Aug. 29, 1939. H. C. RICHARDSON ET AL 2,171,047

HEAT EXCHANGE APPARATUS

Filed Feb. 24, 1937 3 Sheets-Sheet 1

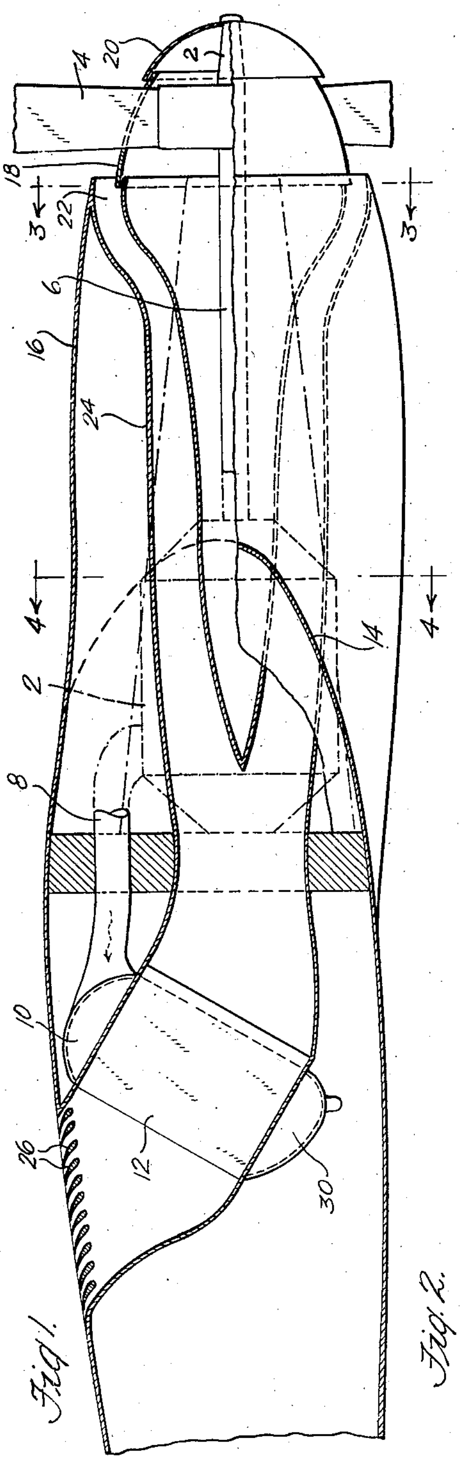

Fig. 1.

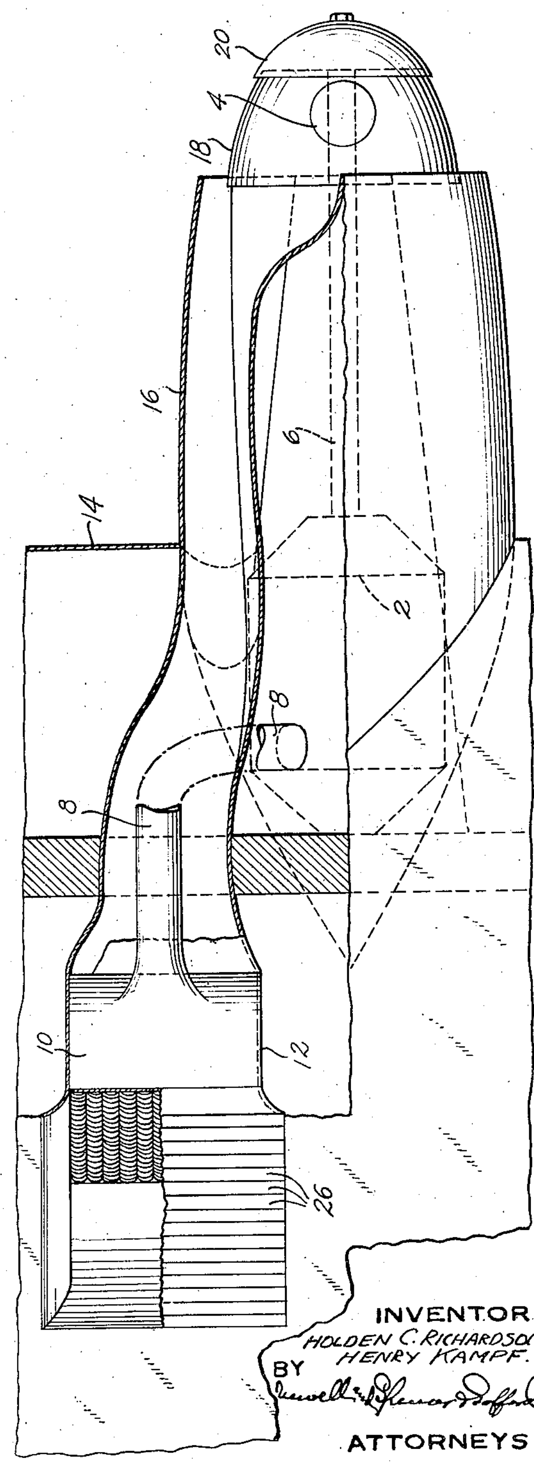

Fig. 2.

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HEAT EXCHANGE APPARATUS

Filed Feb. 24, 1937

3 Sheets-Sheet 2

Fig. 3.

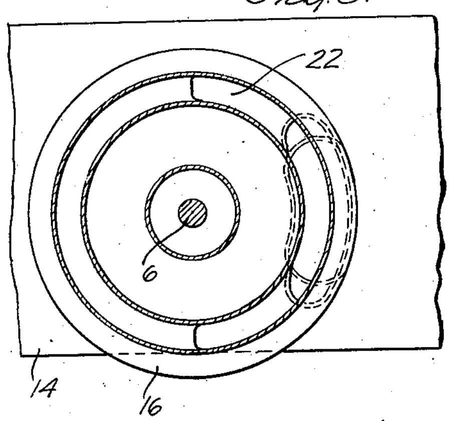


Fig. 5.

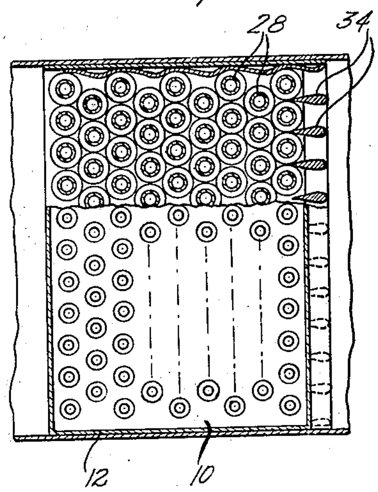
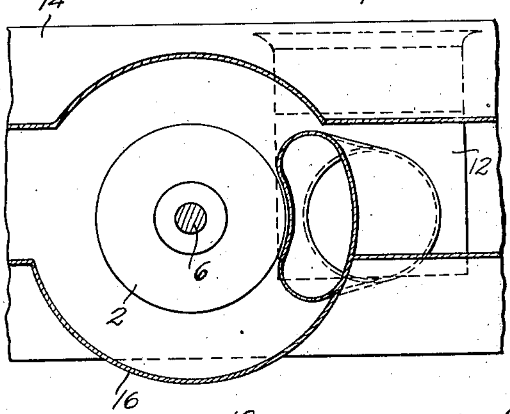


Fig. 4.



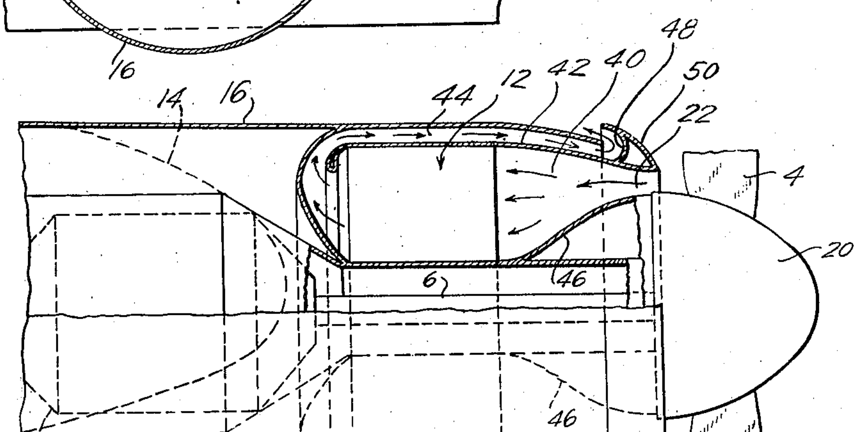


Fig. 6.

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HEAT EXCHANGE APPARATUS

Filed Feb. 24, 1937 3 Sheets-Sheet 3

Fig. 7

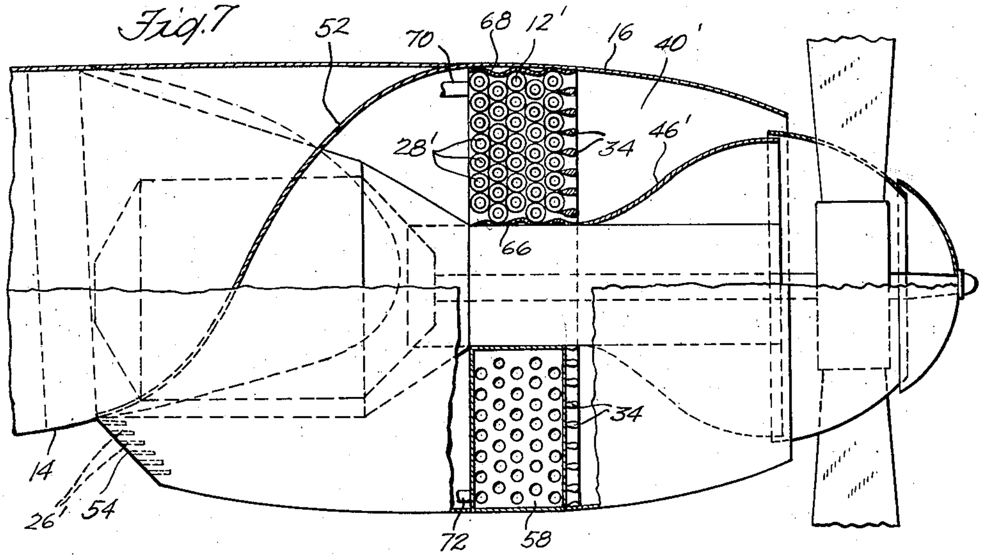


Fig. 8.

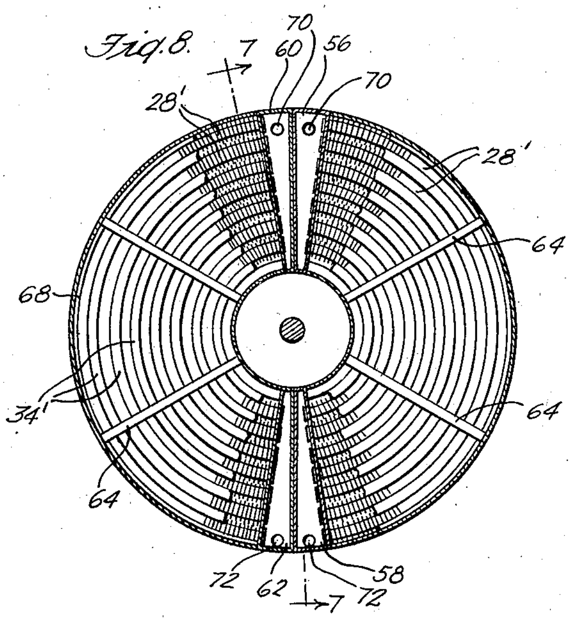


Fig. 9.

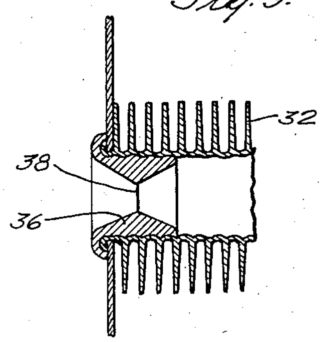


Fig. 10.

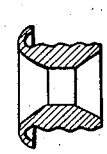
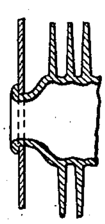


Fig. 11.



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HEAT EXCHANGE APPARATUS

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Application February 24, 1937, Serial No. 127,356

13 Claims. (Cl. 244—57)

This invention relates to heat exchange apparatus and particularly to heat exchange apparatus designed for use with the power plants of airplanes for cooling or condensing purposes.

In the air-cooled motors used with airplanes at the present time, advantage is taken of the slip stream from the propeller for supplying air for cooling purposes and one of the objects of the present invention is so to construct and to arrange cooling means, such as radiators, or condensers for a steam-driven power plant for airplanes, that they can make best use of the air coming from the slip stream to effect in comparatively close quarters a comparatively large heat exchange, with a minimum disturbance of flow of air over the adjacent wing surfaces.

As herein illustrated, the invention is shown as embodied in a condenser for condensing the steam from a steam turbine or a steam engine utilized to drive the propeller of the airplane and an important object of the invention is so to construct the condenser that substantially uniform condensing results can be obtained throughout the condensing structure even though because of space limitations the cooling air must pass over some of the parts of the condenser after it has already passed over others, and even though the tube lengths vary in proportion to the radial distance of their axes from the axis of the condenser.

An important feature of the invention is the symmetrical arrangement of the elements of the condenser with respect to the propeller axis which contributes markedly to the effective operation of the different parts of the condenser. Another important feature of the invention is the control of the distribution of the steam to be condensed to the different parts of the condenser whereby the steam is apportioned to the various parts in proportion to their condensing or heat-exchanging capacity.

Another important feature of the invention is the utilization of directing means, preferably stream-lined and so constructed and arranged as to convert the velocity of the slip stream into pressure whereby, as the air enters the conduit to the condenser, its expansion beyond the entrance tends to convert velocity to pressure at the face of the condenser, and then by the use of Venturi-shaped passages reconvert pressure to increased velocity and to direct the air stream into the air passages in the condenser without undue eddy losses at the entrance to same.

Not only does the invention aim to improve the means which control the supply of cooling air to the condenser, but the invention aims also to provide improved arrangements for discharging the air after it has taken up the heat from the condenser. Important features of the improved discharge arrangement are the provision of means for insuring a smooth discharge and the breaking up of eddies and whirls before the air is discharged into the stream passing over the plane wing and also an arrangement whereby the discharge comes at such a point on the wing that it tends to remove the boundary layer of air and thereby augment the wing lift, while also augmenting the differential pressure between the entrance and exit.

Figure 1 is a section through the forward part of the wing of an airplane and through the motor or turbine cowling, illustrating a condenser embodying the present invention, with passages located at the rear, and at both sides of the propeller shaft;

Figure 2 is a sectional plan view of Figure 1;

Figure 3 is a section on the line 3—3 of Figure 1;

Figure 4 is a section on the line 4—4 of Figure 1;

Figure 5 is a plan, partly in section, of a condenser embodying the present invention;

Figure 6 is a vertical section illustrating a condenser arranged concentrically about the propeller shaft and located near the front of the cowling, with the discharge for the air that has traversed the condenser located near the front of the cowling;

Figure 7 is a vertical section showing a similar arrangement of the condenser but arranged to discharge the cooling air on the under side of the wing;

Figure 8 is a section through the condenser of Figure 7;

Figure 9 is a detail section of the input end of one of the condenser tubes, and

Figure 10 illustrates the nozzles for controlling the input of steam into the condenser tubes.

Figure 11 illustrates a method of controlling the input of steam to the condenser tubes by restricting the diameter of the tube.

In the embodiment of the invention illustrated particularly in Figures 1, 2, 6 and 7 inclusive, the motor 2, for driving the propeller 4 by connections thereto, including the propeller shaft 6, may be of any suitable type, such, for example, as a steam turbine in a steam powered airplane, the exhaust steam from the turbine 2 going through a conduit 8, Figures 1 and 7, to a manifold 10 at the top of the condenser 12.

That part of the propeller connections and turbine 2 which extends beyond the forward edge of the airplane wing 14 is enclosed in a cowling 16, stream-lined to direct the slip stream from the propeller over and under the wing surfaces. The cowling 16, at its forward end, projects slightly over a spinner 18, surrounding and connected to the hub of the propeller 4 and provided with a stream-lined nose 20, this arrangement providing an intake passage 22 for the cooling air for the condenser 12. The cooling air, being a part of the slip stream, enters the passage 22 at a velocity considerably in excess of the velocity of movement of the wing 14 through the air.

In the embodiment of the invention shown in Figs. 1 to 4 inclusive, the air intake passage 22 is at the forward end of an air conduit 24 passing symmetrically past the turbine 2 to conduct the air from the intake 22 to the condensers 12. This conduit 24 is continued beyond the condensers 12 to the upper surface of the wing 14 where it discharges the air after it has picked up the heat from the condenser 12, this discharge being effected in such a way as to tend to remove the boundary layer of air clinging to the upper surface of the wing and thus aid the forces which lift the plane, by delaying burbling. At its discharge end each conduit 24 is preferably provided with stream-lined guides 26 which serve to smooth out eddies that may have formed in the air stream in its passage through the conduits 24 and thus insure its discharge on the upper surface of the wing in a smooth flowing stream merging into the air stream passing over the upper surface of the wing with augmented velocity in a region of reduced pressure.

In the form of the invention shown in Figs. 1 to 5 inclusive, the condenser is made up of upright condenser tubes 28 which extend from the steam manifold 10 to the water manifold 30, these tubes being preferably provided with fins 32 such as shown in Fig. 9 to increase the rate of heat exchange. At the intake end of the condenser 12 stream-lined guides 34 are provided which serve two purposes: First, they are so located with respect to the first row of condenser tubes 28 that they guide the cooling air against the median lines of these tubes and, secondly, by their shape and relation to each other they produce a Venturi effect whereby pressure is converted to increased velocity corresponding to that in the passages through the condenser, the air passing in sinuous streams over the staggered rows of condenser tubes in such manner that it passes from the tips of the fins of one stage of tubes to the base of the fins of the next, and vice versa, thus establishing a turbulence beneficial to heat exchange.

It will be obvious that the air entering the forward end of the condenser will have picked up considerable heat from the first rows of tubes of the condenser before it reaches the rear end of the condenser and that, therefore, its capacity for absorbing heat from these rear tubes will be considerably reduced. To compensate for this, so as to insure proportionate condensing action in each of the tubes, the input of steam into each of the tubes 28 is preferably metered, at least in those tubes in the rows behind the initial row. This metering may be effected by inserting into the ends of the respective tubes opening into the steam manifold 10, nozzles 36, or any other well known means of restriction, the restricted orifices 38 of which may vary in diameter in accordance with the amount of steam it is desired to admit to a particular tube, Fig. 10 showing a slightly different form of the nozzle passage from that shown in Fig. 9.

In the form of the invention shown in Figures 1 to 5 inclusive, the conduit 24, as hereinabove suggested, carries the air past the turbine 2 to direct it into the condensers 12, although the scoop-like intake passage 22 is concentric with the turbine driven shaft and extends about the axis of said shaft. The entrance 22 being of somewhat smaller cross sectional area than that part of the conduit 24 behind the entrance, the air is driven into the entrance 22 by the slip stream and thus, as it expands behind the entrance, it will move with reducing velocity and increasing pressure to the face of the condenser, where velocity is regained as the air passes through the Venturi passages, to the cooling elements.

In the forms of the invention shown in Figures 6, 7 and 8, the condenser 12′ is arranged concentrically about the axis of the propeller shaft 6 and is of the construction described in more detail hereinafter.

In the form of the invention shown in Figure 6, the air from the propeller slip stream enters an annular entrance 22 into a conduit 40 which is formed between a sheet metal guide wall 42, constituting also a partition between the conduit 40 and an annular exhaust air passage 44 surrounding the conduit 40, and an inner guide wall 46 surrounding the propeller shaft 6. The conduit 40 is of such shape that the air, after it has gone through the entrance passage 22, is allowed to expand before it enters the condenser 12′. The outer wall of the discharge passage 44 is formed by the cowling 16.

The wall 46 of the conduit 40 is extended through the condenser 12′ and is then curved up to meet the cowling 16 and thus complete the conduit 44, as shown in Figure 6. The discharge passage 44 is completed by a torus-like member 48 having its inner edge connected to the wall 42 and having its outer edge connected to the shield 50 in such manner that the front edge of the cowling 16 forms a streamline nose for the torus. The air from the discharge passage 44 is thus discharged directly into the slip stream, in a region of reduced pressure augmenting the flow.

In Figure 7 the conduit 40′ for the cooling air is formed directly between the inner wall 46′ and the cowling 16 and the conduit is completed beyond the condenser 12′ by a guide wall 52 which directs the stream of air, after it has passed through the condenser 12′, to a discharge 54 in the lower part of the cowling, so that the air, after it has picked up the heat from the condenser 12′, passes through vanes 26 and enters the stream of air flowing over the under side of the wing 14.

The condenser 12′, as shown particularly in Figures 7 and 8, comprises a series of substantially semi-circular condenser tubes 28′ which extend between a steam header 56, sector-shaped in cross-section, and a water header 58, likewise sector-shaped in cross-section, on the one side of the condenser and between a steam header 60, also sector-shaped in cross-section, and a water header 62, of similar construction, on the other side of the condenser. Supporting and spacing diaphragms 64 maintain the tubes 28′ in proper relation to each other, these diaphragms extending between the inner air guiding wall 66 of the condenser and the outer air guiding wall

68, both of these walls being preferably corrugated as shown in Figure 7 to assist in effecting a sinuous flow of the air over the tubes of the condenser adjacent to the outer and inner walls thereof.

The steam to be condensed enters the steam headers 56 and 60 through pipes 70 and the condensed steam or water leaves the water headers 58 and 62 through pipes 72.

The condenser 12′ preferably has stream-lined guides 34 of the same character as those provided for the condenser 12, except that their longitudinal contours correspond with the longitudinal contours of the condenser pipes 28′.

From the foregoing description, it will be obvious that a compact and efficient condenser or cooling construction has been provided which takes into consideration the space and weight limitations in airplane construction and, at the same time, utilizes existing air flows to produce, with as little disturbance of sustaining forces as possible and with as little loss of propulsive power as possible, a maximum of heat exchanging effect.

What is claimed as new is:

1. Condensing means for use in condensing steam in steam-driven aircraft having a propeller and a driving shaft therefor, said condensing means comprising, in combination, banks of steam condensing tubes extending concentrically about the axis of the propeller shaft and a conduit for condenser cooling air of annular cross section to and through said condensing means having an annular intake behind said propeller to receive a portion of the slip stream therefrom and having a discharge so located as to discharge the air into a low pressure area, said banks of condensing tubes forming an annular structure filling a cross sectional zone of said conduit of substantially greater cross section than the intake part of said conduit.

2. Condensing means for use in condensing steam in steam-driven aircraft having a propeller and a driving shaft therefor, said condensing means comprising, in combination, banks of steam condensing tubes extending concentrically about the axis of the propeller shaft and a conduit for condenser cooling air having an annular intake behind said propeller to receive a portion of the slip stream therefrom and having a discharge so located as to discharge the air into a low pressure area, said condensing tubes forming an annular structure filling a cross sectional zone of said conduit and said conduit being of annular cross section to and through said condenser and increasing progressively in cross-sectional area from said annular intake to said condenser.

3. Condensing means for use in condensing steam in steam-driven aircraft having a propeller and a driving shaft therefor, said condensing means comprising, in combination, banks of steam condensing tubes extending concentrically about the axis of the propeller shaft and a conduit for condenser cooling air of annular cross section to and through said condenser and having an intake behind said propeller to receive a portion of the slip stream therefrom and having a discharge so located as to discharge the air into a low pressure area, said condensing tubes forming an annular structure filling a cross sectional zone of said conduit of substantially greater cross section than the intake part of said conduit, and stream-lined vanes so arranged as to direct the air against the respective condensing tubes of the first band and at the same time reduce eddy losses.

4. Condensing means for use in condensing steam in steam-driven aircraft having a propeller and a driving shaft therefor, said condensing means comprising, in combination, banks of steam condensing tubes extending concentrically about the axis of the propeller shaft and a conduit for condenser cooling air of annular cross section to and through said condenser having an intake behind said propeller to receive a portion of the slip stream therefrom and having a discharge so located as to discharge the air into a low pressure area, said banks of condensing tubes forming an annular structure filling a cross sectional zone of said conduit of substantially greater cross section than the intake part of said conduit and comprising two groups each made up of a steam header and a substantially diametrically opposed water header, banks of substantially semi-circular tubes connecting said headers, the tubes of sucessive banks in the direction of air movement being staggered, and correspondingly curved stream-lined vanes so arranged as to direct the air against the respective condensing tubes of the first bank and at the same time reduce eddy losses.

5. In an airplane having a steam driven propeller, a steam powered motor, and a cowling enclosing said motor, means for condensing the steam from said motor comprising, in combination, a conduit for cooling air for said condenser extending through said cowling from an intake behind the propeller to a discharge adjacent to one of the wing surfaces, and a condenser in said conduit comprising a steam header, a water header and successive banks of tubes connecting said headers, means for insuring uniform distribution of the cooling air over the tubes of the various banks and means at the intake ends of the tubes of certain banks adapted to apportion the input of steam into said tubes to the heat-absorbing capacity of the air when it reaches said banks.

6. Heat exchange apparatus for airplanes comprising, in combination with the motor, the motor cowling and propeller, guides cooperating with said cowling to form an annular air passage with a restricted annular opening arranged to receive a part of the propeller slip stream, banks of heat exchanging tubes arranged in said passage with the tubes of each bank in staggered relation to those of adjacent banks in the direction of movement of air through the passage, and means for concentrating the air upon the tubes of the first bank, said means being stream-lined to eliminate eddies.

7. Heat exchange apparatus for airplanes comprising, in combination with the motor, the motor cowling and propeller, guides cooperating with said cowling to form an annular air passage with a restricted annular opening arranged to receive a part of the propeller slip stream, banks of heat exchanging tubes arranged in said passage with the tubes of each bank in staggered relation to those of adjacent banks in the direction of movement of air through the passage, means for concentrating the air upon the tubes of the first bank, said means being stream-lined to eliminate eddies, and means comprising sinuously curved surfaces for insuring an undulatory movement of the air through said heat exchanger.

8. In an airplane, in combination with a wing thereof, a propeller mounted on the wing, a motor for driving the propeller, a cowling enclosing said motor, and heat exchanging elements located within said cowling, of means concentrically arranged about the propeller shaft to pro-

vide a continuous air passage from an annular scoop entrance arranged to receive a portion of the slip stream from the propeller into an expanding annular passage extending through the condenser and thence through a contracting, velocity accelerating passage to air exhaust apertures to the rear of the cowling, said heat exchange elements being located within and intermediate between the ends of said passage, and stream-lined vanes defining said exhaust apertures and serving to eliminate eddies in the stream of heated air discharged therethrough.

9. An air cooled heat exchanger concentrically and symmetrically arranged about an axis and comprising, in combination, sector shaped intake manifolds, sector shaped exhaust manifolds, and tubular heat exchange members concentrically curved about said axis to form successive banks of tubes connecting said manifolds and affording multiple passages for the fluid to be cooled between the intake and exhaust manifolds, and means comprising entrance defining stream-lined vanes and a sinuously curved surrounding casing for directing the air through said banks of tubes in a direction substantially parallel to the axis about which they are curved.

10. An air cooled heat exchanger concentrically and symmetrically arranged about an axis and comprising, in combination, sector shaped intake manifolds, sector shaped exhaust manifolds, and tubular heat exchange members concentrically curved about said axis to form successive banks of tubes connecting said manifolds and affording multiple passages for the fluid to be cooled between the intake and exhaust manifolds, means for directing the air through said banks of tubes in a direction substantially parallel to the axis about which they are curved, said means comprising a sinuously curved surrounding casing, and stream-lined guide members also concentrically and symmetrically arranged about said axis and so located as to concentrate the cooling air in eddy-free streams upon the axes of the curved tubular cooling members of the first bank.

11. In an airplane, the combination with a propeller and propeller shaft, the airplane wing and propeller supporting means intermediate between the propeller and front spar of said wing, of cooperating interior and exterior guiding elements, coaxially and concentrically mounted about the propeller shaft to form a continuous air passage from an annular scoop in the propeller slip stream into a symmetrical expanding and contracting passage ending in air exhaust apertures, said apertures being formed as a series of contracting passages in the upper surface of the wing to the rear of the front spar in a region of low pressure, and long deep-curved air foil elements in said passages arranged to obtain a boundary layer removal effect and to discharge the air at high speed smoothly into the passing air stream.

12. Condensing means for use in condensing steam in steam-driven aircraft having a propeller and a driving shaft therefor, said condensing means comprising, in combination, banks of steam condensing tubes extending concentrically about the axis of the propeller shaft and a conduit for condenser cooling air of annular cross section to and through said condenser having an annular intake behind said propeller to receive a portion of the slip stream therefrom and having a discharge so located as to discharge the air into a low pressure area, said banks of condensing tubes being located in said conduit and comprising two groups each made up of a steam header and a substantially diametrically opposed water header, and substantially semi-circular tubes connecting said headers, means for insuring uniform distribution of the cooling air over the respective tubes of said condenser, and means at the intake ends of the tubes of certain banks adapted to apportion the input of steam into said tubes to the length thereof as determined by their radial distances from the axis of the condenser.

13. Condensing means for use in condensing steam in steam-driven aircraft having a propeller and a driving shaft therefor, said condensing means comprising, in combination, banks of steam condensing tubes extending concentrically about the axis of the propeller shaft and a conduit of annular cross section for the condenser cooling air, said conduit having an annular intake behind said propeller to receive a portion of the slip stream therefrom and having a discharge so located as to discharge the air into a low pressure area, said condensing tubes forming an annular structure filling a cross-sectional zone of said conduit and said conduit being of annular cross section to and through said condenser and to said discharge, the portion of said conduit on the discharge side of said condenser comprising an outer reversely directed portion surrounding the part extending through said condenser and including a torus-like end portion directing the discharged air into the direction of flow of the propeller slip stream.

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