Fabrication of the Lockheed "Vega" Airplane-Fuselage

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Illustrated with Photographs

THE monocoque type of fuselage construction seems to promise satisfaction of the three requisites of prime importance; namely, high strength-weight ratio, "streamlined" form, and unobstructed interior, according to the author.

The conventional method of building a fuselage consists, first, in the construction of a "form" of the required shape, upon which a layer of veneer is fastened. Other layers are applied, and thus a fuselage shell of two or three plies is completed. But the process is expensive and laborious, involving the handling and individual fitting of many small pieces.

In the process described by the author, a wooden form of the exact shape of one half of the fuselage body, divided on a vertical plane passing through the center line, is built. This form, or pattern, is next suspended in a large box in which reinforcing bars previously have been woven, and concrete is poured in. A reinforced-concrete block weighing from 10 to 30 tons and having a central depression exactly the shape of half of the finished fuselage is thus made.

To assemble a half shell, the outer layer is placed in position in the concrete mold and coated with a casein glue, and the second layer is placed inside the first layer. A coat of glue is given the second layer, the inner layer is put into place inside the other two and air pressure is applied to a rubber bag which fills the space between the plywood shell and the cover of the concrete mold.

After remaining under pressure in the mold for about 8 hr., the half-shell is removed and placed on a drying rack. It is without joints, cracks or laps, perfectly glued throughout and formed to the exact streamline desired. Two half-shells constituting the fuselage are clamped into position on a "skeleton" by special clamps, and automatically align themselves on the framework. They are glued and nailed in place, and cutouts are made for windows and other openings. Installation of seats and fittings completes the structure.

THREE requisites of prime importance govern the design of airplane fuselages; first, the strength-weight ratio must be as high as possible; second, the form must be as nearly as practicable "streamline" in shape, so as to require the least power for propulsion through the air; third, the interior must be unobstructed, because the purpose of the fuselage is primarily that of a cargo carrier. Cost of production and ease of repair are also important considerations, especially from the viewpoint of the commercial operator, who must make his cargo carrier a paying investment, both initial and maintenance costs considered.

The monocoque type of fuselage construction seems to promise satisfaction of these requirements to a greater extent than does any other method. The strength-weight ratio can be made high because of the employment of the stressed material at a greater distance from the neutral axis and also of the elimination of fairing and its supporting structure. The form of the fuselage and its surface texture in our type of monocoque construction satisfies, as nearly as is commercially possible, the requirements for minimum resistance; it is virtually a true streamline shape without surface irregularities. The use of laminated spruce rings or "diaphragms" to support the spruce shell results in an interior which is entirely free from structural cross-bracing members. An additional advantage of this feature is the great reduction of risk in the event of a crash, there being no cross-members to injure the occupants of the cabin. The materials used and the methods by which they are employed in the structure make for a moderate cost in production and ease of repair under service conditions.

The conventional method of building a fuselage consists, first, in constructing a form of the required shape.

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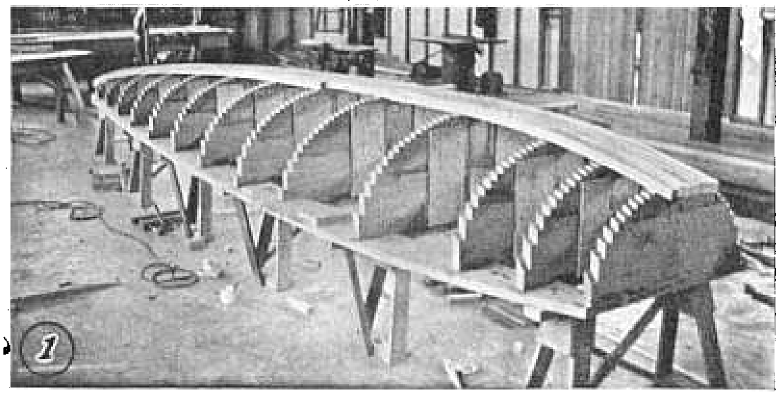
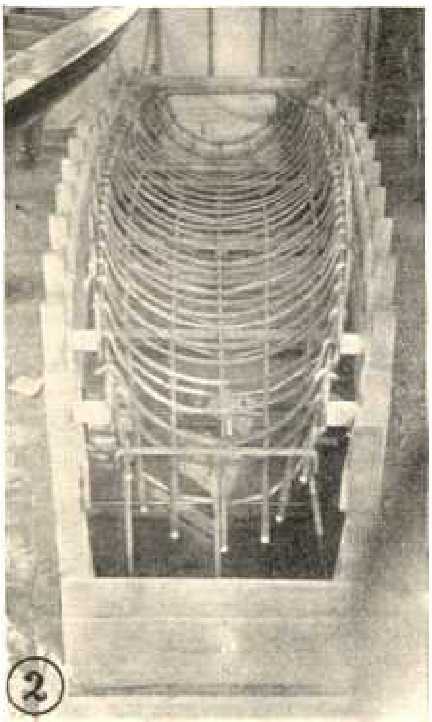
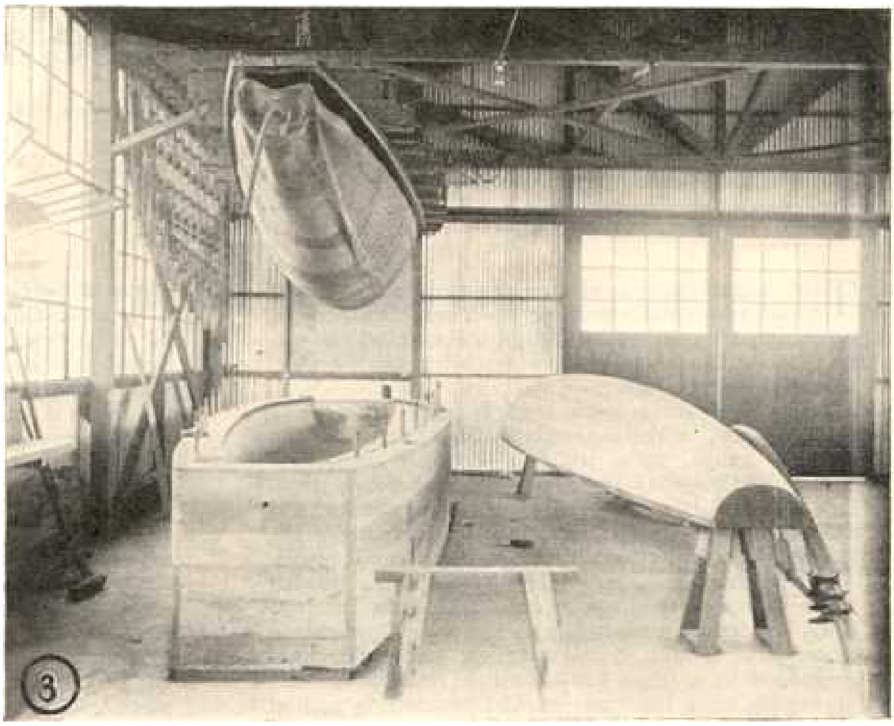
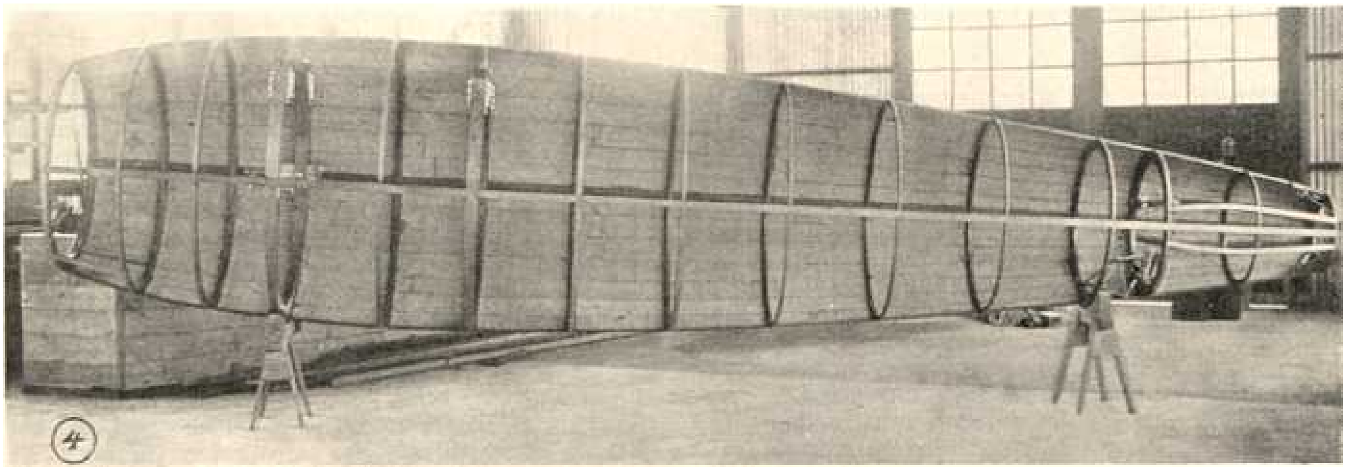
A layer of veneer is fastened over this form. The first layer usually consists of narrow strips 1/16 to 1/8 in. thick, laid diagonally or wrapped around the form. Each strip is separately fitted and fastened to the form by means of tacks, clamps, glue or some binder. After the first layer has been applied, a second layer is assembled, the grain running at an angle to that of the first layer. Each strip is individually glued and is tacked or clamped to the first layer in an effort to produce, as nearly as possible, a homogeneous structure. A fuselage shell of two or three plies is completed in this way, the final layer usually being covered with fabric to help in binding the entire structure together and to produce a better finish.



At best, the whole process is a very expensive and laborious one, involving the handling and individ-







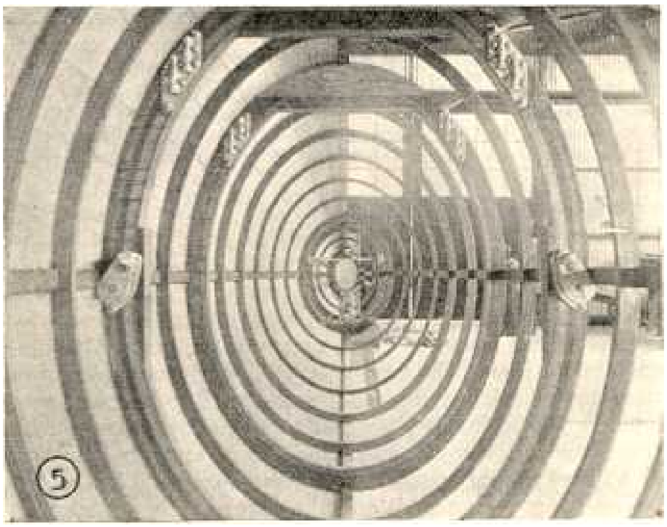
FEATURES OF THE LOCKHEED VEGA FUSELAGE CONSTRUCTION

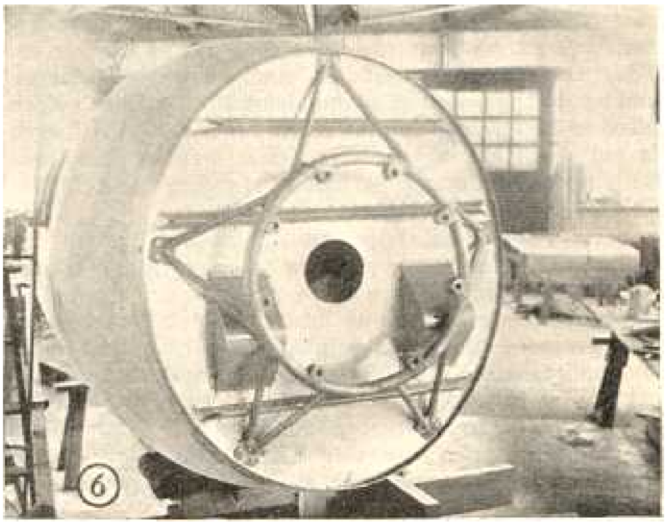
(Fig. 1) Construction of the Form or Male Fuselage-Mold Over Which the Plywood for the Fuselage Shell Is Laid. (Fig. 2) Reinforced-Concrete Box. (Fig. 3) Completed Concrete Form, with Projecting Tie-Bolts for Holding Down the Cover, Which Is Seen Hanging Above, the Rubber Air-Bag Fastened Underneath, and, on the Right, the Male Form with One of the Completed Shell-Layers Resting Over It. (Fig. 4) Finished Half-Shell When Assembled ual fitting of a great many small pieces. It is impossible to provide a uniform pressure on the glued surfaces, and the result is not all that could be desired to produce the strongest possible structure.

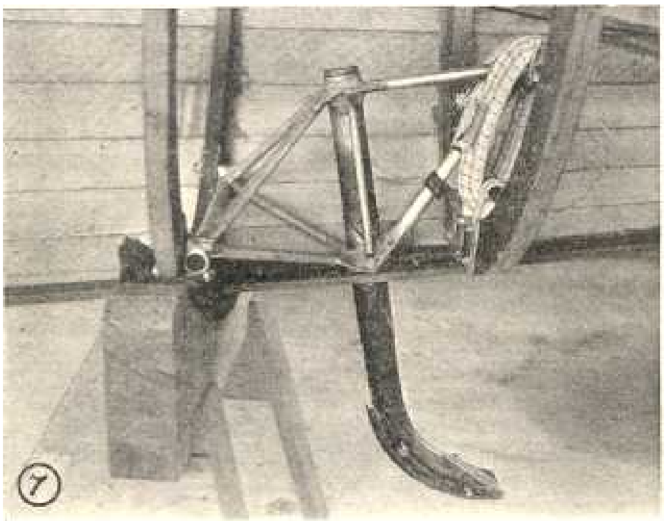
Lockheed Process Described

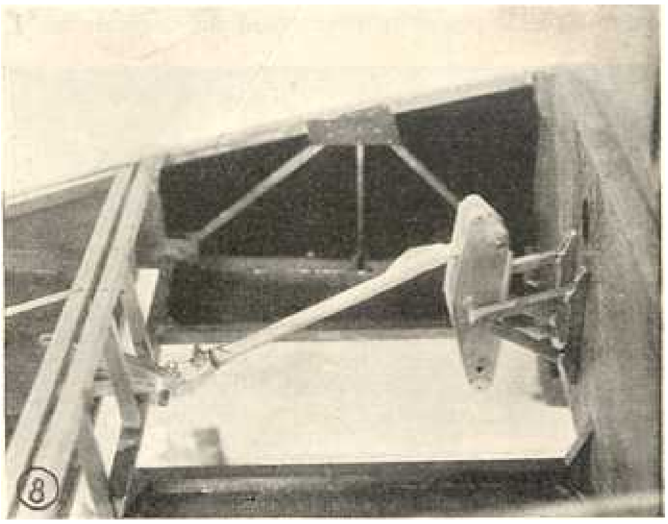
The process in use at our plant, for which the company controls exclusive patent rights, was developed several years ago by Allan Loughead, Anthony Stadlman and associates. The method of construction used produces a perfectly shaped half-shell molded from three layers of cross-grained spruce which are glued together at one time under heavy pressure to form a perfectly homogeneous unit.

The first step in the fabrication process is the design and construction of a suitable mold. The body lines are first laid out to give the required cargo space, with an elliptical center cross-section that tapers gradually to a circular section in front and a small ellipse in the rear. A wooden form, shown in Fig. 1, is then constructed to the exact shape required for one-half of the fuselage body, divided on a vertical plane passing through the center line. This form, or pattern, is finished very smoothly on the outside, and is rigid and well braced. It is then suspended with its formed or curved surface downward in a large box in which reinforcing bars have previously been woven, as shown in Fig. 2. The box is then filled with a good grade of concrete, which is carefully tamped to produce a smooth cast surface against the wooden pattern.









Details of Laminated-Spruce Rings and Other Fittings

(Fig. 5) Interior of the Skeleton Framework, Showing Longitudinal Spacing-Strips and Method of Attaching Fittings to the Rings or "Diaphragms." (Fig. 6) Engine-Mount Ring of Welded Steel-Tubing Construction. (Fig. 7) Tail-Skid Installation and Method of Attaching Members to the Fuselage. (Fig. 8) Aileron-Actuating Mechanism, Which Hinges About the Top Portion of the Aileron and Is Entirely Inside the Wing

After the concrete has thoroughly hardened, the sheathing is removed from the box, and the wooden fuselage pattern is lifted out. Thus a reinforced-concrete block is produced that weighs from 10 to 30 tons, depending upon the size of the fuselage, and has a central depression which is just the shape of one-half of the finished fuselage. Special alloy-steel hold-down bolts are cast into the concrete at intervals of about 2 ft. along the edge of the form. A wooden cover is fitted flush with the top of the concrete mold and is held in place with heavy steel I-beams through which the hold-down bolts pass. A large rubber air-bag having the exact shape of the inside of the mold is fastened by cords to the bottom of the cover, as shown above the mold in Fig. 3.

The fuselage half-shell shown in Fig. 4 is made of three layers of sliced, cross-grained spruce veneer, totaling when complete between 5/32 and 3/16 in. in thickness. The inner and outer layers are each about 1/24 in. thick and run longitudinally from nose to tail, while the central ply is 1/16-in. spruce with the grain at right angles to the other two layers. The longitudinals are gore-shaped strips tapering from approximately 1 in. wide at the ends to 6 in. at the center. They are stacked in bundles, clamped between forms, and cut to the required shape about 30 at a time. Each piece is 25 ft. long and, as sliced spruce in this length is not available, a special splicing machine has been built which produces a perfect scarf-splice about 3/4 in. long in the 1/24-in. veneer.

After cutting to shape, the longitudinal gores are temporarily fastened in position on the original wooden body-form by means of a few tacks, and are secured in the proper relation to one another by strips of paper tape fastened along the joints. The inner and outer longitudinal plies are all made up in the same way and, after preparation, can be folded and stored until ready for use. The transfer ring, which is a 2 x 3-in. band of laminated spruce carried around the edge of the wooden form, is arranged so that it can be removed as a whole when necessary.

When it is desired to assemble a fuselage shell, the outer layer is placed in position in the concrete mold,

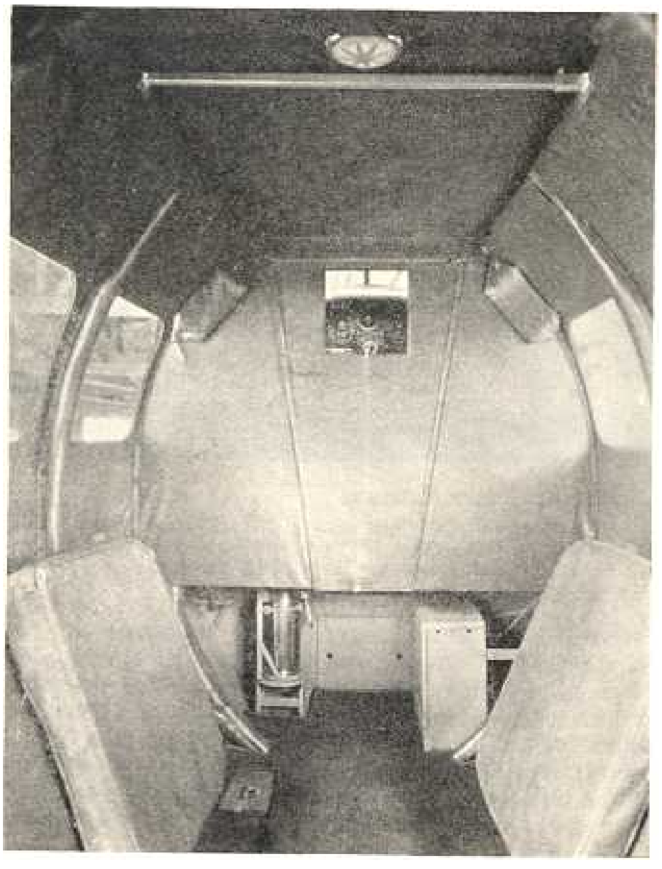


FIG. 9—CABIN INTERIOR, FREE FROM STRUCTURAL CROSS-BRACING MEMBERS

FIG. 10—TAIL VIEW OF VEGA AIRPLANE

The Type of Streamline Section Produced by the Method of Plywood Fuselage-Construction Described Is Evident. Wind-Tunnel Data Show That This Shape Has Considerably Less Than Half the Air Resistance of the Ordinary Steel-Tubing Fuselage

where it is held in place by strips of gummed tape along the edge of the mold. It is then given a coat of casein glue, and at the same time the second or transverse layer, in place on the wooden form shown in Fig. 1, is coated. The second layer is then picked up as a unit by means of the transfer ring, and is inverted in the concrete mold inside the first layer. The second layer is in turn coated with glue on the inside. The last or inner layer is placed inside the other two in the concrete mold, the cover is lowered and bolted down, and air pressure is applied to the rubber bag which fills the space between the plywood shell and the cover. The actual time required to complete the process is only about 20 min. from the application of the first glue until the whole shell is under a pressure of 15 to 20 lb. per sq. in., the total pressure exerted being about 150 tons over the whole sheet of plywood.

Any slight irregularities in the concrete mold or in the thickness of the plywood are compensated by the resilience of the rubber bag, so that every inch of the plywood surface receives approximately the same pressure. The shell remains under pressure in the mold for about 8 hr., after which it is removed and placed on a drying rack where the excess moisture is removed. The resultant half-shell is a homogeneous piece of plywood without joints, cracks or laps, perfectly glued throughout and formed to the exact streamline shape desired.

The "skeleton" framework to which the shell is applied, shown in Fig. 5, consists of a series of elliptical laminated-spruce rings varying in cross-section from 3 in. square, where heavy loads are applied, to about ¾ in. square near the tail of the fuselage, where the loads are light. The rings are held in position by four light spruce strips or "longerons" which serve as spacers and, at the top and bottom, as seam strips on which the two half-shells are joined. Fig. 5 also shows the method of attaching fittings to the diaphragms or rings.

The monocoque shells are clamped in position on the skeleton by means of special strap-type clamps, and automatically align themselves on the framework. They are glued and nailed in place with barbed cement-coated brass nails, care being taken that at points of large load ample gluing and nailing area is provided. Cutouts are made for windows, doors, cockpit openings, and the like, and reinforcing members are used around the larger openings to compensate for the reduction of strength due to the removal of material at the cutout point. Paint or lacquer applied outside, and the installation of seats, controls, a baggage compartment, and upholstering inside, complete the structure.

OTHER SPECIAL CONSTRUCTION FEATURES

Fig. 6 shows the method of mounting the Whirlwind engine. We prefer the welded steel-tubing structure rather than to build out the fuselage with wood construction. In Fig. 7, the mounting of the tail-skid illustrates the fact that all members are mounted directly on the rings or diaphragms, to distribute the stresses over as wide an area as possible. No members are fastened directly to the shell. A feature of the entire construction is that we have tried to keep all controls inside as much as possible. Fig. 8 shows the aileron-actuating mechanism, which hinges about the top portion of the aileron and is entirely inside the wing.

Fig. 9 illustrates the benefit derived by keeping the cabin free of structural cross-members. A serious crash can occur without danger that any of the passengers will be thrown against any sharp structural member that would be likely to cause personal injury or that might fold up on them.

As an example of the advantages peculiar to the plywood type of fuselage construction without structural cross-members, we have had two serious crashes of two different airplanes. Both crashes were of a nature that probably would fold up a steel-tubing fuselage rather completely, and the transverse bracing-members might have injured the occupants very seriously. In one case we had three passengers in the cabin, and in the other, four passengers. In neither of the crashes were any of the passengers injured. We believe this is because of the type of construction. The fuselage has a double curve throughout, which tends to cause it to break outward instead of splintering inward. Further, the fact that the spruce diaphragms are laminated, thus having much the same resilience as plywood, and that the grain is more or less crossed in the laminations, causing them to resist any tendency to splinter, is another feature that minimizes the dangers in a crash.

Regarding the procedure for the repair of the Vega fuselage, we always keep several complete half-shells of the fuselage in stock. In the event of a crash or minor accident which makes a hole, say 1 ft. in size, in the fuselage, we can take out a plywood section between diaphragms and replace it. Whatever the diaphragm spacing is, we merely remove a section of the shell and splice in a section from one of our spare half-shells at exactly the same location. The splice is made carefully and has exactly the same curve as the section that was damaged. When repaired in this way the fuselage is as good as it was originally, and the repair cannot be noticed.

Fig. 10 shows the type of streamline section that we get by using this method of construction. The fuselage has an almost perfect streamline shape, and we know from wind-tunnel data that this shape has considerably less than half the air resistance of the ordinary steel-tubing fuselage. The headpiece herewith illustrates the cleanness of the Vega design and the fact that no struts are used. The concluding illustration shows the finished appearance of the entire airplane, which we term the air-express model, and emphasizes the shape of the fuselage. The model is intended for use as an air-mail plane and has the parasol wing-arrangement.