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The Radio Mechanic and the Airplane

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THE RADIO MECHANIC AND THE AIRPLANE.

General Survey of Types of Machines—Brief Treatise on the Mechanics of the Airplane—Special Precautions in the Installation of Radio Apparatus—Airplane Nomenclature and Dictionary.

IN ORDER that a radio mechanic may undertake the work of installing radio apparatus on airplanes, it is essential that he have some knowledge of the mechanics of the airplane. It is the purpose of this pamphlet to give the reader a general idea of the various types of machines in use and their respective purposes, and to point out in a very brief way the principal features in the mechanics of the airplane with which a radio mechanic should be thoroughly familiar in order to go about his task of installing radio apparatus with assurance that his work will result in no bad effect in the operation of the airplane, and at the same time will produce satisfactory operation of the radio apparatus.

The various types of airplanes now in use in Europe may be classified into four general groups; namely, pursuit, fighting, reconnaissance, and bombing planes. The principal characteristics of these types may be summed up as follows:

Pursuit Planes.—These are small, heavily armed, one motor, one seater, mono-, bi- or triplane machines, with a mounting of one, two or three machine guns, and even in some cases a cannon. They are capable of speeds from 180 to 250 kilometers per hour (110 to 155 m. p. h.) and more, and will climb to a height of 1,000 meters in about two minutes. The maximum elevation or ceiling of their climbing ability is about 6,000 meters and more. They are called upon for an endurance of from two to three hours flight at a time. They are often spoken of as scout machines.

Fighting Planes.—These are medium or large sized, heavily armed two or three seater or more biplanes, mounting two to six or more machine guns and often a cannon. Occasionally a monoplane or biplane is used as a fighter. Many of them are armored. They are driven by two or more motors and equipped with radio apparatus. High speed and good climbing ability are characteristics of this type.

Reconnaissance Planes.—These are medium and large sized biplanes equipped chiefly for reconnoitering purposes. They are armed for defense only and are equipped with radio and photographic apparatus and carry a crew of two or three men. They develop a medium speed and climbing rate, but have long endurance.

Bombing Planes.—These machines are large biplanes and triplanes, with capacity for carrying heavy bombing loads. They are equipped with high-powered motors, but due to the heavy load which they carry they are naturally slow machines and of rather poor ceiling, although these characteristics improve as the bombs are dropped. They are usually equipped with radio apparatus and electrical night-flying apparatus. They have an endurance of at least four hours.

As an example of the bombing class of airplane may be mentioned the English Handley Page machine, the wings of which have a spread of 98 ft. It is driven by two 275-h.p. Rolls-Royce engines and will carry its load of bombs and crew of three men at a speed of 80 m.p.h. and at an altitude of 6,000 ft. These great planes naturally climb slowly, taking 42 minutes to make an elevation of 10,000 ft. The Italians have the large Caproni biplanes and triplanes, driven by three Isotta Fracchini motors of 300 h.p. and more each. The biplanes have a wing spread slightly less than the Handley Page machines and the triplanes a greater spread. They carry a great load of bombs and a crew of five men, including two gunners in some cases. The French have the Caudron, the Letard, and the De Haviland, which are all twin engined, three seaters, with large wing spreads.

In general appearance, the chief points to be noted in connection with this type of machines are: first, the great wing spread; second, the single fuselage (with the exception of the Caproni, which has two fuselages), with the two engine housings, one on either side of the fuselage; and third, the balanced ailerons, rudders, and elevators.

In the reconnaissance class of airplanes may be included the Sopwith two seater, the Morane two seater tractor, the Voisin, Farman Freres, the Armstrong-Whitworth-Beardmore, Maurice Farman, Martinsyde, and others. These types of machines are generally equipped with a single engine mounted in the fuselage and are usually arranged for carrying two passengers. They are used for observation work, photographing, for fire control work with artillery, and for general reconnaissance purposes.

Fighting in the air is the most spectacular use to which the military airplanes are put. Speed and climbing ability are the principal characteristcs. These features are absolutely essential, as they are weapons of offense and defense second only to the guns which the machine carries. The tendency in design for this type of plane at the present time is toward very light weight in ratio to the horsepower of the engines employed. Such machines are very difficult to land on account of the high speed necessary to create sufficient lift.

Examples of the fighting type machine are the single seater Sopwith "Pup," so called because of its small size; the Sopwith "Camel," thus named because it carries two machine guns instead of one; the Morane "Parasol," Nieuport, Bristol "Bullet," the 190 h.p. Bristol Fighter, the Vickers, the Spad, which was a great favorite of the famous Guynemer, the F. E. 8, F. E. 2d, built by the Royal Aircraft factory, the Morane Monocoque, De Haviland, and scores of others. The British aviators alone use at least 15 or more different types of fighting planes.

The smallest machine flown to-day is the Sopwith "Kitten." This tiny plane has a wing spread of but 19 feet. It is driven by a 30-h.p. engine at a speed of 90 m.p.h. Next in size is the Sopwith "Pup," which has a spread of 26 ft. 6 in., and then the Sopwith "Camel," having a wing spread of 28 ft. and driven by a 130-h.p. Clerget engine. This latter fighter can make 97.5 m.p.h. at an altitude of 10,000 ft., and can gain this altitude in 17 minutes. The De Haviland 4 is one of the most efficient larger fighters. It has a spread of about 42 ft. and is driven by a 375-h.p. Rolls-Royce engine. It will climb 10,000 ft. in 9 minutes, to 15,000 in 16.5 minutes, and maintain a speed of 136 m.p.h. at an altitude of 6,000 ft., 133.5 m.p.h. at 10,000 ft. and 126 m.p.h. at 15,000 ft.

Among the bombing machines used by the enemy are the Friedrichshafen, driven by two 225-h.p. Benz engines, and the Gothas. In the reconnaissance class are the Aviatik two seater, the Albatross two seater, the Gothas, and other types. In the fighting class, the Germans are using the Fokker single seater monoplane, the Halberstader biplane, the Albatross single seater biplane, the Aviatik single seater, the Friedrichshafen fighter, with its whale-type fuselage, the Albatros Scouts 1 and 2, Roland and Ago, etc. The last mentioned machine has back tapered wings and but one metal strut where other machines carry two. The reason for the peculiar construction of this machine is that it enables the gunner to direct the fire of his machine gun on either side of the pilot, forward as well as backward.

In our own country, machines of the bombing, reconnaissance, and fighting types are being built and equipped with the Liberty motor. They compare most favorably with the British and

French machines. Several different types of training planes are in use at the American training schools. The Curtiss JN-4-D has a wing spread of 43 ft. and is equipped with a 90-h.p. Curtiss motor and arranged with a dual control so that either of the two passengers may operate the plane. This plane will make 72 m.p.h. and climb at the rate of 300 ft. per minute. The Curtiss JN-4-H machine is practically a duplicate, except that it is equipped with a 150-h.p. engine and consequently is somewhat faster than the JN-4-D. The Curtiss S-3 triplane, having but a single seat, a 100-h.p. motor, and smaller wings, will climb at the rate of 900 ft. per minute. The Standard J-1 airplane is a rather slow machine, which is equipped with a Hall-Scott 100-h.p.motor. It has a wing spread of some 38 ft. The Thomas Morse S-4-B single seater, having a 26 ft. 7 in. spread, is also a training plane.

Airplane Types and Ratings.

Type.	Motor.	Number of cylinders.	Horsepower.	Weight (empty with water).	Gross weight.	Maximum speed at 6,500 ft. elevation.	Continuous flight ability.
				Pounds	*Pounds*	*M. p. h.*	*Miles.*
JN-4-D	Curtiss	8	92	1,430	1,920	75	172.5
JN-4-H	Curtiss	8	150	1,595	2,145	90	225
Thomas-Morse	Le Rhone	9	89	....	....	....	....
De Haviland 4	U. S.-12-A	12	360	2,391	3,582	120	312
Handley-Page	U. S.-21-A	2-12	300	8,270	13,700	93	....

The Mechanics of the Airplane.

The flight of an airplane is secured by driving through the air a surface or surfaces inclined to the direction of motion. Such inclination is called the angle of incidence. In this way, the surface, that is, the lifting planes, secure an upward pressure from the air by virtue of the angle of the plane as it cuts through the air. And when the speed is sufficient, this lift becomes greater than the weight of the airplane, which must then rise. It is well to bear in mind that the lift is always trying to collapse the planes upward.

The resistance of the air to the passage of the airplane is termed the "head resistance," and is also commonly called the "drift." This is overcome by the action of the propeller, which thrusts the airplane through the air. The head resistance is always tending to collapse the plane backward. Thus it is seen that there are four forces always acting on the airplane: the lift, which is opposed to the weight, and the thrust, which is opposed to the drift. The lift is useful, while the drift is detrimental. The proportion of lift to drift is known as the lift-drift ratio, and it is of paramount importance, for upon it depends the efficiency of the airplane. In rigging an airplane greatest care must therefore be taken to preserve the lift-drift ratio, and the radio mechanic should keep this in mind.

The angle of incidence is the inclination of the lifting surfaces to the direction of motion, most commonly, to the horizontal. If the angle of incidence is increased over the angle specified in the original design, then both the lift and the drift are increased also, and the drift is increased in greater proportion than the lift. On the other hand, if the angle of incidence is decreased over the correct amount, the lift and drift are decreased, and the lift is decreased in greater proportion than the drift. Hence it is seen, that any process which will alter the angle of incidence in either direction will act to impair the efficiency of the machine.

The whole weight of the airplane is balanced upon or slightly forward of the center of the lift. If the center of weight is too far forward, then the machine will be nose heavy. If it is too far behind the center of lift, then the airplane is tail heavy. By the stability of the airplane is meant its tendency to remain upon an even keel and to keep its course; that is, not to fly one wing down, tail down, or to try to turn off its course.

The directional stability of an airplane is its natural tendency to hold its course. If this does not exist, the airplane is continually trying to turn to the right or the left, and the pilot may be unable to control it. For an airplane to have directional stability, it is necessary for it to have, in effect, more keel surface behind its turning axis than in front of it. By keel surface is meant everything in view when looking at the airplane from the side—the side of the fuselage, landing gear, wires, struts, etc. Directional stability is sometimes called "weathercock" stability. Everyone knows what would happen in the case of the weathercock if there was too much keel surface in front of its turning axis, which is the point upon which it is pivoted. It would turn around and point the wrong way. That is exactly the manner in which the keel surfaces affect the airplane. Directional stability will be badly affected if there is more drift, i. e., resistance on one side of the airplane than on the other side. Consequently, in installing apparatus on airplanes this matter of balancing the amount of head resistance on the two sides and in front of and behind the center of lift of a machine must be constantly borne in mind.

One reason why an airplane may be directionally bad in its flying, is that the plane surfaces may be distorted. It must be understood that the planes are "cambered" (curved), so that they will pass through the air with the least possible resistance. If the leading edge, bars, or trailing edge should become bent or warped slightly, the curvature is changed with the result that the amount of drift on one side of the plane outbalances that on the other side, giving the machine a tendency to turn off its course.

Stress and Strain.

In order to be able to intelligently install radio apparatus on an airplane without impairing the strength or operating characteristics of the airplane, it is necessary to have a correct idea of the work every wire and every part of the airplane does. The work any part of the machine does is called stress. If it is subjected to undue strain, the material becomes distorted and this distortion is called strain. The simple stress of compression is a force which produces a crushing strain. Examples of airplane members under compression are the interplane and fuselage struts. The simple stress of tension is one which results in the strain of elongation. For example, all the wires of an airplane are under tension—a force tending to pull them in two. When a piece of material is bent, it is subjected to a compound stress, composed of both tension and compression.

Suppose, for instance, that a straight piece of wood is bent to form a circle. Before being bent, a line at either edge and one through the center, longitudinally, are all of the same length, Fig. 1. After the wood is bent into a circle, the center line is still of the same length as it was before, but it will be noted that the top line, now being on the outside of the circle, must be longer than the center line. This could only be brought about through a strain of elongation or stretching of the fiber of the wood at the outer rim, which is then under tension. Hence it is seen that the portion of the wood between the center line and the outer edge of the circle is in tension, and that the greatest tension is at the outer edge of the wood because the greatest elongation takes place there.

It will also be noticed that the line at the inside of the circle, which before being bent was of the same length as the center line, must now be shorter because it is nearest to the center of the circle, and the three circles are concentric. This could only be brought about by the strain of crushing, which is a state of compression. Hence, it is seen that the wood between the center line and the inside circle is in compression, and the greatest compression is nearest the inside edge because the fiber at

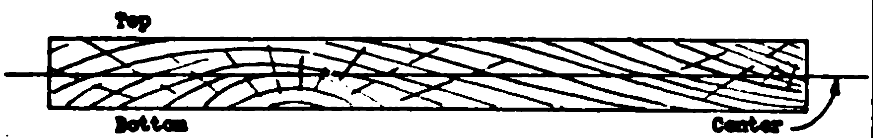

FIG. 1

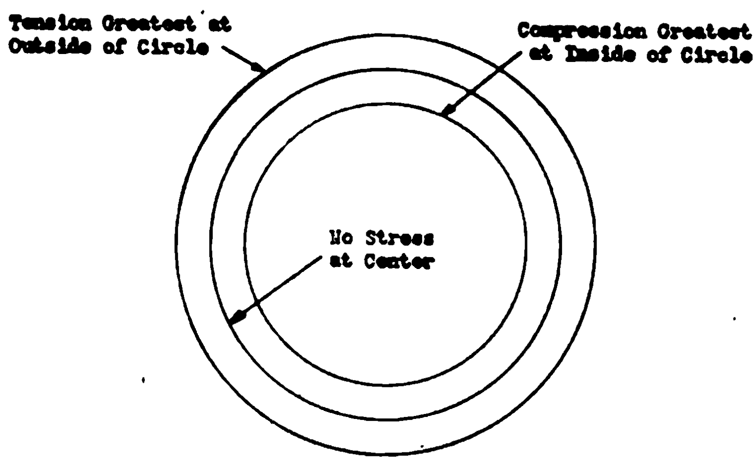

FIG. 2

this innermost edge has been crushed together the greatest amount. The circles of Fig. 2 represent the three lines of the straight stick in Fig. 1.

From the above paragraphs it will be seen that the wood nearest the center line of the piece does the least work, and this is the reason that it is possible to hollow out the center of spars and struts without weakening them unduly. In this way it is possible to reduce the weight of the wood in an airplane by 25 to 33 per cent without sacrificing much of the strength.

A shearing stress is one such that the forces tend to slide one part of the piece over the other. An example of this may be found in ordinary machine bolts used to connect any two members of an airplane together. The two members tending to pull apart or to push toward each other place a stress on the bolt tending to cut it in two, or shear it off.

The stress of torsion is one involving a tendency to twist the fiber of a rod or stick. A twisting stress may be a combination of compression, tension, and shear. An example of torsion is found in the propeller shaft or crank shaft of the engine where the forces at the opposite ends of the shaft are in opposite directions, thus tending to twist the shaft off.

Character of Wood Under Stress.

For its weight, wood takes the stress of compression better than other materials. For instance, a walking stick weighing about ½ lb. will probably stand up to a compression stress of a ton or more before crushing, provided it is kept perfectly straight. If the same stick is put under a bending load,

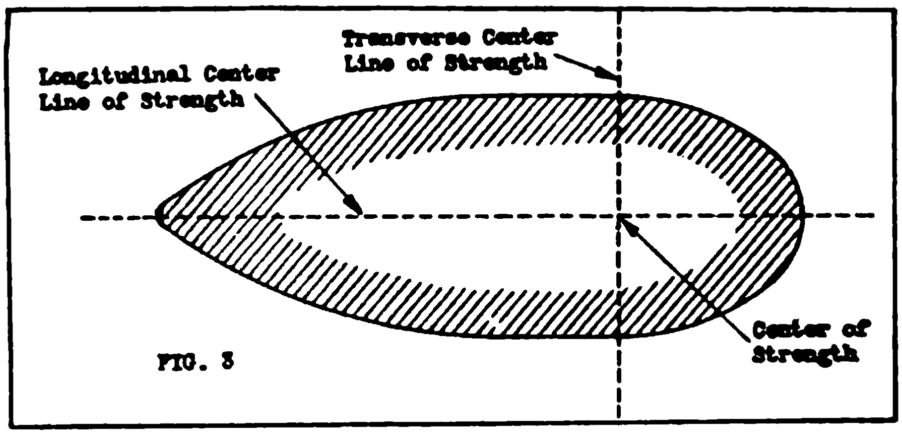

FIG. 3

it will probably collapse under a stress of not much more than 50 lb. These two conditions show a very great difference in strength, and since weight is of greatest importance in an airplane, the wood must be kept as far as possible in a state of direct compression, that is, in direct line with the direction of stress upon it. This involves the careful observance of the following conditions:

1. All the spars and struts of an airplane must be perfectly straight. Fig. 3 shows a section through an interplane strut. If a strut is to be prevented from bending, then the compression upon it must be equally disposed around the center of strength. If it is not straight, there will be more compression on one side of the center of strength than on the other side and this will be a step toward the condition of having a compression

on one side and a tension on the other side. In this case the strut will be forced to take a bending stress for which it is not designed. Even if it should not break, it would become somewhat shorter and thus throw all the wire bracing attached to the top and bottom of it out of adjustment and greatly lessen the flight efficiency of the airplane, to say nothing of the resulting undue and dangerous stress placed upon other wires (see Fig. 4). This simply emphasizes the importance of not placing or bracing any radio apparatus on an airplane in a manner which will cause a bending moment in any direction in any wood member.

2. All struts and spars must be symmetrical. By that is meant that the cross-sectional dimensions must be correct

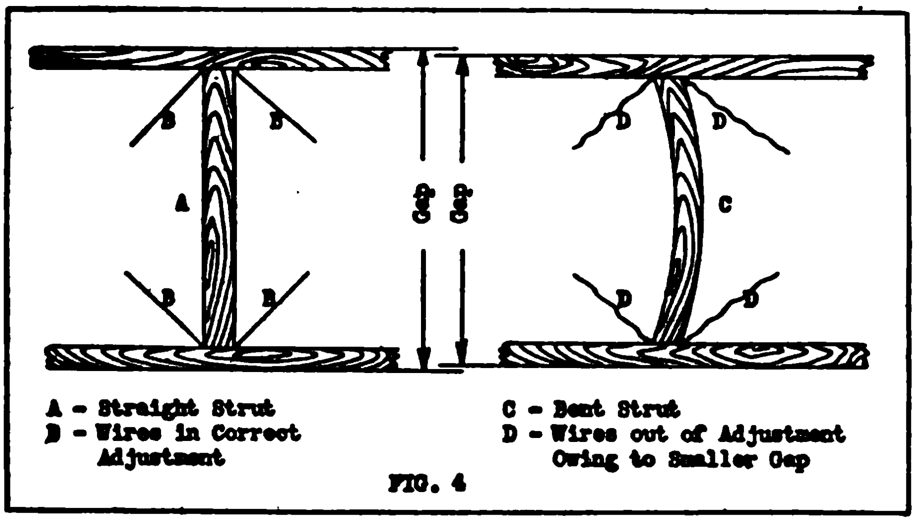

FIG. 4

throughout the full length, otherwise there will be bulging places on the outside with the result that the stress will not be uniformly disposed around the center of strength, and a bending stress will be produced.

3. Struts, spars, etc., must not be damaged. It should be remembered from what has been stated about bending stresses that the outside fibers of the wood are doing by far the most work. If a strut or spar is bruised or scored, it suffers in strength much more than one might think, and if a bending stress occurs, the piece is most likely to break at that point during a flight.

4. The wood must have a good clear grain with no cross grain, knots or shakes. Such blemishes mean that the wood is weaker in some places than in others and that if there is a tendency to bend, the piece will be likely to break at the weak points.

5. All struts, spars, and other wood members must be properly bedded into their sockets or fittings. They must make a good pushing or gentle tapping fit. They must never be so tight as to require driving in with a heavy hammer. Also, they must bed well down all over the cross-sectional area, otherwise the center of compression will be shifted to one side of the cross-sectional area with the result that the force will not be evenly disposed around the center of strength and this will produce a bending stress. The bottom of the strut or spar should be covered with some sort of paint, bedded into the socket or fitting, and then withdrawn to see if the paint has stuck all over the bottom of the fitting. This last is a test to see that the strut or member is in bearing at all points on its cross-sectional area.

6. The atmosphere is sometimes much damper than at other times, and this causes the wood to expand and contract appreciably. This would not matter but for the fact that it does not expand and contract uniformly, but becomes unsymmetrical, that is, distorted. This effect of the elements should be minimized as much as possible by thoroughly varnishing the wood to keep the moisture out of it.

Boring Holes in Wood.—It is a strict rule in airplane construction that no spar shall be used that has an unnecessary hole in it. Before boring a hole in any member, its position should be passed upon by whoever is in charge of the shop. The hole should be of such size that the bolts can be pushed in, or, at any rate, not more than gently tapped into place. Bolts must not be hammered in as this may split the spar. On the other hand, a bolt must not be loose in the hole as in this case it may work sideways and split the spar, or at least throw the wires leading from the lug or socket underneath the bolt head, out of adjustment. Whenever it is possible, a clamp should be used to attach anything to a strut or other wooden member in preference to boring a hole, as the former does not weaken the member.

Washers.—A washer should be placed under every bolt head and also underneath the nut. The size of this washer should be very large as compared with that normally used in ordinary construction work. The purpose of this large washer is to disperse the stress over a large area of wood, otherwise the washer might be pulled into the wood and weaken it, possibly throwing the wires attached to the bolt or fitting out of adjustment.

Locking Nuts.—If split pins are used for the purpose of locking nuts in place, they should be used in such a way that the nut can not possibly unscrew. If the nut is locked by means of burring the bolt, this burring should not be done by means of a heavy hammer in an attempt to spread out the head of the bolt, as that might damage the woodwork inside the plane and possibly bend the bolt inside the strut or member, causing it to split. A small light hammer should be used for the purpose, gently tapping around the edge of the bolt until it is burred over.

Tension of Wire Bracings.—The tension to which wires must be adjusted is of greatest importance. All the wires on an airplane should be of the same tension, otherwise the airplane will likely become distorted and fly badly. As a rule the wires are tensioned too much. The tension should be sufficient to keep the framework rigid. Anything more than that changes the factor of safety, throws various parts of the framework into undue compression, pulls the fittings into the wood, and may in the end distort the whole framework of the airplane. Experience is about the only instructor of what tension to employ and to assist in securing the same tension on all wires. This comes by cultivating a touch for proper tensioning of the wires.

In some cases, wires occur in the airplane which have no opposition wires, as the overhang in the Curtiss machines. In such cases it is essential to be extremely careful not to tighten the wires beyond taking up the slack. These wires must be a little slack, or otherwise they will distort the top spar downward. That will change the camber of the plane and result in changing both the lift and drift of that part of the airplane. Such a condition will cause the machine to lose its directional stability and also to fly one wing down.

In view of the above considerations, the radio mechanic must be very cautious in adjusting the tension of bracing wires whenever he may have occasion to do any work on a plane which requires the temporary removal of any wires, or when he finds it necessary to place additional wires on the plane to support radio apparatus. The general rule to be followed, except in emergency, is that the radio mechanic should not touch any bracing wires or other vital parts of the airplane, this being left to the airplane mechanics.

Wire Loops.—Wires are often bent to form a loop at the end. These loops even when perfectly made have a tendency to elongate and throw the wire tension out of adjustment. Great care should be taken to minimize this as much as possible (Fig. 5). The rules which should be observed are as follows:

1. The size of the loop should be as small as possible within reason. By this is meant that it shoud not be so small as to create the possibility of the wire breaking.

2. The shape of the loop should be symmetrical.

3. The loop should have good shoulders in order to prevent the ferrule from slipping up, but at the same time the shoulders should have no angular points.

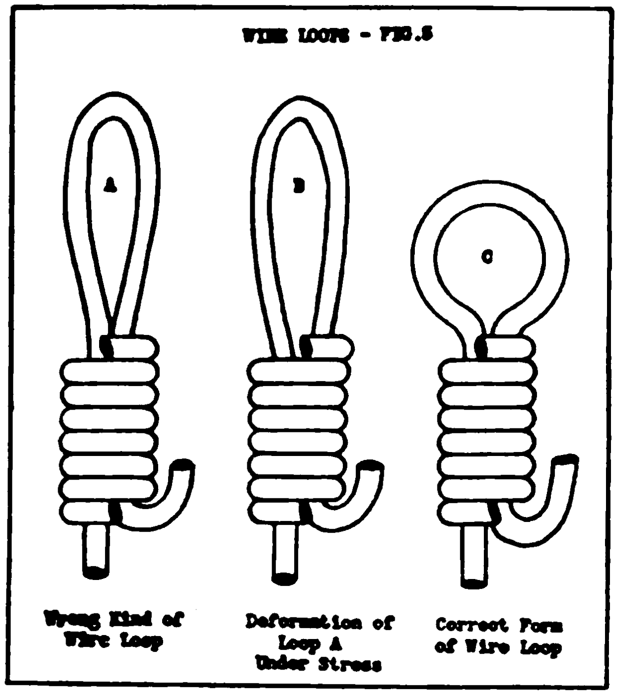

FIG. 5.—Wrong and Right Wire Loops.

4. When the loop is finished it should be undamaged, that is, not badly scored from the tools used in making it, as is often the case.

Produce No Bending Stresses.

It should be remembered that nearly all the wood of an airplane is designed to take the stress of direct compression, and it can not be safely bent. In blocking up an airplane from the ground to do any work upon it, the blocking must be used in such a way as to come underneath the interplane strut and the fuselage strut. Padding should always be placed on the surfaces upon which the airplane is to rest. When pulling a machine along the ground for any purpose, always pull it from the landing gear if possible. If necessary to pull it from some other point, grasp the interplane struts as low down as possible.

In handling parts of an airplane, never lay anything covered with fabric on a concrete floor, as any slight movement will cause the fabric to scrape over the concrete with resultant damage. Struts, spars, etc., should never be left about the floor, as they are likely to become damaged, and it has already been explained how important it is to protect the outside fiber of the wood. It should be remembered also that wood becomes easily distorted; this applies particularly to interplane struts. The best method of caring for them while they are off the plane is to stand them up in as nearly vertical position as possible.

Apparatus on Airplanes.

In order to give the radio mechanic an idea of the large amount of apparatus which must be installed on an airplane, and hence the competition which exists for space within the fuselage, the several different instruments and apparatus are listed in part in the table below. The small pursuit airplanes are usually equipped with very little auxiliary apparatus and few instruments, and with no radio apparatus. The apparatus on the bombing and reconnaissance type planes follow:

APPARATUS ON BOMBING TYPE AIRPLANES.

In Pilot's Cockpit.	*In Bomber's Cockpit.*
Air speed indicator.	Air speed indicator.
Aneroid.	Aneroid.
Clock.	Bomb dropping device.
Compass.	Clock.
Drift indicator.	Compass.
Flare dropping device.	Drift indicator.
Radio sending key.	Radio apparatus.
Incline indicator.	Radio sending key.
Lateral indicator.	Incline indicator.
Map case or roll.	Lateral indicator.
Electric light fixtures.	Map case or roll.
Oil pressure gauge.	Electric light fixtures.
Tachometer.	High altitude sighting device.
Fire extinguisher.	Camera.
Telephone.	Fire extinguisher.
	Telephone.

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APPARATUS ON RECONNAISSANCE TYPE AIRPLANES.

In Pilot's Cockpit.	*In Observer's Cockpit.*
Air speed indicator.	Air speed indicator.
Aneroid.	Aneroid.
Tachometer.	Camera.
Clock.	Clock.
Compass.	Compass.
Gasoline gauge.	Gasoline gauge.
Map case or roll.	Map case or roll.
Oil pressure gauge.	Radio apparatus.
Radio sending key.	Radio sending key.
Fire extinguisher.	Fire extinguisher.
Interphone.	Interphone.

Installation of Radio Apparatus on Airplanes.

The mounting of any auxiliary apparatus on airplanes involves many considerations of great importance. The responsibility therefore rests heavily upon radio mechanics and radio personnel generally to make absolutely certain that all of these considerations are given mature thought before proceeding to mount any radio apparatus which may in the slightest degree alter the structural make-up, control or balance of an airplane. The following general precautions must be observed, and in addition it will usually be strongly advisable to consult an aeronautic expert before making any change in the airplane.

Fire Hazard.—The liability of an airplane catching fire is perhaps the most serious danger encountered, and for this reason an open spark should be guarded against, above all things. Under normal conditions, with the motor running at its best and all gas connections good, there is nevertheless a small amount of unburned combustible gas passing back from the motor section into the cockpit at all times. A small leak in the piping, tank, or carbureter, or a missing cylinder will add to the amount of gas and consequently to the hazard. Under such conditions an open spark from any source would be disastrous. For this reason, vibrator contacts and spark gaps are completely inclosed or at least covered with fine mesh metal gauze. Connections should always be well made, and soldered and taped. All wiring should be firmly secured in a position entirely clear of moving parts such as control wires, wheel supports and foot bar.

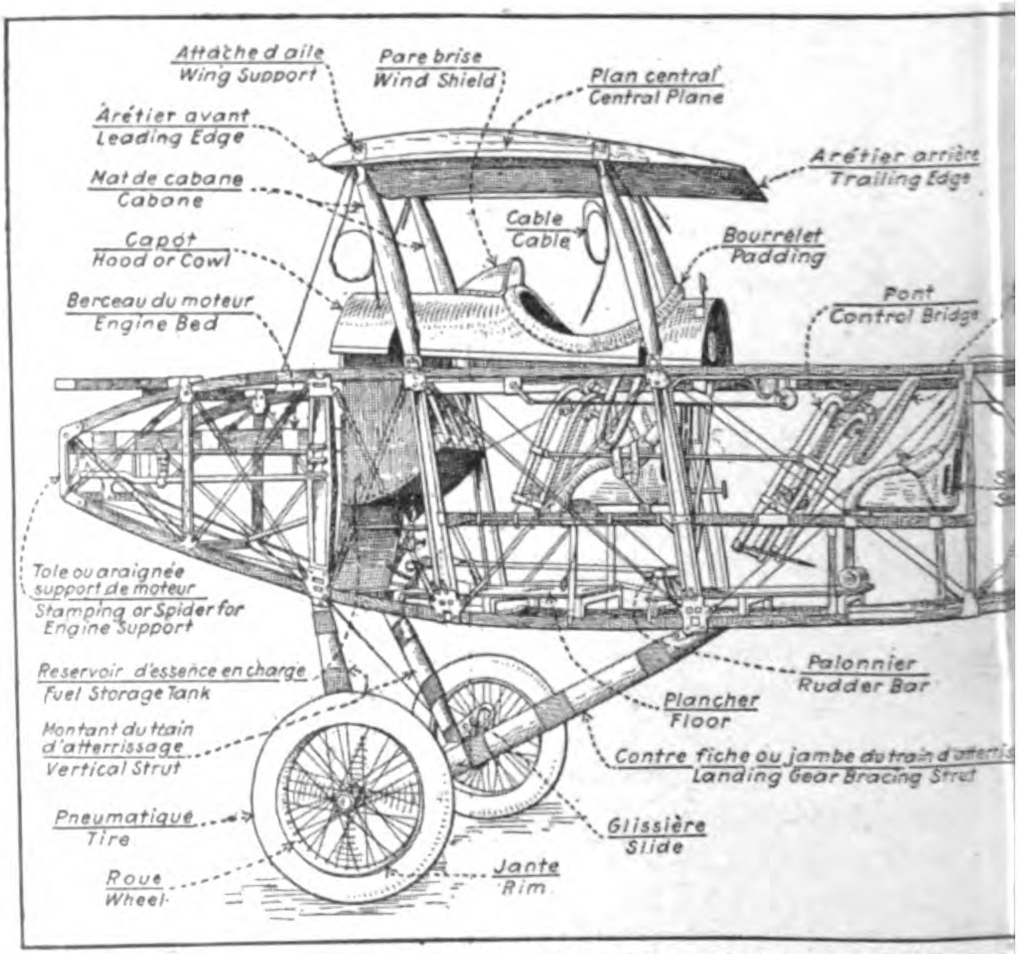
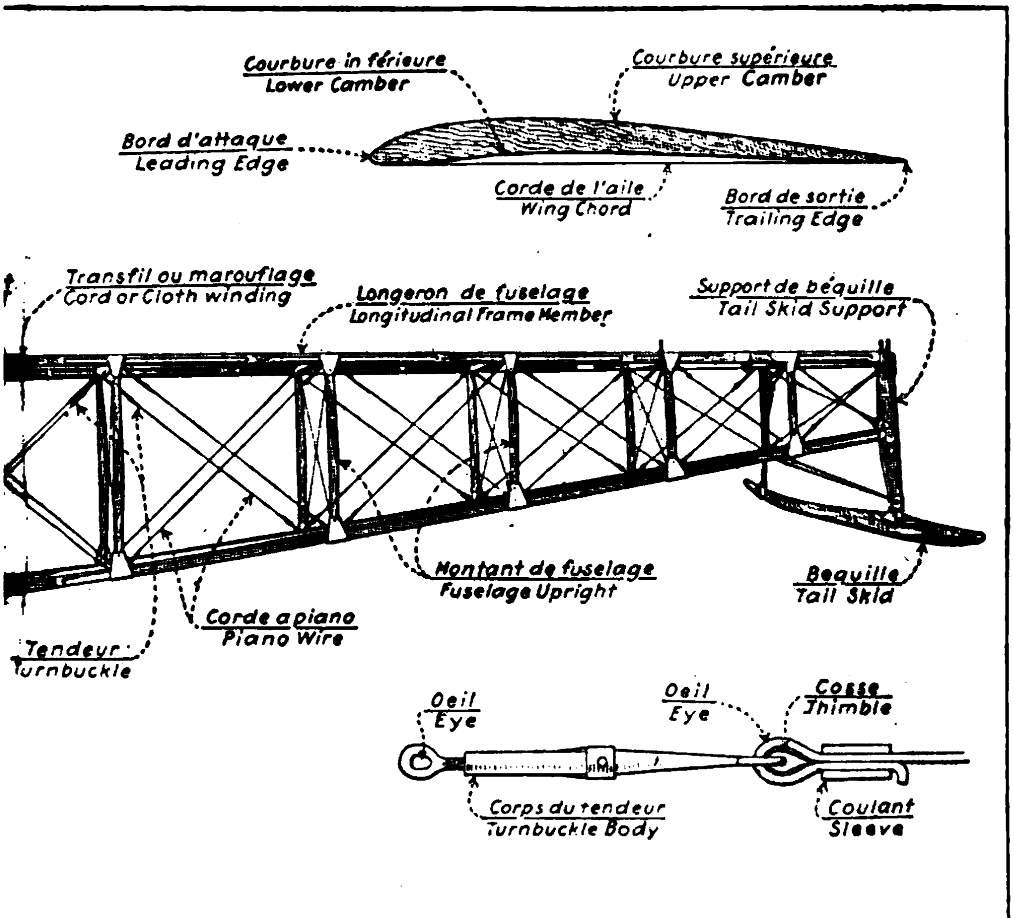


Fig. 6.—Skeleton View of Tractor Biplane w



'arious Parts Named in French and English

The antenna and counterpoise leads should be heavily insulated from the metal stays and framework of the machine generally, and run in as direct a route as possible. There should not be any uninsulated portion of a circuit where it can possibly come in contact with the pilot, the observer, or the plane. The more powerful the raio set, the greater must be the precautions against leakage. Airplane wings and control surfaces are covered with linen, which is coated with 8 or 10 layers of acetone base material, forming a highly inflammable substance easily ignited by a spark. A fire once started on the wing surface, is fanned by an 80 to 120 mile per hour breeze, and will completely envelop the machine in a few seconds.

Ruggedness of Construction.—Except for the fire hazard, the loss of control of airplanes is the most serious danger. All fittings must be made sufficiently rugged to absolutely prevent failure or breakage during flight. A piece of metal or wood weighing an ounce may easily strike the operator or pilot a disabling blow, if it breaks away at flying speed, and, at the very least, a broken fitting renders a set inoperative and makes the flight useless. Radio wires, fittings, etc., must not touch the control wires, foot bar, wheel, or wheel supports when they are in any position. Aside from the danger of wearing away insulation and causing dangerous sparks, there is a further danger of jambing the controls and bringing the machine to earth. After the installation of any radio apparatus is completed, the controls should be operated to the extreme of their movements in all directions, in order to make certain that it is impossible for any part of the apparatus to touch any moving part of the airplane. Wiring in the vicinity of the pulleys must be especially guarded against, as a jambed pulley probably will be fatal to the plane. When apparatus is directly exposed to the wind pressure, as is the case when a generator is mounted on the wing, it should be doubly safeguarded so that no parts can possibly fly off. Control wires have been cut in this manner.

Avoiding Injury to the Airplane.—Airplanes have a smaller factor of safety than practically any other piece of machinery, in order to make them faster and more easily controlled. This should be kept constantly in mind when mounting auxiliary apparatus. No struts, longerons, or other woodwork should ever be weakened by drilling. It is always preferable to clamp or lash around the wood whenever possible. When something must be fastened otherwise, wood screws should be used, the safe rule being that the screws should not enter the wood more than one-sixth its thickness. Only a sufficient number of screws should be used to hold the fittings rigidly in place. All parts of a fitting should be fastened together before mounting on the plane, and dependence should never be placed on the woodwork of the airplane for holding two pieces of auxiliary equipment together when they could be held by exterior fastenings. In lashing or clamping apparatus in place, it is very important that the tension on the fittings should not distort the members or disturb the alignment of the plane. Storage batteries should be carried where there will be no possibility for any electrolyte to spill over or come in contact with metal parts or canvas of the machine or with the skin of the observer or pilot. In cutting the covering fabric to install fittings, the edges cut should be secured or bound, in order not to weaken the fabric to any great extent.

Ease of Operation.—In locating apparatus on an airplane, it should be borne in mind that the operator is usually strapped in his seat and his movements are limited. Any apparatus requiring adjustment during flight should therefore be within easy reach of the operator and made as accessible for manipulation as possible. Accessibility, however, should be sacrificed for the precautions outlined in the three previous paragraphs. The sending key and control switches and adjusting handles should be mounted so as to be worked conveniently from the operator's seat. Good sending from an airplane on a rough day is difficult under the best arrangement of apparatus, and is almost impossible if the key is so mounted that the operator is placed in a constrained position while sending. A rest should be provided for the sending arm, or the key should be so placed as to allow the operator to rest his arm upon his knee while sending.

Interchangeability of Auxiliary Apparatus.—A very important consideration in the mounting of auxiliary apparatus on airplanes is that it shall be quickly and easily taken off and replaced in case of trouble. It should always be possible for a plane to arrive at the hangar with a defective set or exhausted storage battery, have the defective apparatus taken out of the machine and replaced with new equipment, and the machine get away again within five minutes or less.

Location of Apparatus.—In addition to the influence of accessibility and ease of operation upon the location of auxiliary apparatus, there are other considerations which have a bearing in determining the location of this apparatus on a machine. It should be remembered that an airplane is designed for a fine balance in all directions. For this reason, no great weight should be placed anywhere without consulting the aeronautical expert. In general, however, weight can be borne forward more easily than aft and with less liability of disaster, as a heavy aft weight brings about grave danger of a tail spin. Also, the right-hand side of the plane is better for balancing additional weights than the left side, for up to a certain amount the side torque of the propeller will counteract the weight.

On fighting planes, where speed is a prime requisite, all auxiliary apparatus must be mounted inside of the fuselage. It should be remembered that approximately six or eight times as much weight can be carried inside the fuselage as can be carried when the additional surface is exposed to the air currents outside. In this connection, it is interesting to note that the resistance of a fan when revolving is approximately twice as great as it is when locked still. The apparatus can be mounted at exterior positions upon training machines or on those used for observation purposes, since speed is not so important in this work, and more space is sometimes acquired inside the fuselage by this means. Specific detailed instructions as to the location and method of mounting radio apparatus on the airplane will be supplied with each set, and these directions must be followed faithfully. One very important precaution is that of avoiding the installation of any wires, even though insulated, along the metal cowl or other metal part of an airplane, as this would result in considerable loss in radiation.

Compass Location Relative to Radio Sending Apparatus.—It is very important that the radio sending apparatus on airplanes should be installed at such a point that it will not affect the operation of the compass; otherwise, this instrument will be entirely useless. In some airplanes, the observer is placed in the forward seat with a cockpit for the pilot behind him, while in other machines this order is reversed; but in either case, if the sending set is installed in the fuselage somewhere behind the rear cockpit, it will probably have no effect upon the compass, whether the latter is installed in front of the rear seat or in front of the front seat. In any event, the sending set must be far enough away from the compass so that it will have no effect upon it. If it does affect the compass, it will make that instrument useless while messages are being sent. Or in some instances, it has been found that the sending apparatus had a permanent effect upon the compass and put it entirely out of true orientation.

The test to determine whether or not the wireless apparatus has any detrimental effect upon the compass is to place the nose of the airplane toward each of the cardinal directions and then operate the wireless instrument and observe whether it has any effect on the compass in any of these positions. It may frequently happen that in one position the wireless set will have no effect upon the compass, while in another it will affect it seriously.

Airplane Nomenclature and Dictionary.

Aerial.—Pertaining to the air, or in radio work, the wires which radiate the electric oscillations.

Aerobatics.—The art, or almost science, of performing acrobatically in the air, including looping, tail sliding, nose diving, and so forth, all of which are necessary to fighting pilots.

Aerodonetics.—An invented word, to describe the science of soaring flight.

Aerodrome.—An open space arranged for the starting and alighting of airplanes, and with accommodation for machines and repair work.

Aerodynamics.—The science of dynamics as applied to the action of the air, especially in relation to mechanical flying.

Aerofoil.—Literally an "air leaf." A lifting surface of an airplane, which is commonly called a "plane," though it is not a plane surface.

Aero-hydroplane.—A hydroplane boat with wings and empennage fitted so that it flies; more generally called a flying-boat.

Aeronaut.—One who navigates the air, commonly designating an airship pilot (or any of his crew), to distinguish him from an aviator.

Aeronautics.—The science of aerial navigation of all kinds.

Aeronef.—French for aircraft.

Aeroplane.—See Airplane.

Aerostat.—Any lighter-than-air craft, not necessarily navigable, and thus including spherical and kite-balloons.

Aerostatics.—The science of aerostats.

Aerostation.—The general art of handling aerostats.

Aileron.—The flap at the rear of an airplane wing-tip, used for lateral control; i. e., rotation about the fore and aft axis.

Air bottle.—Container for compressed air used for starting big engines.

Air-cooled (engine).—Cooled by air, as opposed to water.

Aircraft.—Any kind of machine which will convey people into the air.

Airman.—One who comprehends the handling of aircraft. The difference between an aviator and an airman is the difference between a sailor and a seaman. A man may be a good sailor and yet a poor seaman.

Airmanship.—The art of handling aircraft. A parallel quality to seamanship.

Airplane.—Commonly, any heavier-than-air craft, with fixed wings and driven mechanically, as opposed to an "airship," which is lighter than air.

Airscrew.—Any screw propeller which moves an aircraft, whether a "pusher" propelling from behind, a "tractor" pulling in front, or a side screw as used on airships; generally called "propeller" on pusher planes and "screw" on tractors.

Airship.—Specifically a dirigible aerostat, as opposed to an airplane.

Air-speed meter.—An instrument designed to measure the velocity of an aircraft with reference to the air through which it is moving.

Albatros.—A famous make of German airplane.

Albatross.—A large seabird, notable for its soaring ability.

Altimeter.—An instrument for indicating the height of an airplane above the surface of the earth.

Amerissage.—French for an alighting on the sea.

Anemometer.—An instrument with which to measure air speed, with reference to the earth or some fixed body.

Aneroid.—A barometer arranged to indicate barometric pressure (and height above starting level) on a dial.

Angle of entry, attack, incidence.—The angle to the horizontal of a line drawn from front to back of an airplane's wings when flying.

Angle iron.—A bent piece of iron or steel used for reinforcing angles of a structure, or a strip of iron or steel of, or approximately of, L section.

Anti-drift (wires).—Wires to stay the wings or spars horizontally backward, against strains likely to force them forward, as in a sudden stoppage on landing, or in a tail slide.

Anti-friction metal.—A soft metal used for engine bearings which melts at low temperatures and so prevents the freezing up of bearings in case of defective lubrication.

Anti-lift (wires).—Wires or cables which take the weight of the wings when on the ground (landing wires).

Aspect ratio.—The ratio between the span and chord of an aerofoil, or of a complete pair of airplane wings.

Atterrissage.—French for a "landing."

Aviatic.—Pertaining to aviation.

Aviatik.—A famous make of German airplane.

Avion.—The French term for an airplane of war, as distinct from commercial or instructional or pleasure airplanes. (*e. g. Avion de chasse,* a "chaser" or "destroyer." *Avion de bombardement,* a bombing machine. *Avion canon,* a machine carrying a gun bigger than a machine gun. *Avion de combat,* a fighting machine.)

Aviation.—The whole art of flying, as opposed to aerostation.

Aviator.—One who flies.

Babbit metal.—An anti-friction alloy.

Backplate.—The sheet-steel plate in the front of a fuselage or nacelle, to which a rotary or radial engine is attached.

Back-wash.—The air disturbance behind an aircraft in motion.

Balanced (rudder or elevator).—A rudder or other control plane which has a portion of its surface in front of its axis to facilitate the work of moving it and to make it more effective.

Balance (to).—To maintain a state of equilibrium.

Ballonet.—An air bag inside an aerostat, to maintain gas pressure, or the separate gas bags of an airship.

Balancing plane.—See Aileron and Elevator.

Balloon.—Practically any flexible receptacle for gas.

Banking.—Inclining an airplane so that the wings assume an angle, or bank, to a transverse horizontal line.

Barograph.—A barometer designed to register its readings on a chart; otherwise, to make a "graph."

Bat boat.—Specifically a Sopwith flying boat, in which the tail booms and empennage are not integral with the hydroplane, as in other flying boats.

Bay.—The portion of a biplane or multiplane wing composed of two contiguous pairs of struts and the wing structure and bracing between them.

Beam.—Any structure designed to sustain weight when supported at points and not along its whole length. Also a ray of light.

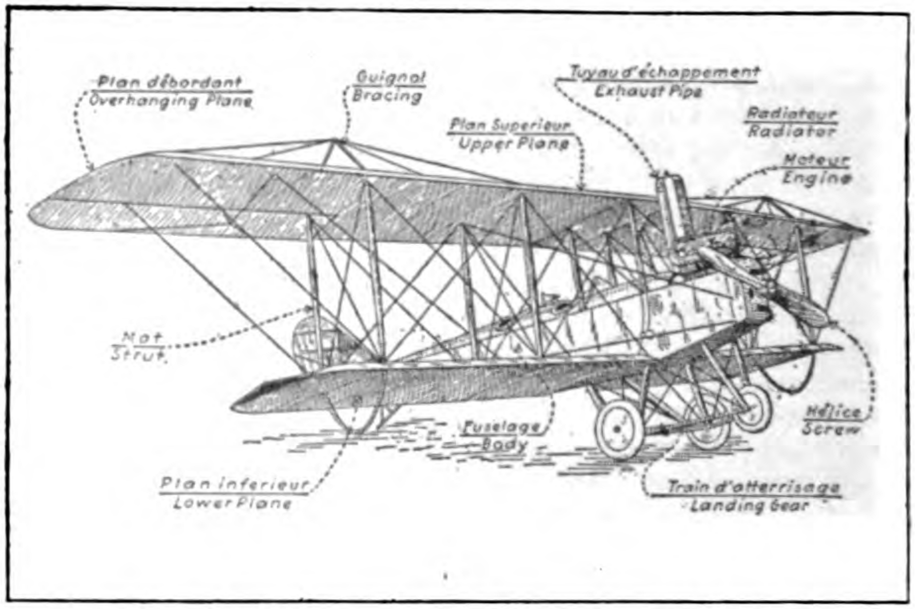


FIG. 7.—Front View of Tractor Airplane.

Bell crank.—Any lever of approximately L shape, with which to transmit motion round a corner.

Bevel gear.—A pair of cog wheels designed with the teeth on the bevel, or at an angle, to transmit power round a corner.

Bifurcate.—To form into a two-membered fork.

Biplane.—An airplane with two pairs of wings, one above the other.

Blades.—The paddle-shaped portions of air screws, outside the boss.

Blower.—A mechanical fan with which to blow up ballonets.

Body.—The portion of an airplane which incloses the pilot, passengers (if any), and generally the engine of an aircraft. (Also called fuselage and nacelle.)

Bonnet.—The metal covering or cowl over the engine and the end of the fuselage or nacelle, as the case may be.

Box kite.—Properly a box-shaped kite, but generally applied to the early types of "pusher" biplanes with front elevators.

Bracing.—Tension members, generally of wire, in a girder structure (load wires, landing wires, drift wires, etc.).

Bushing.—A circular metal lining. Generally the detachable portion of a bearing.

Cabane.—The trestle-shaped or pyramidal structure of tubes above the fuselage of a monoplane, which hold the landing wires. A similar structure is also used in most German biplanes for the attachment of the upper wings, and in some British and French biplanes also.

Cable.—A series of wires, or other material calculated to endure tension, twisted or woven into strands for increased strength.

Cabre.—A flying attitude in which the angle of attack is greater than normal; tail down; down by the stern—tail low.

Camber.—The convexity or rise of a curve of an aerofoil from its cord, usually expressed as the ratio of the maximum departure of the curve from the cord as a fraction thereof. "Top camber" refers to the top surface of an aerofoil, and "bottom camber" to the bottom surface. "Mean camber" is the mean of these two.

Canard.—Literally a duck, French slang for a rumor, but aviatically an airplane with the elevator in front and without a tail, and thus having a duck-like appearance when in the air.

Canvas.—A fabric made of coarse cotton thread, a term frequently employed erroneously for the fine linen fabric of airplanes.

Capacity:

Lifting.—The maximum flying load of an aircraft.

Carrying.—Excess of the lifting capacity over the dead load of an aircraft, which latter includes structure, power plant, and essential accessories.

Car.—Aeronautically, the basket of a balloon, or the nacelle of an airship.

Carlingue (*Carling*).—French for that portion of a "pusher" biplane which incudes the engine-bearers, tank-seating, and the attachments for the seats for the crew, and control mechanism.

Castle nut.—A nut with notches cut in its top surface to permit of the insertion of a split-pin into the bolt on which the nut is screwed.

Cavitation.—The action of a screw (air or water) in sucking fluid in behind it, or rather in causing a vacuum behind it, owing to its section being incorrect for its work.

Cellule.—A useful French term for the whole or part of the box-girder structure which is formed by the wings of a biplane or multiplane; e. g., the right cellule would be the whole of the upper and lower right wings considered as a unit. The right outer cellule would be the box structure comprising the front and rear outside struts, the front and rear struts next toward the fuselage, and everything in between them.

Center of gravity.—The theoretical line along which the weight of the aircraft (or any other body) operates.

Center of lift.—(See Center of pressure.)

Center of pressure.—The theoretical vertical line along which an airplane is supported by the air.

Center of resistance (*or of drift*).—The theoretical line along which the resistance of the air to the forward progress of the aircraft is centralized.

Center of side pressure.—The theoretical line along which the pressure of the air is centralized if the aircraft tries to move sideways (as in turning).

Center of thrust.—The theoretical line along which the air-screw operates.

Chassis.—Landing gear, or undercarriage of an airplane.

Cord.—The distance from the entering edge to the trailing edge of an aerofoil, measured in a straight line.

Cockpit.—The portion of a fuselage designed to accommodate the pilot and passenger or passengers.

Colonnette bolt.—A long bolt, or column, connecting the top of a cylinder direct to the crank case or sometimes to the crank-shaft bearings.

Control.—Generally the lever or wheel which controls the motions of the aircraft laterally and longitudinally. Also applied to the control surfaces.

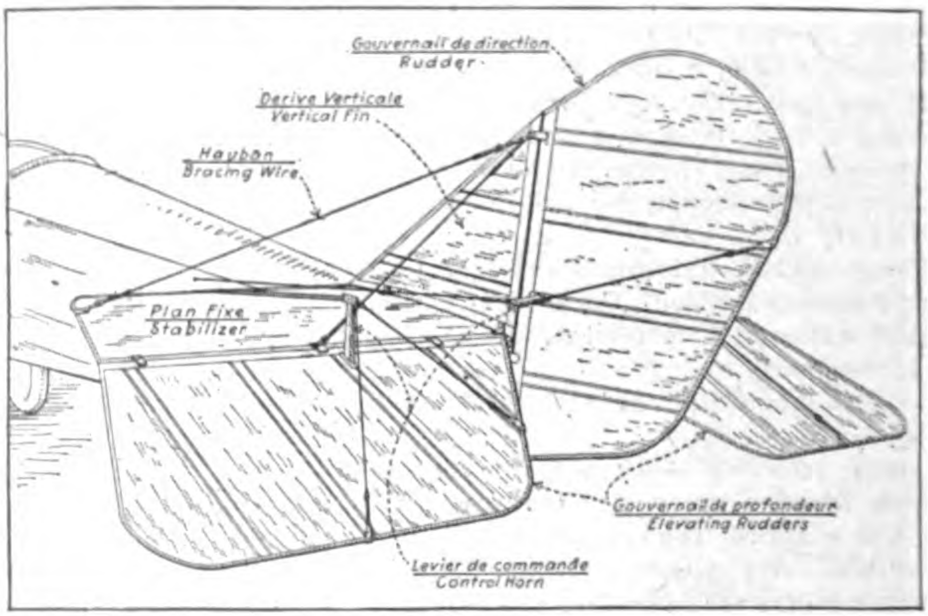


FIG. 8.—Control Members of an Airplane.

Cowl.—The metal covering or bonnet over the engine and the end of the fuselage or nacelle.

Dashboard.—The board in front of an aircraft pilot, on which the navigating instruments are fitted.

Die-casting.—A casting made in a metal die instead of in sand.

Dihedral angle.—An open angle upward—as in airplane wings, the right and left wings form a dihedral angle owing to the outer tips being higher than the butts of the wings where they join the fuselage.

Direct-driven.—A term generally used on an air screw to indicate that it is fixed direct to the engine crank-shaft, instead of being driven by gear.

Dirigible.—A form of balloon, the outer envelope of which is of elongated form, provided with a propelling system, car, rudders, and stabilizing surfaces.

Disk-wheels.—Landing wheels in which the spokes are covered by disks of fabric or metal to reduce head-resistance.

Disk area of a propeller.—The total area of the disk swept by the propeller.

Diving rudder.—See Elevator.

Dope.—A special acetyl-cellulose varnish used to shrink and harden fabric used on airplanes.

Double-surfaced.—Aerofoils or control surfaces in which (as is now almost universal) a framework or skeleton is covered on both sides by fabric, the two surfaces not touching one another.

Drag.—The total resistance to motion through the air of an aircraft.

Drift.—An erroneous expression for "head resistance."

Drift-wires.—Wires or cables designed to prevent wings from folding backward under the strain of head resistance, an erroneous but handy substitute for "head resistance wires."

Dual control.—An arrangement of control mechanism by which either the passenger or pilot (or both) can direct the movements of an airplane.

Dual ignition.—An arrangement of magnetos by which two spark plugs are fired in one cylinder simultaneously. Or an arrangement by which an engine is started by a storage battery system of ignition and subsequently run on a magneto.

Elevator.—A hinged surface for controlling the longitudinal attitude of an aircraft—i. e., its rotation about the lateral axis.

Empennage.—Literally the feathering (of an arrow). In an aircraft, the fixed tail (or stabilizer) with the elevator, plus the vertical fin and rudder considered as a complete unit.

Engine.—The machine which by expansion of gas in its cylinders imparts motion to the aircraft. (Specifically a hydrocarbon engine, as no steam engines are used for the purpose.)

Engine bearers.—The heavy members of the fuselage or nacelle which carry the engine, or its back-plate.

Entering edge.—The front edge of the wing or aerofoil, which enters the air first.

Envelope.—The fabric, or skin bag, which contains the gas of an aerostat or airship.

Extension.—That portion of the upper wings of a biplane or multiplane which extends beyond the span of the lower wings.

Fabric.—The woven material, generally fine linen, which forms the covering of the wings, body, and control surfaces of an airplane. Or the material, generally cotton, of which an airship envelope is made.

Factor of safety.—The figure representing the strength of any portion of an aircraft in proportion to the stress it is called upon to bear; e. g., a factor of safety of 6 implies that the part is six times as strong as the greatest stress which will be put upon it when in use.

Fairing.—A light casing or addition to any part of an aircraft placed and shaped so as to give the part a better stream line shape.

Fan.—Either the cooling fan used on certain air-cooled engines or the blower of an airship, but never the propeller.

Fin.—Small planes on aircraft to promote stability; for example, vertical tail fins, horizontal tail fins, skid fins, etc.

Flatten out (to).—To raise the nose of an airplane after a nose-dive and to make it return to its proper flat flying path.

Flight.—The action of flying a heavier-than-air craft, but can not be correctly applied to the navigation of an airship—which floats.

Float.—A water-tight box, or pontoon, used to sustain seaplanes when on the water.

Flying-boat.—A hydroplane with which wings, empennage, and air screw have been combined. Originated in America by Mr. Glenn Curtiss.

Flying machine.—Virtually an airplane, as opposed to an airship, though the term applies to ornithopters, orthopters, and helicopters.

Foot-bar.—The pivoted horizontal bar which operates the rudder of an airplane.

Fokker.—The name of a famous German airplane.

Frame.—Any arrangement of solid material which acts as a skeleton on which to build up other material.

Fuselage.—The shuttle-shaped body of a tractor airplane, in which the engine is placed in front, the pilot (and passengers, if any) behind it, and the empennage at the after end. (From the French *fusel*, a shuttle.)

Gap.—The distance between the projections on the vertical axis of the entering edges of the upper and lower wing of a biplane.

Gas-bag.—The fabric envelope used to contain gas in any aerostat or airship.

Gills.—The flat plates fitted to the water tubes of radiators other than those of honeycomb pattern.

Girder.—Any structure built of compression struts and tension bracing designed to carry a big load in proportion to its own weight.

Glide.—To descend on an airplane under proper control after the engine has been stopped (*volplane*).

Glider.—A small airplane without an engine, designed to be launched from a high place and to descend under control to lower ground. Used largely for experiments in the past.

Gliding angle.—The flattest angle (i. e., the most acute angle to the horizontal) at which an airplane will descend after the engine has been stopped, and without getting out of control.

Gondola.—The German term for the car or nacelle of an airship.

Gun-bus.—A slang term for a gun-carrying airplane; specially applied to the Vickers' "pusher" biplane, the first machine to be built specially to carry a machine gun.

Guy.—A rope, chain, wire, or rod attached to an object to guide or steady it, such as guys to wing, tail, or landing gear.

Hangar.—French for any kind of shed. Used specifically in English for an airplane shed.

Head resistance.—The resistance offered by the air to the movement ahead of an aircraft. This is actually caused to a greater extent by the suction behind the parts of the aircraft than by the direct resistance in front.

Helix.—Strictly any kind of screw. Aeronautically an air screw.

Hoik (to).—A slang term indicating the action of jerking an airplane rapidly onto an upward path.

Hydro-airplane.—An airplane designed to start from and alight on water. Officially called a "seaplane" and inaccurately called by the daily press a "waterplane."

Hydrogen.—The lightest gas which can be produced commercially. Largely used for the purpose of floating airships.

Hydroplane—A motor boat with a bottom designed so that is slides, or "planes," along the surface of the water. Not a flying machine of any sort.

Ignition.—Primarily the action of firing the gas charge in the cylinder of an engine. Generally the whole system of mechanism which produces ignition.

Incidence (angle of).—The angle at which the cord of an aerofoil or wing is inclined when flying in relation to a horizontal line.

Incidence bracing.—The wires between the front and rear struts of a biplane or multiplane, by which the incidence of the wings is varied or adjusted.

Inclinometer.—An instrument for measuring the angle made by any axis of an aircraft with the horizontal.

Interplane struts.—The vertical, or slightly inclined struts, generally in pairs front and rear, in biplanes and multiplanes, connecting the spars of a lower wing to the corresponding spars of the wing above.

Instrument-board.—(See Dashboard.) Generally contains a revolution indicator, an air speed indicator, a clock, a compass, the ignition switches, and an angle of climb indicator

Joy stick.—A slang word for the control lever.

Kat-hedral.—Kata-hedral, a jesting word coined to express downward drooping wings, as opposed to a dihedral angle.

Kite-balloon.—The German "drachen-ballon." A sausage-shaped balloon used as an elevated observation post in war. The tail, or lower end of the balloon, is designed so that the whole affair operates in the manner of a kite and does not sway up and down or revolve, as does a spherical captive balloon.

Laminations.—A series of strips of solid material placed together to build up a stronger and thicker member. (e. g., the leaves of a spring of a motor car.) Air screws are built up of laminations, or laminæ, of wood glued together.

Landing-carriage.—The struts and wheels below the wings, on which an airplane rests when normally on the ground. (See Chassis.)

Landing-gear.—(See Landing-carriage.)

Leading-edge.—(See Entering-edge.)

Limiting height.—The extreme height to which an aircraft will rise, without altering its design, or its engine, or some other inherent characteristic. Familiarly known as the "ceiling" or "roof" of that particular machine.

Loop (to).—Looping the loop consists in lifting the nose of an airplane, either when flying level or after a preliminary dive, and keeping the elevator up so that the machine finally passes the upward vertical path and falls over backwards. If skillfully done, centrifugal force maintains the pressure of the wings on the air, and the machine performs a perfect loop instead of a back-somersault.

Longerons.—The longitudinal members, generally of wood, in the fuselage or nacelle of an aircraft. Also used by the French for the main spars of the wings.

Long-horn.—A familiar name for the old type Maurice Farman biplane, which had an elevator in front (as well as behind), carried on two long, curved, wooden booms.

Magneto.—An electric generator producing the spark which fires the gas charge and gives power to the engine.

Mast.—A single strut or tube, used in some monoplanes instead of a cabane.

Monocoque.—Literally, a "single-hull." Applied to fuselage of the type originated by the Deperdussin firm in which the fuselage is built up on a former or mold from alternate layers of thin wood strips and fabric cemented together, thus forming a shell without internal longerons or bracing. Erroneously applied to fuselages which are overlaid with a fabric or wood streamline fairing built up on hoops outside the longerons.

Monoplane.—An airplane which has only one pair of wings on the same level, or plane.

Monosoupape.—Literally, "single valve." Applied to the type of Gnome engine which has a single valve in the cylinder-head for the air inlet and the exhaust of the explosion, the gasoline being taken in from the crank-case through ports in the lower part of the cylinders.

Motor.—A common expression for an internal combustion engine.

Multiplane.—Strictly, any airplane with more than one pair of wings, but generally applied to any with more wings than a biplane or triplane.

Nacelle.—Literally, "a cradle." Applied to the bodies of "pusher" airplanes and to the cars of airships.

Negative (angle).—The angle to the true horizontal made by an aerofoil, either wing or tail plane, which is flying with its leading edge lower than its trailing edge.

Non-rigid.—An airship without a rigid frame or keel, and dependent on the gas pressure in the envelope for the maintenance of its shape, the car, or nacelle, suspended direct from the envelope.

Nose dive.—The action of diving an airplane vertically nose first toward the ground.

Obturator ring.—A thin ring of special flexible metal used on Gnome pistons to give extra gas-tightness, and acting like the "sucker" of a pump.

Outrigger.—A term frequently applied to the tail booms of a "pusher" airplane, but originally used only for the booms carrying the front elevators of box-kites of the early Farman types.

Parasol.—A type of monoplane in which the wings are raised above the fuselage to about the position of the upper wings of a biplane, thus covering the pilot's head, and leaving a perfectly clear view below.

Petrol.—Petroleum spirit used as fuel for internal-combustion engines. Known in America as "gasoline," in France as "essence," and in most other countries as "benzin."

Pilot.—An aviator or aeronaut who pilots an aircraft, as distinct from the passenger, observer, gunner, or other occupant. Also any person who has qualified to act as a pilot.

Piston.—The pot-shaped plunger which, by sliding up and down in the cylinder, conveys the expansion of the exploding gas via the connecting-rod to the crank shaft.

Piston ring.—An expanding spring ring placed round a piston to make it gas-tight in the cylinder.

Pitot tube.—An arrangement of tubes, with one end facing the direction of flight, invented by M. Pitot, to indicate the speed of air currents. Now used to indicate the speed of airplanes through the air.

Plane.—Strictly, a perfectly flat surface, but colloquially and erroneously applied to any aerofoil, or surface of an airplane, and sometimes to the whole machine (as in "seaplane," "war plane," "battle plane," etc.).

Positive angle.—The angle made with the horizontal by an aerofoil or surface, which has its leading edge above its trailing edge.

Post.—*Stern post,* the last vertical strut in a fuselage. *Rudder post,* the vertical tube or strut to which the rudder is hinged.

Power plant.—The engine, plus all its accessories, such as tanks, radiators, instruments, control levers, and switches, and possibly including the airscrew.

Propeller.—Strictly, anything that propels, correctly applied to a "pusher" airscrew as distinguished from a "tractor." Commonly used for any airscrew.

Pusher.—Specifically an airscrew placed in back of an airplane and pushing it along instead of drawing it along. Loosely applied to any airplane moved by a pusher screw.

Pylon.—Literally, any kind of post, but generally a built-up post, of uprights and cross-bracing. Used to mark the course on an aerodrome; also, pyramids of tubes used on some monoplanes, instead of masts or cabanes, for supporting the landing wires above and the warp-wires below the fuselage.

Quadruplane.—An airplane with four pairs of wings, one above another.

Race of a propeller.—The air stream delivered by the propeller.

Radial engine.—An engine with the cylinders fixed radially around the crank-case, and with three or more connecting-rods on each crank pin. The cylinders remain still and the crank shaft revolves, as in ordinary engines, and unlike rotary engines.

Radiator.—A metal receptacle for hot water from the engine, arranged to permit the percolation of air so as to cool the water.

Radius rod.—A rod fixed at one end to one part of an aircraft and attached at the other end to another moving part, so as to insure the latter always maintaining the same distance from the former.

Ratchet.—A row of teeth, each tooth being vertical on one side and sloped on the other, so that a spring-held catch, or pawl, can slip up the sloping side. It is then held by the vertical side against return until it is lifted at the will of the person in control.

Revolution indicator.—A mechanism which indicates on a dial in front of the pilot the number of revolutions made per minute by the engine.

Rib.—The fore and aft members of an aerofoil or wing which support the fabric and mantain it in the proper curve.

Rigid.—An airship having an external skeleton so that it does not depend on gas pressure to maintain its shape.

Rotary engine.—An engine in which the cylinders are arranged radially around the crank-case, which rotates with the cylinders around a stationary crank-shaft, the airscrew being fixed to a beak-shaft fitted to the front of the crank-case.

Rudder.—The movable vertical control surface which directs the course of an aircraft over a horizontal plane.

Sausage-balloon.—(See Kite-balloon.)

Scout.—Literally, a maker of military reconnaissances, and so applied to small fast single-seat airplanes, though this type of machine is now used almost entirely for fighting, and reconnaissances are almost always made on two-seaters, carrying a pilot and an observer. The title of "scout" was first applied to the small Bristol biplane.

Seaplane.—The official term, entirely erroneous in origin, for a hydro-airplane.

Section (*wing*).—(See Camber.)

Semi-rigid.—An airship with a non-rigid envelope, but stiffened by a keel or a long spar, along the greater part of its length, the nacelle or nacelles being suspended from the keel or spar, instead of direct from the envelope.

Self-starter.—A mechanism, generally an electric motor driven by a storage battery, but sometimes a small auxiliary petrol engine, which is geared to the main engine of an aircraft to make it possible for the crew to start the main engine without manual labor.

Shock absorber.—Any contrivance designed to diminish the shock of landing an aircraft. Generally the spring contrivance between the wheel-axles and landing carriage of an airplane, which is usually either rubber cord or an oil-pneumatic device.

Side-area.—The projected area of an aircraft when viewed in side elevation.

Side slipping.—Sliding toward the center of a turn. It is due to excessive banking for the turn made and is the opposite of skidding.

Single-surface.—Any surface of an aircraft which consists of fabric exposed on both sides to the air, without an intermediate frame or skeleton. This is irrespective of the number of layers of fabric which compose the single surface.

Skidding.—Sliding sideways in flight away from the center of the turn. It is usually caused by insufficient banking in a turn, and is the opposite of side slipping.

Skids.—Long wooden or metal runners designed to prevent nosing of a land machine when landing, or to prevent dropping into holes or ditches in rough ground. Generally designed to function should the wheels collapse or fail to act.

Skin-friction.—The friction of the air over the skin, or surface, of car body passing through it, as distinct from direct resistance in front or suction behind.

Slip.—This term applies to propeller action and is the difference between the actual velocity of advance of an aircraft and the speed calculated from the known pitch of the propeller and its number of revolutions.

Socket.—Any fitting into which a compression member of a girder fits, generally applied to strut sockets. (See Interplane struts.)

Soaring.—The sustaining of an aerofoil by an upward current of air, without mechanical means. Man-carrying gliders have been known to soar for several minutes at a time in winds blowing up a hill-side. The word is frequently applied erroneously to an airplane climbing steeply by means of its own power plant.

Span.—The measurement of an airplane from the extreme tip of the right wing to the extreme tip of the left wing. Also the extreme measurement, across the machine, of any other horizontal surface, such as the tail, or elevator.

Spar.—The main members of an airplane wing, running from the butt of the wing, where it joins the fuselage or cabane, outward to the wing-tip. Generally made of wood, frequently hollow. Sometimes made of steel tube. The word spar may also be correctly applied to any main compression member of considerable length.

Spark plug.—A plug screwed into a cylinder, and so constructed that an electric spark generated by the magneto takes place between two points inside the cylinder and ignites the gas charge.

Spread.—The maximum distance laterally from tip to tip of an airplane wing. (See Span.)

Stabilizer.—A term for the fixed horizontal tailplane of an aircraft, which governs its longitudinal stability, or pitching tendency. Sometimes erroneously applied to the elevator.

Stabilizer.—See Fins (mechanical). Any automatic device designed to secure stability in flight.

Stability.—The tendency of an aircraft to return to its normal flying position if deflected therefrom by an air current, or by the operation of the controls. *Automatic stability* is procured by mechanical means, such as a gyroscope. *Inherent stability* is procured by the inherent design of the machine combining the effects of its own surfaces on the air with the action of gravity. *Longitudinal stability* refers to the stability of the aircraft fore and aft, or its pitching up and down in a vertical plane. *Lateral stability* refers to the movements sideways, i. e., the twisting around its own longitudinal axis, analogous to the rolling of a ship. *Directional stability* refers to movements on a horizontal plane, analogous to the direction of a motor car on a road.

Stagger.—The amount of advance of the entering edge of the upper wing of a biplane over that of the lower; it is considered positive when the upper surface is forward.

Stall (to).—To allow an airplane to slow down below its proper flying speed so that it falls, either by nose-diving or by rolling over sideways and side-slipping.

Stay.—A wire, rope, or the like, used as a tie piece to hold parts together, or to contribute stiffness; for example, the stays of the wing and body trussing.

Step.—A notch in the bottom of a hydroplane which assists it to plane, or skim over the surface of the water.

Strainer (wire).—(See Turnbuckle.)

Streamline.—The natural flow of air streams. A streamline shape is one given to a body so that in passing through the air it causes the minimum amount of disturbance to the air streams which pass over it or around it, thus minimizing the head resistance.

Stringer.—A longitudinal member placed to stiffen a structure; e. g., stringers are used between the hoops of a mock-monocoque fuselage to stiffen the fairing outside the main longerons.

Strut.—Strictly, any compression member in a girder structure. In airplanes, generally applied to the interplane struts of biplanes or multiplanes, which strut the upper apart from the lower wings, each front strut running from a point on top of the lower front spar to a corresponding point on the bottom of the upper front spar, and having behind it on the bottom rear spar a companion rear strut to the top rear spar.

Swept-back wings.—Wings designed so that when viewed in plan the tips are behind a straight line drawn at right angles to the center line of the airplane from a point at the butt-end of the leading edge. Commonly used on many German machines until the end of 1916; (e. g., all "Taube" type monoplanes had swept-back wings).

Tachometer.—A device for indicating the speed (r. p. m.) of the engine or propeller. Usually operates on centrifugal principle, but sometimes is a magnetic device.

Tailboom.—Any one of the protecting tubes or wooden members, which carry the tail of a "pusher" airplane.

Tail.—Loosely, the whole empennage, but more correctly only the fixed horizontal tail-plane or stabilizer.

Tail-slide.—The result of forcing the nose of an airplane as nearly as possible vertically upward, so that in falling it does so tail first, instead of nose-diving or side-slipping.

Tappet.—The plunger which operates a valve of an engine, more commony called the "lift rod."

Taube.—German, literally a dove or pigeon, hence applied to all airplanes with wings swept back and narrowing to an upward-curved tip, in the style originated by the Austrian inventor, Herr Igo Etrich.

Thrust deduction.—Due to the influence of the propellers, there is a reduction of pressure under the stern of the vessel which appreciably reduces the total propulsive effect of the propeller. This reduction is termed "thrust deduction."

Tinclip.—A slang term applied by aircraft workers to all sheet or strip metal clips, irrespective of material.

Torque.—The force which reacts against the air screw, and endeavors to turn the airplane around on the shaft of the air screw, instead of turning the air screw around on its own axis.

Tractor.—Specifically, an air screw placed in front of an airplane and drawing it along by traction instead of pushing it. Loosely applied to any airplane moved by a tractor screw.

Trailing edge.—The rear edge, when flying, of any aerofoil or surface of an airplane.

Triplane.—An airplane with three pairs of wings, one above another.

Turnbuckle.—A metal barrel threaded internally right handed at one end and left handed at the other, so that by turning it one way it draws both bolts together internally, or vice versa, drives them out simultaneously. For this reason it is used largely in screwing up the tension of airplane wires or cables by inserting a turnbuckle into the line of the wire or cable.

Twin-engined.—An airplane with two engines placed usually side by side in separate nacelles or fuselages.

U-bolt.—A two-legged bolt of U section, used frequently in attaching wires to woodwork.

Undercarriage.—(See Chassis, Landing carriage, Landing gear.)

Useful load.—A term applied to the load which an airplane can carry after being equipped with all necessary fittings for flying, and with water in the radiators. Useful load includes pilot, passenger, fuel, bombs, guns, ammunition, cameras, wireless apparatus, etc.

Volplane.—French for a glide. Literally, planed flight, as opposed to mechanically driven flight.

Wake.—(See Back-wash.)

Warping.—The twisting of an airplane wing by raising or lowering the rear spar to control the machine laterally. Now practically superseded by the use of ailerons.

Warplane.—Press term for an airplane of war, or avion.

Water-cooled (engine).—An engine kept at correct working temperature by water cooling instead of air cooling.

Water-jacket.—The casing outside the cylinder of an engine which contains the cooling water.

Web.—Specifically the vertical part of an airplane rib. More generally any thin vertical member of any girder.

Whirling table.—A species of "round-about," consisting of a long girder arm revolving horizontally on a central pivot, the extreme end being fitted with mechanism for observing experiments with parts of aircraft, such as aerofoils, engines, and air screws.

Wind screen.—A small screen fitted in front of the pilot or passenger to protect him from the air pressure.

Wing.—Any one of the aerofoils of an airplane which supports the weight of the machine, as distinct from the control or stabilizing surfaces, whether aerofoils or not.

Wing loading.—The weight carried per unit area of supporting surface.

Wing-tip.—The extreme outer end of the wing of an airplane.

Yaw.—To swing off the course about the vertical axis owing to gusts or lack of directional stability. *Angle of.*—The temporary angular deviation of the fore and aft axis from the course.

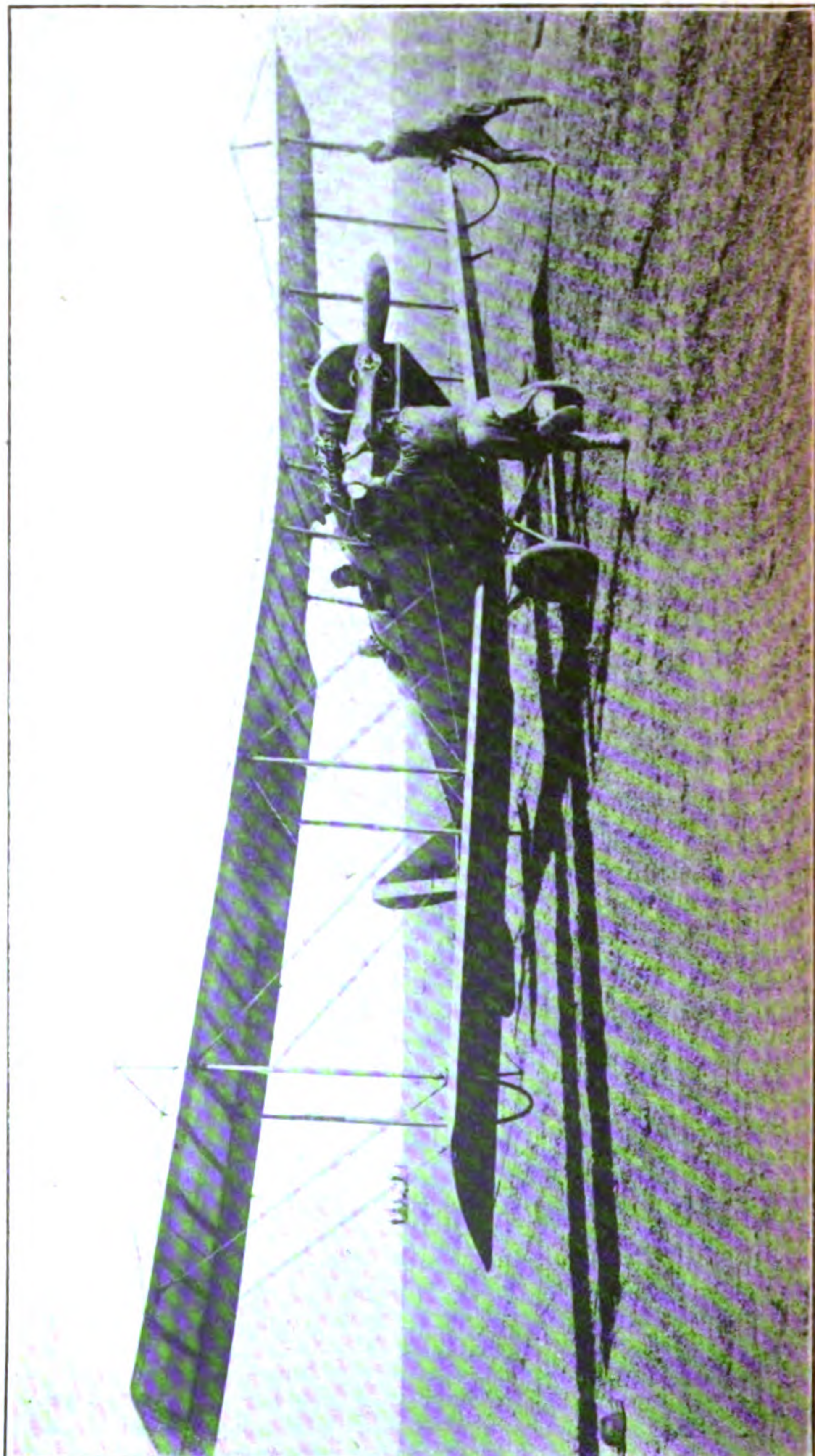


FIG. 9.—Cranking the Engine of a Curtis JN-4-H Airplane.