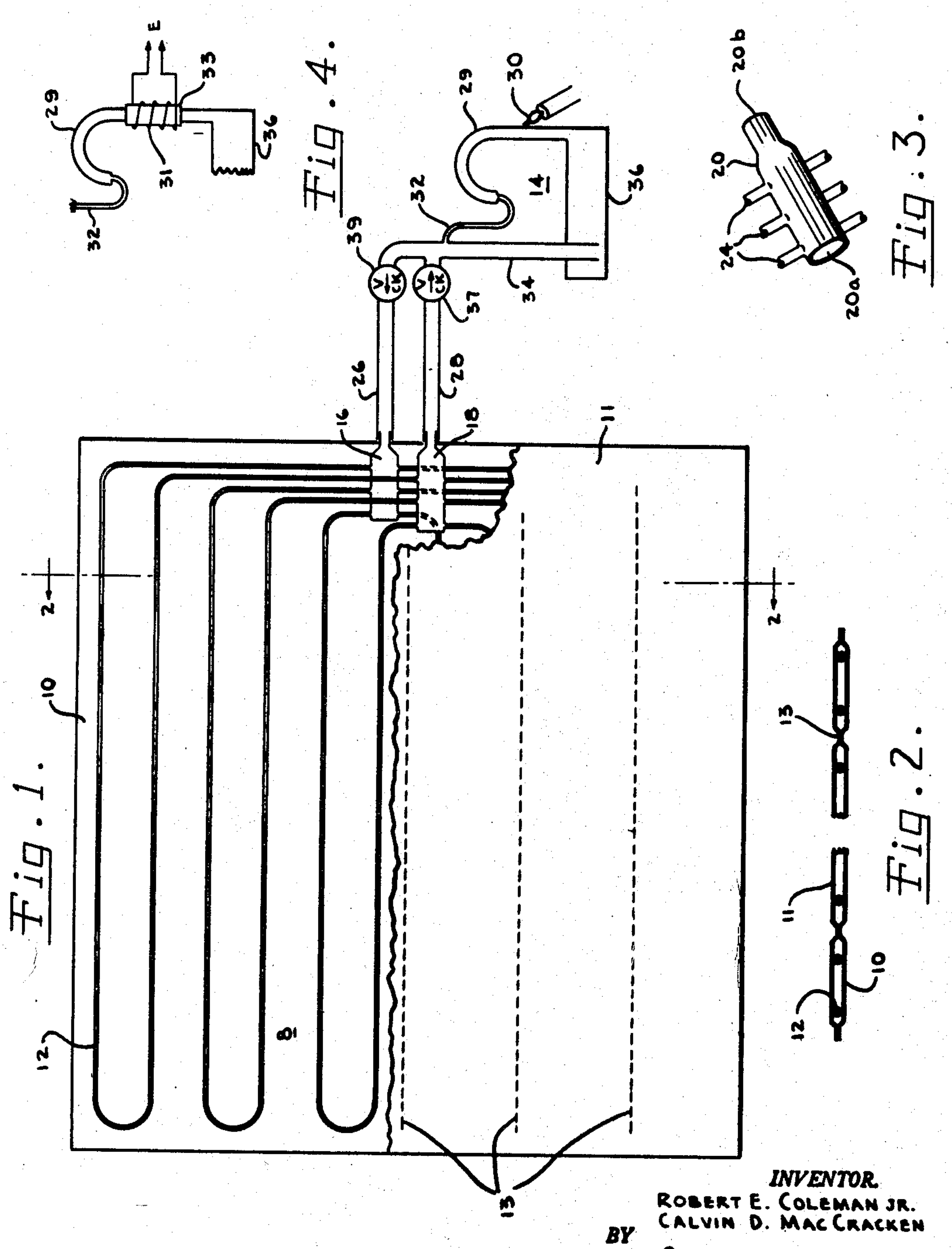
Dec. 3, 1963 R. E. COLEMAN, JR., ET AL 3,112,792

PERSONAL THERMAL DEVICE

Filed Sept. 13, 1952 5 Sheets-Sheet 1



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PERSONAL THERMAL DEVICE

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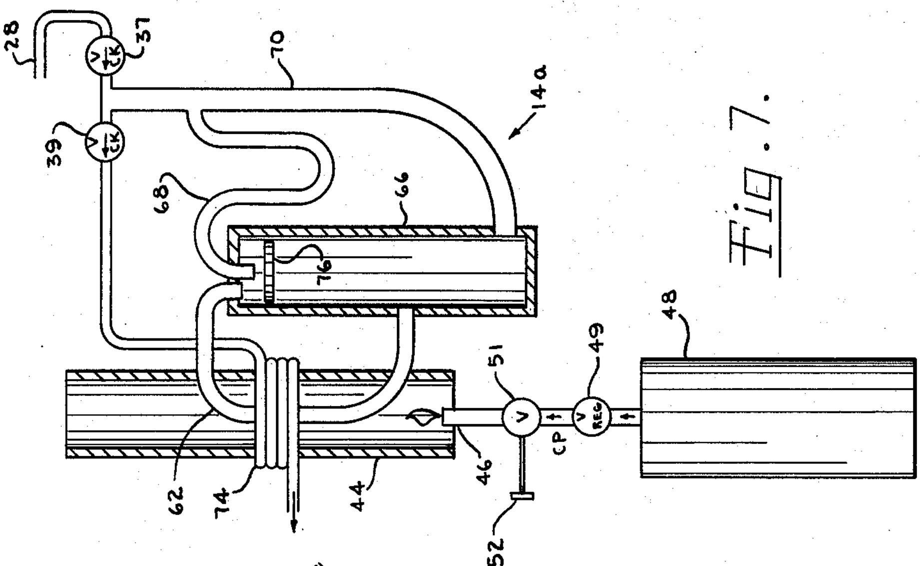

Fig. 7.

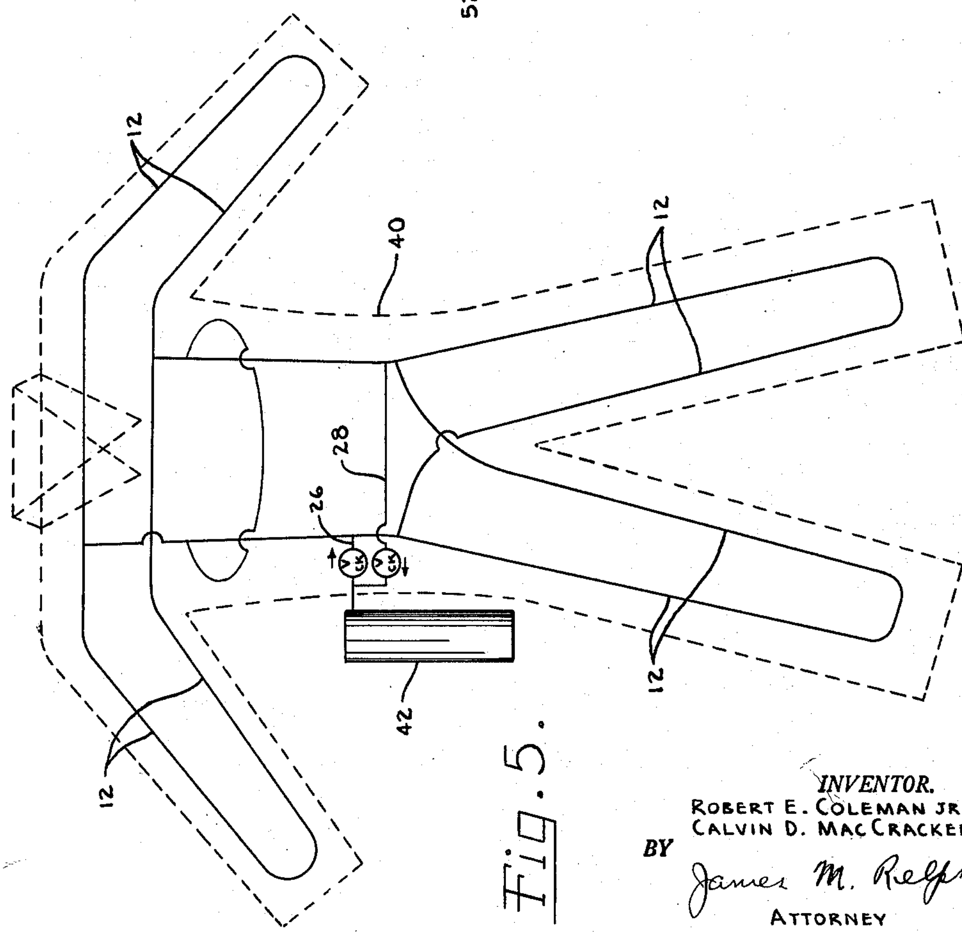

Fig. 5.

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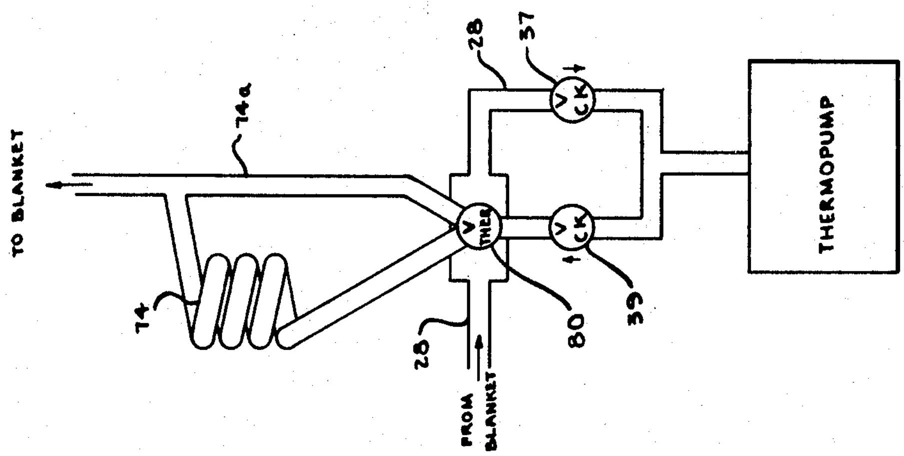

Fig. 9.

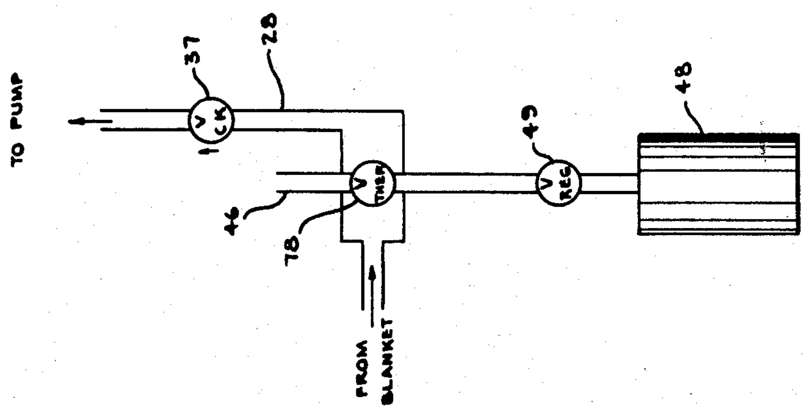

Fig. 8.

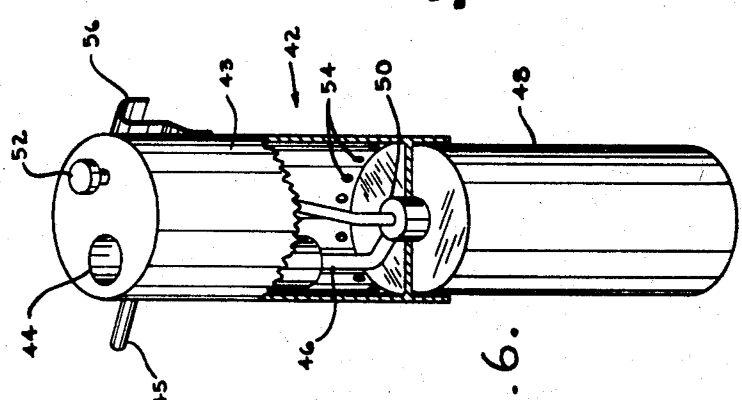

Fig. 6.

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PERSONAL THERMAL DEVICE

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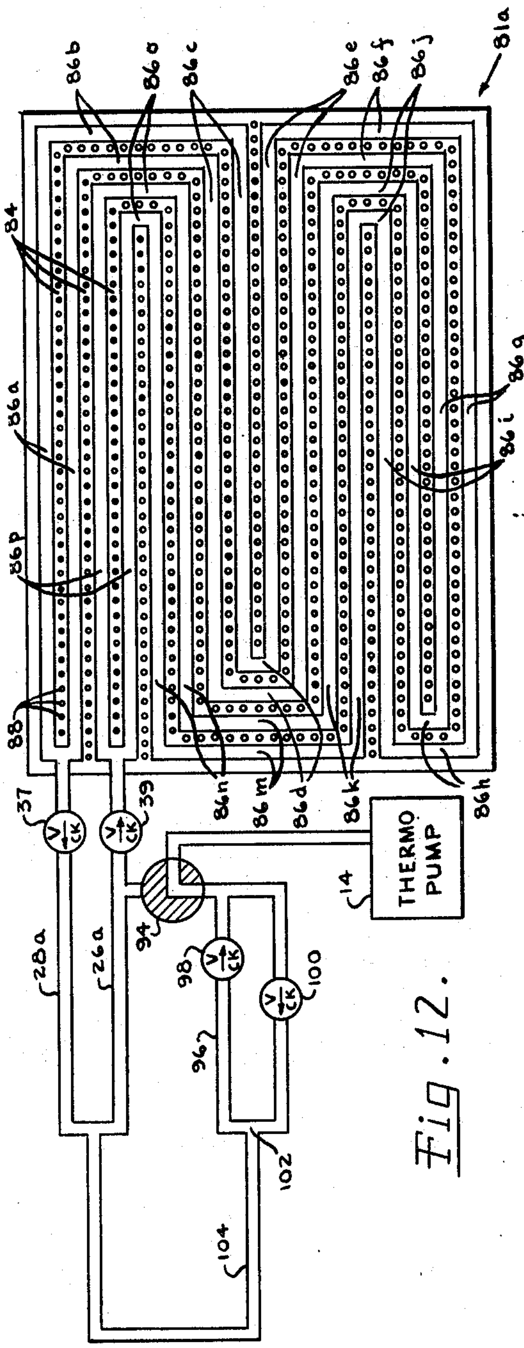

Fig. 12.

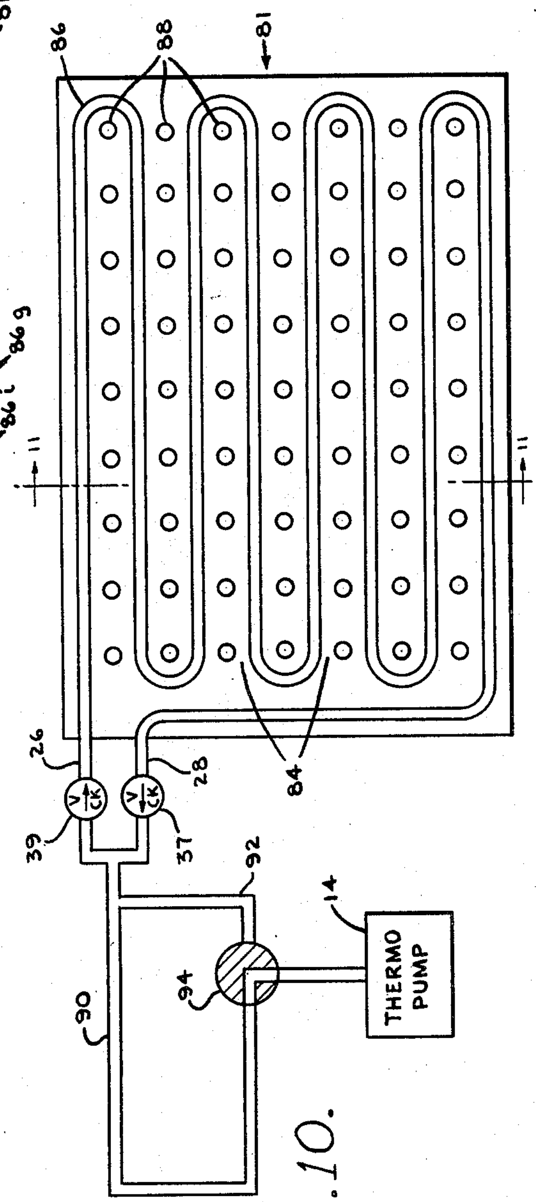

Fig. 10.

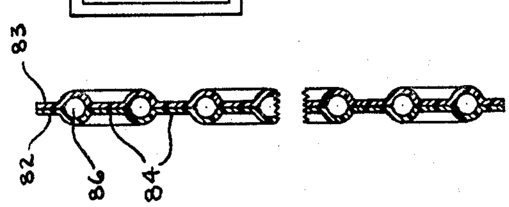

Fig. 11.

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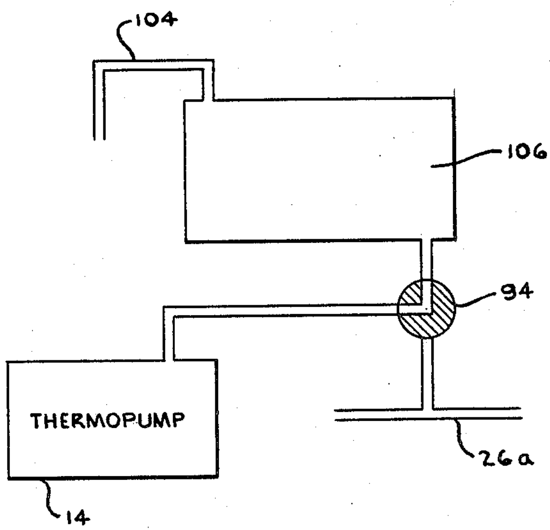

Fig. 13.

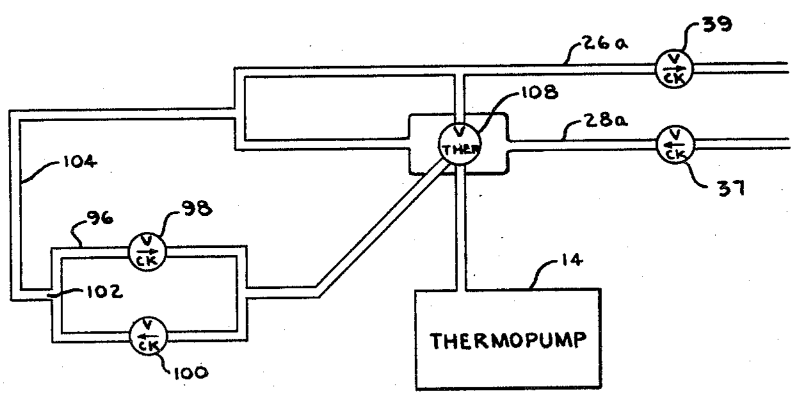

Fig. 14.

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PERSONAL THERMAL DEVICE

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Filed Sept. 13, 1952, Ser. No. 309,416
16 Claims. (Cl. 165—46)

This invention relates to improvements in personal thermal devices, and particularly to improved personal heating and cooling apparatus of the type wherein a temperature controlling fluid is circulated through a thin, flexible heat exchange structure such as a blanket, a garment or the like.

It is among the objects of the present invention to provide an improved personal thermal device of the foregoing type that is small and light in weight, that can be made as an entirely self-contained, readily portable unit, that is inexpensive to manufacture, that involves practically no moving parts, that will operate under a wide variety of ambient temperature conditions, and that is suitable both for heating and for cooling.

In accordance with preferred embodiments of the invention, the foregoing and other related objects and advantages are attained in apparatus wherein a thin, flexible heat exchange structure, such as a garment, a blanket or a pillowcase insert, is provided with liquid conducting passages through which liquid is circulated by means of a heat operated pump (referred to herein as a thermopump). As will be brought out more fully hereinafter, such an arrangement can be embodied in a very small apparatus "package." Depending on the specific use for which the apparatus is designed, the primary heat source for the thermopump may comprise an electrical heater, a small flame supported by a combustible fluid, or a variety of other similar heat sources.

Because of the simplicity and compact configuration of the thermopump, the apparatus has unusual versatility, and finds application in a variety of uses for which comparable prior art devices are of limited or no utility. Moreover, where heating is required, the heat energy is used in a dual capacity as a source of motive power and for heating the circulated fluid.

A more complete understanding of the invention can be had by reference to the following description of illustrative embodiments thereof, when considered in connection with the accompanying drawing wherein

FIG. 1 illustrates a heated blanket arranged in accordance with the invention, with a portion of the blanket surface broken away to show the interior construction,

FIG. 2 is a cross-sectional view of the blanket of FIG. 1, taken on the line 2—2 of FIG. 1,

FIG. 3 is a perspective view of a header unit used in the blanket of FIG. 1,

FIG. 4 is a fragmentary view of a thermopump, showing electrical heating of the pump generator,

FIG. 5 illustrates a heated suit arranged in accordance with the invention,

FIG. 6 illustrates a thermopump and fuel container assembly suitable for use in the system of the present invention,

FIGS. 7–9 illustrate modified forms of fluid heating circuits embodying the invention,

FIG. 10 illustrates a cooling and heating system embodying the invention,

FIG. 11 is a cross-sectional view of the heat exchange structure of FIG. 10, taken on the line 11—11 of FIG. 10, and

FIGS. 12–14 illustrate modified forms of fluid cooling and heating circuits embodying the invention.

As already indicated, the particular heat exchange structure through which the temperature controlling fluid

is circulated in accordance with the present invention may take any one of a variety of different forms. In general, what is contemplated is a flexible structure or web of material capable of conforming to or serving as a covering for part or all of the human body, and may comprise a garment, such as a jacket, coveralls or the like, bedclothing, such as a sheet, a blanket, a sleeping bag, a pillow insert or a mattress cover, or similar items of personal use.

By way of introduction, the invention will first be described as embodied in a heated blanket.

Referring to FIGS. 1 and 2 of the drawing, a heated blanket 8 arranged in accordance with the invention comprises a thin, flexible two-layer heat exchange structure 10, 11, provided between the fabric layers 10, 11 with liquid conducting passages 12 extending throughout the blanket and through which heated liquid is circulated by a thermopump 14.

The superposed fabric layers 10, 11 are sewn together along the outside edges and along spaced lines 13 to provide channels for holding flexible tubing, such as rubber or plastic tubes, forming the liquid conducting passages 12.

For clarity, only a small number of relatively large cross-section tubes 12 are shown in FIGS. 1 and 2. In actual practice, tubing of "capillary" dimensions is preferably used, not only to decrease the quantity of circulating liquid in the blanket structure and to make the surface irregularities due to the tubing less noticeable, but also to avoid stoppages due to kinking of the tubing 12. For example, tubing with an inside diameter and a wall thickness of, say, 40 mils, is found to be appropriate. A suitable material for the tubing is a plastic material, such as one of the so-called vinyl resins, polyethylene, or the like. Furthermore, instead of the six tubing circuits shown in the drawing, twenty or more such circuits may be used to distribute the heat more uniformly.

The loops of tubing 12 are connected between a pair of header units 16, 18, one of which (16) constitutes an input header and the other of which (18) constitutes a return header. The arrangement is such that heated liquid will enter the blanket through the input header 16, flow through the various loops of tubing 12 in parallel, and flow out through the header 18. This parallel flow arrangement has the advantage that it equalizes the heating effect across the blanket, and also reduces the pressure drop or resistance to liquid flow in the tubing 12, as compared with a series path through a single tube looped back and forth across the entire blanket.

It has been found preferable to use small diameter tubing throughout the entire blanket and to connect this tubing to small compact headers or junction units 16, 18 rather than having large diameter header tubes extend along the edge of the blanket. The reason for this is that if long header tubes are used, they must be large enough in diameter to carry the liquid for substantially all of the circuits 12 without appreciable pressure drop. On the other hand, tubing of the required diameter is very likely to kink and materially reduce or even completely cut off the flow of liquid if made flexible enough to conform to folds and the like in the blanket. The header units 16, 18 can be very compact assemblies, fully rigid to obviate kinking and yet extending over no more than one or two square inches of blanket surface area.

As shown in detail in FIG. 3, for example, each header unit may comprise a short length of metal tubing 20, partially flattened to an oval shape throughout a portion of its length, and having the oval shaped end 20*a* sealed off. In the oval shaped portion of the tube 20, short stubs 24 of very small diameter tubing are soldered into the tube 20 in the general plane of the major axis of the oval to connect to the blanket circuit tubes 12. The round end 20*b* of the header tube 20 is adapted to be inserted in the end of a flexible tube (26 or 28 in FIG. 1), leading to or from the blanket 8 and the thermopump 14.

The thermopump 14 of FIG. 1 corresponds generally to the pump described in U.S. Patent 2,553,817—Kleen. Briefly, such a pump comprises a vapor generator chamber in the form of a tube 29, of inverted U-shape, within which to form vapor when heat is applied to the tube 29 from some source such as an open flame 30. The end of one leg of the U-tube 29 is connected through a smaller diameter U-shaped vapor transfer tube 32 to a vertical tube 34 which constitutes a vapor condenser chamber. The lower end of the condenser tube 34 and the other leg of the generator 29 are connected through a reservoir 36. The generator 29, the vapor tube 32, the condenser 34 and the reservoir 36 constitute a closed loop which is coupled to the blanket passages 12 through a pair of check valves 37, 39, the flexible tubing 26, 28, and the headers 16, 18.

The operation of the thermopump 14 is as follows:

When the heat of the flame 30 acts on the generator tube 29 to vaporize the liquid therein, vapor will collect in the upper portion of the U, raising the pressure in the pump and forcing liquid to flow downwardly through the leg of the generator tube and upwardly through the vapor tube 32 and the condenser 34. This, of course, will force liquid to flow out through the check valve 39 and into the blanket circuits 12 through the header 16 as the blanket circuits expand slightly to accept the liquid forced into them. When the liquid level in the pump has been forced down by the vapor to the lowermost point in the vapor tube 32, vapor will begin traveling up through the vapor tube 32. This will create a hydrostatic unbalance between the liquid in the generator and condenser columns, tending to cause liquid to flow downwardly through the condenser tube 34 and upwardly into the generator 29. This counter-clockwise flow of liquid in the pump will force all the vapor out of the generator chamber and into the condenser chamber wherein the vapor will condense, thereby decreasing the pressure in the pump and causing liquid to be suctioned into the pump through the check valve 37 from the return header 18 and the return tube 28. Thereupon, the system will temporarily come to rest until a new volume of vapor begins to collect in the generator tube, whereupon the entire cycle will be repeated. A more complete description of the features and functioning of the thermopump 14 will be found in the above mentioned Kleen patent.

From the brief description just given, it can be seen that the operation of the thermopump 14 will result in a continual cyclical delivery of hot vapor to the condenser tube 34, and that during the expulsion stroke of the pump, liquid heated by the vapor will be forced out of the condenser tube. If the volume of the coupling between the condenser 34 and the check valves 37, 39 is less than that of the pump stroke, hot liquid will pass through the check valve 39 into the blanket inlet tube 26 on each pumping stroke. Thus, it can be seen that the thermopump 14 is peculiarly adapted for utilization in a personal heating system of the type with which the present invention is concerned for the reason that the application of heat can be utilized both to obtain the necessary circulating action and to heat the liquid being circulated.

While the flow of liquid to and from the pump 14 is cyclical, rather than unvarying or continuous, the flexibility of the various tubes and tubing circuits is more than adequate to accommodate the small changes in liquid volume in the system outside the pump 14.

While the heat for generating vapor can be supplied in a number of different ways, a flame operated system is of particular utility for portable apparatus. So far as is known, the system of the present invention provides the first entirely practical portable individual heating or cooling apparatus to be proposed. For example, utilizing a fuel such as bottled propane gas or the like, readily

available in small containers occupying only a few cubic inches of space and weighing about one pound, a system of the type just described is ideally suited for individual use in cold areas. Such a system is particularly useful for evacuation of wounded military personnel from the field of action where weight and bulk of the protective apparatus must be kept at a minimum, and yet where some form of heating is frequently vital to prevent shock. Using a fuel supply of the type just indicated, it is entirely feasible to have a complete system capable of delivering 1500 B.t.u./hr. to the blanket for 10 hours and weighing less than 15 pounds, including blanket, pump and fuel. Of course, for heating applications in extreme cold, an anti-freeze liquid such as alcohol or the like will be used as the circulating medium. Water and other liquids are suitable in situations where the ambient temperature will permit use of higher freezing point liquids.

In domestic as well as military applications, sportsmen and others who have occasion to require some type of artificially supplied personal heating in remote localities where electrical power is not available can use such an apparatus to advantage. Of course, while a bottled gas such as propane may be most convenient to use, other fuels such as wood alcohol, kerosene and the like can also be used where appropriate.

As is shown in FIG. 4, the pump in the heating system of FIGS. 1 and 2 can as well be provided with an electrical heating element 31 wound on the generator tube 29 in place of the flame heater 30 of FIG. 1. If the pump is of metal construction, a layer of insulation 33 will be placed between the heater 31 and the generator tube. With an electrically heated pump as shown in FIG. 4, the apparatus of FIGS. 1 and 2 has important advantages for use in the home. It is essentially noiseless in operation, and as compared with the conventional "electric blanket" it involves absolutely no risk of burns or electrical shock to the user.

As already indicated, the present invention is equally applicable to a personal heating unit in the nature of a suit or garment as well as the blanket-type heat exchange structure shown in FIGS. 1 and 2. The tubing 12 can be sewn into such a garment as well as in a blanket. For example, as shown in FIG. 5, the tubing 12 can be arranged in circuits through the body, arm and leg portions of a "coverall" type garment 40, with the pump and a fuel container assembled in a cylindrical unit 42 hanging from the garment 40 at the beltline. At least one of the tubing circuits 12 normally will be provided in each of the arm and leg portions of the garment 40, with the circuits 12 preferably being connected in parallel between inlet and outlet tubes 26, 28. Of course, a greater number of circuits 12 can be provided for more uniform heat distribution if desired.

FIG. 6 is a somewhat enlarged view of the pump and fuel container assembly 42 of FIG. 5. As shown in FIG. 6, the upper portion of the assembly 42 comprises a cylindrical shell 43 housing the pump 14 (not shown in FIG. 6) and having a flue outlet opening 44 in the upper end through which to discharge exhaust gases from a burner 46 in the lower part of the shell 43. The burner 46 is coupled to a cylindrical fuel container 48 by means of a threaded cap 50 in the bottom of the shell 43 into which the fuel container 48 can be screwed readily for quick interchange of fuel cartridges. A control knob 52 is mounted on the upper end of the housing 43 beside the flue outlet 44 for adjusting the burner output as described hereinafter. The lower end of the housing shell 43 is perforated as at 54 to supply combustion air for the burner 46 and cooling air for the pump condenser. A hook 56 at the top of the shell provides a support for suspending the assembly 42 as shown in FIG. 5.

In FIG. 7, there is shown in somewhat greater detail a thermopump system provided with controls for regulating the delivery of heat to a blanket or garment, as in FIGS. 1–4, and including a slightly modified type of thermopump.

In the FIG. 7 apparatus, there is provided a fuel container 48, containing a combustible gas such as propane or the like. On the outlet line from the gas container 48, there is provided a pressure regulating valve 49 for eliminating fuel pressure variations due to ambient temperature variations and the like. Downstream from the pressure regulating valve 49, there is provided a manually controlled valve 51, operable by a control knob 52, for adjusting the flow of fuel. The valve 51 connects to a burner nozzle 46 which is disposed in the lower end of a flue 44.

Extending laterally into the flue 44 immediately above the burner 46 is the vapor generator tube 62 of a thermopump 14*a* certain features of which are described and claimed in a copending application of R. E. Coleman, filed July 5, 1952, Serial No. 297,371, and assigned to the assignee of the present invention.

The lower end of the generator tube 62 is connected to a generally vertical cylindrical tube 66 which comprises a combined reservoir and vapor collecting chamber. The upper portion of the generator 62 is of inverted U-shape and opens into the top of the vapor collecting chamber 66 at a point slightly off center.

In the center of the top of the vapor collecting chamber 66, a vapor outlet tube 68 protrudes down into the chamber 66 for a short distance, and extends from the chamber 66 to a condenser tube 70 in a manner similar to the vapor tube 32 in the pump 14 of FIG. 1. The condenser chamber 70 is connected at the bottom to the chamber 66, while the top of the condenser tube 70 is coupled through a check valve 39 to a heat exchange 74 comprising a coil of several turns around the flue 44 in the vicinity of the generator arm 62. It will be understood that the free end of the coil 74 will be connected to a header (not shown in FIG. 7) such as the header 16 in FIG. 1. Similarly, a return line 28 from a second header (not shown in FIG. 7) is connected to the condenser 70 through a second check valve 37.

Inside the vapor collecting chamber 66, there is provided a float 76 which will rise and fall in the chamber 66 as vapor is alternately collected in and discharged from the chamber 66.

The system shown in FIG. 7 will be put in operation by igniting the burner 46 to provide a flame inside the flue 44. The flame will envelope the generator 62 and at the same time supply heat to the heat exchanger coil 74. Vapor generated in the generator 62 will pass over into the top of the vapor collecting chamber 66 and accumulate therein, at the same time forcing liquid downwardly in the chamber 66 and up and out through the condenser tube 70. Prior to vapor accumulation, the float 76 will perform one of its functions; i.e., preventing the flow of heated liquid up and out through the vapor tube 68, prior to collection of vapor in the top of the chamber 66.

As vapor continues to collect in the collector 66, the liquid level therein eventually will drop sufficiently to allow the float 76 to drop away from the vapor tube 68. Thereafter, as further quantities of vapor are collected in the collector 66, the float 76 will act as an insulating separator, reducing heating of the liquid to prevent overheating of the pump system.

When the level of the liquid in the chamber 66 drops below the lowermost point in the vapor tube 68, the pump will cycle in the same manner already described in connection with pump 14 in FIG. 1. However, it is to be noted that as the liquid level rises in the chamber 66 during the condensing or suction portion of the pump cycle, the float 76 will seal off the vapor outlet tube 68 before liquid has completely refilled the chamber 66. This tends to maintain a quantity of vapor in the top of the collector 66 at all times, thereby facilitating the start of the next expulsion or pressure stroke of the pump.

It will be understood that by adjusting the control knob 52, the amount of heat supplied to the pump can be adjusted as required, simultaneously changing both the pumping rate and the amount of heat put into the pumped liquid at the heat exchanger coil 74. While the heating of the liquid within the pump itself is adequate for moderately low ambients, the heat exchanger 74 is advantageous for operation under extreme cold conditions.

As an alternative to the manual control of heating illustrated in FIG. 7, it is quite feasible to have thermostatic control of the pump operation or of the temperature of the circulated liquid. In other words, the temperature of the liquid being circulated can be thermostatically controlled without altering the pump output, or both the pump output and liquid heating can be controlled automatically by use of a thermostatic valve supplementing or replacing the manual valve 51 in FIG. 7.

For example, as shown in FIG. 8, the manual valve 51 of FIG. 7 can be replaced by a thermostatic fuel control valve 78 disposed in the return line 28 to be bathed by and responsive to the temperature of the liquid returning from the blanket through the tube 28. This, of course, will control pump output and liquid heating simultaneously. Alternatively, as shown schematically in FIG. 9, the heat exchange coil 74 of FIG. 7 can be connected in parallel with a by-pass line 74*a* to a two-way thermostatic liquid flow control valve 80 disposed in the return line 28 to be bathed by the return fluid from the blanket. In this case, the thermostatic valve 80 is arranged to direct more fluid through the by-pass 74*a* and correspondingly less through the heat exchange coil 74 as the temperature of the returning liquid from the blanket increases. Of course, a combination of both types of control illustrated in FIGS. 8 and 9 is entirely feasible.

As previously indicated, the apparatus of the present invention can be used for personal cooling as well as for heating. In the apparatus of FIG. 1, for example, if the volume of the coupling between the condenser tube 34 and the check valves 37, 39 is greater than the volume of one stroke of the pump 14, it is theoretically possible to keep hot liquid from passing the outlet check valve 39. Under these conditions, liquid will be circulated through the circuits 12 in the blanket 8 without any heating by the pump. The circulating liquid will, however, absorb heat from a person covered by the blanket, and this heat will be lost as the liquid circulates through circuits relatively remote from the body-covering area. Thus, a definite cooling action will be obtained even though the temperature of the circulating medium is not artificially forced below the ambient temperature. In fact, experiments show that circulating a liquid at temperature only a few degrees below the ambient may create a definitely uncomfortable "chilly" condition, if the area of body contact is at all extensive.

Investigation also has shown that there is a psyochological factor involved in "cooling" that has bearing on the apparatus used for cooling, and the way in which it is used. This is based on the fact that the average individual is accustomed to having his head exposed and the rest of his body covered. This means the individual is also accustomed to a slightly higher ambient temperature close to the body below the neck as compared to a similar area about the head. It has been found, therefore, that a "cooling blanket," while cooling the body, is not necessarily the only satisfactory cooling medium, because as long as the head is cooled even slightly, it is found that one can be quite comfortable on a very warm night. In other words, a satisfactory cooling effect can be obtained with a "cooling pillow" under the head as well as with a "cooling blanket" over or under the body. Experiments have shown that a person using a "cooling pillow" as contemplated herein can be quite comfortable under a light blanket when the room temperature is such that the same person feels uncomfortably warm without the cooling pillow, even though completely uncovered.

It should also be noted that a cooling device of the type about to be described is not necessarily limited to use of a thermopump as the liquid circulator, since a mechanical pump can be used that is arranged to circulate liquid through the cooling circuit without affecting the temperature of the circulated liquid. However, the use of a thermopump is deemed preferable since it is essentially noiseless, is less expensive, requires less maintenance, and can also be used for a combination heating and cooling system.

In FIGS. 10 and 11 there is shown a personal cooling system arranged in accordance with the invention. The same apparatus can also be used for heating, as will be explained shortly.

The apparatus shown in FIGS. 10 and 11 includes a thin, flexible heat exchange structure 81 comprising two superposed flexible sheets 82, 83 of water-proof material, having approximately the (rectangular) dimensions of an ordinary bedpillow. The sheets 82, 83 preferably are of plastic material, such as one of the so-called vinyl plastics. The two sheets 82, 83 are sealed together along the edges and along spaced lines 84 to define in the unsealed areas between the sheets 82, 83 integral passages 86 through which to circulate cooling liquid.

Even though the cooling element 81 of FIGS. 10 and 11, when used in the manner described hereinafter, will tend to keep the user comfortably cool, it is possible for small quantities of moisture to accumulate under the user's head and create a "clammy" feeling. Accordingly, in the sealed surface areas 84 between the conducting passages 86, the cooling element 81 preferably is perforated as indicated at 88 so that moisture will not accumulate on the waterproof surface (82 or 83).

In the cooling element presently being described, as compared with the blanket structure of FIGS. 1 and 2, it is seen that the passages 86 are arranged in a continuous circuit between the inlet and outlet tubes 26, 28, rather than all in parallel as are the tubes 12 in the FIGS. 1 and 2 construction. The reason for this is that in the system of FIG. 10, heat exchange between the user and the circulating liquid is more a matter of conduction than of convection. In other words, it is contemplated that the user will lose heat to the surface of the cooling element 81 by contact therewith (with, perhaps, a pillowcase or the like separating the user's head from the cooling surface). Accordingly, for best efficiency, the circuit 86 should be arranged so that no matter how limited the area of user contact, substantially all of the cooling medium will flow through that area. In the case of the heating blanket, on the other hand, what is contemplated is the creation of a warm ambient about the user's body, rather than direct heat exchange contact between the user's body and the warm surface. Therefore, it is not essential that the warming liquid flow through every one of the blanket circuits to every portion of the blanket, but merely that the heated liquid flow through a major part of the blanket to create warmth beneath the blanket which will dispel itself over the entire area covered by the blanket. Secondly, if all of the passages in the cooling element 81 were connected in parallel between the inlet and outlet tubes 26, 28 the pressure of the user's head might well divert all of the cooling flow through passages remote from the user's head, and the cooling effect would be lost. Of course, it is entirely permissible to have two or more parallel circuits through the cooling element, provided that all of the circuits are substantially coextensive and all extend through substantially the entire area of the cooling element. This will be further clarified in connection with the description of FIG. 12 hereinafter.

In thes embodiment of the invention illustrated in FIG. 10, a pair of check valves 37, 39 are provided in the inlet and outlet lines 26, 28. A relatively long (i.e. large volume) tube 90 and a relatively short (i.e. small volume) tube 92 are connected in parallel between a thermopump 14 and the check valves 37, 39, through a selector

valve 94 that permits the user to select either the long line 90 or the short line 92 as the coupling, as explained hereinafter.

In use, it is contemplated that the cooling device 81 will be inserted between the pillow body and the pillowcase of an ordinary bedpillow. Assuming that the valve 94 has been set as in FIG. 10 to complete a circuit to the pump through the line 90, and with the entire system of FIG. 10 filled with liquid, such as water, operation of the thermopump 14 will establish a cyclical flow of liquid back and forth in the line 90. This will force liquid through the check valve 39, around through the passages 86, and back through the check valve 37 as the liquid moves back and forth in the isolation line 90. As the liquid passes under the user's head, it will absorb heat, and will then lose this heat during circulation through parts of the element 81 remote from the user's head and through the coupling lines 26, 28. The relatively large volume coupling line 90 will ensure against any transfer of heat from the pump to the cooling element 81.

In order to use the apparatus of FIG. 10 as a heating system, the valve 94 will be adjusted to place the short line 92 in the circuit rather than the long line 94. This will couple the pump 14 closely to the element 81 so that, on each pump stroke, heated liquid will flow from the pump 14 past the check valve 39 and into the passages 86.

Due to the flexibility of the element 81, it is possible that the weight of a user's head may materially restrict one or more of the passages 86, cutting down the flow of cooling fluid. This effect can be substantially overcome by charging the system with fluid at a pressure slightly above atmospheric pressure to help maintain the cross-sectional shape of the flow passages. For example, a filling pressure of the order of one pound per sq. inch has been founde adequate and yet does not make the element 81 objectionably "stiff" or rigid.

When using the apparatus of FIG. 10 for cooling, the large volume isolation link 90 between the thermopump condenser chamber and the check valves 37, 39 will insure against heat transfer from the pump to the cooling medium. However, this means that the pump condenser will not have the benefit of drawing in relatively cool liquid on such suction stroke. Depending on the heat loss characteristics of the coupling line from the condenser to the check valves, it is possible for the condenser to overheat under these conditions so that the thermopump will fail to operate due to failure of condensation.

Again, it is sometimes found that when the cooling element 81 is inserted in a pillow as just described, the pillowcase does not allow enough heat loss from the circulating liquid to obtain the desired cooling effect.

To avoid these difficulties, auxiliary cooling circuits both for the pump and for the cooling element sometimes can be used to advantage. An arrangement illustrating the use of such auxiliary cooling circuits is shown in FIG. 12. The FIG. 12 system also includes a preferred form of cooling element, as well as a circuit arrangement whereby the system can be used either for heating or for cooling, as desired.

In the FIG. 12 apparatus, a thermopump 14 is connected to circulate liquid through a heat exchange element 81*a*. Between the pump 14 and the element 81*a* in FIG. 12, there is provided an auxiliary cooling or isolation circuit for the pump 14, comprising a tube 96 and a pair of check valves 98, 100. Between the check valves 98, 100, a T connection 102 leads to the cooling element circuit through an isolating line 104.

To provide extra cooling for the liquid circulated through the element 81*a*, the system of FIG. 12 includes a pair of relatively long inlet and outlet lines 26*a*, 28*a*, rather than the comparatively short lines 26, 28 utilized in the FIG. 10 system.

The cooling element 81*a* in FIG. 12 is made up in a manner similar to that shown in FIG. 11; e.g., by sealing together two superposed sheets 82, 83 of waterproof material along spaced lines 84 to define liquid conducting passages 81a—81p in the unsealed areas between the sheets 82, 83. In the FIG. 12 element, however, the circuit arrangement is somewhat different. In the FIG. 10 element 81, it will be noted that the circuit extends from the corner where the liquid inlet 26 is located, to the diagonally opposite corner, along a devious path that extends back and forth across the element 81, and then returns directly along the edge of the element to the outlet opening connecting with tube 28.

If the element 81 is contacted by the user's head in any given area, the surface "downstream" from that area will contain relatively warm liquid, while upstream from that area the liquid will be cool incoming liquid. Thus, a fairly well defined separation will exist between the warm and the cool surface areas. Experiments have shown that this is not entirely desirable. Since the cooling effect or distribution of cool liquid is not uniform across the element 81, there is a tendency for the used to move about restlessly in an attempt to use only the coolest part of the element. In order to overcome this tendency, it has been found desirable to distribute the circuits in such a manner that passages containing relatively cool incoming liquid will be intermingled with passages containing outgoing relatively warm liquid, so that the relatively warm and cool liquid areas will not be sharply separated but will be mingled in such a manner that the user will not prefer one area of the element to another.

A preferred circuit arrangement for accomplishing this is shown in the element 81a in FIG. 12, wherein subscripts a—p have been added to the passage numerals 86 to facilitate discussion.

To avoid confusion, it should be noted first that the passages 86a—86p are connected together to form two substantially identical circuits extending between the inlet and outlet connections 26a, 28a. This has the effect of decreasing the pressure drop or resistance to flow through the cooling element for a given flow rate. For simplicity, in the following discussion, it will be assumed that only a single circuit is involved.

Starting from an origin point at the inlet tube 26a, in the upper lefthand corner of the element 81a as viewed in the drawing, the circuit extends along a devious path through passages 86a—86g, traversing substantially the entire area of the element 81, to a relatively remote point (i.e., the lower lefthand corner) of the element 81a. The circuit then returns to a terminal point at the outlet tube 28a through passages 86h—86p along a path substantially coextensive with and closely paralleling that followed by the passages 86a—86g, so that the passages containing relatively cool incoming liquid are paralleled by passages containing relatively warm outgoing liquid. Of course, the point at which the temperature of the liquid increases will be dependent on the location of the user's head. However, with the circuit arrangement shown, wherein the circuit is, so to speak, "folded back on itself," the paralleled incoming and outgoing liquid paths will distribute the cooling effect more uniformly and across a greater part of the element 81a than in the case of the circuit in the element 81.

While the foregoing discussion has been directed primarily to the case of a bedpillow type of cooling element, it should be noted that the invention is by no means thus limited. For example a larger element of similar construction can also be used for cooling, in the same manner, as a mattress cover, an automobile seat cover or the like.

The pump 14 is arranged to be connected to the cooling element circuit in FIG. 12 either directly, or through the isolation line 104, by means of a selector valve 94, so that the heat exchange element 81a can be used either for heating or cooling.

For example, if the FIG. 12 system is to be used for cooling, the selector valve 94 will be set in the position shown to couple the pump 14 to the element 81 through the isolation circuit 104. This will cause hot liquid forced from the pump 14 to flow past the valve 100, and this hot liquid will cool considerably before being returned through the valve 98 several cycles later. As before, the reciprocating motion of the liquid in the isolation tube 104 will cause cooling circulation through the element 81 and the coupling lines 26a, 28a.

If, on the other hand, the system is to be used for heating, the selector valve 94 will be set to couple the pump 14 directly to the inlet line 26a. This will force hot liquid from the pump 14 directly into the circuit of the element 81a on each pump stroke. Since the liquid drawn back into the pump from the outlet line 28a will have lost most of its heat, the auxiliary cooling circuit 96, 98, 100 will not be needed.

A somewhat simpler substitute for the auxiliary pump-cooling circuit 96—100 of FIG. 12 is shown in FIG. 13. This comprises a tank 106, of volume several times that of the pump stroke, in place of the tube 96 and check valves 98, 100. The tank 106 also can serve as a collector for any air inadvertently trapped in the system when it is filled. In fact, a small quantity of air can purposely be trapped in the tank 106, both to serve as a "cushion" for absorbing the pump stroke if the cooling circuit is inadvertently "kinked off," as well as a thermal isolator for reducing the required volume of the isolation line 104. In operation, the hot liquid discharged from the pump will rise to the top of the tank 106 on each pressure stroke, while on the suction stroke the pump will refill with relatively cool liquid from the bottom of the tank. At the same time, any air in the system will gradually work its way to the highest point in the tank where it will collect and serve the cushioning and isolation functions already stated.

If desired, the control valve 94 in the systems of FIGS. 10–13 can be in the form of a thermostatic valve, arranged as shown in FIG. 14, to hold the maximum temperature of the circulated liquid at some preselected level. The thermostatic valve 108 is placed in the outlet line 28a to "sense" the temperature of the liquid leaving the heat exchange structure 81a. With such an arrangement, an increase in the temperature of the liquid leaving the element 81a will cause the valve 108 to divert some of the liquid leaving the pump 14 to flow through the isolation circuit 96—100, thereby decreasing the heat input to the element 81a. In warm weather, of course, the thermostatic valve 108 will automatically divert all of the pumped liquid to flow through the isolation circuit 96—100, thereby setting the system for cooling action as previously described.

We claim:

1. A quiet-operating personal thermal system utilizing circulating liquid comprising a thin, flexible, heat exchange structure adapted to be placed in thermal contact with a person's body and including means defining liquid conducting passages extending throughout said structure and having inlet and outlet ports, a heat actuated pump, and supply and return liquid-conducting means coupling said pump to said inlet and outlet ports respectively to circulate liquid through said passages, said pump including a supply check valve in said supply liquid-conducting means to said inlet port and a return check valve in said return liquid-conducting means from said outlet port, a vapor generator chamber in which to form vapor by heating whereby to force liquid out of said pump due to displacement of liquid by vapor, means for heating said vapor generator chamber, a vapor condenser chamber in which to condense vapor generated in said generator chamber whereby to draw liquid into said pump to replace the condensed vapor, and a vapor transfer passage between said generator chamber and said condenser chamber.

2. The invention defined in claim 1 wherein said heat exchange structure comprises a fabric blanket having a

plurality of liquid-conducting flexible tubes disposed in said blanket, each of said tubes having one end connected to said inlet port and the other end connected to said outlet port, whereby all of said tubes are connected in parallel liquid-conducting relationship, each of said tubes being bent back near its center with its two halves extending along closely adjacent to each other so that the liquid flows in opposite directions through the two adjacent halves of the tubes, thereby to provide a uniform average temperature along each tube, and said tubes being substantially uniformly spaced throughout said blanket to provide a uniform heating effect throughout the area of the blanket.

3. The invention defined in claim 2, wherein each said tube makes a single pass along a first path from one edge of said blanket to the opposite edge and then returns to said one edge along a path closely paralleling said first path.

4. The invention defined in claim 1 wherein said heat exchange structure comprises superposed sheets of flexible, water-proof, heat-sealable material, said sheets being sealed together along spaced, finite abutting areas to define liquid conducting passages through the unsealed area between said sheets, said sealed areas being substantially equal in width to the widths of the unsealed areas therebetween.

5. A personal thermal system adapted for use with a circulating liquid comprising a thin, flexible, heat exchange structure adapted to be placed in thermal contact with a person's body and including means defining liquid conducting passages extending throughout said structure and having inlet and outlet ports, a heat actuated pump, an inlet tube connecting said pump to said inlet port, an outlet tube connecting said pump to said outlet port, said pump comprising a vapor generator chamber in which to form vapor by heating whereby to force liquid out of said pump due to displacement of liquid by vapor, said generator chamber communicating with said inlet tube, said displaced liquid flowing from said pump to said heat exchange structure through said inlet tube, and a vapor condenser chamber in which to condense vapor generated in said generator chamber, said condenser chamber communicating with said outlet tube, whereby to draw liquid into said pump through said outlet tube to replace the condensed vapor, means for heating said vapor generator chamber, and said inlet tube having a portion arranged in heat exchange relation with said heating means, said heating means supplying the energy to pump the liquid and also to heat the liquid.

6. The invention defined in claim 5 and further including a by-pass tube connected in parallel with said heat exchange portion of said inlet tube, valve means for controlling the relative flow through said by-pass tube and through said inlet tube portion, and a temperature-responsive control coupled to said valve means and being at least partially responsive to the temperature of the liquid returning from the outlet port for controlling said valve means in response to the temperature of the liquid returning from said heat exchange structure.

7. The invention defined in claim 5, and including means for regulating the amount of heat supplied by said heating means to said vapor generating chamber, and a thermostatic control connected to said regulating means, said thermostatic control being at least partially responsive to the temperature of the liquid flowing through said outlet tube for controlling the amount of heat supplied to said vapor generating chamber.

8. The invention defined in claim 5, wherein said heating means comprises a fluid fuel burner, a bottled-gas fuel supply source connected to deliver fuel to said burner, and a thermostatically controlled valve for regulating the flow of fuel from said supply source to said burner, said thermostatically controlled valve being at least partially responsive to the temperature of the liquid returning from said outlet port.

9. A bed cover comprising a flexible layer of fabric, means defining a plurality of flexible fluid carrying passageways within said fabric, a totally enclosed pump unit remotely disposed relative to said bed cover, flexible conduit means interconnecting said pump unit and said passageways, a heat transfer liquid circulated through said passageways by said pump unit, means for varying the temperature of said heat transfer liquid, and means responive directly to the temperature of the liquid returning from said flexible fluid carrying passageways for controlling said means for varying the temperature.

10. A bed cover comprising a flexible layer of fabric, means defining a plurality of flexible fluid carrying passageways associated with said fabric, fluid circulating means remotely disposed relative to said bed cover for circulating a heat transfer liquid through said passageways, flexible conduit means interconnecting said fluid circulating means and said passageways associated with said fabric, temperature responsive means responsive directly to the temperature of the heat transfer liquid returning from said flexible fluid carrying passageways, temperature varying means for varying the temperature of said heat transfer liquid, and means responsive to said temperature responsive means for controlling said temperature varying means.

11. A bed cover comprising a flexible layer of fabric, means defining a plurality of flexible fluid carrying passageways associated with said fabric, a fluid circulating element remotely disposed relative to said bed cover for circulating a heat transfer liquid through said passageways, flexible conduit means interconnecting said fluid circulating element and said passageways associated with said fabric, temperature responsive means responsive directly to the temperature of the heat transfer liquid returning from said flexible fluid carrying passageways, a temperature varying element for varying the temperature of said heat transfer liquid, and means responsive to said temperature responsive means for controlling one of said elements.

12. A heat exchange blanket adapted for use in maintaining a person's body at a comfortable temperature comprising a generally rectangular fabric, a pair of small header units in said fabric near one of its edges and forming liquid inlet and outlet ports for said blanket, a plurality of long liquid-conducting flexible tubes of capillary dimensions each connected at one end to the inlet header and at the opposite end to the outlet header, said tubes being in parallel liquid-conducting relationship between said inlet and said outlet headers, each said tube being bent near the center of its length at a bend forming the tube into a pair of closely adjacent parallel tube sections of substantially equal length with liquid flow through the adjacent sections of each tube being in opposite directions, said tubes being positioned in said fabric with said bends adjacent the opposite edge of the blanket from said headers, said bends being spaced at substantially uniform intervals along said opposite edge with the adjacent parallel sections of each tube extending from the bend in spaced parallel relationship across the fabric to the edge near said headers and thence turning and extending along the latter edge to the headers, whereby said blanket is maintained at a uniform temperature throughout.

13. A thermal blanket comprising two superposed layers of fabric material, said layers being secured together along spaced parallel lines defining a plurality of spaced parallel pockets extending a substantial distance across said blanket between a pair of opposite edges, a pair of small header units extending between said layers near a first one of said edges and centered along said first edge, said header units being positioned near each other and forming liquid inlet and outlet passages, a plurality of long flexible small-diameter tubes, each of said tubes being connected at one end to the inlet header and at the other end to the outlet header, said tubes being in parallel liquid-conducting relationship between the inlet and outlet header, each of said flexible tubes near its center

portion being bent back closely adjacent to itself with the two halves of the tube forming a pair of closely adjacent parallel sections for carrying liquid therethrough in opposite directions, each of said bent tubes being positioned in a pocket, with the respective bends of said tubes all being near the second edge of said blanket, said closely adjacent parallel sections of tube extending back along the respective pockets in spaced parallel relationship to said first blanket edge and thence along said first edge to said headers, whereby the blanket is maintained at a uniform temperature throughout.

14. A thermal blanket adapted for use in maintaining a comfortable uniform temperature adjacent to a person's body and including a fabric panel having a plurality of tubular passageways therein, said tubular passageways comprising an inlet port and an outlet port, liquid supply means and liquid return means along one edge of said fabric panel and being connected to said inlet port and said outlet port, respectively, and a plurality of liquid-conducting flexible tubes each connected at one end to said liquid supply means and each connected at the other end to said liquid return means whereby all of said tubes are connected in parallel liquid-conducting relationship between said liquid supply means and said liquid return means, each of said tubes being bent back adjacent to itself in a U-shaped bend near its middle forming a pair of adjacent parallel tube sections having liquid flow therethrough in opposite directions, said U-shaped bends being uniformly spaced along the opposite edge of said fabric panel from said liquid supply and return means, the parallel sections of all of said tubes being disposed in spaced parallel relationship extending across said fabric panel, whereby even though a substantial temperature differential exists between the fluid entering and leaving said tubes, the average temperature produced by said parallel adjacent tube sections is equal throughout the extent thereof, whereby said fabric panel is maintained at a uniform temperature throughout.

15. A heat exchange blanket adapted for use in maintaining a uniform temperature adjacent to a person's body comprising an area of flexible material having a plurality of tubular passageways, said passageways comprising liquid supply means and liquid return means near one edge of said area, and a plurality of flexible liquid-conducting tubes, each of said tubes being connected at one end to said supply means and at the other end to the return means, said tubes being in parallel liquid-conducting relationship between said liquid supply means and said liquid return means, each flexible tube being bent near its center into a U-shaped bend to form a pair of sections of substantially equal length with liquid flow therethrough in opposite directions, the pair of equal-length sections of each respective tube lying closely adjacent to one another, whereby the liquid flowing through each tube to its U-shaped bend and returning through each tube from its U-shaped bend travels along closely adjacent paths throughout the length of the tube, whereby even though a substantial temperature differential exists between the temperature of the liquid entering and leaving said tubes, the average temperature produced by the adjacent equal-length sections of said tubes is equal throughout the length thereof, whereby said area of flexible material in the blanket is maintained at a uniform temperature throughout.

16. A flexible thermal panel adapted for maintaining a uniform temperature adjacent to the human body comprising an area of flexible material having a plurality of parallel connected fluid-conducting passageways disposed therein in substantially uniformly spaced relationship throughout said area, each of said passageways doubling back upon itself at a point midway of its length, the two halves of each passageway being closely adjacent one another thoroughtout their lengths, whereby the fluid flowing into each passageway to the point midway between its ends follows a path which closely and continuously parallels the path of the fluid flowing from said point out of the respective passageway, whereby even though a substantial temperature differential exists between the temperature of the fluid entering and leaving said passageways, the average temperature produced by the adjacent halves of each passageway is equal throughout the extent thereof, whereby said panel is maintained at a uniform temperature throughout.

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