

Aug. 19, 1969

R. E. HOLADAY

3,462,575

MICROWAVE HEATING DEVICE

Filed May 31, 1967

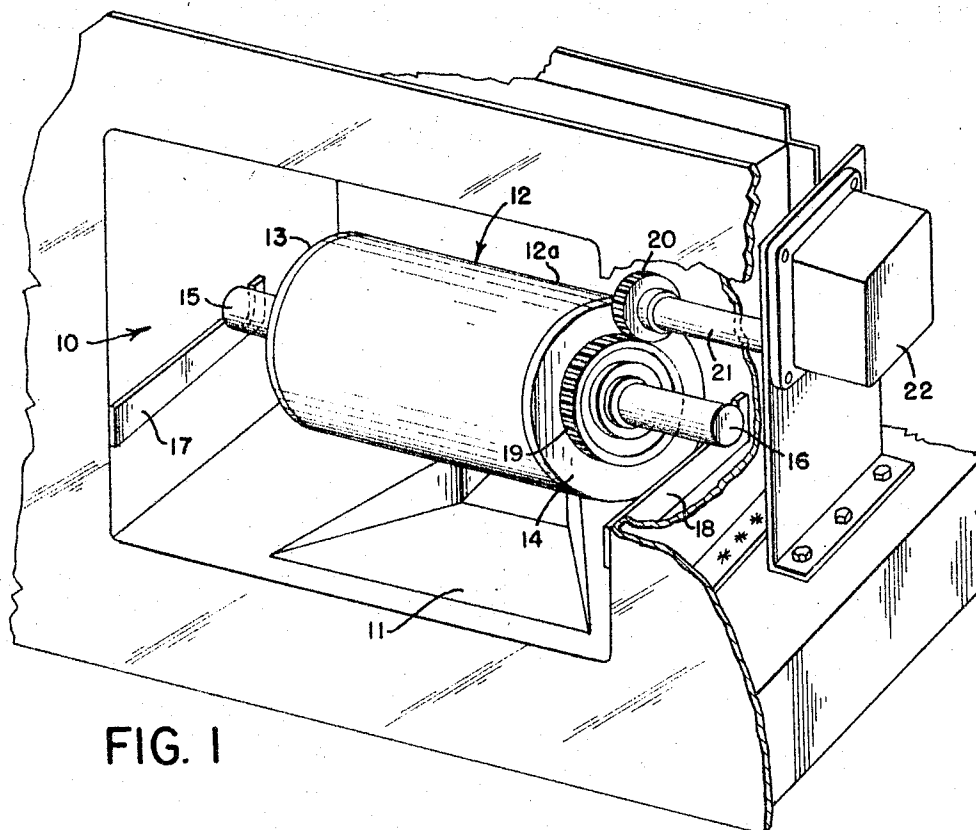


FIG. 1

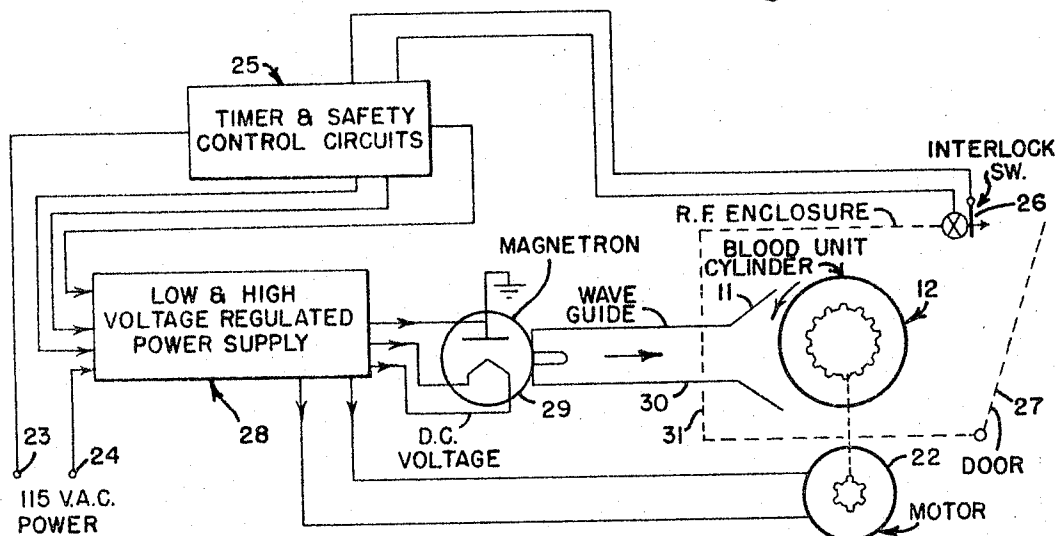


FIG. 2

INVENTOR  
REED E. HOLADAY

BY

*Donald J. Anderson*  
ATTORNEY

1

2

3,462,575

## MICROWAVE HEATING DEVICE

Reed E. Holaday, Minnetonka, Minn., assignor to Holaday Industries, Inc., Hopkins, Minn., a corporation of Minnesota

Filed May 31, 1967, Ser. No. 642,606

Int. Cl. H05b 9/06

U.S. Cl. 219-10.55

3 Claims

### ABSTRACT OF THE DISCLOSURE

A simplified and improved microwave heating device is described. The item to be heated is positioned within a shaped microwave energy field in such a manner that substantially all of the incident microwave energy directed thereon is absorbed by the item to be heated. Said item is rotatably mounted in said position, the axis of rotation is positioned at right angles to the direction of propagation of the incident microwave energy.

This invention relates to a simplified and improved microwave heating device. In one of its preferred embodiments this device takes the form of an apparatus to warm human blood or plasma preparatory to transfusion thereof.

Specifically, the invention relates to a microwave heating device designed and constructed to heat an item throughout its entire volume to some predetermined temperature while minimizing local overheating within the item. To accomplish this, a shaped microwave energy field is generated within an enclosure for confining microwave energy. The item to be heated is rotated within the general confines of that field and the item is positioned generally at right angles to the direction of propagation of the incident microwave energy. The configuration of the generated field and the item together with the container for the item are matched so that the bulk of the incident microwave energy is absorbed directly by the rotating item. In this manner, it is quite simple to determine the microwave energy requirements to achieve the desired final temperature in the item to be heated. Knowing the energy requirements, it is relatively easy to calibrate the heating device so that a given heating cycle will provide the appropriate energy input and raise the temperature of the item from one known initial temperature to a given predetermined final temperature. For example, blood for transfusion is often packaged and stored in plastic pouches of approximately 500 ml. volume. A typical storage temperature is about 5° C. The generally accepted transfusion temperature is about 35° C. Hence, sufficient microwave energy must be supplied to raise the temperature of 500 ml. of blood about 30° C. Knowing the electrical and physical characteristics of the heating device, it is a relatively simple matter to select that cycle time from a calibration curve which will provide the requisite microwave energy to achieve the desired final temperature of the blood sample.

It is known that microwave energy will heat a variety of substances. Devices embodying the microwave principle are numerous in the prior art. Hence the fundamentals of propagation and control of microwave energy and the general operation of microwave heating devices are well known to those skilled in the art.

Radio frequency heating of blood samples preparatory to transfusion is known. However, there has been a reluctance expressed in the literature to apply microwave techniques to the heating of blood for transfusion. It has been felt that the interal molecular stresses created by the subjecting of a blood sample to the conventional microwave energy fields resonating in a more or less conven-

tional microwave oven would result in physical and physiological damage to the blood.

Were one to heat a blood sample in a conventional microwave oven, such as the type employed to heat frozen food, damage would indeed result to the physical and physiological makeup of the blood sample. Illuminated in a more or less conventional resonant cavity with its concomitant resonant modes or standing wave patterns, the blood sample would be subjected to serious local overheating in those vicinities where it was exposed to field areas of high microwave energy. Heating would be quite uneven since, generally speaking, for every area of high energy there is a corresponding area of low energy.

Prior art methods of warming blood preparatory to transfusion, therefore, have been generally less than completely satisfactory. Radio frequency illumination is slow and prior art methods are specifically designed to work with bottled blood. Microwave illumination in conventionally available devices is deleterious. Both time and temperature are critical in the warming of blood. Overheating is to be avoided. At about 40° C., only about 5° C. above the usual transfusion temperature, haemolysis of red blood cells begins. Similarly, when the heating cycle is prolonged unduly at temperatures only slightly above storage temperatures, metabolic processes initiate within the red cells and partial destruction results.

Accordingly, it is a general object of the invention to provide a microwave heating device which provides a rapid warmup of the item to be heated and which avoids local overheating of the item to be heated and which avoids local overheating of the item.

Another object of the invention is to provide a microwave heating device wherein the item to be heated is positioned within a shaped microwave energy field in such a manner that substantially all of the incident microwave energy directed thereon is absorbed by the item to be heated.

A further object of the invention is to provide a microwave blood warmer of an improved design wherein a unit of blood can be rapidly heated from its storage temperature to transfusion temperature without local overheating of the blood sample.

The invention will be described hereinafter as a blood warmer. The novel features believed to be characteristic of the invention both as to organization and method of operation, together with further objects and advantages thereof, will be better understood from the specification considered in connection with the accompanying drawing in which a blood warmer is disclosed as an illustrative embodiment of the invention by way of example only. It is to be expressly understood that the drawing is for the purposes of illustration only and does not constitute a limitation of the invention.

In the drawing:

FIG. 1 is a cutaway perspective view of a microwave blood warmer showing means for rotating a blood sample in accordance with the invention; and

FIG. 2 is a simplified operational schematic diagram for an improved blood warmer in accordance with the invention.

Referring specifically to FIG. 1, there is shown a microwave heating device adapted for the warming of stored blood preparatory to transfusion, including a microwave generator (not shown), a microwave guide (not shown), a microwave heating enclosure generally designated as 10, and a microwave coupling element generally designated as 11. In enclosure 10, rotatably mounted therein is a support and positioning means, permeable to microwave energy, such as the cylindrical plastic container 12 for holding the blood sample. Container 12 comprises a hollow cylinder 12a and ends 13 and 14, at least one of which is demountable to permit insertion of the blood

sample. Respectively integral with said ends are support means such as support hubs 15 and 16. Mounted to the sides of enclosure 10 are mounting support means such as brackets 17 and 18 for supporting container 12 through hubs 15 and 16. A means for rotating container 12 is provided. Engaging gear 19 is mounted on at least one of ends 13 and 14 of container 12 and axially aligned with the long axis of container 12. Engaging gear 19 engages drive gear 20 mounted on shaft 21 extending through the side wall of enclosure 10 and suitably coupled to a drive means such as motor 22.

When a blood sample, typically packaged in a plastic pouch is placed in container 12 and the power is activated, the rotation of container 12 about its axis causes the unit of blood therein to generate a cylinder of rotation, the exact configuration of which is dependent on the shape of the blood sample. Rotation in this manner causes fluid mixing. This combined with the impingement thereon of the shaped microwave energy field directed into the cylinder of rotation provides for rapid and relatively even heating of the blood sample without appreciable local overheating. Mixing from the rotation of the blood sample prevents stagnant areas within the sample. Rotation also improves the uniformity of illumination over the entire volume of the blood sample. Speed of rotation can be critical for liquid samples of relatively high viscosity. Cooler more dense liquid, when quite viscous, resists diffusion into the warmer less dense liquid. Increasing centrifugal force on the rotating liquid by increasing rotational speed tends to throw the cooler more dense liquid to the outer periphery of the cylinder of rotation thereby making it available for absorption of microwave energy and significantly improving the uniformity of heating.

Rotation alone is not enough to provide the requisite rapidity and uniformity of heating. A diffuse or too weak microwave energy field would necessitate overly long exposure to attain transfusion temperature. Areas of too high an intensity of energy in the impinging field could cause local overheating despite rotation. Consequently, the microwave energy field must be carefully controlled to achieve optimum results.

To achieve the requisite shaped and controlled microwave energy field, the entire geometry and configuration of the system must be "balanced." The nature and strength of the propagated microwaves, the configuration and electrical characteristics of the wave guide, the size, shape, volume, and distance away of the sample, the rate of rotation of the sample, and the exact location of the sample container with respect to the generated microwave energy field, all must be very carefully determined. Thus, given a set of electrical parameters defining the microwave source and the wave guide, and given the physical parameters of the sample to be heated, it is necessary to provide a means for directing, focusing, and shaping the microwave energy field so that: (1) the introduction of the microwave energy into the sample is accomplished with a minimum of reflection (that is, the load must be matched to the field); (2) the microwave energy is distributed spatially along the axis of the cylinder of rotation generated by the rotating blood sample; and (3) the incremental energy distribution within the impinged volume of that cylinder of rotation is proportional to the incremental sample volume (for example, in heating a pouch of blood, the field should be generally weaker at the left and right extremities where the pouch configuration necessitates a lower volume of blood, and generally stronger in the center where the bulk of the volume resides).

The means for directing, focusing, and shaping the microwave energy field is provided in the coupling element 11. As pictured in FIG. 1 of the drawing, coupling element 11 is an opening in the floor of enclosure 10 spatially interconnecting the wave guide (not shown) and the interior of enclosure 10. In this embodiment it takes

the form of a microwave antenna element of a non-resonant configuration which provides for a matching of the incident energy to the sector of impingement within the cylinder of rotation, which spreads the energy field to encompass essentially the entire length of the cylinder of rotation, and which tapers the strength thereof with the maximum field strength lying in the center and lower field strengths at the edges. In this manner, rotation of the cylindrical container 12 brings the entire volume of the blood sample into "contact" with the incident microwave energy so that essentially all the incident energy is absorbed, but without appreciable local overheating. Construction and arrangement of such a non-resonant antenna are in accordance with principles well known in the prior art. The location and configuration thereof are generally predictable employing known microwave parameters. From that point, trial and error can be utilized to optimize the geometry of element 11 and the position of container 12. For example, for a plastic pouch containing blood, the general configuration which provides rapid even heating has been found to be a non-resonant antenna element 11 of a generally trapezoidal shape wherein the parallel sides are essentially at right angles to the direction of propagation of the microwaves. The element 11 is positioned so as to direct microwave energy upwards into the enclosure 10 and so as to impinge on the cylinder of rotation generated by the rotating sample.

However, other coupling elements would be equally suitable, provided their position and configuration were such as to provide the requisite matching, the appropriate dimensions, and the appropriate field strength distribution discussed above. These means for achieving directing, focussing, and shaping of the incident microwave energy field are illustrative and not limiting. Other means for accomplishing the same purpose will occur to those skilled in the art. Novelty of the invention does not lie in the specific means for accomplishing the shaping and matching.

Referring specifically to FIG. 2, there is shown a general schematic operational configuration of a preferred embodiment, a microwave blood warmer. To the mains terminals 23 and 24 is fed 115 volt AC power. Timer and safety interlock circuits generally designated as 25 permit operation of the unit only when all conditions for safe operation have been met, for example when the interlock switch 26 is properly closed by latching of door 27, and when the appropriate heating cycle has been programmed in based on the item to be heated, its size, initial temperature, and desired final temperature. The low and high voltage regulated power supply is generally designated as 28 and provides high voltage power to the magnetron 29 and low voltage power to the safety and control circuits 25, interlock switch 26, and motor 22. Microwaves generated by the magnetron 29 are transported through the wave guide 30 and into the coupling element 11. An RF shield 31 protects against emission or leakage of stray energy.

Thus, in summary, the invention provides a microwave heating device which: generates microwave energy; transports it; directs, focuses, and shapes it; and brings it into contact with a rotating sample to be heated in such a manner that essentially all of the incident microwave energy is absorbed by the sample and the sample is heated rapidly to a predetermined final temperature without any appreciable local overheating. All this is accomplished without the use of conventional resonant cavities wherein microwave energy is stored; without the disadvantages of standing waves or resonant modes and their resulting hot and cold spots; and without the employment of the conventional and cumbersome means of equalization of energy within a microwave enclosure, such as movable reflectors or field stirring (mode mixing).

While there has been shown and described what is at present the preferred embodiment of the invention, various modifications and departures will now occur to those

skilled in the art, and it is intended to cover the appended claims all such modifications as are within the spirit and scope of the invention.

What is claimed is:

1. In a microwave heating device employing an enclosure for confining microwave energy, a means for directing microwave energy into said enclosure, a means for positioning and supporting an item to be heated by an incident microwave energy field, and a means for rotating said item about an axis of rotation essentially at a right angle to the direction of propagation of the incident microwave energy field, the improvement comprising:

a microwave coupling element in combination with said positioning and supporting means and said means for rotating said item to be heated, wherein the incident microwave energy impinges essentially entirely within the cylinder of rotation generated by the rotation of said item to be heated, has an incremental energy distribution along said axis of rotation generally proportional to the incremental volume of the item to be heated, and is essentially completely absorbed by said item.

2. The microwave heating device set forth in claim 1, wherein said microwave coupling element is a non-resonant microwave antenna, said antenna comprising a directing, focusing, and shaping configuration characterized by a gradual upward slope of the floor of said means for directing microwave energy into said enclosure and a generally trapezoidal aperture, the parallel sides thereof being essentially at right angles to the direction of propagation of said microwave energy field, said antenna positioned with respect to said item to be heated at a distance such that essentially all of the incident microwave energy field illuminates the cylinder of rotation generated by the rotation of said item and is essentially completely absorbed by said item.

3. In a microwave blood warmer, an enclosure for confining microwave energy, a source of microwave energy, a wave guide for directing said microwave energy into said enclosure, a rotatably mounted cylindrical microwave permeable container for the blood sample axially positioned at essentially a right angle to the direction of propagation of the incident microwave energy field, a non-resonant microwave antenna comprising an upwardly sloped terminal portion of the floor of said wave guide and a generally trapezoidal aperture into said enclosure, whereby the incident microwave energy illumination falls substantially within the cylinder of rotation generated by the rotation of the blood sample, said incident microwave energy illumination having an incremental energy distribution along said axis of rotation of the blood sample generally proportional to the incremental volume of the blood sample and whereby said microwave energy is essentially completely absorbed by the blood sample.

#### References Cited

##### UNITED STATES PATENTS

3,283,113 11/1966 Smith ----- 219—10.55

##### FOREIGN PATENTS

978,197 12/1964 Great Britain.  
1,092,484 11/1967 Great Britain.  
1,217,589 5/1960 France.

##### OTHER REFERENCES

Schwenkhagen: German application 1,120,619, printed Dec. 28, 1961 (Kl 21h36).

JOSEPH V. TRUHE, Primary Examiner

L. H. BENDER, Assistant Examiner