July 8, 1952 N. S. JAPOLSKY 2,602,306

APPARATUS FOR TRANSFER OF HEAT IN GASEOUS MEDIA

Filed Oct. 23, 1947 2 SHEETS—SHEET 1

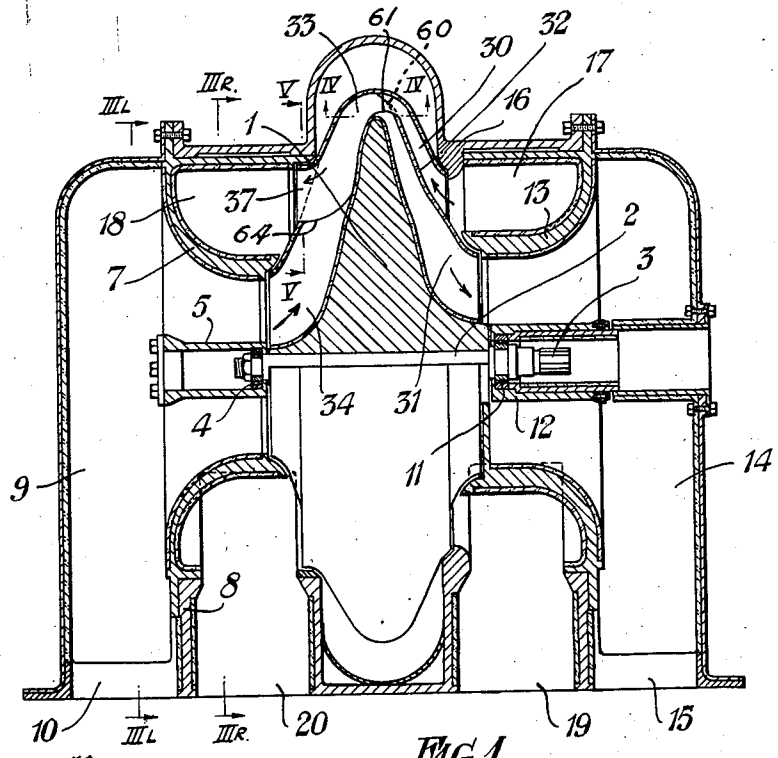


FIG. 1.

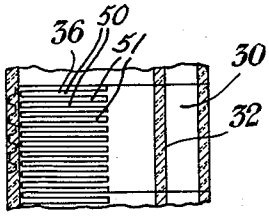


FIG. 4.

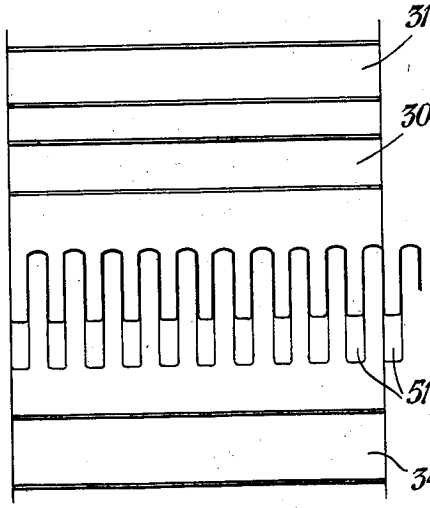


FIG. 5.

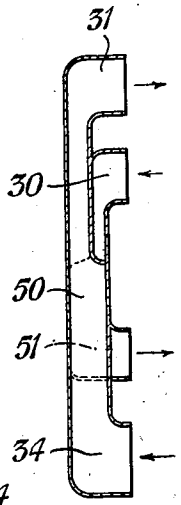


FIG. 6.

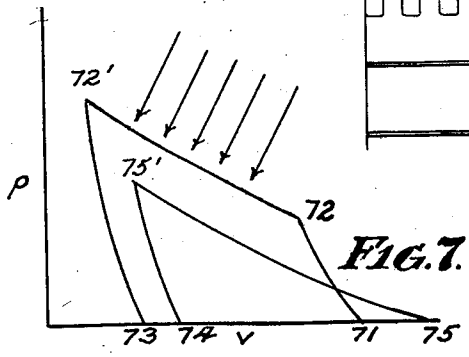


FIG. 7.

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APPARATUS FOR TRANSFER OF HEAT IN GASEOUS MEDIA

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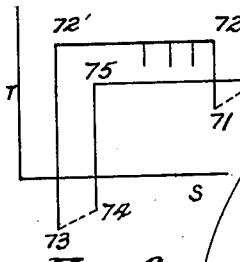


FIG. 8.

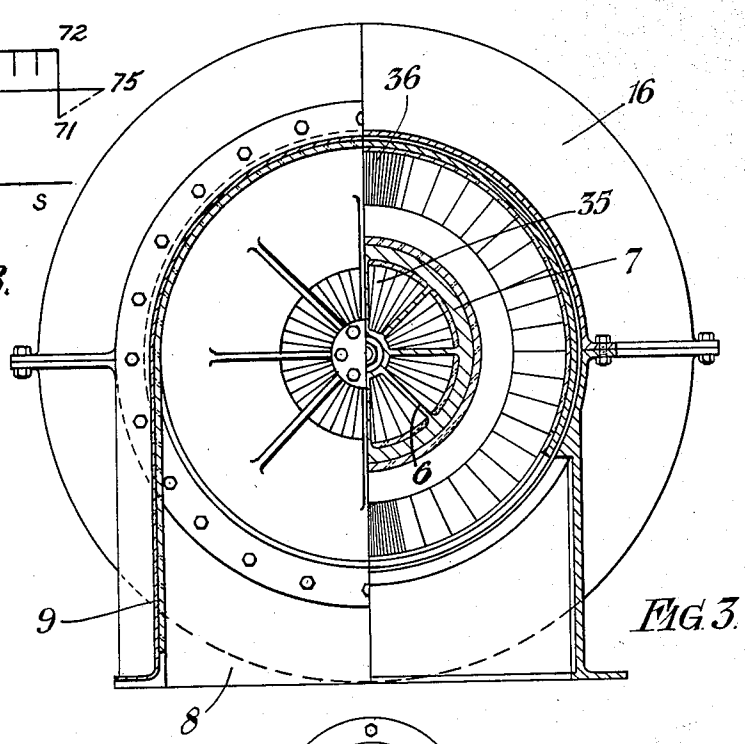


FIG. 3.

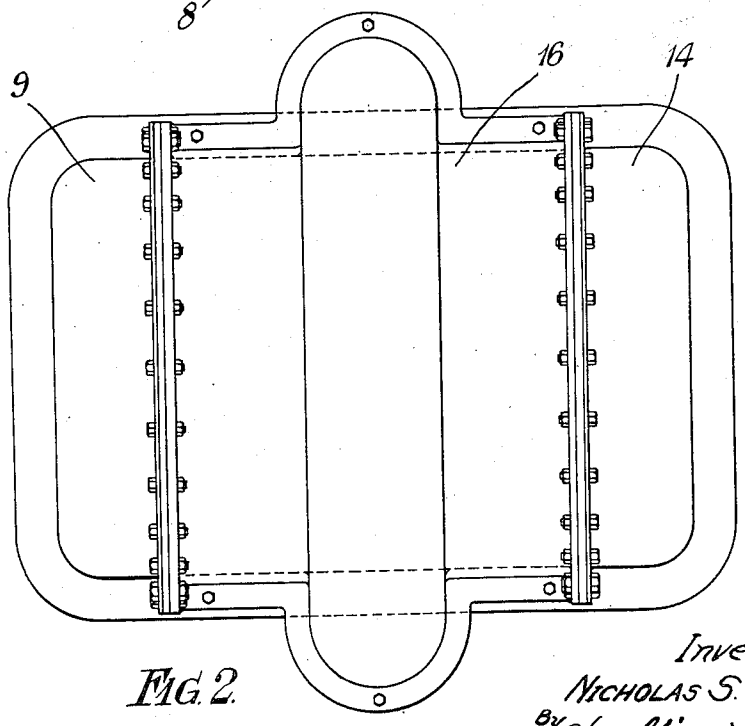


FIG. 2.

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APPARATUS FOR TRANSFER OF HEAT IN GASEOUS MEDIA

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5 Claims. (Cl. 62—136)

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This invention relates to apparatus for transfer of heat in gaseous media and is broadly concerned with apparatus which will permit a gaseous medium to have temperature changes effected therein. The invention can for example be employed in the maintenance of the interior air temperature of a building at some desired level. The invention may be applied both in heating and cooling.

For simplicity of language, hereinafter the word "air" will be used instead of the term "gaseous medium," and it will be understood that in using the word "air" no restriction is intended as to the practical applications of the invention.

According to the invention there is provided apparatus for heat transfer, wherein flow and return channels are disposed in a rotor and are arranged to convey air under the action of centrifugal force, such channels having a zone where heat exchange may take place between them, and where isothermal expansion proceeds in the flow channel and isothermal compression in the return channel, the air in both the flow and return channels being subject to an adiabatic compression prior to entry into the isothermal zone, whereby the air leaving the isothermal zone in the flow channel has its temperature raised beyond that of the air entering such flow channel, the whole process proceeding in the rotor under the action of centrifugal force.

For a better understanding of the nature of the invention and to show how the same may be carried into effect reference will now be made to the accompanying drawings in which,

Figure 1 is a side elevation in central section of a practical form of the heat transfer apparatus,

Figure 2 is a corresponding plan view,

Figure 3 is an end view corresponding to Figure 1, the right-hand half of the view of Figure 3 being a section on the line IIIR—IIIR of Figure 1, and the left-hand side being a section on the line IIIL—IIIL of Figure 1,

Figure 4 is a detail representing a development of a cylindrical section having the generator IV—IV shown in Figure 1,

Figure 5 is a developed diagram of certain flow channels,

Figure 6 is a sectional end view corresponding to Figure 5,

Figure 7 is a flow diagram, and

Figure 8 is a flow diagram.

Referring first to Figures 1 to 4 the machine will be seen to comprise a rotor 1 mounted upon a shaft 2 carried in suitable bearings. In Figure 1 the upper part of the rotor is seen in section

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whilst the lower half is shown in full. The shaft 2 has a gear or other connection 3 for driving from a mechanical source of power. The bearing 4 at one end of the shaft 2 is supported by a tubular element 5 having several radial spider arms 6 (see Fig. 3) which extend to a casing 7 of annular form. The casing 7 is flared out in a direction away from the rotor 1 and is gripped in a wall 8 having an aperture for reception of the casing 7. The flared mouth of the casing 7 opens into a casing 9 which has an open mouth as at 10.

The bearing 11 of the shaft 2 is similarly carried in a tubular element 12 supported by spider arms from a casing 13 which is also of annular form and which flares outwardly in a direction away from the rotor 1. The flared mouth of the casing 13 opens into a further casing 14 having a mouth as at 15. The two flared casings 7 and 13 are enclosed by a cover 16 of inverted U-shape, and which, as appears from Figure 3, is made in two portions. Between the cover 16 and the exterior of the flared casings 7 and 13, there are annular spaces 17 and 18 communicating freely with openings 19 and 20 in the base of the machine.

The rotor 1 is formed with peripheral channels. Such channels may be regarded as consisting of two sets of parallel principal channels, the one for "flow" and the other for "return." These terms are chosen for ease of identification and serve herein to distinguish two channels, one carrying fluid in one direction, and the other carrying fluid in the opposite direction. In Figure 1, the right-hand half of the rotor shows the entrance and initial portion of the annular flow channel at 30, the channel having radial partitions to divide it into a plurality of adjoining passages. The channel portion 30 is separated from a corresponding portion 31 of the annular radially sub-divided return channel, by a partition 32. On the left-hand side of Figure 1, the remainder of the flow channel 30 is seen at 33, and the return channel at 34. It will be observed that the flow and return channel portions 33 and 34 appear to coincide in Figure 1. In fact, the return portion 34 is radially sub-divided by partitions 35 (see Fig. 3) up to the place where the portions 33 and 34 appear to coincide, where numerous closely spaced partitions 36 are provided, to form passages which alternately constitute part of the flow channel and part of the return channel. Thus one set of passages 51, Figures 4, 6 and 7 communicates with the flow portion 30 at 60 and opens at a mouth 37, being blanked off from the channel 31 at 61 and from the channel 34 at 62 whilst the alternate passages

50 are blanked off from the channel 30 and communicate at one end with the return portion 34 and at the other end with the return portion 31. In Figure 3, the closely spaced partitions 36 are not all shown, in order to simplify the drawing. In the detail of Figure 5 a pair of partitions 35 associated with the channel portion 34 are illustrated in relation to the closely spaced partitions 36 providing the adjoining passageways in the region where the flow and return channels are closely associated with one another. In Figure 4 the partitions 36 are seen and it will be observed that these partitions can effectively consist of a single plate which is bent to a sinuous shape.

In order to assist in the understanding of the course of the channels provided in the rotor 1, reference will now be made to the diagrams of Figures 6 and 7. In these figures it is supposed that the channels have been straightened and simplified. The return channel portion 34 is seen to communicate with the return channel portion 31 through the passages 50. These passages alternate with the series of closely spaced passages 51 which all open into the flow portion 30.

In the employment of the machine described above, the rotor 1 is rotated by a source of mechanical power, and as a result air is drawn in at 10 and moves centrifugally through the channel portion 34. In flowing centrifugally in this manner, the air is at first adiabatically compressed and then passes through the passages 50 in the zone of narrow passageways. In flowing in this zone compression continues, but for reasons that will become clear from the following description, the compression is then substantially isothermal. The return path of the air is completed by centripetal motion through the channel portion 31, wherein adiabatic expansion takes place. The motion of the air from the channel 34 to the channel 31 commences and continues by reason of the fact that the radial column of air associated with the channel 34 is considerably longer than that of channel 31. Simultaneously with the return motion of the air, the flow motion proceeds, this motion consisting essentially of entry of a stream of air through the inlet 19 into the portion 30 of the outer channel where there is adiabatic compression with the air moving centrifugally. Thereafter the air passes through the passages 51 and leaves from the mouth 37, the motion being then centripetal and being accompanied by an isothermal expansion. The air passes into the annular space 18 and leaves the machine at the outlet 20. Thus air may be regarded as drawn into the mouth 10 and expelled through the mouth 15. Air will also be drawn into the mouth 19 and expelled through the mouth 20. The initial adiabatic compression occurring in the flow channel 30 will cause the temperature of the air to rise. Isothermal expansion in the passages 51 will tend to result in air delivery at the temperature reached after the adiabatic process. Clearly, in order to carry out an isothermal expansion, heat must be delivered to the air during the isothermal process, and this is achieved by reason of the adiabatic compression which takes place in the initial part 34 of the return channel and the subsequent isothermal compression in the passages 50 during heat exchange. The final adiabatic expansion carried on in the return channel 31 will of course result in lowering of the temperature, and it is therefore to be expected that the air leaving from the mouth 15 will be at a lower temperature than the air entering the mouth 10. It will also be obvious that the air leaving the channel 20 will be at a higher temperature than the air entering the channel 19, and moreover the air leaving the channel 20 will be at a higher temperature than the air entering the mouth 10.

As illustrated in the drawings, the flow channel is indicated at 30 and the return channel is indicated at 31 and 34. In Fig. 1, it will be seen that the return channel 31 and 34 passes just behind the flow channel 30 over an area indicated at the section line V—V. In this area (see Figs. 4, 5 and 6), numerous partitions 50 and 51 exist which ensure that heat exchange is promoted. Fig. 6 represents a simplification of the flow channels 30 and the return channels 31 and 34 by simply straightening them in regard to the path of motion of the fluid therein, whereby such channels may be regarded as being upon a cylindrical surface with axis located at the axis of the shaft 2 (Fig. 1). In Fig. 5 the diagram may be regarded as a development of the cylindrical "surface" obtained by straightening the channels 30, 31 and 34.

Referring again to Fig. 1, the return channel 34 has a greater radial extent than return channel 31, which will promote a flow from the longer to the shorter channel. The radial extent of the two columns of flow channel 30 is substantially the same. While it might be advisable to have the two columns of the flow channel of different lengths, it is not necessary because in the initial operation of the machine the adiabatic compression occurring in the first part of the return channel and the subsequent isothermal compression provided sufficient heat to raise the temperature in one column of the flow channel. The raising of temperature in this way insures that the density of the air in the one column of the flow channel results in the necessary unbalance to ensure a desired counterflow in the flow channel.

If the two channels both had precisely similar thermodynamic processes proceeding in each one of them but oppositely directed, the transfer of heat between the air streams in the two channels would tend to keep the two air streams at constant temperature. However, it will be seen that air enters the return channel and first undergoes adiabatic compression whereby the temperature rises. Thereafter, compression continues in the return channel, but this compression proceeds in a large number of passageways made of conducting material which ensure that there can be heat exchange with the air in the overlapping part of the flow channel. Thus the compression continues in a non-adiabatic fashion and tends to be isothermal with heat being imparted to the air in the flow channel. Continuing further the progress of air in the return channel, after the isothermal compression is ended, an adiabatic expansion proceeds in the right-hand column of the return channel without further heat exchange with the air in the flow channel. Considering now the equivalent series of thermodynamic operations in the flow channel, it will be realized that air enters the flow channel and undergoes an adiabatic compression thereby experiencing a temperature rise until the air enters the region where heat exchange can take place with the air in the return channel. In the heat exchange region, expansion of the air in the flow channel takes place, but heat is received from the return channel air and hence expansion of the flow channel air takes place substantially isothermally. Following the iso-

thermal expansion the flow channel air is directly expelled. It is thought that it must logically follow that the temperature at which the flow air is expelled will be higher than the temperature at which such air is taken into the flow channel.

The P. V. diagram for the machine is shown in Fig. 7 and the T. S. is shown in Fig. 8. The used air from the building enters the pump at 71 and is compressed adiabatically by the first stage of the fan blading to the point 72 where it enters the heat exchanger section. The fresh air from the atmosphere enters at 74 and is also compressed adiabatically up to point 75 where it enters the opposite end of the heat exchange section. The adiabatic compression of both used and fresh air is so adjusted that after compression they are at the same temperature, and since the used air enters the machine at a higher temperature than the fresh air, the amount of compression given to the used air is correspondingly less. The two streams are then led through the heat exchanger section in opposite directions, the used air being compressed further by centrifugal force to the point 72' and the fresh air expanding centripetally to the point 75. Since the facilities for easy heat exchange are provided and since both streams of air enter the heat exchanger at the same temperature, compression and expansion in the heat exchanger takes place isothermally. After passing through the heat exchanger, the fresh air, now heated and expanded to atmospheric pressure, is led into the building. The used air is allowed to expand back between the heat exchanger sections, so doing work on the rotor and being cooled. It then leaves the machine and is exhausted to atmosphere at a temperature below the atmospheric temperature.

The various stages of the process are indicated on the P. V. and T. S. diagrams in Figs. 7 and 8. It will be appreciated that the machine works on an open circuit, the air being taken from and finally delivered to the outside atmosphere. The cycle is completed, therefore, by the isobaric heating process 73—74 and 75—71 shown dotted on these diagrams.

In order that those portions of the flow and return channels intended for adiabatic processes should in fact promote adiabatic processes, such channels are as far as possible heat insulated. In the zone where the flow and return channels run side by side, and where isothermal operations are desired, conditions for maximum heat exchange should be provided. This is indeed the case, since the closely spaced partitions 36 are made from a good heat conducting material, and moreover the immediate proximity of the flow and return passages created by the partitions 36, favours heat exchange.

In the illustration of Figure 1, it appears that the radial extent of the air columns associated with channel mouth 37 and channel 30 are substantially the same, so that no tendency would apparently exist for the motion of the air directed from channel 30 to the channel mouth 37. The motion commences (and continues) for the reason that the air column radially extending from channel mouth 37, becomes heated due to the heat exchange with the air that has been adiabatically compressed in the channel 34 prior to the heat exchange. Since this heating will cause a reduction indensity of the air in the column associated with the channel mouth 37, the motion commences and proceeds.

In describing the mode of operation of the machine above and in the appended claims, such terms as "adiabatic" and "isothermal" have been employed. Although in the ideal case true adiabatic and isothermal processes would occur, nevertheless in practice the zone where isothermal processes should occur may not exactly promote appropriate conditions. Thus for the purposes of the present specification an isothermal process is to be considered broadly as one in which heat exchange is promoted, whilst an adiabatic process is one in which heat exchange is reduced to a practical minimum.

If so desired the fall in temperature caused by the adiabatic expansion in the return channel portion 31, could be employed to reduce the humidity of air entering the flow channel portion 30, by arranging for a pre-cooling operation on the air entering the inlet 19.

The construction of the machine shown in the drawings represents a useful form for raising of the temperature of the air within a building. The mouth 10 can be arranged to draw air from the building, whilst the mouth 20 delivers thereto air at a higher temperature. Both the mouths 15 and 19 can then be open to the atmosphere external to the building. Just as the machine can be used for raising the temperature of a body of air, it can clearly be used for lowering the temperature of a body of air, where a refrigerating or cooling effect is desired. Other applications of the invention will be apparent from consideration of the principles which underlie the same.

I claim:

1. Apparatus for heat transfer comprising a rotor, bearings for supporting said rotor to permit the same to be rotated about an axis, a flow channel disposed in said rotor and opening at either side thereof, to provide an inlet and outlet for air to and from said flow channel, a return channel disposed in said rotor and opening at either side thereof to provide an inlet and an outlet for air to and from said return channel, the inlet of one channel being disposed adjacent the outlet of the other, a first zone in said flow channel extending from the inlet side thereof and in which adiabatic compression of air is promoted, a second zone in said flow channel wherein isothermal expansion of said air is promoted, a first zone in said return channel extending from the inlet thereof and wherein adiabatic compression is promoted, a second zone in said return channel wherein isothermal compression is promoted, and means promoting heat exchange in said second zones of the flow and return channels.

2. Apparatus for heat transfer according to claim 1 in which the return channel has a third zone extending to the outlet thereof and wherein adiabatic expansion is promoted in a region adjacent said first zone of the flow channel.

3. Apparatus for heat transfer according to claim 2 in which the flow channel in the rotor is disposed with said first zone having a radial component of direction for the production of centrifugal flow therein whilst the second zone of said flow channel has also a radial component of direction to allow centripetal flow therein, the return channel having the first and second zones thereof disposed with a radial component of direction to promote centrifugal flow therein whilst the third zone of said return channel has a radial component of direction promoting centripetal flow therein.

4. Apparatus for heat transfer according to claim 1 wherein said means for promoting heat

exchange consist of relatively small adjacent passages which alternately connect with the flow and return channels and which are made of heat conducting material.

5. Apparatus for heat transfer according to claim 1 and further comprisinng a first pair of conduits nested one within the other the inner conduit being arranged to communicate with the outlet side of the return channel and the outer conduit being arranged to communicate with the inlet side of said flow channel, and further comprising a second pair of nested conduits, the inner conduit communicating with the inlet of said return channel and the outer conduit connecting with the outlet of said flow channel.

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