AIRCRAFT CIRCULARS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 185

THE DEWOITINE D.332 COMMERCIAL AIRPLANE (FRENCH)

A Three-Engine All-Metal Low-Wing Monoplane

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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THE DEWOITINE D.332 COMMERCIAL AIRPLANE (FRENCH)*

A Three-Engine All-Metal Low-Wing Monoplane

By Maurice Victor

INTRODUCTION

The Dewoitine D.332, which Doret has just finished and which is making its official performances at the Service Technique, was derived from the long-distance airplane D 33 "Trait-d'Union", present holder of the world's speed record for 10,000 km (6,214 miles) with a mean of 150 km/h (93.2 mi./hr.). The aerodynamic characteristics of the wing and the general form are nearly the same. There were simply added two lateral engines; the landing gear was modified; and the fuselage was enlarged so as to provide for a comfortable cabin. The construction is like that of the "Trait-d'Union": a monospar wing with stressed leading edge and a semimonocoque fuselage.

Dewoitine and his engineer Vautier have produced an airplane which appears to be one of our best commercial airplanes. It may even be claimed that the performances of this airplane equal those accorded (perhaps too generously) to American airplanes. We do not know whether ("everything else being equal" from the viewpoints of safety and comfort) the disposition of the engines and of the pilots' cabin does not tip the scales in favor of Dewoitine, which will certainly be the case within a few months, when the second D.332 will make its tests. This airplane will have a retractable landing gear which will effect a net gain of 30 to 40 km (19 to 25 miles) per hour over the maximum speed with the conventional landing gear. The D.332 will then make 340 km (211 miles) per hour with a range of 2,000 km (1,243 miles).

This airplane has been ordered by the Air-Orient for use on the France - Indo-China line. It is interesting to

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*From Les Ailes, September 7, 1933.

compare the performances required by the contract, those entailing rejection, and those actually realized.

Flight with either engine stopped.- Ceiling required, 2,500 m (8,200 ft.); entailing rejection, 2,250 m (7,380 ft.); realized, 3,500 m (11,480 ft.).

Cruising speed with 55 percent of the power.- Required, 220 km/h (136.7 mi./hr.); rejection, 212 km/h (131.7 mi./hr.); realized, 250 km/h (155.3 mi./hr.).

The above performances were attained with a load exceeding the stipulated load by 100 kg (220 lb.).

For comparison, the cruising speed of the D.332, attained according to the rules of the S.T.Aé., that is, with 80 percent of the power, reached 280 km/h (174 mi./hr.).

The controllability is very good. From the viewpoint of safety, it may be stated that quite recently Doret flew horizontally for an hour with this airplane with the right-hand engine stopped, followed by a similar flight for an hour with the left-hand engine stopped.

DESCRIPTION

Wing

Low monoplane wing of large aspect ratio and tapering plan form with nearly elliptical tips. With an aspect ratio of 8.8, the fineness ratio (L/D) reaches 26.5. Normal lift; very small drag. Fineness ratio of whole airplane, 15. This ratio is practically uniform throughout a large range of angles of attack. Wing sections very carefully designed to improve the efficiency and reduce the torsion to a minimum. Chord at the fuselage, 4.5 m (14.76 ft.); at tip, 2.25 m (7.38 ft.); thickness at fuselage, 0.7 m (2.3 ft.); at tip, 0.15 m (0.49 ft.).

Construction.- Monospar with stressed leading edge. The tips of the ribs form a box which also increases the strength. The spar is divided into six sections in addition to the central section, which is integral with the fuselage and terminates at the sides of the latter. Each half-wing therefore consists of three sections in the direction of the span. The leading and trailing edges are divided in the same way.

The spar, located at one third of the chord from the front, has wide duralumin flanges with a maximum thickness of 3 cm (1.18 in.), both the width and the thickness diminishing along the span according to the variation in the bending moments. Box uprights forming braces; oblique bars reinforced by "omegas." The flanges are joined at different points by special steel and duralumin fittings. Such a joint transmits stresses of the order of 100,000 kg (220,460 lb.).

The leading edge consists of box formers with longitudinal stringers and an auxiliary spar at the extreme front. It is covered by "vedal" (dural protected by a layer of pure aluminum). It is joined to the main spar by continuous hinges with piano-wire hinge pins.

The trailing edge is similarly constructed. It terminates at the rear in an auxiliary spar, to which are hinged the ailerons and the fixed central portions of the trailing edge. The thickness of the covering varies according to the stresses, but is never less than 0.5 mm (0.02 in.).

Each aileron is divided into three parts, in order to permit deformations of the wing without being too hard on the controls. The latter are rigid and consist of three horns and three rods on the top of the wing.

Fuselage

This has a maximum section 1.7 m (5.58 ft.) wide and 2 m (6.56 ft.) high. It is divided into three separable parts. Forward, the control cabin and radio station; baggage compartment of 0.7 m³ (24.72 cu.ft.) under oil tank of central engine. Immediately following and aft of the wing spar is the central part with the passenger cabin and lavatories. Its length is about 6.5 m (21.3 ft.). At the rear end of the fuselage, a baggage compartment of 2 m³ (70.6 cu.ft.) with entrance door on the right, a door communicating with the lavatories, and a door in the rear wall for inspecting the controls.

The location of the wing spar between the control cabin and passenger cabin makes it possible to give the latter the whole height of the fuselage.

Construction.- Semimonocoque type; four main longerons, longitudinal stringers, bulkheads, and intermediate transverse frames; vedal covering. In the vicinity of the cabin, the whole structure is concealed by a covering of plywood. The top is slightly rounded. In order not to obstruct the view, the diagonal bracing consists of small round wires. There are two rows of four comfortable chairs with adjustable backs, transformable into reclining chairs or even into couches. Each passenger has a small folding table and separate ventilation.

Control cabin.- The cabin for the crew is separated from the passenger cabin by a partition forming an upward extension of the main wing spar. The covering of the leading edge being eliminated, the radio (both sending and receiving) and, on occasion, also the mechanic, can sit on the wing spar. In front: two seats abreast for the pilots with dual control; wheel for operating the ailerons, chain transmission; central board with fuel controls. The three engines can be operated independently, or simultaneously, by means of a clutch, by the throttle lever of the central engine. On the left, a small wheel for operating the Flettner servo-rudder; on the right, heat regulator; in the center, auxiliary brake control lever (oil), the normal control being by air, by means of a small lever on the wheel. In addition to the ordinary instruments, there is a gyrorector, two flight controls, a precision altimeter, a drift meter, and a barograph. The whole roof of the control cabin can be quickly removed to facilitate exit. A door communicates with the passenger cabin. Electric installation for night flying; landing searchlight retractable into the bottom of the fuselage.

Control surfaces.- Conventional tail surfaces of normal aspect ratio. Fin hinged to sternpost; stabilizer adjustable in flight by means of screws at the points of attachment of the rear bracing struts, the forward struts being fixed. No elevator compensation. The Flettner servo-rudder automatically compensates ordinary stresses. By its regulation it is possible to counterbalance the dissymmetrical stresses due to the stopping of one of the lateral engines. Metal spars and ribs with vedal covering.

Power Plant

The engines are of the Hispano-Suiza 9 V radial air-cooled type with nine cylinders of 155.6 mm (6.13 in.) bore, 174.7 mm (6.88 in.) stroke, and 29.18 liters (1,780.7 cu.in.) piston displacement. Compression ratio, 5.3; rated power, 575 hp. at 1,900 r.p.m.; 650 hp. power equivalent; three Hispano-Solex carburetors; two Scintilla magnetos. Weight empty, 390 kg (860 lb.); length 1.23 m (4 ft.); diameter with N.A.C.A. cowling, 1.4 m (4.6 ft.). Engine bearers of chrome-nickel tubing with large ribs reinforcing the welded joints; mounted on "silent-blocks." Rigid controls; Viet starter; Levy fire extinguishers; "stop-fire" hand extinguishers in passenger cabin. Circular exhaust manifold with exhaust pipe on the right-hand side. Two-blade Levasseur propellers rotating to the right. Three fuel tanks with a total capacity of 3,200 liters (845 gallons). Those for the lateral engines are installed behind the main spar; the one for the central engine, in front of the control cabin. Fuel drained by gravity by tube extending behind wing. There is no quick-dumping device, due to danger from the fuel vapors. Three oil tanks, each holding 85 liters (22.5 gallons) are installed behind the fire wall.

Landing Gear

Wide track of 6.6 m (21.65 ft.) with independent wheels having tires 1,630 by 365 mm (64.17 by 14.37 in.). Under each engine nacelle there is an elektron fork hinged to the lower flange of the wing spar. This fork guides two Messier oil brakes balanced and terminated by two bearings on which is mounted the axle for the wheel. A rod joins the engine bearer to the end of this fork in order to absorb the recoil. The whole is enclosed in a fairing. Maximum width, 0.7 m (2.3 ft.); height, 1.1 m (3.6 ft.).

The second airplane, now under construction, will have a retractable landing gear. The same device will be retained for accomplishing this result, but the point of articulation of the fork will be slightly advanced, so that the wheel, when retracted, will embed itself in the wing and engine cowling.

The tail wheel has an oleo-pneumatic shock absorber and a swiveling fork.

CHARACTERISTICS

Dimensions:				
Span	29.00	m	95.14	ft.
Length	18.95	"	62.17	"
Height	5.45	"	17.88	"
Wing area	96	m^2	1,033.33	sq.ft.
Aspect ratio	8.8			
Weights:				
Airplane without power plant	3,170	kg	6,988.65	lb.
Engines	1,740	"	3,836.04	"
Cabin equipment	360	"	793.66	"
Airplane empty	5,270	"	11,618.35	"
Fuel	2,020	"	4,453.33	"
Oil	180	"	396.83	"
Radio, goniometer, and electric equipment	175	"	385.81	"
Instruments	40	"	88.18	"
Tools	80	"	176.37	"
Camping outfit	50	"	110.23	"
Food and drugs	20	"	44.09	"
Water supply	35	"	77.16	"
Crew	270	"	595.25	"
Passengers	800	"	1,763.70	"
Freight	400	"	881.85	"

Weights (contd.):

Useful load	4,070	kg	8,972.80	lb.
Total weight	9,340	"	20,591.15	"

Performances:

Maximum speed	300	km/h	186	mi./hr.
Cruising speed (at 55% of normal power)	250	"	155	"
Landing speed, full load	100	"	62	"
Climb to 3,000 m (9,843 ft.)			11 min. 20 sec.	
Climb to 4,000 m (13,123 ft.)			17 " 30 "	
Climb to 5,000 m (16,404 ft.)			25 " 40 "	
Climb to 6,000 m (19,685 ft.)			41 " 0 "	
Theoretical ceiling	6,500	m	21,325	ft.
Range	2,000	km	1,243	miles
Ceiling with one engine stopped	3,500	"	11,483	ft.
Speed with one engine stopped	220	km/h	136.7	mi./hr.
Fuel consumption per hp./hr.	0.235	kg	0.518	lb.
Oil consumption per hp./hr.	0.0065	"	0.0143	"

LEGENDS AND DESCRIPTION OF ILLUSTRATIONS*

FIGURE 1.-General assembly drawing and characteristics of the D.332. The wing is in six parts, numbered from 2 to 7. The seventh part (1) is integral with the fuselage. F, false spar. The two dot-hatched trapezoids are the two lateral fuel tanks, near which are the luggage holds. Span, 29 m (95.14 ft.); length, 18.95 m (62.17 ft.); height, 5.45 m (17.88 ft.); wing area, 96 m^2 (1,033.33 sq.ft.).

FIGURE 2.-Front view of the D.332 in flight.

FIGURE 3.-Front view of the D.332 airplane.

FIGURE 4.-Three-quarter view of the Dewoitine D.332 in flight.

FIGURE 5.-Cabin, looking aft. Note the very long windows. The over-all dimensions of the cabin are: length, 5.9 m (19.36 ft.); width, 1.5 m (4.92 ft.); height, in center, 1.95 m (6.4 ft.) forward and 1.75 m (5.74 ft.) aft. The cabin is designed for 8 passengers. A sliding window of Triplex glass 5 mm (0.2 in.) thick is beside each seat. The windows have a minimum height of 0.4 m (1.31 ft.) and a length of 0.6 m (2.0 ft.). The airplane has two emergency exit panels, one of which is an upper trapdoor giving access to the pilot's compartment. The equipment was specially designed for comfort on account of the length of the flights, some of which are made by night.

FIGURE 6.-Close-up three-quarter front view of the D.332.

FIGURE 7.-Characteristic polars of the D.332, obtained in wind tunnel. Left: polars of wing-tip section. Right: polars of wing alone (continuous lines) and of complete airplane (dotted lines).

FIGURE 8.-The structure of the cabin near the front bulkhead. As usual, the structure consists of box frames and stringers. Instead of using thick bulkheads at short intervals to eliminate bracing, a solution which does not allow of very wide windows, it was thought preferable to place as thin bulkheads as possible far apart from each other, so as to make provision for long bays. Bracing wires, which are then indispensable, are used in great number.

*From L'Aéronautique, October 1933, pp. 219-226, except figures 3 and 6, which were taken from manufacturer's catalog.

FIGURE 9.-A ventilation panel. Some of these panels have negative, others positive, pressure to maintain air circulation in the cabin.

FIGURE 10.-The welded steel-tube armchairs have tilting backs, adjustable headrests, and extensible foot rests.

FIGURE 11.-Interior view of the leading edge of the wing. The leading edge is stiffened internally by a semicircular section and externally by a profile strip. The ribs are cross-braced, which increases the strength of the structure.

Hinges for connection with another wing portion are provided along the outline of the cross section and a fork joint at the tip of the leading edge. These plates serve as a covering only, the main stress being taken by the fork joint.

FIGURE 12.-Wing structure near the point of attachment to the center portion. The covering is secured to the spar by hinges. The hinge element, on which are mounted the box members of the leading and trailing edges, is always secured to the spar by "Parker" screws. Below is shown a detail of intersection of longitudinal stringers with the rib flanges and connection of the latter, by gusset plates, with the bracing tubes.

FIGURE 13.-Portion of the horizontal tail surfaces. Each elevator is controlled at the center of its span. The attachment points of the joint connecting the hinge axes are shown in the figure.

FIGURE 14.-Landing-gear unit. The connection points, numbered 1, 2, and 3 are shown again in the partly cut-out general assembly drawing of the landing gear and engine bearer.

FIGURE 15.- Diagrammatic drawing of the Messier brake system of the D.332. Legend: ——— stiff 3/5 tubes; ——— stiff 5/7 tubes; - - - - - flexible pipes. The fork-type Messier landing gear of the D.332 has a rigid frame secured to the airplane by forks, the gear sliding into this frame. The telescopic unit which carries the wheel is connected with the rigid unit by two Messier shock-absorbing struts working in simple compression. The landing bending stresses are completely absorbed by the telescopic rods. The rigid frame has two special steel tubes

(t) enclosed in a magnesium-alloy sleeve. At the lower end of the two tubes are brass slide bars and a loop for attachment of the bracing tube T. At the upper end are connections with the airplane structure. The movable unit has an axle carrying the wheel, two slide bars t' and components connecting the axle to the two slide bars. The landing gear is in contact with the wing attachment fittings I through the intermediary of spherical bearings, on the one hand, and on the other, with the axle attachment fittings. Compression stresses are thus directly transmitted by the wheel to the landing gear, which transfers them to the wing structure. The great stiffness of the whole unit results in perfect guiding and sliding in all landing positions. The finger (p) supports the rear fairing, and the tube (c) permits balancing the pressures between the two shock absorbers. The D.332 is equipped with disk wheels mounted on roller bearings. The Messier brakes, with drums having a diameter of 60 cm (23.6 in.) are operated by a hydraulic pump system such as used on all heavy-load carriers. The control unit comprises the well-known Messier brake equalizer. By means of a pneumatic transmission, operated from the control wheel, a very gradual braking action is exerted without any effort by the pilot. V, wheel; L, control lever of distribution valve S; arrow A, compressed air intake (Viet compressor); D, expansion chamber; P, rod connecting with rudder bar; R, equalizer; H and H', hydraulic pumps; A and A', feeders; r and r', pressure tanks; M, manometer. F is an emergency brake operated by hand and working without equalizer. F operates the oil pump p, which delivers oil to the intermediate unit J, directly connected with the wheel piping, without passing through the pumps.

FIGURE 16.-Left: method of securing the covering of the leading edge. The metal strips are arranged longitudinally. Center: connection of two spar sections by fork joints. Right: trailing-edge box.

FIGURE 17.-Landing-gear fairing of the Dewoitine 332. The top and center drawing illustrates the assembly of three main elements of a wheel fairing. The small door permits easy inspection of the rear portion of the box which is readily accessible and is intended to house the mechanics' tools.

The drawings below, grouped around the general assembly drawing of the landing gear-engine assembly, represent the dismantled elements of the fairing and of the landing-gear bracing.

The general-assembly drawing includes the following items: 1, 2 and 3, joints; A, B, C and D, demountable elements; xx, yy and zz, designate the lines of assembly of these elements by hinges (o, intersection of xx with yy). These references recur in the detailed drawings. There are two fairings, A.

The forward portion (C) comprises two parts connected along zz. After removing the piano wire zz, each of these parts can be pivoted about its axis xx, thus completely exposing the wheel.

FIGURE 18.-Weight distribution of the D.332. This type of document is given to us for the first time. In addition to the actual value of a very detailed load specification, it is interesting to emphasize the unusually small displacement of the c.g., from its initial position G_1, at the beginning of the flight, to the final position (G) at the end of the journey. It is also interesting to note the position of the centers of gravity of the individual parts, numbered from 1 to 25. The weights are given in kilograms. The axes Ox and Oy are measured in meters.

1. Propeller, 57 kg (kg × 2.20462 = lb.);
2. Center engine + oil + N.A.C.A. cowling: 427.57 + 6 + 12.8 = 446.37 kg;
3. Engine bearer, cowling, and exhaust, 44.6 kg;
4. Oil tank: 8.07 + 60 = 68.07 kg;
5. Freight in forward hold, 140 kg;
6. Central tank + fuel: 42.1 + 660= 702.1 kg;
7. Two propellers, 114 kg;
8. Two engines + oil + N.A.C.A. cowling: 844.64 + 12 + 25.6 = 882.24 kg;
9. Instruments and electrical equipment: 38.6 + 40 = 78.6 kg;
10. Engine bearers, cowlings, and exhaust pipes, 137.07 kg;
11. Two oil tanks + oil: 15.59 + 120 = 135.59 kg;
12. Crew, 270 kg;
13. Starter, accessories and fuel pipes, 171.44 kg;
14. Radio, 135.9 kg;
15. Landing gear and fairings, 619.7 kg;
16. Complete wing, 1,377 kg;
17. Tools and mooring equipment, 130 kg;
18. Freight in the wing compartments, 370 kg;
19. Fuel, 1,360 kg;
20. Fuselage and controls + equipment: 865.75 + 365.84 = 1,231.59 kg;

21. Passengers and provisions, 696.1 kg;
22. Freight in the rear hold, 50 kg;
23. Horizontal tail surfaces, 85.8 kg;
24. Vertical tail surfaces, 27.45 kg;
25. Tail wheel and support, 25.38 kg.

The total weight of the fully loaded airplane is 9,356 kg (20,626 lb.), 8,856 kg (19,524 lb.) on the wheels and 500 kg (1,102 lb.) on the tail skid in the position of flight, against 8,667 kg (19,107 lb.) and 689 kg (1,519 lb.), respectively, with the tail on the ground. At the end of the flight, when the airplane is empty of all consumable and dumpable load, it weighs only 7,156 kg (15,776 lb.). Yet the position of the c.g. changes only from 34 percent of the wing chord at the beginning of the flight, to 37 percent at the end. Practically, this is not felt at the pilot's post and the stabilizer does not need to be adjusted.

A striking example illustrates the excellent stability of this airplane. On the return from Russia, the passengers left the airplane at the Bourget airport, and the D.332 started on a new flight with only Messrs. Doret, Vautier, and two mechanics. The cabin was empty, but the front hold was overloaded with luggage. Irrespective of this fact, no adjustment of the stabilizer was required and the stick forces scarcely varied, according to Mr. Doret.

FIGURE 19.-Fuselage arrangement. The fuselage is in three sections, their connecting points being represented by black dots. The front section carries, at R, the oil tank of the forward engine. Below this tank is a luggage hold S, of 0.7 m^3 (24.72 cu.ft.). Next comes the pilots' compartment, with dual controls and the radio compartment (crew of four). The center section (6 m by 1.5 m by 1.75 m) (19.7 by 4.9 by 5.7 ft.) is given up entirely to the passengers. For long flights it has 8 comfortable chairs which may be extended. The rear portion has a luggage hold S' of 2 m^3.

FIGURE 20.-Attachment fittings of the right engine bearer to the leading edge of the wing (fuselage side). There is shown the leading edge stiffening plate and the welded steel fitting for the joint. The support of the fairing is on top.

FIGURE 21.-Lower end of fully compressed shock-absorbing leg and wheel hub.

FIGURE 22.-Lower left joint of the left-engine bearer and lower right joint of the same bearer. The joint is shown in the same position as in the above general drawing. The engine bearer is of autogenously welded steel tubes.

FIGURE 23.-Top view, looking forward, a duralumin wheel fairing, the rear portion forming a luggage hold. Its bulkheads are shown in the drawing.

FIGURE 24.-Assembly of left landing gear and engine bearer seen from the rear. The fork is represented as completely compressed. The tube which passes diagonally through the wall of the fork box, connects the upper chambers of the shock absorber and balances the pressure in the two shock-absorbing legs.

FIGURE 25.-Fuel circulation. The total capacity of the three tanks is 3,200 liters (845.3 gallons). One of the tanks is located in the fuselage between the center engine and the pilots' cockpit. The other two are in the rear center portion of the wing. Due to the dihedral of the wing, the fuel flows regularly to the collector C, in the lower part of the fuselage. Through this collector, fuel may be supplied to any of the three engines from any tank, but under normal conditions the pumps of each group draw fuel from the corresponding tank.

Normal fuel circulation.- The circulation of the left engine only is described, the others being identical. The circulation system is very simple (double plain-line arrow). The fuel flows from the tank to the collector with flap valve c, from which it is drawn by the pumps. Cocks R and R' being closed, there is no connection with C and with the priming collector C_a.

Breakdown of engine-driven pumps, and priming.- When the left-hand engine breaks down, R and R' are opened and the circulation then takes place as shown by the dash-line arrows. The fuel, raised by the hand pump P_m, passes from the tank to C and is driven through R' to c. The valve of c closes down on its seat, thus preventing return of the fuel to the tank. From c the fuel is conveyed to the carburetors through the mechanical pumps.

Running two engines on the tank of a broken-down engine group.- Suppose the left-hand engine to be stopped. By opening the three cocks of type R, surrounding C, fuel may be supplied from the left tank to the center and right-hand engines. The power-driven pumps, which keep on running, then simultaneously draw fuel from their own tank and from the left tank through C.

In view of the fact that flight conditions with a three-engine airplane, always allow at least a few minutes to decide on and prepare for landing, the quick-emptying orifices and pipes were given small diameters. The dropping of great amounts of fuel may form dangerous explosive mists which must be avoided. On the other hand, the union of the three outlet pipes into one has proved extremely satisfactory for emptying on the ground or in hangars.

The list below permits the identification of the conventional signs of the drawing. P, the drain cock of C; p and p', air breathers of the tanks under slight pressure. When p and p' are obstructed, the pilot may, by opening r, put the tanks in contact with an auxiliary air intake in the fuselage, which cannot be blocked.

Identification List

Tank connections of distance gage.

Air intake pipes (10 by 12; collector of intakes p and p' 14 by 16).

Pressure tubing of gages.

Pressure balancing tubing of gages.

Fuel tubing 10 by 12.

Fuel tubing 12 by 14.

Fuel tubing 14 by 16 and 18 by 20 (14 by 16 for suction and compression of the hand pump and 18 by 20 between the tanks and collector C)

▒	Tubing 30 by 32	quick-emptying (dot hatching).
▒	Tubing 48 by 50	quick-emptying (dot hatching).
⊛	Cocks between pumps and carburetors.	
⊙	Tank outlet cocks.	
⊗	Cock (R) of collector C.	
⊗	Cock (R') of collector C_a.	
◎	Quick-emptying cock.	
⌶	Collector c with flap valve.	
⊘	Filling plugs.	
⊸	Tank breathers.	
⊸	Pressure-balancing vents (gages).	

Translation by
National Advisory Committee
for Aeronautics.

Span: 29.00 m 95.14 ft.
Length: 18.95 " 62.17 "
Height: 5.45 " 17.88 "

Wing area: 96 m^2 1033.33 sq.ft.

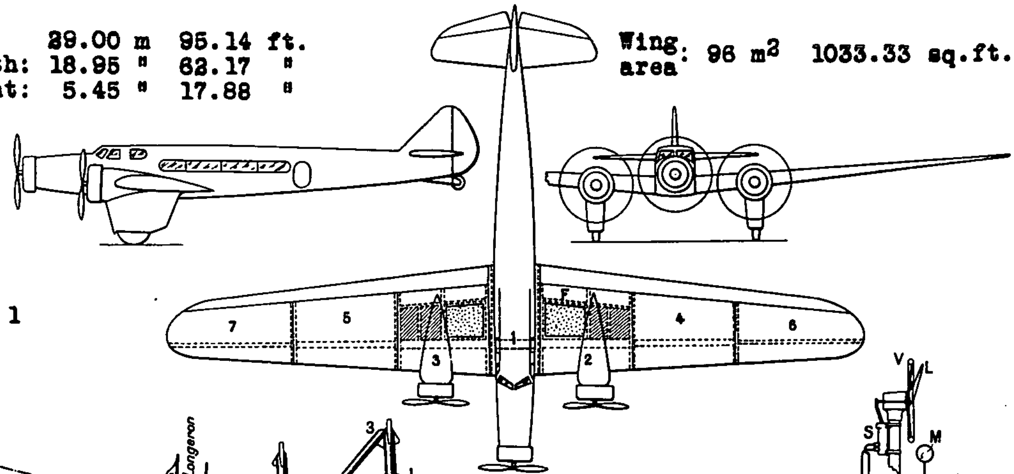


Figure 1

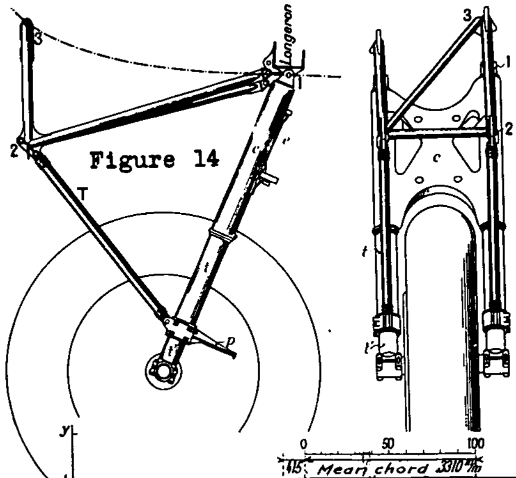


Figure 14

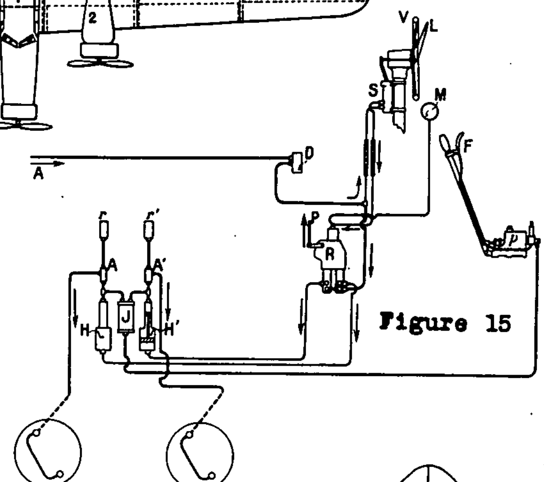


Figure 15

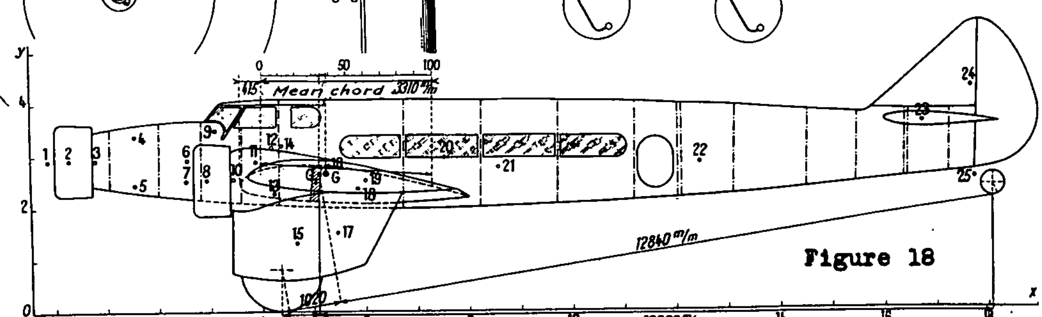


Figure 18

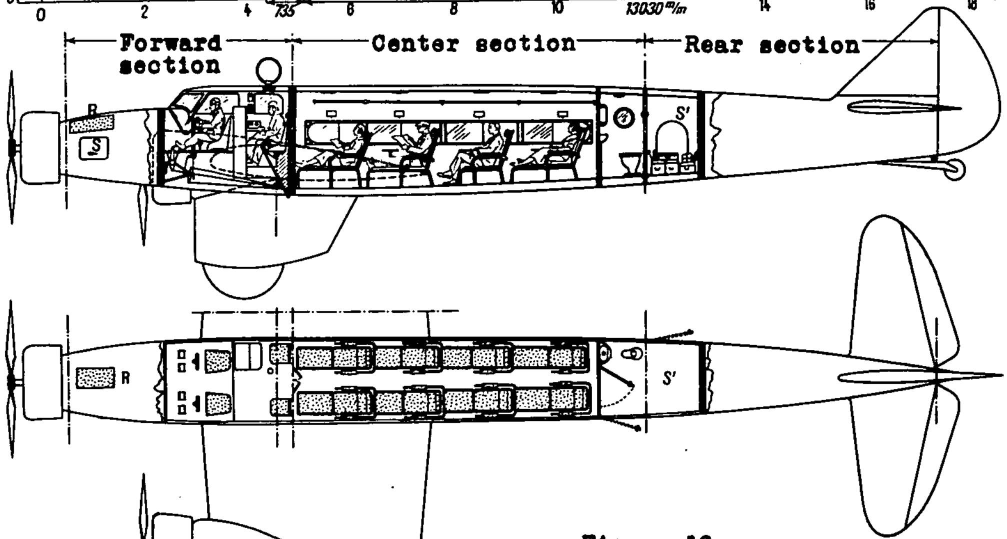


Figure 19

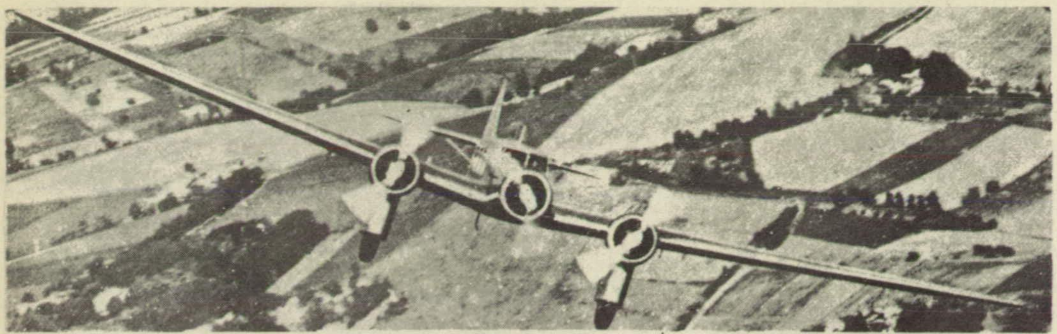


Figure 2

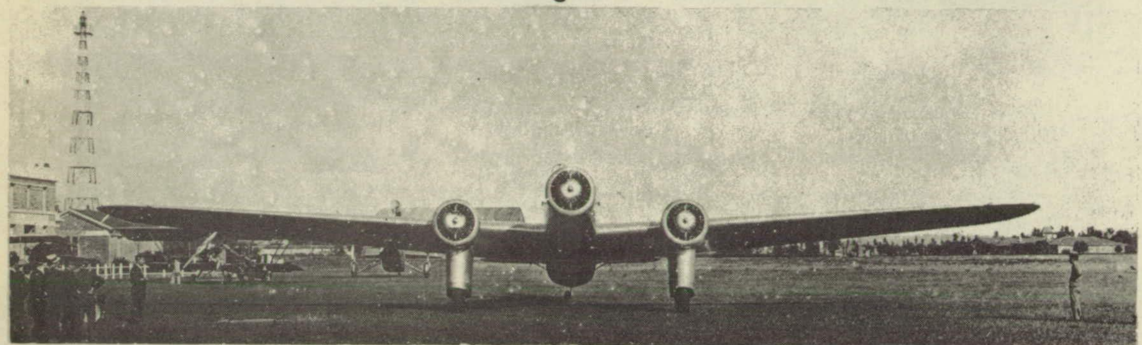


Figure 3

Figure 4

Figure 5

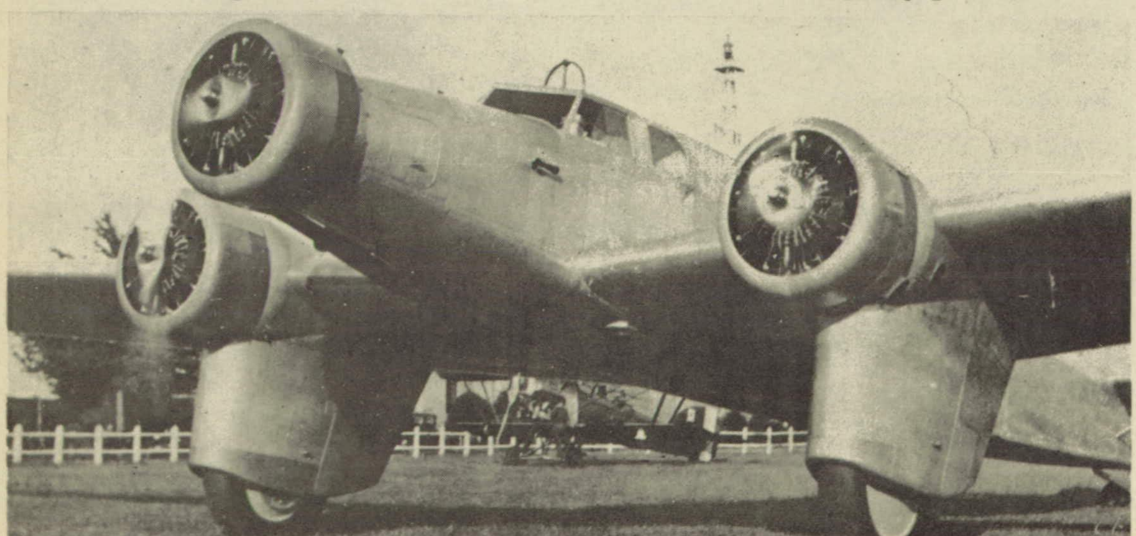


Figure 6

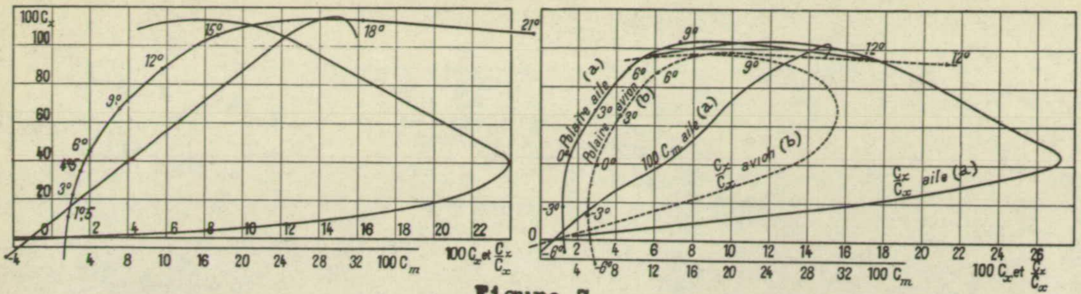


Figure 7
(a) Wing
(b) Airplane

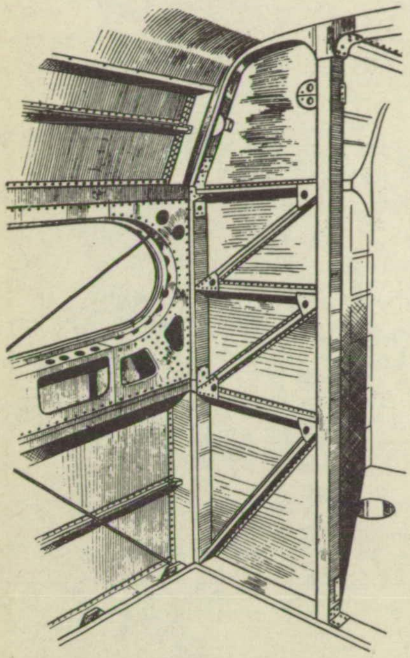
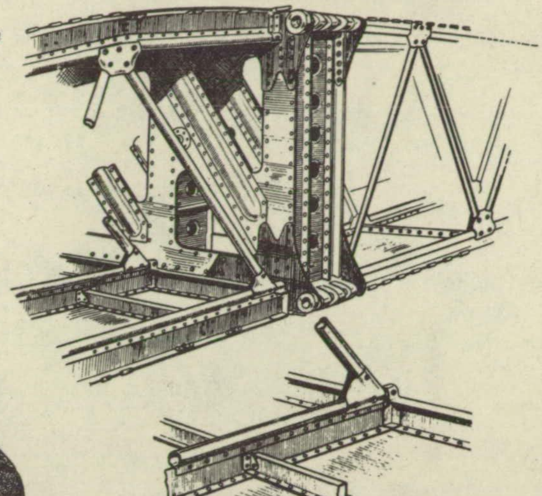


Figure 8



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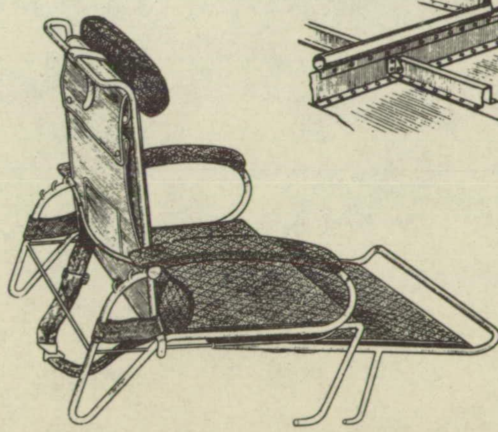

Figure 10

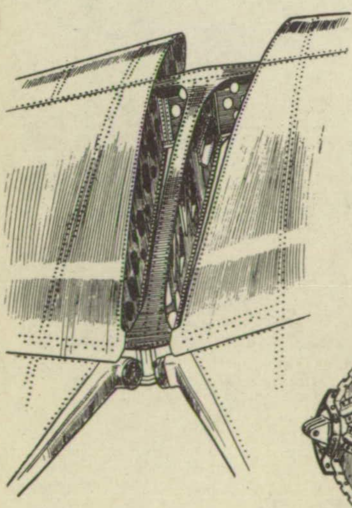

Figure 13

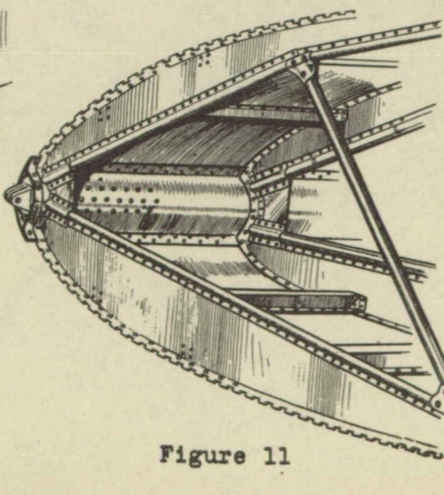

Figure 11

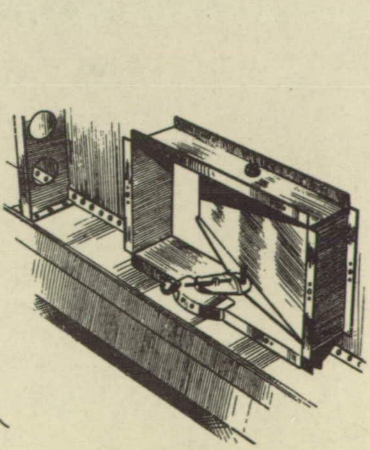

Figure 9

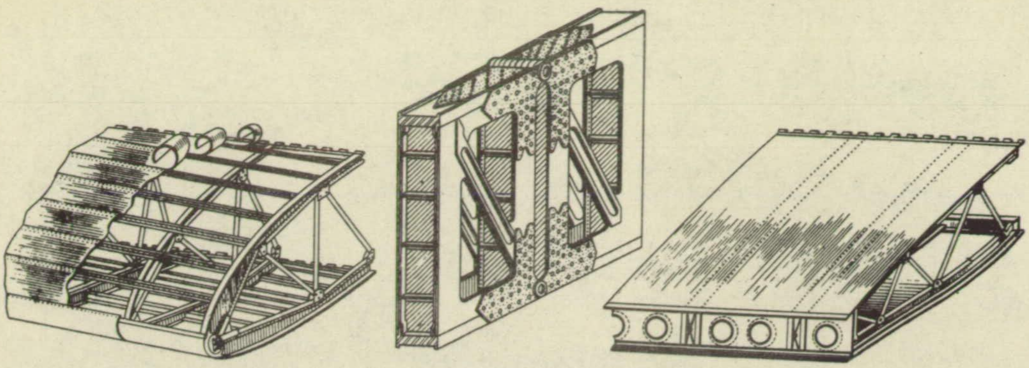

Figure 16

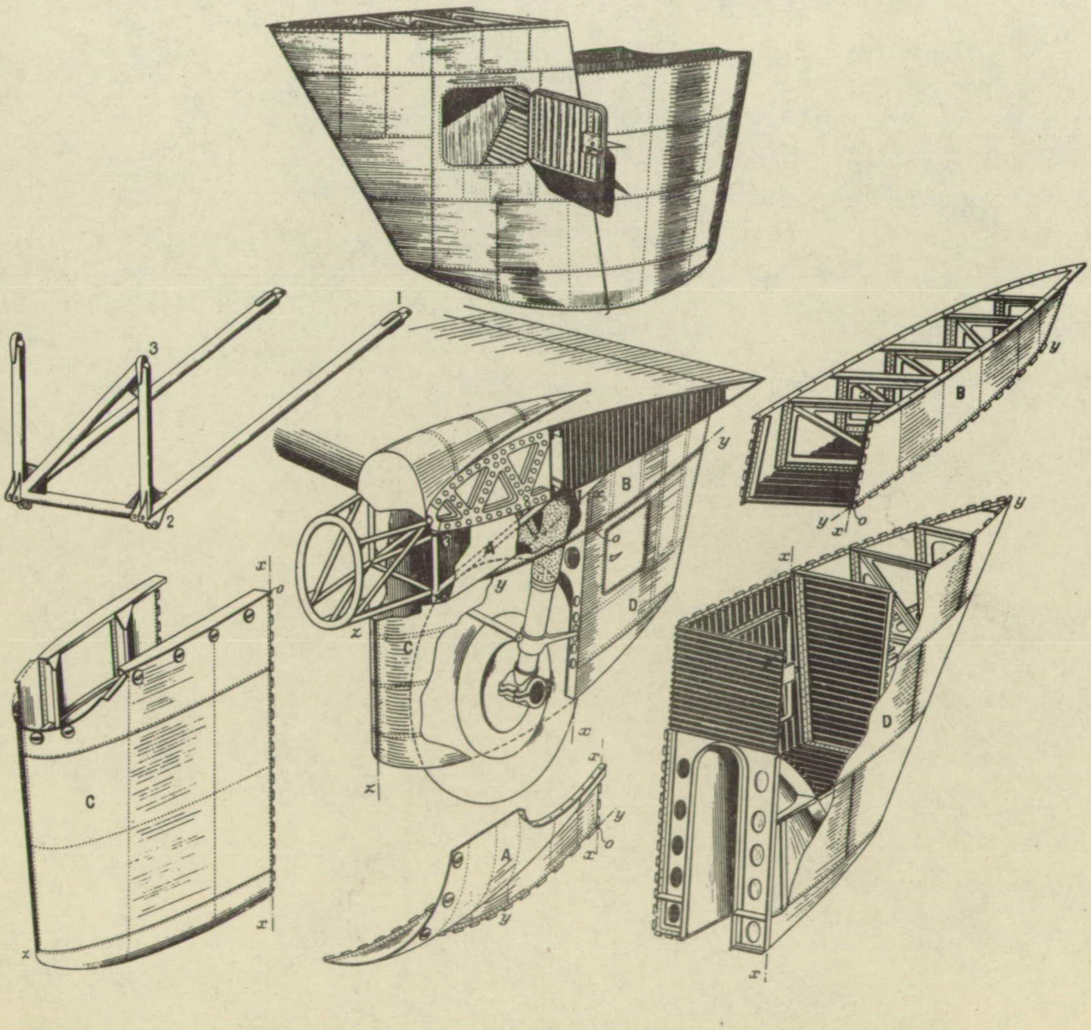

Figure 17

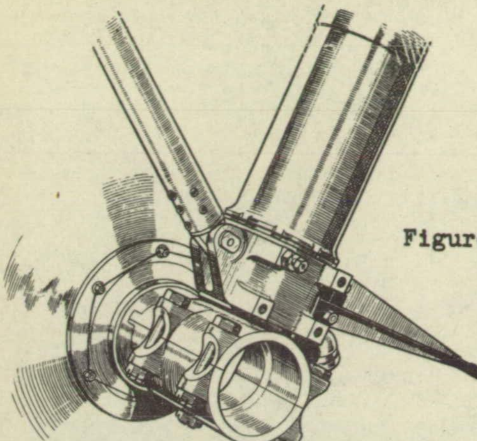

Figure 21

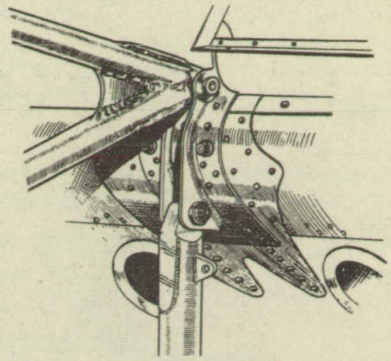

Figure 20

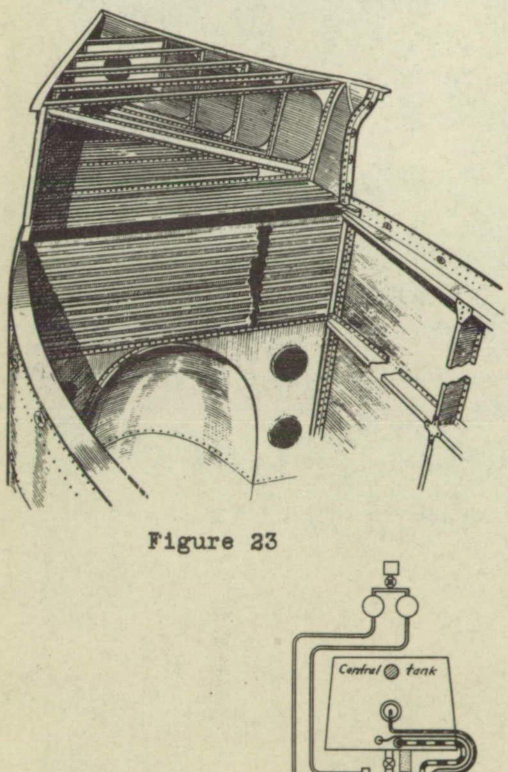

Figure 23

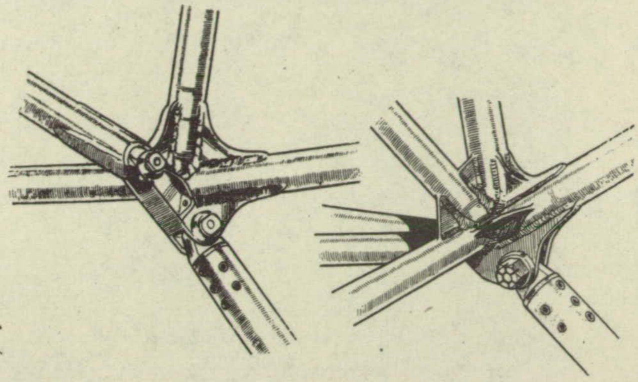

Figure 22

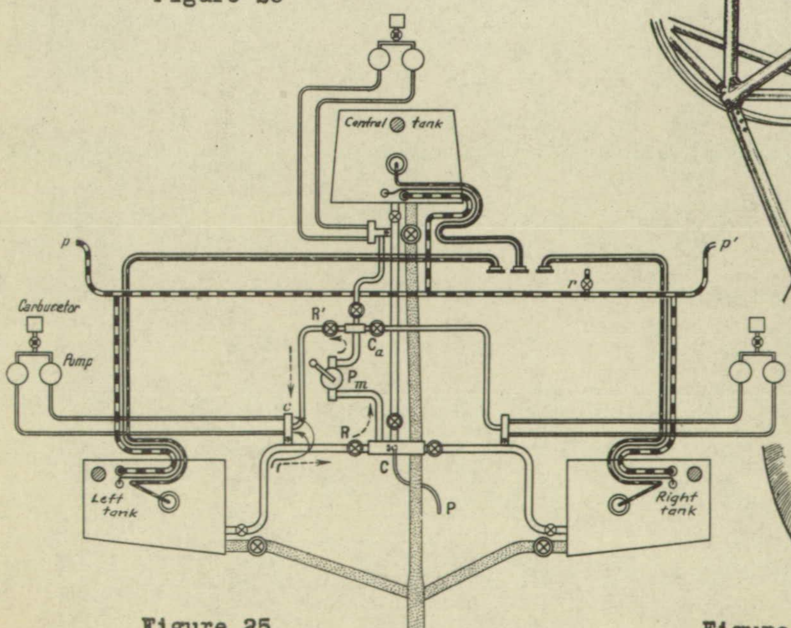

Figure 25

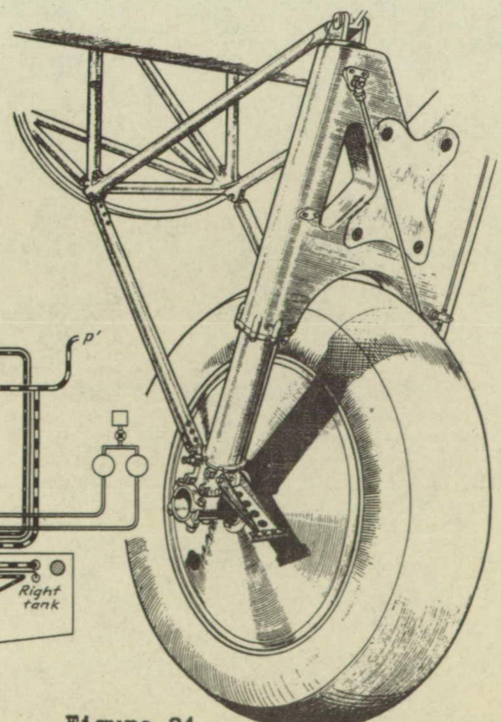

Figure 24