Jan. 25, 1966 J. C. STEWART ETAL 3,231,016

HEAT RECOVERY SILENCER

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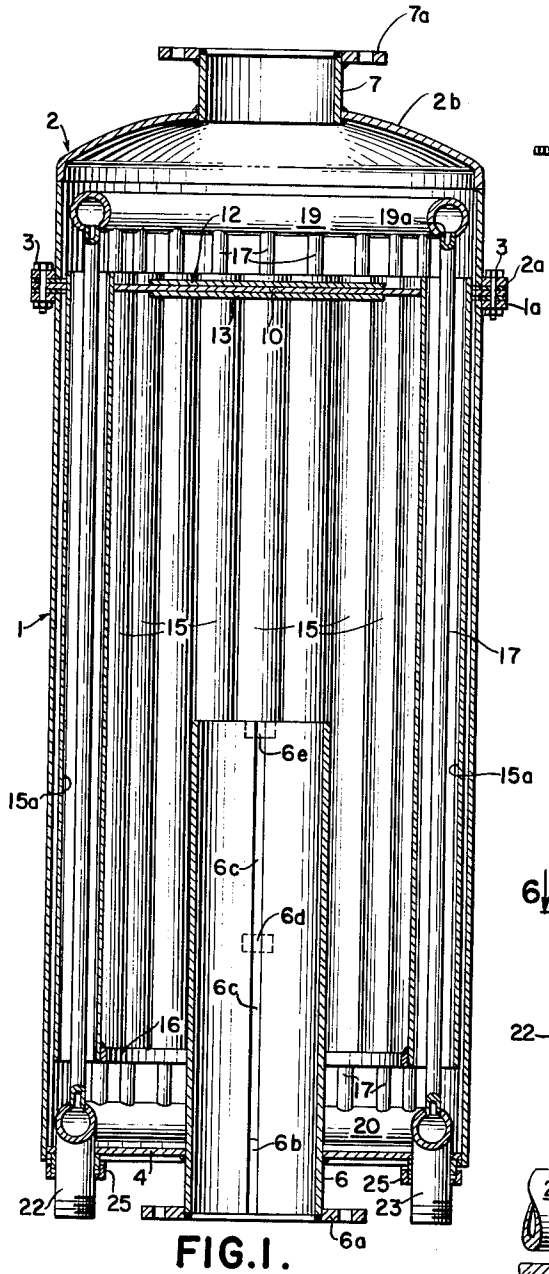


FIG. 1.

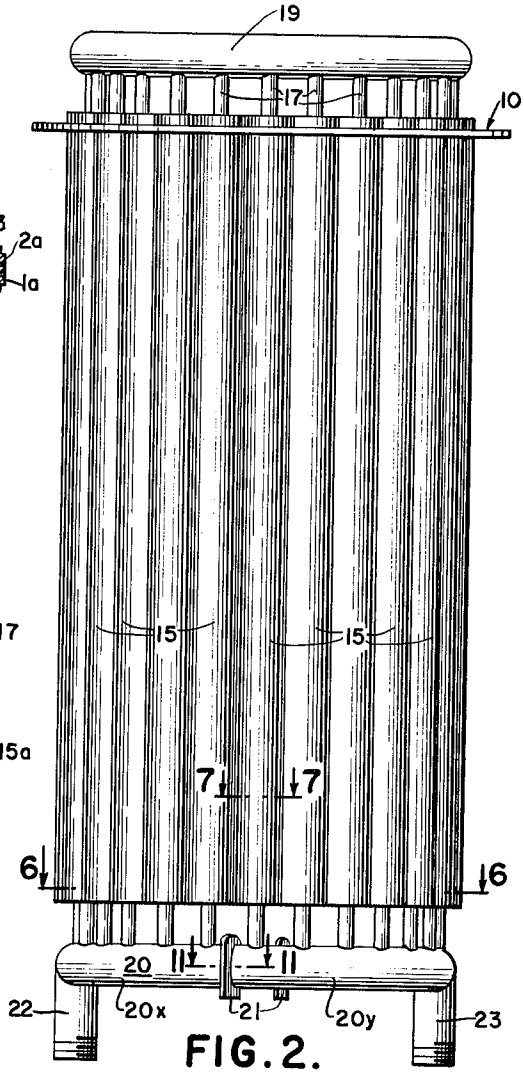


FIG. 2.

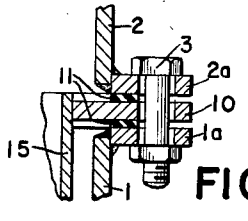


FIG. 8.

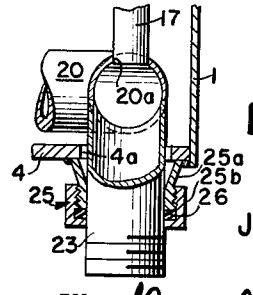


FIG. 9.

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HEAT RECOVERY SILENCER

Filed Nov. 26, 1963 2 Sheets-Sheet 2

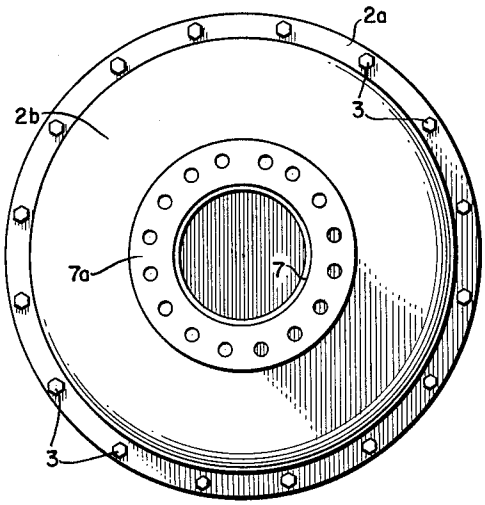


FIG. 5.

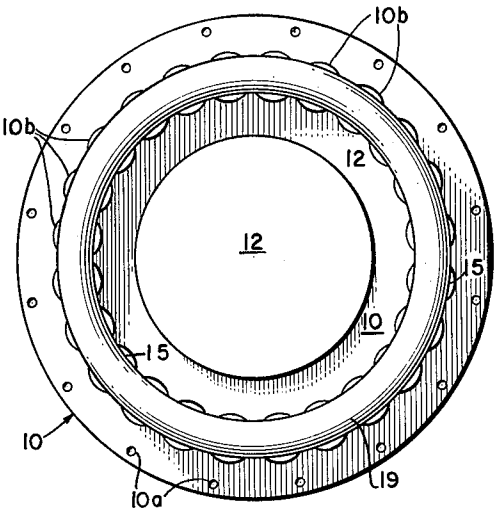


FIG. 3.

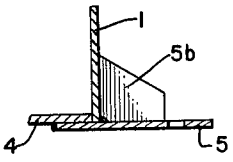


FIG. 10.

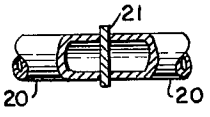


FIG. 11.

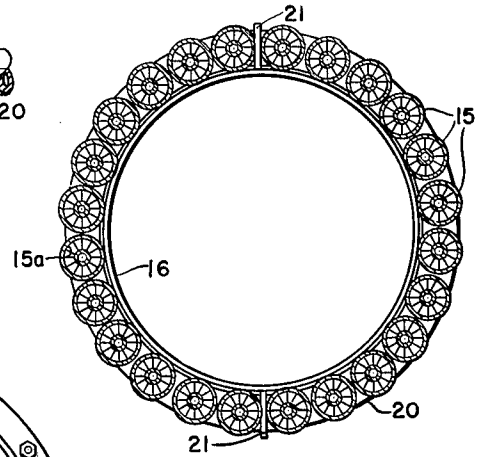


FIG. 6.

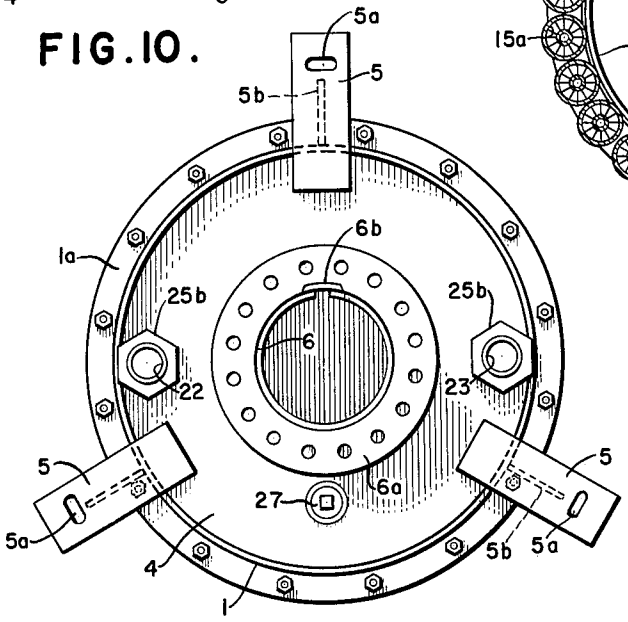


FIG. 4.

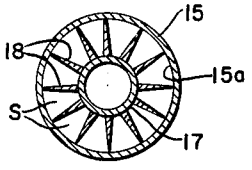


FIG. 7.

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3,231,016

HEAT RECOVERY SILENCER

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Filed Nov. 26, 1963, Ser. No. 326,135
13 Claims. (Cl. 165—164)

This invention relates to improvements in heat recovery silencers for use with internal combustion engines, furnaces, and other heat generating apparatus, and more particularly to units having two fluid paths therethrough, one to receive and pass exhaust gases and the other to conduct a liquid in heat-exchange relationship with said exhaust gases to recover heat therefrom.

Other heat recovery silencers of similar general type have been known in the art, for instance as shown in U.S. Patents 2,397,208 and 2,268,979. There are other heat exchanger patents showing structures used to transfer heat from one fluid medium to another, for example Patents 2,942,855; 2,667,941; and 2,622,853, which patents disclose structures similar in certain details to the present invention.

It is a major object of this invention to provide an improved heat recovery silencer in which increased recovery of heat is achieved within a smaller volume of space than is normally occupied by other heat recovery silencers of similar accoustical and thermodynamic capabilities.

It is another major object of this invention to provide a heat-recovery unit having the greater heat-transfer properties obtainable by using finned heat-exchange tubes to conduct the liquid path and locating the finned tubes within shroud tubes serving to confine the hot gases in close contact with the fins and to insure a high velocity of the hot gases passing through the tubes so that they tend to stay cleaner.

It is also a major object to provide a heat-recovery silencer which is easily dismantled sufficiently to facilitate periodic cleaning of the finned tubes and shroud tubes and in particular to permit access to both ends of each length of finned tube to facilitate proper cleaning thereof despite the shroud tube surrounding it.

More specifically, it is the object of this invention to provide a novel heat-exchange silencer structure including a silencer vessel specially adapted for receiving and supporting a novel tube bundle subassembly including shroud tubes surrounding finned tubes which are manifolded together at their exposed ends, the subassembly being removably mounted in the vessel so that it can be taken out for cleaning. The shroud tubes, though not completely separable from the finned tubes which they surround, can slide lengthwise of the finned tubes for a few inches until they touch the manifold headers joining the finned tubes. This provision for relative motion between the shroud tubes and the finned tubes on which they are coaxially supported makes it easier to dislodge solid deposits and to clean exhaust deposits from the hot-gas passageways between the tubes using a small brush in conjunction with a compressed air or steam lance.

Another object of the invention is to use liquid path tubes having fins which extend longitudinally parallel with the axis of the tubes so as to present a relatively smaller impedance to the flow of exhaust gases between the finned tubes and the shroud tubes than would be presented by the use of tubes having annular radially-disposed fins, the finned tubes shown in the illustrative embodiment having eight to ten times more heat transfer surface area than the same size bare tube would have.

It is yet another object of the invention to provide a heat-exchange silencer that can be mounted in any position with respect to vertical, and in which the fluid flow

in either path can be reversed without substantially affecting performance efficiency, so as to permit not only counter flow of the fluids but also easy connecting of silencer units in various combinations of single or multiple-pass gas flow, single or multiple-pass liquid flow, and/or parallel flows.

Another important object of the invention is to provide a high degree of exhaust silencing using a chamber type silencer with multiple side tubes in a silencer structure which in several serially connected chambers intermingles volumes of exhaust gases of widely differing pressures, and which provides a high degree of cooling of the hot gases which cooling also improves the silencing efficiency.

Other objects and advantages of the invention will become apparent during the following discussion of the drawings, wherein:

FIG. 1 is a longitudinal section view taken through a heat recovery silencer according to the present invention;

FIG. 2 is an elevation view of the removable heat exchange tube bundle employed in the embodiment illustrated in FIG. 1;

FIG. 3 is a plan view of the tube bundle illustrated in FIG. 2;

FIG. 4 is a bottom view of the silencer illustrated in FIG. 1;

FIG. 5 is a plan view of the embodiment illustrated in FIG. 1;

FIG. 6 is a section view taken along line **6—6** of FIG. 2;

FIG. 7 is an enlarged section view taken along line **7—7** of FIG. 2;

FIG. 8 is an enlarged detail view of the bolted flange assembly joining the upper and lower shells and the baffle plate unit illustrated in FIG. 1;

FIG. 9 is an enlarged sectional view illustrating a packing gland structure sealing the inlet and outlet heat-exchange pipes to the lower shell of the silencer vessel;

FIG. 10 is a detail view partly in section illustrating one mounting foot for supporting the silencer; and

FIG. 11 is a section view taken along line **11—11** of FIG. 2.

Referring now to the drawings, a working embodiment is shown for illustrative purposes and includes a closed heat-exchange silencer vessel including two opposed shells comprising a lower shell **1** and an upper shell **2** having opposed bolting flanges **1***a* and **2***a* with aligned bolt holes for receiving a plurality of bolts **3** by which the upper and lower shells are sealed together in a transverse coupling zone or plane, as illustrated in FIG. 8.

The lower shell **1** is closed by a bottom plate **4** welded across the bottom of the vessel in the position illustrated in FIGS. 1 and 4. Although the illustrated silencer can be mounted in any desired position, the present illustrative embodiment is provided with three mounting feet **5** as shown in FIGS. 4 and 10, these mounting feet having bolt holes **5***a* by which they can be secured to any suitable support (not shown), and the mounting feet being preferably welded to the sides of the lower shell **1** and to the bottom plate **4** using strengthening gussets **5***b* in a manner well-known per se. When the silencer is to be used in a horizontal position, it can be supported on a suitable saddle-shaped mounting (not illustrated).

The bottom plate has a large diameter hot-gas exhaust pipe **6** extending therethrough and welded to the bottom plate and including a coupling flange **6***a* at its lower end. This pipe has been formed by bending a piece of sheet metal into a substantially cylindrical shape and then welding a strip **6***b* across the remaining gap so as to close the seam in the portion of the pipe which extends outside of the bottom plate **4**. A considerable length of the seam inside the vessel is left open so as to form slots **6***c*, and the

shape of the pipe 6 is generally maintained by other small straps 6*d* and 6*e* welded across the slot.

The upper shell 2 has an opening into which another hot-gas exhaust pipe 7 extends, the pipe 7 being welded in place in the bell-shaped portion 2*b* of the shell 2 and including a mounting flange 7*a* by which it can be coupled to another pipe (not shown) leading into other apparatus. The pipes 6 and 7 comprise hot-gas passage ways communicating with the inside of the vessel.

The illustrated embodiment of the silencer includes a baffle plate 10 which extends transversely across the silencer normal to its axis and divides the silencer into upper and lower chambers. The shape of the baffle plate can be seen in FIG. 3, and comprises a circular plate having mounting flange means of the same diameter as the outer dimension of the flanges 1*a* and 2*a*, and the plate 10 is further provided with a plurality of bolt holes 10*a* which align with the holes in the flanges 1*a* and 2*a* so that the bolts 3 secure the members 1*a* and 2*a* and 10 together as shown in FIG. 8. Two gaskets 11 are employed to seal the upper and lower shells to the opposite sides of the baffle plate 10. On each side of the baffle plate 10 are secured asbestos disks 12 and 13 which protect the baffle plate 10 against hot exhaust gas entering the silencer through one of the pipes 6 or 7, depending on the direction in which the exhaust gases are introduced into the silencer.

The baffle plate 10 is provided with an annular series or cluster of holes 10*b*, each of the holes receiving a shroud tube 15, which shroud tubes are all oriented parallel with the vertical axis of the silencer vessel and offset from the pipes 6 and 7, and are all welded to the baffle plate 10 at their upper ends. The lower ends of all of the shroud tubes 15 are welded to an annular ring 16 which maintains their relative positions. The shroud tubes 15 are close together, or touching, and the only passageways communicating between the upper and lower chambers of the silencer are through the bores 15*a* of these shroud tubes 15. The baffle plate 10 and the shroud tubes 15 comprise part of the tube bundle subassembly illustrated in FIG. 2.

This subassembly also includes a plurality of inner tubes 17 which are provided with longitudinally extending fins 18 which extend at least through as much of the length of each tube 17 as is located within a shroud tube 15. These fins are best illustrated in FIGS. 6 and 7, and serve not only to greatly increase the efficiency of heat-exchange but also serve as spacers to maintain the inner tube 17 centered within the outer tube 15. The only way for the exhaust gases to pass the partition 10 in travelling from one chamber of the silencer to the other chamber is to pass through the spaces S, between the fins and the tubes 15 and 17. Thus, the hot gases are closely confined so as to provide high velocity travel with excellent heat exchange contact with the fins and with the attached tubes 17.

Each of the tubes 17 extends above and below the shroud tube within which it is housed and terminates in a manifold header, such as the upper manifold 19 and the lower manifold 20. The upper manifold 19 has a series of holes 19*a* of the same diameter as the outside diameter of a tube 17, and these tubes are entered into these holes and sealed therein as by welding or soldering. Similarly, the lower manifold 20 has a series of holes 20*a* sized to receive the lower ends of the tubes 17, which tubes are likewise sealed in the holes. In the present illustrative embodiment, no access is illustrated to the upper manifold 19 which merely interconnects all of the finned tubes 17, and the access to the liquid circuit within the finned tubes 17 is had through the lower manifold 20 which is divided by means of two partitions 21, FIGS. 2 and 10, into similar inlet and outlet circuits. Since the structure is symmetrical, it does not matter which side of the manifold 20 serves as an inlet, and which side serves as an outlet, and for best results, it is desirable that the direction of flow be reversed periodically.

At any rate, the two sides 20*x* and 20*y* of the manifold are provided with inlet and outlet pipes 22 and 23, which pipes are also welded into the manifold 20 as shown in FIG. 9. The structure of the tube bundle has now been fully described, except to state that the baffle plate 10 and the shroud tubes 15 and 16 comprise one unified structure which loosely surrounds and is captivated to another unified structure including the finned tubes 17, the manifolds 19 and 20 and the pipes 22 and 23. These two unified structures can be slid up and down with respect to each other in a direction parallel with the axes of the tubes 15 and 17, and therefore a degree of relative motion between the tubes 15 and 17 is possible, which relative motion tends to break up and dislodge solid deposits from the hot gases, such as ash, carbon, and a certain amount of oily deposit. The passageways through the spaces S can be cleaned by injecting compressed air or steam and perhaps using swabs or brushes while reciprocating the said unified structures with respect to each other.

The upper end of the tube bundle subassembly is sealed to the shells 1 and 2 in the coupling zone of the flanges 1*a* and 2*a* and the baffle plate 10, FIG. 8, and the lower end of the tube bundle subassembly is secured to the lower shell at the bottom plate 4 as illustrated in FIGS. 1 and 9, by passing the tubes 22 and 23 through holes 4*a* in the bottom plate 4 and sealing the holes against leakage of exhaust gases by using a suitable packing gland 25 as shown in enlarged detail in FIG. 9. The packing glands including a short nipple 25*a* welded to the bottom plate 4 and a packing ring 25*b* confining wading 26 therebetween and pressing it against the pipes 22 and 23. These structures can be seen also in FIG. 4 showing the bottom view of the entire silencer assembly. In addition, FIG. 4 shows a clean-out plug 27 extending through the bottom plate 4 so that the lower shell 1 can be flushed by spraying a suitable liquid such as a detergent into the lower shell 1 when the upper shell 2 and the tube bundle subassembly are removed, the cleaning liquid running out through the drain 27.

This invention is not to be limited to the exact form shown in the drawings, for obviously changes may be made therein within the scope of the following claims.

We claim:

1. A silencer and heat-recovery unit for insertion in the exhaust line of an engine, comprising:

(a) two separable shells mating at a coupling zone to form a closed vessel and having an exhaust-line pipe extending through the end of each shell and parallel with the axis of the vessel when the shells are mated;

(b) a baffle plate inserted in the vessel and lying thereacross in said zone where the shells mate;

(c) means for securing together the shells and the baffle plate at said zone;

(d) a multiplicity of shroud tubes each extending through and secured to the baffle plate, the ends of the tubes communicating with the two exhaust line pipes but being offset from and out of alignment therewith and the tubes extending nearly the full length of the vessel in the axial direction;

(e) a multiplicity of heat-exchange tubes within the vessel and each passing through a shroud tube in spaced relation thereto, and the heat-exchange tubes being interconnected at their ends; and

(f) inlet and outlet pipe means coupled with the heat-exchange tubes and each extending through and outside of the vessel.

2. A silencer and heat-recovery unit for insertion in the exhaust line of an engine, comprising:

(a) two separable shells mating in a transverse plane to form a closed vessel and having an exhaust-line pipe extending through the end of each shell normal to said plane and parallel with the axis of the vessel when the shells are mated;

(b) a baffle plate inserted in the vessel substantially in said plane where the shells mate;

(c) means for securing together the shells and the baffle plate in said plane to form in said vessel two chambers each communicating with an exhaust pipe;

(d) an annular series of shroud tubes each extending through and secured to the baffle plate parallel with said axis and communicating with the chambers on opposite sides thereof but out of alignment with said exhaust pipes, the tubes extending nearly the full axial length of the vessel;

(e) an annular series of heat-exchange tubes within the vessel and each loosely passing through a shroud tube, and the heat-exchange tubes being interconnected at their ends; and

(f) inlet and outlet pipe means coupled with the heat-exchange tubes and each extending through and outside of the vessel.

3. A silencer and heat-recovery unit for insertion in the exhaust line of an engine, comprising:

(a) two separable shells mating at a coupling zone to form a closed vessel and having an exhaust-line pipe extending through the end of each shell and parallel with the axis of the vessel when the shells are mated, at least one of the shells being axially elongated and its exhaust-line pipe extending well into the shell but short of said zone;

(b) a baffle plate inserted in the vessel and lying thereacross in said zone where the shells mate;

(c) means for securing together the shells and the baffle plate at said zone;

(d) a multiplicity of shroud tubes communicating with the shells on opposite sides of the baffle plate and each extending through and secured to the baffle plate parallel with said axis but offset from and partially overlapping said exhaust-line pipe;

(e) a multiplicity of heat-exchange tubes within the vessel and each passing through a shroud tube in spaced relation thereto, and the heat-exchange tubes being interconnected at their ends; and

(f) inlet and outlet pipe means coupled with the heat-exchange tubes and each extending through and outside of the vessel.

4. A silencer and heat-recovery unit for insertion in the exhaust line of an engine, comprising:

(a) two separable shells mating at a coupling zone to form a closed vessel and having an exhaust-line pipe extending through the end of each shell and parallel with the axis of the vessel when the shells are mated;

(b) a baffle plate inserted in the vessel and lying thereacross in said zone where the shells mate;

(c) means for securing together the shells and the baffle plate at said zone;

(d) a multiplicity of shroud tubes each extending through and secured to the baffle plate, the ends of the tubes communicating with the exhaust-line pipes but being offset therefrom and the tubes extending nearly the full axial length of the vessel;

(e) a multiplicity of heat-exchange tubes within the vessel and each passing loosely through a shroud tube, and the heat-exchange tubes having plural longitudinally disposed fins on their outer surfaces spacing the heat exchange tubes from the shroud tubes and increasing the heat transfer to the former from the hot exhaust passing therebetween; and

(f) inlet and outlet pipe means coupled with the heat-exchange tubes and extending through and outside of the vessel.

5. A silencer and heat-recovery unit for insertion in the exhaust line of an engine, comprising:

(a) two separable shells mating in a transverse plane to form a closed vessel including a relatively longer chamber on one side of the plane and a relatively shorter chamber on the other side of the plane, and having an exhaust-line pipe extending through the end of each shell normal to said plane and parallel with the axis of the vessel when the shells are mated the pipe extending into the longer chamber and approaching said plane;

(b) a baffle plate inserted in the vessel substantially in said plane where the shells mate;

(c) means for securing together the shells and the baffle plate in said plane to isolate the longer and the shorter chambers, each chamber communicating with an exhaust pipe;

(d) an annular series of shroud tubes substantially in contact with each other and communicating with both chambers, each tube extending through and secured to the baffle plate parallel with said axis and out of alignment with said exhaust pipes, the tubes extending nearly the full axial length of the longer chamber;

(e) an annular series of heat-exchange tubes within the vessel and each passing through a shroud tube and having fins on its outside surface spacing the heat-exchange tube from the shroud tube thereabout;

(f) manifold means joining the respective ends of the heat-exchange tubes; and

(g) inlet and outlet pipe means coupled with the manifold means and disposed parallel with said axis and each extending through a shell.

6. In a unit as set forth in claim 5, both shells and the baffle plate having bolting flanges about their peripheries in the vicinity of said plane, and bolt means for securing all three flanges together.

7. In a unit as set forth in claim 6, the shells having end plates opposite their flanges and supporting the exhaust-line pipes, and having holes for receiving said inlet and outlet pipe means; and packing glands mounted on the end plates at said holes for releasably sealing the end plates to the inlet and outlet pipe means passing therethrough.

8. In a unit as set forth in claim 5, said manifold means comprising one manifold pipe joining all of the ends of the heat exchange tubes on one side of the baffle plate; and a second manifold pipe of toroidal shape connected with all of the other ends of the heat-exchange tubes and coupled at diametrically opposite points with said inlet and outlet pipe means; and partition means within the second manifold pipe blocking direct flow therein between the inlet and outlet pipe means.

9. In a unit as set forth in claim 5, foot means mounted one shell for supporting the unit; and drain plug means at the bottom of that shell when mounted on the foot means.

10. A silencer and heat-recovery unit for insertion in the exhaust line of an engine, comprising:

(a) two separable shells mating at a coupling zone to form a closed vessel and having an exhaust-line pipe extending through the end of each shell and disposed parallel with the axis of the vessel when the shells are mated;

(b) a removable tube bundle assembly comprising a baffle plate for dividing the vessel into two chambers and including means for securing the plate to the shells at said coupling zone, series of tubes passed through the baffle plate in locations such that the tubes are offset from the exhaust-line pipes and disposed parallel with said axis, and said tubes including shroud tubes fixed and sealed to the baffle plate and open on both sides thereof, and heat-exchange tubes each extending in spaced relation through a shroud tube, manifold means connecting the adjacent ends of the heat-exchange tubes together, and inlet and outlet means connected with the manifold means and passing through the vessel and extending outside thereof.

11. A silencer and heat-recovery unit for insertion in the exhaust line of an engine, comprising:

(a) two separable shells each having a bolting flange for securing them together at a coupling zone to

form a closed vessel, and the shells having an exhaust line pipe extending through the end of each shell and disposed parallel with the axis of the vessel when the shells are mated, at least one pipe extending well into the vessel;

(b) a removable tube bundle assembly comprising a baffle plate for dividing the vessel into two chambers and including bolting flange means for mounting the plate to the shells at said coupling zone, annular series of tubes passed through the baffle plate near its periphery and disposed parallel with said axis and said tubes including shroud tubes secured and sealed to the baffle plate and open on opposite sides thereof, the shroud tubes overlapping the longitudinal extent of the said one pipe, and heat-exchange tubes each extending in spaced relation through a shroud tube, manifold means connecting the adjacent ends of the heat-exchange tubes together, and inlet and outlet means connected with the manifold means and passing through the vessel and extending outside thereof; and

(c) removable securing means for securing together said flanges and flange means in fluid-tight sealed relationship.

12. A silencer and heat-recovery unit for insertion in the exhaust line of an engine, comprising:

(a) two separable shells mating at a coupling zone to form a closed vessel and having an exhaust line pipe extending through the end of each shell and disposed parallel with the axis of the vessel when the shells are mated;

(b) a removable tube bundle assembly comprising a baffle plate for dividing the vessel into two chambers and including means for mounting the plate to the shells at said coupling zone, a series of tubes through the baffle plate near its periphery and disposed parallel with said axis and said tubes including shroud tubes extending through the baffle plate and open on opposite sides thereof and secured thereto, and including longitudinally finned heat-exchange tubes each extending through a shroud tube and spaced therefrom by the fins which are slidable therewithin, manifold means connecting the adjacent ends of the heat-exchange tubes together and including inlet and outlet means connected with the manifold means and passing through the vessel parallel with said axis and extending outside thereof; and

(c) releasable packing means for sealing the inlet and outlet means to the vessel.

13. A heat-recovery unit having a hot-gas path and having a liquid heat exchange path, comprising:

(a) two separable shells mating at a coupling zone to form a closed vessel and having a hot-gas pipe extending through the end of each shell parallel with the axis of the vessel when the shells are mated;

(b) a removable tube bundle assembly comprising a baffle plate for dividing the vessel into two chambers and including means for mounting the plate at said coupling zone; a cluster of tubes through the baffle plate offset from the hot-gas pipes and disposed parallel with said axis, and said tubes including shroud tubes extending through the baffle plate and secured thereto and open on opposite sides thereof to complete said hot-gas path through the shells, and the cluster further including heat-exchange tubes each extending loosely through a shroud tube, manifold means connecting the adjacent ends of the heat-exchange tubes together, and inlet and outlet means connected with the manifold means and removably passing through the vessel and forming said liquid path together with the heat-exchange tubes and manifold means; and

(c) removable securing means for securing together the shells and the baffle plate in fluid-tight sealed relationship.

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