AIRCRAFT CIRCULARS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 109

THE DORNIER "Do.X" FLYING BOAT (GERMAN)

A Giant High-Wing Monoplane

Washington
February, 1930

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

AIRCRAFT CIRCULAR NO. 109.

THE DORNIER "Do.X" FLYING BOAT (GERMAN)*

A Giant High-Wing Monoplane.

By Claude Dornier.

The "Do.X" was built in the workshops of the Dornier Aircraft Construction Company at Alteurhein. Its construction was begun on December 19, 1927. The launching and the first trial flight took place on July 12, 1929, 570 days having been required for its completion. When the preliminary work was begun, it had already been decided that the projected aircraft must be a flying boat with a central hull. It was first endeavored to attain the necessary degree of stability without resorting to additional floats. This, however, proved impossible because of the large dimensions of the "Do.X," unless considerable disadvantages were accepted. It was finally decided to adopt the stub wings which, for over ten years, have been successfully used in hundreds of cases (Fig. 1).

The under-water body, in so far as the take-off is concerned, does not materially differ from former types. The central longitudinal step was retained. Its rear end, transversely to the direction of flight, is horizontal, while its front end is slightly V-shaped. The portions of the hull bottom on

*From "Das Flugschiff Do.X," a lecture before the Wissenschaftliche Gesellschaft für Luftfahrt," in November, 1929.

each side of the longitudinal step are slightly concave. The bow is sharply V-shaped, especially in the portion which is above the water line while taxying on still water.

The wing stubs are strongly rounded downward, transversely to the direction of flight, at the points where they meet the sides of the hull. This novel shape, which had not been contemplated in the original design, has both static and hydrodynamic advantages. The thickness of the stubs at their roots is much greater, thus enabling a greatly increased stiffness of the supporting members. During the take-off an outward motion is imparted to the water by the concave shape, while with the old type of construction the water was forced into the angle between the lower surface of each stub and the side of the hull.

An outstanding feature in the design of the "Do.X" flying boat is the division of the hull (for the first time in aircraft construction), into three separate decks (Fig. 2). The upper or so-called "control deck" contains the pilot room, the commander's room, the engine-control room and the rooms for the radio outfit and the auxiliary motors. The middle deck is designed exclusively for passengers. It has a length of 23.5 m (77.1 ft.), a height of approximately 2 m (6.56 ft.), and a maximum width of 3.5 m (11.48 ft.). The bottom deck or hold contains the fuel, provisions, freight and luggage.

During the investigations required by the design work, static problems received considerable attention. The idea of a full cantilever wing was abandoned for the purpose of reducing its weight as much as possible. The choice of a semicantilever wing was also desirable for structural reasons. The wing is of a three-spar type with three struts on each side. This system, used for the first time on the "Do.X," produces exceptional rigidity and torsional strength as a result of the peculiar compound effect. It also insures that damage to one of the struts or spars will not endanger the carrying capacity of the whole system.

It is now a generally recognized fact that the lift is considerably increased by mounting the propellers above the wing. The possibility of using pusher propellers at the trailing edge of the wing with the engines inside the wing, received particular attention. It was concluded, however, that the long shafts required and the difficulty of installing these shafts with the propellers at the trailing edge of the wing would result in additional loads which would far overbalance the aerodynamic advantages of this arrangement.

Structural Details

The wing has a rectangular plan form with slightly rounded tips. The span is 48 m (157.48 ft.) and the chord 9.5 m (31.17 ft.). The total wing area, including the ailerons and the upper wing, is 486.2 m² (5233.4 sq.ft.). The weight of the whole wing system with ailerons, upper wing and struts is 7559 kg (16,665 lb.), giving a mean unit weight of 15.5 kg/m^2 (3.2 lb./sq.ft.). With a full load of 52,000 kg (114,640 lb.), the wing complies with the D.V.L. regulations for passenger transportation now in force. The central spar lies approximately at the point of maximum wing thickness. The front and rear spars are set wide apart. They are both 2.8 m (9.2 ft.) distant from the central spar. The distance between the cross members is as high as 3.6 m (11.8 ft.).

The upper wing is not designed to increase the lift of the main wing, its function, statically considered, being merely to stiffen the engine bearers. With the exception of a few steel fittings, the whole wing structure is made of duralumin. This material was used because it was impossible to procure, in time, steel sections of the requisite dimensions. It is expected that much benefit will be derived from the use of steel on very large aircraft, since only large dimensions enable the use of steel to its fullest advantage.

Figure 3 shows the cross section and a view of part of the central spar at its junction point with a strut. The spar flanges are of pressed duralumin angles and plates, similar to those used in bridge building, additional plates being provided as required. At points of lower flange loading, the vertical webs of the angles are open-worked in order to reduce their weight. The design of the front and rear spars is similar to that of the central spar. At this point it is of interest to note a condition usually experienced when the dimensions are increased, of which the spars afford a particularly good example. This is the fact that, with increasing dimensions of the structural members, the amount of work required per kilogram of the finished structure is reduced. This depends chiefly on the number of joints and rivets. While, for the spars of the "Do.X," we have an average of 2.5 joints per meter, the corresponding figure for the Dornier "Superwal" is 3.3, and for the Dornier "Wal," 5.2. There is a similar relation between the number of rivets per kilogram of finished spar weight, which is 9.8 in the "Do.X," 33 in the "Superwal," and 44 in the "Wal."

The spar construction, which now seems so simple and natural, cost many months of time, especially because a model spar had to be built and submitted to exhaustive load tests. Figure 4 shows the test installation, which had to be specially designed and built for this purpose. Considerable foundation work was required to keep the test installation in place, since the ultimate load supported by half of the spar was nearly 42,500 kg (93,700 lb.). The usual method of loading the spar with sandbags or iron ballast was not feasible. Tanks were therefore secured to the joints and then filled with water. This method of loading gave good results. The behavior of the spar within the elastic range was investigated with particular care. The stresses of the different components were determined by tensiometers. Figure 5 shows control measurements of the stresses in the structural components of the central spar, as determined with a Mayhack instrument, kindly loaned by the D.V.L. (German Experimental Institute for Aviation), which co-operated in the tests. Figure 6 shows the measured and the calculated deflections of the central spar under different loads.

The cross members are also chiefly made of pressed section metal. It was sometimes necessary to provide frames at their point of connection with the front spar, in order to facilitate passage through the wing. The fields created by the intersection of the three spars with the cross members arranged at intervals of from 2.8 to 3.6 m (9.2 to 11.8 ft.) are covered with bending-resistant panels of fabric and sheet metal, which are called "wing-skin panels." The portion of the wing behind the rear spar forms an independent panel. The all-metal leading edge increases the resistance of the front spar to buckling stresses. The "wing-skin panels" are shown in Figures 7 and 8. As already mentioned, they are partly covered with fabric and partly with sheet metal. They are simply and cheaply made and easily mounted. They are secured to the main wing by bolt connections completely enclosed in the wing. Although the wing section is relatively not thick, the spars are so high, on account of the over-all dimensions of the flying boat, that it is possible to walk throughout nearly the whole wing even in flight.

The all-metal upper wing is designed to serve as a mutual stiffening of the engine bearers. It turned out to be relatively heavy, since it weighs 18 kg/m² (3.7 lb./sq.ft.). We have doubtless gone too far in attempting to reduce possible deformations and vibrations to the minimum. The weight of the upper wing is included in the mean unit weight of 15.5 kg/m² (3.2 lb./sq.ft.) for the total wing, as previously mentioned, and affects this mean value unfavorably. Excessive additional stresses of the main wing are avoided by flexible attachments of the portions of the upper wing between the two outer engine nacelles on each side to the inner one of the two.

Since this small upper wing has aroused considerable interest, the polar of the flying boat is shown in Figure 9. The light curve A is the polar of the flying boat without the upper wing, power cars and their supports. It corresponds to the ideal case in which the engines, being completely enclosed in the hull or wing, would cause no additional drag by their cooling systems or propeller mounts. The heavy line B is the polar of the flying boat in its present condition and in gliding flight. The third dotted line C shows the variation of the polar of the "Do.X" with propellers running at cruising speed. The dot-and-dash line D corresponds to the model with power cars and supports but without the auxiliary wing. The surface of the main wing is the datum surface. The auxiliary wing is found to cause a slight reduction in drag at small angles of attack, while it considerably increases the lift at large angles of attack. Of course the ideal case of polar A can never be attained in practice.

The engine nacelles are of framework construction with streamlined covering. Good access is afforded by large doors on each side.

Figure 10 is a side view of the hull. The midship frame has an area of 17.2 m^2 (185 sq.ft.) without the stubs. The frames are placed 0.7 m (2.3 ft.) apart. There are 58 transverse frames in all. The keelson of 23.3 m (76.4 ft.) length and 2.12 m (6.96 ft.) maximum height, which extends from the bow to the stern step (Fig. 11), is an important innovation. It greatly increases the rigidity of the hull. Two auxiliary keelsons are provided on each side of the main keelson at distances of 0.9 and 1.58 m (2.95 and 5.18 ft.). Thus an extremely efficient combined action is obtained in conjunction with the transverse frames. The unusually strong duralumin plates which cover the portion of the hull bottom directly subjected to the action of the waves are divided into panels of approximately 0.63 m^2 (6.78 sq.ft.) area by the intersection of the transverse and longitudinal members.

Figure 12 is an oblique front view of the hull during its construction. Also in the cross members, it was endeavored, within the admissible weight limits, to use pressed section metal. A few of the frames are shown in Figs. 13-16. In Fig. 17 there are plotted for comparison the total and partial weights of the hulls of different Dornier flying boats as functions of the corresponding volumes. The trend of the curves is obvious. Attention is called to the fact that the weight of the hull was 29.9 kg/m^3 (1.87 lb./cu.ft.) for the small "Libelle" flying boat and 26.2 kg/m^3 (1.64 lb./cu.ft.) for the "Wal," while for the "Do.X" it does not exceed 21.0 kg/m^3 (1.31 lb./cu.ft.). Also, the same loading being assumed, the material of the "Do.X" is subjected to much smaller stresses than that of the smaller flying boats. In so far as local stresses are concerned, the conditions of the "Do.X" are much more favorable than those of the smaller flying boats. This is accounted for by the greater thickness of its metal sheets and sections which are less subject to the danger of local buckling. The hull and the stubs are both divided by bulkheads into many compartments. The hull has nine water-tight compartments and each stub has four. The reserve displacement is exceptionally large. The displacement of the stubs alone is 43.5 m^3 (1536 cu.ft.).

The general arrangement of the control surfaces is shown in Figure 18. The total area of the horizontal tail surfaces is 53.4 m^2 (574.8 sq.ft.), while that of the vertical tail surfaces is 19 m^2 (204.5 sq.ft.). All the controls are balanced by auxiliary surfaces. The distance between the elevator and the water-line is 6 m (19.7 ft.). The hull is extended backward for the protection of the rudder against water impacts.

The control surfaces are operated by traction rods suspended on pendulum levers. All the control rods are mounted on ball bearings, which insures a remarkably easy operation of the controls. Trimming devices for balancing both the longitudinal and the transverse moments are also provided. The trimming is effected by changing the angle of attack of the corresponding balancing surfaces. This requires no mechanical power and can be accomplished from the pilot's seat. Figure 19 shows the pilot room on the control deck. The two small laterally disposed hand wheels are used for trimming, while the large hand wheel operates the water rudder. Normal wheel control has been adopted. The visibility is excellent.

Particular care was devoted to the power plant (Fig. 20), which consists of 12 Siemens-Jupiter engines with a reduction gear ratio of 2 : 1. The structural components are unusually strong. Particularly long and exhaustive tests were required. One of these tests is illustrated by Figs. 21 and 22, which show the determination of the stresses set up in an engine bearer under the combined action of thrust, torque and engine weight.

On the "Do.X" for the first time in the history of flight, the pilots are relieved of the supervision of the power plant. As in the past, however, the pilot is given the means of controlling all the engines. This is achieved by means of two immediately adjacent levers, which can be operated jointly by a single grip. Separate operation of the levers enables the pilot to throttle either the starboard or the port group of engines separately, which is particularly useful for maneuvering on the water. All the engines can be stopped simultaneously from the pilot's seat.

The successful mounting of a "free wheel mechanism" between the propeller and the engine would result in a material increase of the flight range. Individual engines could then be fully stopped in cruising flight without incurring increased drag or loss of power from stopped propellers or the idling propellers rotating the engines.

Two mean revolution counters (giving the average r.p.m. of the port and starboard engine groups, respectively) and an electric annunciator have been added. The latter comprises twelve small lamps, one of which lights for each engine stopped. On the basis of the many flights hitherto made, it appears not only possible but highly desirable to relieve the pilot completely of the engine supervision. The starting, distance supervision, and normal stopping of the engines are handled from the control room shown in Fig. 23. The control room is connected with the engine nacelles by a passage running through the main wing. The engines are started by compressed air produced by a small compressor driven by a separate gasoline engine. The whole supply of electric current for the flying boat is also produced by this compressor.

The fuel system is the result of many years of experience. Under normal conditions four cylindrical tanks of 3000 liters (793 gallons) capacity each, and four other tanks of 1000 liters (264 gallons) each - making a total fuel capacity of 16,000 liters (4227 gallons) - are placed directly on the floor of the hull. They are all connected with a so-called "collecting pot" from which the fuel is pumped into two 300-liter (79-gallon) tanks in the leading edge of the wing. A wind-driven pump, an electric pump, and an Allweiler hand pump insure maximum reliability of fuel supply. From the wing tanks the gasoline is delivered to the carburetors by other pumps, the excess fuel flowing back into the "collecting pot." The fuel supply is controlled by gauges located on the control deck. The whole pipe system is readily accessible during flight. The oil tanks are located in the wing and have a total capacity of 1600 liters (423 gallons).

No material difficulties were encountered in the construction of the "Do.X," although its greatly increased dimensions required much new equipment. Figure 24 shows the riveting of the spars. As a result of new construction methods, the wing was assembled in a comparatively short time. Much time was spent in making jigs for the construction of the hull frames. The portion aft of the stern step was built separately from the main hull. Figure 25 shows the beginning of the hull construction. The keelson, which forms the backbone of the whole structure, was placed on an iron beam and the rear portion of the hull was then added. Figure 26 shows the hull shortly before it was covered.

The upper wing, with the power cars and their supports and with all the control rods for the operation of the engines, which were also installed, was fully assembled before being mounted in one piece on the main wing (Fig. 27). The actual assembly of the wing, hull, tail surfaces and power plant, including the installation of the pipe lines, required 60 days (Fig. 28).

The tests began early in the morning of July 12, 1929. Figure 29 shows the flying boat on the truck ready for launching. In Figure 30 the boat is seen in process of launching, which was accomplished without difficulty. Long taxying tests on the water were then made. Figure 31 is a front view of the boat on the water.

Figure 32 shows the "Do.X" on the step shortly before taking off. During attempts to run the boat under full power on the step, it took off unexpectedly. Subsequent to this first unexpected take-off, a few more short leaps were made. The first flights were made on the following day.

Characteristics and Performances

Length of hull	40.05	m	131.4	ft.
Width of hull	3.5	"	11.5	"
Height of hull	6.4	"	21.0	"
Wing span	48.0	"	157.48	"
Wing chord	9.5	"	31.17	"
Wing area (including ailerons and upper wing)	486.2	m^2	5,233.4	sq.ft.
Full load	52,000	kg	114,640	lb.
Gasoline capacity	16,000	liters	4,227	gal.
Oil capacity	1,600	"	423	"
Estimated maximum speed	214	k.p.h.	133	m.p.h.
Estimated cruising speed at 420 m (1378 ft.) altitude	175	"	109	"

Engines (12) - Siemens-Jupiter 500 hp

Corrected weights (corresponding to Dornier's lecture)
of construction group of "Do.X"

Wing with support	7,559.4	kg	16,665.6	lb.
Tail surfaces	878.2	"	1,936.0	"
Controls or steering gear	363.5	"	801.4	"
Hull	8,314.0	"	18,329.2	"
Engine nacelles with supports	1,147.2	"	2,529.1	"
Coating (paint)	350.0	"	771.6	"
Engines	5,121.6	"	11,291.2	"
Exhaust system	39.0	"	86.0	"
Propellers and hubs	1,101.9	"	2,429.3	"
Engine controls	226.9	"	500.2	"
Gasoline system	1,002.4	"	2,210.0	"
Oil system	300.5	"	662.5	"
Gasoline and oil in conduits	120.0	"	264.6	"
Power plant instruments	109.5	"	241.4	"
Flight supervising instruments	6.9	"	15.2	"
Navigation instruments	1.6	"	3.5	"
Miscellaneous instruments	30.4	"	67.0	"
Auxiliary operating instruments	188.0	"	414.5	"
Nautical equipment	270.7	"	596.8	"
	27,131.7		59,815.1	"

Translation by
National Advisory Committee
for Aeronautics.

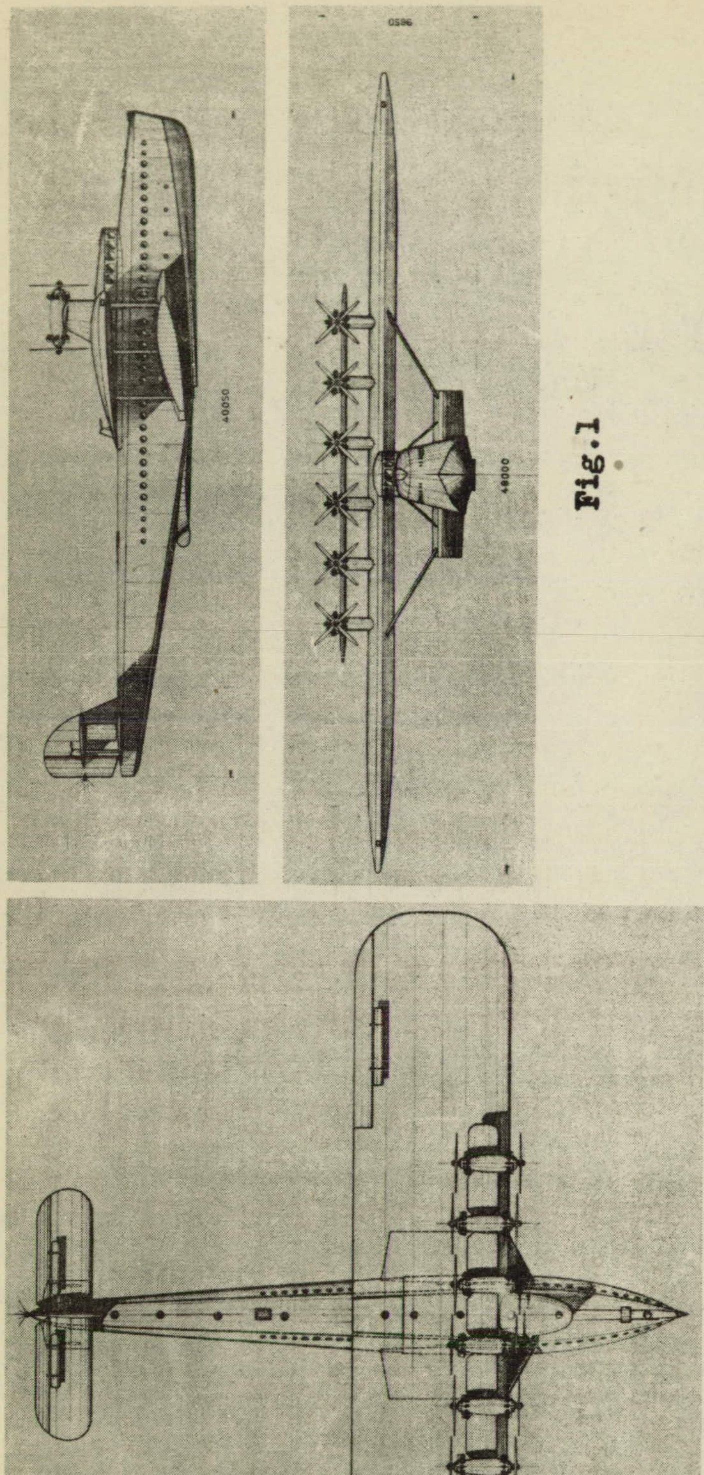


Fig.1

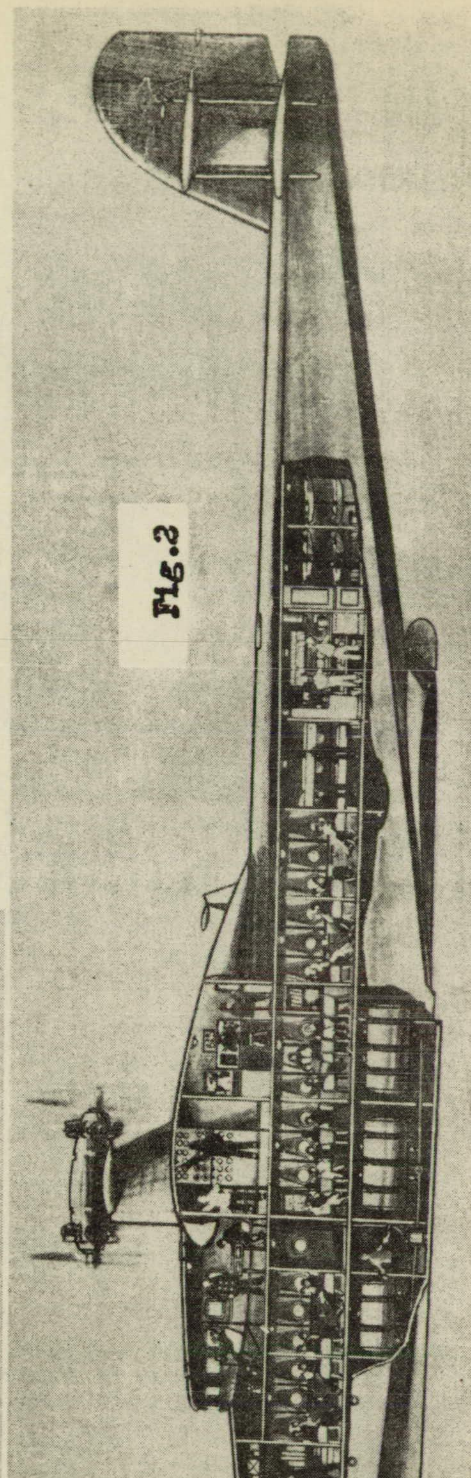


Fig.2

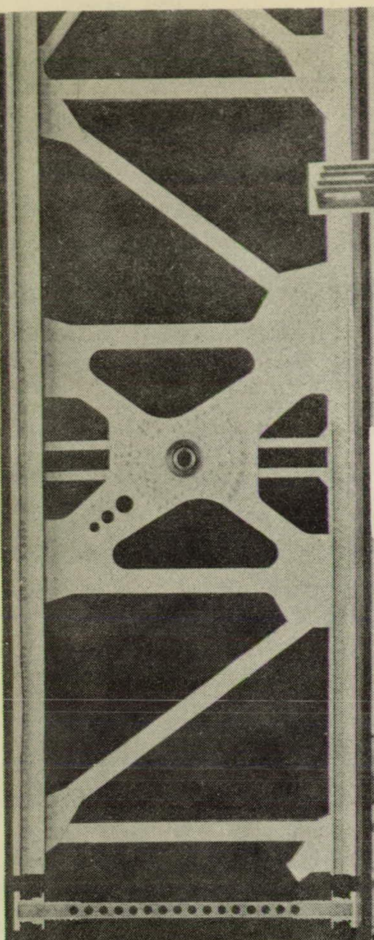


Fig.3

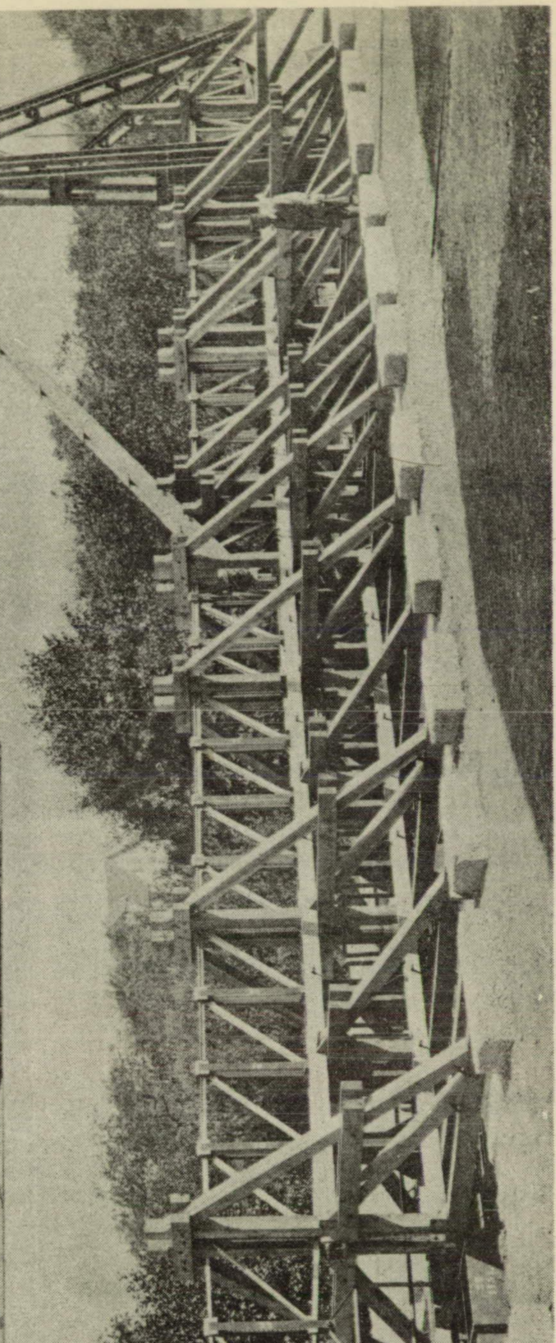


Fig.4

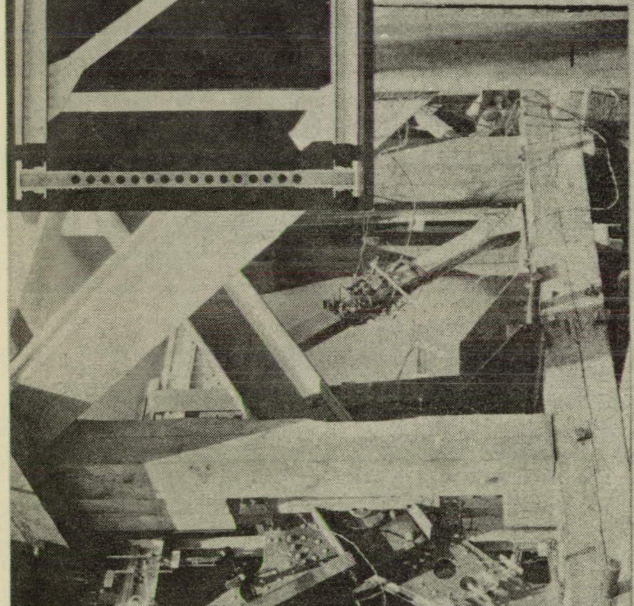


Fig.5

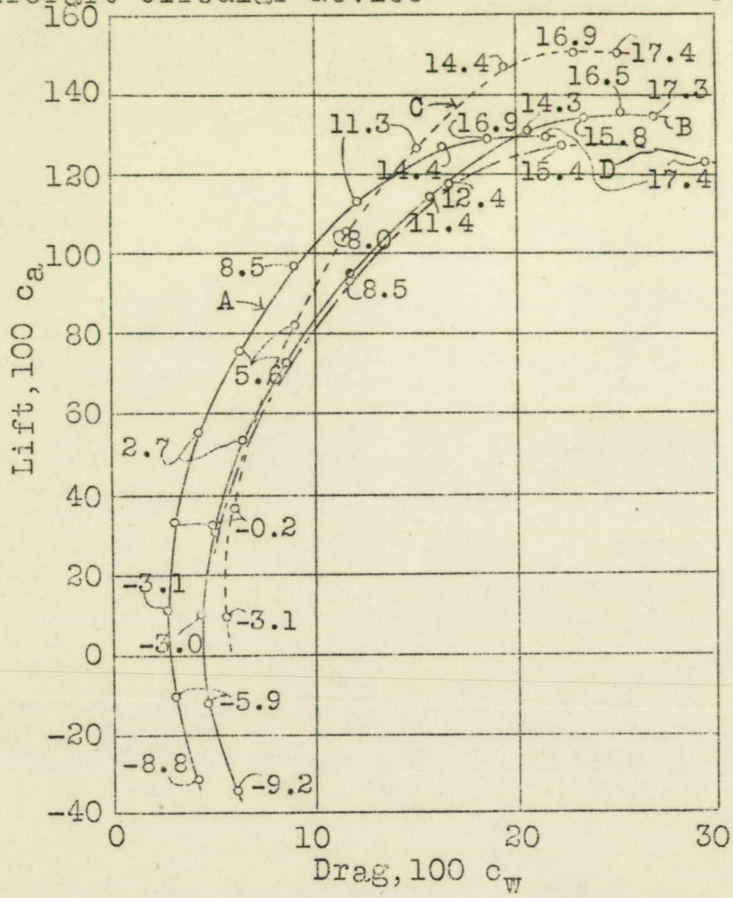


Fig.9 Polar of the Do X flying boat.

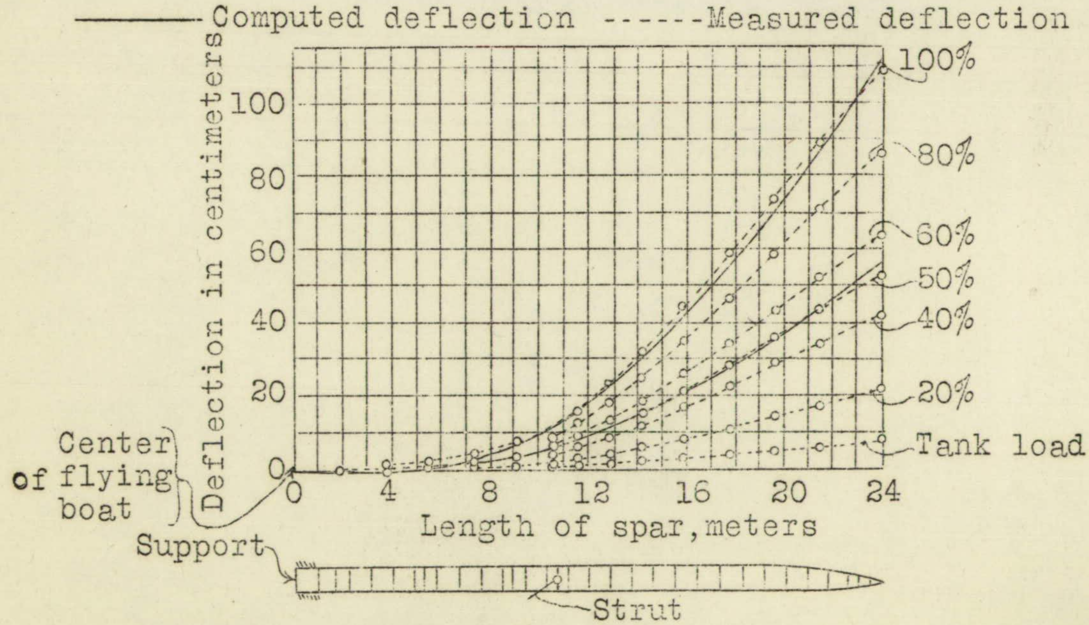


Fig.6

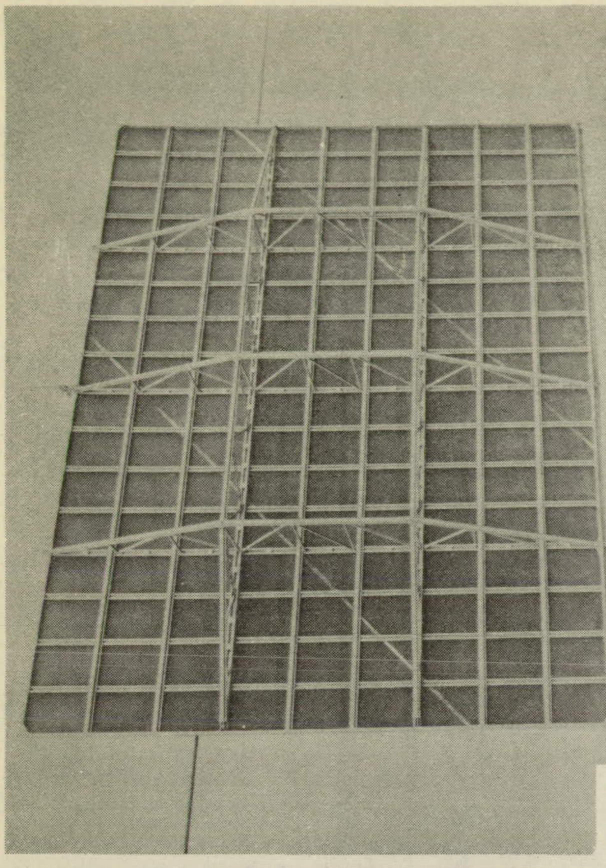


Fig.8

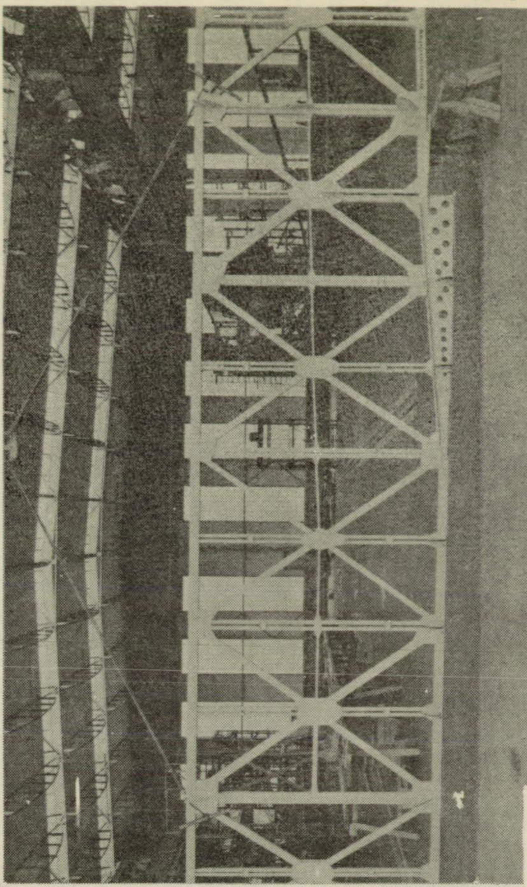


Fig.11

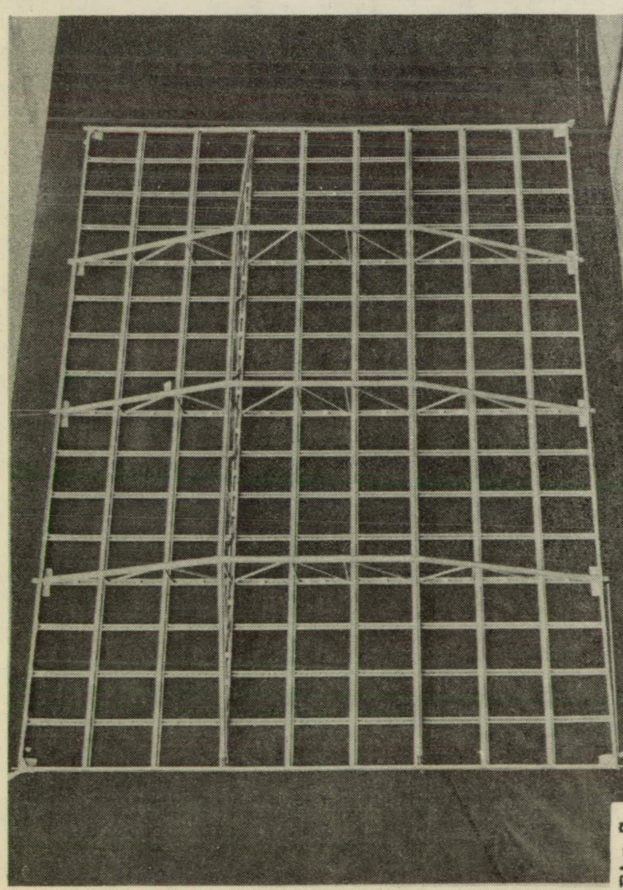


Fig.7

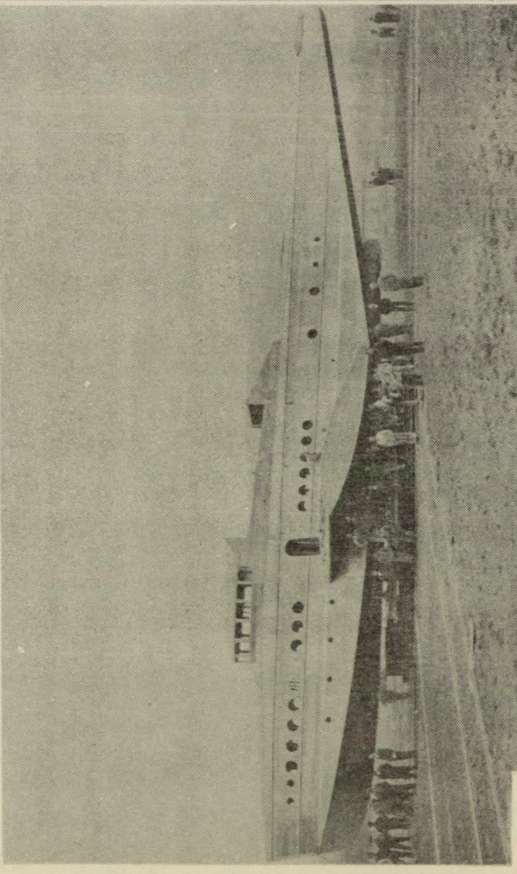


Fig.10

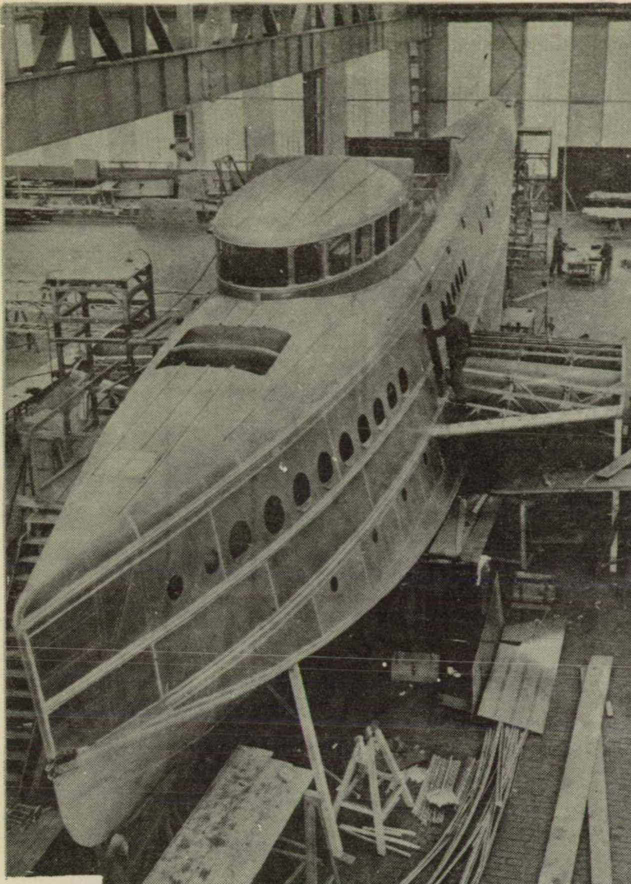


Fig.12

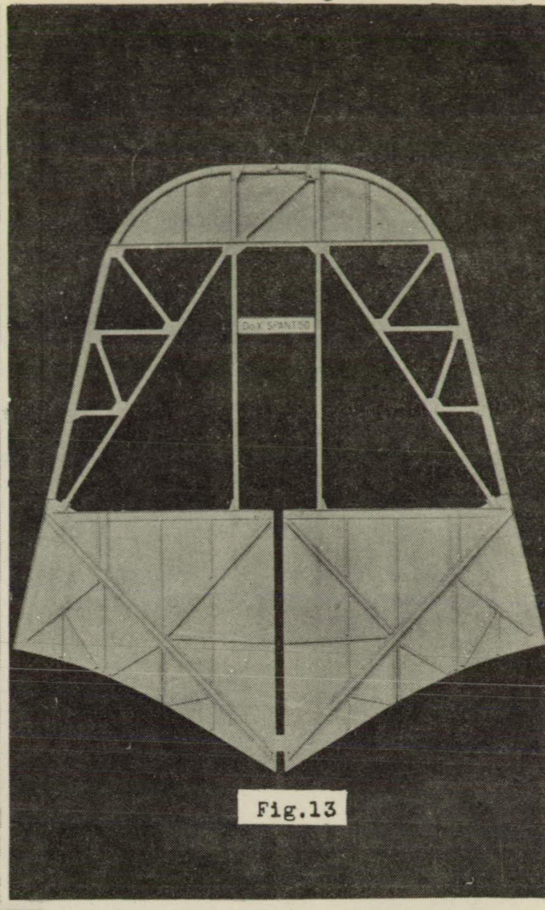


Fig.13

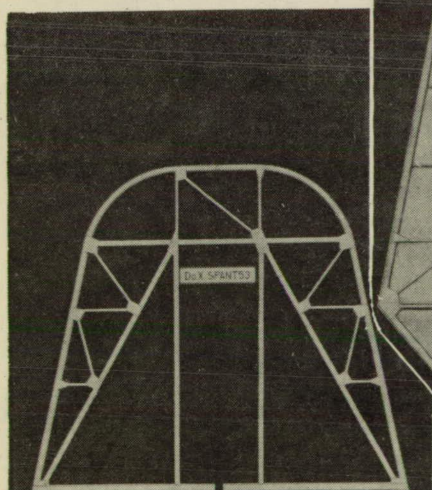


Fig.14

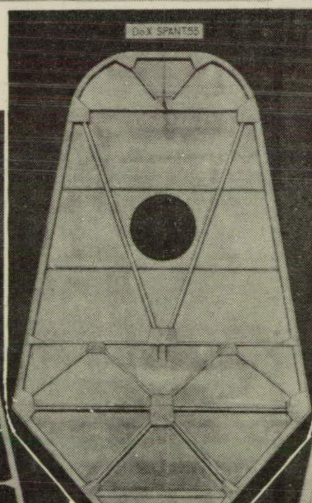


Fig.15

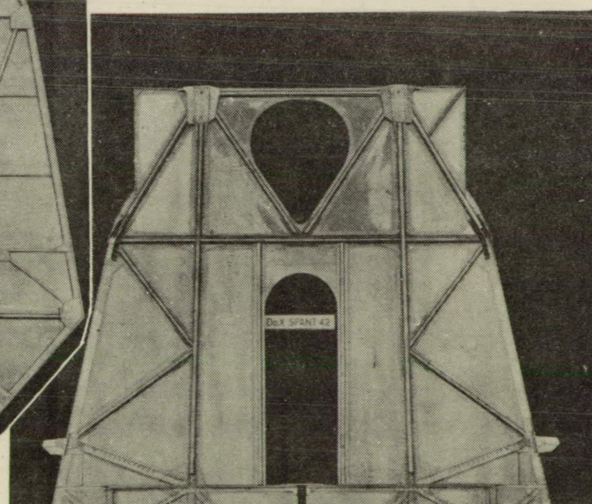
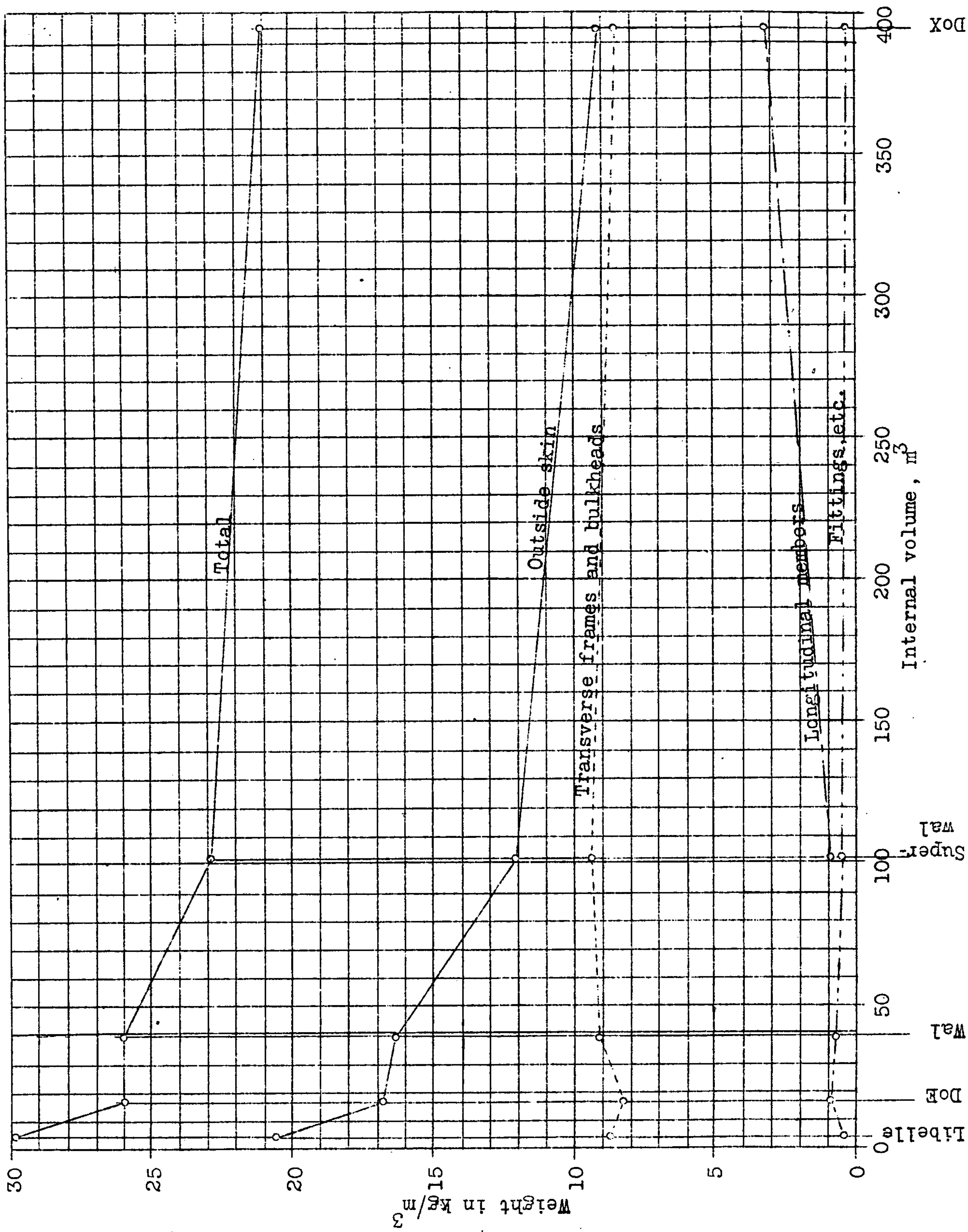


Fig.16


Total
Outside skin
Transverse frames and bulkheads
Longitudinal members
Fittings, etc.
Internal volume, m^3
Weight in kg/m^3
DoX
Super-wal
Wal
DoE
Libelle
0
50
100
150
200
250
300
350
400
30
25
20
15
10
5
0

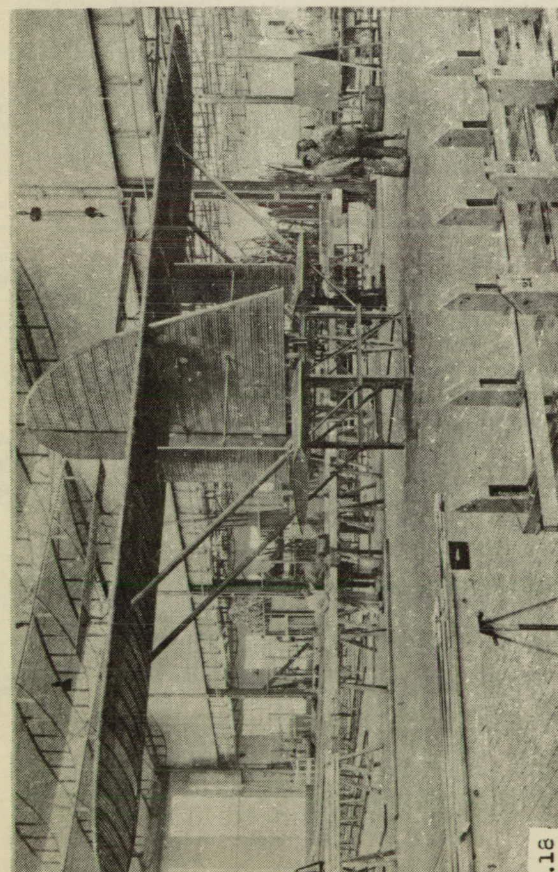


Fig.18

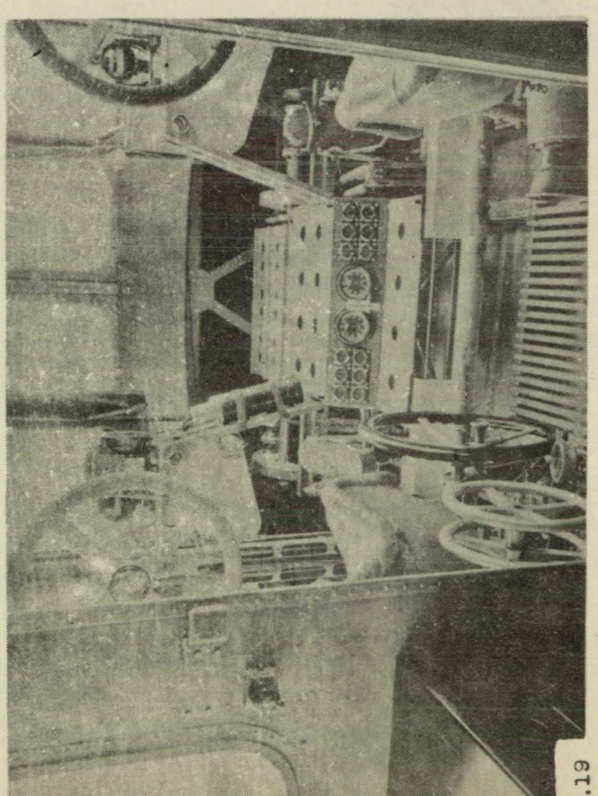


Fig.19

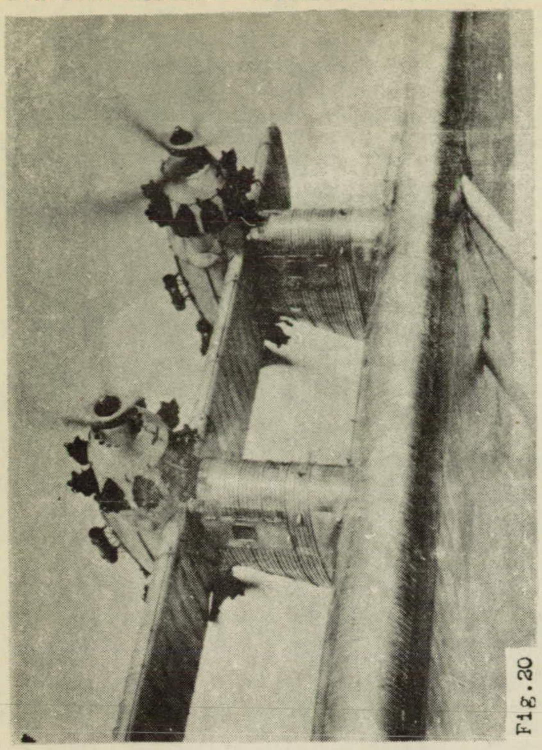


Fig.20

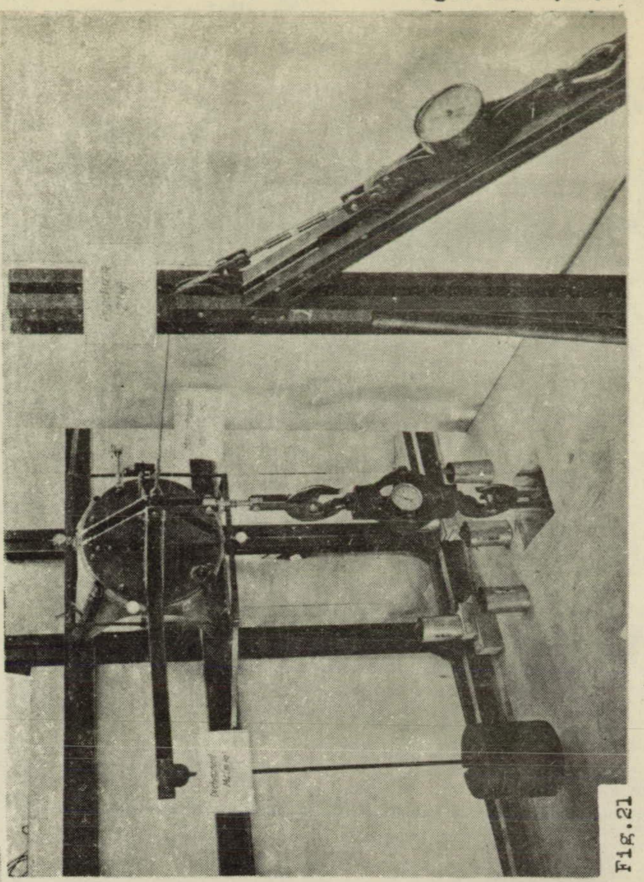


Fig.21

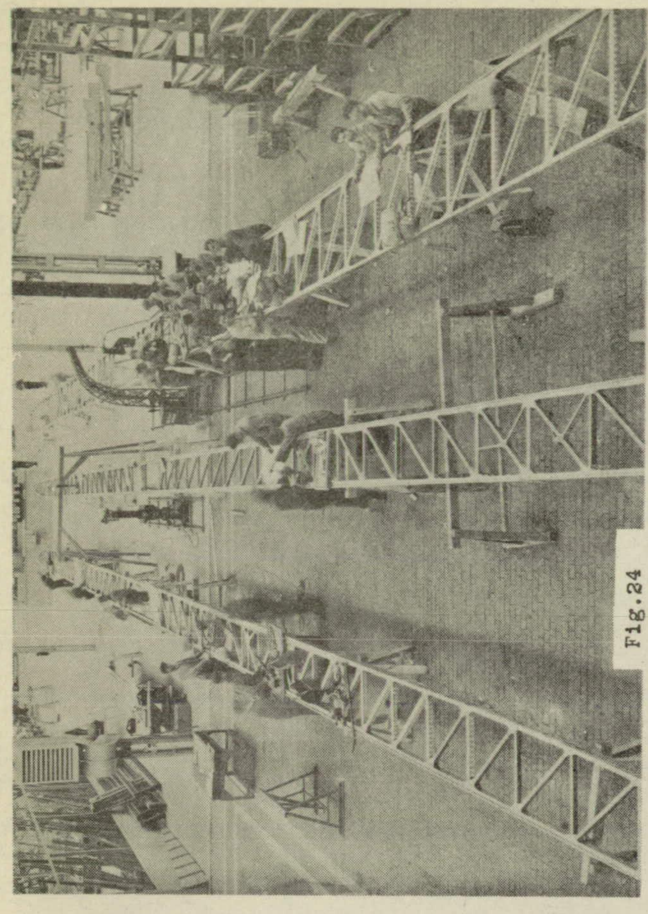


Fig.24

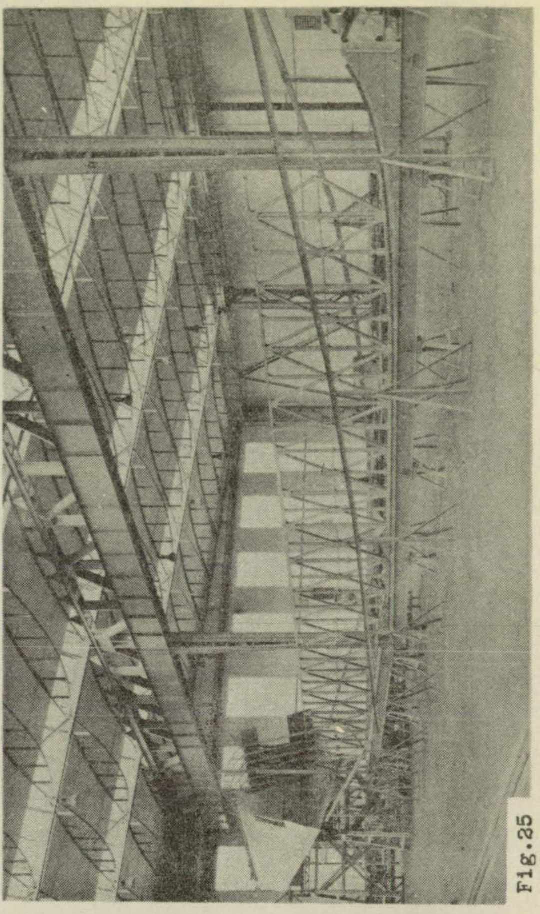


Fig.25

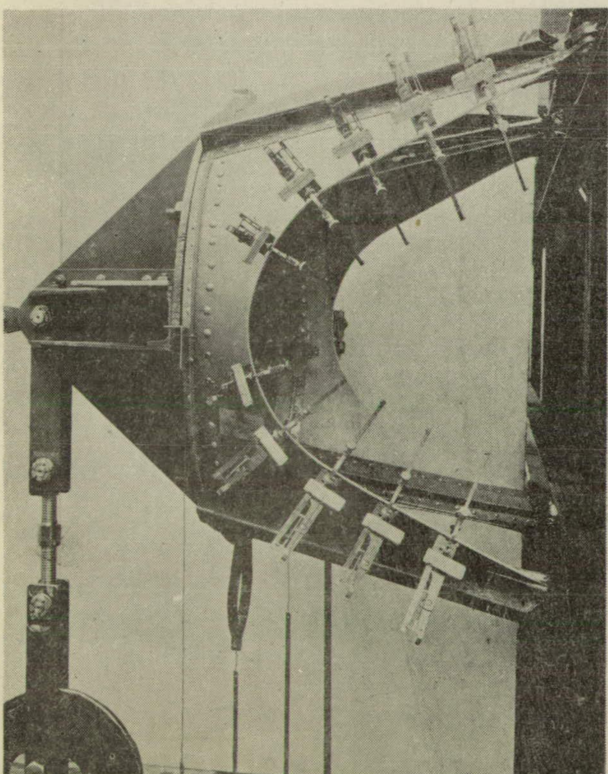


Fig.22

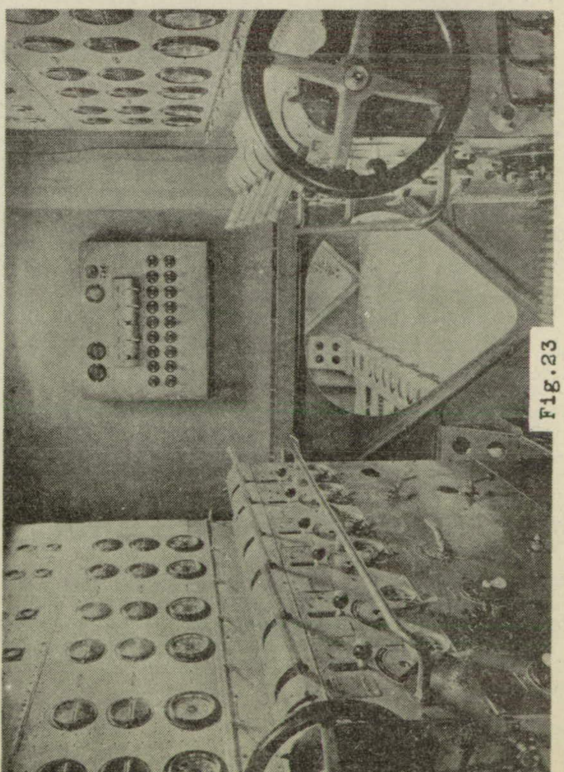


Fig.23

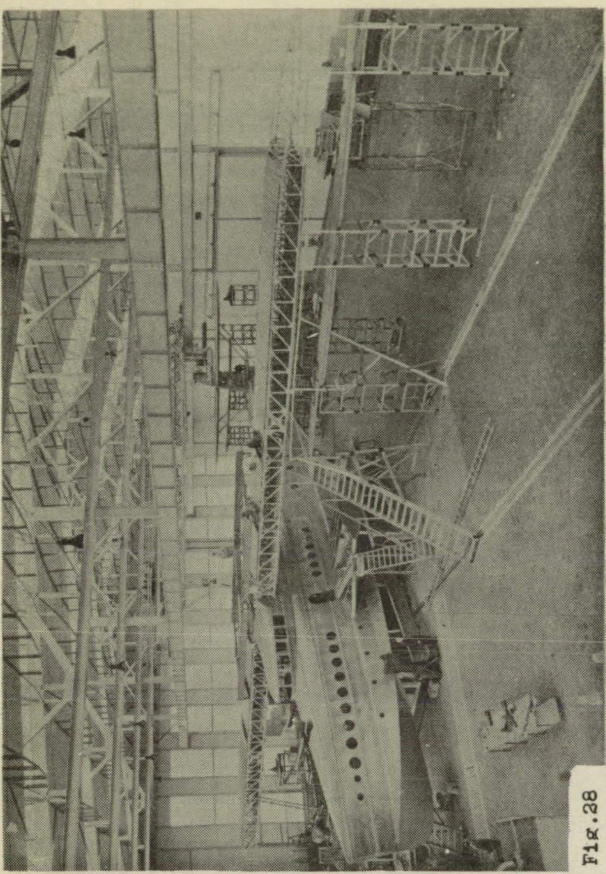


Fig.28

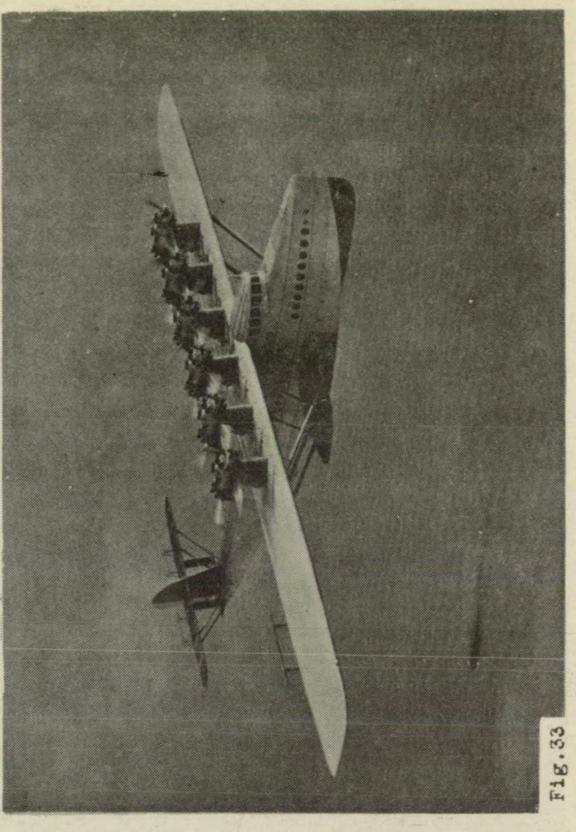


Fig.33

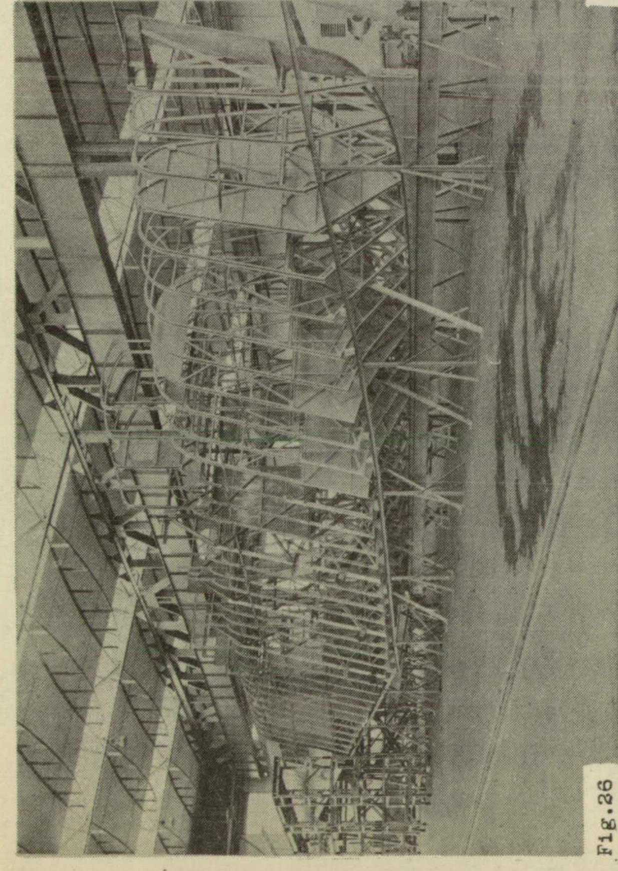


Fig.26

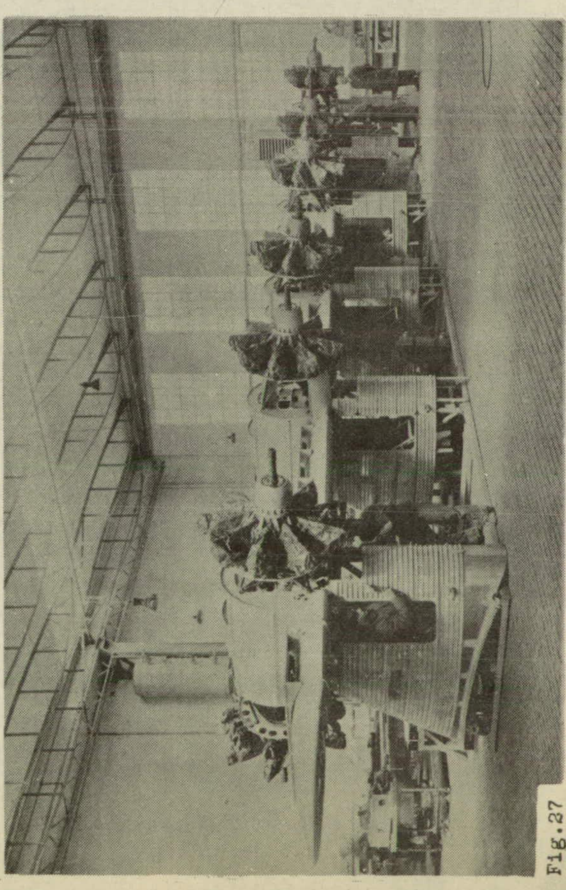


Fig.27

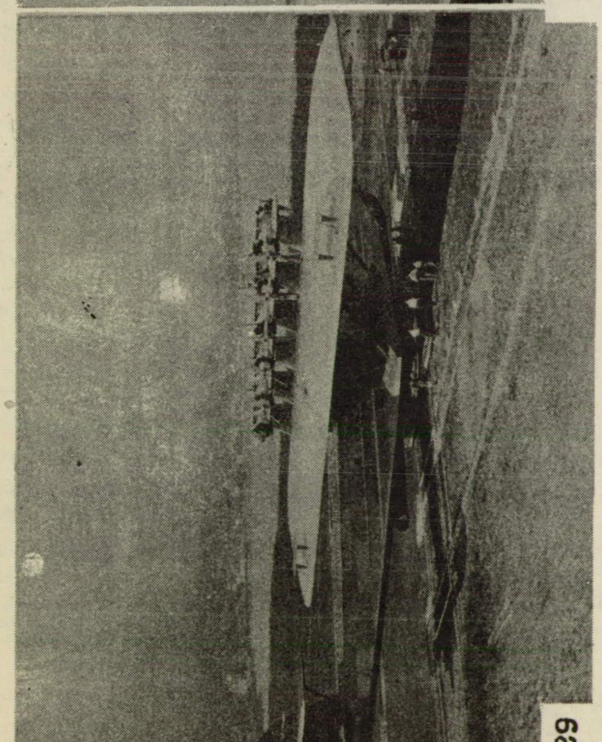


Fig.29

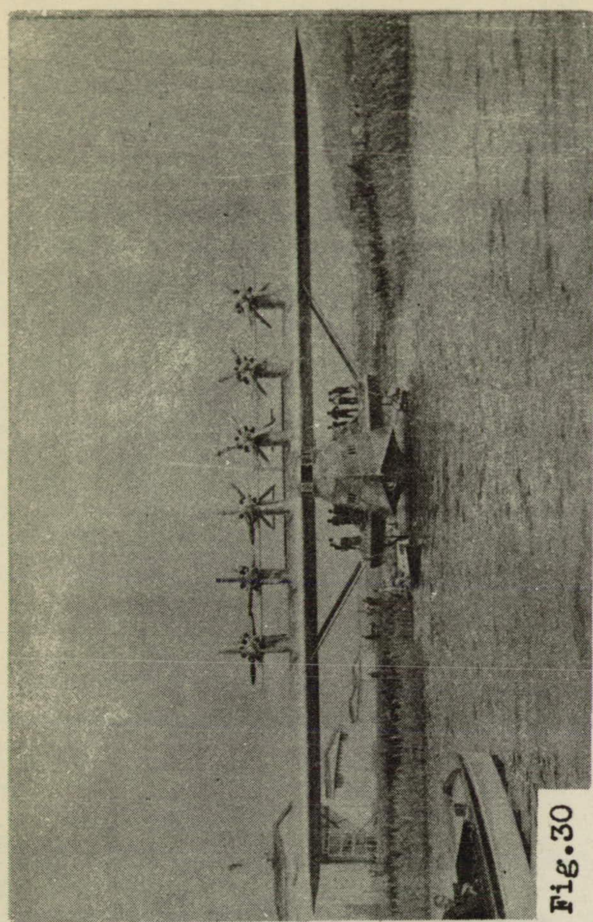


Fig.30

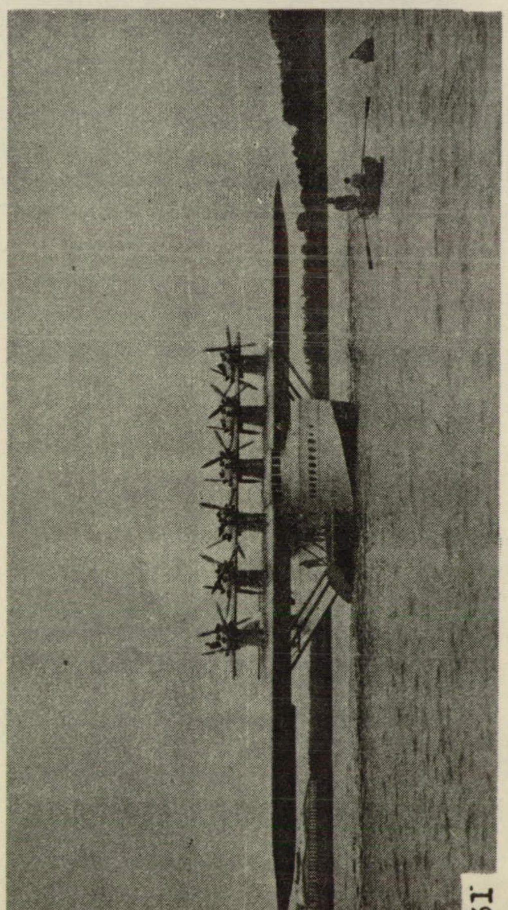


Fig.31

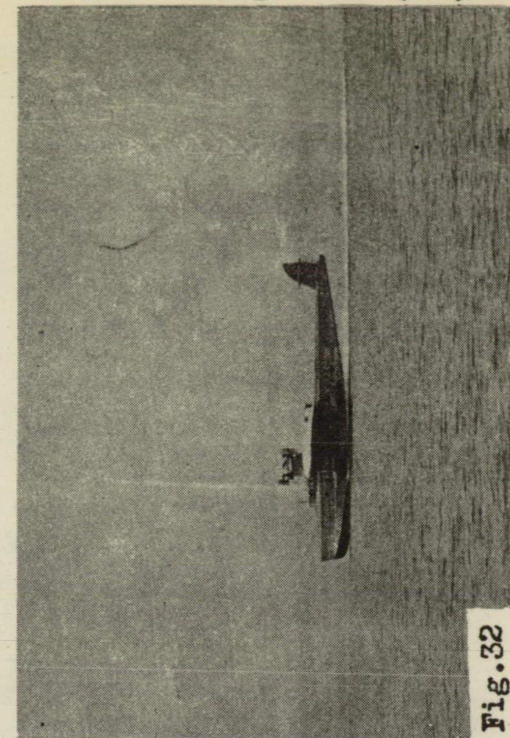


Fig.32