DESIGN ANALYSIS OF REPUBLIC SEABEE

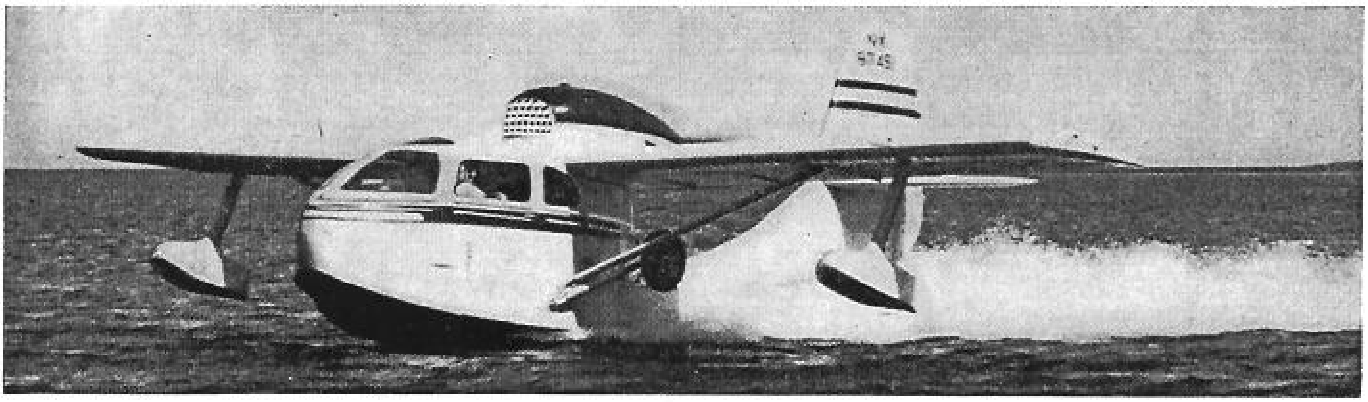
By IRVING STONE, *Assistant Editor, "Aviation"*

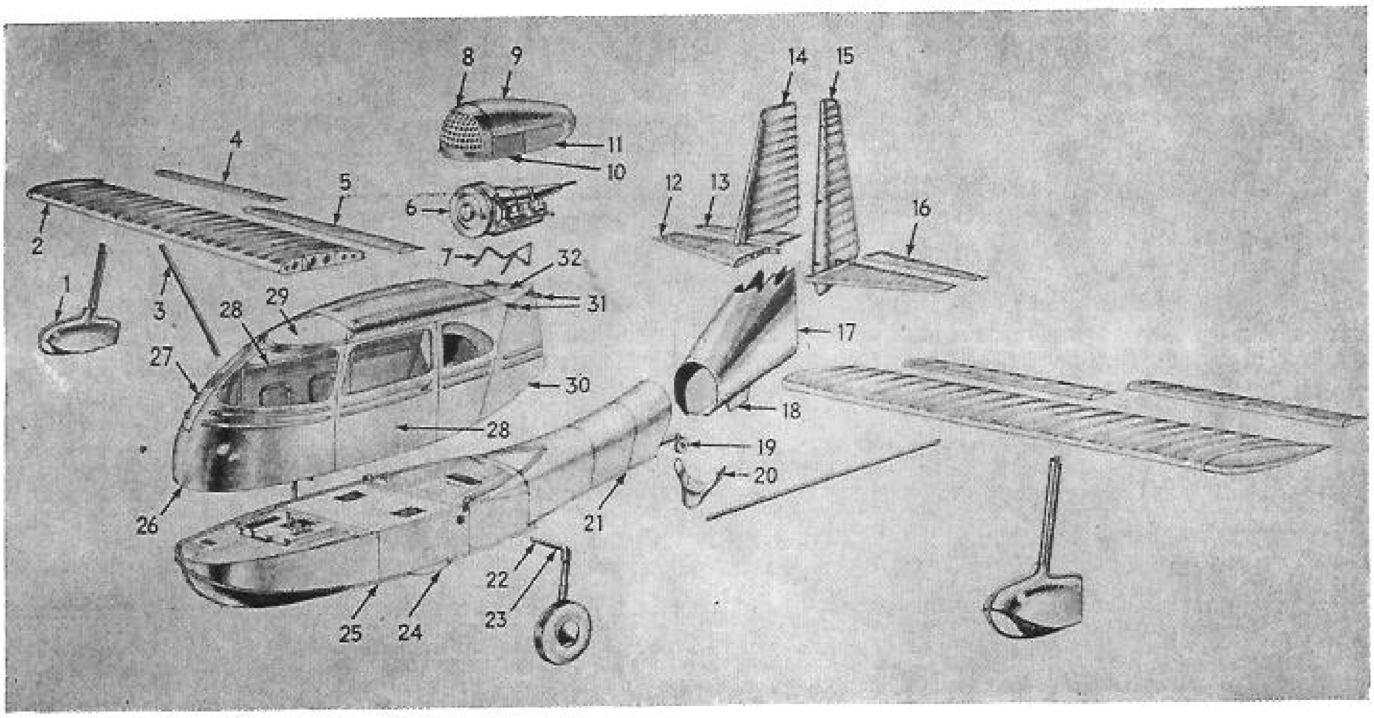
Veering sharply from complex and costly components, this new all-metal four-place amphibian design embodies a revolutionary degree of structural simplicity—the prime factor enabling Republic's engineers to achieve low-cost manufacture without need for huge volume. This notable stride forward is fully detailed in this construction-production study—20th in Aviation's explicit series.

The engineering of Republic Aviation Corp.'s Seabee amphibian marks a turning point in the aviation industry. Structurally, the craft represents such a reasonable—and necessary—departure from intricate conventional design, that its radical makeup-simplicity alone, embodying more-than-adequate strength characteristics, recommends it as a basic pattern for future engineering of aircraft—military, transport, and personal.

In substance, the fixed and movable airfoil structures of the Seabee are essentially ribless components comprising simple spar foundations covered by stiffened skin. The hull—almost a pure monocoque design—consists of a heavy gage shell with relatively few internal connecting members. And stemming from such highly simplified design is the all-important factor of simplified production—the controlling factor in the ability to produce high value airplanes for low cost, without the requirement of large mass output heretofore considered necessary.

The Seabee project has unmistakably demonstrated that design complexity is the fundamental reason for high production costs, since there are narrow limitations to the production engineer's capability of cutting direct manufacturing labor charges when confronted with complicated subassemblies. And it has been shown that when the design is formulated, it must be predicated on attendant tooling and manufacturing problems. This is the first requirement for processing low-cost planes; hence, design and process engineers must work hand-and-





Exploded relation showing: (1) Wing float, (2) wing, (3) wing brace strut, (4) aileron, (5) flap, (6) engine, (7) engine mount, (8) fixed top cowl, (9) raisable top cowl, (10) forward side cowl, (11) rear side wrap-around cowl, (12) stabilizer, (13) elevator, (14) fin, (15) rudder, (16) tab, (17) stern assembly, (18) water rudder, (19) tail wheel, (20) structural fillet, (21) hull afterbody assembly, (22) landing gear hull through-shaft, (23) elbow connecting hull shaft to strut, (24) foot step, (25) hull forebody assembly, (26) cabin assembly superstructure, (27) bow door, (28) side door, (29) crown window, (30) cabin assembly rear primary structure, (31) wing crosstie, and (32) firewall.

glove to develop designs that will permit high-speed production operations. This involves a high degree of standardization of sections, hole sizes, and other structural details. Also, the design must be carefully studied to permit large individual sections to be drawn in dies, replacing a large number of small-part assemblies. It is then the process engineer's function to develop the tooling to perform as many operations at one time as is possible, thus eliminating subsequent direct labor costs.

In sharp contrast to the conventional aircraft structure, containing many small and interlocking component assemblies laboriously put together by hand, the simplified structure of the Seabee lends itself readily to rapid fabrication with equipment of the type generally used in the automobile industry—units such as mechanical presses, press brakes, and automatic screw machines. And, additionally, large sections of the structure are assembled on automatic gang riveting machines.

Using this type of fast-production equipment for the Seabee, each tool is designed for the maximum output. For example, if a mechanical press is capable of 300 strokes per hour, the corresponding tool is designed for the same number of strokes—to produce an average of 300 parts per hour. And to insure operation of equipment at maximum speed, additional manpower is assigned, when such need is found to be necessary.

Assuming a run of 5,000 planes at a given rate, cost for the automotive type tooling is estimated to be approximately $300–$350 per lb. of airframe, and since the airframe weighs about 1,100 lb., overall cost of production tooling is approximately $350,000. But it must be

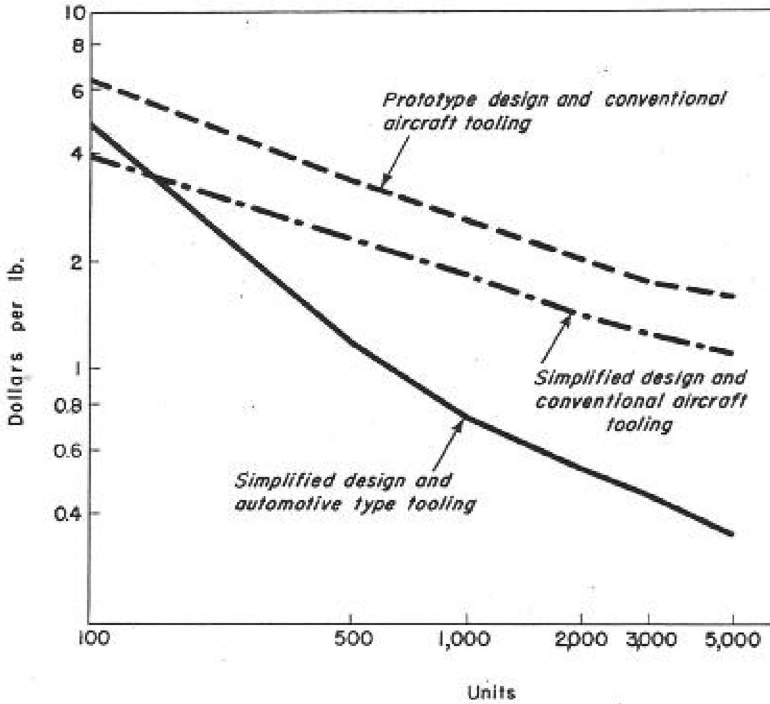
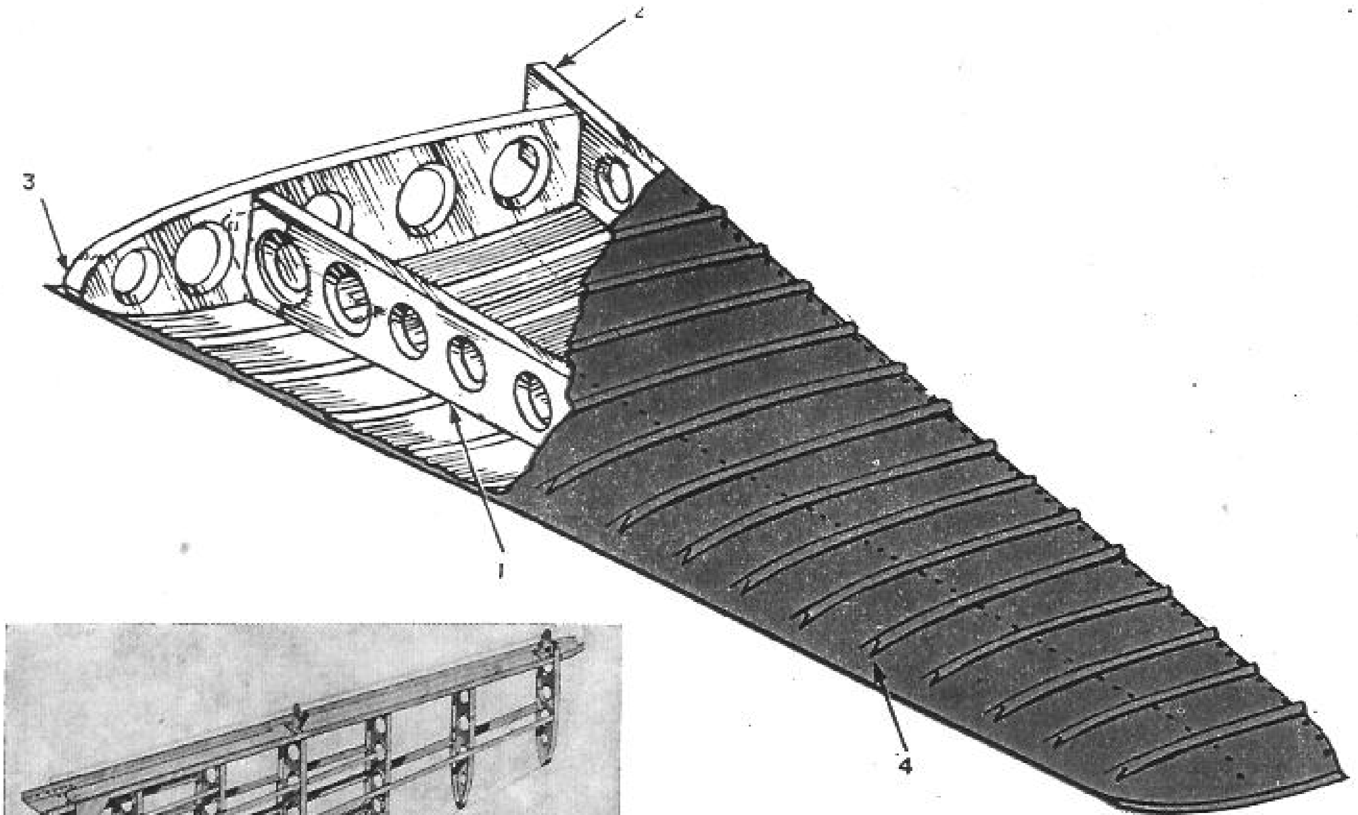
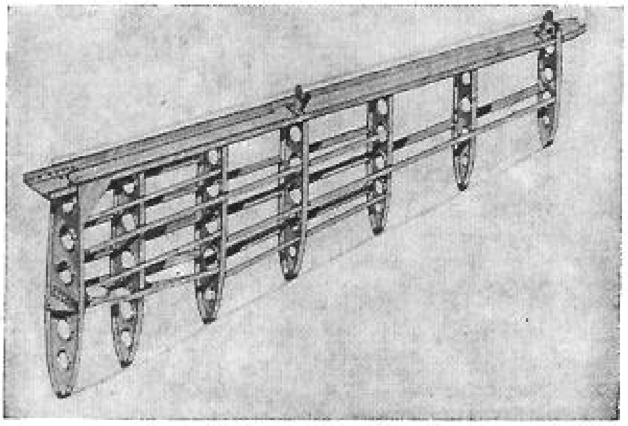


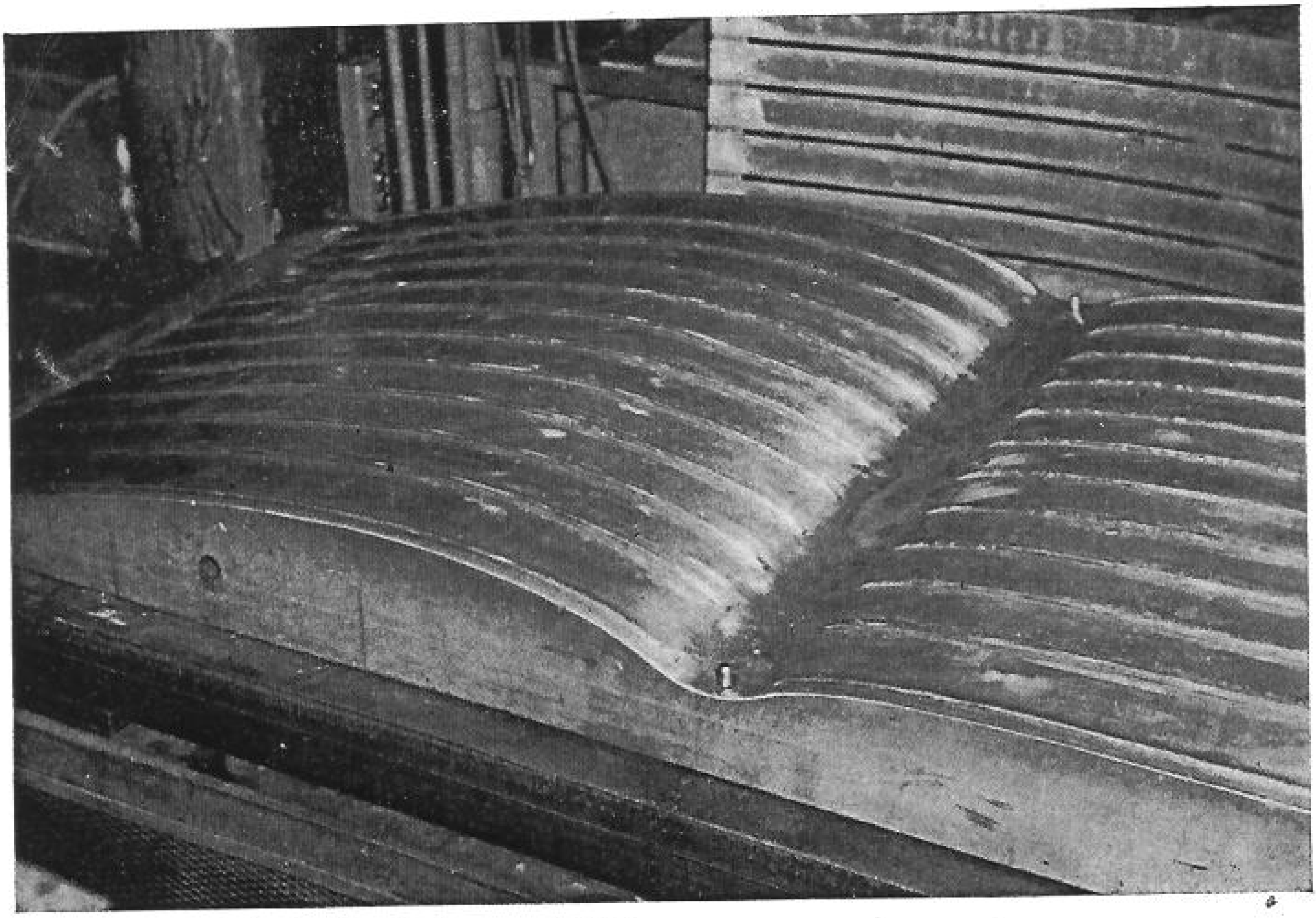
Chart showing distribution of stabilizer cost (labor, tooling, and overhead—less material) in dollars per lb. with prototype design and conventional aircraft tooling, with simplified design and conventional aircraft tooling, and with simplified design and automotive type tooling. It is to be noted that latter tooling pays for itself in less than 200 craft.



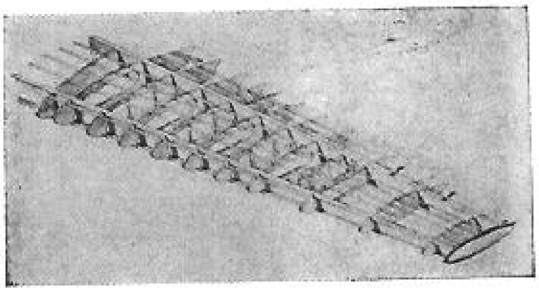


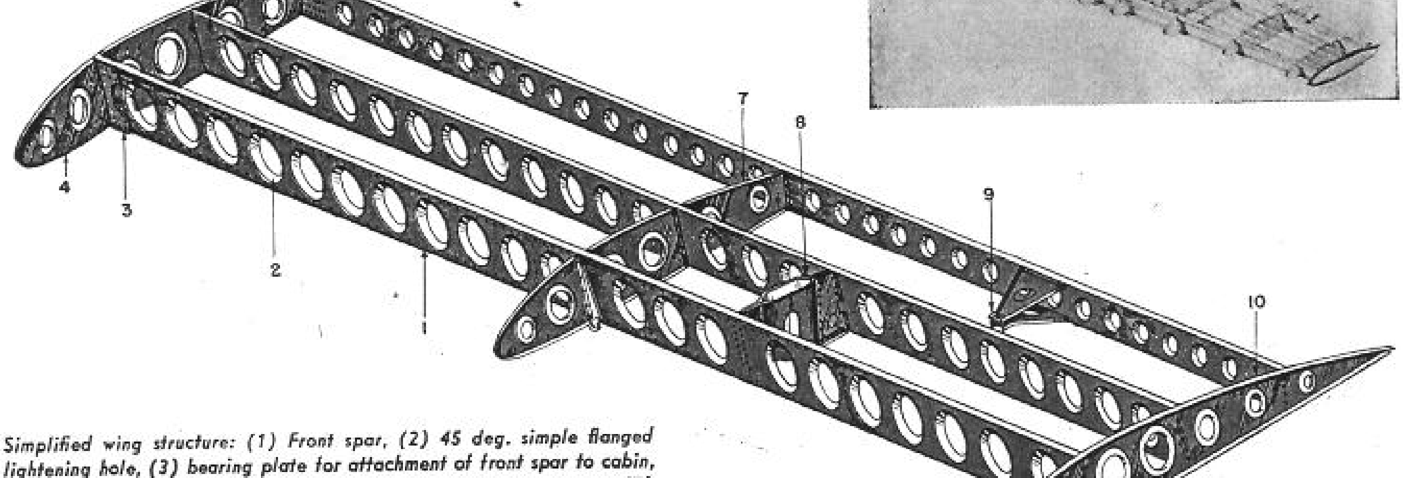
Simplified stabilizer seen here presents marked contrast to comparatively complicated conventional design shown at left. Simplified design components are: (1) Front spar, (2) rear spar, (3) inboard end rib, and (4) single-piece skin formed on camel-back draw die, with 1/4-in. stiffening beads serving to replace conventional frame members. Skin is also shaped to form integral tip, thus obviating need for outboard end rib. Assembly is accomplished almost entirely by automatic riveting.

Simplicity of structural details is typfied in this stabilizer inboard end rib—a single-piece stamping provided with a slot for passage of front spar, which is attached to rib via metal displaced from slot.

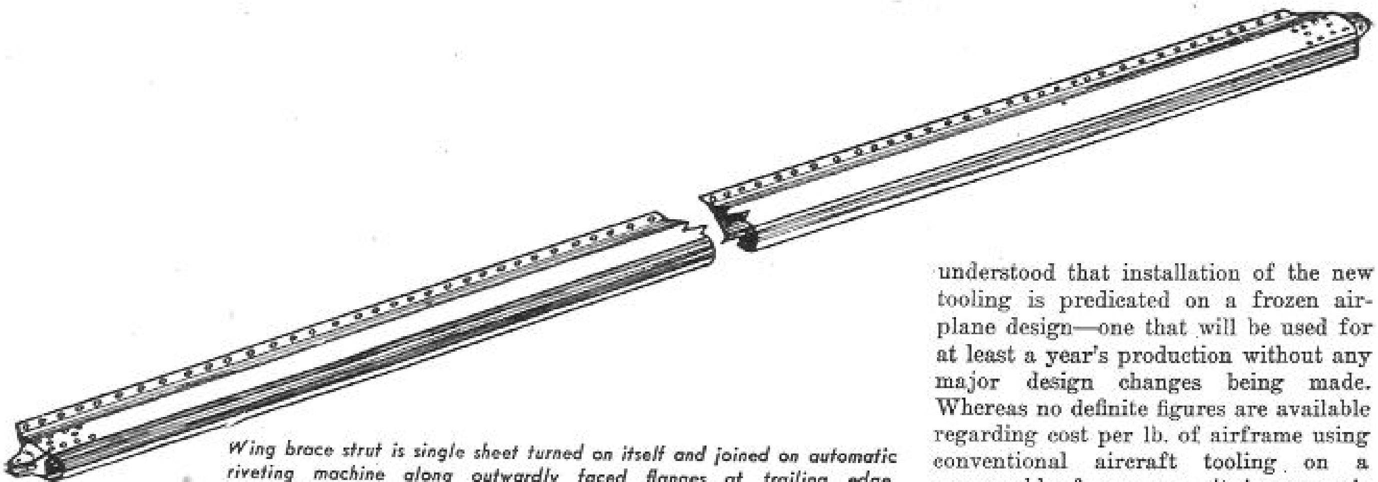


Camel-back draw die for forming skins. This is temporary tool used until production unit is available, and is employed with steel mat (seen in background) which gives sharp impressions of the beads with hydraulic press utilizing rubber female. With mechanical press, steel female will obviate need for mat.

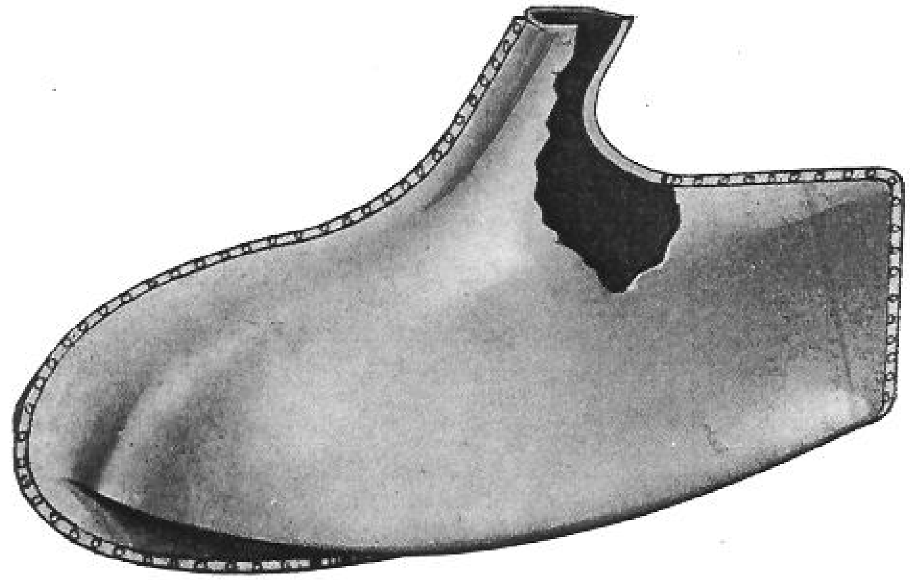


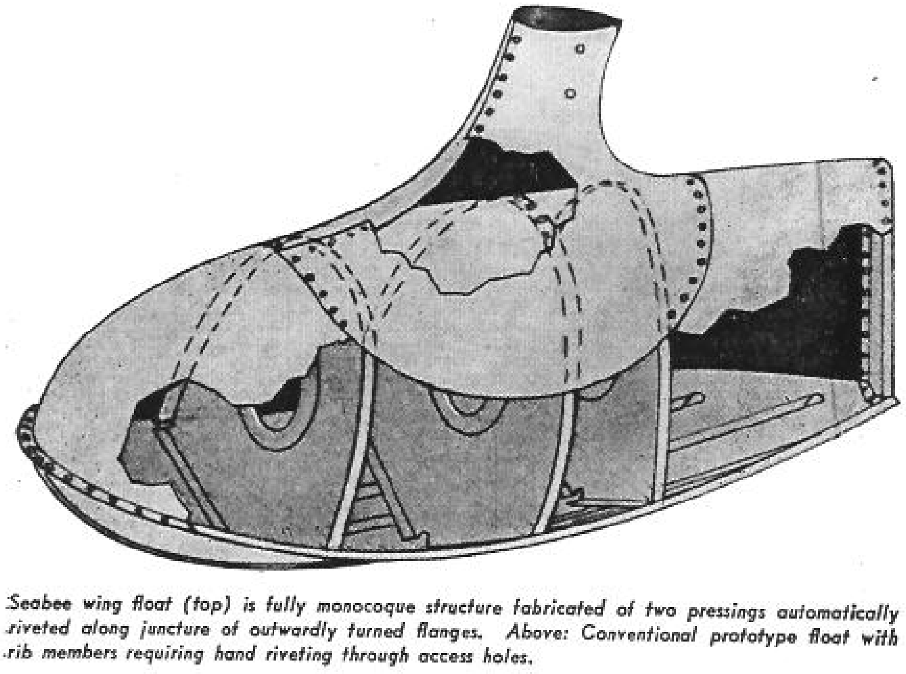


Simplified wing structure: (1) Front spar, (2) 45 deg. simple flanged lightening hole, (3) bearing plate for attachment of front spar to cabin, (4) two-piece inboard end rib, (5) middle spar, (6) rear spar, (7) center rib, intercostal between spars, (8) wing float socket, (9) aileron bellcrank bracket, and (10) outboard end rib with wide flange for attachment of wing tip. Inset: Conventional prototype wing panel with its great number of ribs, also stringers.



Wing brace strut is single sheet turned on itself and joined on automatic riveting machine along outwardly faced flanges at trailing edge. Extruded fittings at ends serve for attachment to hull and wing, respectively.





Seabee wing float (top) is fully monocoque structure fabricated of two pressings automatically riveted along juncture of outwardly turned flanges. Above: Conventional prototype float with rib members requiring hand riveting through access holes.

understood that installation of the new tooling is predicated on a frozen airplane design—one that will be used for at least a year's production without any major design changes being made. Whereas no definite figures are available regarding cost per lb. of airframe using conventional aircraft tooling on a comparable frozen run, it is approximated that the manufacturing cost (tooling, labor, and overhead) would be many times higher than the manufacturing cost with automotive type tooling.

In a study of the economies of utilizing automotive type tooling for the simplified (ribless) structure, distribution of stabilizer tooling, labor, and overhead costs was estimated over production runs of from 100 to 5,000 planes, and it was determined that the new tooling pays for itself in less than 200 craft.

Initial problem attendant with the choice of automotive type tooling was the selection of materials adaptable to fast production methods. After extensive investigation, 61SW was chosen for severely formed parts in which high strength was not important, and R-301W was selected for slight advantage in formability over other high stress material and partly to eliminate heat-treat operations in the manufacturing process. It is estimated that heat-treat per lb. of airframe adds 3c to 6c in direct labor cost.

An important feature of the Seabee production plan is a closely controlled parts flow time—three days from raw material to finished product—to eliminate stock rooms and attendant personal and paper work.

Another major consideration lies in the procurement cost of items such as instruments, electrical switches, interior trim and hardware, and other equipment. In many instances it has been found that good, comparatively inexpensive, automotive type units can be used.

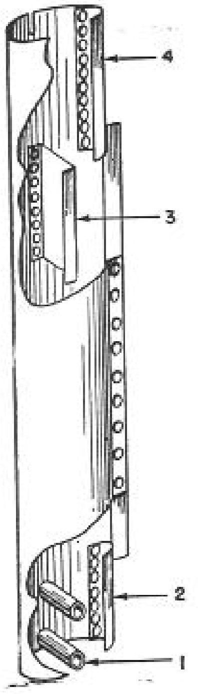
Seabee Design Philosophy

As a prelude to the structural analysis of the Seabee, it is interesting to outline, briefly, the considerations leading to, and the theory underlying, the simplified design.

The prototype plane, which was completed in Nov. 1944, was built only to prove the general design. The craft was a three-place 175-hp. all-metal amphibian monoplane using good but conventional structure throughout, and was an outgrowth of an original design by P. H. Spencer, development engineer.

Manufacturing cost considerations—price would have had to be almost twice the present price (just under $4,000) based on simplified design—prompted Alfred Marchev, Republic's president to direct an investigation to determine how airframe structures could be simplified to reduce manufacturing costs sharply. He believed that extensive simplification could be achieved, with consequent great reduction in number of assembly components, while yet maintaining the high standards required in aircraft construction.

Alfred Z. Boyajian, structures project engineer at Republic, was assigned the task to redesign the Seabee airframe to meet reduced cost requirements. As a preliminary step, he reviewed: (1) The evolution of conventional design, to ascertain why this type of structure had been adopted; (2) production time studies, made available from wartime experience, to establish what, in general, was causing manufacturing costs to be so high; and (3) stress analysis procedures, to determine what conceptions



Wing float strut assembly: (1) Spacer tube for attachment bolts at float, (2) contour plate for float socket, (3) internal reinforcing channel, and (4) contour plate for wing socket.

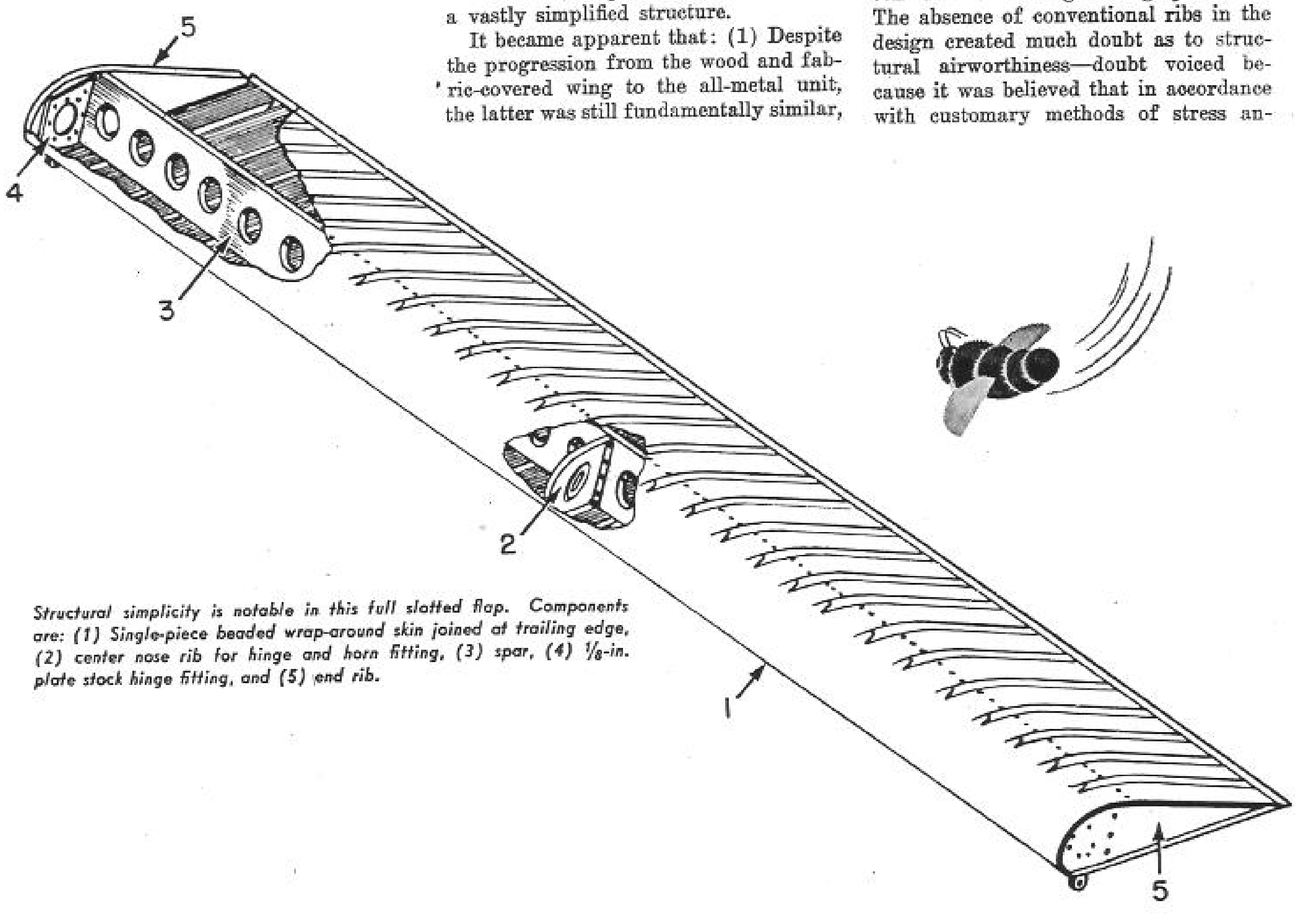
existed which might be altered to justify a vastly simplified structure.

It became apparent that: (1) Despite the progression from the wood and fabric-covered wing to the all-metal unit, the latter was still fundamentally similar, in basic pattern, to the former; (2) production complications arose because of the complex "egg box" structure—many internal interconnected members, in turn connected to the outside cover; and (3) the necessity for the retention of numerous rib components (as "irreplaceable" internal members of the conventional metal wing) had not been clearly established.

When engineer Boyajian's simplified—comparatively ribless—structural design was first proposed on paper it was subjected to much discussion in large conferences of engineering personnel. The absence of conventional ribs in the design created much doubt as to structural airworthiness—doubt voiced because it was believed that in accordance with customary methods of stress an-

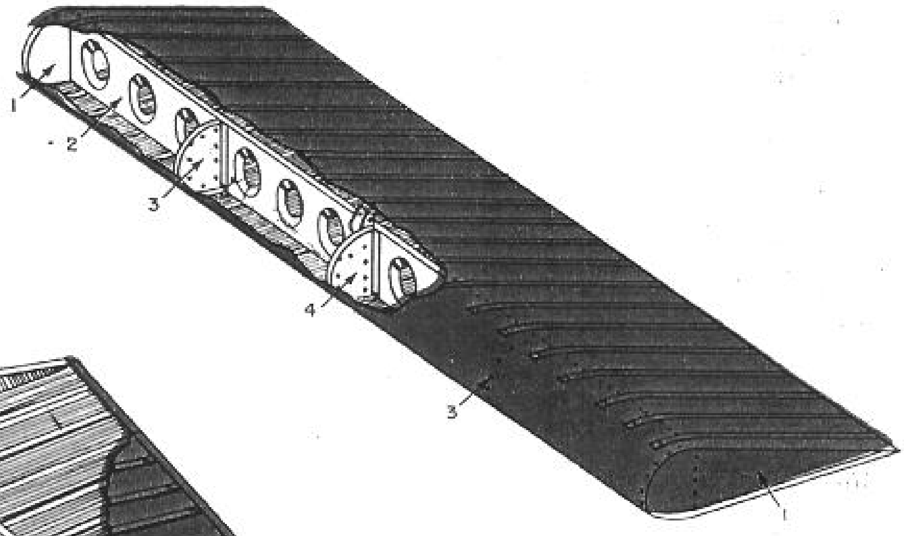
With the Significant Belief—

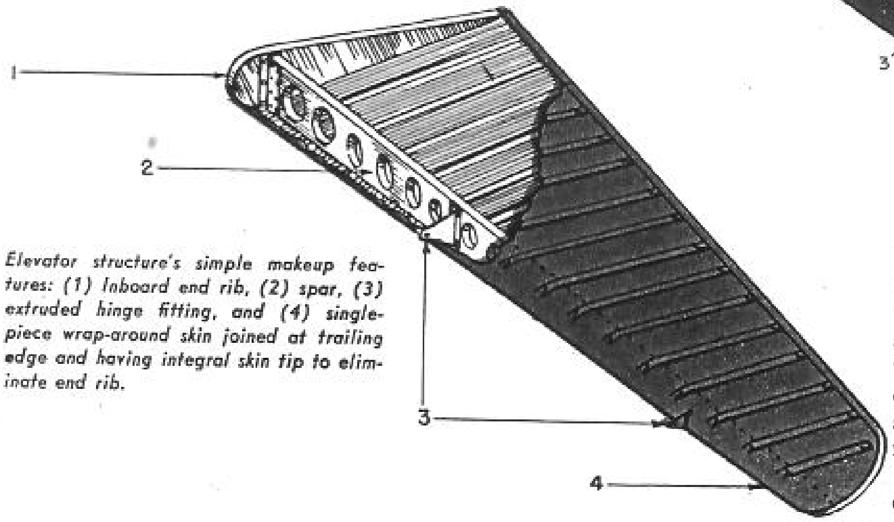
that a knowledge of the design philosophy and production methods behind the Seabee project belongs to the aviation industry, the management of Republic, through Pres. Alfred Marchev, has made a notable contribution by welcoming investigation of its personal plane development by representatives of other aircraft manufacturers. And already a number of these men, as observers, have visited Republic's Seabee division.



Structural simplicity is notable in this full slotted flap. Components are: (1) Single-piece beaded wrap-around skin joined at trailing edge, (2) center nose rib for hinge and horn fitting, (3) spar, (4) 1/8-in. plate stock hinge fitting, and (5) end rib.

Like flap, full slotted aileron seen here also has single wrap-around skin. Other details are: (1) End rib, (2) spar, (3) nose rib carrying hinge, and (4) nose rib carrying horn. Aileron is identical in cross-section to flap, hence forming tools for latter may be used for aileron skin, spar, and rib.





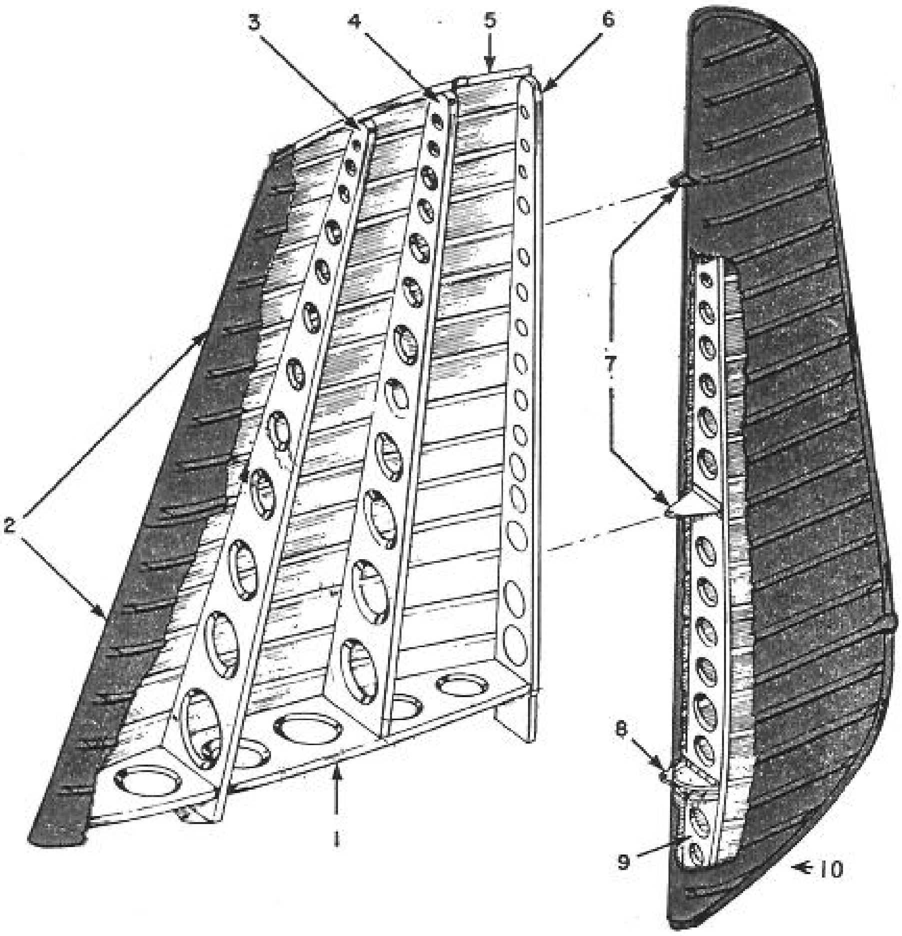
Elevator structure's simple makeup features: (1) Inboard end rib, (2) spar, (3) extruded hinge fitting, and (4) single-piece wrap-around skin joined at trailing edge and having integral skin tip to eliminate end rib.

alysis, the proposed simplified structure was considered to be probably deficient in strength requirements. It was considered, generally, that other than a rib there was no structural member deemed capable of transferring airload shears in a chordwise direction to the bending-resistant spars.

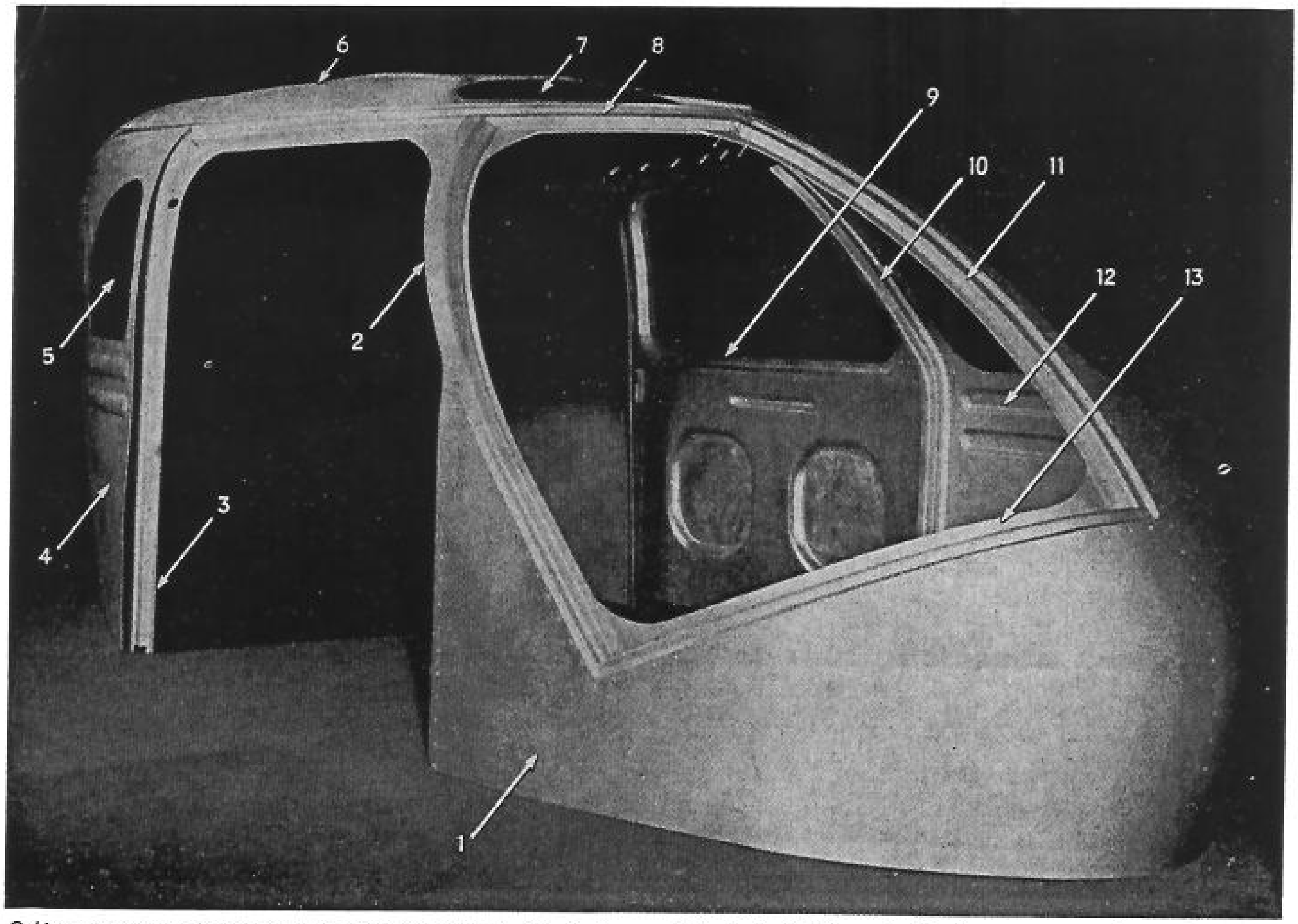
Boyajian's theory was that if the cover of a stressed skin wing were sufficiently stiffened, thus creating a heavy torque box, it should be possible to transfer such airload shears with a minimum of internal structure. He arrived at this conclusion after reasoning that the conventional practice for a stressed skin wing, wherein a section is isolated and analyzed as an independent structure, was not justified, since it was assumed that the other portions of the overall structure did not contribute any vital additional strength characteristics to the isolated section.

True, an isolated ribless section would deflect under airload because of absence of shear rigidity, and would give a large torsional displacement with respect to the end ribs. But a torque box, for example, comprising the stressed skin leading edge would offer appreciable restraint to such torsional displacement. Further, Boyajian believed that the leading edge cell and the aft cells would serve, in some degree, as beams in bending between end ribs, and that the secondary spars would also act so. He also reasoned that individual beads on lead-

CALL HENRY



Fin and rudder assembly: (1) Fin bottom end rib, (2) wrap-around skin, (3) front spar, (4) center spar, (5) integral skin tip, (6) rear spar, (7) rudder hinge fitting, (8) combination hinge and horn fitting, (9) spar, and (10) wrap-around skin joined at trailing edge. It is contemplated to build rudder of l. & r. clamshell sections joined along external flanges at both leading and trailing edges (around entire periphery), thus eliminating spar.



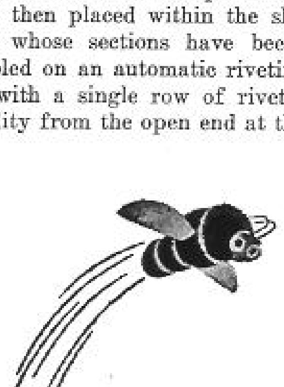
Cabin superstructure frame setup: (1) Right bow panel, (2) double front door post, (3) rear right door post, (4) rear side panel, (5) side window, (6) monopiece roof, (7) crown window, (8) crown bow frame, (9) left side door, (10) single front door post, (11) center bow frame, (12) left bow panel, and (13) lower bow door post. Fabrication simplicity is typified in cabin fixed superstructure, where side panel is blanked from a single piece and formed with stiffening beads and contour in one operation. Cabin rear primary structure attaches to rear side skins of superstructure and encloses baggage compartment decked by firewall.

tion for the spars of the stabilizer unit.

On the conventional stabilizer, skin was .020 24ST Alclad, whereas the simplified stabilizer—having the same outline—has skin of .025 R-301W. External stiffening beads, serving to eliminate the internal framework of the conventional structure, are ¼ in. deep by 4 in. on centers, and are not considered objectionable as speed-impeders. And it is also felt that the external beading lends a decorative touch to the plane surfaces. Actual test on the prototype plane, with and without beading (beads were simulated by wooden strips attached to wings and tail surfaces), showed a reduction of but 3 mph. at high speed—a loss offset by a reduction of 2 mph. in stalling speed.

An example of the type of tooling utilized for fabricating the stabilizer skin—tooling which is typical for fabricating the beaded skins of the wing, other fixed surfaces, and movable surfaces—is the forming die. This is a camel-back draw die which forms the beads with necessary contour and depth. Draw flash is die-trimmed to give the skin its size and outline. Final operation in a bending die forms the camel-back into the leading edge of the structure by folding the skin back from the bulge.

In assembly, front spar is attached to inboard end rib as a first operation. This unit is then placed within the skin envelope whose sections have been preassembled on an automatic riveting machine with a single row of rivets. Accessibility from the open end at the rear

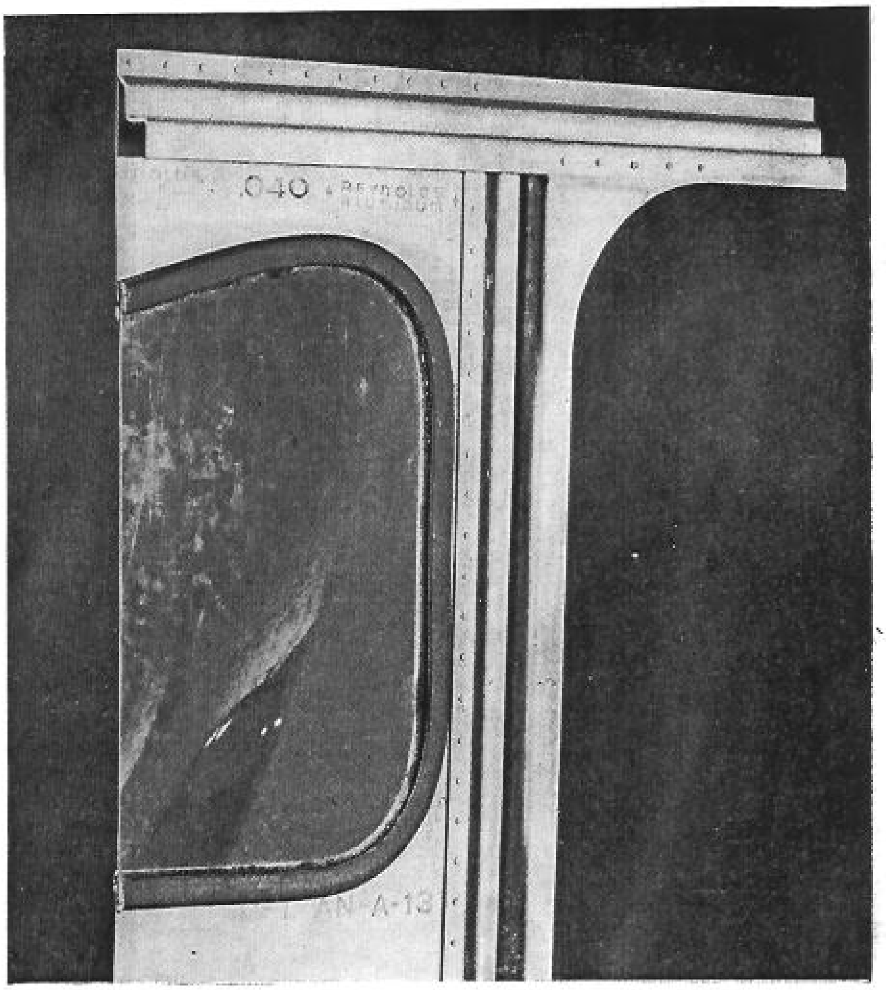


of the envelope permits automatic riveting of the latter to the front spar and end rib. Next, the rear spar is installed and automatically riveted to the skin to form the rear closure of the structure. And the tip is formed with an external flange, also automatically riveted.

Thus, aside from attachment of stabilizer hinges (bolted) and other minor hand operations, the entire assembly is automatically joined—a fairly typical procedure for all the airfoil structures on the Seabee. This simple method of assembly is in marked contrast to the complicated, manual, slow and costly procedure involved in the fabrication of the conventional structure.

Static test of the simplified stabilizer showed about 10% higher strength over the conventional prototype unit, and it also disclosed very satisfactory rigidity. And most important—since it made possible such fast and cost-saving production methods (replacement price of stabilizer panel complete assembly, including attachment parts, is expected to be

Section through cabin structure at rear window and door (inside view, left side, looking forward). Rubber S-extrusion for retaining window is cemented to latter and to panel cutout margin, and serves as weather seal, vibration damper, and trim. Combination angle-and-Z-section crown bow member attaches to side skin and door post gusset portion.



under $35)—was the justification of a new approach in stress analysis.

Following is a comparison of design and production factors of the simplified and conventional stabilizers:

	Conventional	*Simplified*
Parts	42	9
Man-Hours	14.2	2.7
Rivets	521	160
Weight (lb.)	13	13

Now that the application of this simplified design had proved satisfactory for the stabilizer, it was decided to test the construction principles on a much larger unit—the wing panel.

Wing Structure

Conventional prototype wing was a good, typical airfoil structure of 24ST —a tapered, full cantilever unit consisting of ribs, spars, and stringers. Here, again, there were so many interlocking components, all largely inaccessible to automatic machinery, that in the main it had to be assembled almost entirely by hand; hence, it was very costly. Manufacturing of the many detail components was comparatively simple, representing only about 5% of total wing fabrication time; the other 95% was almost all assembly time.

The simplified wing is a rectangular-planform constant-thickness structure, externally braced by a single strut. Reasons underlying the change from tapered to rectangular-planform were as follows:

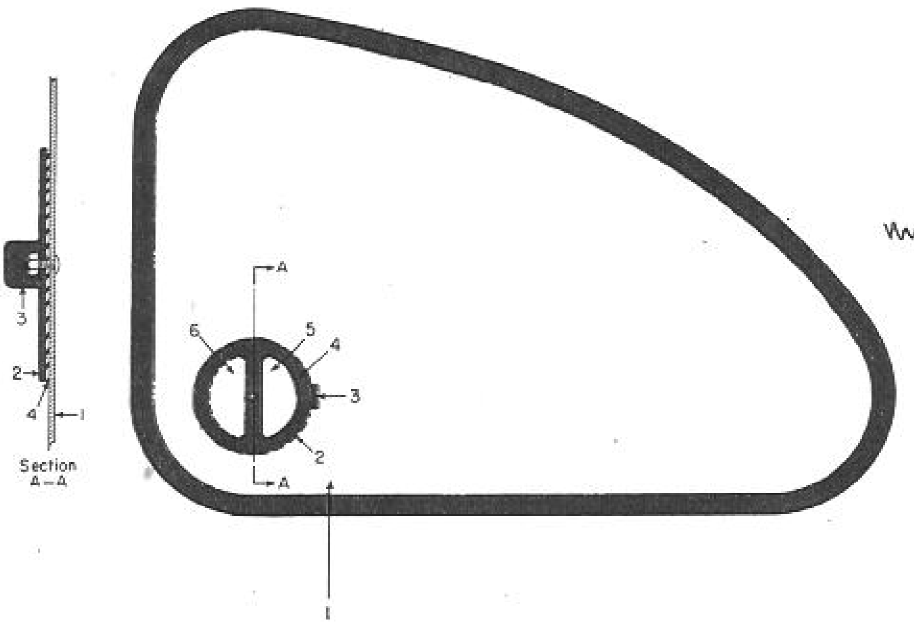
(1) Skin becomes a rectangular sheet, and in bending it to the form of the wing, material losses ordinarily occasioned with a tapered wing are avoided.

(2) A single forming tool can be used for all skin sections on both l. & r. wing panels, whereas on a tapered wing, each skin section requires a separate forming tool, and a different set of tools is required for the opposite wing.

(3) A single tool can be used for fabricating spars in l. & r. panels.

(4) Exact width strip-stock can be used for the spars, since the flat pattern

View of cabin through right side door revealing roomy interior. Seat back cushions are detachable for use as life preservers.



View from outside of cabin side panel window showing simple plastic ventilator installation in closed position: (1) Window, (2) ventilator, (3) ventilator handle, (4) rubber gasket, (5) cutout in window, and (6) cutout in ventilator.

of the unit is rectangular. This avoids material losses and additional operations required for the tapered spar.

(5) Rectangular-planform wing permits flaps and ailerons, and their hinges and brackets, to be interchangeable l. & r., thus eliminating the need for separate tools and material losses attendant with the tapered design.

All of these considerations are extremely important in a simplified structure. In contrast, small differences between two assemblies of a conventional design (such as non-interchangeability of l. & r. skin sections) were not of much consequence, since this condition required only a new set of parts and tools—representing but a negligible portion of total manufacturing costs which were, largely, consumed in assembly handwork. However, in the simplified design—in which handwork has been greatly eliminated—small differences which require additional tools and prevent the use of components interchangeably, add considerably to the cost of the structure.

Simplified wing framework consists of 3 ribs and 3 spars. Ribs are approximately $8\frac{1}{2}$ ft. on centers and spars are approximately 15 in. on centers. Inboard rib is a 2-piece member—nose rib and after-portion. Center rib is made up of 3 pieces intercostal between spars. Outboard rib is a single member providing for the attachment of wing tip by incorporating a wide flange.

Front spar, supplying about 90% of wing bending strength, is an .064 channel constant throughout the span and having straight flanges turned on a bending brake. Extruded angles of 14ST are nested in top and bottom flanges and extend from inboard end approximately three-quarters of the span towards the tip. A simple forging is used on the

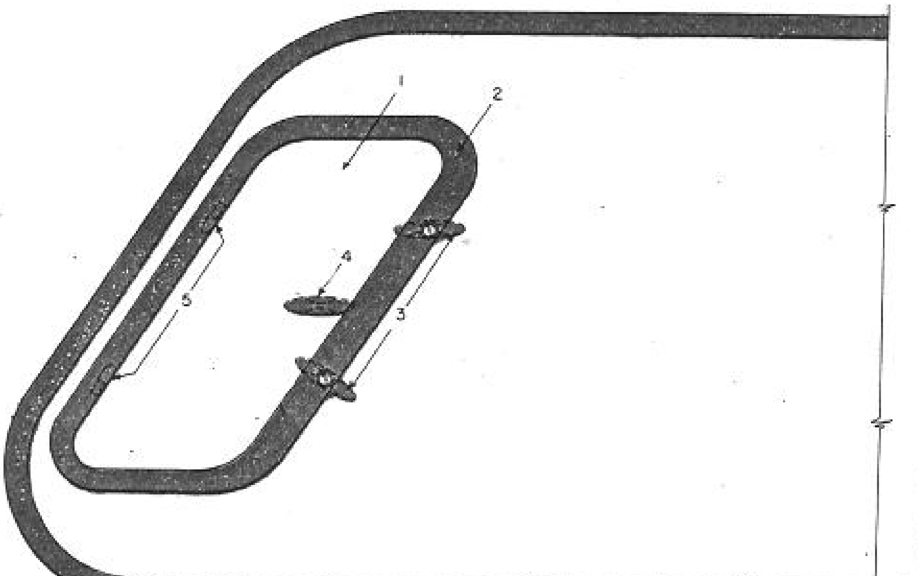
FUNDAMENTAL DESIGN DATA

GENERAL	
Model	RC-3
Type	Amphibian monoplane
Seating	4-place
Construction	All-Metal
Flight instruments	Basic CAA and ball bank
Radio (two-way)	Tower and range
Propeller	Ground adjustable (Reversible pitch propeller optional)
POWER PLANT	
Make and model	Franklin 6A8-215-B8F
Hp. and rpm	215 at 2,500
Fuel used at cruise	13.5 gal. per hr.
PERFORMANCE	
High speed	120 mph.
Cruising at 75% power	103 mph.
Landing speed	58 mph.
Climb, first minute	700 fpm.
Range at cruising	560 mi. (75 gal.)
Full load condition:	
Takeoff, land	800 ft.
Takeoff, water	1,000 ft.
Takeoff time, water	25 sec.
Landing run, land	400 ft.
Landing run, water	700 ft.
WEIGHT	
Gross	3,000 lb.
Empty	1,950 lb.
Useful load	1,050 lb.
LOADING SELECTIONS	
2 people (pilot & passenger)	340 lb.
75 gal. fuel (5.5 hr. at cruise)	450 lb.
3 gal. oil	20 lb.
Baggage	240 lb.
Total	1,050 lb.
3 people (pilot & passenger)	510 lb.
71 gal. fuel (5.3 hr. at cruise)	426 lb.
3 gal. oil	20 lb.
Baggage	94 lb.
Total	1,050 lb.
4 people (pilot & 3 passengers)	680 lb.
45 gal. fuel (3.3 hr. at cruise)	270 lb.
3 gal. oil	20 lb.
Baggage	80 lb.
Total	1,050 lb.
DIMENSIONS	
Span, max.	37 ft. 8 in.
Length, max.	28 ft.
Height, max.	9 ft. 7 in.
Wheel span, main gear	8 ft.
Cabin width, interior	46 in.
Cabin height, interior	50 in.
Cabin length, interior	110 in.
Baggage compartment	20 cu. ft.
Draft, loaded	18 in.

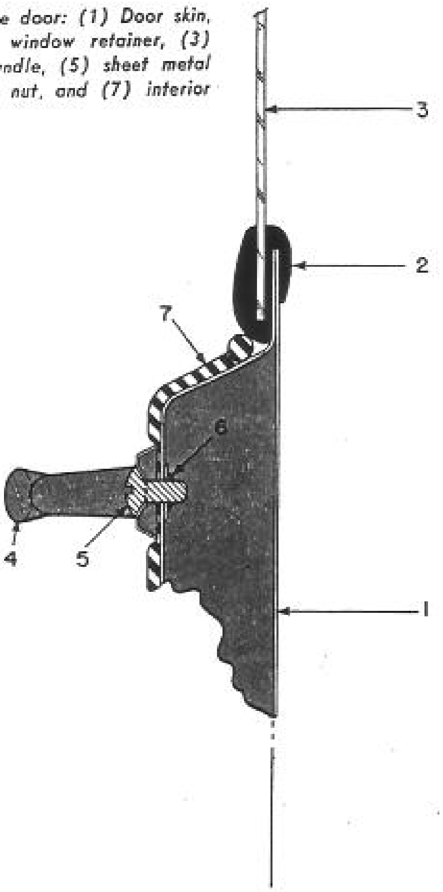
COMPARATIVE DATA

Conventional vs. Simplified

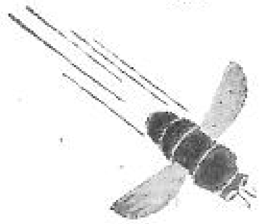
	Conventional Prototype	Simplified Design
Passengers	3	4
Wing area (sq. ft)	171	196
Gross weight (lb.)	2,900	3,000
Weight empty (lb.)	2,130	1,950
Airframe weight (lb.)	1,260	1,140
Airframe parts	1,800	450
Airframe fabrication time (man-hours)	2,500	200
Airframe tool cost at 5,000/yr.	$1,750,000	$350,000



Details of cabin clear-view panel installation: (1) Clear-view panel, (2) plastic frame, (3) lock knob, (4) pull handle, and (5) plastic hinge pin.



Part-section through side door: (1) Door skin, (2) rubber S-extrusion window retainer, (3) window, (4) pull-to handle, (5) sheet metal screw, (6) sheet metal nut, and (7) interior trim.



inboard end of the spar to make attachment to the cabin structure. Attachment for brace strut is accomplished with another forging at the center rib.

Middle spar—essentially a false spar—is an .032 channel member fabricated in a manner similar to the front spar, but has no angle attachments.

Rear spar is a simple .051 channel member having a forging at the inboard end for attachment to the cabin structure.

Between front and middle spars, at about one-quarter the distance from the middle to the tip, is the wing float supporting structure consisting of two pressings forming a socket for the float strut.

All spars are of R-301W material. Lightening holes have simple 45 deg. flanges formed without subsequent heat treating. Because of severe forming, ribs are fabricated of 24SO, and are subsequently heat treated. Rib lightening holes have deep drawn flanges.

Wing skin, with beading similar to that on the stabilizer, is R-301W—.032 on inboard half and .025 on outboard half. Skin sections are pressed on a camel-back draw die, similar to the method used for the stabilizer skin.

In assembly of the wing, skin sections are first spliced on an automatic riveting machine to form a large envelope. Spars are installed progressively, beginning with the front spar, and riveting is done on an automatic riveter afforded access to interior of envelope from rear opening. Rivets are driven through both upper and lower skins and through spar flanges at same time, in about 8 min. Wing tip is quickly installed on outboard rib with sheet metal screws and self-locking sheet metal nuts.

External wing brace strut is a single piece of .091 R-301W turned on itself to provide a streamlined section joined at the trailing edge, on an automatic riveter, along outwardly turned flanges. Extruded fittings on each end of the brace strut carry one bolt for attachment to wing and hull, respectively.

Wing floats are R-301W .051 skins formed in a novel manner. Each float is of fully monocoque construction consisting of l. & r. pressings (clamshells) joined at the plane of symmetry along outwardly turned flanges adaptable for external automatic riveting. The strut connecting the float to the wing slips into a neck section provided in the pressings. Complete float assembly consists of but five parts—two skin sections, two bearing plates for strut bolts, and a drain plug—and can be fabricated in 15 min. This is in sharp contrast to conventional wing floats with numerous bulkheads which are fastened to the skin by reaching through access holes and driving each rivet by hand.

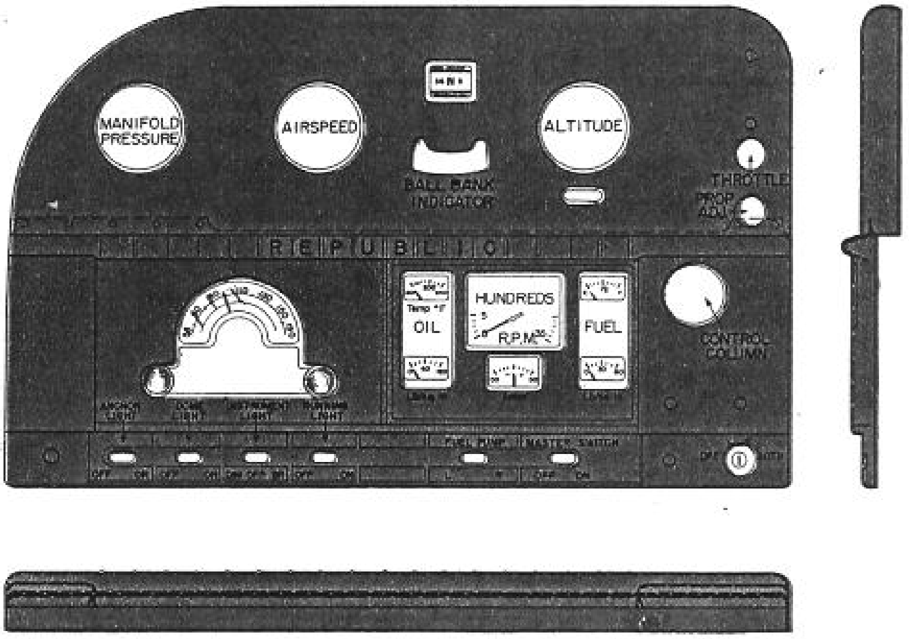
In this simplified wing design, notable lightness is achieved. Complete with flaps, ailerons, brace struts, and miscellaneous fittings, it weighs but 1.45 lb. per sq. ft.—unusual, considering that the average wing loading is 16 lb. per sq. ft.

Basic makeup comparisons of conventional and simplified wing structures are listed below:

	Conventional	*Simplified*
Parts	114	30
Man-Hours	280	10
Rivets	2,627	882
Weight (lb.)	150	110

In static test, the wing sustained a load of 115%, and in torsional rigidity was four times greater than CAA requirements. Another unusual characteristic of the wing structure was that no skin ripples or buckles appeared up to 100% of design load—a condition rarely achieved in a conventional metal wing structure.

These very satisfactory results obtained with the large wing structure justified the application of this theory of



General aspect of instrument panel. Manifold pressure gage (not standard equipment) is used in connection with controllable pitch propeller installation (optional). In addition to units designated on panel, other devices installed are pulls for parking brake, carburetor mixture, and carburetor heat, signal lights for landing gear position, and microphone.

simplified and cost-lowering design.

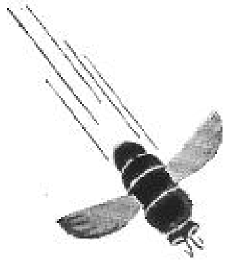
And as a result of the attendant production advantages, cost of replacement for a wing panel complete assembly, including attachment mechanism, is expected to be under $250.

Movable Surfaces

Except for size and shape, the full-slotted flaps, ailerons, elevators, and rudder are fundamentally identical in construction. Each consists of a single beaded skin folded upon itself and joined at the trailing edge, and each has a single stamped channel spar member near the leading edge.

Flaps and ailerons have round-nose end ribs with outwardly turned flanges to afford easy access for automatic riveting.

Elevator has only one rib—inboard end—bolted to the operating torque tube extending between l. & r. units. No outboard end rib is employed because the tip is formed from the skin as a continuation of the trailing edge. The latter is cut out for a flat stock trim tab at the inboard end, the tab being attached by piano hinge.



Upper and lower tips on rudder are fabricated similar to elevator tip, hence obviating need for end ribs.

On the flap there are three ⅛-in. flat stock hinge fittings. Two are mounted on the end ribs, and the third fitting, which includes an operating horn, is mounted on a center nose rib.

On the aileron there are two ⅛-in. flat stock hinge fittings and a separate horn, which are attached to intermediate nose ribs.

On the rudder and elevator, the spar supports T-shaped extruded hinge fittings.

Since the cross-section of the aileron is identical to that of the flap, it is possible to use the flap-forming tools to fabricate the aileron skin, spar, and ribs.

Flap, aileron, elevator, and horizontal stabilizer units are interchangeable with respective opposite-hand installations. Approximate dimensions are: Flap, 9½ ft. long by 16 in. by 4 in. deep at spar; aileron, 7 ft. long by 16 in. by 4 in. at the spar; elevator (tapered in planform), 6 ft. long by 20 in. at max. chord, tapering to 10 in. at tip, by 3 in. average depth at spar; and rudder (double tapered in planform) 8½ ft. long by 18 in. at max. chord by 4 in. average thickness at spar.

Replacement prices for the various complete assemblies, including attachment mechanisms, are expected to be under these figures: Flap, $35; aileron, $50; elevator, $25; and rudder, $25.

Control system is conventional cable installation. Cockpit control is standard wheel arrangement with provision for utilizing removable duplicate wheel for co-pilot, who has rudder pedals but no brake pedals.

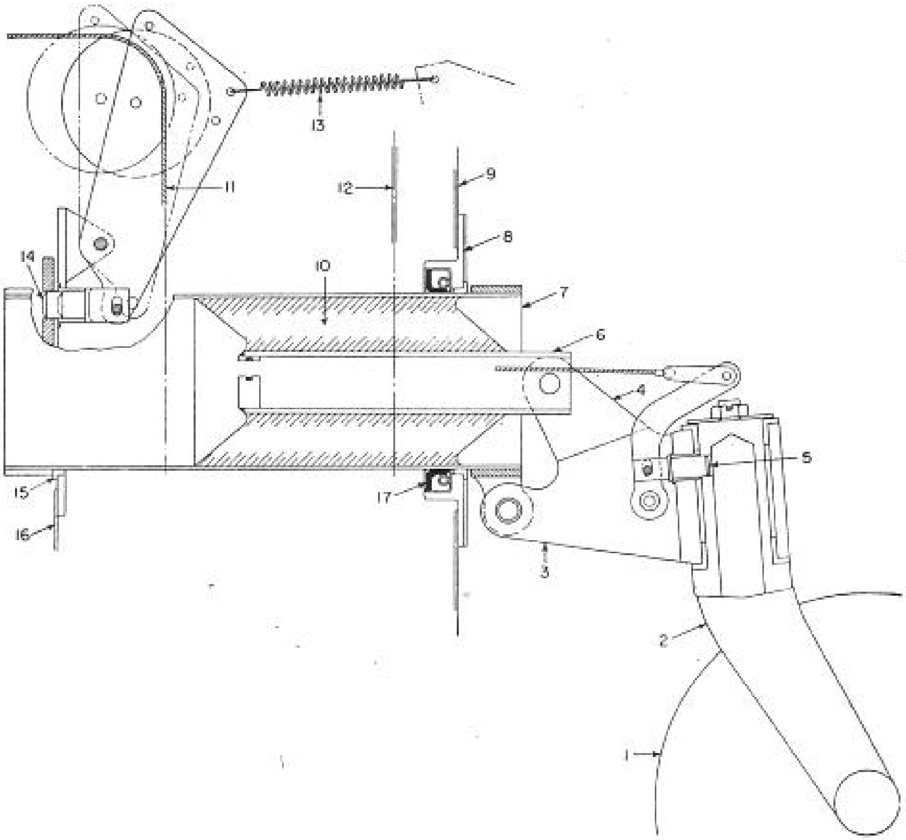
Hull Structure

The hull, designed so as to permit a major portion of riveting to be done on automatic machinery, consists of three separate assemblies—forebody, afterbody, and stern. Assembled, it has six watertight compartments—3 in the forebody, 2 in the afterbody, the stern being the last compartment.

Forebody is comprised of four subassembly units—deck (cabin floor), two sides, and bottom. Deck is made in three sections—forward, middle, and aft. Forward section is a single .051 24SO pressing, subsequently heat treated, and reinforced with 3 hat-sections (2 transverse, 1 longitudinal) supporting cockpit flight controls. Edge of this section has an upwardly turned flange for assembly to the sides by riveting.

Deck middle section is .025 R-301W stiffened by four longitudinal hat-sections supporting the front seats and landing gear brace channels. Margins of middle section are also upwardly flanged for attachment to sides and to front deck section. Attachment to rear deck is by a lap joint. Between the middle section and the sides is a ⅛-in. R-301W Z-section longeron which becomes a simple angle where it overlaps (for about 10 in.) the front and aft sections of the deck.

Deck aft section is a single .051 24SO beaded pressing, subsequently heat treated, and having upwardly turned flanges on the sides. At the rear, the aft section of the deck overlaps the forward skin of the afterbody and also the step bulkhead. A cutout is provided in the aft deck section for access to the fuel cell



Tail gear installation: (1) Wheel, (2) fork, (3) yoke lower arm, (4) yoke upper arm, (5) lock pin, (6) piston, (7) hollow retracting shaft, (8) bearing, (9) second step bulkhead, (10) rubber shock absorber secured to shaft interior and piston exterior, (11) retracting cable (wound around shaft), (12) shockcord, (13) spring, (14) down lock pin, (15) bearing, (16) forward bulkhead support, and (17) spring loaded rubber water seal. During landing, application of ground load to wheel (1) causes leftward displacement of piston (6) and rubber (10) then acts in shear to absorb force imposed. In retraction, cable (11) rotates shaft (7) to nest wheel alongside stern.

(located between middle and aft bulkheads).

First two watertight bulkheads—.040 24SO beaded pressings, heat treated—are sandwiched between the flange junctions of the deck skins.

Sides of forebody are .064 R-301W made up in three sections flanged outwardly at the chine, where it joins the bottom subassembly flange.

At the bow, forward of the front bulkhead, the bottom consists of l. & r. .072 61SW skins (made in a draw die). From the forward bulkhead to the step, the .051 R-301W skin (made on a bending brake) is reinforced by 7-hat section transverse stiffeners having greatest depth of about 4 in. at the keel. On the underside of the chine is an external reinforcing angle extending from the forward bulkhead to the step.

The keel—a T-shaped 14ST extrusion provided with drain plugs for each watertight compartment—runs aft of the first step for splicing to the keel of the afterbody.

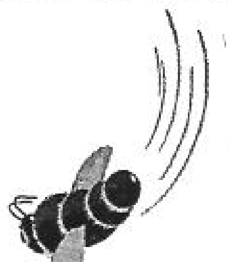
Various simple structures within the forebody serve to support the battery, hydraulic pump, and landing gear mechanism, and also provide anchorage for safety belts.

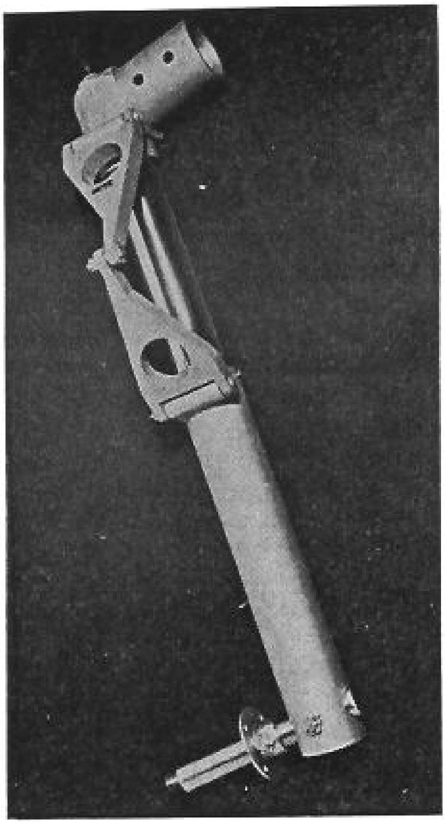
Afterbody—hull section between steps—is comprised of an upper section and the bottom as subassembly units. Upper section is fabricated from three pieces of .051 R-301W, each developable from a flat pattern, joined by simple lap joints. Rivets through the lap joint between first and second skins pick up the flange of the forward watertight beaded bulkhead.

Afterbody bottom is a single sheet of .051 R-301W (formed on a bending brake) reinforced by four hat-sections, as in the forebody.

An indication of the sturdiness of the hull bottom structure is that after more than 600 water landings, no dishing or skin ripples were observed.

The bulkhead at the second step supports the tailwheel and is formed as an .040 24SO beaded pressing, subsequently heat treated. At the lower portion of the bulkhead is a bearing plate reinforcement for attachment of the tailwheel. Flanges of the bulkhead face forward and are sufficiently wide to provide a foundation for a butt joint between afterbody rear skin and stern





Seabee main landing gear strut. New production version of this unit has simple elbow fitting for attachment to hull shaft.

skin. The splice is further reinforced at the bottom by an .051 R-301W structural fairing.

The stern consists of two subassemblies—l. & r. halves—comprising a clamshell skin structure of .040 R-301W with a cutout at the rear top portion beneath the fin. Each half of the clamshell has a single longitudinal and single diagonal Z-section stiffener, two vertical angle stiffeners for the stabilizer support, and a channel section for stiffening the edge of the cutout and to absorb drag loads from the stabilizer. All of these members are attached to the skin by automatic riveting. The clamshells are assembled with a riveted lap joint at the forward top and on all of the bottom, and at the rear they are attached to the rib-shaped closure bulkhead.

A transverse angle across the top of the cutout serves as a fitting for attachment of front spars of stabilizers and fin. Approximately 15 in. back of this angle member is a deep channel for attachment of rear spars of the stabilizers. Fin rear spar attaches to the closure bulkhead at rear of stern.

A series of tubes, one leading from each watertight compartment in the hull, are grouped in the cockpit, under the rear seat, for attachment to a bilge pump, and numerous handholes are provided for inspection and servicing.

Comparison of key factors in the construction of the conventional and simplified hulls is given below:

	Conventional	*Simplified*
Parts	362	63
Man-Hours	590	20
Rivets	6,500	2,400
Weight (lb.)	318	298

Cabin Details

Cabin lines have been established by analytic geometry. Mathematical fairing not only greatly reduced tedious lofting time, but made possible the rapid and precise manufacture and inspection of jigs, tools, and dies.

Cabin consists essentially of two main sections: (1) Rear primary structure, tying the wing and engine installation to the hull; and (2) forward section superstructure, enclosing the cabin proper.

Rear primary structure forward bulkhead—consisting of two beaded pressed sections, .040 upper and .025 lower, with a center cutout for access to the baggage compartment—supports the wing front spars and is reinforced by .064 hat-section uprights at each side. Lower end of each upright is riveted to an external fitting which connects the wing brace strut to the hull. Upper ends of the uprights connect to an inverted hat-section extrusion which serves as a crosstie between front spars of the wing panels and also supports the front end of the engine mount. Similarly, over the main step bulkhead there are two other upright hat-sections which attach to another inverted transverse hat-section connecting the rear spars of the wing panels and also supporting the rear end of the engine mount. Top of rear primary section is an aluminum-coated .019 low carbon steel firewall.

Side skin of the rear primary structure—.040 R-301W stiffened by secondary vertical channels—is comprised of two sections connected along the mating flanges at the trailing end of the cabin structure.

Forward superstructure—cabin enclosure—includes an .091 61SW crown bow member, five door frame uprights, and .040 61SW skins.

Crown bow member is a rolled combination angle-and-Z-section unit. Door frame uprights are identical to crown bow frame but for attachment to latter have gusset portion at the top. Nesting of crown bow and door frame provides effective surfaces for door sealing. The two side doors and the bow doors are .032 61SW large single-piece pressings spotwelded to an .025 outer skin.

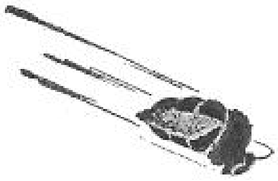
Cabin skin picks up the rivets joining the deck to the hull sides, and is also joined to the crown bow and door frames largely by automatic riveting process.

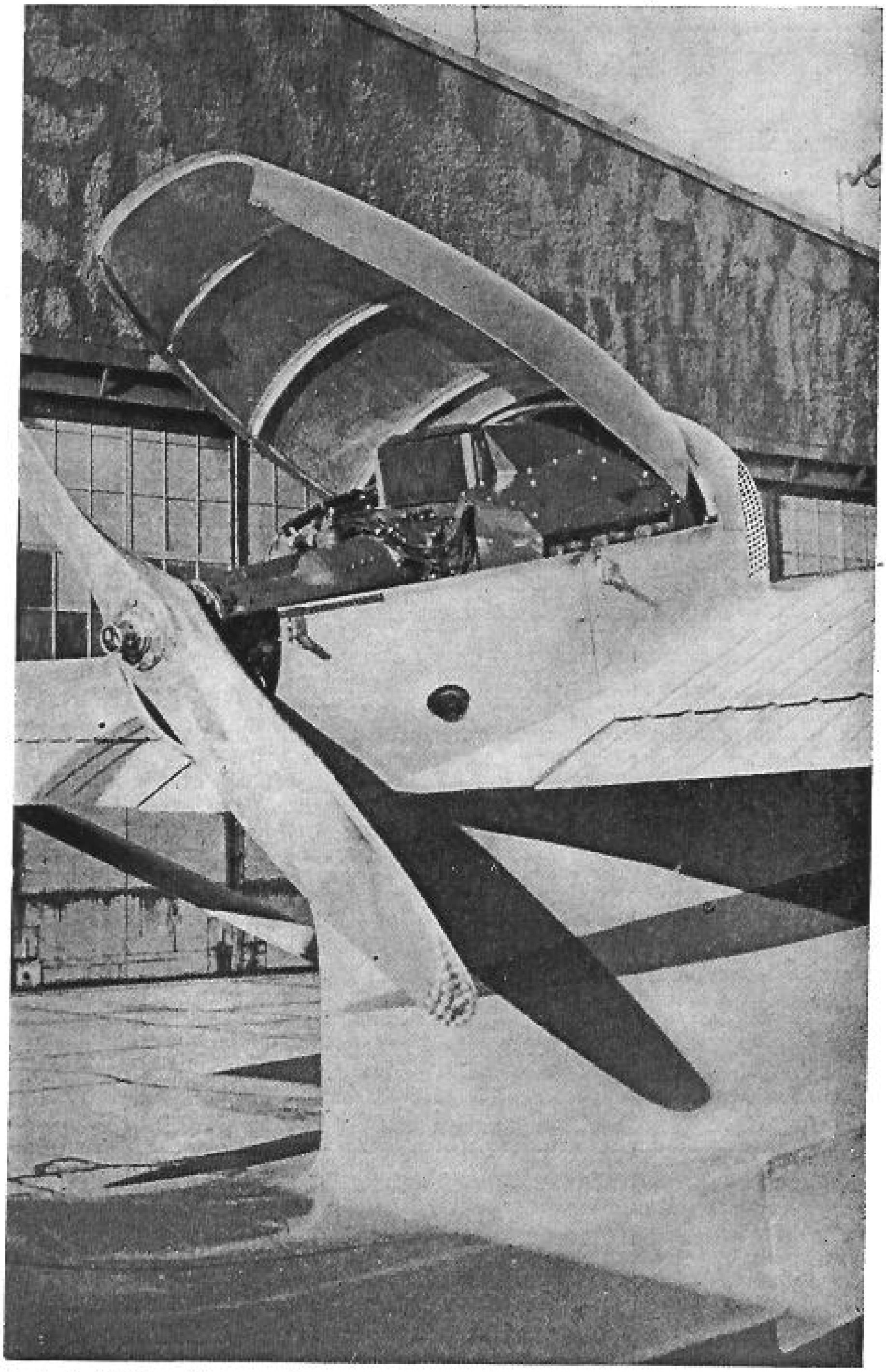
Crown skin is an .040 beaded pressing attached to the crown bow member with the same rivets which fasten the side skins.

Interior trim and upholstery is of Koroseal—waterproof, flameproof, vermin- and mildew-proof — economically utilized in various weights according to degree of service anticipated. Sponge rubber windcord, having a prefabricated edge to simplify attachment, is used for weatherstripping, color-matches the interior, and eliminates necessity of stitching on a separate fabric covering for trimming.

Cabin soundproofing is accomplished by using Fiberglas or similar material.

Retention of each the seven large double-curvature Lucite (Heath) cabin windows is accomplished with a uniquely simple Goodrich rubber S-extrusion, one loop being cemented to the pane and the other loop cemented to the edge of the cabin cutout margin. In addition to serving as a glass retainer, the extrusion functions as a weather seal, a vibration damper, and a decorative trim.





Engine installation with top cowl in open position. All cowling (top, rear side, and forward side) is removable to afford overall access to power plant. Contemplated is removal of air baffling (seen at top of engine, to right of oil cooler) and its incorporation as integral part of top cowl, thus exposing entire upper part of engine when cowl is lifted.

As far as possible, standard automotive type hardware—Cowles door handles, locks (with slight redesign), pull-to handles, and dome light—are used, with careful selection in regard to weight, strength, and cost, which factors also dictated the use of Tinnerman sheet metal screws and nuts.

The back of each Reynolds seat is quickly detachable to serve as a life preserver. Front seat tracks and adjustment mechanism are American Forging & Socket standard automotive types.

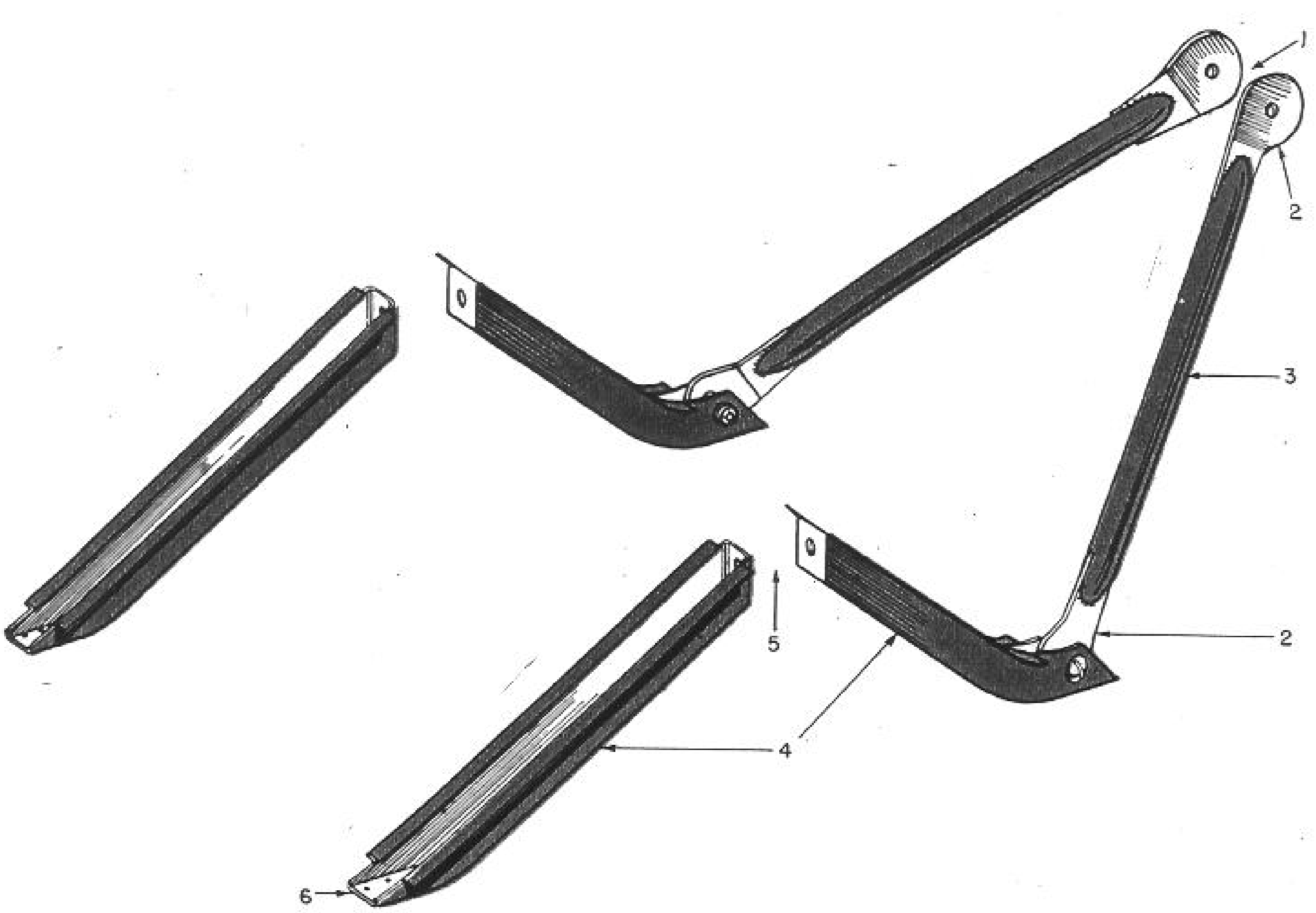
Instrument Panel

Instrument panel is located on left side of cockpit in front of pilot. A package unit in the lower right corner contains Electric Auto-Lite automotive-type engine instruments—oil temperature gage, oil pressure gage, fuel quantity gage, fuel pressure gage, tachometer, and ammeter. By removing four nuts which hold four clamps in the rear of the package, the latter may be removed into the cockpit.

Two-way Hallicrafters radio is adjacent to left of engine panel package; and by removal of four screws on underside of support shelf forward of panel, and disconnection of power supply, antenna, and phone plugs, the radio may also be drawn into the cockpit. Microphone is spring-clipped on the instrument panel and the cord passes through the panel, drawn in from behind by spring tension. Optional radio, with broadcast band and loop antenna provisions, fits the standard installation brackets without any alteration.

Flight panel package contains an airspeed indicator, magnetic compass, altimeter, and ball-bank indicator. The package is drawn into the cockpit by removal of false front by prying, then removing eight screws on the face of the panel. Optional flight panel is equipped with sensitive altimeter, bank and turn indicator, clock with sweep-second hand, and the standard-equipment airspeed indicator and magnetic compass.

The instrument panel also carries the following control switches: Cole-Hersee master switch, and Douglas or Cole-Her-



Simple and sturdy mount for Seabee's 215-hp. Franklin engine: (1) Position of rubber shock mount at rear (propeller end) of engine, (2) welded fitting, (3) supporting tube, (4) supporting hat-section, (5) position of forward rubber shock mount (on crankcase), and (6) forward attachment point to firewall and wing crosstie. Mount components are interchangeable for use on either side of engine.

see domelight, instrument light, anchor light, and running light switches. The Pollak or Bendix ignition switch is designed to control the starter by pressing the key in "Both" position. Key for ignition switch also operates cabin door locks.

Other panel controls are pulls for parking brake, carburetor heat, carburetor mixture, and throttle. Signal lights for landing gear position are also installed.

Right half of cockpit panel is omitted to provide free passage to the bow door.

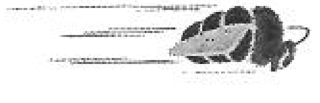
Production installation time for all electric wiring on the craft is approximately 11 min. Wires are furnished in prefabricated terminaled lengths. Spring terminal sockets on switches are used to afford push-pull connections, and knife disconnects are used where wing and tail wires join the cockpit connections.

Landing Gear

Main landing gear utilizes Electrol air-oil struts designed to have a relatively low static air pressure to facilitate servicing. Each strut is fully cantilevered from the hull side and through a bolted elbow connects with a shaft extending through the hull to the opposite gear. Hull shaft is in two sections joined at the hull centerline by a welded sleeve. Channel members at each end of the sleeve provide support by extending to the frame at the hull bottom.

Strut torque arms (scissors) are utilized as step means to the cabin, and top torque arm is designed to receive a towing hook.

Retraction and lowering of the main landing gear (equipped with Goodrich wheels and brakes) is accomplished by hydraulic power from an Electrol hand pump located between cabin front seats. Reservoir, thermal expansion valve, and selector valve (flaps are also operated hydraulically) are integral with the hand pump. A bellcrank on the center sleeve connecting the two sections of the hull shaft attaches to the upper arm of a two-arm toggle linkage; lower arm of linkage is attached to a pivot fitting on the hull structure and above this pivot point is also connected the piston of the hydraulic cylinder. Latter is in turn pivoted on a horn attached to the center sleeve. Extension of the piston breaks the toggle linkage from a past-dead-center positive-lock position and rotates the hull shaft to retract the gear. At full-up position of the gear, the linkage again comes together just past dead center to form a positive lock through contact of positioning stops at the break point.



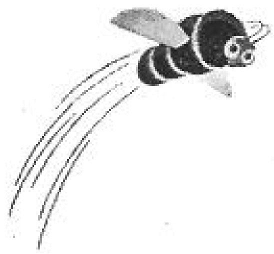
Tail wheel is full swiveling and is locked in the fore-and-aft position by a spring-loaded pin with cable connection to cockpit. The wheel is mechanically raised via a cable connection to the main gear hull shaft. Cable action pulls a lock-pin and then rotates a horizontal shaft on which is pivoted the lower arm of a two-arm yoke on the vertical tail wheel strut. The shaft rotates approximately 132 deg. to place the wheel alongside the boom.

In addition to its function to retract the tail wheel, the horizontal shaft is ingeniously designed to serve as a shock absorber for tail wheel ground loads. It is hollow and surrounds a piston attached to the upper arm of the two-arm tail wheel yoke. In the space between the piston circumference and the interior circumference of the horizontal shaft is a layer of rubber secured to the piston and shaft interior surface. Upon application of ground load to the tail wheel, the piston is displaced inwardly and the surrounding rubber acts in shear to absorb the forces imposed.

Alteration of the tail wheel design is contemplated, to render the unit steerable as well as swivable.

Engine Installation

Power plant is a 6-cyl., aircooled, wet sump Franklin engine, mounted as a pusher, located above and aft of cabin, directly over the firewall decking the baggage compartment. Mounting is essentially a three-point support. Propeller end of power plant is carried by two converging steel tubes with slotted ends welded to heavy attachment plates for bolting to an engine pedestal carrying a rubber shock mount. Attachment plates at bases of supporting tubes are bolted to .049 pressed steel hat-sections, in turn bolted to the firewall. Each of these hat-sections runs forward and up in a longitudinal plane parallel to the engine thrust line and is picked up by



a bolt in another shock mount pedestal on the crankcase. From this pedestal another hat-section on each side runs forward and down and is bolted to the firewall. Components of the mount are interchangeable for use on either side of engine.

Ground adjustable Aeromaster propeller (standard equipment) has laminated maple blades chemically sealed in the ferrule. Blade covering is black Aeroloid plastic sheeting, and Monel metal sheathing over the plastic protects the leading edge. Optional Hartzell reversible pitch propeller is pitch-changed by engine oil pressure with manual operation of valve control in cockpit.

Power plant accessories include Electric Auto-Lite starter, generator, regulator, and distributor.

Cowling

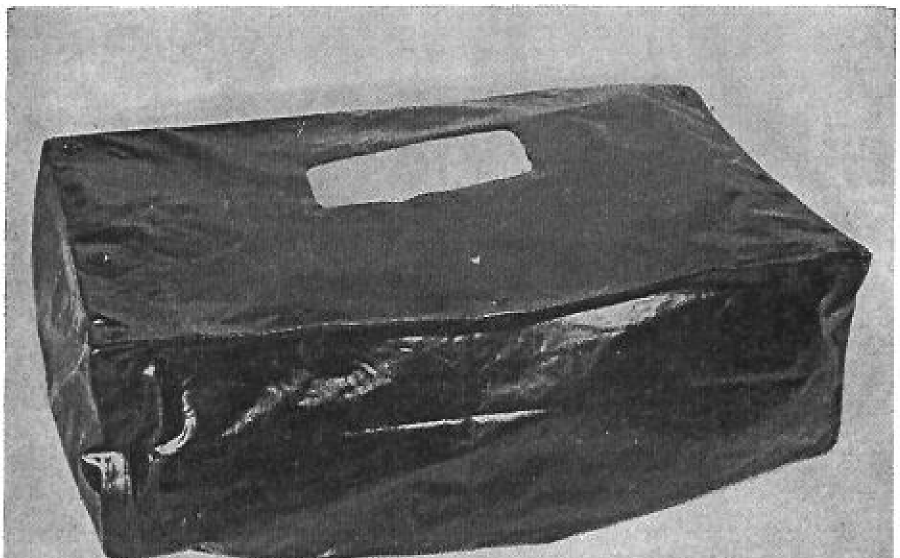
To eliminate fillets and compound curvature of the rear lower cowling, it has been constructed in two sections as simple wrapped sheets. Each section is straight at the sides and meets the wing at 90 deg. Rear of each section wraps around to meet the other section at the centerline of the craft, and attachment to cabin sides is by quick-fasteners. Forward lower cowling on each side is a straight section, also attached by quick-fasteners.

Top cowling, from propeller end forward to engine fan housing, is a single wrap-around sheet pivoted at forward end similar to an automobile hood and is held in the open position by a brace rod on each side. In closed position, top cowling is fastened with quick-latches to lower cowling. Forward of the top cowling is another top section fixed in place.

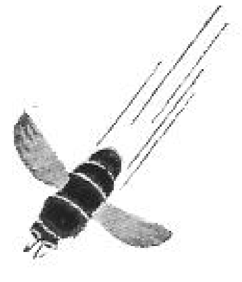
With top cowling up, and with rear side cowling removed, entire engine accessory section is accessible for servicing. Then, by detaching the top cowling by removal of a few bolts and then unfastening forward side cowling, the entire engine installation is accessible.

Fuel cell is a Goodrich bladder type bag, made of rubber-impregnated fabric, located inside the hull just forward of the main step and between two watertight bulkheads. The unit rests on a plastic sheet over the hull bottom stiffeners, and is fastened to the deck structure by snap fasteners which have sufficient play to facilitate adjustment in securing the bag to the male fastener components on the structure.

Top of the bag is provided with an opening approximately 5½ by 12 in. over which a metal cover plate carrying the filler neck and fuel level gage is installed by bolting to the bag and also to the deck skin, which has a corresponding cutout for removal of the fuel cell. A drain at the bottom of the cell connects to a pipe which runs behind the main step where it is fitted with a drain plug.



Fuel cell—rubber impregnated bladder type unit—has cutout for attachment of plate carrying filler neck and fuel level gage.



Acknowledgment: The editors of AVIATION are grateful for the cooperation of the management and engineering departments of Republic Aviation Corp., Farmingdale, N. Y. Particularly credited is A. Z. Boyajian, structures project engineer, Seabee Div. Others who generously cooperated are H. Lasker, plant manager; V. H. Springford, superintendent of production; and engineers G. Hildebrand, body; R. F. Yee, power plant; C. S. Aldrich, landing gear; and J. E. Glover, jr., equipment.