The Sikorsky S-40 Amphibion;
A new giant for the Pan American fleet

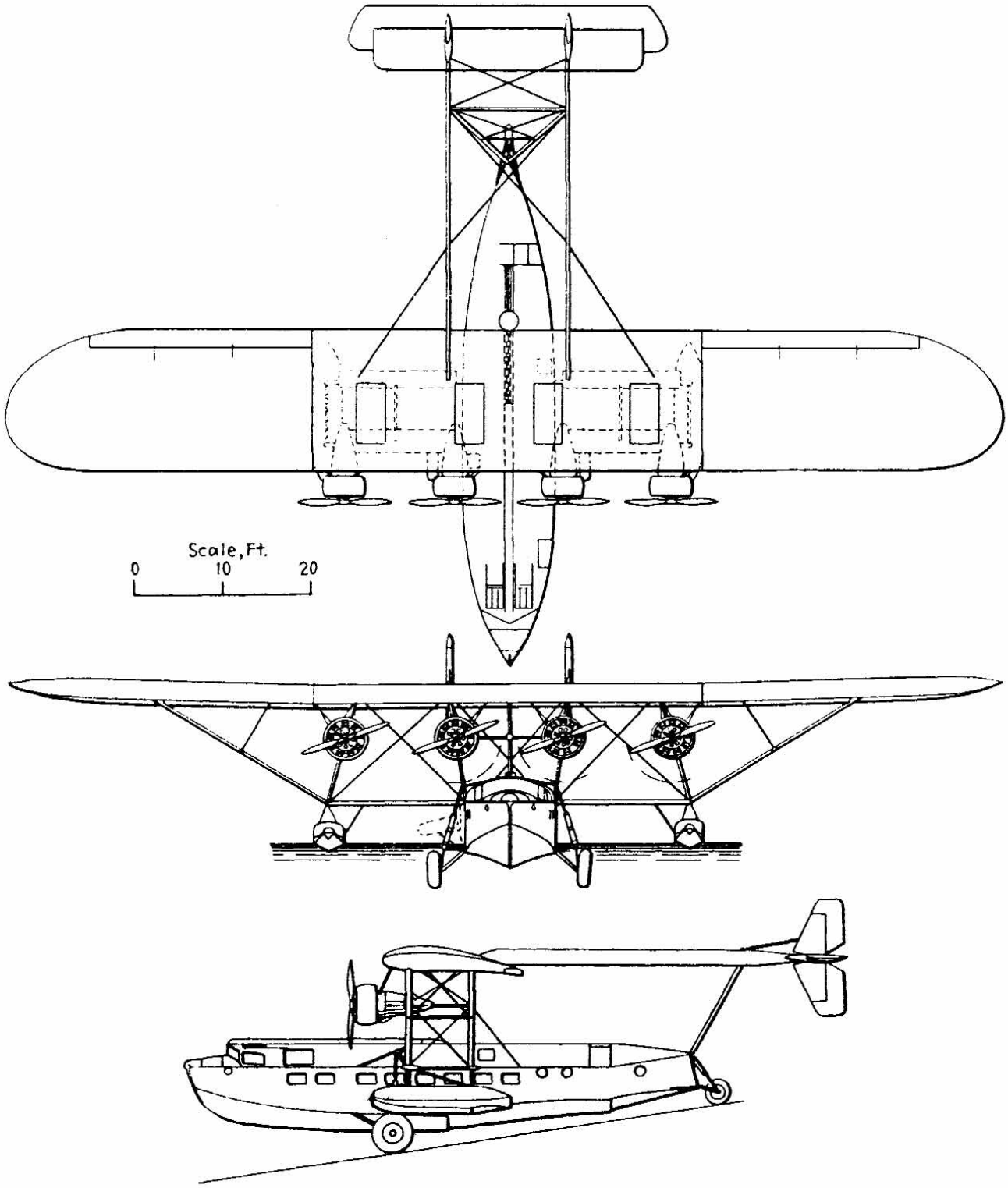
S-40 "American Clipper," NC80V, taking off. It was the first "Clipper" in the Pan American fleet being delivered on October 31, 1931. (Pan American photo from the Al Hansen collection)

[Editors Note: This article is taken from a Sikorsky reprint of an article that appeared in Aviation*, October 1931. Certain words, such as "amphibion" have been left in their original spellings that were common at the time.]*

Following almost immediately on the close of the World War, certain European nations, foreseeing the possibilities which aerial transport offered in binding more closely together the far-flung units of their colonial empires, encouraged the establishment of experimental airlines between certain strategic points, lending their assistance to private enterprise in the form of substantial subsidies. Today, England, France, Germany, and Holland have either surveyed, or put into actual operation, direct air connections to practically all of their outlying possessions. During the early 1920s progress in the United States lagged behind that abroad due largely to the unwillingness of the government to support operations by granting direct subsidies. Since 1927, however, development has been rapid, and in 1931 the American controlled airways, both in the United States and in Central and South America, are second to none.

By processes of merger and consolidation a number of independent airway systems are now in existence in various parts of the world, each having been shaped to meet the several needs of the nation controlling it. Here and there, where geographical conditions permit, these lines make contact, permitting passengers and goods to be transferred from one system to another, but, more often than not, they are widely separated by natural barriers of ocean or mountain range over which regular flying operations have hitherto been considered impractical. It is only natural, therefore, that the various networks, having worked out their individual problems, should turn to the greater one of interconnection, and the establishment of world-wide trade routes of the air.

One of the most important, and at the same time, one of the most difficult interconnecting routes is that between Europe and North America. With a view toward the establishment of mail and passenger schedules over the Atlantic, Pan American



Sikorsky S-40 *Amphibion*

A Pan American Sikorsky S-40 on its way to the Dinner Key Terminal in Miami, Fla., in 1932. (Pan American photo from the Al Hansen collection)

Airways has been making an exhaustive study of means of connecting with the Imperial Airways via Bermuda and the Azores. They have, during the last four years, acquired considerable experience and equipment for the relatively long over-water jumps between the United States, and Central and South America. Their equipment has been limited, however, to airplanes of a gross weight of 7 or 8 tons, and a cruising range of about 500 miles, but nothing has been available to compare with the long-range flying boats developed by England for the India-Australia, or the South African routes. Although present schedules do not yet afford sufficient passenger volume to justify the purchase of airplanes of a comparable size, it was considered that a requirement for long over-water flights with heavy loads was sufficiently imminent to warrant the authorization of two experimental amphibion [sic] flying boats of a size far beyond any which had hitherto been designed and built in the United States.

Since there has been no gradual development from smaller units to ones of the size contemplated it was necessary to hurdle in one jump the gap between the design of an amphibion of 8 tons gross weight, and one of 17 tons. An order was placed with the Sikorsky Aircraft Corporation, however, for the first two machines of this displacement, the first of which has been successfully test flown, and is now ready for delivery. Neither of the boats is intended for trans-Atlantic service, but they will be commissioned on the 1300-mile over-water route between North and South America where their performance will be closely studied with a view toward the development of equipment for the longer trans-oceanic flights. Both purchasers and designers showed some boldness in attacking the problem of the financing and building of airplanes on such a scale at the present time.

General Specifications

The Sikorsky S-40 is a high-wing monoplane amphibion of the same general type as the well-known S-41, which is characterized by the carrying of the tail surfaces on a pair of outriggers. Four Pratt & Whitney direct-drive Hornet engines of 575 hp each mounted as tractors in nacelles hung below and forward of the leading edge of the wing furnish the power. A single vee-bottom hull containing all accommodations for passengers and crew is supported below the wing. And a pair of outrigger floats provide stability on the water. Fully retracting landing wheels and tail wheel have been provided, but the machine may be flown as a flying boat with considerable improvement in performance, and with some 1800 lb. of additional payload available. The general arrangement of the machine and its overall dimensions are shown in the three-view drawing. Rigged as an amphibion, the expected net weight empty is 21,500 lb., which, with a designed gross loading of 34,000 lb., allows some 12,500 lb. for useful load. On the basis of the gross weight, the wing loading is then 18.2 lb. per sq. ft. and the power loading 14.8 lb. per hp. With accommodations for 24 passengers the S-40 is expected to have a range of approximately 950 miles, and with the maximum load of 40 passengers, a useful range of about 500 miles. On test flights with full load the machine has attained a high speed of better than 130 mph, cruises at 110 to 115 mph, and lands at approx-

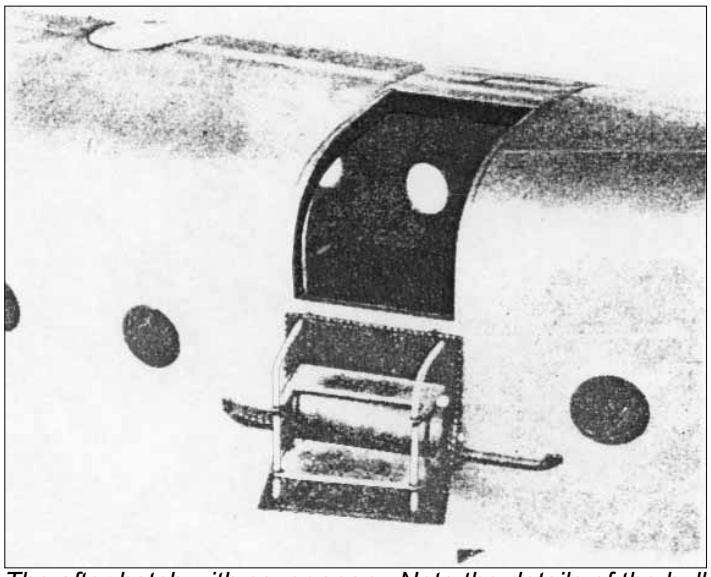
imately 65 mph. A rate of climb of 712 ft. per min. was obtained, and an absolute ceiling of 13,500 ft. is predicted. A ceiling of 6,500 ft. has been reached with full load on three engines, and level flight at 2,000 ft. has been maintained on two engines with a gross loading of 29,000 lb. With 34,000 lb. gross the plane attained an altitude of 5,250 ft. in 10 min. Engineering tests on the S-40 rigged as an amphibion and carrying a 14,300 lb. useful load are expected to be completed by September 1, 1931, and it is expected that the first machine will be ready for delivery to the Pan American Airways some time before October 1, 1931. [The aircraft was delivered October 31, 1931.]

Hull and Wing Floats

In the preliminary work of hull design for the S-40 (which dates back to April 1929) twelve models of varying shapes were exhaustively tested for aerodynamic and water-running characteristics. Part of this work was carried out in the Washington Navy Yard towing basin, but the greater part was done in the Housatonic River by towing models alongside a motorboat (page 288, *Aviation*, May 1931). In the accepted design the vee-bottom has two steps, one located approximately at the mid-point of the 58-ft. hull, and the after step about ten feet from the sternpost. The portion of the bottom just ahead of the after step has been given a decided throw-down, and the keel line aft of the rear step slopes sharply upward to give adequate water clearance when the machine is running on the step. The side plating is vertical, and perfectly flat from chines to gunwales. The decking over the cabins is well rounded from gunwale to gunwale, and is practically level along the top longitudinal chord for the greater part of its length. It is rounded down over the cockpits, and tapers down to the sternpost in a turtle-deck aft of the rear step bulkhead. A short section forward of the cockpit is carried well below the main deck to permit adequate pilot access to the anchor. The displacement of the hull is 109 tons.

The construction is all-metal, incorporating extruded duralumin shapes and Alclad sheets, assembled with dural rivets. The principal structural member of the hull is a deep girder type keel to which the built-up transverse frames are attached at relatively short intervals. Light stringers spaced on short centers interconnect the transverse frames. Six plate-type bulkheads, each equipped with a watertight door, divide the hull into seven water-tight compartments, any two of which may be completely flooded and the plane remain afloat. At the point where the rear wing trussing transfers its load to the hull a skeleton type bulkhead has been substituted. The framing at this point is made up of heavy round dural tubing assembled by means of special fittings. It will be surrounded by a light, non-watertight partition. The construction is shown in one of the accompanying illustrations Gunwales are deep duralumin channels mounted with flanges upward, and with webs drilled out for lightness. The hull plating is riveted directly to the transverse framing, and is reinforced longitudinally by angle stringers. All seams were sealed with fabric and marine glue during assembly.

Three generous-sized hatchways give access to the interior of the hull. The after hatch is designed to be the main entrance, and is located so that passengers may embark either from a tender, or from the ground. The cover swings outward and downward to form a short series of steps for the convenience of the passengers. The other two hatchways are for emergency use, or for the loading of unusually bulky cargo. Four circular ports and eight rectangular windows are provided in each side. The latter are large enough for emergency exit purposes. They are closed with non-shatterable plate glass in frames so arranged that they can be swung outward from the bottom to afford ventilation. Extra reinforcement has been included around the window openings in the hull plating to reduce the possibility of windows being wedged shut in the event of a crash.

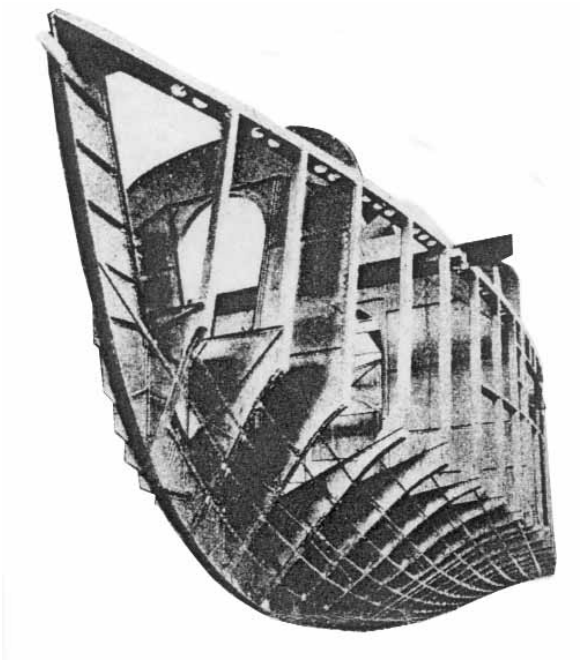


The after hatch with cover open. Note the details of the hull plating and the mounting ring fitted in the deck for the carriage of a spare engine. (Sikorsky photo from Aviation*)*

Incorporated in the hull structure are several interesting and novel features. A rectangular conduit housing the engine control cables and pulleys is located over the cockpit and cabins outside the hull proper. This arrangement permits easy access to the controls without disturbing the hull structure or cabin linings. A short distance aft of the end of the conduit, and just forward of the after hatchway, an engine-mounting ring is built into the cabin roof structure. Normally a circular cover preserves the continuity of the deck line, but in cases where a spare engine is required at some outlying repair station, the cover may be removed, and the engine bolted down to the mounting ring in the deck. This construction affords a very convenient way of transporting such spare equipment in emergencies without sacrificing cabin room, or without the need for complicated handling arrangements to lower an engine into the hull.

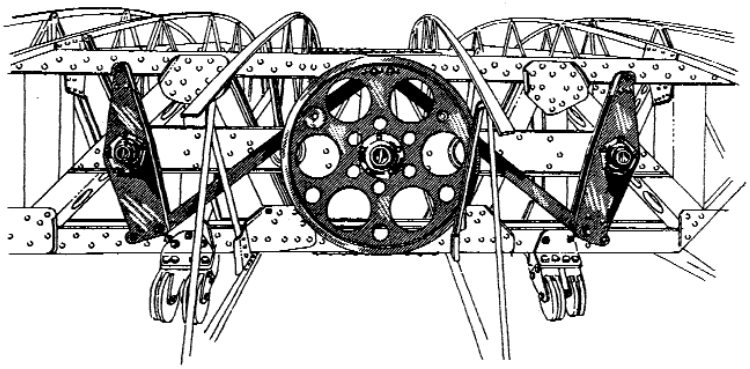
Retractable landing lights are set in the side plating of the hull ahead of the cockpit, and a small hatch in the forward decking gives access to the anchor which can be drawn up into the hawse pipe conveniently by one man using a small wench. A bumper of the usual Sikorsky type is fitted at the bow.

The wing floats are of the same general construction as the



Bow view before plating showing hull lines, and construction of the keel, transverse framing and bulkheads. (Sikorsky photo from Aviation)

main hull, being made up of duralumin framing members covered with Alclad sheet. They are also of the vee-bottom type, with a single step. The most interesting feature is the incorporation of a 246-gal. gasoline tank in each. The tanks have the same width and cross-section as the deck of the float, and the central portion of the decks between the points of attachment of the supporting strut fittings is recessed to form a sort of saddle into which the tanks fit to complete the deck-lines both laterally, and fore and aft. Since the tanks are not integral with the floats there is little likelihood of loss or contamination of gasoline due to damage when taking off or landing. The floats are carried on streamlined horizontal struts, which extend outward from the hull, and form a portion of the wing truss system. A typical outboard fitting is shown in an accompanying sketch. The submerged displacement of each float is 7,250 lb. and their effective righting factor is 4.2 with full load.



Differential control for aileron on rear spar at the center section. Cables from cockpit are fitted around sheave and double aileron cables attach to yoke arms. (Sikorsky drawing from Aviation*)*

Wings and Tail Surfaces

The monoplane wing of the S-40 is made up of a center-section with a spar of 44 ft. fastened directly to the hull and carrying the tail outriggers and the four engine nacelles, and two tip sections, each 34 ft. 11 in. long, making the overall wing span 114 ft. The framing is built up of extruded duralumin sections, and formed dural sheet with a certain amount of steel plates at various fittings. The entire structure is fabric-covered with the exception of a metal skinned portion of the center section over the engine nacelles.

The wings are of the conventional two-spar type. The front and rear beams are of a deep girder truss construction made up of extruded channel flanges and formed sheet channels, connected by gusset plates. Drag struts of similar construction connect the two beams at frequent intervals. The ribs are built up of extruded tee and channel sections, the former being used for cap strips, and the latter for web bracing. Inset ailerons of the balanced type are mounted in the tip section. A false spar carrying the aileron hinges is supported by cantilevered brackets extending outward from the rear spar at each drag strut. All aileron hinges, as well as all other hinges and control pulleys on board, are ball bearing.

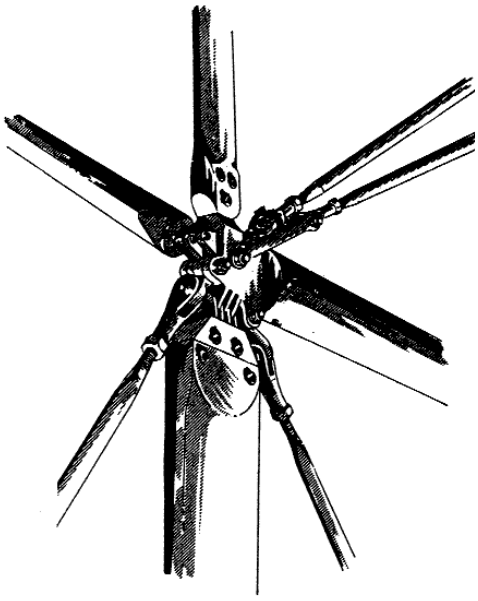
The aileron control is of the cable and pulley type, the cable from each aileron running in toward the center section just behind the rear spar. Within the center section the cables are attached to a pair of yokes, which in turn are connected by links to a large sheave as shown in the accompanying sketch. Control wires from the cockpit come up through the roof of the hull. Rotational movement of the sheave produces a rocking motion of the yokes, which is transmitted by the cables to the ailerons.

Tail surfaces are of the familiar Sikorsky type, including fins and rudders of special airfoil section to correct for unbalanced slipstream effects due to stoppage of one or more engines, and are of the same general construction as the wing, being fabric-covered over dural framing. Counterbalancing is employed on both elevators and rudders, and stabilizer adjustment is obtained by rotating the entire tail assembly, including the fin and rudder, about point of attachment to the outriggers.

The latter differ materially in construction from the usual Sikorsky fabric-covered lattice type. They consist of duralumin box girders built up with plate webs and zee bar flanges. Numerous longitudinal and transverse angles are riveted to the inside surfaces of the web sheet to secure stiffness. In order to make this type of construction feasible, each boom was made up in symmetrical halves and assembled by placing them together and riveting up the outside legs of the top and bottom flange zee bars.

The Power Plant

The four Hornet engines are mounted in dural-framed nacelles cantilevered out from the wing trussing system below and ahead of the leading edge. Each nacelle is well streamlined and its engine surrounded by a Sikorsky type ring cowl. Two-bladed Hamilton Standard propellers, 10 ft. 6 in. in diameter are driven

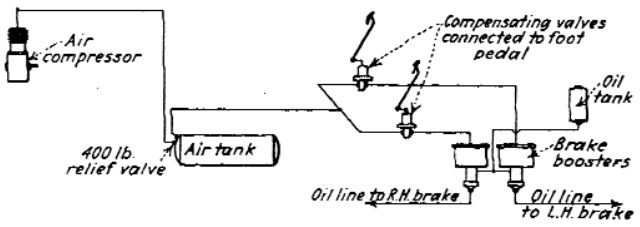


A typical fitting. Outer lift strut and wing float brace joint with fairing removed. (Sikorsky drawing from Aviation*)*

directly by each engine.

The fuel supply of approximately 1,080 gallons is carried in six tanks, four of which, of 147-gal. each, are located within the wing immediately above each engine nacelle, and two others, each of 246-gal. capacity, are located in the wing floats as described previously. Fuel lines are so arranged that any engine or group of engines may be fed from any one or any group of tanks values. Fuel pumps are located outside the hull and are operated by remote control. It is thus impossible for gasoline fumes to enter the cabins and cause discomfort to the passengers. This feature makes possible also the permitting of smoking in the cabins without danger of fire. Electrically driven pumps, located at the float tanks, raise the fuel to the wing tanks as required. A hand pump is provided for use in case of failure of the electric pumps. The float tanks are provided with self-closing dump valves, so that their fuel load may be jettisoned wholly, or in part, in case of emergency. Individual lubricating oil tanks are mounted in each nacelle.

All engine controls pass from the pilot's cockpit through the conduit in the roof of the hull from which they lead upward to the center section of the wing through a streamline housing. From the center section the controls are distributed to the various engines by double cables carried along the front face of the forward wing spar. Over each point of attachment of the engines the controls are diverted downward, into the nacelle by means of an ingenious arrangement of yokes and sheave segments bracketed to the front spar. It is interesting to note the use of heat-treated dural castings for various parts of the control system. All such castings and all forgings or fittings carrying loads of any sort in all parts of the plane were subjected to X-ray examination before being installed.



Schematic diagram of brake system. (Drawing from Aviation*)*

Amphibion Gear

The amphibion gear supplied with the first S-40 is of the usual Sikorsky type, of relatively great size. The two main wheels are of wire spoke construction and carry hydraulically operated brakes similar in design to those used on the S-38. Due to the high pressures required to operate brakes of this size, a servo system has been introduced whereby the hydraulic brake system is actuated by compressed air, which, in turn, is controlled by valves at the brake pedals. The elements of the braking system are shown in one of the accompanying figures.

As in other Sikorsky models, the main wheels are retracted clear of the water but remain in the air stream. Each is fitted with a combination Sikorsky oleo and retraction strut. The oil required for operating the struts is supplied from a storage tank through an engine-driven gear pump. A hand-operated pump is available in the cockpit for emergency use. One minute is required to fully retract the undercarriage by hand. The tail wheel is also retractable, and operates in conjunction with the main wheels. A reminder of the great size of the S-40 is given by the fact that the tail-wheel employed is a standard landing wheel for the S-38. The main landing wheels of the S-40 are equipped with 58x14-in. tires, each wheel and tire alone weigh 600 lb.

Accommodations

The arrangement of the pilot's cockpit is quite conventional. Space is provided for radio equipment and an operator, as well as a mechanic. The two pilots sit side-by-side with complete dual controls. A full set of navigational instruments is available for both. A passageway between the two seats gives access to the anchor compartment. A throttle control of unique and ingenious design which is shown in one of the accompanying photographs is suspended from the cockpit roof between the two pilots. With this arrangement either may, with one hand, control all the engines singly or together, or in any combination that he may choose. The two lower handles are connected to the outboard engines, the two upper ones to the inboard engines, and by grasping the two sets of split handles in the center, all four may be throttled simultaneously. An adjustment, not shown in the picture, makes it possible to synchronize the throttle setting of all engines while the plane is in flight. One of the most important problems from the standpoint of passenger comfort is reduction of noise, for which purpose the entire cabin is being lined with a thick blanket of insulating material between the outer shell and the inner paneling. Observers on board the plane during its trial flights reported that, even without any insulation in the cabin wall, the internal noise was greatly below the level of that in the average transport airplane and that very little vibration was experienced. Because it is believed that a certain amount of vibration enters a hull from outboard propellers, special reinforcement has been

A 1931 photo of an S-40 flying off the Florida coast. The S-40 had 38 seats and a maximum gross takeoff weight of 34,000 lbs. (Pan American photo from the Al Hansen collection)

provided in the skin of the hull in the section which lies in and adjacent to the plane of rotation of the propellers. Other factors which are planned to lessen objectionable vibrations in the cabin are the relatively remote location of the power plants, and the vibration-absorbing capacity of the relatively large mass of the structure. A well-equipped galley, including electric range and a refrigerator, has been installed, and separate lavatories for men and women are provided. It is not the intention to operate the plane crowded to absolute capacity in passengers, but rather to limit the accommodations to the point where each passenger has adequate room to sit or move about in the greatest possible comfort.

Particular attention has been given to the selection and arrangement of the furnishing and fittings of the cabins. Every scrap of material that has been used inside the hull has been made fireproof by chemical impregnation.

Decoration

The problem of interior decoration was placed in the hands of Mrs. Guy Murchie, who has made the furnishing of aircraft her hobby. She has made a study of suitable colors and fabrics, and has made a large number of experimental arrangements to determine the most appropriate combinations for the S-40. She was allowed a maximum of 1,000 lb. to include wall coverings, carpets, seats, cushions, lighting and window fixtures, and galley equipment. By a combination of light, natural finished wood paneling, dull finished silver fixtures, blue carpets, and orange seat covers an effect of cool spaciousness has been achieved which suggests comfort and convenience without intrusion of mechanical aspects of flight.