

[54] **ENCLOSED PUBLIC BATHS AND THE LIKE**

[72] Inventors: **Hans Hilgemann**, Recklinghausen; **Hermann Gettmann**, Wanne-Eickel, both of Germany

[73] Assignee: **Fa. Hans Hilgemann & Co. GmbH**, Hochlarmarkstr, Recklinghausen, Germany

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[58] Field of Search 165/1, 2, 19, 20, 21, 60, 29, 165/30; 62/428

[56]

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Primary Examiner—Charles Sukalo

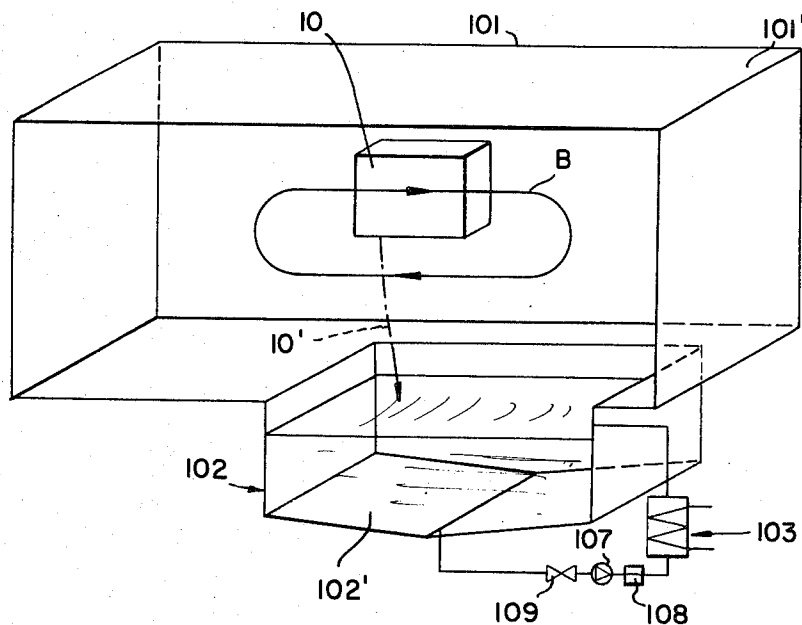
Attorney—Karl F. Ross

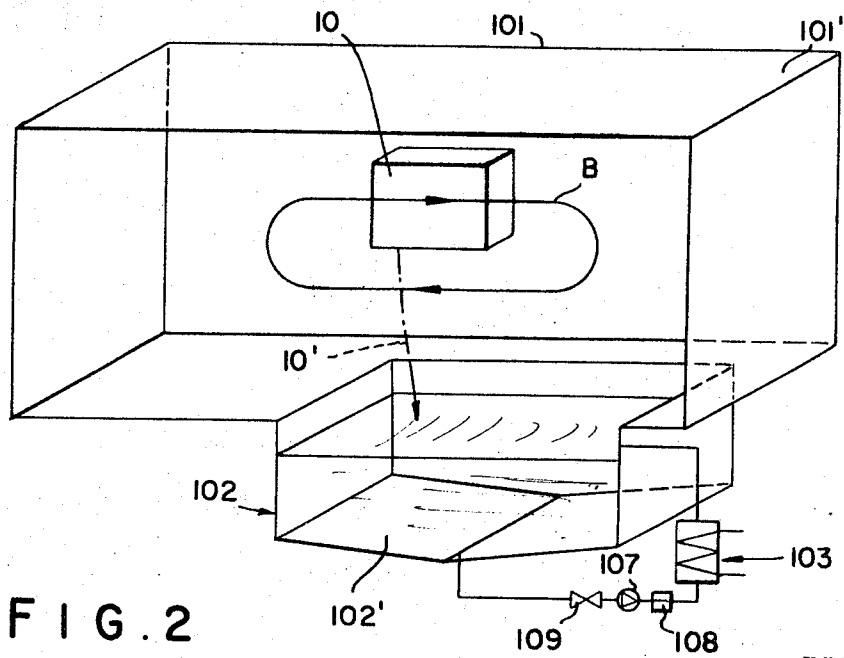
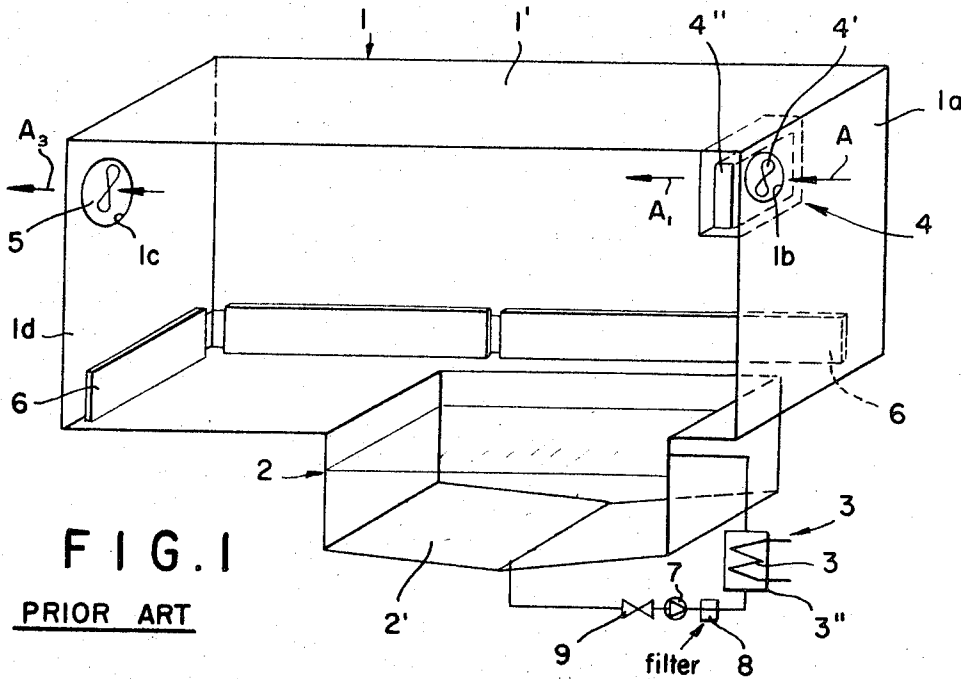
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ABSTRACT

An enclosed bath system, having a bath chamber in which a body of water has its surface exposed to the air in the chamber. A heat pump, having an evaporator, a condenser and a circulating primary heat-transfer fluid carrying thermal energy absorbed at the evaporator to the condenser, circulates air from the chamber into heat-exchanging relation with the evaporator and the condenser successively whereby the evaporator abstracts heat and moisture from the circulated air and the condenser reheats the circulated air prior to its return to the chamber.

14 Claims, 12 Drawing Figures





INVENTORS,
HANS HILGEMANN
BY HERMANN GETTMANN
Karl F. Ross
ATTORNEY

FIG. 3

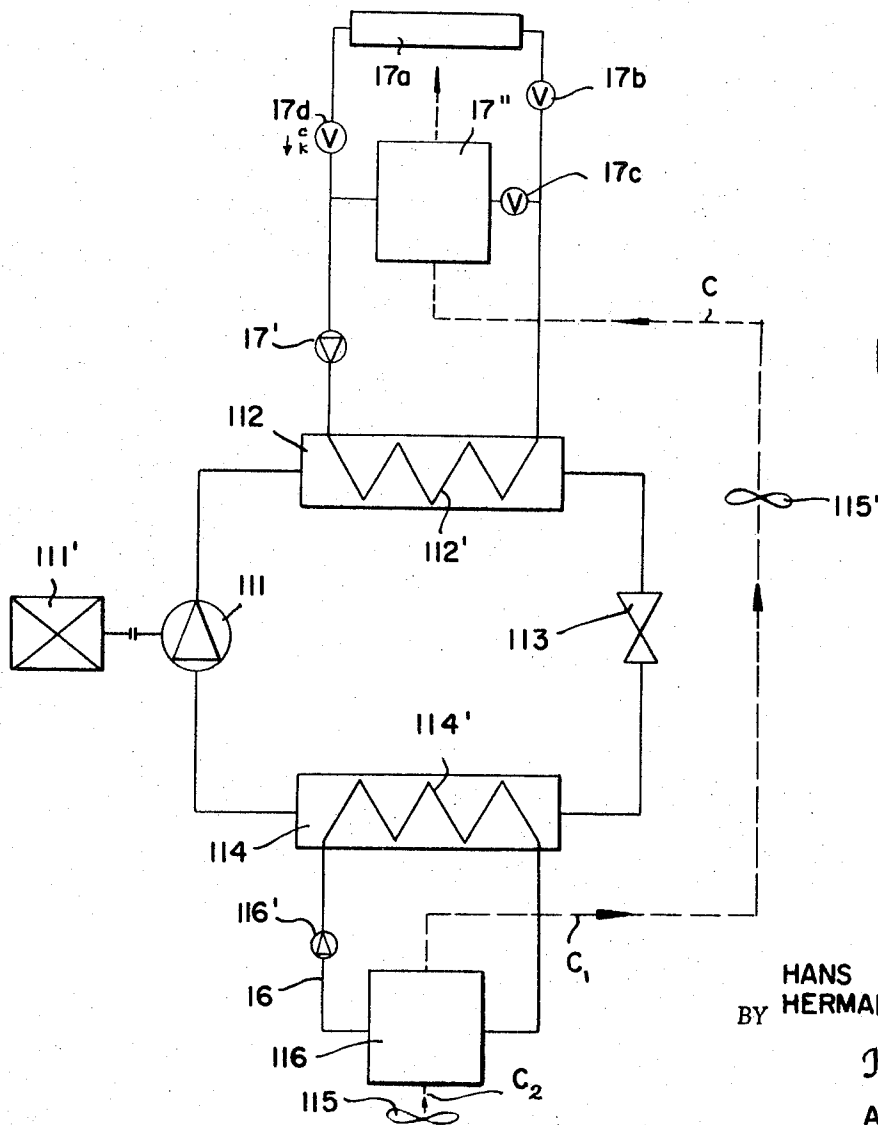
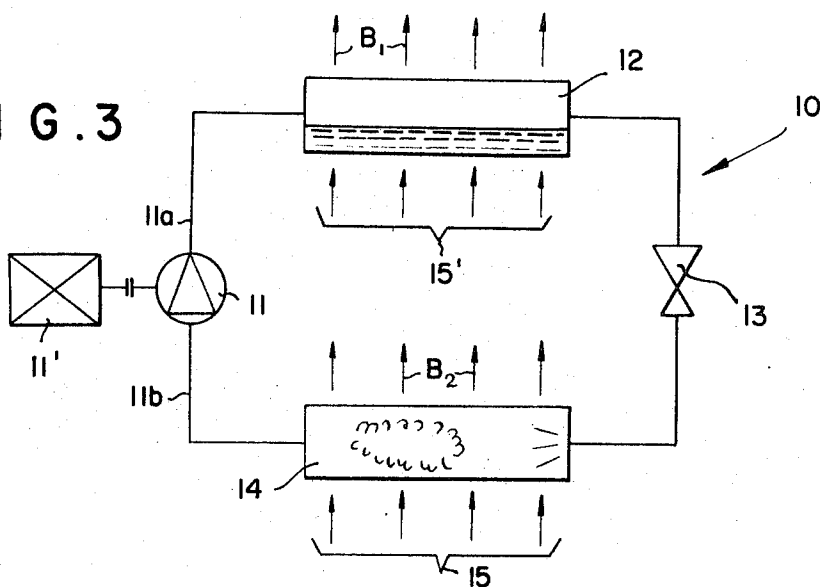
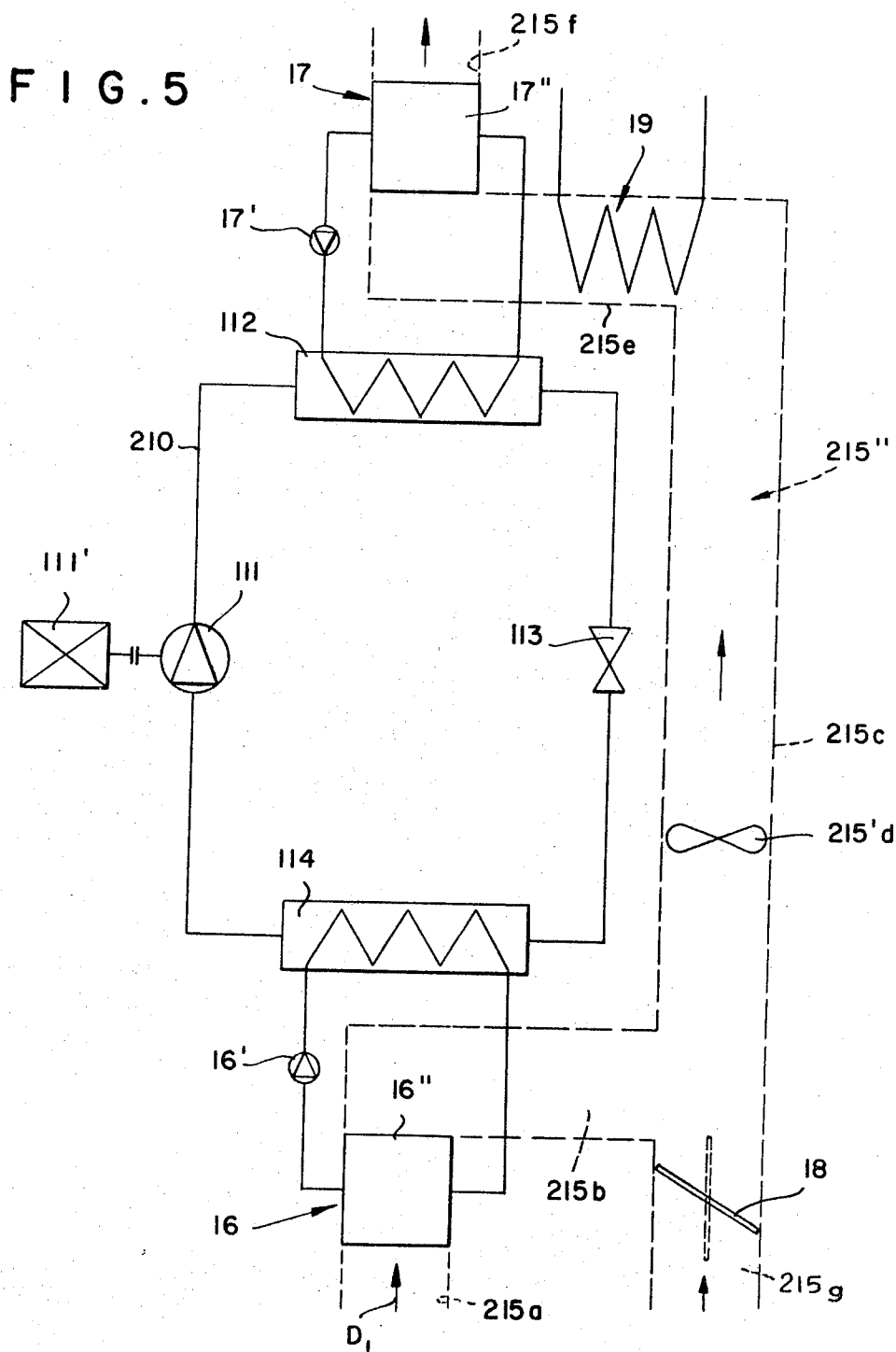


FIG. 4

INVENTORS,
HANS HILGEMANN
HERMANN GETTMANN
BY *Karl F. Ross*
ATTORNEY



INVENTORS,
HANS HILGEMANN
 BY **HERMANN GETTMANN**
Karl F. Ross
 ATTORNEY

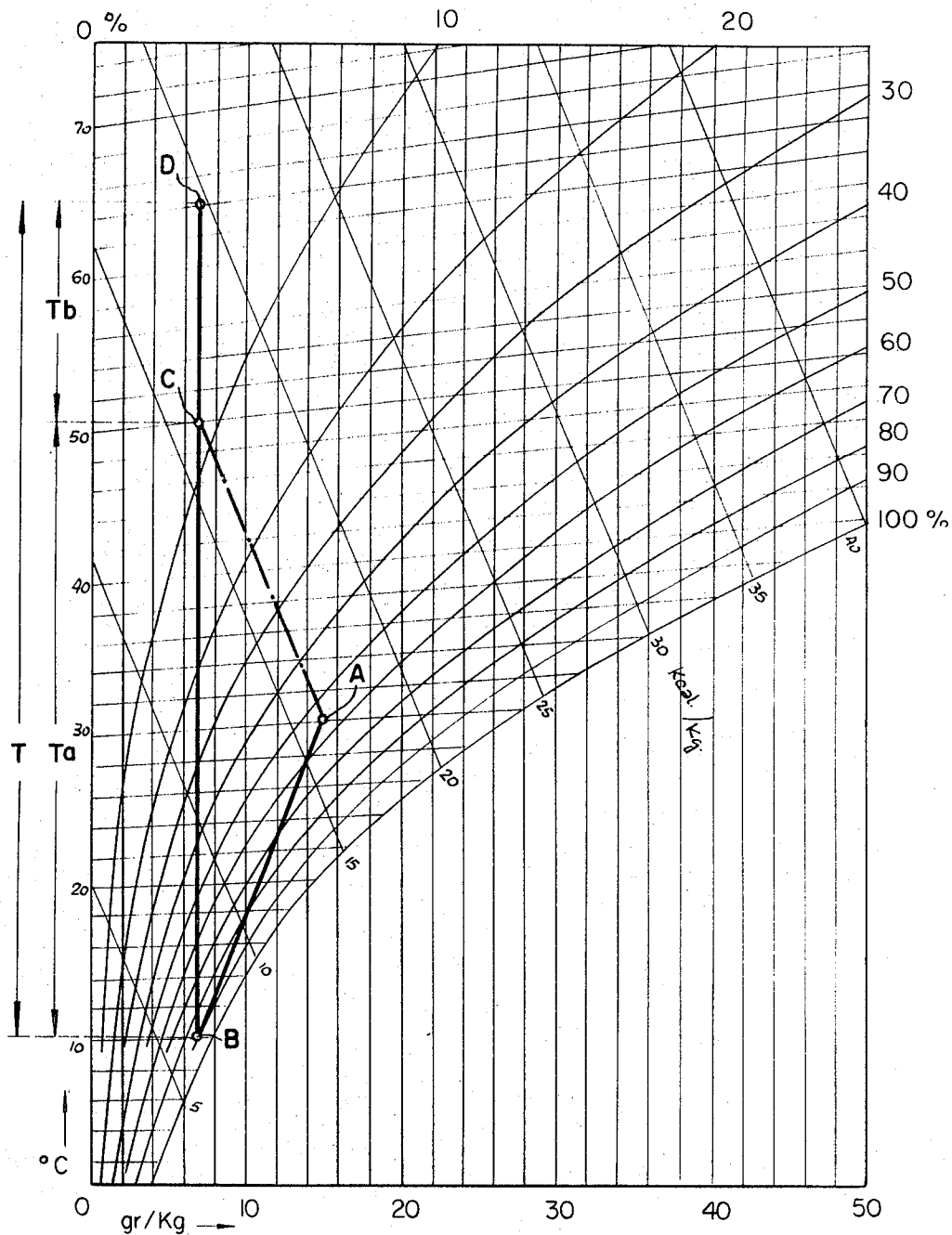


FIG. 6

INVENTORS,
 HANS HILGEMANN
 BY HERMANN GETTMANN
Karl F. Ross
 ATTORNEY

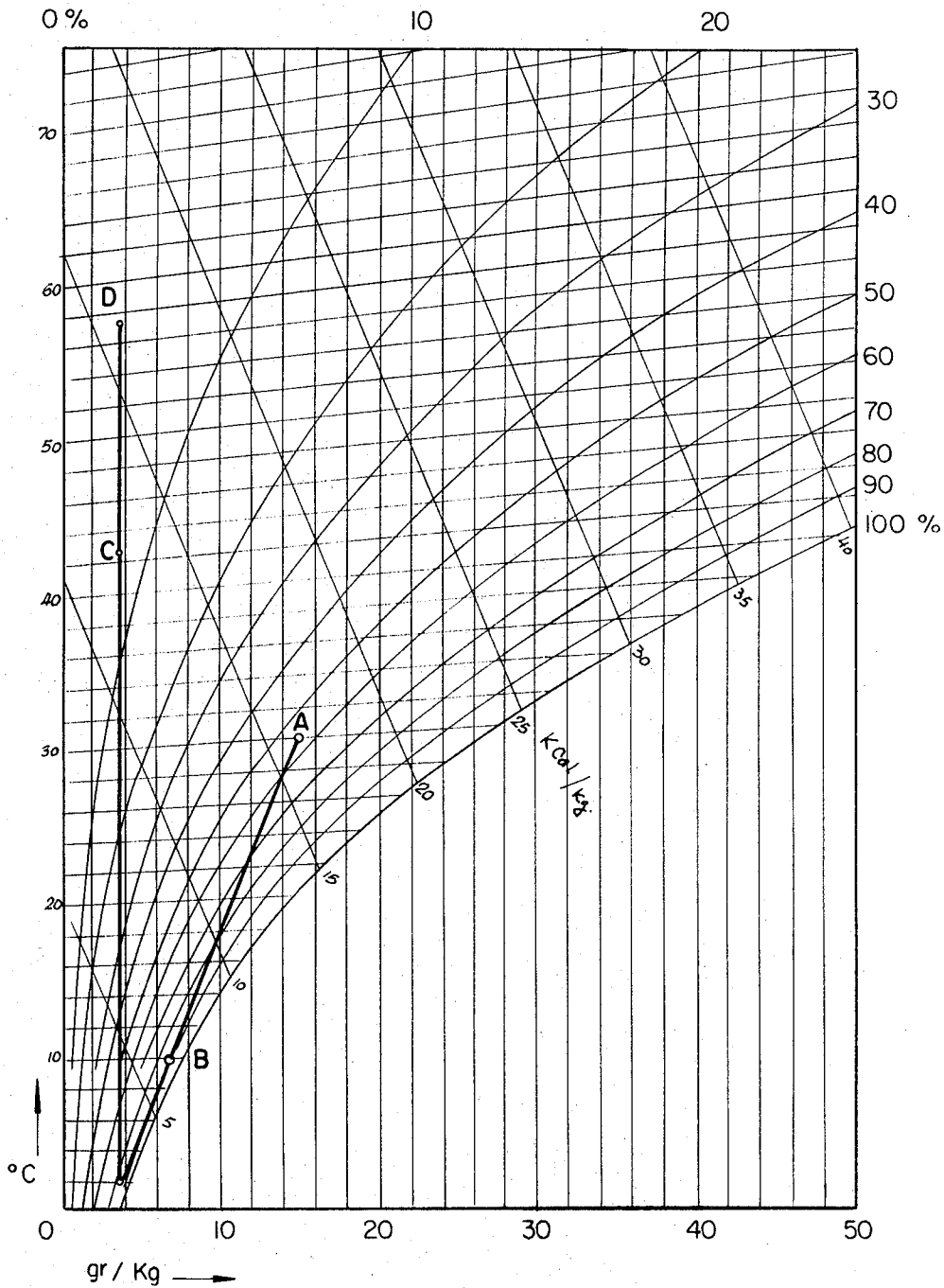
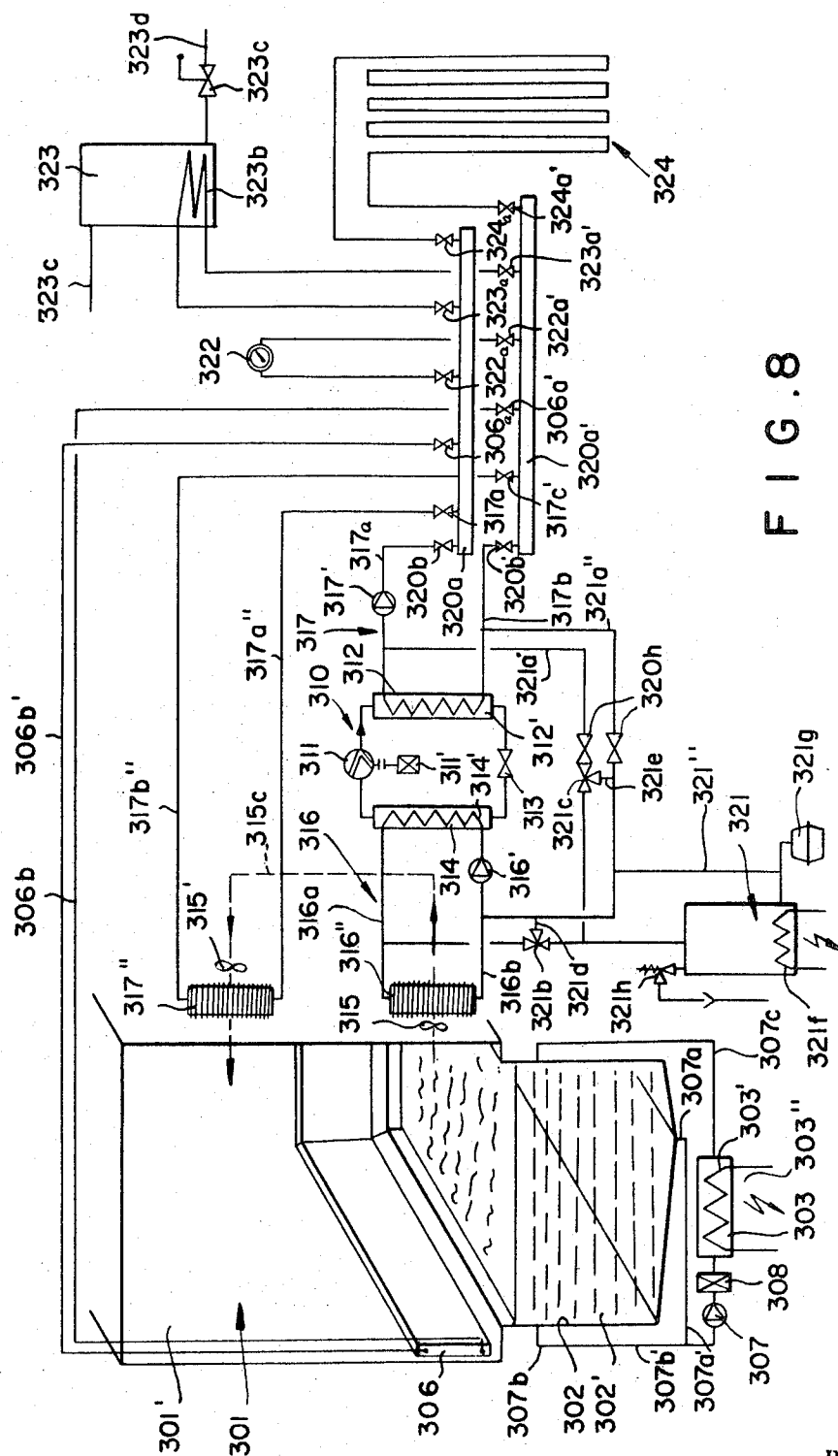


FIG. 7

INVENTORS,
HANS HILGEMANN
HERMANN GETTMANN
BY *J. Ross*

ATTORNEY



INVENTORS,
HANS HILGEMANN
BY HERMANN GETTMANN

John J. Ross
ATTORNEY

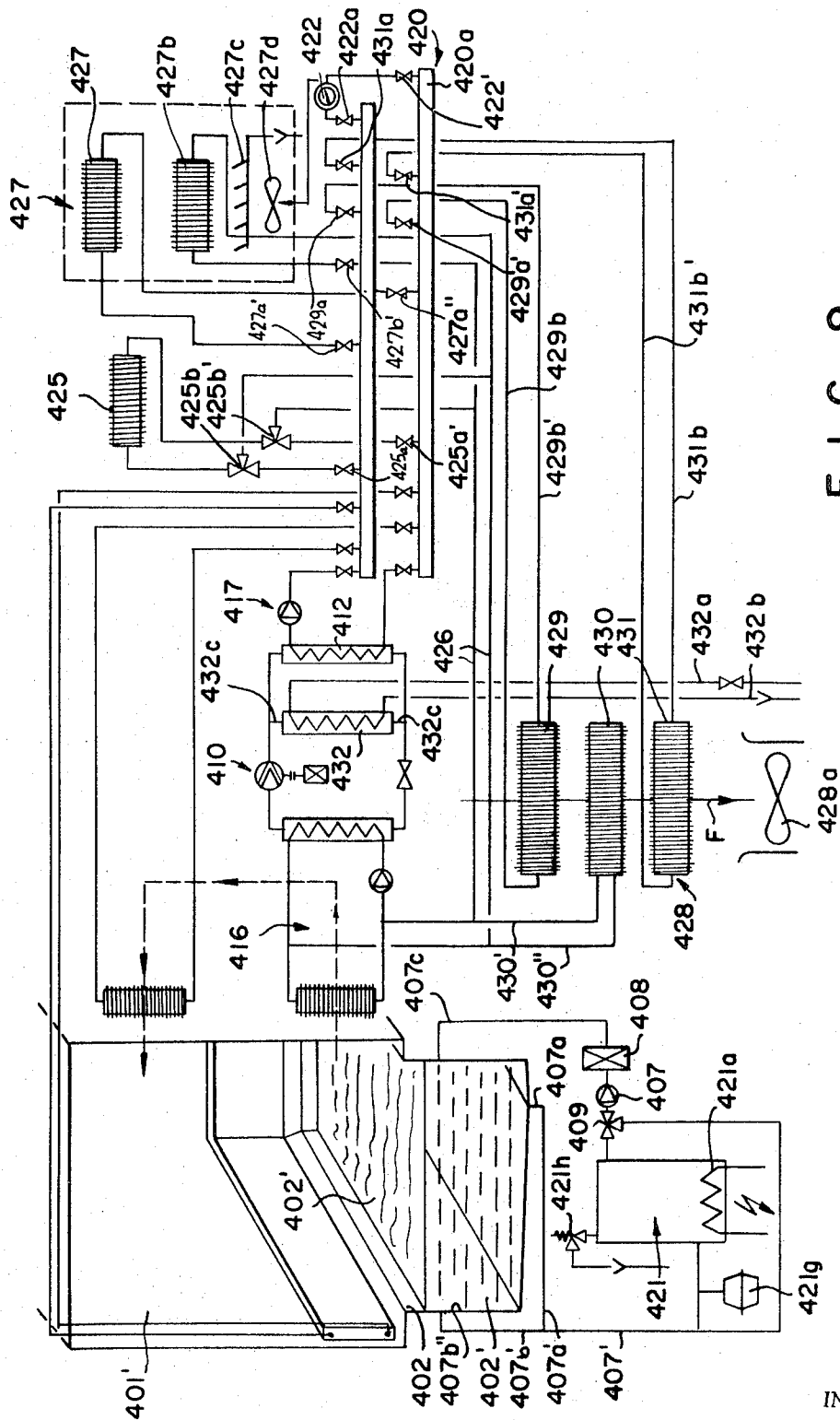


FIG. 9

INVENTORS,
HANS HILGEMANN
HERMANN GETTMANN
BY
Karl F. Ross
ATTORNEY

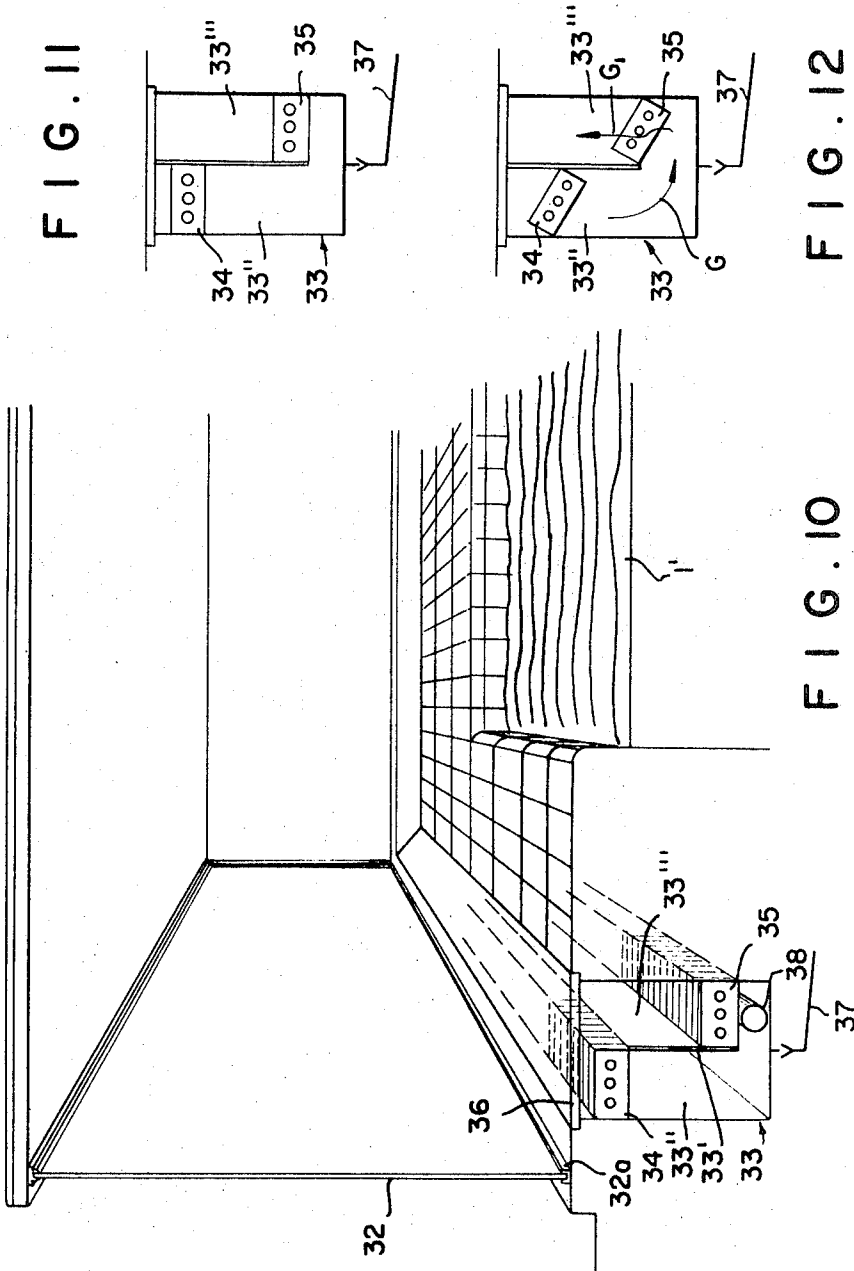


FIG. 11

FIG. 10

FIG. 12

INVENTORS,
HANS HILGEMANN
BY HERMANN GETTMANN
Karl F. Ross
ATTORNEY

ENCLOSED PUBLIC BATHS AND THE LIKE**1. FIELD OF THE INVENTION**

Our present invention relates to public bathing facilities of the enclosed type and, more particularly, to a public-bath arrangement which may include immersion baths for therapeutic purposes, enclosed swimming pool and steambathing facilities, ritual baths and the like in which a warmed body of water is available for bathing and the entire system is enclosed in a heated chamber or structure.

2. BACKGROUND OF THE INVENTION

It has been proposed heretofore to provide enclosed bathing facilities consisting of a large heated pool of water in an enclosure in which the atmosphere is regulated to avoid chilling the users of the bathing facility or the like. In a conventional public bath for therapeutic or recreational purposes, for example, the heated pool is provided within an enclosure maintained at the desired temperature by heating means, e.g., for heating the air drawn into the enclosure and/or radiant or convective heaters in or along the walls of the chamber.

In one such arrangement, heating makes use of an air preparation apparatus by means of which cold external air is drawn into the chamber through one or more ventilator devices, e.g., motor-driven fans, and is heated before being expelled into the bath chamber through one or more hot-air registers. Since the air is circulated through the chamber by being drawn in by the ventilators (and passed from the chamber through exhaust vents and appropriate fans or blowers), the moisture content or humidity of the heated fresh air is generally less than the moisture content or humidity of the air within the chamber. At the same time, a corresponding quantity of moist or humid room air is discharged into the atmosphere. In this manner, the desired humidity level of the air within the bathing chamber is maintained, the level being chosen to prevent sweating of the walls of the chamber and the consequent deterioration of the walls. However, during cold seasons the heat losses through the walls of the chamber, at glass and especially masonry portions thereof, is more pronounced and the temperature of the air in the chamber must be sustained by further heating means. Such heating means has included, in the past, static heat surfaces of the type provided in convection heating and radiant heating devices, i.e., convectors and radiators. These heaters are dimensioned to compensate for heat transmission losses so as to maintain the desired room temperature level.

Such systems have, however, the disadvantage that, on the one hand, relatively warm and moist air is dispelled into the atmosphere and the thermal energy and moisture thereof is lost, while, on the other hand, the air-heating apparatus at the intake side of the chamber is continuously supplying heat and moisture to incoming air. An additional disadvantage resides in the need for static heaters of the type mentioned earlier, requiring still further quantities of energy which must be applied at considerable cost.

3. OBJECTS OF THE INVENTION

It is, therefore, the principal object of the present invention to provide an improved enclosed bathing installation of the general character described and which is of reduced construction cost, affords increased usable space, and is less expensive to operate than theretofore.

Another object of this invention is to provide an enclosed public-bath facility for therapeutic and recreational purposes which avoids the disadvantages discussed above and provides increased thermal economy at minimum cost.

Yet a further object of our invention is the provision of a bathing facility of the enclosed type in which the internal atmospheric conditions can be controlled with ease and with considerable economy with respect to energy supplied from without.

4. SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, with a system in which a heating pump drawing thermal energy from the body of bathing water serves to control the temperature of the air in the enclosure and the humidity

thereof. According to a specific feature of our invention, the heat pump constitutes an air-preparation apparatus including an evaporator, a compressor and a condenser connected in the customary heatpump circulation path. In such a circulation, a high-volatility fluid, e.g., a Freon-type fluorinated or fluorochlorinated hydrocarbon, is compressed and the thermal energy produced during compression dissipated at one stage of each cycle, whereupon the liquified fluid is passed into an evaporator at which it is reconverted to gas while taking up thermal energy corresponding at least to the latent heat of vaporization and derived, in accordance with the present principles, from the water of the bath. Thereafter, the gas is compressed and the thermal energy released is dissipated in the condenser stage.

The present invention provides that heat-exchanger means is included in the cycle in which the heat-pump fluid is heated indirectly by the water of the bathing pool and the thermal energy thus absorbed is transferred to the atmosphere of the room in which the pool of water is enclosed to regulate the temperature and humidity of the internal atmosphere. Consequently, the moist of humid air in the bathing chamber constitutes a primary heat storage reservoir while the pool of water constitutes a secondary heat storage reservoir for the heat pump. Excess thermal energy transferred to the room air from the water pool is conserved by retransfer to the water and the heat-pump cycle may thus serve to cool the room air and thereby extract moisture therefrom or, as necessary, to warm the room air. In fact, it has been found that the heat extracted from the atmosphere heat-storage reservoir will generally suffice to cover the heat losses through the walls of the room and thus prevent sweating of the walls. Preferably the pool of water is electrically heated although any other form of heating may be used as well, depending of course upon the economics of the situation.

According to a more specific feature of the invention, the evaporator of the heat pump or compressor is exposed to the atmosphere in the enclosure and withdraws excess thermal energy from the atmosphere and thereby dehumidifies the atmosphere, while the condenser associated with the heat pump transfers the abstracted atmospheric heat to an energy consumer as will be apparent hereinafter. The condenser may be used to transfer heat to the previously cooled atmosphere and thus serves as an air-heating means. The evaporator, within which the refrigerant fluid is transformed from the liquid state to the vapor state, however, functions primarily as a condenser vis-a-vis the room atmosphere from which excess moisture is condensed. In this manner it is possible to provide a circulation of the room air (via fans or blowers) so that the room air passes into heating exchange with the evaporator and condenser of the heat pump.

Alternatively, intermediate heat-transfer circulations may be provided at each point in the heat-exchange system. Thus at either or both of the primary heat-exchange members of the heat pump, namely, the evaporator and the condenser, a secondary circulation or body of a heat-exchange fluid may be provided.

A typical secondary heat exchange fluid is water, which may be in indirect heat exchange with the refrigerant in one of the primary members to thereafter transfer or absorb thermal energy to or from the air within the enclosure at secondary heat-exchange members. At these members, the room air is passed in direct heat exchange with the secondary heat-exchange liquids and is consequently in indirect heat-exchanging relationship with the refrigerant.

To renew the atmosphere within the enclosure, which may become gradually depleted by the individuals using the facility, fresh air is mixed with the air passed into heat exchange relationship with the evaporator (either in direct, or indirect heat exchange as previously noted). To this end, along the circulation path of the air through the evaporator or through the secondary heat exchanger associated with the evaporator, there will be provided one or more ventilators communicating with the external atmosphere, the fresh-air passage being pro-

vided with throttling flaps or like valve means to control the proportion of fresh air drawn into this circulation.

The water collected by condensation from the moist air at the evaporator is returned to the water pool by a pipe and/or pump arrangement, thereby reducing the loss of water from the bath. This not only diminishes the energy cost of the system but also renders the arrangement more economical in areas in which water may be scarce.

Economical operation of the system of the present invention may involve the use of low-cost energy at low-tariff period and the storage thereof, in effect, for use during high-tariff periods. If the system makes use of electrical energy and the low-tariff period is in the evening, the secondary heat-storage reservoir can be used as an economical repository of thermal energy built up during the evening hours whereupon the repository is drawn upon during the subsequent high-tariff periods to provide the thermal energy necessary for room heating and bath heating.

The low-cost energy is stored in the form of slightly excessively heated water in the bath or pool, the thermal energy being gradually transferred to the internal atmosphere during periods of need. The system is especially effective in the case where insulation of the walls of the facility is incapable of retaining all or most of the heat used in the facility, i.e., when the walls are composed of material of a high heat transmission coefficient such as glass. It will be noted that prior-art facilities of this type must make use of a heating source during hours of the principal use of the facility to overcome the heat loss, whereas the system of the present invention permits the use of low-cost heat, for example, rather than high-cost energy, to raise the temperature or store heat in the water of the bath for subsequent transfer to the internal air as heat loss occurs through the walls. However, even the use of electricity as the prime energy source is economical because the total heat requirements of the system of the present invention is much lower than comparable prior-art systems. The bath constitutes a thermal reservoir of such high capacity as to permit a minor rise in temperature to make available large quantities of heat for the atmosphere.

According to still another feature of this adventure at least part at least part of the heat evolved at the condenser of the heat pump is dissipated in static heaters such as convectors and radiators disposed in the bath chamber or in some other space to be heated proximal to or remote from the bath facility.

The system of the invention thus need not exclusively be provided for the air and temperature conditioning of the bath chamber and associated spaces in the bath house but may allow for the control or operation of dwelling-house heating systems, air-conditioning installations, and water-heating systems or the like close to or remote from the bath chamber.

To this end, the invention provides that the secondary heat storage reservoir, i.e., the water bath and, possibly, an additional hot water storage reservoir, constitutes the thermal reservoir for a heat pump, the thermal energy of which is dissipated in a room-heating system, air-conditioning system or water-heating system of one or more structures or rooms in the vicinity of the bath chamber, thereby eliminating the need for further thermal energy sources.

5. DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is a perspective view diagrammatically illustrating the prior-art system of operating a public bath;

FIG. 2 is a similar view of a system in accordance with the present invention;

FIG. 3 is a flow diagram illustrating the heat pump of this invention as used in the system of FIG. 2;

FIG. 4 is a circuit diagram of the heat pump provided with two heat exchangers for indirect transfer of heat in accordance with the invention;

FIG. 5 is a circuit diagram similar to FIG. 4 and illustrating how the system thereof may be used with a ventilation arrangement;

FIGS. 6 and 7 are Mollier diagrams illustrating the thermodynamics of the system;

FIG. 8 is a circuit diagram, with portions of the bath chamber in perspective, illustrating the system of the present invention in somewhat greater detail;

FIG. 9 is a view similar to FIG. 1 illustrating how the arrangement may be used for the heating of other chambers as well as the bath chamber;

FIG. 10 is a perspective view of a bath chamber having two convectors according to the present invention;

FIG. 11 is a vertical cross-section, in diagrammatic form, through the convector assembly of FIG. 10; and

FIG. 12 is a view similar to FIG. 11 with the convectors positioned somewhat differently.

6. SPECIFIC DESCRIPTION

In the prior-art system illustrated in FIG. 1, the bathing facility comprises a pool 2 of water contained in an enclosure 1, the interior 1' of which constitutes a plenum of room air. The water in the pool 2 is heated by a unit 3 represented in diagrammatic form and comprising, for example, a heating coil 3' brought to an elevated temperature by an external source not otherwise illustrated.

The air in the chamber 1' is heated by a heating unit 4 represented in diagrammatic form and mounted upon the right-hand wall 1a of the structure. An opening 1b is provided in this wall so that a fan 4' can draw fresh air into the chamber 1 as represented by the arrow A and forcing fresh air through a heating register 4'' into the chamber as shown by arrow A₁.

A pump 7 circulates the water contained in the pool 2 and represented at 2', through the housing 3'' around the coil 3' via a filter 8. A valve 9 controls the amount and circulating rate of the water from the housing 3 of the heater and a pipe returns the warm water to the pool 2. The system illustrated in FIG. 1 may be used for therapeutic bathing, recreational bathing and as a public or community bath or swimming pool.

The heater 3 is generally provided to bring the temperature of the water in the pool to about 27° to 28° C.

As the bath temperature increases and during use, water vapor passes upwardly into the atmosphere of the chamber 1' and increases the humidity of moisture content thereof beyond a predetermined level which is selected to minimize or prevent sweating of the walls of the chamber. This humidity level is related to temperature in the sense that the temperature of the boundary layers of air adjoining the wall must remain above the dew point of the moist air in the chamber 1'.

The heater 4 then may deliver fresh air at a temperature of about 30° C. and corresponding to the temperature in the bath chamber, although with the reduced moisture content of outside air. A corresponding quantity of moisture-laden air is discharged through an opening 1c in the opposite wall 1d of the housing (arrows A₂ and A₃) by a ventilator or fan 5. The heat loss by conduction through the walls of the structure, i.e., the so-called transmission losses, are made up by a plurality of static heated surfaces 6 provided at the lowest-temperature regions of the chamber and here illustrated to be convectors or radiators.

It will be apparent that this arrangement is a thermodynamically open system, that the level of water in the pool 2' continuously drops as expelled air carries moisture out of the structure, and that considerable quantities of thermal energy are lost with the expelled air and must be made up by some external heating source.

In FIG. 2, by contrast, the system of the present invention provides for the chamber 101' of the bath structure 101, a thermodynamically closed system which is represented diagrammatically at 10 and circulates air through this closed system (arrows B). The pool 102 is here similarly shown to contain a body of water 102' which may serve as a heat-storage reservoir when it is originally brought to an elevated temperature by a water-heating system 103, 107-109 as previ-

ously described for the system 3, 7-9 of FIG. 1. In this case, the formation of condensate upon the walls of the structure is avoided by dehumidification of the air within the structure during air circulation, while, at the same time, the temperature is maintained. Both operations are performed by a heat pump which is represented generally at 10. The air-heating system 4, the air-discharge system 5 and the static heating system 6 of FIG. 1, all can be eliminated if desired, although frequently such systems may be provided in conjunction with the system according to this invention.

The heat pump of the present invention may be that illustrated diagrammatically in FIG. 3 and generally designated at 10. This system comprises a compressor 11 which is driven by an electric motor 11' and circulates a refrigerant such as a chlorofluorinated hydrocarbon of the Freon type.

By way of example, the compressor 11 may be designed to deliver at its discharge side 11a, a pressure of 16 atmospheres gauge at 70° C. from an input of 2 atmospheres gauge at its intake side 11b. A condensor 12 is provided to dissipate heat from the refrigerant and thereby permit the latter to liquefy, the heat being passed into the atmosphere in the bath chamber as represented by the arrow B₁ which represents a flow of air from a blower or the like diagrammatically indicated at 15' to constitute part of the air-circulation means associated with the heat pump. The details of the air circulation system may be those presented in FIG. 5.

The liquefied refrigerant may then pass through an expansion valve or pressure-reducing valve 13 to an evaporator 14 in which the liquid or compressed gas is expanded to the lower pressure of about 2 atmospheres gauge, while abstracting heat from the room air forced through the evaporator as represented at 15 and by the arrows B₂.

In practice, it has been found that air having a temperature of 30° C. and a moisture content of 15 grams of water per kilogram of air, may be fed through the evaporator 14 and brought at B₂ to a temperature of 10° C. whereupon 7 grams of water per kilogram of air is removed. The cooled and demoisturized air then passes through the condensor 12 and is reheated thereby to a temperature of about 50° C. by heat recirculation and finally to 64° C. by the thermal energy produced by compression of the refrigerant.

As a consequence, the air emerging at B₁ is demoisturized and warmed and is mixed with the remaining air in the chamber to preclude condensation upon the walls and compensate for transmission losses of heat from the structure.

The system of FIG. 3 is shown to operate for the direct heat exchange between the air in the bath chamber and the refrigerant in the heat-pump system. In large community bathing facilities, however, direct heat exchange of this type may not be feasible and we prefer to made use of a secondary heat-transfer medium. FIG. 4 illustrates such an arrangement.

In FIG. 4, the electric motor 111' drives the compressor 111 to force high-pressure fluid to the condensor 112 in which the high-pressure refrigerant is liquefied with the abstraction of heat. The condensor 112 here functions as a heat exchanger transferring this abstracted thermal energy to a coil 112' through which water is circulated in a hot-water cycle represented generally at 17.

The hot-water cycle includes a pump 17' feeding water to the coil 112' and thereby circulating the water through a radiator 17'' through which the room air can be passed by a fan 115' as represented by the arrows C. Heat-exchange member 17'' can be a liquid/gas heat exchanger of the type in which a multiplicity of finned tubes contacts the hot water while air is forced through the spaces between and around the fins of the tubes. In addition, all or part of the thermal energy to be transferred to the air in the bath chamber may be passed through static heaters 17a in the form of convectors or radiators such as have been illustrated at 6 in the system of FIG. 1 and disposed along the floor or the chamber at the walls thereof. Valves 17b and 17c can control the portion of the secondary heat exchange liquid supplied to the static heaters 17a and the heat exchanger 17'', while a check valve 17d prevents back flow of the secondary heat exchange liquid.

Similarly, a cold-water circulation is provided, as shown at 16, to remove moisture from the air. The cold-water circulation includes a coil 114' in the evaporator 114 to which the refrigerant is supplied by a pressure-reducing valve 113, the coil 114' being connected in circuit with a pump 13' and a liquid/gas heat exchanger 16''. This heat exchanger may be composed of finned tubes through which the liquid is circulated and is traversed by room air as represented by the arrows C₁ and forced through the heat exchanger 16'' by a fan 115. Fans 115 and 115' constitute intake fans for the air circulation system. Here too, the air traversing the heat exchanger 16'' is of a low temperature and low moisture content, but is reheated in heat exchanger 17'', prior to its return to the bath chamber.

In FIG. 5, we show a corresponding arrangement in which, however, the air circulation passing through the heat pump is represented in broken lines and designated as 215. In this system, of course, the heat pump members 111, 111', 112 to 114 and secondary heat exchange circulations 16 and 17 are identical to those of FIG. 4.

An intake duct 215a is provided to admit air from a first blower into the heat exchanger 16'' as represented by the arrow D₁, the circulation path including a branch 215b leading from the heat exchanger 16'' into the main or trunk conduit 215c. The latter is provided with a fan 215d by means of which the relatively cool but demoisturized air is supplied to a branch tube 15e leading to the warm-water heat exchanger 17''. The discharge side of this heat exchanger feeds a duct 215f which opens into the room to be warmed.

To admit fresh air into the system, we provide a further branch 215g communicating with the external atmosphere and leading it to the trunk 215c behind the fan 215d. An adjustable lousie flap 18 is provided in branch 215g to control or throttle the flow of fresh air into the system and thus the proportion of fresh air mixed with the recirculated air in the duct 215. A further heating coil 19 is provided downstream of the fan 215d for heating air recirculated through the system in the event of failure of the heat pump 210. The heat pump, of course, is used in a system of the type shown in FIG. 2.

The thermodynamic considerations of the system of this invention are illustrated in the Mollier diagrams of FIGS. 6 and 7. In periods in which the fuel cost is low, the water in the bathing pool or tank can be heated from a temperature of 27° C. to a temperature of about 28° C. or slightly higher. In most instances, for electric power, the low-tariff period corresponds to the evening and it is economical during this time at prevailing low electrical costs to use electrical energy to heat water in the bathing pool. At approximately 6 a.m. the bath heating can be cut off while the heat pump 10 is permitted to continue in operation, it being assumed that this time corresponds substantially to an increase in the energy rates.

The air at a temperature represented at A and plotted along the ordinate in FIGS. 6 and 7, is passed into direct exchange with the evaporator 14 or into indirect heat exchange therewith by, for example, the heat exchanger 16'' and is thereby cooled to point B with a corresponding reduction in the moisture content of about 8 grams per kilogram (as plotted along the abscissa). This moisture is returned to the bath as represented by the dot-dash line 10' in FIG. 2. Upon passage of this cooled and demoisturized air to the condenser 12 or the heat exchanger 17'', the air is risen to the temperature represented at state C by the thermal energy produced at the evaporator and to the additional state D by the thermal energy contribution of the compressor. The total temperature rise T thus consists of the two components T_a and T_b corresponding to the contribution of circulated heat recovered at the evaporator and replaced in the air at the condensor B and corresponding to the added quantity of thermal energy generated at the compressor, respectively.

In the present description the term "evaporator" will be used invariably to refer to the heat-pump member at which the refrigerant liquid is converted to vapor in spite of the fact that it, in effect, constitutes a condenser for the moisture in the room air. Correspondingly, the condenser of the heat pump

will invariably be described as such in spite of the fact that it heats the circulated air.

To operate the heat pump and especially the condensers 12, 112 economically, while preventing the temperature difference between the moist air and the dehumidified air, which is mixed therewith from becoming excessive, it is important to maintain the difference between enthalpy of the refrigerant at the condenser and the enthalpy of the dehumidified air passed therethrough at a level determined by the condensation point of the refrigerant and substantially constant. For this reason, it is preferred to add fresh air to the dehumidified air circulated through the system especially since the fresh air is generally required to replace the diminution of oxygen. Under these circumstances, the portion of the air subject to cooling and finding itself in the state represented at B, may be combined with the fresh air (E) to arrive finally, after heating, at the state represented at D' prior to its return to the bath chamber. Throughout the foregoing considerations, it has been a condition that the heat supplied to the air originally derives from the bath which is heated by means other than the heat pump.

The following Example may clarify the economic factors involved in the present invention.

In a conventional public bath with static heating surfaces operable both day and night to compensate for transmission losses, the quantity of heat necessary to compensate for such losses $Q_T = 10,000$ kcal/hr, the quantity of heat necessary to heat the fresh air introduced into the chamber to the temperature therein is $Q_L = 12,000$ kcal/hr and the quantity of heat necessary to maintain the temperature of the water bath in spite of evaporation is $Q_V = 6,000$ kcal/hr. The total hourly consumption is consequently 28,000 kcal/hr and a cost of approximately \$2.80 can be estimated if low-cost oil heat is used.

A public bath of the same dimensions, operated in accordance with the present invention, requires that the transmission loss $Q_T = 10,000$ kcal/hr and the vaporization energy $Q_V = 6,000$ kcal/hr be replaced. However, the recirculation system eliminates substantially the Q_L insert requiring replacement.

Moreover, during high-energy cost, for example during the day between 6 a.m. and 6 p.m. the Q_T or transmission loss of the system according to the present invention is replaced or drawn from the secondary heat storage reservoir, namely, the water pool 2', by vaporization and convective, conductive and radiative heat transfer to the ambient air in an amount of 6,000 kcal/hr, the remaining 4,000 kcal/hr being supplied by the compressor 11 or 111. The bath of water, however, is cooled only very slowly from its temperature of 28° C. to about 27° C. During the low-cost hours from, say, 6 p.m. to 6 a.m. the following morning, the bath is heated by an expenditure of 12,000 kcal/hr in electrical energy while the heat pump compressor contributes an additional increment of 4,000 kcal/hr. This suffices to bring the temperature of the water in the pool to 28° C. and closes the cycle. While electrical costs may also bring the energy requirements to, for example, \$2.80 per day, there are numerous advantages to the system of the instant invention. Firstly, the quantity of heat Q_V equals 6,000 kcal/hr is repeatedly recovered so that only 10,000 kcal/hr (Q_T) need be supplied to eliminate the heat dissipated into the atmosphere. Only 240,000 kcal/day is required whereas the conventional system must consume 672,000 kcal/day. As the number of glass walls and the area thereof increase in the structure, there is a corresponding decrease in the danger that the walls will sweat and the destructive effect of such sweating. In conventional bathing facilities, however, the sweating must be prevented by use of an additional 8,000–30,000 kcal/hr in the air heating Q_L to bring the total to 20,000–25,000 kcal/hr. This additional heat consumption is completely excluded by the system of the present invention. Practically any heat source may therefore be used with considerable economy.

In FIG. 8, we have shown a system which permits the pool 302 and the water 302' thereof to function as a heat storage

reservoir, the thermal energy of which may in part be used for the heating of ancillary chambers and systems. In this enclosed bath structure 301, the means for heating the bath 302' is represented as including an electrical heater 303 whose heating coil 303' is energized by an external electrical source. Through the surrounding housing 302'' of this heater, the bath water may be circulated by a pump 307 through a filter 308. A drain 307a at the bottom of the tank and an overflow or skimmer 307b communicate with the top of the tank for respective conduits 307a' and 307b' leading to the inlet of the pump 307. At the outlet side, the heater 303 communicates via line 307c with the tank close to the top of the latter. The bath 302' is heated by repeated circulation of the liquid of the bath through the electrical heater 303'.

In this system, moreover, the heat pump 310 includes a compressor 311 driven by an electric motor 311' and feeding refrigerant to a condenser 312 of the liquid/liquid heat-transfer type. The coil 312' of this heat exchanger, through which the secondary heat exchange liquid is circulated, is tied in series with the pump 317' as will become apparent hereinafter. The liquid refrigerant, after traversing the pressure-reducing valve 313, is vaporized in the evaporator 314 which is also of the liquid/liquid heat-exchange type and transfers cold to a secondary fluid circulated by a pump 316' through the coil 314' thereof. In operation, therefore, the refrigerant is drawn in a vapor state into the compressor 311 from the evaporator 314, is compressed and partly or completely condensed or liquefied in the condenser 312 while transferring heat to a hot secondary fluid, before passing into the evaporator 314 where it abstracts heat from the cold secondary fluid.

The cold secondary fluid circulation is a cold-water cycle in which the pump 316' forces cold water through the coil 314' and thereafter through a heat exchanger 316'' as described in connection with FIG. 4. The heat exchanger 316'' is, of course, in the circulation path of air drawn from the chamber 310' above the bath 302' by a fan 315 and cooled by passage through this heat exchanger 316''. The air, via duct means of the type shown in FIG. 5, is then led to the heating unit 317'' in which heat from the secondary fluid is used to reheat the previously cooled and dehumidified air. The fan 315' may facilitate recirculation of the air and may be used in part to draw fresh air into the system.

The hot water for heat exchanger 317'' is delivered to the latter by a manifold system constituting the load of the secondary hot-water system. The manifold system includes a pipe 320a forming the inlet manifold and connected to the pump 317' via a valve 320b while the outlet manifold is represented at 320a' and is connected via a valve 320b' with the intake side of the coil 312' of the condenser 312. Lines 317a'' and 317b'' connect the heat exchanger 317'' via valves 317c and 317c' with the manifold pipes 320a' respectively. When the valves 320b, 320b', 317c and 317c' are open, hot water from the secondary circuit is circulated through the heat exchanger 317''.

When the system of the present invention is used for the heating of spaces apart from the bath chamber, for air-conditioning or hot-water heating, we and 321c are a tertiary heat-storage reservoir, in the form of a hot-water heater 321. The hot-water heater 321 is connected by ducts 321' and 321'' with lines 316a and 316b leading to and from the heat exchanger 316'', respectively, in the cold-water secondary circulation represented generally at 316. Lines 321a' and 321a'' further connect the outlet and inlet of the hot-water heater 321 with the lines 317a and 317b of the hot-water secondary circulation represented generally at 317. Mixing valves 321b and 321c are provided in the line pairs 321', 321'' and 321a' 321a'', respectively, to form mixtures via mixing lines 321d and 321e of hot water with cold return water.

The heater 321 is provided with an electric heating coil 321f as will be apparent from FIG. 8 and communicates with an expansion vessel 321q as well as with a pressure-relief safety valve 321h.

At the hot-water circulation 317, one or more additional hot-water consumers may be provided as is also illustrated in this Figure. For example, we show a set of valves 306a and 306a' for connecting the stationary heating surfaces 306 in the hot-water circuit, via lines 306b and 306b'. The static heating surfaces 306 may be radiators or convectors as described for the members 6 of FIG. 1. Valve 306a and 306a' of course are connected to the lines 320a and 320a' which constitute manifolds for feeding hot water to the consumers and returning the hot water to the heat exchanger 312 as previously described.

Another heating unit which may be employed in accordance with this invention, is a dwelling house hot-water space heater 322 which is connected by valves 322a and 322a' with the manifolds 320a and 320a'. Valves 323a and 323a' feed hot water to and return it from a heating coil 323b in a hot-water heater 323 supplying hot water via a line 323c to the sanitary facilities of a structure within the same building as the bath or in a building nearby. Cold water is supplied to the heater 323 via an inlet pipe 323d and a valve 323e. A floor-heating assembly 324 is connected by valves 324a and 324a' to the manifold.

The water 302' within the bath 302 is heated by circulation through the electric heater 303 during the low-cost periods of electrical power transmission to a temperature of, for example, 29° C., the electric power supply being thereafter cut off. Meanwhile, the water in the hot-water heater 321 is brought electrically to a temperature of about 110° C.

By vaporization of a portion of the bath water into the chamber 301' above the bath, a heat and moisture transfer from the bath to the room air is effected. This moist air, at a temperature of about 30° C., is drawn by fan 315 from the bath chamber and blown through the heat exchanger 316'' where it is cooled as described with respect to FIG. 5 to condense moisture from the air, the condensate being returned to the bath 302'. As shown by the broken line 315c, this cold air is now fed through the heat exchanger 317'' at which it picks up heat and is returned, somewhat demineralized, to the bath chamber. The heat removed from the air at heat exchanger 316'' is recovered as usable heat in the water circulation 317 which heats the available hot water to about 60° C. This 60° C. water is available, according to this invention, to operate a number of heating systems. For example, part of it serves to heat the returned air in the heat exchanger 317'', while another portion is provided for heating the stationary heating elements 306 to compensate for transmission losses through the walls of the structure.

However, especially with small bath structures, the storage capacity of the water 302' is not always sufficient to cover the requirements of all of the hot water consumers (306, 317'', 322, 323 and 324). In this case, the hot-water source 321 is employed and the higher-temperature water of this source may be mixed with cold water from the cold-water cycle 316 via valves 321b and 321c. To this end, valves 320h may be opened to permit additional hot water from the heater 321 to reach the consumer 306, 317'', 322, 323 and 324. When temperature adjustment is required, the mixing valves 321b and 321c may be used. When, for example, it is desired to bring the temperature in the cold water cycle from about 6° C. to about 12° C., only an insignificant quantity of 110° C. water need be withdrawn from the heater 321 which, consequently, may be relatively small.

In case of emergency, for example, upon failure of the heat pump 310, the valves 320h may be opened so that water from the boiler 321 will directly reach the heat consumers mentioned earlier until the heat pump 310 is restored to operation. The size of the hot-water storage and heating unit 321 must be so related to the water volume of the bath 302' that the bath water temperature during the higher-cost periods of power consumption, e.g., during the 6 to 12 hours of daylight operation in the case of electric heating, does not drop more than about 2°, e.g., from 29° to 27° C. and endanger the health and comfort of the bather.

As noted earlier, the balance of the heat requirements may be provided by the compressor 311 although here there is an additional contribution from the heater 321.

The heating system illustrated in FIG. 2 differs from the system of FIG. 1 in that the hot-water heater 421 is incorporated in the bath-water circulation. In this case, the bath chamber is represented at 401' while the pool 402 contains the body of water 402'. Water for heating purposes is drawn from the drain 407a at the bottom of the tank or from an overflow or skimmer 407b close to the top of the tank and lead via lines 407b' and 407a' to a bypass valve 409 via the common line 407'. With the valve 409 in the proper position, the pump 407 circulates the water through a filter 408. The heater 421 is electrically heated as represented by the heating coil 421f and is provided with the expansion chamber 421g and blow-off valve 421h previously described. When the valve 409 is set to connect the heater 421 in line, the water of the bath is circulated through the heater before being returned to the bath via line 407c. After the bath is brought to the desired temperature by circulation of water through the heater, the valve 409 may cut off the heater which nevertheless continues in operation to bring the temperature to a level of, say, 110° C. to provide a secondary storage which may be drawn upon as described with reference to the heater 321.

Another difference between the system of FIG. 9 and the system of FIG. 8 resides in the distribution arrangement 420 by means of which the additional heat consumers are operated. At 425, for example, we show a climatizing unit such as a heater or cooler 425 through which hot or cold water may be passed selectively. For this purpose, the hot water cycle 417, otherwise similar to that of FIG. 8, delivers cold water from the heat exchanger 412 to a pair of manifolds 420a and 420a'. Valves 425a and 425a' branch hot water from the manifolds 420a and 420a' to mixing valves 425b and 425b'. The cold-water input to these mixing valves derives from a pair of cold water lines 426 running to the cold water cycle 416. It will be apparent that the apparatus 425 may conduct hot water, cold water or water of any temperature in between depending upon the mixing valves.

At 427, there is illustrated another type of air-conditioner assembly which may be used in accordance with the present invention while at 428 we have represented a central air-conditioning system. The latter system may include a preheating air/liquid heat exchanger 429, connected by lines 429b and 429b', with the valves 429a and 429a' of the heating manifolds 420a and 420a'. A cooler may be provided at 430 in the form of a liquid/air heat exchanger and is supplied with coolant from the cooling cycle 416 via lines 430' and 430''. An after-warmer 431 in line with the cooler 430 and the prewarmer 429 in the direction of air flow (arrow F) has its lines 431b and 431b' in series with the valve 431a and 431a' of the manifolds. A blower 428a controls the flow of air through the central air-conditioning unit.

The air-conditioning system 427 is provided with two convector-type heat exchangers 427a and 427b arranged one above the other in the house and above a collecting pan 427c for condensed moisture. A fan 427d is provided to blow air through the unit, namely, the convectors 527b and 427a in succession. The system may be used in connection with the floor-heating unit 424 of FIG. 9 so that the air-conditioner 427 serves only to modify the temperature and humidity of the freshly introduced air. Air-conditioning can be carried out with but a single wall opening to admit fresh air and without the air shafts hitherto necessary for the purpose.

Parallel to the condenser 412 of the heat pump 410, we provide a further condenser 432 which may be connected with the city water lines by pipes 432a and 432b. The purpose of this auxiliary condenser is to dissipate heat from the heat pump circuit in which it is connected at 432c when the various hot-water consumers have been thermally saturated. Note that the convector 427a has valves 427a' and 427a'' tying it to the heater manifolds, that convector 427b has a valve 427b' tying it to the cold water network and that valves 422a and 422a'

connect the usual heater 422 to the hot-water manifold. Furthermore, it is possible to connect the city lines directly with the hot-water circulation 417 and thereby eliminate the additional condenser 432 while dissipating the heat as previously described. This has, of course, the disadvantages that the high-oxygen content of a public-water network promotes corrosion not only of the manifold 420a and 420a', but also of the heat consumers connected therewith.

The higher bath temperature, designed to increase the capacity of this heat-storage reservoir, results in an increased vaporization of water and, consequently, an increased danger of sweating of the walls of the chamber. To this end, we have found it to be desirable to provide, in the region of the walls of the structure (represented as a glass wall 32) received in channels 32a, a vertical shaft 33 open upwardly toward the wall via a grate 36 or the like and is divided by a partition 33' into a pair of shaft portions 33'' and 33''' (FIGS. 10 and 11). At the upper part of the shaft portion 33'' closest to the wall 32, we provide a convector 34 of the finned-type type whereas a convector 35 is positioned close to the bottom of the partition 33', somewhat further away from the wall.

The convector ..., is connected with the heat exchanger 316'', 416'' ..., while the convector 35 may be connected with the heat exchanger 317'', 417'' of the hot-water circulation system. In this fashion, the cold convector 34 draws the moist boundary lines of air proximal to the wall 32 downwardly and cools it to a temperature below the dew point of the air within the chamber above the bath so that a portion of the moisture in the air is condensed and precipitates therefrom. A pipe 37 returns the condensed moisture to the bath. The cooled and demoi-
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sturized air is then drawn forwardly at the hot convector 35 and is reheated to the desired room temperature and permitted to rise in an upwardly flowing layer along the downwardly flowing boundary layer.

The significant advantage of this arrangement resides in the formation of an isolation layer of warm air between the cold-air layer along the wall and the moist air otherwise filling the room. The duration of the air streams entering and leaving the shaft and their relationship to the walls can be adjusted by modifying the positions of the fans of the grate 36 which may be of the *jalousie* type. A low-noise air-circulation blower 38 of the squirrel-cage or similar type may, of course, be provided below the convector 35 to promote circulation of air in streams along the walls, as has been described.

In FIG. 12, we have shown a modification of the system of FIG. 11 which, of course, represents the arrangement of the convectors illustrated in FIG. 10. In this embodiment, the convectors 34 and 35 are canted about their longitudinal axis to promote, for the convector 34, a downward drift of moist air toward the lower edge of the convector at which the lowest temperature is maintained. As a result of the effective reduction in the air-flow cross section, the demoi-
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sturized air (arrow G) passes into the shaft portion 33''' at higher velocity with further acceleration by the blower 38 when the latter is provided as shown in FIG. 10. Upon passage through the lower edge of the convector 35, the stream receives a further direction change to the high temperature upper edge of the convector (arrow G) with a corresponding further reduction in flow cross section and the corresponding increase in speed. The high speed gas stream is thus able to flow along the entire height of the wall. It will be apparent that the system of FIG. 8 may also be used with the arrangements of FIGS. 10-12 in which case it may be desired to eliminate the static heating surfaces 306. The same also applies to the system of FIG. 9.

Finally, it may be noted that the heat pumps 310 and 410 do not necessarily require a compressor when the cold and warm heat exchangers 312, 412 and 314, 414 are replaced by convectors arranged as shown, for example, in FIGS. 10 and 12 whereupon an effective circulation of the room air through the heat pump system is provided by convection currents.

Basically, the system described above makes use of the bath as a main heat-storage reservoir which may provide thermal energy for uses not associated with maintaining the at-

mosphere within the bath chamber as long as the maximum cooling of the bath is maintained at about 4° C. Any additional heat source which, in the case of the systems of FIGS. 8 and 9, is the electrically heated boiler or hot water heater 321 and 421. When it is desired to minimize the cooling of the bath, the auxiliary hot-water heater may be used to supply all of the additional thermal requirements of the ancillary devices whereas substantially all of the thermal requirements can be provided from the thermal reservoir constituted by the bath under some cases. For the most part, however, it is desired to maintain the temperature drop of the bath between 1° and 2° C., whereupon part of the heat of the ancillary devices will be supplied by the bath while the remainder is supplied by the auxiliary heater. It has already been noted that bath heating may be maintained, say, for the entire low-tariff period or may be carried out with oil at relatively low cost while the auxiliary heater is electrically operated even during peak tariff periods.

The invention described and illustrated is believed to admit of many modification within the ability of persons skilled in the art and are, of course, intended to be encompassed within the spirit and scope of the appended claims.

We claim:

1. An enclosed bath system, comprising:

a housing defining a bath chamber;

means for receiving a body of water having a surface exposed to the air in said chamber;

a heat pump having an evaporator, a condenser, a circulating primary heat-transfer fluid in the form of a compressible refrigerant carrying thermal energy absorbed at said evaporator to said condenser for dissipation at the latter and a compressor connected between said evaporator and said condenser for circulating said refrigerant;

means for circulating air from said chamber into heat-exchanging relation with said evaporator and said condenser whereby said evaporator abstracts heat and moisture from said circulated air and said condenser reheats said circulated air prior to its return to said chamber; and

means for heating said body of water and constituting the sole energy input apart from said compressor for said bath system and covering all of the thermal energy requirements of said chamber and all of the thermal energy supplied to said heat pump is transferred through the air of said chamber from said body thereto.

2. The system defined in claim 1 wherein said means for circulating air includes means for bringing said air from said chamber into direct contact with said evaporator.

3. The system defined in claim 1 wherein said means for circulating air includes means for bringing said air after heat exchanging relation with said evaporator into direct contact with said condenser.

4. The system defined in claim 1, further comprising a cold-water circuit including pump means for circulating water into heat exchange with said evaporator and a liquid-gas heat exchanger for traversal by the circulated air from said chamber and the cold water of said circuit for transferring heat from said air to said evaporator.

5. The system defined in claim 4, further comprising a hot-water circuit including pump means for circulating water into heat exchanging relation with said condenser and liquid-gas heat exchanger traversed by air from said chamber and hot water for transferring heat to the air prior to its re-entry into said chamber.

6. The system defined in claim 5 further comprising static heating means in said chamber connected to said hot-water circuit for heating said chamber in addition to the heating of the air re-entering said chamber.

7. The system defined in claim 5 further comprising at least one heat-utilizing device independent of said body and said chamber, and means for passing a portion of the hot water of said hot-water circuit to said device.

8. The system defined in claim 7, further comprising at least one cold-consuming device, and means for passing at least part of the cold water of said circuit to said device.

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9. The system defined in claim 1 wherein said means for heating said body of water includes a heater connected with said body and driven by said energy input, and means for electrically heating said auxiliary heater.

10. The system defined in claim 9, further comprising means for circulating water from said body through said heater for heating the water of said body.

11. An enclosed bath system, comprising:

a housing comprising a bath chamber;

means for receiving a body of water having a surface exposed to the air in said chamber;

a heat pump having an evaporator, a condenser and a circulating primary heat-transfer fluid carrying thermal energy absorbed at said evaporator to said condenser for dissipation at the latter;

means for circulating air from said chamber into heat-exchanging relation with said evaporator and said condenser whereby said evaporator abstracts heat and moisture from said circulated air and said condenser reheats said circulated air prior to its return to said chamber;

at least one cold convector extending along said wall and proximal thereto;

means connecting said cold convector in heat-exchanging

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relation with the evaporator of said heat pump for inducing a downward flow of air along said wall;

at least one hot convector extending along said wall but spaced on the opposite side of said cold convector therefrom for inducing an upward flow of warm air inwardly of the downwardly flow of cold air; and

means connecting said hot convector in heat-exchanging relation with the condenser of the heat pump for heating thereby.

12. The system defined in claim 11 further comprising an electric heater constituting a thermal storage reservoir and means for circulating the water of said body through said electric heater.

13. The system defined in claim 11 wherein said housing includes an upwardly open shaft extending along said wall, a partition subdividing said shaft into two shaft portions communicating at the bottom and including a first shaft portion proximal to said wall and receiving said cold convector and another shaft portion distal from said wall and receiving said hot convector.

14. The system defined in claim 1, further comprising means for returning moisture condensed at said evaporator to said body.

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