

March 18, 1952

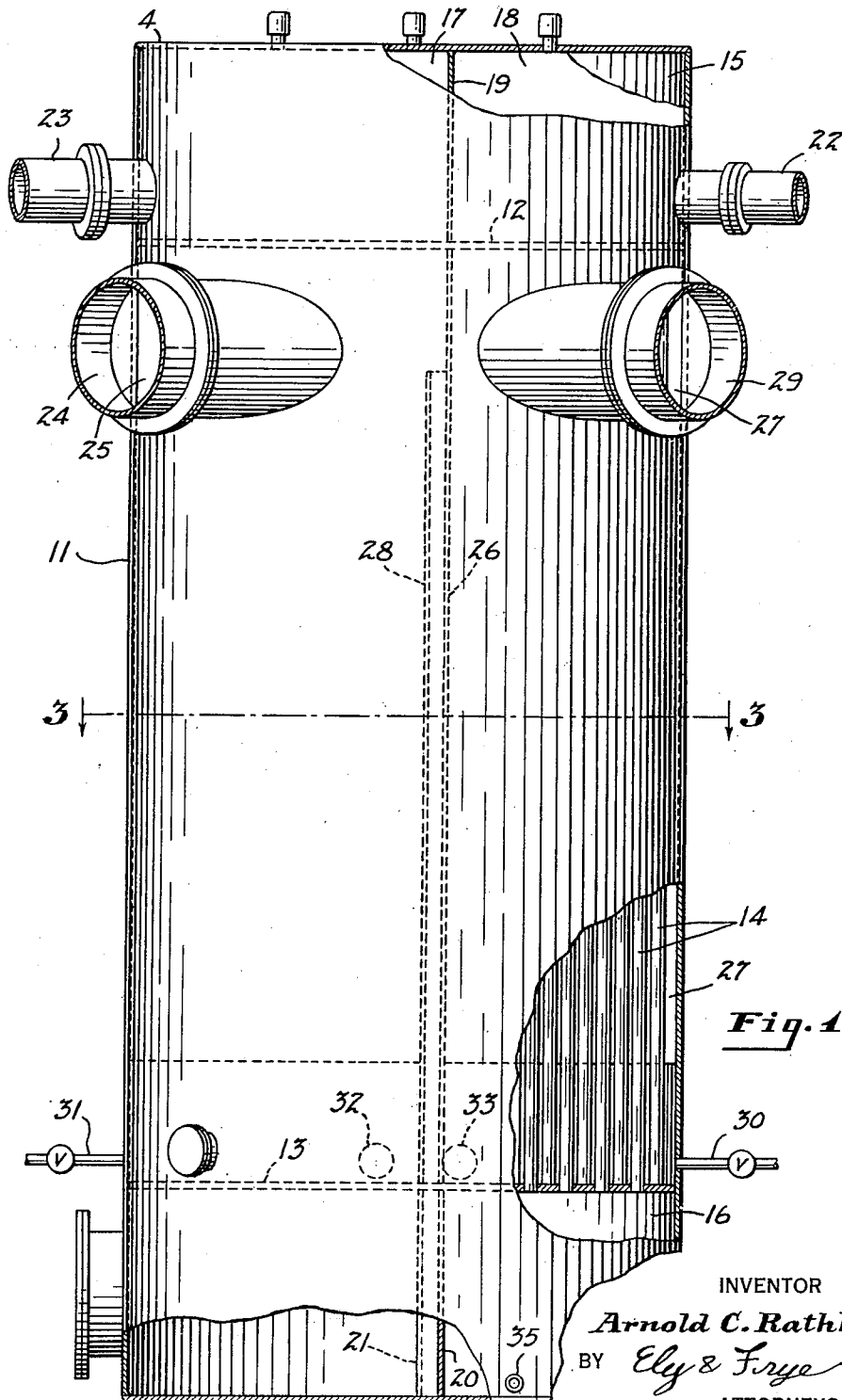
A. C. RATHKEY

2,589,730

HEAT EXCHANGER

Filed Sept. 20, 1949

3 Sheets-Sheet 1



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HEAT EXCHANGER

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3 Sheets-Sheet 2

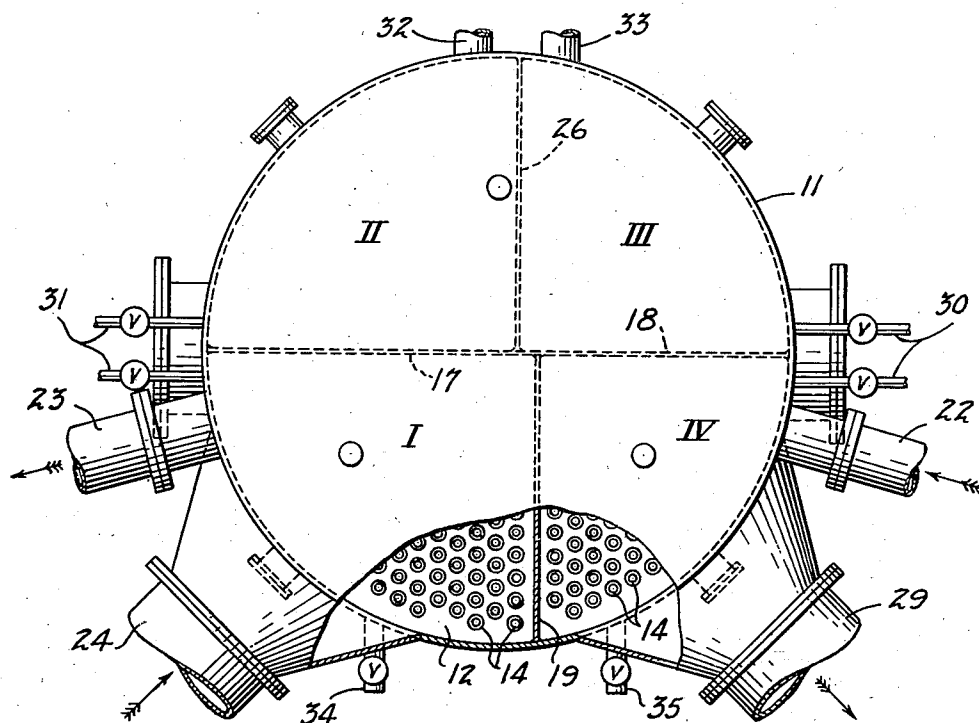


Fig. 2

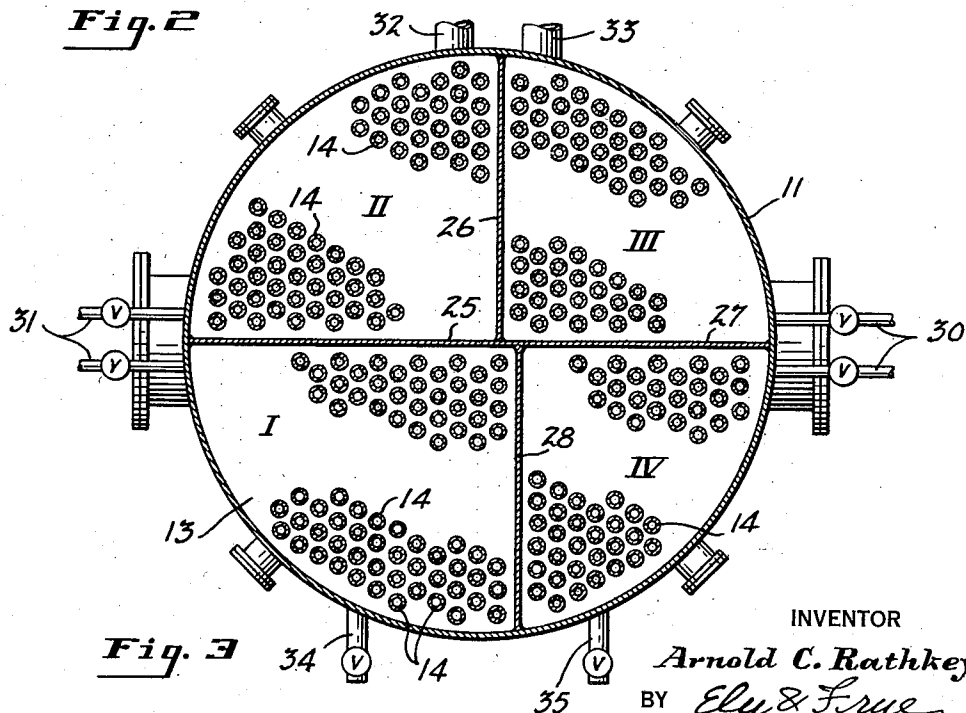


Fig. 3

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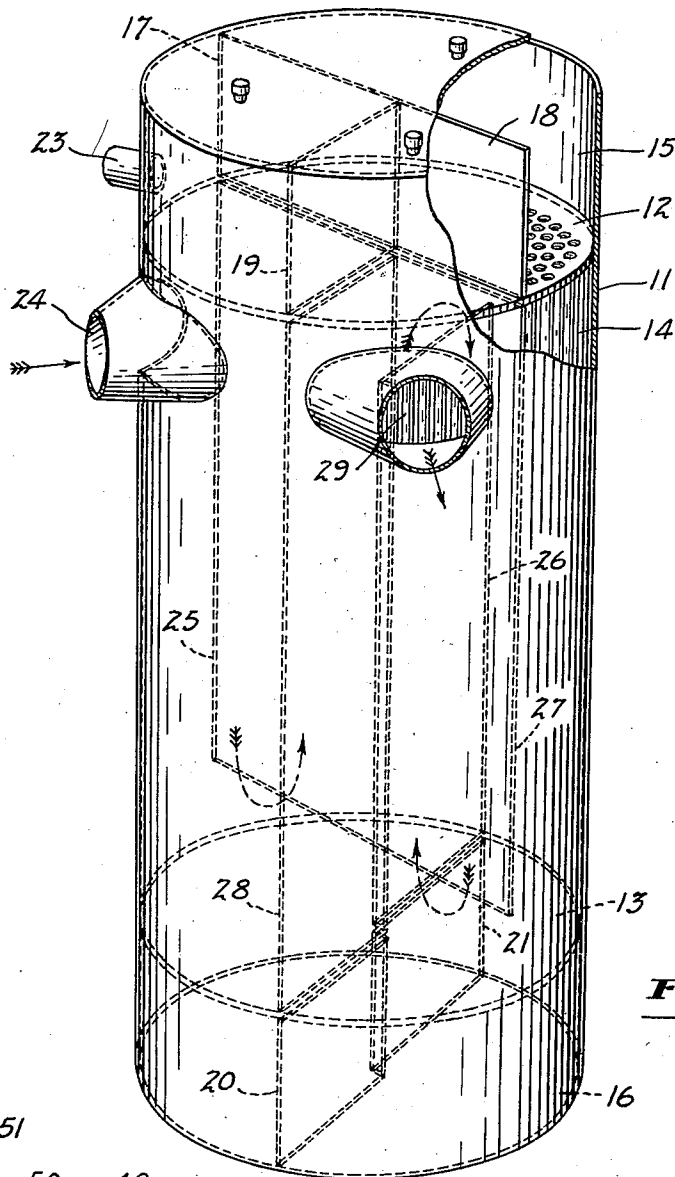


Fig. 4

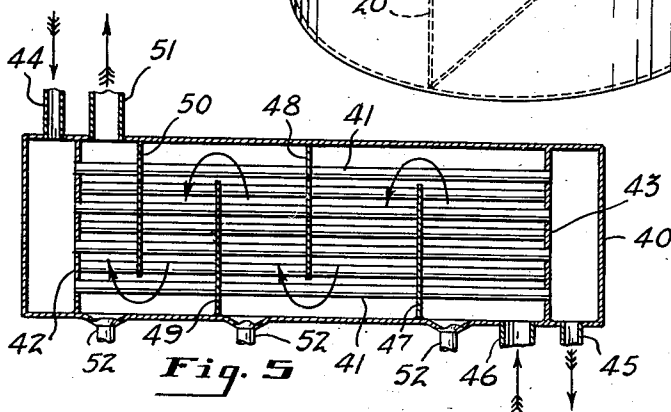


Fig. 5

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HEAT EXCHANGER

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7 Claims. (Cl. 257—223)

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The present invention relates to heat exchangers and more particularly to those heat exchangers in which gases containing condensable constituents are cooled and, in gas works practice, are called condensers.

When cooling gases and especially those which contain condensable constituents, the volume of the gas decreases as it is cooled, not only because of the decrease in temperature but also because of the condensation of the condensable constituents of the gas. In conventional condensers in which the cross sectional area of the gas passage remains substantially constant throughout, the reduction in volume of the gas causes a corresponding reduction in velocity of the gas which results in a non-uniform pressure drop through the condenser. This non-uniform pressure drop through the condenser is highly undesirable and the decreasing velocity of the gas reduces the efficiency of heat transfer by permitting a gas film of varying thickness to cling to the cooling surfaces of the condenser.

Since the pressure drop or loss through a condenser is approximately directly proportional to the square of the velocity and the coefficient of heat transfer is approximately directly proportional to the square root of velocity or some similar exponential function always less than one, it will be seen that when a multiple pass condenser includes one pass at high velocity and another pass at low velocity, an unnecessarily high pressure drop is encountered in the pass at high velocity without a correspondingly high heat transfer. In fact the heat transfer coefficient is improved only slightly by increased velocity while the pressure loss would be greatly increased. For example, doubling the velocity will increase the pressure loss approximately four times but will only improve the heat transfer coefficient by a factor of about 1.41. However, when employing two or more passes at the same gas velocity, there will be produced the lowest combined pressure drop consistent with the best obtainable heat transfer at the particular velocity employed.

It is therefore an object of the present invention to provide a substantially uniform pressure drop throughout the condenser as well as a substantially uniform gas velocity between the gas inlet and the gas outlet whereby the efficiency of heat transfer is maintained at a maximum. To accomplish these results, a condenser is provided in which the cross sectional area of the gas passage varies from the gas inlet end to the gas outlet end to compensate for change in volume of the gas as the temperature of the gas is changed.

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This construction accomplishes another useful purpose in that it provides additional heat exchange surface in that section of the condenser where the duty or heat load is the greatest.

When a gas contains condensable constituents it holds more of these constituents at higher temperatures, so that the entering gas having a relatively high temperature creates a load on the heat exchanger due not only to the removal of sensible heat by cooling but also due to the necessity for removing the comparatively large quantities of latent heat. The latent heat load decreases as the temperature of the gas is lowered in passing through the condenser. The arrangement of the various sections of the condenser is such that the heat exchange surface also decreases in the same direction, while at the same time accomplishing the uniform gas velocity referred to above.

In order to describe the invention more clearly, reference will be made to the accompanying drawings in which:

Figure 1 is a side elevation of the condenser according to the present invention, with parts shown in cross section,

Figure 2 is a top plan view partially in cross section of the condenser shown in Figure 1,

Figure 3 is a horizontal cross section taken along lines 3—3 of Figure 1,

Figure 4 is a diagrammatic perspective view of the condenser showing the location of the baffles, and

Figure 5 is a vertical cross section of a modified form of the condenser according to the present invention.

With particular reference to Figures 1 to 4 inclusive, a vertical cylindrical shell 11 having tube sheets 12 and 13 is provided with a plurality of tubes 14 extending from the upper tube sheet 12 to the lower tube sheet 13 and communicating with headers 15 and 16, respectively. The upper header 15 is provided with vertical baffles 17, 18 and 19 and the lower header 16 is provided with baffles 20 and 21 so that water or other cooling medium which may be introduced through inlet connection 22 will pass alternately downwardly through one set of tubes and upwardly through another set of tubes and will be finally withdrawn from the condenser through outlet 23.

The gas to be cooled is introduced through inlet connection 24 into the condenser below the tube sheet 12, the gases flowing around the tubes 14. The main body of the condenser, between the upper and lower tube sheets 12 and 13 is provided with baffles 25, 26, 27 and 28 so that the

gases being cooled will pass alternately downwardly around the tubes 14 in one section and up past the tubes in another section; the cooled gases finally being withdrawn through outlet connection 29. Near the bottom of the condenser and just above the lower tube sheet 13 there are provided steam inlet means 30 and 31 which may be used intermittently for cleaning the condenser by removal of any condensable materials which may have deposited on the tubes.

The location of the vertical baffles in both the headers 15 and 16 as well as in the main portion of the condenser are shown in Figures 2 and 3. As will be seen from these figures, the baffles divide the cylindrical shell into four substantially pie-shaped sections I, II, III and IV, each of which is smaller in cross-sectional area than the preceding one. For example, the incoming gases enter the largest section I and pass successively through sections II, III and IV and thence through outlet connection 29. The cooling medium, however, passes countercurrently through the condenser and is introduced first through inlet connection 22 to the smallest section IV and then successively through sections III, II and I before being withdrawn through outlet connection 23.

As shown in Figure 3, baffles 25 and 27 are co-extensive and extend across a diameter of the shell 11. Baffle 26 extends at right angles to baffles 25 and 27 along a line parallel to but spaced from the radius of the shell. Baffle 28 is likewise at right angles to baffles 25 and 27 and is parallel to a radius but is further removed therefrom than baffle 26. In this fashion it will be seen that sections I, II, III and IV are successively smaller than the preceding section. The baffles in headers 15 and 16 are coextensive with the corresponding baffles which are provided between the upper and lower tube sheets.

The baffles previously mentioned are perhaps best illustrated in Figure 4. According to this figure, it will be seen that baffle 17 in the upper header 15 separates section I from section II while sections II and III communicate with each other. The other baffles 18 and 19 separate section IV from sections III and I, respectively. In the lower header 16 baffles 20 and 21 are provided so that sections III and IV, which communicate with each other, will be separated from sections I and II which also communicate with each other. With the arrangement shown in Figure 4, the cooling medium enters section IV of the upper header and passes downwardly through the tubes of this section to the lower header. The cooling medium then passes to section III in the lower header and upwardly through the tubes of section III to the upper header and thence across the tube sheet 12 to section II of the upper header, downwardly through the tubes of this section to the lower header and thence upwardly through the tubes of the section I to outlet connection 23.

Within the main body of the condenser, the baffles are arranged so that the gases to be cooled which are introduced into section I will pass downwardly around the tubes thereof to the tube sheet 13, thence across the tube sheet under baffle 25 to section II and thence upwardly around the tubes of section II to a point near the upper tube sheet 12. The gases then pass from section II over the top of baffle 26 to section III and downwardly around the tubes thereof to a point near the lower tube sheet. The gases then pass under baffle 27 to section IV and upwardly

around the tubes thereof to the outlet connection 29. At a point just above the lower tube sheet 13, outlets 32 and 33 (Figures 2 and 3) are provided for removing from the gas passage condensed fluids and tars which accumulate on the bottom tube sheet. Valved outlets 34 and 35 are provided in the lower header 16 to permit the cooling medium to be drained when desired.

The tubes which connect the upper and lower tube sheets may be of uniform size and may be, for example, 2 inches O. D. It will be seen from Figure 3 that the number of tubes decreases successively in sections I, II, III and IV and that the gas passage, which comprises the area around the tubes, likewise decreases successively in the sections I, II, III and IV. The relative cross sectional area of each section with respect to the cross sectional area of the other sections will depend not only upon the nature of the gas being cooled and the nature of the cooling medium, but will also depend upon the desired degree of cooling to be effected, i. e. the temperature gradient between the gas inlet 24 and the gas outlet 29. The quantity of condensable fluids, which depends upon the nature of the gas to be cooled and the temperature gradient, is an important factor since this, to a major extent, determines the decrease in volume of the gases as they pass through the condenser. According to the present invention the cross sectional area of each of the sections I, II, III and IV decreases by an amount substantially directly proportional to the decrease in the volume of the gases being cooled so that a constant pressure drop will be maintained throughout the condenser and so that the velocity of the gases therethrough will remain substantially constant, thus maintaining each of the sections at maximum efficiency.

The modification shown in Figure 5 comprises a horizontal shell 40 which may be cylindrical or rectangular in vertical cross section. A plurality of tubes 41 extend between tube sheets 42 and 43. The cooling medium is introduced through inlet 44 and passes through the tubes 41 and thence through outlet 45. The gases to be cooled, on the other hand, enter the condenser through inlet 46 and then pass countercurrently through the condenser around the tubes. Baffles 47, 48, 49, and 50 are arranged within the condenser, as shown in the figure, so that the cross sectional area of the gas passage will gradually decrease as the gases proceed toward outlet 51. Drains 52 are provided at the bottom of the shell 40, as shown, in order that condensable constituents may be withdrawn either continuously or intermittently.

The principal difference between the condenser shown in Figures 1 to 4 and the condenser shown in Figure 5 is that the total cross sectional area of the tubes for the cooling medium passing through the gas passage does not decrease. Although only two modifications of the condenser according to the present invention have been illustrated, it will be obvious to one skilled in the art that the principle involved in this invention can be applied to other types of heat exchangers and condensers. The principal feature of the present invention is the use of a gas passage having a decreasing cross sectional area in the direction of decreased volume of the gas to permit substantially uniform velocity.

It will, of course, be understood in connection with the modification shown in Figures 1 to 4

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that, if desired, the gas to be cooled may be passed through the tubes and the cooling medium may be passed around the outside of the tubes. In this case the gas will be introduced through outlet 23 and withdrawn through inlet 22 while the cooling medium will be introduced through outlet 29 and withdrawn through inlet 24. In this case, of course, the outlets 32 and 33 would be placed conveniently below the tube sheet 13 for the withdrawal of condensed fluids. Although water has been indicated as a suitable cooling medium, it will, of course, be understood that other coolants, whether liquid or gaseous, may be used in accordance with the present invention. It may, of course, be desirable to use a heated gas as a heating medium for increasing the temperature of a liquid or gaseous medium. To accomplish this the direction of the fluids thru the condenser may be reversed. In any event, the velocity of the gaseous fluid through the heat exchanger will be substantially constant.

Obviously, if desired, the number of passes or sections may be increased or decreased in accordance with the particular requirements of the condenser and the heat exchanger may be arranged for parallel instead of countercurrent flow. For example in Fig. 5, the cooling medium may be introduced through outlet 45 and withdrawn through inlet 44.

What is claimed is:

1. A heat exchanger for fluids comprising a shell and a plurality of spaced substantially parallel tubes arranged within the shell, said shell and tubes constituting two independent passages in heat exchange relation, one passage for the fluid to be cooled and the other passage for the fluid to be heated, the first mentioned passage having a decreasing cross sectional area in the direction of decreasing temperature of the fluid and the second mentioned passage having an increasing cross-sectional area in the direction of increasing temperature of said fluid.

2. A heat exchanger as claimed in claim 1 wherein the passageways are arranged in counter-current heat exchange relation.

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3. A heat exchanger as claimed in claim 1 wherein the passageways are arranged in parallel heat exchange relation.

4. A heat exchanger for fluids comprising two passageways arranged in heat exchange relation, the passageway conducting the fluid to be cooled decreasing in cross-sectional area in the direction of flow of said fluid, the other passageway increasing in cross-sectional area in the direction of flow of the fluid conducted there-through.

5. A heat exchanger as claimed in claim 4 wherein each of the passageways comprises a plurality of sections in series, each section of the passageway for conducting the fluid to be cooled having a smaller cross-sectional area than the preceding section in the direction of flow of said fluid therethrough.

6. A heat exchanger as claimed in claim 4 wherein the fluid to be cooled comprises a gas containing condensable materials, said exchanger further comprising means for withdrawing condensed materials from the passageway for conducting said gas.

7. A heat exchanger as claimed in claim 4 wherein the cross-sectional areas of said passageways vary substantially directly proportionally with variations in the volume of the fluids passing through said passages whereby said fluids pass through said passageways at substantially constant velocity.

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