July 22, 1947. M. PIRY 2,424,416

ENGINE COOLING SYSTEM

Filed Jan. 6, 1944 3 Sheets-Sheet 1

Fig. 1.

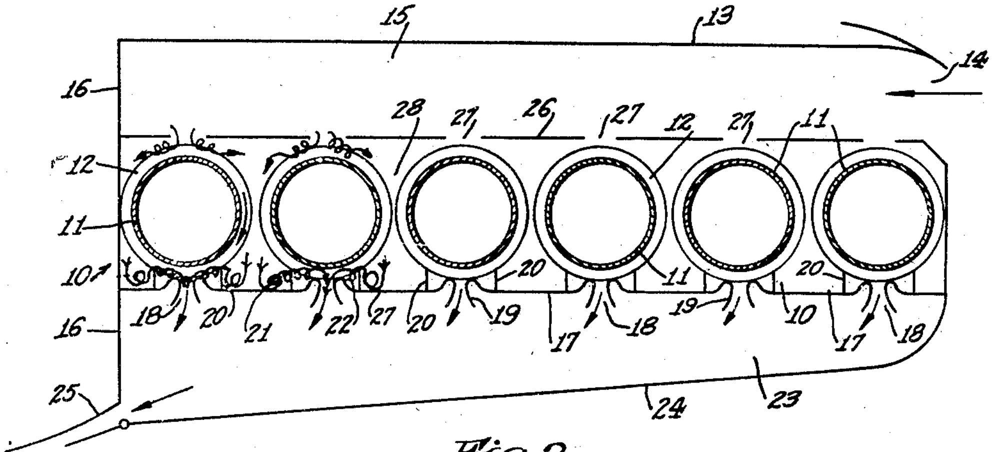
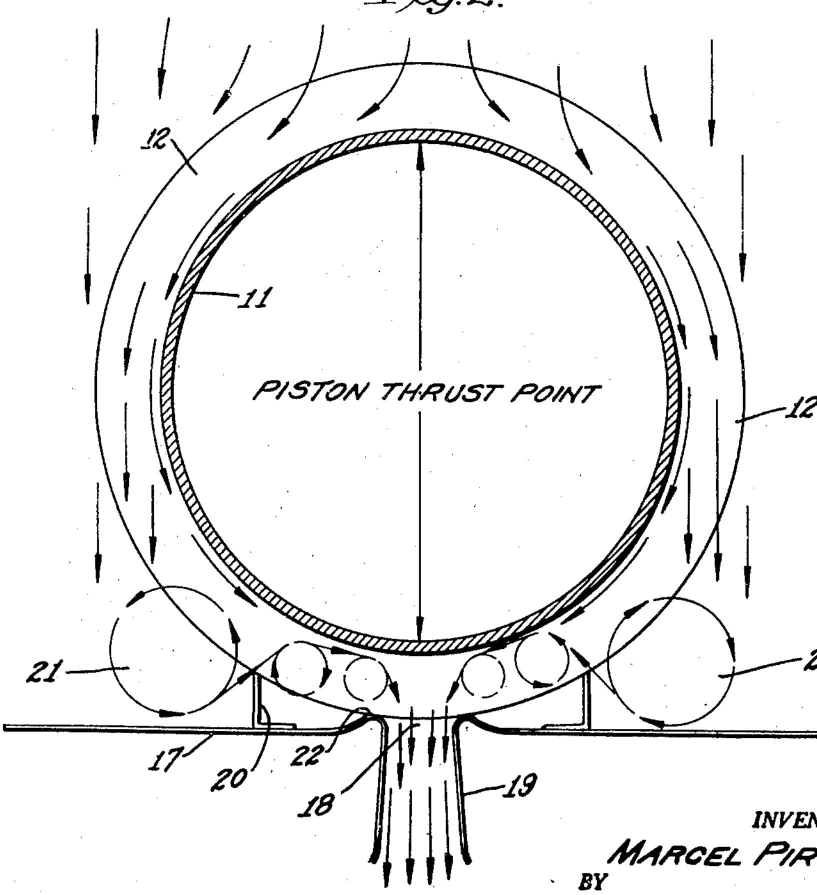


Fig. 2.



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ENGINE COOLING SYSTEM

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Fig. 3.

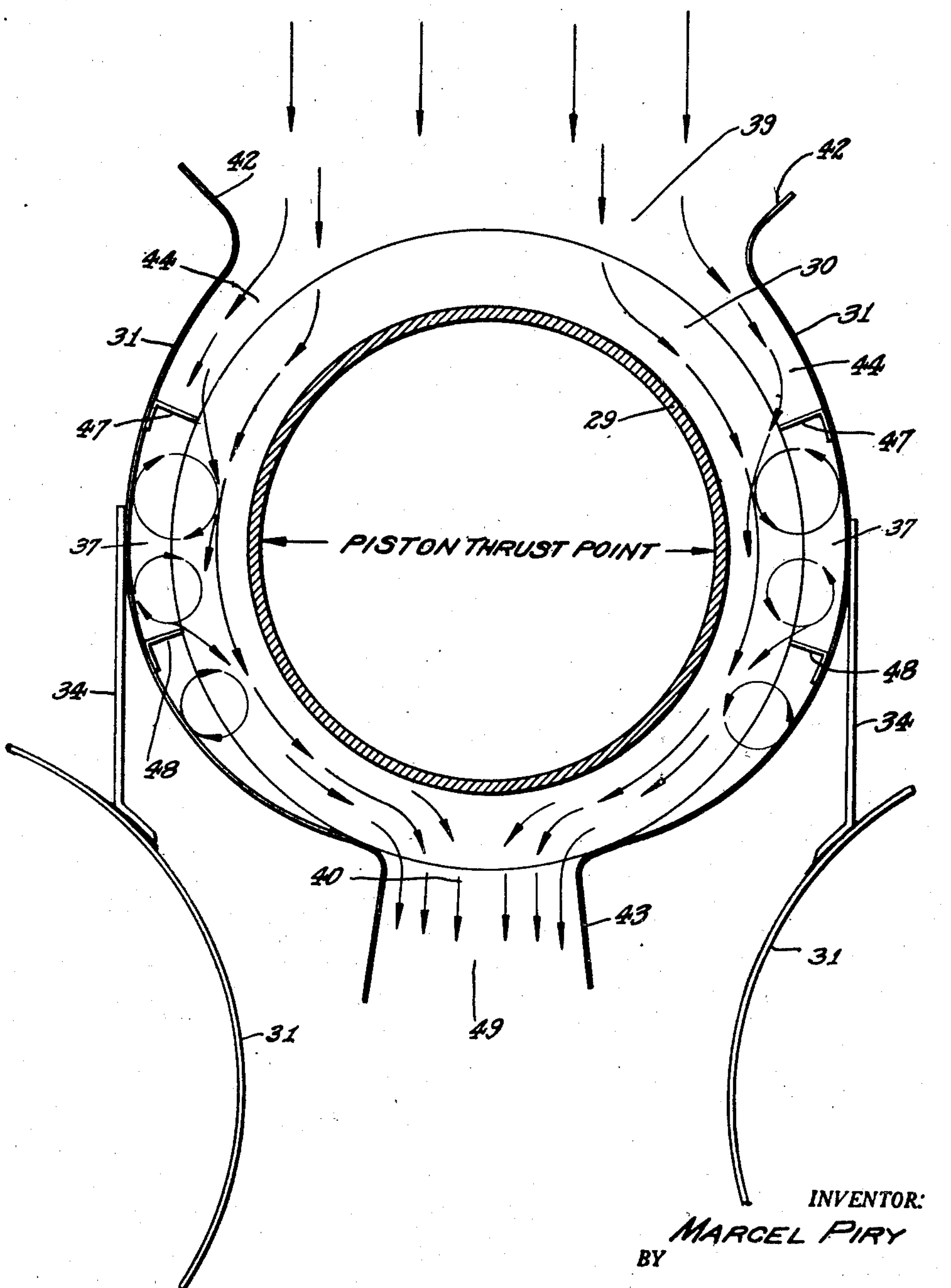

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Fig. 5.

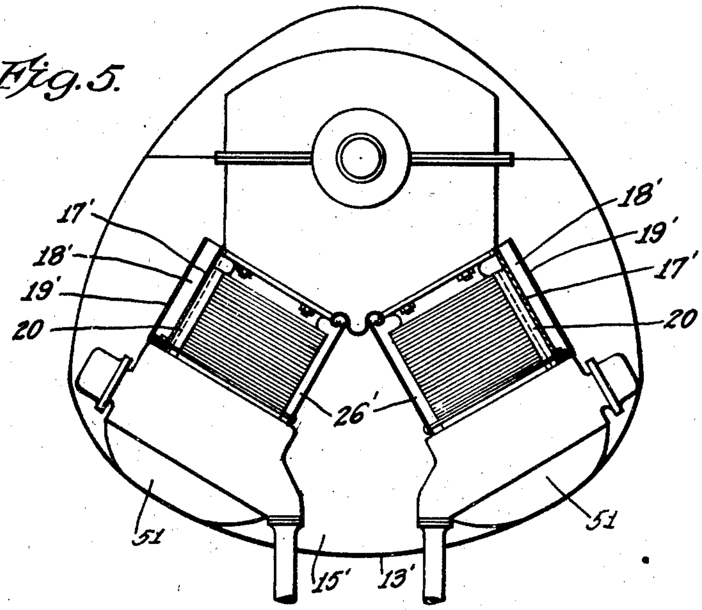
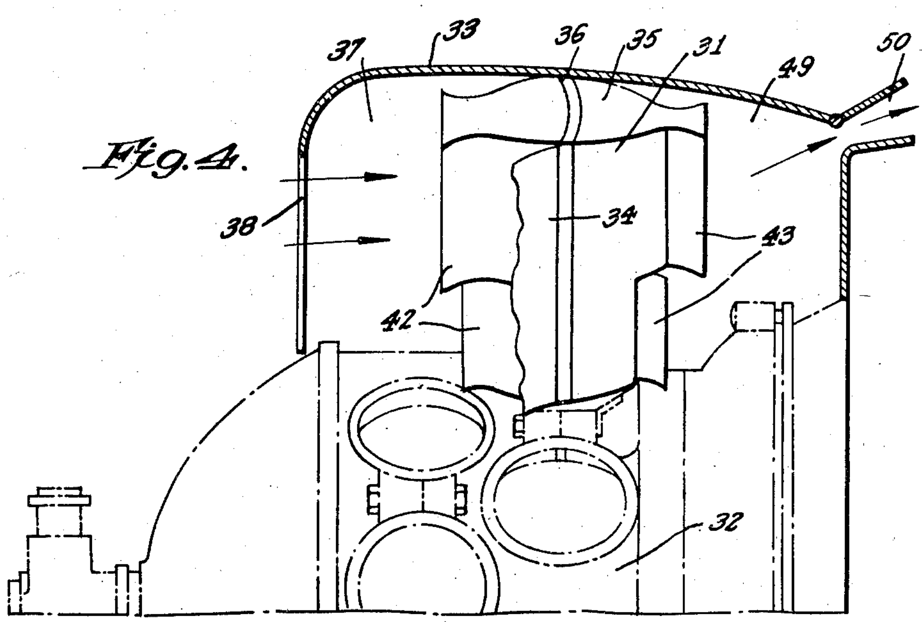


Fig. 4.



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ENGINE COOLING SYSTEM

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Application January 6, 1944, Serial No. 517,188

7 Claims. (Cl. 123—171)

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This invention relates to engine cooling systems and has particular reference to a system for cooling the cylinders of aeronautical engines, although the invention is not limited to that use.

It has been aeronautical engine cooling practice to obtain cooling air from the air stream induced by the propeller or by the movement of the airplane through the air, by collecting it in a substantially closed air scoop, either separately provided or arranged as part of the engine cowling, and having an air intake opening in the air stream. Owing to its velocity the air trapped in the scoop builds up a substantial static pressure, since the aggregate area of the restricted air exit openings between and around the cylinders is made less than the area of the intake opening of the scoop, or the outflow of air from the scoop is otherwise restricted or retarded as by friction or the like. The pressure air accordingly flows out of the scoop at high velocity over the cooling surfaces of the cylinders, which cylinders are provided with fins, spines or other projections to increase their cooling areas, and the cylinders are accordingly relatively uniformly cooled.

In air-cooled engines employing uni-directional cooling air flow, characterized by the fact that the same cooling air is used for cooling the front or upstream and the rear or downstream sides of the cylinder, the temperature of the cooling air is raised as the air progresses through the baffles, and unless provision is made to increase the rate of heat transfer per unit of temperature differential between the fins and the cooling air, the rear or downstream side of the cylinder must be expected to operate at a higher temperature than the front or upstream side, if a uniform heat abstraction is required all around the cylinder, as is usual. Furthermore, experiments have shown that the two portions of the cylinder barrel on which the two piston side thrusts, usually termed "thrust" and "anti-thrust," are applied, receive more heat than the rest of the cylinder barrel because of the heat generated by the friction between the piston and the wall and the heat transmitted by conduction from the piston to the cylinder wall through the piston skirt and, therefore, more heat must be removed by the cooling air over these two regions than over the rest of the cylinder barrel.

Because of the above considerations, it can be seen that the location of the piston thrusts on the cylinder barrel with respect to the direction of the cooling air flow has an important bearing on the cooling characteristics and the baffle design of an air-cooled engine. Nevertheless, all

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engines require an acceptable temperature distribution around the cylinder to avoid excessive distortion and wear. This condition must be met with the cooling air becoming progressively hotter as it proceeds through the baffles and with a heat rejection requirement which is decidedly non-uniform around the cylinder.

Accordingly, when the thrust and anti-thrust sides of the cylinder coincide with the front or upstream and rear or downstream sides of the cylinder, as in the case of an inline engine characterized from the cooling standpoint in that the cooling air flows across the cylinder bank in a general direction virtually perpendicular to the axis of the crankshaft, then the cooling requirements of the front or upstream and rear or downstream sides of the cylinder are greatly increased. Inasmuch as the cooler air engages the upstream or front side of the cylinder, the cooling of that side is not as acute a problem as that presented by the downstream or rear side of the cylinder, since that side receives warmer air previously used for cooling the upstream cylinder surfaces.

It has been found that the streamline or laminar air flow resulting from the usual prior cooling arrangements is not sufficient in many cases to provide adequate heat abstraction at the points requiring greater cooling, such as the aforementioned piston thrust and anti-thrust points, particularly when these points coincide with the upstream and downstream portions of the cylinder, as in the case of the inline engine described. However, a turbulent air flow may produce adequate cooling if properly controlled, notwithstanding the fact that turbulence causes a loss in air cooling pressure, a condition that has long been considered undesirable and inefficient. An example of an engine cooling system embodying turbulence-creating means that has proven very effective in improving the cooling efficiency of internal combustion engine cylinders, particularly the upstream sides thereof, is disclosed in copending application Serial No. 540,043, filed June 13, 1944, by D. B. Cox.

The present invention constitutes an improvement on that system, and also provides auxiliary or alternative arrangements producing the same or similar effects and consequent advantages by providing local turbulence over certain portions of the cylinder where a higher heat transfer per unit of temperature differential between the fins and the cooling air is required, either because the cooling air has been already warmed before reaching these portions or because more heat is to be rejected over said portions, or both, such as the downstream or rear sides of the cylinders in inline engines, although the invention may be used with equal facility on radial engines, as will be described.

In accordance with the invention, such local turbulence is provided by wing baffles having sharp free edges projecting into the air stream flowing adjacent the finned cylinder of an internal combustion engine, so as to create turbulence in the air stream at points receiving more heat for mechanical reasons and thus requiring greater heat abstraction, or at points where the cooling air already preheated calls for a higher heat transfer coefficient. As stated, the local turbulence thus created results in a higher heat abstraction and an explanation of this enhanced cooling effect is that turbulence precludes the maintenance of a layer of hot air on the cylinder cooling surfaces that acts as a heat insulator. The violently turbulent air scours this layer of spent cooling air from the cylinder surfaces and fins, and rapidly and continuously takes its place, with the result that fresh cooling air is always present to remove the heat as rejected by the cylinder at the selected point.

In inline engines the local turbulence provided by these wing baffles will be required primarily at the downstream or rear sides of the cylinders for the reasons mentioned, and these wing baffles may be employed to advantage in conjunction with the turbulence-creating baffle arrangement disclosed in said copending application, which is particularly adapted to cooling the upstream or front sides of the cylinders. In this way the entire cylinder is not only more efficiently cooled by the turbulent air, but selected parts thereof requiring greater cooling or requiring equal cooling with the hotter air, are also locally treated with air whose turbulence is greatly augmented at the selected points.

In a radial engine, characterized from a cooling standpoint by the fact that the cooling air flowing across a cylinder bank has a general direction virtually parallel to the axis of rotation of the crankshaft, the piston thrusts are applied on the lateral sides of the cylinders in the plane of the cylinder row and then only the first of the aforesaid conditions exists, the maximum heat rejection being required on the lateral sides where the cooling air has not yet been considerably preheated. The cooling of the rear or downstream side of the cylinder will not be as critical as in an inline engine because one of the piston thrust points does not occur there, and local turbulence will be helpful primarily at the lateral sides to increase the total heat rejection as required because of the piston thrusts, and secondarily over the rear or downstream half of the cylinder to assure adequate cooling with the warmed air that is available. Thus, the large scale turbulence created by the propeller and generally accepted as sufficient for adequate cooling of the front of the cylinders of a radial engine, may be materially aided by local turbulence created at those points beyond the front sides of the cylinders in accordance with the invention. When the invention is adapted to a radial engine, each cylinder is preferably individually jacketed with the jacket providing smooth intake and exit openings and with the aforementioned wing baffles extending into the air stream for producing turbulence in the air stream at the selected points around the cylinder, preferably at the lateral or piston thrust and anti-thrust sides thereof, and if required, at the rear or downstream side thereof. The jacket plates are spaced from the cylinder fin tips so that the air flows turbulently not only between the fins but also around them to produce the enhanced cooling effect previously described.

It will be seen that, in accordance with experiments performed on engines, the engine cooling system of this invention provides improved temperature distribution around the cylinder, as well as greater evacuation of heat from the cylinder when a drop in pressure of the cooling air is available, this drop in pressure depending upon the design of the cowling and airplane speed. By providing the local air turbulence that is necessary to not only continuously supply pressure cooling air to selected cylinder surfaces, but also to remove the spent cooling air that tends to cling to the surfaces, greater engine efficiency is possible under all operating conditions.

For a more complete understanding of the invention, reference may be had to the accompanying drawings, in which:

Figure 1 illustrates semi-diagrammatically a horizontal section through a single bank inverted inline aeronautical engine equipped with the cooling system of this invention;

Fig. 2 is an enlarged section through a single cylinder of Fig. 1 equipped with the baffling arrangement of this invention, illustrating diagrammatically the typical turbulent flow of the air around and through the cylinder fins;

Fig. 3 is a transverse section through a cylinder of a radial engine equipped with the baffling arrangement of this invention;

Fig. 4 illustrates the manner of applying the invention to a radial engine; and

Fig. 5 is an end view of an inverted V-type of aeronautical engine showing the baffling arrangement of this invention applied thereto.

Referring to Fig. 1 of the drawing, numeral 10 designates a bank of six cylinders 11 in inverted inline arrangement, each equipped with the usual cooling fins 12, which term includes spines, or other equivalent cooling projections increasing the cooling surfaces of the cylinders. Enclosing one side of the cylinder bank 10 is an air scoop 13 of sheet metal, plastic, or the like, having the air intake opening 14 directed in the direction of travel of the airplane and preferably located in the slip-stream of the propeller, so that the air flows into the chamber 15 at a pressure higher than atmospheric pressure, or the pressure air may be otherwise supplied to chamber 15. The scoop 15 is accordingly located at the upstream side of the cylinder bank 10, which may also be considered the front of the bank from the cooling standpoint, since the air flows substantially transversely of the bank, i. e., from front to rear. It will be understood that the scoop chamber 15 is closed at the rear by fire wall 16 and extends inwardly to the crank-case at the top and to the camshaft housing at the bottom, so as to completely enclose one side of the cylinder bank 10.

A baffle plate 17, either one-piece or assembled, extends along the downstream side of the cylinder bank 10, being suitably secured to the crank-case and camshaft housing at its upper and lower edges, respectively. This baffle plate 17 is provided with slots 18, located opposite the axes of the corresponding cylinders 11 or otherwise, and fitted with outwardly turned flanges 19 providing a generally Venturi-shaped contour for exit slots 18, as shown. The exit slots 18 preferably extend the full height of the cylinders, including head and barrel, or less, as required. The aggregate area of all of the exit slots 18 or of the passage area available at the location of the wing blades to be described is made less than the area of the air intake opening 14 of the scoop 13, so that a substantial static air pressure is built up within the chamber 15 by the kinetic energy of the inflowing air. However, the same effect may be obtained by making the said aggregate area smaller than the passage area of the scoop chamber 15 regardless of the area of the intake opening 14, the shape of which can be made to provide a Venturi tube effect so that the intake velocity is recuperated in the form of static pressure.

In the inline engine illustrated in Fig. 1, the piston thrust points coincide with the aforementioned front or upstream and the rear or downstream sides of the cylinders as indicated in Fig. 1, and since the rear side does not have unwarmed air available for cooling purposes, special cooling is required at the rear or downstream side of the cylinders in many cases. Accordingly, there are positioned adjacent the downstream or rear sides of the cylinders a plurality of wing blades or baffles 20 having sharp free edges projecting laterally into the air streams traversing the intercylinder spaces toward exit slots 18. As shown in Fig. 1, these wing baffles 20 are preferably positioned near the exit slots 18, and may be arranged at right angles to the lee baffle plate 17, as shown, although they may be otherwise positioned and in any required number, in order to intercept the air streams at points where greater cooling or greater heat transfer coefficient is required in order to attain the desired temperature distribution around the cylinders.

In operation of the engine cooling system of Figs. 1 and 2, and with particular reference to enlarged Fig. 2, it will be understood that the air within chamber 15 is under substantial static pressure and accordingly flows through exit slot 18 at considerable velocity.

After flowing between and over the fins on the front or upstream sides of the cylinders in bank 10, the air then flows between the cylinders with little turbulence, but inasmuch as the air tends to continue to flow in a straight line, it impinges against the flat surface of the lee baffle plate 17 and turbulence is created in the region approximately at 21, which might be termed a mixing space, since the air circulates vigorously and achieves a substantially uniform temperature.

As the air flows toward the exit opening 18, owing to the lower pressure at that point, it is intercepted by the wing baffles 20, which project into its shortest path from area 21 to the exit opening 18. As the air flows over the sharp intercepting edge of the wing baffles 20, its turbulence is increased in the manner shown by the arrows, between and around the fins 12, so as to scour off the layer of hot air tending to cling thereto, principally near the root of the fins. The inner ends of the flanges 19 are preferably reversely turned inwardly at 22, as shown, to further create turbulence prior to the streamline exit flow of the air through the Venturi exit slot 18.

It will be observed that the wing baffles extend inwardly to the tips of the fins 12, so that the air is caused to flow between them, and as the turbulence is created at the sharp edges of baffles 20, it all takes place between the fins 12, this insuring that the scouring action is attained immediately at the cooling surfaces. If desired, the edges of the wing baffles 20 may be spaced slightly from the fins 12, so that some turbulent air flows over the tips of the fins. By means of these wing baffles 20, local areas of the cylinder are particularly well cooled and they may be placed at any point where such special cooling is required, and any number may be used at various points at the head or barrel of the cylinder. Also, the baffles 20 may extend the full height of the cylinders, or less, as required. For example, they may be located on the barrel only, or on the head only, or on parts thereof.

Referring now to Fig. 1, the spent cooling air issuing from the exit openings 18 into the low pressure chamber 23 formed by the cowling 24 is withdrawn through the exit gill 25 over which the slip-stream flows and thus creates a suction to promote the withdrawal of spent cooling air from chamber 23.

As previously stated, the wing baffle arrangement just described may be employed to advantage in conjunction with the turbulence-creating means of said copending application, in order to augment the turbulence created thereby and to provide turbulence at selected portions of the cylinders to which the turbulence created by said means may not reach or extend. To this end, the engine shown in Fig. 1 may be fitted with the turbulence-creating front baffle plate 26 such as is shown in said copending application. This front baffle plate 26 extends along and over the upstream side of cylinder bank 10, between the crank-case and camshaft housing, and is provided with vertical openings or slots 27 opposite the axes of the corresponding cylinders and extending the full height of the cylinders. The portions of the plate 26 forming the slots or openings 27 are sharp-edged, so as to create turbulence in the air flowing through them from chamber 15 into the space 28 formed behind the baffle plate 26, as aforementioned, and described in greater detail in said copending application. The aggregate area of slots or openings 27 is preferably greater than that of exit slots 18, although not necessarily so.

In operating the system of the present invention in connection with the front turbulence-creating plate 26, the air passing through slots or openings 27 from high pressure chamber 15 into space 28 is rendered turbulent by the sharp edges of openings 27 and scours the cylinders and fin surfaces. After passing around the widest part of the cylinders, the air strikes the lee baffle plate 17 and turbulence is recreated in the region 21 with wing baffles 20 increasing the turbulence before the air passes out of exit slots 18, in the manner previously described. The width of the front openings 27 may be adjusted with respect to the wing baffles 20 to secure turbulence of any desired degree at various selected parts of the engine cylinder, and it will be understood that wing baffles 20 may be placed at or near the openings 27 and in some cases may replace the front baffle plate 26 altogether. In short, the wing baffles 20 are extremely simple in construction and may be readily mounted at any point on the engine to obtain desired turbulence at any one or more points.

An example of use of the wing baffles near the upstream side of the cylinder in lieu of a front baffle plate like 26 in Fig. 1 is illustrated in Fig. 3, as applied to a radial engine, for example.

Fig. 3, in conjunction with Fig. 4, shows a double row radial engine, each cylinder 29 of which has the usual fins 30, but is jacketed by two half-baffles 31, which jointly substantially envelop the cylinder heads and barrels, being secured at their inner ends to the crank-case 32 and at their outer ends to the streamlined cowl 33. The space between jacketing baffles 31 of adjacent cylinders is closed by plates 34, which are sealed airtightly against cowling 33, as are the heads 35 of the jackets, as by gasket 36, so that the interior 37 of the cowling 33 forms an air scoop similar to the air scoop 13 of Fig. 1. The air stream entering the cowling opening 38 accordingly is blocked off by the jackets 31, plates 34, and gasket 36, so that it is constrained to flow into the jacket formed around each cylinder by the jacketing baffles 31, the air entering the opening 39, as shown in Fig. 3. The exit slots 40 formed between the two jacketing baffles 31 of all cylinders, or the passage available at the location of the wind blades aggregate an area less than that of the intake opening 38 of the cowling 33, so that a substantial static pressure builds up within chamber 37.

As shown especially in Fig. 3, the front edges 42 of the baffles 31 defining the intake opening 39 are curved outwardly and their rear edges are provided with outwardly-flaring flanges 43 imparting a Venturi shape to exit slot 40. The baffles 31 only closely engage the tips of the fins 30 of the cylinder 29 at the tangent point at the rear or downstream side, and are spaced therefrom elsewhere as shown at 44 in Fig. 3. Because the piston thrust points are located at the opposite lateral sides of the cylinders of a radial engine, in the plane of the cylinder row and transversely to the general direction of air flow from front to rear, as indicated in Fig. 3, the lateral sides of the cylinder require special cooling. To that end local turbulence in the air stream is created at these piston-thrust points in accordance with the invention. Accordingly, wing blades 47 and 48 are provided extending radially inwardly from the inner surfaces of the baffle plates 31 toward the fins at the lateral sides of the cylinder, as shown in Fig. 3.

In operation of the system of Figs. 3 and 4, the air enters opening 39 from chamber 37 at a greater pressure than that at which the air leaves the exit slot 40, and the air flows between the fins 30 and between their tips and the jacketing baffles 31 through the spaces 44 as shown by the arrows. The air then impinges upon the wing baffles 47, which extend to the tips of the cylinder fins 30, and hence the air flow is partly intercepted, so that considerable turbulence is imparted thereto as shown by the arrows in Fig. 3. The turbulence accordingly serves to scour off the spent hot cooling air which tends to cling to the cylinder and fin surfaces, especially near the root of the fins.

In its course further turbulence is imparted to the air by the following wing baffles 48 so that continued circulation and scouring results, after which the warm cooling air flows around and between the cylinder fins and out through the streamlined exit opening 40 into the spent cooling air chamber 49 for flow through the exit gills 50 shown in Fig. 4. High heat abstraction is thus obtained on the rear or downstream side of the cylinders of a radial engine where it is required because of the piston thrust in those sides and a high heat transfer coefficient is attained over the rear which makes it possible to assure cooling

with already warm cooling air. The width and length of the openings 39 and 40, the distance between the tips of the fins and the baffles and the location of the wind blades, may be adjusted for suitable temperature distribution around the cylinders.

By adjusting the areas of the openings as described, and repositioning or increasing the number of wing baffles to create local turbulence, the system of this invention may be accommodated to the cooling requirements of any radial engine as well as of the inline engine of Fig. 1, and other types of engines to which the invention is applicable.

For example, the wing baffle arrangement of Fig. 1 may be applied with equal facility to an inverted inline V-type engine, as shown in Fig. 5, where two lee baffle plates 17′ of the form shown in Fig. 1 and similarly fitted with flanges 19′ defining exit slots 18′, extend along the outer sides of the two banks of cylinders. These baffle plates 17′ are fitted with the wing baffles or blades 20′ adjacent the exit slots 18′ and create turbulence in the air streams passing over them, in the manner described in connection with Fig. 1. If front turbulence-creating baffle plates 26′ corresponding to front baffle plate 26 in Fig. 1 are desired, they are arranged to extend along the inner or upstream sides of the two cylinder banks, as shown. The cooling air scoop is formed by that portion 13′ of the cowling extending between the camshaft housings 51 and having an opening directed in the direction of travel of the engine so as to collect cooling air which builds up a substantial static pressure within scoop chamber 15′ by reason of its velocity and the enclosure thereof, including lee baffles 17′ whose exit openings 18′ or cooling air passage areas at the wing blades have an aggregate area less than that of the air intake opening. The remaining structure shown in Fig. 1 is employed in the V-engine shown in Fig. 5.

Although the invention has been illustrated and described in connection with certain inline, V, and radial engines, it is equally applicable to other types of internal combustion engines, and is otherwise susceptible of changes in form and detail within the scope of the appended claims.

I claim:

1. In an internal combustion engine having spaced cylinders located in an air stream, the combination of an air scoop for substantially enclosing one side of said cylinders and having an opening for directing a portion of the air stream into said scoop, a first baffle plate extending along and adjacent said one side of said cylinders providing openings opposite the cylinders, those portions of said baffle plate having relatively sharp edges projecting into the air streams flowing from said scoop through said openings for creating turbulence in the air flowing over said cylinders, a second baffle plate extending along and adjacent the opposite side of said cylinders and providing restricted openings for guiding said streams over the cylinders at relatively high velocity, and additional baffles on said second baffle plate projecting into said streams adjacent said passages for further creating turbulence in said streams flowing over said cylinders.

2. In an aeronautical engine having spaced cylinders located in an air stream, an air scoop for substantially enclosing one side of said cylinders and having an opening for directing a portion of the air stream into said scoop, a first baffle plate extending along and adjacent said one side

of said cylinders providing openings opposite the cylinders, those portions of said baffle plate having relatively sharp edges projecting into the air stream flowing from said scoop through said openings for creating turbulence in the air flowing over said cylinders, a second baffle plate extending along and adjacent the opposite side of said cylinders and providing restricted openings of less total area than the area of said scoop opening and the total area of said first baffle plate openings, whereby the air entering said scoop builds up a substantial pressure in the chamber between said scoop and the second baffle plate for causing said streams to flow over the cylinders at relatively high velocity, auxiliary baffles on said second baffle plate projecting into said streams adjacent said passages for further creating turbulence in said streams flowing over said cylinders, and flanges on said second baffle plate at opposite sides of said passages for conducting the spent cooling air therefrom.

3. In an internal combustion engine having a plurality of the cylinders provided with cooling fins and arranged side by side, the combination of means for conducting air against the upstream sides of the cylinders, comprising slots provided with sharp edges, baffle means at the downstream sides of the cylinders provided with slots disposed opposite said first mentioned slots and of smaller area than said first mentioned slots, and turbulence creating means located in the intercylinder stream of air.

4. In an internal combustion engine having a plurality of the cylinders provided with cooling fins and arranged side by side, the combination of means for conducting air against the upstream sides of the cylinders, comprising slots provided with sharp edges, baffle means at the downstream sides of the cylinders provided with slots disposed opposite said first mentioned slots and of smaller area than said first mentioned slots, and baffle means provided with a sharp edge located adjacent said fins at a point between said first and second mentioned slots.

5. In an internal combustion engine having at least one cylinder provided with cooling fins, the combination of means for conducting a stream of air under pressure to one side of said cylinder for flow therearound, a baffle plate at the other side of said cylinder extending toward and having an edge disposed closely adjacent to the fins of said cylinder, said baffle plate being arranged at an angle to said stream so that said stream impinges against said baffle plate to create turbulence in the air adjacent to said fins, and additional baffle means adjacent to said baffle plate and disposed between said air stream conducting means and said edge of said baffle plate, said baffle means projecting toward and having an edge disposed adjacent to said fins for intercepting said stream to direct said air between said fins and create further turbulence in said stream adjacent and between said fins.

6. In an internal combustion engine having at least one cylinder provided with cooling fins, the combination of means for conducting a stream of air under pressure to one side of said cylinder for flow therearound, baffle means at least partially enclosing the other side of said cylinder, said baffle means having edges closely adjacent to said cooling fins providing an opening adjacent said cylinder through which at least part of said stream flows, and additional baffle means interposed between said opening and said air stream conducting means extending toward and terminating closely adjacent to said fins to direct air between said fins and having a relatively sharp edge intercepting said stream for creating turbulence therein as it flows over and between said cylinder fins toward said opening.

7. In an internal combustion engine having at least one cylinder provided with cooling fins, the combination of means for conducting a stream of air under pressure to one side of said cylinder, baffle means at the other side of said cylinder having an opening therethrough having edge portions substantially in contact with the outer edges of said fins for guiding said air stream over said fins, and additional baffle means disposed on opposite sides of said opening and between said opening and said air stream conducting means and projecting inwardly toward and having free edges substantially in contact with said fins for intercepting said stream to create turbulence in the air flowing over and between said fins.

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