

Feb. 3, 1948.

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2,435,557

AIR-COOLERS FOR INTERNAL-COMBUSTION TURBINES

Filed Oct. 8, 1943

4 Sheets-Sheet 1

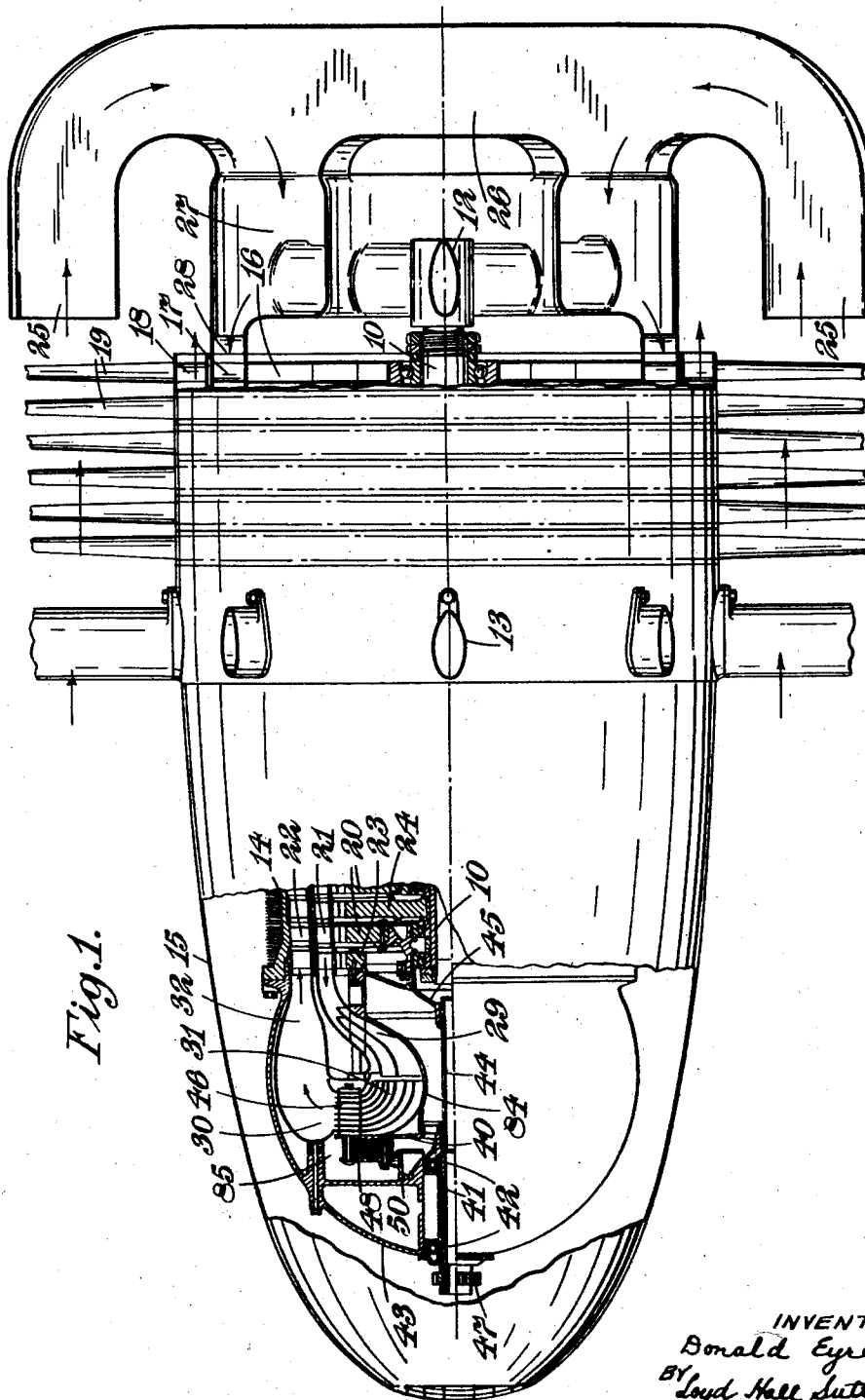


Fig. 1.

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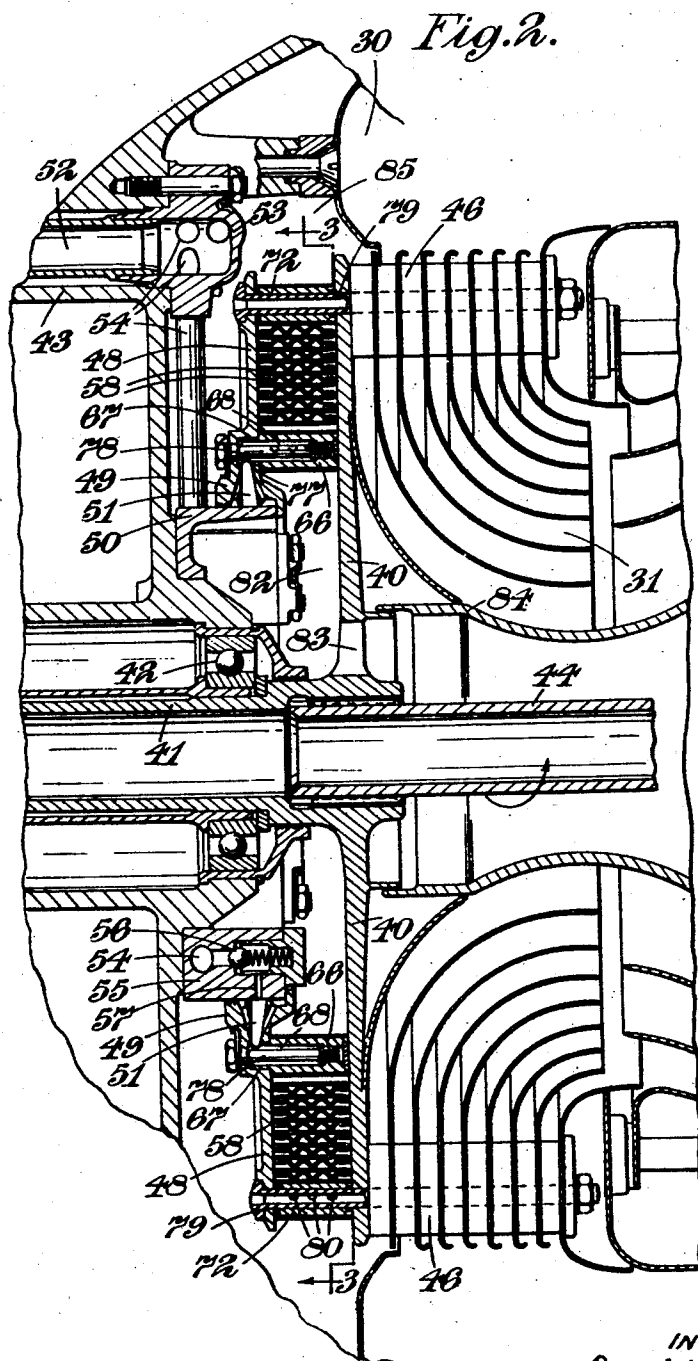
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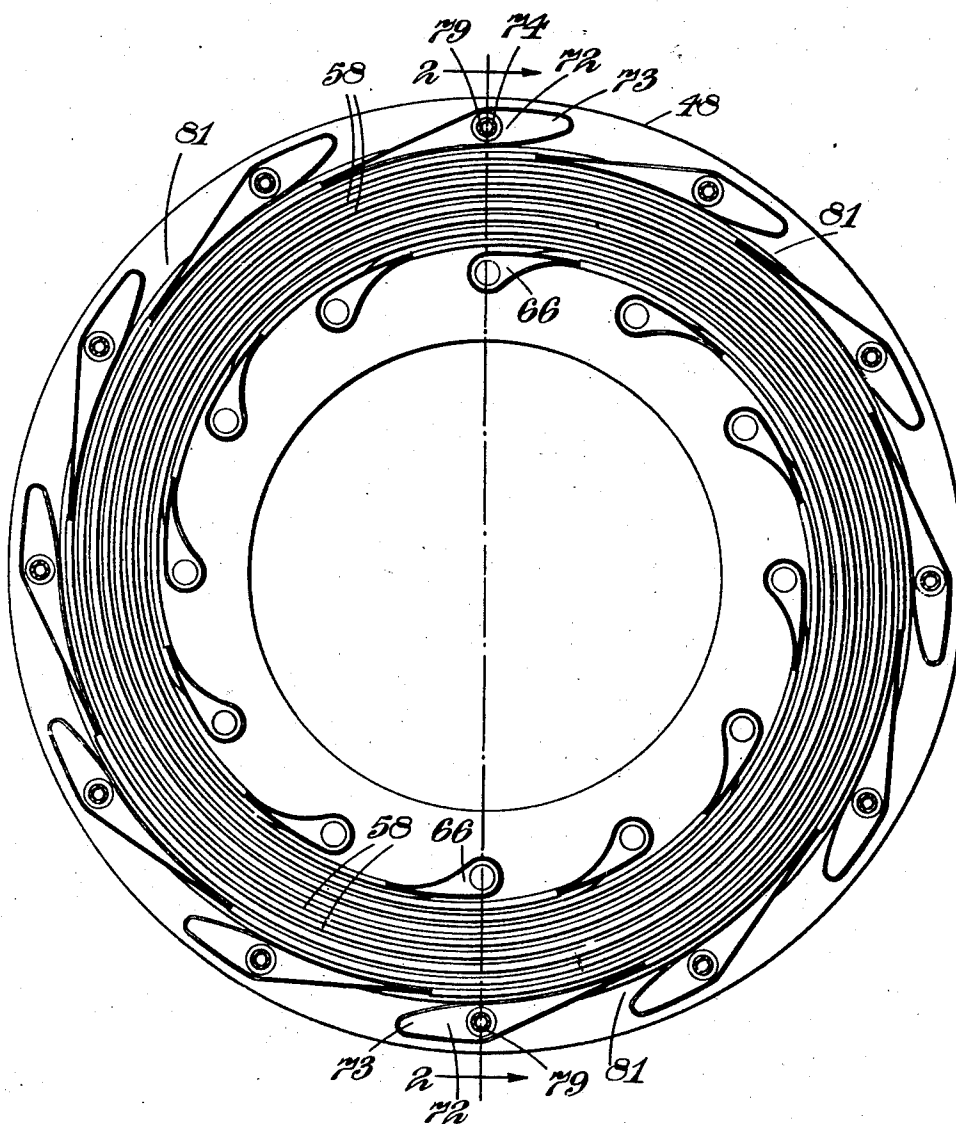
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Fig. 3.



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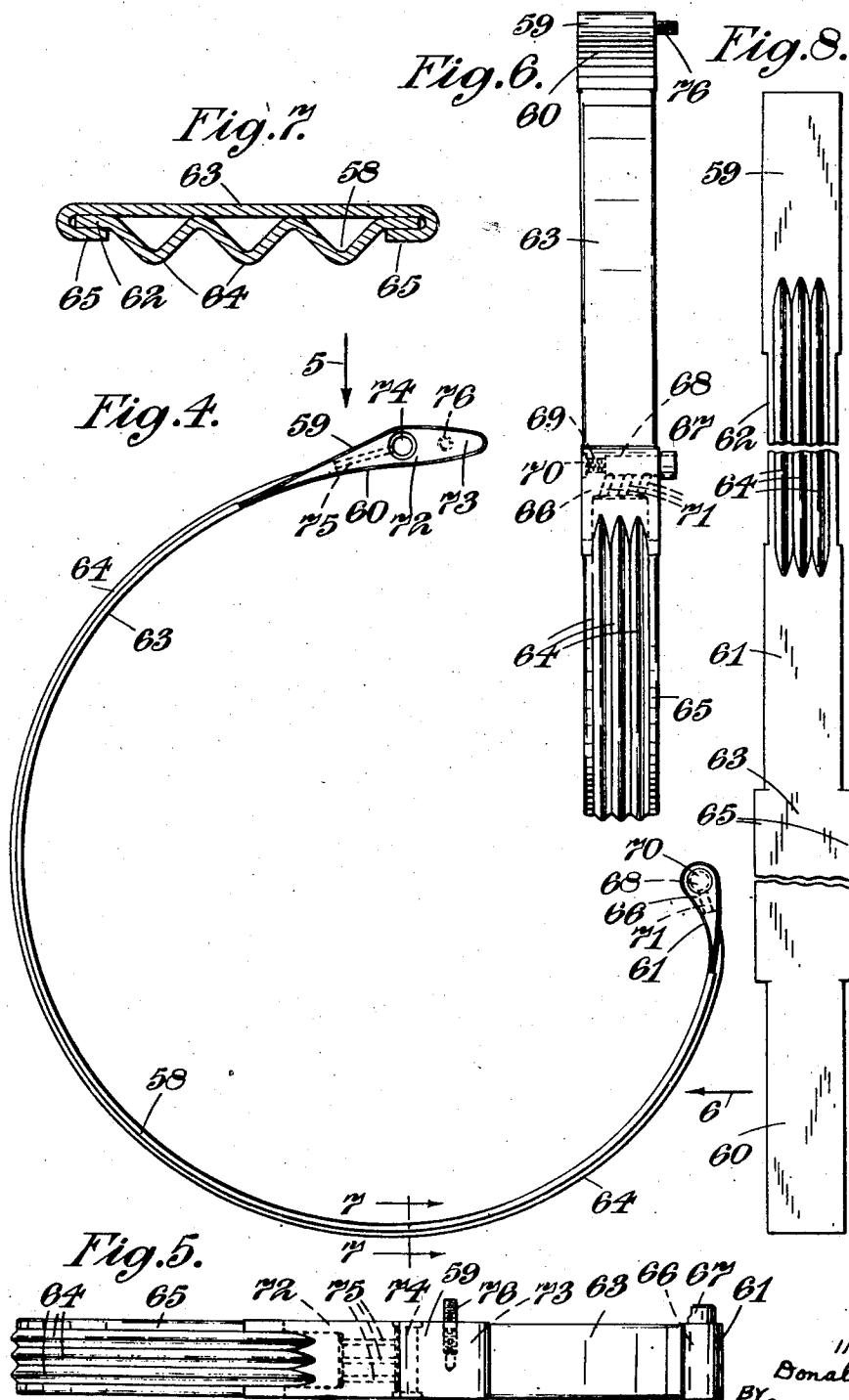
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4 Sheets-Sheet 4



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2,435,557

AIR-COOLER FOR INTERNAL-COMBUSTION
TURBINES

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Application October 8, 1943, Serial No. 505,550
In Great Britain November 5, 1942

3 Claims. (Cl. 60—41)

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This invention relates to internal-combustion turbines of the kind in which a compressor delivers compressed air to a combustion chamber into which fuel is delivered by a rotating burner, the products of combustion passing from the combustion chamber through the turbine, and in which the fuel is delivered to the burner through an air-cooler through which also flows a portion of the air delivered by the compressor so that this air is cooled by the fuel. The cooled compressed air may be used for pressure balancing or cooling purposes in the compressor and turbine or for any other purpose for which it is needed. Since the burner is rotating it must be supplied with fuel through a collecting ring rotating with the burner and a stationary feed to that ring. The object of the present invention is to provide an improved air-cooler for an internal-combustion turbine of the above kind.

According to the present invention there is provided an internal-combustion turbine of the above kind wherein the air-cooler is constituted by a plurality of passages rotating with the burner, connecting, and conveying fuel from, the collecting ring to the burner, and spaced apart to provide between them air passages communicating at one end with the delivery from the compressor and at the other end with a space in which cooled compressed air is required. With this construction the air-cooler rotates with the burner and this has the advantage that it can be made smaller and that the connections by which the fuel is fed to the burner can be made simpler than is possible when the air-cooler is stationary and the fuel must be conveyed from it to the rotating burner.

Preferably, the fuel passages are spirally arranged around the axis of rotation of the burner so that the ends of the air passages between them that communicate with the delivery of the compressor, face in the direction of rotation of the burner, whereby the rotating of the air-cooler with the burner causes a flow of air through the air passages in the correct direction.

Conveniently, the fuel passages are formed by flattened tubes each longitudinally corrugated on one face and curved longitudinally in an involute curve or a curve approximating thereto; and assembled with the corrugated face of each in contact with the other face of an adjacent tube to provide air passages between the corrugations. One face of each tube may be flat and engage the internal crest of the corrugations in the other face, and the tubes may be assembled with the external crest of the corrugations

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on each engaging the flat face of an adjacent tube, preferably with the corrugated face of each tube outermost.

Each tube may be formed by longitudinally corrugating the sheet metal strip, folding one half of the strip over on to the other and securing the two halves together along their abutting edge or edges. A pair of end elements may be secured one at each end of the tube between its faces and may be formed with passages to provide communication to the interior of the tube. The end elements may also form the means for securing the tubes on a rotatable support for the burner. The end element at the fuel-delivery end of each tube may also be shaped to provide an air scoop between itself and the adjacent like end elements so as to assist the circulation of air through air passages between the tubes.

An internal-combustion turbine incorporating the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a plan, partly in section, of the turbine. This figure is diagrammatic.

Figure 2 is a section, on a larger scale, on the line 2—2 of Figure 3, through a burner and air cooler in the turbine;

Figure 3 is a section on the line 3—3 of Figure 2 and shows the cooler elements;

Figure 4 is a side elevation of one cooler element;

Figures 5 and 6 are elevations of the cooler element shown in Figure 4 as seen when looking in the direction of the arrows 5 and 6 respectively in Figure 4;

Figure 7 is a section, on a larger scale, on the line 7—7 of Figure 4, and

Figure 8 is a plan of a blank from which a cooler element is made.

As shown in Figure 1, the turbine comprises a stationary shaft 10 which is supported by suitable bearings from two sets of streamlined struts 12 and 13 which, in turn, are carried by an annular tunnel (not shown) surrounding the rear end, right-hand end in Figure 1, of the turbine. The struts 13 also support a casing 14 for the high-pressure part of the turbine and an outer casing 15 that encloses the forward parts of the turbine. A set of rotors 16 are mounted to rotate on the shaft 10 and are formed each with an inner ring of shrouded compressor blades 17, an outer ring of shrouded turbine blades 18 and a set of propeller blades 19 that rotate in the annular tunnel aforesaid.

The rotors 16 are arranged alternately to rotate in opposite directions and provide a propulsive thrust by means of their blades 19. A second set of blades 20 are mounted to rotate on the shaft 10 within the casing 14 and have each an inner ring of shrouded compressor blades 21 and an outer ring of shrouded turbine blades 22. The last rings of compressor and turbine blades to the left are stator blades and are carried by an annular stator 23 secured to the casing. The third rings of compressor and turbine blades from the left are also stator blades and are carried by a stator 24 which serves to support the forward end of the shaft 10.

Air enters the unit through forwardly directed air-intakes 25 and a passage 26 into an annular chamber 27. The air passes from the chamber 27 through a ring of stator blades 28 to the compressor blades 17 which compress the air and deliver it to the compressor blades 21. These blades further compress the air and deliver it through an annular diverging passage 29 to an annular combustion chamber 30. Fuel is burnt in the air by means of a burner assembly generally designated 31 and the products of combustion pass through an annular converging passage 32 to the first ring of turbine blades 22. The products of combustion then expand through the turbine blades 22 and 18 and are discharged rearwardly from the last ring of turbine blades.

The construction described above forms the subject-matter of the co-pending application Serial No. 505,389 by A. A. Griffith, filed October 7, 1943 (British application No. 4,699/41), and is more fully described therein. The present improvements will now be described.

The burner assembly comprises a disc 40 carried by a shaft 41 that rotates in bearings 42 carried by a casing 43. This casing is supported from the casing 14. The shaft 41 is splined on to a shaft 44 that is connected by a spider 45 to the end rotor 20 so that the burner assembly is rotated by this rotor. The disc carries twelve burners 46 which are shaped as blades so that the air flow past them tends to rotate the burner unit clockwise as seen in Figure 3. The shaft 41 carries a gear pinion 47 (Figure 1) which drives auxiliary units, such as fuel pumps, and an electric motor which is used for starting the turbine but which may be arranged to operate as a generator when the turbine is running.

The burner assembly also comprises an annular disc 48 of which the hub 49 rotates on the cylindrical outer surface of a stationary distributing ring 50. The hub of this disc is formed with an annular groove 51 which acts as a collecting ring for fuel and is fitted with suitable seals to prevent leakage of fuel between it and the distributing ring. Fuel is supplied to the collecting ring by a conduit 52, a connection box 53, six conduits 54 (of which one only is shown) and six valve chambers 55 spaced equally around the distributing ring 50. Each valve chamber contains a non-return valve 56 and the fuel leaves it through a passage 57 to enter the collecting ring 51. The fuel flows from the collecting ring 51 through twelve tubes 58 (see also Figure 3) whose construction will be described later, to the twelve burners 46 which are arranged in a circle around the periphery of the disc 40. The construction of these tubes 58 is as follows:

Each tube is formed from a sheet metal strip, shown in Figure 8, brass being a suitable mate-

rial, which has its two end portions 59 and 60 and its centre portion 61 of the same width. The portion 62 is reduced in width while the portion 63 is increased in width. The reduced portion 62 is corrugated longitudinally at 64 with three, or any other number of, corrugations which extend beyond the ends of the reduced portion into the central portion 61 and the adjacent end portion 59. The remainder of the strip is flat and the length of the wider portion 63 is the same as that of the reduced portion 62 and is several times the length of each end portion 59 and 60 and of the central portion 61. This strip is bent about its centre so that the reduced portion 62 registers with the wider portion 63 and the central portion 61 forms a loop. The edges 65 of the wider portion 63 are then folded over the edges of the reduced portion 62, as shown in Figure 7, so as to bring the outer face of the folded edge flush with the edges of the end and central portions 59, 60 and 61. The joints between the edges of the wider and reduced portions 62 and 63 are then soldered, preferably with silver solder, so as to form a closed flattened tube in which the inner crests of each corrugation lie against the inner face of the opposite flat side of the tube, as shown in Figure 7. The spaces within the corrugations form fuel passages. After the side edges of the tube are hard soldered together, the whole flattened tube is curved, as shown in Figure 4, to form an involute with the corrugated face outermost and with the loop formed by the central portion of the blank nearer the base circle of the involute than the other end of the tube.

The loop 61 in the tube receives an inner end element 66 (Figures 4 and 6) having a part cylindrical portion merging into a tapered tail. A spigot 67 projects from one side of the end element 66 and is concentric with the cylindrical portion thereof and a bore 68 is formed through this spigot and extends completely through the element. The end 69 of this bore remote from the spigot 67 is screw-threaded and is closed beyond the screw-threaded portion by a blanking disc 70. Passages 71 are formed in the tail portion of the element 66 so as to provide communication from the bore 68 to the corrugations in the tube 58. Fuel can thus flow through the bore of the end element into the tube and hence to its outer end.

The ends 59 and 60 of the strip at the outer end of the tube 58 are splayed apart to receive an outer end element 72 which is of approximately aerofoil shape and has a nose portion 73. The outer end element has a bore 74 that extends completely through it and passages 75 in the tail that place the interior of the tube 58 in communication with the bore 74. This element 72 also carries a stud 76 and is inserted between the splayed portions 59 and 60 of the outer end of the tube 58 which portions are folded over it so as to meet at their ends where they are joined by being soldered to the end element. Both the end elements 66 and 72 are hard soldered in position so as completely to close the tube except for the inlet and outlet through the bores 68 and 74 of the end elements.

The spigot 67 on the inner end element of each tube 58 fits into one of a number of sockets 77 spaced around the annular disc 48 (Figure 2) near its inner edge. The inner end element 66, and therefore the inner end of the tube, is secured in position by a set-screw 78 passing through the annular disc 48 and the bore 68 in

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the inner end element (with a clearance) and screwed thereto. The collecting ring 51 in the annular disc opens into the socket 77 so as to place the bore of the inner end element in communication with the collecting ring. The tube 58 lies between the two discs 40 and 48 and its width is the same as the space between them. The outer end of the tube is secured in position by means of a hollow burner bolt 79 which passes through both discs and through the bore in the outer end element 72. The burner bolt 79 is perforated at 80 so that the fuel flowing through the tube can pass through the outer end element in the burner bolt and thence to the burner. It will be understood that there is a separate burner bolt for each tube and that these burner bolts are equally spaced around the periphery of the supporting discs. Each burner bolt also holds to burners on the assembly and conveys the fuel from its tube 58 to the openings in the burner through which it is injected into the air stream. Each stud 76 extends through a hole in the disc 48 and receives a nut so that each end element 72 is held to two spaced points and cannot be turned by the air pressure on it due to the rotation of the assembly.

The number (in the case shown, twelve) of tubes 58 and their length are so selected that, being of involute shape and of even thickness, they pack tightly together with the crests of the corrugations 64 in one face of each tube in contact with the flat face 63 of the adjacent tube. A number of shallow air passages is thus provided between each pair of adjacent tubes and each passage extends spirally through the annular pack of tubes so as to open at one end through the outer surface of the pack and at the other end into the space 82 within the pack. The outer ends 81 (Figure 3) of the air passages communicate with an annular space 85 partitioned off from the combustion chamber 30 so that some of the compressed air will be delivered into this chamber and will enter the outer ends 81 of the air passages and flow along them to the space 82 inside the pack of tubes. The air flowing through the air passages is cooled by the fuel flowing through the tubes in the opposite direction and the cooled compressed air can be led away from the central space inside the pack of tubes, through openings 83 in the disc 40 and the space within an annular partition 84, to the turbine bearings where it is employed to balance the gas pressure acting on the turbine discs and for cooling the bearings as described in application Serial No. 505,391 by A. A. Griffith, filed October 7, 1943, now Patent No. 2,429,681 (British application No. 5,152/41).

It will be seen that the construction provides a very compact form of air-cooler having very long narrow air passages and correspondingly long and narrow fuel passages for the fuel which constitutes a cooling medium. The corrugations 64 are on the outer side of each fuel tube so that the fuel will tend to be thrown into the corrugations by centrifugal action and to flow along the corrugations where it exerts a maximum cooling effect on the air to be cooled.

Ignoring the outer end element 72 of each tube 58, the outer surface of the assembly of tubes is roughly cylindrical. The outer end elements 72 of the tubes project beyond the cylindrical surface as shown in Figure 2 and the nose part 73 of each end element is so shaped that it provides a divergent entrance 81 to the air passages between its tube and an adjacent tube. These

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divergent entrances 81 act as air scoops and face in the direction of rotation of the burner and air-cooler assembly so that air is forced into passages by the rotation of the assembly. The construction thus provides for a considerable mass flow of air through the cooler and for efficient cooling of the air flowing through it. The end elements 80 and 72 serve to support the tubes 58 in the assembly as well as to provide communication between the interior of the tube and the collector ring 51 and burner bolts 79 respectively.

The tubes 58 are shown as being of uniform depth throughout their length and provide air passages of uniform cross-sectional area. The area of the air passages can be made to vary from one end to the other by making the depth of each tube vary also and in this case each tube would be bent to a curve which is only approximately an involute in order that they should pack tightly.

I claim:

1. An internal-combustion turbine comprising a compressor, a combustion chamber into which the compressor delivers compressed air, a burner unit rotating in the combustion chamber, delivering fuel thereto, and comprising a collecting ring rotating with the burner unit and a stationary fuel feed to that ring, a turbine through which the products of combustion from the combustion chamber expand and an air cooler constituted by a plurality of passages rotating with the burner, connecting and conveying fuel from the collecting ring to the burner and spaced apart to provide between them air passages communicating at one end with the delivery from the compressor and at the other end with a space in which cooled compressed air is required.

2. An internal-combustion turbine comprising a compressor, a combustion chamber into which the compressor delivers compressed air, a burner unit rotating in the combustion chamber, delivering fuel thereto, a collecting ring rotating with the burner unit and a stationary fuel feed to that ring, a turbine through which the products of combustion from the combustion chamber expand and an air cooler constituted by a plurality of burners arranged in a circle about the axis of rotation, and a plurality of passages, which passages each connect, and convey fuel from, the collecting ring to a separate burner and are spirally arranged around the axis of rotation of the burner to rotate therewith and spaced apart to provide between them air passages of each of which one end communicates with the delivery from the compressor and faces in the direction of rotation of the burner and the other end communicates with a space in which cooled compressed air is required.

3. An internal-combustion turbine comprising a compressor, a combustion chamber into which the compressor delivers compressed air, a burner unit rotatable within the combustion chamber and comprising a number of burners spaced around the axis of rotation of the burner unit, a collecting ring rotating with the burner unit and a stationary fuel feed to that ring, a turbine through which the products of combustion from the combustion chamber expand and an air cooler which comprises a plurality of flattened tubes each longitudinally corrugated on one face and curved longitudinally in an approximately involute curve, which tubes are mounted on the burner unit with the corrugated face of each in contact with the other face of an adjacent tube

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to provide air passages between the corrugations and with one end of each tube communicating with a separate burner and the other end communicating with the collecting ring.

4. An internal-combustion turbine comprising a compressor, a combustion chamber into which the compressor delivers compressed air, a burner unit rotatable within the combustion chamber and comprising a number of burners spaced around the axis of rotation of the burner unit, a collecting ring rotating with the burner unit and a stationary fuel feed to that ring, a turbine through which the products of combustion from the combustion chamber expand and an air cooler which comprises a plurality of flattened tubes each connecting the collecting ring to a separate burner and each longitudinally corrugated on one face and having the opposite face flat and in engagement with the internal crests of the corrugations, and each curved longitudinally in a substantially involute curve, which tubes are assembled together on the burner unit to rotate therewith with the corrugated face of each in contact with the flat face of an adjacent tube to provide air passages between the corrugations, each of which passages communicates at one end with the combustion chamber through a mouth opening in the direction of rotation of the burner unit and at the other end with a space within which cooled compressed air is required.

5. An internal-combustion turbine according to claim 4 wherein each tube is curved to bring its corrugated face outermost.

6. In an internal-combustion turbine, the combination with a rotating burner unit having a number of burners equally spaced in a circle around the axis of rotation of the burner unit to rotate therewith, a collecting ring rotating with the burner and a stationary fuel feed to that ring, of an air cooler comprising a plurality of flattened tubes each communicating at one end with a separate burner and at the other end with the collecting ring to convey fuel from the ring to the burner and each having one face longitudinally corrugated and the opposite face flat and in contact with the internal crests of the corrugations, which tubes are supported on the burner unit to rotate therewith with the corrugated face of each tube in contact with the flattened face of an adjacent tube to provide air passages between the tubes which open externally of the assembly of tubes to face in the direction of rotation of the burner and also open internally of the assembly of tubes.

7. In an internal-combustion turbine, the combination with a rotating burner unit comprising a

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plurality of burners equally spaced in a circle around the axis of rotation of the unit to rotate therewith, a collecting ring and a stationary fuel feed to the collecting ring, of an air cooler comprising a plurality of tubes assembled on the burner unit to rotate therewith each connecting the collecting ring to a separate burner, and collectively providing a plurality of air passages between them, each of which tubes is formed by longitudinally corrugating a sheet metal strip, folding one half of the strip over on to the other and securing the two halves together along each of their abutting edges.

8. The combination according to claim 7 wherein each strip is folded about a transverse line intermediate its ends and a portion of the strip on one side of the said line is wider than the mating portion of the other side of said line to provide marginal strips of the first portion which extend beyond both edges of the second portion and are folded thereover and secured thereto to form the tube.

9. In an internal-combustion turbine, a rotating burner unit comprising a rotatable support, a plurality of burners mounted on the support in a circle around its axis of rotation, a collecting ring formed in the support, stationary means for feeding fuel to the collecting ring, a plurality of flattened tubes each curved longitudinally substantially to an involute and assembled on the support each to provide communication from the collecting ring to a separate burner, and to provide between them a plurality of narrow air passages extending from an approximately cylindrical outer surface of the assemblage of tubes to the inside of the assemblage of tubes, the outer end of each of which tubes is so shaped that it extends approximately tangentially of the assembly and in the direction of rotation of the support to provide, between itself and the end of an adjacent tube, an air scoop which leads to one of the air passages and ensures an air flow therethrough.

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