying, are as follows:

1. FROST. A white, semi-crystalline frost which covers the surface of the aircraft. This has little or no effect on flying but may obscure vision by coating the windshield. It may also interfere with radio by coating the antenna with ice. Generally forms in clear air when a cold aircraft enters warmer and damper air during a steep descent.

Frost which forms on the wings when an aircraft is standing on the ground, however, should be removed, as this will interfere with the take-off.

2. RIME. An opaque, or milky white deposit of ice which accumulates on the leading edges of wings, struts, and wires. Forms when flying through filmy clouds. The deposit has no great weight, but its danger lies in the aerodynamic alteration of the wing camber and in coating the offices of the carburetor and instruments.

3. RIME-GLAZED. A transparent, glassy coating of clear ice which forms when flying through dense clouds. In addition to the dangers noted above, there is the weight of the accumulation and the vibration caused by the unequal loading of wings, struts, and especially the blades of the propeller. When large blocks break off, the vibration may become serious enough to fracture the structure of the aircraft.

4. CLEAR. A heavy coating of glassy ice which forms all over the aircraft when flying in rain. The danger is great owing to loss of lift, because of the altered wing camber, the increase of drag on account of the enlarged profile area of the wings, and finally the weight of the large mass of ice which may accumulate in a short time.

Modern transport aircraft are fitted with various systems designed to remove or prevent the formation of ice. These include (i) de-icing fluids released through slinger rings or porous leading edge members to flow over the blades of the propellers or the surfaces of the wings. (ii) rubber boots, which pulsate and break the ice off in sheets after it has already formed. (iii) thermal de-icing, which introduces sufficient heat inside the wings, through ducting, to melt the ice off as it forms.

Few single engine aircraft, or even light twin-engine types incorporate any means of ice prevention. A few tips for pilots flying aircraft in this category will therefore be in order.

"When ice formation is observed in flight," Captain Wise observes, "there is only one certain method of avoiding its hazards—and that is to get out of the icing layer as quickly as possible!" This may be done by climbing above the ice forming zone—which obviously would require a ship having good performance and fitted with radio and proper instruments for flying "over the top". The first alternative would be to descend and fly "contact" below the ice forming zone. The advisability of this course would depend on the ceiling and visibility along the route at the lower level concerned.

The final alternative would be to turn back, or, if the accumulation of ice had already become serious, to make a forced landing immediately.

In any event, the decision must be made rapidly since once ice has commenced to form, the condition may become critical in a matter of approximately six minutes.

Pilots flying in light aircraft which are not fitted with an outside air temperature gauge will be well advised to take a tip from Captain Wise and carry a strut thermometer. If the company or service operating the aircraft does not provide this, a satisfactory thermometer can be bought in any five and ten cent store and taped or strapped to a strut or wing. This little gadget offers the cheapest form of life insurance which can be purchased anywhere in the world.

During their barnstorming days, Captain Wise and Flatspin Fumble started out in a couple of light airplanes about the same time one day to a destination 150 miles away. Capt. Wise noted his strut thermometer warning that he was in an icing zone soon after take-off. He circled the airport twenty minutes in an effort to find a non-freezing layer but succeeded only in picking up a light coating of ice on his leading edges and windshield. He landed immediately and cancelled out his flight plan. Flatspin Fumble went on—but telephoned in about an hour later that he had cracked up 85 miles away trying to get down with a heavy load of ice.

Captain Wise, who took the telephone call, enquired first regarding injuries. Then he asked Fumble whether he was right in his mind.

"What do you mean?" snapped Flatspin.

"You must have seen that condition building up for miles—"

"Listen, get this," interrupted Flatspin. "I don't quit the first minute the going gets tough. At least I got a lot further than you did."
"With a broken airplane you're not getting anywhere right now. There's a bigger demand for old pilots than good pilots in aviation, pal, and paste this in your cockpit—the ground is full of people who tried to do what you just did."

LINE SQUALLS

A line squall is a heavy squall of wind accompanied by clouds extending to great heights and the passage of a long line of low, black, roller-like cloud, which often stretches in a straight line for several hundred miles, and from which heavy rain or hail falls for a short time. Thunder and lightning frequently occur. The squall is also accompanied by a sudden wind change from southerly or south-westerly to westerly or north-westerly, together with a sudden drop in temperature and pressure and a rise in barometric pressure. The actual wind squall lasts only for a few minutes but is often extremely violent, constituting a serious menace to both shipping and to aircraft. The signs indicating the approach of a line squall are unmistakable. Aircraft on the ground should be immediately hungared. Those in the air should at all costs avoid this violent weather phenomenon.

AIR MASSES

In the past, the weatherman based his predictions on the weather mainly upon the existence and movement of high and low pressure areas and the wind and weather systems which are associated with them. Today, the whole system of weather forecasting is based upon the properties of Air Masses (of which pressure is only one factor)—the changes which occur as an Air Mass moves away from its source, and the weather phenomena which can be predicted along the "Front" where two Air Masses of different properties come in contact.

An AIR MASS is an extensive body of air within which the temperature and humidity (in a horizontal plane) are practically uniform.

An Air Mass takes on its original properties from the surface area over which it has formed. An Air Mass over the South Atlantic would be warm and moist. An Air Mass over Mexico would be warm and comparatively dry. When it moves away from its source, an Air Mass may be heated or cooled from below, acquire dryness or moisture, and its properties will accordingly change.

The principal Air Masses of North America are as follows:

- **Pc** (or cP)—Polar Continental—A cold dry air mass which originates in the Canadian Arctic and brings a cold wave when it moves south.
- **Fp** (or mP)—Polar Pacific—Cold moist air which forms over the North Pacific.
- **Pa** (or mP)—Polar Atlantic—Cold moist air which forms over the Atlantic.
- **Tc** (or cT)—Tropical Continental—A warm air mass which forms over the hot dry plains of Mexico and the southern U.S.A. and sometimes moves north in winter.
- **Tp** (or mT)—Tropical Pacific. Hot moist air which originates over the South Pacific and moves north in Winter.
- **Tg** (or mT)—Tropical Gulf. A hot moist air mass which forms over the Gulf regions.
- **Ta** (or mT)—Tropical Atlantic. Hot moist air originating in the South Atlantic.

An explanation of Air Mass Symbols will be found in "Weather Map Symbols" (Air Masses).

It is the interaction of these Air Masses as they come in contact, with their conflicting properties of heat and cold, dryness and moisture, which brings about our weather changes.

THE POLAR FRONT

The present day theory which explains the formation of depressions, or lows, developed by the Norwegian, is known as the POLAR FRONT THEORY. It is based on the existence of AIR MASSES.

The polar regions are covered by a mass of cold air and the equatorial regions by a mass of warm air. The two masses are separated by a line, or "front" called the POLAR FRONT.

The air on the northern side (considering the northern hemisphere) of this surface of separation is termed Polar Air. It is normally cold, and dry. The air on the southern side is termed Tropical Air. It is normally warm, and moist.

Due to the difference in the properties of these two air masses, the Polar Front is known as a SURFACE OF DISCONTINUITY. Depressions form along this Surface of Discontinuity, the Polar Front, and are the means whereby interchange takes place between the warm and cold air masses.

![Fig. 15. Line Squall.](image)

![Fig. 16. The Polar Front.](image)

Along the Polar Front, the cold polar air flows from the north-east towards the south-west on the north side (Fig. 16) while the warm air flows from south-west towards the north-east on the south side. The arrangement is not a stable one but is subject to continual disturbances due to the warm air bulging north and the cold air bulging southward. This northward bulge, once having started, continues to develop, the cold air on the northward side swinging round at the back and
emphasizing the bulge. (Fig 17). This bulge is the new Depression, (or Low Pressure Area) just born, which normally travels north-eastward along the Polar Front, carrying with it the wind and weather characteristics produced by the interaction of the two different Air Masses concerned.

Warm and Cold Fronts

Fig. 18 shows the further development of the bulge referred to above. The two currents of air of different properties compounding the Depression are clearly shown marked "cold air" and "warm air". The Polar Front has now been bent or broken into two lines marked the "Warm Front" and the "Cold Front".

A WARM FRONT is, then, the sloping surface or dividing line between a mass of warm air advancing on a mass of cold air.

A COLD FRONT is the sloping front line ahead of a mass of cold air overtaking a mass of warm air.

The area contained within the bulge of the Polar Front is marked "Warm Sector". It will be seen that the Warm Sector contains the warm or Equatorial Air concerned in the Depression, while the rest of the area covered by the Depression is composed of the Polar Air concerned. The two lines of Discontinuity, the Warm Front, and the Cold Front, are marked by abrupt changes in wind direction, and temperature.

Note that the Isobars (Fig. 18) are bent into the form of a "V" or "Trough" at both the Warm and Cold Fronts.

The Warm Front

As a mass of warm air advances on a mass of cold air, the warm air, being lighter, ascends over the cold air in a long gentle slope. The rising warm air gives rise to the cloud sequence shown in Fig. 19 ranging from high Cirrus, down through Altostratus to Nimbostratus. Thus the approach of a Warm Front is marked by a gradual falling ceiling, followed by a long belt of steady rain. The passing of the Warm Front is marked by a rise of temperature, due to the entry of the Warm Sector. The cloud lifts, and tends to break.

The Cold Front

When a mass of cold air overtakes a mass of warm air, the cold air undercuts the warm air violently. The rapid ascent of the warm air gives rise to Cumulonimbus cloud with a short period of squally, showery rain, sometimes very heavy and accompanied by thunder. A sharp fall in temperature is also experienced with the passage of the Cold Front.

Occluded Fronts

With the progress of time, as a Depression advances, the Cold Front gradually overtakes the Warm Front and lifts the Warm Sector entirely from the ground. It is simply a case of the cold air catching up with itself as it flows around the depression. Thus only one Front remains, which is called an OCCLUDED FRONT or LINE OF OCCLUSION. An Occluded Depression soon commences to fill up and die away.

The cold air, in the distance it has travelled, may have undergone considerable change. Therefore it may not be as cold as the air it is overtaking. In this case, (COOL air advancing on COLDER air) the Front is known as an OCCLUDED WARM FRONT and has the characteristics of a Warm Front, with low cloud and continuous rain and drizzle. Fig. 21.
Weather maps are issued in all countries to show the state of the weather on the date and hour of publication of the map. They are also used to forecast the weather by indicating the speed and direction of movement of High and Low Pressure Areas from day to day with their accompanying Frontal conditions. Practically all the principal countries of the world publish elaborate Air Weather Maps with numerous symbols to indicate phenomena of special import to flying, such as the speed and direction of the wind, the state of cloudiness of the sky, temperature and dew point, air masses, rain, hail, thunderstorms, etc. In addition, special charts are issued in conjunction with the weather map to show the winds aloft, highest and lowest temperatures, precipitation areas and amounts, "yesterday's" fConic and pressure system pattern, and 700-millibar "constant pressure" pattern.

**STATION MODEL**

Weather stations are indicated on weather maps by a ball or circle, called the Station Circles. This circle is also used to indicate the cloudiness of the sky—black being completely overcast, white, clear, and the percentage of cloudiness between these two extremes being represented by a corresponding percentage of black and white.

The letter "M" in the station circle means that the weather report for the station is missing that day.

The direction of the wind is indicated by a line radiating from the ball, and the force of the wind is indicated by "bars" or "feathers" corresponding to the numbers of the Beaufort Scale.

Around the Station Circle numbers and symbols are arranged to indicate all the various elements of the weather which have been observed at the station at map making time. The complete diagram is known as a STATION MODEL. (Fig. A).

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**THE WEATHER MAP**

The theory of the Polar Front, which, for the sake of simplicity has been described in the form of its original conception, might leave the impression that Depressions form only along some well defined line lying somewhere midway between the Poles and the Equator. Air masses are in a constant state of formation over all the land and water areas of the world. Once formed, they tend to move away from the source regions over which they form. The same frontal processes and phenomena occur whenever a mass of warm air and a mass of cold air come in contact.

There is a widespread impression among pilots that all bad weather is associated with fronts. This is not entirely true. Fog generally occurs when no fronts are present, and thunderstorms may also occur in an air mass which has no frontal characteristics.
WEATHER MAP SYMBOLS

The various symbols and code figures which are grouped around the Station Model are shown in the following tables:

Amount of Cloud

<table>
<thead>
<tr>
<th>Code</th>
<th>Amount of Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No clouds.</td>
</tr>
<tr>
<td>1</td>
<td>One-tenth, or less.</td>
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<td>2</td>
<td>Two or more than one-tenth.</td>
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<td>3</td>
<td>Four-tenths.</td>
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<td>4</td>
<td>Five-tenths.</td>
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<td>5</td>
<td>Six-tenths.</td>
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<tr>
<td>6</td>
<td>Seven or eight-tenths.</td>
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<td>7</td>
<td>Nine-tenths, or overcast with openings.</td>
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<tr>
<td>8</td>
<td>Completely overcast.</td>
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</table>

Wind Force — Beaufort Scale

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<tr>
<th>Code</th>
<th>Wind Force</th>
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<td>0</td>
<td>Calm: 1-3 mph (1.3 kts)</td>
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<tr>
<td>1</td>
<td>4-7 mph (4.6 kts)</td>
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<tr>
<td>2</td>
<td>8-12 mph (7-10 kts)</td>
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<td>3</td>
<td>13-18 mph (11-16 kts)</td>
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<td>19-24 mph (17-21 kts)</td>
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<td>25-31 mph (22-27 kts)</td>
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<td>15</td>
<td>115-125 mph (100-108 kts)</td>
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<tr>
<td>16</td>
<td>126-136 mph (109-118 kts)</td>
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The figures down the left-hand column and across the top are Code Figures, used by meteorologists. They are used here merely as a cross reference to identify the symbols. Read down to the double figure, and then across to the appropriate single figure in each case.

Cloud Type — Low

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Cloud Type — High

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</tbody>
</table>

The figures down the left-hand column and across the top are Code Figures, used by meteorologists. They are used here merely as a cross reference to identify the symbols. Read down to the double figure, and then across to the appropriate single figure in each case.
Cloud Height

<table>
<thead>
<tr>
<th>Code No.</th>
<th>Feet</th>
<th>Code No.</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0-119</td>
<td>6</td>
<td>3500-4999</td>
</tr>
<tr>
<td>1</td>
<td>150-299</td>
<td>7</td>
<td>5000-6499</td>
</tr>
<tr>
<td>2</td>
<td>300-599</td>
<td>8</td>
<td>Above 6000</td>
</tr>
<tr>
<td>3</td>
<td>600-999</td>
<td>9</td>
<td>6500-7999</td>
</tr>
<tr>
<td>4</td>
<td>1000-1999</td>
<td></td>
<td>or no cloud</td>
</tr>
<tr>
<td>5</td>
<td>2000-3499</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Time of Precipitation

<table>
<thead>
<tr>
<th>Code No.</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No precipitation</td>
</tr>
<tr>
<td>1</td>
<td>Less than 1 hr. ago.</td>
</tr>
<tr>
<td>2</td>
<td>1 to 2 hrs. ago.</td>
</tr>
<tr>
<td>3</td>
<td>2 to 3 hrs. ago.</td>
</tr>
<tr>
<td>4</td>
<td>3 to 4 hrs. ago.</td>
</tr>
<tr>
<td>5</td>
<td>4 to 5 hrs. ago.</td>
</tr>
<tr>
<td>6</td>
<td>5 to 6 hrs. ago.</td>
</tr>
<tr>
<td>7</td>
<td>6 to 12 hrs. ago.</td>
</tr>
<tr>
<td>8</td>
<td>More than 12 hrs. ago.</td>
</tr>
<tr>
<td>9</td>
<td>Unknown</td>
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</tbody>
</table>

Barometric Tendency

<table>
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<tr>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Past Weather

<table>
<thead>
<tr>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

3: Sandstorm or duststorm, or drizzling or blowing snow. 4: Fog, or smoke, or thick dust haze. 5: Drizzle. 6: Rain. 7: Snow, or rain and snow, or ice pellets (sleet). 8: Showers. 9: Thunderstorm.

FRONT SYMBOLS

<table>
<thead>
<tr>
<th>On Printed Charts</th>
<th>On Weather Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Cold Front</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Continuous blue line</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Cold Front (close)</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Broken blue line</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Warm Front</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Continuous red line</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Warm Front (close)</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Broken red line</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Stationary Front</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Alternate red and blue line</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Stationary Front (close)</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Alternate red and blue line</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Occluded Front</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Continuous purple line</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Occluded Front (close)</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲ ▲ ▲</td>
<td>Broken purple line</td>
</tr>
</tbody>
</table>

Frontogenesis

A Front which is increasing in intensity is labelled on the weather map FRONTGENESIS.

<table>
<thead>
<tr>
<th>On Printed Charts</th>
<th>On Weather Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>▲ ▲ ▲ ▲</td>
<td>Cold Front</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲</td>
<td>Blue</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲</td>
<td>Warm Front</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲</td>
<td>Red</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲</td>
<td>Stationary Front</td>
</tr>
<tr>
<td>▲ ▲ ▲ ▲</td>
<td>Blue and Red</td>
</tr>
</tbody>
</table>

Frontolysis

A Front which is disappearing or decreasing in intensity is labelled on the weather map FRONTOLYSIS.

Squall Line

A SQUALL line is a line of thunderstorms or squalls usually accompanied by shifting winds. Indicated on the map by broken lines:

\[ \begin{array}{cccccccc}
\Box & \rightarrow & \rightarrow & \rightarrow & \rightarrow & \rightarrow & \rightarrow & \rightarrow & \rightarrow & \rightarrow \\
\end{array} \]

Storm Tracks

The paths followed by individual disturbances are called STORM TRACKS. They are indicated on weather maps by arrows and symbols. The symbols indicate the past positions of the low pressure centre at 6 hrs. intervals:

\[ \begin{array}{cccc}
\Box & \rightarrow & \rightarrow & \rightarrow & \rightarrow \\
\end{array} \]

Interpreting the Weather Map

A reproduction of a typical Weather Map is inserted further along. Note the frontal pattern, the distribution of pressure, and the general circulation of the wind. As a clue to the many and varied deductions a pilot may arrive at by a study of the weather map, the following are just a few observations Captain Wise came up with following a casual glance at the particular map sheet referred to above:

The front lying near Needles (35°-115°) within the next 24 hours will likely become a full developed cold front, since it is labelled "Frontogenesis", which means a front increasing in intensity.

The front lying through Burbank (35°-120°) is likely to disappear, since it is labelled "Frontolysis", which means a front decreasing in intensity.

The front lying over Hatteras (35°-75°) within the next 12 hours will probably be over Snow Hill. Referring to the 1:30 p.m. map for yesterday, Captain Wise notes that the front has moved 100 miles in the past 12 hours. A comparison of the two maps shows that the front is intensifying. The pressure is dropping, the isobars are closer, and the front is developing a "wave". It is therefore reasonable to assume that it will move more rapidly during the next 12 hours and to forecast it at 1:30 p.m. over Snow Hill which is 150 miles beyond its present position over Hatteras.

At 1:30 p.m. yesterday the wind velocity was less at San Antonio (30°-100°) that it was at, say, Roswell (30°-105°), Minot (50°-100°) or Travers City (45°-85°). The "yesterday" map insert does not contain the customary wind velocity map symbols. Captain Wise estimated the wind force by noting the closeness of the isobars. San Antonio is in an area where the isobars are wider apart than those in the vicinity of the other places referred to, and would therefore have less wind.

At map time, the icing level at Quebec (45°-70°) was approximately 9000 feet. The surface temperature shown on the weather map at Quebec is 53°F. However, a cold front is lying immediately south of Quebec. Due to the slope of the cold frontal surface, the warm air ahead of the front would be overlaying the cold surface at Quebec. Instead of using the surface tem-
perature at Quebec, we therefore use the surface temperature ahead of the front, which is 60°F.

The freezing level is 32°F. The lapse in temperature between the surface and freezing level is therefore 60 — 32 = 28°F. Assuming a normal temperature lapse rate of 3.5°F per 1000 ft, the icing level over Quebec would be 28 = 8 (3000 ft).

3.5

Air Masses

P (Polar) denotes relatively cold air from the northern regions. T (Tropical) denotes relatively warm air from the southern regions. Letters placed before P and T indicate air of maritime characteristics (m) or continental characteristics (c) Letters placed after P or T show that the air mass is colder (k) or warmer (w) than the surface over which it is moving. A plus sign (+) between two air masses indicates mixed air masses. An arrow (→) between two symbols indicates "transitional" (changing from one to another). Two air mass symbols, one above the other, and separated by a line, indicate one air mass aloft and another below.

Air mass symbols are formed from the following letters:

M: Maritime, C: Continental, A: Arctic, P: Polar, T: Tropical, E: Equatorial, S: Superior (a warm, dry air mass having its origin aloft), K: colder, and W: warmer than the surface over which the air mass is moving.

Precipitation

Areas where precipitation is occurring at the time of observation are shaded (grey on printed charts; green on weather maps).

Pressure Pattern Flying

Since the High and Low Pressure Areas, and the Winds associated with them are clearly indicated on the weather map, a careful study of the pressure pattern on the map will enable a pilot to take advantage of the most favorable winds. Such a selection of an advantageous route and altitude to fly is called PRESSURE PATTERN FLYING. At the expense of a little extra time and trouble when flight planning, it pays off in a big way.

AIRWAY WEATHER REPORTS (SEQUENCES)

A WEATHER REPORT (SEQUENCE) is a statement of weather conditions actually existing at a particular place at a given time. The sequence in which weather data is transmitted in code by teletype is as follows:


SYMBOLS USED IN TELETYPE WEATHER SEQUENCES

Station

Weather reporting stations are assigned two or three-letter identifications. e.g. "WG" — Winnipeg, "PIT" — Pittsburgh.

Sky Condition

Clear Obscured
Scattered clouds Partially obscured
Broken clouds Thin
Overcast

Multiple layers of cloud are stated in hundreds of feet above ground, with the final "00" of the figure omitted. (e.g. "4" means 400 feet.) Higher layers follow lower layers in ascending order.

Example: 10 30 100 3 means: 1000 feet Scattered ... 3000 feet Broken ... 10,000 feet Overcast.

Ceiling

M Measured W Indefinite
A Aircraft P Precipitation
B Balloon E Estimated

Ceilings are stated in hundreds of feet above ground — with the final "00" of the figure omitted. (e.g. "23") means, 2300 feet. The ceiling figure is always preceded by a letter indicating the nature and method of determining the ceiling. For example, "E30" means, ceiling estimated, 3000 feet. The letter "V" following the ceiling figure means that the ceiling is variable.

Visibility

The horizontal visibility is reported in figures representing miles and fractions of miles. (e.g. "10" means: 10 miles. "½" means: one quarter of a mile.) The letter "V" following the visibility figure in miles means "Visibility variable". (If the visibility is 6 miles or less, the reason is always given under the "State of Weather" or "Obstructions to Vision").

State of Weather

R Rain E Ice pellets (sleet)
lc Ice crystals A Hail
S Snow AP Small hail
SG Snow grains T Thunderstorm
SF Snow pellets SW Snow showers
ZR Freezing rain RW Rain showers
L Drizzle L+ Heavy thunderstorm
ZL Freezing drizzle EW Sheel showers

TORNADO is always written in full.

The addition of a minus (—) sign to any of the above means "Light". Double minus (——) means "Very Light". The addition of a plus (+) sign means "Heavy or Severe". The omission of any sign means "Moderate".


Obstructions to Vision

F Fog D Dust
GF Ground fog BS Blowing snow
IF Ice fog BD Blowing dust
H Haze BN Blowing sand
k Smoke BY Blowing spray

Sea Level Pressure

Sea Level Pressure is indicated by a group of three figures representing tens, units, and tenths of Millibars. The initial "9" or "10" is omitted.


In Canada, sea level pressure varies roughly between 960.0 and 1050.0 millibars.

Temperature

Temperature is indicated by figures representing its value to the nearest degree Fahrenheit. e.g. "9" means: 9°F. Below zero temperature is indicated by a minus (-) sign preceding the figure. e.g. "—20" means: 20°F. Zero degrees is shown as "0".

Dewpoint

The Dewpoint is indicated by figures representing
its value to the nearest degree Fahrenheit, e.g. "4" means: 4°F. Below zero dewpoint temperature is indicated by a minus (—) sign preceding the figure, e.g. "—15" means: —15°F.

Wind

Wind direction is shown by arrows, as follows:

| C | Calm |
|   | ➤ South |
|   | ➡ North |
|   | ➡ North-northeast ➢ Southwest |
|   | ➢ Northeast ➡ West-northwest |
| ➢ East ➢ East-northeast ➢ North-northwest |
| ➢ East-southeast ➢ North-northwest |
| ➢ South-southeast |

Wind velocity is indicated by figures indicating mph (Canada) or knots (U.S.A.). A plus (+) sign following the wind speed figure means "Gusts". The speed of the peak gust may be added after the plus sign, e.g. 25+38 means: "Wind northwest, 25 mph, gusting to 38 mph."

Q means "squalls", e.g. 25Q means: "Wind northwest, 25 mph, with squalls. Peak gusts with the squalls may be indicated by a figure following the Q, e.g. 25Q+42 means "Wind northwest, 25 mph, with squalls, gusting to 42 mph."

A second set of wind arrows (following the present wind direction and velocity) indicates a wind shift. The direction arrows are followed by a four-figure group giving the time the wind shift occurred. e.g. 18+16510Z means: "Wind northwest, 19 mph. A shift from west-southwest to northwest occurred at 3:10 p.m. Greenwich Mean Time." ("Z" is the symbol used to indicate G.M.T., which is the official time used in Airway Weather Reports).

The figures are sometimes followed by minus (—) meaning light velocity, or plus (+) meaning strong velocity, e.g. 18+16161E— means: "Wind west-northwest 18 kts., gusts, moderate wind shift from south at 4:18 p.m., Eastern Time.

Altimeter Setting

The Altimeter Setting is indicated by a group of three figures representing the pressure in inches and hundreds of inches. The first figure (whether 3 or 2) is omitted, hence 30.00 inches is written 300. 29.72 inches is written 972. (A number beginning with 5 or higher presupposes an initial 2; a number beginning with 4 or lower presupposes an initial 3.)

Pressure Tendency

The Pressure Tendency is sometimes included. It is indicated by a three figure group in code. This information is intended mainly for the use of forecasters.

Clouds

| CI | Cirrus |
|    | ST | Stratus |
|    | CS | Cirrostratus |
|    | SC | Cirrocumulus |
|    | AS | Altostratus |
|    | AC | Altocumulus |
|    | ACC | Altocumulus |
|    | Castellanus |
|    | NS | Nimbostratus |

Remarks

Any additional remarks are shown in teletype symbols and in abbreviations of plain English words, e.g. DRK NW means: "Dark overcast in northwest".

Missing Data

Any items which are normally sent, but for some reason are missing from the transmission, are indicated by the letter "M" entered in place of the missing data.

Date and Time

Airway Weather Reports are preceded by five-figure groups and letters indicating the date and time. The first two figures give the day of the month and the next four figures the time (on the 24-hour clock). Time used on all teletype weather networks in North America is GMT, or "Z" Time.

Frequency

Normally, weather teletype sequences are transmitted over a national network by airport weather stations once every hour at 30 minutes past the hour. "Special" reports may be transmitted at more frequent intervals when the weather is changing rapidly.

EXAMPLE — AIRWAY WEATHER REPORT

WG SS 3 1 M7 1 1/2 R.FK 926/41/39 4/925/404

SF3 ST7 VSBY IN.

WG: Code letters of station reporting (WG means Winnipeg).

SS: Type of report (S means special. 5 means the fifth for the day).

M7: Sky condition (M means 300 feet. O means scattered).

M7G: Ceiling (M means measured. 7 means 700 feet. O means overcast).

1/4: Visibility (1/4 means 1/4 miles).

R.FK: Obstructions to vision (R means light rain).

F means fog. K means smoke.

926: Sea level pressure (926 means 992.6 millibars).

41: Temperature (41 means 41°F).


4: Wind (4 means wind northeast, 4 mph.).

925: Altimeter setting (925 means 29.25 inches mercury).

404: Pressure tendency, in code.

SF3 ST7: Clouds (SF3 means stratus fractus, 3/10ths, moving from the north-east. ST7 means stratus, 7/10ths).

VSBY IN: Remarks (means visibility 1 mile to the north).

WINDS ALOFT REPORT

Weather Stations report the upper winds four times daily. The reports cover the wind speed and direction at thousand-foot levels up to 10,000'; From 10,000' to 20,000', at two thousand-foot levels; and above 20,000' at five thousand-foot levels. Heights are above mean sea level.

EXAMPLE:

CHA 15Z 01309 20812 0515 43616 3421

DECODED, the above reads:

CHA: Chatanooga

15Z: 15:00 GMT (Greenwich Mean Time).

01309: Surface wind from 130° at 9 kts.

20812: 2000 ft. Wind from 80° at 12 kts.

0515: 3000 ft. Wind from 50 at 15 kts.

43616: 4000 ft. Wind from 360 at 16 kts.

3421: 5000 ft. Wind from 340 at 21 kts.

*Note: At odd altitudes, the altitude figure is omitted.
WEATHER FORECASTS

A WEATHER FORECAST is a statement of anticipated conditions expected at a particular place, over an area, or along a route during a given period, based on available information. The forecaster will usually state the degree of confidence with which the Forecast is made.

In planning a flight, the pilot must have reasonable knowledge of the following facts:

1. Whether the ceiling and visibility at his terminal—or at alternate landing places—will be sufficiently good to make a safe landing. If the flight is to be made by visual contact, the ceilings and visibilities must be "VFR" along the entire route.

2. He must know the wind conditions at various flight levels to estimate the time and fuel required, and to choose a route and altitude to fly that will give him the most favorable winds.

3. He must know at what levels to expect icing conditions and how to avoid severe icing zones.

4. He must know where thunderstorms, turbulence or hail may be encountered, so that he may delay the start of his flight or land en route to avoid dangerous weather in the air.

Since the weather is constantly changing, the conditions shown in a Weather Report may change during a flight and a Forecast of the changes must be obtained before departure.

AN AREA FORECAST is a general statement of weather conditions to be expected over a particular region during a 12 hour period.

EXAMPLE:
FCT 12Z-24Z
C ONT
CLDS AND WX. HEIGHTS MSL UNLESS NOTED. CNDS IN 50 MILE WIDE SQAL LINE ZONE THRU SERN ONT MOSTLY 60° BUT VSBSY BRFLY 2-4 MIS AND CIGS NEAR 20 HND ABV GND WITHIN HVYR TSTM AREA. THIS SQAL LINE WILL MOVE SEWD ABT 25 MPH AND DSPT BY ABT 16Z.

TURBC. MDT TO HVY IN TSTM
OUTL 24Z SUN TO 12Z MON. TSTMS CNTRL AND WRN PTN WILL END BY ERY AFTN. ELSW UNRSTD VSBSY AND NO CLDS BLO 10 THSD MSL.

DECODED, the above reads:
Area forecast for period 12:00 to 24:00 GMT for Central Ontario.

Clouds and weather. Heights are above mean sea level unless noted. Conditions in a 50 mile squall line zone through southeastern Ontario mostly 6000 foot overcast but visibilities briefly 2 to 4 miles and ceilings near 2000 feet above ground within heavier thunderstorm area. This squall line will move southeastward about 25 M.P.H. and dissipate by about 16:00 GMT.

Icing. Light to occasionally moderate icing in clouds above 12,000 feet except locally heavy in thunderstorm areas. Freezing level height 12,000 feet to 14,000 feet.

Turbulence. Moderate to heavy in thunderstorms.

Outlook. 24:00 GMT Sunday to 12:00 GMT Monday. Thunderstorms in central and western portion will end by early afternoon. Elsewhere unrestricted visibilities and no clouds below 10,000 feet above mean sea level.

A TERMINAL FORECAST states in specific terms the ceiling, visibility and wind conditions expected at a particular air terminal. Terminal Forecasts are transmitted 4 times daily and are usually for a 12 hour period.

EXAMPLE:
YC 12Z-24Z

DECODED, the above reads:
YC, Calgary
12Z-24Z: Period from 12:00 to 24:00 GMT.
30°C90°↑&↓12: 3000 feet scattered clouds, ceiling 9000 feet, overcast, surface wind south-southeast 12 kts.

1400Z C20°6RW—↑&↓15: By 14:00 becoming ceiling 2000 feet, overcast, visibility 6 miles, light rain showers, surface wind south-southeast 15 kts.

1900Z C30°↑&↓15: By 19:00 becoming ceiling 3000 feet, broken clouds, surface wind south-southeast 15 kts.

A WINDS ALOFT FORECAST provides an estimate of upper wind conditions at selected flight levels. Winds aloft FORECASTS are transmitted every 6 hours and are for a 12 hour period.

EXAMPLE:
CMA
10Z 4-1820 7-2135 10-2525 20-2935
16Z 4-3225 7-3025
DECODED, the above reads:

OMA: Omaha
10Z: Beginning at 10:00 GMT.
4-1820: 4000 ft. Wind from 180° at 20 kts.
7-2135: 7000 ft. Wind from 210° at 35 kts.
10-2525: 10,000 ft. Wind from 250° at 25 kts.
20-2535: 20,000 ft. Wind from 290° at 35 kts.
16Z: At 16:00 GMT.
4-3225: 4000 ft. Wind from 320° at 25 kts.
7-3025: 7000 ft. Wind from 300° at 25 kts.

Temperatures aloft are included for certain stations. Winds aloft with temperatures are shown as follows:
10-2540/3 (10,000 ft. Wind from 250° at 40 kts.
Temperature ±3°C.)

Note: Winds at heights not reported can be obtained by interpolation. e.g.: At 10:00Z (04:00C) at Omaha the wind would be from 190° at 25 kts.

The pilot gets his picture of the current weather along his intended route from the forecast, a study of the weather map, teletype and radio reports, and from what he sees. At times, when no forecaster is available, he must make his own analysis from available data.

Weather maps are drawn by forecasters. One of these maps is drawn every 6 hrs. at most weather stations. Weather maps are drawn with a series of previous maps displayed before the forecaster. A satisfactory weather map can only be drawn when the forecaster has a knowledge of the previous weather. The value of a forecast depends upon whether there has been a correct determination of the life history of the air masses and the movements of fronts and centres.

It is always advisable to look at a weather map, not from the standpoint of an observer, but with a view to looking for the weather, wind circulation, ceilings and visibilities along the route and to either side of the route to be flown. The pilot should know which way to turn in case the weather “closes in” at his terminal. Always have an “out” in case the forecast fails to materialize.

If radio is carried, keep a constant check on the weather reports which are broadcast regularly by radio range stations. If at any time in doubt, call an air traffic centre and ask for the weather ahead.

**SOURCES OF WEATHER INFORMATION**

PRE-FLIGHT. For forecasts and weather information, contact the “Meteorological Office” or “Weather Bureau” at your local airport. If there is no Weather Station at the airport, but there is a D.O.T. or C.A.A. Communications Station, that station will provide you with weather information. Flight Information Manual (U.S.) lists the telephone numbers of the Weather Reporting and Airway Communication Stations.

If neither of these facilities exist, phone the nearest public weather office.

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**IN-FLIGHT.** You can request weather information in flight from any D.O.T. or C.A.A. Communications Station by radio. All airway radio range or radio beacon stations having voice facilities broadcast the weather at 15 and 45 minutes past the hour. (In Canada at 22 and 52, or 25 and 55 minutes past the hour.) In addition, special weather reports are broadcast off-schedule immediately when available. You should avoid calling for weather information during the 15 and 45 minute periods in order to avoid interrupting the broadcast. If your need is urgent, however, you may request the announcer to delay the regular scheduled broadcast to provide the information you need.

Airway Communications Stations answer calls on the low frequency range voice channel, or VHF range voice channel on which the range operates unless you request a reply on some other channel. In order to avoid delays, it is advisable to state what channel you are listening on when calling for weather reports.

See also Radar Advisory Service.
Air Navigation

The Earth on which we live is a ball, or sphere, technically an oblate spheroid. Not knowing any better, the human race has, for centuries lived on the OUTSIDE of the sphere—enduring heat and cold, clouds and rain, snow and sleet, fog, mist, and mortal uncertainty. In due course, cities of the future will be located underground in a world of perfectly regulated heat, light and air conditions.

Meanwhile, we are here to-day and gone to-morrow, and must make the best of our cabbage-patch world, such as it is. Man is a restless soul, and travel and curiosity have always been two of his most cultivated and persevering habits. To make it possible to move about on this great Terrestrial Sphere then, he must have some master plan to enable him to define position, direction and distance.

Prime Meridian is the meridian which passes through Greenwich, England. The meridian on the opposite side of the world to the Prime Meridian would, of course, be the 180th. This is called the INTERNATIONAL DATE LINE for here the time changes a day.

CHANGE OF LATITUDE AND LONGITUDE. One position on the Earth's surface is related to another by the Change of Latitude (written Ch. Lat.) and Change of Longitude (Ch. Long.) between the two places.

If an aircraft is to proceed from a place, say, Dunnville, to a place, Harrisburg, the Ch. Lat. is named north or south according to whether Harrisburg is north or south of Dunnville. Similarly, the Ch. Long. is named east or west, depending on whether Harrisburg is east or west of Dunnville. Example:

<table>
<thead>
<tr>
<th>Place</th>
<th>Lat.</th>
<th>Long.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harrisburg</td>
<td>60°27'N.</td>
<td>40°20'W.</td>
</tr>
<tr>
<td>Dunnville</td>
<td>45°30'N.</td>
<td>15°30'E.</td>
</tr>
<tr>
<td></td>
<td>14°57'N.</td>
<td>55°50'W.</td>
</tr>
</tbody>
</table>

In the above example, Harrisburg is obviously NORTH of Dunnville 14° 57' of Latitude, hence its Ch. Lat. is 14° 57' NORTH. You will note that Harrisburg is WEST of Dunnville, but as Dunnville is EAST of the Prime Meridian, the Ch. Long. in this case is the sum of the Longitude of the two places. Not that any community 15° east of the Prime Meridian is likely to have a name such as Dunnville, but the example is merely chosen to help you to get the general idea.

TIME AND LONGITUDE

The Earth rotates about its own axis. It also revolves in an elliptical orbit around the Sun. As a result of these revolutions of the Earth, it appears to us as though the Sun were revolving around the Earth instead.

The time between one apparent passage, or transit of the Sun over a Meridian (noon) and the next, is called an APPARENT SOLAR DAY, and varies throughout the year.

To provide a convenient method of measuring time, an imaginary Sun, called the Mean Sun, is assumed to travel at a uniform rate of speed throughout the year. The interval between two successive transits of the Mean Sun is called a MEAN SOLAR DAY.

The Mean Solar Day is divided into 24 equal hours.

The close relationship between a day and the rotation of the Earth about its axis provides another system of measuring time, called TIME IN ARC. The Mean Sun is assumed to travel once around the Earth every Mean Solar Day, and therefore travels through an angle of 360° of Longitude in that time. Hence, MEAN TIME may be expressed in terms of Longitude, and vice versa.
Air Navigation

12:00 (noon) GMT — Greenwich Mean Time
= 08:30 NST — Newfoundland Standard Time.
= 08:00 AST — Atlantic Standard Time.
= 07:00 EST — Eastern Standard Time.
= 06:00 CST — Central Standard Time.
= 05:00 MST — Mountain Standard Time.
= 04:00 PST — Pacific Standard Time.

Note: The above abbreviations are frequently contracted to "Z" (Greenwich Mean Time) "A" (Atlantic Standard Time) "E" (Eastern Standard Time) etc.

Fig. 1A. Great Circle.

Fig. 1B. Rhumb Line.
HEADING AND BEARINGS

The direction of any point on the surface of the Earth from an observer is known, if the angle at the observer between a Meridian passing through the observer and a Great Circle joining him to the object is known. This angle is the TRUE BEARING or AZIMUTH of the point. The angle is measured clockwise from the Meridian through 360°. (Fig. 2).

The direction of an aircraft head at any moment (i.e., its heading), is the angle between the longitudinal axis of the aircraft and a Meridian, or in other words, is the bearing of the nose of the aircraft from the pilot’s point of view. (Fig. 3).

Since the Meridians are imaginary lines, the angle between a Meridian and a particular Heading or Bearing cannot be measured directly. By the aid of a compass, however, the direction of the Meridian may be determined, however, and the angle ascertained.

The Earth is a magnet and like any other magnet has a North and South Magnetic Pole. The Lines of Force of the Earth’s Magnetic Field flow from South to North inside the Earth and from North to South outside. A compass needle will be influenced by the Earth’s Magnetic Field and will lie in one of the Magnetic Lines of Force with its North seeking Pole pointing to Magnetic North.

The Magnetic Line in which the Compass Needle lies is called a MAGNETIC MERIDIAN.

See also “The Polarity of a Magnet”.

VARIATION

The Magnetic Meridians do not coincide with the True Meridians. This is because the North Magnetic Pole does not coincide with the True, or Geographical Pole, but rotates around the latter in a circle, in a direction E-S-W, completing the circuit once in every 560 years.

The angle between the True Meridian and the Magnetic Meridian in which the compass needle lies, is called MAGNETIC VARIATION.

Since the Magnetic North Pole is not stationary, but moving in a circle, obviously the Variation is not constant at any one place, but changes slowly from year to year. This is called ANNUAL CHANGE and must be taken into consideration when taking the Variation for any particular locality from old maps.

ISOGONIC LINES

Lines drawn through places of the same magnetic Variation on the Earth are called ISOGONIC LINES. If the Earth’s magnetic lines of force followed an orderly pattern such as the True Meridians do, these Isogonic Lines would be the same as Magnetic Meridians. However, a glance at a map on which the Isogonic Lines are plotted show that these bend and twist in an irregular manner similar to the courses of rivers and streams. The kinks and curves are due to the presence of local magnetic bodies in the Earth.

AGONIC LINES

In each Hemisphere there will be places where the North Pole and North Magnetic Pole will be in transit, that is, where they will lie in the same straight line. These places will, therefore, have no magnetic Variation. Lines drawn through places of “no Variation” are called AGONIC LINES. Like the Isogonic Lines they twist and curve, due to the local attraction of magnetic bodies in the Earth.

The Agonic Line for the Western Hemisphere passes approximately through Fort William, Ontario, and a little east of Chicago, Illinois. East of this line the Variation is Westerly and West of it the Variation is Easterly.

HOW THE VARIATION AFFECTS THE COMPASS

From this it will be seen that if the Magnetic Pole lies West of the True Pole from a given point, the compass needle will point West of True North. Hence, the Magnetic Meridian will lie West of the True Meridian.

In this case the VARIATION is named WEST. (Fig. 4).

Similarly, if the compass needle points East of True North, the Magnetic Meridian will lie East of the True Meridian, and the VARIATION will be named EAST.

Fig. 5 is intended to represent a compass installed in an aircraft whose nose is pointed towards True North. The LUBBER LINE is permanently fixed in the fore and
air of the aircraft and therefore always indicates the
direction the aircraft is heading. The compass card is
always read off against the Lubber Line.

The compass needle is pivoted and is free to point
always towards Magnetic North, regardless of what
direction the aircraft may be heading. In Fig. 5 there is
no Variation. The Magnetic Meridian, in which the
compass needle lies, coincides with the True Meridian
in which the longitudinal axis of the aircraft lies.

Fig. 6 illustrates Westerly Variation. The compass
needle is deflected 30° West of the True Meridian.
Notice that when the compass needle is deflected
towards the West, it drags the whole compass card
around with it and the reading opposite the Lubber Line
is more than it should be—i.e., the compass reads 30°
instead of 0°. Hence, the rhyme:

VARIATION WEST. MAGNETIC BEST (Better than
True).

Similarly, Fig. 7, when the needle is deflected East
of the True Meridian, the compass card is rotated so that
a smaller reading is opposite the Lubber Line—i.e., the
compass now reads 320° instead of 360°, or 40° less
than it should. (Note: North may be read as either 0°
or 360°.) Hence:

VARIATION EAST. MAGNETIC LEAST (Less than
True).

It is necessary for a pilot to be able to convert True
Headings and Bearings to Magnetic Headings and
Bearings, and vice versa, rapidly in the air.

To convert Magnetic to True:
Subtract Westerly Variation
Add Easterly Variation
To convert True to Magnetic:
Add Westerly Variation
Subtract Easterly Variation

Variation is considered to be an ERROR and the algebraic sign for Westerly Variation is Minus (−). For Easterly Variation, it is Plus (+); that is, the algebraic sign indicates the correction necessary to convert Magnetic to True. These algebraic signs are always the same—whether we add or subtract.

PROBLEM I: To convert a Magnetic Bearing to True.
EXAMPLE: Magnetic Bearing 80°. Variation (1931) 14° West, decreasing 6 minutes annually. Required: The True Bearing in 1941.

SOLUTION:
Variation (1931) 14° West
Decrease (6 minutes x 10 yrs.) 1°
Variation (1941) 13° West
Magnetic Bearing (1941) 80° West
Variation (1941) 13° West
True Bearing 67°

PROBLEM II: To convert a True Heading to Magnetic. Required: The Magnetic Heading:
EXAMPLE: True Heading 136°. Variation 8° East

SOLUTION:
True Heading 136°
Variation 8° East
Magnetic Heading 28°

DEVIATION
Variation of the compass is caused by the needle being deflected from the True Meridian due to the influence of the Earth’s Magnetic Field.

The compass is also affected by the Magnetic Field associated with the metal in the airframe and engine. This causes the needle to be deflected in turn from the Magnetic Meridian.

The angle through which the compass needle is deflected from the Magnetic Meridian is called DEVIATION.

Deviation is named East (or +) if the North seeking end of the needle is deflected to the East of the Magnetic Meridian. It is named West (or −), if the needle is deflected to the West of the Magnetic Meridian.

The effect of Deviation is neutralized in aircraft as far as possible by “swinging the compass” and inserting corrector magnets. It is rarely possible, however, to completely eliminate it. The deviation remaining after the compass has been “swung” is tabulated on a compass Deviation Card to enable the pilot to make allowance for it. (See Fig. B, “Compass Swinging”.)

HOW DEVIATION AFFECTS THE COMPASS
If Deviation causes the compass needle to be deflected West of the Magnetic Meridian, the Compass Card will be dragged around anti-clockwise, and the reading opposite the Lubber Line will be more than it should be. Hence the rhyme:

DEVIATION WEST, COMPASS BEST (Better than Magnetic).

Similarly, if the compass needle is pulled over East of the Magnetic Meridian, the Compass Card will be rotated clockwise, and the reading opposite the Lubber Line will be less than it should. Hence:

DEVIATION EAST, COMPASS LEAST (Less than Magnetic).

To convert Compass to Magnetic:
Subtract Westerly Deviation
Add Easterly Deviation

To convert Magnetic to Compass:
Add Westerly Deviation
Subtract Easterly Deviation

The algebraic sign is Minus (−) for West and Plus (+) for East, regardless of whether we add or subtract when working conversions. It is necessary to fix this point firmly in mind before undertaking to swing a compass.

PROBLEM III: To convert a Magnetic Heading to Compass.
EXAMPLE: Magnetic Heading 270°. Deviation 3° East.

Required: The Compass Heading.

SOLUTION:
Magnetic Heading 270°
Deviation 3° East
Compass Heading 267°

PROBLEM IV: To convert a Compass Heading to Magnetic.
EXAMPLE: Compass Heading 2°. Deviation 4° East.

Required: The Heading Magnetic.

SOLUTION:
Compass Heading 2°
Deviation 4° East
Magnetic Heading 6°

COMPASS ERROR
The compass needle is affected by both variation and deviation. After both forces have had a sort of tug-of-war with it, the needle will finally come to rest in the resultant of the two magnetic fields. The final deflection of the compass needle from True, is called the COMPASS ERROR. It may be defined as the algebraic sum of Variation and Deviation. Example:

Variation, 4° East +4°
Deviation, 3° West −3°
Compass Error +1° (or 1° East)

PROBLEM V: To find the Compass Heading corresponding to a True Heading of 60°. Variation 8° West. Deviation 3° East.

SOLUTION:
True H. Var. Mag. H. Dev. Com H.
60° 8° W. 68° 3° E. 65°

PROBLEM VI: To find the True Heading corresponding to a Compass Heading of 359°. Variation 14° West. Deviation 2° East.

Comp. H. Dev Mag. H. Var. True
359° 2° E. 1°(361°) 14° W. 347°
THE COMPASS

The function of the Magnetic Compass is to indicate the direction of any Magnetic Meridian, and also to measure bearings on distant objects.

A compass will continue to perform satisfactorily in a steady climb or glide, provided that neither exceeds more than 20°. In turns or rapid changes of speed, however, the compass will not indicate direction correctly. This will be dealt with in detail in "Vagaries of the Magnetic Compass".

CONSTRUCTION OF THE MAGNETIC COMPASS

The Magnetic Compass consists of north seeking magnets (usually two) attached to a float, to which is also attached the COMPASS CARD. This complete magnet system is mounted on a pivot and is free to rotate. The whole assembly is mounted within the COMPASS BOWL.

To damp out oscillations of the magnet system the bowl is filled with alcohol—which also helps to reduce the weight carried by the pivot. An expansion chamber is provided to allow for expansion of the alcohol due to temperature changes. The bowl and container are of brass, being non magnetic.

The Compass Card is usually graduated in 5° divisions (the Compass Headings). The last "0" is omitted from the numbers, which are shown as "3" for "30°", "33" for "330°", etc. The card is read through a window on which is painted a white vertical line called the "Lubber Line".

The LUBBER LINE indicates the direction of the aircraft's head.

It should be exactly in, or parallel to, the longitudinal axis of the ship.

The Compass is fitted with CORRECTOR MAGNETS permanently installed and connected by gears. They can be adjusted by keys to correct for Deviation.

Since the headings are painted on the reciprocal side of the card, which the pilot sees looking forward, the card appears to swing the wrong way when rudder is applied.

See also "The Gyrosyn Compass".

COMPASS SWIVING

(1) The Compass Swinging Base

A Compass Swinging Base is a flat, level base on which the aircraft may be placed and headed in turn on all the cardinal and quadrantial magnetic headings to correct for Deviation. The Magnetic Meridians are usually painted, if the base is concrete, or laid out with ropes and pegs, if on bare ground. The base must be laid out well clear of any magnetic influence, such as metal hangars, gas pumps, etc.

A Compass Swinging Base should be checked at least once every five years and corrected for annual Magnetic Variation Change.

If no compass swinging base is available, an aircraft compass can be swung by using a LANDING COMPASS to line the aircraft up on the different headings.

(II) Precautions Before Swinging

1. See that Compass Swinging Base is level and swept clean.
2. Test compass for serviceability (discoloration of liquid or paint, bubbles, pivot friction, broken glass, defective shock absorbing devices, rusty grid ring, defective clamp, etc.)

3. Check compass level and alignment in aircraft.
4. Remove corrector magnets (if old type corrector box).
5. Check tires for even inflation.
6. Place aircraft controls in neutral and see that all equipment normally carried is placed aboard.
7. Hang plumb bobs from nose and tail (for aligning aircraft).
8. Place aircraft in rigging position (trestle under tail).
9. Turn propeller by hand. If this is found to cause any disturbance to compass, swing compass with engine running.
10. Switch on radio equipment. If this is found to affect the compass, swing with radio equipment functioning.
11. See that person swinging has no magnetic objects on his person.

(III) Swinging the Compass

1. Place aircraft on N. Take out Deviation
2. Place aircraft on E. Take out Deviation.
3. Place aircraft on S. Take out half the Deviation.
4. Place aircraft on W. Take out half the Deviation.
5. Commencing with the corrected reading on W., place aircraft successively on Magnetic Headings every 30°—that is, W., 300°, 330°, N., 030°, 060°, E., 120°, 150°, S., 210°, 240°. Take compass readings on all 12 points. Enter readings on Deviation Card (Fig. E) which is then placed near the compass in the aircraft. Enter details in the Aircraft Log.
SWINGING THE COMPASS IN THE AIR

Some types of retractable undercarriages will be found to be magnetized to such an extent that they will cause considerable deviation of the compass when retracted. In such cases the compass must be swung in the air with the undercarriage retracted.

The most accurate method of swinging in the air involves the use of an astro compass and a navigator. Since neither an astro compass nor navigator are likely to be available to the average commercial flying operator, this method will not be detailed here. As a directional gyro is standard equipment on most commercial aircraft, however, the following substitute method, if not as accurate, is more practicable from a commercial pilot’s point of view.

1. Select a road or railroad on the map whose bearing is as nearly as possible magnetic north and south, and one as nearly as possible magnetic east and west. Use the latest variation data to calculate the magnetic bearings. The larger the scale of the map used to measure the bearings, the more accurate these will be. A 1 inch-to-1 mile topographical map is ideal, if this is available. If roads or railroads are scarce in the area, the airport runways may be utilized. Airway runway bearings are numbered to the nearest $10^\circ$ magnetic and accurate bearings to the nearest degree should be obtained if these are to be used.

2. Smooth air is essential, and preferably no wind—but at most not more than a light wind, causing as little drift as possible. An observer should be carried to make the compass corrections while the pilot concentrates on holding the aircraft straight and level.

3. Take off and align the aircraft heading on magnetic north by sighting up the north-south road or railroad. Set the directional gyro (D.G.). Hold the heading constant by D.G. and correct the magnetic compass to match the D.G. heading.

4. Repeat the process on east.

5. Align the D.G. on south. Correct half the compass error on south.

6. Repeat the process on west. Correct half the error on west.

7. Commencing from west, clockwise, fly successive headings every $30^\circ$. Note and record the magnetic compass readings on each D.G. heading flown.

8. Enter the readings obtained on the compass deviation card, the same as when swinging the compass on the ground (above).

Note: The directional gyro precesses $3^\circ$ every 15 minutes. The circuit should not be flown more than 5 minutes without realigning the D.G. on one of the roads selected.

THE VAGARIES OF THE COMPASS

Capt. Wise once bet Flatspin Fumble a dollar that if he was “on instruments” under the hood, with his bank and turn indicator covered, he could put him on a course due North by his compass—and in less than five minutes he would be flying due South! It looked like a perfect financial approach to a sirloin steak dinner—with mushrooms—to Flatspin and he promptly took him on. That evening, Flatspin strolled into the airport lunch counter and ordered a plate of fish and chips!

What caused Fumble’s undoing was the effect known as northerly turning error. The magnetic compass is not always strictly on the level. Its deliberate little falsehoods, however, can be detected and compensated for by the pilot who thoroughly understands what this business of aviation is really all about.

The Earth’s lines of force are horizontal at the Equator but become vertical towards the Poles. This causes the compass to dip in northerly latitudes.

To compensate for dip the magnet system is balanced pendulously on a pivot bearing on a cup. As the magnet tends to dip, the centre of Gravity moves back (in effect weighting the south end) and prevents dip in excess of about three degrees (Fig. 12).

NORTHERLY TURNING ERROR

When an aircraft turns, whether flat or banked, two forces are set up. Centripetal Force acts towards the centre of the turn. Centrifugal Force acts towards the outside of the turn. Centripetal Force acts through the pivot. Centrifugal Force acts through the Centre of Gravity which, being displaced back of the pivot, sets up a TURNING MOMENT, tending to rotate the magnet system and so causing Deviation (Fig. 13).

On turns from North, Northerly Turning Error causes the compass to UNDER REGISTER the turn—or LAG.

On turns from N. to E., the forces acting on the magnet system (Fig. 13) cause EASTERLY Deviation. “Deviation East, Compass Least”. Example: An aircraft deviates $15^\circ$ from a course due North towards the East, causing $10^\circ$ of easterly deviation. Magnetic heading of aircraft, $15^\circ$. Compass reads $5^\circ$.

On turns from N. to W., the forces acting on the magnet system cause WESTERLY Deviation. “Deviation West, Compass Best.” E.g. Magnetic heading, $345^\circ$, compass reads $335^\circ$.

The amount of deviation set up varies with the RATE of the turn. Hence, the effect of N.T. error can be summarized as follows:

<table>
<thead>
<tr>
<th>FOR</th>
<th>S</th>
<th>210</th>
<th>210</th>
<th>W</th>
<th>300</th>
<th>330</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEER</td>
<td>179</td>
<td>209</td>
<td>241</td>
<td>270</td>
<td>298</td>
<td>334</td>
</tr>
</tbody>
</table>

Fig. B. Compass Deviation Card.
TRAVELLING

1. Slow turn. Compass indicates turn in right direction, but under registers the turn. (Magnet system turning slower than the aircraft.)

2. Medium turn. No turn registered by Compass. (Magnet system turning at same rate as the aircraft.)

3. Steep Turn. Turn in opposite direction indicated. (Magnet system turning faster than the aircraft.)

On turns from South, Northerly Turning Error causes the compass to OVER REGISTER the turn, or LEAD.

Turns from S. to E. cause Easterly Deviation. "Deviation East, Compass Least." E.g. Magnetic heading, 165°, Compass reads 155°.


The effect of N.T. Error is less pronounced on South headings than it is on North headings. This is because Liquid Swirl tends to accentuate the deviation on North, but dampens it on South.

N.T. Error effect only occurs while the aircraft is actually turning. When the turn is stopped, the deviation will slowly disappear and the compass will settle on its correct magnetic heading.

The effect of N.T. Error is nil on East and West headings.

ACCELERATION AND DECELERATION

When an aircraft increases its speed, a force is set up in the direction in which the aircraft is moving. This is ACCELERATION and will act through the pivot of the compass. The magnet system, however, tends to lag behind, and an opposite force, INERTIA, acts through the centre of gravity. On East and West headings, this causes a TURNING MOMENT, tending to rotate the magnet system and so causing Deviation (Fig. 14).

When the aircraft decreases its speed, DECELERATION causes a similar effect, but the Deviation will be in the opposite direction.

On E. and W. Courses ACCELERATION causes the compass to register a turn towards NORTH.

On E. courses, the forces acting on the magnet system cause Easterly Deviation. "Deviation East, Compass Least." E.g. An aircraft flying due E. increases its speed, causing 10° of easterly deviation. Magnetic heading of aircraft, 90°. Compass reads 80°.

On W. headings, the forces acting on the magnet system cause Westerly Deviation. "Deviation West, Compass Best." E.g. Magnetic heading, 270°. Compass reads 280°.

On E. and W. headings DECELERATION causes the compass to register a turn towards SOUTH.

On East headings, Deceleration causes Easterly Deviation. E.g. Magnetic heading, 90°. Compass reads 100°.


The deviation of the compass will only occur while the acceleration or deceleration of speed is applied. Immediately the aircraft is again in equilibrium, the compass will return to its normal magnetic heading.

The effect of Acceleration and Deceleration compass error is nil on North and South courses.

THE ASTRO COMPASS

Close to the Magnetic Pole, the earth’s Magnetic Lines of Force dip vertically towards the Pole. The compass needle lies in a horizontal plane, and as the strength of the magnetic lines of force tends to disappear in the close vicinity of the Pole, the magnetic compass loses its ability to point the way, and becomes anything but dependable companion. A large area exists in Northern Canada where the magnetic compass is unreliable. Within this area, D.O.T. regulations require that aircraft weighing 12,500 lbs. or over must be fitted with an Astro Compass. The Astro Compass is not influenced by the earth’s Magnetic Field, but indicates direction with reference to the Sun, Moon, Planets or Stars. These heavenly bodies have been man’s guiding beacons in the skies since time immemorial. The examinations for Commercial, Senior Commercial and Transport Pilot licenses in Canada require a knowledge of the Astro Compass.

The ASTRO COMPASS is an instrument designed to enable a pilot or navigator to determine the True Heading of his aircraft. (It can also be used to take a bearing on an object.)
In the simplest possible terms, the Astro Compass is a Bearing Plate with a movable Sighting Device mounted above it. The bearing of a heavenly body can be set on the bearing plate, and when the movable sights are properly aligned on the heavenly body, the North Mark on the bearing plate will coincide with True North. The bearing plate can now be read off against a Lubber Line (aligned in the fore and aft axis of the airplane) to indicate the TRUE HEADING of the aircraft. The Directional Gyro can now be set to the True Heading, and the aircraft steered with reference to the Directional Gyro in lieu of the magnetic compass.

How do you find the true bearing (or azimuth) of the heavenly body to set on the bearing plate? The Astro Compass automatically does this for you provided you supply it with the following information:

1. Your Latitude,
2. The Local Hour Angle of the body.
3. The Declination of the body.

Your position, in latitude and longitude, is that assumed by yourself, based on your own D.R. navigation.

The position of the Sun, Stars and other astronomical bodies can be accurately predicted for any given moment of time. They are recorded in a handy volume called the AIR ALMANAC. By opening the AIR Almanac to the Greenwich date, hour and minute of time on which you wish to check your True Heading, you can look up the Greenwich Hour Angle and the Declination of the Sun, Moon, Aries, or the particular Planet you wish to sight on. The Sidereal Hour Angle and Declination of any navigation Star can similarly be found.

Now, the GREENWICH HOUR ANGLE (GHA) of a heavenly body is the angle between the Meridian of the body and the Greenwich Meridian — in other words, it corresponds to Longitude. It is measured westward from 0° to 360°.

The DECLINATION of a heavenly body is its angular distance North or South of the Celestial Equator (hence it corresponds to Latitude). It is measured in degrees and minutes north or south of the Celestial Equator, the same as Latitude.

The SIDEREAL HOUR ANGLE (SHA) of a Star is the angle between the Meridian of the Star and the FIRST POINT OF ARIES measured westerly from Aries from 0° to 360°.

The FIRST POINT OF ARIES (Ω) sometimes referred to as the "Vernal Equinox", is a point on the Celestial Equator arbitrarily chosen as a reference point to measure the Hour Angles of Stars.

To find the Greenwich Hour Angle (GHA) of a Star, look up the Sidereal Hour Angle of the Star in the Air Almanac and also the Greenwich Hour Angle of Aries. The GHA of the Star is the algebraic sum of both.

$$\text{GHA} = \text{GHA}_\Omega + \text{SHA}$$

The LOCAL HOUR ANGLE (LHA) of a heavenly body is the angle between the Meridian of the body and your Meridian. (In other words, the difference of longitude.) It is the algebraic sum of the GHA of the body and your Longitude.

$$\text{LHA} = \text{GHA} + \frac{E}{W} \frac{\text{Longitude}}{\text{}}$$

If you have found the definitions of Hour Angles at all confusing, you will find them quite easy to understand by reference to Fig. Z.

Note: In measuring the hour angles of heavenly bodies, it is simpler to think of the position of the body as a point on the surface of the earth, rather than one in the sky — in other words, to bring the body down on the ground for convenience in measuring. Such a point is called the SUB STELLAR POINT. It is defined as the point on the surface of the earth directly beneath the heavenly body at any given instant of time.

From the foregoing, it will be clear that to find your True Heading by Astro Compass, you must have a reasonable knowledge of your position, know the correct time (GMT) and be able to get a sight on a heavenly body.

The Astro Compass, in addition to the bearing plate and sighting device mentioned previously, has a number of movable drums and scales (Fig. Y). To find your True Heading by Astro Compass:
1. Level the instrument.
2. Set your latitude (nearest degree) on the LATITUDE SCALE.
3. Set the Local Hour Angle of the body on the LHA SCALE.
4. Set the Declination of the body on the DECLINATION SCALE.
5. Rotate the BEARING PLATE until the body you are using is lined up in the SIGHTING DEVICE.
6. Read the TRUE HEADING against the LUBBER LINE.


UNITEDS OF DISTANCE AND SPEED

The standard unit for the measurement of distance recognized by International Civil Aviation Authorities is the Nautical Mile. Effective October 1st, 1954 the Nautical Mile was officially adopted in the United States as the exclusive unit of distance for use in all Military and all Air Carrier operations.

Unless otherwise requested, U.S. Airway Radio Facilities (Communications Stations, Air Traffic Control Towers, Air Traffic Control Centres, etc.) state values of speed and distance in Knots and Nautical Miles — with the exception of visibility, which is given in Statute Miles.

Pilots of private and business aircraft operating in the United States are not compelled to use nautical units of speed and distance, and may, if they prefer, use the familiar Statute Mile. Airway Radio Facilities will, upon request from pilots of private and business aircraft, convert speed and distance values given in Nautical Miles to Statute Miles.

Surface wind velocity, in the past reported in Miles-per-hour in the U.S., is now reported in Knots. (Below a value of 30 mph, the difference between miles-per-hour and knots is negligible and can, for all practical purposes, be ignored.) American Airway Radio Facilities will, however, upon request from private pilots, convert winds from knots to mph.

In Canada, the official unit of distance is the Statute Mile. Airway Radio Facilities state values of distance and speed in Statute Miles and mph. Surface winds are given in mph. Before this Edition has been revised, however, it is quite possible that Canada may have adopted the Nautical Mile. It is therefore important that Canadian students should learn to convert from Statute to Nautical Miles. For this reason, some of the navigation problems which follow have been scaled in Nautical Miles.

The abbreviation, officially adopted for nautical miles is "n. miles" or "n. ml." — for statute miles, "s. miles" or "s. ml."

A STATUTE MILE is a distance of 5280 feet.

A NAUTICAL MILE (6080 feet) is the average length of one minute of latitude. For all practical purposes it may be taken as the length of one minute of arc along any Great Circle.

A KNOT is a speed of one nautical mile per hour. 66 Nautical Miles = 76 Statute Miles.

To convert knots to mph, multiply knots by 1.15.
To convert mph to knots, divide mph by 1.15.

A scale of nautical miles (based on the scale of the chart at mid latitude) is printed on all I.C.A.O. aeronautical maps.

Practically all circular slide-rule computers have statute mile—nautical mile conversion indexes printed on the inner scale.

TIME, SPEED AND DISTANCE CONVERSIONS

Hours and Minutes.
To convert minutes to hours, divide by 60 (60 min. = 1 hr.) e.g. 30 min. equals 30 ÷ 60 = .5 hrs.

To convert hours to minutes, multiply by 60.
 e.g. .75 hrs. equals .75 × 60 = 45 min.

Time in Flight.
To find the time in flight, divide the distance by the groundspeed. e.g. The time to fly 120 naut. miles at a groundspeed of 60 knots is 120 ÷ 60 = 2 hrs.

To convert this time to minutes, multiply by 60.
 e.g. .5 hrs. × 60 = 30 min.) Answer: 1 hr. :30 min.

Distance.
To find the distance flown in a given time, multiply groundspeed by time. e.g. The distance flown in 1 hr. :45 min. at a groundspeed of 120 knots is 120 × 1:45 = 210 naut. miles.

Groundspeed.
To find the groundspeed, divide the distance flown by the time. e.g. An aircraft flies 270 naut. miles in 3 hrs. The groundspeed is 270 ÷ 3 = 90 knots.

NAVIGATION TERMS

The Navigation Terms authorized by the International Civil Aviation Organization (I.C.A.O.) for international use have not been made mandatory by the Civil Aeronautics Administration in the United States, or the Department of Transport in Canada. Navigation texts and manuals published in these two countries make use of terms which are no longer familiar in other parts of the world. The student of navigation may find this inconformity of terms somewhat confusing, but little difficulty should be experienced if the following simple conversions are memorized throughout:

<table>
<thead>
<tr>
<th>I.C.A.O.</th>
<th>U.S.A.</th>
<th>Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track (intended)</td>
<td>Course</td>
<td>Track (Route)</td>
</tr>
<tr>
<td>Heading</td>
<td>Heading</td>
<td>Heading</td>
</tr>
<tr>
<td>Track (made good)</td>
<td>Track</td>
<td>Track (Route)</td>
</tr>
</tbody>
</table>

WIND AND DRIFT PROBLEMS

HEADINGS COURSES AND TRACKS

The HEADING of an aircraft is the angle between the longitudinal axis of the aircraft at any moment and a Meridian. In other words, it is the direction the nose of the aircraft is pointing, measured from an imaginary line running north and south. If the Heading is measured from a True Meridian, it is referred to as a True Heading, if from a Magnetic Meridian, as a Magnetic Heading. If it is measured from the direction of a Compass Needle, it is referred to as a Compass Heading. The angle is measured clockwise through 360°.
The COURSE or TRACK (intended) is the direction an aircraft intends to travel over the ground. "Course" is a term which has been in use in the United States for over a score of years and which has not yet been officially discarded—although "Track" is the term which has been authorized by the I.C.A.O. for international use. The synonymous terms, Course and/or Track are used, where applicable, throughout this manual for the convenience of American readers. The intended Course, or Track, may be represented by a straight line drawn on a map. Its direction is the angle between this line and a Meridian, measured clockwise through 360°. As in the case of Headings, Courses or Tracks, are named True, Magnetic or Compass with reference to the Meridian from which they are measured.

In Canada the term ROUTE was, in the past, used instead of TRACK. Now the term "Track" is favored, but for the benefit of those who have become accustomed to "Route", both terms are recognized.

The TRACK MADE GOOD is the actual path traveled by the aircraft over the ground. Like the Intended Track, it may be represented by a line drawn on a map and (provided it is a reasonably straight line) its direction measured from a True or Magnetic Meridian or Compass North.

As referred to previously, a TRUE MERIDIAN is a Meridian on the surface of the earth joining the True North and South Poles. On practically all maps used for air navigation purposes the Meridians shown are True.

A MAGNETIC MERIDIAN is a Meridian on the surface of the earth in which a Compass Needle will lie when influenced only by the Earth's Magnetic Field. In actual practice Magnetic Meridians are not shown on maps but are found by adding or subtracting the Variation at any particular place to or from the True Meridian.

COMPASS NORTH is the direction in which a particular Compass Needle will lie when influenced by both the Earth's Magnetic Field and local magnetic influences (Deviation) in the aircraft. The actual reading on a compass at any time is the angle between the aircraft's head and Compass North.

THE COMPOSITION OF VELOCITIES

The VELOCITY of a body is the rate of change of position of a body in a given direction, hence it involves both speed and direction.

A Velocity may be represented by a straight line. The direction may be shown by the direction of the line and the speed by the length of the line to scale.

A body may be subjected to two or more Velocities at the same time and these may not act in the same straight line.

For example, an aircraft may be flying on a heading due North at 80 mph, and the wind is blowing from the West at 20 mph. The aircraft will have two Velocities, one towards the North at 80 mph and the other towards the East at 20 mph.

These two Velocities are equivalent to a single Velocity which is called the RESULTANT. The Resultant, in this case, would represent the Track and Groundspeed of the aircraft (Fig. 15).

When the Components act in the same straight line, the Resultant is obtained by addition or subtraction. When the Components act in other than the same straight line, the Resultant may be found by a PARALLELOGRAM of VELOCITIES, or a TRIANGLE OF VELOCITIES.

THE PARALLELOGRAM OF VELOCITIES

If a moving point possesses simultaneously Velocities represented in speed and direction by two sides of a Parallelogram, A-B and B-C (Fig. 16) drawn from a point, their Resultant will be represented in speed and direction by the diagonal of the Parallelogram (A-C) passing through the point. The sides A-D and D-C represent the same Velocities and hence their Resultant is also A-C.

![Fig. 16. PARALLELOGRAM OF VELOCITIES](image)

Note: Arrowheads should always be used to show the direction of the Components clearly. A Single arrowhead represents the Heading of the aircraft. Double arrowheads represent its Course or Track. Triple arrowheads indicate the Wind.

TRIANGLE OF VELOCITIES

If a moving point possesses simultaneously Velocities represented by two sides, A-B and B-C, of a triangle taken in order, they are equivalent to a Velocity represented by the third side, A-C (Fig. 16).

APPLICATION OF THE TRIANGLE OF VELOCITIES

The solution of navigational wind and drift problems is based on the principal of the Triangle of Velocities.

For the Heading and airspeed of an aircraft can be represented by one side of a triangle. The Wind and Windspeed, drawn to the same scale, can be represented by another, and the Course or Track and Groundspeed by the third.
A knowledge of any four of these is sufficient to complete the triangle, from which the remaining two may be determined.

The Dalton Dead Reckoning Computer

Wind and drift problems may be solved on navigation computers in a fraction of the time it takes to plot them on paper. The types of navigation computers in use are too many and varied to be dealt with individually here.

One of the most widely used is the Dalton E6B, shown in Fig. 17, and this is the only type which will be described in detail here. (The Dalton E6C and E-10 types are exactly the same in principle, except that they are scaled for higher speeds. The same instructions therefore apply to either of these types.)

The Instrument has a COMPASS ROSE which can be rotated. The dial inside the Compass Rose is a transparent window on which pencil marks can be made, and erased. In the centre of the window is a dot with a ring around it, the GROMMET, which is a reference point used in plotting. Through the window can be seen a grid marked out in concentric arcs and radial lines. This is printed on a sliding plastic strip. The concentric arcs represent speed in mph or knots and will be referred to as SPEED LINES. The radial lines represent degrees of drift to right or left, and will be referred to as DRIFT LINES. At the top is a scale graduated in degrees of drift to right or left, the DRIFT SCALE. This may also be used as a VARIATION SCALE to apply magnetic variation, east or west. In the centre is an index referred to as the TRUE INDEX.

**Fig. 17. The Dalton E6B Computer**

1. Variation Scale.  
2. Speed Lines.  
4. Drift Scale.  
5. Drift Lines.  
6. Compass Rose.

**BASIC PROBLEM I**

To find the Heading to steer to make good a given Course or Track and Groundspeed, knowing the Wind and Windspeed.

**EXAMPLE:** A Piper Cub is to proceed from De Lesseps Field to Camp Borden, the True Course or Track is 332°. The airspeed of the aircraft is 85 kts. The Wind is 280° (True) at 25 kts. (Note: The direction from which the wind blows is always given). REQUIRED: The Heading to steer and the Groundspeed.

**SOLUTION:** First draw a vertical line to represent a Meridian. True or Magnetic as the case may be, on your plotting paper and mark the scale you are using in one corner. This applies to the solution of all wind and drift problems.

1. From A draw A-B, 332°, to represent the True Course or Track (Fig. 18).

2. From A draw A-C, 100° (i.e. downwind) 25 miles to scale, to represent the Wind and Windspeed.

3. With C as centre and radius 85 miles to scale (the airspeed) describe an arc cutting A-B at D. Join C-D.

Then in the triangle A-C-D, A-C represents the wind and windspeed, C-D the heading and airspeed, and A-D the track and groundspeed.

The Heading to Steer is the angle C-D makes with the Meridian—319° True. (This is the same whatever the distance to be flown, so long as the wind and the airspeed of the aircraft remain constant.)
The Heading to Steer by compass is found by applying the Variation and Deviation to the True Heading.

The drift is the angle between the Heading and the Track—in this case, 13° to Starboard.

The length of the line A-D represents the ground speed—67 kts.

The time taken is found by dividing the total distance by the ground speed and multiplying by 60. Camp Borden is 39 n. miles from De Lesseps Field. The estimated elapsed time would therefore be: 

\[39 \times 60 \div 67 = 35 \text{ minutes.}\]

**SOLUTION BY DALTON COMPUTER**

1. Set the wind direction, 280°, on the Compass Rose opposite the True Index.
2. From the Grommet, draw a line 25 knots UP the centre line (the wind speed).
3. Set the True Course or Track, 332°, at the True Index.
4. Set the tail of the wind line on the 85-knot Speed Line (the airspeed).
5. Read the Groundspeed at the Grommet — 67 knots. Fig. 19.
6. From the Drift Line passing through the tail of the wind line, measure the Wind Correction Angle (angle between Heading and Track—see "Wind Correction Angle"). Heading is 13° to left of Track. Wind correction angle 13° left.
7. Read the True Heading on the Drift Scale opposite the 13° "Drift Left" mark—319° True. Fig. 19.

**BASIC PROBLEM II**

To find the Wind and Windspeed, knowing the Heading and Airspeed and the Track and Groundspeed.

**EXAMPLE:** An Aeronca Chief is flying on a course 33° Magnetic, at a cruising speed of 95 kts. It is making good a Track 48° Mag. and a groundspeed 100 kts. What is the Wind and Windspeed?

**SOLUTION:**
1. From A draw A-B, 33°, 95 kts to scale, to represent the heading and airspeed (Fig 20).
2. From A draw A-C, 48°, 100 kts. to scale, to represent the Track and Groundspeed.
3. Join B-C.

Then the angle B-C makes with the Meridian (transferred) represents the Wind and Windspeed—from 299° Mag. at 26 kts.

The direction of the wind is always from the heading to the Track.)

**SOLUTION BY DALTON COMPUTER**

1. Set the Track, 48° Mag. opposite the True Index.
2. Set the Grommet on the groundspeed, 100 knots.
3. Mark a cross at the intersection of the 95-knot Speed Line and the Drift Line representing the Heading of 33° Mag. (Heading is 15° left of Track, so use 15° left Drift Line.)

4. Rotate the Compass Rose so the cross is on the centre line above the Grommet.

5. Read the wind direction, 299° Mag, opposite the True Index, and the wind force, 26 knots, on the centre line, between the cross and the Grommet. Fig. 21.

**BASIC PROBLEM III**

One other navigation problem which can be solved by the triangle of velocities or by computer is:

To find the track and groundspeed, knowing the heading, airspeed, wind and windspeed.

Since this has little, if any, value to the pilot navigator, it has been deleted from this manual.

**WIND CORRECTION ANGLE**

The Wind Correction Angle, or Crab Angle, is the angle between the Heading of an aircraft and its course or track. In other words, it is the angle at which the pilot heads the airplane across the track to keep the wind from blowing him off the track.

It is generally assumed that the Wind Correction Angle corresponds to the Drift Angle in degrees. This does not necessarily always hold true. Fig. C illustrates a case where they differ considerably.

An airplane flies on a heading 090° from A towards B which is 64 nautical miles from A. The airplane's cruising speed is 64 knots.

The wind is from 315° at 32 knots (B-C).

In 1 hour the airplane will be over C.

B-A-C is the Drift Angle—14° to starboard.

To allow for wind, and make good the track A-B, the triangle of velocities A-X-Y is constructed. A-X is the wind and windspeed, X-Y is the heading and airspeed. A-Z is the heading (parallel to X-Y).

B-A-Z is the Wind Correction Angle—21° to port.

Fig. C. Wind Correction Angle.

**FUEL HOURS**

Many navigation problems are based on Fuel Hours combined with the Basic Problems which we have already studied. The fundamental factors required for the solution of all Fuel Hour problems are:

1. The Fuel Consumption.
2. The Quantity of Fuel available in the tanks.
3. The Groundspeed of the aircraft.
4. The TIME the aircraft can fly on its available fuel (less reserve) can be found from 1 and 2.

The DISTANCE the aircraft can fly in that time can be found from 3.

**PROBLEM I:** A pilot starts to fly from Harrisburg, Pennsylvania to Portland, Maine (World Aeronautical Chart No. 310—*Hudson River Sheet*). The course, or track, is 055°T. and the distance 354 nautical miles (n.m.). The plane has a cruising speed of 120 knots. Fuel capacity is 95 gals. Fuel consumption is 19 gals./hr. Unable to get a forecast wind, the pilot assumes no wind. At the end of 30 minutes, he finds himself over Schuylkill Airport. With this wind, the pilot is anxious to know if he has sufficient fuel to reach Portland (without drawing on his 45-min. reserve).

**SOLUTION:** Fuel consumption is 19 gals./hr. The fuel reserve requires 19 gals. × .75 hrs. (45 min.) = 15 gals. The safe fuel hours available are therefore 95 — 15 = 80 gals.

Schuylkill Airport is 41 n.m. from Harrisburg which the plane has covered in 30 min. Its groundspeed is therefore 82 kts.

At a groundspeed of 82 kts., the flight from Harrisburg to Portland (354 n.m.) will take 354 ÷ 82 = 4.3 hrs.

In 4.3 hrs. it will burn 4.3 × 19 = 81.7 gals. which is just sufficient to reach Portland without drawing on its reserve.

**PROBLEM II:** A pilot wishes to fly from Goshen, Indiana to Fargo, N.D., via Joliet, Illinois, along the airways. He wishes to know the farthest point he can reach along the route before refuelling. (The places required may be found on World Aeronautical Chart No. 308—*Illinois River Sheet*). A schematic diagram of the route is shown in Fig. D.

The plane has a cruising speed (true) of 100 knots. Its fuel capacity is 25 gals., and its consumption 5¼ gals/hr. The wind is from the North at 30 kts.

**SOLUTION:** The aircraft's safe endurance is 25 ÷ 5.5 = 4.54 hrs.—less reserve, 45 min. (.75 hrs.) = 3.79 hrs.

The course or track from Goshen to Joliet is 270°T. and the distance 107 nautical miles (n.m.) By plotting or computer (Basic Problem I) the groundspeed on the leg to Joliet will be 95 kts. At this groundspeed, the elapsed time to Joliet will be 107 ÷ 1.13 hrs. Safe fuel hours remaining are 3.79 — 1.13 = 2.66 hrs.

The course or track from Joliet towards Fargo is approximately 316°T. Using the same wind by plot-
ting or computer, the groundspeed on this leg will be 77 kts. At this groundspeed, in 2.67 hrs. the plane will travel 77 × 2.66 = 205 n.m. The airport safety nearest this distance along the track is La Grosse (197 n.m.)

**RADIUS OF ACTION**

The Radius of Action (R/A) is the distance an aircraft can fly and return under given conditions without refuelling.

It is found by the following formula:

\[
\frac{O \times H}{O + H} = R/A.
\]

Where:  
F = Safe fuel hours (less 45 minutes reserve)  
O = Ground speed out.  
H = Ground speed home.

**EXAMPLE:** Find the R/A of a Piper Tri-pacer along a Course, or Track, 33°True. Wind from 20°T. at 20 kts. Cruising speed 110 kts. Fuel endurance 5 hours.

**SOLUTION:** 1. From A (Fig. E) draw A-B 90° to the Track Out and produce back to some point C (to represent the Track Home).
2. From A, draw A-D 353°, 20 knots to scale (the wind, down-wind).
3. With centre D, and radius 110 knots (the air-speed) describe arcs cutting A-B and A-C at E and F. Join D-E and D-F.

Then A-E = Ground Speed Out = 102 kts.  
A-F = Ground Speed Home = 114 kts.

The safe fuel hours = 5 hours, less 45 min. reserve, which is 4 hrs. 15 min., or 4.25 hrs.

Then \[
\frac{O \times H}{O + H} = 4.25 \times \frac{102 \times 114}{102 + 114} = 223 \text{ n.miles}
\]

The Heading to steer out is 83°T. (D-E)
The Heading to steer home is 283°T. (D-F)
The Time to Turn is found by the formula:

\[
\frac{R \times A}{O} = 2.24 \text{ hrs., or 2 hr. 14 min.}
\]

An aircraft forced to turn back might be in difficulties such as the loss of an engine and be forced to fly at less than its normal cruising speed. In emergencies such as these, there is little time for calculation. The REDUCED AIRSPEED of the aircraft in distress should therefore be anticipated in advance in calculating the Point of No Return. A good figure to assume is 40% of normal cruise speed.

**EXAMPLE:** A aircraft cruising at a True Airspeed of 250 kts. is flying from A to B along a Course, or Track, 95°T., a Distance of 200 n.miles. The Wind is from 30°T. at 30 kts. The Reduced Airspeed is assumed to be 40% of the normal cruise speed, or 150 kts.

**SOLUTION:** 1. Draw A-B, the projected flight, 95°, 300 n.miles to any convenient scale. (Fig. F.)
2. From some point X draw XW, 30°, 30 knots (the wind down-wind). For convenience, a much larger scale can be used to plot this portion of the problem than that used to draw the line A-B.
3. With centre W and radius 150 n.miles (the Reduced Airspeed) describe arcs cutting X-B and X-A at O and H. Join W-O and W-H.

W-H is the Heading to steer Out, 85°T.
W-O is the Heading to steer Home, 285°T.
X-O is the Reduced Ground Speed Out, 135 kts.
X-H is the Reduced Ground Speed Home, 159 kts.
5. Join D to B. Through C draw a line parallel to D-B cutting A-B at P.

P is the Critical Point, or Point of No Return. It is 162 n.miles from A.
6. With centre W and radius 250 kts. (the True Airspeed) describe an arc cutting A-B (produced) at Q. Join W-Q.

W-Q is the ACTUAL GROUND SPEED Out, 236 kts.
The Time to Turn is the time to fly 162 n.miles at the Actual Ground Speed Out, that is: 60 × 162 = 16 min.

**POINT OF NO RETURN**

On long flights over oceans, jungle, or featureless country such as the Arctic, there is a position somewhere along the route from which it is equally quick to fly to the point ahead or return to the starting point. This is called the CRITICAL POINT or POINT OF NO RETURN. Beyond this point, if trouble occurs, it is impractical to turn back and mandatory to go on.

By formula:

\[
P = \frac{D \times H}{O + H}
\]

The Time to Turn is found by:

\[
P = \frac{D \times H}{O + H}
\]

Where:  
D = Total Distance of the flight.  
O = Reduced ground speed out.
CALCULATING RECIPROCALS

By RECIPROCAL, is meant the reverse, or opposite, of a given direction such as a Heading, Course, Track or Bearing.

e.g. Track .............. 187°
     Reciprocal .............. 007°

The Reciprocal is found by adding or subtracting 180—adding if the direction is 180 degrees, or less—subtracting if it is greater than 180 degrees.

Adding or subtracting 180 quickly in the air may not be found an easy process to those untrained in rapid mental mathematics. To such, the following simple methods will be found helpful:

To add 180—add 200 and subtract 20.

To subtract 180—subtract 200 and add 20.

The Heading of an aircraft includes allowance for wind drift and this will have an entirely different effect when travelling in an opposite direction. A RECIPROCAL HEADING cannot therefore be calculated by adding or subtracting 180 as in the case of a TRACK, or a BEARING.

A Reciprocal Heading may be calculated roughly, however, by the following simple method:

Calculate the reciprocal of the heading out, and double the wind correction angle the opposite way.

If the wind correction angle out has been 5° to port, to double it the opposite way, you ADD 10° (to starboard) to the reciprocal of the heading out to obtain the heading home. (Any correction applied to the right, or starboard, or clockwise, is added.)

If the wind correction angle out has been 5° to starboard, you SUBTRACT 10° (to port) from the reciprocal of the heading out to obtain the heading home. (Any correction applied to the left, or port, or anticlockwise, is subtracted.)

EXAMPLE: A pilot is flying a Compass Heading of 122°. He runs into bad icing conditions and decides to turn home.

A glance at his Flight Plan tells him that his True Heading is 117° and his Track (True) is 122°.

The Reciprocal of his Heading is 297° (117° + 200 — 20 = 297°).

He is, therefore, steering 5° to Port of his Track (to correct for a drift of 5° to Starboard).

To double the wind correction angle the opposite way, he would now steer 10° Starboard at 297°.

His True Heading for home would therefore be 297° + 10° = 307°.

Using the same variation he had on his heading out and the deviation applicable to his new heading, he can now easily determine the Compass Heading to steer for home.

CALCULATING THE CLIMB OR LET-DOWN

C.A.A. commercial pilot examination requirements include the solution of climb and let-down problems.

PROBLEM: An airplane is flying towards Springfield, Missouri—elevation 1267 ft. ASL (above sea level)—at an altitude of 10,000 ft. ASL, and with a groundspeed of 165 kts. The pilot wishes to descend at a rate of 400 ft. per min. and arrive over the airport at 1000 ft. above the ground, maintaining a constant groundspeed of 120 kts. How many minutes before his Estimated Time of Arrival over Springfield should he start his descent?

SOLUTION: Springfield has a field elevation of 1267 ft. ASL. Therefore 1000 ft. above ground will be 1267 + 1000 = 2267 ft. above sea level.

The pilot's descent will be 10,000 — 2267 = 7733 ft.

At a rate of 400 ft./min., the time required to let-down will be 7733 = 19.3 min.

PROBLEM: After landing at Springfield the pilot referred to above takes off and climbs to a cruising altitude of 9,000 ft. ASL, at a rate of 300 ft./min. In the climb, he makes good a groundspeed of 165 kts. How far, in nautical miles, will be he from Springfield when he reaches cruising altitude?

SOLUTION: Springfield is located at an elevation of 1267 ft. ASL. The climb to cruising altitude will therefore be 9,000 — 1267 = 7733 ft. At a rate of 300 ft./min., this will take him 7733 = 25.7 min. At a groundspeed of 165 kts., he will travel 165 X 25.7 = 70.6 n.miles.

FINDING THE WIND VELOCITY IN THE AIR

Of all the various methods devised for finding the wind velocity in the air, the only one which has any practical value from a pilot-navigator's point of view is the Track and Groundspeed Method—since this does...
not involve any deviation of the aircraft from its course or track towards its destination.

**TRACK AND GROUNDSPEED METHOD**

**EXAMPLE:** A Cessna 170 sets out to fly from Strathburn to Presque Isle on a navigation exercise. The cruising speed is 120 mph. Using the wind obtained from the weather bureau, the pilot plots his heading to steer, 120°T.

Eight and one-half minutes after leaving Strathburn, he is over the mouth of Talbot Creek. A line joining this position to Strathburn on the map (Fig. 26) will represent his actual track made good, 107°T.

The distance, Strathburn to the mouth of Talbot Creek, is 18 miles.

18 miles

Therefore the groundspeed is 8½ min.

- 18 miles
- 8½ min.

Knowing the Heading and Airspeed (120°T—120 mph) and the Track and Groundspeed (107°T—127 mph) the wind velocity can now be plotted as detailed in Basic Problem II, Fig. 20 above. (Ans. Wind from 217°T at 30 mph).

**THE AIR POSITION**

No pilot can ever become hopelessly lost if he knows his Air Position. THE AIR POSITION of an aircraft at any time is its imaginary position, assuming that there has been no wind since it left the ground. It will be obvious then that if the Air Position is known, the worst a pilot can be in error as regards his GROUND POSITION is a distance and direction equal to the speed and direction of the wind for the length of time he has been flying.

The Air Position is recorded by navigators on what is known as an AIR PLOT. This is the laying down on a map or chart of the Heading and Airspeed of the aircraft during the entire time the ship is in the air.

While it is not possible for the Pilot-Navigator to keep an Air Plot and fly the ship at the same time, it is of the utmost importance that he should keep a mental picture of his Air Position in his mind. By jotting down in his log the exact time that each change in compass heading is made—should his whereabouts become uncertain in poor visibility—he can run back over his log and construct a rough diagram of his Air Position in his mind. Thus, when some landmark does appear in view below, he has a good general idea of the area on his map to search in order to identify it.

Note: The keeping of a "Log" does not necessarily mean writing endless volumes of figures down on a comprehensive form. The few simple notations required by the Pilot-Navigator, such as time of departure, headings flown, times over points along the route, groundspeeds calculated, etc. can be jotted down on the back of a cigarette box or the border of the map if a note book doesn't happen to be handy.

**POSITION LINES**

Suppose you are standing on a street in Washington down which you can see the Capitol dome rising above the end of the avenue of trees. You consult your street guide and identify the street as Pennsylvania Avenue. You know you are somewhere on Pennsylvania Avenue, but you have no means of knowing exactly where. However, you note that you are standing at the crossing of a street named Twelfth Street. Now you locate the intersection of Pennsylvania Avenue and Twelfth Street on the map and you have fixed your exact position.

Position lines are obtained by observing the bearing of two or more objects and are plotted on a map or chart to fix the position of the observer in the same way that the intersection of Pennsylvania Avenue and 12th Street were used to locate a position above.

**EXAMPLE:** A Catalina Flying Boat is patrolling out to sea off the Atlantic Coast. The Port of St. Hilda is sighted and is found to bear 15° True. If the bearing of St. Hilda is 15° from the flying boat, then the direction of the flying boat is the reciprocal (opposite) of 15°, or 195° from St. Hilda. A line is drawn on the chart from St. Hilda 195° (A-B in Fig. 28). This is a POSITION LINE, somewhere on which line it is known the aircraft must be at a particular time. A Position Line is identified by arrowheads at either end and the time at which it was obtained is clearly marked, in this case 10.15 hrs.

Suppose at the same time, the Beech Head light ship was found to bear 45°. A second Position Line (C.D.) may be drawn 225° from the light ship on the chart.

Where the two Position Lines intersect gives the position of the aircraft at 10.15 hrs. This is called a FIX and is distinguished by a circle drawn around the intersection of the lines.

It will be seen that in Fig. 29 a third Position Line...
(EF) has been plotted from a bearing on Dog Island of 345° (Reciprocal 165°). The purpose of including this third Position Line in the figure is to show that where three or more Position Lines are used, they may not always intersect at a common point. Note that EF does not pass through the intersection of A-B and C-D, but forms a small triangle, or “cocked hat”. This is due to small errors in taking the bearings, or in plotting. If the “cocked hat” is small, the Fix is taken to be the dot (•) shown in the centre of the triangle. If the “cocked hat” is excessively large, no reliance can be placed on the Fix.

When plotting a Fix by two or more position lines the angle between the position lines should not be less than 30° wide.

**TRANSFERRED POSITION LINES**

In actual practice it would be difficult to obtain two or more bearings from a moving aircraft at the same time.

Suppose the bearing of St. Hilda was obtained at 10.15, but the bearing of the Beach Head light ship was not obtained until 20 minutes later, at 10.35.

The two Position Lines are plotted as before, A-B and C-D in Fig. 30, but in this case it will be noted that they do not intersect. We can make them intersect however by transferring one Position Line for 20 minutes, say A-B (the 10.15 Position Line) and so establishing the position of the aircraft at 10.35.

To do this we must estimate the Track and Groundspeed of the aircraft. We assume the Catalina to be making good a Track of 90° True at a speed of 155 knots. In 20 minutes the ship would therefore have travelled 51 1/2 nautical miles.

From any point along A-B, say, E, lay off the ASSUMED ROUTE 90°, 51 1/2 nautical miles to scale. The length of this line fixes the point F, and is known as the RUN.

Through F draw a line parallel to A-B. This is a TRANSFERRED POSITION LINE (G-H in Fig. 30) and C-D, the 10.35 Position Line, is the Fix, or exact location of the aircraft at 10.35. This is called a RUNNING FIX.

A line (X-Y) drawn through this point parallel to EF (the Assumed Track) represents the ACTUAL TRACK.

There are many methods of obtaining Position Lines—by Transit, by Direction Finding Radio, by observations of Celestial Bodies, etc. It is of the utmost importance therefore that the simple methods detailed above, explaining their use in fixing the position of an aircraft, must be thoroughly understood by the elementary student in order to enable him later on to tackle the more advanced problems he will encounter in Radio and Celestial Navigation.

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**MAPS**

**PROJECTIONS**

The earth is a sphere and therefore its surface cannot be represented accurately on a flat plane. The map maker’s problem can be readily appreciated by cutting a rubber ball in half—and then attempting to flatten out one of the halves in a flat plane.

Since the surface of a sphere cannot be accurately projected on to a map, a map must show the portion of the Earth’s surface it represents distorted to some extent.

There are four basic elements in the information that a map may contain. These are:

1. Areas.
2. Shapes.
4. Distances.

According to the particular purpose of a map, one or more of these elements is preserved as nearly correct as possible, with consequent unavoidable distortion in the remaining elements.

The mathematical bases on which maps are constructed are termed PROJECTIONS.

**THE CONIC PROJECTION**

Characteristics

Most of the maps used for flying are based on some form of Conic or Polyconic Projection. I.C.A.O. World Aeronautical Charts are based on the Lambert Conformal Conic Projection. For practical purposes,
the properties of these projections may be generally taken as follows:

1. Meridians are curves or straight lines converging towards the nearer pole. If they are curves, the curvature is often so small as to be inappreciable.

The angle which one Meridian makes with another is called CONVERGENCE. It varies with Latitude. At the Equator there is no Convergency between Meridians. At the Poles the Meridians converge at angles equal to the Change of Longitude between them. Hence, Convergency = Ch. Long. x sin Mean Lat.

2. Parallels of Latitude are curves which are concave towards the nearer pole. On any but large scale maps, the curvature is considerable.

3. The scale of distance is practically uniform throughout the entire map sheet, the maximum distortion being not more than $\frac{1}{2}$ of 1%.

4. A straight line drawn between any two points on the map may be assumed, for all practical purposes, to represent A GREAT CIRCLE.

Since a Great Circle does not cross every Meridian at the same angle, a straight line on the map will not be the same when measured on two or more different Meridians. Hence a straight line, or Great Circle route, cannot be flown without changing heading at regular intervals.

To make good a given Track, or straight line, on this type of map it is necessary to change heading 2° for every 5° of Longitude. Flying East, the 2° is added. Flying West it is subtracted.

For flights up to roughly 300 miles, the heading change referred to above may be averaged by measuring the Course or Track on the Meridian nearest the centre. (Fig. 31).

The basic idea upon which the Conic Projection is developed is that of supposing a cone to be superimposed over the surface of a sphere. (Fig. 32A) If the cone were opened and unrolled, the Meridians and Parallels would appear as shown in the lower sketch (Fig. 32B).

The Polyconic Projection is developed around the basic idea of imagining a series of cones to be superimposed on the surface of a sphere, each cone having a successive parallel of Latitude as its base (Figs. 33A and 33B).

**MERCATOR’S PROJECTION**

**Characteristics**

All charts used for flying over coastal regions are constructed on the Mercator’s Projection. The principle characteristics of this project are as follows:

1. Meridians are straight and parallel lines.
2. Parallels of Latitude are straight and parallel lines.
3. A straight line drawn between any two points on the chart will represent a RHUMB LINE.
4. Owing to the method of projection, there is no constant scale of distance on a Mercator’s chart and areas are greatly exaggerated in high latitudes.

Mercator’s charts are, as a rule, graduated on the right and left hand sides for Latitude, and at the top and bottom for Longitude. The divisions of the Longitude scale are only to be used for laying down and taking off the longitude of a place. THE LONGITUDE SCALE MUST NEVER BE USED FOR MEASURING DISTANCE. Since 1 minute of Latitude is always
equal to one nautical mile, the Latitude scale is used for measuring distance.

**Projection**

The principle on which the Mercator’s Projection is based is CYLINDRICAL. Its approximate form may be visualized by imagining a light at the centre of a globe to cast a shadow of the meridians and parallels on a cylinder of infinite length enclosing it. As will be seen in Figs. 34A and 34B, the shadows of the more northerly Parallels of Latitude will be cast wider apart on the cylinder than they actually are on the sphere.

![Fig. 34A. Mercator Projection. Fig. 34B. Mercator Development.](image)

The shadows of the Meridians on the cylinder will be straight and parallel lines to infinity, whereas on the sphere they converge to meet in a point at the Poles. It is, in other words, as though the Meridians were stretched apart at the Poles to the same distance they are apart at the equator. This causes extreme exaggeration of Longitude in Northerly Areas.

**SCALE**

The scale of a map is the relation between a given distance on the Earth and the length of that distance as measured on the map. The scale of a map is printed on the margin and may be expressed in the following ways:

1. **A STATEMENT IN WORDS**—showing the relation between any unit on the map and a corresponding unit on the ground. Example: “Eight miles to one inch” —meaning that one inch on the map equals 8 miles on the ground.

2. **A REPRESENTATIVE FRACTION OR NATURAL SCALE**—showing the number of units on the ground corresponding to one unit on the map. Example: 1:506,880, meaning that one inch on the map equals 506,880 inches on the ground (or 8 miles to one inch).

![Fig. 36. Fully Divided Scale Line.](image)

![Fig. 37. Open Divided Scale Line.](image)

3. **A GRADUATED SCALE LINE** — showing the exact length of any particular unit (miles, yards, metres, etc.) in convenient divisions, such as 8 miles, 10 miles, 100 miles, etc. Examples of open divided and fully divided scale lines are shown in Figs. 36 and 37.

4. **LATITUDE and LONGITUDE SCALES.** Latitude and Longitude Scales, graduated in degrees and 5 or 10 minute divisions, will usually be found along the right and left hand sides, and the top and bottom, respectively, of maps and charts.

All Meridians of Longitude and Parallels of Latitude drawn on Aeronautical Charts are numbered on the borders of the map. Meridians and Parallels shown on the map are divided into One Minute divisions.

![Fig. 38. Longitude Scale graduated in 5 Min. Divisions.](image)

**RELIEF**

The representation of relief, or ground height above sea level on aeronautical maps, is of primary importance. On maps used for air navigation, it is essential that the height and position of the highest parts of hills and mountains should be clearly shown, and that sufficient detail should be given to make easy the recognition of prominent features. The various methods by which relief can be shown are:

1. **LAYER TINTING**—This consists of colouring the map to represent different levels. Green is generally used for heights immediately above sea level, with light green and shades of light and dark brown as the height increases. Where differences in elevation are considerable, a layer tinted map is very easily read, since the relief stands out as on a model, but it is not possible to show minor variations of height, and the impression may be given that the ground within the tinted areas is level.

2. **CONTOURS**—A contour is a line running along the surface of the ground at the same height above sea level throughout its length.

The difference of altitude between two successive Contours is called the VERTICAL INTERVAL (V.I.). The gradient of a slope may be obtained by measuring the distance in plan, called the HORIZONTAL EQUIVALENT (H.E.) between two adjacent contours.

Thus, suppose the V.I. to be 200 ft. and the H.E. 1800 ft., the gradient is 200/1800 or 1:9. Provided the V.I. is constant, the closer the contour lines lie together, the steeper the slope of a hill.

![Fig. 39. A Hill represented by Contour Lines.](image)

3. **SPOT HEIGHTS**—These are figures printed on a map, to show the height above sea level at any particular point. Example: Barker Field 0 600.

4. **HACHURES**—Lines drawn down the direction of the steepest slope. The steeper the slope, the heavier and closer the lines are drawn. Example: |||||. 
5. HILL SHADING—Similar in principle to hachuring. Like hachuring, it tends to obliterate other important detail and is seldom used on aeronautical charts.

COMPASS ROSE

A circle overprinted on a map or chart divided into 360°, from which directions may be measured, is called a COMPASS ROSE. For an example, see Fig. 2. ("Omnigation").

MAP READING

Map reading, either on the ground or in the air, calls for a clear understanding of the scale of the map and a "sense" of that scale—in other words, a sense of proportion. It also requires an understanding of the direction of True or Magnetic North and of the symbols used on the map.

The direction of North should never be in doubt. Remember that the right and left hand edges of the map sheet are not always parallel to the Meridians and the lines of gridded maps must not be confused with Meridians.

The Magnetic Variation is generally clearly stated. On the U.S. Aeronautical maps and Canadian Air Navigation Maps, the isogonic lines (lines joining places of equal variation) are overprinted in broken magenta lines. On flights up to 300 miles, the variation should be averaged for the entire route. This is done by using the isogonic line which intersects the track (as nearly as possible) midway between the point of departure and the destination. On flights of longer duration, the heading should be altered at regular intervals to allow for accumulated changes in variation.

The key to a chart is the title. This should be read through carefully. In the title, the locality covered, the scale, the date of survey, and a list of conventional signs and abbreviations will be found.

FOLDING A MAP OR CHART

A map should be folded into a strip about eleven or twelve inches wide with the Track lying somewhere about the centre of the strip.

It should then be folded "accordion" fashion, so that successive portions of the Track can be read by turning the folds over one by one (Fig. 40).

If more than one map sheet is used, the sheets should be numbered and arranged in the order in which they will be required. This is important. Flatspin Fumble generally gets into a melee with his maps as soon as he arrives at the edge of the first sheet. By the time he locates the map sheet he requires and gets it folded and oriented, he has completely lost contact with the ground and by this time is generally miles off his Track.

LANDMARKS

WATER—Can be seen at great distance and offers the best landmark of all. During wet seasons it must be remembered that flood areas may easily be mistaken for lakes. Some rivers and streams may be obscured by trees in summer and therefore hard to identify.

HEIGHTS OF LAND—Can be seen for very great distances but are not as numerous as other landmarks.

ROADS—It is sometimes difficult to distinguish main roads from unimportant ones. Many main roads are tarred and are therefore less conspicuous than secondary roads. Cross roads are good landmarks. Concrete highways are particularly good.

RAILWAY LINES—These do not show up as clearly as roads, but are less numerous and therefore serve as distinctive and useful landmarks. Railway crossings or junctions are specially prominent and present distinctive patterns.

TOWNS—Towns can usually be readily identified by shape, and particularly by the pattern of roads or railway lines entering or leaving them. The general colour of towns varies in different districts. Smoke haze over larger cities makes them sometimes very difficult to recognize, particularly in dull weather and when approaching them towards the sun.

GOLF COURSES AND RACE TRACKS—These are both fairly good landmarks and are possible landing grounds for ships having reasonably low landing speeds.

FLYING BY MAP READING

Skill in map reading does not begin and end in the ability to pick out conspicuous landmarks and locate them on the map.

Further, and most emphatically, it does not consist of following rivers, railways, etc., around. When visibility is normal, an efficient pilot should be able to fly a direct route to his destination by map reading alone.

Map reading is a great deal more difficult at low altitudes than it is at higher ones, due to the larger scale.

When flying by map reading, it is advisable to orient the map to the direction in which the aircraft is proceeding along its route, even though this may mean that the lettering on the map is sideways or upside down.

I.C.A.O. AIR NAVIGATION MAPS

The aeronautical charts developed by the I.C.A.O. for universal uniformity in all countries of the world are constructed on conformal conic projections, except in Polar regions, where the Polar stereographic projection is used.

Meridians are converging lines and Parallels of Latitude are curves, concave towards the near pole. Straight lines on the map are Great Circles.
The symbols for aerodromes, air navigation radio aids, obstructions, prohibited areas, topographical features, etc. are shown on the reverse side of the charts.

The World Aeronautical (Regional) Charts are designed primarily for visual navigation. The scale is 1 to 1,000,000 (roughly 16 miles to 1 inch).

The Aeronautical (Sectional) Charts are designed primarily for visual flying. The scale is 1 to 500,000 (roughly 8 miles to 1 inch).

In Canada the Sectional Charts are constructed on the Transverse Mercator’s Projection and are scaled 8 miles to 1 inch.

Three Scale Lines are printed on the lower border of the chart. One of these is graduated in Statute Miles, one in Nautical Miles and the third in Kilometers. A Conversion Scale for the conversion of meters to feet, or vice versa, is printed on the left hand margin.

All Meridians of Longitude and Parallels of Latitude shown on the chart are numbered on the borders. Parallels are also conveniently numbered within the body of the chart. Meridians and Parallels, at 30° intervals, are divided into 1 minute divisions.

Relief is shown by contour lines and layer tints. The latter shade from light green (sea level to 1000 ft.) to lighter green, and gradually to deeper shades of buff to indicate higher altitudes.

On some maps green is used to indicate wooded areas. In which case, white is used instead of green to indicate the sea level to 1,000 ft. layers.

Abrupt isolated slopes are indicated by hachures or hill shading. Spot heights of hill or mountain tops, railway stations, and lakes are indicated in black figures.

Radio Beams and other facilities in the medium-low frequency range are overprinted in magenta. Omni and other VHF facilities are overprinted in blue. Eventually, as all medium-low frequency radio facilities are replaced by VHF, all features of aeronautical interest will be overprinted in blue.

THE PILOT NAVIGATOR

A pilot flying alone obviously cannot use such instruments as a plotting board, bearing compass, drift sight, etc. However, a good knowledge of the principles of navigation will enable him with practice to make very accurate mental calculations en route.

With good average visibility, favorable weather, and a good map of the territory to be flown over, successful navigation depends on little more than the ability to read a map in general terms.

With low visibility, or over comparatively featureless country, however, steering an accurate heading by compass becomes of primary importance. The route and ground speed must be checked frequently, and accurate map reading is essential in order that the exact position of the aircraft may be checked at frequent intervals.

THE "TWO-POINT" METHOD OF FLYING A RANGE

When it is not possible to obtain a wind before departure, or time does not permit of plotting it, a satisfactory method of determining the heading to steer is that known as flying a range.

Two points are selected along the Track about 5 or 10 miles apart. The pilot, having gained the height it is intended to maintain throughout the flight, flies a heading by map reading that will pass over these two points. His compass will then indicate the heading to steer for the balance of the flight. Other points along the route may be selected subsequently and a series of ranges flown. This method is particularly useful if it is necessary to alter heading during a flight to a destination other than that originally intended.

GROUND SPEED CHECK

By noting the distance between check points along your route and keeping track of the time, the ground speed may be found. e.g.: Distance from Reykjavik to Hlidufell mountain (Fig. X) — 50 s.m. Time — 20 min. GROUND SPEED = 150 mph. Now, knowing the distance to your next check point, (Say the Pjorsa River, which crosses the Track at approximately the right hand edge of Fig. X) — 47 s.m., you can estimate your time of arrival over this point. e.g.: At a ground speed of 150 mph, time to fly 47 miles = 19 min. Time over Hlidufell was, say, 10:05. E.T.A. over Pjorsa River should be 10:24.

THE "ONE IN SIXTY" RULE

An error in the Course or Track of one degree will cause an error in position of about one mile in a distance of 60 miles.

A pilot on a cross country course who has got off his Track will be able to estimate the distance he is off in miles quite easily but it is very difficult to know how many degrees it is necessary to alter heading by compass to correct the error.

Suppose an aircraft is 2 miles off its track after travelling 50 miles. The error in the track will be roughly 4°. Therefore the correction to the compass heading will be 4° to correct the error. This will put the aircraft on a track parallel to the required track but 2 miles from it. Suppose the aircraft is 60 miles from it: destination. An additional 2° correction to heading will gradually close the track. Therefore a total correction of 6° will bring the aircraft in to its destination.

PREPARATION FOR A FLIGHT

The map should be studied to select the route. The nature of the country to be flown over, refuelling points, emergency landing areas, and prohibited areas, are factors which will influence the selection of the route.

Avoid areas where there is no chance of making a safe forced landing.

Fig. X, the course or track selected should be laid off on the map and its direction, magnetic, indicated by figures above and below the line, showing the track in degrees out and home. Arrows should be used to distinguish between the track out and home. If the flight
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is a long one, the figures should be spotted in at frequent intervals, allowing for changes in variation. A distance scale should be marked along the track to assist in making ground speed checks at, say, 50 or 100 mile intervals. (Some prefer to mark prominent check points, noting the distance to each.)

The character of the country should be carefully studied, particularly as regards high ground and dangerous obstructions. Outstanding landmarks should be noted.

Before undertaking a long flight, meteorological reports or the weather map should be carefully studied. These will give valuable indications of the type of weather and changes of wind to be expected throughout the course of the flight.

Determine the wind at the height selected to fly from the Winds Aloft Forecast. Now plot the True Heading to steer, and apply the variation to obtain the Heading Magnetic. (Deviation is later applied by noting the correction to any particular magnetic heading from the deviation card in the aircraft.)

The ground speed having been calculated by plotting, the expected time of arrival at the first intended point of landing can now be estimated.

Further details on procedure from this point on will be found in the Chapter on Airmanship—Procedure When Starting On a Cross Country Flight.

PLOTTING INSTRUMENTS
THE CIRCULAR SLIDE-RULE

Mental calculation in navigation is much simplified by the use of Computers. One of those which solve wind and drift problems has been described in the "Application of the Triangle of Velocities", basic problems I, II and III. The cover of this Computer contains a Circular Slide-Rule for the solution of time, speed and distance problems. On many other types, the Circular Slide-Rule will be found on the back of the Computer.

The Circular Slide-Rule illustrated in Fig. 42 is practically identical on all types of navigation computers. Being logarithmic in principle, the circular slide rule can be used to solve any problem of multiplication, division or proportion. From a navigational point of view, however, its value lies in the rapid solution of time, speed, distance, and conversion problems.

Note that the Slide Rule consists of inner and outer scales. The inner scale may be rotated to any position opposite the outer scale. The figures on a slide-rule may represent any proportion or multiple of ten. "10" on the outer scale may therefore represent 1, 10, or 1000. "45" on the inner scale may represent 4.5, 45, or 450. In the latter case, if 450 represented 450 minutes, the equivalent hours and minutes could be read directly, namely 7 hrs. 30 min.

Time and Distance. For time and distance problems, the outer scale represents Miles, and the inner scale Minutes (and equivalent Hours and Minutes) Examples.

**PROBLEM:** Knowing the Ground Speed (140 mph) and the Time (48 min.) Find the Distance.

**SOLUTION:** Set "140" on the Miles (outer) scale opposite "60" on the Minutes (inner) scale. Read the Distance on the Miles scale opposite 48 on the Minutes scale. Answer: 112 miles.

**PROBLEM:** Knowing the Ground Speed (146 mph) and the Distance (100 miles). Find the Elapsed Time.

**SOLUTION:** Set "146" on the Miles (outer) scale opposite "60" on the Minutes (inner) scale. Read the Time on the Minutes scale opposite 100 (10) on the Miles scale. Answer: Elapsed Time, 41 min.

**PROBLEM:** Knowing the Distance (30 miles) and the Time (15.5 min.). Find the Ground Speed.

**SOLUTION:** Set "30" on the Miles (outer) scale opposite "15.5" on the Minutes (inner) scale. Read the Ground Speed on the Miles scale opposite 60 on the Minutes scale. Answer: 116 mph.

Fuel Consumption. The Miles (outer) scale may be used to represent Gallons and the Minutes (inner) scale, Time.

**PROBLEM:** Knowing the consumption in gals. per hr. (16). Find the endurance with a given quantity of fuel (72 gal.)

**SOLUTION:** Set "16" on the outer scale opposite "60" on the inner scale. Opposite 72 on the outer scale, read the Endurance on the inner scale. Answer: 270 min. (4 hrs. 30 min.)

**PROBLEM:** Knowing the fuel consumed (12 gal.) in a given time (2 hr. 21 min.). Find the fuel consumption.

**SOLUTION:** Set "12" on the outer scale opposite "2 hr. 21 min." on the inner scale. Read the fuel consumption in gals. on the outer scale opposite 60 min. on the inner scale. Answer: 5.1 gals. per hr.

Conversion. Nautical to Statute Miles. The "Naut." and "Stat." Mile Indexes will be found on the inner scale (towards the left hand side in Fig. 42). Set the Naut. Mile Index opposite any figure on the outer scale representing nautical miles, and read the corresponding statute miles opposite the Stat. Mile Index — or vice versa.

Imperial to U.S. Gallons. Mark 10 (for 1) on the inner scale as the Imperial Gallons Index, and 12 (for 1.2) as the U.S. Gallons Index. Set any figure on the outer scale — 7.2 Imp. Gals. for example — opposite 10 on the inner scale. The figure opposite 12 on the outer scale will be the corresponding U.S. Gals. Answer 8.65 U.S. gals.

Centigrade to Fahrenheit. This conversion cannot be worked on the Slide-Rule. Although omitted from
the drawing, the Dalton Mark VII Computer illustrated (and practically all navigation computers) have a Centigrade to Fahrenheit Conversion Table printed on them.

Altitude and Air Speed Correction. The Slide-Rule has two special sets of scales for applying the temperature correction necessary to convert Indicated Air Speed to True Air Speed, and Indicated Altitude to True Altitude. The methods used are completely explained on the Computer, Fig. 42.

Note: The "Barometric" Altitude referred to means Pressure Altitude. To obtain the Pressure Altitude, set 29.92 on the Barometric Scale on your altimeter.

THE DOUGLAS PROTRACTOR
The DOUGLAS PROTRACTOR, in addition to measuring angles, may be used as a PARALLEL RULER. The instrument is square, with a compass rose graduated in 360° marked around the outer edges. It is transparent so that when placed on a map, the map is visible through it.

The method of measuring a Course or Track on a map is shown in Fig. 43. Place the Protractor on the map with the hole in the centre lying on the Track at a point where the north-south line on the Protractor lies along a Meridian. If this is not convenient, one of the parallel lines may be lined up parallel with the nearest Meridian. The Track is read off where it cuts the edge of the Protractor — in this case 56° in one direction, or 236° in the opposite direction.

Note: The figures "10" and "20" marked on the parallel lines are used by engineers to measure the "slope" of an angle, but have no significance to the Pilot-Navigator.

RULER AND DIVIDERS
In addition to the Circular Slide-rule and Protractor described above, a set of DIVIDERS or a RULER, or both, are all the plotting instruments that the Pilot-Navigator requires. The latter are used for measuring distance, or laying off time or distance scales.
Radio

Radio is the modern magic genie that creates invisible traffic arteries in the skies, whose voice reaches out to the airman in the overcast from the unseen world below—his guide to the weather that lies along his route, to the traffic pattern plan he must observe, to the vast amount of timely information he must receive to make flying as it is practiced today a safe and practical undertaking.

Radio has been perfected to the point where it has come to be regarded in the present-day world of aviation as indispensible. While the vast airway radio networks of the United States and Canada offer rapid and reliable means of communication and air navigation, it should never be taken for granted that radio equipment is infallible. It can, and does, on occasion fail. Complete dependence on radio has provided the prelude to all too many an airplane disaster. A pilot should by all means make full use of his radio equipment. He should never, however, forget the simple traffic rules and signals that apply when his radio fails to function, nor cease to practice elementary navigation as a precaution against the time when he may be caught with his radio dead.

![Wave Length](image)

**Fig. 1. Wave Length.**

**Wave Length and Frequency**

When a stone is dropped in water (Fig. 1) waves are set up. While the height, or strength, of the waves grows weaker as they travel away from the point where the stone hit the water, the length of the waves (W.L.) never varies.

A radio transmitter sets up waves in the air in the same way that the stone does in water. The length of these waves remains constant, but the strength, or amplitude, decreases with distance from the transmitting station.

The actual linear measurement of the wave is known as the Wave Length and is referred to in meters. The period in which a wave "vibrates," or rises and falls between its crest and trough, is called a Cycle. The number of Cycles in one second of time is called Frequency.

Very Low to High Frequencies are expressed in Kilocycles (kc.) that is, "thousands of cycles". For example, 3023.5 Kilocycles stands for 3,023,500 cycles per second.

Very high Frequencies (VHF) are expressed in Megacycles (Mc.), that is, millions of cycles. 100 Megacycles stands for 100,000,000 cycles per second.

The relationship between Wave Length and Frequency is as follows: The Wave Length in meters is equal to 300,000 divided by the Frequency in kilocycles per second. e.g. $300,000 = \text{Wave length Kc. per sec. in meters}$

Conversely, the Frequency in kilocycles per second is equal to 300,000 divided by the Wave Length in meters. e.g. $300,000 = \text{Kilocycles per sec. in meters}$

**Frequency Band Limits**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Frequency</th>
<th>Wave Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLF Very Low</td>
<td>0 - 30</td>
<td>300,000 - 10,000</td>
</tr>
<tr>
<td>LF Low</td>
<td>30 - 300</td>
<td>100,000 - 1,000</td>
</tr>
<tr>
<td>MF Medium</td>
<td>300 - 3,000</td>
<td>1,000 - 100</td>
</tr>
<tr>
<td>HF High</td>
<td>3,000 - 30,000</td>
<td>100 - 10</td>
</tr>
<tr>
<td>VHF Very High</td>
<td>30 - 300</td>
<td>10 - 1</td>
</tr>
<tr>
<td>UHF Ultra High</td>
<td>300 - 3,000</td>
<td>1000 - 10 cm</td>
</tr>
<tr>
<td>SHF Super High</td>
<td>3,000 - 30,000</td>
<td>10 - 1 cm</td>
</tr>
<tr>
<td>EHF Extremely High</td>
<td>30,000 - 300,000</td>
<td>1 - 1 mm</td>
</tr>
</tbody>
</table>

**LONG WAVE**

**ULTRA SHORT WAVE**

**Fig. 2. Wave Length and Frequency.**

**Radio Bands**

Airway radio communications and radio navigation aids have for the past 20 years operated in the Low Frequency (L/F) Medium Frequency (M/F) and High Frequency (H/F) ranges. These facilities still exist, but are rapidly becoming obsolete and will eventually disappear as they are replaced by Very High Frequencies (VHF).

In the L/F, M/F, H/F utilization scheme, frequencies between 200 kc. and 400 kc. are referred to as being in the "Airway Band". Radio Ranges transmit on frequencies within this band. Most Airport Control Towers transmit on 278 kc. In some cases, where two Towers are located so close together that their transmissions may overlap, one will be assigned a frequency other than 278 kc. Broadcast stations transmit in the Medium Wave Band on frequencies between 550 kc. and 1500 kc., which is therefore known as the "Broadcast Band". Broadcast Stations, as well as providing news and entertainment, can be used for directional bearings or for "homing" on with the radio compass.
No matter whether you are flying on or off airways in Bakersfield, Bangor, Birmingham, Bergen, Bologna, Bangkok, Berne, Brisbane or Bizerte, ARC’s workhorse of air navigation aids can be depended upon. Some 60,000 transmitters, operating over land and sea the world over, act as ready-made sources for guidance to pilots of aircraft equipped with ARC’s Type 21A ADF. Its reliability under long-continued use in the sticky tropics, frozen arctic or sandy deserts has earned it a reputation as one of ARC’s most successful contributions to air navigation. Its low weight and compactness make dual installations practicable even in the light twins. If you are planning to modernize your existing radio installation, or are about to purchase a new aircraft, we urge you to specify ARC’s Type 21A ADF for a long term investment in air safety.

Ask your ARC dealer for a quotation on the Type 21A ADF and on other ARC equipment listed below.

---

**Type 21A ADF Weighs Only 19.7 Pounds**

Component Unit Weights:
- Receiver, 6.6 lbs.; Loop, 4.3 lbs.; Loop Housing, 0.5 lbs.;
- Indicator, 1.3 lbs.; Control Unit, 1.4 lbs.; Power Unit, 5.2 lbs.;
- FAA Certificate No. 1R-69 U.S. Military: AN/ARH-59
- British Certificate of Approval VC-78

---

**ARC’s Type 21A Automatic Direction Finder**

---

**Dependable Airborne Electronic Equipment Since 1928**

**Aircraft Radio Corporation, Boonton, N. J.**

- UHF LOC Receivers
- Miniaturized Automatic Direction Finders
- Course Directors
- LF Receivers and Loop Direction Finders
- UHF and VHF Receivers and Transmitters (5 to 360 Channels)
- Interphone Amplifiers
- High Powered Cabin Audio Amplifiers
- 10-Channel Isolation Amplifiers
- Omnidirectional Signal Generators and Standard Course Checkers
- 900-2100 MC Signal Generators

**Anthony Foster & Sons Ltd.**

302 Church St., Toronto, Canada — Sole Canadian Distributor
Frequencies between 3,000 kc and 30,000 kc are known as High Frequencies. Plane-to-plane and plane-to-ground transmission is in the Short Wave, High Frequency Band. Most airway stations "guard" (that is, listen continuously on) 3023.5 kc. This frequency has replaced 3105 kc. — which was formerly regarded as the universal transmitting frequency from air to ground.

The frequency 5680 kc. has been allocated to ground stations and aircraft operating in Northern Canada for use in emergency, when other normal frequencies are busy, have failed, or when an aircraft is not equipped with a ground station's normal frequency.

The Ultra Short Wave, Very High Frequency (VHF) Band lying within the spectrum between 30 mc. and 300 mc. has now come into general use for communications, airway traffic and navigation.

The universal VHF EMERGENCY FREQUENCY is 121.5 mc. It is single channel simplex.

SINGLE CHANNEL SIMPLEX means communication in one direction only at a time — transmitting and receiving on the same radio frequency.

DOUBLE CHANNEL DUPLEX means communication in one direction at a time — but transmitting on one radio frequency and receiving on another.

A few of the more common transmitting frequencies which you will require for communication with Airway Communications Stations are as follows:

Most Air Traffic Communication Stations (Canada and U.S.) listen on 121.5, 122.1, and 126.7 mc. Also (Canada) 122.2 mc.

These stations transmit voice signals (Canada and U.S.) on 122.2, 126.7, 121.5 mc. and 255.4 mc.

Most Air Traffic Centres (U.S.) listen on 301.4 mc. (and on discreet frequencies in the 119 - 125.7 mc. Band) (Canada). All Canadian Centres listen on 119.7 mc.

Both U.S. and Canadian Centres transmit on these same frequencies.

Most Towers, (Ground Control and Approach Control facilities) (Canada and U.S.) listen on 121.5, 121.7 (or 121.9), 122.5, 243.0, and 126.18 mc. Also (Canada) 118.3 and 119.1 mc. (U.S.) 257.8 and on discreet frequencies in the 118 - 126.7 mc. Band.

These stations transmit (Canada and U.S.) on 121.5, 121.7 (or 121.9), 126.18, 257.8 and 243.0 mc. Also (Canada) on 153.31, 118.3, 119.5 and 121.7 mc.

Private Advisory Stations (Canada) transmit and receive on 122.8 mc. Aeronautical Advisory Stations (U.S.) at airports where no control tower exists on 122.8 mc. — at airports served by a control tower on 123.0 mc. These frequencies are known as "UNICOM", or the "Private Flyer's Frequency" and may be used between private aircraft en route as well as for communication with ground stations.

The national reply channel from Air Traffic Control Stations (formerly referred to as INSACS — Interstate Airway Communications Stations) to private aircraft is 122.2 mc. D.O.T. air navigation radio aids in Canada transmit and receive on this frequency, which is the channel used for Radar Advisory Service.

The following is the complete allocation of VHF channels to the various aeronautical facilities under the Frequency Utilization Plans of Canada and the U.S.A. In the case of Air Navigation Aids (such as Omiranges, ILS Localizers, etc.) the frequencies are those on which the navigation signals are transmitted, and are also the frequencies on which stations with simultaneous voice facilities will reply to your call.

108.1 thru 111.9 mc. ILS Localizers with simultaneous voice channel, operating on ODD tenth decimal frequencies (108.1, 108.3, etc.). Navigation signals and voice communication to all aircraft.

108.2 thru 111.8 mc. Omiranges (VOR) operating on EVEN tenth decimal frequencies (108.2, 108.4, etc.). Navigation signals and simultaneous voice signals to all aircraft.

112.0 thru 117.9 mc. Omiranges (VOR). Navigation signals and simultaneous voice communication to all aircraft.

118.1 thru 121.3 mc. Air Traffic Control. Towers and Approach Control Towers. Voice communication to scheduled and itinerant aircraft. (See also 123.6 thru 126.8 mc.)

121.7 thru 121.9 mc. Scheduled and itinerant aircraft to Air Traffic Centres.

122.7 mc. (U.S.) Air Traffic Control Stations to aircraft. (In reply to air-to-ground calls from aircraft to stations on 126.7 mc.)

121.5 mc. Emergency. Air-Ground. The term “emergency” is used in a broad sense. In addition to actual distress, the frequency may be used (i) when communication on normal channels has failed, or (ii) when an aircraft is not equipped with the normal frequencies required to call a particular ground station.

121.7 thru 121.9 mc. All aircraft and Air Traffic Control Towers (Ground Control). Two-way.

122.1 thru 122.3 mc. (U.S.) Private aircraft en route. Air Traffic Control Stations will reply on VOR voice channel (unless reply on 122.2 mc. is requested by pilot). (Canada) All aircraft to ranges.

122.2 (U.S.) National reply channel from A.T.C. Stations to private aircraft. (Canada) Radar Advisory Service and two-way communications from Radio Aids facilities to all aircraft.

122.5 thru 122.9 mc. Private aircraft to Towers.

123.8 mc. Private aircraft and Aeronautical Advisory Stations (U.S.). Private Advisory Stations (Canada). Two-way and air-to-air.
123.0 mc. (U.S.) Aeronautical Advisory Stations. Two-way and air-to-air.
123.1 thru 123.5 mc. Flight test and flying schools. Aircraft to company stations.
123.6 thru 126.5 mc. (U.S.) Air Traffic Control.
123.7 thru 125.5 mc. (Canada) Not assigned.
125.7 thru 126.5 mc. (Canada) Scheduled aircraft to Towers.
126.18 mc. (Canada) Military aircraft and Towers. Two-way.
126.7 mc. (U.S.) All civil aircraft to Air Traffic Communications Stations. (Canada) Scheduled aircraft and Ranges. Two-way. Private Aircraft to Ranges.
126.9 mc. (Canada) All aircraft and Airway Stations en route. Two-way.
126.9 thru 131.9 mc. (U.S.) Air carriers to company stations.
127.1 thru 131.9 mc. (Canada) Private and scheduled aircraft and company stations. Two-way.
132 mc. and higher. (U.S.) Government.
243.0 mc. and higher.

IMPORTANT: Because of the confusing number of VHF Channels in use, and the frequent changes that are continually taking place, it is advisable when calling any Airway Communication Station, Control Tower or other facility, to state the frequency on which you expect them to reply.

NOTE: Beacon Stations with voice facilities in Canada, and some radio range stations, are equipped with a "busy" signal, similar to a busy signal of a telephone. If you get this signal when you call, you know that the station operator is temporarily busy with other duties, or talking on another frequency. Wait a few minutes and try your call again.

GROUND AND SKY WAVES
Waves emitted from a Low/Medium/High Frequency Transmitting Station are of two types (Fig. 9). GROUND WAVES follow the surface of the earth. SKY WAVES go up and are reflected back to earth from the Ionosphere or Heaviside Layer.

Between the point where the Ground Waves end and the Reflected Waves strike the earth, there is a "skip" Zone, where very erratic signals or no signal at all is heard.

This accounts for the fact that you may sometimes hear a station, then lose it, and later hear it again as you fly.

At night the Sky Waves travel at a flatter angle than during the day, causing a Skip Zone of greater extent, but a signal distance far greater than during the day.

Sometimes sunspot activity, or electromagnetic disturbances can upset the reflecting ability of the Ionosphere. When this occurs, the radio waves are not reflected back to Earth, and a "fade-out" is experienced.

THE M/F RADIO TRANSCEIVER
"TRANSCEIVER" means a radio transmitter and receiver combined in one control unit. The General Electric Radio illustrated in Fig. 4 is typical of the simple type of personal plane radio set that was popular in the past and is still in common use in a great many countries in the world where Medium Frequency is still the only radio facility available.

1. Band Scale. The upper figures at the top are the frequencies you tune in to listen to radio ranges or towers. They cover the Airway Band, that is, 200 to 420 kc.
2. The lower figures are the frequencies you tune in to listen to stations on the Broadcast Band that is, 550 to 1500 kc. (Note: "55" represents "550" and so on.)
3. Band Switch. The Band Switch performs three functions:
(i) Switches the equipment on and off. Turn the knob clockwise to switch the set "on".
(ii) Selects the band (either airway or broadcast).
(iii) Selects the antenna (either loop or straight wire).

Range-Voice. This position is for listening to voice signals from radio-range stations. In this position the non-directional straight wire antenna is in use and the RANGE FILTER is in operation. The range filter dampens out the coded range signals, enabling you to hear voice signals clearly.

Range-Ant. (Antenna) Switch to this position to listen to coded radio range signals on the non-directional fixed wire antenna.

Range-Loop. In this position the fixed loop antenna is in operation and you can select any station on the airway band, 200 to 420 kc—for taking an aural bearing on or for homing on.

BC (Broadcast-Loop). In this position the fixed loop antenna is in operation and you can select any station on the broadcast band, from 150 to 1500 kc—for taking an aural bearing or for homing on a broadcast station.

Note: The set illustrated is normally supplied with a fixed loop. The plane of the fixed loop lies at right angles to the longitudinal axis of the aircraft, so that a "null", or no signal is heard when the nose of the plane is pointed towards or directly away from the station.

This, and practically all types of personal plane radio sets can also be fitted with a rotatable loop which can be manually rotated by means of a hand crank. An azimuth dial is supplied with the rotatable loop on which the relative bearing of the radio station may be read without having to turn the aircraft off its track. (See "The Automatic Radio Compass").

BC Ant. (Broadcast Antenna) In this position the non-directional, fixed wire antenna is in operation to listen to any stations on the broadcast band, between 150 and 1500 kc.

4. Tuning. Turn the knob until the index line is
opposite the frequency of the station you wish to listen to. Rotate it back and forth until you receive the signal loud and clear.

5. Volume. Turn the volume control clockwise to adjust the audio level in the headset, the same as you do on any ordinary domestic radio set.

Transmission. When you wish to transmit, simply press the button on the microphone and talk. “Side tone” enables you to hear your own voice in your earphones, and hence to monitor your own transmission.

When finished speaking, you must release the button in order to receive. (The button automatically switches the set back to the receiver position.)

The set described, and most lightweight personal plane radio equipment, is designed for transmission on one frequency only, namely 3023.5 kc. Some types are available, however, in which crystals can be inserted to permit transmission on a wider range of channels.

**LINE OF SIGHT TRANSMISSION**

Very High Frequency radio waves have different properties entirely from the M/F "Ground and Sky Waves" described above. They do not "bounce" between the reflecting ionosphere and earth, but continue straight out into space. This means that they can only be received by an aircraft on a "line of sight" position in relation to the station. VHF waves do not follow the curvature of the earth, nor bend around obstructions. For this reason, the higher the altitude at which the aircraft is flying, the greater distance it will be able to receive VHF signals. See Fig. 19.

![Fig. 19. Line of Sight Transmission.](image)

Although "Line of Sight" transmission reduces the distance at which signals can be read at low altitude, this shortcoming is offset by the fact that stations below the horizon several hundred miles apart cannot interfere with one another. Actually, except in mountainous terrain, an aircraft flying at 1000 feet is within VHF range of every station within a 45-mile radius. At 10,000 feet altitude, the reception distance is 140 miles.

VHF offers virtual freedom from static noise interference. Conversation is much like talking over an ordinary telephone. In addition to quiet reliable communication, VHF equipment is smaller and lighter than corresponding M/F equipment, and consequently less power is required for normal communication.

**THE VHF TRANSCEIVER**

The Aircraft Radio Corporation VHF Transceiver illustrated in Fig. A is fairly representative of the many different makes of VHF equipment which are available at the time that this is written. Note that it is extremely simple and exceptionally compact.

1. Tuning. Turn the crank until the desired frequency on the frequency dial lies directly below the centre index. The receiver illustrated is tuned to 129.3 megacycles (mc).

2. Off. (Sensitivity) Rotating this knob switches the equipment on and off, and also controls the sensitivity.

3. Volume LO-HI. This switch provides a choice of two volume levels. Ordinarily, the LO position will furnish a strong enough signal. With the switch in the HI position, further adjustment can be obtained by increasing the sensitivity control.

4. Trans. (Transmitter) To transmit, simply turn the selector switch to the particular transmitting channel desired. Make sure that you have turned the station you are about to call and that it is not transmitting to someone else. Press the microphone button to talk. Release to listen. VHF channels are static free and communication is very similar to conversation on an ordinary telephone.

The Receiver described in "I. Tuning" above is a typical example of a "Tunable" type receiver. The Collins VHF Receiver illustrated in Fig. B, is a typical example of a "Crystal Controlled" type receiver. Any one of the 360 fixed channels provided in the set is automatically tuned as soon as the correct frequency number is selected.

![Fig. B. Collins VHF Transmitter and Receiver.](image)

**Frequency Selection.** Turning the outer "Dial A" (which rotates behind the circular face) selects the desired frequency in whole numbers, e.g.: 118 (118 megacycles). Turning the inner "Knob B" selects tenths and twentieths of megacycles, e.g.: 118.05 (118 decimal five one hundredths — or one twentieth — megacycles).

**Frequency.** The frequency selected appears in the slot above Knob B.

**Lamps.** Illuminate the set. Turn to remove.

**Operation Switch.** Moving the switch to "SCS" —
Single Channel Simplex—enables you to transmit and receive simultaneously on the one single channel selected. Moving the switch to “DCD”—Double Channel Duplex—enables you to receive on the channel selected but transmit on a frequency 6 megacycles higher (on a separate antenna).

Volume Control. This is automatic. The audio level may, however, be adjusted up or down within the set.

**PROCEDURE**

Standard phraseologies are recommended in the interest of clarity and brevity. However, it is not compulsory for any pilot to use them. If you wish to communicate with a radio facility in your own words, by all means do so. Only BE BRIEF. Above all, do not request transportation, accommodation, or other personal services from airways communication stations. They will no longer accept such messages.

Radio facilities are identified by their names, not their call letters—e.g.: MONTREAL TOWER, MEGANTIC RADIO, CLEVELAND CENTRE, JOLIET OMNI, etc.

When referring to numbers, each digit is stated separately. For example, “Ten” is spoken “ONE ZERO,” and so on.

A number which contains a decimal point is spoken as follows: “ONE TWO ONE DECIMAL FIVE” (121.5).

Time used is 24-hour time. Twenty-four-hour time begins at 00:00 (midnight). The last minute of the last hour begins at 23:59 and ends at 00:00—which is the beginning of the first minute (ending at 00:01) of the first hour of the next day.

Note: All Air Traffic Control facilities in North America operate on Greenwich Mean Time (GMT, or “Z” Time). See “Time and Longitude”.

In Airport Traffic Control procedure, the hour is often omitted and the time referred to in minutes past the hour only. For example, 10:25 would be referred to as :25 and spoken “TWO FIVE.” However, if the hour is included in the time, it is spoken in four digits, e.g.:

8:45 a.m. (written 08:45) is spoken “ZERO EIGHT FOUR FIVE.”

12:30 a.m. (written 00:30) is spoken “ZERO ZERO THREE ZERO.”

2:35 p.m. (written 14:35) is spoken “FOUR FIVE.”

Flight altitudes are always given in thousands and hundreds of feet above sea level. e.g.: “ONE THOUSAND” “TWO THOUSAND FIVE HUNDRED.” Above 13,000 feet, altitudes are given as follows: (13,000) “ONE THREE THOUSAND.”

To avoid confusion due to similarity in sound of some of the letters of the alphabet (such as “B” and “C”) a phonetic alphabet has been devised. It is not compulsory, but advisable to use it when calling the registration letters of your aircraft. Example: FEM is spoken, “FOX TROT ECHO MIKE.”

Once having definitely established your identity on the first call-up, and had it confirmed back, it is then no longer necessary to continue the use of these rather cumbersome two-syllable words. You may subsequently find it more convenient to refer to your registration letters as “FEM”.

**Pronunciation of Numerals**

<table>
<thead>
<tr>
<th>0</th>
<th>ZEE-RO</th>
<th>4</th>
<th>FOW-er</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WUN</td>
<td>5</td>
<td>FIFE</td>
</tr>
<tr>
<td>2</td>
<td>TOO</td>
<td>6</td>
<td>SIX</td>
</tr>
<tr>
<td>3</td>
<td>TREE</td>
<td>8</td>
<td>AIT</td>
</tr>
<tr>
<td>7</td>
<td>SEV-en</td>
<td>9</td>
<td>NIN-er</td>
</tr>
</tbody>
</table>

**Standard Phrases**

The following words and phrases should be used whenever applicable:

**Word or Phrase**

Roger

“Okay. I have received your message.”

Acknowledge

“Let me know you have received and understand this message.”

Do you read?

“I have called you more than once. If you are receiving me, reply.”

How do you hear me?

Self explanatory.

Speak slower

Self explanatory.

Stand by

“I must pause for a few seconds. If the pause is to be longer than a few seconds, add “Out.”

Say again

“Repeat. Never use the word “Repeat”—it is reserved for military purposes.”

I say again

“Proceed with your message.”

Go ahead

“Repeat this message back to me after I have given ‘Over.’”

Read back

Self explanatory.

That is correct

“Communication is difficult. Please send every phrase twice,” or “I will send every phrase twice.”

Words twice

Correction

“I have made an error. The correct version is . . . .”

Affirmative

“Yes”

Negative

“No”

Over

“My transmission is ended. I expect a reply from you.”

Out

“My transmission is ended. I do not expect a reply from you.”

**Taxi Clearance**

Ask the tower for permission to taxi. The tower will reply, clearing you to the runway in use and will give you the wind direction and velocity, the altimeter setting, and the time. (This should be done on the Ground Control frequencies 121.3 or 121.7 mc. The purpose of Ground Control is to relieve congestion on the tower frequency. Remain tuned to Ground Control for taxi instructions. Change to Tower frequency when ready for take-off clearance.)

Aircraft: “NORWOOD TOWER—THIS IS CESSNA FOUR TWO NINER ZERO NOVEMBER—ON WEST RAMP READY TO TAXI—VFR TO FORESTVILLE—OVER”.

Tower: “CESSNA FOUR TWO NINER ZERO NOVEMBER—CLEARED TO RUNWAY TWO SEVEN”—

**Phonetic Alphabet**

<table>
<thead>
<tr>
<th>A</th>
<th>Alta</th>
<th>F</th>
<th>Foxtrot</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Bravo ”BRAH-voe”</td>
<td>G</td>
<td>Golf</td>
</tr>
<tr>
<td>C</td>
<td>Charlie</td>
<td>H</td>
<td>Hotel</td>
</tr>
<tr>
<td>D</td>
<td>Delta</td>
<td>J</td>
<td>India</td>
</tr>
<tr>
<td>E</td>
<td>Echo</td>
<td>J</td>
<td>Juliet “Jool-ee-YET”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>K</th>
<th>Kilo “KEE-loe”</th>
<th>S</th>
<th>Sierra</th>
</tr>
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<tbody>
<tr>
<td>L</td>
<td>Lima “LEE-moh”</td>
<td>T</td>
<td>Tango</td>
</tr>
<tr>
<td>M</td>
<td>Mike</td>
<td>U</td>
<td>Union</td>
</tr>
<tr>
<td>N</td>
<td>November</td>
<td>V</td>
<td>Victor</td>
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<td>O</td>
<td>Oscar</td>
<td>W</td>
<td>Whiskey</td>
</tr>
<tr>
<td>P</td>
<td>Papa “POP-ah”</td>
<td>X</td>
<td>X-Ray</td>
</tr>
<tr>
<td>Q</td>
<td>Quebec “KAH-BECK”</td>
<td>Y</td>
<td>Yankee</td>
</tr>
<tr>
<td>R</td>
<td>Romeo</td>
<td>Z</td>
<td>Zulu</td>
</tr>
</tbody>
</table>
WIND WEST ONE ZERO* — ALTIMETER TWO
NINER SEVEN FIVE: TIME ZERO FIVE:.
Aircraft: "ROGER" or "NINER ZERO N" (After com-
munication has been established, the aircraft regis-
tration may be abbreviated to the first three numbers
or letters).

"Runway 27 lies approximately 270° Magnetic. Your compass or
directional gyro should therefore read 270° when you line up
for take-off.

"The wind is from West at 10 Kts. Winds given by control
towers are MAGNETIC whereas those given by meteoro-
logical stations are TRUE.

*Set the Barometric Scale on your altimeter to 29.75.

*Set your clock to 05 minutes past the hour.

Flight Plan

If you have not previously filed a flight plan and
now wish to do so: (See footnote.)

Aircraft: "SUMMIT TOWER — THIS IS PIPER PAPA
TANGO VICTOR — HERE IS MY FLIGHT PLAN —
SUMMIT — EIGHT THOUSAND FVR** VIA VICTOR

TURN APPROVED — CLEARED FOR TAKE-OFF."
Aircraft: "ROGER FOUR ZERO VICTOR."

After take-off, remain tuned to the tower frequency.
The tower will usually call you after take-off, give you
any necessary traffic information, your time off, and a
clearance from the tower frequency. (Aircraft doing
domestic flying will remain tuned to the tower frequency
at all times.)

Tower: "BONZANA FOUR ZERO VICTOR — OFF AT
ONE FIVE — CLEARED TO LEAVE TOWER
FREQUENCY."

Aircraft: "FOUR ZERO VICTOR — ROGER OUT."

En Route Reports (Controlled VFR)

An aircraft flying Visual Flight Rules is not required
to report its position to intermediate stations en route.
However, an aircraft flying Controlled VFR must obtain
air traffic clearances and file en route position reports
at all compulsory reporting points, or other reporting
points which may be specified by ATC.

You have filed a flight plan at Rockport for a flight
to Westerville, controlled VFR, at 10,000 ft., via Green
Airway No. 5 and Victor Airway No. 90. Reporting
points along your route are: Mitchell Radio, Penridge
Radio and Clear River Omni. See Fig. E. You have
taken off at 14:00 and are climbing to your intended
altitude. Contact Rockport Radio for a clearance to
enter the block airspace:

Aircraft: "ROCKPORT RADIO—THIS IS OTTER KILO
TANGO MIKE—ON ONE TWO TWO DECIMAL
ONE MEGACYCLES—OVER."

"Always state the frequency on which you are
calling and on which you expect a reply. When you call
on either 122.1 or 3033.5 kc., a range or omni will
automatically reply on its listed navigation aid frequency
—unless you request otherwise, as for example, "Reply
on one two six decimal seven."

Station: "KILO TANGO MIKE ROCKPORT
RADIO—GO AHEAD."

Aircraft: "OVER ROCKPORT AT ONE TWO—AT
EIGHT THOUSAND FIVE HUNDRED—VFR—
REQUESTING TEN THOUSAND CONTROL-
LISHED VFR TO WESTERVILLE VIA
GREEN FIVE AND VICTOR NINER ZERO—
OVER."

*Meaning 12 minutes past the hour (14:12).

Station: "ATC CLEARS KTM TO WESTERVILLE
RADIO VIA GREEN FIVE AND VICTOR
NINER ZERO—CLIMB TO AND MAINTAIN
THOUSAND VFR—REPORT REACHING
THOUSAND—OVER."

Aircraft: (Repeats clearance back) "ATC CLEARS
KTM TO WESTERVILLE RADIO VIA GREEN
FIVE AND VICTOR NINER ZERO—CLIMB
TO AND MAINTAIN THOUSAND VFR
—REPORT REACHING THOUSAND—
OVER."

Station: "ROCKPORT RADIO ROGER OUT."
You report on reaching 10,000 ft. at 14:15 as instructed:

Aircraft: "ROCKPORT RADIO—KTM AT TEN THOUSAND AT ONE FIVE—ESTIMATING MITCHELL AT THREE THREE—PENRIDGE—OVER."

Station: "CHECK YOU AT TEN THOUSAND AT ONE FIVE—ESTIMATING MITCHELL AT THREE THREE—PENRIDGE—ALTIMETER TWO NINER SEVEN FOUR—OVER."

Aircraft: "KTM" or "ROGER OUT."

When you pass over Mitchell Radio (your first reporting point) check the time, calculate your ground speed and your estimated time of arrival over Penridge Radio, your next reporting point. File your position report:

Aircraft: "MITCHELL RADIO—THIS IS OTTER KILO TANGO MIKE—ON ONE TWO TWO DECIMAL ONE MEGACYCLES—OVER."

If the station does not immediately reply:

Aircraft: "MITCHELL RADIO—THIS IS OTTER KILO TANGO MIKE—STANDING BY ON THREE THREE FIVE KILOCYCLES' (or the appropriate frequency)—DO YOU READ—OVER."

"Meaning you are tuned in on 335 kc. on your range receiver.

If a station does not answer you after two or more calls have been made, you may issue a GENERAL CALL, requesting any station hearing you to contact the station you are calling. e.g.:

Aircraft: "ANY STATION RECEIVING ME—ANY STATION RECEIVING ME—THIS IS KILO TANGO MIKE—ADVISE MITCHELL RADIO I AM CALLING HIM ON ONE TWO TWO DECIMAL ONE MEGACYCLES—KTM OUT."

When contact with the station has been established:

Aircraft: "BY MITCHELL AT THREE THREE—TEN THOUSAND—CONTROLLED VFR—ESTIMATING PENRIDGE AT ONE FIVE ZERO THREE—CLEAR RIVER—OVER."

Station: "CHECK YOU BY MITCHELL AT THREE THREE—TEN THOUSAND—CONTROLLED VFR—ESTIMATING PENRIDGE AT ONE FIVE ZERO THREE—CLEAR RIVER—ALTIMETER TWO NINER SEVEN FIVE" (and any other information considered necessary such as the weather ahead, etc.) "OVER."

Aircraft: "KTM—ROGER OUT."

You pass over Penridge at 15:03 and decide to request permission to descend for a landing at Westerville on arrival:

Aircraft: "PENRIDGE RADIO—THIS IS OTTER KILO TANGO MIKE ON ONE TWO TWO DECIMAL ONE MEGACYCLES—OVER."

Station: "KILO TANGO MIKE FROM PENRIDGE RADIO—GO AHEAD."

Aircraft: "BY PENRIDGE AT THREE THREE—TEN THOUSAND—CONTROLLED VFR—ESTIMATING CLEAR RIVER AT THREE NINER REQUESTING CONTROLLED DESCENT THROUGH NINE THOUSAND FIVE HUNDRED TO LAND WESTERVILLE—OVER."

Station: "ATC ADVISES KTM TO MAINTAIN TEN THOUSAND TO CLEAR RIVER OMNI FOR FURTHER CLEARANCE—CALL FIVE MINUTES EAST OF CLEAR RIVER—OVER."

Aircraft: (Repeats clearance) "ATC ADVISES KTM TO MAINTAIN TEN THOUSAND TO CLEAR RIVER OMNI FOR FURTHER CLEARANCE—CALL FIVE MINUTES EAST OF CLEAR RIVER—KTM OVER."

Station: "ROGER KTM—ALTIMETER TWO NINER SEVEN FOUR—PENRIDGE RADIO OUT."

Midway between Penridge and Clear River you decide to check the weather at your destination and call Clear River Omni to obtain this information. Clear River Omni has acknowledged your call:

Aircraft: "REQUESTING THE LATEST WESTERVILLE WEATHER AND ALTIMETER SETTING—OVER."

Station: "KTM—HERE IS THE WESTERVILLE WEATHER—ONE THOUSAND SCATTERED . . . etc., etc."

You arrive 5 minutes east of Clear River at 15:34 and call the Station:

Aircraft: "CLEAR RIVER OMNI—THIS IS OTTER KILO TANGO MIKE—ON ONE TWO TWO DECIMAL ONE MEGACYCLES—OVER."

Station: "KILO TANGO MIKE FROM CLEAR RIVER OMNI—GO AHEAD."

Aircraft: "FIVE MINUTES EAST OF CLEAR RIVER AT THREE FOUR—STANDING BY FOR FURTHER CLEARANCE TO LAND WESTERVILLE—OVER."

Station: "ATC CLEARS KTM TO DESCEND BELOW NINE THOUSAND FIVE HUNDRED (or BLOCK AIRSPACE) IMMEDIATELY—REPORT LEAVING NINE THOUSAND FIVE HUNDRED—TRAFFIC IS EASTBOUND DC3 ESTIMATING CLEAR RIVER AT FOUR FIVE—OVER."

"Meaning there is a DC3 eastbound which will be over Clear River at 15:45.

Aircraft: (Repeats clearance) "ATC CLEARS KTM TO DESCEND BELOW NINE THOUSAND FIVE HUNDRED IMMEDIATELY—REPORT LEAVING NINE THOUSAND FIVE HUNDRED—TRAFFIC IS EASTBOUND DC3 ESTIMATING CLEAR RIVER AT FOUR FIVE—KTM OVER."

Station: "CLEAR RIVER OMNI OUT."

When you pass through the 9500-foot level on your descent, report as follows:

Aircraft: "CLEAR RIVER OMNI—THIS IS KTM LEAVING NINE THOUSAND FIVE HUNDRED AT THREE NINER—OVER."

Station: "KTM—CHECK YOU LEAVING NINE THOUSAND FIVE HUNDRED AT THREE NINER—CONTACT WESTERVILLE TOWER FOR LANDING INSTRUCTIONS—ALTIMETER TWO NINER SEVEN TWO—OVER."

Aircraft: "KTM ROGER OUT."

Arrival

When approximately 15 miles from your destination, call the tower. When the tower replies, give your altitude, and position in miles and direction from the
airport. The tower will reply, giving you the runway to use, wind direction and velocity, traffic, and any other information or instructions considered necessary:

**Aircraft:** “MADISON TOWER — THIS IS BEECHCRAFT TWO NINER NINER ZERO — ON ONE TWO TWO DECIMAL FIVE MEGACYCLES — OVER.”

**Tower:** “BEACHCRAFT TWO NINER NINER ZERO — THIS IS MADISON TOWER — GO AHEAD.”

**Aircraft:** “BEECH NINER NINER ZERO — ONE FIVE MILES SOUTHWEST AT ONE FIVE — AT THREE THOUSAND” (or, if over a reporting point or prominent landmark, “OVER CLAPPISON’S CORNERS”) — "LANDING MADISON — OVER.”

*Meaning at fifteen minutes past the hour.

**Tower:** “BEECH NINER NINER ZERO — ONE FIVE MILES SOUTHWEST AT ONE FIVE — AT THREE THOUSAND — CLEARED TO ENTER TRAFFIC PATTERN — RUNWAY THREE ONE” — WIND WEST ONE FIVE — ALTIMETER TWO NINER SEVEN ZERO.”

**Aircraft:** “ROGER NINER NINER ZERO.”

*Should the traffic be right-handed instead of the conventional left-handed circuit, this will be indicated as follows: “CLEARED TO ENTER THE RIGHT TRAFFIC PATTERN.”

**Tower:** “BEECH NINER NINER ZERO — FIFTEEN MILES SOUTHWEST AT THREE THOUSAND — CLEARED TO THE FIELD — RUNWAY THREE ZERO — ALTIMETER TWO NINER SEVEN ZERO.”

**Aircraft:** “ROGER.”

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**Initial Approach**

In Canada, when you have been “Cleared to the Traffic Pattern”, join the circuit on the Downwind Leg of the Traffic Pattern, unless authorized to make some other form of approach. While on the Downwind Leg, shortly before starting to turn on to the Base Leg of the circuit, request an Initial Approach Clearance:

**Aircraft:** “EMERSON TOWER — THIS IS D. H. DOVE FOUR NINER THREE FIVE UNION — ON INITIAL APPROACH — OVER.”

**Tower:** “DOVE FOUR NINER THREE FIVE UNION — CLEARED INITIAL — YOU ARE NUMBER FOUR TO LAND.”’ *or any other instructions necessary*

*Meaning there are three other aircraft in the circuit ahead of you.

**Aircraft:** “ROGER THREE FIVE UNION.” or “35U.”

**Final Approach**

If traffic around the airport is light, instead of clearing you “To the Traffic Pattern”, the Tower may, instead, clear you “To the Field”. In this case, no Initial Approach Clearance is required and it is not necessary to contact the Tower again until you are on Base Leg ready to turn in on final approach.

In the United States, no Initial Approach Clearance is required at any time. When the Tower has cleared you to “The Traffic Pattern”, you join the Traffic Pattern on the Downwind Leg, but are not expected to call the Tower again until you turn on the Base Leg.

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**Taxi Clearance**

After landing, taxi straight ahead and clear the runway as quickly as possible.

Your time of landing and taxi instructions will be given by the Tower as considered necessary, or requested by the pilot if required.

**Aircraft:** “YANKEE UNION DELTA — TAXI INSTRUCTIONS — OVER.”

**Tower:** “YANKEE UNION DELTA ON AT ONE FIVE TURN NIGHT AT END OF THE RUNWAY AND TAXI PAST THE TOWER TO GATE FIVE.”

**Aircraft:** “ROGER Y U D.”

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**Ground Control**

At certain designated airports VHF GROUND CONTROL has been established to handle traffic on the ground and thus relieve traffic congestion on the Tower frequencies. Ground Control operates on specially designated frequencies — usually 121.9 mc. or, alternately, 121.7 mc.

At airports where Ground Control is established, departing aircraft should communicate with the Tower on the appropriate Ground Control frequency for taxi
and other clearance information, and remain tuned to this frequency until ready for take-off.

In-bound aircraft, after landing and clearing the runway or landing area in use, should tune in the appropriate Ground Control frequency for taxi instructions and further communication with the Tower. e.g.: Aircraft: "RICHMOND HILL GROUND CONTROL — THIS IS LOCKHEED ROMEO DELTA TANGO — TAXI INSTRUCTIONS — OVER."

Distress

In an emergency, repeat the word MAYDAY, followed by your aircraft identification three times. If time permits, your message should give your estimated position, altitude, the type of aircraft, the nature of the emergency, and your intended action (such as crash landing in timber, forced landing on water, etc.). Following the transmission of your message, hold the button on your microphone pressed down for 20 seconds — to enable D/F Bearings to be taken on you:

Aircraft: "MAYDAY — MAYDAY — MAYDAY — OSCAR NOVEMBER ROMEO — OSCAR NOVEMBER ROMEO — OSCAR NOVEMBER ROMEO — FIVE ZERO MILES SOUTH OF GRAND FALLS AT ONE SEVEN TWO FIVE EASTERN — FOUR THOUSAND —ANSON FIVE —ICING — WILL ATTEMPT CRASH LANDING ON ICE — (Keep microphone button depressed 20 seconds) OSCAR NOVEMBER ROMEO — OVER."

Station: "OSCAR NOVEMBER ROMEO — OSCAR NOVEMBER ROMEO—OSCAR NOVEMBER ROMEO — THIS IS GANDER RADIO — GANDER RADIO — GANDER RADIO — ROGER MAYDAY — GANDER RADIO OUT."

See also "RADAR ADVISORY SERVICE".

Urgency

Urgency signals are preceded by the word PAN repeated three times. They are given priority over all other communications except Distress Calls:

Aircraft: "PAN — PAN — PAN — CLEVELAND TOWER — THIS IS DE HAVILLAND GOLF FOXTROT ECHO — ADVISE STINSON FOUR NINE ONE NOVEMBER THAT HIS UNDERCARRIAGE IS DAMAGED — OVER."

Safety

The safety signal is the word SECURITY repeated three times. The use of this signal indicates that a station is about to transmit a message concerning the safety of navigation, or important meteorological warnings to aircraft in flight.

Aircraft With Radio Receiver Only

When the aircraft is on the ground and has received instructions from the tower:

Tower: "ACKNOWLEDGE BY MOVING YOUR AIRES" (or "RUDDER"—whichever is visible to the tower).

When the aircraft is in the air:

Tower: "ACKNOWLEDGE BY DIPPING YOUR WINGS."

When the aircraft is either on the ground or in the air at night:

Tower: "ACKNOWLEDGE BY FLASHING (or "BLINKING") YOUR LANDING LIGHT."

THE MORSE INTERNATIONAL CODE

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THE Q CODE

QDR—Give me my Mag. Bearing from you.

QDM—Give me the Mag. Heading to steer, with zero wind.

QTE—Give me my True Bearing from you.

QTF—What is my position, by D/F Fix.

The complete Q Code may be found in "Procedures for Air Navigation Services—ICAO Q Code", published by the International Civil Aviation Organization, Montreal ($1.50).

THE AUTOMATIC RADIO COMPASS

DF means Direction Finder. The abbreviation is used in connection with any type of direction finding equipment, either transmitting or receiving, e.g. A Loop in an aircraft: A Directional Radio Beacon Station, etc.

ADF means Automatic Direction Finder. e.g. The Automatic Radio Compass.

The fundamental principle of the Radio Compass is based on the directional properties of the Loop Antenna. The Loop Antenna is a metal ring (enclosing coils of insulated wires) arranged so that it may be rotated around its vertical axis. It is contained within a streamlined housing, preferably mounted well forward on the underside of the fuselage.

Fig. 5. Radio Compass Azimuth Dial.

When the Loop is turned so that its plane is in line with the transmitting station, a MAXIMUM signal is received (Fig. 6A).

When the Loop is turned with its plane sidewise to the station, a MINIMUM or NULL signal is received. Fig. 6B.

(In either case — a Maximum or Null signal — the width of the signal can be narrowed by Adjusting The Volume.)
The position of the Loop is indicated by a hand on the face of the Azimuth Dial, which is graduated in degrees of azimuth from 0 deg. to 360 deg. (Fig. 5). The position of the Loop in relation to the longitudinal axis of the airplane is actually at right angles to the hand. The hand therefore points to the direction of the station being received, as measured from the longitudinal axis, or nose of the airplane.

Time was, when the operation of the Direction Finding Loop Antenna was surrounded by complications. The Loop was rotated manually and the direction of the station being heard determined aurally, by rotating the Loop until an "Aural Null" signal was received — the position of the Loop being indicated by a pointer on the dial. This led to Ambiguity, since the null signal could be from either one of two directions — directly opposite. The direction of the station was found by rotating the Loop about 10 deg. If the needle moved to the right when the Loop was rotated to the right, the station was ahead. If it moved to the left when the Loop was rotated to the right, the station was behind.

The modern Radio Compass is completely automatic. Ambiguity is mechanically compensated for. The Loop is automatically oriented towards the station tuned and rotated by a small electric motor. The operation of the Radio Compass is simplicity itself and gives fully continuous and automatic radio compass bearings on any station to which the Receiver is tuned.

Quadrantal Error — The Radio Compass is affected by an error very similar to Deviation in the Magnetic Compass. This is called QUADRANTAL ERROR — or sometimes "Radio Compass Deviation". It is caused by refraction, or bending of the incoming radio waves by the metal structure of the airplane. It is determined by "swinging" the aircraft on the ground, and in the air, and logged on a Radio Compass Calibration Chart which is mounted in the cockpit — similar to the magnetic compass Deviation Card. Some modern loops (the A.R.C. for example) are fitted with compensating screws which permit the Quadrantal Errors on headings every 30° apart to be corrected — thus eliminating the need for the calibration chart in the cockpit.

The A.R.C. Automatic Radio Compass illustrated in Fig. B is typical of the many different types of ADF which are currently in use and weighs only 24 lbs. It serves a dual purpose. In addition to its primary purpose as an automatic radio compass, it may be used as an ordinary M/F Receiver to listen to towers, ranges, broadcast stations, etc.

1. VOL. (Volume Control). This knob switches the Receiver on and off and also adjusts the volume.

2. Antenna Selector. Enables the pilot to select either the "Ant" or "Comp" antennas installed with the set.

3. ANT. (Antenna). Moving the switch to this position enables the pilot to listen to ranges, towers, etc. on the range and communications receiver.

4. COMP (Compass). This position selects the directional loop antenna which is used for homing or taking bearings.

4. MC BAND (Band Selector). "MC" means megacycles. Move the pointer to the band in which the particular frequency lies which you wish to tune. On the type of Receiver shown, the different bands are identified by their frequency range. The frequencies are shown in megacycles. To convert these to kilocycles, multiply by 1000. e.g.: .19 — 40 (mc.) = 190 — 400 (kc). When you select this band, you can tune in any frequency between 190 and 400 kilocycles.

5. Tuning Crank. The crank is rotated until the frequency required appears in the window above, opposite the centre line. The receiver in the illustration is tuned to 649 kc. To tune, turn the volume control full on. Rotate the tuning crank back and forth until you receive a maximum reading on the Tuning Meter (5). Then turn the volume down. Check the station identification signal to be sure the desired station is being received. If the signal is too weak in the COMP position, switch to ANT for identification purposes.

6. Tuning Meter. Indicates visually that a maximum signal is being received.

7. COMP TEST. This switch is used to check the needle indication on the azimuth dial. When the switch is moved to the right or left, the needle (and the loop) move with it. If the signal being received is a reliable one, the needle will return to its original position as soon as the COMP TEST switch is released.

7. Lamps. These supply indirect lighting of control panel. Turn to remove or replace.

Homing — To fly toward any range or broadcasting station, tune to the frequency of the station. Turn the nose of the plane until the hand on the Azimuth Dial points to "0." Now simply keep the pointer on zero until you arrive over the station. When you pass over it, the pointer will swing around to 180 deg., indicating that the station is now behind you.

If there was no wind, the Track made good when homing on the Automatic Radio Compass would be a
straight line towards the station. The wind, however, tends to drift the aircraft to one side or the other of such a straight line. A continuous process of correction for drift occurs as the radio compass keeps heading the nose of the aircraft towards the station. The resultant track flown is a curved line (Fig. O top).

The progressive change in the heading of the aircraft will be indicated to the pilot by his magnetic compass or directional gyro. One method of narrowing the curvature of the track flown is as follows:

A. (Fig. O). The pilot has tuned the station he wishes to home on and centred the Radio Compass (R.C.) needle on "O". As the course or track intended is 90° Magn., his Directional Gyro (D.G.) will read 90°.

B. After flying some minutes, the pilot notes his heading by D.G. has altered to 95°. This tells him that he is drifting to port and that the wind therefore is from starboard. He heads the nose of the aircraft, say, 3° more into wind, steering 357° by R.C. instead of "O". (98° Magn. by his D.G.).

Note that when the heading is altered to STARBOARD by the Directional Gyro, the heading on the Radio Compass alters to PORT — in other words, "down wind."

If his heading continues to alter to starboard by D.G., he steers a few more degrees into wind and continues this process until he finally observes that his heading by D.G. remains constant. He has now counteracted wind drift and established a heading straight towards the station.

Dual ADF—Some aircraft are equipped with two Automatic Radio Compasses (Dual ADF) having a single azimuth dial with dual pointers. With dual ADF, a pilot may take simultaneous bearings on two stations, or he may home on one station and at the same time obtain a continuous bearing on another station, giving him a running position fix.

When wide oscillation, or "hunting" of the needle occurs, average the oscillation and fly the average heading.

In order to minimize so-called "night effect" when homing towards a city, choose a station to home on, if possible, with a low frequency. This is important at night because erroneous directional bearings are more likely to occur on higher frequency stations than on lower, and more often at night than in the daytime.

Bearings — To take a bearing on any range or broadcasting station that is off your track, tune in to the frequency of the station. The hand on the Azimuth Dial will indicate the direction of the station from the heading, or longitudinal axis of the aircraft. This is known as a RELATIVE BEARING.

A Relative Bearing may be converted to a Geographical Bearing, either True, Magnetic or Compass, as required. (Fig. 7).

The Relative Bearing of the station from the aircraft is 30 deg.

The Heading of the aircraft by compass is 75 deg. Therefore the Compass Bearing of the Station is (75 + 30) = 105 deg. C.

The Deviation is 5 deg. West. Therefore the Magnetic Bearing is (105 - 5) = 100 deg. M.

**Fig. 7. Conversion of a Relative Bearing (shown on dial) to a Geographical Bearing.**
The Variation is 10 deg. West. Therefore the True Bearing is (100—10) = 90 deg. T.

(When the arithmetical sum of the Heading and Relative Bearing is more than 360 deg, subtract 360 to obtain the Geographical Bearing, e.g. Bearing 80 deg plus Heading 350 deg equals 360 deg. 360—20 deg = Geographical Bearing.)

The True Bearing can be used to plot a POSITION LINE on a map. Draw the line on the map away from the Station, i.e. in, using the Reciprocal of the Bearing. This is a Position Line, somewhere on which line the airplane is known to have been at the time the bearing was taken.

Note: Since the Meridian at the Station will not be parallel to the Meridian at the aircraft where the bearing was taken (due to Convergence) it is necessary to draw a False Meridian at the Station parallel to the Meridian near the assumed position of the aircraft. The reciprocal of the Bearing, or POSITION LINE is then measured from this False Meridian.

When two or more Bearings are taken nearly simultaneously on several different stations, and the Position Lines plotted on a map, the point where the Position Lines intersect will be a Fix—or the position of the aircraft at the time the bearings were taken.

When plotting a Fix by two or more position lines, the angle between the position lines should be not less than 30 deg.

Position lines obtained by radio DF bearings may be plotted on I.C.A.O. aeronautical maps, since radio bearings are great circle bearings and a straight line on this map projection represents a Great Circle. If it is necessary to plot a radio bearing on a Mercator chart, the Conversion Angle must be applied to change the bearing from a Great Circle to a Rhumb Line. The CONVERSION ANGLE is equal to half Convergence. Since Convergence = Ch. Long. \times \sin \text{Mean Lat.} it follows that the Conversion Angle = \( \frac{1}{2} \text{Ch. Long.} \times \sin \text{Mean Lat.} \)

A FIRST CLASS BEARING by DF (direction finding) Radio is one which is accurate to within \(+5\) or \(-5\) deg.

A SECOND CLASS BEARING is accurate to within \(+5\) or \(-10\) deg.

A THIRD CLASS BEARING varies more than \(+10\) or \(-10\) deg.

The width of a SECTOR OF POSITION therefore varies from 4 to more than 10 deg.

The RADIO MAGNETIC INDICATOR (RMI) automatically converts Relative Bearings to Magnetic Bearings without any calculation on the pilot’s part.

Inaccuracies of the DF Loop

Night Effect — Particularly at sunrise or sunset, bearings taken on a Direction Finding Loop at night may be subject to error. This usually disappears when the airplane is within some minimum distance of the station (varying from 20 to 50 miles).

Terrain Effect. Mountainous terrain, alternate areas of land and water, and proximity to coastlines also give rise at times to erroneous bearings.

Ice and Sleet on radio antennas tend to swing range courses from their published headings and also reduce signal strength.

Rain or Snow Static

When flying a Radio Range in rain or snow, severe static may be encountered. This condition may be improved by the use of the Loop Antenna. For this purpose the Loop is rotated manually to its Maximum signal position — with the plane of the Loop in line with the longitudinal axis of the aircraft. The Loop is oriented to this position when the hand on the Azimuth Dial points to 90 deg.

**THE LM/MF RADIO RANGE**

In the same manner that motor cars follow the public highways from place to place and trains follow the railway lines across the continent, the radio range provides a coast to coast network of invisible "beams" that aircraft may follow, even though flying totally blind.

LM/MF means Low Frequency/Medium Frequency. Radio ranges transmit in the low-medium frequency band between 200 and 400 kilocycles.

The basic principle of the radio range is aural, that is through the medium of sound. When the pilot is "on the beam" he hears an "On Course" sound, a steady hum. When he is off, he hears a Morse A Signal, "de da" (…) or a Morse N signal, "da de" (…) which tells him that he is off the beam to the right or left as the case may be.

The radio beams which lie along the routes of airways are not continuous, but are composed of chains of beams transmitted by radio range stations located at intervals roughly 55 to 150 miles apart. A radio range station sends out four beams more or less in the form of a Greek cross though not necessarily a right angled one.

Normally, radio waves sent out from a transmitting station radiate in the form of a circular pattern, the same as the waves formed when you drop a stone in water.

A Radio Range Station, however, transmits on a specially-designed type of antenna, called a Loop. The shape of the wave pattern radiating from a single loop is shown in Fig. 8. (The loop is represented as it would appear it viewed from above). The signals being transmitted by the loop illustrated are a series of Morse A's ("de da, de da, de da", etc.). The intensity of the signals is strong where they originate around the loop and grow weaker as they radiate out away from the station, until they finally fade completely.

A Radio Range Station transmits simultaneously from two such loops lying across each other as shown at the centre of Fig. 9. One loop transmits a series of A's. The other transmits a series of N's. Along the narrow (shaded) beams where the opposing lines of force intersect at equal strength, the dots and dashes of the A's merge with the dashes and dots of the N's and a steady monotone is heard. This is the "On Course" signal of the "Beams", more commonly referred to in radio navigation as the four COURSES, or LEGS of the Radio Range. They are named the North, East, South...
and West legs in clockwise order, the North Leg being that lying closest to True North.

It will be seen that there are two sectors where an A signal will be heard and two where an N signal will be heard. These are referred to as the A QUADRANTS and N QUADRANTS of the Range. They are named the Northeast, Southeast, Southwest and Northwest Quadrants. The Northeast Quadrant is that bounded by the North and East Legs.

In the U.S. the Quadrant in which True North lies is always an N Quadrant. If the North Leg of the range lies exactly True North, the N Quadrant is that lying immediately west of North. In Canada, the Quadrant which contains a true bearing of 135° towards the station is always an N Quadrant.

The identification letters are Repeated Twice. The first signal is transmitted in the N Quadrant, while the A remains silent. The second is transmitted in the A Quadrant, while the N remains silent.

From this it will be seen that the Identification Signals can be used to identify the Quadrants equally as well as the A and N signals. Some pilots prefer to rely on the station identification signals entirely as they are easier to read under bad static or other conditions of poor reception.

In the ON-COURSE both identification signals are heard with equal strength.

In the BI-SIGNAL ZONES one signal will be strong and the other weak.

In the DISTINCT A or N ZONES one signal only will be heard.

In an N Quadrant the signal will be heard, followed by a pause. In an A Quadrant there will be a pause followed by the signal. This is because the signal is transmitted in the N Quadrant first, and provides a means of distinguishing an N Quadrant from an A Quadrant.

Owing to the inability of the human ear to distinguish minute differences in signal strength between signals of the same type, there is a zone lying close to the On-Course wherein a pilot can distinguish a slight A or N bi-signal indication, but where the identification letters appear to be of equal strength. This is known as the TWILIGHT ZONE.

(Note: Modern radio range stations are of the Adcock type. Instead of two loops at right angles, four vertical towers are arranged in pairs, so that each pair forms a directional antenna functioning similar to a loop. A fifth tower (non-directional) is located in the centre of the square formed by the other four, which transmits voice signals simultaneously with the range signals—an arrangement which was not possible with older loop-type stations.)

Fig. 10 shows the pattern of a Radio Range Station more or less as it is shown on the map.

Note the four legs of the Range. The headings of the

Legs, towards and away from the Station, are always given as MAGNETIC.

The A's and N's shown alongside the range legs indicate the quadrants, but are not printed on aeronautical charts. On charts, the solid line on one side of the shaded range leg always indicates the N side.
The zones indicated by the dotted lines (which are not shown on maps) are the TWILIGHT ZONES. The rectangular box, printed on the map alongside the Range Station, contains all the information a pilot must have in order to identify and make use of the facilities of the Range.

The figures (368) give the frequency on which the Range transmits — which you tune in on your radio receiver to listen to the Range. Unless otherwise stated, these are in Kilocycles.

Adjacent radio ranges broadcast on different transmitting frequencies, to avoid the signals of one overlapping another.

The letters (YZ) followed by their graphic representation in Morse dots and dashes are the identification letters of that particular Range.

The functions of Radio Ranges are fourfold, namely:

1. They may be used to navigate over long distances from place to place.
2. They can be used to make instrument approaches to airports.
3. Radio Range Stations may be used for communication. You may ask them for winds aloft, weather reports, clearances, permission to alter your flight plan, etc.
4. Radio Range Stations automatically broadcast the weather at regular stated intervals.

The weather broadcasts are usually 30 minutes apart. In the U.S.A. at 15' and 45' past the hour. In Canada at 22' and 52', or 25' and 55' past the hour.

BRACKETING A BEAM

Let us say you wish to fly westerly (270 deg.) along the Radio Beam illustrated in Fig. 11 whose published heading is 270 deg. — 90 deg. You have tuned in the Range and are in the N Quadrant at (A). You fly southwesterly to intercept the beam at an angle of approximately 45 deg. If there was no wind, when you enter the twilight zone on the right hand side of the beam, you could simply turn on to a heading of 270 deg. and follow the right hand edge of the beam.

The wind, however, probably will drift you into the beam or out into the N Quadrant, making a correction for drift necessary. Bracketing enables you to make a fairly accurate correction for drift.

When you enter the On Course instead of turning to 270 deg., turn on a heading 20 degrees to starboard of 270 deg. (250 deg.) This will take you out into the N Quadrant. As soon as you hear the N signal distinctly, turn to a heading 20 degrees to port of 270 deg. (250 deg.) and fly back into the On Course. Now turn out ten degrees to starboard of 270 deg. (280 deg.) and fly out into the N Quadrant. Then back 10 deg. to port of 270 deg. (260 deg.) and so on. As you zigzag back and forth, the length of time it takes you to fly into the On Course compared with the time taken to fly out into the N Quadrant will give you a very good indication of the wind direction and speed. Suppose you estimate your drift to be 5 deg. to starboard. Then a heading of 265 deg. should keep you on the right hand edge of the beam with only very minor further corrections.

BISECTORS

The Bisectors of Radio Ranges are drawn midway between the legs, dividing the Quadrants in half. As the Range Legs do not necessarily intersect each other at 90 deg. angles, it will be obvious that the Bisector of a Quadrant will not be the same as the Bisector of its opposite Quadrant. In order to make them so, the Average Bisector of the Quadrants is used. This is illustrated in Fig. 12.

Airline Captains’ Route Books contain diagrams of the Radio Ranges with the Average Bisectors shown. Air navigation maps, however, do not. Private pilots must work out the Average Bisectors for the Ranges they expect to use and mark them on their maps themselves.

![Fig. 12. Bisectors and Average Bisectors.](image-url)

The Bisectors can be found with a compass and protractor quite simply as follows: With the Range Station as centre, describe an arc with the compass cutting the two Legs of the Quadrant at A and B (Fig. 12). With A and B as centres, describe arcs intersecting at C. Draw a line through C to the Range Station. This is the Bisector, which can now be measured with a protractor.

To find the Average Bisectors, add the Bisector of one Quadrant to the reciprocal of the Bisector of the opposite Quadrant and divide by two. The Average Bisectors are taken to the nearest five deg., e.g. 308 deg. — 310 deg.

THE PROCEDURE TURN

The Procedure Turn enables a pilot flying on instruments along a beam to make a complete 180 deg. turn and fly back along the beam in the opposite direction. Such precision is not necessary when you are flying “visual contact” on the ranges, but should nevertheless, be practiced if you intend to progress to instrument flying later on.

Fig. 13 illustrates a Procedure Turn. The pilot is flying 090° deg. Magnetic on the Beam. First he turns 45 deg. left (in this case 045° deg.) and flies this heading for one minute. Next he executes a Rate One turn of 180 deg. (for one minute) away from the Range Station.
This brings him on to a heading of 225 deg., continuing which he will enter the beam at a 45 deg. angle. On crossing the Beam he then turns to 270 deg. and flies along the edge of the Beam.

**ORIENTATION**

Orientation is the process whereby a pilot on instruments, not knowing his exact position, can identify the Quadrant of a Range which he is in, find a particular leg of the Range and follow it in the right direction to the Range Station.

From this point he can execute an instrument let-down to the airport with sufficient precision to be on the Final Approach Leg with the runway in use directly ahead of him when he breaks out under the overcast.

The procedure necessary to performing an approach and let-down on instruments is a highly complicated and exacting science requiring much skill, precision and practice on the part of the pilot. It is not the purpose of this manual to explore this subject fully. We will, however, touch lightly on the subject of orientation. The information given will be helpful to a student or private pilot flying visual contact in finding his way to an airport should he temporarily have lost his bearings, and will at least provide a beginning to the vast store of knowledge he must acquire should he aspire to a Transport Pilot rating.

**Orientation—Fade-90 Deg. Method**

There are many methods of orientation in use, each of which has its own particular advantages and disadvantages. Some are complicated and limited to Ranges whose Beams cross at—or nearly at—right angles. Others are difficult in the case of a Quadrant with a wide angle, and so on.

The **Fade-90 deg. Method** (sometimes referred to as the Combination, or Standard Method) makes use of a fade or build-up in signal strength to identify the Quadrant, and a 90 deg. turn to identify the Leg. It is generally considered the simplest and most universally applicable of all, and is the only method which will be described here.

A pilot is in the vicinity of a Radio Range, whose signals he is receiving, but does not definitely know his own position. Let us assume it is the Range shown in Fig. 14.

(1) He is receiving an A signal, though he does not know which of the two A Quadrants he is in. He turns on to the Average Bisector closest to the course he is flying—in this case, 120 deg. As he flies in this direction he notices the A signal commencing to FADE. This tells him that he is flying away from the Station and is obviously, therefore, in the Southeast Quadrant.

He makes a 180 deg. turn on to the reciprocal Average Bisector, 300 deg., to take him toward the Station.

(2) He turns on to the Average Bisector nearest to the course he is flying, in this case 300 deg., and notices that he is getting a BUILD-UP. This tells that he is in the Southeast Quadrant and flying toward the Station.

From an original position at (1) or in that vicinity, he will eventually intercept the East Leg of the Range. From an original position at (2) or in that general area, he will intercept the South Leg—but in either case he does not know which leg it will be, and his problem is to identify it.

He holds his heading of 300 deg. until he has flown through the On Course and entered the twilight zone on the far side. He now executes a 90 deg. turn to the right.

In the case of (1) the 90 deg. turn takes him out into an N Quadrant. This definitely establishes the fact that he has crossed the East Leg. He has now only to do a 180 deg. Procedure Turn, bringing him back to the edge of the Beam, which he brackets and flies along the right-hand edge to the Cone of Silence which marks the position of the Range Station.

In the case of (2) the 90 deg. turn takes him back into the On Course. This identifies the Beam as the South Leg. He crosses through it and on reaching the twilight A zone, brackets the right-hand edge of the beam to the Cone of Silence.

After crossing the beam from position (1) and making the 90 deg. right turn, a very strong west wind could conceivably drift him back into the On Course, leading him to believe that he had intercepted the South Leg. The heading he would establish in following the
Occasionally some range stations are characterized by "swinging" beams. Particularly at sunrise or sunset, the beams may swing from side to side as much as 25 deg. (Fig. 17).

Metallic ores or mountains may cause certain beams to "shift" as much as 10 deg. to 15 deg. from their published headings. Stations located at or near tidewater are frequently unstable (Fig. 18).

**THE VISUAL-AURAL RADIO RANGE**

The LF/MF Frequency Radio Ranges, which have been described above, possess many shortcomings. The most serious of these is the static noise encountered in the LF/MF band, which often makes radio reception difficult at a time when it is most urgently required. The LF/MF range is also subject to such vagaries as bent beams, multiple courses and night effect.

Complicated procedures, such as bracketing and orientation — which have been only partially covered in this manual — demand much skill and concentration on the part of the pilot. To overcome these disadvantages, the VHF VISUAL-AURAL RADIO RANGE ("VAR") has been developed in the U.S.A.

The Very High Frequency Range offers virtual freedom from static noise interference. It is, however, subject to one restriction, namely limited usable distance. This is because VHF transmission is "Line of Sight."

Although it is possible to receive VHF signals at high altitudes as far as 200 miles away from the station, at lower altitudes its practical operation is reduced to 50 miles. VAR stations are therefore spaced about 100 miles apart on the airways.

The Visual-Aural Radio Range provides instantaneous identification of the Quadrant an aircraft is in without recourse to any complicated orientation procedures. This is accomplished by the combination of visual and aural signals, which will be explained further along.

**Blue and Yellow Sectors**

The field patterns of the visual courses of the VAR (Fig. 20) resemble lima beans in shape. One pattern is modulated at 150 cycles per second (cps). This is the BLUE SECTOR. The other is modulated at 90 cps. This is the YELLOW SECTOR. The localizer instrument which identifies these sectors for the pilot does so by comparing the 90-cycle and 150-cycle signals being received. This results in the needle being deflected into the color area in which the aircraft is flying.

Regardless of the position or heading of the aircraft, the needle will always be deflected in that color area in which the aircraft is flying.
A and N Sectors

Like the conventional LF/MF radio range, the aural courses of the VAR are produced by the keying of the Morse letter N in one sector and the Morse letter A in the other. The identification letters also are transmitted in the same order as in the LF/MF ranges—first in the "N" sector and then in the "A" sector. The field patterns of the signals however, unlike the "figure 8" of the conventional ranges, are lima-bean shaped, similar to the field patterns of the visual courses, and are modulated at a frequency of 1020 cps. (Fig. 21).

The identification signals of VAR ranges are proceeded by the letter "V" (.) followed by a short pause, and then the identification letters. This is to enable a pilot to distinguish instantly between the aural signals of VAR ranges and those of medium or low frequency ranges. (The "V" is transmitted at appreciably higher speed than the location identification letters.)

The Visual Courses and Aural Courses of the VAR are aligned at right angles (Fig. 22). As the VAR is intended primarily to be flown by reference to the visual courses, these are usually aligned with the airway on which the Range is located. On Green and Red Airways, the BLUE SECTOR is on the north side and the YELLOW SECTOR on the south. On Amber and Blue Airways, the BLUE SECTOR is on the west side and the YELLOW SECTOR on the east.

The primary purpose of the aural part of the system is to indicate to the pilot on which side of the range station he is flying. As will be seen from Fig. 22, Quadrant identification is instantaneous, since no quadrant will give the same combination of visual and aural signals as any other quadrant.

The width of the visual courses of the VAR in relation to the needle deflection on the instrument in the cockpit is illustrated in Fig 23. As will be seen, from one-point deflection left covers approximately 4 deg.

From full deflection right to full deflection left covers approximately 20 deg.

![Visual Course Width to Instrument Indication](image)

**Fig. 23. Relation of Course width to Instrument indication.**

**The Omnimrange**

The usefulness of both the LF/MF Radio Range and the Visual-Aural Radio Range is limited by the fact that they only provide four fixed courses. To navigate towards a station it is necessary for a pilot to intercept one of the beams and then fly along it towards his destination. The only time he knows his exact direction from the range station is when he is on one of the courses, or legs.

The present VAR stations in the United States will, in the course of time, be converted to VISUAL OMNIRANGE (VOR) stations.

These function in the static-free VHF channels between 108 and 117 Mcycles. Instead of four fixed legs for aircraft to follow in order to reach a station, the Omni Range beam sweeps completely round the compass at a rate of many times per second—like the hands on a watch. The time it takes the beam to sweep from North to where it reaches the aircraft obviously can be used to calculate the position of the aircraft from the station, or the station from the aircraft. This is done electronically. The Omni range therefore provides a multiple number of courses towards or away from the station, or from any point on the compass.

In addition to providing invisible high ways a pilot may follow in any direction towards or away from an Omni Station, the Omni Ranges may be used to fix his position. This is done by rapidly tuning two Omni Stations, and reading off their bearings. These will give him two position lines. When these are drawn on a map, the point where they intersect will be his Fix.

The principle of the Omnimrange is based on the comparison of the PHASE DIFFERENCE between two radiated signals, the difference in phase varying with change in azimuth.

One of these signals is non-directional. It has a constant phase throughout its 360 deg. of azimuth. It is called the REFERENCE Phase.

The other signal rotates at a speed of 1,800 rpm. It varies in phase with azimuth, and is called the VARIABLE Phase.

At Magnetic North the Reference and Variable signals are exactly in phase. In all other directions, the maximum of the Variable signal will occur at some time later than the maximum of the Reference signal. The time which elapses between the maximums of the two signals at any point will identify the azimuth angle at that point. (Fig. 24).
By way of a simple illustration of this principle, let us use the case of an airport rotating beacon. The beam of light is rotating clockwise at, let us say, six rpm. This is one complete revolution every 10 seconds, or 36 deg. of azimuth per second. Suppose the green airport identification light was timed to flash each time the beam swept past Magnetic North.

Now if we had a stop watch we could determine our direction from the beacon. When we saw the flash of the green light, we would start the watch. When the rotating beam swept past us, we would stop it. The number of seconds shown on the watch multiplied by 36 would be our magnetic bearing from the beacon.

Example: Time between flash of green light and sweep of rotating beacon past us is four sec. 4 x 36 = 144. Then our bearing from the beacon is 144 deg. Magnetic. Fig. X.

This is exactly what the Omirange equipment does for a pilot, except that the timing between the reference and variable signals is done electronically, and the bearing obtained is automatically indicated by a pointer on the dial of an instrument in the cockpit.

Several different types of aircraft instruments are in use for working the Omni Ranges. These are all visual. Though they vary individually in method, they all achieve the same purpose, that of keeping the aircraft accurately on course. The pilot need never worry about compass corrections, variation or deviation! No matter what his drift is, the compensating crab will be automatic — because the Omni is position sensitive, not heading sensitive.

In order to quickly acquire "know-how" to fly the Omirange accurately and without effort, it is most important that you thoroughly understand that last statement above. The Omni instruments in your cockpit (which we will describe in the following paragraphs) are designed to tell you the bearing or direction of your aircraft from the Omni Station — regardless of the direction the nose of your airplane may be pointing (See Fig. 28). In other words, the Omni Bearing is not a RELATIVE BEARING, as in the case of the loop in the radio compass, but a MAGNETIC BEARING between the airplane itself and the Omni Station. When you fly towards or away from an Omni, you do so by maintaining a line of constant bearing. Obviously, to do this, you must keep letting the nose around into wind to prevent the wind from drifting you off the bearing line you are endeavoring to maintain. In doing so, your are automatically correcting for wind drift with no effort or calculation of any kind on your part.

The Omirange Receiver

The Aircraft Radio Corporation Omirange Receiver illustrated in Fig. D may be used to monitor either Omni (VOR), Visual-Aural Radio Range (VAR) or Instrument Landing System (ILS) Facilities.

The knob at the lower left operates both the ON-OFF switch and the VOLUME control.

The crank, lower right, is for tuning. Turn the Tuning Crank until the frequency of the Omirange you wish to receive appears on the circular dial opposite the index pointer, top centre. The receiver illustrated is tuned to 117.1 mc.

For Omni operation, turn the selector switch to "Omni", as shown.

For ILS or VAR operation, turn the selector switch to "VAR LOC" (VAR or Amplitude Localizer) or "PH LOC" (Phase Localizer) whichever is appropriate to the type of signal it is desired to receive.

Omni Navigation Instruments
In addition to the VHF Receiver the instruments required for VOR navigation are as follows:

Course (or Bearing) Selector — (Fig. 25). This is a dial graduated in 360 deg. of azimuth, with a rotating hand, or pointer. It has a KNOB which can be used to
set the pointer at any desired reading in degrees on the dial.

Cross Pointer Indicator — (Fig. 26). This is the same localizer instrument which is used in the ILS instrument landing system. It has a row of horizontal dots as a fixed reference to a selected glide approach angle, and a movable horizontal line which indicates whether the aircraft is above or below this path. This feature is not used in connection with Omnisage navigation.

The row of vertical dots provides a fixed reference to a selected “on course” direction—in this case, any one of the infinite numbers of beams which radiate out like the spokes of a wheel from the Omnisage Station are referred to as RADIALS. The movable vertical line, or “needle”, indicates whether the aircraft is on a particular radial, or to the right or left of it.

Since the glide path feature is not required in flying the omnisage, the Cross Pointer Indicator is sometimes referred to as the Deviation Indicator: more often as simply the Left-Right Needle.

Radials are referred to by numbers. The number indicates the magnetic bearing of the Radial away from the Station. e.g.: “Gillam 45” would be the radial you would follow if you wished to fly in a direction Magnetic Northeast FROM Gillam Omni Station. The reciprocal of a Radial, or the beam you follow TOWARDS the station, is known as a COURSE. The Course to Gillam would be 125.

When a Radial is used to provide a flight path along a Victor Airway it is no longer referred to as a “Radial” but as a “Victor Airway”. e.g.: Victor Nine (V9).

To-From or Sense Indicator—(Fig. 27). Since the magnetic bearing of an Omnisage Radial can be ambiguous, the Sense Indicator is used to indicate whether the aircraft is on a bearing towards or away from the Omnisage Station.

If the needle points to TO, the bearing is towards the Station from the aircraft. If the needle points to FROM, the bearing is away from the Station towards the aircraft.

A red area lies between the TO and FROM on the dial of the instrument. When the needle lies in the red area it means that an unreliable signal or no signal at all, is being received.

OMNISAGE

To determine the Bearing of an Aircraft from an Omnisage Station:

1. Tune in the Omnisage on the Receiver. The frequencies on which Omnisage Stations transmit may be found on maps (in a box printed blue near the station — Fig. 2) or in Airman’s Guide (U.S.) Air Navigation Radio Aids, or Canada Air Pilot (Can.). Omnisage Stations are identified by three letters in code. e.g.: Indianapolis — IND . . . . . . . . . . In Canada, 2 letters are used, e.g., Toronto — YZ . . . . . . . .

Some Omnisage Stations are identified by a recorded voice identification, followed by three letters in code, e.g.: “Indianapolis Omni” (voice) . . . . . . (IND in code). If the Omnisage Station is unattended and does not provide two-way voice communication, the word “Unattended” will precede the word “Omni”, e.g.: “Cooksve Unattended Omni”. Always listen for the identification signal to be sure you have the right station.

Fig. 7. How an Omnisage is shown on a map.

2. Rotate the hand or pointer on the Course (or Bearing) Selector. As you do so, the vertical needle on the Cross-Pointer Indicator will commence to move towards the vertical row of dots. When the needle becomes centred, the reading on the Course Selector is the MAGNETIC BEARING of the Omnisage Station.

Regardless of the heading of the aircraft, it is somewhere on the bearing line indicated by the Course Selector. However, the bearing may be either the bearing from the station, or to the station. The To-From Indicator resolves this ambiguity.

If, in rotating the hand on the Course Selector until the needle centres, you get a bearing TO the station, but you want a bearing FROM the station instead, simply continue to rotate the hand on the Course Selector another 180°.

Fig. 8 illustrates the sectors in which either a TO or a FROM signal is received when the Course Selector is indicating an omnirange bearing. If the Course Selector reads 160° (left) or 45° (right) from the omnisage station in the centre of the circle, any aircraft that is within the unshaded segment, regardless of the direction the airplane may be headed, will be FROM the station. Any aircraft that is within the shaded portion will be TO the station—even though it may actually be headed in a direction away from the station. Bear in mind, however, that the needle will ONLY be centred when the airplane is actually ON the course or radial indicated on the Course or Bearing Selector, (160° or 45° as the case may be.)

Fig. 8. Omnisage To-From Bearings.
Fix by Omnimrange Bearings

In the same way that we were able to fix the position of an aircraft by Position Lines obtained by compass bearings, (See "Position Lines"—Navigation), we can also obtain a FIX by bearings taken on two or more omni stations.

![Diagram of Omnimrange Bearings](image)

The pilot of the aircraft in Fig. F is flying along a Track, A-B. He wants to check his position. He tunes in the Omni Station Y, and rotates his course or bearing selector until the needle on his cross-pointer indicator is centred. As will be seen, his course selector will read 273° (FROM). He now tunes in Omni Station X, and obtains a reading on his course selector of 185° (FROM). By drawing the two Position Lines, 273° and 185° from the omni stations on the map, the point where they intersect will be his position at the time the bearings were taken.

![Diagram of Omnimrange Bearing](image)

To fly a Course towards an Omnimrange Station:

Suppose you wish to plan a flight from some place on the map to another place where an Omnimrange is located: Measure the magnetic course or track on the map from the place where you are now to the Omnimrange you wish to fly to. (The Magnetic Compass Rose printed around the Omni Station on the map (Fig. 2) is for your convenience in measuring.) The magnetic track you have just measured is the "Course" you intend to make good to the Station.

1. Set the Course Selector to the Magnetic Course you obtained above, which it is desired to make good to the Station.

2. Head the aircraft in a direction calculated to make good the intended Course.

3. Observe the Sense Indicator. Unless the aircraft is more than 90 deg. from the selected Course, the sense indicator will show TO.

4. The Cross Pointer Indicator will now point towards the direction the aircraft must be steered to reach the selected Course. "Steer into the needle" until the vertical line is centred — then simply hold it there.

Note: "Steering into the needle" means turning the aircraft in the direction the needle has moved. If the needle moves to the right, it means the aircraft is getting off course to the left. Apply right rudder to turn the aircraft in the direction the needle has signalled. When the needle returns to zero, it means that the aircraft is back on the desired course.

When you pass over the station, the Sense Indicator will change from TO to FROM. This positively identifies your passage over the station. Suppose you should wish to return to the station. Execute a 180° turn—but be sure to turn the Course Selector 180°. If you do not do this you will be flying a course "towards" a station on a FROM indication. The sensing of the needle will be reversed, and instead of turning "towards" the needle, you will have to turn away from it to centre it.

At any time that you find this to be the case, and turning the plane towards the right moves the vertical needle to the right instead of to the left, it means the sensing is reversed and you are on a reciprocal course to the course intended. A 180° turn will heel you in the right direction—unless, as in the paragraph above, it is your definite intention to fly in the opposite direction. In which case, a 180° adjustment of the Course Selector will put the needle sensing right.

So far we have laid much emphasis on the need of doing no more than simply "flying the needle". Now let us offer a word of caution. Flying the needle can be overdone! Always remember that your omni equipment tells you where you are rather than how to get there. To get there, you must HEAD the airplane in the right direction. Do not become "needle conscious" to the extent of neglecting your "heading consciousness". To navigate by Omni, always turn first to a heading approximately that of the course or radial you intend to make good—then use the needle as a GUIDE to correct the heading, rather than as a primary flight instrument. By doing this, you will avoid swinging wildly back and forth across the intended course or radial, trying to get the needle to stay in the centre. Remember that the Omni bearing and the aircraft
heading will never be very far out of agreement, the difference being the wind correction angle. So centre the needle by making gentle corrections to your heading rather than concentrating on the needle itself, and you will find that flying the omni is the easiest thing you ever tried to do.

To Fly a Radial away from an Omnimrange Station:
The procedure is exactly the same as that described above, except that the aircraft is headed in a direction calculated to make good the Radial away from the Station, and the Sense Indicator will read FROM.

Cone of Ambiguity
Over any Omnimrange Station there exists a CONE OF AMBIGUITY. Within this Cone, the To-From and Cross Pointer Indicators will swing violently and the Course Selector will spin.

Errors of the Omnimrange
"Site Effect" Error is caused by topographical features in the immediate vicinity of the Omni Station — such as fences, power lines, buildings, etc.

"Terrain Effect" Error is produced by the reflection of signals during flights in the close vicinity of mountains, or in "shadow" areas caused by mountains masking out the signals.

Receiver Error is caused by the failure of a particular receiver to translate the signal received into an accurate bearing indication.

Ground Station Error is due to faults in the structure or equipment installed at a particular Omnimrange Station.

The vagaries of the VOR system are not of great magnitude compared with those of the LF/MF Radio Range. Site and Terrain Errors are experienced for short periods and tend to average out before the plane can respond. Receiver Error can be eliminated by careful selection and proper maintenance of good reliable equipment. Ground Station Error, the most serious of those enumerated above, is seldom in excess of two degrees, and in no case greater than 3½ degrees of error in displacement, plus or minus.

These vagaries of the Omnimrange appear in the form of minor irregularities such as course roughness, occasional brief flag alarm activity, course deflections, and limited distance range. Over unfamiliar routes, be on the alert for these abnormalities.

The LOW FREQUENCY OMNIRANGE (MOR) is identical to the VOR in principle but operates on frequencies between 385 and 415 kc. It is designed for long distance radio navigation.

The TERMINAL VOR (TVOR) is a low-powered (50 watts) Omnimrange intended primarily for installation in terminal areas. (On or adjacent to an airport) to provide navigation guidance to aircraft during approach and let-down to the airport.

The LOW POWER (LVOR) is essentially the same as a TVOR and is intended primarily for installation in en route areas to supplement the navigation aid service provided by the VOR (Omnirange) system. The LVOR serves as a "gap filler" between Omni Stations in the VOR system.

TVOR and LVOR facilities operate in the 108.0 — 112.0 mc. frequency band.

VICTOR AIRWAYS
A network of VHF Airways has been established in the United States which make use of Omnimrange facilities instead of the low frequency radio ranges which are located along the older Airways system. The new Airways are referred to as 'VICTOR' (or 'VOR') AIRWAYS. They are flown by reference to Omni Stations which are located approximately 100 miles apart along the Airways. The 'VICTOR' Airways are numbered like highways. Odd numbers run north and south. Even numbers run east and west.

VICTOR Airways which offer the most direct routes between points are designated PRIMARY ROUTES. Others, which parallel them, are designated ALTERNATE ROUTES. The Alternate Routes are referred to by their geographical proximity to the Primary Routes. For example, "VICTOR Three East" (V 3 E) would lie east of "VICTOR Three" (V 3).

VICTOR Airways, like the lower frequency Airways, are 10 miles wide. They are overprinted in blue on aeronautical charts. Primary Routes are represented by solid lines. Alternate Routes are indicated by broken lines.

See also "Airways" (Airmanship).

For the purpose of traffic separation, the Airways are divided into 1000-foot levels (*indicated height above sea level*). If you are flying north or east bound — you fly ODD heights. (e.g. 1000' - 3000' - 5000' etc.) If you are flying south or west bound — you fly EVEN heights. (e.g. 2000' - 4000' - 6000' etc.)

When flying Victor Airways, you fly the Omni Radial which lies down the centre of the airway.

Under conditions of low visibility it is extremely important to fly close to the centre line of the airway, particularly in the vicinity of terminal areas. An adjacent VICTOR Airway may lie as close as 15° to the one you are using—on which other traffic may be operating at the same altitude you are. Fig. V shows how a VICTOR Airway appears on an aeronautical chart.

**Fig. V. Victor Airway (Controlled)**

Note that the Magnetic Bearings of the Airway illustrated are exact reciprocals: I.e. 90° and 270°. On the map, these opposing bearings are shown by alternate thick and thin lines, and they are exact reciprocals, due to differences in Magnetic Variation. For example, VICTOR Airway No. V8 is 077° eastbound from Davenport, I11., but 261° westbound from Aurora, I11.

Radar

The name Radar is an abbreviation of "Radio detection and ranging". Principal uses in aviation are (i) Fixing position of aircraft in flight. (ii) Air Traffic control and search and rescue. (iii) Tracking guided missiles. (iv) Bombing at night or through overcast. (v) Detecting thunderstorm activity. (vi) Approach and landing guidance to aircraft (GCA).

Radar operates in the 3,000 - 10,000 mc. frequency band. Super high frequency radio signals reflect back from objects, they strike. Extremely short bursts of radio energy, called "pulses", are fired into space along a "beam" from a highly directional radar antenna. These pulses strike aircraft, ships, buildings and other objects and are reflected back to the sender. The time it takes the pulse to travel to the reflecting object and return, is timed electronically in milli-seconds. If two seconds to determine the distance of the object from the sender. This information is displayed on the face of a cathode ray "scope" or "screen" in the form of a small "blip" of light (see Fig. E. — GCA). The distance of the blip from the sender at the centre of the screen is measured by means of minute "range markers" on the face of the
screen, and its direction by an azimuth scale around the circumference of the screen (not shown). The "beam", which is referred to in radar terminology as a "trace", will only pick up objects towards which it is pointed directly. In order to "see" objects around the entire horizon from the sender's position, the beam is rotated by a scanner.

**RADIO BEACONS**

In addition to the Radio Ranges, several other types of Radio Beacons are in use along the airways.

**Z Type Marker**—These operate on 75 Megacycles and require a VHF receiver in the aircraft for their reception. They transmit a cone-shaped signal field over the station and provide a more positive check than the Cone of Silence, which is sometimes difficult to identify. They are identified by a steady high-pitched sound signal and a light on the instrument panel which reaches maximum brilliancy over the station.

**Fan Type Marker**—These also operate on 75 Megacycles. They are located on the beams of certain radio ranges (usually about 20 to 25 miles from the station) and provide a definite position check for aircraft.

Fan Markers are elliptical in shape and are roughly 3 miles wide and 12 miles long.

The Fan Marker on the first Leg clockwise from True North transmits one dash (—) on the second Leg clockwise from True North, two dashes (— —) on the third and fourth Legs three (— — —) and four (— — — —) dashes respectively. When more than one Fan Marker is located on a Leg, the second Marker from the Range Station emits two dots (.) preceding the dashes, the third three dots (...) etc.

Some Fan Markers are also identified by voice alternating with the dots and dashes, e.g.: "New Rochelle Fan" (voice).

**Bone-shaped Marker**—Bone, or dumbbell shaped markers serve much the same purpose as Fan Markers. Because of their narrow width at the centre (approximately 1 1/2 miles) they provide a more definite Holding Pattern and are provided primarily for approach control.

**Marker Beacon**—These project a fan-shaped vertical projection of narrow dimensions upward on a frequency of 75 mc. They are placed along the line of approach to the runway. Their purpose is to let the pilot know his distance from the field when making an instrument landing approach. The Outer Marker is about 4.5 miles from the approach end of the runway. The Middle Marker is about 3000 feet. Sometimes a Boundary Marker is located about 300 feet. The Outer Marker causes a purple light to flash a series of dashes on the instrument panel. The Middle Marker causes an amber light to flash a series of dots and dashes. The Boundary Marker causes a white light to flash a series of dots. In addition to the visual indications, the pilot may also receive the signals audibly in his earphones.

**Marine Beacon**—These transmit in the Medium Frequency Band a signal consisting of several letters in code. They do not transmit continuously, except when there is fog, but at periods of so many minutes past the hour which are clearly stated on aeronautical charts.

**Racon (Radar Beacon)** is a secondary radar that is triggered by impulses from a primary radar. It comprises a receiver, time-delay device and transmitter. Some means of coding the outgoing pulse is provided. The equipment in the aircraft consists of a primary radar operating on an appropriate frequency for challenging the Racon.

Example: An aircraft flying west of north challenges a Racon east of north. It gets back a coded reply indicating identity, azimuth and distance.

**Compass Locators**—These are low-powered, non-directional radio beacons operating in the 200-400 kc. band. They are frequently installed in the same location as the Outer and Middle Markers. When an aircraft is equipped with dual ADF, they can be used (i) To "home" from the radio range station to the outer marker. (ii) To assist the pilot in executing a holding pattern. (iii) To assist in tracking the approach course, and (iv) To indicate when the markers have been passed.

Compass Locators are identified in the United States by two letters in code. The two letters are derived from the three letter identification of the station. For example, Chicago's identification letters are "CH". The Compass Locator installed at the Outer Marker beacon is identified as "CH" (voice). The Compass Locator at the Middle Marker Beacon is "HI" (...) . Some Compass Locators also have voice identification. e.g.: "Birmingham Outer Locator" (voice) followed by ... ... ("BI" in code).

**Non-Directional Beacons.** Low powered non-directional Radio Beacons operate in the 200-415 kc. band. They are installed at some Fan Markers and at other locations near airports to assist with instrument approach and holding pattern procedures. In the United States they are not directly associated with Instrument Landing Systems, (ILS) as the Compass Locators are.

In Canada, NON-DIRECTIONAL BEACONS may be installed at the Outer or Middle Marker positions of the ILS. They operate, however, independent of the ILS on a continuous basis. They are identified by a single letter. e.g.: Ottawa—"O". The term "Compass Locator" has been discontinued in Canada.

**DME (Distance Measuring Equipment).** The ground equipment (DME Transponder) is essentially a radar. The aircraft equipment indicates distance on a meter.

Example: A plane challenges or interrogates a Beacon, and receives a signal that actuates a mileleage meter showing the distance from the plane to the beacon.

**Loran.** A long range navigation aid to determine the position of an aircraft by means of pulsed radio signals from special land-based radio stations. The aircraft receiver picks up these pulses and measures the time difference between the pulses from a pair of fixed around stations. The indications are reproduced visually on a 3" cathode ray tube in the aircraft. By noting the relative positions of these pulses on the cathode ray tube and applying this data to Loran charts, the navigator can determine his position with great accuracy.

**Decca.** A navigation system which automatically indicates the position of an aircraft at any time on a chart without any calculation on the pilot's part. The chart, called a "Flight Log", is displayed in a case about the size of an automobile license plate which is positioned in the cockpit where it is visible to the pilot. The position of the aircraft is continuously indicated on the chart by a moving pen. As the pen follows the movements of the aircraft, it leaves a trace on the chart of the exact Track flown by the aircraft since the beginning of the flight.

The principle of Decca is a chain system of broad-
casting stations transmitting low-frequency signals continuously. The chain consists of a "master" station surrounded by three "slave" stations arranged in a star-shaped pattern. For identification purposes, the slaves are referred to as purple, red and green. The system is based on the phase comparison of the transmissions from the four stations, resulting in a pattern of stationary waves which can be represented on charts as purple, red and green position lines, and numbered for identification purposes. The intersection of two position lines gives a fix. The constantly changing position of the fix — conforming to the movements of the aircraft — is electronically transmitted to the moving pen, which indicates the exact position of the aircraft at any given instant.

GCA. The GROUND CONTROLLED APPROACH system is a method of guiding a pilot on instruments down to the runway for a landing by means of verbal instructions from the ground.

The radar operator on the ground can "see" the plane in the radar scanning screens (Fig. E) which he has in a panel before him. Lines and circles on the scanning screens provide the radar operator with azimuth, range and altitude data which enable him to guide the pilot down to the runway of the airport.

Ground instructions are normally transmitted to the pilot at the present time by voice, but new developments are in progress which will enable instructions to be given visually by television, or by electric impulses which will be transmitted directly to the automatic pilot.

One advantage of the GCA system is that it does not require heavy complicated equipment in the aircraft. A radio receiver and normal flight instruments are all that are required.

The GCA system can be used (i) to lend valuable assistance to lost aircraft. (ii) To "see" the weather and detect approaching storms. (iii) To control traffic by bringing incoming aircraft to the proper heading, range and altitude for a landing.

Fig. E. GCA Scanning Screens.

Right: The SURVEILLANCE SCREEN. Circular lines are 5 miles apart. The "pips" are aircraft. The radar surveillance antenna, rotating through 360°, scans a radius 30 miles out and 10,000 feet up. Position of every aircraft within a 2,000 square-mile area is continuously shown on the Surveillance Scope.

Left: The GILFILLAN AZEL SCOPE. Exact position of the aircraft is constantly shown on the screen in three dimensions — altitude, azimuth and range. (The aircraft silhouettes have been sketched in to make the principle more easily understood. In actual practice the aircraft appear as pips, the same as in the illustration on the right.) The GCA operator has two such Azel Scopes, one covering a 10-mile area, and the other a 3-mile area. The latter is scaled up to provide greater precision on final approach. The equipment is accurate to within plus or minus ten feet.

Note: If a G.C.A. unit has been inoperative, it requires 20 to 30 minutes to warm up. A pilot requiring G.C.A. should therefore try to alert the facility as far in advance as possible.
ILE. The INSTRUMENT LANDING SYSTEM is a method of guiding a pilot through the overcast to a landing by means of visual reference to instruments in the cockpit.

The system consists basically of two radio projections transmitted from the airport. One is the LOCALIZER BEAM. This is a projection resembling a half-moon shaped disk standing on its edge. Its vertical plane is aligned with the runway and its purpose is to keep the pilot lined up with the runway during his approach. The other is the GLIDE PATH BEAM. This is a projection shaped like a platter lying on its side. This beam guides the pilot along the proper downward approach path to enable him to hit the end of the runway.

The instrument in the cockpit which enables the pilot to follow these two beams is the LOCALIZER or CROSS POINTER INDICATOR. (Insert in Fig. F.) The crossed pointers give the pilot his directions. If he gets off to the right or left of the approach to the runway, the vertical needle tells him which side and how far. The horizontal needle tells him when he is above or below the proper glide path.

Two cone-like projections, the OUTER and MIDDLE MARKER BEACONS, by means of both flashing light signals on the panel and aural signals in the earphones, tell the pilot his distance from the runway as he intercepts the markers.

A further development of the system combines ILS with the automatic pilot, enabling the aircraft to be flown down the two beams to a landing automatically.

Insert shows the Localizer or Cross Pointer Indicator. The instrument illustrated shows the pilot is off the localizer beam to the right, and must steer left "into the needle" to centre the vertical needle and get back on the beam. He is above the glide path, and must fly down "into the needle" to centre the horizontal needle and get back on the glide path.

Note: The above needle indications apply when the pilot is INBOUND towards the field. When flying OUTBOUND away from the field, the needle sensing is reversed.

Always remember that radio navigation aids are a valuable aid to—BUT NOT A SUBSTITUTE FOR—Dead Reckoning. Never neglect your compass nor Pilot Navigation.

Before starting out on a trip on which you intend to make use of the Radio Ranges, always consult the latest issue of AIR NAVIGATION RADIO AIDS. AIRMAN'S GUIDE OR FLIGHT INFORMATION MANUAL.

NOTAMS: Notices to Airmen, are broadcast by Radio Range Stations and are also published in printed form. They convey information of special import regarding the facilities in their respective areas.
Flatspin Fumble’s opinion of aero engines in general can be summed up in his own words: “Most of them are a pile of junk,” he observes. What Flatspin Fumble and a great many other pilots of his limited qualifications fail to realise, is that they are looking straight into the “junkman’s” visage every morning when they shave. The fact that Captain Wise has only a fraction of the number of forced landings that Fumble does, Flatspin grudgingly admits. “Sure, Wise gets all the lucky breaks,” is his simple explanation of this disparity.

Present day aircraft engines are, contrary to Flatspin Fumble’s muddled opinions on the subject, modern masterpieces of precision workmanship and quality material and represent the achievement of years of research and engineering experience in their design.

The fact is, that the life and efficiency of an aero engine depends to an appreciable extent upon the use or abuse the motor suffers at the hands of the pilot. Sudden “gunning” of the throttle places undesirable stresses on the working parts of an engine. Switching off an overheated motor is a form of torture that should be punishable by a heavy fine. Excessive racing of an aero engine progressively reduces the reliability of the engine and the safe period between overhauls.

Proper care and concern in the handling and running of an aero engine at the hands of an experienced pilot will keep that engine off the old age pension long beyond its normal span.

It is by no means necessary that a pilot should learn to be a mechanical engineer, but an elementary knowledge of the principles and construction of internal combustion engines is necessary if the proper procedure in running and handling is to be observed. (Note: An INTERNAL COMBUSTION engine is one in which the heat is created by the burning of the fuel within the engine itself, rather than in an external furnace, as in the case of steam engines.)

**POWER**

An aero engine is frequently referred to as a “power plant” and its product as power. First then, let us consider briefly the basic meaning of these terms. Power may be simply defined as the rate of doing WORK. Work, in turn, is HEAT transformed into ENERGY. The amount of power an internal combustion engine can produce is dependent on the amount of heat which can be generated by the burning gases. This, in turn is limited by the mechanical ability of the engine to transform as much of this heat as possible into useful work.

The standard unit in use for measuring the power produced by an engine is ONE HORSEPOWER. This represents the amount of work done when 33,000 lbs. are raised 1 ft. in one minute.

The power developed within an internal combustion engine is called INDICATED HORSE POWER. Due to friction, etc., all this power is not available for useful work. The power which is available, after friction and other losses, is called BRAKE HORSE POWER.

The total amount of Indicated Horse Power an engine can produce may be represented by the formula:

\[
\text{PLAN} = \frac{P \times L \times A \times N}{33,000}
\]

Where:
- \(P\) = The Mean Pressure in lbs. per sq. inch
- \(L\) = The length of the stroke in feet
- \(A\) = The area of the piston in sq. inches
- \(N\) = The number of impulses (or power stroke) per minute.
"P", the PRESSURE, in an internal combustion engine is obtained by admitting a mixture of vaporized gasoline and air into a cylinder, compressing this mixture, and burning it. As the gases burn, they expand, exerting an enormous pressure on the piston head. The piston is driven down, pushing the connecting rod down, which in turn forces the crankshaft to turn at high speed. Note that the piston is driven down not by an "explosion" of the gases, as is commonly supposed by beginners, but by their burning (or combustion) expansion and resultant pressure.

"L" the length of the STROKE, is the distance the piston travels up or down inside the cylinder.

"A", the AREA of the Piston, means the area of the top or "head" of the piston.

"N," the number of IMPULSES, is the number of times the engine fires in one minute. In a 4-stroke engine this would be equivalent to half the number of revolutions of the crankshaft for each cylinder multiplied by the number of cylinders.

Aviation progress demands continued search for greater and greater power output from aircraft motors. This involves constant improvement in the mechanical ability of engines to produce power from heat.

Since the Horse Power (h.p.) of an engine is the total product of the four factors referred to in the formula, it is obvious that an increase of all, or any one or more of these, will increase the power output of the engine.

"L" and "A", being dependent on the length of the stroke and area of the piston, are fixed and cannot be varied without altering the design of the engine.

"P" and "N", however, are variable, and are the factors which can be stepped up in the search for greater power. Among some of the means adopted to boost mean effective pressure may be mentioned: High compression ratios; Higher octane fuels; Supercharging, improved scavenging, etc.

An engine's power varies in direct proportion to the speed at which it is run. Hence, the pilot may at will vary "N" by manipulation of the throttle. Designers seek to improve this factor by the design of high speed engines.

THE 4-STROKE CYCLE PRINCIPLE

Almost all aircraft engines in use operate on what is known as the FOUR-STROKE CYCLE. This means that the piston travels four strokes (two up and two down) to complete one cycle. During this operation the Crankshaft revolves through 2 complete revolutions.

1. The Induction Stroke

The inlet valve open, the piston moves down from the top to the bottom of the cylinder, creating a partial vacuum in the cylinder. The mixture, under atmospheric pressure, rushes in past the open inlet valve and fills the cylinder. The exhaust valve remains closed.

2. The Compression Stroke

Both valves closed, the piston moves up from the bottom to the top of the cylinder, compressing the mixture.

3. The Power Stroke

Both valves closed. The compressed mixture is fired by a spark from the spark plug. The burning gases, expanding under tremendous heat, create the pressure which drives the piston down with terrific force. This force is sufficient to complete the other three strokes in addition to providing the energy required for useful work.

4. The Exhaust Stroke

Exhaust valve open. The piston moves up from the bottom to the top of the cylinder, pushing the burnt gases out past the open exhaust valve. The inlet valve remains closed.

CONSTRUCTION FEATURES

The two main types of aero engines in current use are RADIAL and IN-LINE engines.

In-Line

In this type of engine, the cylinders are arranged side by side in a row along the crankcase. Each separate piston works on an individual crank-throw.

The practical limit is six cylinders in one row, the reason being that it is difficult to make a crankshaft sufficiently stiff to avoid vibration which would be long enough to accommodate a greater number of cylinders. Where a larger number of cylinders is required, it is customary to arrange these in two or more BANKS. Hence, we have V-Type X-Type and H-Type in-line engines. The latter has two crankshafts side by side.

Many in-line engines are INVERTED, that is, the engine is installed upside down to provide better visibility for the pilot. These obviously must be of the "dry sump" or pressure lubricated type. Otherwise the oil would drain down from the sump into the cylinders.

Advantages:

1. Smoother running.
2. More even cooling.
4. Small frontal area—more streamlined—less drag.
The Tyne is an advanced twin spool high compression engine in the 5,000 h.p. class. It has been designed to give a very low specific fuel consumption and is backed by the unique experience gained by Rolls-Royce in more than 5,000,000 hours operation of gas turbine engines in scheduled airline service.

The Canadair CL-44 long-range transport is a development of the Bristol Britannia for Canadian requirements. The Tyne will also power the Vickers Vanguards ordered by British European Airways and Trans-Canada Air Lines.
Disadvantages:
1. Long crankshaft.
2. Heavier.
3. Less compact and accessible for service and maintenance.

Radial

The cylinders are arranged radially around a "barrel-shaped" crankcase. This type engine has always an odd number of cylinders, (five, seven, nine.

Horizontally Opposed

Extremely popular in the light airplane field, the horizontally opposed engine, as the name implies, has two banks of cylinders working on the same crankshaft which lie directly opposite to each other in the horizontal plane.

The outstanding advantage of this motor type is its flat, or "pancake" shape. While at present confined within the low-cost light airplane engine range, brief mention is deemed necessary here, since the design is ideal for installation of the engine completely inside the wing. The demand for higher speed and lower drag will undoubtedly hasten developments along these lines in the immediate future.

Fig. 6. Gipsy In-Line Engine.

Fig. 7. Lambert Radial Engine.

Cylinders.

Air cooled: The heads are of light alloy for lightness and cooling. Screwed, shrunk or bolted to a steel barrel.

Liquid cooled: Separate steel liners surrounded by a cast light alloy jacket, in which the liquid coolant circulates.

(Note: A CASTING is a metal shape produced by pouring molten metal into a sand mold.)

Pistons and Rings

Pistons are light alloy (usually forged) for lightness and heat conduction.

(Note: A FORGING is a metal shape produced by working or hammering metal, made malleable by heating.)

Pistons usually have two or three rings for compression, that is, to prevent any leakage of pressure between the piston and cylinder walls.

They also have one or more oil, or "scraper" rings to prevent too much oil leaking past the pistons into the combustion chamber.

The Piston Pin (called the "gudgeon" pin in Great Britain) is of case hardened steel hollow for lightness and is "floating" — that is, free to rotate in the piston and connecting rod small end.

Valves and Valve Gear.

With the exception of one or two "sleeve valve" types, most zero engines have mushroom "poppet" type valves.

These are of chrome-silicon or tungsten steel.

Exhaust Valves are generally sodium cooled—that is, filled with sodium which melts and provides quick distribution of heat, thus carrying some of the heat away from the head of the valve to the stem. They are faced with "stellite" which resists burning and corrosion.

Valve Seats are nickel-chrome-manganese steel, or
114 aluminum bronze, shrunk or screwed into the cylinder.

Crankcase.

In-Line: Made of two light alloy castings joined, the
top half of which carries the cylinders and the bottom
half forms the sump.

Radial: Forged, for lightness and strength. Fre-
quently made in two halves, split through the plane of
the cylinders and bolted together, or sometimes in the
form of a hollow, barrel-shaped shell into which the
cylinders are screwed.

Crankshaft and Connecting Rods.

The Crankshaft is machined from high tensile forged

steel. It is made hollow for lightness and to carry the
oil.

Sometimes made in two or three portions, clamped
together.

The Connecting Rods are steel, forged.

In In-Line engines the Connecting Rod big ends, which
bear on the Crank-pin, may be plain, split, or
forked. The latter enable two connecting rods to work

on one crank-pin, as in the case of V-type engines.

Radial engines have one Master Connecting Rod to
which the others, called Link Rods, are attached by
Wrist Pins.

Reduction Gears.

Many modern engines are GEARED. This means
that the engine turns at higher speed than the airscrew
which it drives. In this way, Geared Engines are made
to develop greater power than direct drive engines
with the same propeller speed.

The gearing consists of two sets of gear wheels. One
of these is driven by the crankshaft and meshes
with the other, which in turn drives the propeller hub
shaft. The reduction in speed is governed by the
relative number of teeth in the two sets of gears.
the propeller shaft is required to be on the same centre line as the crankshaft.

**Fig. 11. Radial Connecting Rod Assembly.**

**Auxiliary Drives.**

The crankshaft drives the propeller. It is also made to drive various AUXILIARY GEARS which in turn drive oil pumps, magnetos, generators, dynamos, air compressors, and other essential auxiliaries.

The auxiliary gears are generally grouped in a GEAR BOX placed at the rear of the engine, to avoid increasing the frontal area.

In some cases a single flexible HALF-TIME SHAFT, driven by the crankshaft, is used to drive all the auxiliary gears.

**COOLING**

We have previously considered the fact that the source of all power is heat. It will therefore be obvious that the modern aero engine, which is a unit designed to develop great power, must generate terrific heat. The heat of combustion reaches temperatures inside the cylinder actually as high as 4500°F. An appreciable portion of this heat is absorbed by the engine parts, the cylinder walls, piston heads, etc. This would cause excessive overheating—to the extent of actually fusing or melting the metal parts—if some means were not provided for dissipating it.

Platspin Fumble’s comments on this seeming anomaly are: “First you create the heat by burning fancy priced high-octane gas, and then you try to get rid of it by coolers, fins, baffles and what have you!”

Which, of course, didn’t make sense to Fumble until he tried coming home one day with his oil pressure low and his temperature running as high as the gauge could register. Having to buy a new engine made quite an impression on Platspin’s mind with respect to the need for adequate cooling of aero engines!

**Air Cooling.**

In air-cooled engines, FINS are added to the cylinders. These provide a greater area of metal to absorb the heat, which in turn is carried away by the air flowing past the cylinders.

Baffles are frequently used to distribute the cooling air around the cylinder heads. In In-Line engines, AIR PASSAGES are provided to carry the airflow past the cylinders.

**Liquid Cooling.**

In liquid cooled engines, the cylinders are surrounded by jackets containing the cooling liquid which absorbs the heat and in turn dissipates it to the air through the medium of a RADIATOR.

The cooling liquid most commonly in use is ETHYLENE GLYCOL. This has a boiling point around 260°F, and (mixed with water) a freezing point around 30°F.

**Advantages of Liquid Cooling:**

- Engine completely enclosed—less drag.
- More even cooling.
- Disadvantages:
  - Extra weight of liquid and cooling system.
  - Danger of leaks.
  - Vulnerability in war time.

**Composite Cooling.**

In this type of cooling system the water is allowed to boil. The steam is then condensed, and the condensate returned to the cooling system.

**LUBRICATION**

Lubricating oil has four important functions to perform:

1. Cooling—Carries away excessive heat generated by the engine.
2. Sealing—Provides seal between piston rings and cylinder walls, preventing “blow-by” loss of power and excessive oil consumption.
3. Lubrication—Maintains oil film between moving parts, preventing wear through metal to metal contact.
4. Flushing—Cleans and flushes interior of engine of contaminants which enter or are formed during combustion.

**Requirements of Good Oil**

1. Viscosity—i.e. **Resistance to flow. “Stickiness” or “body.”**

Good viscosity gives proper distribution of oil throughout the engine and prevents rupturing of the oil film which lubricates the engine parts over the wide range of temperatures in which aero engines work. An oil with a high VISCOSITY INDEX is one in which the changes in viscosity, due to widely varying operating temperatures, are small.

The use of oil of too high Viscosity for existing climatic temperatures will cause **high oil pressure.**

The use of oil of too low Viscosity for existing climatic temperatures will cause **low oil pressure.**

2. High Flash Point—i.e. **The temperature beyond which a fluid will ignite.** This should be in excess of the highest engine temperature.

3. Low Carbon Content — To leave as little carbon as possible should oil work past scraper ring and burn. Also low wax content.

Oils which have good resistance to deterioration and the formation of lacquer and carbon deposits are said to have good **OXIDATION STABILITY.**

4. Low Pour Point—i.e. **The temperature at which a fluid solidifies.** Necessary for cold weather starting.

**Additives** — Some oils contain ADDITIVES. These may be classified as follows: (i) Detergents—Those which improve engine cleanliness. (ii) Oxidation Inhibitors — Those which improve oil stability. (iii) Anti corrosion Additives — Those which deter corrosion. (iv) Pour-point Depressants — Those which lower the pour-point. Also various other “improvers” including
in "wetability" and anti-foaming additives.

It is important that oil which contains additives should be added ONLY to oil of the same type.

The grade of oil recommended for various seasonal aircraft engine requirements is designated by an S.A.E. NUMBER, or as the Saybolt Universal Viscosity AT 210° F., expressed in "seconds". The engine oil grade is, therefore, frequently referred to as, say, S.A.E. 50, or as a "100 second oil". In the United States it is common practice to add 1000 to the Saybolt Viscosity, so that this particular grade could also be referred to as "Grade 1100". For engines of moderate horsepower, the following grades are generally used:

<table>
<thead>
<tr>
<th>Saybolt</th>
<th>S.A.E.</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Fall or Spring</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Winter</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>Arctic</td>
<td>65</td>
<td>30</td>
</tr>
</tbody>
</table>

Oil Temperature

It is necessary to keep the oil temperature in an engine between certain well defined limits. This is because the lubrication of the engine depends on the viscosity of the oil, which in turn is governed by temperature.

If the oil gets too hot, its viscosity will be impaired and may not be enough to keep a good film of oil on the engine parts.

If it gets too cold, the oil will become thick and will not flow through the passage ways, resulting in improper lubrication.

Engine manufacturers always lay down certain limits which must be strictly observed, otherwise the life of the engine may be seriously impaired.

Methods of Lubrication.

1. Force Feed: In this method the oil is forced under pressure from a pressure pump through the hollow crankshaft and lubricates the main and big end bearings under pressure. It is then sprayed through tiny holes to lubricate the remaining parts of the engine by a fine mist, or spray.

2. Splash: The oil is contained in a sump, or reservoir, at the bottom of the engine. It is churned by the revolving crankshaft into a heavy mist which splashes over the various engine parts. This type of lubrication is practically obsolete in present-day aircraft engines.

3. Hand Feed: Certain parts, such as rocker arms, magneto bearings and other external parts, require to be manually lubricated by grease or oil.

Dry Sump Lubrication

A DRY SUMP engine is one in which the oil is contained in a separate tank and is forced under pressure from a PRESSURE PUMP through the hollow crankshaft to lubricate the engine as described in Force Feed above. The oil is then drained into a SUMP from which it is pumped by a SCAVENGING PUMP, which has 20% greater capacity than the Pressure Pump—to insure that the oil does not accumulate in the engine. Thence it passes through an OIL COOLER and is returned to the tank.

Fig. 14 shows the system of oil circulation in a Dry Sump Engine. The BY-PASS around the FILTER is provided in case, through carelessness, the FILTER should be neglected to be cleaned. In which event, dirty oil is considered definitely a lesser evil than no oil at all! The PRESSURE RELIEF VALVE provides a means of regulating the oil pressure and its BY-pass a safety device in case the pressure should become excessive. Other parts, such as the Oil Temperature and Pressure Gauge will be self explanatory.

CARBURETION

The heat energy in an internal combustion engine is developed from the combustion of a mixture of gasoline and air.

The proportion of gasoline to air is governed by weight—not by volume.

In order to burn a pound of gasoline in an engine, from 14 to 15 lbs. of air are required.

The following fuel air ratios (by weight) indicate the effect, on a typical engine, of varying the Mixture Ratio at full throttle, constant speed.

Richest Running Mixture About 1 to 8
Best Power Mixture " 1 to 14
Chemically Correct Mixture " 1 to 15
Lowest Fuel Consumption Mixture " 1 to 18
Leanest Running Mixture " 1 to 20

TOO LEAN a mixture, however, may cause rough engine operation, sudden "cutting out", "popping back" or backfiring, detonation, overheating, or appreciable loss of power.

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Fig. 14. Schematic Diagram, Dry Sump Lubrication System.

Fig. 15. Principle of a Simple Carburetor.
TOO RICH a mixture may also cause rough engine operation, appreciable loss of power, or actual failure.

An engine will run hotter with a lean mixture than with a rich mixture because the lean mixture is slower burning and the cylinder walls are exposed to high temperatures for a longer period of time. Also a richer mixture contains more liquid gas for cooling.

The Carburetor

The FUNCTION OF THE CARBURETOR is to vaporize the fuel (gasoline) and mix it with air in the proper proportion.

Action of the Carburetor

The engine draws air through the VENTURI—(Called in England the CHOKE TUBE) (Fig. 15), which increases the velocity of the air and reduces the pressure. The reduced pressure around the NOZZLE, draws the fuel, which is under atmospheric pressure, from the jet in the form of a fine spray. This is then carried along with the air and mixed with it.

The Mixture, regulated in volume by the THROTTLE VALVE, enters the INDUCTION, or INTAKE MANIFOLD, and thence is distributed to the individual Cylinders.

Some portion of the gasoline does not vaporize and is still left in liquid form when it enters the cylinder. This is vaporized by the heat of the engine. (One of the several reasons why an engine should be warmed up slowly.)

Fuel in liquid form does not burn. When gasoline burns it is really only the vapour coming off the liquid which is consumed.

The gasoline in the carburetor is contained in the FLOAT CHAMBER into which atmospheric pressure is admitted. The level of the gasoline is controlled by a FLOAT, which regulates the fuel entering the Fuel Chamber through the FUEL SUPPLY LINE by means of the FLOAT VALVE, or NEEDLE, which is opened or closed as the float rises or falls.

The level of gasoline in the Float Chamber governs the level of gasoline in the Nozzle, as can be seen in Fig. 15. Should the Float become punctured, gasoline would leak into it, increasing its weight and permitting the level to rise. This would cause gas to flow from the Nozzle, thereby flooding the carburetor.

The Complete Carburetor

The complete carburetor is a highly complicated affair incorporating many devices necessary to control the mixture ratio under widely varying conditions imposed on the modern aircraft engine. As such, it is beyond the scope of this elementary work. Several of the additional working parts, however, should be familiar even to the student pilot and will be briefly described.

Idling

When an engine is idling, the throttle is so far closed that the air velocity past the jet is practically zero and no fuel is drawn from the nozzle. An auxiliary, or IDLING JET, is provided at the edge of the closed throttle, where the air velocity is sufficiently high, owing to the narrow passage, to draw the necessary amount of fuel into the air stream.

Acceleration

During sudden acceleration, the fuel in liquid form which travels to the cylinders along with the vaporized fuel and air, is unable to increase its velocity as rapidly as the latter. This causes a temporary leanness at the cylinders which must be compensated for by temporarily adding more fuel at the carburetor. This is accomplished by the ACCELERATION PUMP. The device consists of a piston controlled by the throttle which works up and down in a cylinder containing gasoline at the float level. The piston is drilled with two holes, beneath which is a CHECK VALVE. When the throttle is opened slowly, the check valve remains open and no fuel is pumped. When the throttle is opened suddenly, however, the check valve closes and the fuel in the cylinder is pumped into the air stream through the ECONOMIZER DISCHARGE NEEDLE.

The Mixture Control

As an airplane goes up, the air gets less dense. A given volume of air, therefore, weighs less. It is obvious then, that at higher altitudes the proportion of air by weight to that of fuel will become less, and the mixture will become over rich, causing waste of fuel and loss of power.

To correct this condition, the MIXTURE CONTROL is fitted to the carburetor. There are many different forms of this device. One of these is a NEEDLE VALVE, which restricts the amount of fuel flowing from the float chamber to the nozzle. Operated by the pilot, it can be used to lean the mixture to compensate for altitude. Another is shown in Fig. 17. This is known as the BACK SUCTION type. A back suction pipe or passage interconnects the air space in the float chamber to the reduced pressure area in the venturi. Closing the Mixture Control Valve restricts the atmospheric pressure entering the float chamber, and the Back Suction Passage reduces the pressure in the chamber. This reduced pressure forces less fuel through the nozzle, and leans the mixture.

Fig. 17. Principle of the Back Suction Mixture Control.

Idle Cut-off

Some engines are fitted with an IDLE CUT-OFF control to stop the engine. This is simply an extreme "lean" position of the Mixture Control, which reduces the pressure within the float chamber to such a low value that no fuel at all flows through the jet. Idle Cut-off will stop the engine immediately with no tendency towards pre-ignition or after-burning. It also makes the engine easy to start since the carburetor and fuel lines remain filled with gasoline.

Automatic Mixture Control

Some engines are fitted with a Mixture Control which automatically compensates for changes in the pressure and temperature of the air entering the carburetor. The device consists of a sealed bellows containing gas which expands and contracts with changes in pressure and temperature. The movement of the bellows is used to operate the Mixture Control Valve
automatically. On some carburetors a single automatic control is provided. On others, the pilot may select "Automatic Rich" or "Automatic Lean". The former is used for take-off and when higher power is required. The latter is used to give the most economical fuel consumption at normal cruise power. Provision is sometimes made for both Manual and Automatic Mixture Control. In this case, the pilot will be able to select "Full Rich" and "Idle Cut-off" in addition to Auto Rich and Auto Lean.

**Carburetor Icing**

Liquid gasoline must be changed into a vapor and mixed with air to become combustible. This is the function of the carburetor. Heat is required to change a liquid into a vapor. Most of this heat is taken from the air which passes through the carburetor and into the manifold. The carburetor thus becomes a miniature refrigerator.

Most air contains water vapor. As the heat is extracted from the air this water vapor condenses, and is liable to freeze. The vaporization of gasoline may lower the temperature in the carburetor and manifold as much as 20° to 60°. It is therefore possible to get carburetor icing with an outside air temperature as high as 85°F.

When atmospheric temperature is below 20°F., the danger of carburetor icing is not serious, since the possibility of water vapor being present in air at such low temperatures is very slight.

Carburetor icing is indicated by a loss of power and, if severe enough, may cause complete engine failure.

All aircraft carburetors are fitted with some means of preheating the air which enters the intake. Many aircraft are fitted with a Carburetor Air Temperature Gauge which tells the pilot the temperature of the mixture. This should be maintained at not less than 35°F. For take-off, however, the carburetor heat control should always be in the COLD AIR position. This is because the full power of the engine cannot be developed when the intake air is heated (heated air has less density than colder air).

The possibility of ice formation may be detected, (in aircraft that are without a Carburetor Air Temperature Gauge) by applying carburetor heat. If no ice is present, the application of heat will cause a loss of power indicated by a drop in manifold pressure. If ice is forming, the application of heat will cause an increase in manifold pressure, because the ice is being removed.

If you do not have a Carburetor Air Temperature Gauge as a guide, apply carburetor heat to test for ice periodically. Continuous use of excessive carburetor air heat at high rpm could lead to detonation.

See also "The Carburetor Air Temperature Gauge".

**FUEL INJECTION**

The Fuel Injection System dispenses with the Carburetor and hence with the hazard of carburetor icing. Other advantages of fuel injection are: (1) More uniform distribution of fuel to all cylinders—since the fuel is separately metered to each cylinder. (2) Better cooling, through the elimination of lean hot mixtures to some of the more distant cylinders. (3) Saving on fuel through more uniform distribution. (4) Increased power through the elimination of carburetor air preheating (heated air has less density than cold air).

Fig. 18, Schematic Diagram, Fuel Injection System.

Fig. 18 is a schematic diagram of a typical Fuel Injection system such as many small aircraft engines employ. The fuel is pumped from the FUEL TANK by the SUPPLY PUMP to the FUEL RESERVOIR at about twice the rate required by the engine. The surplus fuel is by-passed through the RETURN LINE back to the Fuel Tank, but at a restricted rate that maintains the fuel in the reservoir under pressure. The by-pass eliminates any tendency to vapor lock while in operation.

The fuel passes from the Reservoir through the METERING VALVE to the FUEL INJECTION PUMP. The Metering Valve controls the amount of fuel delivered to the Fuel Injection Pump.

The Fuel Injection Pump delivers the fuel to the NOZZLES. These atomize it into a fine spray which is discharged into the air stream entering the Intake Manifold.

The THROTTLE which controls the Air Intake is linked to the Fuel Metering Valve. The fuel and air control units, so linked, are calibrated so that they automatically supply the correct mixture for any particular position of the throttle.

**FUELS**

Fuels for modern high compression engines require to burn slowly and expand evenly rather than "explode" quickly. The fuels which possess this quality are known as HIGH OCTANE FUELS.

The Octane rating of a fuel is arrived at as follows:

Octane is a substance which possesses minimum detonating qualities.

Heptane is a substance which possesses maximum detonating qualities.

The proportion of Octane to Heptane in a fuel is expressed as percentage. Hence, 73 Octane means 73% Octane and 27% Heptane characteristics in the fuel.

The natural gas limit is 72 Octane. Fuels of higher Octane than this are treated with Tetra Ethyl Lead, or are "cracked" by a heat process which increases their volatility. They are also treated with sulphuric acid, lime, etc., to remove the gum, acid and other impurities.

DETONATION means the inability of a fuel to burn slowly. Rather, the fuel starts to burn, but suddenly "explodes". This puts a high stress on engine parts, causing a "ping". Detonation causes overheating, warped valves, piston trouble, etc.

Detonation can be readily distinguished by rising engine head temperature.

Causes: (i) Use of incorrect fuel. (ii) Overheating, sometimes caused by pilot climbing too steeply, thereby reducing flow of air around the cylinders. (iii) Too lean a mixture.
Temporary Remedy: In an emergency, use the choke. This enriches the mixture, which in turn tends to cool the engine due to the evaporation of the raw gas in the cylinders. Also reduce the power as much as possible.

Permanent Remedy: Persistent detonation indicates that a fuel of too low octane is being used. Use fuel of the octane rating ONLY specified by the engine manufacturer.

PRE-IGNITION is another trouble maker which is sometimes confused with Detonation. Pre-ignition, however, is a premature ignition of the mixture due to glowing carbon particles, or other causes of "local hot spots". It is often experienced when attempting to start a hot engine and usually results in a backfire.

Damage to an engine from pre-ignition can be disastrous, causing warped pistons, cracked cylinder heads and other serious damage.

VAPOR LOCK in the fuel line can be caused by high atmospheric temperatures, causing the gas to vaporize and block the flow of liquid fuel in the line.

SUPERCHARGING

An engine designed to operate at normal sea level atmospheric pressure is called a NORMALLY ASPIRATED ENGINE. As has been previously pointed out, in our discussion of the Mixture Control, as altitude increases, the density of the air decreases, causing an over-rich mixture and loss of power.

The SUPERCHARGER is a fan or blower which forces additional air into the manifold (via the carburetor to the cylinders). This is called FORCED INDUCTION.

Forced Induction may be used to increase the power, or "soup up" an engine at low altitudes, in which case the pressure over and above sea level atmospheric pressure which is forced into the manifold is called BOOST.

When Forced Induction is used at high altitudes, however, to make up the deficiency in pressure due to the lower density of the air—and hence maintain sea level power—it is called SUPERCHARGING.

The pressure in the Induction Manifold is known as BOOST PRESSURE and is indicated on a MANIFOLD PRESSURE GAUGE, which registers the actual manifold pressure at any time in INCHES OF MERCURY ("Hg."). A pressure expressed as 29.92 inches of mercury equals 14.69 lbs. per sq. in. pressure at a density of approximately .077 lbs. per cubic foot at Sea Level, Standard Air.

IGNITION

The Polarity of a Magnet

When a bar of iron is magnetised, it acquires a NORTH and SOUTH POLE.

Unlike Poles attract. Like poles repel. Hence the MAGNETIC LINES OF FORCE in a magnet pass from S. to N. inside the magnet, and from N. to S. outside (Fig. 20).

The field in which these Magnetic Lines of Force lie around a magnet is called its MAGNETIC FIELD.

If the bar is bent into a horseshoe, the Lines of Force will flow in the same manner from S. to N. inside and N. to S. outside the magnet (Fig. 21).

If a soft iron bar is placed between the poles of a horseshoe magnet, the Lines of Force will flow through the bar (Fig. 22). This is because the iron offers 280 times less resistance than air does.

Magnetism and Electricity are inseparable. If an electric current is passing through a conductor, a magnetic field will be set up around that conductor. If, on the other hand, a conductor is made to CUT the lines of a Magnetic Field, an electric current will be INDUCED in the conductor.

Consider the soft iron bar (Fig. 22) to rotate, so that it is continually cutting the lines of the magnetic field. An ALTERNATING CURRENT will be continually induced while the bar is rotating.

Here we have the primary element in what is known as the ROTATING ARMATURE TYPE MAGNETO—a horseshoe magnet with a rotating soft iron core, called the ARMATURE, generating a low tension alternating current by induction. In other types of magnetos the magnets rotate and the core is stationary. The principle, however, is the same.

The complete Magneto combines all the elements of an entire ignition system, viz: (1) Generating a Low Tension current as above; (2) Transforming this to high pressure, or High Tension, and (3) Distributing the H.T. Current to the spark plugs.

We shall see how the magneto performs functions (2) and (3) above, but first let briefly consider its most essential parts.

(1) PERMANENT MAGNETS: Horseshoe type Cobalt (or tungsten) steel to retain their magnetism for long period.

(2) ARMATURE CORE: Soft iron. Laminated for rapid magnetising and demagnetising.
(3) PRIMARY WINDING: 200 turns of heavy insulated copper wire. Wound around the Armature Core. Generates Low Tension Alternating Current—about 6 to 15 Volts. 

(Note: Electromotive Force (E.M.F.) is the force or pressure which moves electricity. The unit of E.M.F. is one VOLT.)

(4) SECONDARY WINDING: 12,000 turns of light insulated copper wire. (Ratio to Primary about 60 to 1.) Wound around the Primary. Generates High Tension Alternating Current—about 15,000 to 35,000 Volts.

(5) CONTACT BREAKER: Localized in Primary Circuits. As points open and close, Primary Circuit is opened and closed at the desired moment.

(6) DISTRIBUTOR: Has a rotating arm which makes contact with separate segments as it rotates. Each segment is connected to an individual spark plug. Thus, Distributor distributes current to the separate plugs.

(7) SAFETY SPARK GAP: Located in the Secondary Circuit. An excessive voltage in the Secondary Circuit (usually due to a short circuit in the High Tension Lead) will jump the safety Spark Gap and go to ground, thus preventing damage to the armature.

(8) CONDENSER: Consists of alternate sheets of mica and tinfoil. "Soaks up" the induced current flowing in the Primary when the latter is abruptly arrested by the opening of the breaker points. In this way, prevents the current jumping across the gap and so burning the points.

Burnt Points in the Contact Breaker will cause a low voltage current and hence a weak spark at the plugs. Continual burnt or dirty points are a definite symptom of a faulty condenser.

(9) SPARK PLUGS: Aero spark plugs are specially constructed to withstand terrific heat. For insulation, mica was formerly used but, due to improved processes, porcelain insulated plugs are now more generally specified.

When the plugs are cleaned, and the gap adjusted, it is important that they be tested under PRESSURE equivalent to the normal pressure in the engine in which they will be installed.

(10) SWITCH: The switch is located in the Primary Circuit. When an engine is switched "off", the switch is closed. This means that the Primary Circuit is grounded and the breaker points cannot function.

**MAGNETO OPERATION**

The Armature revolves between the Poles of the Magnet and reaches a point where the maximum flow of flux of magnetic lines of force is flowing through the core (about 10° past the vertical). An induced current is being generated in the windings (Fig. 21).

With the Breaker Points closed, the Primary Circuit is complete, and the Primary Current flows through the breaker points to ground.

When the Breaker Points open, the flow of current in the Primary Circuit is arrested. The Magnetic Field around the Primary Winding collapses, falling inwards on itself, and cutting the conductors of the Secondary Winding. A High Tension current is induced in the Secondary Winding.

The High Tension current is then led through a Collector Ring to the Distributor which distributes the current to the individual plug required to fire.

As long as the switch remains open (or on "contact") the Primary Current will flow through the Contact Breaker which "makes" and "breaks" the Primary (by the opening and closing of the points) and so continuously induces a High Tension current in the Secondary at each exact instant that this is required.

At this same instant, the Distributor arm must be contacting the segment of the particular plug which it is desired to fire.

When the switch is closed (or "off"), the Primary Current flows through the switch to ground and hence does not pass through the contact breaker.

Engines are sometimes equipped with what is known as an IMPULSE COUPLING. This is a unit which will, at the time the spark occurs, give one of the magnetos fitted to the engine a brief acceleration and produce a hot spark for starting.
DUAL IGNITION

Modern aero engines are normally fitted with 2 spark plugs in each cylinder, and 2 magnetos. The purpose of DUAL IGNITION is two-fold:

1. Safety. If one system fails, the engine will still operate.
2. Performance. Improved combustion of the mixture increases the power output. The failure of one magneto in a dual ignition system will cause a loss in power of approximately 75 rpm, or greater, at normal engine cruising speed.

SHIELDING

To prevent the ignition currents interfering with radio, the whole ignition system—magneto, plugs, and wiring, are surrounded with a metal covering which is grounded. This is known as SHIELDING.

TIMING

In discussing the Four Stroke Cycle, we considered the various strokes as beginning and ending as the piston reached the Top or the Bottom of the cylinder. In actual practice, better performance is obtained from the engine by what is known as Valve Lead, Lag, and Overlap. Valves require time to open and close. They are therefore timed to open early and close late in order not to waste any of the induction or exhaust strokes.

Valve LEAD is timing the valve to open early.
Valve LAG is timing the valve to close late.
Valve OVERLAP is allowing both valves to remain open at the same time.

Fig. 24 shows a typical timing diagram for a modern high speed engine. T.D.C. refers to Top Dead Centre, the point where the piston reaches the top of the cylinder, and B.D.C. to Bottom Dead Centre. The circles represent the rotation of the crankshaft, 180° between T.D.C. and B.D.C. Note:
1. That the Inlet Valve opens 15° early on the Induction Stroke.
2. The Inlet closes 75° late on the Induction Stroke. This is to use the momentum of the incoming gases to force the maximum charge into the cylinder.
3. The Spark occurs 25° early on the Power Stroke. This is to allow complete combustion of the mixture so that the maximum pressure is reached when the piston passes T.D.C. and is travelling down on the Power Stroke.
4. The Exhaust opens 70° early on the Exhaust Stroke. This is because any pressure remaining in the cylinder after B.D.C. is passed opposes the motion of the piston coming up on the Exhaust Stroke.
5. The Exhaust closes 20° late on the Exhaust Stroke. This means that both valves are open together, or overlapped on the Induction and Exhaust Strokes for 35°. The Exhaust Valve remaining open late, helps to 'scavenge' the burnt gases. The momentum of the outgoing exhaust gases leaves a partial vacuum in the cylinder which accelerates the entry of the incoming charge.

Valve Timing

VALVE TIMING means timing the valves to open at the right time and meshing the cam gear.

To time the valves on an Aero engine:
1. Disconnect the cam shaft gear from the crankshaft gear.
2. Put the piston at the required number of degrees advance before T.D.C. on No. 1 cylinder.
3. Turn the camshaft until the push rod is just riding the cam.
4. Mesh the cam gear with the crankshaft gear.

An engine is so designed that when the inlet valve is correctly timed on the induction stroke on No. 1 cylinder, all the other valve openings and closings will automatically be timed.

Valve Clearances

A clearance is necessary between the Valve Stem and the Rocker to prevent the valve being forced off its seat when it gets hot and expands. This is called the VALVE CLEARANCE, or sometimes TAPPET CLEARANCE, of the engine.

The clearances are set cold, allowance being made for the correct clearance to be attained when the valves reach their normal working temperature.

Incorrect Clearances

Clearances set too wide will cause a loss of power, vibration and excessive wear.

Clearances set too close are apt to warp the valves and cause serious trouble.

To set the Clearances on an Aero engine:
1. Set each cylinder successively at the top of the Power Stroke.
2. Loosen the lock screw.
3. Turn the adjusting screw until the proper clearance is found with the aid of "feelers". The clearances specified by the engine manufacturer must be rigidly observed.
4. Tighten the lock screw, taking care not to turn the adjusting screw when doing so.

The Valve, or Tappet Clearances on an Aero engine must be adjusted frequently, at least every 20 hours. It is therefore well worth a pilot's time and effort to learn to perform this operation.
IGNITION TIMING

As has been noted above, the spark on modern high speed engines also occurs early to allow complete combustion and maximum pressure to be developed when the piston passes Top Dead Centre and is travelling down.

IGNITION TIMING means timing the magneto to fire at the right time.

To time the ignition on an aero engine:
1. Turn on to B.D.C. on the Compression Stroke on No. 1 cylinder.
2. Turn the crankshaft slowly to the required number of degrees advance, using a timing disk or pointer.
3. See that distributor arm is opposite No. 1 segment.
4. Adjust magneto until the points are just breaking.

Note: Ignition timing requires the utmost precision. It is imperative that the timing set by the manufacturer should be adjusted to the split second.

ENGINE FAULT FINDING TABLE

<table>
<thead>
<tr>
<th>Training Planes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ENGINE WILL NOT START.</td>
</tr>
<tr>
<td>No Spark at Plugs (plugs fouled or incorrectly set—H.T. leads crossed—switch &quot;off&quot; or defective switch—mag, ground wires broken or grounded—defective mag.—wet plugs, leads or mag.</td>
</tr>
<tr>
<td>Weak Spark (breaker points dirty or incorrectly set).</td>
</tr>
<tr>
<td>Insufficient Fuel (tanks empty—fuel cocks &quot;off&quot;—insufficient priming—air vents in tanks clogged—leaks or stoppages in fuel system—defective fuel pump—float needle valve sticking—altitude control open—carburetor tuned too weak).</td>
</tr>
<tr>
<td>Flooding (excessive priming—fuel pressure too high—carburetor tuned too rich).</td>
</tr>
<tr>
<td>Cold Engine (engine stiff to turn).</td>
</tr>
<tr>
<td>Water or Dirt in Fuel.</td>
</tr>
<tr>
<td>Mechanical Defects (plugs loose—cylinders scored—piston rings stuck, broken or scored, etc.).</td>
</tr>
<tr>
<td>Insufficient Cranking Speed.</td>
</tr>
<tr>
<td>Incorrect Throttle Setting.</td>
</tr>
</tbody>
</table>

2. ENGINE MISSES.
   - Defective Plugs (oiled up, incorrectly set, or cracked).
   - Defective Magneto (timing incorrect).
   - Water or Dirt in Fuel Line.
   - Mechanical Defects (sticking valve — crack in cylinder).
   - Low Compression in One or More Cylinders.
   - Cold Engine or Overheated Engine.
   - Lack of Fuel (fuel tank vents clogged—fuel cock not fully open—lean mixture).

3. BACKFIRE.
   - Incorrect Timing (H.T. leads crossed—spark too far advanced).
   - Defective Carburetor (sticking float, needle or toggles).
   - Lean Mixture (dirty filters—altitude control open—fuel pressure low—leaks in fuel system—carburetor tuned too weak).
   - Water, Dirt or Air Lock (in carburetor or fuel line).
   - Sticking Valve.
   - Hot Engine (carbon in cylinders—overheated valves, plugs, etc.).

4. LOSS OF POWER.
   - Defective Plugs (oiled up—incorrectly set).
   - Incorrect Timing (magneto defective—not properly synchronized—faulty wiring—breaker points burned or pitted).
   - Insufficient Fuel (leaks or stoppages in fuel system—defective fuel pump—float needle valve sticking—weak mixture—throttle or carburetor throttle valve not fully open—altitude control open—carburetor iced up).
   - Excessive Fuel (rich mixture—choke open—fuel pressure too high—air intake restricted).
   - Improper Lubrication (wrong grade of oil—incorrect oil temperature—leaks—low oil pressure—dirty filters).
   - Carburetor Heat used Unnecessarily.
   - Loss of Compression (plugs loose—piston rings worn—valve seats worn—clearances out—springs weak—valves warped, stuck, or seating improperly—incorrect timing).
   - Poor Fuel (or water or dirt in fuel).
   - Engine Too Cold, or Overheating.
   - Pre-Ignition.
   - Internal Friction.
   - Engine Needs Overhaul.

5. ROUGH RUNNING.
   - Airscrew or Engine Bearings Loose or Out of Balance.
   - Bent Crankshaft.
   - Defective Plugs.
   - Defective Magneto (timing, wiring, etc.).
   - Incorrect Mixture (too rich or too lean).
   - Wrong Valve Clearance (or sticking valve).
   - Cold Engine.
   - Detonation, or Pre-Ignition.

6. ENGINE STOPS.
   - Lack of Fuel (tanks exhausted—gas cocks knocked "off"—water or dirt in fuel—fuel tank air vents clogged—filters clogged—air lock in fuel system).
   - No Spark (Switches knocked "off"—magneto grounded).
   - Structural Failure (due to faulty lubrication—internal friction—mechanical failure).
   - Over-rich Mixture.

7. ENGINE CONTINUES TO RUN WITH SWITCHES OFF.
   - Defective Switch or Wiring.
   - Overheating.
   - Pre-Ignition.
8. ENGINE WILL NOT TAKE THROTTLE.
Lean Mixture.
Cold Engine.
9. BLUE SMOKE FROM EXHAUST.
Worn or Stuck Piston Rings.
10. BLACK SMOKE OR LONG RED FLAME FROM EXHAUST.
Excessive Rich Mixture.
11. ENGINE OVERHEATING.
Detonation.
Stuck Rings.
Insufficient Oil Supply.
Lean Mixture.
12. EXCESSIVE OIL CONSUMPTION.
Blocked or Frozen Breather (causing excessive pressure).
Sticking Valves.
13. LONG YELLOW FLAME FROM EXHAUST.
Lean Mixture.

STARTING PRECAUTIONS
Refer to Chapter on Airmanship.

STARTING ROUTINE
Refer to Chapter on Airmanship.

RUNNING UP THE ENGINE
Refer to Chapter on Airmanship.

OPERATION OF THE ENGINE
Refer to Chapter on Airmanship.

REFUELLING
Refer to Chapter on Airmanship.

THE PROPELLER

The function of the propeller, or airscrew, is to convert the TORQUE or turning moment of the crankshaft into THRUST or forward velocity.

To do this, the propeller is so designed that as it rotates it moves forward along a corkscrew or helical path.

The propeller blade is an airfoil section, similar to the airfoil section of a wing. As such, it meets the air at an Angle of Attack as it rotates, and thus produces Lift and Drag, in the same way that the airfoil section of a wing does. In the case of the propeller however, these forces are designated respectively as THRUST and TORQUE (Fig. 26).

PITCH

The distance in feet a propeller travels forward in one revolution is called the PITCH.

If the propeller were working in a perfect fluid, the distance it would travel forward in one revolution would be a theoretical distance dependent on the blade angle and diameter of the propeller. This is called the THEORETICAL PITCH or GEOMETRIC PITCH.

In a medium such as air, however, the propeller encounters lost motion and the distance it travels forward is somewhat less than its theoretical pitch. This lesser distance is called the PRACTICAL PITCH or EFFECTIVE PITCH.

The difference between the Theoretical Pitch and Practical Pitch is called Propeller Slip.

The angle at which the blade is set (like the Angle of Incidence of a Wing) governs the pitch. Hence we have "Coarse Pitch", meaning that the blade is set at a large angle, and "Fine Pitch", meaning that the blade is set at a small angle.

A "Coarse Pitch" propeller will travel forward a greater distance with each revolution and hence pull an airplane forward at greater speed—much like the high gear in a motor car.

"Coarse Pitch" is also known as "High Pitch" and is frequently referred to as "Decrease rpm".

A "Fine Pitch" propeller, on the other hand, will have less torque, or "drag", and will consequently revolve at a higher speed around its own axis, thereby enabling the engine to race, or develop greater power, much as the low gear in a motor car does.

"Fine Pitch" is also known as "Low Pitch" and is frequently referred to as "Increase rpm".

Therein lies the disadvantage of the FIXED PITCH propeller. If we choose a Coarse Pitch, we will have a propeller which will develop high cruising speed at comparatively low engine r.p.m. with consequent good fuel economy. On the other hand, we will have poor take-off performance, climb, and top speed.

If we choose a Fine Pitch we will have good take-off, climb and high top speed. But we will have a propeller which will "windmill"—with resultant comparative inefficiency for cruising, both in the matter of speed and fuel economy.

VARIABLE PITCH

To overcome the disadvantages referred to above, propellers whose blade angle, and consequent pitch, may be altered to meet these varying conditions of flight have been developed. Those whose blades may be altered on the ground are termed ADJUSTABLE PITCH PROPELLERS. Those whose blades may be adjusted to various angles by the pilot in flight are termed CONTROLLABLE PITCH PROPELLERS. Others, whose blades automatically adjust themselves to the particular propeller load involved at any given engine speed are called CONSTANT SPEED PROPELLERS.

The methods used for varying propeller pitch may be (i) Mechanical, (ii) Hydraulic, or (iii) Electrical—or a combination of two or more of these methods.

(i) Mechanical Propellers
These propellers are hand controlled by the pilot through direct linkage to the propeller, or by electrically driven motors. Stops are set on the propeller governor the blade angle and travel.

(ii) Hydraulic Propellers
In hydraulic variable pitch propellers, the basic method used to change the propeller pitch is a hydrau-
ically operated cylinder that pushes or pulls on a cam connected to gears on the propeller blades. This cam action is somewhat similar to an automatic screwdriver—you push the handle in, and the screwdriver rotates the screw.

These propellers are divided into two main groups—the COUNTERWEIGHT BRACKET types and the HYDROMATIC types. The first group (Counterweight Bracket type) is further subdivided into two groups as follows: CONTROLLABLE PITCH and CONSTANT SPEED propellers.

Counterweight

In the CONTROLLABLE PITCH PROPELLER, oil pressure is the force that moves the cylinder to twist the blades towards Fine (Low) Pitch, or “Decrease rpm”. This oil is drawn from the engine oil pressure system. Occasionally a gear pump is used to boost the engine oil pressure to ensure quick and positive action on the larger type propellers.) The oil which changes the pitch is controlled by a PILOT VALVE, operated by a lever and linkage from the cockpit.

The force which moves the blades the opposite way, towards Coarse (High) Pitch, or “Decrease rpm”, is Centrifugal Force, generated by the counterweights.

The CONSTANT SPEED PROPELLER uses the same oil pressure and counterweight principal to twist the blades towards the desired pitch angle. In the Constant Speed Propeller however, the Pilot Valve is operated by a GOVERNOR which is manually controlled from the cockpit to select the desired engine rpm. The Governor consists of spinning FLYWEIGHTS mounted at the top of a shaft directly coupled to the engine and rotating at engine speed. When the engine speed increases, centrifugal force causes the flyweights to fly outward—lifting the pilot valve and cutting off the supply of oil pressure to the propeller cylinder. This permits the counterweights to move the blades towards a coarser (higher) angle, thereby decreasing the engine rpm—and automatically restoring the engine speed to the desired constant rpm. The reverse happens when an engine underspeed condition develops.

Particularly in cold weather, the Constant Speed Propeller should be left in “Decrease rpm” when the engine is stopped. In this position, the oil is drained from the cylinder. (Low temperature congeals the oil and makes pitch changing difficult.)

When the engine is started, the propeller should be left in “Decrease rpm” for about 1 minute, then shifted to “Increase rpm” for warm-up. “Increase rpm” should be used for take-off. Also for landing (in case maximum power is required to go around again). For any particular engine speed required for climb or cruise conditions, the pilot selects the desired rpm, and the constant speed propeller automatically maintains the proper blade angle required to keep the engine speed constant—regardless of the airspeed or altitude of the airplane.

Hydromatic

The HYDROMATIC CONSTANT SPEED PROPELLER makes use of a powerful force called CENTRIFUGAL TWISTING MOMENT, which tends to turn the blades towards the Fine, or Low Pitch position. The use of this natural force eliminates the need for the counterweights. (Note that the Centrifugal Twisting Moment moves the blades towards Fine, or Low Pitch—whereas the centrifugal force generated by the Counterweights is used to move the blades towards Coarse, or High Pitch.)

The Hydromatic Propeller uses a piston to twist the blades, which is directly acted upon both sides by oil pressure.

Oil pressure is used to move the blades towards “Decrease rpm”. Oil (at engine pressure) is also used to assist the Centrifugal Twisting Moment to move the blades towards “Increase rpm”. The Pilot Valve is a three-way affair, arranged to (i) Admit high pressure oil to the outboard face of the piston, moving the blades towards “Decrease rpm”, (ii) Close off the supply of oil, holding the blade angle constant, (iii) Admit oil at engine oil pressure to the inboard face of the piston, assisting the Centrifugal Twisting Moment to move the blades back towards “Increase rpm”.

These positions of the pilot valve are controlled by the Governor.

With the Hydromatic Propeller, the engine is started with the propeller in Fine (Low) Pitch, or “Increase rpm”. This reduces the load, or “drag” on the propeller during starting and warm-up.

Feathering

In multi-engined aircraft, when one engine is stopped, it is desirable to “feather” the propeller on the dead engine. FEATHERING means turning the blades to the extreme Coarse, or High Pitch position, where they are “streamlined” and cease to turn. Feathering reduces the drag on the blades. It stops the propeller from “windmilling” and hence causing possible damage to the defective engine. Also excessive vibration.

For feathering or unfeathering, an auxiliary oil pressure supply is required, because when the propeller is feathered the engine is no longer running. This oil pressure is supplied by an Auxiliary or “Feathering” Pump, operated by an electric motor. The auxiliary oil pressure is supplied to either face of the piston to move the blades towards “feather” or “unfeather”, as the case may be, through the pilot valve system. A push-button FEATHERING SWITCH is operated manually by the pilot to feather or unfeather the propeller.

(III) Electrical Propellers

The device used to vary the blade angle in the ELECTRIC CONTROLLABLE PROPELLER is an electric motor which turns the blades through a gear speed reducer and bevel gears. The Governor is similar in principal to that used with the hydraulic propeller, except that the movement of the fly weights in this case opens and closes electric circuits. One circuit contains a field which causes right-hand rotation of the motor. The other contains a field which causes left-hand rotation. The direction of rotation of the motor moves the blades towards “Increase rpm” or “Decrease rpm”, whichever is required.

A two-way switch enables the pilot to select either “Manual” or “Automatic” operation. In the “Manual” position, the propeller operates as a fixed pitch propeller thereby saving the current drain on the battery, and wear and tear on the control mechanism. In “Automatic” control the governor automatically holds the engine speed constant for any desired rpm selected by the pilot.

JET PROPULSION

Flatspin Fumble thinks that it is the blast of air which a jet engine exhausts that pushes it forward. It is not the jet, but the reaction to the jet which provides the forward thrust. Jet propulsion is based on Sir Isaac Newton’s Third Law of Motion, namely that every FORCE will have an equal and opposite REACTION.
Imagine a sphere (Fig. 27) suspended by a cord and filled with pressure. The sphere will remain motionless, because the pressure is exerted evenly against all sides. The pressure at A is balanced by the equal and opposite pressure at B. The pressure at C is balanced by the equal and opposite pressure at D.

![Fig. 27. Principle of Jet Propulsion.](image)

Now punch a hole in the sphere allowing air to escape at A. The pressures at C and D are still equal and opposite. The pressure at B is still pushing on the sphere, but the pressure at A is rushing out of the opening and has nothing to push on. The pressures are now unbalanced, and the pressure at B pushes the sphere forward. The Thrust at A has its Thrust Reaction at B. This is the jet.

The elementary principle of the turbo-jet engine is illustrated in Fig. 28 which is a simple diagram of the gas flow in the Orenda engine.

![Fig. 28. Orenda Turbo jet Engine.](image)

The starter motor is shown at A. Air enters the Air Intakes at BB, at atmospheric temperature and pressure. It is compressed by the ten-stage Compressor, C. It enters the Flame Tubes, DD, and burns with the compressed air to produce terrific heat. The heated gases expand, and the pressure produced turns the blades of the two-stage Turbine G, which in turn drives the Compressor through the Main Shaft F. The jet stream now rushes past the Exhaust Cone H, and out through the Exhaust Tail Pipe at II.

Initially, the jet engine is started by a spark, the same as a piston engine, but as soon as the fuel ignites, the ignition is switched off and the fire burns continuously.

The engine is controlled by the amount of fuel fed to it. Cutting off the fuel stops the engine.

The fuel used is kerosene. Any hydrocarbon, or for that matter hair tonic, can be used in a jet engine as long as it can be blown through a nozzle and burned.

Why do some jet engines leave black smoke trails? Poor combustion.

The fuels used in gas turbine engines consist almost entirely of hydrocarbons — that is, compounds of hydrogen and carbon. When the fuel is burned, the hydrogen and carbon combine to form, ideally, water and carbon dioxide. If, however, the combustion is not complete, particles of carbon are formed which are visible as black smoke.

The engine is lubricated by a pressure spray or flow of mineral oil which is fed to the three bearing assemblies.

Why doesn't the jet blast out the front end of the engine? Because there is a pressure drop through the engine from the nose to the tailpipe, coupled with a tremendous increase in velocity. The highest pressure is experienced in the compressor.

Temperatures in the combustion chambers and around the turbine in a jet engine run as high as 1300°F.

Because of the heat of the jet stream, a person should not stand closer than 150 to 200 feet directly back of the tailpipe.

The jet engine weighs roughly one quarter the weight of a piston engine and propeller of similar power output.

The frontal area of the jet engine is approximately one tenth that of a radial piston engine's frontal area.

The jet engine's power is rated in pounds of static thrust instead of in horse power. At a speed of 375 miles per hour, one lb. of thrust equals roughly one horse power. At 600 m.p.h. at sea level, the Ghost engine's 5000 lbs. of static thrust is equivalent to 8000 true thrust horse power. Assuming 66% propeller efficiency for the piston engine, this would be equivalent to 12,000 h.p.

THRUST is simply "Force"—measured in lbs. (or Kilogrammes).

Like the piston engine, the Jet Engine's power depends upon the weight of air it can consume. As altitude increases, the density of the air, that is, its weight, decreases. That is why superchargers are used to maintain the power of piston engines at altitude. The turbine engine suffers from loss of power at altitude, but this is compensated for by the lower drag (resistance to forward speed) and the "ram" effect of the jet's higher speed, which rams more air into the engine to produce a "supercharging" effect.

The PRESSURE RATIO of a jet engine is the ratio of the air pressure at the intake to that at the outlet. (Do not confuse with "Compression Ratio" of a piston engine.)

**THE TURBOPROP ENGINE**

In addition to jet propulsion, the gas turbine engine can also be used (in lieu of the reciprocating piston engine) to drive a propeller. One of the simplest of the several different methods at present in use for driving the propeller is illustrated in Fig. 30. This is known as the Direct-Connected method. The Turbine drives both the Compressor and the Propeller directly.

![Fig. 30. Turboprop Engine.](image)

**THE BY-PASS ENGINE**

The propeller generates thrust by accelerating a large mass of air to a relatively low velocity. The jet accelerates a relatively small air mass to a very high velocity. For low aircraft speeds the propeller is most efficient. For high aircraft speeds, the jet excels. This
Rehearsal for Mach 3 at 100,000 feet

IROQUOIS development engines have completed over 5,000 hours of bench running in these test cells at Malton and in flight tests.

Over 100 hours were accumulated during a recent series of test runs at the NACA Lewis Flight Propulsion laboratory, Cleveland, Ohio.

Further tests will be conducted in Orenda's new high altitude facility to investigate IROQUOIS performance over the widest range of speed and altitude.

IROQUOIS test results at NACA Lewis Flight Propulsion laboratory, Cleveland, U.S.A.

1. Probably highest dry thrusts recorded in North America for turbosets.
2. Successful operation under sustained high inlet temperatures.
3. Normal weights up to 80,000 feet, the limit of the tunnel, proved effectiveness of Orenda patented method.
4. Attitude handling improvements incorporated within two months.
5. Thrust/weight kn.
6. Thrust—in the 20,000 lb. class (without afterburner)

ORENDA ENGINES LIMITED
MALTON, CANADA

MEMBER A.V. ROE CANADA LIMITED & THE HAWKER SIDDELEY GROUP
Aero Engines

is because the jet engine produces its greatest propulsive efficiency at high aircraft speeds. At low aircraft speeds, its thrust efficiency falls off and its fuel consumption becomes excessive. The Rolls-Royce Conway "By-pass" is designed to improve the efficiency of the jet engine at low aircraft speeds. As will be seen by reference to Fig. X, part of the air from the low-pressure compressor by-passes the high-pressure compressor, the combustion chambers, and the turbine. This relatively low velocity air is mixed with the high speed hot gases from the combustion chambers in the tail pipe—thus reducing the overall velocity of the jet stream.

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THE AFTERBURNER

In a Turbo-jet engine, the ratio of air to fuel is roughly 85 to 1. About a fourth of this air is used to burn the fuel, whose heat expands the air, causing it to rush out the tail pipe at tremendous velocity. The AFTERBURNER is a device designed to use this excess air to burn more fuel, and create a burst of additional power—a sort of violent "kick in the pants".

The Afterburner is a length of tube added to the engine's exhaust tail pipe, through which the stream of jet air is escaping. Fig. XI shows the type of burner assembly used in the Allison Engine afterburner to inject fuel into the air stream and ignite it. It resembles, somewhat, the burner on a gas stove and is designed to provide turbulence and keep the fuel-air mixture from being blown out the tail pipe before it can burn.

The "eyelid" or "clamshell" assembly at the exhaust end is controlled by nozzles that open and close automatically. Its purpose is to enlarge the outlet opening to prevent overheating when the afterburner is turned on.

The Afterburner provides bursts of increased thrust of as much as 35%. This added power is available for take-off, climb, or emergency combat use. Why do we not use this increased power continuously? Excessive fuel consumption—roughly 1½ lbs. of fuel per lb. of thrust.

Fig. XI. Allison Engine Afterburner.

ENGINE INSTRUMENTS

Instrument Markings

For the guidance of pilots, colored bands are used on engine and aircraft instruments to indicate safe operating ranges and operating limits. (Fig. 31).

![Fig. 31. Markings on Instruments]

White—Indicates the operating speed range in which the flaps may be lowered. Used on air speed indicators only.

Yellow—Caution. Indicates that the pilot is approaching the operating range limit.

Green—Shows the normal operating range.

Red—Indicates maximum or minimum limit. Usually a vertical red line, but on some instruments, such as the carburetor air temperature gauge, it may be a red band indicating the icing temperature range, etc.

Oil Pressure and Temperature Gauges

The OIL PRESSURE GAUGE (Fig. 32) indicates the oil pressure supplied by the oil pump to lubricate the engine. The instrument is calibrated in lbs. per sq. in.

The basic principle of the Oil Pressure Gauge is the BOURDON TUBE. A Bourdon Tube is a flat tube of metal bent into the form of a "hook", or half circle. One end of the tube is attached to a pressure tube which leads from the source of pressure. The other end is sealed and connected to links and levers which, in turn, actuate the hand on the face of the instrument. When pressure enters the Bourdon Tube, the "hook" tries to straighten itself out. This motion, via the links and levers, is used to rotate the hand on the face of the instrument. The oil pressure which you read on the gauge is generally obtained at a point between the oil pump and a pressure regulating valve whose function is to maintain any desired working pressure, say 50 p.s.i.

In starting an engine with cold oil in the system, the Oil Pressure Gauge will invariably read high, owing to the difficulty of forcing the sluggish oil through the small aperture in the pressure regulating valve. As the oil warms up and the flow through the pressure regulator improves, the pressure gauge will record the pressure accurately. High oil pressure should cause no concern until the oil is allowed to warm up and reach its normal viscosity, which might require 15 minutes.

If, on the other hand, it remains high, the engine is not getting proper lubrication. High oil pressure will force oil into the combustion chamber. Here it will burn, causing a smoky exhaust and badly carboned piston heads, rings, valve seats, cylinder heads, etc.

Low oil pressure can cause more serious trouble still. If it is permitted to drop low enough, there will be no film of oil at all between the working surfaces of the engine and you will therefore have metal rubbing on metal—with such ruinous results as burned out main bearings, etc. Never let the oil pressure fall...
below the recommended minimum (which is roughly 40% of the maximum pressure at cruising power).

The OIL TEMPERATURE GAUGE (Fig. 33) is an instrument which shows the temperature of the oil in degrees Fahrenheit or Centigrade.

The Oil Temperature Gauge, like the oil pressure gauge, is based on the principle of the Bourdon Tube—except that in this case the pressure which actuates the Bourdon is obtained from a bulb containing a liquid such as Methyl Chloride, which expands or contracts due to temperature changes of the oil in which it is immersed. The expansion of the liquid in the bulb exerts pressure which is led into the Bourdon Tube through a CAPILLARY TUBE. (A Capillary Tube is a metal tube having a fine, almost hair-like bore). The movement of the Bourdon Tube, via links and levers, rotates the hand on the face of the gauge.

There is an intimate relationship between the oil temperature and oil pressure, due to changes in the viscosity of oil which temperature changes effect.

In starting an engine with cold oil, when the pressure gauge reads high, the Oil Temperature Gauge will read correspondingly low. As the oil warms up, both instruments will approach their normal readings at about the same rate.

An abnormal drop in oil pressure and coincident rise in oil temperature is a sure sign of trouble. However, even when the pressure shows no marked rise or fall, increasing oil temperature is a warning of excessive friction or overload in the engine.

Excessive low oil temperature is undesirable. Cold oil does not circulate freely and may cause scoring of the engine parts. Low temperature would be accompanied by a corresponding rise in pressure.

It should always be remembered that oil, in addition to lubrication, acts as a coolant.

The Thermocouple

The THERMOCOUPL, or CYLINDER HEAD TEMPERATURE GAUGE (Fig. 34) records the temperature of one (or more) of the engine cylinder heads.

The Vapour-Pressure Type works on exactly the same principle as the oil temperature gauge described above.

The Electric Type has two wires of dissimilar metals (rhodium and iridium for example) welded together, with the point of the weld embedded in the cylinder head metal, or even protruding into the combustion chamber. When this junction of dissimilar metals is heated, a small galvanic current is set up in the circuit of a Milliammeter. The hotter the junction gets, the higher the Milliammeter reads. The Milliammeter is calibrated in degrees F. or C. instead of in milliamps.

Excessively high cylinder head temperatures are an immediate sign of engine overloading. High head temperatures decrease the strength of metals and result in detonation, pre-ignition and eventual engine failure.

When operating the engine on Lean Mixture, the maximum cylinder head temperature permissible is lower than when operating on Rich Mixture. The engine manufacturer's recommended limits should be strictly observed.

The Carburetor Air Temperature Gauge

The CARBURETOR AIR TEMPERATURE GAUGE (Fig. 35) may be installed to indicate the temperature of the mixture entering the manifold, or it may record the temperature of the intake air entering the carburetor. Its purpose is to warn the pilot of icing conditions in the carburetor which may lead to engine failure.

The Carburetor Air Temp. Gauge is an electrically operated Resistance Thermometer, based on the Wheatstone Bridge principle. The WHEATSTONE BRIDGE consists of four resistance arms, or spools, arranged to form a "bridge" with a galvanometer connected across the centre. (A GALVANOMETER is an instrument for measuring small currents of electricity). When a known voltage supply is connected across the instrument, and the resistance is the same in all the arms, no current will flow through the indicator and the pointer on the dial will register zero. When the resistance in one of the arms is affected by a change in temperature, the current flowing through the system will be unbalanced. The difference will flow through the indicator, causing it to travel in one direction or the other. The variable resistance arm is a bulb, placed where it will be affected by the temperature of the air in the manifold or carburetor intake.

The Carburetor Air Temp. Gauge is, of course, the pilot's guide to the operation of the carburetor heat control unit. Hot air is selected on or off to keep the mixture temperature within the recommended limits.

If the instrument is installed to record the intake air temperature, this should be maintained at around 35° to 40°F. If it is installed to record the intake air temperature, this should be maintained at about 85° to 90°F.

Always select COLD AIR when starting the engine—to avoid the danger of a back-fire.

Never take off with the carburetor heat control on HOT AIR. The full power of the engine cannot be obtained and the take-off run will therefore be prolonged. Bring the carburetor air temperature within safe limits during run up and taxiing, then select COLD AIR for take-off. If icing conditions are suspected HOT AIR can be selected immediately after take-off. Since the full power of the engine is not required for cruising, moderate carburetor heat does not affect the performance of the engine in flight. Excessive carburetor air heat, on the other hand, may cause detonation, and
should be avoided when icing conditions are not present.

When flying in icing conditions, use at least 75% of power to obtain sufficient heat for the carburetor air heater. Maintain cylinder head temperatures as near maximum as possible.

Icing in the carburetor is indicated by a loss of power (drop in r.p.m. and boost) with no change in throttle setting.

When ice has formed in the carburetor, select full HOT AIR until the ice has disappeared. Then maintain only enough to prevent further ice formation.

If the ice is severe and sufficient heat cannot be generated to clear it, a back-fire may succeed in blowing it out. This is done by leaning the mixture — but should only be resorted to in an extreme emergency.

The OUTSIDE AIR TEMPERATURE GAUGE works on exactly the same principle as the Carburetor Air Temp. Gauge—except that it records the temperature of the free air surrounding the aircraft, to warn the pilot of icing conditions. Despite its vitally important function, the Outside Air Temp. Gauge is conspicuously absent on most small training and personal planes. No pilot should expose himself to the risk of icing conditions on this account, since a thermometer purchased in the 5 and 10 cent store, fastened to a strut where it is plainly visible from the cockpit, will adequately serve the purpose.

The Tachometer

The TACHOMETER, or R.P.M. INDICATOR (Fig. 36) is an instrument which shows the speed at which the engine crankshaft is turning in revolutions per minute.

Tachometers are of many types, the more common being (1) Mechanical—either Centrifugal or Magnetic and (2) Electrical—either direct or alternating current.

The Centrifugal Type Tachometer works directly off the rock stub shaft of the engine. As this rotates, it spins a Bowden Cable in a sheathing (as in a car speedometer). The Bowden Cable in turn rotates a shaft to which are attached two flyballs, or inertia weights. The faster these are rotated, the further they fly apart against a spring which tends to pull them together. Hence, at any given r.p.m., they “stratify” in a given orbit. The motion of the flyballs, via links and levers, moves the hand on the face of the dial calibrated in r.p.m.

The Magnetic Type is similar to the automobile magnetic speedometer which utilizes a magnet rotated by the crankshaft. The magnet exerts its influence on an aluminum or phosphor bronze disk, which tends to rotate with the magnet. The induced torque in the disk is proportional to the speed of the magnet and its displacement is therefore a measure of the magnet’s speed. The disk actuates a hand on the dial of the instrument calibrated to indicate rpm.

The Electric Tachometer function in much the same way as the Magnetic Tachometer. An electrical generator at the engine itself transmits an electrical output to a synchronous motor, which, in turn, rotates a magnetic tachometer mechanism.

The rpm is directly proportional to the power output of the engine. 2000 rpm, therefore represents twice the power developed at 1000 rpm. (up to certain limits where the mean piston speed reaches something like 1500 feet per min. and the volumetric efficiency of the engine falls off).

Operating Limits: Operation of the engine at greater speed than that recommended results in excessive mechanical stresses and may cause failure of major engine parts.

When a fixed pitch or controllable propeller is fitted, the rpm is controlled by the operation of the Propeller Governor Control.

The Manifold Pressure Gauge

Supercharging in modern engines is accomplished either (1) by increasing the pressure of the air entering the carburetor, or (2) more commonly, by increasing the pressure of the air-fuel mixture after it leaves the carburetor. The pilot, in order to control supercharging, must know the pressure of the air, or air-fuel mixture leaving the supercharger. The instrument that tells him this is the MANIFOLD PRESSURE, or BOOST GAUGE.

The Manifold Pressure Gauge (Fig. 37) is essentially an aneroid barometer with a metal expansion box similar to that contained in the altimeter. Pressure is admitted to the box by a metal tube led from the intake manifold of the engine. The expansion and contraction movements of the box—due to varying pressure—are transmitted by a multiplying mechanism to the hand on the face of the instrument which is calibrated in Inches of Mercury. Absolute. (ABSOLUTE simply means that the zero of the scale is absolute zero, and not the sea-level atmospheric pressure of 29.92 inches of mercury, which is the zero of many pressure measuring instruments.)

In Britain the manifold pressure is indicated on a BOOST GAUGE, which registers the pressure in lbs. per sq. inch instead of in inches of mercury. Standard sea level pressure, 14.7 lbs./sq. in., is "0" Boost. Pressure above or below this is expressed in pounds plus (+) or minus (−). Since 15 lbs./sq in. equals roughly 30" Hg.—and therefore 1 lb. equals roughly 2" Hg.—it is not difficult to convert British boost to manifold pressure in inches of mercury.

"0 Boost" = 30" Hg. (Approximately)

"+ 1 Boost" (which is 15 +1, or 16 lbs./sq in.) = 32" Hg.

"− 2 Boost" (which is 15-2, or 13 lbs./sq in.) = 26" Hg.

Since the power of the engine may be increased by either (a) increasing the rpm or (b) increasing the pressure, both of which are variables, it follows that there is an intimate relationship between the Tachometer and the Manifold Pressure Gauge.

If the rpm and manifold pressure of an engine at any given altitude are known, and the temperature correction for altitude applied, the brake horse power of the engine can be determined from a chart. Reversing the process, an engine may be operated up to its critical altitude at any power desired by maintaining a
specified boost and rpm. Some engine manufacturers recommend higher rpm and lower boost while others recommend lower rpm and higher boost to obtain a given power. These factors are governed by the design of each particular engine. It is therefore most important that the recommended power settings for any particular engine, for each specified condition, be strictly adhered to. These are usually stated on a placard placed somewhere within the cockpit.

Manifold Pressure Limits: Excessive manifold pressure raises the compression pressure, resulting in high stresses on the pistons and cylinder assemblies. If the pressure exceeds the limit for which the octane rating of the fuel has been selected, detonation will result. Excessive pressure also produces excessive temperature, which may cause scoring of the pistons, sticking rings, and burned out valves.

When increasing power, increase the rpm first, and then the manifold pressure.

When decreasing power, decrease the manifold pressure first, and then the rpm.

B.M.E.P.—BRAKE MEAN EFFECTIVE PRESSURE, means the average pressure within the cylinder during the entire period of the power stroke, from the time the piston is at top dead centre until it reaches bottom dead centre.

METO POWER means "Maximum except take-off" power.

**Operating Range Chart**

The operating ranges for the various engine instruments which we have discussed above are indicated in the following chart—which is for the P & W Wasp Junior engine ONLY. Similar operating data is available for all engines, and should be strictly adhered to in every case.

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<tr>
<td>Warm up</td>
<td>1000</td>
<td></td>
<td>Min. 50</td>
<td>205°C</td>
<td>40°F</td>
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<td>Ground Test</td>
<td>2000</td>
<td>30°Hg, Auto Min.</td>
<td>38°C</td>
<td>100°F</td>
<td>132°C</td>
<td>Min. 4°C</td>
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<td></td>
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<tr>
<td>Take-off</td>
<td>2300</td>
<td>36.5° Auto Max.</td>
<td>85°C</td>
<td>185°F</td>
<td>288°C</td>
<td>Min. 4°C</td>
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<td></td>
<td></td>
<td>Rich</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Maximum</td>
<td>2200</td>
<td>33° Auto Max.</td>
<td>85°C</td>
<td>185°F</td>
<td>250°C</td>
<td>50°F</td>
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<td>30° Auto Max.</td>
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<td>232°C</td>
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<td></td>
</tr>
<tr>
<td>Maximum</td>
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<td>23½° Auto Max.</td>
<td>75°C</td>
<td>167°F</td>
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<td>Lean</td>
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<td>29° Auto Max.</td>
<td>75°C</td>
<td>167°F</td>
<td>205°C</td>
<td></td>
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<td>Lean</td>
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**NOTE:** All frequencies above are as units or as indicated as such. No frequencies are available at any of the listed stations.
Airframes

The reader may never experience the predicament of being down in the Arctic, 500 miles from the nearest outpost of civilization, with a damaged wing bracing strut or undercarriage. Canada’s Northcountry pilots, always noted for their outstanding resourcefulness, have been known, in many such emergencies, to successfully come home on hand whittled propellers, improvised struts and other ingenious make-shift repairs. The average pilot will probably never have occasion, in the course of his career, to rebuild or repair his own plane. Nevertheless, a fundamental knowledge of the components of the airframe, their functions, structure, and particularly their limitations of strength and resistance to deterioration, is a very essential part of his qualifications.

LOADS AND STRESSES

By LOAD, or LOADING, is meant simply weight. The WING LOADING of an airplane is the Gross Weight of the airplane divided by the Area of the lifting surfaces and is expressed in lbs. per sq. ft.—meaning the number of lbs. that each sq. ft. of lifting surface must support.

The SPAN LOADING of an airplane is the gross weight divided by the span, and is expressed in lbs. per foot.

The weight of an airplane standing on the ground (or its weight due to gravity alone) is called a DEAD LOAD.

In flight, however, the weight of an airplane may be increased many times by ACCELERATION, (rapid change of speed and direction). The additional loading imposed is called a LIVE LOAD.

The LOAD FACTOR is the ratio of the Gross Weight of the airplane to the actual Air Load acting on the wings. In other words, it is the ratio of the Dead Load to the Live Load referred to above. When an airplane is in level flight, the lift of the wings is exactly equal to the weight of the airplane. The Load Factor is then said to be 1. When, during a pull out, a steep turn, or other maneuver causing ACCELERATION, the Load on the wings is increased to twice the weight of the airplane, the Load Factor is said to be 2. In a hard landing, the total load acting upward on the wheels may be as much as 3 times the weight of the airplane. This situation is called the LANDING LOAD FACTOR. A Load Factor of 3 is often expressed as 3g’s. In this case refers to “gravity”. Hence, 3g’s means a load on the wings equal to three times the weight of the airplane due to gravity alone.

A Load may be considered as the PRESSURE it exerts. The term is also sometimes used in the sense of the RESISTANCE to a motor of the machinery it drives: e.g., ENGINE LOAD, the resistance to an engine; PROPELLER LOAD, the resistance to a propeller, etc.

A STRESS is the force, or combination of forces, exerting a strain. A pressure of your hand on the surface of, say, an empty cigarette box, is a stress.

A STRAIN is the distortion in form or bulk of a body due to stress. If the cigarette box is crushed, it is said to be strained. A wire stretched is another example of strain.

There are five distinct types of stress:
1. COMPRESSION—or “crushing”, as in the case of the cigarette box. Aircraft wings are subjected to compression stresses.
2. TENSION—or “stretching”, as in the case of the wire. Bracing wires in aircraft are usually in tension.
3. TORSION—or “twisting”. A screwdriver is subjected to severe torsional stress when forcing a screw into hard wood. Undercarriages must be made to withstand torsional stresses.
4. SHEARING—or “cutting”. The blades of scissors exert a shear stress on a piece of paper, which is “sheared” as a result.
5. BENDING—as the name implies, means the bending of a long member due to a load or weight being imposed on it. Aircraft spars, or beams, must resist severe bending stresses.

An airplane structure in flight is subjected to many stresses due to the varying loads that may be imposed. The designer’s problem is to try to anticipate the possible stresses that the structure will have to endure, and to build it sufficiently strong to withstand these. This problem is complicated by the fact that an airplane structure must be light as well as strong.

An airplane designed for a Load Factor of 6 means that the wings are designed to take a load equal to six times the weight of the airplane. This means that the wing will break at a load factor of 6, which is therefore called the ULTIMATE LOAD FACTOR. The load factor at which a permanent set or distortion of the structure begins to take place is called the YIELD LOAD FACTOR. This is usually about two-thirds of the Ultimate Load Factor.

The flight maneuvers which impose high Load Factors are: steep turns, pull-outs, flick rolls, tail slides, and inverted loops. These should be executed with due consideration on the pilot’s part for the stresses which the particular airplane he is flying is designed to withstand.

Other conditions which impose high Load Factors are: (1) Gusts. For this reason, the rougher the weather, the slower the airplane should be flown. (ii) Weight. If an aircraft is overloaded, the allowable load factors will be reduced accordingly and the pilot is likely to damage the structure in maneuvers that would normally be quite safe. Therefore when doing aerobatics always see that the airplane is lightly loaded.

GUST LOAD. Gusts are sudden vertical currents of air. An airplane in a rising or descending current of
air is not affected. When, however, the velocity or direction of the air current changes abruptly—such as when flying at high speed through successive up-and-down gusts—load changes are imposed on the airplane structure. When an airplane flies out of a down-gust, and immediately into an up-gust, for example, the effect on the wings is to suddenly increase the angle of attack. The lift is then in excess of the weight, and the airplane accelerates in an upward direction—just as it would if the pilot suddenly pulled back on the controls. If the total lift were to exceed the total weight by a factor of 2, the airplane would experience a Zg. acceleration. This is known as a GUST LOAD.

Gust Loads can be sufficiently severe to be dangerous. Extremely rough air should be avoided. In moderately rough air, as stated above, speed should be reduced—but not below a safe margin, since there is a risk of stalling the airplane in rough air. The speed which should be maintained is the Maneuvering Speed specified by the aircraft manufacturer in the Flight Manual. See “Airspeed Limitations” (Theory of Flight).

Strength and lightness have been mentioned as essentials in the structure of an airplane. Another factor almost as essential as strength is RIGIDITY. Excessive deflection or bending under a load may lead to a loss of control with serious consequences.

Lack of rigidity may also lead to FLUTTER. This is a rolling or weaving motion which arises when a deflection of a part of the structure causes the air forces on it to change in synchronism with its natural period of vibration. Flutter is most likely to occur in wings and control surfaces and may lead to structural failure. To prevent flutter the wing and tail structures must be made stiff, both against bending and twisting. As referred to in Theory of Flight, the moving surfaces are also frequently mass balanced as a further means of prevention of flutter.

The narrow margin of safety permitted by weight limitation in aircraft makes it necessary that every member must bear its proper share of the load in every condition of flight. To attain uniform and adequate structural safety it is essential to calculate what load each part may be called upon to carry. Such a determination of loads is called a STRESS ANALYSIS. This is a complicated mathematical process, and is distinctly only a job for the trained engineer.

DESIGN

The Characteristics of a Successful Airplane

The designer of an airplane having an engine of known horse power must obtain as far as practicable the following:

(i) The highest possible flying speed, with the lowest possible landing speed.
(ii) The best rate of climb.
(iii) The maximum pay or service load.
(iv) Good range.
(v) The desired amount of stability, with the necessary amount of maneuverability.
(vi) Good all round visibility.
(vii) Simplicity of design to facilitate maintenance and repair.

Essential Structural Qualities

The structural qualities essential to the successful operation of airplanes are:

(i) Rigidity—sufficient to prevent vibration, distortion and flutter.
(ii) Flexibility—sufficient to absorb and distribute shocks and uneven strains.
(iii) Parts that show definite signs of deterioration prior to actual failure.
(iv) Materials which are resistant to corrosion, fatigue and decay.
(v) Best strength-weight ratio.

Requirements of a Successful Airplane

The conflicting requirements of aircraft built for entirely distinct and different purposes, means that a successful airplane must represent some compromise in its design. A fighter, for instance, would be designed for high speed, climb and maneuverability at the expense of load, range, stability and low landing speed. A bomber, on the other hand would require load, range and stability as primary considerations. Having the special purpose for which it is required in view, the requirements of a successful airplane may then be summarized as follows:

(i) The design must be such that the airplane will best perform the operations for which it is built.
(ii) The airplane must be inexpensive to build and suitable for quantity production.
(iii) Repair and maintenance must require a minimum of expense and time.
(iv) The airplane must as far as possible be aerodynamically efficient.

MATERIALS

Woods

SPRUCE: Straight grained and satiny. Used for struts, spars, and in float and hull construction.
ASH: Strong, flexible, coarse grained. Used for longerons, tail-skids, cabane struts, and bent members such as wing tip bows, hull members, etc.
BIRCH: Hard, Tough and durable. Used for propellers.
MAHOGANY: Close grained, hard and durable. Used for plywood covering, rib webs and for deck, hull and bulkhead planking of floats and hulls.

Metals

STEEL: Low Carbon Steels are tough, ductile and readily weldable but are incapable of being surface hardened except by case hardening.
Mild Steels can be hardened to some extent, exhibit greater strength (at the expense of ductility) but are not as easily welded as low carbon steels. Used for fuselages and control surfaces.
High Carbon Steels exhibit increased strength and hardness but at the sacrifice of ductility and weldability.
Alloy Steels, such as Chrome Moly, possess exceptional strength characteristics and resistance to impact and vibration. They are used in the fabrication of fuselages. Alloy Steels containing Nickel (called Stainless Steel) are remarkably corrosion resistant. They are used for stressed skin structures and particularly in boat and seaplane construction.
DURAL: An aluminum wrought alloy containing copper and magnesium. Has a very high tensile strength and fatigue endurance. Susceptible to corrosion but can be treated by anodising. Used for ribs, tanks, bulkheads, propeller blades, fittings, etc., etc.
ALCAD: A Sandwich of dural between two layers of pure aluminum. (The aluminum layers constituting about 5½% of the whole.) Exceptionally corrosion resistant, hence used extensively in seaplane and flying boat construction. Needs no anodising.
MAGNESIUM ALLOY: An alloy in which magnesium forms the principle constituent. Combines great tensile strength with amazing light weight (one-third lighter than aluminum) hence is entering more and more extensively into aircraft engine construction. Very corrodeable in sea water, and should always be anodised.

Fabrics

The fabric now practically standard for aircraft use is mercerized cotton. It is stitched with a double lock seam to form the covering of the airframe, and is then sprayed with dope. This is a solution of cellulose acetate and nitrate which dries quickly, leaving a film that makes the fabric air tight and weatherproof. It also strengthens and shrinks the fabric so that it is as tight as a drumhead.

CORROSION

Corrosion must be treated as the enemy of all metal parts of an airplane. Generally speaking, corrosion is of two types:

(i) Oxidation: This is produced by atmospheric conditions due to the moisture in the air. The effect is worse in the vicinity of salt water. The action consists of the dissolving of the surface by oxidation. Such oxidation is easy to detect. It may be removed and the surface treated with some preventative so further damage will not occur.

(ii) Intercrystalline: This type is more serious. It is caused by chemical or electrolytic action between the alloys in the metal itself. It may not become visible until considerable damage has been done. Surface protection aids very little in the prevention of this type of corrosion. The affected parts must be removed and replaced.

Another form of corrosion may be brought about by two different kinds of metal being placed in contact without first being treated by the process known as CADMIUM PLATING, or METALIZING. This consists of depositing a coating of the resistant solution on the surface of the metal, in terrous metals and anodising non-ferrous metals.

AIRFRAME CONSTRUCTION

The AIRFRAME is the complete structure of an airplane, including the fuel tanks and lines, but without instruments and engine installed. It therefore includes the fuselage, wings, tail assembly and undercarriage.

THE FUSELAGE

Braced Type: In the early days, the fuselage was a frame made up of wooden members, wire braced. These materials are now obsolete, having been replaced by metal. The modern Braced Type fuselage is made up of steel tubes, usually welded or bolted together to form the frame. The LONGERONS (three, four or more long tubes running lengthways) are the principle members and are braced, or held together, to form the frame by VERTICAL or DIAGONAL members, the whole assembly being in the form of a TRUSS. Fig. 1 illustrates two types of steel tube braced fuselage construction, N-Girder, and Warren Truss. Fuselages are sometimes constructed of dural in the form of tubes, (either round or square) "T", or channel sections. The covering may be fabric, metal or plywood.

Monocoque: This type consists of a series of round or oval BULKHEADS held together by STRINGERS (long strips running lengthwise). The Bulkheads carry the loads, the stringers being merely superstructure. The early types of Monocoque construction were of wood, plywood covered. Present Monocoque construction is of metal, metal covered. Since the covering of a Monocoque fuselage must be made stiff, the skin is capable of carrying some of the load. This is known as a STRESSED SKIN structure. A perfect Stressed Skin structure would be one in which the skin, in addition to providing the covering and forming the shape, would be capable of carrying all the load, without any internal bracing. Such a structure does not at present exist, although the increasing development of PLASTICs may be a step in this direction.

Geodetic: The structure resembles a wire basket, the members running spirally around and crossing each other at right angles to form a triangular pattern.

Geodetics form the shape as well as the structure. The members run in geodetic lines, such a line being the shortest distance between two points on a curved surface. The arrangement of the members is such that they tend to stabilize one another. This provides a structure of great strength.

Hence, the advantages claimed for Geodetics are (1) The saving in weight over other structures, (2) Less vulnerability in war time.

The disadvantages are (1) Such a structure is very difficult to stress. (2) The structure is flexible and hence must be fabric covered. (3) Slow to produce.
The Wing

Four general systems of wing construction are now in use on modern airplanes. These are: (1) Wooden frame, fabric covered. (2) Metal frame, fabric covered. (3) Metal frame, metal covered (main strength in the frame). (4) Metal frame, metal covered (main strength in the covering, or skin). This is known as a STRESSED SKIN, with characteristics similar to those referred to in Monocque Fuselages, above.

For elementary purposes, the conventional two-spar, fabric covered wing, generally used in most training plane types will be described.

The main members in a wing are the SPARS. These are beams running the length of the span which carry most of the load. The two spars are intended to stiffen the wing against Torsion, or twisting, although some wings are constructed with one spar (MONO-SPAR) and some with more than two (MULTISPAR). Wooden spars are made of spruce and may be solid, "box", or "I" beam in section. Some spars are laminated and in cases where the spar runs the entire span of the aircraft it is frequently necessary to splice it.

The RIBS run from the leading to the trailing edge. They are cambered to form an airfoil section and their purpose is to give the wing its shape and to provide a framework to which the fabric is fastened. The ribs are built up of CAPSTRIPS (or BOOMS) which form the shape and which are reinforced by a web, or a trusswork of little bracing members, in between them. Ribs designed to form the shape of the wing only are called FORMER RIBS. In some cases, ribs stiffened by heavier construction are spaced at regular intervals. These are intended to take compression loads and are called COMPRESSION RIBS. To strengthen the leading edge, nose ribs are sometimes installed between the front spar and leading edge. These are generally known as FALSE RIBS.

In most present day wings, COMPRESSION or DRAG STRUTS are used in place of compression ribs.

They serve the same purpose and are usually steel tubes installed between the front and rear spars.

Further internal bracing is secured by DRAG and ANTI-DRAG WIRES. These are wires running diagonally from the front to the rear spars, the drag wires taking drag loads and the antidrag wires antidrag loads, as their names imply.

EXTERNAL BRACING is secured in monoplane types by WING BRACING STRUTS which extend out from the fuselage to about the mid-section of the wing. In biplane types, STRUTS are placed between the wings, well out towards the tips. These are braced by INCIDENCE WIRES which run diagonally between the struts, and FLYING and LANDNG WIRES which run diagonally between the struts and the fuselage. The flying wires transmit part of the load to the fuselage in flight and the landing wires support the weight of the wing on the ground.

Some wings are constructed with no external bracing at all. These are known as CANTILEVER wings. Since there is no external support to such a wing, the spars must be made sufficiently strong to carry the load into the fuselage internally with no outside assistance.

TRANSMISSION OF LOADS — Internally, The load on a wing comes first on the fabric. It is then transmitted to the ribs and from these to the spars and thence carried into the fuselage.

Externally, In an externally braced wing, part of the load is taken by the bracing struts or the flying or landing wires, as the case may be, and thence transmitted to the fuselage.

AILERONS. These are surfaces, usually of airfoil section, hinged to the trailing edge of the wing towards each wing tip for the purpose of lateral control. Their internal construction is much like that of the wing itself. They are usually hinged to the rear spar. In some cases where the chord of the aileron is narrow it is necessary to fit a FALSE SPAR for this purpose.

FLAPS. When fitted, these form a part of the wing structure. Like the ailerons, they are usually hinged to the rear spar. A full description of flaps and their function will be found in the chapter on Theory of Flight.

WING TIP BOW. This is generally a metal tube, curved to give the wing tip the particular shape required.

WING ROOT. This is a section of the wing nearest the fuselage which is usually reinforced to permit the passengers and crew to walk on it.

WING ROOT FITTINGS. The fittings which attach the wing, or the separate wing panels, to the fuselage.
The Tail Unit Assembly

THE TAIL PLANE or STABILIZER. An airfoil placed at the rear end of the fuselage to balance the aircraft and hence provide longitudinal stability.

ELEVATORS. Surfaces hinged on the trailing edge of the stabilizer. To give longitudinal control.

FIN. A fixed vertical surface placed ahead of the stern post to provide directional stability. The fin is usually offset from the centre, or cambered on one side, to offset the slipstream from the propeller.

RUDDER. A moveable surface hinged to the fin to give directional control.

The airfoils comprising the tail unit assembly are similar to, but of lighter construction than those of the main structure. The tail unit is positioned so that it is in the air flow and not blanketed by the main planes or other parts of the structure.

Undercarriages.

The function of the landing gear is to take the shock of landing. Also to support the weight of the airplane and enable it to maneuver on the ground. The earliest type of landing gear was a THROUGH AXLE, similar to the wheel and axle arrangement on a cart or wagon. This is now completely obsolete.

Fixed Undercarriages are of two main types, namely SPLIT AXLE and TRIPOD. The former has the axle bent upwards and split in the centre to enable it to clear obstructions on the ground (Fig. 8). The split axle is suspended on shock cord wound around a fuselage member which enables the whole assembly to spread when the load comes on it. A strut or tie rod is usually incorporated to brace the structure against side loads, and an oleo to absorb the shock of landing. The latter will be described further on.

The tripod landing gear is illustrated in Fig. 7. This consists of three members hinged so as to form a triangle. Two of these are rigid. The third is an oleo leg, designed to telescope and hence shorten its length when the load comes on the wheel. On landing, the whole assembly spreads outwards and upwards until springs, rubber discs, or other devices take the weight.

Retractable Undercarriages are made to retract or fold up into the wing or fuselage in flight. The mechanical means and methods for accomplishing this are many and varied. The wheel may fold sideways outwards towards the wing or inwards towards the fuselage. This is most common on high speed military aircraft where the wing camber is shallow. On most multi-engine aircraft the wheel folds straight back or forward into the nacelle and is left partly projecting. This is to protect the belly of the ship in the case of a wheels-up landing. Some retractable undercarriages are made to turn through 90° as they travel up and so fold into the side of the fuselage.

Most retractable undercarriage legs are cantilever, being a single oleo leg with no external bracing. They are hinged at the top to permit them to fold. The means of retraction may be a hand gear, electric motor, or motor-driven hydraulic pump. Where mechanical means are used, a hand gear is also provided for lowering in an emergency.

Tricycle Landing Gear. The practice of placing a third wheel forward is finding increasing acceptance in modern aircraft design. This prevents nosing over on bad ground or when the brakes grab. It also places the aircraft in flying position at all times, providing better visibility on the ground and greatly facilitating take-off. The front wheel may be fixed or retractable and sometimes steerable.

Shock Absorbers

The purpose of the shock absorber is to prevent landing shock damage to the fuselage or body of the airplane. Pilots may accidentally impose heavy stresses due to faulty landings. If these stresses were not properly absorbed by landing gear they could easily cause failure in the airplane structure.

Shock absorbers may be generally divided into four classes:

(i) Low Pressure Tires: On some types of light airplanes these are the sole means provided for absorbing shocks. The principal difficulty with tires (and some of the other shock absorbing devices) is that they do not dissipate the shock but store it and kick the airplane back into the air after a rough landing.

(ii) Oleo: When the airplane hits the ground the momentum must be absorbed in the undercarriage. To absorb this energy on springs or rubber alone would result in the aircraft being bounced into the air again. On practically all modern aircraft, the energy produced on landing is destroyed by making it force oil (an incompressible fluid) from one side of a piston to the other through a small orifice. The displacement of the oil is thus delayed, which cushions the shock of landing. This is because the bulk of the energy is absorbed in forcing the oil through the restricted orifice.

The simple oleo (Fig. 7) consists of an INNER CYLINDER which is attached to the fuselage and an OUTER CYLINDER fastened to the wheel. On landing these will telescope, and the oil will be displaced from the lower to the upper, but is delayed in doing so by the restricted orifice. Since the oil once displaced, will not return until the airplane again leaves the ground the oleo leg serves only to absorb the shock of landing. Further shocks whilst taxiing or taking off on the
ground are taken by the spring shown in Fig 8 (Oleo-Aerol), or by compressed air, Fig. 9 (Oleo-Pneumatic).

(iii) Rubber: Two types of rubber shock absorbers are in use, usually in conjunction with the oleo to cushion further shocks after landing. These are in the form of rubber DISCS or DOUGHNUTS, and SHOCK CORD, which is an elastic cord wound around two moving members.

(iv) Spring Steel: Used on certain light aircraft with considerable success.

The gear consists of a single strap of Chrome Vanadium Steel bent to form the shape of the complete undercarriage structure. It is attached to the fuselage in a cradle bulkhead by a bolt.

Fig. 7. Simple Oleo. Fig. 8. Oleo-Aerol. Fig. 9. Oleo-Pneumatic.

**Brakes**

The advantage of the use of brakes on aircraft is two-fold:

(i) They provide quick deceleration, or pull-up, after landing. This permits higher initial, or “hotter”, landing speeds, which is important for heavy and high speed aircraft, particularly on short runways.

(ii) Differential, or individually operated brakes, ensure better control after landing, to prevent “ground loops,” etc. They also provide better maneuverability on the ground.

Aircraft brakes operate similar in principle to automobile brakes and are of three types, namely MECHANICAL, HYDRAULIC and PNEUMATIC. They are usually of the internal expanding type which has a SHOE or SHOES mounted inside the BRAKE DRUM. These shoes are forced to expand against the brake drum when pressure is applied. The resulting friction creates a drag on the wheel, causing it to slow down. In the case of the mechanical brake the pressure is applied directly by the pilot’s foot pressing on the BRAKE PEDAL. With hydraulic brakes, the pressure of the pilot’s foot sets up hydraulic pressure in a cylinder. This in turn forces two pistons outward. These are connected to the shoes by CONNECTING LINKS and hence force the shoes to expand. Through a difference in the length of the connecting links, the primary shoe is made to expand first, followed by the secondary shoe. This gives a softer brake action. A WHEEL ADJUSTING SCREW is provided for necessary brake adjustments. Fig. 10 shows a typical Hydraulic Brake.

![Fig. 10. Hydraulic Brake.](https://example.com/fig10)

Most pneumatic brakes are similar in construction to the hydraulic brakes described above, but utilize air pressure to actuate them.

The Principle of the Dunlop Pneumatic Brake is somewhat like the idea of placing an automobile tire on the inside of the brake assembly. Air pressure admitted to this tire, or PRESSURE BAG, causes it to expand, forcing the BRAKE SHOES to move radially outward against the surface of the BRAKE DRUM.

**Engine Mountings**

The engine is supported by a structure, usually of steel tubing welded together, called the ENGINE MOUNT, which is made flexible to absorb vibration from the engine and prevent it from being transmitted to the fuselage. This is usually accomplished by RUBBER BUSHINGS which are made springy in the direction of the engine rotation but rigid otherwise, in order to hold the engine steady fore and aft.

**Fire Wall**

Between the main structure and the engine is the FIRE WALL. This is made of a heavy sheet of stainless steel or often a sandwich of asbestos between two sheets of dural. Openings for fuel and control lines are made small, with bushings to insure a snug fit. The fuel tank must be behind the Fire Wall, whereas the oil tank may be ahead of it—oil being less inflammable than gasoline.

**Tank Installations**

Fuel tanks may be carried in the wings or in the fuselage. They are usually made of thin tinned steel, aluminum alloys, or aluminum. They are fitted with baffle plates to strengthen them and to prevent slopping of the fuel. Two or more tanks are generally fitted (one gravity) in case of the failure of one.

![Fig. 11. Torque Tube Aileron Control.](https://example.com/fig11)
Nylon impregnated with synthetic rubber is a newer material than metal for the manufacture of fuel tanks. It is light in weight, easy to repair, and requires minimum servicing. It offers the unique advantage of great flexibility.

Controls
The control and stabilizing surfaces are operated by systems of separate design.

Ailerons: Three types of control systems are in general use. These are: (i) Cables and pulleys, (ii) Push and pull rods and (iii) Torque tubes (Fig. 11). When stick control is used, any of these systems may be employed. With wheel control, cables and pulleys are generally used, but push and pull rods may be.

![Diagram](image)

**Fig. 12. Push and Pull Rod Elevator Control.**

Elevators: This may be either (i) a Rocking Beam and cable or (ii) a Push and pull rod system (Fig. 12). This is the same whether wheel or stick control is used.

![Diagram](image)

**Fig. 11. Cable Rudder Control.**

Rudder: Almost always a cable system, directly joining the rudder horns and rudder bar pedals (Fig. 13). Pulleys are omitted wherever possible in both rudder and elevator controls.

**FLIGHT TESTING**
Flight testing must be carried out following the erection, re-conditioning, overhaul, major repair or modification of an airplane. At training schools it is a general policy to have instructors test aircraft at the beginning of the day before the students take over.

The procedure for flight testing varies according to the special characteristics of the particular airplane to be tested or the specific nature of the repairs or modifications.

For a General Test the following procedure is suggested:
(i) Test engine on ground and ensure that all engine and aircraft controls function normally.
(ii) Take off, climb to reasonable height, and carry out the following sequence of tests at normal cruising speed:
(a) Fly straight and level to test rigging and all running instruments.
(b) Series of turns to test for manoeuvrability.
(iii) Check engine at full throttle. If supercharged, attain necessary altitude for this test.
(iv) Climb to sufficient height to test altitude control.
(v) II of a suitable type, carry out some aerobatics.
(vi) Check flaps, retractable landing gear, variable pitch, warning devices, etc., during approach to land, if applicable.

**FLYING (RIGGING) FAULTS**

<table>
<thead>
<tr>
<th>Fault</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tendency to Yaw</td>
<td>(i) Fin or rudder not in alignment.</td>
</tr>
<tr>
<td></td>
<td>(ii) Fuselage warped or bent.</td>
</tr>
<tr>
<td></td>
<td>(iii) Drag greater on one side than the other, caused by streamlined wires or struts turned sideways, distorted surface, bombs, generators, etc., on one side.</td>
</tr>
<tr>
<td></td>
<td>(iv) Elevators not in alignment with stabilizer on one side.</td>
</tr>
<tr>
<td>Tendency to Roll</td>
<td>(i) Incidence of the main planes greater on one side than the other.</td>
</tr>
<tr>
<td></td>
<td>(ii) Ailerons out of alignment with the control column central.</td>
</tr>
<tr>
<td></td>
<td>(iii) Dihedral greater on one side than the other.</td>
</tr>
<tr>
<td></td>
<td>(iv) Surfaces distorted, giving more or less lift on one side.</td>
</tr>
<tr>
<td></td>
<td>(v) Unequal distribution of the load due to wing tanks, bombs, etc., giving, in effect, unequal wing loading.</td>
</tr>
<tr>
<td>Nose or Tail Heavy</td>
<td>(i) Stagger incorrect.</td>
</tr>
<tr>
<td></td>
<td>(ii) Incidence of tail plane incorrect.</td>
</tr>
<tr>
<td></td>
<td>(iii) Incidence of main planes incorrect.</td>
</tr>
<tr>
<td></td>
<td>(iv) Loading incorrect.</td>
</tr>
</tbody>
</table>

**Log Books**
The life of the airframe and engine is recorded in the Log Books.
The flying time, repairs, modifications and inspections must be recorded in the Journey and Aircraft Log.
Running time, repairs and modifications, etc., must be recorded in the Engine and Propeller Log(s). These are kept separately from the aircraft log since engines and propellers are frequently changed in aircraft.

**Inspection**
An aircraft must be inspected by a qualified maintenance engineer and certified as airworthy in the aircraft log periodically as specified in Civil Air Regulations. Part 43.22 and 43.23 (U.S.) and Air Regulations, 215 (Can.).

All entries must be signed by an air engineer and the pilot must sign the Aircraft Log accepting the aircraft as airworthy at least daily when the aircraft is flown.
Examination Guide

The sample examination questions which appear in this section are based on those contained in both the Private and Commercial Examination Guides published by the Civil Aeronautics Administration for the guidance of American pilot-trainees. They are designed to assist you in preparing for the "cross country type" examination which is now in vogue. This examination is based on the present-day concept of the airplane as a safe, convenient, and speedy means of transportation. The questions are arranged in logical sequence in the form of an imaginary cross-country flight, and are intended to test your ability to successfully plan and execute the flight, your knowledge of air traffic rules, weather, navigation, radio, and the operation of the aircraft and engine insofar as they apply to safe, efficient cross-country flying.

It cannot be too strongly emphasized that they are SAMPLE QUESTIONS ONLY, not the actual questions which you will be called upon to answer—so do not attempt to memorize the answers. The questions are offered merely as a guide to the subject matter on which they are based. Study that subject matter until you know it sufficiently well to be prepared to answer any question of a similar nature which could possibly be constructed on an examination paper.

The questions are not trick questions. Each statement means exactly what it says. Do not look for hidden meanings. C.A.A. Examination Questions are not based on exceptions to the rule. Each statement is based on the commonly accepted general rule.

Always read the statement first. Be sure you understand what it means. Decide the correct answer in your own mind (or plot it if it is a problem)—before you look at the multiple choice answers. Then select the answer which most nearly coincides with your own reasoning. Remember that only ONE of the multiple choice answers is completely correct. The others may be answers that result from misconception, wrong interpretation of the question, or from incorrect procedure. Be sure that the one you select answers the question completely and specifically.

The correct one of the four multiple choice answers will be found in "Answers To The Questions", following Question 117. Mark your selection of the correct answer before you consult the table.

Do not be discouraged if your answer does not exactly agree with the one which appears in this manual, particularly in the case of questions based on the map sheet, Airman's Guide, or Flight Information Manual. Every effort is made to keep this publication completely up-to-date by constant revision, but changes occur so fast that it is difficult to keep pace with them all. An airport or radio range location may be moved before a new edition appears in print. Omnirange and other VHF radio facilities are particularly subject to alteration of their assigned frequencies or even station location.

In this manual the examinations for private and commercial pilot licenses have been combined in one exercise. Those questions which apply to commercial pilots are marked (C). Those which apply to private pilots are marked (P).

In addition to the knowledge of radio aids required to obtain either a private or commercial pilot's license, a Radio Operator's license is required in both Canada and the United States to operate an aircraft radio transmitter. The examination for the license consists of a few simple questions to ensure that you understand how to operate the set. You are not required to know Morse code or to understand electronic circuits.

Examination Material

Some of the examination questions are intended to test your ability to quickly locate basic flight information in the Flight Information Manual and Airman's Guide. Copies of these publications, together with the appropriate World Aeronautical Chart, are supplied with the C.A.A. examination kit.

Canadian Examinations

The Meteorology-Navigation exam for a Private Pilot's license in Canada is very similar to the C.A.A. cross-country type exam—except that the Canadian counterpart does not involve flight along airways. Separate examination papers on Air Regulations, Aircraft, Engines and Instruments must be written by Canadian private pilot applicants.

At the present time there is no examination on Radio Aids for private pilots in Canada. However, an elementary knowledge of this subject will be required at a future date and private pilots using this manual would be well advised to familiarize themselves with the type of questions which appear in the exercises which follow.


For the benefit of Canadian students, sample types of exam. questions which may possibly appear on the Department of Transport papers above (which are not covered in the C.A.A. cross-country examination) have been added in the form of a supplement "Canadian D.O.T. Questions".
Study Material

A knowledge of the information contained in the following publications is mandatory. They should be studied in detail before attempting the examination, and retained for continuous reference afterwards:

Civil Air Regulations (CAR) Part 43. (5c) The section of air regulations (U.S.) governing general operating rules, aircraft requirements, maintenance, instruments and equipment, general piloting rules, student, private, and commercial privileges and limitations.

Civil Air Regulations (CAR) Part 60. (10c) The section of air regulations (U.S.) governing operation over the high seas, authority of the pilot, general, visual and instrument flight rules.

Flight Information Manual. (50c) A C.A.A. publication issued annually. Covers air navigation lighting and radio aids, ADIZ, air traffic control procedures, approach lighting systems, direction-finding data, good operating procedures, radar weather advisory and weather bureau service, standard broadcast station data, search and rescue, VOR receiver check points.

Airman's Guide. ($2.25 per year) A C.A.A. publication issued bi-weekly. EVERY issue contains special notices to airmen, including current condition of facilities, restrictions, changes in restricted areas, location identifiers, minimum IFR en route altitudes, civil airways, control areas, zones and reporting points, VOR receiver check points, standard instrument approach procedures, etc. Every OTHER issue contains radio facility data — lists radar facilities, instrument landing systems, and radio facilities with their frequencies, identification, station class, range courses, and other data. EACH QUARTERLY issue carries the directory of airports — type, class, elevation, runway lengths and numbers, lights, service, obstructions, fuel grades, weather information available, Unicom, etc.

The above publications are all obtainable from U.S. Government Printing Office, Washington 25, D.C.

The Air Regulations. (25c) The official authority in Canada governing registration, certification and marking of aircraft, aerodromes, personnel licensing, rules of the air, VFR, IFR, lights and signals, air traffic control, commercial air service operations, and certain miscellaneous provisions.

Air Navigation Orders. Cover much the same subject matter as the Air Regulations, but are more specific and detailed in their contents.

Information Circulars. Are issued as required, and cover practically every subject to do with aviation in Canada. They are of an informative nature, whereas the Air Regulations and Navigation Orders are mandatory.

Notams. Are issued as required, and deal mostly with matters of a more urgent nature, such as danger, prohibited and restricted areas, obstructions, restrictions, airport construction, new facilities, changes in navigation and control procedures, etc.

Air Navigation Radio Aids. A D.O.T. publication issued every two months. Lists general information on radio facilities, including VHF aeronautical frequency plan, radio ranges, communications, weather broadcasts, calling procedures, etc., Loran stations, notam code, directory of D.O.T. offices, radio range and radio beacon stations, GCA station listings with their radio frequencies, weather broadcast times, range courses, ILS, etc.

The above are all obtainable from the Department of Transport, Ottawa, Ontario.

The following publication, while not a "must" for examination requirements, contains extremely valuable information for both VFR and IFR operations, and should be in the possession of all Commercial and Transport pilots in Canada:

Canada Air Pilot. ($5.00) Published in two volumes, East and West of Winnipeg respectively. Contains complete and detailed data on all aerodromes, seaplanes bases, customs airports, radio ranges (VOR and LF/MF), airways, radio stations, beacons, broadcasting stations, fan markers, radio frequency bands, instrument approach and landing procedures, D/F procedures, ADIZ, SIZ, and mountain regions. Radio Facility Charts show all airways with their radio facilities, magnetic bearings, minimum altitudes, and distances between reporting points, etc. Aerodrome Charts show airport runways, radio aids, instrument landing procedures, field data, ground facilities, etc.

The above publication is obtainable from the Surveyor General, Department of Mines and Technical Surveys, Ottawa, Ontario.

The following texts contain useful information on the subjects on which the examinations are based:

Path of Flight. (75c) An introductory booklet presenting basic elementary information about the navigation of aircraft.

Facts of Flight. (50c) A short, concise text presenting basic and practical information about the safe operation of aircraft.

Pilot's Radio Handbook. (55c) A radio guidebook which presents simple explanations on how to use your radio effectively.


Flight Instruction Manual. ($1.50) A basic reference manual containing information on theory of flight, principles of safe flight, inspection and care of aircraft, and performance and analysis of flight maneuvers.


The above publications are obtainable from the U.S. Government Printing Office, Washington 25, D.C.

Elementary Flying Training Manual. (22.50) A complete guide and handbook of instruction in elementary flight training.

The above publication is obtainable from the Department of Printing and Stationery, Ottawa, Ontario.

Learn to Fly. Many readers have written for advice on how to go about getting into aviation — what it costs to learn . . . where the schools are located . . . what physical, educational, citizenship requirements are involved in obtaining a pilot's license — and the possibilities of a career in aviation. The answers to these questions (as far as Canadian citizens are concerned) have been published in a 24-page booklet entitled "Learn to Fly. It is yours for the asking from Aviation Department, Shell Oil Company of Canada Ltd., Toronto, Ontario.

Civil Air Regulations. Part 43 and Part 60. Flight Information Manual, and Airman's Guide (U.S.). Air Navigation Radio Aids, Air Regulations, Air Navigation Orders, Information Circulars and Notams (Canada) contain information that is mandatory in obtaining a pilot's license in either the United States or Canada. Other than certain specific information concerned in these publications, the requirements for Private or Commercial Pilot's license examinations are fully covered in this manual.
FACTORs

This examination is based on a simulated round-

robin flight from TUL (Tulsa Municipal Airport) 36°
12' : 95° 38', to MKC (Kansas City Airport) 39°
7' : 94° 37', to TOP (Topeka Billard) 39° 4' : 95°
37', to ICT (Wichita Municipal Airport) 37° 39' : 97°
26', and return to Tulsa.

These places are all located on World Aeronautical
Chart No. 360, Kansas River sheet, which will be
found folded inside the Weather Map insert. To assist
you in finding the airports on the map, their co-ordi-

nates have been stated above, e.g. Tulsa Airport is located
at Latitude 36° 12’ North : Longitude 95° 38’ West.

Weather forecasts and sequence reports are in-
cluded for Chanute and Whiteman AFB (Air Force
Base). These are located as follows: CNU (Chanute)
37° 39' : 95° 22', SZL (Whiteman AFB) 38° 43' : 93° 35'.

The plane you are assumed to be flying, typical of
several currently in use, is a 4-place airplane with
conventional fixed gear, and manually controllable
flaps. It is equipped with a hydraulically controlled
pitch propeller and has the following radio equip-
ment installed:

- Low-frequency receiver.
- VHF receiver with omni (cross pointer indicator,
bearing selector, and TO-FROM indicator).
- VHF transmitter.

The airplane is to be flown in accordance with the
CAA Approved Airplane Flight Manual and placards
with this text:

"This airplane must be operated as a normal
category airplane in compliance with the flight manual.
No acrobatic maneuvers, including spins, approved.

Maximum baggage 120 lbs.
Both tanks on for take-off and landing.
Radio call N 000".

THE PROBLEM

You are a commercial pilot, hired by a fixed base
operator at Tulsa Oklahoma. You are notified on
Monday that you are scheduled the following day to
fly two business men VFR from Tulsa to Kansas City,
to Topeka, to Wichita, and return. Your revenue pas-
sengers require a 2-hour stay at Kansas City and
Topeka, and plan to terminate their flight at Wichita.

After your discussion with the boss about the pro-
posed charter flight the following day, you refer to
World Aeronautical Chart No. 360 (26th Edition) to lay
out your proposed route. Tentatively, you set up the
below:

**Leg 1** — TUL to MKC: Tulsa Airport via Red Airway 11
east to Claremore intersection*.
- Thence via Amber Airway 4 to Chanute (LP/MF)
  Radio, Thence direct to Kansas City Airport.

**Leg 2** — MKC to TOP: Kansas City Airport direct to
Topeka Billard.

**Leg 3** — TOP to ICT: Topeka Billard via Victor Airway
V77 to Wilsey Reporting Point. Thence via
V77 to Wichita (VOR) Radio. Thence direct to
the airport.

**Leg 4** — ICT to TUL: Wichita Airport direct to Tulsa
Airport.

*Meaning the intersection of the northeast leg of the
Tulsa radio range and the south leg of the Chanute
radio range, near Claremore.

After drawing lines on your map to represent the
True Course (Track) between the airports you intend to
visit, you mark prominent check points along the route,
noting the distances between each. In addition, you
note communication and navigation facilities available
en route.

Following your chart study, you place a phone call
to the Weather Bureau at Tulsa for a forecast of the
weather for the following day. Upon contacting the
forecaster, you should immediately:

1. Identify yourself as a pilot.
2. State your intended route and intended time of
   take-off.
3. Advise that you will be flying VFR.

From the forecast, it appears that the weather will
be satisfactory for VFR flight along your flight route
the following morning. However, some local rain
showers may occur, there may be some turbulence at
lower levels, and considerable wind and gustiness on
the surface at many of the stations in the general area.

You leave home the following morning (Tuesday) in
order to arrive at Tulsa Airport at approximately
0730C (1330 GMT, or 'Z' Time) one hour before the
proposed time of departure. A careful check of the
latest weather available reveals the following data of
importance to your flight:

*Effective June, 1958 all Air Traffic Control facilities
in the U.S. operate on Greenwich Mean Time (GMT, or
"Z" Time), ATC facilities will, however, state both GMT
and local Zone Time in communications with civil non-
air-carrier aircraft. E.g.: "Time 1615 Greenwich — 1015
Central".

WEATHER DATA

Terminal Forecast (Tuesday)
Period 1200 — 2400Z
TUL C30© + 25 1600Z 20© C60© + 10
CNU C30© + 12 1500Z 30© C80© + 15
TOP C30© + 14 1400Z 30© + 15
SZL (Whiteman AFB) C25© 1500Z 30© 1800Z
MKC 05© 15

Hourly Weather Sequence Report
Tuesday
1330Z
TUL M27© 173 20 1100/003
CNU S2 12 © E25© 10 125© 50/44 12 22© 30/987
BINOVC NW
TOP M13© 85© 48 20 © + 15 © 26 © 976©
RB27 BINOVC
SZL E25© 15 © + 017 © 50 © 42 © + 16 © 956©
MKC 05© 20 © 48 © 35 © 20 © 012©

Wins Aloft Forecast
Tuesday
TOP 1000 2200Z
40215 73520 102930 152935 202840

Wins Aloft Report

Tuesday
TOP 09Z 20255 0538 40435 0432 60335 0231 80225
3630 03530 23532 43331 63224

Since much of the success of a flight is directly
dependent on careful flight planning, you — as pilot in
command — familiarize yourself with all available
information appropriate to your cross-country flight.
This "pre-flight briefing" includes a study of the Air-
plane Flight Manual — Weather Data — Sectional and
World Aeronautical Charts — Airman's Guide — and
Radio Aids, DOT Circulars and Notams would be
referred to in lieu of Airman's Guide and Flight Infor-
mation Manual. Canada Air Pilot, if available, is
extremely valuable both for pre-flight and in-flight
reference.)
Airplane Flight Manual

Specifications and Limitations

**Engine:** Do not exceed 2600 rpm. manifold pressure — normal operating range 15 to 24 inches Hg.

**Fuel:** Use 91 minimum octane gasoline.

Usable capacity 46 US gals. (23 gals. in left tank and 23 gals. in right tank.)

Average fuel consumption 12 gals. per hour, cruising.

**Airspeed:**

- Never exceed ........... 185 mph (160 kts)
- Caution range .............. 160-185 mph (140-160 kts)
- Normal cruising .......... 140 mph (122 kts)
- Maneuvering ............. 125 mph (109 kts)
- Maximum, flaps down: 100 mph (87 kts)

**Weight:**

- Empty weight as equipped ........... 1625 lbs.
- Maximum gross weight ............ 2550 lbs.

**Oil:**

- 2 US gals. in engine sump.

<table>
<thead>
<tr>
<th>COMPASS CORRECTION CARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>For: 0 30 60 90 120 150</td>
</tr>
<tr>
<td>Steer: 0 29 58 86 115 146</td>
</tr>
</tbody>
</table>

**Stalling Speed**

<table>
<thead>
<tr>
<th>No stall warning is evident</th>
<th>Condition</th>
<th>Angle of Bank Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPH/KTS IAS</td>
<td></td>
<td>0 20° 40° 60°</td>
</tr>
<tr>
<td>Power off: flaps up</td>
<td>55/51</td>
<td>61/53 67/58 83/72</td>
</tr>
<tr>
<td>Power off: flaps down</td>
<td>55/48</td>
<td>57/50 67/58 78/68</td>
</tr>
<tr>
<td>Power on: flaps up</td>
<td>53/46</td>
<td>55/48 60/52 75/65</td>
</tr>
<tr>
<td>Power on: flaps down</td>
<td>50/43</td>
<td>52/45 57/49 70/61</td>
</tr>
</tbody>
</table>

**Landing Distance**

<table>
<thead>
<tr>
<th>Flaps Down</th>
<th>Altitude</th>
<th>Outside Air Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0°F. 20°F. 40°F. 60°F. 80°F. 100°F.</td>
</tr>
<tr>
<td></td>
<td>Sea Level</td>
<td>1590 1650 1710 1765 1820 1870</td>
</tr>
<tr>
<td></td>
<td>2000 Feet</td>
<td>1700 1755 1815 1870 1925 1975</td>
</tr>
<tr>
<td></td>
<td>4000 Feet</td>
<td>1795 1830 1885 1940 1995 2045</td>
</tr>
<tr>
<td></td>
<td>6000 Feet</td>
<td>1905 1940 1985 2030 2085 2140</td>
</tr>
<tr>
<td></td>
<td>7000 Feet</td>
<td>1960 2000 2040 2080 2130 2180</td>
</tr>
</tbody>
</table>

**Take-off Distance**

<table>
<thead>
<tr>
<th>Flaps Up</th>
<th>Altitude</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sea Level</td>
<td>1370 1480 1590 1700 1810 1920</td>
</tr>
<tr>
<td></td>
<td>2000 Feet</td>
<td>1670 1790 1920 2030 2140 2250</td>
</tr>
<tr>
<td></td>
<td>4000 Feet</td>
<td>2000 2150 2280 2450 2610 2800</td>
</tr>
<tr>
<td></td>
<td>6000 Feet</td>
<td>2390 2560 2740 2940 3140 3380</td>
</tr>
<tr>
<td></td>
<td>7000 Feet</td>
<td>2740 2840 3050 3280 3510 3770</td>
</tr>
</tbody>
</table>

**Climb**

<table>
<thead>
<tr>
<th>Flaps Up MPH/KTS IAS</th>
<th>Best Climb Speed</th>
<th>Rate-of-climb Ft./Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100/87 Sea Level</td>
<td>815 790 765 740 715 690</td>
<td>690 595 495 395 345 250</td>
</tr>
<tr>
<td>98/85 2000 Feet</td>
<td>715 690 670 640 620 595</td>
<td></td>
</tr>
<tr>
<td>96/83 4000 Feet</td>
<td>620 595 570 545 520 495</td>
<td></td>
</tr>
<tr>
<td>94/82 6000 Feet</td>
<td>525 495 470 450 425 395</td>
<td></td>
</tr>
<tr>
<td>93/81 7000 Feet</td>
<td>475 450 420 395 370 345</td>
<td></td>
</tr>
<tr>
<td>91/79 9000 Feet</td>
<td>380 360 330 300 280 250</td>
<td></td>
</tr>
</tbody>
</table>

* Landing and take-off correction: Reduce distances by approximately 10 percent for each 6 mph (5 kts.) windspeed.
THE QUESTIONS

The first part of the examination concerns itself with preflight activity prior to take-off from Tulsa.

(P) Private pilot’s examination question.

(C) Commercial pilot's examination question.

1. (P) (C) Before beginning a cross-country flight, you as pilot-in-command should concern yourself with preflight planning. Such “preflight briefing” as indicated in the statement preceding this question is:
   (1) Advisable but not required by CAR.
   (2) Good operating practice and is required by CAR.
   (3) Good operating practice to be done at the discretion of the pilot-in-command.
   (4) Not required.

COMMENTS: See CAR (Civil Air Regulations) 60.11.
In Canada, Air Regs. Part V, 504.

2. (P) (C) Weather information is of prime concern to the pilot in preflight planning. Terminal forecasts and teletype sequence reports are especially helpful. Issuance and period covered for these reports are as follows:
   (1) Terminal forecasts are issued 4 times daily and usually cover a period of 12 hours. Sequence reports are issued every hour, approximately on the half hour.
   (2) Terminal forecasts are issued twice daily and usually cover a period of 48 hours. Sequence reports are issued every hour, approximately on the half hour.
   (3) Terminal forecasts are issued 4 times daily and usually cover a period of 12 hours. Sequence reports are issued every 30 minutes at approximately 15 and 45 minutes past the hour.
   (4) Terminal forecasts are issued 4 times daily and usually cover a period of 6 hours. Sequence reports are issued every hour, approximately on the half hour and are broadcast by CAA communications stations at 15 and 45 minutes past the hour.

COMMENTS: See “Airway Weather Reports (Sequences)” and “Terminal Forecast”.

3. (P) All CAA airway communications stations having voice facilities on continuously operated radio ranges or radio beacons broadcast weather information and NOTAMS (notices to airmen). These broadcasts are made:
   (1) Twice hourly, on the hour and the half hour.
   (2) At 15 and 45 minutes past the hour.
   (3) Hourly, on the half hour.
   (4) At 15, 30, and 45 minutes past the hour.

COMMENTS: See “The LF/MF Radio Range”. In Canada the correct answer would be: at 22’ and 52’ or 25’ and 55’ past the hour.

4. (P) Your principal source of information for weather conditions which exist between reporting stations is from:
   (1) Pilot reports en route (PIREPS) or direct contact with a pilot who has just flown the area.
   (2) C.A.A. Control Towers.
   (3) Commercial broadcast stations.
   (4) The weather sequence report.

COMMENTS: See “Procedure on a Cross Country Flight”.

5. (C) According to the Winds Aloft report for TOP the wind direction and speed at 5,000 ft. were approximately:
   (1) 30° at 35 kts.
   (2) 320° at 64 kts.
   (3) 50° at 38 kts.
   (4) 40° at 32 kts.

COMMENTS: See “Winds Aloft Report”.

6. (P) (C) Winds Aloft forecasts are available for many stations and cover a period of 12 hours. These forecasts often prove very helpful in trip planning. Referring to the preceding Winds Aloft Forecast we find that the wind direction and speed at 10:00 and 22:00 at 5000 feet (by interpolation) would be approximately:
   (1) 350° at 20 kts.
   (2) 10° at 15 kts.
   (3) 30° at 15 kts.
   (4) 40° at 32 kts.

COMMENTS: See “Winds Aloft Forecast” (Meteorology).

7. (C) According to the 13:30 sequence report for Tuesday, the ceiling at Chanute (CNU) was:
   (1) 200 feet scattered.
   (2) 1,200 feet with lower scattered.
   (3) Estimated 2,500 feet, overcast.
   (4) Overcast, 1000 feet.

COMMENTS: See “Symbols Used in Weather Sequences” and “Airway Weather Reports (Sequences)”.

8. (P) Since your first point of intended landing is Kansas City, you carefully check the 13:30 hourly sequence report for that point. According to the report the:
   (1) Ceiling is unlimited — visibility over 15 miles — sea level pressure 1020.5 millibars — temperature 48°F — dewpoint 35°F — wind north 20 kts. — altimeter setting 30.12 inches.
   (2) Ceiling is zero — visibility 15 miles, increas-
ing — sea level pressure 1020.5 millibars — temperature 48° — dewpoint 35° — wind north 20 kts. — altimeter setting 30.12 inches.


(4) Ceiling unlimited — visibility over 15 miles — sea level pressure 1020.5 inches — temperature 35° — wind north 20 kts. — altimeter setting 30.12 inches.

COMMENTS: See "Symbols Used in Weather Sequences" and "Airway Weather Reports (Sequences)".

9. (C) The report of weather and obstructions to vision at Topeka (TOP) was:

(1) Moderate rain.
(2) Light rain showers.
(3) Very light freezing rain.
(4) Light snow showers.

COMMENTS: See "Symbols Used in Teletype Sequences" and "Airway Weather Reports (Sequences)".

10. (C) According to the sequence report the surface wind at Chanute (CNU) was from the:

(1) Northeast at 22 kts. with peak gusts to 30 kts.
(2) Southwest at more than 22 kts.
(3) North-northeast at 22 kts. with peak gusts to 30 kts.
(4) North-northeast at 44 kts.

COMMENTS: See "Symbols Used in Weather Sequences" and "Airway Weather Reports (Sequences)".

11. (C) At Topeka (TOP) the sequence report indicates that the:

(1) Pressure in millibars was 29.76.
(2) Ceiling was 8,000 feet.
(3) Spread between temperature and dewpoint was 6 degrees.
(4) Visibility was reduced to 4 miles.

COMMENTS: See "Symbols Used in Weather Sequences" and "Airway Weather Reports (Sequences)".

12. (P) (C) According to the terminal forecast, it is anticipated that the sky coverage at Whiteman AFB (SZL) at 18:00 would be:

(1) 3000 feet scattered — 9000 feet broken.
(2) 4500 feet scattered.
(3) 3500 feet broken.
(4) 4500 feet scattered.

COMMENTS: See "Terminal Forecast".

13. (P) You plan to fly the Topeka to Kansas City leg of your trip at 4000 feet ASL rather than 2000 feet ASL because:

(1) You are flying southbound on a Victor Airway.
(2) You would encounter heavy cloud at the lower level.
(3) According to the Winds Aloft Report, you would have a more favorable wind.
(4) To avoid severe turbulence at the lower altitude.

COMMENTS: The answer is self explanatory. Your southbound course (Track) on Victor Airway 77 is 218° (Magnetic). According to the Winds Aloft Report, the wind at 2000 ft. ASL is from 30°T at 25 kts. At 4000 ft. ASL the wind is from 40°T at 33 kts. (Note: Flying on airways, you fly southbound at even heights.)

14. (P) If you were to fly the Kansas City to Topeka leg at 6000 feet ASL, the wind direction and speed as forecast for TOP would be approximately:

(1) 360° at 20 kts.
(2) 10° at 15 mph.
(3) 190° at 15 kts.
(4) 15° at 20 kts.

COMMENTS: The wind at 4000 ft. is forecast from 20° at 15 kts. At 7000 ft. it is from 350° at 20 kts. The wind at 6000 ft. is found by interpolation. See "Winds Aloft Forecast".

15. (P) You would be less likely to encounter the thundershowers forecast for Topeka (Terminal Forecast) if your arrival there was:

(1) 12:00.
(2) After 16:00.
(3) Before 12:00.
(4) Before 10:00.

COMMENTS: See "Terminal Forecast".

16. (P) If circumstances required you to make a landing at Chanute Airport shortly after 15:00, according to the Terminal Forecast, what weather conditions you might expect to find:

(1) Scattered clouds at 3000 ft. — ceiling 8000 ft., broken — wind northwest at 15 kts., gusty.
(2) Ceiling 3000 ft. overcast — wind north at 20 kts.
(3) Cumulus cloud at 3000 ft., overcast — wind north at 20 kts. — ceiling 9000 ft.
(4) Broken clouds at 300 ft. — ceiling 800 ft., scattered — wind northwest at 15 kts., increasing.

COMMENTS: See "Terminal Forecast" and "Symbols Used in Weather Sequences".

17. (P) The moisture content of the air definitely affects the ceiling and visibility. The temperature and dewpoint relationship presented in the hourly sequence report is highly significant to the pilot because it may represent a critical condition of the air. Dewpoint is:

(1) A figure representing the relative humidity.
(2) The temperature to which air must be cooled at constant pressure to become saturated.
(3) The amount of moisture present in the air.
(4) The temperature to which air must be warmed to become saturated.

COMMENTS: See "Humidity" and "Formation of Clouds and Rain".

18. (P) When the spread between dewpoint and temperature is:

(1) Wide, the air can be said to be saturated with moisture.
(2) Negligible, the air can be said to be highly saturated with moisture.
(3) 10°, you would likely find the ceiling to be below VFR minimums.
(4) 2°, you would likely find the ceiling above VFR minimums.

COMMENTS: See "Humidity".

19. (P) If an intermediate landing at Chanute were made after 15:00 and the wind remained as forecast, you would likely land on runway:

(1) 31.
(2) 27.
(3) 18.
(4) 06.
COMMENTS: The wind is from N.W. (315°). Runway 31 lies roughly 310°M. and would therefore be approximately into wind. "Airport Runways".

As part of your preflight study you review the VFR minimums outlined in the Flight Information Manual on Part 60 of the Civil Air Regulations. (If a similar flight were being made in Canada, the equivalent information would be found in Air Navigation Order, Series V, No. 3.)

20. (P) For VFR flight within Control Zones the minimum ceiling, visibility and/or proximity to clouds (without ATC clearance) are:

(1) 700 feet — 3 miles — 500 feet under, 2000 feet horizontally, and 1000 feet above cloud.
(2) 1000 feet — 3 miles — 2000 feet horizontally, and 500 feet above or below cloud.
(3) 1000 feet — 3 miles — 500 feet under, 2000 feet horizontally and 1000 feet above cloud.
(4) 1000 feet — 1 mile — 500 feet under, 1000 feet above, and 2000 horizontally from cloud.

COMMENTS: See CAR (Civil Air Regulations) 60.30. Flight Information Manual, Air Traffic Control Procedures. Also "Weather Minimum for VFR Flight". In Canada, Air Navigation Order, Series V. No. 3. No minimum ceiling is specified. Visibility 3 miles — 1 mile horizontally and 500 feet vertically from cloud.

21. (P) During some portion of your round-robin VFR flight you will be within the boundaries of Control Areas. If the flight visibility should go below 3 miles while within the boundary of a Control Area you:

(1) Should land as soon as possible outside the control area.
(2) Could legally continue your flight only by flying at an altitude of 700 feet or less above the surface.
(3) Could legally continue your flight as long as you have a ceiling of 1000 feet and visibility of at least 1 mile.
(4) Should get an ATC clearance to continue within the control area.

COMMENTS: See C.A.R. Part 60.30. Also "Weather Minimum for VFR Flight".

22. (P) If you wish to land at an airport within a Control Zone which is reporting a ceiling of 800 feet, visibility 4 miles, the only way in which you might do so legally is to:

(1) Maintain an altitude below 700 feet above the surface, since that will keep you out of a control area.
(2) Contact the control tower (by radio or telephone) and obtain authorization to enter the control zone.
(3) Proceed into the control zone, so long as the visibility remains more than 3 miles, then request a clearance from the tower to land.
(4) Continue into the control zone, remaining "clear of clouds".

COMMENTS: See C.A.R. Part 60.30. Also "Weather Minimum for VFR Flight" and "Special VFR". In Canada, no minimum VFR ceiling is specified. Answer (3) above would therefore apply. (Except that the aircraft must not be flown less than 500' above the surface.) See Air Navigation Order, Series V, No. 3.

23. (C) During your preflight briefing, you review current publications for information pertinent to your flight. Facts concerning air navigation radio aids, locations where accuracy checks may be made on VOR receivers, location of the instrument landing systems and notices of hazardous conditions may be found:

(1) On the reverse side of aeronautical charts.
(2) In the Airman's Guide.
(3) In the Flight Information Manual.
(4) In the Airport Study Guide.


24. (C) You wish to refresh your memory with respect to correct radio phraseologies, certain air traffic control procedures, and light gun signals. To do this, you would refer to:

(1) Part 60 of the C.A.R.
(2) Radio Study Guide.
(3) Flight Information Manual.
(4) Airman's Guide.

COMMENTS: See Flight Information Manual. Also "Study Material".

25. (P) By reference to the appropriate source or sources you find that there are ground-to-air communications available on 122.8 mc. at:

(1) Kansas City Mo.
(2) Chanute Kan.
(3) Garnett Kan.
(4) Coffeyville, McGugin Kan.

COMMENTS: See Airman's Guide (Directory of Airports).* In Canada, similar information would be found in Air Navigation Radio Aids.

26. (P) A radio receiver is required to land at:

(1) Tulsa Okla.
(2) Wichita Kan.
(3) Kansas City Mo.
(4) Topeka, Billard Kan.

COMMENTS: See Airman's Guide (Directory of Airports).* In Canada, similar information could be found in Canada Air Pilot or in Notams.

27. (P) At one of the following airports you are informed that (i) There are obstructions at the ends of all runways (ii) Cautioned re downdrafts (iii) Advised to use runways. To which airport are these instructions applicable:

(1) Kansas City, Fairfax Kan.
(2) Topeka Kon.
(3) Chanute Kan.
(4) Tulsa, Young, Mo.

COMMENTS: See Airman's Guide (Directory of Airports).* In Canada, similar information could be found in Canada Air Pilot and Notams.

28. (P) At which of the following CAA Stations will all four of the radio aids listed below be found:

Scheduled broadcast station.
LF/MF four-course radio range.
VOR omnirange.
VHF station location marker at range station.

(1) Hutchinson, Kan.
(2) Topeka, Kon.
(3) Dodge City, Kan.
(4) Butler, Mo.


29. (P) You check on the availability of the following facilities at Kansas City:
This weather map shows the isobaric pattern that existed 12 hours previous to the time of the large weather map shown above. The areas where precipitation was falling at 1:30 p.m. yesterday are covered with black dot shading. A comparison of the two maps will reveal how the weather pattern has changed in the past 12 hours.
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(h) Runway lights available only on prior request.
(i) Minor aircraft and engine repairs only.
(j) Unicom. radio communication on 122.8 mc.
(k) Storage, major aircraft and engine repairs.

By referring to the appropriate source you find that the following services and facilities are available at Kansas City:

1. MKC has an LF/MF radio range — "Z" marker — VOR — approach and ground control tower: TOP has a non-directional beacon—LF/MF radio range and DME: ICT has an LF/MF radio range — "Z" marker — VOR — and a tower with approach control.
2. MKC has an LF/MF radio range — "Z" marker — VOR — tower with approach and ground control: TOP has VOR—DME—a non-directional radio beacon—tower with ground control — and LF/MF radio range (Forbes AFB): ICT has an LF/MF radio range — "Z" marker — VOR — and a tower with ground control.
3. MKC has a compass locator — LF/MF radio range — VOR — tower with approach and ground control: TOP has VOR—LF/MF radio range — "Z" marker: ICT has an LF/MF radio range — Unicom. — "Z" marker — VOR — and a tower with VHF fan marker.
4. MKC has an LF/MF radio range — "Z" marker — VOR — tower with approach and ground control: TOP has VOR—DME—a non-directional radio beacon—tower with approach and ground control — LF/MF omnirange: ICT has an LF/MF radio range — fan marker — VOR — and a tower with ground control.


*Facilities listed in Airman's Guide change rapidly.

The answers listed in this manual may not exactly agree with the latest current issue of Airman's Guide. However a copy of the Airman's Guide on which the examination questions are based is supplied with the examination kit.

31. (C) In case you might wish to divert to Hutchinson, Kan., you check to determine what runways are available, whether it is equipped with UNICOM for radio communications, and if there are any temporary hazardous conditions on the field. In doing so you refer to:

1. Airport Study Guide.

COMMENTS: See Airman's Guide.

32. (P) Prior to your telephone call to get weather information for your flight you referred to the proper source to get the restricted number which is used for aviation weather information only. This Weather Bureau number may be found in the:


Following your study of the weather situation, radio and airport facilities, you review C.A.R. requirements.

33. (P) You check to make certain that you have met recency of experience requirements since you will be carrying passengers. You cannot legally carry passengers unless within the:

1. Preceding 90 days you have made at least 5 take-offs and landings to a full stop in an aircraft of the same category, class, and type as the one which you will be flying.
2. Preceding 60 days you have made at least 5 take-offs and landings to a full stop in an aircraft of the same category, class, and type as the one which you will be flying.
3. Preceding 90 days you have made at least 3 take-offs and landings to a full stop in an aircraft of the same category, class, and type as the one which you will be flying.
4. Preceding 90 days you have made at least 5 take-offs and landings to a full stop.

COMMENTS: See C.A.R. Part 43.68

34. (P) During your flight you will make extensive use of your two-way radio for communications. In addition to a currently valid private pilot certificate you must possess and carry on your person at least a:

1. Third class medical certificate issued within the past 24 calendar months, and an FCC radio-telephone operator permit.
2. Third class medical certificate.
3. Second class medical certificate issued within the past 12 calendar months, and an FCC radio-telephone operator permit.
4. Third class medical certificate issued within the past 12 calendar months, and an FCC radio-telephone operator permit.


35. (C) In case your passengers should delay you longer than anticipated at their en route stop-overs, it is possible that you might reach Wichita after sunset. If you should arrive at Wichita 20 minutes after sunset, C.A.R. would require that within the preceding 90 days you:

1. Meet no additional flight experience requirements.
2. Make three night take-offs and landings to a full stop.
3. Make at least five take-offs and landings at night.
4. Make five night take-offs and landings to a full stop during the period from one hour after sunset to one hour before sunrise.

COMMENTS: See C.A.R. Part 43.68(b). In Canada, Air Regs., Part I (49). The period in which night flying regulations become effective in the United States is one
hour after sunset and one hour before sunrise. In Canada, one half hour. See “Night”.

36. (C) You check to determine if the aircraft which you will fly VFR is appropriately equipped for carrying passengers for hire at night. The minimum equipment required by C.A.R. in this instance is:
   (1) Position lights — one electric landing light — flares — spare fuses.
   (2) Position lights — Verey pistol — flashlight — spare fuses.
   (3) Flares — 2-way radio — position lights — landing lights.

   COMMENTS: See C.A.R. Part 43.30(b). In Canada, Air Regs., Part V, 558. Also “Running Lights”.

37. (C) You review the airplane and engine logbooks to determine whether appropriate inspections have been made. The aircraft may not be flown for hire unless it has been inspected by a certified mechanic with appropriate rating within the preceding:
   (1) 30 days.
   (2) 100 hours of flight time.
   (3) 50 hours of flight time.
   (4) 6 calendar months.


38. (C) (P) Since it is the pilot’s responsibility to ascertain that certain certificates and documents are aboard the airplane and appropriately displayed, you check to make certain that they are on hand. These required documents include:
   (1) Registration certificate, Flight Manual, and current airworthiness certificate.
   (2) Current airworthiness certificate, operations limitations (Form 308) and Airplane Flight Manual.
   (3) Certificate of registration, certificate of airworthiness, journey and aircraft logbook, radio equipment license, license or permit for each crew member.
   (4) Airplane operating limitations set forth in a manner acceptable to the Administrator of the C.A.A., current airworthiness certificate, registration certificate.

   COMMENTS: See C.A.R. Part 43.10 In Canada, Air Regs., Part VIII, 821. In Canada, the correct answer would be No. (3) above. See also “Pilot’s Inspection before Flight”.

39. (P) Civil Air Regulations state certain notification requirements for the following types of accidents when incident to flight: structural failure of an aircraft, engine, or propeller — collision of two or more aircraft in the air — serious or fatal injury to any person.

   If an accident which requires notification should occur to the aircraft which you will be flying, one of the following statements describes the proper action to be taken:
   (1) You, as pilot, are required to notify (if physically able to do so) a designated office or representative of the C.A.A. immediately.
   (2) The owner of the aircraft is required to notify a designated office or representative of the C.A.A. within 48 hours.
   (3) The State law enforcement officer investigating the accident must report to the C.A.A. within 48 hours.
   (4) No action on the part of the pilot or the owner is necessary if the accident is investigated by a representative of the State Aeronautics Commission.


   Following your review of the weather situation, weather minimums, radio and airport facilities, you study closely the aeronautical chart you will refer to during the trip and prepare it for your flight by drawing lines to represent your True Course, or Track, for each leg, measuring the distance between points of intended landing, and marking the distances between check points along the route.

40. (P) After carefully studying your route, and referring to the reverse side of the chart, you determine that along your proposed route:
   (1) You will need to fly off course to avoid a Caution or Restricted Area.
   (2) You will have to file a DVFR flight plan to penetrate an Air Defence Identification Zone.
   (3) You will have to fly slightly off course to avoid a Prohibited Area.
   (4) You will have to exercise extreme caution while flying through one Caution Area en route.

   COMMENTS: See reverse side of chart. The symbols for caution, restricted, air defence, and prohibited areas will be found there. See C.A.R. Part 620. Also “ADIZ”.

41. (P) The total distance you propose to fly is approximately:
   (1) 374 s.miles (325 n.miles)
   (2) 421 s.miles (385 n.miles)
   (3) 552 s.miles (479 n.miles)
   (4) 603 s.miles (523 n.miles)

   COMMENTS: Be sure you select the particular airports specified.

42. (P) The True Course (Track True) from Kansas City Airport to Topeka Billard is:
   (1) 205°
   (2) 266°
   (3) 257°
   (4) 186°

   COMMENTS: The True Course (Track True) from Kansas City to Topeka is a straight line drawn on the map between the two points. Normally, you measure the true course or track on a Meridian midway between the two points. (This is unnecessary in this case because the distance is so short.) See “The Conic Projection”. Also “The Douglas Protractor”.

43. (P) The Magnetic Course (Track Magnetic) from Kansas City to Topeka is:
   (1) 205°
   (2) 275°
   (3) 266°
   (4) 257°

   COMMENTS: The True Course, or Track, measured on the map is 266°. The magnetic Variation is 9°E. “Variation East, Magnetic Least”. The Magnetic Course or Track is therefore 266° + 9° = 257°M.

44. (C) Weather permitting, you plan to fly the first leg of your trip at 3000 feet A.S.L. From the Claremore intersection to Chanute Radio — with an outside temperature of 41°F (5°C), an IAS of 135 mph (117 kts) and a wind based on the forecast for TOP 4000’ for the period 10:00-22:00 — your ground speed would be approximately:
   (1) 113 mph (98 kts).
   (2) 98 kts (110 mph).
(3) 125 mph (108 kts).
(4) 151 mph (133 kts).

COMMENTS: Your indicated airspeed is 135 mph (117 kts). With an outside ambient air temperature of 41°F (5°C) you convert this 135 mph IAS on your computer to a true airspeed of 140 mph (122 kts). (Note: The Dalton Computer airspeed correction is based on "Pressure Altitude". If you wish to be precisely accurate, move your altimeter setting to 29.92 temporarily to obtain your exact pressure altitude.) Your Course, or Track, via Amber Airways No. 4 is 356° Magnetic, which is 284° variation. The forecast wind is from 20°T at 15 kts (17 mph). By plotting or computer, your groundspeed should be approximately 125 mph (108 kts).


45. (C) For that portion of the first leg of your trip which will be flown "on airways", minimum visibility for VFR flight at 3000' ASL would be:
   (1) 2 miles.
   (2) 1 mile.
   (3) Sufficient to avoid collision with other aircraft.
   (4) 3 miles.

COMMENTS: See "Weather Minima for VFR Flight".

46. (C) The second leg of your trip, Kansas City to Topeka, will be flown at 4000' ASL "off airways". Minimum visibility for VFR flight "off airways" at this altitude would be:
   (1) 3 miles.
   (2) 2 miles.
   (3) 1 mile.
   (4) Sufficient to avoid collision with other aircraft.

COMMENTS: See "Weather Minima for VFR Flight".

47. (C) As previously indicated, a portion of your flight to Kansas City will be "on airways". Since you will be flying at 3000 ft. ASL, Civil Air Regulations require that your aircraft not shall be flown:
   (1) Less than 500 ft. vertically, or 1 mile horizontally from any cloud formation.
   (2) Less than 500 ft. vertically under, 1000 ft. vertically over, and 2000 ft. horizontally from any cloud formation.
   (3) Less than 500 ft. vertically under, 500 ft. vertically over, and 2000 ft. horizontally from any cloud formation.
   (4) Less than 1000 ft. vertically, or 2000 ft. horizontally from any cloud formation.

COMMENTS: See "Weather Minima for VFR Flight". In Canada, the correct answer would be No. (1) above.

48. (P) If you fly the second leg of your trip, Kansas City to Topeka Billard at 4000 ft. ASL at a true airspeed of 140 mph (122 kts), and use the TOP winds aloft report, your Compass Heading (see compass correction card) should be approximately:
   (1) 276°.
   (2) 270°.
   (3) 284°.
   (4) 264°.

COMMENTS: Your True Course, or Track, from Kansas City to Topeka Billard is 266°. Your True Airspeed is 140 mph (122 kts). The Wind is from 40° at 35 kts (40 mph). By plotting or computer (Basic Problem 1) the True Heading is 278°. The Magnetic Variation is 8°E. "Variation East, Magnetic Least". The Magnetic Heading is 278° – 8° = 270°. Referring to the Compass Correction Card, For 270°M Steer 276°C. The Compass Heading is therefore 276°. See "Basic Problem I" (Navigation). "Variation" and "Deviation".

49. (P) If you are able to maintain an average ground speed of 142 mph (123 kts) during your round-robin cross-country flight, you will find it necessary to gas at least once. If you maintain a 1-hour fuel reserve during the entire trip and gas only twice, it must be done at:
   (1) Kansas City.
   (2) Topeka.
   (3) Wilsey.
   (4) Wichita.

COMMENTS: This is a fuel-hour problem. Your total fuel capacity is 46 U.S. gals. Average fuel consumption is 12 gals. per hour. Your safe fuel hours are therefore 46 ÷ 12.8 hours (less 1 hr. reserve) = 2.5 hours. If at an average ground speed of 142 mph, in 2.8 hrs, you would travel 142 × 2.8 = 398 s.miles. You could not
   60
reach Wichita, which is approximately 420 miles, and would therefore have to refuel at Topeka, which is 276 miles. See "Fuel Hours".

During your preflight preparation you review the Airplane Flight Manual and Load Factor Chart, copies of which you keep in your brief case.

50. (P) You note the stalling speed of your airplane with power off, flaps up, and wings level, is 59 mph (51 kts). You also note that in a 40° bank the stalling speed is:
   (1) 60 mph (52 kts).
   (2) 67 mph (58 kts).
   (3) 63 mph (55 kts).
   (4) 59 mph (51 kts).

COMMENTS: See "Airplane Flight Manual". Also "Stalling Speed in Turbulence".

51. (P) Two of the most important factors which affect the performance of an airplane are temperature and altitude. Assume that you will take off under the following conditions:
   Airport — 5000 feet above sea level.
   Temperature — 80°F
   Airspeed — 80 mph (70 kts).

You take off directly into a surface wind of 12 mph (10 kts). With flaps up, your take-off to clear a 50-ft. obstacle will be approximately:
   (1) 2875 feet.
   (2) 2610 feet.
   (3) 3200 feet.
   (4) 3140 feet.

COMMENTS: Refer to the Airplane Flight Manual. By interpolation, the take-off distance with a temperature of 80°F at 5000 ft. is the mean of the distances at 4000 ft. and 6000 ft., in other words 2610 + 3140 = 2875

ft. With a 12 mph (10 kts) wind, this distance is reduced by 575 ft. (20% of 2875) = 2875 ft. less 575 ft. ... 2300 ft.
52. (P) In the example given in the previous question your "ground run" will be approximately:

(1) 920 ft.
(2) 1150 ft.
(3) 1044 ft.
(4) 1380 ft.

COMMENTS: The Airplane Flight Manual states that the ground run is 40% of the total distance. 40% of 2300 = 920 feet.

53. (P) Referring to the Load Factor Chart, you learn that in a 70° bank you would impose a load factor which, under certain circumstances could prove dangerous. (1 "G" represents the total weight of the aircraft). In "G" units, the load factor so imposed would be:

(1) More than 3 G's.
(2) Almost 3 G's.
(3) 2 G's.
(4) 6 G's.

COMMENTS: See "Load Factor Chart", "Loads and Stresses", and "Loading in turns".

54. (P) The Bernouilli principle deals with the energy of particles in motion. Its application in aerodynamics may be stated as follows:

(1) For every action there is an equal and opposite reaction.
(2) Energy can be neither created or destroyed.
(3) When the velocity of the flow of air is increased, there is an accompanying decrease in pressure.
(4) In a streamline flow of air, the greater the speed, the greater the lateral pressure: the less the speed of air, the less the lateral pressure.

COMMENTS: See "Bernouilli's Theorem".

55. (P) Which of the following is a correct statement concerning the lifting force developed by the wing of an airplane being operated normally:

(1) One third of the lift is supplied by the area of low pressure above the wing.
(2) Most of the lifting force results from the low pressure area below the wing.
(3) Most of the lift results from the dynamic pressure supplied when the relative wind strikes the lower surface of the wing.
(4) Most of the lifting force is the result of an area of relatively low pressure above the wing.

COMMENTS: See "Airflow Around an Airfoil".

56. (P) The five principal factors which affect the magnitude of lift and drag of an airplane wing are:

(1) Angle of attack — gross weight — lift coefficient — shape of the airfoil — wind velocity.
(2) Angle of attack — shape of the airfoil — wing area — airspeed — air density.
(3) Angle of attack — shape of the airfoil — aspect ratio — coefficient of lift — gross weight.
(4) Angle of attack — thrust — gross weight — airspeed — air density.

COMMENTS: See "Lift and Drag Curves".

57. (P) In comparison with a take-off and climb made under calm conditions, in climbing an airplane into wind you should recognize that one of the following conditions exists:

(1) The angle of climb is increased.
(2) The rate of climb is increased.
(3) A lower angle of attack is normally employed.
(4) Increased power is normally used.

COMMENTS: See "Climbing".

58. (P) In level flight at a constant airspeed:

(1) Thrust exceeds drag.
(2) Lift exceeds the weight of the airplane.
(3) Lift equals gravity.
(4) Thrust equals gravity.

COMMENTS: See "Forces Acting on an Aircraft".

You now concern yourself with preflight inspection, loading and servicing aircraft.

59. (C) (P) According to the information received from your boss, one passenger weighs 172 lbs. and the other 195 lbs. Your weight is 179 lbs. Your revenue passengers have three pieces of luggage weighing 36, 26 and 21 lbs. each. With maximum (usable) fuel aboard and oil tank filled, the take-off weight of the airplane would be:

(1) The same as the certified gross weight.
(2) Slightly more than the certified gross weight.
(3) 5 lbs. less than the certified gross weight.
(4) 56 lbs. less than the certified gross weight.

COMMENTS: The Airplane Flight Manual specifies the empty weight of the airplane as 1625 lbs. The loaded weight is therefore as follows:

Empty weight: 1625 lbs.
2 passengers: 367 lbs.
3 pieces baggage: 83 lbs.
Pilot: 179 lbs.
46 gals. fuel (@ 6 lbs./gal): 276 lbs.
2 gals. oil (@ 7.5 lbs./gal): 15 lbs.
Take-off weight loaded: 2545 lbs.

This is 5 lbs. less than the certified gross weight of 2550 lbs. specified in the Flight Manual.

In computing the loaded weight of the plane above, the actual weights of the pilot and passengers have been used. In actual practice, the pilot assumes for all practical purposes an average weight of 170 lbs. per person for passengers and crew. See C.A.R. Port 3. In Canada, pilot and male passengers are assumed to average 165 lbs. See D.O.T. Circular 0/6/37. Also "Weights" and "Factors".

60. (C) While making an inspection of the aircraft, you receive a phone call from one of the revenue passengers stating that, if possible, he would like to bring a friend along. You learn that the weight of the prospective passenger is 160 lbs. After computing the limiting effect of the extra load, you advise that allowing a 30-minute fuel reserve, and take-off at maximum gross weight — you would be:

(1) Unable to fly nonstop from Kansas City to Topeka on Leg 2.
(2) Unable to fly nonstop from Tulsa to Kansas City on Leg 1.
(3) Unable to fly nonstop on any of the three legs of the round-robin flight.
(4) Able to carry the extra passenger.

COMMENTS: Your loaded weight, less fuel required, now becomes:
Empty weight: 1625 lbs.
3 passengers: 527 lbs.
Baggage: 63 lbs.
Pilot: 173 lbs.
Oil: 15 lbs.
30 min. reserve — 6 gals \times 6 lbs.: 2465 lbs.

Your maximum gross weight is 2550 lbs. which leaves 2550 — 2465 = 85 lbs. available for fuel. Your fuel consumption is 12 gals. \times 6 lbs. = 72 lbs./hr. You therefore have 85 = 1.18 hrs., or 1 hr. 11 min. fuel endurance. With a ground speed of roughly 125 mph (109 kts) on your first leg, you would be able to fly approximately 148 s.miles (129 n.miles). The distance from Tulsa to Kansas City is 222 s.miles (193 n.miles).

Note: See COMMENTS, Question (59) above with regard to the use of average, rather than actual weights for passengers and crew.

Your two passengers arrive at the airport at 14:00. You concern yourself with the problem of proper load distribution, observing placarded weight limits for the baggage compartment, and maximum load limitation.

61. (P) If the plane is improperly loaded and the aft e.g. limit is exceeded to any appreciable extent, it will be:
   (1) Difficult to put into a stall and spin.
   (2) Nose heavy.
   (3) Difficult to get off the ground.
   (4) Easy to stall and spin, and recovery would be more difficult than under conditions of proper loading.

COMMENTS: See “Weight and Balance.”

Next you consider the advisability of flight planning as you go.

62. (C) When going on a cross country flight you should file a flight plan because:

(1) It is required when any part of the flight is to be made on airways at 3000 feet or more above the surface.
(2) It is required when flight visibility is less than 1 mile in open country or 3 miles in control areas.
(3) It is advantageous in that search and rescue service is assured in the event of failure to arrive at destination.
(4) It is mandatory when you are carrying passengers for hire or reward.

COMMENTS: See “Procedure when Starting on a Cross Country Flight”.

On your first leg you will be compelled to file a DVFR Flight Plan since you will penetrate an Air Defence Identification Zone. You file this in person or by telephone in order to avoid congestion on the airport radio communication channels.

63. (P) Based on the TOP forecast wind at 3000 ft. and a true airspeed of 140 mph (122 kts) and allowing for a loss of time in your climb of 1 min. per 500 ft., your estimated elapsed time indicated in your flight plan (Fig. 1) is:

(1) Long by approximately 13 minutes.
(2) Short by approximately 15 minutes.
(3) Exactly correct.
(4) Within \pm 5 minutes of being correct.

COMMENTS: The Flight Plan estimated elapsed time (Fig. 1) is based on actual ground speeds for each portion of the flight, i.e.: Tulsa to Claremore via Red Airway 11 — Claremore to Chanute via Amber Airway 4 — Chanute direct to Kansas City by D.R. It does not, however, include time lost in climb to cruising altitude, 3000 ft. ASL. Tulsa has a field elevation of 674 ft. ASL. Hence, you would have to climb 3000' — 674' = 2326' to reach cruising altitude. With a loss of time of 1 minute per 500 ft., this would add 2326 \div 500 \approx 4.6 minutes.
to your elapsed time. In actual practice, such detailed navigation procedures are not necessary in filing a flight plan. The distance (direct) is approximately 214 s.miles (186 n.miles). With the forecast wind, you would approximate your average ground speed to be roughly 125 mph (108 kts). This would give you an estimated elapsed time of 1 hr. 43 min. — which for all practical flight plan purposes is sufficiently accurate.

64. (C) You make certain that no less than 91 octane gas is used in filling your tanks. Use of gasoline with a lower octane rating may cause:

(1) Rough operation and lower manifold pressure.
(2) Detonation.
(3) Pre-ignition and increased output.
(4) The spark plugs to foul.

COMMENTS: See “Fuels”.

65. (P) With respect to the following statements concerning fuel, indicate the one statement which is untrue:

(1) Automobile gasoline is unfit for use in airplane engines.
(2) Aviation gasoline with an octane rating lower than that specified is not recommended.
(3) Aviation gasoline with an octane rating higher than that specified may, in some cases, prove harmful.
(4) Engine “knocking” always indicates that the wrong grade of fuel is being used.

COMMENTS: Not always. By “knocking” is meant detonation. This may also be caused by overheating and too lean a mixture. See “Fuels”.

66. (C) You check the oil to determine its adequacy and whether or not it should be changed. Normally, it should be changed:

(1) Every 100 hours.
(2) When it appears dirty.
(3) As specified in the Flight Information Manual.
(4) As recommended by the engine manufacturer.

COMMENTS: See “Refuelling”.

67. (P) When a check of the dip stick indicates a need for two quarts of oil, the attendant informs you that he has only detergent-type oil available. This means that:

(1) It should never be used in engines over 125 h.p.
(2) It can be used only in engines with suitable filters and flexible oil lines.
(3) It is the latest type of oil, and should always be used when available.
(4) The oil contains additives, and should be added to the same type of oil only.

COMMENTS: See “Requirements of Good Oil”.

68. (P) A careful pilot will always conduct a thorough inspection of his aircraft before flight. Many times in checking the engine a pilot will look under the cowling to see if the engine is still there, but will not give it an appropriate inspection.

Listed below are some of the more important items to check during a routine preflight inspection of the engine by the pilot, with other items which normally would not be part of such an inspection:

(a) Check for tightness and safetying of parts.
(b) Check spark plug gap.
(c) Look for evidence of leakage of oil or fuel.
(d) Check oil supply visually.
(e) Check breaker point condenser for short or open circuit.
(f) Check meshing of magneto scribe points for appropriate timing to engine.
(g) Check cowling for cracks and security.
(h) Check exhaust stacks for cracks and security.
(i) Check spark plug terminal assemblies for cleanliness and tightness.
(j) Check adjustment of automatic choke.
(k) Drain some fuel from bottom of sump and inspect for sediment and water.
(l) Check adjustment of automatic spark retarder.
(m) Check security of engine mount.

Select the answer below which lists the items with which you, as a pilot, should concern yourself in making a routine preflight inspection of the engine.

(1) (a) (b) (c) (d) (e) (g) (i) (k) (m)
(2) (a) (c) (d) (g) (h) (j) (k) (m)
(3) (a) (c) (d) (e) (g) (h) (j) (k) (m)
(4) (a) (c) (d) (g) (h) (i) (j) (k) (l) (m)

COMMENTS. See “Pilot’s Engine Inspection”.

69. (P) Preparatory to an initial run-up of your engine, you position your aircraft to take into account the wind which is fairly strong. In this regard it is an important safety practice to:

(1) Face your airplane into wind.
(2) Maneuver your airplane into a cross-wind position.
(3) Place your airplane in a down-wind position.
(4) Position your airplane so it will not stir up dust.

COMMENTS: See “Starting Precautions”.

70. (P) Before engaging your starter to warm up your engine, your propeller:

(1) Should be pulled through several times in order to build up adequate compression for starting.
(2) Need not be pulled through several times as would be done with an airplane with a starter.
(3) Should be pulled through several times to loosen congealed oil and partially prime the engine.
(4) Should not be pulled through because of the danger of a “kickback”.

COMMENTS: See “Starting Precautions”.

71. (C) Before starting the engine and after referring to the outside temperature at Tulsa, the carburetor heat control should be placed in:

(1) Neutral position.
(2) Full cold position.
(3) Full hot position.
(4) Approximately one-half hot position.

COMMENTS: See “The Carburetor Air Temperature Gauge”. Also “Carburetor Icing”.

72. (P) In attempting to start your engine you inadvertently overprime it. You should:

(1) Lean the mixture.
(2) Drain the carburetor bowl.
(3) Have the propeller pulled through backwards several times with throttle closed.
(4) Turn it over with throttle wide open.

COMMENTS: You turn the propeller over several times with the throttle open to clear the cylinders of excess fuel. See "Starting Routine".

73. (P) Immediately after starting your engine you should check carefully to see that:
   (1) Oil pressure rises within 3 minutes.
   (2) Throttle is cut back to idling speed.
   (3) Oil temperature rises within a few seconds.
   (4) Oil pressure rises within a few seconds.

COMMENTS: See "Running Up the Engine".

74. (P) In making the magneto check, you should always:
   (1) Make the check at full throttle.
   (2) Move the switch from BOTH to RIGHT, to BOTH, to LEFT, and back to BOTH.
   (3) Move the switch from BOTH to LEFT, to RIGHT, and back to BOTH.
   (4) Move the switch from BOTH to RIGHT, to LEFT, and back to BOTH.

COMMENTS: See "Running Up the Engine".

75. (P) During your run-up you should check to see that carburetor heat is available. This may best be accomplished by:
   (1) Applying carburetor heat at idling rpm and checking the tachometer for a drop in rpm.
   (2) Visually checking mechanical action of the carburetor heat prior to starting the engine.
   (3) Applying carburetor heat during take-off and checking the tachometer for a drop in rpm.
   (4) Applying carburetor heat at magneto run-up rpm and checking the tachometer for a drop in rpm.

COMMENTS: See "Running Up the Engine".

76. (C) You set your sensitive altimeter to the elevation of Tulsa Airport which is 674 ft. Above Sea Level. If properly calibrated, your barometric scale should indicate a setting of approximately:
   (1) 1017.3 millibars.
   (2) 30.03 inches.
   (3) 30.12 inches.
   (4) 1020.5 millibars.

COMMENTS: When the Altimeter Setting is set on the Barometric Scale, the Altimeter will register the altitude of the field Above Sea Level. Conversely, when you set the altitude of the field, 674 ft., on your altimeter, the barometric scale will record the correct altimeter setting. Referring to the last available hourly sequence report for TUL at 13:30, the altimeter setting is 30.03 inches of mercury. See "Altimeter Errors". Also "Airway Weather Reports (Sequences)".

77. (P) Following your initial run-up, you taxi out to the runway in use. Your airplane is a high wing monoplane with conventional landing gear (not tricycle) and a steerable tail wheel. When taxiing into a moderate wind the wheel should be:
   (1) Moved back and forth to spoil lift.
   (2) Held in a neutral or slightly rearward position.
   (3) Held in a full forward position.
   (4) Held in a neutral or slightly forward position.

COMMENTS: See 78 below.

78. (P) When taxiing in a direct crosswind of any magnitude, the aileron control should be:
   (1) Held toward the direction from which the wind is blowing.
   (2) Held away from the direction from which the wind is blowing.
   (3) Held in neutral position.
   (4) Moved from side to side.

COMMENTS: Taxiing and other airplane handling problems are beyond the scope of this groundschool manual. They will be explained to you by your flying instructor as part of your flight training program.

79. (P) Assuming that the surface wind at Tulsa is the same as that reported at 13:30, you will take off:
   (1) South.
   (2) North.
   (3) Southwest.
   (4) Northeast.

COMMENTS: The surface wind reported in the TUL 13:30 weather sequence is from north at 10 kts. You would therefore take off on the runway which lies nearest into north. (In the case of Tulsa, this would be runway 35). See "Airway Weather Reports (Sequences)". Also "Airport Runways".

After getting a take-off clearance from the Tower, you take off and remain tuned to the tower frequency until cleared by the tower, at which time you will be given your exact take-off time which was 14:36.

80. (C) You then remain tuned to the national VHF channel for Air Traffic Control Stations to private aircraft, which is:
   (1) 122.2 mc.
   (2) 121.5 mc.
   (3) VHF range frequency.
   (4) 341 kc.

COMMENTS: See "Radio Bands".

81. (C) In making VHF contact with those A.T.C. Stations along the route not equipped to transmit on the national VHF channel to private aircraft, reply would normally be made by the station on:
   (1) 122.1 mc.
   (2) 121.5 mc.
   (3) VHF range frequency.
   (4) 122.5 mc.

COMMENTS: See "Radio Bands".

82. (P) As previously stated, your exact time off was 14:36. Using a true airspeed of 100 mph (87 kts) in your climb, which gives you a rate-of-climb of approximately 500 ft./min., you climb to 3000 ft. ASL. At this rate you should reach cruising altitude at:
   (1) 14:15.
   (2) 14:41.
   (3) 14:55.
   (4) 14:00.

COMMENTS: Tulsa Airport is 674 ft. ASL. To reach your cruising altitude of 3000 feet, you would have to climb 3000 - 674 = 2326 ft. With a rate-of-climb of 500 ft./min., this would take you 2326 = 4.6 min. You would therefore reach cruising altitude at 14:36 + 4.6 = 14:41.

83. (C) After take-off from Tulsa at 14:36, you climb to flight altitude (3000 ft. ASL) at 500 ft./min. In the
climb you make good a groundspeed of 86 mph (75 kts). Under these circumstances you should reach cruising altitude:

(1) Crossing the Caney River.
(2) Approximately 3 s.miles (2 n.miles) north of the Tulsa omnirange station.
(3) Over the dumb-bell fan marker on the northeast leg of the Tulsa range.
(4) 15 s.miles (13 n.miles) east of Collinsville.

COMMENTS: Referring to Question 82 above, it took you (approximately) 5 minutes to climb to cruising altitude. 5 minutes is roughly .8 hrs. With a groundspeed of 86 mph (75 kts) in .8 hrs. you would travel 86 × .8 = 7 s.miles (6 n.miles). Following the northeast leg of the Tulsa radio range on Red Airway 11, this would put you roughly 3 miles north of the Tulsa omnirange station.

84. (C) The True Course (Track) and Distance from Chanute Radio to Kansas City Airport are approximately:

(1) 24°T. 111 s.m. (97 n.m.).
(2) 19°T. 121 s.m. (105 n.m.).
(3) 28°T. 100 s.m. (87 n.m.).
(4) 35°T. 113 s.m. (88 n.m.).

85. (P) If your airplane has a maximum angle of climb at a speed of 94 mph (82 kts) but the manufacturer’s manual recommends climbing at 100 mph (87 kts) the most probable reason for the higher recommended airspeed would be:

(1) To obtain better visibility with the nose lowered.
(2) To obtain better cooling of the engine.
(3) Because the head temperature runs higher at the higher airspeed.
(4) Danger of “stalling out” in the climb at the lower airspeed.

COMMENTS: See “Climbing”.

86. (P) Some outstanding check points you might use between Claremore and Chanute Radio would be:

(1) Forks of the Verdigris River—Highway east out of Coffeyville — Rail lines east out of Cherryvale.
(2) Canew River — Notawa — Rail line north through Havana — Parsons.
(3) Notawa Airport — Kansas/Oklahoma state boundary — Rail line running west out of Cherryvale — Parsons Airport.
(4) Forks of the Verdigris River — Jensen Airport — Rail lines east out of Cherryvale — Humboldt.

COMMENTS: See “Landmarks”.

87. (P) You pass over Claremore (radio range intersection) at 14:46 and proceed north on the southwest leg of the Chanute LF/MF radio range. You cross the forks of the Verdigris River at 08:59. This time and distance check indicates your ETA at Chanute Radio should be:

(1) 14:59.
(2) 15:01.
(3) 15:28.
(4) 15:32.

COMMENTS: The distance from Claremore (radio range intersection) to the forks of the Verdigris is 28 s.miles (24 n.miles). This took you 13 minutes. You therefore made good a groundspeed of 130 mph (113 kts). The distance from your check point, the forks of the Verdigris River, to Chanute Radio is 63 s.miles (55 n.miles). With a groundspeed of 130 mph (113 kts) the time to fly 63 miles would be 63 ÷ .48 hrs. × 60 = 130.

29 min. Your revised ETA at Chanute Radio is 14:59 + 29 = 15:28.

88. (P) North of Chanute, at approximately 15:36, you are 3 miles east of Iola Airport. With your low-frequency receiver tuned to 284 kc., you should receive the following signal:

(1) A steady beam, or “on course” signal.
(2) An N signal (______).
(3) An A signal (______).
(4) A steady series of identification signals.

COMMENTS: See “The LF/MF Radio Range”.

88. (P) Referring to your chart, you observe the four legs of the LF/MF Radio Range at NUU (Navy Olathe Radio). By such reference you can determine the “A” and “N” quadrants. The method used to identify the quadrants is to observe:

(1) That adjacent to an “N” quadrant the range leg limits are bounded by a solid line.
(2) That adjacent to an “A” quadrant the range leg limits are bounded by a solid line.
(3) The magnetic bearing shown on the range leg.
(4) That true north is always within one of the N quadrants.

COMMENTS: See “The LF/MF Radio Range”.

89. (P) Still on course, you approach the Kansas City area and tune in NUU, Navy Olathe Radio on 371 kc. The range signal which you get is a steady hum or “on course” signal. Shortly thereafter you receive the on course hum with a faint _______ in the background with the “N” signal becoming increasingly stronger. This indicates that you:

(1) Are about to cross the southeast leg of the range.
(2) Have crossed the south-southeast leg of the range.
(3) Have crossed the south-southwest leg of the range.
(4) Are about to cross the east-southeast leg of the range.

COMMENTS: See “The LF/MF Radio Range”.

91. (P) Beyond Paola you see a railway line running northeast below you. You tune in Kansas City Radio on 112.1 mc. and take an omni bearing which indicates 2° to the station. This means that you are:

(1) Dead on your Course (Track).
(2) About 5 miles right of your Course (Track).
(3) Approximately 3 miles left of your Course (Track).
(4) In the “A” quadrant of the Kansas City radio range.

COMMENTS: See “Omniglon”.

92. (C) You arrive at Kansas City at 16:23. After a two-hour stop-over, you take off at 18:25 for Topeka. You level off at cruising altitude, 4000 ft. ASL. Your indicated airspeed (with 1300 rpm and 22 in. of manifold pressure) is 132 mph (115 kts). Outside temperature is observed to be 34°F. (1°C.). Based on the winds aloft forecast for TOP (at 4000 ft.) your ETA at Topeka Billard would be approximately:

(1) 18:51.
(2) 18:38.
(3) 19:01.
(4) 18:47.
COMMENTS: With a temperature of 34°F. (1°C.) at 4000 ft. altitude, your indicated airspeed of 132 mph (115 kts) by computer, is equivalent to a true airspeed of 140 mph (122 kts). The distance from Kansas City to Topeka Billard is 54 n.miles (47 n.miles). The forecast wind at 4000 ft. is from 20° at 15 kts (17 mph). By plotting or computer, (Basic Problem 1) the ground speed is 146 mph (127 kts). The elapsed time will be 54 = .37 hrs. X 60 = 22 min. 18:25 + 22 = 18:47. See "The Circular Slide-rule", "Winds Aloft Forecast", "Basic Problem 1" (Navigation) and "Time, Speed and Distance Conversions".

93. (C) You tune your low frequency receiver to 272 kc. and receive an "A" signal (___). Based on the groundspeed determined in Question (35) you should cross the northeast leg of the Forbes Radio Range at approximately:

- 18:10.
- 18:45.
- 17:59.
- 18:20.

COMMENTS: Forbes AFB Radio Range is about 12 s.miles southwest of Topeka Billard, and transmits on 272 kc. Approaching from Kansas City, you would be in the southeast "A" quadrant of the range. Assuming you made good your intended True Course, or Track, of 280°, the distance from Kansas City Airport to the northeast leg would be 49 s.miles (43 n.miles). With a groundspeed of 146 mph (127 kts), this would take 49 = .33 hrs. X 60 = 20 min. 18:25 + 20 = 18:45.

94. (P) As you approach Topeka Billard you check the field elevation indicated on your chart. The airport is:

- 278 ft. ASL.
- 5100 ft. MSL.
- 880 ft. ASL.
- 1078 ft. ASL.

COMMENTS: See reverse side of aeronautical chart.

You call Topeka Tower giving your position and altitude and request landing instructions. The Traffic Controller comes back with the following instructions:

"FREUMAN NOVEMBER ZERO ZERO FOXTROT "EIGHT MILES EAST - FOUR FOUR - AT FOUR THOUSAND - CLEARED TO ENTER TRAFFIC PATTERN - RUNWAY THREE FIVE - WIND NORTH ONE FIVE - TRAFFIC IS AIRFORCE JET FIGHTER MAKING TOUCH AND GO LANDINGS."

95. (P) From the preceding message you know that:

- You are cleared to land.
- You may not be permitted to land because of the jet fighter.
- Your downwind magnetic heading will be approximately 170°.
- The wind is 16 mph.

COMMENTS: See "Procedure" (Radio), "Airport Runways", "Procedure When Approaching to Land", and "Units of Distance and Speed".

96. (P) If, as you enter the traffic pattern downwind, you find that your radio transmitter is inoperative, you should look for a light signal from the tower. If you are given a steady red light, you would:

- Know that the airport is unsafe and you should not land.
- Know that the traffic is so congested that you should leave the control zone.
- Give way to other traffic and continue circling.
- Obey the general warning signal and exercise extreme caution in landing.

COMMENTS: See "Procedure When Approaching to Land."

97. (P) You know that an aircraft in distress has the right-of-way over all other traffic:

- Except an aircraft towing a glider.
- Except an aircraft on final approach.
- Except an aircraft that is approaching.
- In all cases.

COMMENTS: See "Rules of the Air".

98. (P) Since the surface wind is gusting, causing turbulence as you approach to land, it is important to:

- Always use full flaps.
- Land as slowly as possible.
- Maintain the same airspeed you would in smooth air.
- Carry a little excess airspeed to assure positive control.

COMMENTS: See "Gust Conditions."

99. (P) When on final approach for landing, the right-of-way is normally given to:

- Faster aircraft.
- Slower aircraft.
- Aircraft at higher altitude.
- Aircraft at lower altitude.

COMMENTS: See "Rules of the Air."

100. (P) Upon landing at Topeka, your altimeter (if properly calibrated and adjusted to the correct "Altimeter Setting") will indicate the elevation of the airport above:

- See level.
- Terrain.
- The point of departure.
- Topeka Billard Airport.

COMMENTS: See "Altimeter Errors."

101. (P) After landing and turning off the runway in use, the tower instructs you to switch to Ground Control frequency for taxi instructions. In doing so, you tune your receiver to:

- 121.5 mc.
- 120.7 mc.
- 121.9 mc.
- 121.7 mc.

COMMENTS: See "Ground Control" (Radio). Airman's Guide (Air Navigation Radio Aids) indicates whether ground control is handled on 121.9 mc. or 121.7 mc. In Canada, the information is found in Air Navigation Radio Aids. If in doubt, request this information before switching over from tower frequency.

Upon contacting Ground Control, you close your VFR Flight Plan, and service your plane.

At approximately 20:45 your passengers return. You file a VFR Flight Plan by telephone with TOP C.A.A. Communications for a twenty one hundred hour take-off, you then return to the plane, load your passengers, and request the gas attendant to pull the prop through a few times.
You plan to fly this leg via Victor Airway 77 to Wilsey Reporting Point, thence to ICT Radio, and thence from the omni station direct to the airport.

102. (P) You tune your omnirange receiver to the appropriate frequency for navigation guidance, which in this case would be:

1. 304 kc.
2. 117.8 mc.
3. 113.8 mc.
4. 121.5 mc.

COMMENTS: The frequency on which Topeka VOR Radio transmits can be found on the aeronautical chart and checked in Airman’s Guide. In Canada, similar data may be checked in Air Navigation Radio Aids.

103. (P) You set the Bearing Selector on your omni receiver to 227° and head west-southwest. When the needle on your cross-pointer indicator centre:

1. Your TO-FROM meter will read “From”.
2. You will be on a radial 47° from TOP.
3. Your TO-FROM meter will read “To”.
4. You will be on a True Bearing 227° from TOP.

COMMENTS: See “To Fly a Radial away from an Omnipoint Station” (Omnirange).

104. (P) You tune in Salina VOR station and get a bearing of 93° “From” the station. Since the left-right needle on your cross-pointer indicator showed you previously to be almost exactly on course, you should now see directly below you:

1. Admire Reporting Point.
2. Herington Airport.
3. Converse Form.

COMMENTS: Since you are on course, you are on the blue line on the map which represents V77. Draw a bearing line 93° from Salina Radio. This should intersect V77 just about Council Grove.

105. (C) Beyond Council Grove you tune your omni receiver to 112.8 mc. (EMP). You set your omnibearing selector to read 290°. Assuming you are making good an average groundspeed of 155 mph (133 kts) and remain on course, your needle should become centred at approximately:

1. 21:01.
2. 21:22.
4. 21:42.

COMMENTS: Draw a bearing line on the map from Emporia omnirange 290°. When the needle centres, you will be on this position line where it intersects Victor Airway 77. This point is approximately 58 s.miles (59 n.miles) from Topeka Billard Airport. With a groundspeed of 153 mph, the elapsed time would be 68.43 hrs × 60 = 26 min. You took off from Topeka 153

Billard at 21:00 hours — right? 21:00 + 26 = 21:26.

Over Wilsey Reporting Point at 21:30 you tune in 113.8 mc. and get a 207° bearing “To” Wichita on your omnibearing selector. “Flying the needle”, you proceed towards Wichita on this 207° course.

106. (C) A little later you tune in 116.8 mc. and get a bearing 85° “From” Hutchinson. This establishes your position:

1. Over Peabody.
2. Southeast of Marion.
3. Midway between Peabody and Florence.

COMMENTS: This is actually a Fix by two omni Position Lines. You are already on one position line, the 207° course to Wichita (which is the same bearing line as a 27° “From” Wichita radial). You have obtained a second bearing line from Hutchinson. Where the 65° bearing line from Hutchinson intersects the 27° bearing line from Wichita is your position — approximately over Peabody.

*Note: On the chart (25th Edition) the 27° radial line from Wichita passes through the 22° segment on the compass rose. This is an error on the chart. Wilsey Reporting Point should be approximately 17 miles NE of where it is actually shown on the chart and should bear 27° from Wichita Radio.

107. (P) After checking the outside air temperature you realize that conditions are favorable to carburetor icing. Under the circumstances, you should:

1. Leave full heat applied until all ice is dissipated.
2. Turn carburetor heat off and adjust mixture control to obtain maximum rpm.
3. Decrease the amount of carburetor heat until rpm increases.
4. Turn carburetor heat off and open throttle to obtain desired power.

COMMENTS: See “Carburetor Icing”.

108. (P) If carburetor ice is present, the restriction to airflow frequently causes a richer mixture and some loss of power. Application of carburetor heat will likely cause a further immediate loss of power. In this case you should:

1. Leave full heat applied until all ice is dissipated.
2. Turn carburetor heat off and adjust mixture control to obtain maximum rpm.
3. Decrease the amount of carburetor heat until rpm increases.
4. Turn carburetor heat off and open throttle to obtain desired power.

COMMENTS: See “The Carburetor Air Temperature Gauge”.

109. (C) (P) In view of the increase in turbulence being encountered, you slow down to the speed at which an abrupt change in turbulence may be made safely. This speed is designated as the:

1. Never exceed speed.
2. Maneuvering speed.
3. Maximum utility speed.
4. Limiting speed.

COMMENTS: See “Gust Load”. Also “Airspeed Limitations”.

110. (C) The Magnetic Course (Track) from Wichita to Tulsa would be approximately:

1. 127°.
2. 305°.
3. 140°.
4. 131°.

COMMENTS: Draw a line on the map joining Wichita Airport to Tulsa Airport. This is the True Course, or Track. Measure it on a Meridian as near as possible to the center. The True Course or Track is 140°. The Magnetic Variation is 9°E. “Variation East, Magnetic Least”. The Magnetic Course or Track, is therefore 140° - 9° = 131°.

111. (P) Based on the TOP Winds Aloft Report, at 4000 ft., an indicated airspeed of 133 mph (116 kts), and
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an outside temperature of \(35^\circ\text{F}. \) \(2^\circ\text{C}\), the groundspeed for your flight from Wichita to Tulsa should be:

1. 140 mph (122 kts).
2. 132 mph (115 kts).
3. 122 mph (140 kts).
4. 148 mph (129 kts).

**COMMENTS:** By computer, an indicated airspeed of 133 mph (115 kts) "true out" to 140 mph (122 kts) TAS. The True Course (Track) from Wichita to Tulsa is \(140^\circ\). The distance is 132 s.miles (115 n.miles). The wind at 4000 ft. is from 40\(^\circ\) at 35 kts. (41 mph). By plotting or computer (Basic Problem 1) the groundspeed is 140 mph (122 kts).

112. (C) En route from Wichita to Tulsa you notice on your left a small town on a river at the intersection of several railroads, and on your right, an airport. You tune in Ponca City Radio on 113.2 mc. You centre your needle and read 5\(^\circ\) "From" the station. From this check by map and radio you find that you are:

1. On course.
2. About 4 miles to the right of your course.
3. Several miles to the left of your course.
4. At 10\(^\circ\) off course.

**COMMENTS:** Draw a bearing line 5\(^\circ\) from Ponca City VOR station. Adjacent to where this omni position line intersects your course, or track, you will readily recognize the town as Winfield, and the field as Strother.

113. (C) You are cruising along and maintaining 4000 ft. ASL. You know that with a power setting of 22 inches on the manifold pressure gauge you should be utilizing 50\% power. Several minutes after reading 22 inches on the manifold pressure gauge, you check again and find that your manifold pressure now reads 20 inches. You immediately check your altimeter and find that it still registers 4000 ft. This would indicate that:

1. The manifold pressure gauge has failed.
2. You are accumulating carburetor ice and should apply carburetor heat.
3. You have entered better atmospheric conditions and are now obtaining 50\% power with only 20 inches of manifold pressure.
4. The atmospheric pressure has dropped 2 inches.

**COMMENTS:** See "The Carburetor Air Temperature Gauge".

Some 20 miles from Tulsa Airport you tune to the tower frequency of 118.7 mc. When within 15 miles of the field you call the tower, giving your position, and request landing instructions. From Tulsa Tower you receive the following reply:

"ZERO FOX Trot - ONE FIVE MILES NORTHWEST - FOUR TWO - AT FOUR THOUSAND - CLEARED TO ENTER THE TRAFFIC PATTERN - RUNWAY THREE ZERO - WIND NORTHWEST ONE ZERO."

114. (C) The "RUNWAY THREE ZERO" in the above tower instruction on which you are to land:

1. Has a true direction of about 1\(^\circ\).
2. Has a true direction of about 30\(^\circ\).
3. Has a magnetic direction of about 300\(^\circ\).
4. Is the first one to the left of true north.

**COMMENTS:** See "Taxi Clearance", "Arrival", and "Airport Runways".

115. (C) "FOUR TWO" in the above landing instruction means:

1. Descending to 4200 ft.
2. Being on a radial 42\(^\circ\) from the field.
3. Descending 420 ft. per min.
4. Being at a given location at 42 minutes past the hour.

**COMMENTS:** See "Arrival". Also "Procedure" (Radio).

116. (C) Per instruction, you enter the traffic pattern. In making the approach for your landing, you adjust the propeller to "high rpm" ("fine pitch") in order to:

1. Keep the engine running at reduced speed.
2. Reduce the length of the landing roll.
3. Provide maximum thrust if it is necessary to go around again.
4. Provide a shallower gliding angle.

**COMMENTS:** See "Hydraulic Propellers".

117. (C) When the tower clears you to land, you are notified that the surface wind is quite gusty. In view of this condition, your best landing procedure would be to:

1. Make a partial-power wheel landing and keep the airplane in a well controlled, tail-high attitude as long as possible.
2. Make a partial-power stall landing in order to have minimum lift at the time of ground contact.
3. Land the airplane at a higher than normal landing speed, and bring the tail to the ground as soon as possible.
4. Land the airplane in a full-stall attitude in order to keep the tail on the ground.

**COMMENTS:** See "Gust Conditions".

After landing you close your VFR Flight Plan and supervise the servicing of your aircraft.

At this point we conclude the "sample" examination. The resourceful student or instructor will be able to visualize many other similar questions which might appear on the actual examination.

**ANSWERS TO THE QUESTIONS**

1. 30. (2) 59. (3) 88. (3)
2. 31. (4) 60. (2) 89. (1)
3. 32. (1) 61. (4) 90. (2)
4. 33. (1) 62. (3) 91. (2)
5. 34. (1) 63. (4) 92. (4)
6. 35. (1) 64. (2) 93. (2)
7. 36. (1) 65. (4) 94. (3)
8. 37. (2) 66. (4) 95. (3)
9. 38. (4) 67. (4) 96. (3)
10. 39. (1) 68. (2) 97. (4)
11. 40. (2) 69. (1) 98. (4)
12. 41. (3) 70. (3) 99. (4)
13. 42. (2) 71. (2) 100. (1)
14. 43. (4) 72. (4) 101. (3)
15. 44. (3) 73. (4) 102. (2)
16. 45. (4) 74. (2) 103. (1)
17. 46. (1) 75. (4) 104. (4)
18. 47. (2) 76. (2) 105. (3)
19. 48. (1) 77. (2) 106. (1)
20. 49. (2) 78. (1) 107. (3)
21. 50. (2) 79. (2) 108. (1)
22. 51. (3) 80. (1) 109. (2)
23. 52. (1) 81. (3) 110. (4)
24. 53. (2) 82. (2) 111. (1)
25. 54. (3) 83. (2) 112. (2)
26. 55. (4) 84. (1) 113. (2)
27. 56. (2) 85. (2) 114. (3)
28. 57. (1) 86. (1) 115. (4)
29. 58. (3) 87. (3) 116. (3)
CANADIAN D.O.T. QUESTIONS

Most of the types of questions which have been covered in the C.A.A. cross-country examination above are applicable to the D.O.T. examinations for Private and Commercial licenses in Canada. The following supplementary sample questions for Canadian students, however, are not covered by the American examinations:

CIVIL AIR REGULATIONS

1. You are flying at night, off airways, at 2000 feet, and observe the white (or red and white flashing) light of an airplane at approximately your altitude and in your immediate vicinity. If there is a possibility of collision, Civil Air Regulations require that:
   (1) The other pilot alter course to the right.
   (2) The other pilot alter course to the left.
   (3) You alter course to the right.
   (4) You alter course to the left.


2. Before beginning a flight, a pilot should:
   (1) Always file a VFR flight plan.
   (2) Familiarize himself with all information appropriate to the intended operation.
   (3) Give his airplane a periodic inspection.
   (4) Top up the fuel tanks.

COMMENTS: See Air Regs. Part V, 504. In the U.S., C.A.R. Part 60.11. See also "Procedure when Starting on a Cross Country Flight".

3. You are flying an aircraft outside of a control area on a cross country flight at an altitude of more than 3000 ft. above the surface. Your magnetic course (track) is 155°. Flight visibility is 2½ miles. Your altitude should be:
   (1) Odd thousands plus 500 ft.
   (2) Even thousands plus 500 ft.
   (3) Optional.
   (4) Assigned to you by ATC.

COMMENTS: See Air Navigation Order, Series V, No. 2. In the U.S., C.A.R. Part 60.32. See also "Airways", and "Change in U.S. Cruising Altitudes".

4. While you are flying over a sparsely populated area your course crosses a highway on which there is a congestion of automobile traffic. The minimum height at which you may fly over this highway is:
   (1) Not specified in Civil Air Regulations.
   (2) 500 ft.
   (3) 1000 ft.
   (4) Sufficient to avoid hazard to the occupants of the automobiles.

COMMENTS: See Air Regs. Part V, 529(b). In the U.S., C.A.R. Part 60.17. See also "Weather Minima for VFR Flight".

5. A flashing white light from the control tower to an aircraft taxiing or about to take off means:
   (1) Clear the runway.
   (2) Delay your take-off.
   (3) Return to the ramp or hanger.
   (4) Be on the alert for hazardous conditions.

COMMENTS: See Air Regs. Part V, 561(2). In the U.S., Flight Information Manual. See also "Aerodrome Procedure".

6. An Airplane flying at night must display on its right, or starboard wing tip the following light:
   (1) A red light visible for 5 miles through an angle of 110°.
   (2) A white light visible for 3 miles through an angle of 220°.
   (3) A flashing green light visible for 3 miles through an angle of 120°.
   (4) A green light visible for 5 miles through an angle of 110°.


7. It is necessary to carry the registration certificate of an aircraft:
   (1) When the aircraft is being operated for hire.
   (2) When operating in foreign countries.
   (3) At all times.
   (4) Only when flying cross country.

COMMENTS: See Air Regs. Part VIII, 821. In the U.S., C.A.R. Part 43.10. See also "Pilot's Inspection Before Flight".

8. You are piloting an aircraft, two-way radio equipped, approaching Winnipeg, where it is your intention to land. You have been cleared to the traffic pattern by the tower. Where would you normally enter the circuit:
   (1) On the base leg.
   (2) On the downwind leg.
   (3) Into wind.
   (4) Straight-in on final approach.

COMMENTS: See D.O.T. Information Circular 0/47/52. In the U.S., Flight Information Manual (Air Traffic Control Procedures). See also "Procedure When Approaching to Land".

9. An aircraft has an engine on fire over a remote area. What radiotelephony call-up signal would the pilot transmit three times:
   (1) Mayday.
   (2) Pan.
   (3) Urgent.
   (4) S.O.S.


10. You are about to land when your radio receiver becomes inoperative. How would the tower communicate a clearance to land:
    (1) By a flashing green light.
    (2) By a steady amber light.
    (3) By an alternating red and green light.
    (4) By a steady green light.

COMMENTS: See D.O.T. Information Circular 0/47/52. In the U.S., Flight Information Manual (Air Traffic Control Procedures). See also "Procedure When Approaching to Land".

ANSWERS TO THE QUESTIONS

1. (3) 4. (2) 7. (3) 10. (4)
2. (2) 5. (3) 8. (2)
3. (1) 6. (4) 9. (1)

NAVIGATION

1. A pilot begins a flight from Iola (38°-95°) to Concordia (40°-36°). He is unable to get a wind report and assumes there is no wind. At the end of 1 hour
of flight he locates himself over the town of Cottonwood Falls (38°-97'). He knows the wind is blowing from approximately:

(1) 030°.
(2) 045°.
(3) 090°.
(4) 350°.

**COMMENTS:** This is an application of the "Track and Groundspeed Method" of finding the wind velocity in the air.

The True Course (intended Track) from Iola to Concordia on the map is found to be 313°. Assuming no wind, the pilot adopted this as his Heading. His heading was therefore 313°T, and Airspeed 95 mph.

The Track he made good, Iola to Cottonwood Falls, is found on the map to be 299°T, and the distance 72 miles, which he covered in 1 hour. His Groundspeed was therefore 72 mph.

Knowing the Heading and Airspeed and Track and Groundspeed, the wind and windspeed can now be determined by plotting or computer. Wind from 350° at 32 mph. See "Track and Groundspeed Method"; Also "Basic Problem II" (Navigation).

2. For the flight planned in question No. 1, with an assumed no-wind condition, the pilot estimated his time of arrival at Concordia. On account of the Wind his actual time of arrival was approximately:

(1) 25 minutes later.
(2) 35 minutes earlier.
(3) 35 minutes later.
(4) 46 minutes later.

**COMMENTS:** The distance from Iola to Concordia on the map is 169 miles. With an airspeed of 95 mph, the pilot's estimated elapsed time to Concordia would be 1 hr. 47 min.

Over Cottonwood Falls he found the wind to be from 350° at 32 mph. The True Course (Track) from Cottonwood Falls to Concordia on the map is 324°, and the distance, 110 miles. To make good a Track direct from Cottonwood Falls to Concordia with this wind and windspeed, we find by plotting or computer (Basic Problem I) that his true heading would have to be 332° and he would have a groundspeed of 65 mph. His time from Cottonwood Falls to Concordia would therefore be 101 = 1.55 hrs., or 1 hr. 33 min. Adding 65

the 1 hr. it took him to reach Cottonwood Falls, his elapsed time from Iola to Concordia would total 2 hr. 33 min. This is 46 min. longer than his original estimated time (with no wind) of 1 hr. 47 min. See "Basic Problem I" (Navigation) and "The Circular Slide Rule".

3. A pilot flies from Fayetteville (36°-94') to Anthony (37°-98'). Without refueling, he would like to continue to Fairbury (40°-97'). The wind throughout the entire trip is from 150° at 20 mph. Without using his reserve fuel the farthest airport along his proposed course (track) the pilot can reach is located near:

(1) Hutchinson.
(2) McPherson.
(3) Salina.
(4) Concordia.

**COMMENTS:** This is a fuel-hour problem combined with Basic Problem 1.

From the map, we find that the true course (track) from Fayetteville to Anthony is 290°T, and the distance 232 miles. We now have all the factors required to solve Basic Problem I (the Wind and Windspeed, the Airspeed, and the True Course (Track) required). By plotting or computer we find the plane will have a groundspeed of 109 mph for a distance of 232 miles and will therefore reach Anthony in 2.13 hrs. (2 hr. 08 min.).

Its consumption is 6 gals./hr. In 2.13 hrs. it will therefore use \( 2.13 \times 6 = 12.78 \) gals.

Fuel remaining at Anthony is therefore 27—12.78 = 14.22—less 6 gals. (1 hr. reserve) = 8.22 gals.

With a fuel consumption of 6 gals./hr., the fuel hours available with 8.22 gals. = \( 8.22 \div 6 = 1.37 \) hrs.

The true course (track) from Anthony towards Fairbury is 013°T. Using the same wind, by methods detailed in Basic Problem I, the plane will have a groundspeed of 109 mph. At a groundspeed of 109 mph, in 1.37 hrs. the plane can travel 109 \times 1.37 = 148 miles. The airport lying safely within this distance on the route is Solina (118 miles).

See "Fuel Hours"; "Fuel Consumption" and "Computing the Load"; Also "The Circular Slide Rule" and "Basic Problem I" (Navigation).

4. A pilot begins a flight from Norton (40°-100') to Nevada (38°-94'). He departs from Norton at 10:40 and passes over the town of Osborne at 11:20. At this established groundspeed, the pilot is concerned whether he has sufficient fuel to reach Nevada. The fuel consumed for the entire trip will be approximately:

(1) 13 gallons.
(2) 15 gallons.
(3) 17 gallons.
(4) 19 gallons.

**COMMENTS:** On World Aeronautical Chart No. 360, (Kansas River Sheet) the distance from Norton to Osborne is found to be 70 miles. The pilot has covered 70 miles in 40 min. His groundspeed is therefore 70 \times 60 = 105 mph.

The total distance from Norton to Nevada is 333 miles. At 105 mph., the pilot's elapsed time will be 333 \div 3.17 hrs. (3 hr. 10 min.).

The plane's fuel consumption is 6 gals./hr. In 3.17 hrs. it will therefore use 3.17 \times 6 = 19 gals.

See "Fuel Hours". Also "The Circular Slide Rule".

5. On a flight from Miami (37°-95') to Marion (38°-97') a pilot determines the wind to be approximately from the south at 20 mph. He must therefore use a wind correction angle (crab) of approximately:

(1) 4°L.
(2) 15°R.
(3) 15°L.
(4) 9°R.

**COMMENTS:** The True Course (Track) from Miami to Marion on the map is 311°T. The Wind is from 180° at 20 mph. The True Airspeed is 95 mph. With these factors, using the methods detailed in Basic Problem I, we find that the True Heading will be 302°. The Wind Correction Angle is 311° — 302° = 9° left, or to port. See "Basic Problem I" (Navigation) and "Wind Correction Angle".

6. On a flight from Gage (36°-100') to Emporia (38°-96') a pilot found that his wind correction angle was 12° right. For a return flight under the same wind conditions his compass heading would be approximately:

(1) 235°.
(2) 220°.
COMMENTS: This is another application of the Reciprocal Heading problem.
The True Course (Track) from Gage to Emporia is 55°T.
The wind correction (Track) is 12°R.
The True Heading is therefore 67°.
The reciprocal of the True Heading (67° + 180°) is 247°T.
Subtract twice the wind correction angle (24°L).
The True Heading Emporia to Gage is therefore 223°.
Variation (taken from the map) is 10°E.
The Magnetic Heading is therefore 213°.
Deviation (from the deviation card) is 2°W.
The Compass Heading is therefore 215°.
COMMENTS: See “Calculating Reciprocals”.

A pilot flying at 9,000 ft. pressure altitude notes that his indicated air speed is 100 mph and the temperature is 59°F. His true airspeed is approximately:
(1) 98 mph.
(2) 103 mph.
(3) 108 mph.
(4) 115 mph.

A rough correction can be obtained by adding 2% to the Indicated Airspeed for every 1000 ft. above sea level.
The altitude is 900 ft. 9 × 2 = 18%.
18% of 100 mph = 18 mph.
18 mph added to 100 mph = 118, the True Airspeed.
COMMENTS: See “The Airspeed Indicator”. Also “The Circular Slide Rule”.

A pilot on a cross country flight becomes lost and tries to fix his position. He locates a small city that has a river running near it, and a railway junction on the eastern outskirts. A highway passes through it running north and south. He notices a race track on the southeast side near an airfield. About 15 miles south of the place he flew over a tower about 400 feet high. He checks his map and decides he is over:
(1) Salina (39°-98°).
(2) Concordia (39°-98°).
(3) Sedalia (39°-93°).
(4) Enid (36°-88°).

COMMENTS: The correct answer is self-explanatory. See the reverse side of the aeronautical chart for symbols.

On a flight from Gage (36°-100°) to Hays (39°-99°) what is approximately the highest terrain you would have to pass over:
(1) 3000 feet.
(2) 1950 feet.
(3) 2000 feet.
(4) 2500 feet.

COMMENTS: See symbols on reverse side of aeronautical chart.

10. What is the length of the longest runway at Wichita?
(1) 1000 feet.
(2) 10,000 feet.
(3) 1372 feet.
(4) 2780 feet.

COMMENTS: See symbols on reverse side of aeronautical chart.

11. You are flying over Clay Centre (39°-97°) and your Compass Heading is 217°. What is your True Heading:
(1) 214°.
(2) 210°.
(3) 210°.
(4) 220°.

COMMENTS: This is a simple deviation-variation conversion problem. From the deviation card in the airplane we find that a compass heading of 212° is equivalent to a magnetic heading of 210°. From the map we note that the variation is 10°E. Therefore the true heading is 220°.

COMMENTS: See “Variation”, and “Deviation”.

12. Name one of the more common uses of the Astro Compass:
1. To determine the true heading of an aircraft.
2. To fix position by reference to astronomical tables.
3. To determine the relative bearing of the Sun, Moon, or a Star.
4. To enable a navigator to steer a great circle course.

COMMENTS: See “The Astro Compass”.

ANSWERS TO THE QUESTIONS
1. (4) 5. (4) 9. (4)
2. (4) 6. (2) 10. (2)
3. (3) 7. (4) 11. (4)
4. (4) 8. (2) 12. (1)

AIRCRAFT AND ENGINES

1. The performance of an airplane is greatly affected by the wing loading. This is a value which is:
(1) Ratio of the wing area to horsepower.
(2) Total load the wing will carry.
(3) Gross weight of the airplane divided by the wing area.
(4) Gross weight divided by the span.

COMMENTS: The correct answer is self-explanatory. See “Loads and Stresses”.

2. A particular airplane has an empty weight of 1025 lbs., and is certificated for a gross weight of 1680 lbs. The fuel tank capacity is 39 gals., and the oil capacity is 2 gals. With a 190-hp, pilot, a 225-lb, passenger and 40 lbs. of baggage, the maximum amount of fuel which may be carried without overloading the airplane is:
(1) 31 gallons.
(2) 30 gallons.
(3) 30 gallons.
(4) 35 gallons.

The Gross weight of the airplane is 1680 lbs.
The Empty weight is 1025 lbs.

Disposable load
Pilot 190 lbs.
Passenger 225 lbs.
Baggage 40 lbs.
Oil (2 US. gal. × 7.5 lb.) 15 lbs. 470 lbs.
Leaving available for fuel 185 lbs.
Since 1 US. gal. of fuel weighs 6 lbs., then 185 lbs. = 185 × 30.8 gals. (say 31).


3. If a thin coating of frost or light snow has formed on the wings of an airplane, the take-off should not be attempted until it has been removed because:
(1) The coating will disturb the airflow over the wings and destroy some of the lifting capacity.
(2) The added weight overloads the airplane.
(3) The covering is cold and brittle.
4. The stalling speed of an airplane, when flying up-wind as compared to down-wind:
   (1) Would differ by an amount equal to the speed of the wind.
   (2) Is the same.
   (3) Is less when flying down-wind.
   (4) Is less when flying up-wind.
   COMMENTS: The correct answer is self-explanatory. See "Ice on Wings" (Skiplanes). Also "Frost" (Icing).

5. The maximum allowable air speed with flaps extended is lower than cruising speed because:
   (1) Flaps are not designed to withstand the loads which would be created at high speed.
   (2) The flaps will retract automatically at higher speeds.
   (3) The flaps are used only when preparing to land.
   (4) The use of flaps makes the controls more effective at low speed.
   COMMENTS: See "Flaps".

6. In which of the following air temperature ranges is carburetor icing least likely to occur?
   (1) 0° to 20°F.
   (2) 20° to 32°F.
   (3) 32° to 40°F.
   (4) 40° to 70°F.
   COMMENTS: The possibility of water vapour being present in air at temperatures between 0°F and 20°F is less than in the other temperature ranges. See "Carburetor Icing".

7. Overheating of an engine may be caused by:
   (1) Worn connecting rod bearing.
   (2) Operation with too rich a mixture.
   (3) A shorted condensor.
   (4) Operation with too lean a mixture.
   COMMENTS: See "Carburetion". Also "The Thermocouple".

8. Blue smoke from the exhaust would probably indicate:
   (1) A rich mixture.
   (2) Worn or stuck piston rings.
   (3) A lean mixture.
   (4) A stuck exhaust valve.
   COMMENTS: Worn piston rings will permit oil to leak into the combustion chamber which, when burned, will cause blue smoke to appear in the exhaust. See "Pistons and Rings". Also "Engine Fault Finding Table".

9. The use of gasoline with a lower octane rating than specified for a particular engine may cause:
   (1) The spark plugs to foul.
   (2) Detonation.
   (3) Too low an engine operating temperature.
   (4) Excessive vibration due to the slower burning fuel.
   COMMENTS: See "Fuels".

10. If during a flight at normal cruising speed, one magneto of a "dual ignition" system failed completely, it would normally cause:
   (1) A loss of approximately 75 rpm.
   (2) The engine to overheat.
   (3) Excessive vibration of the engine.
   (4) Considerable extra load to be placed on the other magneto.
   COMMENTS: See "Dual Ignition".

11. What device is used in the lubrication system of an engine to regulate the oil pressure:
   (1) The oil pressure relief valve.
   (2) The oil filter.
   (3) The oil pressure pump.
   (4) The filter by-pass.
   COMMENTS: See "Dry Sump Lubrication".

12. A higher cylinder head temperature is permissible when operating:
   (1) In rich mixture.
   (2) In lean mixture.
   (3) In coarse pitch.
   (4) At high altitude.
   COMMENTS: See "The Thermocouple".

13. What device is used on an engine to increase the pressure of the air or mixture in the induction system:
   (1) The carburetor.
   (2) The fuel injection pump.
   (3) The supercharger.
   (4) The acceleration pump.
   COMMENTS: See "Supercharging".

14. Why is "Auto Rich" mixture used during a climb:
   (1) It provides full fuel flow while automatically compensating for changes in altitude.
   (2) Because it gives the least fuel flow when maximum power is developed.
   (3) It prevents the manifold pressure from exceeding the prescribed limits.
   (4) It automatically adjusts the propeller pitch for maximum rate of climb.
   COMMENTS: See "Automatic Mixture Control".

15. What would cause a carburetor to flood:
   (1) Excess fuel in the gas tank.
   (2) Turning the propeller over too fast.
   (3) A punctured float in the carburetor.
   (4) A frozen air vent in the fuel tank.
   COMMENTS: See "Action of the Carburetor".

16. If you applied carburetor heat and the engine rpm increased, you would know that:
   (1) There was no carburetor ice.
   (2) Carburetor ice had already formed.
   (3) You were not using enough carburetor heat.
   (4) You were using too much carburetor heat.
   COMMENTS: See "Carbureter Icing" and "The Carburetor Air Temperature Gauge".
17. With what type of engine would you expect to find a manifold pressure gauge installed on your panel:

(1) A normally aspirated engine.
(2) A geared engine.
(3) A jet engine.
(4) A supercharged engine.

COMMENTS: See “Supercharging”. Also “The Manifold Pressure Gauge”.

18. Why should cabin heaters which obtain heat from the exhaust system be inspected at frequent intervals:

(1) To ensure there is no heat loss due to leaks in the system.
(2) To guard against leakage of exhaust gas fumes into the heater system.
(3) To check for metal fatigue due to constant heat expansion and contraction.
(4) Because of the danger of fire from carbon deposits.

COMMENTS: See “Care of the Airplane”.

19. The needle on a bank and turn indicator moves to the left. The ball also rolls toward the left. What is the airplane doing:

(1) A left turn, skidding outwards.
(2) A left turn, correctly banked.
(3) A climbing left turn.
(4) A left turn, slipping inwards.

COMMENTS: See “The Bank and Turn Indicator”.

20. A pilot is flying over a radio range station from which he has just received an altimeter setting of 29.92 inches (which is Standard Air). His altimeter reads 5000 feet, where the outside air temperature is 41.2°F (Standard Air). He also has a radio altimeter which registers 1500 feet. What is the elevation of the range station above sea level:

(1) 3500 feet.
(2) 7500 feet.
(3) 1500 feet.
(4) 4500 feet.

COMMENTS: Since the altimeter setting and temperature happen to correspond to the pressure of standard air at 5000 feet, his indicated altitude will be the same as his true altitude above seal level. The radio altimeter registers height above ground. The altitude of the station on the ground is therefore 5000' -1500' = 3500'. See “The Altimeter”, “The Radio Altimeter”, “Standard Atmosphere”.

21. When an airplane is in level flight and the lift on the wings is exactly equal to the weight of the airplane, it is said to have:

(1) An ultimate load factor of 1.
(2) A yield load factor of 1.
(3) A load factor of 1.
(4) A wing loading of 1.

COMMENTS: See “Loads and Stresses”.

22. What is the most commonly recommended practice for eliminating condensation in the fuel tanks:

(1) Drain a pint of fuel from the tank sumps each night.
(2) Strain all fuel as it is put in the tanks.
(3) Fill each fuel tank after every flight.
(4) Install a quick drain gascolator.

COMMENTS: See “Refuelling”.

ANSWERS TO THE QUESTIONS

1. (3) 9. (2) 17. (4)
2. (1) 10. (1) 18. (2)
3. (1) 11. (1) 19. (4)
4. (2) 12. (1) 20. (1)
5. (1) 13. (3) 21. (3)
6. (1) 14. (1) 22. (3)
7. (4) 15. (3) 23. (1)
8. (2) 16. (2)

METEOROLOGY

1. If you were standing on the 41st degree of Latitude North and faced the wind, you would know that a low pressure area would be lying on your:

(1) Left.
(2) Right.
(3) Rear.
(4) Front.

COMMENTS: See “Pressure”.

2. The dissipation of fog is assumed to result from:

(1) An increase in the wind velocity so as to blow the fog away.
(2) Condensation of the suspended water droplets in the fog in the form of rain or dew, thus eliminating the suspended droplets from the atmosphere.
(3) Heating from below from sunlight which filters down through the fog or stratus layer.
(4) Cooling of the air mass with a resulting decrease in the vapor pressure of the air mass.

COMMENTS: See “Fog”.

3. What are the general characteristics of a warm front:

(1) Good flying weather.
(2) Clear but unstable air.
(3) Precipitation, low ceilings and poor visibility.
(4) Clear, good ceilings and stable air.

COMMENTS: See “The Warm Front”.

4. What kind of front accompanies a line squall:

(1) Cold front.
(2) Warm front.
(3) Stationary front.
(4) Occluded front.

COMMENTS: See “Line Squalls”, and “The Cold Front”.

5. Maximum icing conditions are usually encountered between temperatures of:

(1) 32°F to 40°F.
(2) 15°F to 32°F.
(3) 0°F to 15°F.
(4) —10°F to 0°F.
COMMENTS: See "Icing".

6. If you were making a cross country flight from Salt Lake City, Utah, to Charlotte, N.C. and found that a high pressure area was located in northwest Colorado and a low pressure area was located in the northwest area of Kentucky, what course should you fly to have the most favorable wind:

(1) North of the high and south of the low.
(2) North of the high and north of the low.
(3) South of the high and south of the low.
(4) South of the high and north of the low.
COMMENTS: See "High and Low Pressure Areas".
Also "Pressure Pattern Flying".

7. To enable large hailstones to form, vertical currents within the clouds will be around:

(1) 25 mph.
(2) 50 mph.
(3) 75 mph.
(4) In excess of 100 mph.
COMMENTS: See "Hail".

8. The normal lapse rate or decrease of temperature with altitude is:

(1) 3.5°F per 1000 feet.
(2) 4.5°F per 1000 feet.
(3) 5.5°F per 1000 feet.
(4) 6.5°F per 1000 feet.
COMMENTS: See "Lapse Rate".

9. If you were flying westerly and you encountered a range of mountains which were lying north and south and you attempted to fly through a saddle on a west heading with the wind from the west, you would expect:

(1) To lose altitude rapidly on the west side of the saddle.
(2) To lose altitude rapidly on the east side of the saddle.
(3) To lose altitude rapidly while in the saddle.
(4) To gain altitude rapidly on the east side of the saddle.
COMMENTS: See "Up-drafts and Down-drafts" (Local Winds).

10. If you left on a cross country flight and took off from a high pressure area and flew towards a low pressure area without changing your altimeter setting you would expect:

(1) Your true altitude to be lower than your indicated altitude.
(2) Your true altitude to be higher than your indicated altitude.
(3) Your true altitude to be the same as your indicated altitude.
(4) Your pressure altitude to be the same as your indicated altitude.
COMMENTS: See "Altimeter Errors".

11. Stratus clouds are generally found at what height:

(1) Surface to approximately 6500 feet.
(2) 6500 feet to approximately 14,000 feet.
(3) 14,000 feet to approximately 19,000 feet.
(4) 19,000 feet to approximately 30,000 feet
COMMENTS: See "Clouds".

12. The ratio of the actual amount of water vapor present in air compared to the amount the same volume of air could hold if it were saturated, is called:

(1) The relative humidity.
(2) The absolute humidity.
(3) The dewpoint.
(4) Condensation.

COMMENTS: See "Humidity".

13. If you were landing at an airport that had a south wind at 2000 ft. altitude, you could expect the surface wind to be from:

(1) South.
(2) West.
(3) East.
(4) Southeast.
COMMENTS: See "Veering and Backing".

14. You are flying on a cross country and you observe a row of thunderstorms with lightning reaching the ground under most of the cumulus clouds. You see dust rising ahead of the thunder storms and between the clouds there is a patch of sky that is light colored approximately one mile wide. As the pilot of the aircraft your SAFEST plan would be to:

(1) Fly between the thunderstorms in the centre of the light area.
(2) Turn around and find a place to land until the line squall passes over you.
(3) Find an area where there is not so much lightning and fly on through.
(4) Fly as low as possible and avoid the areas with the lightning.
COMMENTS: See "Line Squalls", and "Thunderstorms".

ANSWERS TO THE QUESTIONS

1. (2) 6. (1) 11. (1)
2. (3) 7. (4) 12. (1)
3. (3) 8. (1) 13. (4)
4. (1) 9. (2) 14. (2)
5. (2) 10. (1)

RADIO AIDS

1. What is a first class bearing:

(1) One which is accurate to within 5°.
(2) One which is accurate to within 2°.
(3) One which has been taken by a First Class Navigator.
(4) A relative bearing converted to true.
COMMENTS: See "Bearings" (Radio).

2. An aircraft flying along an LF/MF Airway should fly:

(1) Along the on-course in the centre of the beam.
(2) On the left hand side of the airway, flying away from the station.
(3) Along the right hand side of the airway, in the twilight zone.
(4) At even thousands of feet if flying north-bound.
COMMENTS: See "Airways".

3. What is meant by "Frequency":

(1) The length of time between station identification signals.
(2) The number of cycles in a kilocycle.
(3) The number of cycles in one second of time.
(4) The period in which a revolving beacon rotates.
COMMENTS: See "Wave Length and Frequency".

4. Where are 'Z' Markers located:
   (1) On the final approach leg.
   (2) At the intersection of radio range courses.
   (3) In the neighborhood of dangerous obstructions.
   (4) At radio range stations.

COMMENTS: See "Radio Beacons".

5. How are radio range bearings shown on aeronautical charts:
   (1) In nautical miles.
   (2) In statute miles.
   (3) In degree magnetic.
   (4) In degrees true.

COMMENTS: See "The LF/MF Radio Range".

6. What do you hear in the twilight zone:
   (1) The A and N signals will be heard intermittently.
   (2) A distinct A or N signal will be heard.
   (3) An A or N signal will be heard faintly above the on-course.
   (4) One identification signal will be weak and the other strong.

COMMENTS: Note also that the identification signals will be heard at equal strength. See "The LF/MF Radio Range".

7. What does the needle on the radio compass azimuth dial indicate:
   (1) The heading of the aircraft.
   (2) The relative bearing of the station.
   (3) The true bearing of the station.
   (4) The track made good.

COMMENTS: See "The Automatic Radio Compass". Also "Bearings" (Radio).

8. For ADF operation, the Radio Compass needs:
   (1) A sense antenna in addition to the loop.
   (2) A trailing antenna at least 10 feet long.
   (3) A range filter.
   (4) A "ram's horn" antenna positioned above the fuselage.

COMMENTS: The subject is not covered in the text of this manual. The sense antenna is a T-shaped antenna. Its purpose is to resolve ambiguity.

9. When does the loop antenna give a minimum signal:
   (1) When the loop is upright.
   (2) When the plane of the loop is in line with the station.
   (3) When the plane of the loop is at right angles to the station.
   (4) When the volume is turned low.

COMMENTS: See "The Automatic Radio Compass".

10. When the radio compass needle reads zero, how does the plane of the loop lie:
    (1) In line with the longitudinal axis.
    (2) In line with the bearing of the station.
    (3) At right angles to the lateral axis.
    (4) At right angles to the longitudinal axis.

COMMENTS: See "The Automatic Radio Compass".

11. With the magnetic compass unserviceable, an aircraft is homing on a non-directional radio beacon bearing 055° from the aircraft. No wind. No quadrantal error. How should the loop lie:
    (1) With its plane at right angles to the longitudinal axis.
    (2) With its plane in line with the longitudinal axis.
    (3) With its plane at 055° to the longitudinal axis.
    (4) With its plane in line with the bearing of the beacon.

COMMENTS: See "The Automatic Radio Compass".

12. How do you identify a radio range station:
    (1) By its identification signals.
    (2) By its frequency.
    (3) By referring to the map.
    (4) By the location of the fan markers.

COMMENTS: See "The LF/MF Radio Range".

13. The automatic radio compass is homing. The true heading is 090°. What is the true bearing of the station from the aircraft:
    (1) 023°.
    (2) 340°.
    (3) 150°.
    (4) 160°.

COMMENTS: See "Bearings" (Radio).

14. How do you determine that drift is present when homing by radio compass:
    (1) If reading on directional gyro is higher than radio compass, drift is to starboard.
    (2) By variation of the directional gyro or magnetic compass when maintaining a constant heading by radio compass.
    (3) By variation of the radio compass when maintaining a constant heading by directional gyro or magnetic compass.
    (4) When reading on magnetic compass and radio compass do not agree.

COMMENTS: Answer No. 3 might also be considered correct, except that when homing, the radio compass is the primary instrument by which a constant heading is steered. See "Homing".

15. At what intervals are weather reports broadcast from radio range stations:
    (1) No fixed intervals.
    (2) 15 minutes.
    (3) 45 minutes.
    (4) 30 minutes.

COMMENTS: See "The LF/MF Radio Range".

16. What is the most common use of the radio compass:
    (1) Tracking a beam.
    (2) Radio range orientation.
    (3) Homing.
    (4) Instrument landing.

COMMENTS: See "Homing".

17. What is found directly over a radio range station:
    (1) A twilight zone.
    (2) Maximum signal strength.
    (3) A 'Z' marker signal.
    (4) A cone of silence.
COMMENTS: Answer No. 3 would be equally correct if the aircraft was fitted with a Marker Beacon Receiver capable of receiving a 75 megacycle signal. See “The LF/MF Radio Range”, and “Z Type Marker”.

18. Why is the loop sometimes used for reception:
   (1) To get better modulation.
   (2) To reduce precipitation static.
   (3) To improve the volume.
   (4) To prevent ice formation.

COMMENTS: See “Rain or Snow Static”.

Answers to the Questions

1. (2) 7. (2) 13. (4)
2. (3) 8. (1) 14. (2)
3. (3) 9. (3) 15. (4)
4. (4) 10. (4) 16. (3)
5. (3) 11. (1) 17. (4)
6. (3) 12. (1) 18. (2)

CONTROLLED VFR

A special endorsement to a Private or Commercial Pilot’s License is required in Canada to fly “Controlled VFR” in the Block Airspace above 9,500 ft. east of the Rockies, or 12,500 ft. west of the Rockies.

The examination consists of approximately 40 questions, the answers to which are written, not multiple choice. Approximately 15 questions are based on Radio Aids, including radio ranges, omni ranges, Victor airways, radio beacons, frequencies, the radio compass, altimeter settings, etc., as covered in detail in the Chapter on Radio. The remaining questions are based on En Route Procedures and Standard Phraseologies.

The following texts will prove useful references when preparing to write the exam.: Canada Air Pilot ($5.00 per year per volume) Air Navigation Radio Aids. Information Circular 0/15/56, Air Navigation Order Series V, No. 2 (no charge) all obtainable from the D.O.T., Ottawa Flight Information Manual ($6.00 per year) obtainable from the C.A.A., Washington.

PART 1

1. What frequencies do radio ranges transmit navigation signals on?
   Ans.—Various frequencies in the band between 200 kc. and 400 kc.


2. Where should an aircraft fly in relation to the beam, or radial.
   (a) When flying along an LF/MF Airway?
   (b) A Victor Airway?
   Ans.
   (a) On the right-hand side in the twilight zone.
   (b) On the left hand side in the twilight zone.

COMMENTS: See “Airways”.

3. What is meant by “Frequency”?  
   Ans.—The number of cycles per second.

COMMENTS: See “Wave Length and Frequency”.

4. What is heard before the cone of silence is entered?
   Ans.—A sudden burst of static.

COMMENTS: See “The LF/MF Radio Range”.

5. Where are “Z” Markers located?
   Ans.—At radio range stations.

COMMENTS: See “Radio Beacons”.

6. What do you hear in the “twilight zone”?
   Ans.—An A or N signal faintly above the on-course signal. (Note: Also the station identification signals will appear to be equal strength).

COMMENTS: See “The LF/MF Radio Range”.

7. What does the needle of the automatic radio compass indicate?
   Ans.—The relative bearing of the station from the aircraft.

COMMENTS: See “Bearings” (Radio).

8. When the radio compass needle reads zero, how does the plane of the loop lie?
   Ans.—At right angles to the longitudinal axis of the aircraft.

COMMENTS: See “The Automatic Radio Compass”. Also “Homing”.

9. How do you identify a radio range station?
   Ans.—By its identification signal.

COMMENTS: See “The LF/MF Radio Range”.

10. At what regular intervals are weather reports broadcast from radio range stations?
    Ans.—30 minutes.

Note: Special reports are also broadcast from time to time.

COMMENTS: See “The LF/MF Radio Range”.

11. What communication frequencies do most radio range stations listen on?
    Ans.—303.5 kc., 122.1 and 122.2 mc., 126.7 mc., 121.5 mc. (emergency).

COMMENTS: See “Radio Bands”.

12. What does the altimeter setting given by a ground station indicate to a pilot when it is set on his altimeter?
    Ans.—His indicated height above sea level.

COMMENTS: See “Altimeter Errors”.

13. What frequencies do Air Traffic Control Centres listen on?
    Ans.—119.7 mc.

COMMENTS: See “Radio Bands”.

14. How would you identify:
   (a) The Fan Marker on a radio range beam lying nearest, clockwise, to True North.
   (b) A second Fan Marker located further out on the same beam.

Ans.—
   (a) By one dash.
   (b) By two dots and one dash.

COMMENTS: See “Fan Type Marker”.
15. What frequencies could you use to call a VOR (Omni) station on?
   Ans.—3023.5 kc., 122.1 mc., 126.7 mc. and 121.5 mc. (emergency).
   COMMENTS: See “Radio Bands”.

16. What frequencies would you need to fly the Victor airways?
   Ans.—112.1 through 117.9 mc.
   COMMENTS: See “Radio Bands”.

17. Why is it important to use an altimeter setting from a station as close as possible to your present position?
   Ans.—Because the barometric pressure changes from place to place.
   COMMENTS: See “The Altimeter”.

   Note: The frequencies on which all Canadian ranges, omni ranges (VOR) and other radio aid facilities transmit and receive can be found listed in “Air Navigation Radio Aids”.

PART 2

18. What information should a Controlled VFR Flight Plan contain?

   You are the pilot of an aircraft, CF-ABC. You have filed a Controlled VFR Flight Plan at Stephenville for Gander at 13,000 ft. via Green Airway No. 1 and Red Airway No. 13. Reporting points along your route are: Buchans (compulsory) and Hunts Lake (non compulsory). Radio Facility Chart RF7 (from the “Canada Air Pilot”) which covers all the data applicable to this flight will be found tucked inside the folded weather map opposite Page 128. You take off at 10:00" and are over Stephenville at 10:10 climbing towards your intended altitude:

   *Note: All times used in Air Traffic Control procedures in Canada are "Z" Time, that is. Greenwich Mean Time.

19. At what height should you request clearance to enter the block airspace?
   Ans.—At approximately 8,500 feet.

20. How would you word your request?
   Ans.—“Over Stephenville at one zero—eight thousand five hundred—VFR—requesting one three thousand controlled VFR to Gander via green one and red one three.”

21. How would the clearance be given to you?
   Ans.—“ATC clears Alpha Bravo Charlie to Gander Radio via green one and red one three—climb to and maintain one three thousand VFR—report reaching one three thousand.”

   You reach 13,000 ft. over Stephenville at 10:16 and fly along the radio range towards Buchans. You reach Buchans radio range station, at 10:59.

22. How would you know you were there?
   Ans.—By passing through the cone of silence if on course, or by the reversal in the A and N quadrant signals if to one side of the cone.

23. What was your ground speed from Stephenville?
   Ans.—100 knots.

24. At what time would you estimate you would be over Hunts Lake?
   Ans.—11:45.

25. Assuming ATC requested you to report your position over Hunts Lake (although it is non compulsory) how would you word your position report over Buchans?
   Ans.—“By Buchans at five nine—three thousand—controlled VFR—estimating Hunts Lake at one four five—Gander.”

26. How would Buchans acknowledge the position report you have given as your answer to the question above. (The altimeter setting at Buchans is 29.92)?
   Ans.—“Check you by Buchans at five nine—three thousand—controlled VFR—estimating Hunts Lake at one four five—Gander—Altimeter two nine.”

27. Buchans Range Radio transmits on 209 kc. If you called them on 122.1 mc. to file your position report, what frequency would they reply on?
   Ans.—209 kc.

28. If instead you called them on 126.7 mc., what frequency would they reply on?
   Ans.—126.7 mc.

   Note: If they had simultaneous transmission, they might also reply on 209 kc.

29. Approaching Gander, you wish to know the weather there.
   (a) Where could you obtain this information and
   (b) How would you word your request?
   Ans.—
   (a) From Gander Radio or Tower.
   (b) “Request the latest Gander weather and altimeter setting.”

   Hunts Lake is a non compulsory reporting point, 19 n. miles from Gander. It is not a radio facility but the intersection of the Buchan and Gander radio range legs lying along Green Airway No. 1 and Red Airway No. 13 respectively. You have picked this point to commence your let-down for a landing at Gander. Ten miles west of the station at 11:40 you estimate your arrival at Hunts Lake at 11:45. You call Gander Center (or Radio) and they acknowledge your call.

30. How would you request a clearance to descend below the block airspace?
   Ans.—“Ten miles west of Hunts Lake at four zero—estimating the intersection at four five—requesting controlled descent through nine thousand five hundred (or out of block airspace) to land Gander.”

31. How would Gander clear you?
   Ans.—“ATC clears ABC to Hunts Lake—maintain one three thousand to Hunts Lake intersection—then descend through nine thousand five hundred—maintain VFR at all times—report leaving nine thousand
five hundred."

32. You commence your descent at 11:59. How would you advise Gander ATC of this action?

Ans.—"By Hunts Lake at five niner—controlled VFR—descending out of block airspace" (or "leaving one three thousand") immediately."

33. How would you let ATC know when you pass the 9,500 foot level on your let-down (at 12:04).

Ans.—"Leaving nine thousand five hundred (or block) at zero four—maintaining VFR—changing to tower frequency."

Fifteen miles west of Gander you are at 3900 feet at 12:12. You call Gander Tower and they acknowledge your call.

34. How would you ask for landing instructions?

Ans.—"Fifteen miles west at one two—three thousand nine hundred—landing at Gander."

35. Assuming there is a fair amount of traffic in the traffic pattern at Gander, give a typical example of the type of clearance you might possibly receive from the Tower there.

Ans.—"Cleared to enter the traffic pattern—runway zero four—wind north one five—call on downwind leg."

**ABBREVIATIONS**

The ABC's spelled out in this index apply only to the abbreviations used in this manual. They do not, by any matter of means, attempt to cover the complete ABC lingo of aviation.

A or AST—Atlantic Standard Time.  
ADF—Automatic Direction Finder.  
ADIZ—Air Defence Identification Zone.  
AFB—Air Force Base.  
ARTC—Air Route Traffic Control.  
ASL—Above Sea Level.  
ATC—Air Traffic Control.  
ATCS—Air Traffic Communication Station.  
BHP—Brake Horse Power.  
SMEP—Brake Mean Effective Power.  
C or CST—Central Standard Time.  
C—Centigrade.  
CAA—Civil Aeronautics Administration.  
CADIZ—Canadian Air Identi. Zone.  
Can.—Canada.  
CAR—Civil Air Regulations.  
CAVU—Ceiling and Visibility Unlimited.  
CG—Centre of Gravity.  
CP—Centre of Pressure.  
CPS—Cycles per second.  
D/F—Direction Finder.  
DME—Distance Measuring Equipment.  
DOT—Department of Transport.  
D/R—Dead Reckoning.  
E or EST—Eastern Standard Time.  
EHF—Extremely High Frequency.  
ETA—Estimated Time of Arrival.  
F—Fahrenheit.  
GCA—Ground Controlled Approach.  
GMT—Greenwich Mean Time.  
GCT—Greenwich Civil Time (US).  
Hg.—Inches of Mercury.  
HP—Horse Power.  
Hrs.—Hours.  
IAS—Indicated Air Speed.  
ICAN—International Air Navigation.  
ICAO—International Civil Aviation Organization.  
ILS—Instrument Landing System.  
INSAC—Interstate Airways Communications Station (now renamed Air Traffic Communication Station).  
ISA—International Standard Atmosphere.  
Kc.—Kilocycles.  
Kts.—Knots.  
LF/MF—Low/medium Frequency.  
M or MST—Mountain Standard Time.  
Mc.—Megacycles.  
Min.—Minutes.  
Mph.—Miles per Hour.  
MSL—Mean Sea Level.  
Miles—Nautical Miles.  
NORDO—No Radio.  
NOTAMS—Notices to Airmen.  
P or PST—Pacific Standard Time.  
PIREP—Pilot Reports.  
RONLY—Receiver Only.  
SIZ—Security Identification Zone.  
S.miles—Statute Miles.  
TAS—True Air Speed.  
UHF—Ultra High Frequency.  
US—United States.  
V—Victor Airway (VOR).  
VHF—Very High Frequency.  
VOR—Visual Omni Range.  
Z—Greenwich Mean Time.

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