Sept. 25, 1962 J. R. MILLER 3,055,641

HEAT EXCHANGER

Filed May 3, 1960

FIG. 1

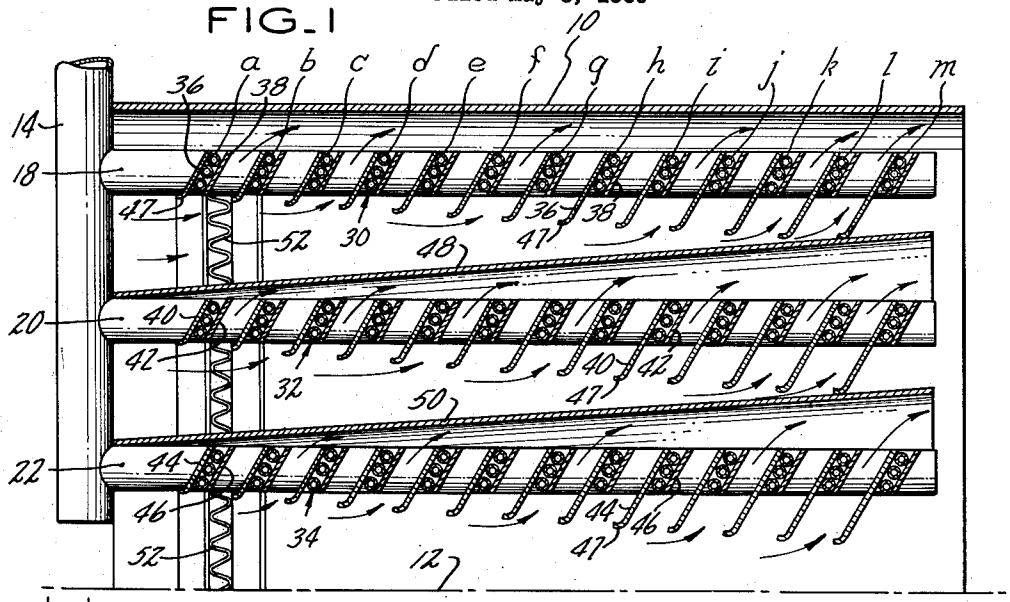


FIG. 2

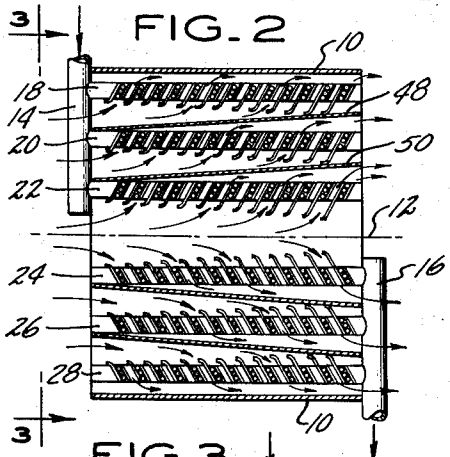


FIG. 4

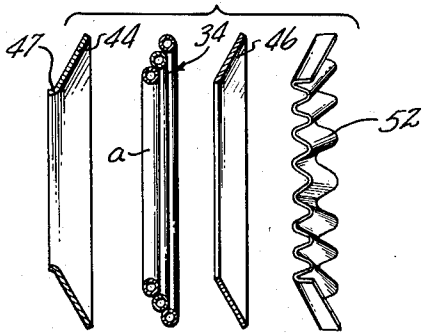


FIG. 3

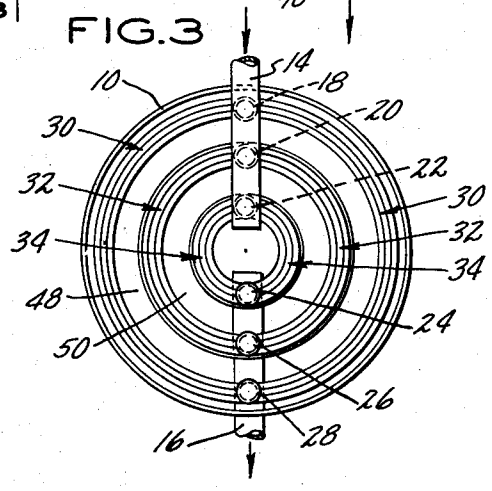
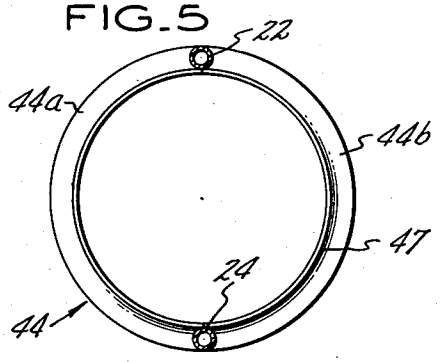


FIG. 5



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HEAT EXCHANGER

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This invention relates to heat exchangers and has as one of its objects to provide an improved heat exchanger of the crossflow type.

Another object of this invention is to provide an improved heat exchanger of cylindrical configuration particularly adapted for use in axial-flow gas turbine engines in which the heat exchanger is concentric with and surrounds an axial shaft of the engine.

In such an installation it is proposed to discharge air from the engine compressor axially into one end of the cylindrical casing of the heat exchanger and to discharge the air axially at the other end of the casing into the engine turbine. Liquid metal, or some other suitable heat-transfer fluid, is circulated through a heat source, which may be a nuclear reactor, and through banks of concentric semicircular tubes extending transverse to the axis of the casing between longitudinal headers within the casing.

A further object of this invention is generally to improve the construction and performance of heat exchangers.

These and other objects and advantages of the heat exchanger comprising this invention will be evident or will be pointed out in connection with the following detailed description of a preferred embodiment of the invention shown in the accompanying drawing. In this drawing:

FIG. 1 is a longitudinal radial section taken through the cylindrical heat exchanger of this invention;

FIG. 2 is a similar view on a smaller scale showing a diametrical section through the heat exchanger;

FIG. 3 is an end view taken on lines 3—3 of FIG. 2 with parts omitted to facilitate illustration;

FIG. 4 is an exploded sectional view through the innermost heat-transfer core; and

FIG. 5 is an end view on an enlarged scale of this innermost core, the view being taken on a section through the innermost headers between adjacent cores.

Referring to FIG. 2, the heat exchanger of this invention includes an outer cylindrical casing **10** open at both ends through which one of the heat exchange fluids, here air, is axially directed. It will be noted that the casing is unobstructed in the vicinity of its longitudinal axis **12** so that an engine shaft may be extended axially through the casing. A radial inlet manifold **14** is provided at the upstream end of the heat exchanger and a diametrically opposite outlet manifold **16** is provided at the downstream end of the heat exchanger. Three longitudinal inlet headers **18**, **20** and **22** are provided in fluid communication with the inlet manifold **14** and three longitudinal outlet headers **24**, **26** and **28** are similarly connected to the outlet manifold **16**.

Fluid flow between the inlet and outlet headers is accomplished through banks of semicircular tubes which connect the several headers. These are best shown in FIG. 3 where it will be seen that an outer bank **30** connects inlet header **18** with outlet header **28** on each side of these headers; an intermediate bank **32** connects inlet header **20** with outlet header **26** on each side of these headers; and an inner bank **34** connects inlet header **22** with outlet header **24** on each side of these headers. Herein, each bank consists of thirteen groups of three tubes each, the groups *a*, *b*, *c* through *m*, being arranged

in spaced relation along the length of the headers, as is best shown in FIG. 1.

These groups of tubes are not disposed in radial planes, but rather lie in oblique planes as indicated in FIGS. 1 and 2. This arrangement provides an offset-flow pattern for the air flowing generally axially through the casing. The tubes of each bank have a conical ring **36** brazed to the three tubes on the upstream side thereof and a somewhat similar conical ring **38** brazed to the downstream side. These conical rings are of different diameters for the different banks **30**, **32**, **34**. Thus, banks **32** have smaller conical rings **40** and **42** and banks **34** have even smaller conical rings **44** and **46**. These conical rings are preferably made in two semicircular pieces, as will be evident from FIG. 5, where the upstream conical ring **44** is shown as comprised of two semicircular members **44***a* and **44***b* and ends of which are shaped to conform to and are welded to the header members **22** and **24**. Further, the upstream rings **36**, **40** and **44** have their inner annular edges deflected upstream toward the oncoming air and these scoop-like edges **47** of the rings extend progressively farther into the air stream toward the downstream end of the heat exchanger. This is shown most clearly in FIG. 1. Additionally conical baffles **48** and **50** are provided in the annular spaces between adjacent banks of tubes which direct the air into the scoop-shaped edges of the rings, as indicated in FIG. 1. As a result, air which enters at the upstream end of casing **10** flows between each of the banks of tubes throughout the length of casing **10**, as indicated by the arrows in FIG. 2.

The annular spaces between the longitudinally spaced groups of tubes *a*, *b*, *c*, etc., are provided with semicircular corrugated sheets **52**, one set of which is shown behind the headers **18**, **20** and **22** in FIG. 1, and is also shown in detail in FIG. 4.

In the operation of the heat exchanger, air, which enters the upstream end of the heat exchanger over the entire circular area presented by the upstream end of casing **10**, is deflected by the scooped edges of conical rings **36**, **40** and **44** into the annular passages between adjacent groups of tubes *a*, *b*, *c*, etc. The air is forced to travel in a radial direction by the corrugated sheets **52** which are secured to the adjacent conical rings in heat-conducting relationship. The heated air then is discharged axially at the downstream end of the casing.

The crossflow fluid, which may be liquid metal, for example, enters the inlet manifold **14** which supplies the three inlet headers **18**, **20**, **22**. From these headers it flows through the semicircular banks of tubes to the three longitudinal outlet headers **24**, **26** and **28** into the outlet header **16**.

It will be evident that as a result of this invention a particularly compact and effective heat-transfer device has been provided which is particularly well-adapted to be used in axial-flow gas turbine engines.

It will also be evident that the construction of the heat exchanger presents no unusual problems in manufacture and assembly.

While only one embodiment of the invention has been shown for purposes of illustration, it will be understood that various changes may be made in the construction and arrangement of the parts within the scope of the invention.

I claim:

1. In a heat exchanger, a cylindrical outer casing open at both ends through which a first fluid is directed from an inlet at one end to an outlet at the other end, said inlet and outlet extending over the entire cross-sectional area of said casing, a radial inlet manifold at the inlet of said casing which extends substantially to said casing

axis, said inlet manifold being closed at its inner end and having a fluid inlet at its outer end for a second fluid, a radial outlet manifold at the outlet end of said casing which extends from said casing substantially to said casing axis, said outlet manifold having its inner end closed and having a fluid outlet for said second fluid at its outer end, said inlet and outlet manifolds being diametrically opposite one another and at opposite ends of said casing, a plurality of axially extended header pipes connected with said inlet manifold at spaced points along its length, a plurality of axially extended header pipes connected with said outlet manifold at spaced points along its length, said header pipes extending the full length of said casing and being closed at their free ends, and banks of semicircular tubes connecting corresponding inlet and outlet header pipes along the length of said header pipes forming a cylindrical matrix which fills said outer casing, said banks of pipes lying in oblique planes and having their ends abutted to said header pipes, each bank of oblique pipes having a conical ring brazed to it on its upstream side and a conical ring brazed to it on its downstream side.

2. A heat exchanger as defined in claim 1 in which the upstream conical rings of the banks of tubes have their inner edges deflected upstream toward the oncoming first fluid.

3. A heat exchanger as defined in claim 2 in which conical baffles are provided in the annular spaces between the adjacent banks of concentric tubes which direct the first fluid into the scooped edges of the rings.

4. A heat exchanger as defined in claim 3 in which the inner scooped edge of each conical ring in a downstream direction is extended successively farther inward into the first fluid stream.

5. A heat exchanger as defined in claim 3 in which the inner scooped edge of each conical ring is extended in a downstream direction closer to the adjacent conical baffle.

6. A heat exchanger as defined in claim 3 in which the annular spaces between the banks of tubes are filled with semicircular corrugated sheets for directing the first fluid flow radially between the banks.

7. A heat exchanger as defined in claim 1 in which extended heat-transfer surfaces are provided in an inclined radial direction that is three-dimensional in an axial-radial sense so that the extended surface on the front side of one oblique bank of tubes can slide freely with respect to the extended surface on the back side of an adjacent oblique bank of tubes as a result of differential thermal expansion or mechanical action.

8. In a heat exchanger, a cylindrical outer casing open at both ends through which a first fluid is axially directed, a plurality of inlet headers extending lengthwise of said casing, said inlet headers lying in a radial plane of said casing, a plurality of outlet headers extending lengthwise of said casing, said outlet headers lying in a radial plane of said casing diametrically opposite to the radial plane of said inlet headers, an inlet manifold supplying a second fluid to one end of said inlet headers, said inlet headers being closed at their opposite ends from said manifold, an outlet manifold collecting said second fluid from said outlet headers, said outlet headers being closed at their opposite ends from said outlet manifold, a plurality of banks of semicircular tubes connecting corresponding inlet and outlet headers along the length of the latter on both sides of said headers, each bank of tubes including a plurality of tubes arranged at an oblique angle to the header axis to which they are secured, a conical plate secured to the downstream side of each bank of tubes, a second conical plate secured to the upstream side of each bank of tubes, said upstream conical plates having their inner edges extended inwardly beyond said banks of tubes, each bank having its second conical plate extended inwardly slightly more than that connected to the next upstream bank, conical baffles located in the annular spaces between certain of said headers extending downstream and outwardly, and two semicircular corrugated plates in the annular space between each downstream conical plate of each bank of tubes and the upstream conical plate of the next downstream bank of tubes.

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