Nov. 6, 1962 J. MULDER 3,062,509

HEAT REGENERATOR

Filed May 29, 1953 2 Sheets-Sheet 1

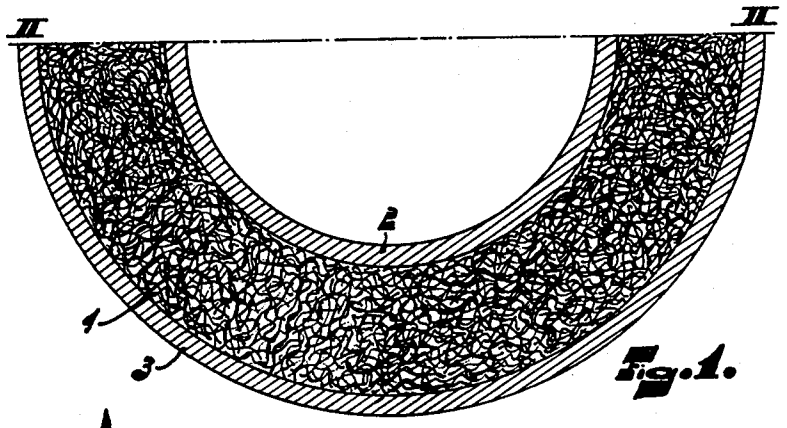


Fig. 1.

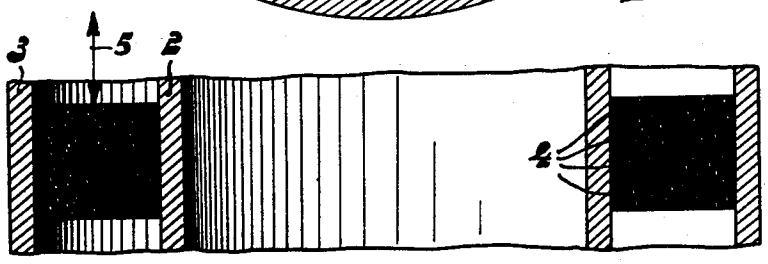


Fig. 2.

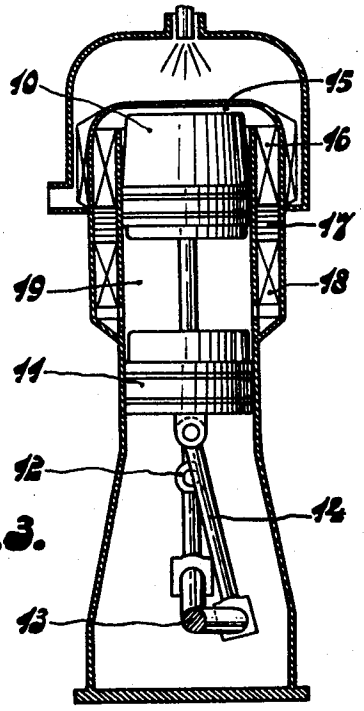


Fig. 3.

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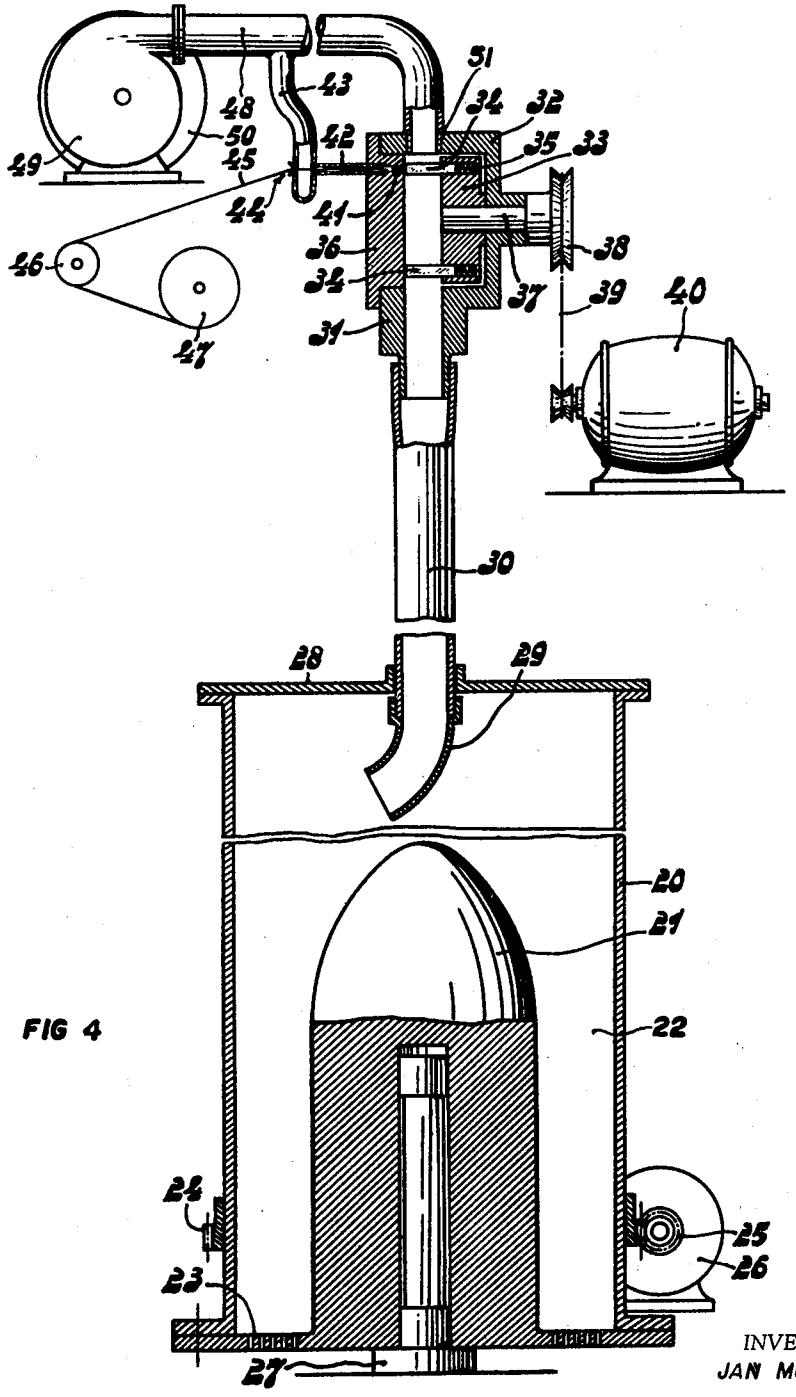


FIG 4

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HEAT REGENERATOR

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1 Claim. (Cl. 257—270)

The invention relates to a regenerator comprising wire material, having a hydraulic diameter of less than 200μ. The term "hydraulic diameter" is to be understood to mean herein the quotient of four times the surface area divided by the circumference of the cross-section of the wire material. Wire-regenerators are known per se; it is known, for example, to manufacture regenerators by coiling metal wire formed or not formed by crinkles.

It is furthermore known that the output of a regenerator may be enhanced by reducing the diameter of the wire. This measure is applied to the known regenerators, so that they are frequently manufactured from wire material having a hydraulic diameter of less than 50μ.

The applicant has now found that not only the wire diameter, but also the degree of inhomogeneity of the regenerator exerts great influence on the output thereof.

The inhomogeneity of the regenerators hitherto known is comparatively high; locally differences of 20% and more may occur. The inhomogeneity may be ascertained by taking a radiograph of a layer of regenerator material of uniform thickness.

The applicant has now found by surprise that the homogeneity of a regenerator invented by the applicant materially exceeds that of the known regenerators. The local filling factor of the regenerator according to the invention may deviate not more than 5% from the mean value of the filling factor. The term "filling factor" is to be understood to mean herein the ratio between the volume of the wire material and the volume of the regenerator.

The regenerator according to the invention, comprising wire material having a hydraulic diameter of less than 200μ, has the feature that it comprises a large number of metal wire portions, having a substantially uniform wire profile, the maximum length of these wire portions being 10 cm., the minimum length 2 mm., whilst the regenerator exhibits a substantially homogeneous felt-like structure. Where reference is made herein to a felt-like structure, this is to be understood to mean a structure resembling felt macroscopically, it being, however, not required for the wire portions to be secured to one another as is, in general, the case in felt manufacture. As a wire material for the regenerator according to the invention use may be made of a material having a circular, rectangular or other transverse profile.

Regenerators according to the invention are preferably used in hot-gas reciprocating engines. The term "hot-gas reciprocating engine" is to be understood to mean herein a hot-gas reciprocating apparatus, a refrigerator and a heat pump, the latter two operating on the reversed hot-gas reciprocating engine principle.

In one embodiment of the invention the wire portions are secured to one another. The portions may, for example, be secured to one another by sintering. As an alternative, the wire portions may be coated by a metal layer, by means of which the wire portions are secured to one another by heating. By securing the wire portions to one another the structure of the filling mass is, however, not modified.

In a further embodiment of the invention the regenerator has the feature that the cross sectional area of the wire portions has a hydraulic diameter of not more than

50μ, whilst the filling factor of the regenerator varies between 3% and 30%, preferably between 5% and 20%.

The regenerator according to the invention may be formed by layers, which are arranged substantially transversely to the main direction of flow of the gas through the regenerator.

In certain cases it may be advantageous in a further embodiment of the invention to provide curled portions or crinkle-wire. The term "crinkle wire" is to be understood to mean herein a deformation of the wire such that the wire exhibits a periodical change in shape; the wire may, for example, be zigzagged.

The regenerator according to the invention may be manufactured in a simple manner. The wire portions may, for example, be distributed in a space in a manner such that a layer of substantially uniform thickness is formed on the bottom of this space, after which this layer is compressed in order to obtain the required filling factor.

The wire portions are preferably transported by means of a turbulent flow of air to the space. Owing to the turbulence of this flow of air, the wire portions are distributed chaotically, which materially furthers the homogeneity of the regenerator.

The device for manufacturing the regenerator according to the invention has the feature that it comprises a space having a cross sectional area of a shape and a size substantially corresponding to those of the cross sectional area of the regenerator to be manufactured, a downcomer communicating with the space and means for supplying the wire portions thereto.

In a further embodiment of the invention the device comprises at least one spray mouth for supplying the wire material and a space having a cross sectional area, of which the shape and the size correspond substantially to those of the cross sectional area of the regenerator to be manufactured, this space having on one side a wall which is pervious to gas, whilst the spray mouth communicates with the space through a downcomer.

A structurally simple construction may be obtained by providing the device with a cutting member, by means of which wire portions of the desired length are cut from sheet material or wire material, these portions being supplied to the space. The spray mouth and the space are preferably caused to rotate relatively to one another.

In order that the invention may be readily carried into effect, it will now be described with reference to the accompanying drawing, which shows a regenerator according to the invention, a hot-gas reciprocating engine comprising such a regenerator and a device for manufacturing the regenerator.

FIG. 1 is a plan view of a regenerator according to the invention and

FIG. 2 is a sectional view of this regenerator taken on the line II—II of FIG. 1.

FIG. 3 shows a hot-gas reciprocating engine comprising such a regenerator.

FIG. 4 shows a device by means of which the regenerator according to the invention may be manufactured.

FIGS. 1 and 2 show a regenerator according to the invention. This regenerator comprises wire material 1, having a diameter of less than 200μ. It is made from a large number of metal wire portions, having a substantially uniform wire profile, the maximum length of these wire portions being 10 cm., the minimum length 2 mm. In the regenerator shown this length may, for example, be 3 cm., whilst the hydraulic diameter is 60μ. The regenerator exhibits a felt-like structure. The regenerator shown may be sintered, so that the wire portions adhere to one another; the structure is, however, not modified, so that this sintering or the metallisation does not affect the porosity of the regenerator. As is shown in the

figure, the regenerator may be surrounded by two cylindrical walls 2 and 3 and may comprise a plurality of layers 4. The wire portions of the regenerator shown are arranged substantially transversely to the main direction of flow of the gas; this direction is indicated by the double arrow 5.

FIG. 3 shows a hot-gas reciprocating engine comprising a regenerator according to the invention. The hot-gas reciprocating engine is of the displacer-piston type and comprises a displacer piston 10 and a piston 11, reciprocating with constant phase difference. By means of a connecting-rod system 12 the displacer piston 10 is coupled with a crank of the crank shaft 13. The piston 11 also is coupled by means of a connecting-rod system 14, with a crank of the same crank shaft. The space 15 is the hot space of the hot-gas engine and this space communicates through a heater 16, a regenerator 17 and a cooler 18 with the space 19 between the displacer piston 10 and the piston 11. The regenerator 17 is of the type described above and has a filling factor varying between 3% and 30%, for example, a filling factor of 13%.

FIG. 4 shows a device by means of which the regenerator according to the invention may be manufactured. The device comprises a space having an outer wall 20 and a core 21. The cross sectional area of the space 22 between the outer wall 20 and the core 21 has a shape and a size corresponding substantially to the shape and the size of the cross sectional area of the regenerator to be finally manufactured. This space 22 is provided at the bottom with a wall 23 pervious to gas. The wall 20 is provided on the outer side with a toothed rim 24, which engages a worm 25 of an electric motor 26. The wall 20 and the core 21 are rotatable about their vertical axis and secured to a structure 27. At the top provision is made of a lid 28, through which is taken a supply pipe 29, relatively to which the wall 20 is adapted to rotate. The supply pipe 29 communicates with a duct 30, which communicates in turn with a device 31, in which the wire material to fill the space 22 is cut into portions of substantially equal lengths. The device 31 comprises a housing 32, in which a body 33 is adapted to rotate. This body is provided with knives 34, which are urged against the wall 36 of the housing by means of springs 35. The body 33 is provided with a shaft 37, on which is seated a rope disc 38, so that the body 33 can be rotated by means of the rope 39 by the motor 40.

The wall 36 has an opening 41 which communicates with a narrow duct 42. The latter communicates with the duct 43, which has a materially larger cross sectional area and which is provided in the wall opposite the duct 42 with a small aperture 44. Through the aperture 44 may be taken a wire 45 extending as far as in the duct 42. The wire 45 is led over the roller 46 and coiled on the supply coil 47. The duct 43 communicates with the duct 48 of a compressor 49, which may be driven by a motor 50.

The housing 32 has an opening 51, which communicates through the air duct 48 with the compressor 49.

The device operates as follows. The air supplied through the duct 43, having, for example, a pressure of 4 atmospheres, transports the wire 45 through the duct 42, the wire thus passing through the opening 41, thus extending beyond the wall 46. The rotating body 32 periodically cuts off portions from this wire, these portions being transported by the air supplied through the duct 48 and caused to turbulate, through the duct 30 to the space 22. During the transit in the duct 29, the wire portions are set into turbulence. Since the quantity of air supplied through the duct 48 is comparatively small, it will have little or no influence on the motion of the wire portions in the materially larger space 22. The wire portions are distributed from the pipe 29 in the rotating space 20, so that the pervious wall 23 of this space has a uniform felt-like layer formed on it. The length of the wire portions is in this case not more than 10 cm. and not less than 2 mm., whilst the hydraulic diameter of the wire is smaller than 200μ and may, for example, be 30μ. When the space 22 is filled with a sufficiently thick layer, the topside of the space may be removed and the layer may be compressed to the desired filling factor lying between 3% and 33%, preferably between 10 and 25%.

In the device described above three motors are provided, driving the compressor, the cutting member and the space 20 respectively. If desired the three said parts may be driven by one motor.

By means of the device shown in FIG. 4 regenerators may be made having an annular cross sectional area, as is shown in FIGS. 1 and 2. However, as an alternative, regenerators having other cross sectional areas, for example, a circular sectional area, may be manufactured in the same manner. In this case the space 22 does not comprise a core 21.

Claims directed to an apparatus for and a method of making my regenerator are being presented in my copending U.S. patent application, Ser. No. 778,249, filed December 4, 1958.

What is claimed is:

A regenerator for a hot-gas reciprocating engine comprising a housing having an inlet opening and an outlet opening for a gaseous working medium adapted to flow along a path therebetween, a felt-like mass in said path and having a substantially homogeneous structure with a filling factor between about 3% and 30%, said mass comprising metal wire portions of substantially uniform cross section and of lengths between about 2 mm. and 100 mm. depending upon the shape and size of the regenerator, said metal wire portions having a hydraulic diameter less than about 200 microns and extending in random directions substantially in planes perpendicular to the flow path.

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