United States Patent [19]

Naylor

[11] 3,858,646

[45] Jan. 7, 1975

[54] HEAT EXCHANGER

[76] Inventor: **Harry E. Naylor,** 2723 Hennepin Ave., Minneapolis, Minn. 55405

[22] Filed: **May 28, 1974**

[21] Appl. No.: **473,806**

[52] **U.S. Cl.** **165/145,** 165/156, 165/162

[51] **Int. Cl.** **F28f 9/26**

[58] **Field of Search** ..... 165/43, 66, 156, 163; 237/12.3 A, 12.3 R

[56] **References Cited**

UNITED STATES PATENTS

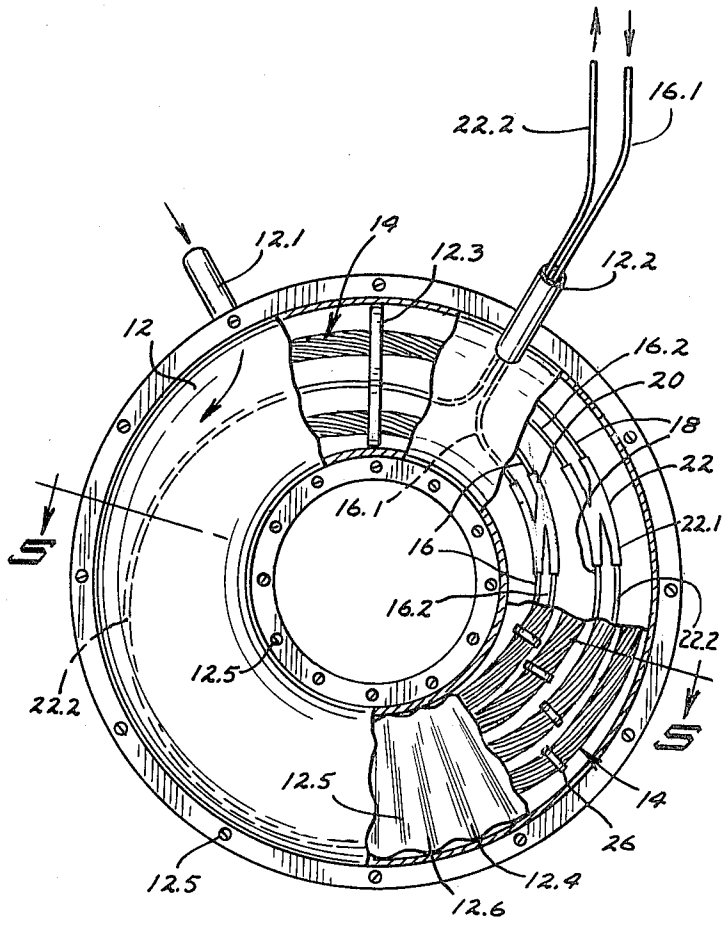
1,046,842	12/1912	Offutt	165/66
1,852,490	4/1932	Sullivan	165/156 X
2,990,162	6/1961	Otten	165/145 X
3,335,790	8/1967	Aranyi et al.	165/163 X
3,526,274	9/1970	Gardner	165/163 X

Primary Examiner—Charles J. Myhre
Assistant Examiner—Theophil W. Streule, Jr.
Attorney, Agent, or Firm—H. Dale Palmatier; James R. Haller

[57] **ABSTRACT**

A heat exchanger for exchanging heat from an initially hot gas to an initially cooler gas. The heat exchanger includes a toroidal shell with inlet and outlet ports for passing the hot gas through the shell and an inner transverse wall for limiting annular flow of the hot gas to a single revolution within the shell. A coil of tubing is contained within the shell and is arranged in a plurality of spaced, annular bundles about the axis of the toroidal shell with sequential turns of tubing lying in different bundles and each turn of tubing within a bundle being spaced from the other turns of tubing in that bundle. The bundles are twisted with respect to one another about a centrally positioned annular support ring. At its down stream end, the tubing passes outwardly of the heat exchanger and the heated gas issuing therefrom may be used to drive, for example, a turbine.

10 Claims, 8 Drawing Figures



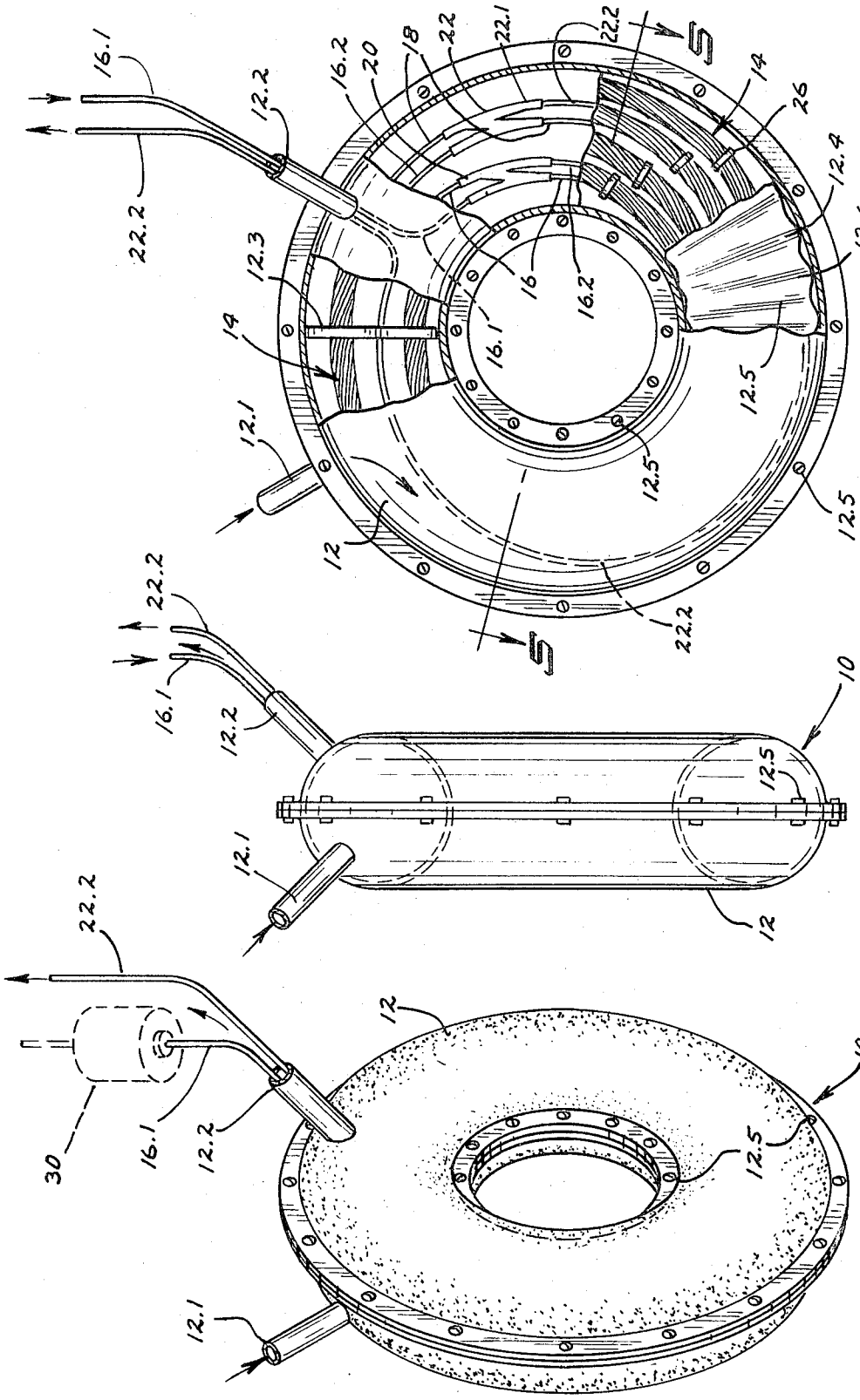


FIG. 1

FIG. 2

FIG. 3

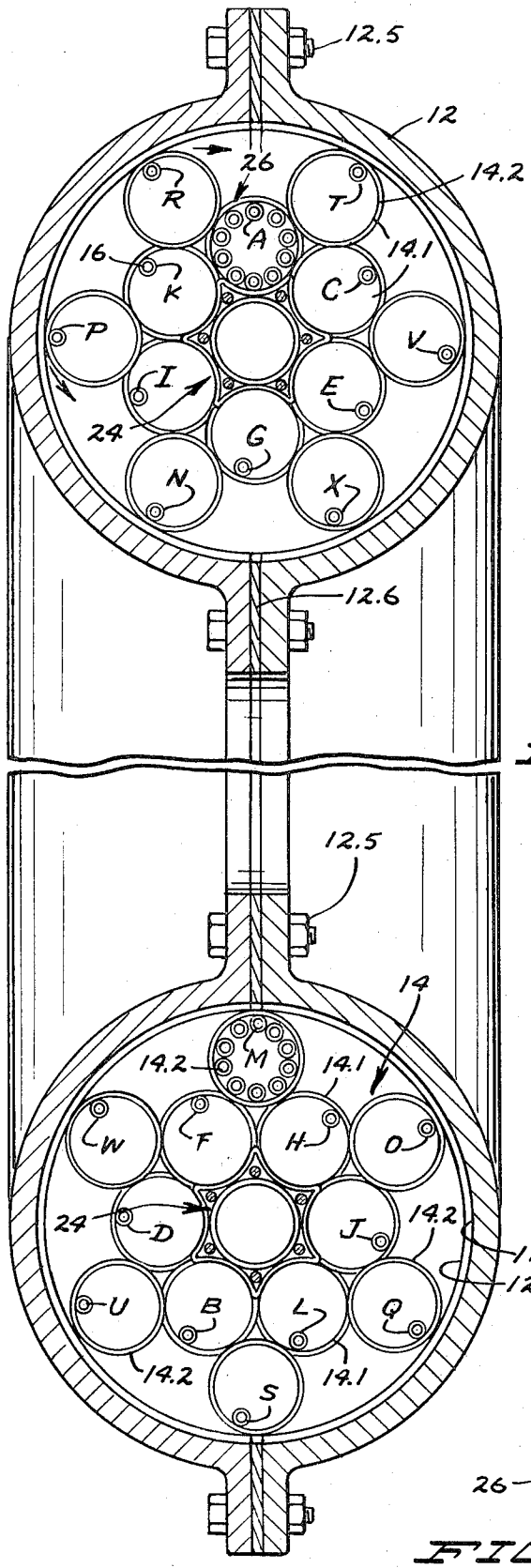


FIG. 4

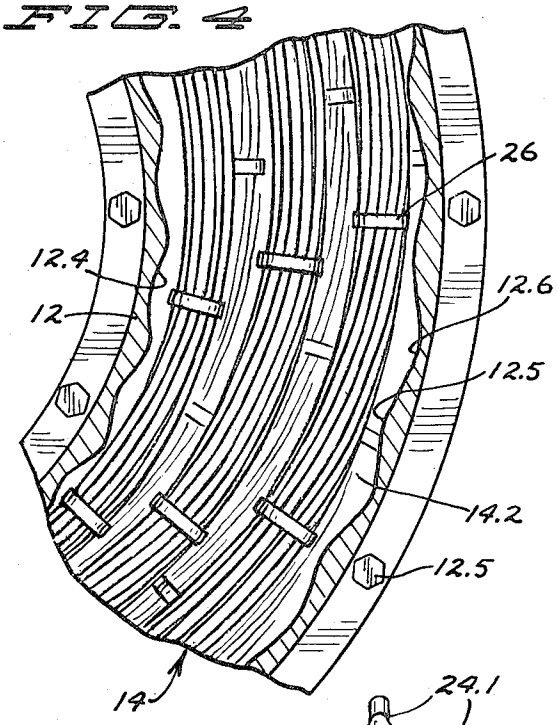


FIG. 5

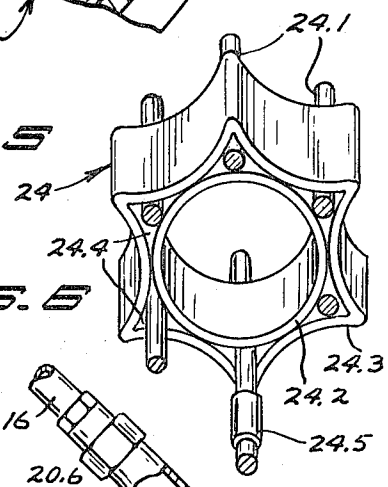


FIG. 6

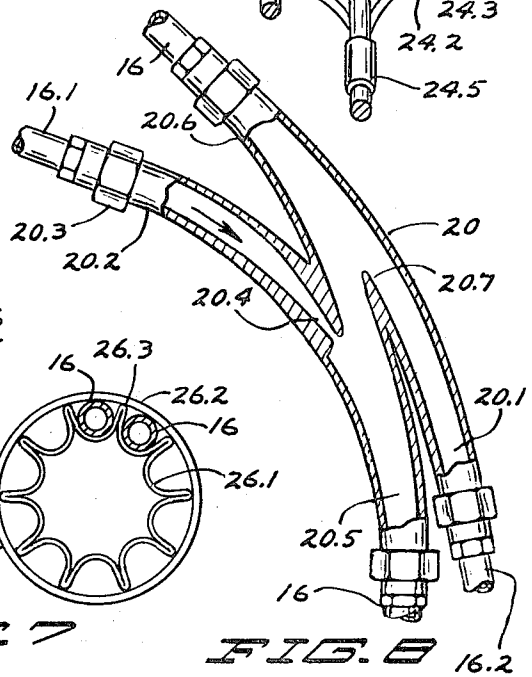


FIG. 8

FIG. 7

HEAT EXCHANGER

BACKGROUND OF THE INVENTION

The exhaust gases which issue from internal combustion engines such as those of automobiles ordinarily are quite hot and may have temperatures in the range of 3,500° F., or higher. Little, if any, use has been made of such high temperature exhaust gases. Whereas such gases in the past were flowed through a muffler and thence out to the atmosphere, modern automobiles make use of various types of pollution control equipment which limit the amount of undesired exhaust gases which are released to the atmosphere. Yet the heat which the exhaust gases contain is not effectively utilized, and is substantially lost. One difficulty in putting the heat energy of hot exhaust gases to use is the difficulty in extracting the heat from such gases. A heat exchanger for this purpose should be highly efficient in order to extract a reasonable quantity of heat from the rapidly flowing hot exhaust gas, and yet must be sufficiently compact so as to be carried within the body of an automobile. A heat exchanger of this type, to the best of my knowledge, is not available, and is much to be desired.

BRIEF SUMMARY OF THE INVENTION

The present invention relates to a heat exchanger for exchanging heat from a rapidly flowing hot gaseous stream to a gas such as steam for eventual use in powering a turbine or the like. The heat exchanger includes a toroidal shell having inlet and outlet ports for admitting and discharging a hot gas such as the exhaust gas of an automobile, and the shell includes an inner transverse wall which limits the annular flow of the hot gas to a maximum of a single revolution in the shell. Mounted within the shell is at least one coil of continuous tubing which is arranged in a plurality of spaced annular bundles about the axis of the toroid. The tubing passes sequentially from one bundle to another in each turn of tubing about the toroidal axis, and each turn of tubing in a bundle is spaced from other turns of tubing in that bundle. Each bundle contains more than one turn of tubing, and preferably as many as about 10 turns of tubing. The tubing bundles are supported with respect to one another by a centrally positioned annular support ring carried within the shell, the ring supportively contacting the bundles and the bundles being uniformly helically twisted about the support ring. Means are provided for flowing a gas to be heated into one end of the tubing and for receiving the heated, expanded gas from the tubing at its other end. The individual turns of tubing in each bundle are desireably also uniformly helically twisted and are held in fixed, spaced relation with respect to one another by clips, each bundle having a hollow interior permitting passage of the hot gas therethrough and also permitting passage of the hot gas between spaced, adjacent turns of tubing in that bundle. The bundles extend substantially to the inner surface of the shell, and the helical rotation of the bundles about the support ring provide a helical path for the hot gas in its passage through the shell. The hot gas is thus brought into heat-exchange proximity with substantially the entire surface of tubing within the shell. The gas to be heated preferably passes into the tubing through a jetting connector which has an internal jetting orifice for jetting the gas to be heated into the tubing and also for entraining for partial recirculation a portion of the gas which has passed through the bundles of tubing. In a desired embodiment, the support ring supports about its circumference a plurality, preferably six in number, of primary tubing bundles, and a plurality, preferably six in number, of secondary tubing bundles are arranged in supportive contact about the periphery of the primary bundles and in substantial contact with the inner surface of the shell. In the latter embodiment, jetting connectors may be employed to jet the gas being heated into the tubing of the primary bundles and also to jet the gas received from the primary bundles into the secondary bundles, from whence it issues in the form of a hot, expanded, rapidly moving gas which may be employed to power a turbine or the like to in turn aid in the propulsion of an automobile for example, resulting in increased efficiency and reduced fuel rise.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view of a heat exchanger of the invention, showing an inlet pump in phantom lines;

FIG. 2 is an end view of the heat exchanger of FIG. 1;

FIG. 3 is a semi-schematic side view in partial cross section of the heat exchanger of FIG. 2;

FIG. 4 is a cross sectional, partially broken away view of the interior of the heat exchanger of FIG. 3;

FIG. 5 is a semi-schematic, cross sectional, broken away view taken along line 5—5 of FIG. 3;

FIG. 6 is a perspective view, shown partially in cross section and broken away, of an annular support ring depicted in also FIG. 5;

FIG. 7 is a cross sectional view of a tubing bundle, showing two tubes in place; and

FIG. 8 is a cross sectional view of an entrainment jetting nozzle employed in the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to FIGS. 1 and 2, the heat exchanger of the invention is labeled generally as 10 and includes a toroidal or doughnut-shaped hollow shell 12 having inlet and outlet ports 12.1, 12.2 through which a hot gas, such as the exhaust from an automobile, may pass into and out of the toroidal shell 12. As shown in FIG. 3, the toroidal shell includes a transverse wall 12.3 which extends across the interior of the shell and which limits the flow of a hot gas passing into the port 12.1 to a single revolution at maximum before the gas passes out of the toroidal shell through port 12.2. Viewed axially as in FIG. 3, the ports 12.1, 12.2 are spaced approximately 40° apart, each port being spaced approximately 20° from the transverse wall 12.3. The hot gas, such as the exhaust from an automobile, may be led into port 12.1 directly from the exhaust manifold, and the gas issuing from the exhaust port 12.2 may be thence passed to a muffler, pollution control equipment, or the like. Desirably, the heat exchanger is installed in an automobile or otherwise used with the ports 12.1, 12.2 facing in a generally downwardly direction.

A length of tubing is carried within and circumferentially of the shell, as shown in FIGS. 3–5, the tubing being arranged in a series of tubing bundles designated generally 14. Desirably, two continuous lengths of tubing are employed, one length of tubing 16 being ar-

ranged in a series of inner, or primary tubing bundles **14.1,** and the other length **18** of tubing being arranged in a plurality of outer, or secondary bundles **14.2** (FIG. **5**). The continuous length of tubing **16** makes a plurality of turns within the shell about the toroidal axis thereof, and passes from one primary bundle to another primary bundle in each such turn. In similar fashion, the other continuous length of tubing **18** makes a plurality of turns about the toroidal axis of the shell and passes from one secondary bundle to another secondary bundle in each turn. At one end, the one length of continuous tubing **16** is connected through a jetting connector **20** to an inlet pipe **16.1,** the coupling joining the inlet pipe **16.1** to the connector **20** permitting substantially unimpeded flow between the inlet pipe and the connector. The one length **16** of tubing is also reconnected at its other end to the connector **20,** as shown in FIGS. **3** and **8** and as described in greater detail below. A short length of connector tubing **16.2** joins an outlet port **20.1** of the jetting connector **20** to a second, identical jetting connector **22** (FIG. **3**). The other length of tubing **18** is attached to the second connector **22** and thence passes circumferentially within the shell within a series of tubing bundles **14.2,** the latter section of tubing being inserted back into the connector **22** for purposes to be described below. The exit port **22.1** of the second connector **22** communicates with an outlet tube **22.2** which passes outwardly through the exhaust port **12.2** of the shell, the heated, rapidly moving expanded gas being carried exteriorly of the shell by the outlet tube for use in driving a turbine or the like.

The jetting connector **20** is shown in greater detail in FIG. **8,** the inlet port **20.2** being joined through a suitable coupling **20.3** to the inlet pipe **16.1.** The walls of the inlet port **20.2** are tapered inwardly into a constricted orifice **20.4** for the purpose of increasing the velocity (and decreasing the pressure) of the gaseous stream entering through the inlet pipe **16.1.** The gas to be heated passes through the lower port **20.5** of the connector into the one section of tubing **16** for circulation within the primary tube bundles, and thence returns to the upper port **20.6** of the connector **20.** The connector includes a sharp internal edge **20.7** facing the upper port **20.6** and adjacent the constricted orifice **20.4.** Heated gas entering through the upper port **20.6** may pass either outwardly through the exhaust port **16.2** (and thence to other length **18** of tubing) or may be drawn again into the lower port **20.5** of the connector for recirculation through the primary tubing bundles. The structure of the second connector **22** is identical to that of the first connector **20,** heated gas being received from the connector tube **16.2** and being fed to the other length **18** of tubing with provision being made for recirculation through the secondary tubing bundles, the heated gas being ultimately discharged into outlet tube **22.2.**

The primary tubing bundles **14.1** are supported within the toroidal shell by a centrally positioned, annular support ring designated generally as **24** (FIGS. **5** and **6**). The annular ring **24** includes a single length of supporting wire **24.1** which is coiled into a plurality of turns which themselves are rigidly connected together at spaced circumferential intervals about the toroid by means of interfitting circular and star-shaped clips **24.2, 24.3** respectively. The inner, circular clip **24.2** provides a central support for the wire **24.1,** and the star-shaped clip **24.3** is mounted rigidly over the circular clip and provides a series of internal openings **24.4** in which the turns of the wire **24.1** are rigidly held. The ends of the length of wire **24.1** are joined together by a threaded sleeve connector **24.5.** The wire shown in FIG. **6** is preferably arranged into six turns, corresponding to the six points of the star-shaped clip **24.3.** When arranged in the center of the toroidal shell, the supporting ring **24** co-acts with the inner surface **12.4** of the shell to rigidly support the primary and secondary bundles therebetween. As will be noted from FIG. **5,** the secondary tubing bundles **14.2** desirably are arranged to abut the outer surfaces of the primary bundles, lying between and exteriorly of adjacent primary bundles and against the inner surface **12.4** of the toroidal shell **12.** The latter surface is corrugated transversely of the direction of flow of the hot gas through the toroidal shell, the ridges and valleys of the corrugations being designated **12.5** and **12.6** respectively, in FIGS. **3–5.** The outer, or secondary tube bundles **14.2** lie against the ridges **12.5** of the corrugated surface **12.4,** permitting the hot gas to flow transversely in valleys **12.6.** The spacing between adjacent tubes in each bundle also permits the hot gas to pass interiorly of each bundle, thereby permitting substantially complete contact of the gas with the outer surface of each tube.

The turns of tubing in each of the primary and secondary bundles are spacedly supported by a series of circumferentially spaced bundle clips **26** (FIGS. **3–6** and particularly FIG. **7**). Each of the bundle clips includes an inner, star-shaped clip **26.1** and an outer, ring clip **26.2** which are tightly interfitted. The turns of tubing **16, 18** are tightly held between the inner and outer clips, between the "points" of the star-shaped clip **26.1** as shown best in FIG. **7.** The inner star-shaped clip is made from a length of flat strapping which is transversely bent and the ends joined together to assume a shape shown in FIG. **7,** each "point" of the star-shaped structure including two thicknesses of strapping, as shown at **26.3** in FIG. **7** to suitably space apart adjacent turns of tubing. The bundle clips are placed at circumferentially spaced points along the length of each bundle, as shown best in FIG. **4,** the outer surface of the outer, ring-shaped clip **26.2** bearing against the outer walls of the tubing in adjacent bundles to thus space the bundles apart one from another.

As explained above, the lengths of continuous tubing **16, 18** in the primary (inner) and secondary (outer) tubing bundles **14.1, 14.2** pass from one bundle to another in each turn of tubing about the toroidal axis of the shell. With reference to FIG. **5,** representative tubing cross sections are shown in both the primary and secondary bundles, the remaining cross section of tubing being omitted for purposes of clarity. Referring first to the primary bundles, tubing **16** having the cross section denoted A in the upper portion of FIG. **5** passes annularly in the shell to appear in the bottom portion of FIG. **5** as cross section B, appearing again in the upper portion of FIG. **5** as cross section C and again in the bottom portion of FIG. **5** as cross section D, and so on sequentially through cross section L for reinsertion in the same bundle containing cross section A. The tubing **16** continues then through another series of turns passing from bundle to bundle until each position in the primary bundles has been filled. In similar fashion, the tubing **18** which is arranged in secondary bundles may pass from the cross section denoted M in the lower por-

tion of FIG. 5 to cross section N in the upper portion of FIG. 5 and so on sequentially through cross section X in the upper portion of FIG. 5 for eventual reinsertion the secondary bundle containing cross section M, the tubing thence passing from one bundle to another in each turn until all of the positions in the outer bundles have been filled. As shown best in FIG. 4, the turns of tubing thus described have a helical, twisted configuration about the longitudinal axis of each bundle to promote good heat exchange contact between the individual turns of tubing and the hot gas flowing in the toroidal shell. The tubing desirably describes substantially a complete helical revolution in each turn about the toroidal axis. In similar fashion, the bundles which are helically twisted about the central supporting ring 24 describe substantially a complete helical revolution in each turn of the bundle within the toroidal shell. It is desired that the direction of twists of the individual turns of tubing be the same (clockwise or counterclockwise) as the direction of twist of the bundles about the supporting ring 24, thereby giving greater direction to the flow of hot gas through the toroidal shell. Alternatively, the directions of twist may be different so that the direction of flow of the hot gas imparted by the twisted bundles is at an angle to the direction of twist of the individual tubes within each bundle.

In a typical heat exchanger of the invention, the toroidal shell may be of high temperature steel and may be supplied in two halves which are joined together by bolts 12.5 using a suitable temperature-resistant gasket 12.6. The transverse wall 12.3 within the shell may be of asbetos or other temperature-resistant material, and may be suitably connected to the inner walls of the shell by metal flanges (not shown). The transverse wall 12.3 prevents the hot gas entering through port 12.1 from passing through more than a single complete revolution through the shell, and forces the gas to exit through the shell port 12.2. Although a small amount of leakage of hot gas through the wall 12.3 may be permitted, it is desired that the wall be substantially impermeable to gas; the hollow centers of the bundles 14.1, 14.2 and of the central support ring 24 thus desirably are filled and thus sealed off by the same material employed for the wall at points where these elements pass through the wall 12.3. The interfitting circle and star clips 24.2, 24.3 are evenly spaced circumferentially evenly along the length of the central supporting ring 24, the clips being spaced, in one embodiment, approximately 2 inches apart and being spot welded together and to the wire 24.1 to impart rigidity to the supporting ring 24. The clips 24.2, 24.3 may be of stainless steel, one-eighth inch in thickness and one-half inch wide along the circumference of the supporting ring. The tubes 16 and 18 may be of hollow stainless steel tubing have external and internal diameters of nineteen-sixty-fourths and three-thirty-seconds inches, respectively, and the star and ring bundle clips 26.1, 26.2 may be of stainless steel strapping having a thickness of one-thirty-second inches and a width circumferentially of the bundles of one-half inches, the thickness of these clips providing a minimum spacing between adjacent turns of tubing. The latter clips may be spaced 2 inches along the circumference of the bundles and staggered from bundle to bundle as shown in FIG. 4 so that the thickness of the outer ring clip 26.2 acts as a spacer between adjacent bundles.

To manufacture the device of the invention, the continuous length of tubing of the inner bundles 14.1 is bent into loops of the desired size, the loops being sequentially positioned in the recesses of the star-shaped clips 26.1 and the bundles being formed about the periphery of the central supporting ring 24. Then the outer or secondary bundles are formed similarly from another length of continuous tubing 18, and are arranged about the outer surfaces of the primary bundles, as shown in FIG. 5. Thereafter the entire assembly may be positioned with the shell halves, with provision being made for the passage of inlet and outlet tubes 22.2 and 16.1.

In use, a gas to be heated such as steam from an automobile radiator is passed through a filter to remove any entrained solid impurities and is then pressurized by a pump 30 (FIG. 1) to pressure of 200 to 400 PSI, although considerably higher pressures may be desired in the event extremely long tubing sections are used. The steam passes through the inlet pipe 16.1 and into the inlet port 20.2 of the jetting connector 20, and thence passes through each of the turns of tubing in the primary tubing bundles. The downstream end of the tubing 16 of the primary tubing bundles passes back into the jetting connector 20, and a portion of the heated steam may be recycled for passage again through the primary tubing bundles. A portion of the steam is ejected into the connector tube 16.2 and passes then through the other jetting connector 22 for eventual passage through the tubing 18 of the secondary tubing bundles, the steam eventually issuing in very hot, greatly expanded form through the outlet tube 22.2 from whence it may be directed to a turbine or the like for use in furnishing supplementary power to an automobile, resulting in fuel savings. The gaseous exhaust of the automobile engine, which may be at a temperature of 3,500° F. or more, passes through the inlet port 12.1 of the shell and travels thence generally annularly for exhaust through the exhaust port 12.2 of the shell, the transverse wall 12.3 of the shell preventing recirculation of the exhaust gases, and the corrugated inner surface of the shell imparting increased turbulance to the flow of hot gas. The outer surface of the shell desireably includes a cladding of insulation to prevent undue heat loss through the shell walls.

While I have described a preferred embodiment of the present invention, it should be understood that various changes, adaptations, and modifications may be made therein without departing from the spirit of the invention and the scope of the appended claims.

What is claimed:

1. A heat exchanger which comprises a toroidal shell having inlet and outlet ports for admission of a hot gas to the interior of the shell and for discharge of the gas, the shell having a transverse inner wall limiting revolution of the hot gas in the toroidal shell to a maximum of one revolution; a plurality of turns of at least one continuous length of tubing, the tubing turns being arranged in a plurality of spaced, annular bundles within and about the axis of the toroidal shell, the tubing passing from one bundle to another in each turn thereof about the toroidal axis and each turn of tubing in each bundle being spaced from adjacent turns of tubing; an annular support ring carried within the shell and supportively contacting the bundles with the latter being uniformly helically twisted about the support ring; means for flowing a gas to be heated into one end of the

tubing; and means at the other end of the tubing for leading hot, expanded gas exteriorly of the shell.

2. The heat exchanger of claim 1 including a jetting connector at one end of the tubing for jetting the gas to be heated into the tubing.

3. The heat exchanger of claim 1 wherein the bundles of tubing include a primary series of bundles supported by the annular ring and containing a continuous length of hollow tubing, and a secondary series of bundles arranged exteriorly of the primary bundles and in supportive contact with inner walls of the toroidal shell, the secondary bundles containing a second, continuous length of tubing communicating with the first-mentioned length of tubing.

4. The heat exchanger of claim 3 including a jetting connector at one end of the tubing in the primary bundles for jetting a gas to be heated into the last-mentioned tubing, and a second jetting connector communicating the primary and secondary bundles for jetting gas received from the primary bundles into the tubing of the secondary bundles.

5. The heat exchanger of claim 3 wherein the primary and secondary bundles of tubing are twisted helically in the same direction about the support ring.

6. The heat exchanger of claim 5 wherein each tubing bundle is twisted helically through substantially one revolution about the annular support ring in each turn of the tubing bundle about the toroidal axis of the shell.

7. The heat exchanger of claim 5 wherein individual turns of tubing within each bundle are helically twisted with respect to the longitudinal axis of that bundle, each turn of tubing making substantially one helical revolution about the bundle axis.

8. The heat exchanger of claim 4 wherein the toroidal shell has a transversely corrugated inner surface in supportive contact with the secondary tubing bundles, the inner surface of the shell and the centrally positioned annular support ring cooperating to rigidly support the primary and secondary bundles of tubing within the shell.

9. The heat exchanger of claim 2 wherein the jetting connector includes means for recirculating a gas to be heated through the tubing bundles.

10. A heat exchanger comprising a toroidal shell having inlet and outlet ports for admitting a hot gas to the interior of the shell and for discharging the gas therefrom, the shell having an inner transverse wall limiting annular flow of the hot gas to a maximum of one revolution within the shell and the shell having an inner, transversely corrugated surface for imparting turbulance to the hot gas; a coil of continuous, primary tubing arranged in a plurality of spaced annular bundles within the toroidal shell, each successive turn of tubing passing from one bundle to another and each turn of tubing in a bundle being spaced from other tubing turns in that bundle, a centrally positioned, annular support ring carried within the shell and in supportive contact with the primary tubing bundles; a coil of continuous secondary tubing arranged in a plurality of spaced, annular secondary bundles about the axis of and within the toroidal shell and lying outwardly of the primary tubing bundles, each turn of secondary tubing passing from one secondary bundle to another and the secondary tubing bundles being supported within the shell by exterior surfaces of the primary bundles and by internal surfaces of the toroidal shell; the turns of tubing in each primary and secondary bundle being held together by bundle clips spaced circumferentially of the bundles, and each of the primary and secondary bundles being helically twisted with respect to the support ring and each of the tubing turns within each bundle being helically twisted about the longitudinal axis of that bundle; first and second jetting connectors, the former connecting ends of the primary tubing and the latter connecting ends of the secondary tubing and each connector having an out-flow port, the out-flow port of the first connector communicating through a connector tube with the second connector and the out-flow port of the second connector being connected to an outlet tube for leading hot, expanded gas exteriorly of the toroidal shell, each connector having an internal jetting orifice for increasing the speed of gas entering the connector.

* * * * *