AIRFRAMES

The term airframe is one that seems to be misinterpreted in many cases and the definition used most commonly is "An airplane without its engine installed". One can readily see that before the student can begin to study such a complicated and complex piece of planning and designing, he must have at least an elementary knowledge of terms that are applicable to this kind of structure.

Students who have had mechanical engineering or applied mechanics will immediately see that the terms listed below are only a few of the ones used in elementary engineering. It must be kept in mind, however, that no attempt is being made here to go into specific detail of design, the idea being to give the student enough general knowledge about the machine, or machines, he is going to work with to be of help to him in handling and caring for them properly and without undue abuse.

In physics we were taught that there were three states or kind of matter namely, solids, liquids, and gases. Each of these have their own peculiarities, but the one we are most interested in is the one that is classed as a solid. The solid can be of various kinds, and due to the fact that they withstand loads of various kinds, solids are always used in the fabrication or building of structures.

Some solids come in the form of a pure element such as gold, copper, silver, and so on, others are growths such as wood produced by nature's marvellous and mysterious action called growing. Regardless of where they come from or how produced, they all have strength (the ability to keep a definite shape) and weight, and this is why solids play an important part in building. We will say very little about weight at present, but most solids are compared by weight to water, which is accepted as a standard, and the ratio of a substances' weight to that of water is called specific gravity.

The amount of a given material at hand, and its cost, usually dictates to the designer and manufacturer what the object is going to be made of. For instance, if we were in the midst of a large forest and were building a hydro line, it is highly improbable that we would use cement and gravel, to build poles, and racks, when all we would have to do would be cut down the nearby trees for poles. Supply and demand set the price of most things—if the original cannot be had, a substitute must be found which sometimes proves better than the original.

Stress

When a load is applied to any material, it produces internal forces trying to resist this load. Such forces are called **stress.** Stress is usually measured or expressed in terms of force per unit area, such as pounds per square inch. When we stress—analyse a structure, we calculate how much it is designed to carry.

Strain

The stretch, elongation, or change in shape within certain limits.

Deformation

When the body fails to rejoin its original shape after deformation, it is said to take on a permanent set or deformation.

Hardness

Hardness of a material is its resistance to permanent set. If the material is hard and breaks easily we say it is brittle. If it is soft and changes shape to a permanent set without rupture, the term malleable is used

Yield Point

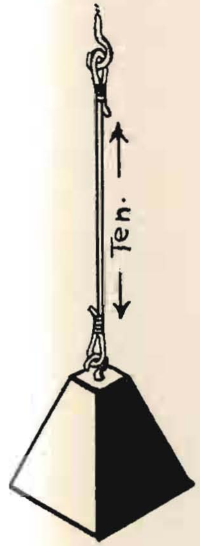
When a load is applied and change of shape takes place, but no longer in proportion to the load applied, the yield point is reached.

Fatigue

After change of shape has taken place, a change also takes place in the molecular structure of the material, the strength of which becomes so low, that in some cases, it breaks. The reason for this is beyond the scope of these necessarily brief notes, and we must assume this to be caused by fatigue.

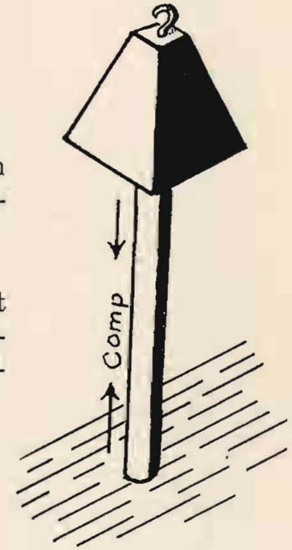
Kinds of Stress

There are five kinds of stress that are generally accepted: Tension, Compression, Shear, Bending, and Torsion.



Tension is that which resists being pulled apart.

Compression is that which resists being pushed together.



Shear is that which resists being cut or separated in one plane.

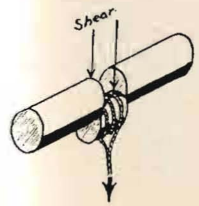


Fig. 3.

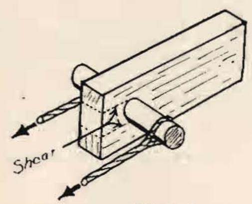


Fig. 4.

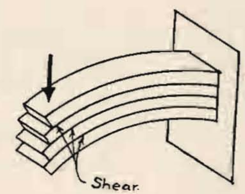


Fig. 5.

Torsion is resistance to being twisted.

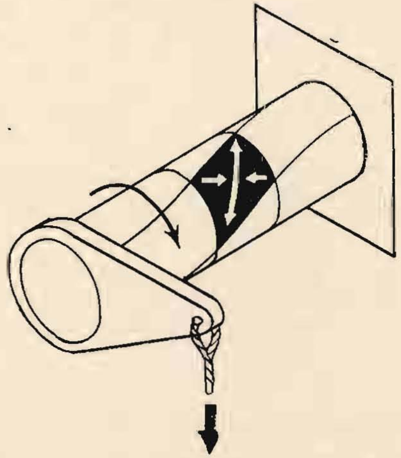


Fig. 6.

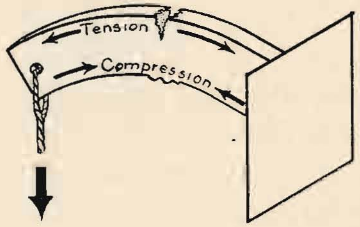


Fig. 7.

Bending is resistance to distortion by a side load.

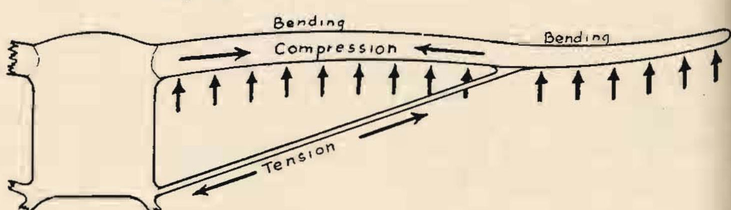


Fig. 8. Loading on a wing.

Wood

Nature's method of producing material is by growth. The exact types of growth will be dependent on the climate and conditions under which growth takes place. Usually a rapid growth will produce a light, weaker type of material, whereas growth that takes a long period of time, produces wood of heavier and usually stronger texture. Types of trees that have foliage that are needle shaped, and the seeds in cone form are called (coniferous). This type of wood is usually softer, and in some cases quite resinous (pine spruce). The type having broad, flat leaves is known as non-coniferous. Woods from this type are usually harder and heavier (oak, maple, birch).

Wood as a material for construction has definite advantages; it is easily worked, comparatively cheap, and the supply is unlimited. Its disadvantages, however, are the facts that it has to be seasoned (or dried), as its strength depends largely on its moisture content. For the purpose of fastening, glueing is used to a large extent, and most glueing being water-solvent, the moisture content will have an important bearing on its strength. In tropical climates where the humidity is high, fungus

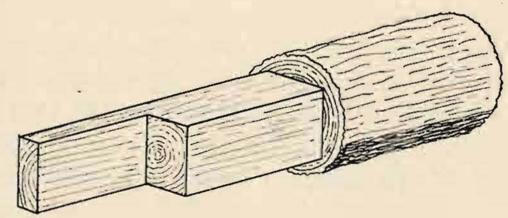


Fig. 9. Illustration of the grain of wood, as timber is cut from a log.

growth grows quite rapidly in certain types of wood, and in this state renders it unfit for structural components.

In general, it can be said that wood is a material that, if used in its proper place, is equally as good as metal. In aircraft Sitka spruce is used to a large extent, and this soft, light wood is as strong as mild carbon steel per unit weight, but it is larger in volume.

Metal

Metals in their virgin state are mined from the deposits in rock and earth formations. When refined in their pure state are classed as elements such as iron, copper, gold, silver, etc. Many of these metals have characteristics that are undesirable for building materials (expensive, strength, ability to resist corrosion, etc.), therefore to use them commercially we mix them together to obtain the desirable material as demanded. In this state they are known as alloys. All metals have what is known as a heat of fusion, commonly known as their melting point. In this molten state, if the metal be poured in a mold or form when cooled and hardened, it is known as **casting.** In a casting the metal itself might be porous and coarse grained, thereby causing weakness. To avoid this the metal can be reheated and hammered (forged) into shape, and it is them called **forging.** During the process of hammering or forging, the grain becomes finer, and the material will be stronger. In this way we have a component that is stronger, and more reliable per unit weight. If the metal is rolled or drawn into shape, it will be classed as **extrusion.** This method is used for producing long members in the form of rods, bars, or angle pieces.

Metal lends itself particularly well to this production method, because it can be blanked and formed easily and cheaply. Of late the trend in aircraft, as well as in automobile design, has been toward an all metal machine, but the shortage of strategic metals has caused such a delay in production that new and cheaper materials are constantly being searched for.

Plastics

The term Plastic is defined in the dictionary as that substance which can be molded or formed. From this it follows that plastics that are molded under heat and pressure, will have a definite strength depending on the material used. Due to the shortage of strategic materials in the aircraft industry, a field has been thrown wide open to the manufacture of any material with sufficient strength to be classed as structural material. The newspapers have so publicized plastics that the general public are of the oponion that a plastic can be mixed much in the same way as a child makes mud-pies. Unfortunately this is a pipe-dream.

In the past we have utilized wood in various forms and that type known as plywood, which is nothing more than layers of veneer placed at an angle to each other, glued together, pressed until dry making a type of wood which resembles a sandwich or biscuit that has proved very satisfactory. Its chief weakness is that it has been fastened with a glue that has not been strictly reliable. Recent developments have produced a new type of glue of the phenol-resin type, which when mixed gives a glue or bonding agent that is impervious to moisture, oils, and will not support combustion. This type of plywood is known as plastic-bonded. This is the so-called plastic which is being used for major structural components. It can be molded under heat and pressure, and when finished is in excellent condition to take on a desirable aircraft finish. By utilizing this material we are opening up a source of supply that has promise and unlimited supply—our forests. Smaller components such as door handles, knobs for instruments, or for any place where a small light weight object of low strength is required can use plastics from soya beans, woodpulp, or various refuse materials that are waste products of some larger industrial process.

MEMBERS

The object or objects that take up those various forces that we have been considering are usually termed as "MEMBERS". Depending on the particular job each member has to do, and its size and shape, lies the success or failure of the structure. These various members are usually classified according to the load applied. A few of the main types of members are listed below, but it must be kept in mind that each one could be subjected to any number or combination of loads, and for this reason the designer must know the exact behaviour of the object he is designing. The aircraft might fly and handle extremely well in the air, but under continued hard landings from students, the under carriage member might fail. From this it can be readily seen that for each and every need and condition that exists, a structure having its own particular qualities must be designed. The same aircraft that failed under the students' handling, might prove to be capable of living up to the expectation of an experienced pilot who is appreciative of the proper and careful handling of any equipment within his control.

Tie

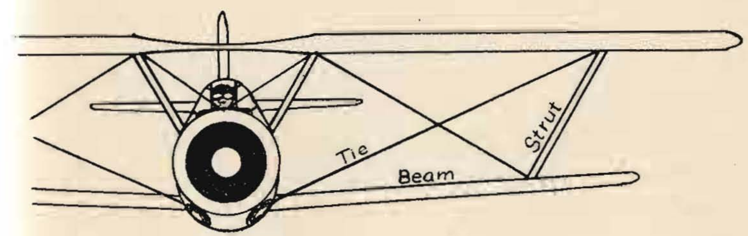
Ties are members designed to take loads in tension only, such as in the figure below. In some cases it is not necessary for these members to have stiffness; therefore, they can be in the form of cable or wires—i.e. drag and anti-drag wires.

Strut

Members that are stressed to resist compression in the direction of their length. Strut members must, therefore, be sufficiently stiff to take up these compression loads (if not sufficiently stiff they fail by bending) e.g. the leg of a table with a load on it.

Beam

Members designed to take side loads, thus resisting bending. Sometimes beams are designed to act as a tie or strut, at the same time fulfilling the duty of a beam. It can be readily seen that the term beam is quite ambiguous, and the member must be very versatile and carefully engineered.



FRAMING

When we apply these members in actual construction for the building of a structure, the term framing is sometimes used. The name for the individual type depends on how the frame is braced.

Deficient Type

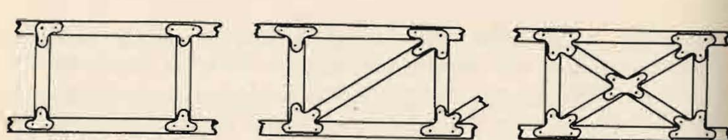
This type of the construction takes resistance to distortion but the application of loads will cause it to change shape.

Perfect

This type has an additional member and in this way resists distortion, and the member then, (which is in reality a strut designed to take tension or compression) takes the load the way the structure is being forced.

Redundant

This type has two diagonals, in other words one more than is actually necessary.



Deficient. Perfect. Redundant.

CONNECTIONS

Consideration has been given to the analysis and design of members that are under stress, but so far no attention has been given to the fastening or connecting of such members. Our troubles would be over (in more cases than one) if chewing gum, or some similar sticking substance was used. Structurally we find that the exact behaviour of the components in the structure are more or less governed by the type of fastening used.

We remember that all metals have what is called a heat of fusion, commonly called a melting point. From this it follows that if two metals or pieces of metal are brought up to a temperature, a common fused joint will be the result. Other types of fastening are bolting, rivetting, glueing, brazing, and soldering, which will be explained in detail later on. Regardless of the location of fastenings or the number of them, it is extremely important that we know as much about each type and its peculiarities, so that a careful and accurate conclusion can be drawn as to the final strength of the joint.

It is rather hard in some cases to decide just what method or methods of fastening should be used, for regardless of how old an accepted idea or theory may be, there is always an exception to every rule. Flush-rivetting, spot-welding, exploded-rivetting and synthetic glues are all playing an important part in modern aircraft.

Welding.

Welding in general takes in all fused joints. In other words, it follows that heat must be applied. Regardless of how the heat is obtained, it is the heat of fusion of metal that makes this type of joint possible. The one method of welding that has proved quite successful over a considerable length of time is the open flame or oxy-acetylene. Other types are spot-welding, where the heat is derived from the resistance of the metal itself to the passing of a low voltage, high ampherage current through it. Arc welding is achieved by a similar method; seam welding is nothing more than continuous spot-welding.

Aphorism.

"The job of the designer is a series of headaches, do not give him an extra one by trying to abuse his dream-child beyond repair."

Brazing.

Is a joint that utilizes a lower melting point rod. Thus the objects to be fastened are not brought up to their heat of fusion but only to the melting temperature of the rod being used, (usually brass or bronze). This type of joint is only a surface adhesion, and therefore has not the strength of a fused or welded joint (it is however, often called bronze-welding). The chief advantage of this type of joint is the fact that it is cheaper and requires less skill. The disadvantage is that it is hard to estimate the actual strength of it, as this is dependent on the area of adhesion.

Soldering.

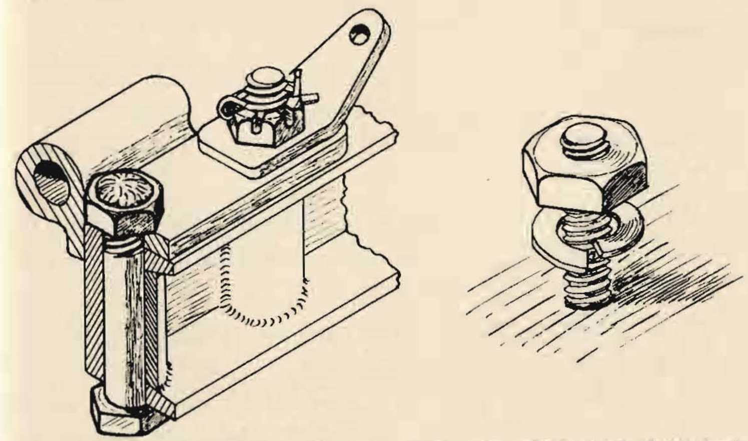
Soldering is another typical surface adhesion, using an extremely low melting point, the material being in the form of a lead and tin alloy, called solder the strength of which is dependent on the percentage of tin and lead in the solder. The chief advantage of this type of joint is the fact that it is quite easy to do and very cheap. No real load, therefore, should be placed on the joint of this type. These joints are used chiefly to prevent relative movement of parts. In the case of electrical connections they are used to insure proper electrical contact.

Glueing

A method of adhesion for wood parts, classed as a surface adhesion. Due to the fact that wood is of a porous nature, the application of glue sets up a penetrating action that is dependent on a variety of things, such as the temperature of application, the type of wood in question, and the pressure exerted by the clamps. The main types of glues used in the past have been animal, blood albumen, or casein obtained from milk. These types, however, have not proved too satisfactory under the varying conditions met by aircraft, due to the fact that they are soluble, making their strength an uncertain quantity. The discovery of the Phenol type of glues that can be mixed with water and are immediately ready for use, thus setting up, in drying, an irreversible chemical process that is not bothered by heat or cold, is waterproof, will not support combustion, and is not attacked by fungous growth, opens an entirely new field for the extension of wooden aircraft in aviation. Considerable experiment has been done in the bonding of woods together with this type of glue. To these plastic bonded ply-woods and structures the term "plastic" has been given, although this is really a misinterpretation of the meaning of the term plastic.

Bolting.

Fastening by means of a bolt and nut, the nut being locked by means of a lock washer, split pin or rivetting over the part of the bolt protruding beyond the nut. This type is quite satisfactory but is not as neat as welding and takes extra time to bore, fit, and assemble. It can be carefully stress analyzed and is therefore chosen in some cases where the joint has been designed as a safety fitting, having the bolt sheer first, as an indication of overload.

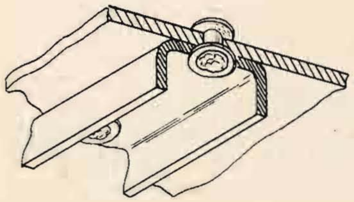


Note that the first nut is locked by peining the end of the bolt, and the second by a split pin.

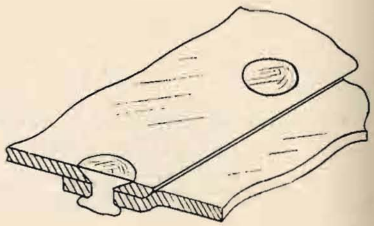
This nut will be locked against turning off by the sharp edges of the locking washer.

Rivetting

This is practically the same as bolting, except a rivet, having a head on one end, is placed through a drilled hole, and then pounded or peined to form a head on the other end. Ofter a burr or washer is placed on the rivet before peining to reinforce the material. It is a good type of joint, but demands time and skill, and dismantling for inspection or repair is difficult.



A brassier or oval headed rivet with a burr.



Counter-sunk or flush rivetting.

Fuselage

This is the portion of the aircraft which houses the crew, from which the pilot controls the aircraft, and to which the engine, wings, tail assembly and undercarriage are attached.

The flying boat derives it name from the fact that the fuselage with no undercarriage, takes on a boat-like appearance, and is called a hull.

The exact design of the fuselage varies according to the task of the aircraft; for example, a freighter must have ample room for storage of bulky objects, whereas a fighter with only pilot space required, can be neat and compact.

Following are the types of fuselage construction:—

Braced Girder Type.

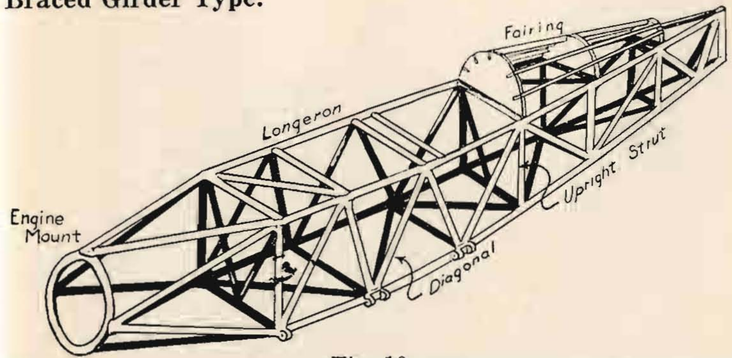


Fig. 10.

It can be either wood or metal, if wood, it will be fastened by bolts and glue; and if metal, by welding, rivets or bolts.

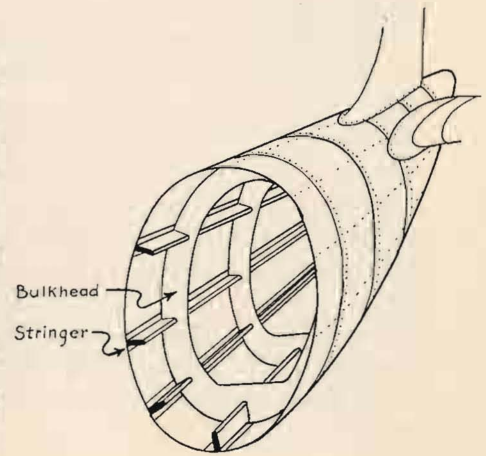
The structure consists, usually, of four longerons or lengthwise members, spaced by uprights or struts separating the frame into bays, yhich are braced by diagonal struts or wires. The frame is faired with light strips and covered with fabric to streamline it.

This type lends itself particularly well to light training aircraft, where ease of repair and low initial cost is desired.

(e.g. DeHaviland Tiger Moth, Nordyne Norsman).

Monocoque Type

Fig. 11.



This structure utilizes a tough outer skin (a single shell; hence the name) to carry the stresses in the fuselage. It is supported and formed by bulkheads and stiffened by stringers or longerons. This type of construction where the outer covering is designed to take up part of the load is known as STRESSED SKIN.

Semi-monocoque is the same type of structure, but depends to a greater extent on its inner frame-work for strength.

(e.g. Lockheed Hudson).

Geodetic Type

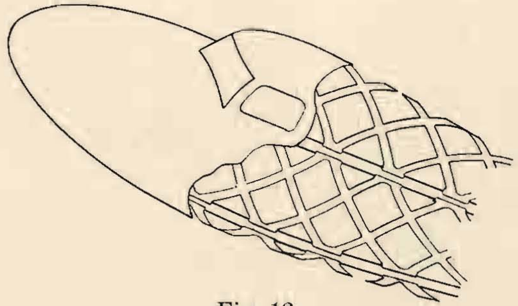


Fig. 12.

This fuselage closely resembles a woven wire or wicker basket, in which there are no main members, each part being dependent on an other. This method of construction gives us a light flexible structure, particularly resistant to shell fire, due to the absence of main members such as longerons, whose damage might cause a major structural failure.
(e.g. Vickers Wellington Bomber).

Wings

The wing is the structure of the aircraft designed to produce lift when it is moved through the air. The airplane is sustained in flight by this reaction.

The shape or contour of the crosssection is given to the wing by former ribs, which are supported by the longitudinal members, called spars. A suitable system of bracing distributes the load throughout the structure.

Some types are covered by fabric and require internal members for support, whereas others, using a heavy covering of plywood or metal, to a large extent derive their strength from this covering, called a **stressed skin** wing.

Regardless of wing design they all produce lift, which is transferred to the fuselage by external bracing, or by the stiffness of a **full cantilever** wing from its internal bracing.

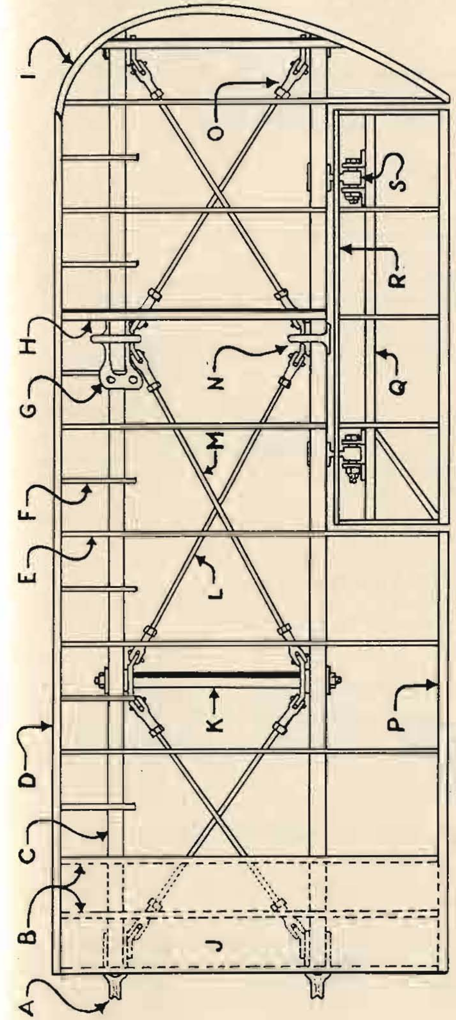


Fig. 13.

A Typical Two Spar Fabric Covered Wing.

A. Wing root fitting.
B. Reinforced walkboard ribs.
C. Spar.
D. Leading Edge.
E. Former Rib.
F. Nose Rib or Riblet.
G. Interplane Bracing Fitting.
H. Reinforced Compression Rib.
I. Wing Tip Bow.
J. Walkboard.
K. Compression Tube.
L. Drag Wire.
M. Anti-drag Wire.
N. Interplane Bracing Fitting.
O. Turnbuckle and Jam Nut.
P. Trailing Edge.
Q. Aileron Spar.
R. Aileron Leading Edge.
S. Aileron Hinge.

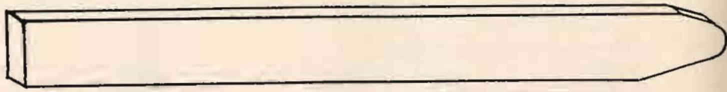


Fig. 14. Solid Spar. (Usually wooden).

Fig. 15. Routed or Spindled Spar. (For lightness).

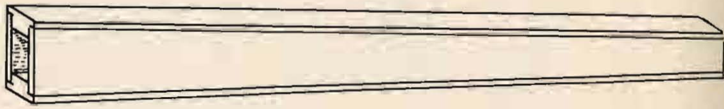


Fig. 16. Hollow Box Spar.

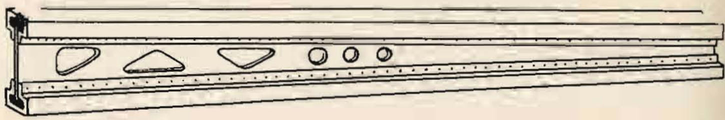


Fig. 17. 1 Section Spar with tubular flanges.

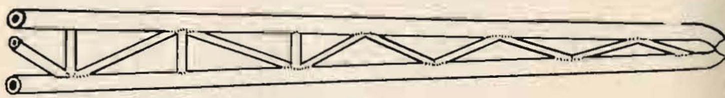


Fig. 18. Tubular Trussed Spar.

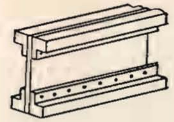


Fig. 19.

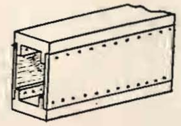


Fig. 20.

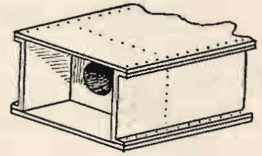


Fig. 21.

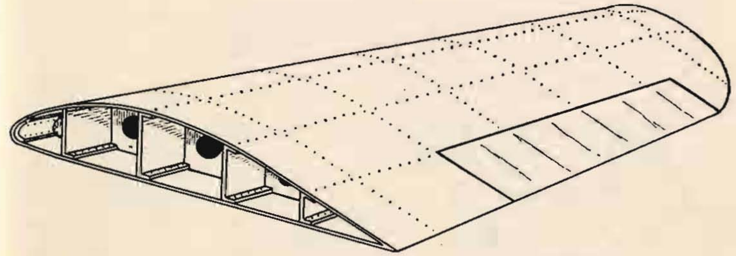


Fig. 22.

The Skin Stressed Wing.

Note relationship of the skin to heavy flanges or capping sheets of Spars.

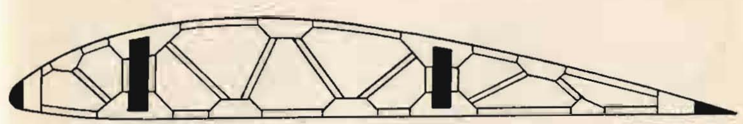


Fig. 23. Braced Girder or Truss Type.

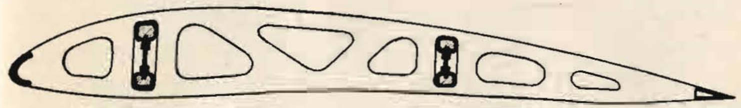


Fig. 24. Blanked or Stamped Type.

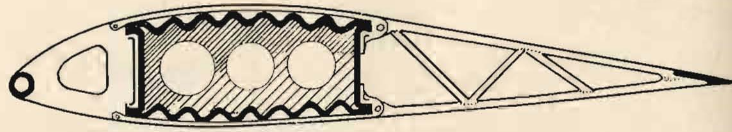


Fig. 25. Composite Type. (Built around a box spar).

Fabric Covering.

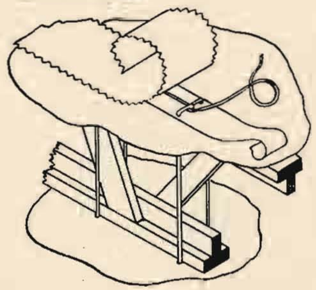


Fig. 26. Rib Stitching.

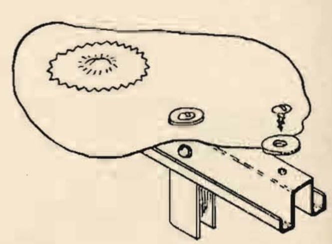


Fig. 27. Self-tapping Screws.

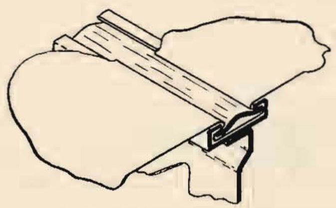


Fig. 28. Clamp Strip.

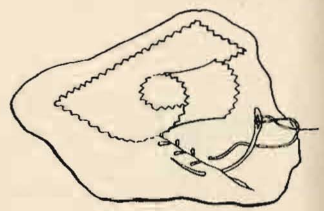


Fig. 29. Patching a tear.

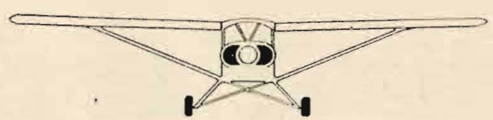


Fig. 30. Externally Braced High Wing. Externally Braced Landing Gear.

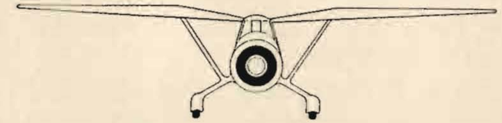


Fig. 31. Semi-cantilever High Gull Wing. Full Cantilever Landing Gear with Fairing or Pants.

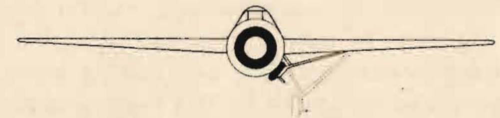


Fig. 32. Full Cantilever Mid-wing. Retractable Landing Gear.

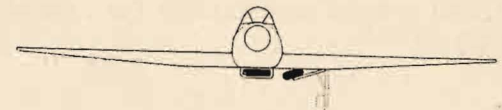


Fig. 33. Full Cantilever Low Wing. Retraceable Landing Gear.

Undercarriage

If the aircraft is a land-based plane, when resting or moving on the ground it is supported by an undercarriage. The exact design for this is determined by the purpose for which the airplane is to be used.

Modern high-speed types of aircraft, which have been developed for efficiency and manoeuverability, will have a retractable undercarriage which is withdrawn out of the airstream, into the wing or fuselage, thereby eliminating unnecessary drag. A system of lights, instruments or warning knobs, are used to indicate the position of the undercarriage, and to tell the pilot if it is locked in the desired position. The retracting is done hydraulically (by fluid under pressure), electrically or manually by a hand operated mechanical linkage.

Slower speed aircraft, such as trainers and freighters, generally have a fixed undercarriage to withstand hard landings and heavy loads. This type can be externally braced, or full cantilever, and may be streamlined by the addition of a fairing or covering, called spats or pants.

The purpose of the undercarriage, aside from support on the ground, is to take up the initial shock of landing and to dampen out rebounds and rolling bumps. These shocks are taken up partly by the tires, and partly by oil or spring-shock absorbers.

Other important design factors are, width for stability on the ground, height of undercarriage for propellor clearance, and general accessability for ease of maintenance and repair.

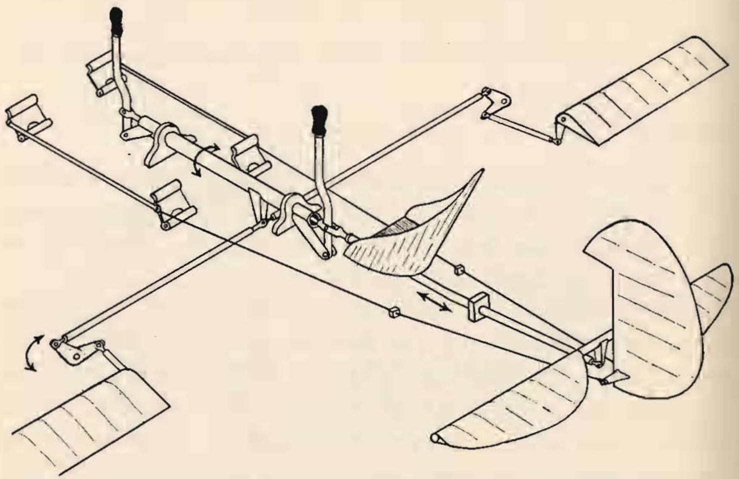


Fig. 34. Typical Dual Control System of a Training Airplane.

On conventional aircraft the tail is supported by a tailwheel, steerable in some cases, and full swivelling in others. This wheel is also equipped with a shock-absorber, to take up the shocks of landing and taxying.

Some newer types of airplanes use a nosewheel rather than a tailwheel. Manoeuvering on the ground is improved by a steerable nosewheel, and brakes can be used more roughly without the danger of nosing over.