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RICHARD-PENHOET COMMERCIAL SEAPLANE

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Historical Sketch

The writer evolved the general design of this seaplane in 1920, after having completed the design of a three-engine seaplane for the Marseilles-Algiers line. While working on the latter, he was impressed with the idea that the future of commercial marine aviation would depend on the realization of powerful seaplanes capable of breasting the sea, and that it was important to devèlop the new type of flying boat so as to afford the maximum degree of safety both in the air and on the water.

At that time, when construction was just beginning to free itself from the empirical rules to which it had hitherto been subject, he resolved to tackle the problem in its most general theoretical form. He sought to discover at the outset the maximum performance carrying capacity and radius of action of a large seaplane.

In collaboration with his brother Maurice, he established the laws of similitude for airplanes, a work which is now classic and which was the subject of a communication by its authors to the first International Congress of Aerial Navigation, and of various published articles. These articles served as the basis

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for the calculations of the project. (See "Premier Congres International de la Navigation Aerienne," Paris, November, 1921, Volume I, pp. 24-32; also N.A.C.A. Technical Memorandum No. 118.) Although they do not always enable the accurate determination of the general characteristics, they have the advantage, however, of outlining the actual possibilities within quite narrow limits. We take the liberty of recalling here some very simple formulas which enable the solution of this problem:

$$\Pi = \Pi \left(1 - \frac{1}{1 + AS^{1/2}} + a\right) + r\, T_o + s + u$$

or,

Π = the total weight;

T_o = the total power;

r = the weight per horsepower of the engine and its supports;

S = the wing area;

s = the weight of the fuel carried;

u = the useful load;

A and a = the coefficients of construction which are constant for a given type of seaplane;

$d = \frac{\Pi}{S}\left(\frac{\Pi}{T_o}\right)^2$, the ceiling coefficient.

If we take into account the fact that, for a given ceiling, Π, S and T_o are bound by the expression

$$\Pi = d^{1/3} \quad S^{1/3} \quad T_o^{2/3},$$

we find that the maximum of S/Π (and hence the maximum radius of action) is attained when

$$T_o = 2\,\frac{u}{r} \quad \text{and} \quad S - \frac{3}{2\,A\,\psi}\,S^{5/6} + \frac{2}{A}\,S^{1/2} + \frac{1}{A^2} = 0$$

or,

$$\psi = \frac{3\,u}{d^{1/3}\;T_o^{\,2/3}}$$

which defines, for given d and u, the general characteristics of the seaplane having the maximum radius of action.

Description of Richard-Penhoët Seaplane

Type.- The R.P. seaplane is a multi-engine monoplane with a central hull and without external bracing. The trim of the seaplane on the water is assured by two wing floats, one on each side of the hull, 9 m (29.53 ft.) from its axis.

Wing.- This has an area of 270 m² (2906 sq.ft.), an aspect ratio of 6, and comprises three sections: a rectangular central section having a uniform cross section or profile and a span of 13.5 m (44.29 ft.), and two symmetrical trapezoidal sections with variable profiles, each section having a span of 13.125 m (43.06 ft.), the chords being, respectively, 9 m and 5 m (29.53 ft. and 16.4 ft.). It has a lateral dihedral with slopes of 0.095 to the horizontal. The profile was derived from the Eiffel 391 and is of diminishing thickness, 20% at the junction points, 12% at the tips.

The wing structure consists of longitudinal and transverse members. Among the former, there are the four patented main spars of the Vierendeel box-girder type. The spruce flanges, reinforced with high-resistance steel wires having a breaking strength of 180 kg/mm² (256,000 lb./sq.in.), are joined to the turned and glued upright reinforcing ribs of ash by webs of birch plywood reinforced externally and stiffened internally.

Among the latter, there are 22 main ribs composed of triangular girders of high-resistance steel with a breaking strength of 75 kg/mm² (106,675 lb./sq.in.), which join the spars solidly to each other and support the two false spars, the auxiliary spars and the ailerons. In the central wing section, eight of the main ribs are extended forward and terminated with a frame to which the engine supports are attached. The horizontal transverse bracing of the whole consists of two groups of high-resistance steel wires placed along the top and bottom of the wing.

The shape of the profile is given by I-shaped wood ribs with spruce flanges and openwork plywood webs supported in part by the spars and false spars and in part by the auxiliary spars distributed along the wing chord in such manner that the maximum intervals between the intermediate ribs are 0.75 m (2.46 ft.). The latter are covered in front with plywood 1.5 cm (0.59 in.) thick, judiciously stiffened in front, thus forming a light rigid leading edge.

The covering consists of doped and enameled fabric. In order, however, to reduce the cost of upkeep and the danger of fire, the front portions of the wing near the engines are covered with thin sheet duralumin ribbed and corrugated.

The whole trailing edge is terminated by the ailerons, consisting of triangular girders completely covered with plywood and hinged to the false wing spar in the vicinity of the main ribs by ball bearings.

Hull.- This has a length of 26 m (85.3 ft.), a maximum width of 3.8 m (12.47 ft.) and a height of 4 m (13.12 ft.). It has a single open and easily replaceable step, whose edge is 0.75 m (2.46 ft.) behind the center of gravity. Its double bottom consists of eight compartments separated from one another by water-tight partitions of special rubberized fabric.

Its simple lines were designed from both the hydrodynamic and aerodynamic viewpoints. Its trim on the water is 3° nose-up, which assures an easy and quick take-off. It is shaped like a boat as to bow and keel, and like a fuselage as to its upper and rear portions. The double-curved bottom has a decided V-shape culminating at the step.

It has a triple riveted covering of spruce, mahogany and teak, of variable thickness, 6 mm (0.236 in.), at the extreme front, 15 mm (5.91 in.) at the step, and 3 mm (0.118 in.) at the rear end. The bottom is made perfectly tight by interposing doped and varnished fabric between the different layers of wood.

Fifteen longitudinal glued and riveted ash strips transmit the stresses and shocks of alighting and taxying to the framework.

The uprights of the bulkheads also serve as the uprights of the four main girders of the hull. These continuous girders are of mixed construction, the lower members being made of wood, and the upper of high-resistance steel. At the rear end the four main girders terminate in a steel post, which is extended upward and serves for attaching the fin and rudder. In the bow, these girders form a solid support for the central engine.

The upper part of the hull is covered with birch plywood 4 mm (0.157 in.) thick, and is protected by sheet aluminum at the passage of the propeller of the central engine. The mooring devices are solidly attached to the front part of the deck.

The sides of the hull are covered with birch plywood 3 mm (0.118 in.) thick, the lower portion being further protected by a 3 mm covering of teak, and are joined to the deck and to the bottom by chines and to the upright members of the bulkheads by a very close checkerwork of ash strips. In the rear and upper portions the checkerwork is alone retained and fabric is used instead of plywood.

Floats.- With a total displacement of 2 m^3 (70.63 cu.ft.) and a structure similar to the bow of the hull, they are suspended from the wing at the end of a completely enclosed framework.

Empennages.- The horizontal empennage is constructed like the wing and consists of two parts: a semi-fixed part of 33 m² (355.21 sq.ft.) and a movable part of 11 m² (118.40 sq.ft.).

The fabric-covered, all-metal vertical empennage is hinged to the rudder post on the one hand, and to the hull by an adjusting device on the other hand. The area of the fin is 4 m² (43.06 sq.ft.); that of the rudder, 7 m² (75.35 sq.ft.).

Controls.- These comprise the steering parts and the stabilizing parts. The former are movable, balanced, and have dual controls, one by hand and one by servo-motor. A lever within reach of the pilot insures instantaneous and sure transition from one method of control to the other without displacement of the parts, even during a maneuver. The stabilizing parts, namely, the horizontal stabilizer, the fin, and the central ailerons are semi-fixed and can be operated in flight by means of simple and irreversible controls.

Power Plant.- This has a total power of 2100 HP., and consists of five air-cooled Jupiter radial engines. The central engine installed in the bow of the hull and the lateral engines borne by the wings actuate two-bladed tractor propellers of 3 m (9.84 ft.) diameter. The plane of revolution of the propellers on the lateral engines is 0.6 m (23.6 in.) in front of the leading edge of the wing.

All the parts behind the engines (pumps, filters, carburet-

ors, magnetos) can be inspected during flight. For this purpose a duralumin walkway supported by the main ribs affords easy access through the inside of the wing, the free height being 1.6 m (5 ft. 3 in.).

Two groups of four tanks of 525 liters (139 gallons), located in the wing, contain the fuel required for seven hours' flight at full power. Each tank is provided with a device for quick emptying, which insures its evacuation within less than 30 seconds. They are provided with level indicators comprising a transmitter placed on the tank itself, 8 "repeaters" (one for each tank) located in the mechanics' cockpit, and 2 "totalizers" (one for the port side and one for the starboard side), placed within view of the pilot. The piping, which connects them, is done in such manner that each engine can be supplied equally well from either one of the groups.

The engines are started with carbureted air furnished by a small auxiliary compressor. A distributer of air and ignition current located in the mechanics' cockpit, enables the starting of all five engines, one after another, in an extremely short time.

A set of fire extinguishers, automatic and controllable, completes the general equipment of the engines.

Control Cockpits.- On account of the number and diversity of the instruments, two cockpits have been provided, one for the pilots and one for the mechanics.

The former, located in the leading edge of the wing, assures perfect visibility for the pilots. It has dual control and the seats are easily accessible during flight. In addition to the usual instruments, a set of five levers enables the pilot to modify at will the revolution speed of one or more or all of the engines. A "safety box" affords him the possibility of testing the efficacy of the fire extinguishers during flight. The instruments controlling the speed of the engines are visible to both the pilots and mechanics at the same time. The mechanics' cockpit is located in the wing at the level of the central engine. Here are grouped side by side the instruments for controlling the engines, the electric switchboards, including the switch for charging the storage batteries, the starting rheostats of the servo-motor, the instruments for starting the engines, as likewise all navigation instruments requiring constant watching during flight. The location of the cockpit enables the mechanics to pass quickly to any part of the seaplane requiring immediate attention.

Equipment.- On the sides behind the wing, two doors afford access to the hull, which has two stories. The entrance is to the upper story from which a stairway leads down to a central cabin 10.5 m (34.45 ft.) long, 3.5 m (11.48 ft.) wide, and 2 m (6.56 ft.) high, in which 20 passengers can be very comfortably installed.

A compartment in the bow contains the anchors, grappling irons, ropes, etc.

In the rear there is a radio cabin equipped with apparatus powerful enough to telegraph about 1500 km (932 miles) and to telephone about 800 km (497 miles).

Still farther to the rear are the toilet rooms, the commander's cabin and the baggage rooms.

The different compartments are lighted - 18 windows provided with sliding panes for ventilation.

The balance of the seaplane does not permit the use of the extreme rear of the hull, which is nevertheless spacious and is provided with a walkway affording access during flight to the steering controls.

The upper story is reserved entirely to the crew, which has access by means of walkways and metal ladders, to all the delicate parts of the mechanism.

Characteristics

Span	39.75 m	(130.41 ft.)
Length	27 "	(88.58 ")
Height	6.5 "	(21.32 ")
Power, (5 Jupiter engines)	2100 HP.	
Full load	17500 kg	(48581 lb.)
Weight empty	12260 "	(37029 ")
Useful load	5240 "	(11552 ")
Crew and 7 hours' fuel	3440 "	(17584 ")
Freight	1800 "	(13968 ")
Wing area	270 m²	(2906.25 sq.ft.)

Characteristics (Cont.)

Maximum chord	9 m	(29.53 ft.)
Minimum "	5 "	(16.40 ")
Maximum thickness	1.8 m	(5.91 ")
Area of movable ailerons	26.0 m²	(279.87 sq.ft.)
" " semi-fixed "	13.0 "	(139.93 ")
" " horizontal stabilizer	33.0 "	(355.21 ")
" " elevator	11.0 "	(118.40 ")
" " fin	4.0 "	(43.06 ")
" " rudder	7.0 "	(75.35 " "
Wing loading	65.0 kg/m²	(13.31 lb./sq.ft)
Power "	8.0 kg/HP	(17.4 lb./HP.)

Performances

During the trial tests the full load reached the figure of about 17500 kg (48581 lb.), which was made up as follows:

Wing

Spars	3285 kg	(7242 lb.)
Main ribs, wing coverings, and brace wires	1011 "	(2229 ")
Secondary ribs	322 "	(710 ")
Ailerons, controls, counterpoises	300 "	(661 ")
Fabric, dope, walkways	470 "	(1036 ")
Total	5388 "	(11878 ")

Performances (Cont.)

Hull

Bulkheads	975 kg	(2150 lb.)
Top girder	485 "	(1068 ")
Sides (between bottom and deck)	1360 "	(2998 ")
Housing over cockpits	350 "	(772 ")
Hull coverings and partitions	400 "	(882 ")
Total	3570 "	(7870 ")

Empennages

Horizontal empennage	460 kg	(1014 lb.)
Rudder	60 "	(133 ")
Fin	50 "	(110 ")
Controls	17 "	(37 ")
Total	587 "	(1294 ")

Engines

5 engines	1900 kg	(4189 lb.)
Propellers	130 "	(288 ")
Piping, radiators, controls, starter, fire extinguishers	425 "	(937 ")
Total	2455 "	(5412 ")
Fuel and oil tanks	260 kg	(573 ")
Total empty weight	12260 "	(27029 ")

Performances (Cont.)

Useful Load

Servo-motor	200 kg	(441 lb.)
Radio, auxiliary groups, storage batteries	550 "	(1213 ")
Electric apparatus	100 "	(220 ")
Anchors and miscellaneous rigging	120 "	(265 ")
2 pilots, parachutes, etc.	200 "	(441 ")
1 mechanic	70 "	(154 ")
Fuel and oil	1800 "	(3968 ")
Ballast	2200 "	(4850 ")
Total	5240 "	(11552 ")

The seaplane has made eight trips in all, amounting to about six hours' flight. During these trial flights the following facts were noted.

The take-off was made without difficulty, even from a rough sea, with waves 1.5 m (4.92 ft.) high, and without any help from the pilot. The trim was found to be perfect at the very first flight. The maneuverability was entirely satisfactory. The seaplane responded to the engines and obeyed the hand without excessive effort on the part of the pilot. The maneuvers could be made with the same precision by means of the servo-motor as by hand and without impairing the reflexes of the pilot. This machine was thrown in and out of gear during flight without any difficulty. Its behavior on the water is perfect, even when quite rough and in a cross wind. Lastly, taxying and towing were both effected in the best shape.

In short, it may be affirmed, after these excellent results, that the fears, entertained by many regarding the piloting of large seaplanes, have entirely vanished and that, as was to be expected, the behavior on the water is greatly improved by its large dimensions.

As to the performances, it is too early to announce the results. The tests will be continued and will be modified as the finishing touches are made. At present the timed ground speed is 160 km (about 100 miles) per hour. During the tests, an altitude of 1200 m (3937 ft.) was reached in 30 minutes under full load. Fig. 10 shows the laboratory polars and also a modified polar which takes account of the action of the propeller slip stream. The abovementioned performances, as also the corresponding angles of attack show a remarkable agreement with the corrected polar. They thus justify the calculation methods used to determine them. They will be the subject of a future communication by us.

As indicated by the diagram, the propeller efficiency in these experiments did not exceed 55%. This low value may be attributed to

1. The nearness of the plane of revolution of the propellers to the leading edge of the wing, 0.6 m (23.6 in.). Since

the velocity of the air stream undergoes important variations in this plane, the adaptation of a propeller to a given velocity seemed impossible, the calculations, as well as the flight measurements by means of a "badin" (an air-speed indicator) having shown that these variations attain as high as 50% of the velocity at infinity.

2. The small diameter of the propellers, 3 m (9.84 ft.), renders the above effect more sensitive to the velocity variations superposed on the engine puffs, while it increases the relative importance of the presence of the unhoused engine.

3. Lastly, the high engine speed of 1720 R.P.M. made it impossible to obtain any great efficiency in the air stream retarded by the various abovementioned influences.

Experiments are being undertaken for the purpose of remedying these defects. The plane of revolution of the propellers will be carried to 2 m (6.56 ft.) in front of the leading edge and the diameter of the propeller may be increased to a maximum of 4.2 m (13.78 ft.), which will enable the use of reduction gears. The results to be expected from these changes are not doubtful, since the polar indicatos very clearly in what degree the performances are improved by increasing the propeller efficiency. The combined increase of power and decrease of K_x assures gains, particularly in speed, which, at first thought, might appear surprising.

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

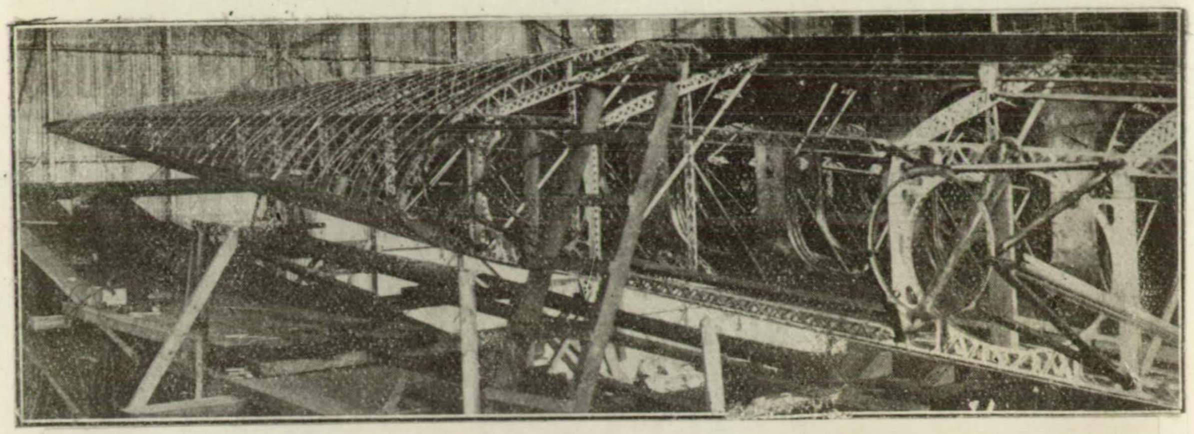

Fig.1 Front view of starboard wing, showing structure of leading edge.

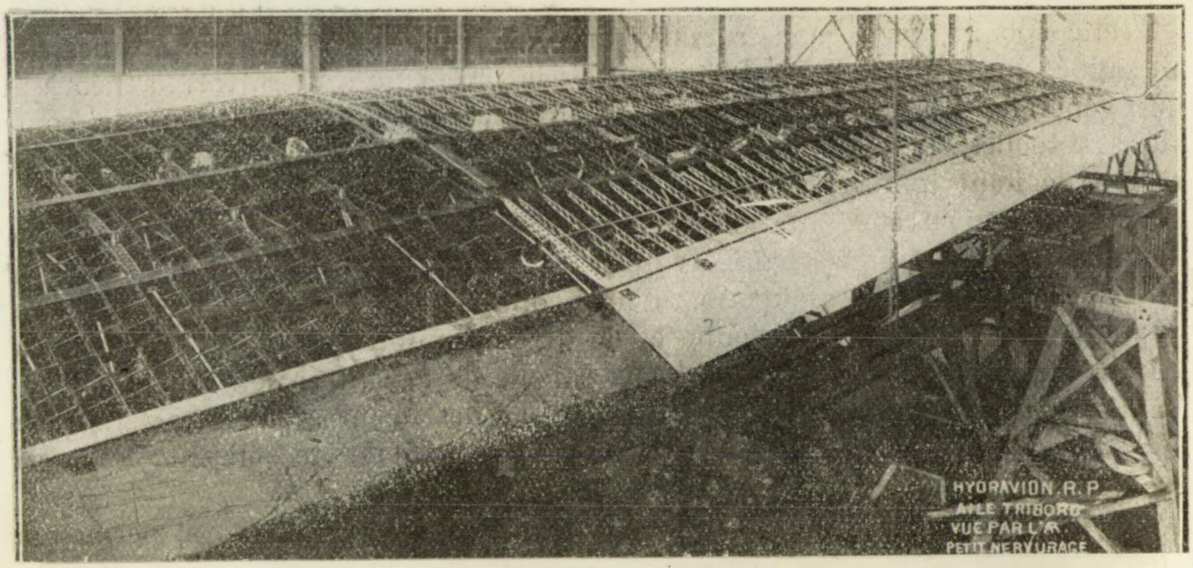

Fig.2 Rear view of starboard wing. Aileron at the right.

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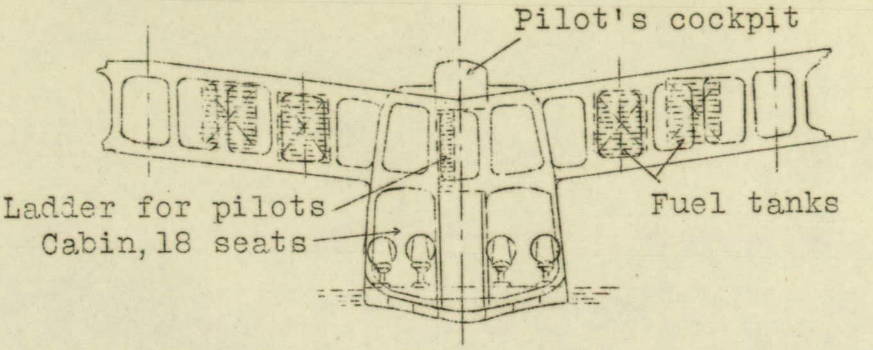


Fig.4 Sectional elevation of Richard-Penhoët seaplane.

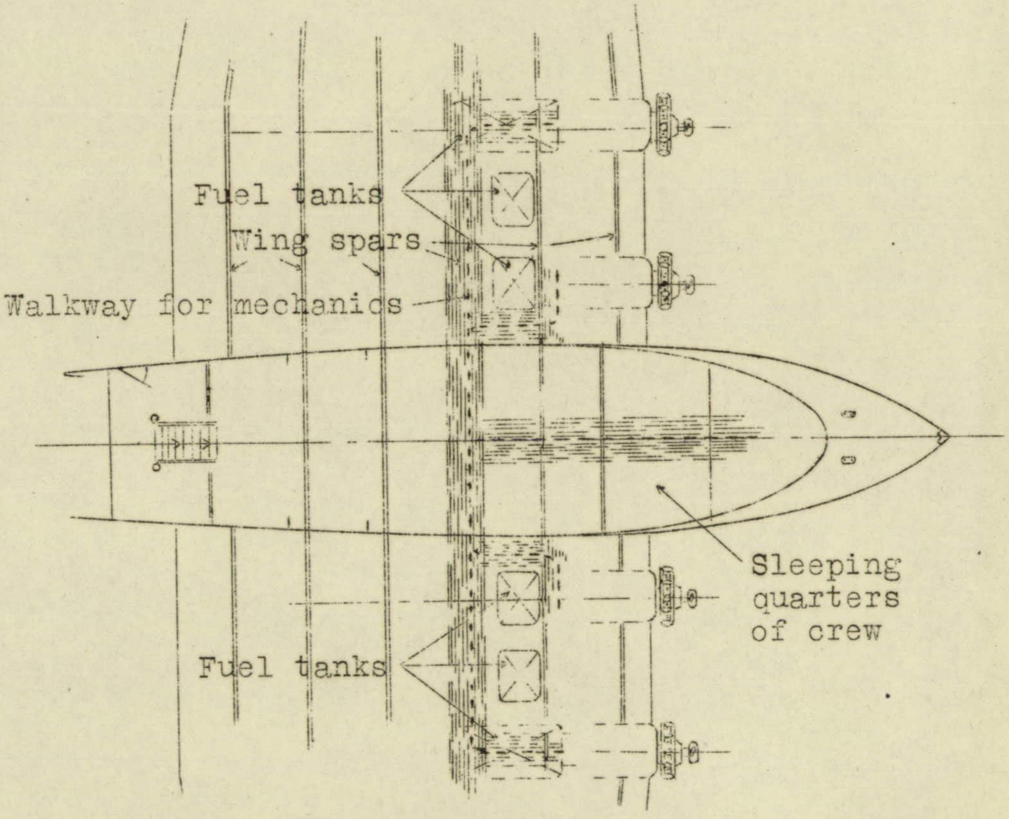


Fig.5 Sectional plan of Richard-Penhoët seaplane.

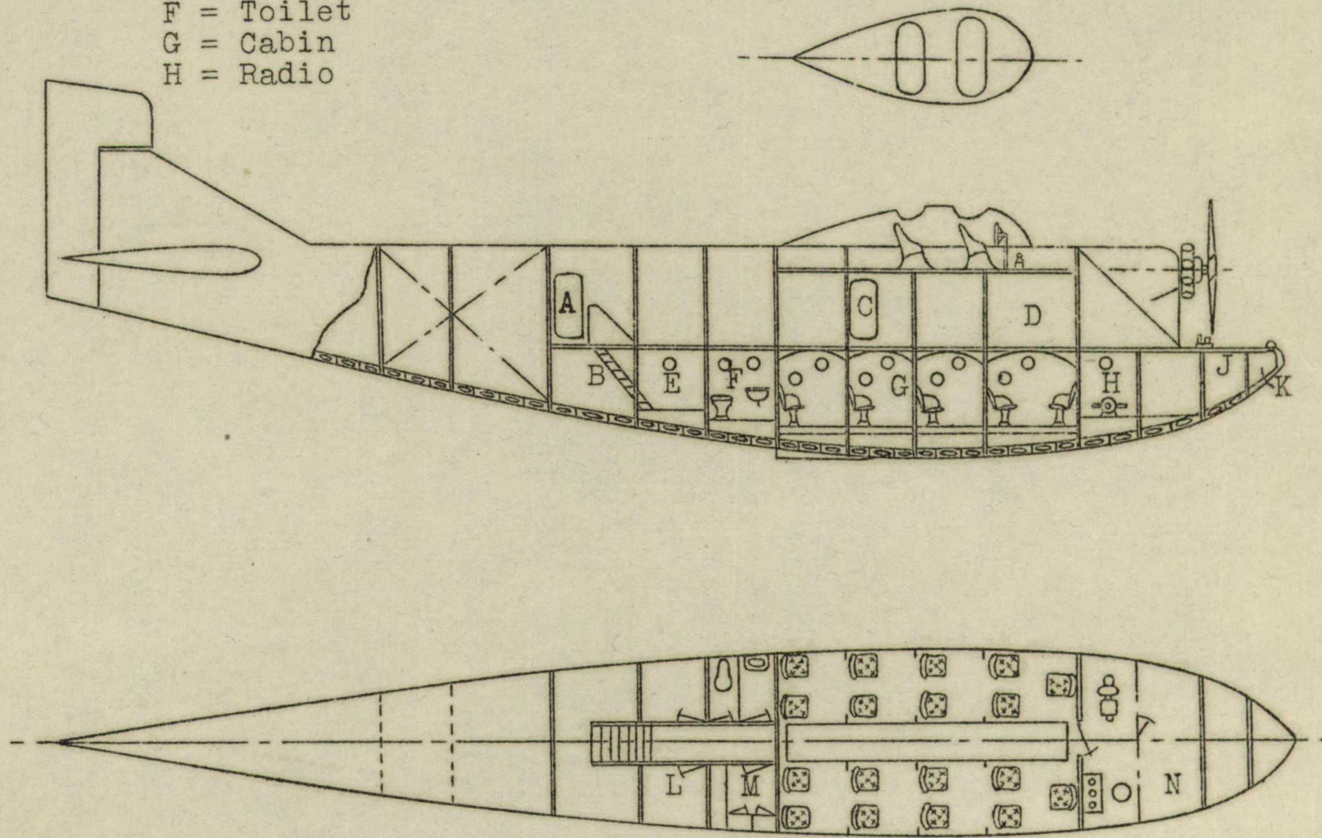
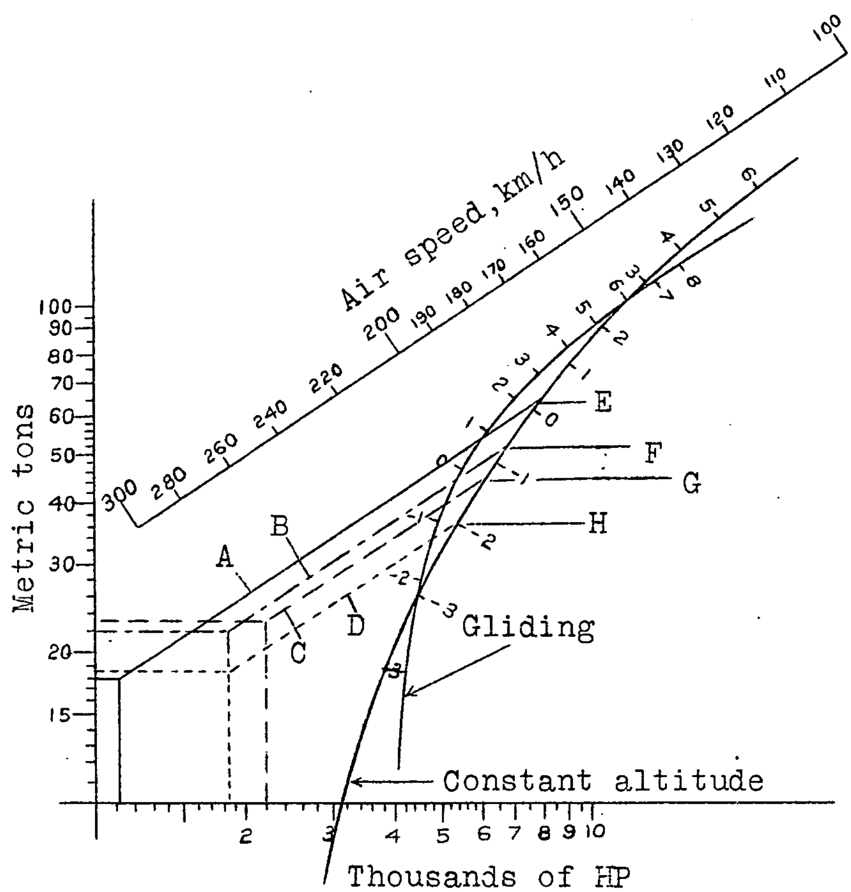


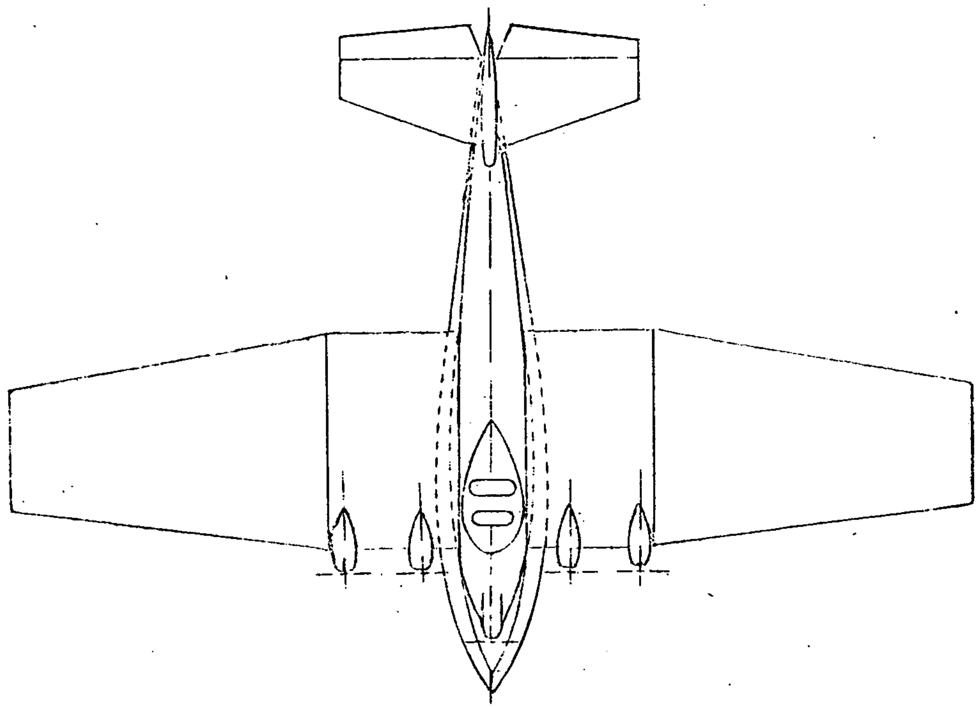
Fig.9 Section of hull of the Richard-Penhoët seaplane.

A =	ρ = 53%	V = 157km 97.56 M.P.H.	Practical ceiling	1000m 3281 ft.
B =	ρ = 70%	V = 175km 108.74 M.P.H.	" "	2000m 6562 ft.
C =	ρ = 70%	V = 215km 133.59 M.P.H.	" "	2500m 8202 ft.
D =	ρ = 70%	V = 210km 103.49 M.P.H.	" "	3500m 11483 ft.



E =	Actual performance,	π =	18000kg 39683 lb.
F =	Performance with 5 Farman engines,	π =	22000kg 48502 lb.
G =	" " 5 Hispano "	π =	23000kg 50706 lb.
H =	" " 5 Farman "	π =	18500kg 40785 lb.

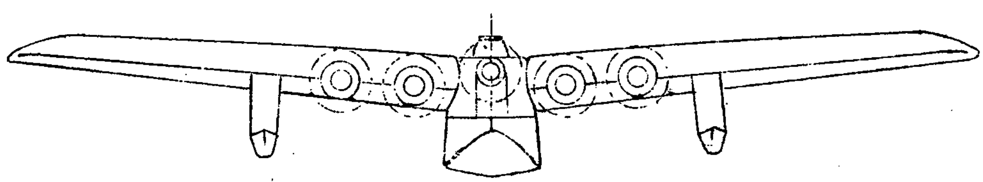
Fig.10 Polars of Richard-Penhoët seaplane.



Span 39.75m (130.41ft.)

Length 27.00m (88.58ft.)

Height 6.5m (21.32ft.)



Maximum chord 9m (29.53ft.)

Minimum chord 5m (16.40ft.)

Wing area 270m^2 (2906.25sq.ft.)

5 engines delivering 2100 H P.

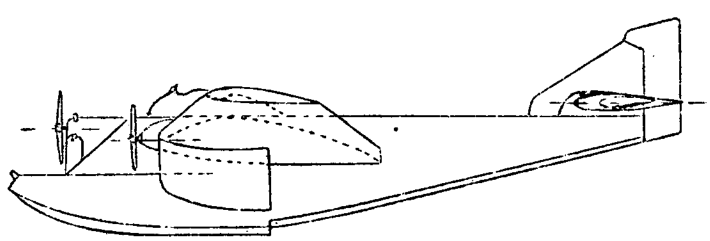


Fig.11 Plan and elevations of the Richard-Penhoët seaplane.