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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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KIRSTEN-BOEING PROPELLER

By H. Sachse

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By H. Sachse.

A means of propulsion for both aerial and marine craft, differing completely from the conventional screw propeller, has been invented by the German-American, Professor F. K. Kirsten of the University of Washington, with the aid and cooperation of the American airplane manufacturer, Mr. W. E. Boeing. The successful experiments led to the organizing of the "Kirsten-Boeing Engineering Company," in Seattle, Washington, for the further improvement and manufacture of the "Kirsten-Boeing" propellers.

The advantages of this new propeller consist essentially in the adjustability of the thrust in any desired direction, in the plane perpendicular to the axis of rotation of the system, and in its high efficiency. The propeller, which, in appearance, greatly resembles the paddle-wheels used on river steamers, differs fundamentally from the latter, however, in that all the blades work simultaneously in the fluid medium (air or water). This fact necessitates a suitable rotation of the individual blades, in order to control the direction of the thrust. Fig. 1 is a diagrammatic representation of the

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outline of such a propeller with six blades. The arrow A indicates the direction of rotation of the whole system. The requisite control of the blades, for directing the thrust, is obtained by rotating the individual blades in a direction (arrow B) opposite to the direction of rotation of the system as a whole and, in fact, at half the angular velocity, so that each blade turns only 180° during a complete revolution of the whole system. The forces acting on the individual blades, in a medium assumed to be at rest, are then indicated in the diagram. By means of the flow tangential to the blade, the latter derives a force, which is resolved, in the diagram, into two components. One of these components lies in the direction of the flow, tangential to the circumference of the circle, and represents the drag resistance of the blade, which is overcome by the torque of the driving engine. The other component is again resolved into a "thrust component" and a lateral force, so that the lateral forces of the different blades counteract one another. The sum of the thrust components is then the total propeller thrust.

Fig. 2 shows the path of an individual blade and shows the direction of the resulting flow and its cross-section. The desired direction of thrust can be obtained by changing the position of the blades, without changing the direction of rotation, by a simple device not affected by the forces generated.

In accord with the above considerations, a small propeller of 10.23 inches diameter and 5.91 inches length of blade was tested in the wind tunnel of the University of Washington. The functioning of this experimental propeller proved very satisfactory. A larger model enabled the performance of more accurate experiments on the revolution speeds and the forces generated at various relative speeds, between the propeller and the flowing medium, and established the fact that the best result depends on the ratio of the width of the blades to the diameter of the propeller. The results thus obtained rendered it possible to undertake experiments on a larger scale.

The ability to change the direction of thrust is very advantageous for an airship with its three-dimensional directions of motion. If the propellers are installed with their axes of rotation perpendicular to the vertical plane of the airship, it is then possible to direct the thrust upward, in order to make the airship descend, or to direct the thrust downward, so as to make the airship rise, or to drive the airship either forward or backward. If, on the other hand, the propellers are so disposed that their axes of rotation lie in the vertical plane, then the thrust can be exerted in any direction in the horizontal plane for steering the airship laterally. The maneuverability of the airship is thus extraordinarily increased.

A large airship propeller was then made, as seen on the testing stand in Fig. 3. It had 24 blades 4 ft. 9.1 in. long and 22 in. wide, the diameter of the whole propeller being about 15 ft. 1.1 in. On the left stands the driving engine, a 400 HP. Wright airplane engine which, through a reduction gear, drove the propeller at only 225 R.P.M. It thus generated a thrust of about 212 pounds. Fig. 4 shows the propeller running. The small streamers indicate the direction of flow. The picture also shows the balance for measuring the thrust, which is suspended between the propeller and a fixed point. The hub is cast aluminum. The rim (Fig. 6) is constructed of duralumin, while steel cables are used for bracing. Some of the supports for the blade axles are also shown. On the driving side, the cast piece with the four openings, through which the radial driving shafts for rotating the blades are introduced, are shown in Fig. 7. Fig. 8 shows the structure of an individual blade with a duralumin tubular axle, duralumin ribs and fabric covering. After good results had been obtained with these experimental propellers, as regards efficiency, facility of control and quiet operation, owing to the low revolution speed, it was planned to install the Kirsten-Boeing propellers on the American airship "Shenandoah," as shown in Figs. 9-10. It is seen that the outer rim was left off, so that the blades project directly into the open air. There were six main propellers thus designed, with their axes at an angle of 30° to the horizontal plane. With these propellers it is possible to so adjust the thrust as to produce forward and backward and upward and downward motions of the airship. The two rear propellers lie in the vertical plane and replace the customary rudders. These propellers increase the forward thrust in straight-ahead flight. Referring to the drawings, it is worth noting that all the driving shafts, struts, supports and engines have been put inside the hull. This arrangement necessitates the use of an incombustible lifting gas, e.g., helium. The gas bags are inflated only just enough to lift the airship to the desired pressure height. If, after a long flight, the airship gets too light from the consumption of the fuel, its ascent can be arrested by the proper adjustment of the propellers. In practice, the airship will be supplied with only enough gas to lift one-half of the fuel required for the trip, the balance of the lift required during the first half of the journey being supplied by the propellers. The possibility of controlling the airship in the vertical direction by means of the propellers renders it unnecessary to valve the very valuable helium gas in order to bring the ship down. For the same reason, the heavy and cumbersome devices for recovering ballast water from the exhaust gases of the engines can be eliminated.

In regard to the ballast and trim difficulties, the airship can be kept on an even keel at all times, since the thrust of any propeller can be changed instantly to any direction required to counteract any tendency of the ship to rise or fall. The limits of this possibility naturally depend on the magnitude of the available propeller thrust. In this case the propellers were designed for a thrust of about 1800 pounds each, making a total thrust of about 10,800 pounds for the six main propellers.

Since the control of an airship, equipped with the Kirsten-Boeing propellers, is independent of the flight speed and has, through the action of the propellers, very great "rudder-forces" at its disposal, the hull can be made shorter and more compact for a given gas capacity, and the airship can be made stronger with the same weight of material. The attendance of the airship is likewise greatly simplified, due to the fact that the engines always revolve in the same direction, regardless of the direction of the thrust. In ordinary maneuvers, it is not necessary to stop the engines or disconnect any couplings, even when it is desired to bring the ship to a complete stop. The direction of the thrust of all the propellers can be controlled by one man through simple mechanical and electrical devices located in the pilot house. The installation of an automatic control is entirely feasible.

The total weight of an airship equipped with Kirsten-Boeing propellers will be less than that of one equipped with the conventional screw propellers. The weight of the steering gear, power cars, etc., on such an airship, is greater than that of the Kirsten-Boeing propellers. Moreover, an airship equipped with Kirsten-Boeing propellers would require less ballast and a smaller crew, since it would not be necessary to have men stationed at the engines to receive orders.

The American naval authorities were said to favor the installation of these propellers on the "Shenandoah," but the plan was not carried out, due to the destruction of the airship. Since no other airship is now available for this purpose, the further development of this type of propeller is arrested for the present.

In the meantime advantage was taken of the knowledge acquired to design propellers for driving boats. Three model propellers were made and installed in turn on an experimental boat. The boat propeller required special measures to keep the water away from the driving mechanism. The first model had sixteen blades, each blade carrying, at its upper end, a steel cog-wheel, which meshed with a large central gear-wheel, which had an inner row of cogs and revolved on satellite gears around an adjustable stationary wheel. Each blade was provided with ball bearings at its upper end and pockwood bearings at its lower end. In the tests it was found that the means employed for keeping the water away from the steel wheels and ball bearings were insufficient. A second model was made, in which the wheels lay at the base of the spindles and consisted of bronze. These wheels meshed again with a central driving gear, likewise of bronze, on a shaft which extended to the head of the propeller and was there rotated by small steering wheels, as shown in Fig. 11. This model demonstrated that the bronze wheels met the requirements in spite of the fact that no protection was employed and the wheels were allowed to run directly in the water. This discovery helped to overcome the main difficulty, which was connected with the design of the propeller. The trial trips covered a distance of over 4000 nautical miles in both salt and fresh water, thereby demonstrating the practical utility of the propeller in its present form. The propeller was installed in a boat about 38 feet long and 6 feet, 7 inches wide, with a 150 HP. engine. The speed attained was about 25 nautical miles (28.8 land miles) per hour. After the trial trips, the propeller was tested in the naval model-testing basin in Washington. It was found to have an efficiency of about 80% with a slip of 20%. The further results of these tests are given in a report by Admiral Taylor, included in the Navy Yard publications. The boat, equipped with a Kirsten-Boeing propeller, requires no rudder, on account of the adjustability of the thrust, and has exceptional maneuvering ability. It can be shifted quickly from full speed ahead to full speed astern. It can describe a circle of about 100 feet radius at full speed or turn on the spot. After the experiments with the second model, the construction was greatly simplified. Fig. 12 is a section through the third and last model.

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

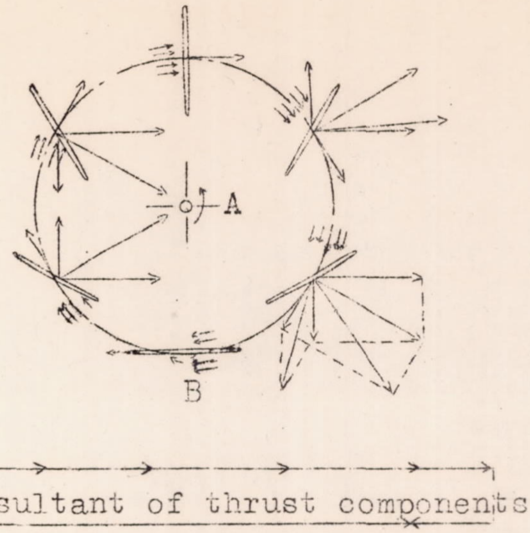


Fig.1 Diagram of propeller.

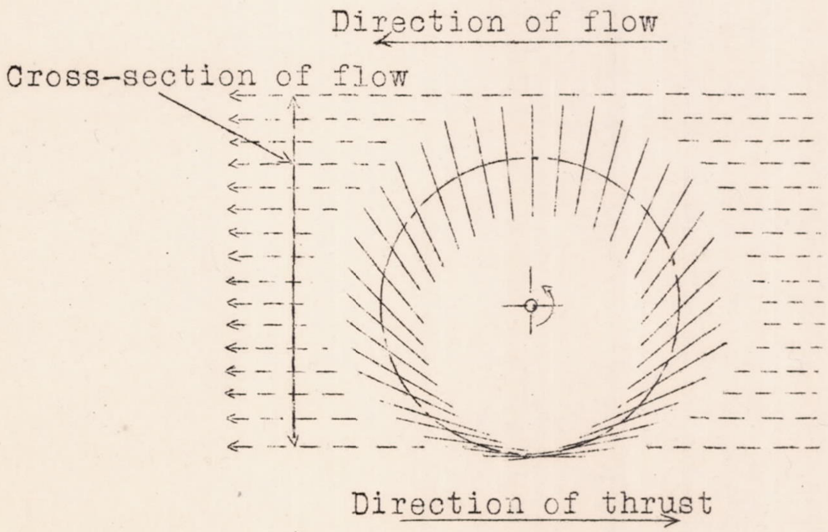


Fig.2 Path of each blade.

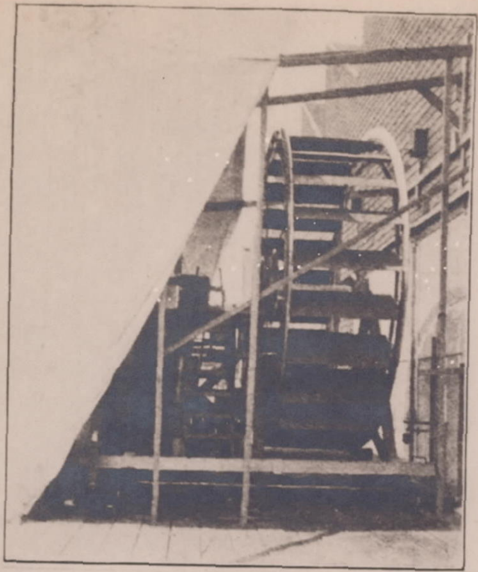


Fig.3. Propeller on testing stand.

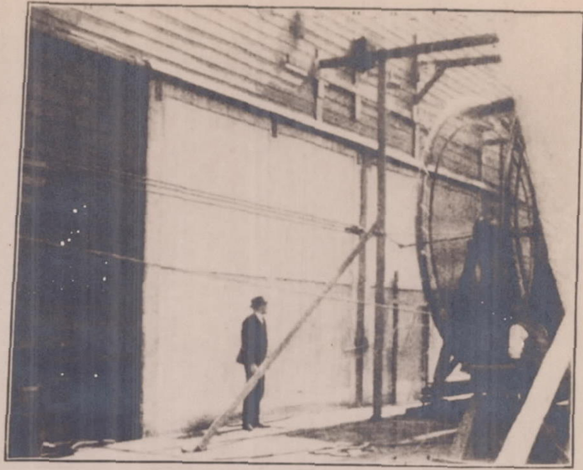


Fig.4. Propeller running(Thrust-measuring device).

Fig.5. Propeller rim.

Fig.6. Enlarged view, showing structure

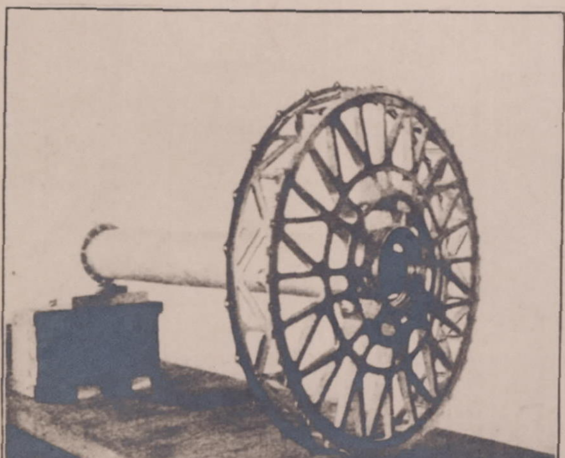


Fig.7. Hub.

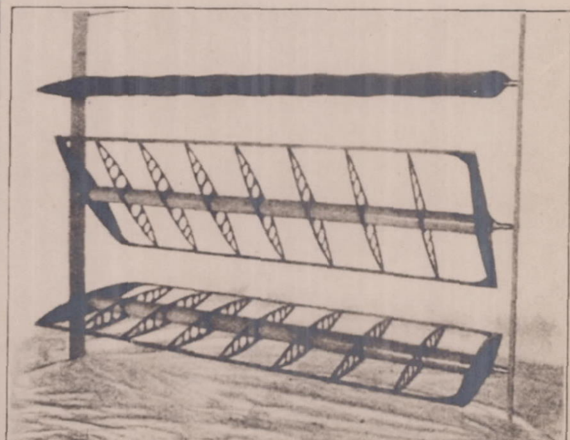


Fig.8. Blades, showing structure.

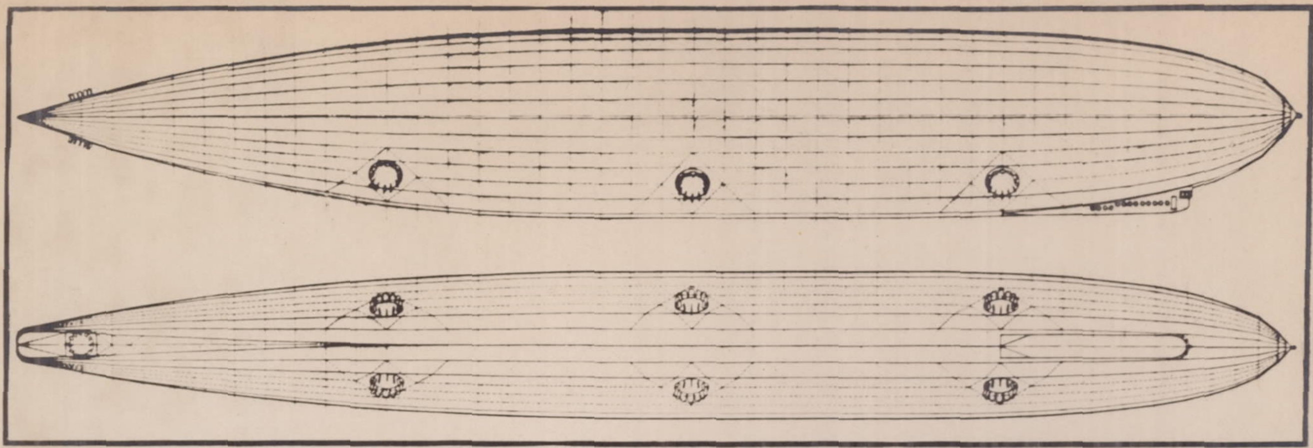


Fig.10 Outboard profile, side elevation and inverted plan of airship 207.5 m (680.8 ft.) in length with K-B props.

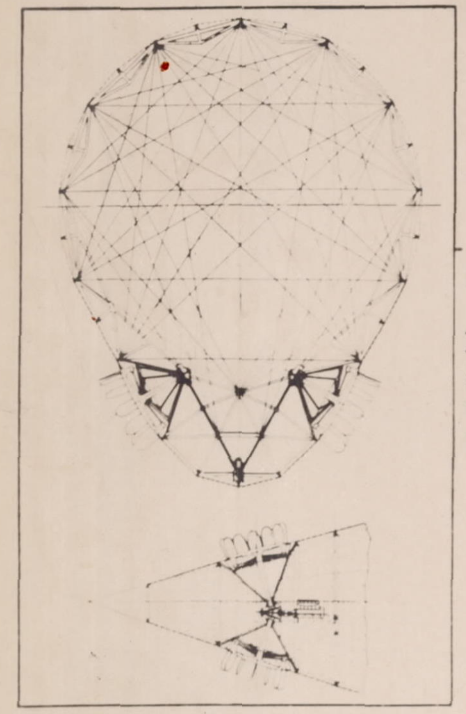
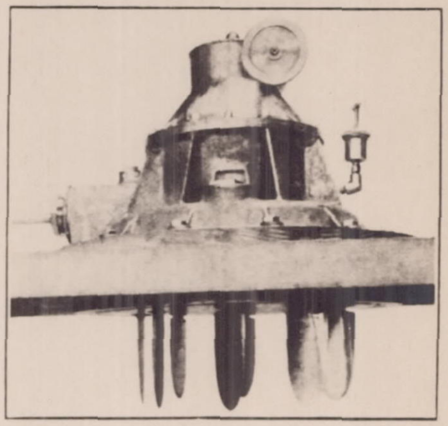


Fig.9 Cross-section amidship and longitudinal section at stern, showing the installation of the K-B propellers.



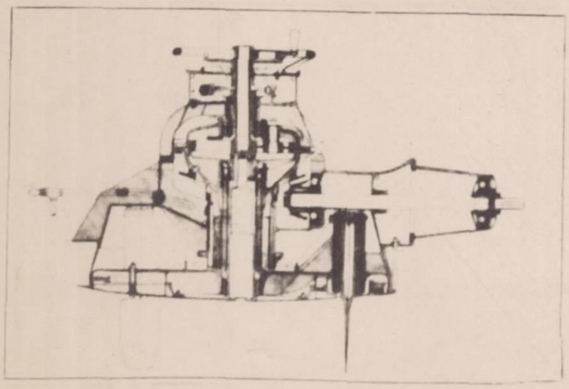


Fig.11 Cross-section of boat propeller (2nd.model)

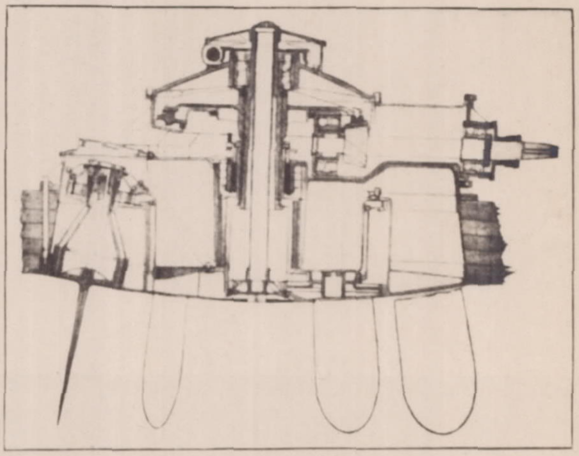


Fig.12 Cross-section of boat propeller (3rd.model)