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Laing et al.

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[54] **HEAT PUMP WITH TWO FLUID CIRCUITS**

[75] Inventors: **Nikolaus Laing,** Aldingen near Stuttgart, Germany; **Ludwig Ludin,** Anglikon-Wohlen, Switzerland

[73] Assignee: **Physikalisch-Technisches Entwicklungsburo Laing,** Aldingen bei Stuttgart, Germany

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Nov. 14, 1970 Italy 915728/70

[52] **U.S. Cl.** **62/333,** 62/499
[51] **Int. Cl.** **F25b 3/00**
[58] **Field of Search** 62/333, 499

[56] **References Cited**

UNITED STATES PATENTS

2,805,558	9/1957	Knight	62/499
2,811,841	11/1957	Grimshau	62/499
3,025,684	3/1962	McLain	62/499

Primary Examiner—Meyer Perlin
Attorney, Agent, or Firm—Karl F. Ross; Herbert Dubno

[57] **ABSTRACT**

A reversible heat pump, to be used for cooling or heating a space bounded by a wall, has two rotary heat exchangers coaxially mounted on opposite sides of that wall and interconnected by a hub traversing same. The hub includes a highly heat-conductive partition between the fluid-circulation systems of the two heat exchangers. A rotary compressor, forming part of the exterior circulation system, has a housing rigid with the external heat exchanger and an impeller freely rotatable on a shaft of that heat exchanger, this impeller being secured to an armature of a squirrel-cage motor whose field windings are fixedly mounted on the supporting wall structure. The motor armature and the compressor are enshrouded by a magnetically permeable cowl forming a rotary chamber which is filled with a primary heat-carrying fluid, such as Freon, as well as lubricating oil and which communicates with a radiator drum on the periphery of the external heat exchanger. A similar radiator drum on the periphery of the internal heat exchanger is permeated by a secondary heat-carrying fluid, such as a low-boiling alcohol, circulating along the thermally conductive partition in heat-transfer relationship with the primary fluid.

22 Claims, 4 Drawing Figures

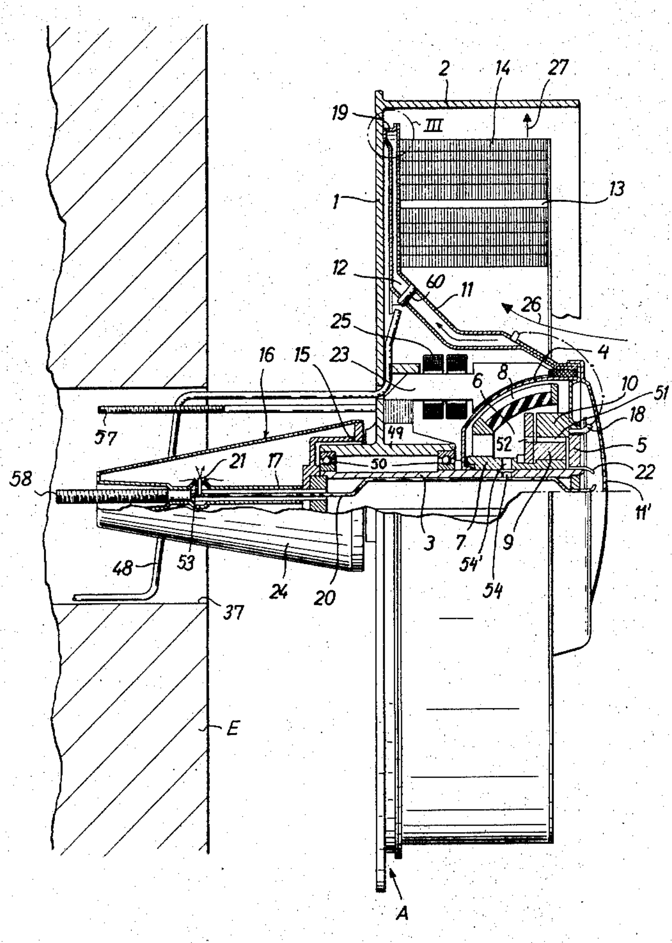

FIG. 1a

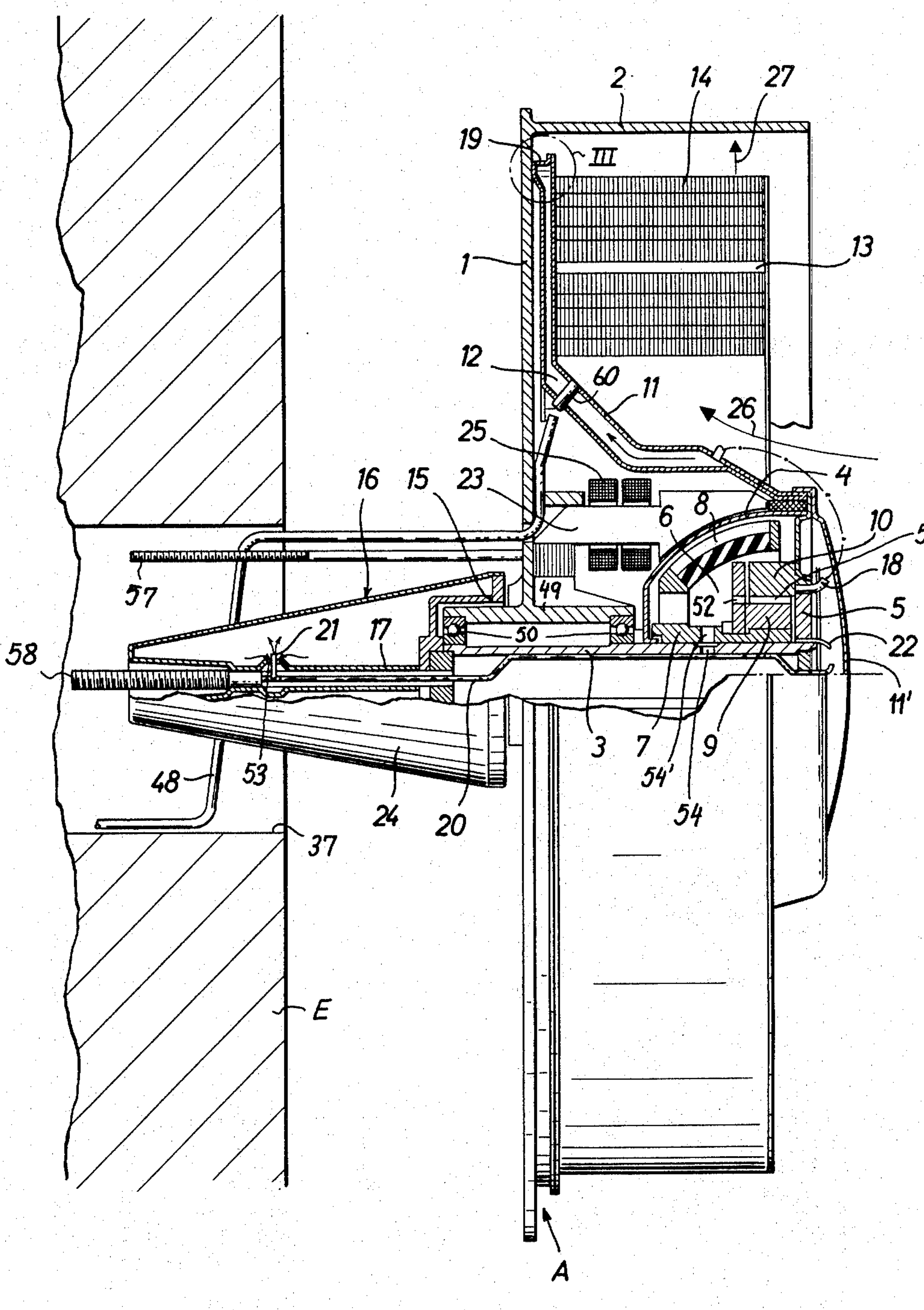
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FIG. 1b

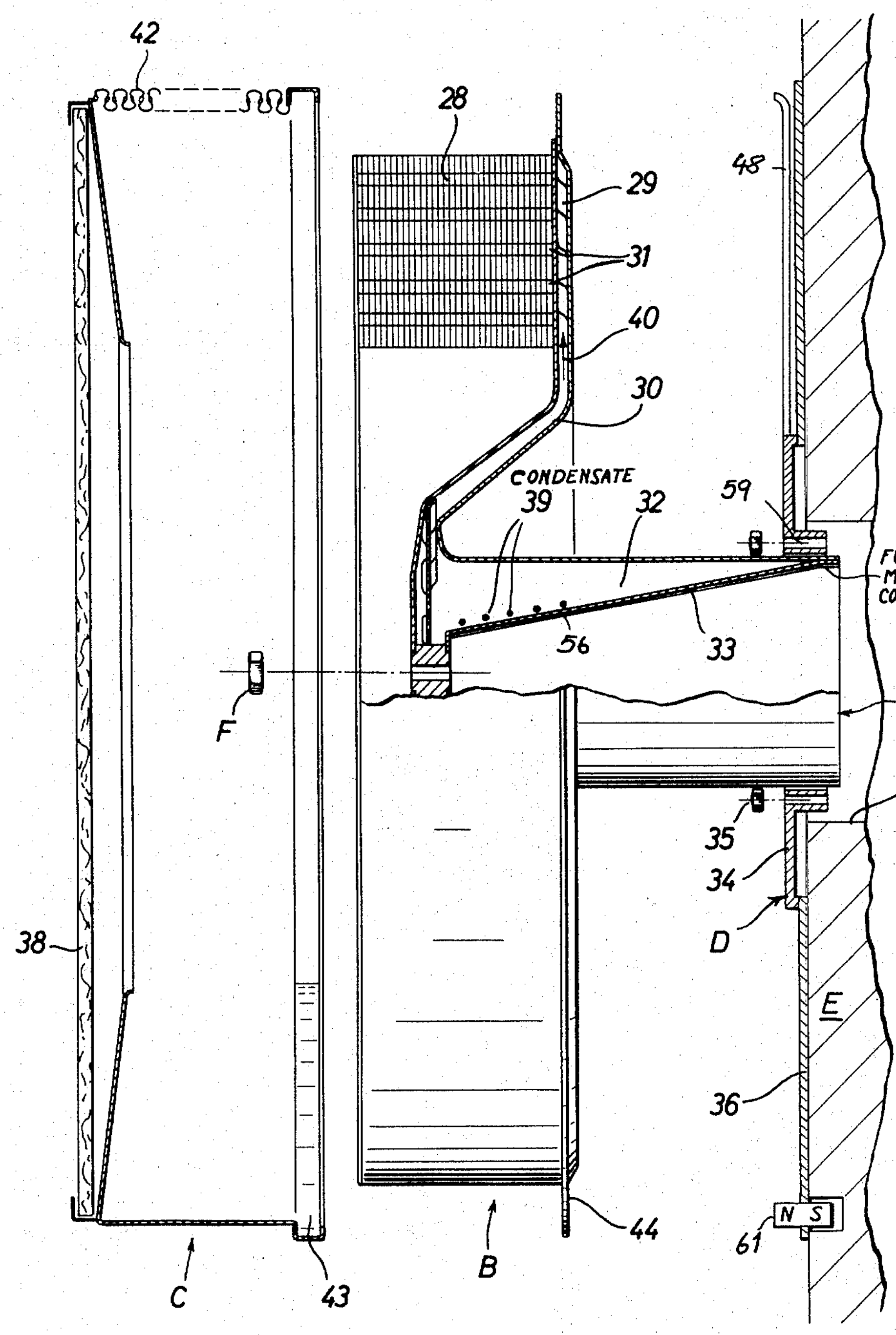
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FIG. 2

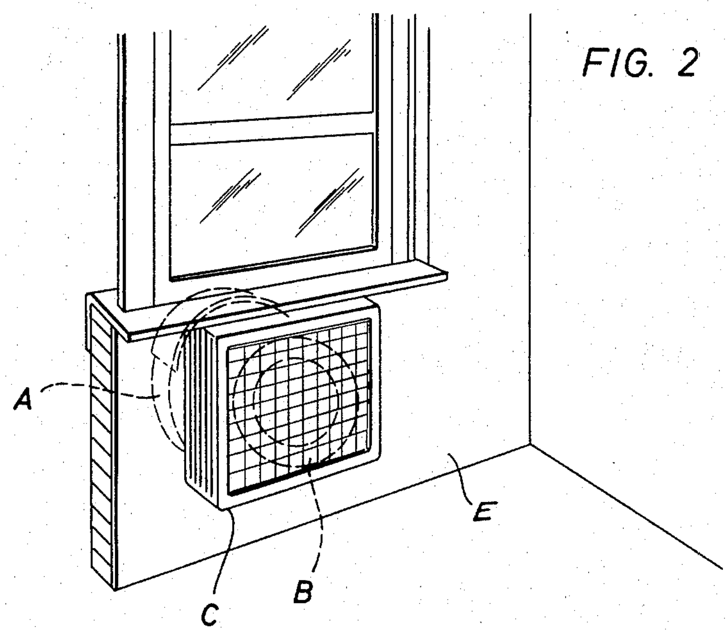
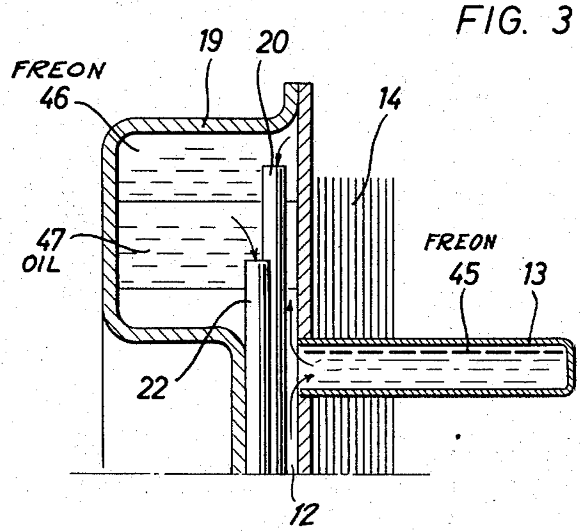


FIG. 3



HEAT PUMP WITH TWO FLUID CIRCUITS

This is a continuation of application Ser. No. 198,721, filed Nov. 15, 1971.

This application is related to copending application Ser. No. 42,018 filed June 1, 1970, now U.S. Pat. No. 3,696,634.

Our present invention relates to a thermogenic device such as a heat pump, of the general type disclosed in that copending application, wherein a pair of rotary heat exchangers are coaxially mounted for joint rotation on opposite sides of a wall across which a temperature differential is to be maintained. Two heat-carrying fluids, circulating along closed flow paths in the two heat exchangers, are in heat-transferring relationship inside a common hub structure rotatably supported in an opening of the wall. With the aid of a thermodynamically effective device such as a compressor in one of the flow paths, serving for the substantially adiabatic changing of the temperature of the fluid traversing that path, one of the two heat exchangers operates as a heat source while the other one acts as a heat sink; the latter extracts heat from its surroundings and transfers it to the former for transmission to the ambient atmosphere. Thus, depending on the direction of flow in the path containing the compressor, the opposite portion of such a dual unit may serve to cool or to heat a space bounded by the wall in which it is mounted; the bulkier and frequently noisier compressor-equipped portion may then be located externally of a building or room whose temperature is to be controlled. Instead of a compressor, a Peltier-type electronic current generator may be used to transfer heat from one fluid stream to the other.

In the system disclosed in U.S. Pat. No. 3,696,634, heat transfer between the two pump portions is effected by passing the primary heat-carrying fluid through a coil within the hub structure and letting the secondary heat-carrying fluid circulate about the coil. Prior to assembly of the two portions into a rotary unit, through a joinder of their respective hubs within the wall aperture, the conduits on the side of the external heat exchanger must be sealed to prevent the escape of primary fluid since the coil is located in the hub of the internal heat exchanger; this can be carried out in conventional manner with the aid of frangible diaphragms which are pierced upon the establishment of the junctions between the coil ends and the conduits. An object of our present invention is to provide an improved system of this nature in which the need for such temporary seals is obviated, with simplification of assembly and with increased safety against leakage.

This object is realized, pursuant to our present invention, by providing the two rotary heat exchangers with hollow hubs which, after assembly, are coaxially coupled for joint rotation and contact each other along a thermally conductive partition; the flow paths for the primary and secondary fluids extend from respective drum radiators, mounted on these hubs, to opposite sides of the partition so that heat may pass from one fluid to the other directly through that partition. In an advantageous embodiment, the hubs have tubular wall portions of preferably frustoconical configuration which are telescopically interfitted to provide an extended area of contact; the thermal conductivity of the partition constituted by these wall portions may be enhanced by coating at least one contact surface with a layer of a relatively low-melting metal or alloy which after assembly can be heated above its melting point to fill any existing voids between the surfaces and to bond the two hubs to each other by fusion.

The primary fluid may be a fluorochlorinated hydrocarbon, such as Freon 22, as usually employed in air-conditioning equipment. The secondary fluid, which generally will be in a partly liquid state, should have a freezing point below the lowest operating temperature and may be a low-boiling (e.g., methyl or ethyl) alcohol.

Advantageously, the conduit system of the primary flow path includes one or more nozzles trained upon the thermally conductive partition to distribute the expanding cooling fluid over a wide area thereof if the system is operated as an air conditioner. The nozzle may be the terminal of a capillary tube which bypasses the compressor as it draws the liquified coolant from the periphery of the corresponding drum radiator into the hub whence it is returned to the compressor for recirculation to the radiator at an elevated temperature. For room-heating operation, the compressor feeds the nozzle with hot, compressed primary fluid which condenses inside the hub, giving up its latent heat to the secondary fluid beyond the partition, and is then drawn by the capillary to the radiator for revaporization before returning to the compressor.

Another problem arising in the operation of such a unit, equipped with a compressor, is the provision of simple means for driving that compressor inside the hermetically sealed primary flow path of one (usually the external) heat exchanger, itself rotatably mounted in its wall-engaging support. The use of a sealed-in compressor motor for this purpose is not convenient since it requires the feeding thereof through mobile contacts such as slip rings. Thus, a further object of our invention is to provide efficient means for driving both the dual heat-exchange unit and the inaccessible compressor with the aid of a single prime mover, such as an electric motor, having a fixedly mounted stator or torque generator.

The system of U.S. Pat. No. 3,696,321 comprises, as a common prime mover for the heat-exchanger unit and the compressor, an electric induction motor with a sealed-in stator and armature, the latter being rigid with both the compressor rotor and a ring magnet inside the hub structure coacting with a fixed annular magnet surrounding that structure to generate eddy currents in a magnetically permeable sleeve forming part of that structure whereby the same is entrained at a speed lower than that of the compressor rotor to create relative motion between that rotor and the compressor housing secured to the hub. In accordance with a feature of our present invention, only the motor armature is disposed inside the sealed flow path of the primary fluid, being coupled with one of the two relatively rotatable compressor sections (i.e., the impeller) while the other compressor section (the housing) is driven, together with the surrounding hub and radiator, by fluidic entrainment, i.e., by the reaction torque generated in the compressor itself. This reaction torque is proportional to the degree of compression of the coolant vapors between the impeller and the housing wall, the pressure in turn being a function of vapor temperature. Such a fluidic coupling, therefore, has a self-regulating effect in the case of an air-conditioning unit since sluggish heat dissipation at the external radiator, due to insufficient rotary speed, accelerates the rotation of the unit, thereby increasing the throughput of ambient air until the drag balances the increased reaction torque. The speed of the rotary unit may also be controlled, if desired, by an eddy-current generator aiding or opposing the fluidic entrainment; in the first instance, such a generator may comprise a rotary magnet coupled with the motor armature as in the system of the prior application, whereas in the second instance it may include one or more stationary magnets whose spacing from a coacting conductor is preferably adjustable to vary the braking effect.

Such a fluidic coupling, though more fully described hereinafter in conjunction with a dual heat pump of the specific type discussed above, has also more general application in other thermogenic devices such as, for example, steam engines with rotary boilers and rotary condensers.

The secondary fluid may also be carried to or from the corresponding radiator, in its liquid state, by capillary action; thus, the internal heat exchanger may form a multiplicity of narrow, generally radial channels extending, as in the system of the copending application, between the radiator and the associated hub. Instead of capillary tubing or channels, wicks may be used to carry the liquid.

The above and other features of our invention will now be described in detail with reference to the accompanying drawing in which:

FIGS. 1*a* and 1*b*, to be positioned side by side, show elevational views (partly in section) of the two disassembled halves of a two-circuit heat pump embodying our invention;

FIG. 2 is a perspective view showing the unit of FIGS. 1*a* and 1*b* installed in a building wall; and

FIG. 3 is an enlarged axial sectional view of the region designated III in FIG. 1*a*.

FIG. 1*a*, which illustrates the external portion A of a heat-exchanger unit according to our invention, shows a mounting plate **1** bearing upon the outside of a building wall E, e.g., underneath a window as seen in FIG. 2. Plate **1** has a peripheral flange **2**, serving as a mudguard, and a sleeve **49** provided with bearings **50** for a central tubular shaft **3**. This shaft supports a spherically curved shell or cowl **4** of magnetically permeable material enclosing, together with an end wall **5**, a hermetically sealed chamber **6** included in a closed path for the circulation of a coolant such as Freon 22. Freely rotatable on horizontal shaft **3** is another tubular shaft **7** supporting a squirrel-cage rotor **8** which constitutes the armature of an induction motor having a laminated stator **23** surrounded by field windings **25**; stator **23** is fixedly mounted on plate **1** and is externally supplied with alternating (e.g., three-phase) current from a source not shown. Armature **8** comprises an array of short-circuited conductor bars which move close to the inner surface of cowl **4** and follow its curvature.

A compressor in chamber **6** comprises two relatively rotatable coaxial sections, i.e., an impeller **9** keyed to rotor shaft **7** and a housing **10** integral with end wall **5**. Housing **10** has an eccentric inner peripheral surface brushed by a pair of diametrically opposite impeller blades or vanes **51** which are radially movable in section **9** and are maintained in contact with the housing surface by centrifugal force as is well known per se. The periodically expanding and contracting space between the vanes **51** (only one shown) communicates intermittently with chamber **6** through an inlet port **52** and with an outlet tube **18**; though the inlet and the outlet are shown in the same plane in FIG. 1*a*, they are of course peripherally offset from each other. The reaction torque exerted by the impeller **9** upon the housing **10** entrains the wall **5** along with shaft **3** and cowl **4** in the direction of rotation of shaft **7** but at considerably reduced rate compared with that of shaft **7**; the latter may turn, for example, at a speed of 2,900 RPM, with reference to stator **23**, upon energization of the windings **25**.

End wall **5**, covered by an end cap **11'**, is integral with a disk **11** which carries on its outer periphery a drum-type radiator consisting of a multiplicity of horizontal tubes **13** which are provided with annular or helical ribs **14**, preferably of very thin aluminum foil, in highly thermally conductive contact therewith. As best seen in FIG. 3, tubes **13** are closed at their exposed ends and open at their supported ends into an annular space **12** within the disk **11**. This space communicates with conduit **18** to receive compressed cooling fluid therefrom. Another conduit **22**, also traversing the wall **5**, leads from the bearing gap between shafts **3** and **7** to a peripheral channel **19** forming an enlarged extension of space **12**. Conduit **22** is a capillary tube serving to return lubricating oil, driven centrifugally outwardly along with the compressed vapors, to the chamber **6**; tube **22** extends only far enough into channel **19** to dip into an oil layer **47** floating on a film of liquid coolant **46** condensed in radiator **13, 14** after giving up its excess heat to the outer atmosphere, as illustrated at **45**. A further capillary tube **20** reaches into the film **46** to draw the liquid into a hollow hub **16** of frustoconical configuration joined in fluidtight fashion to the shaft **3** by means of a cup-shaped end member **15**; tube **20** passes through the bore of shaft **3** and through an axial duct **17** in hub **16**, terminating in one or more nozzles **21** trained upon the inner peripheral surface of the frustoconical hub wall. Duct **17** has an opening **53**, surrounding the nozzle **21** with clearance, permitting the return of the expanded and vaporized fluid to the shaft bore after it has cooled the frustoconical surface **24** of the hub **16** which is made of highly thermally conductive material. From the interior of shaft **3** the fluid returns to chamber **6** through lateral apertures **54, 54'** in shafts **3** and **7**, thereby completing the circuit.

The rotation of disk **11** causes ambient air to be axially aspirated (arrow **26**) and radially discharged (arrow **27**) by centrifugal action so as to sweep the surfaces of radiator **13, 14.** with the compressed vapors from conduit **18** (which may be duplicated at peripherally spaced locations) heated to a temperature higher than ambient, subunit A acts as a heat sink. If the connections of the conduits are altered so that compressor **9, 10** delivers the hot fluid to nozzle or nozzles **21** for condensation at the peripheral surface of hub **16**, with return of the condensate to channel **19** by capillary action and recirculation of the vapors to chamber **6**, this subunit operates as a heat source.

The other half B of the rotatable unit, shown in FIG. 1*b*, comprises a hollow hub **55** with a frustoconical sleeve **33** of highly heat-conductive material fitting closely around the contact surface **24** of hub **16** when the two hub portions are coaxially nested within an opening **37** of building wall E. Sleeve **33** advantageously consists of elastically deformable material, such as a thin sheet of alloy steel, and is shown internally coated with a layer **56** of low-melting alloy or metal designed to promote heat transfer between sleeves 33 and 16. Coating 56, when heated to a sufficiently high temperature, flows over the surface 24 and bonds the two hubs together after they have been mechanically interconnected by bolts 57, 58 (FIG. 1*a*) and nuts 35, F (FIG. 1*b*). Bolts 57 (only one shown), integral with mounting plate 1, pass through bores 59 in a ring 34 which rests against a mounting plate 36 bearing upon the internal surface of housing wall E as part of a fixed supporting structure D. Central bolt 58 is a solid extension of the horizontal duct 17.

Subunit B further comprises a radiator drum consisting of finned tubes 28, similar to those shown at 13, 14 in FIGS. 1*a* and 3, which open at their supported ends 31 into an array of peripherally spaced channels 29 in a disk 30 mounted on hub 55. These channels are narrow enough to exert a capillary effect upon the liquid phase of a secondary heat carrier, such as alcohol or Freon 11, precipitating at 39 onto the frustoconical surface of sleeve 33 which is chilled by the vapors expanding along the opposite surface of the partition 24, 33, 56 separating the primary and secondary fluid circuits from each other. The secondary circuit includes a tapering annular chamber 32 communicating with channels 30. The condensate, assisted by centrifugal forces in its outward travel as indicated by an arrow 40, is revaporized in tubes 28 and returns in gaseous form to chamber 32. (When the unit is operated as a space heater, capillary action draws the liquefied secondary fluid from the tubes 28 into chamber 32 for volatilization along the sleeve 33 heated by the condensing primary fluid on the opposite side of the partition.)

Subunit B is enclosed by a protective casing C having a filter screen 38 and a corrugated peripheral wall 42 which may be perforated with tiny holes to facilitate the circulation of ambient air but which retains precipitated moisture inside the casing. This moisture collects in an arcuate trough 43, hugging the lower periphery of the rotary heat exchanger B over an arc of about 90°, and is swept up by a peripheral flange 44 of disc 30 to the zenith of its orbit whence it is discharged from the casing by a flexible drain pipe 48 extending along mounting plate 36 onto which the casing C is fitted. Pipe 48, traversing the ring 34 and the wall opening 37 as well as the opposite mounting plate 1, opens onto a frustoconical recess of disk 11 which is provided with an annular array of short transverse tubes 60 (only one shown) guiding the accumulating water onto the ribs 14 of the external radiator drum, thereby further assisting in the cooling of the primary fluid.

The rotary speed of the unit A, B may be controlled by an eddy-current brake illustrated as comprising an annular array of permanent magnets 61 (only one shown) confronting the electrically conductive annular flange 44 (FIG. 1*b*), these magnets being threaded into the nonmagnetic plate 36 so that their distance from flange 44 may be varied to adjust the braking effect.

The separation of two fluid circuits by a thermally conductive partition 24, 33 may be also be utilized in a system wherein the compressor 9, 10 is replaced by one or more Peltier-type current generators or thermopiles inserted between the outgoing branch and the return branch of the primary and/or the secondary flow path, or between the two flow paths, to transfer heat substantially adiabatically within a circuit or from one circuit to the other.

We claim:

1. A heat pump divided into two portions emplaceable on opposite sides of a wall for maintaining a temperature differential thereacross, comprising:

wall-engaging support means;

a first rotary heat exchanger including a hollow first hub journaled in said support means and a first radiator drum on said first hub provided with a first set of channels for conducting a first heat-carrying fluid in heat-exchanging relationship with ambient air;

a second rotary heat exchanger including a hollow second hub journaled in said support means coaxially with said first hub and a second radiator drum on said second hub provided with a second set of channels for conducting a second heat-carrying fluid in heat-exchanging relationship with ambient air, said hubs being coupled for joint rotation and contacting each other along a thermally conductive partition;

first conduit means in said first heat exchanger for circulating said first fluid in a closed first flow path between said first set of channels and said partition;

second conduit means in said second heat exchanger for circulating said second fluid in a closed second flow path between said second set of channels and said partition in heat-transferring relationship with said first fluid by way of said partition;

thermodynamically effective means in said first heat exchanger for changing the temperature of said first fluid traversing said first flow path; and

drive means for rotating said heat exchangers with reference to said support means.

2. A heat pump as defined in claim 1 wherein said first and second hubs have telescopically interfitted tubular wall portions centered on the hub axis and together constituting said partition.

3. A heat pump as defined in claim 2 wherein at least one of said wall portions has a contact surface in engagement with the other wall portion provided with a lower-melting metallic coating fusion-bonded onto said other wall portion.

4. A heat pump as defined in claim 2 wherein said wall portions are substantially frustoconical.

5. A heat pump as defined in claim 2 wherein said support means comprises a pair of spaced-apart mounting plates perpendicular to the hub axis, said wall portions being located in the space between said mounting plates.

6. A heat pump as defined in claim 1 wherein said first radiator drum is provided with a peripheral channel for accumulation of a liquid phase of said first fluid, said first conduit means including a capillary extending from said channel to the interior of said first hub.

7. A heat pump as defined in claim 1 wherein said first means includes at least one nozzle within said first hub trained upon said partition for discharging said first fluid onto same.

8. A heat pump as defined in claim 1, further comprising a collector for condensed ambient moisture underneath said second heat exchanger on said second support and drain means for said condensed moisture passing alongside said hubs from said collector to said first support for discharge into the atmosphere.

9. A heat pump as defined in claim 8 wherein said drain means terminates in the vicinity of said second

radiator drum for directing said condensed moisture unto same.

10. A heat pump as defined in claim **1** wherein said drive means comprises an electric motor with a stator on said first support and with a rotatable armature inside said first hub electromagnetically entrainable by said stator, said thermodynamically effective means including a compressor with two relatively rotatable sections centered on the hub axis, one of said sections being coupled with said armature for joint rotation, the other of said sections being rigid with said first heat exchanger.

11. A heat pump as defined in claim **10** wherein said one of said sections is an impeller provided with vane means, said other of said sections being a housing entrainable by said impeller at a reduced rotary speed.

12. A heat pump as defined in claim **10** wherein said first hub comprises a magnetically permeable cowl separating said stator from said armature and enshrouding part of said first flow path.

13. A heat pump as defined in claim **12** wherein said cowl is spherically curved.

14. A heat pump divided into two portions emplaceable on opposite sides of a wall for maintaining a temperature differential thereacross, comprising:

wall-engaging support means;

a hub structure journaled in said support means;

a first and a second rotary heat exchanger including a radiator drum provided with a set of channels for conducting a respective heat-carrying fluid in heat-exchanging relationship with ambient air;

first and second conduit means in said first and second heat exchangers, respectively, for circulating those fluids through the channels of their radiator drums in closed first and second flow paths approaching each other in said hub structure closely enough to enable effective heat transfer between said fluids;

a compressor in said first heat exchanger for densifying the fluid thereof traversing said first flow path in one direction while being bypassed by said first conduit means for passage in the opposite direction, said compressor having two relatively rotatable sections located in said hub structure and centered on the axis thereof; and

drive means for rotating one of said sections with reference to said support means, the other of said sections being rigid with said first heat exchanger for laggingly rotating same about said axis by fluidic entrainment.

15. A heat pump as defined in claim **14** wherein said drive means comprises an electric motor with a stator on said support means and with a rotatable armature inside said hub structure electromagnetically entrainable by said stator, said one of said sections being coupled with said armature for joint rotation.

16. A heat pump as defined in claim **15** wherein said hub structure forms a chamber about said compressor included in said first flow path, said chamber being bounded by a magnetically permeable cowl separating said armature from said stator.

17. A heat pump as defined in claim **16** wherein said cowl is substantially spherically curved about said axis, said armature comprising a squirrel-cage rotor with conductors closely spaced from said cowl and curved along the inner surface thereof.

18. A thermogenic device comprising:

stationary support means;

a rotatable body provided with a shaft journaled in said support means, said body forming a hermetically sealed enclosure about a closed flow path for a heat-carrying fluid;

fluid-circulating means in said body including a compressor with two relatively rotatable sections in said flow path centered on said shaft, one of said sections being freely rotatable on said shaft, the other of said sections being rigid with said body; and

an electric motor with a stator on said support means and with a rotor in said enclosure electromagnetically entrainable by said stator, said one of said sections being mechanically coupled with said rotor for joint rotation at a relatively high speed whereby said other of said sections is fluidically driven together with said body at a relatively low speed, said enclosure including a magnetically permeable shell separating said stator from said rotor.

19. A thermogenic device as defined in claim **18** wherein said one of said sections is an impeller provided with vane means exerting a reaction torque upon said other of said sections.

20. A thermogenic device as defined in claim **18**, further comprising brake means on said support means for controlling the rotary speed of said body.

21. A thermogenic device as defined in claim **20** wherein said brake means comprises an eddy-current generator.

22. A thermogenic device as defined in claim **18** wherein said shell is spherically curved.

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