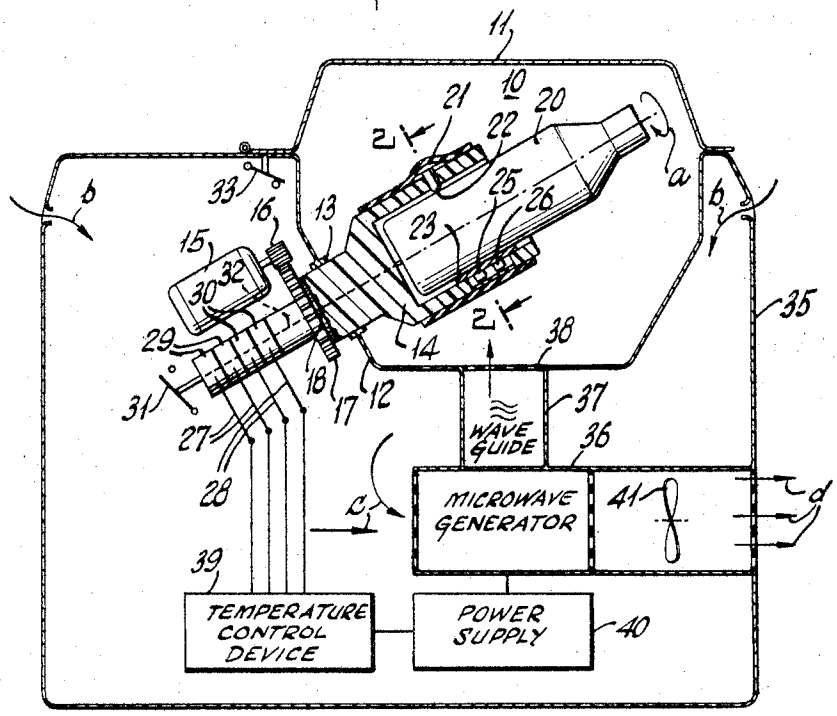
Feb. 11, 1969 P. C. MÜLLER 3,427,422

MICROWAVE HEATING APPARATUS

Filed May 18, 1966

Fig. 1.



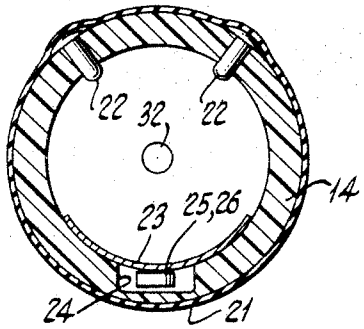


Fig. 2.

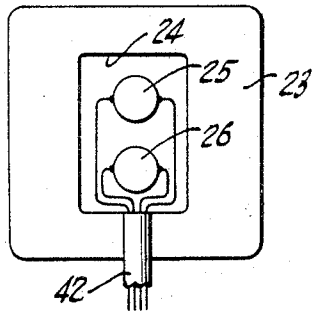


Fig. 3.

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MICROWAVE HEATING APPARATUS

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ABSTRACT OF THE DISCLOSURE

A non-metallic bottle containing a liquid to be heated is mounted by friction in a hollow open-ended cylindrical holder of microwave-permeable insulating material and rotatively mounted in an enclosed heating space about its axis forming a predetermined vertical incline angle with the horizontal. A microwave energy beam is injected into said space in a vertical direction and impinged upon said holder and bottle being rotated about said axis.

The present invention relates to microwave high frequency heating apparatus of the general type including a microwave generator with means to apply a microwave energy beam unto the material or substance to be heated disposed in an enclosed heating space or chamber, and more particularly to improved heating apparatus of this type for the heating of easily coagulable liquid substances, and/or substances liable to bubble or foam formation during heating, in particular preserved blood, and stored in non-metallic bottles or the like containers.

Among the objects of the invention is the provision of high frequency heating apparatus of the referred to type by which a liquid, such as blood plasma, can be heated to a desired temperature substantially instantly and relatively rapidly without the danger of coagulation or foam formation; whereby the desired final heating temperature is maintained within relatively close tolerances; which apparatus is both simple in design and efficient in operation; and which may be fabricated economically and used at low operating cost.

The invention, both as to the foregoing and ancillary objects as well as novel aspects thereof, will be better understood from the following detailed description of a preferred practical embodiment, taken in conjunction with the accompanying drawing forming part of this specification. In the drawing, wherein like reference numerals denote like parts of the different views thereof:

FIG. 1 shows, in part diagrammatically and in part in section, microwave heating apparatus constructed in accordance with the principles of the invention;

FIG. 2 shows a section, to an enlarged scale, taken on line 2—2 of FIG. 1; and

FIG. 3 more clearly shows the temperature sensing device of the automatic temperature control forming part of the preceding figures.

With the foregoing objects in view, the invention, according to one of its aspects, involves generally the provision of means providing an enclosed microwave treating space or chamber having disposed therein an open-ended hollow and rotatably mounted container holder of microwave permeable insulating material, the inside space enclosed by said holder substantially conforming to the configuration of the containers storing the liquid to be heated, in particular preserved blood or a like easily coagulable liquid substance. There is furthermore provided according to the invention means to frictionally support the containers by or urge the same against the inside wall of the holder, to cause rotation of the containers and the liquid stored therein together with the holder and to effect a close thermal contact with the temperature-sensing element of an automatic temperature control device operably combined with the heating apparatus of the invention, in the manner described in further detail in the following.

In operation, the container holder is rotated about an axis coincident with the axis of the container mounted therein, such as a bottle or the like oblong storage vessel, while a microwave energy beam is impinged from a microwave generator (magnetron, klystron, etc.) upon the holder and the liquid container via suitable wave guide means connecting the generator with the heating space or chamber. The temperature-sensing element in cooperation with the automatic temperature control device serves to heat the liquid by direct action of the microwave energy to a desired temperature and to maintain it at this temperature, for example 35° in the case of blood plasma. Due to the rotation of the liquid, coagulation and bubble or foam formation is substantially eliminated or minimized and the heating time to the desired temperature reduced to a minimum.

According to an especially advantageous construction of the heating apparatus according to the invention, the oblong bottles or the like containers, and in turn the rotatable container holder, are disposed at an inclined angle with the microwave beam being impinged thereon in a substantially upward or vertical direction, in such a manner as to achieve an improved mixing or stirring effect (by friction with the bottle wall) on the liquid stored in the bottle or container, combined with ease in handling and exchange of the containers. Besides, the inclination of the containers and application of the microwave energy at an angle or vertically in relation to the rotating axis of the liquid results in a relatively faster heating of the lower portion of the liquid, causing this warmer liquid to rise to the top with the result of a greater mixing or stirring action and, in a turn, a further reduced heating time. The apparatus of the invention has been found especially suitable for the heating of preserved blood in substantially preventing coagulation or foam formation, while reducing heating time to a minimum.

Further details and features of the invention will become more apparent as the description proceeds in reference to the drawing.

The microwave treating space proper or chamber **10** is closed by a hinged snap lid or cover **11** for the positioning therein and withdrawal of the containers storing the liquid to be heated. Rotatively mounted in an inclined wall **12** of the chamber **10**, by means of a bearing **13**, is a container or vessel holder **14** in the form of an open-ended hollow member consisting of microwave permeable insulating material and having an inside space substantially conforming to the configuration of a bottle or the like container **20** storing the liquid to be heated, such as preserved blood or plasma. As a consequence, the holder **14** and with it the container **20**, being driven by an electric motor **15** via a reduction gearing **16**, **17** and friction coupling **18**, is rotated, as indicated by the arrow *a* in the drawing, about an inclined axis enclosing a suitable angle with the horizontal of preferably less than 45°. As an example, a rotating speed of the container of about 30 revolutions per minute and an incline angle of about 30° have been found to produce satisfactory results in treating or heating blood plasma.

The container **20**, which can be easily inserted into and withdrawn from the holder **14** on account of the inclined mounting of the latter, is held or retained in the holder by friction, whereby to rotate together with said holder and to maintain a close thermal contact with the temperature-sensing element mounted upon the inside wall of the holder and forming part of an automatic

temperature control device, serving, in cooperation with a suitable microwave generator, to raise the temperature of the liquid to be treated to and to maintain it at a desired temperature, such as 35° in the case of preserved blood.

In the example shown, the friction mounting means for the container **20** is comprised of a rubber or the like flexible sleeve **21** encircling the hollow portion of the holder **14** in stretched condition, said sleeve acting upon the outer perimeter of the container **20** via a pair (in the example shown) of non-metallic pressure pins **22** of greater length than the wall thickness of said holder and mounted slidably in radial bores of said holder, whereby said pins fitted with suitable outer heads engage the inside of the sleeve **21**, on the one hand, and the container, on the other hand, to result in an adequate frictional engagement between the container **20** and holder **14**, or temperature-sensing device described in the following.

The temperature-sensing device comprises, in the example shown, a thin metallic sheet **23** having soldered or otherwise connected thereto a thin-walled metal casing or screen **23** disposed in a recess of the holder **14** and housing a pair of temperature-sensitive resistors or thermistors **25** and **26** supported in heat-conducting contact by the sheet **23**. As an example, the element **23** may consist of a thin bronze sheet having a thickness of from 0.1 to 0.3 millimeter, though not limited thereto, and possessing a very small heat capacity. The thermistors **25** and **26** being electrically and magnetically shielded by the housing **23** are connected, via suitable conductors (not shown) mounted in shielded condition within the axis of the holder **14**, each to a pair of slip rings **29**, **30**, respectively, cooperating in a known manner with pairs of stationary brushes or sliding contacts **27**, **29**, respectively, the latter being in turn connected to an automatic temperature control device **39** of known construction connected to the power supply **40** of the microwave generator **36** of the heating apparatus, such as a magnetron, klystron, etc., having its output applied, via a suitable coupling wave guide **37**, to the heating chamber **10**, to impinge a microwave energy beam upon the liquid in the container **20** to be heated. The outlet end of the wave guide **37** may be closed in water-tight fashion by a Teflon or the like microwave permeable plate or closure **38**.

In order to prevent operation of the heating apparatus during idling condition, that is, when no container is placed in the holder **14**, or during exchange of the containers, a safety switch **31** operated by a spring-urged plunger **32**, mounted axially within the holder **14** and slip rings **29**, **30** and engaged at its inner end by the bottom of the container **20** in the mounted position, serves to disconnect the generator as long as there is no container in the device. Similarly, the generator **36** may be disconnected during opening of the lid **11** by the provision of a further safety switch **33** operably connected with said lid, as indicated.

In operation, the temperature control device **39**, including a suitable temperature standard, operates in a known manner to connect and disconnect the generator **36**, via its power supply **40** in the example shown, whenever the temperature of the container or liquid stored therein falls below or rises above the desired value, that is 35° on the case of preserved blood, whereby to raise the liquid to and to automatically maintain it at said temperature within a desired accuracy or tolerance range.

In order to prevent temperature fluctuations of the heating apparatus during prolonged use in the operating room or the like, the chamber **10** and generator **36** are enclosed, according to an improved feature of the invention, in an outer housing **35** having its temperature stabilized or maintained at the temperature of the ambient atmosphere. For this purpose, the microwave generator **36** together with the coupling wave guide **37** are suction cooled by the provision of a fan or blower **41** disposed in airtight manner between the outlet duct of the generator cooling device and an opening in the housing wall **35**, the inlet of the generator cooling device being connected with the outside atmosphere through suitable inlet ports in the housing wall **35**. As a consequence, air is continuously sucked into the housing and forced through the generator cooling ducts, as indicated by the arrows *b*, *c* and *d* in the drawing, the heated air being discharged to the outside, in such a manner as to maintain the temperature within the housing **35** within a range of ±2° of the ambient temperature and to maintain the liquid temperature within ±1° of 35° C. in the case of preserved blood as an example. After the temperature, upon initially starting the device, has reached the desired value, a control signal by the sending resistor **25** applied via the contacts **37** causes the automatic control to disconnect the generator **36**, and vice versa, to reconnect the same after the temperature decreases below said value to a predetermined extent, in a manner well known in the operation of automatic temperature control devices.

The second thermistor, **26** connected to the contacts **29** is independent of the thermistor **25** and may serve to operate a suitable temperature indicator or measuring device (not shown).

With specific reference to the heating of preserved blood, the microwave power is advantageously adjusted such that a container of 500 cm.^{3} capacity may be heated from +5° to +35° C. in approximately 3 to 5 minutes. The degree of accuracy is within 1° C. even with contents of from 300 to 500 cm.^{3}. This accuracy and the relative short heating time can be attained only if the blood is moved slowly and gently, in particular by rotation, as shown and described, to avoid the formation of bubbles. It is, however, also possible to employ, in place of continuous rotation, a to and fro or rocking motion of the holder or container mounted therein. In the latter case, the containers may be disposed in horizontal, inclined or vertical position.

Besides, the diffused irradiation of the blood or other liquid in the container **20**, disposed at an incline angle of less than 45°, in the example shown and described in the foregoing, largely prevents the blood from coagulating.

In the foregoing the invention has been described in reference to a specific illustrative device. It will be evident, however, that variations and modifications, as well as the substitution of equivalent parts or devices for those shown for illustration, may be made without departing from the broader scope and spirit of the invention as set forth in the appended claims. The specification and drawings are accordingly to be regarded in an illustrative rather than in a restrictive sense.

I claim:

1. Microwave heating apparatus for the treatment of liquids stored in non-metallic containers comprising in combination:

(1) means to provide an enclosed microwave treating space,

(2) an oblong open-ended hollow container holder of microwave-permeable insulating material enclosing a space substantially conforming to the configuration of the containers of the liquid to be heated, for removably mounting a container within said holder,

(3) resilient means to effect frictional engagement between said holder and the container mounted therein,

(4) means rotatively supporting said holder within said treating space about its axis forming a predetermined vertical incline angle with the horizontal,

(5) means to rotate said holder and container mounted therein about said axis,

(6) a microwave generator including wave guide coupling means connecting the same with said treating space, to impinge a microwave beam in a substantially vertically upward direction unto said holder and the container mounted therein,

(7) temperature-sensing means upon said holder in thermal contact with the container mounted therein, and

(8) automatic temperature control means operably connecting said sensing means with said generator, to heat the liquid stored in said container to and maintain it at a predetermined temperature.

2. Microwave heating apparatus as claimed in claim 1, said temperature-sensing means consisting of a strip of heat-conducting metal of low thermal capacity and mounted upon the inside wall of said holder, said strip held in close thermal contact with the container mounted therein by said resilient means, and a heat-sensitive electrical resistor disposed in a recess of said holder and affixed to said strip.

3. Microwave heating apparatus as claimed in claim 2, including metallic screening means enclosing said resistor.

4. Microwave heating apparatus as claimed in claim 1, said resilient means consisting of a sleeve of flexible material encircling said holder in stretched condition, and at least one pressure pin of greater length than the wall thickness of said holder, said pin arranged slidable within a bore through said holder with one end thereof engaging said sleeve and with its opposite end engaging the container mounted in said holder.

5. Microwave heating apparatus as claimed in claim 1, including a housing having air inlet and outlet means and enclosing said treating space, said holder rotating means, said generator and said temperature control means, and further means to aspirate and circulate ambient air through said generator via said inlet and said outlet means.

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U.S. Cl. X.R.

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