April 29, 1952 A. H. FLETCHER ET AL 2,594,761

HEAT EXCHANGER

Filed Dec. 29, 1947 7 Sheets-Sheet 1

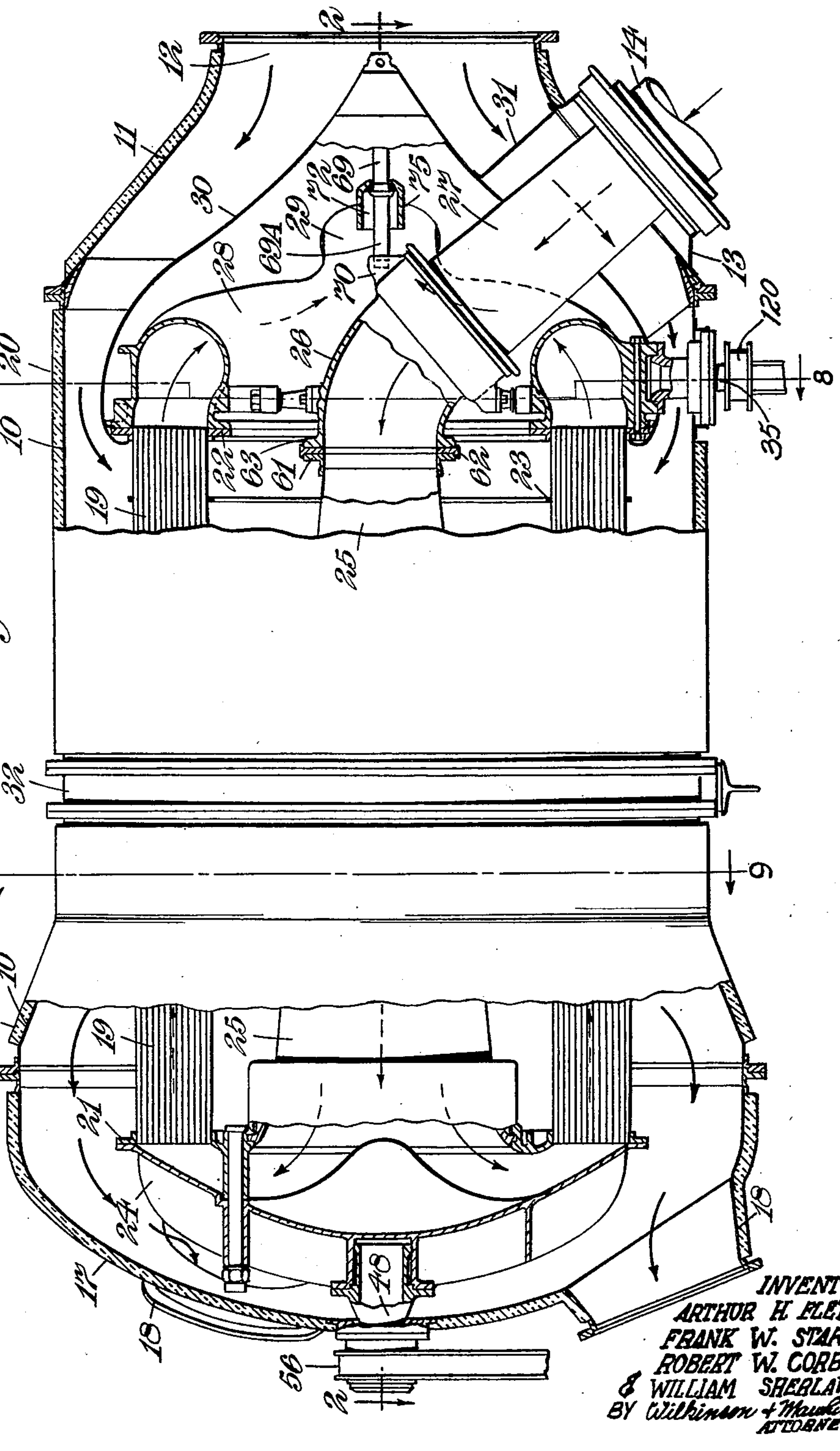

Fig. 1.

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HEAT EXCHANGER

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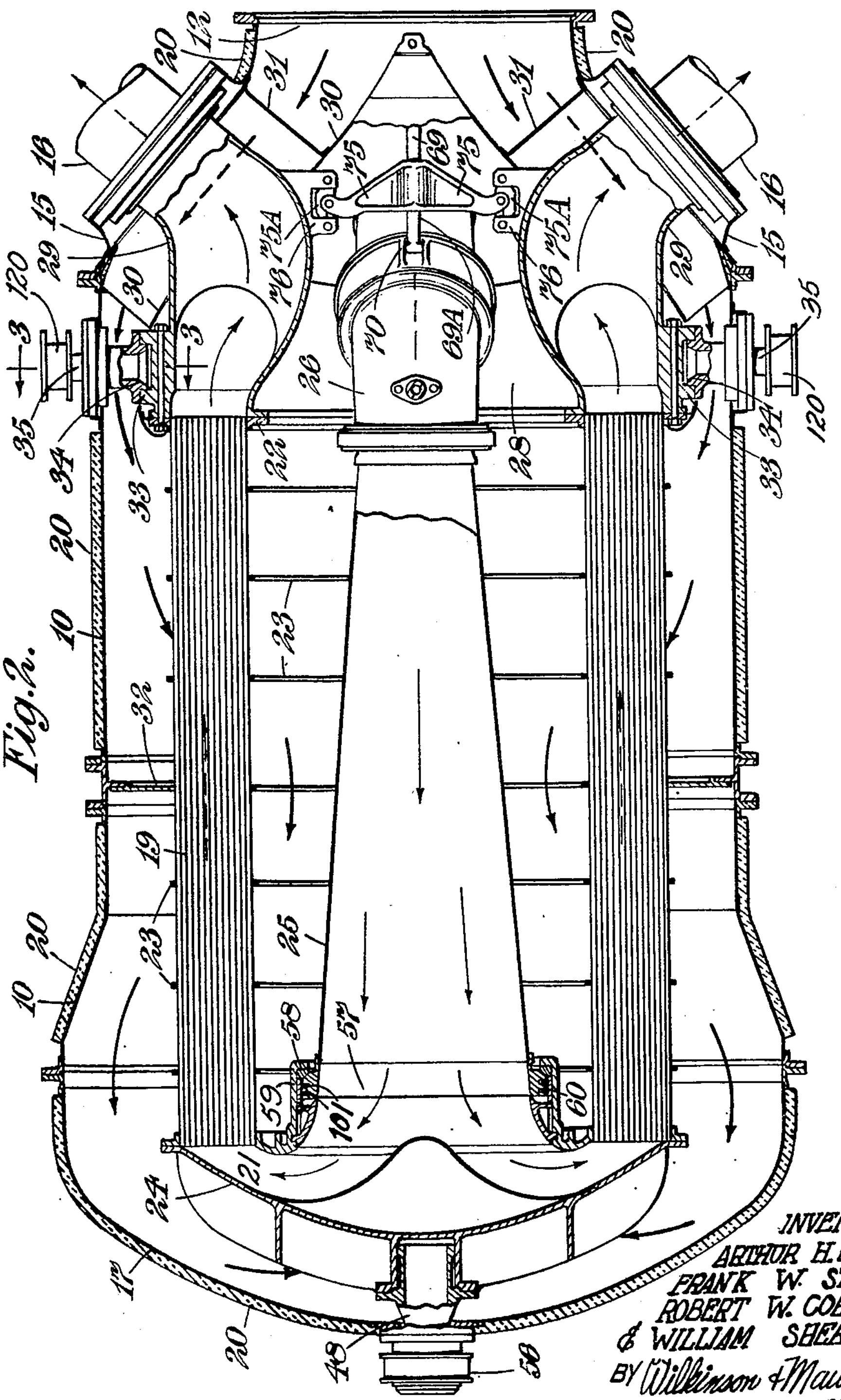

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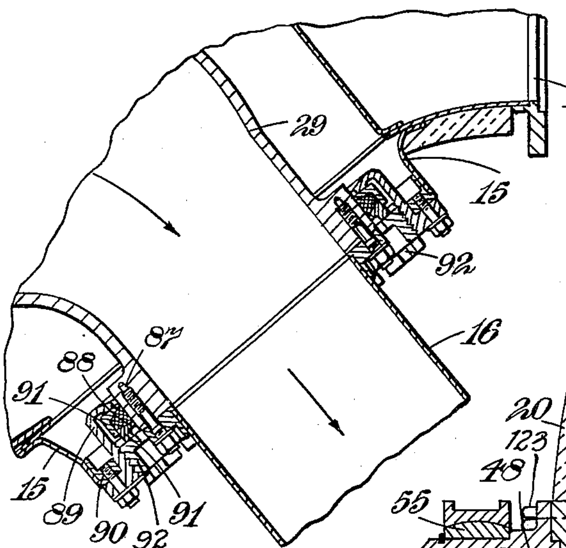


Fig.6.

Fig.4.

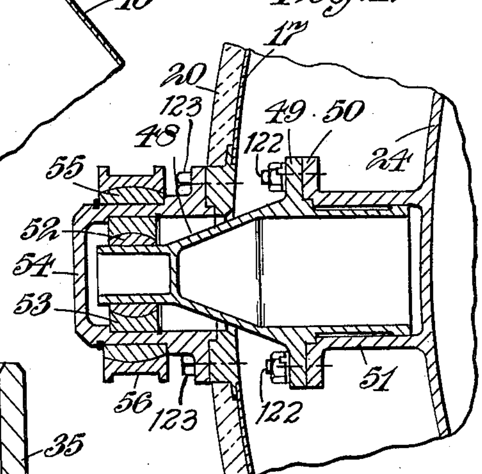
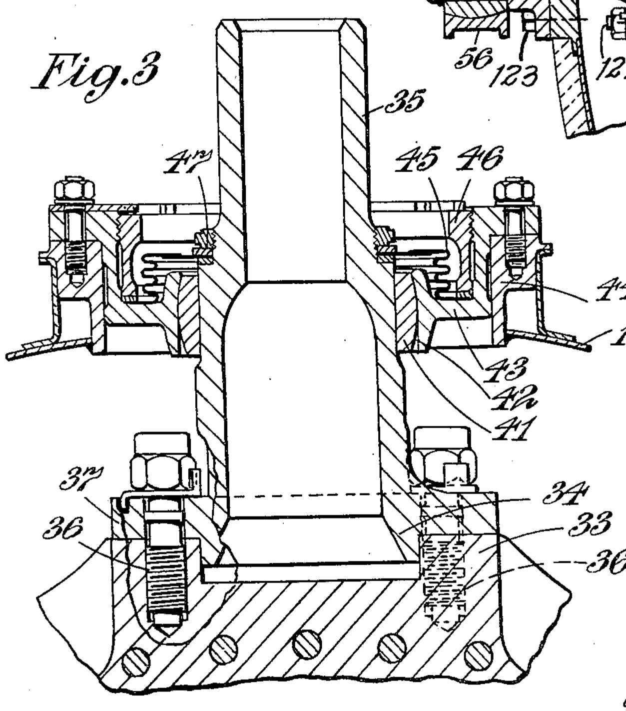


Fig.3



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HEAT EXCHANGER

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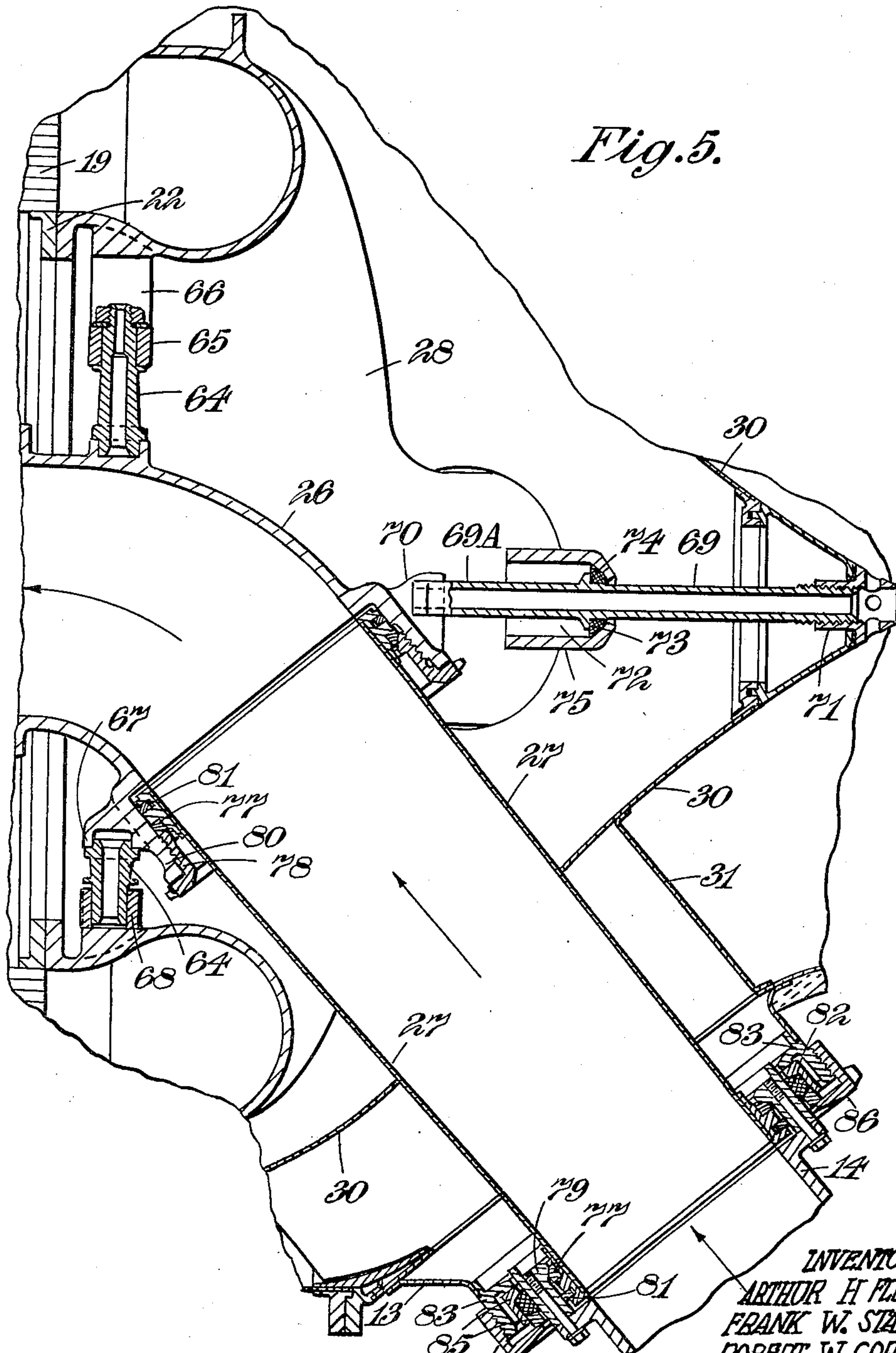

Fig. 5.

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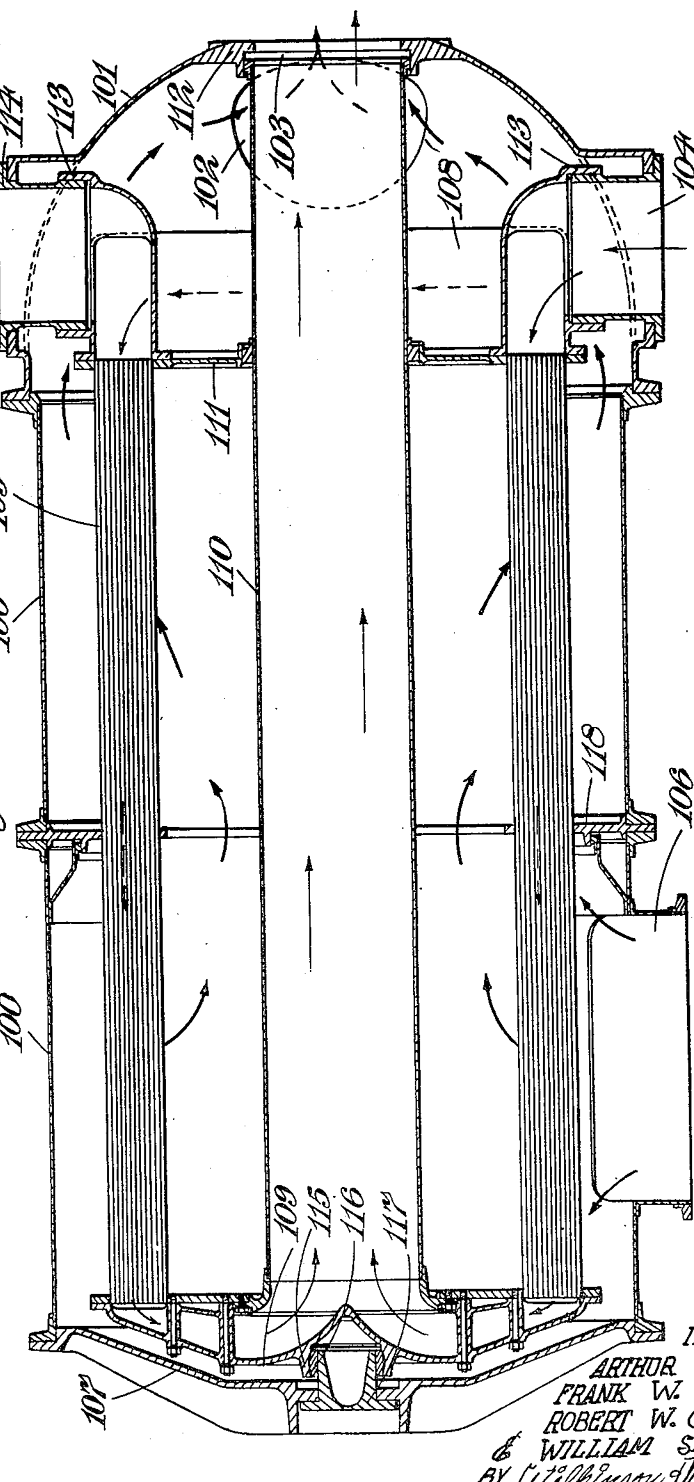

Fig. 7

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Fig. 8.

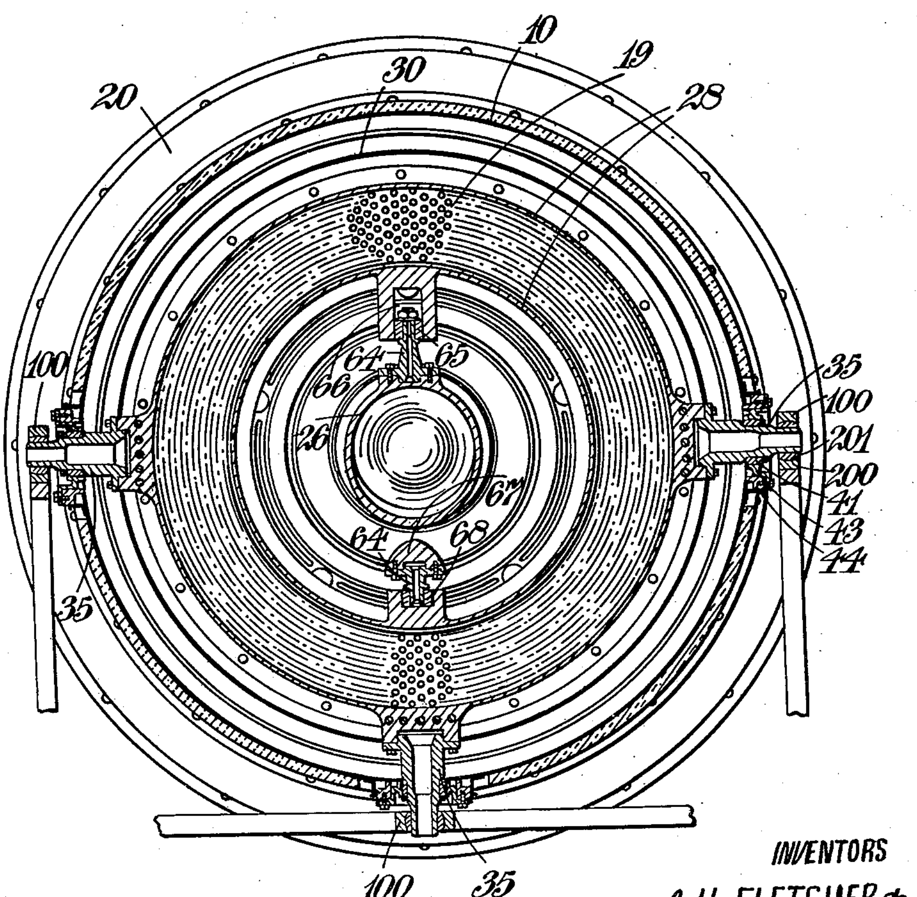

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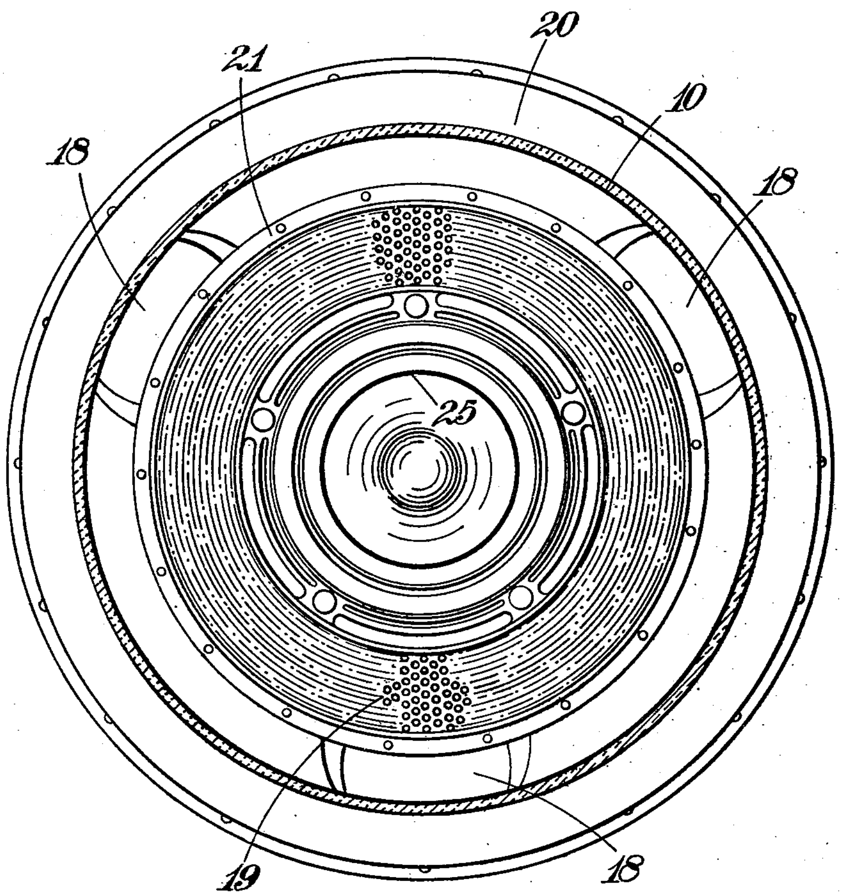
Fig. 9.



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Patented Apr. 29, 1952 2,594,761

UNITED STATES PATENT OFFICE

2,594,761

HEAT EXCHANGER

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Application December 29, 1947, Serial No. 794,274
In Great Britain January 2, 1947

5 Claims. (Cl. 257—226)

The present invention relates to heat-exchangers for gas-turbine engines; such engines normally comprise a compressor-system, combustion-equipment and a turbine-system, air delivered by the compressor-system being heated in the combustion-equipment and subsequently passed through one or more turbines. The use of heat-exchange means for abstracting heat from the exhaust-stream from a turbine and transferring such heat to air compressed by the compressor-system is desirable from the point of view of improving the overall thermal efficiency of the engine, in particular when such an engine is utilised to provide a source of shaft-power.

The present invention is applicable in general to gas-turbine engines incorporating a heat-exchanger.

A further application of the invention is to gas-turbine engines in which the working medium flows around a closed cycle and in which heat is transferred to it in combustion equipment incorporating heat exchange means for transferring the heat from the combustion gases to the working medium, which may be air or other suitable gas.

The invention therefore relates to heat-exchangers for gas-turbine engines of the kind in which heat-transfer is effected from one gaseous medium, for example, exhaust gas or combustion products, which is relatively hot, to a second gaseous medium, for example, air or a working medium, delivered by a compressor-system, which medium is relatively cool. For the sake of convenience, throughout this specification the relatively hot gas or combustion products will be referred to by the general term "hot gas," and the relatively cool air or working medium will be referred to by the term "air."

It will be appreciated that the design of heat-exchangers for the purposes indicated gives rise to serious problems associated with the relatively high temperatures and pressures involved and an object of the present invention is to provide a heat-exchanger in which stresses between the parts of the heat-exchanger due to relative expansion are substantially avoided.

Another object is to avoid the transfer of loads between parts of the heat exchanger, such loads arising from pressure and/or thermal loading of the parts.

Another object of this invention is to provide a construction of heat exchanger of the kind referred to in which uniform relative expansion between the matrix and the casing can be accommodated without causing stress in either the matrix or the casing.

One construction of heat-exchanger of the type referred to according to this invention comprises a casing having an inlet and an outlet for one medium, a hollow matrix of heat-exchanger tubes through which the other medium flows within the casing with inlet and outlet connections to the matrix, and means located in a plane through the matrix to support it in the casing against movement normal to the plane but to permit movement at the periphery of the plane due to uniform expansion.

The locating means preferably includes spigot devices with their axes in the plane and connecting the matrix and casing to permit relative movement of the spigot and socket in the plane and to restrain relative movement in a direction normal to the plane. For example, the locating means may comprise trunnion members interconnecting the matrix and the casing in such manner as to permit relative movement of the matrix and casing trunnion means in the plane and to restrain movement of the matrix normal to the plane, which trunnions are conveniently spigoted to the matrix to slide in said plane and arranged to engage the casing through a spherical bearing member in order to permit slight distortions due to unequal expansion. Alternatively, the matrix may be supported in the plane by sliding spigot and socket connections of each of which one member is carried by the matrix and the other by the casing and the said connections may serve to convey the medium flowing through the matrix tubes.

According to a further feature of the invention a heat exchanger of the type referred to may comprise means locating the heat exchange matrix within the casing, which locating means extend through the casing and constitute the external support for the heat exchanger structure as a whole. In this manner part or whole of the weight of the heat exchanger matrix is transmitted directly to the external support, whereby loading of the casing by such weight is avoided.

According to a feature of this invention additional supporting means is provided between the matrix and casing at a point outside said plane and is arranged to accommodate relative expansion between the matrix and casing in a direction normal to the said plane. The additional supporting means may also be in the form of a sliding spigot and socket device accommodating relative expansion between the matrix and casing in a direction normal to the plane.

According to yet another feature of this invention, the inlet and outlet connections to the matrix are engaged with the casing in a gas-tight manner where they pass through it, and in such manner as to be capable of tilting, or sliding or both tilting and sliding relative to the casing. The sliding freedom may be axially and/or transversely of the connection. By adoption of this feature of the invention, loads due to the pressure within the matrix are self-contained within the matrix and duct connections and are not transmitted to the casing. A duct connection to the matrix may also comprise a number of sections which are capable of tilting or sliding relative to one another, so that relative expansion is accommodated by relative displaecment of the parts.

It is preferred that the hot gas connections be made to the casing and the air connections to the matrix, which arrangement has advantages from the point of view of mechanical construction, bearing in mind that the air is at a higher pressure and consequently has a smaller volume than the gas. However, in certain cases it may be desirable to pass the hot gas to the matrix and the air to the casing.

Two constructions of heat-exchanger for use with a gas-turbine plant will now be described by way of example of the above and other features of this invention. In the description reference is made to the accompanying drawings in which:

Figure 1 is an elevation of one construction of heat-exchanger partly drawn in section,

Figure 2 is a section on the line 2—2 of Figure 1,

Figure 3 is a detail section on the line 3—3 of Figure 2 on a larger scale,

Figure 4 is a detail view of a matrix support,

Figure 5 is a detail view of the air inlet connection to the matrix,

Figure 6 is a detail view of the air outlet connection,

Figure 7 is a sectional plan through an alternative construction of heat-exchanger,

Figure 8 is a section on the line 8—8 of Figure 1, and

Figure 9 is a section on the line 9—9 of Figure 1.

Referring to Figures 1 to 6 and Figures 8 and 9, there is illustrated a heat-exchanger suitable for use in a gas-turbine power-plant, in which the heat-exchange is effected between air under pressure and hot exhaust gas.

The heat-exchanger comprises an outer casing formed from a number of flanged sections 10 fabricated from a heat-resistant steel and bolted together, a domed inlet-end cover 11 having a hot gas inlet neck 12, a neck 13 for locating an air-inlet duct 14 and a pair of necks 15 for locating air outlet ducts 16, an outlet-end cover 17 having three symmetrically-disposed gas outlet connections 18, and a hollow annular heat-exchange matrix 19 of tubes supported within the casing coaxially therewith. The casing carries externally suitable lagging 20.

The hollow matrix 19 comprises a plurality of tubes of, for example, stainless steel supported between an inlet header plate 21 and an outlet header plate 22 with their axes substantially parallel to the axis of the matrix and are supported intermediate their length by a number of splitter rings 23. The tubes communicate at their inlet ends with an inlet manifold 24 to which air is conducted through a divergent pipe 25 located centrally within and extending lengthwise of the matrix 19. The pipe 25 is connected to the air inlet duct 14 through an elbow 26 and

connecting pipe 27. The outlet end of the tubes communicate with an annular outlet manifold 28 having a pair of outlets 29 communicating with the air outlet pipes 16.

The hot gas enters the casing through the neck 12 and is deflected by a substantially conical deflector 30 to the annular space between the matrix 19 and the casing, shields 31 being provided around the outlets 29 and the connecting pipe 27. The hot gas then passes inwardly into the centre of the matrix through the spaces between the matrix tubes, a baffle 32 being provided between the casing sections 10 to prevent the gas from flowing direct to the outlet. The baffle 32 extends radially inwards from the wall of the casing to within the matrix and is suitably perforated to permit the passage of the tubes. The hot gas then flows outwardly from the space within the matrix 19 around the end of the manifold 24 to the hot gas outlets 18.

In the drawings the hot gas flow is indicated by heavy black arrows and the air flow by light arrows.

By the arrangement of the air-inlet and outlets and the hot gas inlet at one end of the heat-exchanger, installation and maintenance of the apparatus in a power-plant is facilitated since the majority of the pipe connections are located at one end.

According to one important feature of this invention, the matrix is supported in the casing so as to be located axially with respect to the casing in one plane and so as to be free for relative expansion. The purpose of this mode of support is to ensure that heavy stresses are not developed in the heat-exchanger due to the differential expansion of the parts thereof.

In this construction, the matrix 19 is located axially of the casing in a plane through the outlet manifold by the latter being formed with three radially-directed sockets 33 each mounting a trunnion 35 through spigot 34. The trunnion 35 extends through the wall of the casing to constitute external supporting means for the heat exchanger, there being provided sliding freedom as described below between the trunnions and the casing. In this way the matrix is located axially with respect to the casing in the transverse plane containing the trunnions whilst relative radial expansion is permitted without imposing a strain on the casing.

The form of the trunnions 35 is illustrated in greater detail in Figure 3. The trunnion is located in position on the socket 33 by the spigot portion 34 and by studs 36 threaded into the wall of the socket and passing through a flange 37 on the trunnion 35.

The trunnion 35 carries mid-way along its length a collar 41 the outer surface 42 of which is part spherical and this collar engages in a socket ring 43 attached to the casing section 10 by being bolted to a strengthening ring 44 welded on to the casing. The collar 41 is free on the trunnion 35 to provide sliding freedom between the trunnion and casing, and thus permit relative radial expansion of the matrix and casing. An extensible legging or bellows 45 is provided between the outer end of the trunnion 35 and the socket ring 43 to prevent the escape of hot gas through the socket. A clamping ring 46 is provided to hold one end of the legging against the socket ring and its other end is gripped between washers 47 on the trunnion 35. The spherical form of the collar permits a degree of canting of the trunnion 35 with respect to the socket ring 43, whereby the manifold and casing are permitted a degree of distortion due to thermal expansion, without imposing stresses on the parts.

The trunnions 35 also provide means for supporting the heat exchanger in a suitable external supporting structure by being received in sockets 120 thereof. In this manner the weight of the heat exchanger matrix is transmitted directly to the external structure through trunnions 35 lying in the transverse horizontal plane. The third trunnion lying in the vertical plane serves to locate the heat exchanger laterally in the external supporting structure. The trunnion extensions may include spherical seatings 200, 201 (Figure 8) accommodating for universal angular freedom between the trunnions and the external support. It will be appreciated that in this manner the heat exchanger casing is relieved of loading which might otherwise be imposed on it by the weight of the matrix housed therein.

The opposite end of the matrix 19 is supported in the outlet-end cover by an axially-directed trunnion 48, which is illustrated in detail in Fig. 4. The trunnion 48 is formed with a flange 49 which abuts a flange 50 on a socket 51 cast in one piece with the air inlet manifold 24 and studs 122 similar to the studs 36 pass through the flange 49 and thread into the flange 50. The outer end of the trunnion 48 is free to slide in a spherical surfaced collar 52 supported within a complementary bush 53 carried by a cap 54 bolted by bolt 123 to the outlet-end cover 17. In this way the inlet manifold end of the matrix 19 is permitted relative axial expansion with respect to the casing. The arrangement also allows for a degree of thermal distortion of the matrix and casing assembly without imposing thermal loading thereon.

The cap 54 carries on its outer surface a spherical surfaced collar 55 which is engaged in a similarly formed socket member 56 forming part of the external supporting structure for the heat exchanger.

It is a further important feature of the invention that the matrix 19 and the associated connections thereto are arranged so that allowance is made for their expansion relative to the casing and for differential expansion of the matrix and its associated elements to avoid the development of heavy stresses in the matrix and its associated connections and so that any stresses are self-contained within the pipe connections to avoid loading the casing. It will be seen that the gas makes an even number of traverses over the matrix, whereby with the arrangement of the inlet and outlet air and gas connections described, the expansion of the tubes of the matrix is substantially uniform throughout. Thus, considering the gas flow across the tubes adjacent the gas inlet, the tubes of this section disposed at outer radius are subjected to hot gas maximum temperature; the axial expansion of the outer tubes of this section will, therefore, be relatively great. The tubes at inner radius of this section will be subjected to exhaust gas which is somewhat cool; the axial expansion of the inner tubes of this section will, therefore, be somewhat less than that of the outer tubes of the section. However, considering the outer tubes of the section adjacent the gas exit, these tubes will be externally subjected to exhaust gas which has been cooled; the axial expansion of this section of the tubes is therefore considerably less than that of the section adjacent the gas inlet. Again, the inner tubes of the matrix section adjacent the gas outlet are subjected externally to exhaust gas which has been partially cooled; the expansion of these tubes, therefore, will be somewhat greater than that of the outer tubes of this section. Combining the overall expansions of the complete lengths of tube, it will be appreciated that substantial uniformity of axial expansion is obtained. As explained above any axial expansion of the matrix is taken up in the trunnion 48 while radial expansion is allowed for by the trunnions 35.

The divergent air inlet pipe 25, elbow 26 and connecting pipe 27 are all supported by the matrix assembly and by the pipe 14 so that any displacement of these parts due to relative expansion does not give rise to stresses in the heat-exchanger casing.

The pipe 25 is provided at its wider end with a flange end-fitting 57 having a part spherical seat to bear on a complementary seating ring 58 carried by an inwardly directed flange portion of the inlet header plate 21. A sleeve 59 secured to the header plate 21 retains the flange 57 on its seating. The end-fitting 57 also carrier a pair of gas-sealing rings 101 which seal the connection against the escape of high pressure air into the casing. This arrangement allows relative axial expansion of the pipe 25 and matrix 19 and also relative canting. The narrower end of the pipe 25 is located by being provided with a spigot member 61 engaging within a spigot ring 62 which also spigots on a flange 63 on the elbow 26.

The elbow 26 is connected to the air outlet manifold by a pair of oppositely-directed trunnions 64 (Figure 5), the uppermost of which engages by guide block 65 in a slot 66 on the manifold 28 and the lowermost of which locates in a slot 67 on the elbow and with a guide block 68 on the manifold 28.

Figure 5 also illustrates in some detail, in conjunction with Figure 2, means by which the baffle deflector 30 is supported within the casing at the gas entry 12. To this end a beam 75 is formed at its extremities with part cylindrical surfaces engaging slide blocks 75A, whereby the blocks have pivotal movement with respect to the beam, and are guided in slots formed in brackets 76 on the outlets 29. The beam in this manner has lateral and tilting freedom with respect to the outlets, permitting relative expansion of the latter, and constitutes an abutment for a tie-rod 69, which is provided with a part spherical abutment collar 73 engaging a corresponding face 74 formed at the end of a cylindrical bore 72 in the beam 75. The right-hand end of the tie-rod 69 is engaged by a nut 71 forming the apex of the conical deflector 30, so that tightening of this nut clamps the baffle through the tie-rod 69 and beam 75 to the outlets 29. The tie-rod 69 extends through the beam as illustrated at 69A, its left-hand end being slidingly engaged in a socket formation 70 on the elbow 26. The socket formation serves to locate the tie-rod 69 and beam 75 centrally between the outlets 29.

The connecting pipe 27 is engaged with the elbow 26 and air inlet duct 14 through joint permitting relative tilting of the parts. Each joint comprises a spherical-surfaced ring 77 engaging a complementary seat on a ring 78, or 79, the ring 78 being threaded into the bell-mouth 80 of the elbow and the ring 79 being bolted on the end of the inlet duct 14. Gas sealing rings 81 are also carried by the ends of the connecting pipe 27 to reduce leakage of pressure air from the system. The ring 79 is slidingly engaged in the neck 13 through a packing gland 82 located in a stiffening fitting 83 welded to the neck 13 and is also capable of a movement transverse to the axis of the inlet by the gland rings 85 being supported at their ends only and not peripherally between radial faces on the fitting 83 and gland nut 86.

The connection between the air outlets 29 and the outlet ducts 16 and the casing is similar in that axial sliding movement is permitted between the duct and casing; additionally, relative transverse sliding movement is permitted. Referring to Figure 6, a thick lip 87 is provided at the end of the outlet 29 on which is located a gland 88 in housing 89 secured on a stiffening fitting 90 welded on the end of the neck 15. The gland packing is received between and gripped by gland rings 91 which are tightened on the packing by a gland nut 92 which threads into the housing 89. The gland rings 91 bear on radial faces on the housing 89 and gland nut 92 and are free peripherally, so as to permit relative transverse freedom, the gland rings sliding between the faces on the housing 89 and gland nut 92. Alternatively, the connection between the outlets and the casing may be of the same construction as that between the connecting pipe 27 and the casing.

It will be appreciated that since the air is at a higher pressure than the hot-gas there will be axial loads tending to maintain the spherical seats between the manifold 24 and pipe 25, between the elbow 26 and the connecting pipe 27 and between the latter and the inlet duct 14, in engagement, and the arrangement is such that the load in the pipe due to its internal pressure will be self-contained.

From the foregoing specific description, it will be appreciated that a heat-exchanger is provided which can be readily assembled in a power-plant, which is relatively simple to maintain as the majority of the connections are to one end of the apparatus, and in which loads due to relative expansion of the matrix and casing and supply pipes and to the pressure within the matrix assembly are not transmitted to the casing. Moreover, relative expansion between the parts of the matrix assembly is taken up by relative canting of the parts of the assembly through the spherical surfaced joints. Again the arrangement of the gas flow is such that the overall expansion of the parts of the matrix itself is substantially uniform so that distortion of the matrix due to relative expansion of parts is substantially avoided.

Whilst as described above it is preferred to arrange that the supply pipe to the inlet manifold of the matrix is located within the matrix, it may in certain circumstances be desirable to locate an air outlet pipe within the hollow matrix. One such arrangement is illustrated in Figure 7 which shows an alternative construction of heat exchanger.

The heat exchanger comprises a casing formed from two or more fabricated, heat-resistant steel sections 100 connected together through flanges, an end cover 107 closing one end and at the other end an end cover 101 having hot gas outlets 102, a central air outlet 103 and an air inlet 104, the air inlets and outlet communicating with a matrix assembly 105. A lateral hot gas inlet 106 is provided in the casing.

The matrix is similar to that above described and has an annular inlet header 108 communicating with the tubes of the matrix at their inlet ends and an outlet header 109 communicating with their outlet ends. An outlet pipe 110 is secured at one end to the header 109 and extends centrally through the hollow matrix to engage slidably in header plate 111 of the inlet header and also in a socket formed by stiffening ring 112 around the air outlet 103.

The matrix assembly 105 is supported in the casing against axial movement in the plane of the air inlet 104 by the inlet header 108 being formed with radial sockets 113 slidingly spigoted on the air inlet connection 104 and a blanked-off connection 114 located diametrically opposite the air inlet 104. The connection 114 may be employed as an additional air inlet. The matrix in the plane of the air inlet 104 is thus located axially but free for relative radial expansion. The outlet header 109 is formed with an axially directed socket 115 having a spherical face cooperating with a correspondingly shaped collar 116 carried slidingly by a hollow spigot member 117 secured to the casing. This arrangement permits axial relative expansion of the matrix assembly 105 with respect to the casing without imposing stresses on the casing. Relative expansion between the pipe 110 and the casing is accommodated in the sliding joint between the socket 112 and the end of the pipe.

In use hot gas enters the casing through the inlet 106 flows around and through the matrix into the interior thereof, then axially within the matrix past baffle 118, then outwardly through the right-hand half of the matrix to the space between it and the casing, and finally axially around the outside of the header 108 to the gas outlets 102. The baffle 118 extends radially inwards to beyond the tubes of the matrix thus preventing a direct flow of hot gas from inlet 106 to outlet 103 and the plate 111 prevents a direct flow of hot gas from the interior of the matrix to the outlet 103.

As in the previous construction, the tubes of the matrix have a substantially uniform expansion (by arranging that the hot gas makes an even number of passes through the matrix) thereby avoiding distortion of the matrix.

It will be noted that in both constructions above described, the hot gas first flows over the matrix tubes at their outlet ends and then over their inlet ends, thus obtaining a high efficiency of heat exchange.

Since in gas-turbine power-plants, the hot gas is at a lower pressure and has a greater volume than the air, it is preferred to pass the air through the matrix and the gas through the casing.

It will be appreciated that the hot gas may be made to traverse the matrix more than twice by providing suitable deflecting baffles, it being preferred that the number of traverses be kept even so that the expansions of the tubes of the matrix are substantially equal.

We claim:

1. A heat exchanger of the kind referred to comprising a casing having an inlet and an outlet for one medium, a hollow matrix of heat-exchanger tubes within the casing and having an inlet connection and an outlet connection for the second medium, a plurality of trunnions connected to said matrix with their axes in a plane transverse to the axis of said matrix, a plurality of socket rings, one for each of said trunnions, mounted on said casing, a further trunnion connected to said matrix in a plane removed from said transverse plane and having its axis parallel to the axis of said matrix, a further socket-ring

for said further trunnion mounted on said casing, each of said trunnions being capable of movement in the direction of its axis with respect to its associated socket ring, and some of said trunnions and their associated socket rings having means permitting relative tilting between the casing and matrix, said means being arranged between said socket rings and said trunnions.

2. A heat-exchanger as claimed in claim 1, wherein said last means includes a collar formed with a cylindrical bore to receive a trunnion and having a part spherical exterior surface engaging a socket ring.

3. A heat exchanger of the kind referred to comprising a casing having an inlet and an outlet for one medium, a hollow matrix of heat exchanger tubes within the casing having an inlet connection and an outlet connection for the second medium, a supporting structure for said heat exchanger, a plurality of trunnions connected to said matrix with their axes in a plane transverse to the axis of said matrix and radiating from a common focal point, a socket ring for each of said trunnions carried by said casing, said trunnions extending through said socket rings to be received by the supporting structure, a further trunnion connected to said matrix, in a plane removed from said transverse plane and with its axis parallel to the axis of said matrix and passing through said common focal point, and a further socket ring for said further trunnion mounted on said casing, all of said trunnions being capable of movement in the direction of

their axes with respect to their associated socket rings.

4. A heat exchanger as claimed in claim 3, wherein means is associated with some of said trunnions and socket rings for permitting relative tilting between said trunnions and socket rings, said means including part spherical bearing means arranged between said trunnions and their associated socket rings.

5. A heat exchanger as claimed in claim 4, wherein said part spherical bearing means includes a collar having a cylindrical bore to slidably receive a trunnion and having a part spherical exterior bearing surface engaging the socket ring associated with the trunnion.

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