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STRUCTURAL DETAILS OF GERMAN GLIDERS

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The Wings

The most important part of airplane building is the design and construction of the supporting wings. Whoever has once flown in a very gusty wind can understand to what stresses the wings are subjected and with what care they must be designed and constructed. The design naturally depends on the dimensions and loading and also on whether they are to be cantilever or externally braced. In glider construction, aerodynamic considerations are comparatively unimportant. It is sought to reduce the wing loading as much as possible, and the structure of the wings is correspondingly simple. This statement is especially applicable to the construction of "hang gliders." A small wing loading is especially desirable for gliders with a large structural drag, in order to keep the sinking speed as low as possible. Generally speaking, a minimum wing loading is the principal requirement for mere gliders, while good aerodynamic design of all parts is very important for "soarers." The mean wing loading of gliders varies therefore between 5 and 8 kg/m² (1.02 and 1.64 lb./sq.ft.), while it lies between 8 and 12 kg/m²

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(1.64 and 2.46 lb./sq.ft.) for soarers. A glider with a small wing loading is superior in all respects to one with a larger wing loading. The excellence of a soarer depends on other characteristics. This is well illustrated in nature, the best soarer among the birds, the albatross, having the greatest wing loading, up to 16 kg/m² (3.28 lb./sq.ft.). For this reason the wings of gliders and soarers have different aspect ratios. The greater the aspect ratio, the less the travel of the center of pressure and the easier, on wing-controlled aircraft, the wings can be rotated about their lateral axis. With increasing span, however, the construction becomes more difficult and the weight of the wings increases disproportionately. It is obvious, therefore, that efficiency and weight must be suitably balanced. In practice, soarers are made with an aspect ratio as high as 18 ("Espenlaub"). The albatross often has an aspect ratio of 20. In general, present-day soarers have spans of 12-15 m (40-50 ft.) and aspect ratios of 10-15. For gliders the aspect ratio is smaller, in order to reduce the weight. On monoplane gliders the span is 8-12 m (26-39 ft.) and the chord 1-1.5 m (3.3-4.9 ft.). On biplanes the span is often reduced to 6 m (less than 20 ft.). The wings must be made in sections of such length that they can be loaded into an ordinary railway car for transportation. For spans of less than 12 m (39.4 ft.), the wings are usually made in two sections, or at most, with a short central cabane section rigidly connected with the fuselage.

Longer wings are made mostly in three sections, the middle section being usually the longest. The wing shapes vary greatly, without greatly affecting the flight characteristics. The wing tips are usually rounded, in order to prevent the formation of vortices. Extending the wing tips aft produces inherent stability, which may be so great as to render tail surfaces superfluous. Figure 1 gives the wing shapes of five well-known soarers.

The flight properties of a soarer depend largely on the cross section of the wing, i.e., the "profile." Figure 2 includes the profiles for four birds (No. 1, brant goose; No. 2, eagle; No. 3, owl; No. 4, vulture) which soar over the land, and two birds (No. 5, gull; No. 6, albatross) which soar over the sea. A comparison of the profiles of the land and sea soarers shows that the former are relatively thin and are thickened only at the leading edge, while the latter are considerably thicker and have their greatest thickness at about one-third of the chord from the leading edge. If we adopt the view that the land soarers utilize ascending thermal winds and winds which are deflected upward by mountain slopes, we find these differences comprehensible, for thick profiles enable a great increase in the angle of attack, without any sudden lessening of the lift or much increase in the drag. They are, therefore, especially adapted for dynamic soaring flight. Hence the Gottingen profile 441 (Fig. 2, No. 7) is often used ("Vampyr"). This has an especially high lift coefficient and its sinking speed is quite constant for a large range of the angle of attack. The similarity of the Göttingen profile 441 to the albatross profile is noteworthy.

According to measurements by Gustav Lilienthal, the ratios of the chord to the thickness of the wings of various birds are as follows:

	Upper part of wing	Lower part of wing
Pheasant	20	30
Brant goose	17	15
Carrion crow	13	20
Urubu	9	17
Brahminy kite	8	14
Swan	6.75	13
Golden Eagle	5	13
Pelican	6	13
Frigate bird	6.5	10
Condor	6.7	8.2
Albatross	5	8

Of the above birds, the pheasant and brant goose employ only flapping flight and the crow soars very seldom, while the others only soar. The soaring ability of birds, according to the above table, increases with the thickness of their wings. It is seen, moreover, that for the best soarers, the wings diminish less in thickness toward the tips.

The wing profile of the Pondicherry vulture is very peculiar, in that it has a recess on the lower side just back of its leading edge. According to Hankin, similar recesses are possessed by the adjutant, crane, and flamingo, hence by land soarers with a high wing loading. It is therefore to be assumed that the recess facilitates soaring. According to Hankin the birds with the recessed wing profile soar swifter than those with the eagle or owl wing profile while, on the contrary, the gliding angle of the latter profiles is better than that of the recessed profile. Hankin's observations refer, however, only to soaring in ascending thermal currents, and hence it is not advisable to imitate the recessed profile. Airplanes with this profile were wrecked in their first tests. The recessed profile is likewise unsuited for dynamic soaring flight beeause it develops vortices, which increase the drag.

The chief components of an airplane wing are the spars and ribs. The former are designated according to their location as leading-edge former, front spar, rear spar, and auxiliary spar. If either the front or rear spar is much stronger than the other, it may also be termed the main spar (Fig. 3). Airplane wings are generally made with two spars, though there are exceptions, including single-spar types with rigid plywood leading edges, which have given good results. The thickness of the spars depends on the thickness of the wing and this, in turn, depends on whether the wing is braced or cantilever. It is advisable to utilize the whole wing thickness for the spars, even though the strength computation does not call for it, because the rigidity of a spar depends only on its thickness. If only one spar is used, it should be situated, if possible, in the center of pressure of the wing, especially when the wings are to be manipulated for controlling the flight. The spars previously used on engine-driven airplanes can hardly be used on gliding or soaring airplanes, because their weight is disproportional to their strength. The simplest spars are the ones having a thick web with flanges, as used by Pelzner on his hang glider. Box spars and I-girders with plywood webs, which combine small weight with great strength, are now commonly used. The webs are often open-worked so as to resemble lattice girders, in which case they are sometimes reinforced by narrow strips. The flanges for the box spars can usually be bought ready-made in all dimensions. Fine-grained, knotless pine is generally used for this purpose and, when necessary, is first spliced, whereby care must be taken that splices of the upper and lower flanges do not come opposite one another. Then follows the fitting of the plywood webs, which must be done with the greatest accuracy. The webs are glued to the flanges and secured with small brads. The glued surfaces must be firmly pressed together, because the strength of the spar depends on the perfect gluing of the flanges and webs. It is very important to keep the spar straight during its construction.

This can be most easily accomplished on a perfectly level support. Since plywood sheets can be procured only in certain sizes, the webs must be spliced more or less, as shown in Figure 7. Of course this must be done before gluing them to the flanges. Here also care must be taken that two splices do not come opposite each other. The flanges are often reinforced with thin plywood, as shown in Figure 8, in order to support the edges of the webs and thus relieve the stresses on the glue. This reinforcement must likewise be made under strong pressure, but only after the glue on the sides of the webs has become well set. Box spars are always used when only one spar is used without the plywood leading-edge former, because they are much more torsion resisting than I-spars. The latter are used as main spars only when there are two or more spars, or when the whole leading edge of the wing, from the top of the spar around to its bottom, is covered with plywood ("Vampyr," "Konsul," "Greif," etc.). The construction of an I-girder is considerably easier and also cheaper, on account of the smaller quantity of material required. The webs are prepared in the same way as for box spars, but web sections are not joined until after the flanges have been added, the plywood connecting pieces being glued on both sides of the web. The flanges of I-spars are often grooved to receive the edges of the web. This method is not recommended, however, since it increases the cost, with no commensurate advantage. In using such flanges, the web must fit tightly in the groove and the flanges must be driven on firmly with the interposition of a piece of wood between the hammer and the flange. Any open-working of the spar web is done with the aid of a stencil after the flanges have been attached.

The ribs receive the air pressures and transmit them to the spars. Their shape is determined by the wing profile. There are two main types, those with triangular bracing (Fig. 12), and those with open-worked plywood webs (Figs. 13-15). The latter are more difficult to make and more expensive, but their greater strength makes them decidedly preferable to the former. The ribs at the junctions of the wing sections and the attachments of the struts are often of the box type (Fig. 15), since these can withstand greater stresses. The variations in the plywood ribs depend on whether the wing is to be rigid or flexible. The web is often a single piece, which is shoved over the spar and secured with corner brackets. It is also often made in two or three sections, so that the spars can be made the full thickness of the wing. Webs of the same height are made with a pattern, which always facilitates the work. The task is more difficult when the wing tapers toward the tips. In the latter case, each individual rib must be made with the greatest care from the working design. The intervals between the ribs differ greatly. Some constructors prefer to use many ribs, in order to obtain a smooth surface without hollows, while others use only a few ribs and cover the wings largely with plywood. In general, the intervals are 30-50 cm (12-20 inches). With greater intervals, intermediate ribs are used. These generally extend but a short distance back of the main spar and serve principally to prevent the hollowing of the fabric and consequent profile changes (Fig. 17).

The weakest point of a rib is at the spar. In breaks, especially of single-spar wings, the failure usually occurs at this point. The risk is not so great with sectional ribs. With continuous ribs, the flanges are often reinforced at this point by pieces of plywood, or special flanges are used, which are wider at this point. Under no circumstances must nails be used to fasten the rib flange to the spar, since the material, weakened by the nails, would break on the least provocation.

The ribs are shoved over the spars and secured by small triangular pieces which are glued and nailed. The ribs are then glued at equal intervals to the leading-edge former. The wing is then strengthened against torsion by the introduction of diagonal side walls, which must intersect every rib interval or every second interval. This is not necessary on biplanes, since the same object is accomplished by the external bracing. On biplanes every space, or every other space, is braced only by steel wires, in order to prevent any lateral displacement of the ribs. The same method is employed on cantilever monoplanes controlled by wing warping. The torsional rigidity is then maintained by the steering controls connected with the control stick, which is operated by the pilot. In the diagonal bracing, it is important to use firmly fitting attachments which will not weaken the spars. One end of the steel wire is secured as shown in Figure 18, while the other end is attached to a turnbuckle, in order to be able to adjust the whole wing after the brace wires are installed. After the wing has been adjusted, all the turnbuckles are secured as shown in Figure 19. No subsequent alterations can be made in the diagonal bracing, for which reason great care must be taken to adjust both wings symmetrically as regards the angle of setting. Soarers with zero angle of wing setting have often been flown successfully. For example, the angle of wing setting of the "Vampyr" was zero at the fuselage. Likewise, wings with a negative or positive angle of setting at the fuselage and a negative angle of setting at their tips, whereby some degree of automatic stability is attained, have been found usable.

The setting of a wing depends on its profile, wherefore fiduciary lines for the best angle of setting cannot be laid down. It should not, however, be more than four degrees at the fuselage and should diminish toward the wing tips. In no case should the angle of wing setting be greater at the tips than at the fuselage. For wings with flexible trailing edges, the angle of setting can be greater than on perfectly rigid wings. It should also be noted that the angles of glide of two otherwise similar gliders, one of which has wings with flexible trailing edges and the other has perfectly rigid wings, differ greatly from each other. The angle of glide improves with increasing flexibility of the rib ends, since the air can then flow off without forming vortices. This is the case, however, only so long as the flexibility does not give rise to a fluttering of the trailing edge.

The Fuselage

The choice of the fuselage always depends on financial or structural considerations, for of course the head resistance of an aircraft, in which the pilot is exposed to the air current, reduces the flight speed, which is important for aircraft intended to utilize dynamic soaring effects. This factor drops out for mere gliders which are intended only for sailing in winds deflected upward by mountain slopes. Only the trellis or skeleton type is advisable for training airplanes, because it is cheaper to make and easier to repair.

The 1921 wing-controlled Munich monoplane (Fig. 28) had the simplest union between wings and tail. The whole structure consisted of four steel tube longerons joined so as to form triangles. On monoplanes the runner is almost always built into the fuselage structure. Figure 29 shows the framework of Harth's soarer. It is easy to recognize the triangular structure, which renders diagonal bracing superfluous. The material was duralumin tubing. A and B indicate the centers of rotation of the wings. Struts directly in front of the pilot's head should be avoided. On biplanes the wings and tail are best united by four longerons, two for each wing. These may be mutually braced by transverse struts. If it is desired, however, to build a real fuselage, it is not advisable to leave it uncovered. The small additional cost of the covering is fully offset by the improvement in its flight characteristics.

The fuselage can be made in three different types: with open wood frame; welded steel or duralumin tubes; or wood frame covered with plywood, which distributes the stresses, thus dispensing with the brace wires and more or less with the struts. The simplest type to construct is the one shown in Figure 30, which is made square throughout and has no specially designed bulkheads.

Fuselages of this type are almost always covered with fabric. If it is to be covered with plywood, the framework can be made of smaller timbers. In the cockpit, diagonal struts and wires must be avoided under all circumstances, since it must be roomy enough not to interfere with the greatest movements of the steering controls. It is better to put up with a little greater air resistance than to handicap the pilot by enclosing him in cramped quarters, thus taking away his view and fatiguing him prematurely by an uncomfortable posture. As shown in Figure 33, the diagonal struts in the cockpit are replaced by plywood gussets, or even by an ash hoop. Experience has shown that it is advisable to place the pilot's seat so high that his head will be exposed to the unobstructed air current, which greatly facilitates the utilization of favoring winds. Of course, the chair and headrest (if there is one) must be padded. Moreover, it is desirable for all struts and spars in the cockpit to be wound with linen, which not only strengthens the wood but, most important of all in case of accident, also affords protection against splintering and consequent injuries to the pilot. This danger can be still further diminished by using ash for the front portion of the longerons and spruce or pine for the rear portion, the spliced junctions coming behind the cockpit. Ash is strong and tough and has but little tendency to split. The gluing together of hard and soft wood, however, must be done with great care, since otherwise the glued joints will not hold. It is expedient to spread thick glue on the ash first and wait a few minutes for it to penetrate the pores before spreading glue on the pine. The glued splice should then be put under the customary pressure. It is not advisable to continue the ash longerons the whole distance, since this would unnecessarily increase the weight of the fuselage. Moreover, ash is difficult to work. The longerons and struts should diminish in cross section toward the stern, to correspond to the smaller stresses. In the event of a nose dive, it is desirable to have as little weight as possible behind the pilot. If the landing gear is not provided with shock absorbers, it is desirable to pad the pilot's seat well or provide it with springs, in order to soften the landing shock for both pilot and fuselage. The fuselage ends in either a horizontal or vertical wedge, which is correspondingly used for the attachment of the elevator or rudder. The vertical wedge is more common on gliders because of the better keel effect, while the horizontal wedge is better for soarers, in order to facilitate curving flight.

Another very light type of fuselage was successfully employed on the Aachen gliders "Schwarzer Teufel" (Black Devil) and "Blaue Maus" (Blue Mouse). In this type, two box girders or I-girders serve as longerons, to which are attached thin strips to support the fabric covering and give the fuselage the desired shape.

Steel tubing or other metal has been but little used in the construction of gliders and soarers, because this requires expert workmen provided with specially equipped workshops. This type, though heavier, is stronger and more durable. The securing of the wings to a metal fuselage is simpler and easier.

The construction of a plywood fuselage postulates some experience in fuselage or boat building, for it can be accomplished only with the aid of a special form. The bulkheads must first be made in exact conformity with the working designs, which is done in various ways according to the shape and the requisite strength of the fuselage. The front bulkheads, especially those which are designed to receive the wing fittings, are made of heavy plywood, while the rear, less-stressed bulkheads are made of thin strips with plywood reinforcement. One advantage is the elimination of the diagonal struts, since the bulkheads afford sufficient rigidity. The inside of such a fuselage is therefore more roomy, thus facilitating the installation of the seat and steering controls. An oval fuselage requires more bulkheads than an angular fuselage for the preservation of its shape. This requirement is met by inserting one or two light auxiliary bulkheads between every two main bulkheads. The number of longerons likewise depends on the shape of the fuselage. In general, four main longerons are employed, with smaller intermediate longerons as required. Round bulkheads, however, require only three longerons. The actual construction of the fuselage is begun after the completion of all the bulkheads. A board, whose dimensions correspond to the length and breadth of the fuselage, is firmly secured by screw clamps to two paper-hanger's "horses." For a round fuselage, a keel corresponding to its bottom line is secured to the board and the bulkheads are attached to the keel by means of screw clamps. For an angular fuselage, cleats corresponding to the number and location of the bulkheads are fastened to the board. The longerons are then fitted into notches in the bulkheads and glued, corner blocks being glued into the angles between the longerons and bulkheads. Then all inner parts, like the seat and steering controls, are installed and, lastly, the plywood covering is added. This is easily done with angular bulkheads. Glue is applied to the longerons and bulkheads and the plywood nailed on in as large sheets as possible and so that the joints always come on a bulkhead. For round or arched fuselages, the difficulty increases with the curvature, wherefore the plywood plates must be smaller and must be applied slowly, beginning with the narrow side. Both lateral and longitudinal bending must not be attempted with the same plate as this would produce buckling and unevenness. After the upper and lateral portions have been covered, the fuselage is detached from the keel or cleats and its bottom is also covered with plywood.

Landing Gear

Often too little attention has been given to the correct construction of the landing gear. We repeatedly see gliders, otherwise well built and with good flying ability, which experience difficulty in taking off or are irreparably damaged in the attempt, due to faulty landing gear. The landing gear must be regarded as an organic part of the glider and not as an auxiliary attachment. Offermann published in "Flugsport," 1921, No. 18, interesting and important observations on the construction of runners, but unfortunately few constructors seem to have derived any advantage from them. The landing gear is also the "starting gear" and it is only in the latter sense that we are considering it here. Runners are now commonly used on gliders and preferably one central runner instead of the former double-runner system. The few attempts to use landing gears with wheels met with little success. The correctly built central runner is doubtless the best solution of the starting problem, since it weighs but little, is easily constructed and offers the least head resistance. The greater friction of the central runner in taking off is of no practical importance. For example, the "Espenlaub V" (Fig. 40), which has a very simple central runner, required only two men to launch it in a wind of 4-6 m (13-20 ft.) per second. There is no danger that a glider with a central runner will tip over on the wing at a low take-off or landing speed, such danger existing only when the glider is standing still. Even then the glider tips so slowly that there is no danger of doing any damage. Hence protecting devices on the wing tips are seldom used. The single-runner type has the advantage over the double-runner type, in that, aside from the smaller air resistance, the landing gear (and hence the whole glider) is less endangered in landing with a side wind, because it is much easier to head into the wind. Nevertheless double runners are often used on school machines, in order to render the take-off easier for the pupil. Straight rigid runners (the so-called "sled gear") (Fig. 41) are commonly used, though very mistakenly so, because flexible, or at least bent, runners can be easily made and greatly facilitate the take-off.

If we inspect Figures 42-45, we can see why straight rigid runners make the take-off difficult, if not impossible. It is assumed that the angle of wing setting is zero. The take-off gang pulls on the cable and the pilot raises the elevator, in order to give the wings the requisite angle of attack. It must be assumed that the pressure on the elevator, resulting from the take-off speed, is great enough to cause the glider to nose up and thus increase the angle of attack, since otherwise the take-off would not be possible. When this happens, however, the aircraft is deprived of its supporting surface, since its whole weight now rests on the tip of the runner which plows into the ground (Fig. 43). The ground friction increases enormously and the aircraft again tips forward. This frequently happens but, instead of looking for the cause, the take-off gang is generally increased. Thus 10 to 12 men are frequently required on the starting cable. Often the glider finally takes the air, but more often it remains on the ground. The excessive pull of the large take-off gang sometimes causes a bad start, which usually ends with more or less serious damages. Somewhat better, though still not to be recommended, is the arrangement shown in Figure 44, which compels the wings to assume the angle of attack required for the take-off. This would probably enable the take-off, but the time required would depend entirely on the pull by the gang and on the strength of the wind. The maneuvering ability of the glider is first developed in the air, which fact may likewise lead to accidents. It is therefore better to construct the landing gear in such a way as to afford the maximum maneuverability on the ground. Such is the case when the runner is perpendicular to the line of gravity in every position of the aircraft, which necessitates a curved shape of the runner (Fig. 45). In order to ameliorate any unintentional pitching, which would require constant manipulation of the elevator, the runner is given a parabolic shape. Moreover, a circular shape would cause the runner to press into the ground more and thus increase the friction. It is still better to use spring runners which adapt themselves automatically to the surface of the ground. If the runner is used for the static structure of the fuselage, springiness can be obtained only through the medium of a so-called "blind" runner. This blind runner is used for the static structure and the real runner is so attached to the static runner by means of springs or rubber cords that they can yield and thus allow the runner to fit the ground. In the construction it is only necessary to see that the resting point of the real runner at the various angles of attack does not coincide with its point of attachment to the blind runner.

Naturally the above statements do not apply to wing-controlled gliders. These can have straight rigid runners, because the alteration of the angle of attack does not necessitate any change in the position of the fuselage and consequently of the runner.

The runner of the 1921 Stuttgart monoplane (Fig. 46) can be recommended for school gliders. The landing gear on the Darmstadt monoplane "Geheimrat" was very practically constructed (See N.A.C.A. Technical Memorandum No. 433, p. 16). It consisted of two runners at the outer edges of the fuselage, the space between the fuselage and runners being occupied by an air cushion protected by sheet duralumin. This type of landing gear, however, is complicated and expensive. The present most common type of landing gear is the single central runner with projecting and consequently flexible rear end (Fig. 45). With the correct position and curvature this runner may be considered ideal, especially when the landing shock is partially absorbed by an upholstered or spring seat. The previously mentioned "Espenlaub V" (Fig. 40) has such a central runner, which is so long as to render a special tail skid unnecessary. In a normal landing, this type of gear distributes the shock evenly between the different joints. The runner itself should be wide enough to prevent its sinking into the ground. A width of 6-8 cm (2.4-3.2 in.) is generally sufficient, although this depends on the weight of the glider and the nature of the ground. The take-off from a sand dune naturally requires a wider runner than from a grassy field.

The runners are generally made of ash or elm. Large runners are bent, after being allowed to soak several days in cold water or a few hours in hot water. Forcible bending and gluing, without first softening the wood, are liable to result in the loosening of the runner in the event of a hard landing. It is attached to the bottom of the fuselage with the aid of a vertical board, about 2 cm (0.8 in.) thick and generally made of light plywood. The lower edge of this board is given the desired shape of the runner. The board is then fitted and glued in notches provided for the purpose in the bottom of the bulkheads. It is braced laterally by small blocks and plywood gussets. The runner is then glued and screwed on, as shown in Figure 47. Of course the vertical board cannot be used on gliders without any real fuselage. In this case a curved central runner can be attached only with the aid of a "blind" runner.

The runner may be made in thin strips glued singly to the bottom of the vertical board and then secured by screws. By this method the projecting ends can be left of different lengths, as shown in Figure 48, in order to make the runner more flexible and springy. In order to prevent the runner from catching in ruts when landing with a side wind, the bottom strip of the runner is rounded and its edges trimmed.

As already mentioned, wheel landing gears have failed of general adoption, because they are more complicated and expensive and because the facilitation of the take-off is more than offset by the increase in the drag and in the length of the landing run. However, individual wheel landing gears have been used with good results. The monoplane "Espenlaub IV" had, for example, a wheel landing gear, whose drag was reduced to a minimum by placing the axle and upper third of the wheels inside the oval fuselage. A central runner was nevertheless adopted for the "Espenlaub V."

Figures 49-51 show a simple and practical landing gear wheel, which was described by Schalk in "Flugsport" 1922, No. 14. It consists of a hub with brass bushings, plywood spokes, rim and covers. The hub (Fig. 49) is turned from hard wood. The two brass bushings are roughened on the outside and driven into the hub. The five spokes (Fig. 50) are set at an angle of 72° to one another and attached to the hub with cold glue and nails. They are made of 5-mm (0.2-in.) plywood. The rim is made by winding a thin ash strip around a circular disk (Fig. 51). The tapered end of the strip is held against the disk by a clamp and wedge. After the first turn, wedge No. 1 is carefully removed and cold glue is applied, all the wedges being successively removed and replaced after the second turn. This process is repeated until the whole strip is wound on. The glue can be reinforced with small nails. The last end must be well nailed. After the glue is dry, the wedges and disk are removed and the rim is given a trapezoidal cross section. It is then put over the spokes and the conical covers are glued on. The latter are made by cutting and fitting a plywood disk 1 mm (0.04 in.) thick by 54 cm (21.3 in.) in diameter. The overlapping edges are smoothed off, in order to make as uniform a surface as possible. The whole is then carefully shellacked and varnished. If the wheels are used for transporting the glider, it is advisable to protect the rims with leather strips, in order to save wear and deaden the peculiar noise. The leather strips can be glued on with leather cement, the so-called "Vienna paste." According to loading tests made by Engineer Kromer of the Kyffhäuser Technical School, such a wheel has vertical breaking strength of about 300 kg (660 lb.).

An intermediate method between the wheel and the runner landing gears was adopted by the aviation section of the Hannover Technical High School. The gliders "Vampyr," "Greif," and "H 6" had rotatable leather balls similar to footballs. They conformed to the shape of the fuselage and each one had a valve provided with a rubber tube. This almost ideal solution combines minimum air resistance with minimum ground friction and good shock absorption. One disadvantage, however, needs to be remedied. If the aviator is compelled to land against a steep declivity, there is danger that the glider will roll backward and be more or less damaged. This happened once at Andreasberg, when Schwarz was compelled to land against a steep hillside, and again in the Rhön Mountains when Martens on the "Strolch" had to land in the same way. In both cases the elevator and the tail end of the fuselage were badly damaged. This danger might be avoided by means of a brake skid operated by the pilot or by installing the wheels or balls in such a way that they cannot turn backward.

It has already been mentioned that no tail skid is required with sufficiently long runners. With short runners or with ball landing gears, however, a tail skid is required to support the tail and protect the tail surfaces. Figures 52-53 show the tail skids commonly used both on airplanes and on gliders. The method shown in Fig. 52 can be used when the fuselage ends in a vertical wedge. The air resistance is less by this method. The rubber cables must, of course, be rendered easily accessible through a trap door. It is desirable for the skid to be capable of yielding somewhat laterally. The life of the skid is thus increased and the stresses on the stern of the fuselage, when turning, are diminished. The height of the skid must be such as to allow a sufficiently horizontal motion of the fuselage to enable the increasing of the angle of attack in taking off. When possible, it is better to dispense with the tail skid altogether.

The Steering Organs

While we are striving for minimum sinking speed and angle of glide, we must also endeavor to increase the maneuverability, in order to bring the aircraft promptly into the most favorable position for any given air current. Like engine-driven airplanes, gliders require three control organs, namely, for lateral and longitudinal stability and for directional steering. The organ for maintaining longitudinal stability also serves for vertical steering. The fundamentally new thing on gliders is wing steering, which we will consider here. The control surfaces are made considerably larger on gliders than on engine-driven airplanes, in order to correspond to their considerably lower speed. The commonest error on gliders consists in making the control surfaces too small and therefore ineffective. On "hang" gliders the lateral and longitudinal stability and the angle of attack are controlled by shifting the weight of the pilot. Only a vertical fin, or possibly a rudder, is provided, in order to head the glider into the wind or give it limited directional control.

For preserving lateral stability, preference is given ailerons hinged to the outer portions of the wings. The ailerons are so connected that the upward deflection of either one is accompanied by a downward deflection of the other.

Wing warping was employed by Harth, Messerschmidt, and others, but failed to come into general use. The reason for this resides in the difficult construction of the wings for this purpose and in the fact that gliders like the "Strolch," "Konsul," "Espenlaub IV," "Hannover H6" ("Pelikan") and others with ordinary ailerons give better results, although such ailerons cause more vortices and therefore greater air resistance than flexible warping with harmonious transitions. For static soaring flight, the very slight increase in the air resistance due to the ailerons is of no practical importance, and the controlling effect of suitably dimensioned ailerons is fully sufficient. Of course the shape makes a difference, since square ailerons have to be deflected more than oblong ones and produce a greater retarding or braking effect. Hence the preference is given very narrow ailerons extending throughout a large portion of the wing span and often tapering to a point toward the fuselage, in order to avoid any break in the trailing edge. The manner of hinging the ailerons to the wings is also important. The formation of an intervening slot must be avoided in so far as possible or the slot must at least be covered by a strip of plywood. Figures 54-55 show typical aileron hinges. Should these forms be impracticable, the hinging should be done according to Figures 56-57, which have only a one-sided slot. On light gliders, for which simplicity and cheapness are important considerations, the method of hinging shown in Figure 58 may be used. This very simple method was tried on the 1921 biplane of the Darmstadt Aviation Club with satisfactory results and was accepted by the examining committee of the W.G.L. ("Wissenschaftlichen Gesellschaft für Luftfahrt").

A good twisted or braided hemp cord c, of 3-5 mm (0.12-0.20 in.) in diameter is tightly stretched between two fixed points and attached to both the wing and aileron by windings, as shown in Figure 58, the cord fitting into a groove in the aileron spar a, and also into corresponding grooves in the blocks b, which are glued to the rear spar of the wing at intervals of 15-25 cm (6-10 in.). The windings d, are then doped and after they are dry, the rope is cut so as to leave short ends, which are nailed to the ends of the aileron spar a. Of course this kind of hinge can also be used for elevators and rudders, but only on simple gliders. The ailerons must be sufficiently rigid not to yield in operation and weaken their effect.

Elastic wing warping can be accomplished in various ways. For example, on the monoplane "Teufelchen" (Little Devil) the Aviation Section of the Charlottenburg Technical High School used an interior tube running parallel to the spar, the ends of the tube being rigidly attached to the terminal ribs. In this case the wing was purposely made flexible, in order to enable warping. The undoped wing tips could then be warped by rotating the tube by means of a hand lever and intermediate spurs. The "Greif" (N.A.C.A. Technical Memorandum No. 433, p. 10) had a similar wing-warping device.

It was more difficult to provide for warping the whole wing as was done by Harth and Messerschmidt (N.A.C.A. Technical Memorandum No. 433, p. 19). Originally, the ribs were rotated about the spar by means of cables, but later by torsion tubes. Nesemann used a patented combination of aileron and wing warping, as shown in Figure 59. The rotatable aileron was covered over with flexible surfaces, which were attached to the main ribs and were held closely to the aileron surface by their own tension aided by auxiliary springs. These smooth transition surfaces prevented the formation of harmful vortices.

Longitudinal stability is usually obtained by an "elevator," which is rotatable about a horizontal axis at the stern of the fuselage. There is often a horizontal "stabilizer" in front of the elevator, but in recent years this has frequently been omitted, especially on the best soarers, in order to make the aircraft longitudinally more sensitive and consequently better adapted for the fullest possible utilization of gusts. Since a glider fuselage nearly always ends in a horizontal wedge, the elevator is easily installed. The longitudinal section of such a balanced elevator is always streamlined. It is built like a wing with I-girders or box girders and ribs. Its center of rotation lies at or slightly in front of one-third the distance from the leading edge. Its axis is usually a steel or duralumin tube, though its attachment to the wood ribs is difficult. When there is a horizontal stabilizer, the elevator is hinged directly to it, the same as the rudder is hinged to a vertical fin. On tailless gliders, the altitude and longitudinal control reside in the separately maneuverable ailerons or in wing warping. Since the wing tips are extended backward on such aircraft, the leverage thus obtained is generally sufficient for steering and stabilization. The placing of the elevator in front of the wing has been tried only on Klemperer's "Ente" (N.A.C.A. Technical Memorandum No. 434, p. 8).

Lateral changes in direction are likewise produced by a vertical rudder at the stern of the fuselage (with the above-mentioned exceptions), which is sometimes preceded by a vertical stabilizing fin. The longitudinal section of the rudder likewise always has a streamline shape. The shapes of the elevator and rudder must be such that they cannot interfere with each other, even at their maximum deflection. If the vertical or lateral steering is controlled by the wings or by ailerons, no rudder nor elevator is needed at the stern, but in this case horizontal and vertical stabilizing fins are almost always provided.

As already mentioned, wing warping originated with the endeavor to take immediate advantage of fluctuations in the wind, without using the indirect way through the elevator. For this purpose, Harth and Messerschmidt warped the whole wing and thus obtained excellent results above the gentle slope of the Heidelstein in the Rhön Mountains. Not only did Harth gain altitude by increasing the angle of attack and changing the flight direction, but often succeeded in taking off without the aid of the starting cable by utilizing a favoring gust. The technical difficulties and the small structural strength of wing-controlled gliders then led to the substitution of ailerons. These were first used, and with good results, on the Bavarian Aero Club's 1921 monoplane glider designed by Finsterwalder and Von Lössl. Changes in the angle of attack were effected by rotating both ailerons in the same direction, while lateral stability was maintained by rotating them in opposite directions.

On the Darmstadt monoplane "Geheimrat" (N.A.C.A. Technical Memorandum No. 433, p. 16), the whole wing is rotatable. This is intended only for utilizing the gusts and not for lateral control as this is exercised by ordinary ailerons. For the longitudinal control there is a stern elevator, which can be operated by means of a small lever. The elevator was adjusted according to the wind conditions and was not operated during the flight. This method enabled the widest adaptation to the most variant wind velocities. Although no elevator is necessary for a wing-controlled glider, the installation of one on this plan has been found advantageous. If a wing-controlled glider should, for any reason, be thrown into a nose dive, it would generally be impossible to flatten out again, on account of the strong forces acting on the wings. The greater leverage of a stern elevator would, however, be more effective in such an emergency.

In designing wing-controlled gliders, it is important to use a profile with relatively small travel of the center of pressure. The correct leverage of the control stick is also important, as otherwise the pilot's strength might not suffice to hold the wings. It is also expedient to provide a maximum deflection limit to prevent over-deflection, which usually causes a fall.

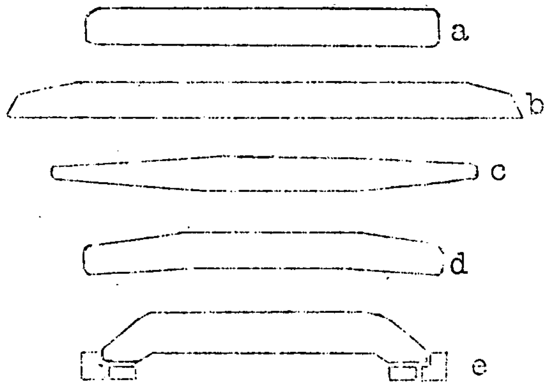
The operation of the various controls should correspond to the feel, for which reason it is advisable not to depart from the customary stick control. The ailerons or wing warping should be controlled by lateral motions of the stick; the elevator by pulling and pushing the stick; and the rudder by the use of the feet. Wheel control may be better for giant airplanes, but it is not suitable for a glider or soarer, where the pilot must depend largely on the feel of the controls. Whenever possible, only one control stick should be used, since, although a second stick can be operated successfully, its presence complicates the piloting.

In order to function in two directions, the control stick must have a double or ball joint. On the Aachen monoplane "Schwarzer Teufel" the tubular duralumin stick runs through a hollow steel ball with which it is rigidly combined. The steel ball is held in a spherical collar of aluminum alloy, so that the stick is movable in all directions. This is probably the simplest and lightest control stick. Figure 63 shows the mounting of the control stick on the wing-controlled monoplane "Störtebecker."

Here one angle of a triangle is connected with the control stick by plywood gussets, while the two other angles are connected with push rods which actuate the wings.

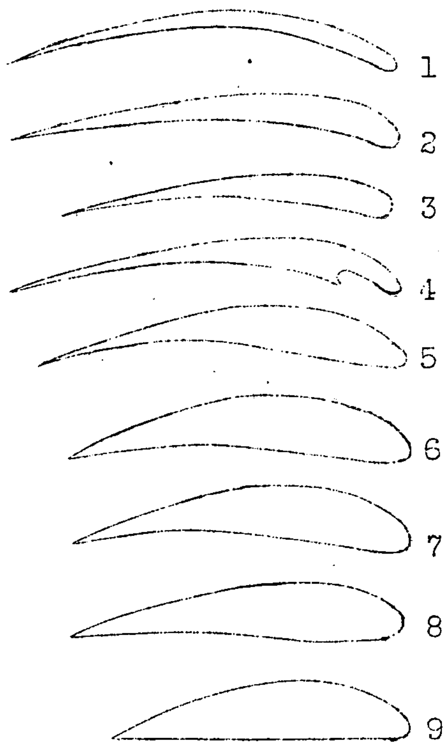
The steering levers and surfaces are connected either by cables which pass over pulleys of the largest possible diameter, or by duralumin or steel tubes in combination with push rods. The latter method is continually becoming more general. It offers greater advantages in assembling and disassembling, and the friction is generally less. The rudder is always connected with the pedals by cables.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.



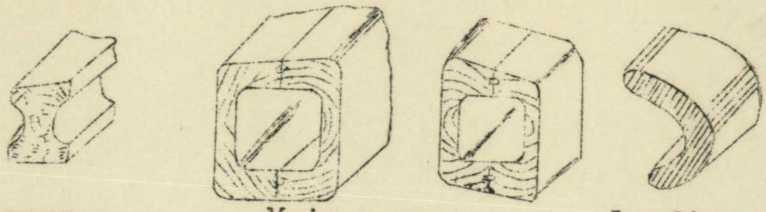
a Edith
b Konsul
c Pelikan
d Vampyr
e Charlotte

Fig.1



1 Brandgans
2 Alder
3 Eule
4 Geier
5 Möve
6 Albatros
7 Göttingen 441
8 " 535
9 Junkers

Fig.2 Profiles.



Auxiliary spar Main spars Leading-edge former

Fig.3 Cuts through spars of engine-driven airplane.

a Ash
b Pine

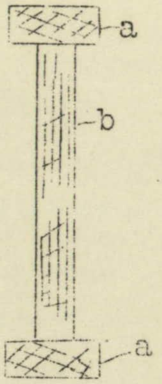
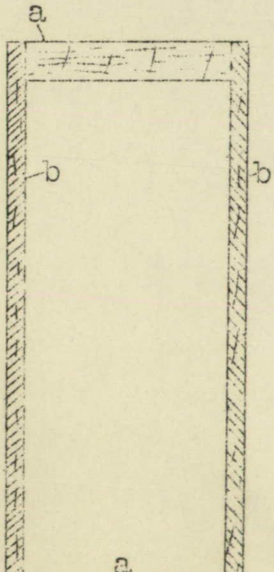
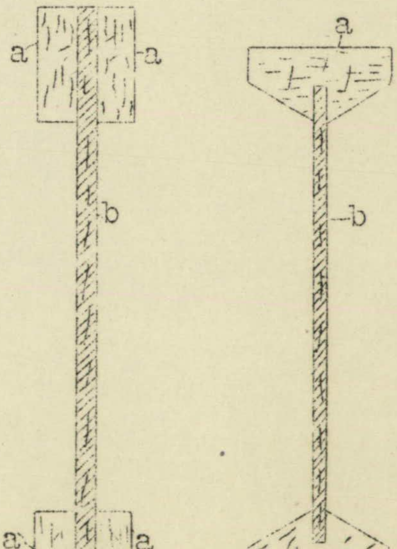


Fig.4 Pelzner spar



a Pine flanges
b Plywood webs
Fig.5 Box spar



a Pine flanges
b Plywood webs
Fig.6 I girders.

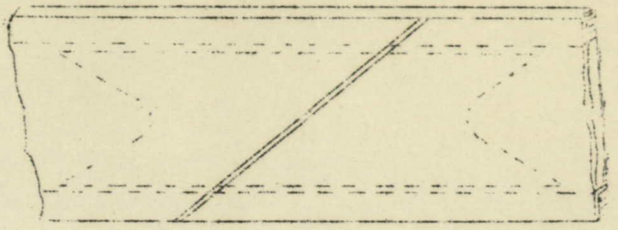


Fig.7 Splicing the web of a box spar.

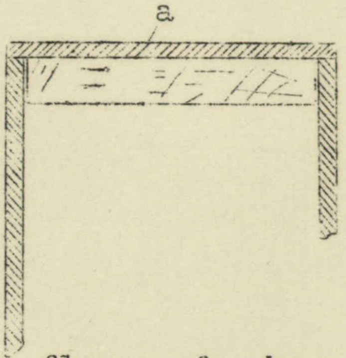


Fig.8 Reinforcing the flange of a box girder with thin plywood.

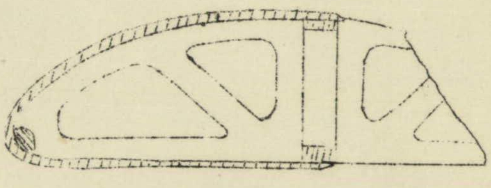


Fig.10 Plywood covering of leading edge of wing.

a Longitudinal members
b Corner brackets for stiffening
c Plywood webs

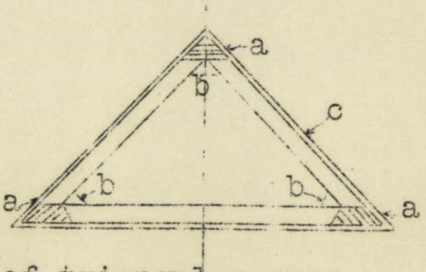


Fig.11 Cross section of triangular spar.

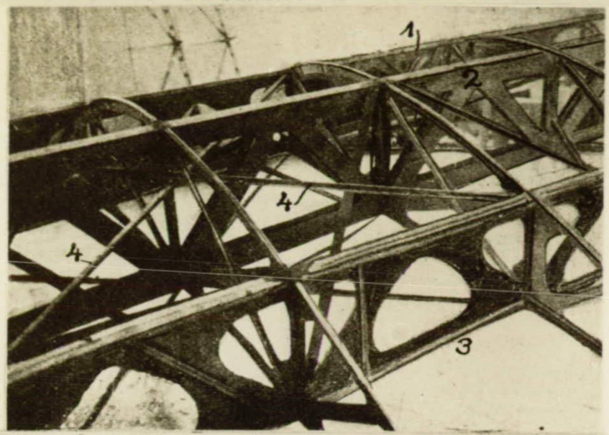


Fig.9 Wing structure of Aachen monoplane "Blaue Maus"
Nos.1,2 and 3 indicate the spars;
No.4 the diagonal braces.

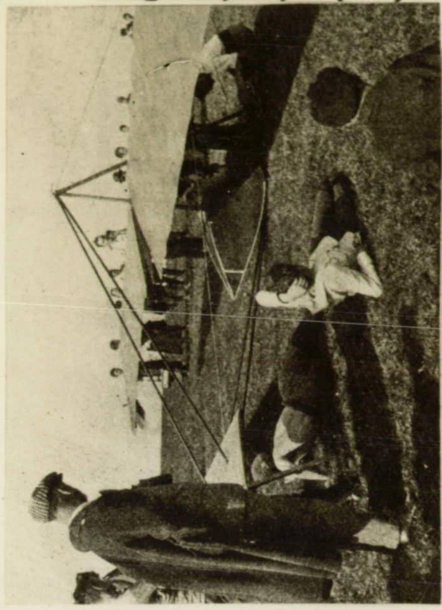


Fig.28 Frame of 1921 Munch monoplane

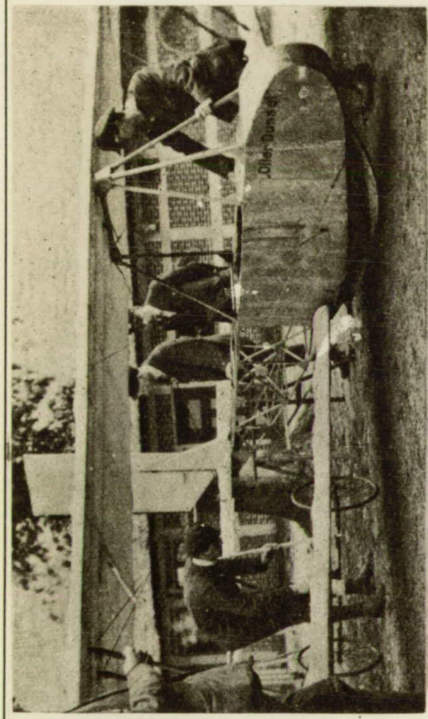


Fig.34 School biplane glider "Oller Dussel".
Wings are staggered too much and the struts are too close together.

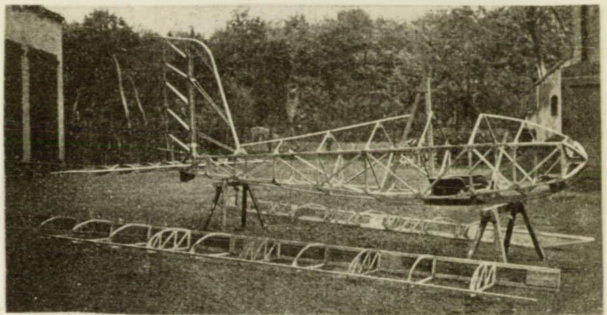


Fig.31
Fuselage of "Stortebecker" without bulkheads

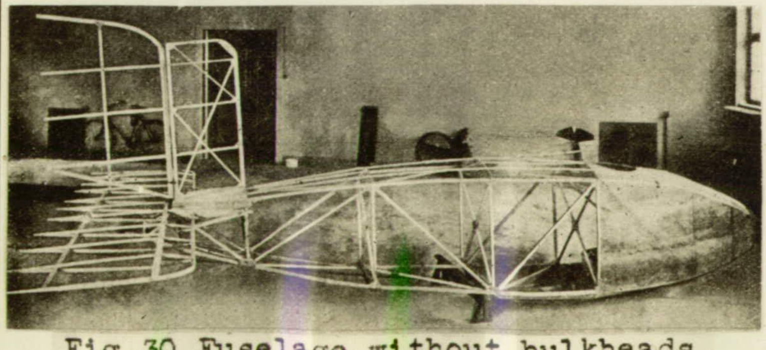


Fig.30 Fuselage without bulkheads

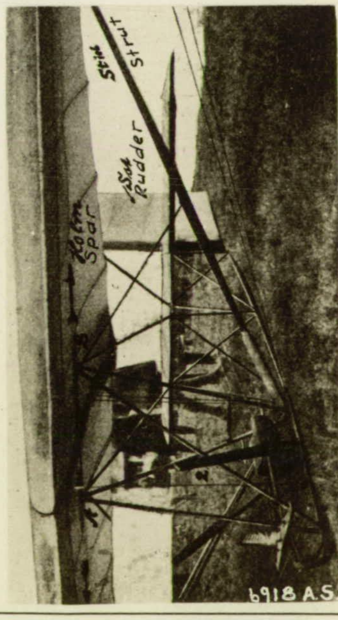


Fig.29 Framework of Harth soarer

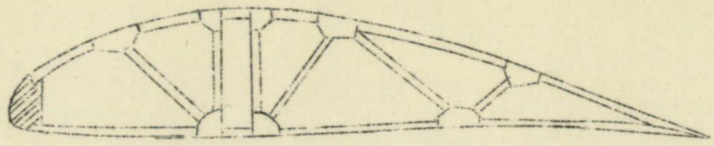


Fig.12 Braced rib with junction gussets.

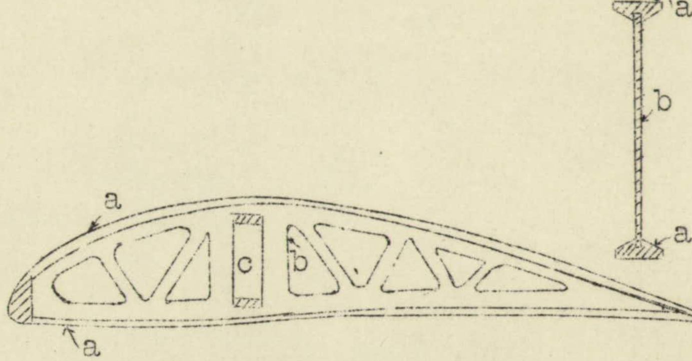


Fig.13 Plywood rib.
a Flange.
b Web.
c Box spar

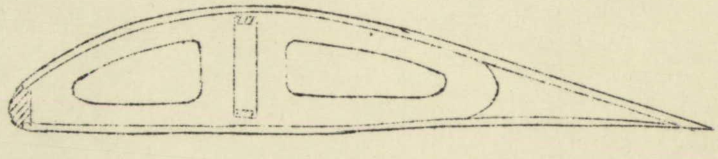


Fig.14 Plywood rib with flexible trailing edge.

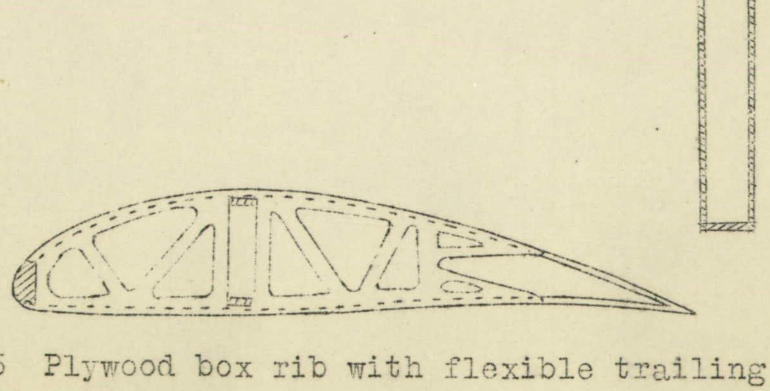


Fig.15 Plywood box rib with flexible trailing edge.

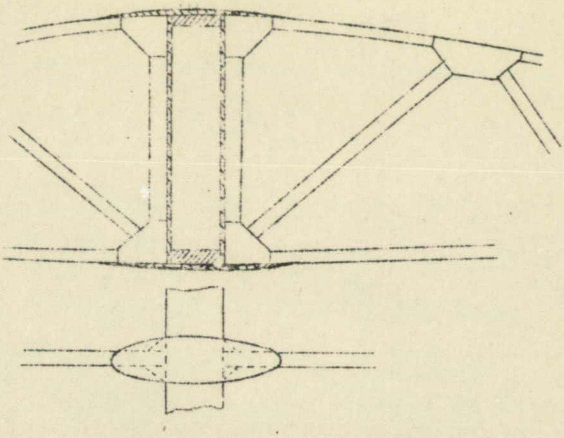


Fig.16 Divided rib for full-height spar with plywood reinforcing strips over flanges.

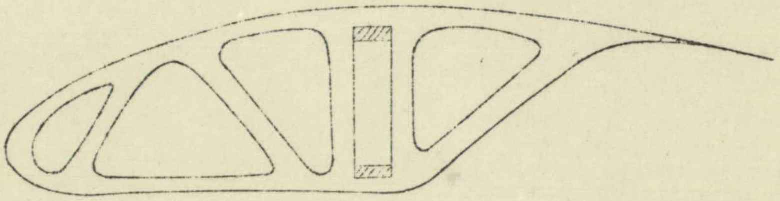
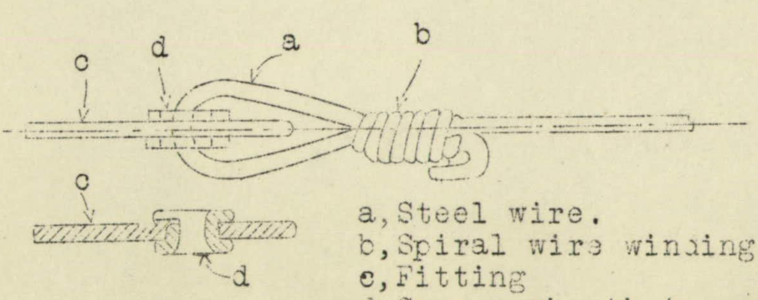


Fig.17 Intermediate plywood rib for preserving the profile.



a, Steel wire.
b, Spiral wire winding.
c, Fitting
d, Copper sheath to protect fitting.

Fig.18 Attachments for brace wires.

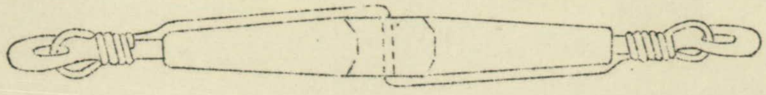


Fig.19 Turnbuckle secured by iron wire.

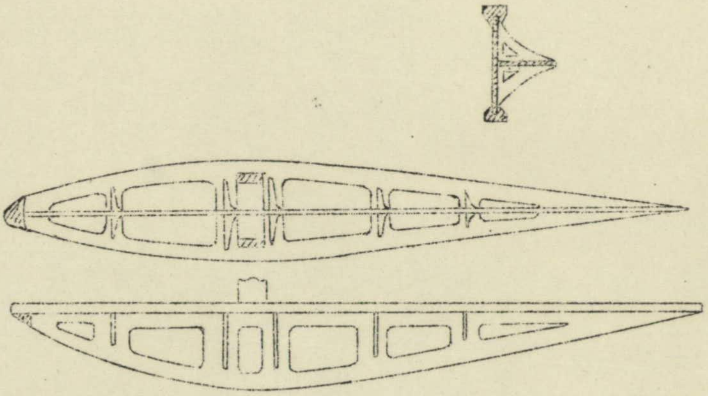


Fig.20 Separable ribs for wings and control surfaces.

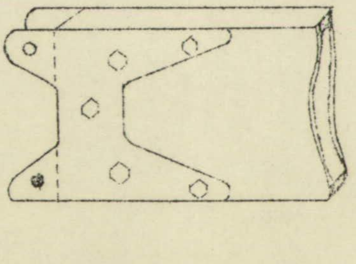


Fig.21 Spar fitting.

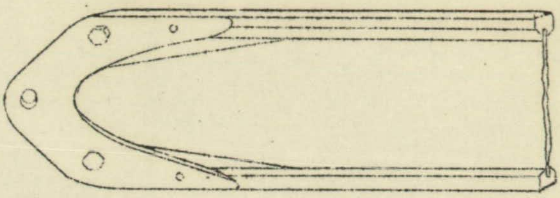


Fig.22 Spar fitting for braced wings.

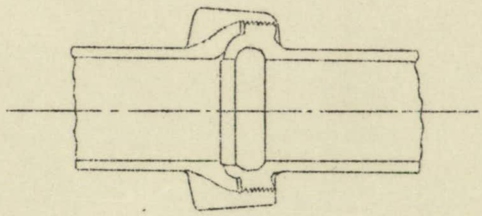


Fig.23 Junkers wing connections.

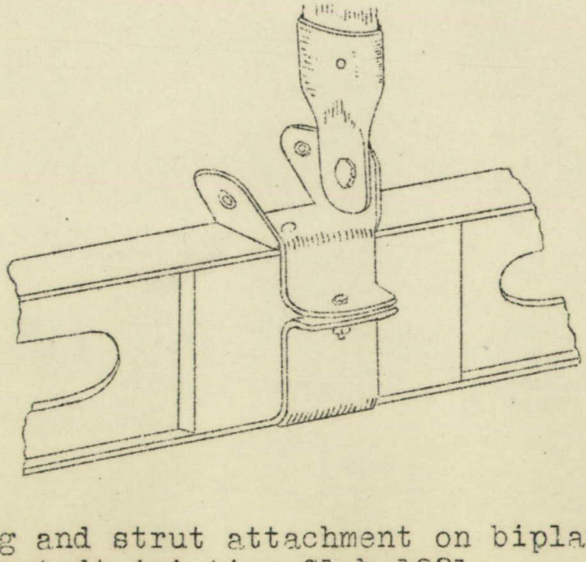
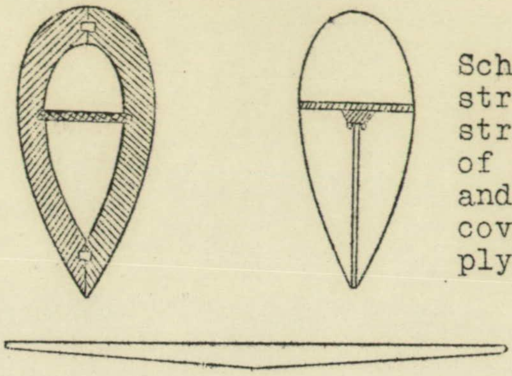


Fig.24 Wing and strut attachment on biplane of Darmstadt Aviation Club,1921.

Ordinary two-part strut



Schon-Hasenfuss strut for small stresses with webs of 3 mm plywood and one-piece covering of 1 mm plywood.

Fig.25 Hollow struts.

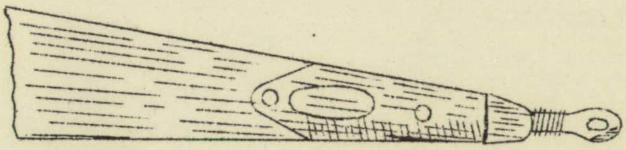
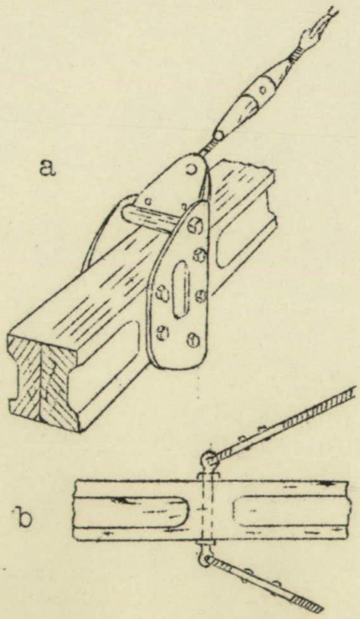


Fig.26 Adjustable strut attachment of sheet steel with half of a turnbuckle welded to it.



a Right fitting for brace wire
b Wrong " " " "

Fig.27

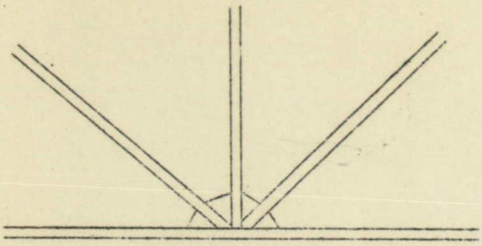


Fig.32 Stiffening the junctions with triangular blocks

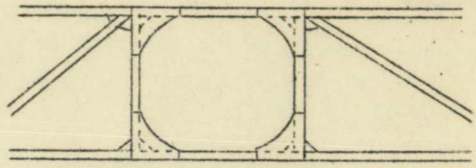


Fig.33

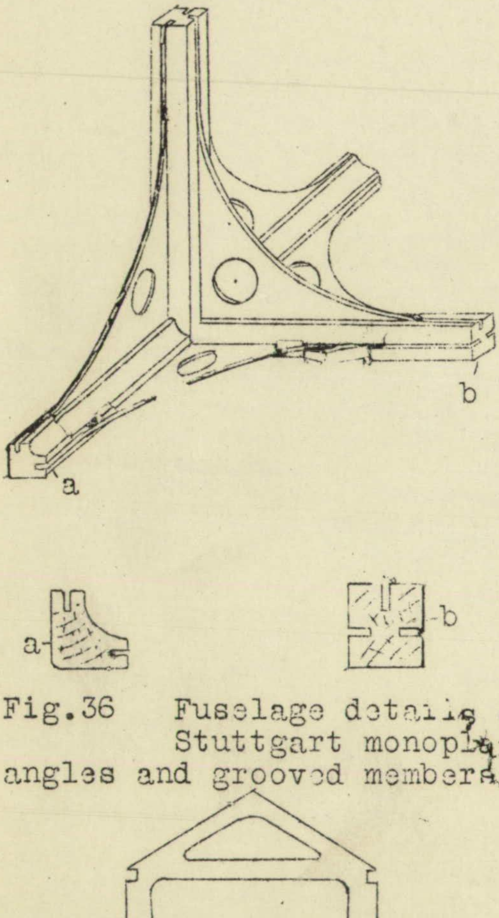


Fig.36 Fuselage details of 1921 Stuttgart monoplane.Plywood angles and grooved members.

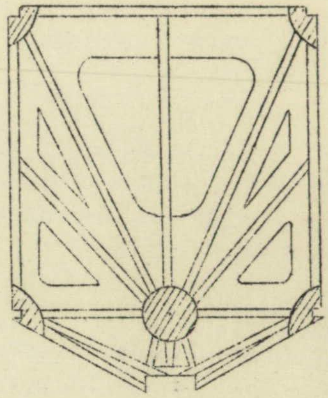


Fig.37 Bulkhead of "MU Schoop"

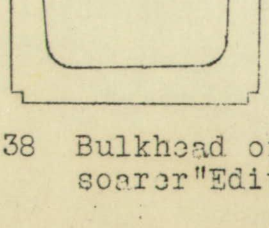


Fig.38 Bulkhead of soarer"Edith".

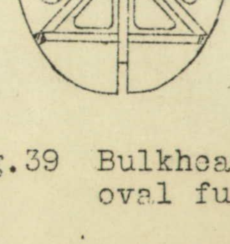


Fig.39 Bulkhead of oval fuselage.

Fig.41 School glider with two rigid runners. (Sled gear).

Fig.40 Soarer "Espenlaub V" with central runner.

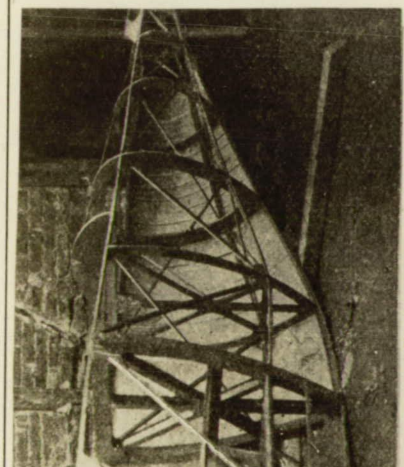


Fig.35 Fuselage of Bonner soarer "Schlagel and Eisen". The wing bulkhead is especially strong. The longerons are small, because the plywood covering will distribute the stresses.

Fig.60 "Schlagel and Eisen" just after take-off. The slots preceding ailerons and rudder are unfavorable. The method of hinging shown in Figs. 54-55 is better.

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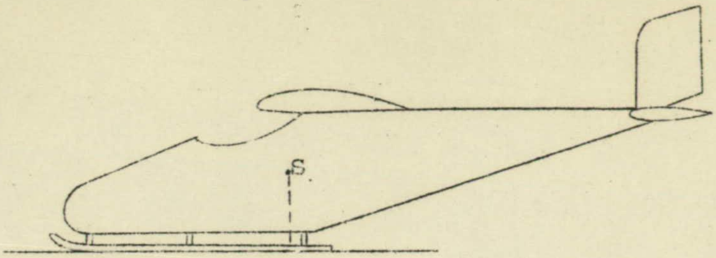


Fig.43

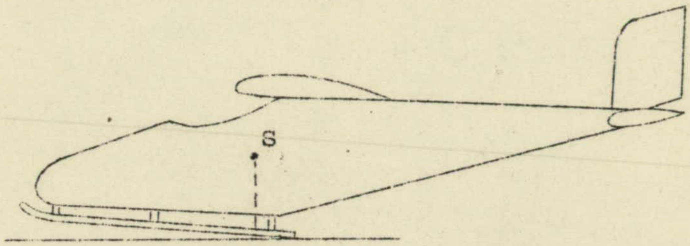


Fig.43

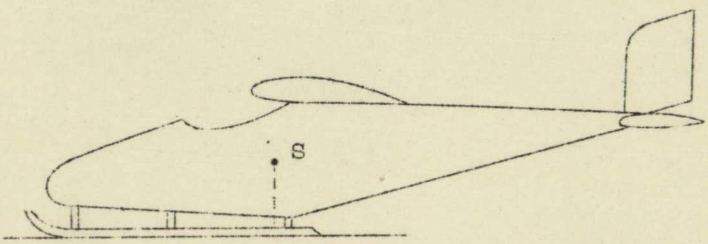


Fig.44

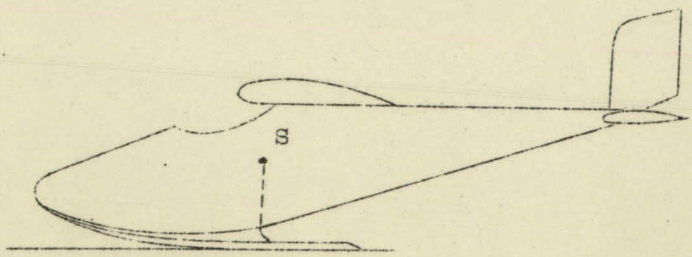
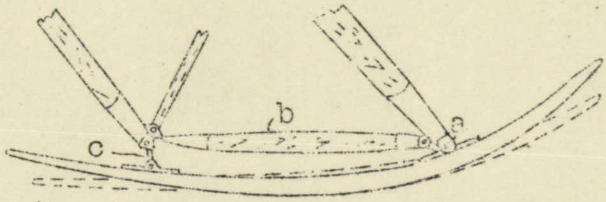
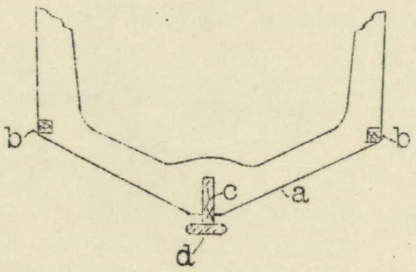


Fig.45



a Hinge
b Connecting strut
c Hinged intermediate rod

Fig.46 Spring runner on 1921 Stuttgart monoplanes.



a Bulkhead
b Longeron
c Board
d Runner

Fig.47

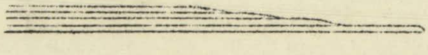


Fig.48 Tip of plywood runner.

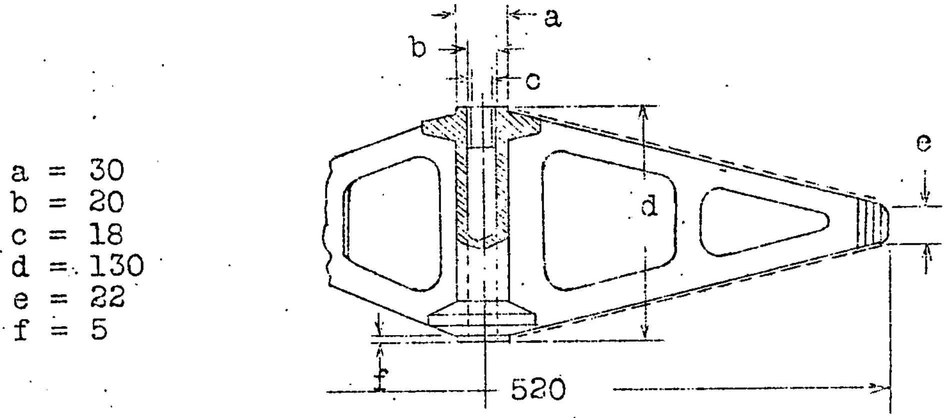


Fig.49

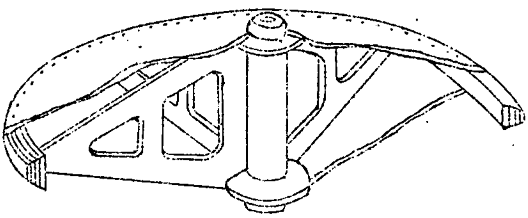


Fig.50

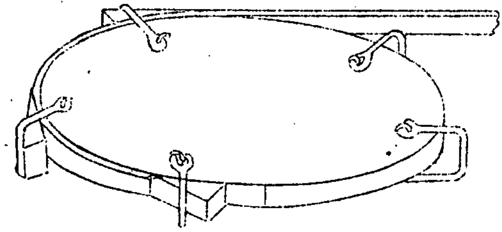


Fig.51

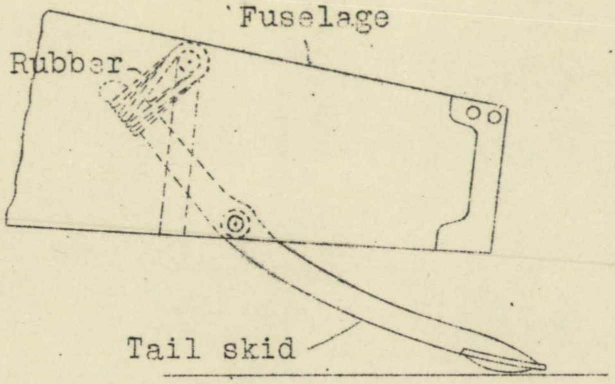


Fig.52

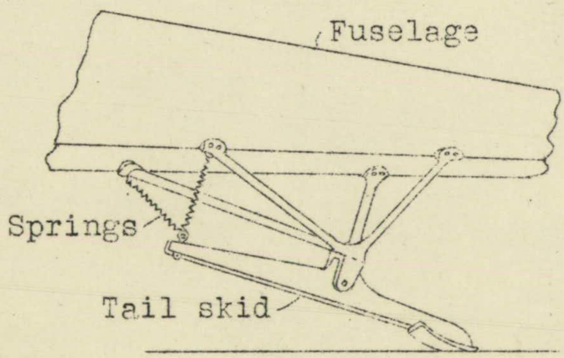


Fig.53

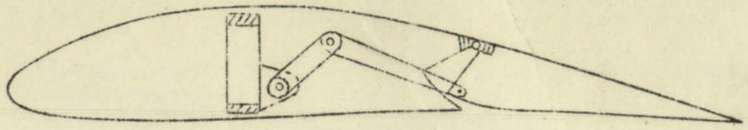


Fig.54

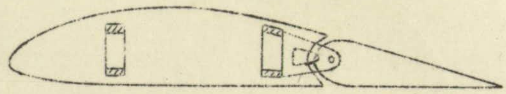


Fig.55

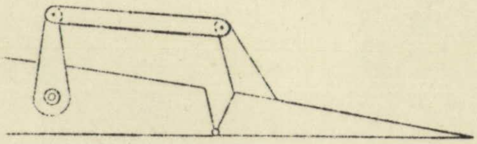


Fig.56

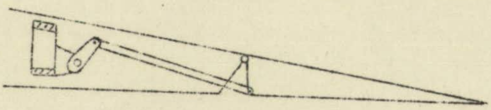


Fig.57

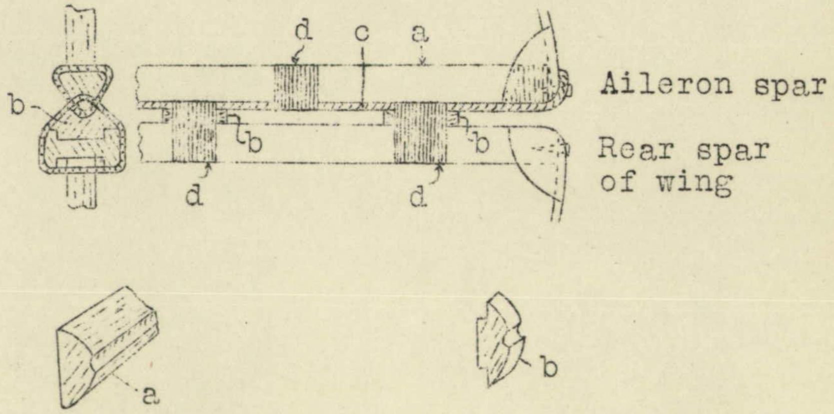


Fig.58

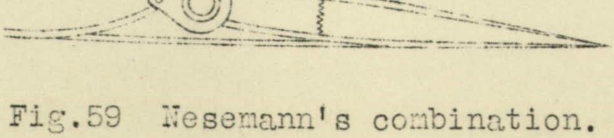


Fig.59 Nesemann's combination.

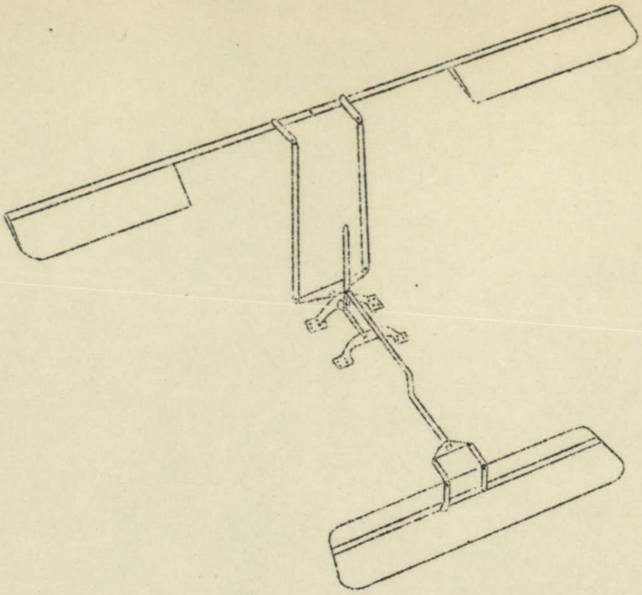


Fig.61 Normal control system.

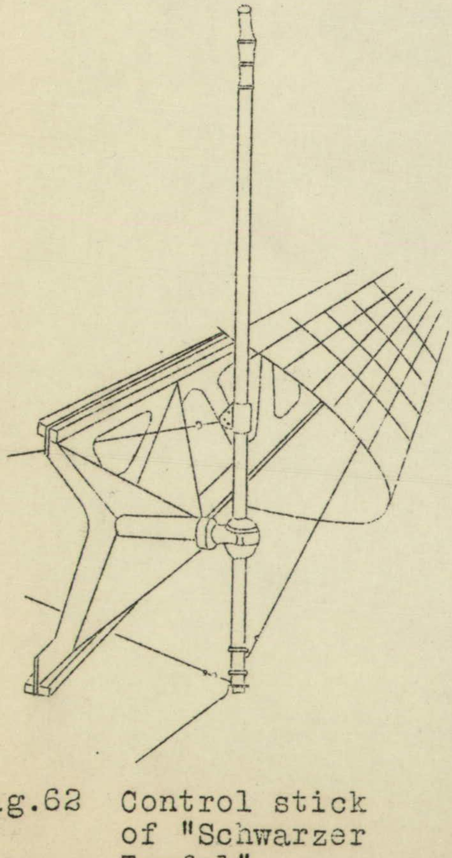
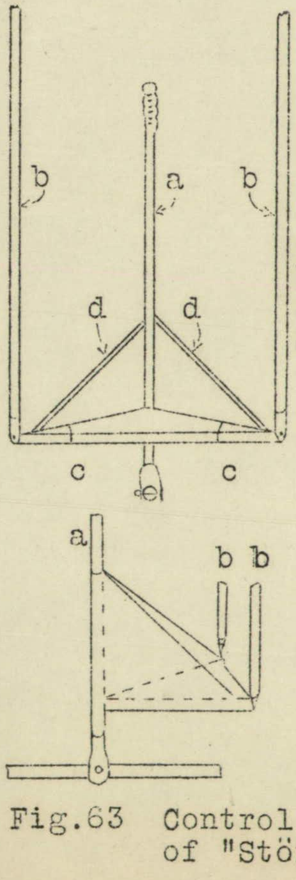


Fig.62 Control stick of "Schwarzer Teufel".



a, Control stick.
b, Connecting struts.
c, Sheet-steel fittings.
d, Plywood gussets.

Fig.63 Control stick of "Störtebecker".