(12) UK Patent Application (19) GB (11) 2 098 040 A

(21) Application No 8209336
(22) Date of filing 30 Mar 1982
(30) Priority data
(31) 56/046690
56/16545
56/147384
56/148490
56/152688
56/153213
56/168462
(32) 31 Mar 1981
30 Sep 1981
2 Oct 1981
5 Oct 1981
13 Oct 1981
14 Oct 1981
20 Oct 1981
(33) Japan (JP)
(43) Application published
10 Nov 1982
(51) INT CL³
H05B 6/80
B65B 55/16
B67C 3/02
G01F 11/22

(52) Domestic classification
H5H 2M 3C 3S
B8C 40A4 F11
B8N 6B1B3B P
B8T 201 203 204 FA
(56) Documents cited
GB 1222208
GB 1135240
GB 0639144
(58) Field of search
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A2D
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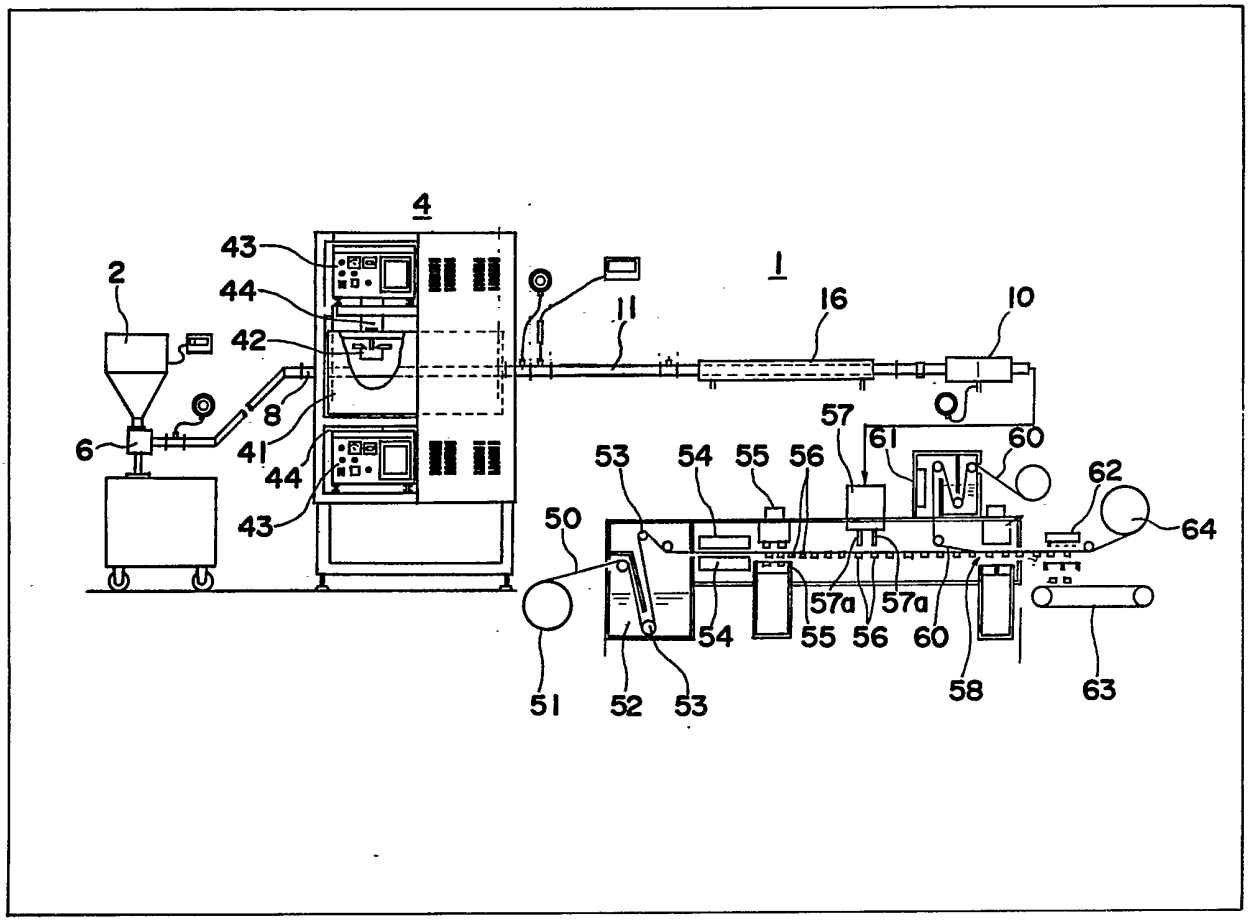
(54) **System for and method of sterilization of food material**

(57) In a method of and system for sterilization of food material, such as minced meat or jam, by using microwaves, the food material is pumped through a microwave-transparent feed pipe (8) to the outside of which microwave power is applied by means of a microwave heating device (4) to heat the food material up to a sterilizing temperature, there being a pressure control device (10), for increasing the pressure in the feed pipe to greater than one atmosphere so as to facilitate the heating of the food material to above its saturation temperature. The sterilized food material is transferred to a packaging machine.



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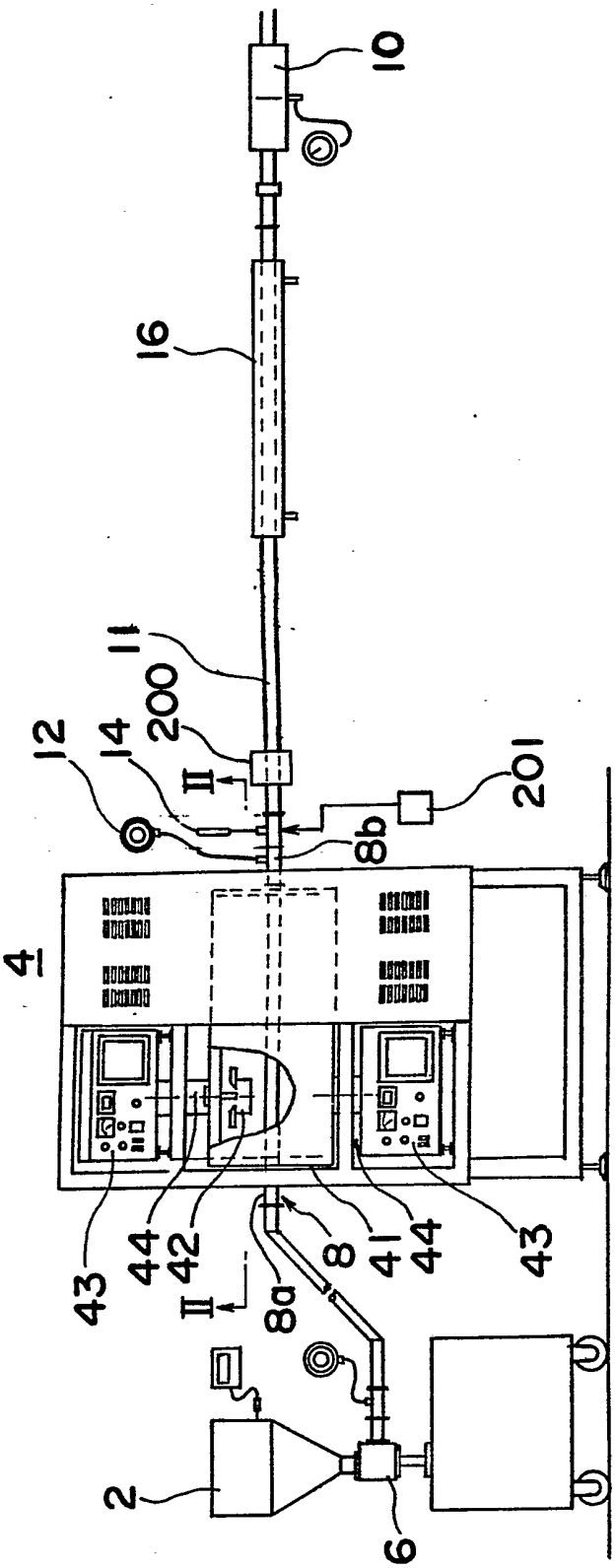
10
16
11
200
12
14
II
201
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4
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II
8a
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2
6

Fig. 1A

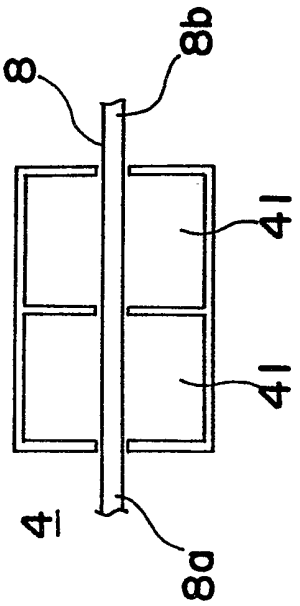
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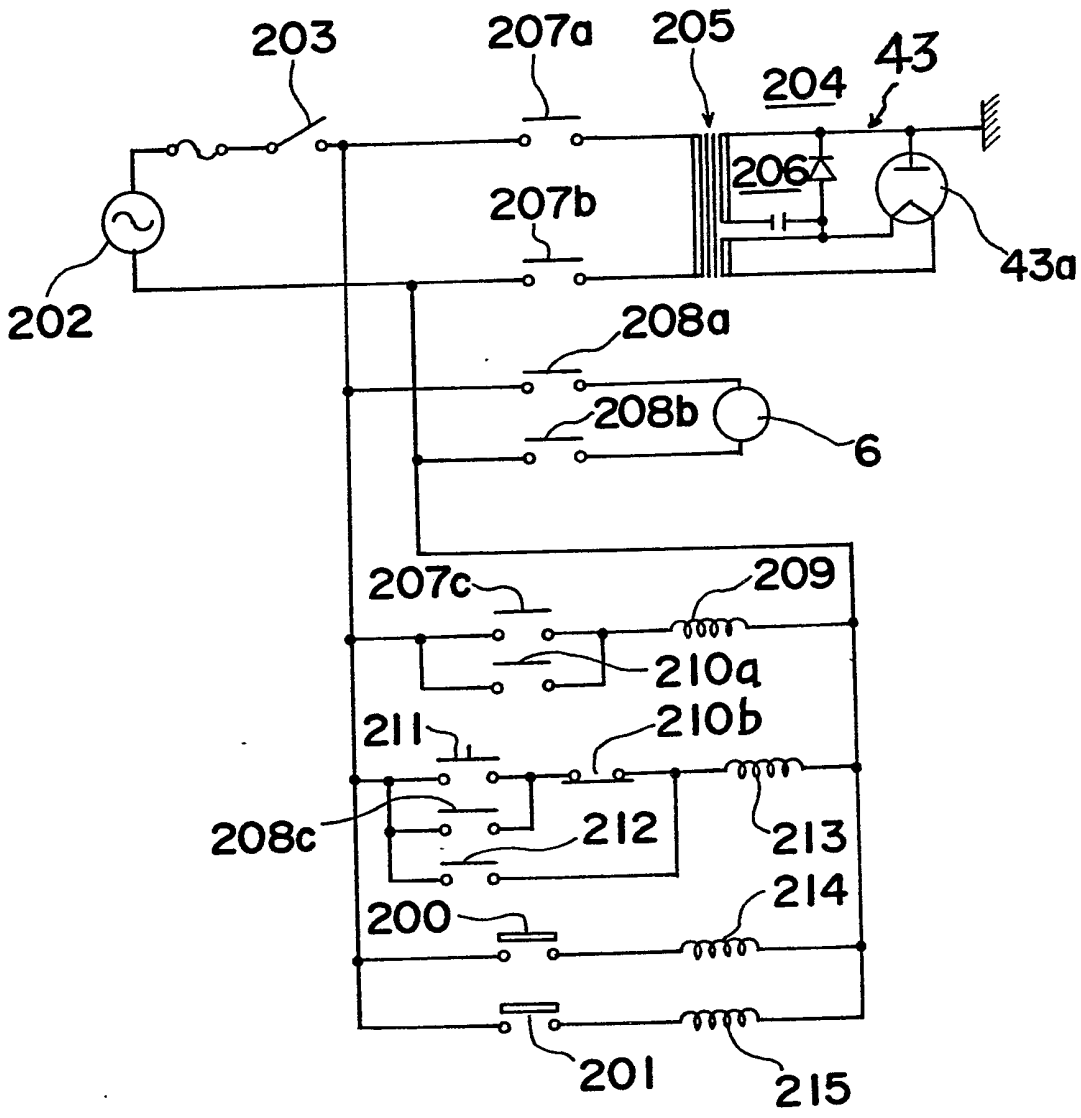
Fig. 1B

Fig. 2


203
207a
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206
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43a
202
208a
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207c
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212
213
214
200
201
215

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Fig. 3a

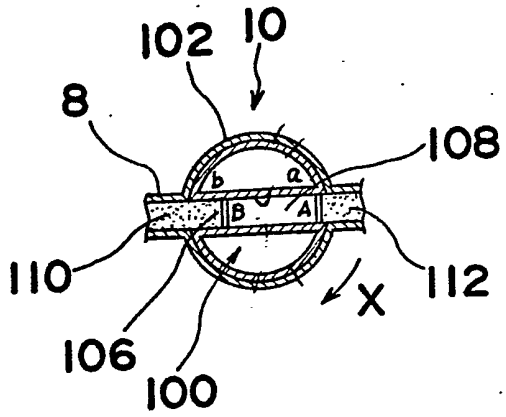

Fig. 3b

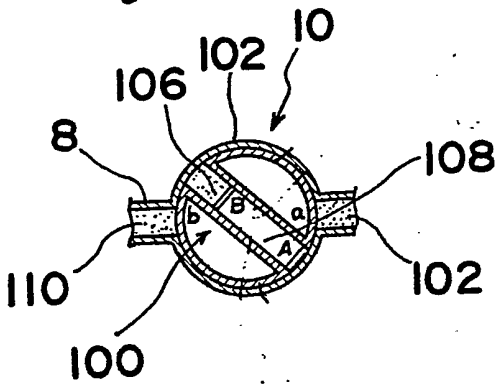

Fig. 3c

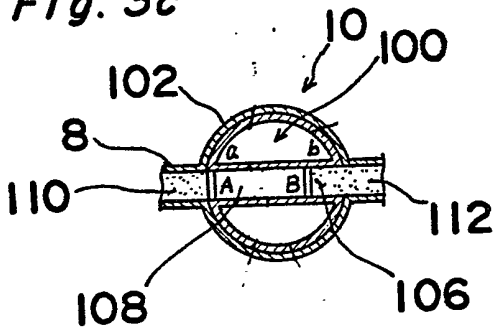

Fig. 3d

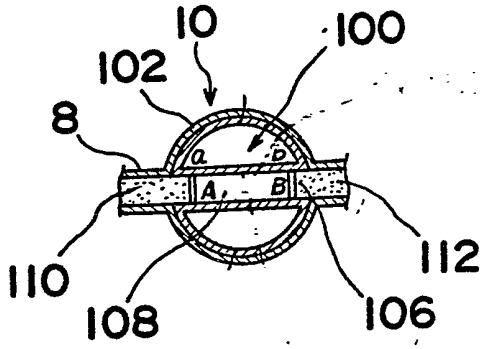

Fig. 4

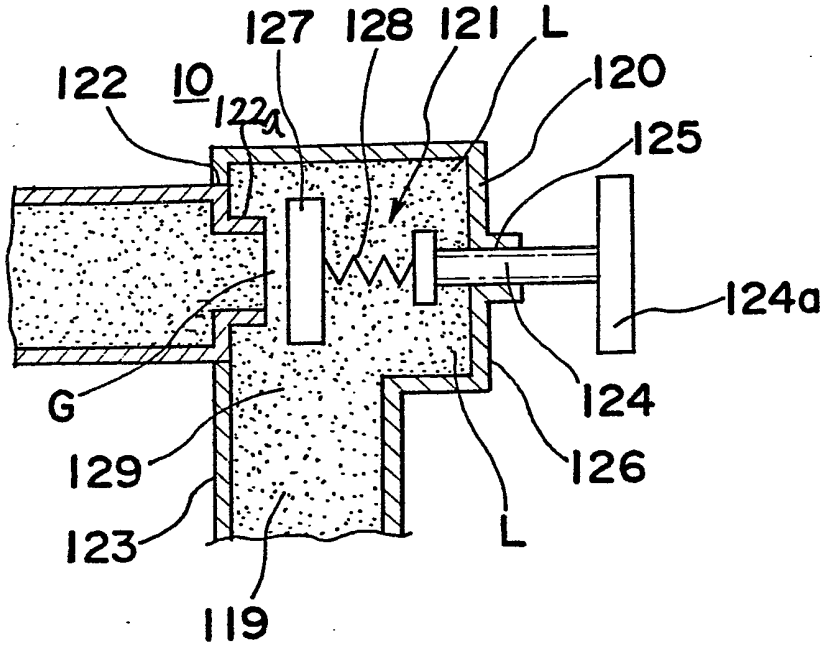

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Fig. 5

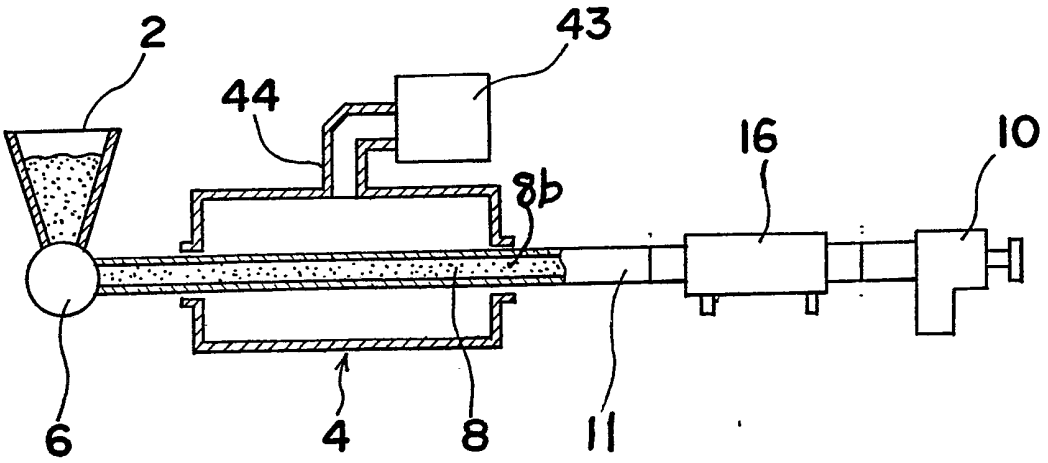

Fig. 6

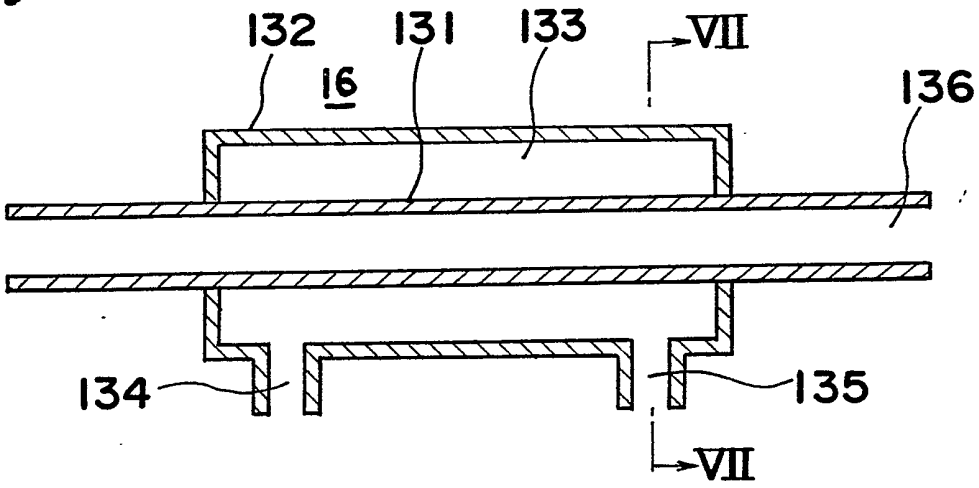

Fig. 7

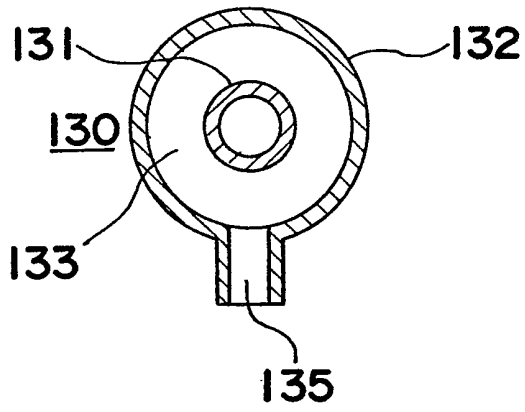

Fig. 8

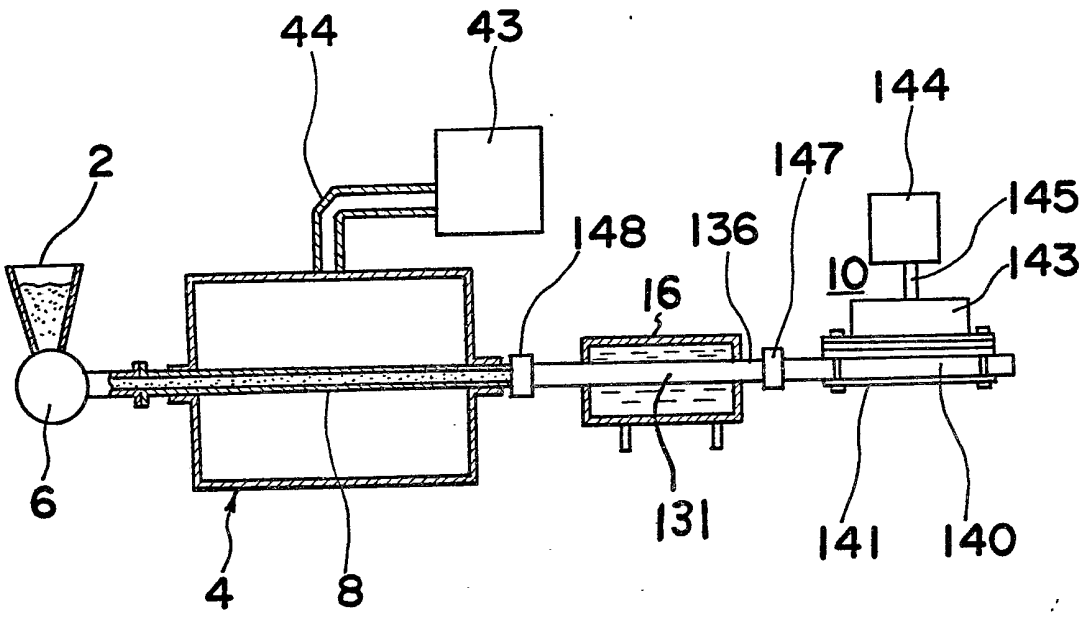
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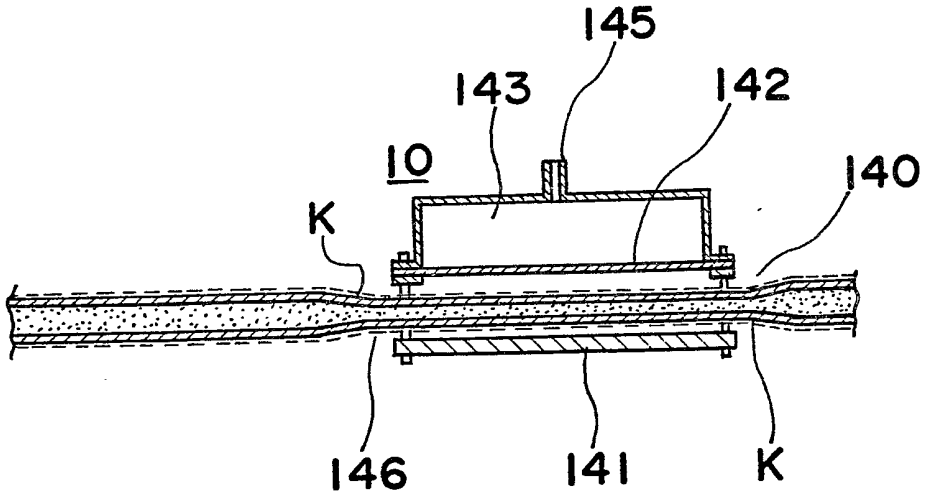
Fig. 9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K

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Fig. 10

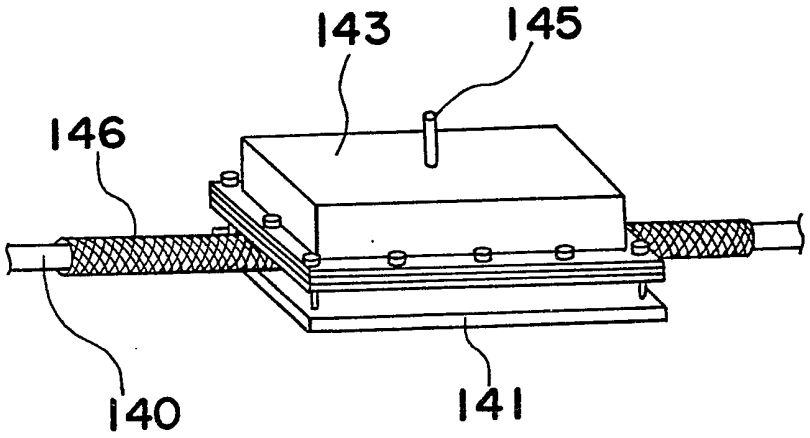

Fig. 11

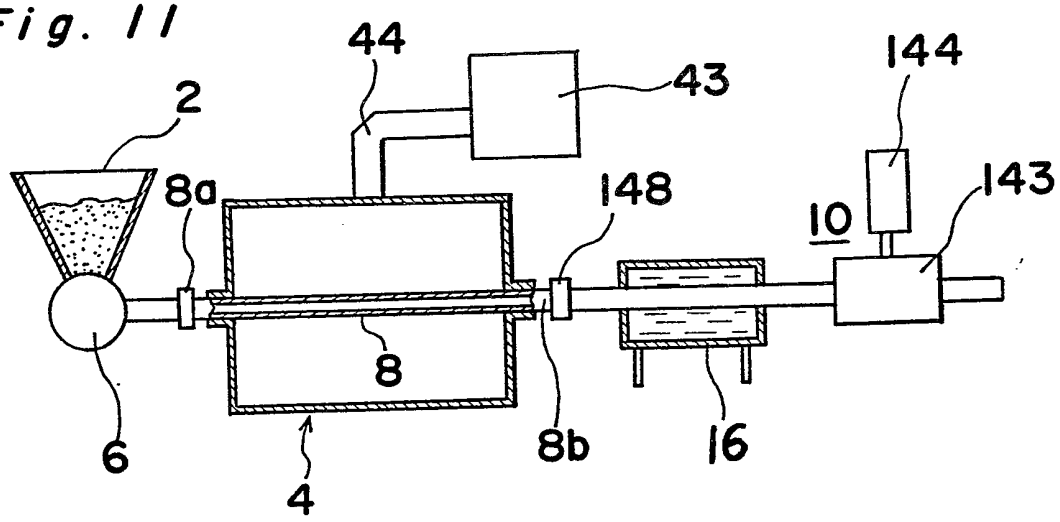

Fig. 12

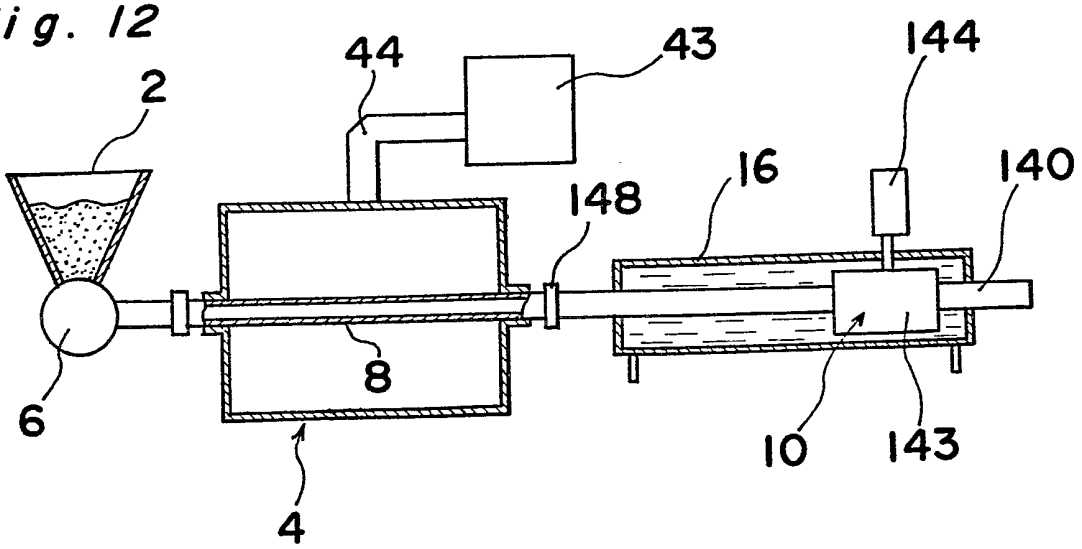

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Fig. 13

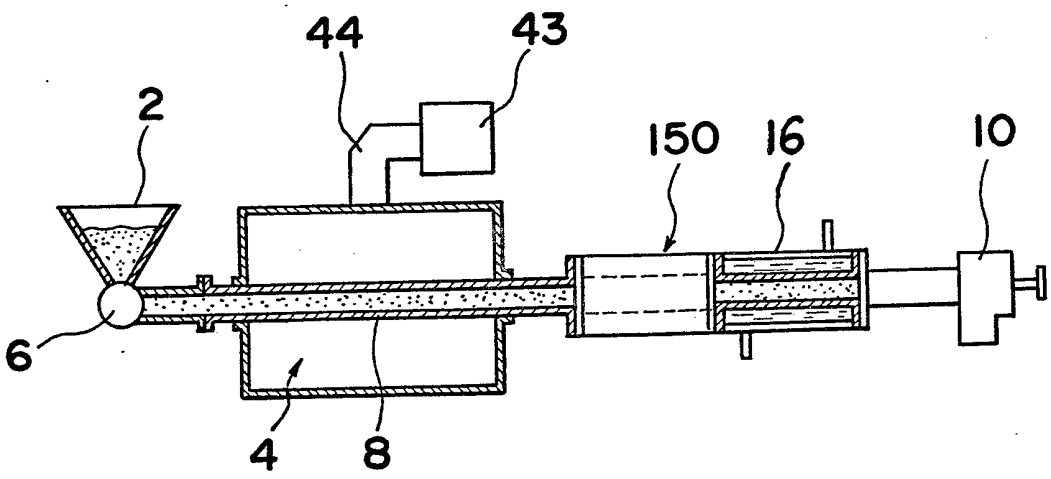


Fig. 14

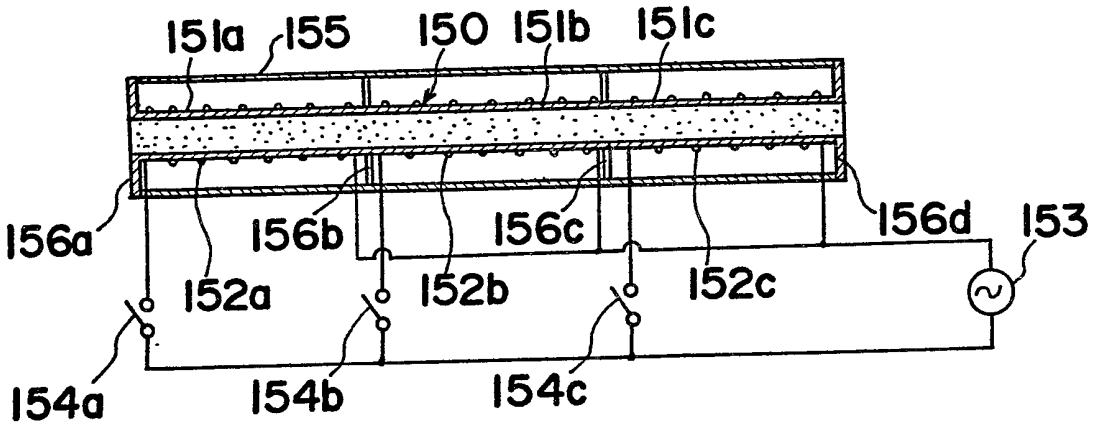


Fig. 15

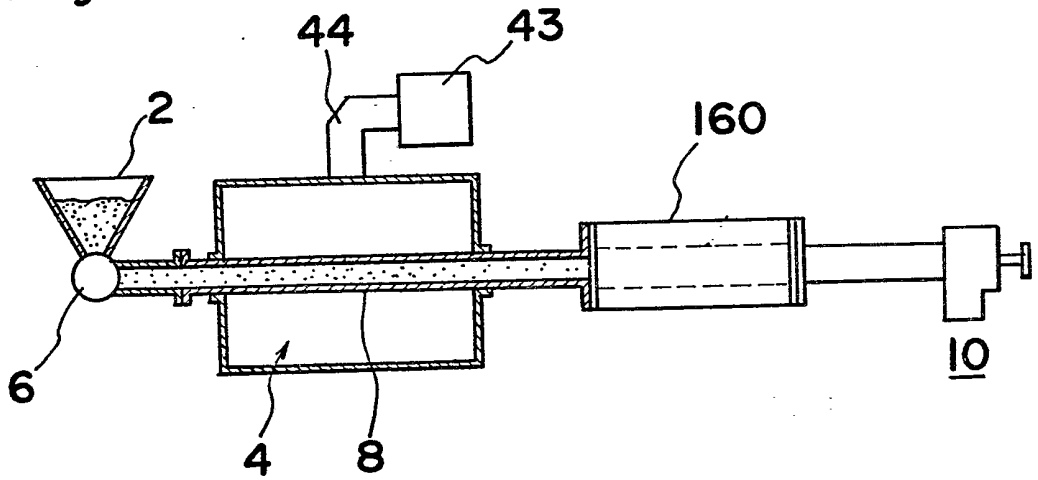


Fig. 16

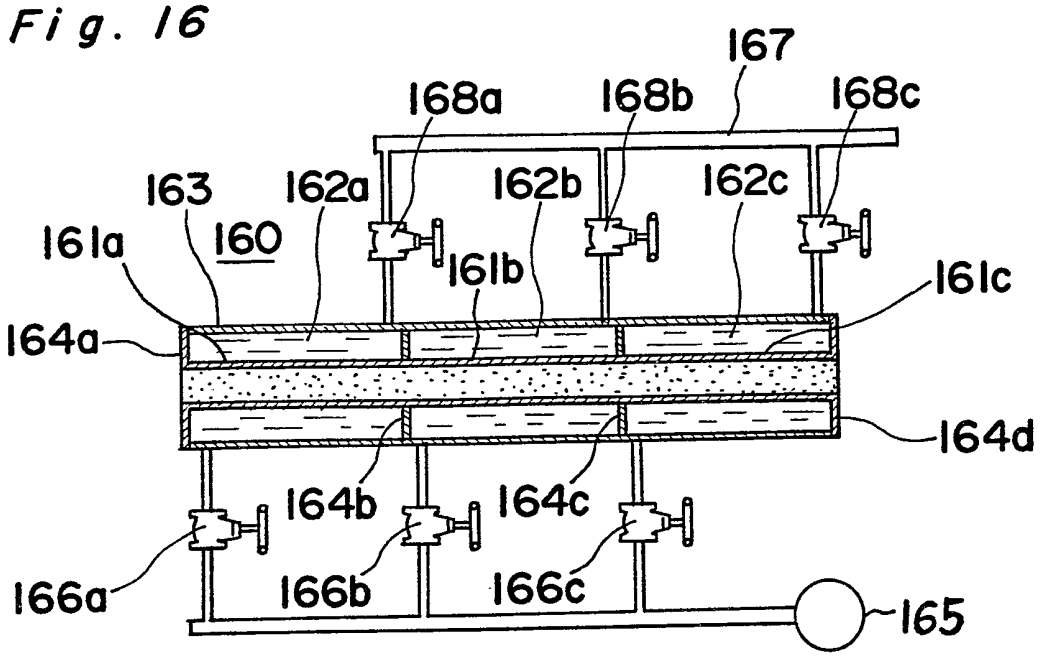


Fig. 17

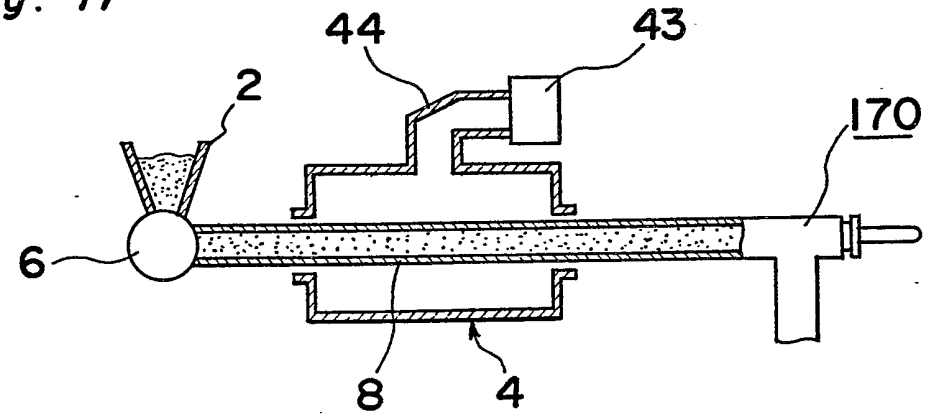
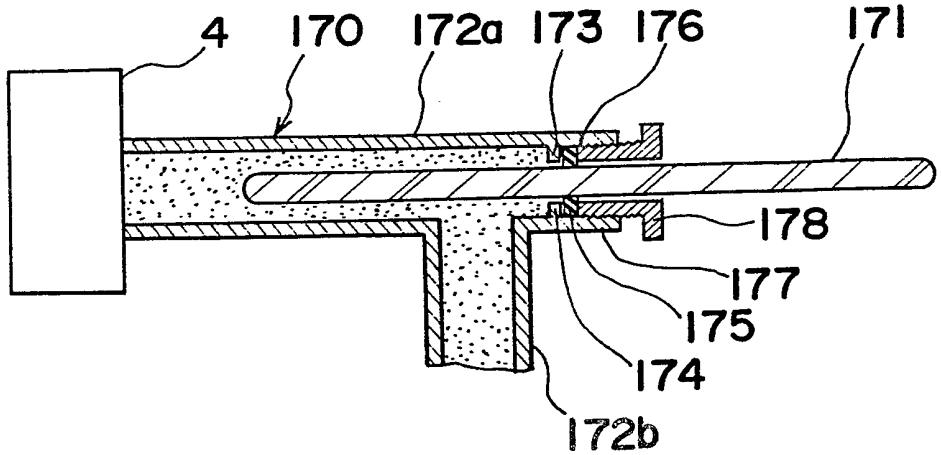


Fig. 18



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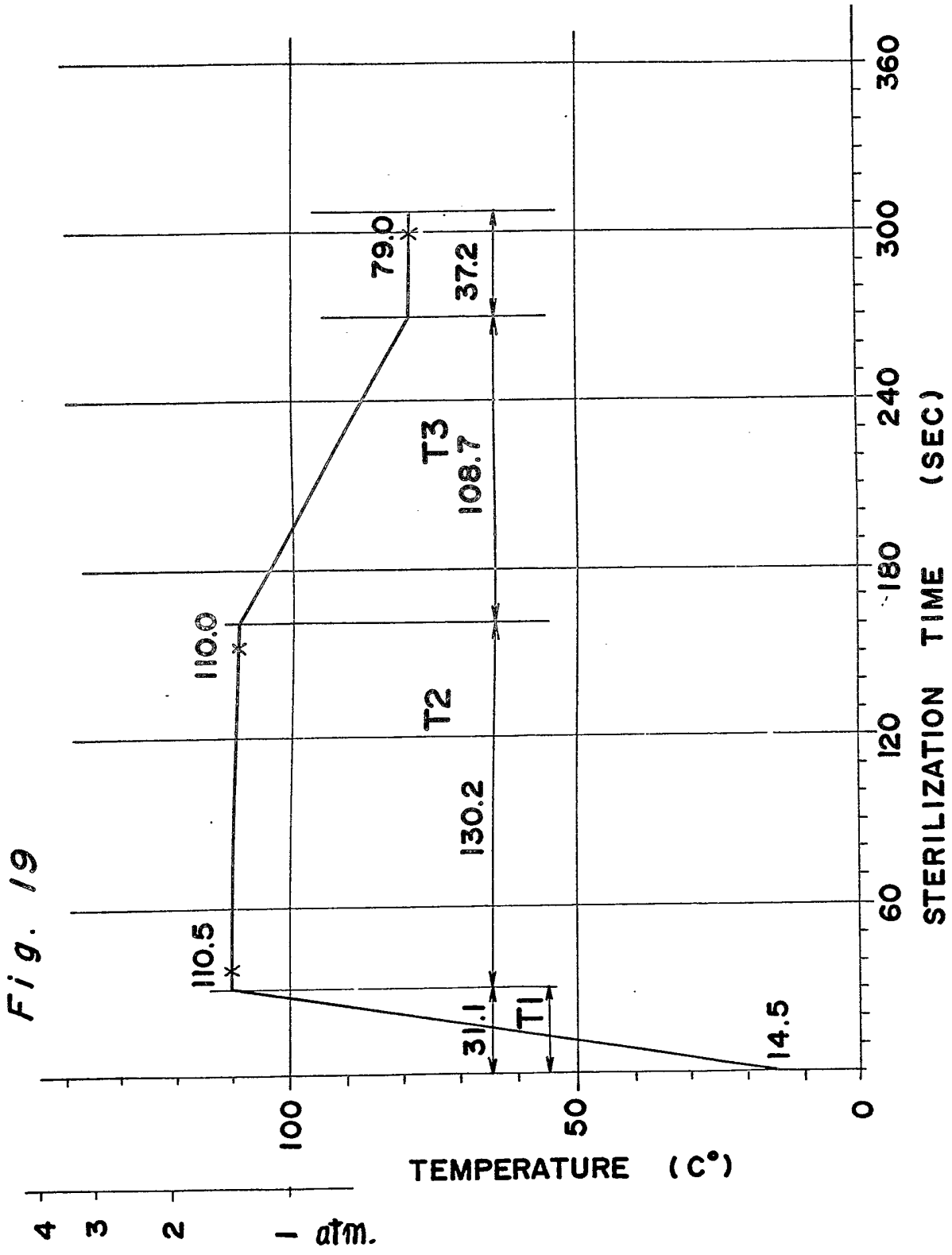

Fig. 19

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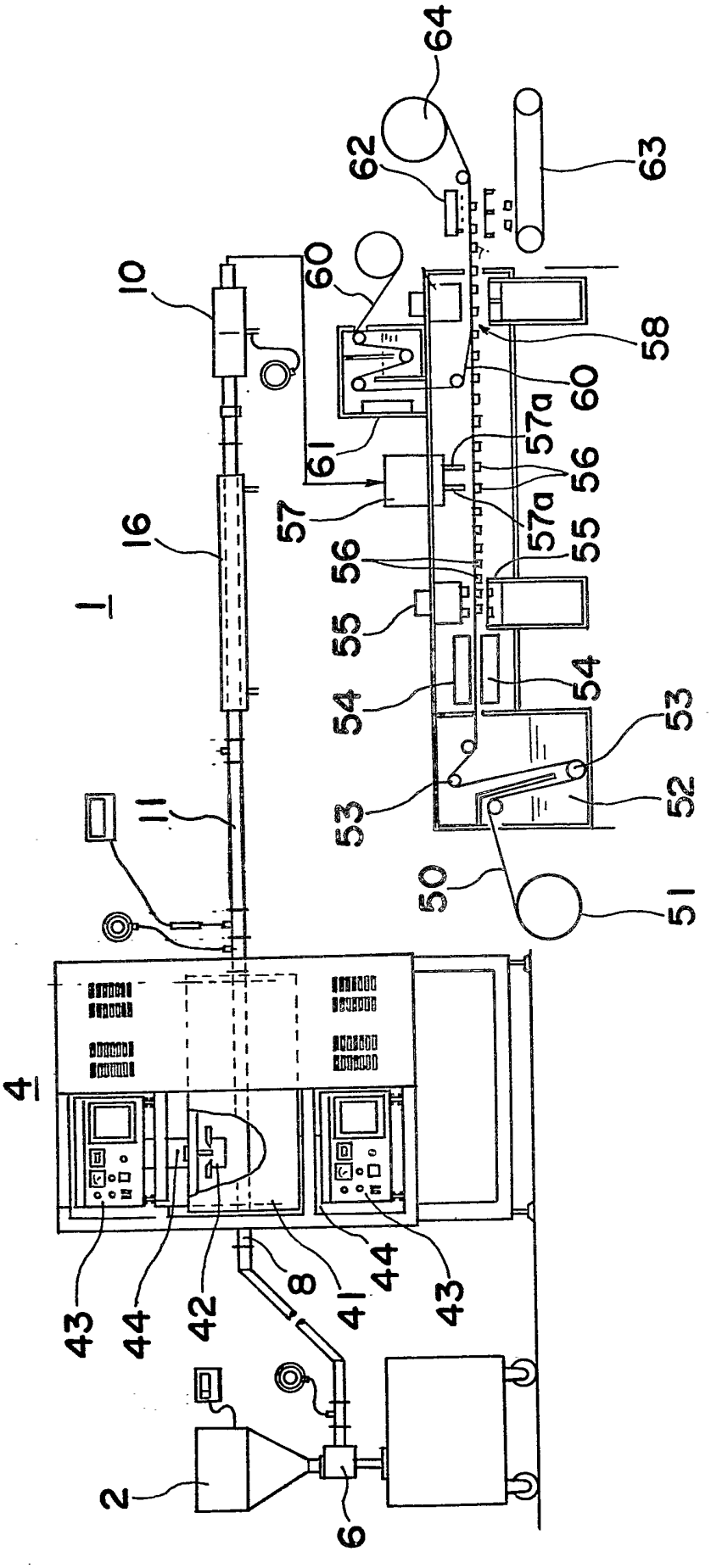

Fig. 20

SPECIFICATION

System for and method of sterilization of food material

The present invention relates to a sterilization system of food material using a microwave heating device and to a method of sterilization of food material by microwave.

Conventionally, sterilization of food material such as jam, miso and/or minced meat is made in such a manner that the food material is transferred in the vicinity of a high temperature radiator heated by steam, whereby the food material is heated up to a sterilization temperature. However, such conventional method takes long time to heat the food material up to the required sterilization temperature.

In order to heat food material rapidly up to a required high temperature, microwave heating may be proposed. A possible sterilization system using microwave comprises a feed pipe passing through a chamber to which microwave is applied. The food material to be processed is transferred in the feed pipe to be heated by the effect of microwave.

For sterilization of food material, it is required to heat the food material higher than 100°C, preferably higher than 110°C. However, in a microwave sterilization system as described above, since the food material is transferred with near the atmosphere pressure such as 1 atm (atmospheric air pressure), the food material cannot be heated to the required high temperature for sterilization.

It is an object of the present invention to provide a system for sterilization of food material using microwave to enable a rapid sterilization.

According to a first aspect of the present invention, there is provided a system for sterilization of food material comprising at least one chamber connected with a microwave power source, a feed pipe made of a low dielectric loss material passing through the chamber, a feed pump to feed heating food material to be processed to the feed pipe from one end of the feed pipe, and pressure control means provided to receive heating food material from the other end of the feed pipe for increasing the pressure in the feed pipe to a pressure higher than 1 atm.

According to a second aspect of the present invention, there is provided a method sterilization of food material which comprises feeding heating food material to be processed in a feed pipe, applying a microwave power to the feed pipe to heat the food material and applying a pressure higher than the atmosphere pressure in the feed pipe.

According to a third aspect of the present invention there is provided a food packaging machine which comprises means for filling sterilized food material into the respective containers, means for sterilizing food using microwave heating system and means for sealing the containers after the sterilized food material is filled in the respective containers.

The present invention will now be described in greater detail by way of example with reference to the accompanying drawings, wherein:—

Fig. 1A is a general side view showing an embodiment of the system for sterilization of food material according to the present invention;

Fig. 1B is a cross-sectional view of a microwave heating device employed in a sterilization system shown in Fig. 1A, taken along the lines I-I;

Fig. 2 is a circuit diagram of a control device employed in the sterilization system shown in Fig. 1A;

Figs. 3a through 3d are cross-sectional views showing one embodiment of a pressure control device employed in the sterilization system shown in Fig. 1;

Fig. 4 is a cross-sectional view of other embodiment of a pressure control device employed in the sterilization system shown in Fig. 1A;

Fig. 5 is a schematic general view showing a sterilization system according to the present invention;

Fig. 6 is a cross sectional view of a cooling device employed in the sterilization system shown in Fig. 5;

Fig. 7 is a cross sectional view of the cooling device shown in Fig. 6 taken along the lines VII-VII;

Fig. 8 is a general cross sectional view of a further embodiment of the sterilization system according to the present invention;

Fig. 9 is a side cross sectional view showing an embodiment of the pressure control device shown in Fig. 8;

Fig. 10 is a perspective view of the pressure control device shown in Fig. 8;

Fig. 11 is a side cross sectional view of a modification of sterilization system according to the present invention;

Fig. 12 is a side cross sectional view of another modification of the sterilization system according to the present invention;

Fig. 13 is a side cross sectional view showing a further embodiment of the sterilization system according to the present invention;

Fig. 14 is a side cross sectional view showing detail of a sterilization time control device employed in the embodiment shown in Fig. 13;

Fig. 15 is a side cross sectional view showing a further embodiment of the sterilization system according to the present invention;

Fig. 16 is a side cross sectional view showing an embodiment of the sterilization time control device shown in Fig. 15;

Fig. 17 is a side cross sectional view showing a further embodiment of the sterilization system according to the present invention;

Fig. 18 is a side cross sectional view showing the speed control device employed in the embodiment shown in Fig. 17;

Fig. 19 is one example of operational characteristics of the sterilization system shown in Fig. 1A with the horizontal axis taken for sterilization time and the vertical axis taken for the temperature of food material; and

Fig. 20 is a general side view showing a food packaging system in which the sterilization system according to the present invention is employed.

Before proceeding the explanation of the embodiments, it is noted that like parts throughout figures are designated by like references numerals.

Referring now to Fig. 1A, there is shown a general system for sterilization of paste-like food material

such as jam or miso or the like or minced food material such as minced meat. In Fig. 1A, heating food material as described above which is to be sterilized is fed from a hopper 2 to a microwave heating device 4 through a feed pump 6 of a constant volume type.

The microwave heating device 4 comprises a plurality of heating chambers 41 each having a stirrer 42, microwave oscillators 43 using magnetrons (not shown) and wave guides 44 for introducing microwave oscillated by the oscillators 43 to the corresponding heating chambers 41 in a known manner. In the embodiment shown in Fig. 1A, two heating chambers 41 are provided as shown in Fig. 1B.

A circular feed pipe 8 made of plastic resin material such as polytetrafluoroethylene having a low dielectric loss of 4.2×10^{-4} or VYCOR (trade name, supplied by CONING GLASS CO.) is adapted to pass the two heating chambers 41, the inlet port of the feed pipe 8 is connected with the outlet of the feed pump 6 so that the heating food material fed from the feed pump 6 is transferred in the heating chambers 41 for heating under the effect of microwave.

In this embodiment, the feed pipe 8 has a circular path of diameter of 15 mm. Preferably, the diameter of the feed path is less than 30 mm.

The outlet port of the feed pipe 8 is followed by a cooling device 16 having a pipe, as shown in Fig. 6, connected to the feed pipe, details of which will be described hereinafter through a holding pipe 11 made of a stainless material. The holding pipe 11 is covered by a foamed urethane resin material (not shown) for preventing heat radiation.

Between the microwave heating device 4 and the cooling device 16, a pressure gauge 12 for measuring pressure of the heating food material in the feed pipe 8 and a thermometer 14 for measuring sterilization temperature of heating food material are provided.

The cooling device 16 is followed by a pressure control device 10, from which the sterilized material is taken out.

In the system as shown in Fig. 1A, heating food material is fed to the microwave heating device 4 from the feed pump 6 under a constant pressure, and in turn the heating food material is transferred through the feed pipe 8 from the inlet 8a to the outlet 8b, keeping a high pressure, for example 2.7 atm by the help of the pressure control device 10 as hereinafter described, so that the heating food material is heated up to a suitable high temperature caused by a dielectric heating effect of microwave, then the food material is sterilized. Microwave energy radiated in the heating chamber 41 is stirred by the stirrers 42.

In Fig. 1A, a material detection switch 200 to detect the heating food material transferred in the outlet port is provided in the vicinity of the microwave heating device 4 and the switch 200 is turned ON by the heating food material transferred thereto under a constant pressure. The pressure switch 201 becomes ON when the inner pressure of the feed pipe 8 reaches a predetermined level, i.e., 2.7 atm.

Fig. 2 shows a circuit arrangement for controlling the oscillator 43 and feed pump 6 which comprises a commercial power source 202, a power supply switch 203, a high-voltage supplying circuit 204 consisting of a high-voltage transformer 205 and a doubler rectifying circuit 206 for supplying a high voltage power to the magnetron 43a, first relay switches 207a and 207b connected to both ends of the primary winding of the high-voltage transformer 205, second relay switches 208a and 208b connected to both ends of the feed pump 6, other contact 207C of the first relay and a first relay coil 209 directly connected with the first relay switch 207c, and when the first relay coil 209 is excited, the first relay switches 207a, 207b and 207c simultaneoulsy become ON. The device further includes a third relay switch 210a connected in parallel with the first relay switch 207c, a sterilization start switch 211 of self return type, a second relay switch 208c, a fourth relay switch 212 and a second relay coil 213 connected in series with the sterilization start switch 211 and the third relay switch 210b, and when the second relay coil 213 is excited, the second relay switches 208a, 208b and 208c simultaneously become ON. Numeral 214 indicates a third relay coil which is connected in series with the material detection switch 200, and the relay switches 210a and 210b become ON and OFF respectively upon excitation of the third relay coil 214. There is further provided a fourth relay coil 215 connected in series to the pressure switch 201, and when the fourth relay coil 215 is excited, the fourth relay switch 212 becomes ON.

Thus, when the sterilization start switch 211 is pushed to turn ON after the power supply switch 203 is turned ON, the second relay coil 213 is excited to simultaneously turn the second relay switches 208a, 208b and 208c ON. Such excitation of the second relay coil 213 is self-held by "ON" of the second relay switch 208c, and the feed pump 6 is driven by "ON" of the second relay switches 208a and 208b to start transferring of the heating food material into the feed pipe 8 under a constant pressure. When the heating food material reaches the material detection switch 200, the material detection switch 200 is turned ON so that the third relay coil 214 is excited to turn the third relay switches 210a and 210b ON and OFF respectively. By becoming "OFF" of the third relay switch 210b, the second relay coil 213 is released from self-hold so that transferring of the heating food material by the feed pump 6 is stopped. Further, the first relay coil 209 is excited due to "ON" of the third relay switch 210a to turn the first relay switches 207a, 207b and 207c ON. Such excitation of the first relay coil 209 is self-held by "ON" state of the first relay switch 207c while a microwave is supplied to the microwave heating device 4. Upon supplying of the microwave, heating of the food material is started.

With progress of heating, the food material generates vapor, and the internal pressure of the feed pipe 8 is gradually increased by the vapor pressure. When the internal pressure of the feed pipe 8 reaches 2.7 atm, i.e., when the temperature of the heating food material reaches the sterilization temperature, the pressure switch 201 is turned ON. Then the fourth relay coil 215 is excited to turn the fourth relay switch 212 ON and thereby to excite the second relay

coil 213 so that transferring of the heating food material by the feed pump 6 is started again. Thereafter the heating food material transferred into the feed pipe 8 is completely heated and sterilized under a pressure of 2.7 atm.

By interrupting the feed pump 6 once as described above, the unsterilized food material which already filled in the feed pipe 8 under a low inner pressure during the start operation of the sterilization system is not exhausted from the microwave heating device 4.

And by starting the feed pump 6 again after the inner pressure in the feed pipe 8 is increased up to 2.7 atm, said unsterilized food material can be heated up to 130°C by the high inner pressure.

Through this operation, only fully sterilized food material can be taken out from the sterilization system.

The heating food material thus heated and sterilized in the microwave heating device 4 is fed to the cooling device 16 through the holding pipe 11.

While the heating food material thus heated is transferred from the outlet 8b of the feed pipe 8 to the cooling device 16 through the holding pipe 11, the heating food material keeps its high temperature under the natural temperature radiation so as to continue the sterilization of food material. Thus, the food material is sterilized before it reaches the cooling device 16.

The temperature of food material for sterilization according to the present invention is selected higher than 100°C and the suitable temperature for sterilization is determined depending on the quality of food material in such a manner that the quality of food material is not lost by undesired high temperature.

The period of time during which food material is subjected to the microwave effect is from 30 sec to 150 sec.

The microwave power per Kg of heating food material is, for example, 15 KW.

The sterilization effect of the present invention is also obtained on various movable food materials, such as soup, juice, soy milk, syrup, margarine and wine.

In a case where the inner pressure in the feed pipe 8 is at the atmosphere pressure, i.e., 1 atm, the heating food material is not heated over the saturation temperature of water, i.e., 100°C.

To solve this problem, the pressure control device 10 is provided for increasing the inner pressure in the feed pipe 8.

One detailed embodiment of the pressure control device 10 according to the present invention is described hereinafter.

Referring to Fig. 3, a rotational pipe 100 having a cylindrical path 106 in the central portion is rotatably mounted in a cylindrical casing 102 with the semi-cylindrical surfaces of the rotational pipe 100 rotatably fitted with the inner surface of the casing 102 and the cylindrical path 106 has a generally similar size of the diameter of the feed pipe 8. The rotational pipe 100 is rotated by means of an electric motor (not shown) with a constant speed of below 100 r.p.m. in a direction as depicted by an arrow X. A piston 108 is accommodated within the cylindrical path 106 so as to be reciprocally moved in said cylindrical path 106 in synchronism with the rotation of the rotational pipe 100 in such a manner as described hereinafter.

The inlet port 110 of the casing 102 is connected with the outlet of the cooling device 16, and the outlet port 112 of the casing 102 works to take out the sterilized food material.

In this embodiment, the feed pump 6 of a constant pressure type is used.

By this arrangement, when the heating food material is fed from the cooling device 16 after sterilization, the heating food material is taken out from the pressure control device 10 by a constant volume in such a manner as described below. Assuming that one end of the cylindrical path 106 is faced with the outlet of the cooling device 16, the heating food material fed from the cooling device 16 is filled in the cylindrical path 106 under the constant pressure applied by the feed pump 6, moving the piston 108 in right direction from the leftmost position as shown in Fig. 3a. The heating food material is filled in the cylindrical path 106 until the piston 108 is moved to the rightmost position, on the other hand, the rotational pipe 100 is rotated as shown in Fig. 3b to transfer the filled food material to the outlet port 112 of the casing 102. When the rotational pipe is rotated by 180° as shown in Fig. 3c, the end B of the piston 108 reaches the outlet port 112. The heating food material is pushed out of the cylindrical path 106 through the outlet port 112 by the piston 108 which is moved in the right direction as the heating food material is pushed into the cylindrical path 106 from the left hand direction by the pressure applied by the feed pump 6 as shown in Fig. 3d. By repeating the rotation of the rotational pipe 100 as described above, the heating food material can be taken out from the pressure control device 10 by a constant volume.

In the arrangement described above, as the rotational speed of the rotational pipe 100 is lower, i.e., speed of taking out the heating material from the cooling device 16, in other words, from the feed pipe 8 is lower, the pressure occurring in the feed pipe 8 becomes higher, therefore, by adjusting the speed of the rotational pipe 100, the pressure occurring in the feed pipe 8 can be controlled at a constant pressure such as 2.7 atm by setting the maximum pressure of the feed pump 6 at 2.7 atm. By adjusting the pressure in the feed pipe 8 at 2.7 atm, the heating food material in the feed pipe 8 can be heated to a temperature of 130°C in the microwave heating device 4, thereby the heating food material can be effectively sterilized by heat.

The other embodiment of the pressure control device 10 used in a sterilization system according to the present invention is shown in Fig. 4.

Referring to Fig. 4, a casing 120 enclosing a control valve 121 is connected with the outlet port of the cooling device 16 through an inlet port 122 formed on a side wall member 123 with the end portion of the outlet port 112 projected into the interior of the casing 120.

An adjusting screw 124 is rotatably engaged with a screw hole 125 defined in the side wall 126 opposed

to the said side wall 123. A pressure plate 127 is connected to the inner end of the screw 124 through a coil spring 128 to allow a resilient displacement in a horizontal direction with one surface of the pressure plate 127 opposed to the opening of the outlet pipe 122a of the cooling device.

From the outlet port 129 defined on the bottom wall of the casing 120, the sterilized food material is taken out through a connecting pipe 119 extending vertically.

By the arrangement shown in Fig. 4, by rotating the screw 124 by a knob 124a, the pressure plate 127 can be moved rightward or leftward so that the gap G between the surface of the pressure plate 127 and the end of outlet pipe 122a of the cooling device can be changed, thereby changing the pressure in the feed pipe 8.

When the pressure occurring in the cooling device 16, i.e., in the feed pipe 8 is low, the displacement of the pressure plate 127 in the right direction in Fig. 4 is small, the amount of the volume of the heating food material transferred from the outlet pipe 122a of the cooling device 16 to the outlet port 129 through the gap G is small compared with the amount of the volume of the heating food material fed from the feed pump 6 whereby the volume of the heating food material in the feed pipe 8 is increased to increase the inner pressure in the feed pipe 8. On the other hand, when the pressure in the feed pipe 8 is relatively high, the displacement of the pressure plate 127 in the right direction in Fig. 4 is large, the volume of the heating food material transferred through the gap G increases, whereby the amount of the heating food material in the feed pipe 8 decreases to cause the pressure in the feed pipe 8 to be lowered. By the operation as mentioned above, the pressure in the feed pipe 8 is kept constant.

By adjusting the screw 124 to control the pressure in the feed pipe 8 at 2.7 atm, the temperature of the heating food material in the feed pipe 8 can be controlled at 130°C, thus, the heating food material can be effectively sterilized.

Fig. 5 shows the detailed embodiment of the cooling device 16 provided between the microwave heating device 4 and the pressure control device 10 for cooling the heating food material taken out from the microwave heating device 4.

The cooling device 16 consists of a cooling path 131 in the form of a pipe made of a high heat conductivity material such as stainless steel for passing the heating food material therethrough and an enclosure 132 disposed outside of and coaxial with the cooling path 131 to provide a path 133 for cooling water so as to cool the heating material passing through the cooling path 131. The water is introduced from the inlet port 134 into the path 133 and in turn being exhausted from the outlet port 135. Said cooling path 131 is connected with the outlet port of the holding pipe 11 with the same diameter as that of the outlet port 8b of the feed pipe 8.

In operation, the cooling water is fed from a pump (not shown) to the inlet port 134, passing through the path 133, being exhausted from the outlet port 135. On the other hand, the heating food material processed in the microwave heating device 4 with a temperature of 130°C flows the interior of the cooling path 131, whereby the heating food material can be cooled by exchanging the heat with the cooling water. The heating food material is taken out from the outlet 136 of the cooling path 131 with a temperature of below about 100°C.

Since the temperature of the heating food material is lowered under 100°C at the outlet 136 of the cooling path 131 as mentioned above, water in the heating food material is not suddenly evaporated upon flowing out of the heating food material from the pressure control device 10. Therefore, the heating food material can be smoothly taken out from the pressure control device 10. In other words, the heating food material can be transferred in the feed pipe 8 uniformly, resulting in uniform sterilization of the heating food material.

A further embodiment of the present invention is shown in Figs. 8 through 10 in which the pressure control device is formed by a deformable pipe. In Figs. 8 through 10, a pipe 140 made of a deformable material such as silicon rubber tube or fluorine rubber tube is laid between a fixed base plate 141 and a diaphragm 142 secured on the bottom of an air chamber 143. An air source 144 is connected with the inlet port 145 defined on the top plate of the air chamber 143 so as to feed a pressurized air into the interior of the air chamber 143 to fill the air therein to deform the diaphragm 142 downwardly for depressing the pipe 140.

The pipe 140 may be covered with a meshed tube 146 to protect therefore.

In the embodiment shown in Fig. 8, one end of the deformable pipe 140 is connected with the outlet port 136 of the cooling path 131 of the cooling device 16 as shown in Fig. 6 through a junction member 147. The cooling device 16 is connected with the feed pipe 8 through the holding pipe 11 and a junction member 148.

By applying the air with a possible pressure into the air chamber 143 from the air source 144, the diaphragm 142 is deformed downwardly, whereby the diaphragm 142 depresses the deformable pipe 140 to decrease the cross sectional area of the deformable pipe 140. Thus the volume of the heating food material flowing in the deformable pipe 140 can be decreased so that the pressure in the feed pipe 8 of the microwave heating device 4 can be increased.

By adjusting the pressure of the air fed from the air source 144, the pressure in the feed pipe 8 can be adjusted at 2.7 atm, to assure effective heating, i.e., sterilization of the heating food material by the microwave heating device 4.

One advantage of the embodiment shown in Figs. 8 through 10 is in that the configuration of the side cross sectional view of the deformable pipe 140 changes continuously as shown by an arrow mark K in Fig. 9 without cornered portion as shown by an arrow mark L in Fig. 4, the heating food material transferred in the deformable pipe 140 does not remain therein.

This means that unsterilized heating food material which was already filled in the deformable pipe 140 before sterilization can fully be exhausted before the sterilized food material reaches the deformable pipe

140 so that the sterilized food material is prevented from being mixed with the unsterilized food material as may occur in the embodiment shown in Fig. 4.

Fig. 11 shows a modification of the embodiment shown in Fig. 8 in which the deformable pipe 140 extends to the outlet port of the cooling device 16 with a junction member 147 in Fig. 8 being omitted. By this arrangement, the unsterilized material can be more completely exhausted.

Although there remains another junction member 148 near the outlet port of the feed pipe 8, this junction member is disposed close to the microwave heating device 4, the heating food material existing in the junction member 148 can be heated enough so that the remainder in the junction member 148 can be sterilized by the heat transferred from the sterilized food material which was already heated by the microwave heating device 4.

Fig. 12 shows another modification of the embodiment shown in Fig. 11 in which the pressure control device 10 shown in Figs. 8 through 10 is mounted in the cooling device 16.

In the respective embodiments shown in Figs. 8 through 12, the cross sectional area of the deformable pipe 140 can be controlled not only by an air pressure but also by a hydraulic pressure or a force applied from a mechanical device.

In the respective arrangements described above, before the heating food material is exhausted from the outlet of the microwave heating device 4, since the temperature drops by natural heat radiation, the sterilized material processed in the microwave heating device 4 can maintain its high temperature of about 130°C for a possible time for continuing sterilization.

Therefore, the time period during which the heating food material is subjected to sterilization (referred to as sterilization time hereinafter) is independent of the kind of the heating food material, in other words, the sterilization time cannot be controlled depending on the quality of the heating food material. Therefore, quality of the heating material might be harmed if the sterilization time is undesirably long.

The embodiment shown in Figs. 13 and 14 can improve this problem.

Referring to Figs. 13 and 14, there is provided an auxiliary pipe 150 made of stainless steel tube connected between the outlet port of the feed pipe 8 and the cooling device 16. As shown in Fig. 14, the auxiliary pipe 150 is divided into three sections 151a, 151b and 151c with respect to the axial direction of the pipe 150 with an equal length. Electric heaters 152a, 152b and 152c are uniformly wound around the auxiliary pipe 150 corresponding to the respective sections 151a, 151b and 151c. The first heater 152a, the second heater 152b and the third heater 152c are connected with the commercial power source 153 through the first switch 154a, the second switch 154b and the third switch 154c respectively.

Said auxiliary pipe 150 including heaters 152a, 152b and 152c is enclosed by a casing 155 separated by partition walls 156a, 156b, 156c and 156d.

The auxiliary pipe 150 is directly connected with the cooling device 16.

The distance between the outlet of the microwave heating device 4 and the inlet port of the auxiliary pipe 150 is set in such a manner that the temperature of the sterilized food material is kept about 130°C during transfer of the sterilized food material from the outlet of the microwave heating device 4 to the inlet of the auxiliary pipe 150 under the natural heat radiation.

In a case where the heating food material requires long sterilization time, all the switches 154a, 154b and 154c are made ON to heat the heaters 152a, 152b and 152c, the heating food material sterilized is further subjected to sterilization while it is transferred over the first, second and third sections 151a, 151b and 151c, by the heat generated from the heaters 152a, 152b and 152c.

In a case where the necessary sterilization time is relatively shorter than the above case, the switches 154a and 154b or only 154a are made ON, so that the sterilization time can be controlled depending on the quality of the heating food material.

A further embodiment of the present invention is shown in Figs. 15 and 16 in which only cooling device 160 divided into three sections is provided with the auxiliary pipe omitted. As shown in Fig. 16, the cooling pipe 160 is divided into three sections 161a, 161b and 161c, which are surrounded by the corresponding cooling chambers 162a, 162b and 162c formed by a casing 163 and the partition walls 164a, 164b, 164c and 164d. The respective inlet ports of the cooling chambers 162a, 162b and 162c are connected with a cooling water source 165 through the valves 166a, 166b and 166c. Also the respective outlet ports are connected with an exhausting pipe line 167 through the valves 168a, 168b and 168c.

In this arrangement, in a case where the necessary sterilization time is short, all the valves 166a, 166b, 166c, 168a, 168b and 168c are opened to flow the cooling water through the cooling chambers 162a, 162b and 162c respectively, thereby the respective sections 161a, 161b and 161c of the cooling pipe 160 are cooled. Then the sterilized food material coming from the microwave heating device 4 is cooled during transfer from the section 161a to the section 161c, whereby the sterilization area outside the microwave heating device 4 is shortened resulting in shortening of the sterilization time.

In a case where the necessary sterilization time is longer than the above case, the valves 166b, 166c, 168b and 168c or 166c and 168c are opened to cool the sections 162b and 162c or only 162c.

By the operation as described above, the sterilization time can be controlled to meet the quality of the heating food material.

Figs. 17 and 18 show a further embodiment of the present invention. A pressure control pipe 170 which also operates as a speed control device made of polytetrafluoroethylene has a horizontal pipe 172a and a vertical pipe 172b connected with the horizontal pipe 172a at the corner of the pressure control pipe 170. One end of the horizontal pipe 172a is connected with the outlet port of the feed pipe 8 of the microwave heating device 4 and from the lower end of the vertical pipe 172b, the sterilized food material is taken out. In Fig. 17, a cooling device as described

above may be provided between the pressure control device and the microwave heating device. At the corner of the pressure control pipe 170, a control rod 171 is movably inserted in the horizontal pipe 172 along the axis of the horizontal pipe through the opening 173 defined in the corner wall 174.

A sealing ring 175 made of a heat resisting material such as a silicon rubber is fitted in the recess 176 surrounded by the corner wall 174 and a cylindrical wall 177 projected from the corner wall 174. A screw 178 is engaged within the recess 176 to press the sealing ring 175. The control rod 171 is adapted to pass the screw 178 and the sealing ring 175.

By this arrangement, when the screw 178 is loosened, the control rod 171 can be moved horizontally manually to adjust the length of the control rod 171 in the horizontal pipe 172a, and when the screw 178 is tightened, the control rod 171 is fixed by the friction of the sealing ring 175, since the sealing ring 175 is pushed by the end of the screw 178.

In operation, the heating food material is fed to the feed pipe 8 of the microwave heating device 4 from the constant volume pump 6 with a constant volume per unit time, being heated in the microwave heating device 4 in a similar manner as described above. The heating food material is heated up to the sterilization temperature of 130°C at the outlet port of the feed pipe 8.

In a case where the control rod 171 is not projected in the horizontal pipe 172a, the sterilized food material flows in the horizontal pipe 172a and the vertical pipe 172b with the same speed in the feed pipe 8, keeping the sterilization temperature due to the effect of temperature insulation of the feed pipe 8 and the speed control pipe 170.

On the other hand, in a case where the control rod 171 is projected in the horizontal pipe 172a, since an effective volume of the horizontal pipe 172a through which the sterilized food material is transferred is decreased, the pressure in the feed pipe 8 is increased, and the sterilized food material in the horizontal pipe 172a flows with a higher speed compared to such as case where the control rod 171 is not projected in the horizontal pipe 171. Therefore, the pressure and the speed of the sterilized food material can be controlled depending on the length of the control rod 171 in the horizontal pipe 172a.

According to this embodiment, inner pressure in the feed pipe 8 and the sterilization time can be easily set to suitable values depending on the quality of the heating food material only by changing the length of the control rod 171 in the horizontal pipe 172a.

One example of the sterilization of food material using the sterilization system shown in Fig. 1 according to the present invention is hereinafter described.

An aqueous suspension of B.coagulans spores was added to aqueous 3 % CMC solution having viscosity of 30,000 to 35,000 cps. The solution (14.4°C) was passed through the microwave heating device 4 at the rate of 200 g/min to sterilize the solution at 110°C. On the initial condition and after sterilization, samples of the solution were collected and cultivated in agar plates for B.coagulans at 55°C for 2 days in a known manner. Average of the plate counts is as follows:

TEMPERATURE (°C)	*SPORE COUNT (spore/g)*
14.4°C (initial)	1.2×10^6
110°C	1.9×10^4

As understood from the result, the method of sterilization using a microwave heating device according to the present invention has a remarkable sterilization effect.

Fig. 19 shows a time schedule adopted in the experiment as described above, wherein the sample was heated from 14.4°C to 110.5°C by the microwave heating device for about 31.1 sec. during the period T1, thereafter the sample was transferred from the outlet port of the microwave heating device 4 to the cooling device 16 under the natural temperature radiation for 130.2 sec. during the period T2 keeping the sterilization temperature. At the inlet of the cooling device 16, the temperature of the sample was lowered to 110°C. The sample was cooled in the cooling device 16 for about 108.7 sec. during the period T3.

The applied power of the microwave per Kg of the food material was 18 kw with 2450 MHz.

The applied power of the microwave per Kg of the food material may be within the range of 4 to 20 Kw.

Fig. 20 is an embodiment of a food packaging system using the sterilization system according to the present invention.

In Fig. 20, a plastic resin sheet 50 for making cups is rewound from a roll 51 and is advanced to pass a first sterilization tank 52 filled with peroxide, being guided by a plurality of rollers 53. The resin sheet 50 is passed between the electric heaters 54.

After heated by the electric heaters 54, the resin sheet 50 is passed through a cup forming machine 55 having a pair of dies to form a plurality of cups 56 in the resin sheet 50 by pressing the dies on the resin sheet 50. The respective cups 56 formed in the resin sheet 50 are transferred below the filling machine 57 which receives the sterilized food material such as jam or minced meat and/or other food material as listed hereinbefore from the sterilization system 1 according to the present invention. The sterilized food material is filled in the corresponding cups 56 through the nozzle 57a of the filling machine 57.

The respective cups 56 filled with the food material are transferred to a sealing machine 58. A cover sheet 60 made of plastic resin is fed above the cups 56 through a second sterilization tank 61 so that the cover sheet 60 is adhered on the top of each of the cups to close the opening of each of the cups 56. The cups thus sealed are transferred to a punching machine 62, whereby each of the cups 56 sealed by the cover sheet 60 is separated from the resin sheet 50 by the punching machine 62. The separated cups are taken up on a conveyer 63 as products, on the other hand, the remainder of the resin sheet 50 is taken up by a take-up roll 64.

It is noted that, according to the present invention, by controlling a period of time during which the heating food material stays in the microwave heating device, the sterilization of food material may be completed at the outlet of the microwave heating

device.

Depending on the quality of food material, application of microwave using the system shown in Fig. 1 is effective to sterilize the food material without heating up to a high temperature.

CLAIMS

1. A system for sterilization of food material which comprises at least one chamber connected with a microwave power source, a feed pipe made of a low dielectric loss material passing through the chamber, a feed pump to feed heating food material to be processed to the feed pipe from one end of the feed pipe, and pressure control means provided to receive heating food material from the other end of the feed pipe for increasing the pressure in the feed pipe to a pressure higher than 1 atm.

2. A system for sterilization of food material according to claim 1, wherein said pressure control means comprises means for taking out the heating food material from said other end of the feed pipe by a constant volume of the heating food material.

3. A system for sterilization of food material according to claim 1, wherein said pressure control means comprises a pressure plate opposed to an outlet port of a pipe connected to the feed pipe, a resilient member to bias the pressure plate to the outlet port of the pipe connected to the feed pipe and a screw engaging with the resilient member to adjust the biassing force of the pressure plate.

4. A system for sterilization of food material according to claim 1, wherein said pressure control means comprises a deformable pipe provided for receiving the heating food material fed from the feed pipe and means for changing the cross sectional area of the deformable pipe to control an inner pressure of the feed pipe.

5. A system for sterilization of food material according to claim 4, wherein said control means comprises an air chamber and a diaphragm fixed on the air chamber in the vicinity of the deformable pipe.

6. A system for sterilization of food material according to claim 4, wherein said control means is a mechanical means for applying a force on the deformable pipe.

7. A system for sterilization of food material according to claim 4, wherein said control means is means for applying hydraulic pressure on the deformable pipe.

8. A system for sterilization of food material according to claim 1, wherein said system further comprises cooling means disposed between the feed pipe and the pressure control means.

9. A system for sterilization of food material which comprises at least one chamber connected with a microwave power source, a feed pipe made of a low dielectric loss material passing through the chamber, a feed pump to feed heating food material to be processed to the feed pipe from one end of the feed pipe, pressure control means provided to receive heating food material from the other end of the feed pipe for increasing the pressure in the feed pipe to a pressure higher than 1 atm and means for adjusting the sterilization time disposed between the other end of the feed pipe and the pressure control means.

10. A system for sterilization of food material according to claim 9, wherein said sterilization time adjusting means comprises a pipe member, a plurality of electric heaters disposed on the corresponding sections divided in the axial direction of the pipe member and a plurality of electric switches for supplying electric power to the heaters selectively.

11. A system for sterilization of food material according to claim 9, wherein said sterilization time adjusting means comprises a pipe member connected with the other end of the feed pipe, a plurality of chambers disposed serially in the axial direction of the pipe member and a plurality of valves each being connected with the corresponding chambers to supply cooling water to the chambers selectively.

12. A system for sterilization of food material according to claim 1, wherein said pressure control means comprises a pipe member having a horizontal pipe with one end connected with the feed pipe and a vertical pipe connected with the horizontal pipe at the other end of the horizontal pipe and a control rod movably inserted in the horizontal pipe to change an effective volume through which the heating food material is transferred.

13. A system for sterilization of food material according to claim 1, wherein said system further comprises a control circuit arrangement for operating said feed pump to start to feed the heating food material until the heating food material reaches outlet of the feed pipe, then interrupting the feed pump until a pressure in the feed pipe increases at a required pressure.

14. A method of sterilization of food material which comprises feeding heating food material to be processed in a feed pipe, applying a microwave power to the feed pipe to heat the food material and applying a pressure higher than the atmosphere pressure in the feed pipe.

15. A method of sterilization of food material using a system comprising a chamber to which a microwave power is applied, a feed pipe with a circular shape in cross section and made of a low dielectric loss material passing through said chamber and a stirrer for stirring the microwave power in the chamber, whereby food material is transferred in the feed pipe under the effect of the microwave power applied thereto so as to be sterilized.

16. A method of sterilization of food material according to claim 15, wherein said food material is heated up to higher than 100°C in the feed pipe.

17. A method of sterilization of food material according to claim 16, wherein said system further comprises a holding pipe connected with the outlet of the feed pipe, whereby the food material is transferred in said holding pipe keeping a temperature obtained in the feed pipe so as to continue sterilization.

18. A method of sterilization of food material according to claim 15, wherein said feed pipe has an inner diameter of 15 mm to 30 mm.

19. A food packaging machine which comprises means for making a plurality of containers, means for filling sterilized food material into the respective containers, means for sterilizing food using mic-

rowave heating system and means for sealing the containers after the sterilized food material is filled in the respective containers.

20. A food packaging machine according to claim 19, wherein said microwave heating system comprises at least one chamber connected with a microwave power source, a feed pipe made of a low dielectric loss material passing through the chamber, a feed pump to feed heating food material to be processed to the feed pipe from one end of the feed pipe, and pressure control means provided to receive heating food material from the other end of the feed pipe for increasing the pressure in the feed pipe to a pressure higher than 1 atm.

21. A food packaging machine according to claim 20, wherein said pressure control means comprises means for taking out the heating food material from said other end of the feed pipe by a constant volume of the heating food material.

22. A food packaging machine according to claim 20, wherein said pressure control means comprises a pressure plate opposed to the outlet port of a pipe connected to the feed pipe, a resilient member to bias the pressure plate to the outlet port of the pipe connected to the feed pipe and a screw engaging with the resilient member to adjust the biassing force of the pressure plate.

23. A food packing machine according to claim 20, wherein said pressure control means comprises a deformable pipe provided for receiving the heating food material fed from the feed pipe and means for changing the cross sectional area of the deformable pipe to control an inner pressure of the feed pipe.

24. A food packaging machine according to claim 20, wherein said control means comprises an air chamber and a diaphragm fixed on the air chamber in the vicinity of the deformable pipe.

25. A food packaging machine according to claim 20, wherein said control means is a mechanical means for applying a force on the deformable pipe.

26. A food packaging machine according to claim 20, wherein said control means is means for applying hydraulic pressure on the deformable pipe.

27. A food packaging machine according to claim 20, wherein said system further comprises cooling means disposed between the feed pipe and the pressure control means.

28. A system for sterilization of food material constructed and arranged to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

29. A method of sterilization of food material substantially as herein described with reference to the accompanying drawings.

30. A food packaging machine constructed substantially as herein described with reference to and as illustrated in the accompanying drawings.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1982.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.