US 20120122072A1

(19) **United States**

(12) **Patent Application Publication**

Bilchinsky et al.

(10) **Pub. No.: US 2012/0122072 A1**

(43) **Pub. Date: May 17, 2012**

(54) **METHOD AND SYSTEM FOR HEATING AND/OR THAWING BLOOD PRODUCTS**

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(21) Appl. No.: **13/128,355**

(22) PCT Filed: **Nov. 10, 2009**

(86) PCT No.: **PCT/IL2009/001059**

§ 371 (c)(1), (2), (4) Date: **Nov. 15, 2011**

Related U.S. Application Data

(60) Provisional application No. 61/193,248, filed on Nov. 10, 2008, provisional application No. 61/253,893, filed on Oct. 22, 2009.

Publication Classification

(51) **Int. Cl.**
A01N 1/02 (2006.01)

(52) **U.S. Cl.** **435/2**; 422/44

(57) **ABSTRACT**

A device for heating one or more blood product units using electromagnetic (EM) energy is disclosed. The device comprises a chamber sized and shaped for containing at least one frozen blood product unit, a dielectric heating unit for applying electromagnetic (EM) energy at a plurality of frequencies to the at least one blood product unit, and a controller for operating the dielectric heating unit to heat the at least one frozen blood product unit to about a body temperature in less than 3 minutes according to a heating pattern.

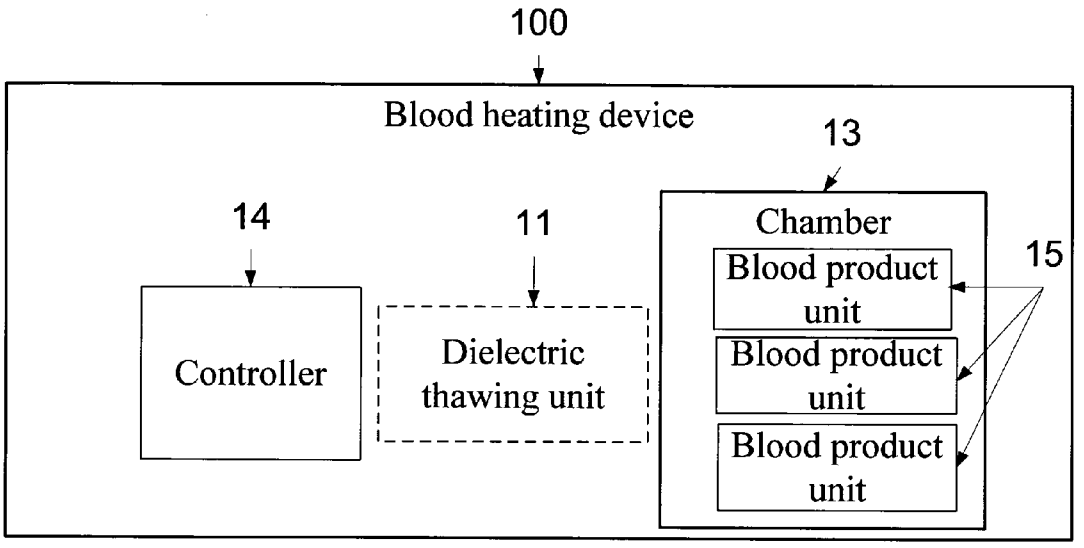
100
Blood heating device
13
14
11
Chamber
15
Blood product unit
Blood product unit
Blood product unit
Controller
Dielectric thawing unit

FIG. 1

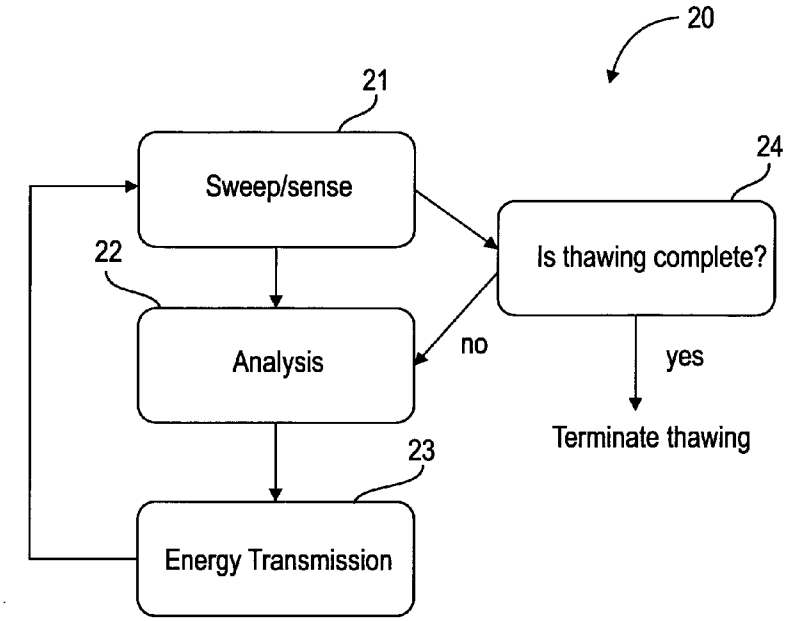
20
21
Sweep/sense
24
Is thawing complete?
22
Analysis
no
yes
Terminate thawing
23
Energy Transmission

FIG. 2A

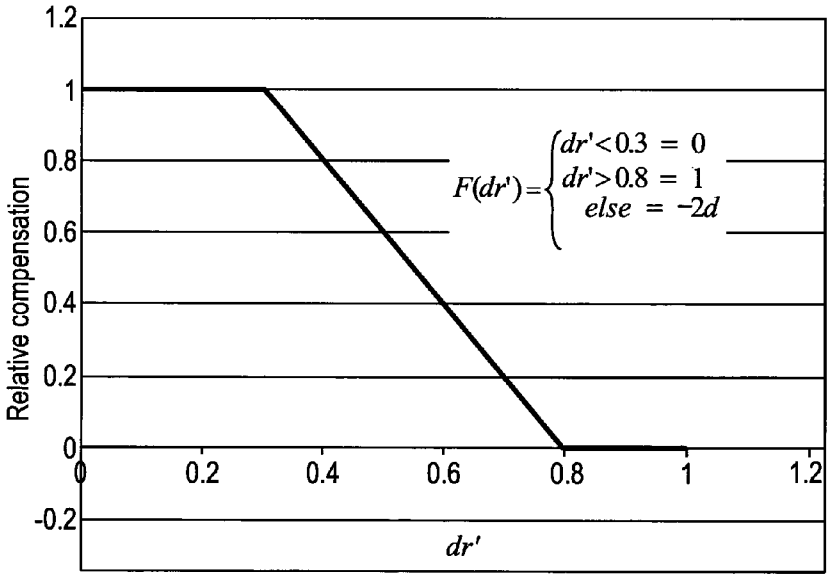
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Relative compensation
0
0.2
0.4
0.6
0.8
1
1.2
dr'
F(dr') = { dr'<0.3 = 0; dr'>0.8 = 1; else = −2d

FIG. 2B

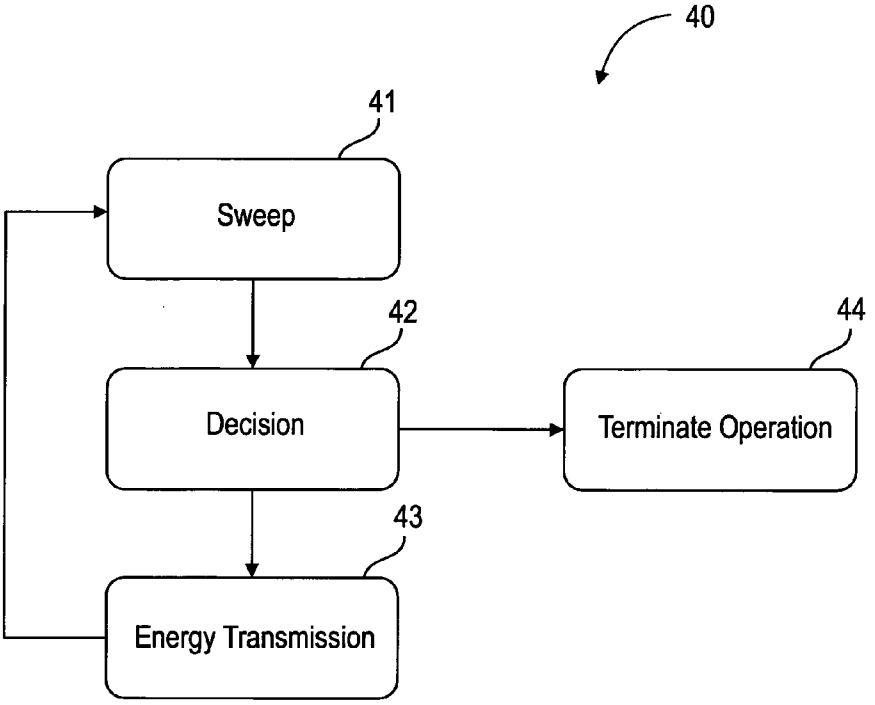
40
41
Sweep
42
Decision
44
Terminate Operation
43
Energy Transmission

FIG. 2C

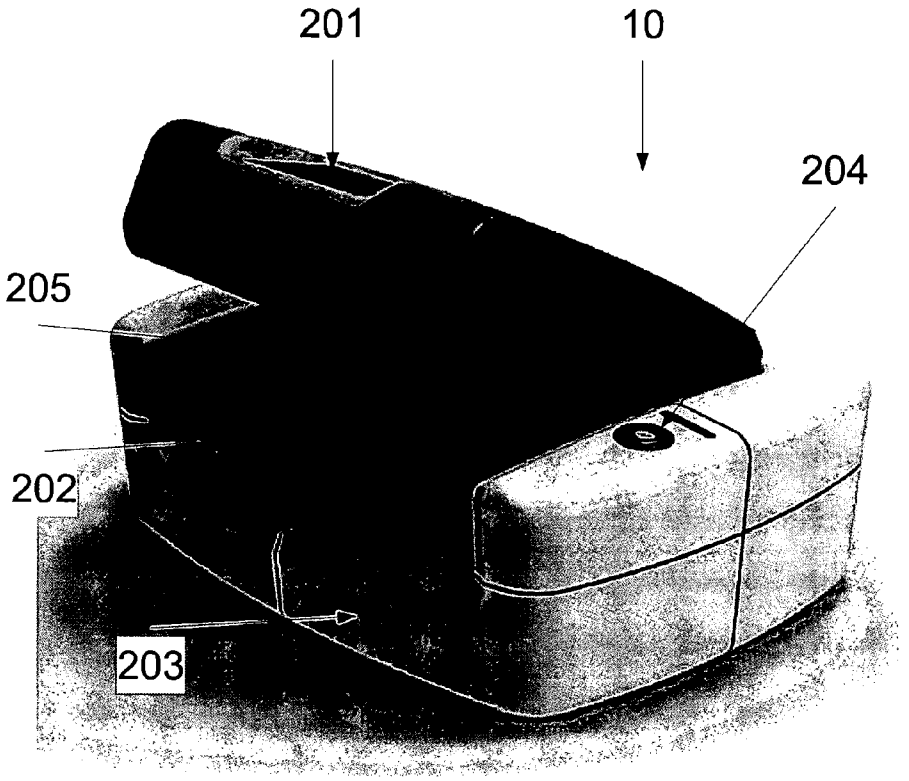

FIG. 3A

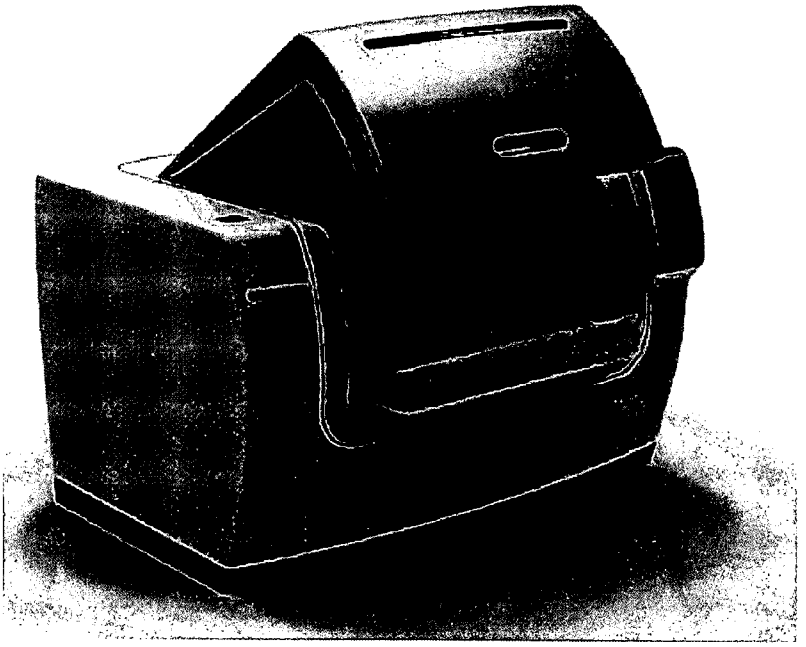

FIG. 3B

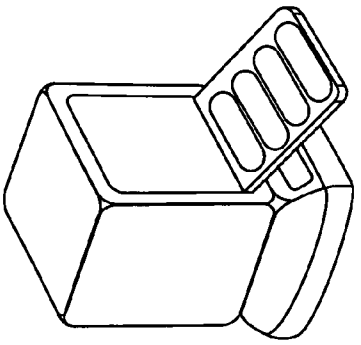

FIG. 3E

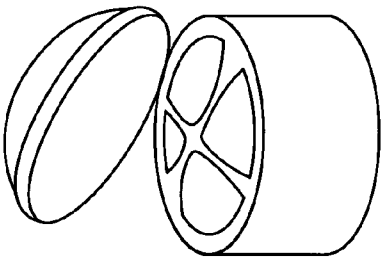

FIG. 3H

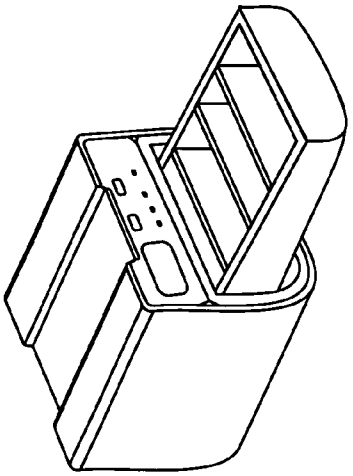

FIG. 3D

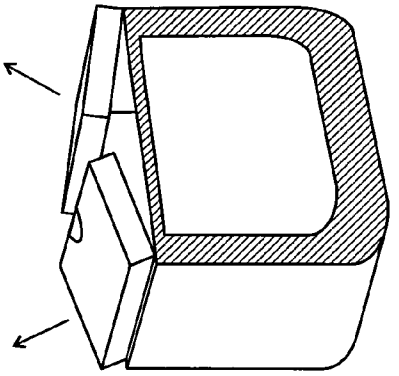

FIG. 3G

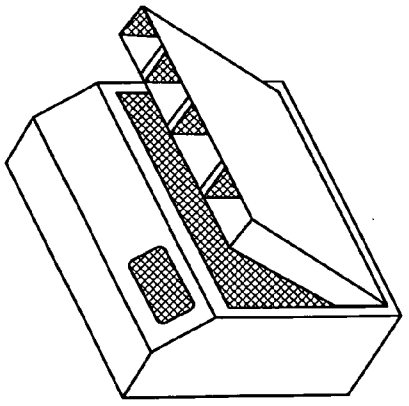

FIG. 3C

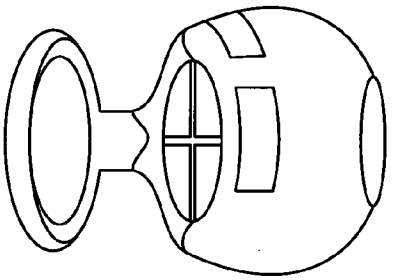

FIG. 3F

FIG. 3I

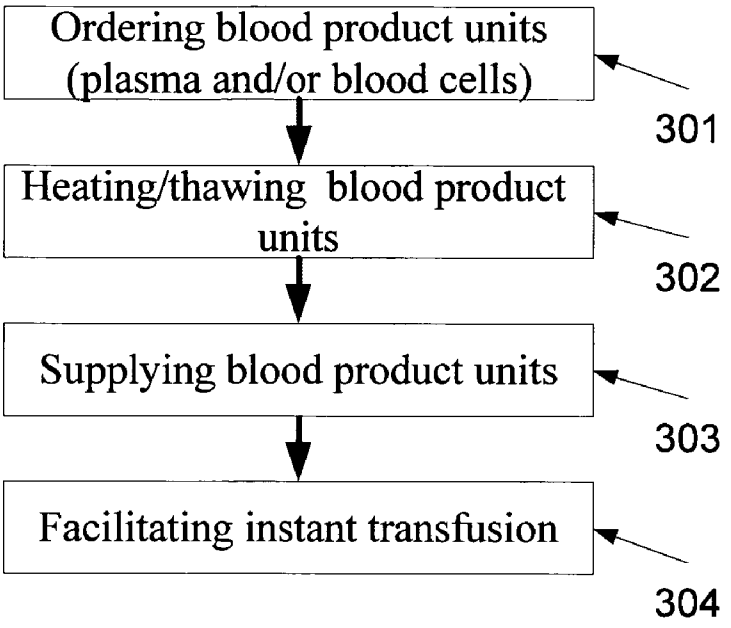
Ordering blood product units (plasma and/or blood cells)
301
Heating/thawing blood product units
302
Supplying blood product units
303
Facilitating instant transfusion
304

FIG. 4A

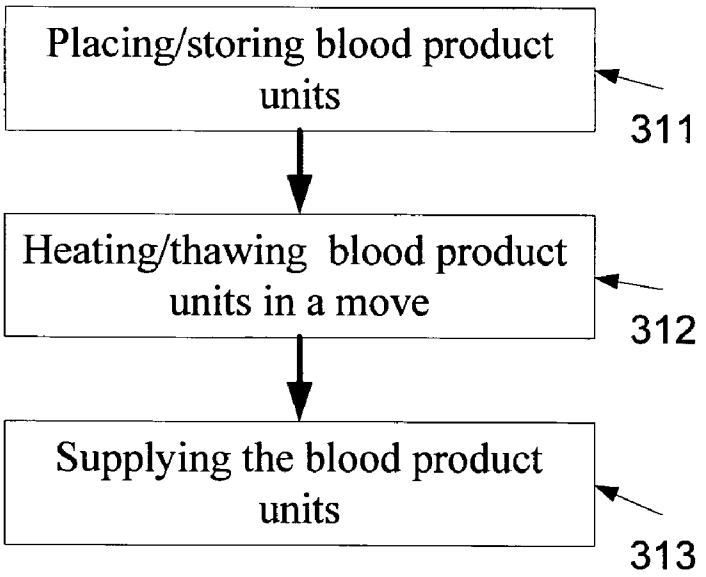
Placing/storing blood product units
311
Heating/thawing blood product units in a move
312
Supplying the blood product units
313

FIG. 4B

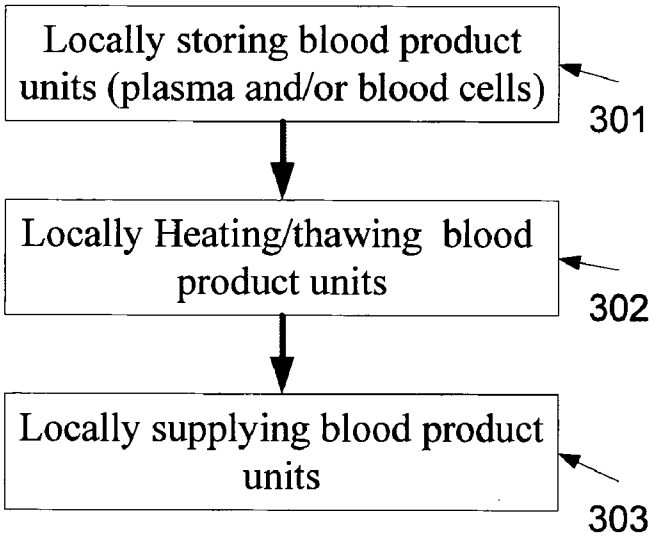
Locally storing blood product units (plasma and/or blood cells)
301
Locally Heating/thawing blood product units
302
Locally supplying blood product units
303

FIG. 5

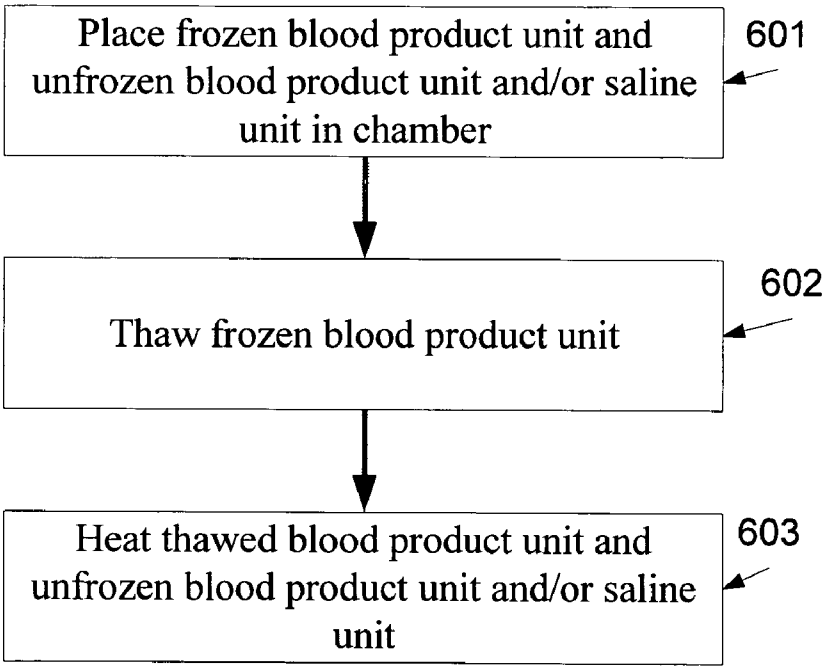
Place frozen blood product unit and unfrozen blood product unit and/or saline unit in chamber
601
Thaw frozen blood product unit
602
Heat thawed blood product unit and unfrozen blood product unit and/or saline unit
603

FIG. 6

METHOD AND SYSTEM FOR HEATING AND/OR THAWING BLOOD PRODUCTS

RELATED APPLICATIONS

[0001] The present application claims the benefit under 119(e) of U.S. Provisional Patent Application No. 61/193,248 filed 10 Nov. 2008 and U.S. Provisional Patent Application No. 61/253,893 filed 22 Oct. 2009 and is related to two PCT applications Agent References: 47408 and 46672 filed on 10 Nov. 2009, the disclosures of which are incorporated herein by reference.

FIELD AND BACKGROUND OF THE INVENTION

[0002] The present invention, in some embodiments thereof, relates to method and system for heating blood product units and, more particularly, but not exclusively, to methods and systems for heating blood product units using electromagnetic (EM) energy.

[0003] In hospitals and medical care centers, blood, blood products and saline solution are use to transfuse patients in need. Saline, a salt solution, is normally maintained at room temperature. Blood products, such as red blood cells (RBC), platelets, and plasma, are stored in frozen and/or cooled form in sealed bags for later use. When frozen, the blood components are generally stored at temperatures below −18° C. Conventionally, fresh frozen plasma is thawed by immersing it in a 37° C. water bath. This normally takes about half an hour. Alternatively, the bag of frozen blood product may be thawed by heating it within a microwave oven. Microwaves developed for the rapid warming of blood products were introduced in the mid-1950s. After first trials in the 1960s and 1970s, several reports of overheating appeared and their use declined despite of their much shorter heating times; see Sherman L A, Dorner I M. A new rapid method for thawing fresh frozen plasma. Transfusion 1974; 14: 595-7; Arens J F, Leonard G L. Danger of overwarming blood by microwave. Journal of the American Medical Association 1971, 218: 1045-6 and Sohngen D, Kretschmer V, Franke K, et al. Thawing of fresh-frozen plasma with a new microwave oven, Transfusion 1988; 28: 576-80.

[0004] An example for a system for thawing blood product units is provided in U.S. Pat. No. 5,374,811, filed on May 6, 1992 that describes a method and apparatus for safely and rapidly rewarming large quantities of frozen or refrigerated blood combines microwave, or radio frequency radiation, heating with a forced air system. Forced air is flowed over units of blood or tissue from those units that will absorb the most microwave energy, generally those units closest to the source of microwave energy, to those units that will absorb the least microwave energy, generally those units furthest from the source of microwave energy. The forced air initially thaws the closest units so that they begin to absorb significant microwave energy. The forced air, preferably chilled, then prevents overheating of those closest units by transferring heat to more distant units, beginning their thawing and contributing to their rewarming. The microwave energy source is turned off when the output temperature of the forced air reaches a preselected temperature and the flow of forced air continues until the output temperature stabilizes. The apparatus includes a separated stack of perforated plates, each plate holding two units, mounted inside a microwave oven. Forced air drives a turbine rotor which rotates the plates while the air leaving the turbine flows down among the stacked plates and out the microwave oven.

[0005] Another example is provided in U.S. Pat. No. 5,616,268, filed on Jul. 7, 1994 that describes a microwave thawing system for thawing bags of frozen blood products features non-invasively monitoring the internal temperature of the blood product during thawing, and controlling the level of warming energy applied to the blood product based on the monitored temperature. The noninvasive monitoring is performed with one or more antennas which receive electromagnetic energy from the frozen blood product during thawing. The inventors of U.S. Pat. No. 5,616,268 claim that because the applied energy level is controlled based on the temperature of the blood, the blood can be thawed rapidly with little risk of damage from overheating. Pressure is applied to the bag to maintain a uniform distribution of blood within the bag and to separate the thawed blood from the still-frozen blood during thawing; for example, the pressure moves the liquid blood to the periphery of the bag and retains the frozen blood in the center of the bag. As a result, the continued application of thawing energy to the frozen blood poses little risk of overheating (and contaminating) the liquid blood. The warming energy and the electromagnetic energy are transmitted and received, respectively, through receive waveguides configured to provide high isolation between its transmit and receive ports.

SUMMARY OF THE INVENTION

[0006] According to some embodiments of the present invention there is provided a device of heating a blood product unit using electromagnetic (EM) energy. The device comprises a chamber for containing at least one frozen blood product unit, a dielectric heating unit which applies electromagnetic (EM) energy to the at least one frozen blood product unit, and a controller which operates the dielectric heating unit to heat the at least one frozen blood product unit to about a body temperature in less than 3 minutes according to a heating pattern.

[0007] Optionally, the controller is configured for operating the dielectric heating unit to heat the at least one frozen blood product unit to about a body temperature in less than 1 minute according to a heating pattern.

[0008] According to some embodiments of the present invention there is provided a device of heating a blood product unit using electromagnetic (EM) energy. The device comprises a chamber for containing at least one frozen blood product unit, a dielectric heating unit for applying electromagnetic (EM) energy to the at least one frozen blood product unit, and a controller for operating the dielectric heating unit to heat the at least one frozen blood product unit. The device is configured to perform at least a portion of the applying electromagnetic (EM) energy at a time when the blood product unit being stationary.

[0009] Optionally, the at least portion is at least 50% of the duration of the applying of electromagnetic (EM) energy.

[0010] Optionally, the at least portion is at comprises applying at least 50% of the total amount of electromagnetic (EM) energy that being applied to the frozen blood product unit.

[0011] Optionally, the device further comprises a freezing chamber for freezing the at least one frozen blood product unit.

[0012] Optionally, the device further comprises a unit positioning element sized and shaped to support the at least one frozen blood product unit in the chamber.

[0013] More optionally, the unit positioning element is automatically extracted when the chamber being opened.

[0014] More optionally, the unit positioning element comprises at least one slot for placing the at least one frozen blood product unit.

[0015] Optionally, the controller is configured for operating the dielectric heating unit so as to allow substantially uniformly heating the at least one frozen blood product unit regardless to the position thereof in the in the chamber.

[0016] Optionally, the controller is configured for operating the dielectric heating unit so as to allow substantially uniformly heating the at least one frozen blood product unit without receiving designated instructions from a human operator.

[0017] Optionally, each the frozen blood product unit is contained in a bag having a maximal thickness between 2 cm and 6 cm.

[0018] Optionally, each the frozen blood product unit is contained in a bag is of irregular thickness.

[0019] Optionally, the controller operates the dielectric heating unit regardless of the shape of the frozen blood product unit.

[0020] According to some embodiments of the present invention there is provided a device of heating a blood product unit using electromagnetic (EM) energy. The device comprises a chamber for containing at least one cooled blood product unit having a temperature above 0° C. and below 15° C., a dielectric heating unit for applying electromagnetic (EM) energy to the at least one cooled blood product unit, and a controller for operating the dielectric heating unit to heat the at least one cooled blood product unit to about a body temperature in less than 1 minute according to a heating pattern.

[0021] According to some embodiments of the present invention there is provided a device of heating a blood product unit using electromagnetic (EM) energy. The device comprises a chamber for containing at least one cooled blood product unit having a temperature above 0° C. and below 15° C., a dielectric heating unit for applying electromagnetic (EM) energy to the at least one cooled blood product unit, and a controller for operating the dielectric heating unit to heat the at least one cooled blood product unit. The device is configured to perform at least a portion of the applying electromagnetic (EM) energy at a time when the blood product unit being stationary.

[0022] Optionally, the controller is configured for operating the dielectric heating unit to heat the at least one cooled blood product unit uniformly to about a body temperature in 20 seconds or less according to a heating pattern.

[0023] Optionally, the at least portion is at least 50% of the duration of the applying of electromagnetic (EM) energy.

[0024] More optionally, the at least portion is at comprises applying at least 50% of the total amount of electromagnetic (EM) energy that is applied to the cooled blood product unit.

[0025] More optionally, the chamber is sized and shaped for containing the at least one cooled blood product unit.

[0026] Optionally, the device is sized for being installed in a member of a group consisting of: an ambulance, an operating room, and an emergency room.

[0027] Optionally, the EM energy is at a plurality of frequencies.

[0028] According to some embodiments of the present invention there is provided a method heating a blood product unit using electromagnetic (EM) energy. The method comprises (a) placing at least one frozen blood product unit in a chamber, (b) thawing the at least one frozen blood product unit by applying EM energy to the at least one frozen blood product unit at a plurality of different frequencies, and (c) heating the at least one frozen blood product unit in the chamber by applying the EM energy to about a body temperature. The thawing and the heating are performed cumulatively in less than 3 minutes.

[0029] According to some embodiments of the present invention there is provided a method heating a blood product unit using electromagnetic (EM) energy. The method comprises (a) placing at least one frozen blood product unit in a chamber, (b) thawing the at least one frozen blood product unit by applying EM energy to the at least one frozen blood product unit, and (c) heating the at least one frozen blood product unit in the chamber by applying the EM energy to about a body temperature. The at least a portion of the thawing and the heating is performed when the at least one blood product is stationary.

[0030] Optionally, the thawing and the heating are performed cumulatively in less than 1 minute.

[0031] Optionally, the EM energy is at a plurality of frequencies.

[0032] More optionally, the method comprises selecting a maximum power to be dissipated in the at least one frozen blood product unit in a manner which avoids overheating, wherein the EM energy is below the maximum power at all the plurality of different frequencies.

[0033] More optionally, the method comprises gathering data pertaining to at least one of the thawing, the heating and change of at least one characteristic of the at least one frozen blood product unit during at least one of the thawing and the heating and scoring the quality of the at least one frozen blood product unit according to the data.

[0034] More optionally, the method comprises tagging each the at least one frozen blood product unit with a respective quality score according to the scoring.

[0035] More optionally, the method comprises reading instructions from at least one tag attached to the at least one frozen blood product unit and performing at least one of the thawing and the heating according to the instructions.

[0036] More optionally, the method comprises moving the at least one frozen blood product unit during at least one of the heating and the thawing.

[0037] More optionally, the method comprises storing the at least one frozen blood product unit at a freezing temperature in the chamber before performing the step (b).

[0038] More optionally, the at least one frozen blood product unit is a frozen plasma unit.

[0039] According to some embodiments of the present invention there is provided a method heating a cooled blood product unit using electromagnetic (EM) energy. The method comprises (i) placing at least one cooled blood product unit in a chamber, and (ii) heating the at least one cooled blood product unit by applying EM energy to the at least one cooled blood product unit to about a body temperature. The heating is performed in less than 1 minute.

[0040] Optionally, the heating is performed in 20 seconds or less.

[0041] According to some embodiments of the present invention there is provided a method heating a cooled blood product unit using electromagnetic (EM) energy. The method comprises (i) placing at least one cooled blood product unit in a chamber, and (ii) heating the at least one cooled blood product unit by applying EM energy to the at least one cooled blood product unit to about a body temperature. At least a portion of the heating is performed when the at least one blood product is stationary.

[0042] Optionally, the at least one cooled blood product comprises red blood cells.

[0043] According to some embodiments of the present invention there is provided a method for heating a blood product unit using electromagnetic (EM) energy. The method comprises placing a plurality of blood product units in a chamber, applying EM energy to the plurality of blood product units, measuring the temperature of each the blood product units, and ending the applying when the temperature of each the blood product unit is above a minimum threshold.

[0044] Optionally, the ending is performed automatically.

[0045] Optionally, the minimum threshold is 25° C. or more.

[0046] Optionally, the ending comprises ending the applying when the temperature of any of the blood product unit is above a maximum threshold.

[0047] More optionally, the minimum threshold and the maximum threshold are no more than 15° C. apart.

[0048] More optionally, the minimum threshold and the maximum threshold are about 2° C. apart.

[0049] According to some embodiments of the present invention there is provided a method for thawing a blood product unit using electromagnetic (EM) energy. The method comprises placing at least one blood product unit in a chamber, applying EM energy to the at least one blood product units at a time when the at least one blood product unit comprises frozen and thawed portions, and ending the applying when the temperature of all portions of the at least one blood product unit is between 2° C. and 15° C.

[0050] Optionally, during the process no part of the blood product exceeds 40° C. or 30° C. or 20° C.

[0051] Optionally, no material cooling is applied during the process.

[0052] According to some embodiments of the present invention there is provided a method for managing blood product unit supply. The method comprises receiving a request for at least one frozen plasma unit and at least one cooled blood cells unit, heating the at least one cooled blood cells unit and the at least one frozen plasma unit to about a body temperature cumulatively in less than 3 minutes by applying electromagnetic (EM) energy, and jointly transferring at least one of the at least one heated cooled blood cells unit and at least one of the at least one frozen plasma unit to allow a transfusion thereof.

[0053] Optionally, the method comprises performing the heating in a member of a group consisting of: an ambulance, an operating room, and an emergency room.

[0054] Optionally, the heating comprises automatically acquiring the frozen plasma unit and the cooled blood cells unit from a freezing storage and automatically placing the frozen plasma unit and the cooled blood cells unit in a heating chamber, the applying being performed in the heating chamber.

[0055] According to some embodiments of the present invention there is provided a method for managing blood product unit supply. The method comprises providing a dielectric heating device and a freezing chamber in a member of a group consisting of: an ambulance, an operating room, and an emergency room, storing at least one frozen blood product unit in the freezing chamber at the member, heating the at least one frozen blood product unit to about a body temperature in less than 3 minutes by using the dielectric heating device in the member, and providing the at least one heated frozen blood product unit for transfusion in the member immediately after the heating.

[0056] According to some embodiments of the present invention there is provided a method for managing blood product unit supply. The method comprises receiving a request for at least one frozen plasma unit and at least one of one or more cooled blood product units and one or more unheated saline units, placing both the at least one frozen plasma and the at least one of one or more cooled blood product units and one or more unheated saline units unit in a chamber, and applying electromagnetic (EM) energy into the chamber thereby thawing at least the at least one frozen plasma unit without heating the at least one of one or more cooled blood product units and one or more unheated saline units by more than 15° C.

[0057] Optionally, the applying electromagnetic (EM) energy is terminated when the at least one cooled blood product unit and the at least one frozen plasma unit are heated to about a body temperature.

[0058] Optionally, at least one of one or more cooled blood product units and one or more unheated saline units consist of one or more packed red blood cells unit.

[0059] According to some embodiments of the present invention there is provided a vehicle for heating blood product units. The vehicle comprises dielectric heating device having a chamber sized and shaped for containing at least one frozen blood product unit and configured for applying electromagnetic (EM) energy to the at least one frozen blood product unit, and a chassis for supporting the dielectric heating device. The dielectric heating device is configured to perform at least a portion of the applying electromagnetic (EM) energy when the vehicle is on a move.

[0060] According to some embodiments of the present invention there is provided a method of managing blood product unit supply. The method comprises receiving a request for at least one chilled or frozen blood product unit at a storage site, placing the at least one chilled or frozen blood product unit in a heating device, and transporting the at least one chilled or frozen blood product unit within the heating device to a use site being remote from the storage site The heating device is operated such that the temperature of at least one of the at least one chilled or frozen blood product unit increases during the transporting by at least 10° C. in all portions thereof.

[0061] Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will

control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

[0062] Implementation of the method and/or system of embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a combination thereof. Moreover, according to actual instrumentation and equipment of embodiments of the method and/or system of the invention, several selected tasks could be implemented by hardware, by software or by firmware or by a combination thereof using an operating system.

[0063] For example, hardware for performing selected tasks according to embodiments of the invention could be implemented as a chip or a circuit. As software, selected tasks according to embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In an exemplary embodiment of the invention, one or more tasks according to exemplary embodiments of method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions and/or data and/or a non-volatile storage, for example, a magnetic hard-disk and/or removable media, for storing instructions and/or data. Optionally, a network connection is provided as well. A display and/or a user input device such as a keyboard or mouse are optionally provided as well.

BRIEF DESCRIPTION OF THE DRAWINGS

[0064] Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

[0065] In the drawings:

[0066] FIG. **1** is a schematic illustration of a blood product heating device for thawing and/or heating one or more blood product units, according to embodiments of the present invention;

[0067] FIG. **2**A is a flowchart showing how a blood product heating device such as the one depicted in FIG. **1** may be operated to thaw one or more frozen blood product units, according to exemplary embodiments of the invention;

[0068] FIG. **2**B is a graph of frequency vs. time for an exemplary decision function, according to exemplary embodiments of the invention;

[0069] FIG. **2**C is a simplified flow chart of a method of operation of a device according to exemplary embodiments of the invention;

[0070] FIGS. **3**A-**3**H are schematic illustrations exemplary portable blood product heating devices, according to some embodiments of the present invention;

[0071] FIG. **3**I is a schematic illustration of an exemplary portable blood product heating device having a freezing chamber, according to some embodiments of the present invention;

[0072] FIG. **4**A is a flowchart of a method for managing the supply of blood product units for transfusion, according to some embodiments of the present invention;

[0073] FIG. **4**B is a flowchart of a method for managing the supply of blood product units for transfusion, according to some embodiments of the present invention; and

[0074] FIG. **5** is a method for locally preparing and providing one or more blood product units for transfusion, according to some embodiments of the present invention.

[0075] FIG. **6** is a method for providing one or more blood product units and/or saline solution units for transfusion together with one or more thawed blood product units.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0076] The present invention, in some embodiments thereof, relates to method and system for heating blood product units and, more particularly, but not exclusively, to method and system for heating blood product units using electromagnetic energy.

[0077] According to some embodiments of the present invention, there is provided a device and a method for thawing and heating one or more frozen and/or cooled blood product units, such as plasma, with or without additives, for example cryoprecipitate, and blood cells units, for example packed red blood cells and/or saline units, to about a body temperature in less than three minutes, for example in about a minute or less. A cryoprecipitate, is normally a precipitate that results from cooling or even freezing of plasma, and is often administered in a mixture with fresh frozen plasma. The device includes a chamber that is sized and shaped for containing blood product units, for example 1, 4, 7, 12, and/or any intermediate number. Optionally, the blood product units are placed on a unit positioning element, optionally detachable from the chamber. It should be noted that as the heating pattern may be determined by an analysis of the absorption of different frequencies, the placement of the blood product units may not have to be predefined and/or exact. The device further includes a dielectric heating unit that applies electromagnetic (EM) energy at a plurality of frequencies to the blood product units in the chamber. The dielectric heating unit is operated by a controller. Optionally, the operation is performed according to a heating pattern that allows heating the blood product units to about a body temperature in less than 3 minutes. Optionally, the thawing is performed as described in U.S. 61/193,248 ('248), which is incorporated herein by reference. Optionally, the device is a portable device. Optionally, the device is sized and shaped for being positioned in an ambulance, a trauma room, an operating room (OR), and/or emergency room (ER) or any other location that is remote from a blood bank (e.g. near or within an intensive care unit or conventional hospital ward) without taking much space.

[0078] According to some embodiments of the present invention there, is provided a method for managing a supply of blood product units, optionally frozen. The ability to heat a blood product unit to a body temperature in less than 3 minutes allows heating plasma and red blood cells blood product units in a ratio of 1:1 upon request and providing them for transfusion immediately. Optionally, the blood product units are heated at a blood bank and provided, optionally simultaneously, to a trauma room, an operating room (OR), and/or emergency room (ER). In other embodiments the blood product units are provided to the transfusion site, for example at the trauma room, the operating room (OR), and/or the emergency room in a frozen or cooled form and thawed and/or heated at the transfusion site. In other embodiments the blood product units are locally stored and heated at the

transfusion site, for example at the trauma room, the operating room (OR), and/or the emergency room. In other embodiments, a portable device is capable of completing the thawing and/or heating of the blood product units during transit from the site of storage to the site of transfusion. As the heating process is prompt and the size of the heating device, and optionally a freezing chamber that is used for storing the blood product units, is relatively limited, blood product units may be locally stored at the transfusion site. Such storage reduces the time needed for providing a blood product unit at a temperature which is ready for transfusion.

[0079] According to some embodiments of the present invention, there is provided a method for heating a plurality of frozen blood product units. First, the frozen blood product units are placed in a heating chamber. Then, EM energy is applied to thaw and heat the frozen blood product units, optionally at a plurality of different frequencies. Now, the temperature of each one of the frozen blood product units is measured. This allows ending the EM energy thawing and/or heating processes when the temperature of each one of the frozen blood product units is above a minimum threshold (e.g. 25° C. or more, 30° C. or more, 35° C. or more or even 37° C.). Such a method allows expediting the thawing and/or heating processes while assuring that all the frozen blood product units are in a requested temperature, such as about a body temperature (e.g. between 30 and 37° C. or between 35 and 38° C.). Optionally, the thawing and/or heating processes may be ended if any of the frozen blood product units is above a maximum threshold (e.g. 25° C. or more, 30° C. or more, 35° C. or more or even 37° C. or more). In such an embodiment, the quality of the frozen blood product units cannot be affected by overheating.

[0080] According to some embodiments of the present invention, a device and a method are provided for thawing and/or heating one or more frozen and/or cooled blood product units which remain stationary during the thawing and/or heating. For brevity, a cooled blood product unit means a frozen blood product unit, for example in a temperature of −30° C. or below and/or chilled or cooled blood product unit, for example in a temperature between about 0.01° C. and about 10° C.

[0081] According to some embodiments of the present invention, there is provided a device and a method for thawing and/or heating one or more frozen and/or cooled blood product units on a move, for example during the transportation of the cooled blood product units from a blood bank to a transfusion site. Optionally, the device is a designated cart having a heating device integrated thereon.

[0082] Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

[0083] Reference is now made to FIG. **1**, which is a schematic illustration of a blood product heating device **100** for thawing and/or heating one or more blood product units, according to an embodiment of the present invention. The blood product heating device **100** integrates a dielectric heating unit **11** for thawing and/or heating one or more blood product units **12** which are placed in a chamber **13**. The dielectric heating unit **11** is constructed and operated as described in one or more of the patent applications which are included Table 1 below, with one or more of the changes as detailed below. Optionally, the dielectric heating unit **11** includes one or more EM generators and one or more feeds for dissipating EM energy in the chamber **13**, optionally at a plurality of frequencies. The chamber **13** is sized and shaped for containing one or more blood product units **15**. The blood product units **15** may be simply placed at any position in the chamber, or alternatively they may be placed in marked places or specially shaped recesses, etc.

[0084] Optionally, the blood product heating device **100** is a portable device sized and shaped to be easily or conveniently transported. Optionally, the dimensions of the blood product heating device **100** are similar to the dimensions of a conventional desktop printer, for example about 25 cm wide, about 35 cm length, and about 20 cm height. Such dimensions allow placing the blood product heating device **100** in an ambulance, a trauma room, an operating room (OR), and/or emergency room (ER) without taking much space. As depicted in FIGS. **3**A-**3**H, various housings may be designed for containing the blood product units **15**.

[0085] According to some embodiments of the present invention, the power source of the EM energy is external to the blood product heating device **100**. For example, the power source may serve a number of blood product heating devices **100** which are located in different transfusion sites in a hospital and/or a medical center and/or placed externally to the transfusion site, for example on the roof and/or in a machine room, for saving space and/or facilitate the maintenance and sterilization procedures. See '199, which is incorporated herein by reference for similar embodiments and implementations. At other times, the power source may be portable and attached to the product heating device **100** such that the device may be moved and operated at the same time. It should be noted that when the energy source is attached to the blood product heating device **100**, a cart may be used for easier locomotion of the device.

[0086] For clarity, as used herein, a dielectric heating unit **11** means a unit that uses radio frequency (RF) radiation for thawing, heating and/or causing any change in the temperature to a saline solution unit or a blood product unit that is placed in the chamber **13**, such as a dose of plasma, a dose of red blood cells, and/or a combination thereof. For clarity, a dose or a unit of red blood cells may be a standard RBC unit or a standard saline solution unit or a standard fresh frozen plasma unit. Normally, such blood product units contained in bags and have a thickness of about 1-2 cm around the mid section. For example, the dielectric heating unit may be defined as described in one or more of the documents listed in Table 1 below, all of which are incorporated herein by reference:

TABLE 1

hereinafter	Ser. No.	Country	Title
'235	IL2007/000235	PCT	Electromagnetic heating
'236	IL2007/000236	PCT	Electromagnetic heating
'864	IL2007/000864	PCT	Food preparation
'231	IL2008/000231	PCT	Drying apparatus and methods and accessories for use therewith
'073	IL2007/001073	PCT	RF controlled freezing
'201	61/064,201	USA	A method and a system for a modular device
'431	12/230,431	USA	Dynamic impedance matching in RF resonator chamber 13

TABLE 1-continued

hereinafter	Ser. No.	Country	Title
'592	12/153,592	USA	Electromagnetic heating
'248	61/193,248	USA	Device and method for thawing using RF energy
'799	61/230,799	USA	Method and system for dielectric heating and cooking
'199	IL2009/000199	PCT	A method and a system for a modular device

[0087] As depicted in FIG. **1**, the blood product heating device **100** includes a controller **14**. Optionally, the controller **14** operates the dielectric heating unit **11** according to thawing and heating patterns which are adapted for the thawed and/or heated blood product units, for example red blood cells (e.g. packed red blood cells) and/or plasma. Optionally, the controller **14** operates the dielectric heating unit **11** so that the blood product units **15** are heated to about a room temperature in less than 3 minutes, optionally in less than 1 minute. For brevity, thawing and heating may be referred to herein as heating.

[0088] Exemplary Thawing

[0089] Attention is drawn to FIG. **2**A, which depicts a flowchart **20** showing how the blood product heating device **100** may be operated to thaw a frozen load, such as a frozen blood product unit, according to exemplary embodiments of the invention. A more elaborated discussion pertaining to this exemplary thawing may be found in '248, which is incorporated herein by reference.

[0090] After the one or more blood product units **15** are placed in chamber **13**, a sweep **21** is performed. Sweep **21** may comprise one or more sweeps, allowing the obtaining of an average of several sweeps, thereby obtaining a more exact result. Additionally or alternatively, sweep **21** may be repeated with different field adjusting elements (FAE) properties or different load/plate positions (optionally the sweep is performed several times at each configuration). An FAE is any element within the chamber that may affect the results of sweep **21**. Accordingly, an FAE may include for example, any object within the chamber, including one or more of metal components within the chamber, an antenna, or even a blood product unit. The position, orientation, shape and/or temperature of an FAE are optionally controlled by controller **14**. In some embodiments of the invention, controller **14** is configured to control several consecutive sweeps. Each sweep is performed with a different FAE property (e.g., changing the position or orientation of one or more FAE) such that a different spectral information may be deduced. Controller **14** may then select the FAE property based on the obtained spectral information.

[0091] In order to improve the accuracy of the analysis of the sweep results, in an exemplary embodiment, the amount of power that is actually transmitted (e.g. if the power transmitted at different frequencies is not identical) at each frequency is included in the calculation, in order to deduce the percent of transmitted energy that is dissipated in the chamber **13**.

[0092] Once one or more sweep results are obtained, an analysis **22** is performed. In analysis **22** a thawing algorithm is used to define the transmission frequencies and the amount of energy to be transmitted at each frequency, based on the spectral information that was obtained at sweep **21**. Consequently, energy **23** is transmitted into the chamber **13**, optionally as dictated by analysis **22**. Optionally, the desired dissipated power is below the expected power which is below the maximum power multiplied by the dissipation ratio.

[0093] In an exemplary embodiment of the invention, the one or more blood product units **15** are scanned 120 times in a minute. Higher (e.g. 200/min, 300/min) or lower (e.g., 100/min, 20/min, 2/min, 10/thawing time, 3/thawing time) rates may be used, as well as uneven sampling rates. In some cases, the information is provided using other means, such as an RF/bar-code readable tag (e.g., with previous scanning information or thawing presets) or using temperature sensors.

[0094] In an exemplary embodiment of the invention, the rate of sweeping depends on the rate of change in spectral information between sweeps, for example, a threshold of change in dissipation and/or frequencies (e.g., a 10% change in sum integral) may be provided or different change rates associated with different sweep rates, for example using a table. In another example, what is determined is the rate of change between sweeps (e.g., if the average of the changes between sweeps was less than the change between the last two sweeps). Optionally or alternatively, changes in the system (e.g. movement of the plate) may affect the sweep rate (typically major changes increase the rate and minor or no changes decrease it).

[0095] This process is optionally repeated for a predetermined period of time or until termination by a user. Alternatively, the thawing process may be terminated automatically **24**. At **24**, which may be performed after each sweep, before each energy transmission and/or at any other stage of the process, sweep results and/or a sensor reading are used to decide whether or not thawing may be or should be stopped. For example—if a phase change completion is detected or if the object's temperature is measured to be above a given temperature (e.g. outer temperature 5° C. or more), thawing may be terminated. In another example, if the total energy dissipated into the one or more blood product units **15** reaches a predetermined amount of energy that is needed for thawing to a desired final temperature (e.g., taking into account the initial temperature and composition of the one or more blood product units **15**, thawing may be stopped.

[0096] The transmission parameters for thawing, comprising (frequency/power) pairs, are optionally selected to increase (or even maximize) energy dissipation in frequencies that have low dissipation ratios in the one or more blood product units **15** (e.g. predominantly solid or ice portions) and reduce (or even minimize) energy dissipation at frequencies that have a relatively high dissipation ratio (e.g. predominantly thawed portion, such as liquid or water). For example, in low dissipation ratios, the device will be set to produce efficient power dissipation (e.g., as a factor of the possible maximal dissipation possible) while at the high dissipation ratios, the device will be set to dissipate much less energy than may be dissipated.

[0097] An exemplary thawing algorithm transmits zero power at frequencies with dissipation ratio above a predetermined threshold (e.g. 70% dissipation) of the maximum dissipation ratio in the selected working frequency range $[f_1, f_2]$ and non-zero powers at other frequencies of that range. In some cases, the powers are selected in a binary fashion—either maximal or minimal. Alternatively, intermediate power levels are provided, for example for portions with intermediate dissipation levels.

[0098] In an exemplary embodiment of the invention, the device includes a memory having stored thereon a plurality of threshold values, hpl values, dissipation/power ratios and/or parameters for various properties of the one or more blood product units **15**. Optionally, the device and/or the user select between such stored options as an initial setting or as a final setting for thawing. For example, a fixed hpl of 80% (of the maximal power of the amplifier at each frequency) may be used for frozen bovine meat of a certain weight.

[0099] Exemplary Thawing Algorithm

[0100] An exemplary thawing algorithm is the following. In a selected working range $[f_1, f_2]$, high and low boundary powers (hpl, lpl) are selected and any applied power is maintained between these boundaries.

[0101] The boundary low power level (lpl) is the minimum power level where dissipation in the one or more blood product units **15** is high enough to be useful. For example, if 15% is selected to be the minimal useful dissipation, lpl will be set for each frequency to be 15% of the maximal power that may be transmitted. Alternatively it may be set at a pre-selected low power for all frequencies (e.g., 60 Watts or less) or any combination of the aforementioned; if the dissipation in the one or more blood product units **15** at a given frequency is below lpl, the transmitted power at that frequency will be set at zero.

[0102] The boundary high power level (hpl), determines the highest allowed dissipated power. This means that the highest power outputted is constrained to avoid undesired thermal effects. In addition, the actual power outputted at a given frequency may be selected according to spectral information, in particular, to selectively target unthawed areas. Optionally, the power levels are generally inversely related to dissipation. As may be noted, reducing maximum oven power will generally lengthen thawing times. In some cases, the power levels applied meet binary criteria: hpl for low dissipating portions and some other value (such as zero) for high dissipating areas.

[0103] Using an excessively high hpl may cause an unacceptable uneven temperature distribution in the one or more blood product units **15** and may result in thermal runaways. The more sensitive a load is to transmitted power (e.g., at a certain working band), the lower would be the power of an acceptable hpl. Optionally, the working band is selected according to which working band better distinguishes water from ice.

[0104] Generally, for sensitive blood product units **15**, a low hpl is set, but such hpl may be used also for less sensitive blood product units **15**, albeit at the cost of increasing the thawing time. Nonetheless, at times it may be preferred to set for each load the highest hpl that would provide an acceptable post thaw temperature distribution in the load (e.g. ±15° C., ±10° C., ±5° C., ±2° C. or even more uniform). The acceptable post thaw temperature distribution can depend, for example, on one or more of the composition of the one or more blood product units **15**, and its sensitivity to overheating (e.g. whether damage is caused; its extent and reversibility; and to what extent the damage is material). It is noted that at times, speed of thawing is preferred over quality, in which case a higher hpl may be used, and the post thaw quality would be suboptimal. These factors have an effect on the quality score of the heated and/or thawed one or more blood product units **15**, for example as described below.

[0105] Optionally, the device is provided with a user selectable tradeoff (e.g., knob or data input) between uniformity, maximum temperature and/or rate of thawing.

[0106] It is noted that in accordance with some embodiments of the invention, prevention of hot spots is actively preferred over uniformity of thawing, heating and/or energy dissipation.

[0107] Optionally, hpl is set low enough so that a thawed section will not be over heated before heating at its respective frequencies is stopped or reduced.

[0108] Exemplary Methods of Determining hpl (High Power Level)

[0109] hpl may be determined in various manners, for example, by trial and error. In an exemplary embodiment of the invention, several hpl settings are tried to determine the maximal hpl which would provide an acceptable temperature distribution in the one or more blood product units **15**, post thawing. Such trials may continue during thawing, for example, being performed every scan, every second or every minute or at intermediate time scales. In an exemplary embodiment of the invention, hpl is started at low values and increased gradually. Optionally, the hpl is set per item type.

[0110] In an exemplary embodiment of the invention, preset hpl values are provided for various combinations of properties of the blood product units **15**, such as one or two or more of shape, weight, temperature, desired effect and/or bag's material type. Optionally, a user selects properties and the device suggests and/or uses an hpl accordingly.

[0111] Optionally, hpl is updated periodically during thawing.

[0112] In an exemplary embodiment of the invention, hpl is estimated (initially or in an ongoing manner) with the assistance of changing the blood product units **15** and/or chamber **13** so that more useful spectral information is acquired. In general, if the acquired spectral information is better, a better cut-off between ice and water may be identified, allowing a higher hpl to be used for the ice sections and a faster heating at a same quality (e.g., evenness) and/or a higher quality heating at same speed.

[0113] Alternatively, and while not wishing to be bound by theory, it is proposed that the sensitivity of the blood product units **15** may be determined based on the relative dissipation of energy in thawed and frozen portions of the blood product units **15**. When the dissipation in frozen portion and thawed portion is relatively similar (e.g. 10-15% dissipation difference, such as between 40% and 50% dissipation ratio) (e.g. due to low water content), the sample is deemed to be of high sensitivity (e.g., the distinction between ice and water requires a more sensitive determination). The greater the disparity is between dissipations in thawed and frozen parts, the lower the sensitivity of the blood product units **15**. Therefore, hpl may be determined by obtaining the spectral information of the blood product units **15** and comparing the maximal dissipation (d_{max}) with the minimal dissipation (d_{min}) in a working frequency band. The greater the difference is between d_{min} and d_{max} the lesser the sensitivity of the blood product units **15**, and higher the hpl that should optionally be used.

[0114] It is noted that the hpl may be allowed to be higher if a better selection of power to intermediate dissipation frequencies is provided.

[0115] Also alternatively, and while not wishing to be bound by theory, it is proposed that hpl may be determined based on the maximum power that can be dissipated in the

blood product units **15** at each frequency (ep(f)) and ldl. hpl may be set to be such that the portion of the frequencies being used, for example all frequencies within a working band (e.g. the band spanning 800-1000 MHz)) (or other set of frequencies) that are considered to dissipate into the blood product units **15** and for which lpl<ep(f)<hpl would be less than a preset threshold. For example, this threshold may be selected to be 10% or 20% or 30% or any value in-between. Optionally, this method is based on a realization (and/or for cases that) that the device is typically limited in maximum power and that practically, the closer the hpl is to the maximum power, the less easy it may be to provide different power levels at different, near, frequencies. Optionally, the percentage depends on a desired tradeoff between quality and/or speed.

[0116] Accordingly, a thawing protocol may use a single hpl value (e.g. if dedicated to blood product units **15** having similar sensitivity; or a low hpl that would be suitable for most contemplated blood product units **15**). Alternatively, the protocol may use a selection between several possible hpl values (e.g. a selection between a number of preset values or optionally setting the value manually or automatically to correspond to a given load, for example a certain blood product unit and/or acceptable post thaw temperature distribution). Finally, the protocol may use any value (e.g. calculated automatically or selected manually) within the power capabilities of the device. An example of a relatively high hpl may be 300 Watt or 80% of the maximal power from the amplifier at that frequency. An example of a relatively low hpl may be 120 Watts or 30% of the maximal power from the amplifier at that frequency. Interim values are possible as well.

[0117] Exemplary Determination of Dissipation Function dr(f)

[0118] dr(f) denotes the dissipation ratio as a function of frequency, namely the percentage of transmitted power through each feed (e.g. feed j) that is dissipated in the blood product units **15**. This function has potential values between 0 and 1, and is optionally computed as shown in Equation 1, based on the measured power and using measured spectral information. However, as noted herein, a binary function or non-linear and/or non-monotonic function may be used (e.g., and determined in a factory or during calibration).

$$dr_j(f) = \frac{P^j_{incident,watt}(f) - \sum_i P^{(i)}_{returned,watt}(f)}{P^j_{incident,watt}(f)} = 1 - \frac{\sum_i P^{(i)}_{returned,watt}(f)}{P^j_{incident,watt}(f)} \quad \text{(eq. 1)}$$

[0119] Normalization of dr(f)

[0120] The dissipation ratio in frozen portions (e.g. ice) is relatively lower than that of the thawed portions (e.g. liquid/water), but a large amount of ice can show considerable dissipation. In order to distinguish dissipation in at frequencies having a low dissipation ratio (e.g. ice) from dissipation at frequencies having a high dissipation ratio (e.g. liquid water), while reducing the effect of relative mass, the dr(f) function is optionally normalized to the whole range between 0 and 1; This normalization may be useful also in other cases where the difference between dissipation in frozen portions and thawed portions is relatively small, regardless of the cause (e.g., low water content). The normalized function—dr'(f)—may be used to calculate the compensation factors, as shown below.

$$drh = \min\{dr(f)\}_{f\in[f_1,f_2]}$$

$$drl = \max\{dr(f)\}_{f\in[f_1,f_2]}$$

$$dr'(f) = (dr(f) - drl)/(drh - drl) \quad \text{(eq. 2)}$$

[0121] In case of some blood product units, the use of dr'(f) is optionally avoided, and in original dr(f) used instead. Optionally, a device is configured to have both protocols for alternative use. The choice between the protocols may be based on user input (e.g. user interface or machine readable tags) or on a sensor reading within the device (e.g. a weight sensor). Alternatively, dr'(f) may be used for all blood product units **15**.

[0122] The maximum power that can be dissipated in the blood product units **15** at each frequency (depicted as ep(f)) is optionally calculated as follows, given that $P_{maximum\,j,\,watt}$ is a maximum power available from the amplifier at each frequency.

$$ep_j(f) = dr_j(f) P_{maximum\,j,watt}(f) \quad \text{(eq. 3)}$$

[0123] Using the above, the compensation function (coeff (f)) is optionally calculated. This function is optionally used to determine the relative amount of energy that should dissipate in the blood product units **15**

[0124] at each frequency, as a function of dr'(f), for example as shown in eq. 4A:

$$coeff(f) = F(dr'(f)) \quad \text{(eq. 4)}$$

$$F(dr(f)') = \begin{cases} dr' < 3 & 0 \\ dr' > 0.8 & 1 \\ \text{Else} & -2dr' + 1.6 \end{cases} \quad \text{(eq. 4A)}$$

[0125] In an exemplary embodiment of the invention, frequencies may be classified as "ice", "water" and/or "mixed ice/water" according to their dissipation ratio. Optionally, higher power is provided into ice and mixed ice/water and plain water is provided with low or no power.

[0126] Optionally, there is provided a dissipation threshold below which the dissipation into the blood product units **15** is so low that no power is transmitted, as the blood product units **15** portion is assumed to not be ice. In an exemplary embodiment of the invention, the device is designed to have a very low intrinsic dissipation at any frequencies or a known dissipation at only some frequencies (where the threshold may then be raised).

[0127] It is noted that large pieces of ice may have a relatively high dissipation. Optionally, if there are no (or few, e.g., below a threshold) low-dissipation frequencies and it is known that the blood product units **15** is frozen, then it is assumed that the lowest dissipation frequencies are ice and power (at regular or somewhat reduced levels) is provided at such frequencies, until lower dissipation frequencies appear, indicating the formation of smaller frozen regions.

Example dr(f)

[0128] An example for a function according to Equation (4) is depicted in FIG. **2**B. As can be seen, two limits are set. At frequencies that dissipate into the blood product units **15** less

than a pre-set threshold (e.g. dr'(f)<0.3 in the example of FIG. **2**B) the maximal allowed power which is a minimum between the ep(f)/dr(f) and hpl(f)/dr(f) will be transmitted. At frequencies that will at dissipate into the blood product units **15** more than a pre-set value (e.g. dr'(f)>0.8 in the example of FIG. **2**B) no energy will be transmitted. At all other frequencies (0.3<dr'(f)>0.8 in the example of FIG. **2**B) the power transmission will be calculated using the selected function. In the case of FIG. **2**B this was a generally linear function, but other functions, optionally non-linear, may be used that provide an inverse correlation between dr'(f) and coeff(f) (e.g. exponential, step function, piecewise linear, polynomial and/or general look-up table, optionally with interpolation). Optionally, the function prefers applying power to low-dissipation areas to an extent greater than a simple inverse function. Optionally, the function is selected based on a perceived risk of damage to the blood product units **15**.

[0129] Exemplary Actual Power Calculation

[0130] gl(f) is the power to be dissipated in the object to be heated, taking into consideration the maximum power that can be dissipated in the blood product units **15** at each frequency (ep(f)) and hpl(f) and the compensation function (coeff(f)), as follows:

$$gl(f)=\begin{cases} hpl < ep(f) & hpl\cdot coeff(f) \\ lpl < ep(f) < hpl & ep(f)\cdot coeff(f) \\ \text{else} & 0 \end{cases} \quad \text{(eq. 5)}$$

[0131] Using gl(f) the power to be transmitted from the amplifier (nopw(f)) in order to cause the desired dissipation in the blood product units **15**, at each frequency, is optionally calculated as follows:

$$nopw(f)=gl(f)/\mathrm{dr}(f) \quad \text{(eq. 6)}$$

[0132] nopw(f) will always be lower than $P_{maximum,j,watt(f)}$, which is the maximum power extractable from an amplifier at each frequency for the following reason:

$$gl(f)=\begin{cases} hpl < ep(f) & hpl\cdot coeff(f) \\ lpl < ep(f) < hpl & ep(f)\cdot coeff(f) \\ \text{else} & 0 \end{cases} \quad \text{(eq. 7)}$$

$$\max\{gl(f)\} = ep(f)coeff(f) = dr(f)P_{maximum,j,watt}coeff(f)$$

$$\max\{nopw(f)\} = \max\{gl(f)\}/dr(f) = P_{maximum,j,watt}coeff(f)$$

[0133] Calculation of hpl Using Average Dissipation

[0134] FIG. **2**C shows hpl being calculated as a function of the average dissipation ratio within the working band or within the selected frequencies. Optionally, this is based on the assumption that a low average dissipation means a high sensitivity and vice versa. Other functions may be used as well, for example, a table matching hpl to average dissipation.

[0135] As seen in the graph, a low average dissipation ratio indicates a high sensitivity of the blood product units **15** and accordingly dictates a low hpl. The low value of hpl is optionally selected to be slightly above lpl (to provide a minimal working range). For example, the minimal hpl value may be between 70 and 120 Watts (e.g. 80 Watts). The maximal level of hpl may be chosen to be as high as the maximal possible amplifier power or slightly below that. As seen in FIG. **2**C, when the average dissipation ratio is below a preset lower limit, hpl is selected to be the lowest hpl allowed, and when the average dissipation ratio is above a preset upper limit, hpl is selected to be the highest hpl allowed. The lower limit for average dissipation ratio may be, for example, between 0.1 and 0.3 (e.g. 0.2) while the upper limit may be for example between 0.5 and 0.9 (e.g. 0.6).

[0136] In-between values of average dissipation optionally dictate an intermediate hpl value. It is to be appreciated that while FIG. **2**C depicts a generally linear correlation for the intermediate average dissipation ratio values, other functions, optionally non-linear, may be used that provide a positive correlation between the average dissipation ratio and hpl (e.g. exponential, step function, polynomial, step-wise linear).

[0137] In some cases, the frequency distribution is in frequency bands, so that one band can be recognized as matching ice (e.g., low dissipation) and another matches water (e.g., high dissipation). Optionally, instead or in addition to calculating hpl, gl(f) is set to be zero or at lpl (or any other preset low value) for bands associated with water and at any preset high value (e.g. hpl or a maximum available power or other setting) for ice-associated bands. Optionally, the classification of bands as water/ice is updated optionally periodically based on spectral information that is periodically acquired.

[0138] While particular ways of calculating hpl and gl(f) are described above, the methods can be combined, for example, arithmetically or logically, for example, using an average value of several methods or using a minimum or maximum or multiple methods. For example—a Gaussian function of dr(f) (or of dr'(f)) may be used to calculate gl(f).

[0139] According to some embodiments of the present invention, the controller **14** collects data documenting thawing and/or heating processes. Optionally, the collected data is stored in a repository, such as a flash memory. The documented data is collected using a measurement of the efficiency of absorption of energy in one or more blood product units being heated as function of frequency. Optionally, the controller **14** controls one or more characteristics of the thawing process, for example the amount of power absorbed in the heated one or more blood product units, based on the collected measurement of energy absorption efficiency (for example, by transmitting power to compensate for the variations of energy absorption and/or variations of energy transmission). This may be done by adjusting, for example, input power at each transmitted frequency and/or choosing frequencies to be transmitted and/or adjusting (for example, moving or rotating) one or more field adjusting elements and/or moving the heated one or more blood product units and/or changing antenna characteristics. This may be done before operation, and/or at times also one or more times during operation (for example, several times a second), based on measurements of energy absorption during heating or during a short hiatus in the heating.

[0140] Optionally, the controller **14** operates the dielectric heating unit **11** according to reading of dielectric characteristics of one or more blood heated units. Reading may be obtained one or more times during heating (for example, several times a second). For example, end of thawing process, when a phase change is sensed. This can implement a cessation of heating. For brevity, heating of a frozen blood product

unit that contains plasma may include thawing and heating of a cooled blood product unit that contains red blood cells may include heating.

[0141] Reference is now also made to FIG. **3**A, which is a schematic illustration of an exemplary portable blood product heating device **100**, according to some embodiments of the present invention. Similarly to FIG. **1**, the portable blood product heating device that is depicted in FIG. **3**, the blood product heating device **100** includes a chamber **205** and a controller and a dielectric heating unit (not shown) that allows the thawing of one or more blood product units (not shown). FIG. **3** further depicts an optional touch screen **100** that allows controlling the thawing and/or heating processes. It should be noted that any other man machine interface (MMI) may be used for controlling the blood product heating device **100**, for example a keypad, a keyboard, a set of buttons and the like. In fact, in some embodiments, a dedicated device may be operable with no MMI, whereby for example by closing the device with a load in the device, the device will automatically perform a predetermined protocol (thaw and/or warm) and terminate automatically.

[0142] The blood product heating device **100** may further include a unit positioning element, e.g. a tray, that is sized and shaped to support a blood product unit, for example a bag containing 145-285 cubic centimeter (CC) of plasma. Alternatively, the bag may contain between 40-500 ml of a blood product or even between 40-1,000 ml, or a volume higher than 1 liter. Optionally, the bag may have irregular shape and/or irregular width (being thicker at some portions and thinner on others). Bag thickness may be for example above 1 cm, above 3 cm or even 5 cm or 6 cm or more, or any intermediate value or range. In thickness it is meant the minimum dimension of the bag, between length width and thickness. Optionally, a tray that is sized and shaped for supporting a number of blood product units may be used, for example 2, 4, 6, 8, 10 and/or any intermediate number may be used. Optionally, the tray is detachable, allowing replacing the tray that is placed in the chamber **205** of the blood product heating device **100**. For example, a tray for 1 blood product unit may be replaced with a tray for a plurality of blood product units and vice versa. Optionally, the unit positioning element is extracted from the chamber so as to ease the mounting and/or the dismounting of one or more blood product units thereon and/or therefrom, for example as shown at FIG. **3**B.

[0143] It should be noted that other unit positioning elements may be used, for example designated containers which are sized and shaped to be placed in the chamber **13** and/or as depicted in FIGS. **3**C-**3**H. As described above, the thawing and/or heating pattern may be dynamically determined according to the absorption of different frequencies. In such embodiments, the blood product units may not have to be placed in exact locations. The heating pattern is determined dynamically according to the properties of the blood product units in the chamber **13** and therefore the operator does not have to spent time on the exact positioning thereof in order to achieve optimal outcomes.

[0144] In some embodiments of the present invention, the blood product heating device **100** includes an actuation unit for maneuvering the blood product units during the heating and/or the thawing processes. Optionally, the actuation unit is connected to the unit positioning element and configured for move it so as to shake, stir, agitate spine, and/or vibrate, the blood product units which are mounted thereon, repeatedly or intermittently.

[0145] Optionally, the vibrations are applied after the thawing of the blood product units and/or during the heating of blood product units, for example after a temperature of around 5° C. is detected in some or all of the blood product units. The vibrations may be applied contentiously and/or intermittently. At times, the device may be configured not to apply vibrations at least during a portion of the time when EM energy is applied. This may in fact be a significant portion of the heating (measured in time or energy). For example—at least 25%, at least 50% or even at least 80% of the irradiation may be performed at a time that the blood product unit(s) remain stationary.

[0146] In some embodiments of the present invention, the blood product heating device **100** integrates a temperature sensor for measuring the temperature of the heated blood product units. Such a temperature sensor may provide the base temperature and/or used for monitoring the heated blood product units. Optionally, the temperature sensor comprises a sensor, for example an infrared temperature sensor, such as the OS101 Series Miniature Low-Cost Non-Contact Infrared Temperature Sensor/Transmitter from NEWPORT and an infrared temperature sensor such as the OS136 Series Miniature Low-Cost Non-Contact Infrared Temperature Sensor/Transmitter from OMEGA Engineering. The temperature sensor may be used for monitoring and/or adjusting the heating process and/or the heating pattern.

[0147] According to some embodiments of the present invention, the controller **14** ends the heating process according to the temperature of the one or more blood product units. The temperature may be estimated according to the outputs of the aforementioned temperature sensor and/or according to temperature sensing elements which are attached to the blood product units, for example as described below. When a number of blood product units are heated, the controller **14** separately monitors the temperature of each one of them.

[0148] Optionally, the controller **14** changes the dissipation of electromagnetic (EM) energy in the chamber according to the temperature of the blood product units. In such a manner, the heating of the blood product units may be more uniform, for example as described in the documents listed in Table 1. Optionally, the dissipation is changed by one or more properties of one or more FAEs in chamber **13**.

[0149] Optionally, if the temperature of all the blood product units is above a predefined range, the heating process ends. In such a manner, all the blood product units are heated to the predefined range during a certain heating session. Additionally or alternatively, the heating process stops if the temperature of any of the blood product units is increased above the predefined range and/or any other threshold. For example, the heating stops as all the blood product units are above a minimum threshold of 25° C. or more, 30° C. or more, 35° C. or more or even 37° C. or more. In such a manner, all the frozen blood product units may be in a requested temperature, such as about a body temperature, for example between 30 and 37° C. or between 35° C. and 38° C. Optionally, the thawing and/or heating processes may be ended if any of the frozen blood product units is above a maximum threshold, for example 25° C. or more, 30° C. or more, 35° C. or more or even 37° C. or more. In such an embodiment, the quality of the frozen blood product units cannot be affected by overheating.

[0150] As commonly known, blood product units, such as plasma units, and at times also red blood cell units, are stored in temperatures below −18° C. For example, standardized

fresh frozen plasma units of 300 g can be stored for up to one year at −30° C. or below and are only thawed immediately prior to use. In use, the blood product heating device **100** is designed for thawing and heating the one or more frozen blood product units which are placed in the chamber **205**. As the blood product heating device **100** may use a dielectric heating unit as described in one or more of the documents listed in Table 1, the blood product unit may be heated to a temperature of about 37° C. in less than 3 minutes, for example 1 minute or less. Such heating allows rapidly and safely thawing blood product units and raising their temperature to about a body temperature, for example 30-37° C., without damaging the blood product unit or risking the blood product unit and the blood bank or hospital staff with contaminations which are a concern with warm water baths. It should be noted that by increasing the temperature of the blood product unit to about body temperature the blood product heating device **100** may allow the immediate transfusion thereof. A transfusion of blood in lower temperatures may reduce the temperature of the recipient, which is usually in a trauma situation. Such a temperature reduction may cause hypothermia or worsen it. Hypothermia may complicate a patient's condition, for example by inhibiting coagulation and/or clot formation and/or result in blood loss.

[0151] Optionally, dielectric heating unit **11** allows heating one or more blood product units **14** so that the temperature of each blood product unit is uniform within 10° C., 6° C., 4° C. or 2° C. when heating is completed, even if each blood product unit has an irregular shape and/or composition and/or is positioned at a random, irregular and/or non-exact location or position in chamber **13**. Exemplary embodiments may provide this uniformity by directly RF thawing and/or heating each blood product unit such that over 50% of the thawing and/or heating are by direct RF heating and not by conduction from other portions of the device. In some embodiments of the invention, such direct RF thawing can reach 70, 80, or 90 or more percent.

[0152] Optionally, dielectric heating unit **11** transmits frequencies and/or power via one or more feeds (e.g. antennae) that are installed in the chamber. These frequencies and/or power are varied in a controlled manner to produce a desired heating pattern (for example, by more than 1, 2 or 5 MHz). This variation may occur several times during operation (for example, several times a second). In an embodiment of the invention, the desired pattern is a uniform heating pattern.

[0153] Optionally, dielectric heating unit **11** includes multiple inputs in which the frequencies of the inputs are different by more than 5, 10 or 25 MHz. Optionally, dielectric heating unit **11** includes multiple inputs in which the frequencies of at least one of the inputs changes dynamically during heating such that the frequencies at the inputs vary by 5 MHz or more. Optionally, dielectric heating unit **11** utilizes a wideband and high efficiency (above 40%) solid state microwave amplifier to feed energy into the chamber **13** and optionally utilize waste heat generated by the generator to heat the air in the chamber **13**. Optionally, the dielectric heating unit **11** utilizes wasted heat generated by the RF energy generator to heat a medium, for example air in the chamber **13**, or water, as in a water heater. Optionally, the dielectric heating unit **11** causes a resonance structure and/or designed pattern, inside a resonator to radiate by (selectively or generally) irradiating the resonance structure and/or designed pattern thus using it as a radiation source (i.e. creating a passive source).

[0154] Optionally, the dielectric heating unit **11** has a high-efficiency (at least 50%, at times above 70% or even 80%) RF heater. The efficiency is defined as power absorbed in one or more heated blood product units versus power at the output of the power source. This allows the possibility of a heater that operates using a solar energy source. The power absorbed by one or more heated blood product units may be calculated based on knowledge of power input and efficiency of power transfer to the one or more heated blood product units. This allows for the calculation of a current temperature and/or a turn off-time based on actual heating rather than some estimated heating time as presently used with microwave cookers.

[0155] According to some embodiments of the present invention, the blood product heating device **100** includes a freezing chamber (e.g. for freezing blood product units) and/or a cooling chamber (e.g. for storing cooled blood product units), for example as depicted in FIG. **3**I. An exemplary heating device that integrates a freezing chamber that is also used for heating using irradiation is described in '073, which is incorporated herein by reference. The freezing chamber may allow storing the one or more blood product units in a freezing temperature, for example below −18° C., −30° C., −40° C. or any intermediate temperature. The cooling chamber may allow storing the one or more blood product units in a cooling temperature, for example any temperature being above freezing and below one of 15° C., 10° C. or 8° C., and any range in between. Exemplary cooling ranges include between 2° C. and 15° C. or between 4° C. and 8° C. Additionally or alternatively, the chamber **13** may be connected to one or more freezing elements that allow freezing the blood product units in a freezing temperature, for example below −18° C., −30° C., −40° C. or any intermediate temperature. In such an embodiment, frozen blood product units are thawed and heated, for example as described above, without having to open the chamber **13** and/or to relocate them from their storage location. Additionally or alternatively, the chamber **13** may be insulated such that temperature changes in the blood product units due to the conditions outside the device would be delayed.

[0156] According to some embodiments of the present invention, the blood product heating device **100** is designed to maintain the thawed and/or heated blood product units at a certain temperature, for example about 37° C. In such a manner, the heated blood product units do not have to be used immediately after the heating process. For instance, after the blood product units are heated, for example as a preparation for a field operation, the physician may postpone the blood transfusion and maintain the blood product unit that is about to be used in a body temperature. In fact, the temperature in which the blood product units may be maintained may be any temperature above freezing (e.g. 4° C. or more) and the final heating step (which may at times take 10 seconds or less) be performed upon demand.

[0157] Optionally, blood product units which are placed in chamber **13** are thawed and/or heated automatically to a body temperature at a push of a button or in response to the mounting thereof the chamber **13** and/or the closing of the chamber **13**. In such a manner, the operator of the blood product heating device **100** may receive a blood product unit that is prepared for transfusion without having to be familiar with complex heating protocols or any form of device operation requirements.

[0158] Reference is now also made to FIG. **4**A, which is a flowchart of a method for managing the supply of blood product units for transfusion, according to some embodiments of the present invention.

[0159] As described above, the blood product heating device **100** is designed for heating blood product units from frozen to about a body temperature in less than 3 minutes, for example 1 minute or less and from a temperature above freezing (e.g. between 2° C. and 10° C.) to about a body temperature in less than 1 minute, for example 20 seconds or less (e.g. 10 seconds). Such a prompt temperature increase allows a blood bank to prepare a blood product unit for transfusion immediately upon request and not in advance. This may reduce the need for pre-thawing blood product units and therefore may respectively reduce the amount of thawed blood product units which are disposed when remain unused.

[0160] It should be noted that currently plasma and red blood cells units are stored at the blood bank respectively at about −30° C. and about 4° C. Plasma is usually stored up to one year and blood cell unit is stored up to one month. For brevity, heating of a cooled blood product unit that contains plasma may include thawing and heating of a cooled blood product unit that contains red blood cells may include thawing and/or it may be limited to heating a non-frozen blood product unit.

[0161] Normally frozen plasma is thawed upon need where the first request is normally for O type (before a patient's blood is typed) and then a second request may arrive for the proper blood type. Blood cells unit are normally maintained as packed red blood cells (pRBC) and is ready for immediate use, but given cold. As the thawing of the plasma unit takes time, transfusions are delayed and the proper ratio of 1 plasma unit for each blood cells unit is not maintained. It should be noted that the quality of thawed plasma units is reduced over time.

[0162] In some embodiments of the present invention frozen and thawed blood products may be placed in a chamber and heated using by irradiation, such that the frozen material would thaw but the material that was thawed before operation would not over heat. This allows for performing one or more of the following without overheating a blood product unit or any portion thereof: (a) thawing a blood product unit that comprises thawed and frozen portions before heating; and (b) thawing a frozen blood product unit in a chamber in the presence of a non-frozen blood product unit. The latter option allows for example introducing into a device frozen plasma units together with non-frozen (cooled) packed red blood cell units and operating the device to heat all the units to a desired final temperature (e.g. about body temperature) at the same time. This also allows placing the different blood product unit in the device at a ratio that is intended for use (e.g. 1 plasma unit:1 packed red blood cell unit) and optionally heating them for transfusion temperature simultaneously or substantially simultaneously.

[0163] As depicted in FIG. **4**A, first, as shown at **301**, a caretaker, for example a physician, a nurse, and a medical assistant, orders one or more blood product units, for example plasma and packed RBC units, from the blood bank.

[0164] Then, as shown at **302**, the blood bank heats and/or thaws the requested blood product units according to the request, for example using the blood product heating device **100**. For example, blood product units which contain blood cells may be heated at the same ratio as blood product units which contain plasma which are thawed and heated.

[0165] Optionally, the order sent as shown at **301** includes a set of instructions that is sent to the blood product heating device **100** that automatically initiates one or more heating sessions accordingly. In such an embodiment, the blood product heating device **100** may be loaded by mechanical means, for example one or more robotic arms and/or conveying belts, which load one or more frozen and/or cooled blood product units from a blood storage, such as a designated freezer. Optionally, blood product units are preloaded to the blood product heating device **100** that maintains them in a freezing temperature. In such an embodiment, the chamber **13** includes one or more cooling element. Optionally, a combination of plasma and blood cells is prepared. Such a combination is prepared for immediate transfusion.

[0166] Now, as shown at **303**, the one or more heated and/or thawed blood product units are transferred to the orderer thereof, for example, the aforementioned thawed plasma and heated blood cells. It should be noted that when a device, such as the blood product heating device **100**, is not available, a blood product unit of blood cells is usually transferred while a respective blood product unit of plasma is thawed. When such a treatment protocol is followed, the plasma is infused after the blood cells. As the blood product heating device **100** allows thawing the plasma in less than 3 minutes, for example 1 minute, it may be sent together with the blood product unit that includes the blood cells, facilitating a simultaneous transfusion thereof, as shown at **304**. Alternatively, the blood product unit may be supplied in frozen form to the site of transfusion (or a place nearer to the site of transfusion than the blood bank or site of storage) and heated therein (i.e. performing step **303** before step **302**).

[0167] Reference is now made to FIG. **4**B, which is a flowchart of a method for heating blood product units, according to some embodiments of the present invention. First, as shown **311**, the blood product units in a heating chamber of a heating device, such as the aforementioned blood product heating device **100**, of transportation means, such as a cart or an ambulance. Additionally or alternatively, the device **100** together with its power source (e.g. battery) may be sufficiently light weight, such that the device may be operated when in transport (e.g. on a cart or when being manually carried). Now, as shown at **312** the heating and/or thawing process is initiated, for example as described above. The heating and/or thawing process may be performed while the transportation means is on a move, for example while the cart, which is loaded with the blood products units, is conveyed to a transfusion site and/or during a ride of the ambulance. In such embodiments, the heating and/or thawing is performed without having to delay the transfusion. Now, as shown at **313**, the blood products units are supplied at the transfusion site, for example at the location to which the cart has been conveyed and/or in the treatment comportment of the ambulance.

[0168] Reference is now made to FIG. **5**, which is a method for locally preparing and providing one or more blood product units for transfusion, according to some embodiments of the present invention. As described above and depicted in FIG. **3**, the size of the blood product heating device **100** may be limited, facilitating the positioning thereof in an ambulance, a trauma room, an operating room (OR), emergency room (ER), field OR, and/or field ER. This allows immediate availability of blood/plasma at the correct ratio and/or temperature.

[0169] In some such embodiments, as depicted in **401**, frozen and/or cooled blood product units, are stored on site, for example in the ambulance, the trauma room, the OR, and/or the ER. For example, the blood product units are stored frozen in a dual purpose device that includes a freezing chamber for storing blood product units and a heating chamber, such as the chamber indicated by numeral **14**.

[0170] Now, as shown at **402**, one or more blood product units are heated and/or thaw on site. Optionally, the heating and/or thawing is performed by the blood product heating device **100**, similarly to the described above in relation to **302**.

[0171] Then, as shown at **403**, the heated and/or thaw blood product units are infused, optionally simultaneously, similarly to the described above in relation to **304**.

[0172] According to some embodiments of the present invention, the blood product unit is tagged with data pertaining to the heating and/or thawing process and/or the quality of the blood product units. In such an embodiment, a heated blood product unit is tagged with data that is gathered during the thawing and/or heating thereof and/or with a quality score that is based on the gathered data.

[0173] For example, the data may include the final temperature and/or the launch temperature of the heated blood product unit, the amount of EM energy that has been absorbed by the blood product unit, the amount of EM energy that has dissipated in the chamber during the heating process, data pertaining to the technical qualification of the blood product heating device **100**, the rate of the blood product unit's temperature change and/or increase during the heating process and/or the like. Optionally, the quality score is based on some or all of the aforementioned gathered data.

[0174] Optionally, the tagging is performed by updating an updatable memory element, such as an RFID tag or any other tag, which is attached to the heated blood product unit. In another embodiment, each blood product unit has a unique ID and the blood product heating device **100** updates a record associated with the unique ID with the gathered data and/or quality score. Optionally, the unique ID is attached and/or printed to the package of the blood product unit, for example as a barcode or a serial number. The record is optionally stored in a storage device, such as a flash drive, a memory card, and the like. Optionally, the blood product heating device **100** comprises a communication interface that allows forwarding records which are stored on the storage device to a remote server, for example to a medical data center that monitors the blood product unit supply and/or a client terminal of a physician, such as a laptop, a personal digital assistant, and the like.

[0175] Optionally, the controller **14** operates the dielectric heating unit **11** according to data that is associated with the heated blood product unit, for example instructions which are stored on an RFID tag and/or coded on a sticker which is attached thereto. The instructions may define a pattern that is adapted for the content of the blood product unit, for example blood cells and/or plasma, the amount of blood products in the heated blood product unit, a number of blood product units that is placed in the chamber **13** for heating and the like.

[0176] Attention is drawn to FIG. **6**, depicting an exemplary method for managing blood product unit supply, taking advantage of the ability to heat frozen material without substantially heating the liquid (e.g. without such thermal runaways as may damage a blood product unit or render a saline unit too hot for immediate use).

[0177] In step **601**, at least one frozen plasma unit and said at least one of one or more cooled blood product units and one or more unheated saline units unit are placed together in a chamber. In step **602** heating is performed comprising applying electromagnetic (EM) energy into said chamber thereby thawing the frozen plasma unit without heating the cooled blood product unit and/or the saline solution unit to such an extent that might cause the unit to be unusable at the end of thawing (e.g. due to damage or due to the need to wait for it to cool). Examples for such overheating include heating by more than 30° C., by more than 15° C., by more than 10° C. or by more than 5° C.

[0178] This method may further include step **603**, where the thawed units are heated together with other units in the chamber, to reach essentially the same temperature in all units (e.g. about a body temperature).

[0179] A potential benefit of this method and of devices adapted for performing it is that the different frozen and unfrozen units may be heated in a single device such that they reach a desired temperature at about the same time. Thus, the different units may be heated for example in a proportion as they may need to be used.

[0180] An additional potential benefit of the ability to thaw ice without excessively heating non-frozen material (either when present in a single blood product unit, such as a partially thawed unit) or in different units (e.g. when one unit is stored in frozen form, for example FFP) and another is provided in non-frozen form (such as refrigerated pRBC).

[0181] It is expected that during the life of a patent maturing from this application many relevant systems and methods will be developed and the scope of the term an RFID tag, a dielectric heating unit, a field adjusting element, and an MMI is intended to include all such new technologies a priori.

[0182] Exemplary Heating of RBC

[0183] Blood was collected from healthy volunteers (male and female) under the approval of the Rambam medical center human trail committee. The blood donations (450 cc each) were separated using the 2 bag system, as described in the American Association of Blood Banks (AABB) guidelines, to pRBC and plasma by the medical center staff. The blood was stored at 2-8° C. at the blood bank in Rambam and the plasma was rapidly frozen in a conventional −80° C. freezer. After 3 days, the FFP was transferred to −20° C.

[0184] Heating was performed in a device constructed according to the present invention with a working RF band between 800-1000 MHz, at either 600 Watts or 900 Watts.

[0185] The blood heated in either oven from 4° C. to 37° C. within 20 seconds or less. All pRBC units were tested at the Rambam medical center for hemolysis index both before and after heating. Furthermore, the samples were sent to pathology expert lab for cell count. According to both tests there was no significant change in the blood before and after heating.

[0186] As used herein the term "about" refers to ±10%.

[0187] The terms "comprises", "comprising", "includes", "including", "having" and their conjugates mean "including but not limited to". This term encompasses the terms "consisting of" and "consisting essentially of".

[0188] The phrase "consisting essentially of" means that the composition or method may include additional ingredients and/or steps, but only if the additional ingredients and/or steps do not materially alter the basic and novel characteristics of the claimed composition or method.

[0189] As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or "at least one compound" may include a plurality of compounds, including mixtures thereof.

[0190] The word "exemplary" is used herein to mean "serving as an example, instance or illustration". Any embodiment described as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments and/or to exclude the incorporation of features from other embodiments.

[0191] The word "optionally" is used herein to mean "is provided in some embodiments and not provided in other embodiments". Any particular embodiment of the invention may include a plurality of "optional" features unless such features conflict.

[0192] Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

[0193] Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases "ranging/ranges between" a first indicate number and a second indicate number and "ranging/ranges from" a first indicate number "to" a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

[0194] It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

[0195] Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

[0196] All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

1-55. (canceled)

56. A device for heating at least one blood product unit using electromagnetic (EM) energy, comprising:

a chamber for containing at least one frozen blood product unit;

a dielectric heating unit which applies electromagnetic (EM) energy to said at least one frozen blood product unit; and

a controller, which operates said dielectric heating unit to heat said at least one frozen blood product unit to about a body temperature according to a heating pattern, at a plurality of radio frequencies.

57. The device of claim **56**, wherein the controller is configured to operate said dielectric heating unit to heat said at least one frozen blood product unit to about a body temperature in less than 3 minute according to a heating pattern.

58. A device for heating a blood product unit by applying electromagnetic (EM) energy, comprising:

a chamber for containing at least one cooled blood product unit having a temperature above 0° C. and below 15° C.;

a dielectric heating unit for applying electromagnetic (EM) energy to said at least one cooled blood product unit; and

a controller for operating said dielectric heating unit to heat said at least one cooled blood product unit to about a body temperature according to a heating pattern, at a plurality of radio frequencies.

59. The device of claim **58**, wherein said controller is configured for operating said dielectric heating unit to heat said at least one cooled blood product unit uniformly to about a body temperature in 20 seconds or less according to a heating pattern.

60. The device of claim **56**, wherein said device is sized for being installed in a member of a group consisting of: an ambulance, an operating room, and an emergency room.

61. A method of heating at least one frozen blood product unit placed in a chamber by applying electromagnetic (EM) energy, comprising:

(a) thawing said at least one frozen blood product unit by applying EM energy to said at least one blood product unit at a plurality of different radio frequencies; and

(b) heating said at least one frozen blood product unit in said chamber to about a body temperature by applying said EM energy.

62. The method of claim **61**, wherein said thawing and said heating are performed cumulatively in less than 3 minute.

63. The method of claim **61**, wherein said EM energy is at a plurality of frequencies.

64. The method of claim **63**, comprising selecting a maximum power to be dissipated in the at least one frozen blood product unit in a manner which avoids overheating, wherein said EM energy is below said maximum power at all said plurality of different frequencies.

65. The method of claim **61**, comprising gathering data pertaining to at least one of said thawing, and said heating during at least one of said thawing and said heating and scoring the quality of said at least one frozen blood product unit according to said data.

66. The method of claim **61**, comprising tagging each said at least one frozen blood product unit with a respective quality score according to said scoring.

67. The method of claim **61**, comprising reading instructions from at least one tag attached to said at least one frozen blood product unit and performing at least one of said thawing and said heating according to said instructions.

68. The method of claim **61**, wherein said at least one frozen blood product unit is a frozen plasma unit.

69. A method for heating a plurality of blood product units placed in a chamber using electromagnetic (EM) energy, comprising:

applying EM energy to said plurality of blood product units;

measuring a temperature of each said blood product units; and

ending said applying when the temperature of each said blood product unit is above a minimum threshold.

70. The method of claim **69**, wherein said ending is performed automatically.

71. The method of claim **69**, wherein said minimum threshold is 25° C. or more.

72. The method of claim **69**, wherein said ending comprises ending said applying when the temperature of any of said blood product unit is above a maximum threshold.

73. A method for thawing a blood product unit placed in a chamber using electromagnetic (EM) energy, comprising:

applying EM energy to said blood product unit at a time when said blood product unit comprises frozen and thawed portions; and

ending said applying when the temperature of all portions of said blood product unit is between 2° C. and 15° C.

74. The method of claim **73**, wherein during the process the temperature of no part of the blood product exceeds 40° C.

75. A method for managing blood product unit supply, comprising:

receiving a request for supply of at least one frozen plasma unit and at least one cooled blood cells unit;

heating one or more cooled blood cells units and one or more frozen plasma units to about a body temperature cumulatively in less than 3 minutes by applying electromagnetic (EM) energy at a plurality of radio frequencies; and

jointly transferring at least one of the one or more blood cells units and at least one of the one or more plasma units according to the request.

76. The method of claim **75**, comprising performing said heating in a member of a group consisting of: an ambulance, an operating room, and an emergency room.

77. The method of claim **75**, wherein said heating comprises automatically acquiring said frozen plasma unit and said cooled blood cells unit from a freezing storage and automatically placing said frozen plasma unit and said cooled blood cells unit in a heating chamber, said applying being performed in said heating chamber.

78. The device of claim **56**, wherein the heating pattern is determined by an analysis of absorption of different frequencies in the blood product unit.

79. The device of claim **78**, wherein analysis comprises defining transmission frequencies and amount of energy to be transmitted at each frequency, based on spectral information.

80. The device of claim **56**, wherein power levels of transmitted frequencies are inversely related to energy dissipation at the same frequencies.

81. The device of claim **56**, wherein said heating pattern is dynamically determined according to absorption of different frequencies in said blood product unit.

82. The method of claim **61**, wherein heating is according to a heating pattern determined by an analysis of absorption of different frequencies in said blood product unit.

83. The method of claim **82**, wherein the analysis comprises defining transmission frequencies and amount of energy to be transmitted at each frequency, based on spectral information.

84. The method of claim **61**, wherein power levels of transmitted frequencies are inversely related to energy dissipation at the same frequencies.

85. The method of claim **61**, wherein heating is according to a heating pattern dynamically determined according to absorption of different frequencies in said blood product unit.

86. The device of claim **56**, wherein the controller is configured for operating said dielectric heating unit to heat said at least one frozen blood product unit to about a body temperature in less than 3 minutes according to a heating pattern.

87. The device of claim **58**, wherein said device is sized for being installed in a member of a group consisting of: an ambulance, an operating room, and an emergency room.

88. The method of claim **63**, wherein the plurality of frequencies is a plurality of radio frequencies.

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