

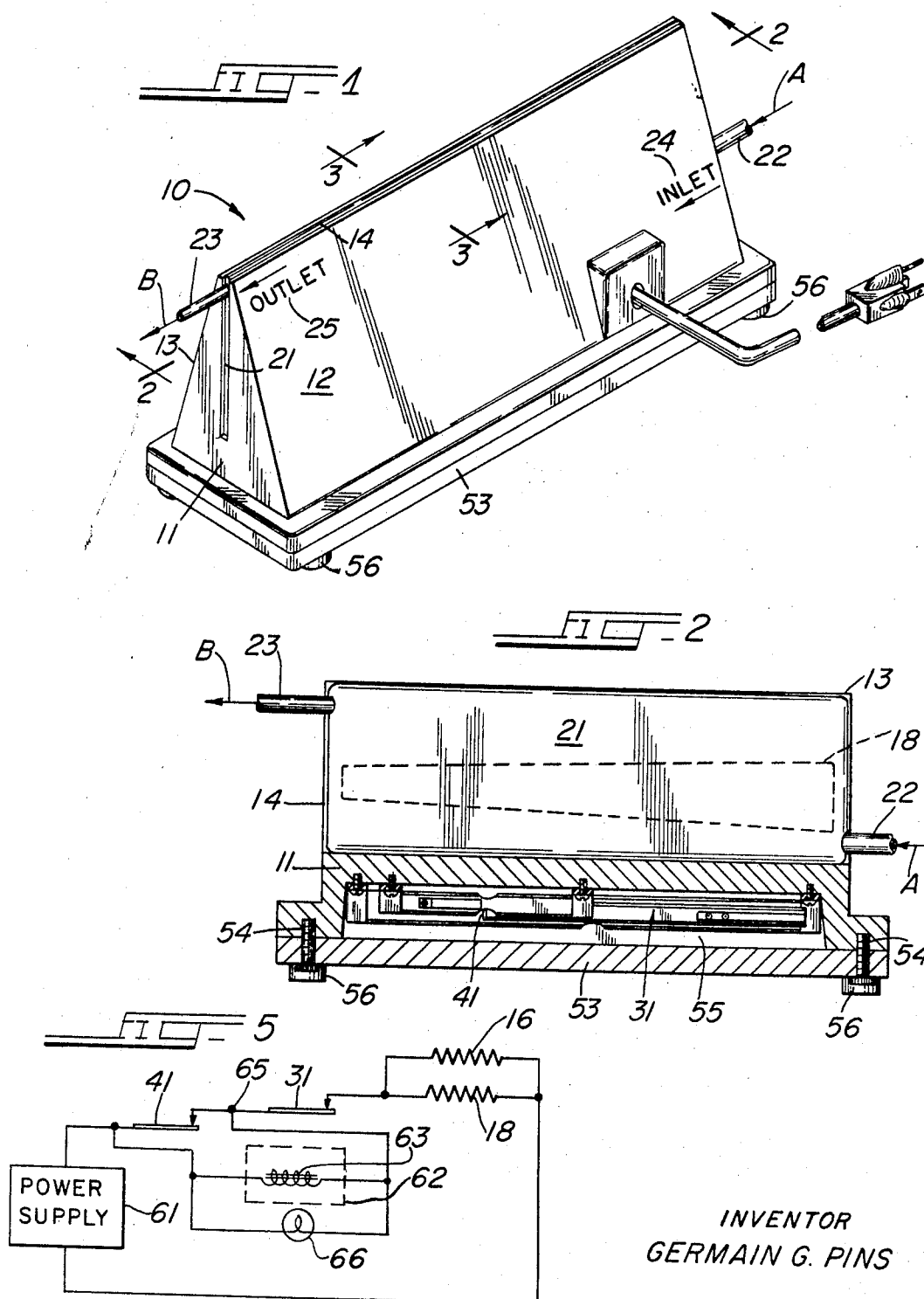
Oct. 28, 1969

G. G. PINS
THERMOSTATICALLY CONTROLLED ELECTRICALLY
HEATED CLINICAL BLOOD WARMER

3,475,590

Filed Oct. 25, 1966

2 Sheets-Sheet 1



INVENTOR
GERMAIN G. PINS

BY *Wallace, King & Dorn*
ATTY S.

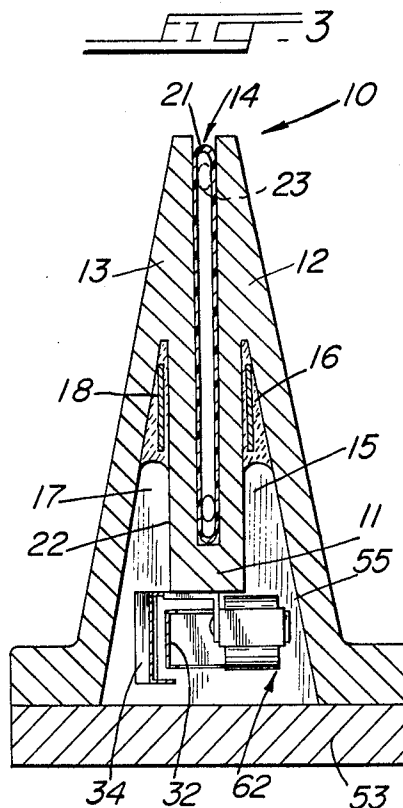
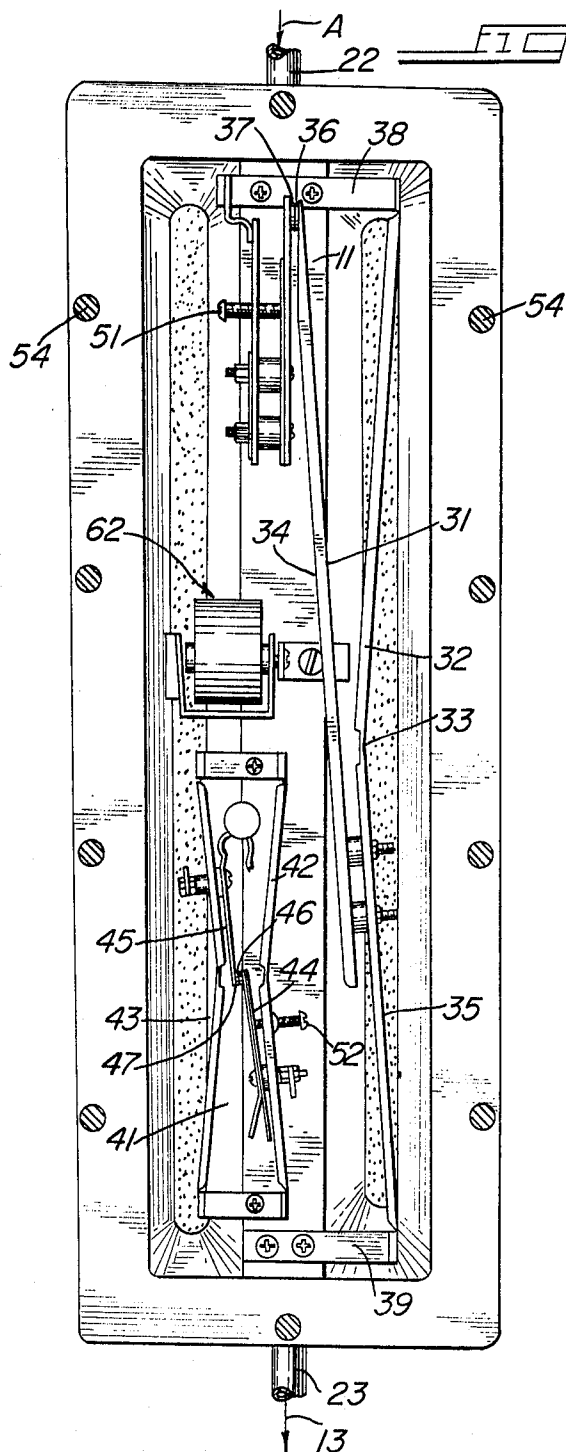
Oct. 28, 1969

G. G. PINS
THERMOSTATICALLY CONTROLLED ELECTRICALLY
HEATED CLINICAL BLOOD WARMER

3,475,590

Filed Oct. 25, 1966

2 Sheets-Sheet 2



INVENTOR.
GERMAIN G. PINS
BY *Wallace, Kinger & Dorn*
ATTY.

1

3,475,590

THERMOSTATICALLY CONTROLLED ELECTRICALLY HEATED CLINICAL BLOOD WARMER

Germain G. Pins, Dubuque, Iowa, assignor to Thermolyne Corporation, Dubuque, Iowa, a corporation of Illinois

Filed Oct. 25, 1966, Ser. No. 589,262

Int. Cl. H05b 1/00, 3/06, 11/00

U.S. Cl. 219—302

6 Claims

ABSTRACT OF THE DISCLOSURE

A clinical blood warmer for dry heating blood or other body fluids for transfusion, comprising a thermally conductive heater block with a long narrow slot and electrical heaters mounted in the sides of the slot. A disposable, thin flat plastic blood sac having an inlet and an outlet is removably positioned in the slot. When filled with blood, the sac substantially completely fills the slot so that its sides engage the slot sides and the blood flowing through the sac is heated by conduction. The heaters are effectively tapered so that the heat output of thereof gradually diminishes from the inlet end of the sac toward the outlet end thereof. Precision thermal control is provided by a pair of thermostats; the first being thermally coupled to the entire block and the second being set for a higher temperature than the first and thermally coupled to the outlet end of the block.

This invention relates to a new and improved blood warmer for heating refrigerated blood to a temperature suitable for direct transfusion. The blood warmer of the invention may be employed in the preparation of whole blood for transfusion purposes and may also be utilized for transfusions of plasma and other fluids.

Blood is ordinarily refrigerated for storage, being stored at temperatures of approximately 4° C. Before utilization, the blood must be warmed to near body temperature of 37° C. For surgery, it is the customary practice to warm a sufficient quantity of blood to meet all anticipated transfusion needs during the surgery. The quantity estimate is necessarily high, with the result that, in many instances, a substantial quantity of blood is heated to transfusion temperature without actually being used. The excess blood cannot be refrigerated a second time and must be destroyed, resulting in substantial waste.

For accident victims or other emergency cases, the time required to warm blood for transfusion can be a critical factor. In emergency room equipment, it is essential to have sufficient effective blood heating capacity to take care of the needs of several patients and thereby protect against the requirements of multiple accident victims. It is thus seen that if the blood can be maintained under refrigeration until the exact time that it is needed and then warmed to near body temperature within a few seconds, the destruction of unneeded blood for surgical patients can be avoided and the waiting period for the warming of blood for emergency patients can be virtually eliminated.

There are a number of critical factors applicable to a clinical blood warmer. The blood warmer must heat the blood to a temperature close to body temperature. To be more specific, the blood supplied for transfusion must not fall below a temperature of 28° C. and must not reach a temperature above 40° C. These thermal conditions must be maintained regardless of the flow rate at which the blood warmer is required to operate. A practical range of flow rates for a clinical blood warmer is from 0 to 150 cubic centimeters per minute. That is, a flow of approximately 150 cubic centimeters per minute may be required in rapid transfusion cases whereas in

2

other instances the flow may be interrupted entirely for substantial intervals of time during a complete transfusion procedure.

A further condition is that the blood must stay in a sterile system. Substantially self-contained sterile blood systems are known in the art. Some of these systems utilize plastic sacs through which the blood is passed. A thermal change is effected, for the blood in the sac, the sac being suspended in a liquid heat-transfer medium. Systems of this kind, which have been utilized primarily for temperature reduction of the blood in low-temperature surgery, may lead to spilling of the heat-transfer liquid and are generally messy in operation.

It is a principal object of the invention, therefore, to provide a new and improved clinical blood warmer for heating refrigerated blood to a temperature suitable for direct transfusion at any flow rate within a substantial range of flow rates starting at zero and extending to about 150 cubic centimeters per minute.

A specific object of the invention is to provide for close critical control of the temperature of the blood flowing from a clinical blood warmer in a system that is completely closed and sterile and that requires no heat-transfer liquid, hence constituting a "dry" heating apparatus.

A specific object of the invention is to provide a new and improved overheating protection apparatus for a clinical blood warmer that automatically warns of an overheat condition that is likely to repeat.

A further object of the invention is to provide a clinical blood warmer for heating refrigerated blood to a restricted and precisely controlled range suitable for direct transfusion, despite large variations in the rate of blood flow through the blood warmer, at minimum cost and with minimized possibility of malfunction.

Accordingly, the invention relates to a clinical blood warmer for heating refrigerated blood to a temperature suitable for direct transfusion at any flow time within a substantial flow rate range starting at zero. The blood warmer comprises a block of thermally conductive material comprising two side walls of large surface area facing each other across a narrow longitudinal slot extending into the block between the side walls. An electrical heater is mounted on one side wall of the block and extends longitudinally of the block adjacent the aforesaid slot. Preferably, there is one electrical heater embedded in each of the two side walls. A precision thermal control is electrically connected to the heater and is thermally connected to the block, being employed to control operation of the heater in accordance with the temperature of the block. A thin, disposable blood sac is removably positioned within the slot in the block; the blood sac preferably has an inlet conduit located near the bottom of the slot and an outlet conduit located near the top of the slot. The sac, when filled with blood, fills substantially all of the slot and is in direct contact with the interior surfaces of both side walls. Blood passing into and through the sac is heated by conduction and radiation from the surfaces of the block and by convection currents within the sac. In the preferred construction described hereinafter, the heater elements are effectively tapered from one end toward the other end of the slot with the inlet and outlet conduits for the blood sac being disposed adjacent the large and small ends of the heaters, respectively.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings, which, by way of illustration, show a preferred embodiment of the present invention and the principles thereof and what is now considered to be the best mode contemplated for applying these principles. Other embodiments of the invention embodying the same or equivalent principles may

3

be made as desired by those skilled in the art without departing from the present invention.

In the drawings:

FIG. 1 is a perspective view of a clinical blood warmer constructed in accordance with one embodiment of the present invention;

FIG. 2 is a sectional elevation view taken approximately along line 2—2 in FIG. 1;

FIG. 3 is a transverse sectional elevation view taken approximately along line 3—3 in FIG. 1;

FIG. 4 is a bottom view of the blood warmer with the base removed to show the thermal control; and

FIG. 5 is a simplified schematic diagram of an appropriate electrical circuit for the blood warmer.

Referring to the drawings, they illustrate a clinical blood warmer 10 for heating refrigerated blood to a temperature suitable for direct transfusion. Blood warmer 10 comprises a block 11 of thermally conductive material; typically, block 11 may be constructed as a unitary aluminum casting. Block 11 comprises two side walls 12 and 13, as most clearly illustrated in FIGS. 1 and 3. Each of the two side wall portions 12 and 13 of block 11 is relatively thick and each has a large surface area facing the other wall across a narrow longitudinal slot 14 that extends the full length of the block between side walls 12 and 13. In a typical construction, slot 14 may be approximately one-fourth inch wide, four inches high, and ten inches long.

As shown in FIG. 3, side wall 12 of block 11 tapers from top to bottom, being relatively narrow at its upper edge and substantially thicker at its lower edge. A relatively deep vertical recess 15 is formed within side wall 12 and a first electrical heater 16 is mounted within the recess. Side wall 13 is of similar configuration, having a recess 17 within which a second electrical heater 18 is mounted. Preferably, the heater elements 16 and 18 are embedded within slots 15 and 17 in a refractory cement, but any other appropriate means for mounting the electrical heaters within the side walls of the block 11 and that provides for good heat transfer to the block can be utilized.

The electrical heaters 16 and 18 are preferably not uniform throughout their lengths. As shown in FIG. 2, the heater 18 is tapered from the right-hand end of block 11 toward the left-hand end of the block. The tapering of the heater element need not be accomplished by a physical narrowing throughout its length. If a resistance wire heater is employed, the tapering can be effected on an electrical basis, with more turns of heater wire located near the right-hand end of the block than near the left-hand end. Moreover, it is not essential that a constant gradient be maintained across the length of the block. But it is desirable that more of the electrical heater capacity be concentrated near one end of the block, the inlet end as defined more fully hereinafter, than at the other or outlet end of the block. Heater 16 (FIG. 3) is also tapered in construction, either on a physical basis or an electrical basis.

A thin, disposable blood sac 21 is removably positioned within slot 14 when blood warmer 10 is put to use. Preferably, the blood sac 21 is fabricated from a thin plastic material having good heat transfer characteristics; for example, the blood sac may be made from polyvinylchloride or polyethylene film. As best shown in FIG. 2, sac 21 is provided with an inlet conduit 22 and an outlet conduit 23. The sac is positioned in slot 14 with the inlet conduit 22 located at the bottom of slot 14 and at the right-hand end of the slot as seen in FIG. 2, thereby positioning the outlet conduit 23 at the upper left-hand corner of the slot. The inlet and outlet conduits 22 and 23 need not be physically different from each other but may be appropriately coded to assist the user in making sure that the sac inlet and outlet are properly oriented within the block 11 of the blood warmer. The exterior of the block 11 may be provided with

4

appropriate markings, such as the markings 24 and 25 in FIG. 1, to indicate to the user the proper locations for the inlet and outlet conduits. When sac 21 is filled with blood, it fills substantially all of slot 14 and engages the interior surfaces of side walls 12 and 13 in close, thermally conducting relationship as best shown in FIG. 3.

The blood warmer 11 further includes a precision thermal control that is mounted in the lower portion of block 11. The thermal control is best illustrated in FIG. 4, taken in conjunction with FIGS. 2 and 3. The thermal control comprises a first thermostat 31 including a thin V-shaped actuating member 32. The opposite ends of actuating member 32 are firmly anchored to the ends of block 11. The actuating member is of channel-shaped configuration with the channel walls cut away at the central portion of the V to afford a hinge portion 33. An elongated contact arm 34 is affixed to and supported by one leg 35 of actuating member 32 (FIG. 4). Arm 34 carries a first contact member 36 that is normally engaged by a second contact 37, contact 37 being mounted in fixed position on the thermal block 11 of the blood warmer.

The V-shaped actuating member 32 of thermostat 31 is constructed of a material having approximately a zero coefficient of thermal expansion; the alloy known as "Nilvar" may be used. In operation of the blood warmer, heating of thermal block 11 causes the block to expand. As the block expands, the end anchors 38 and 39 for actuating member 32 move away from each other. Since the actuating member does not expand or contract with thermal changes, the separation of anchors 38 and 39 from each other causes the actuating member to flatten and ultimately pulls contact 36 away from engagement with contact 37. This particular form of thermostat is highly advantageous in that it restricts the time lag in the thermostat, as compared with thermal changes in block 11, to a minimum by making the thermal block itself the active heat sensing element of the thermostat.

The precision thermal control apparatus for blood warmer 10 further includes a second thermostat 41. Thermostat 41 comprises two V-shaped actuating members 42 and 43 which are similar in construction to the actuating member 32 of thermostat 31. Actuating members 42 and 43 extend for only a fractional part of the length of block 11, being anchored to the block at the outlet end of the blood warmer. Actuating members 42 and 43 support two contact arms 44 and 45, respectively, maintaining two electrical contacts 46 and 47 normally engaged with each other. Thus, thermostat 41, like thermostat 31, utilizes block 11 as an active element in the thermostat. Thermal expansion of the outlet end of block 11 beyond a predetermined critical level causes actuating members 42 and 43 to pull away from each other to an extent sufficient to open contacts 46 and 47. Thermostats 31 and 41 are provided with appropriate adjusting elements 51 and 52, respectively, to provide for precise determination of the temperature at which the thermostat contacts open.

The bottom portion of blood warmer 10 is closed off by a bottom plate 53, mounted on block 11 by appropriate means such as a plurality of screws 54. Thus, the space 55 around the precision thermal control 31, 41 is totally enclosed. Insulator feet 56 are mounted on plate 53 to support the blood warmer.

A typical electrical circuit for blood warmer 10 is illustrated in FIG. 5. As shown therein, the two thermostats 41 and 31 are electrically connected in series with each other to one terminal of a suitable power supply 61. The two thermostats are in series with the two electrical heaters 16 and 18, the heaters being returned to the other terminal of the power supply. Power supply 61 may be a conventional sixty cycle A.C. source.

In the circuit arrangement of FIG. 5, there is a warning signal device 62 comprising a conventional buzzer in-

cluding an operating coil 63. Coil 63 is connected from the common terminal 65 of thermostats 31 and 41 back to the power supply. A signal lamp 66 may be connected in parallel with the buzzer coil 63.

In operation, blood sac 21 is placed in slot 14 with its inlet and outlet conduits 22 and 23 disposed as shown in FIGS. 1-4. The blood warmer is connected to its power supply and, after an appropriate time interval for heating of block 11, a flow of blood into and through sac 21 is initiated as indicated by the arrows A and B in FIGS. 1, 2 and 4. The adjustment of thermostat 31 is such that this thermostat operates to open its contacts 36 and 37 (FIG. 4) whenever the block reaches a temperature of approximately 41° C. This limits the temperature of the blood flowing from outlet conduit 23 to a usable level for transfusion purposes.

The blood within sac 21 is heated by conduction through the thin walls of the sac. There is also some heating by radiant heat from the side walls of block 11. Moreover, there is a continuing heating by thermal convection of the blood within the sac. That is, as the refrigerated blood enters the heater through conduit 22, it is at the bottom of sac 21. As the blood is warmed, it rises within the sac, establishing continuing convection currents. The blood removed from the sac through conduit 23 is always the warmest blood within the sac.

As noted above, the blood warmer 10 must operate at flow rates anywhere from zero to 150 cubic centimeters per minute. At high flow rates, it is important to increase the blood temperature as rapidly as possible at the initial or input end of sac 21; this is the point at which heat transfer occurs most rapidly due to the high temperature differential between the entering blood and the elements of the blood heater. This high heat transfer rate is accomplished by the location and configuration of heaters 16 and 18, since the major heating capacity is disposed adjacent the inlet end of the blood warmer.

In normal operation, only the thermostat 31 controls energization and de-energization of the electrical heaters 16 and 18. The second thermostat 41 is set to a temperature slightly higher than thermostat 31; a temperature differential of one-half to one degree centigrade is typical. In the event that thermostat 31 fails for any reason, thermostat 41 operates to open the heater circuit soon enough to prevent substantial overheating of the blood. Opening of thermostat 41 is effective to connect the buzzer 62 in the operating circuit, since the low impedance shunt through the thermostat is now open. Moreover, the lamp 66 is also energized. The buzzer, the lamp, or both indicate to the attending physician or nurse that the temperature of the blood warmer is going too high and that maintenance is required. This arrangement protects the blood warmer against possible malfunction such as the fusing of contacts 36 and 37 of thermostat 31 after extended use.

I claim:

1. A clinical blood warmer for dry heating of refrigerated blood or other body fluid to a temperature suitable for direct transfusion at any flow rate within a substantial flow rate range starting at zero, said blood warmer comprising:

heater block means of thermally conductive material comprising two side walls of relatively large surface area facing each other across a narrow longitudinal slot extending into said block means between said side walls;

electric heater means, mounted in heat exchanging relation with said block means and extending longitudinally of said block means adjacent said slot, for heating said block means;

a precision thermal control, electrically connected to said heater and thermally connected to said block means, for controlling operation of said heater in accordance with the temperature of said block means; and

a thin, flat disposable blood sac removably positioned within said slot and having an inlet conduit at one end of the block means and an outlet conduit at the opposite end of the block means, said sac, when filled with blood, filling said slot substantially completely so that the opposite sides of the sac each engage one of said side walls, blood passing into and through said sac being heated by conduction and radiation from the slot surfaces of said block, through said sac;

said heater means being effectively tapered from said one end of said block means toward said opposite end so that the heat output of said heater means gradually diminishes from said one end of the slot toward the opposite end of the slot.

2. A clinical blood warmer according to claim 1 in which said inlet conduit is located near the bottom of said slot and said outlet conduit is located near the top of said slot.

3. A clinical blood warmer according to claim 1 in which said precision thermal control comprises two series-connected thermostats, one thermally connected to the entire length of said block means and the second thermally connected to only said opposite end of said block means, said second thermostat being set for a slightly higher temperature than said one thermostat.

4. A clinical blood warmer according to claim 3 in which said second thermostat is electrically connected to a warning device to indicate overheating of said blood warmer.

5. A clinical blood warmer for dry heating of refrigerated blood or other body fluid to a temperature suitable for direct transfusion at any flow rate within a substantial flow rate range starting at zero, said blood warmer comprising:

heater block means of thermally conductive material comprising two side walls of relatively large surface area facing each other across a narrow longitudinal slot extending into said block means between said side walls;

electric heater means, mounted in heat exchanging relation with said block means and extending longitudinally of said block means adjacent said slot, for heating said block means;

a precision thermal control, electrically connected to said heater and thermally connected to said block means, for controlling operation of said heater in accordance with the temperature of said block means; and

a thin, flat disposable blood sac removably positioned within said slot and having an inlet conduit at one end of the block means and an outlet conduit at the opposite end of the block means, said sac, when filled with blood, filling said slot substantially completely so that the opposite sides of the sac each engage one of said side walls, blood passing into and through said sac being heated by conduction and radiation from the slot surfaces of said block, through said sac;

said precision control comprising first and second independently settable thermostats, the first thermostat being thermally connected to substantially the entire length of the block means for measuring overall block temperature, the second thermostat being thermally connected to said opposite end of said block means to measure the temperature of the block means adjacent said sac outlet conduit, said second thermostat being set for a slightly higher temperature than said first thermostat.

6. A clinical blood warmer according to claim 5 in which said second thermostat is electrically connected to a warning device to indicate overheating of said blood warmer.

(References on following page)

References Cited

UNITED STATES PATENTS

2,562,821 7/1951 Rothweiler.
 2,576,558 11/1951 Bede ----- 219—325 X
 2,932,718 4/1960 Marsters ----- 219—521 X
 3,109,084 10/1963 Walsh ----- 219—512 X
 3,140,716 7/1964 Harrison et al. ---- 128—214 X

3,216,492 11/1965 Weaver ----- 128—214 X
 3,293,868 12/1966 Gonzalez ----- 128—399 X
 3,370,153 2/1968 Du Fresne et al. ---- 219—302

ANTHONY BARTIS, Primary Examiner

U.S. Cl. X.R.

128—214, 399; 165—46; 219—325, 330, 521