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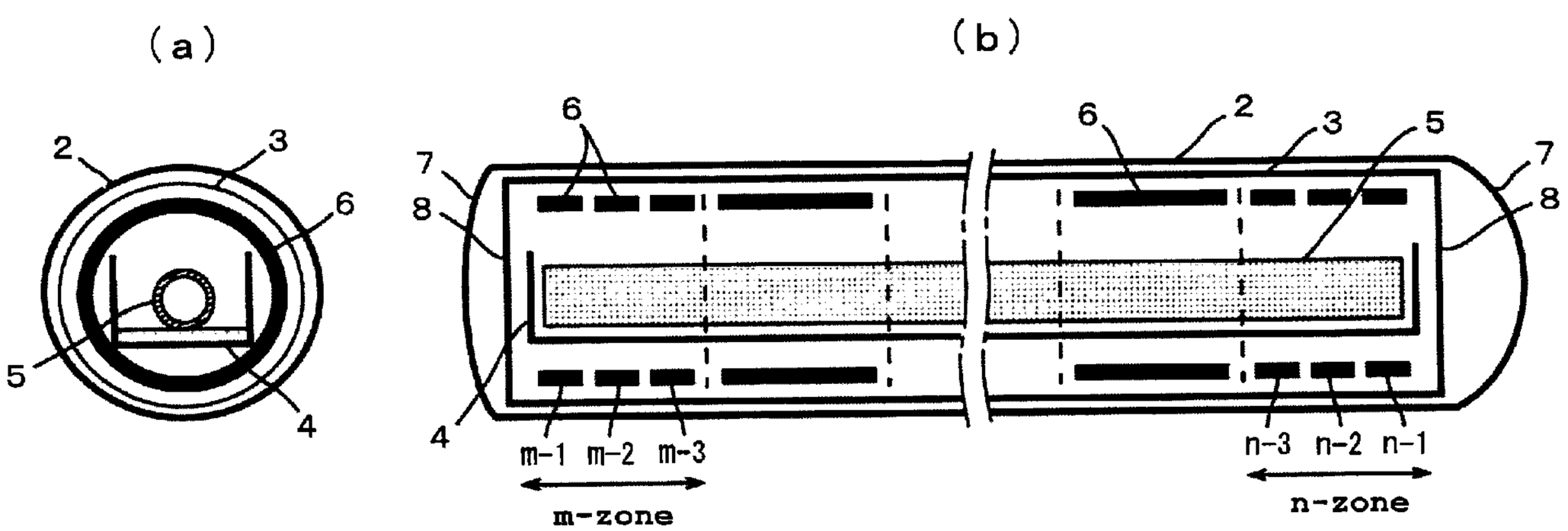
(72) **Inventeurs/Inventors:**
KUBOTA, KAZUTO, JP;
OKADA, SEIJI, JP;
TATSUOKA, MIKIO, JP

(73) **Propriétaire/Owner:**
NIPPON STEEL & SUMITOMO METAL CORPORATION, JP

(74) **Agent:** GOWLING LAFLEUR HENDERSON LLP

(54) **Titre : PROCEDE DE TRAITEMENT THERMIQUE D'UN LONG MATERIAU, PROCEDE DE FABRICATION D'UN LONG MATERIAU ET FOUR DE TRAITEMENT THERMIQUE UTILISE DANS LES PROCEDES SUSMENTIONNES**

(54) **Title: METHOD FOR HEAT TREATING LONGER-LENGTH PRODUCT, METHOD FOR MANUFACTURING LONGER-LENGTH PRODUCT, AND HEAT TREATMENT FURNACE USED FOR SAID METHODS**



(57) **Abrégé/Abstract:**
Provided is a method for heat treating longer-length products, using a cylindrical batch-type heat treatment furnace, in which endmost heating zones each is divided into a plurality of divisions, and a heat source is disposed in each of divisions and other heating zones. In advance, the heating output pattern of each heat source in each division of endmost heating zones is determined based on the measurement result of actual temperature in the end portion of the product to be heat treated at the time of heating. At the time of heat treatment for the product to be heat treated, the heating output of individual heat source is controlled based on the heating output pattern and further the measurement result of in-furnace temperatures of each division of endmost heating zones and each of other heating zones. Thus, the product can be heated uniformly throughout the overall length with high accuracy.

ABSTRACT

Provided is a method for heat treating longer-length products, using a cylindrical batch-type heat treatment furnace, in which endmost heating zones each is divided into a plurality of divisions, and a heat source is disposed in each of divisions and other heating zones. In advance, the heating output pattern of each heat source in each division of endmost heating zones is determined based on the measurement result of actual temperature in the end portion of the product to be heat treated at the time of heating. At the time of heat treatment for the product to be heat treated, the heating output of individual heat source is controlled based on the heating output pattern and further the measurement result of in-furnace temperatures of each division of endmost heating zones and each of other heating zones. Thus, the product can be heated uniformly throughout the overall length with high accuracy.

DESCRIPTION

TITLE OF INVENTION

METHOD FOR HEAT TREATING LONGER-LENGTH PRODUCT, METHOD FOR MANUFACTURING LONGER-LENGTH PRODUCT, AND HEAT TREATMENT FURNACE USED FOR SAID METHODS

TECHNICAL FIELD

[0001]

The present invention relates to a method for heat treating longer-length products, with which products that have longer-length than before can be heat treated, a method for manufacturing longer-length products using this heat treating method, and a heat treatment furnace used when the heat treating method and the manufacturing method are carried out.

[0002]

Unless otherwise described, the terms in this description are defined as follows:

"Longer-length product": Defined as a steel bar and any other longer-length product, including a longer-length metal tube of a small diameter.

"Effective furnace length": Defined as a furnace length corresponding to a maximum length of a product that can be heat treated at a uniform temperature in a heat treatment furnace.

"Gradient heating": Defined as heating performed by incorporating differences of temperatures in varying outputs of heat sources disposed in divisions of endmost heating zones of a long and cylindrical batch-type heat treatment furnace with opposite ends thereof being enclosed when a product to be heat treated is heated by using the heat treatment furnace, the heat treatment furnace being configured so that the furnace is divided into a plurality of heating zones along a longitudinal direction, including endmost zones; the endmost zones each being further subdivided into a plurality of divisions; and the heat source is disposed in each division of the endmost heating zones.

BACKGROUND ART

[0003]

In general, the batch-type heat treatment furnace is used for the heat treatment of longer-length products such as metal tubes and steel bars.

FIG. 1 is schematic views showing a general configuration example of a conventional heat treatment furnace for longer-length products, FIG. 1 (a) being a transverse sectional view, and FIG. 1 (b) being a longitudinal sectional view. As shown in FIG. 1, the heat treatment furnace is a cylindrical vessel with opposite ends thereof being enclosed and with the inner space thereof being divided into a plurality of heating zones along a longitudinal direction. The vessel wall of the furnace is of a double construction consisting of a water-cooled wall 2 and a heat-insulating wall 3, and each of both end walls thereof is also of a double construction consisting of a water-cooled wall 7 and a heat-insulating wall 8. On the inner peripheral surface of the peripheral wall of furnace, an electric heater 1 is disposed as a heat source for each heating zone. On both end walls of the furnace, the heater 1 is not provided.

[0004]

A longer-length product is heat treated by charging a product to be heat treated 5 as being held on a trailer 4 into a space surrounded by the electric heater 1, that is, into the heating zones in the heat treatment furnace, and by heating the product to be heat treated 5 by using the heaters 1. The heat treatment temperature is controlled by individually controlling the outputs of the heaters 1 based on the in-furnace temperature measurement results obtained by thermometers provided in the furnace.

[0005]

As shown in FIG. 1, in the conventional heat treatment furnace, although a plurality of heat sources (electric heaters) are provided on the peripheral wall of furnace, no heat source is provided on any of end walls of furnace. Therefore, heat is dissipated from the end portions of the longer-length product, so that the temperatures of the end potions thereof decrease significantly as compared with the temperature of the central portion thereof. For the conventional heat treatment furnace, on account of the occurrence of this temperature decrease, the permissible

length that could be subjected to heat-treatment for a longer-length product is restricted, and thus the effective furnace length is shortened.

[0006]

Accordingly, the conventional heat treatment furnace is designed so that the length of in-furnace space, that is, the overall length of the portion in which the heaters are disposed is much longer than the length of the product to be heat treated, and the effective furnace length is way longer than the length of the product to be heat treated.

[0007]

For the conventional heat treatment furnace, unfortunately, if the length of the heat treatment furnace is increased to extend the effective furnace length for the purpose of heat treatment of a product that is longer than before, the equipment refurbishment cost increases accordingly. Also, in the case where the furnace length is not increased, the length of product to be heat treated must be inevitably decreased, so that the user's requirement cannot be met flexibly. The conventional heat treatment furnace poses such problems.

[0008]

As a method for controlling the temperature of the product to be heat treated, the methods described below have been proposed.

For example, Patent Literature 1 discloses a method for controlling the in-furnace temperature to a predetermined temperature. With this method, in the batch-type heat treatment furnace for heat treating a workpiece held in the furnace by a plurality of burners, the temperatures of the combustion regions of burners are feedback controlled so as to reach the predetermined value and become constant, and on the other hand, the target temperature of the combustion region is restricted to be a preset value when the in-furnace temperature reaches within a specific temperature range lower than the target temperature, whereby the in-furnace temperature is controlled to the predetermined constant temperature.

[0009]

Patent Literature 2 discloses a method for controlling the temperature. With this method, in a vacuum furnace having openings for charging and discharging an article to be treated, the openings being provided on the front and rear ends of

furnace, the calorific value of a lower heater and the calorific values of the front and rear zones and the intermediate zone of an upper heater are controlled independently of each other. In the vacuum furnace, an article to be treated is heated primarily by radiation from a heater, and it is difficult to uniformly heat the article to be treated because convective heating scarcely occurs. Therefore, defective quality may be brought about on account of this nonuniform heating. This method is used to overcome this problem.

[0010]

Unfortunately, these temperature controlling methods are to control individual heat sources (burners or heaters) independently based on the detected in-furnace temperature to keep the in-furnace temperature at a proper temperature and to prevent variations in in-furnace temperature by causing the in-furnace temperature to follow up a change in temperature, and these methods do not take into account the kind of product to be heat treated and the mutual interference of heat sources, so that these methods are insufficient as a method for controlling the temperature in the whole of furnace. Accordingly, as a method taking into account these factors, the methods described below have been proposed.

[0011]

Patent Literature 3 discloses a method for controlling the temperature of a heating furnace. With this method, in the heating furnace configured so that temperature control is carried out independently for heaters arranged in heating zones as being subdivided into plural divisions, the deviation of the measured temperature of each heater from the set temperature that is assigned to each heater is multiplied by a correction value as a function of time only or of time and temperature, the correction value giving heater output distribution peculiar to the furnace in a soaking region, and the resultant value is given as a heater output control value.

[0012]

Patent Literature 4 discloses a control method used for a vacuum furnace in which a plurality of heaters for heating a product to be treated are provided, a calorific value regulator is provided individually in an electric power supply path for each heater, and between the calorific value regulator and a temperature detector provided in the furnace, an individual deviation setting instrument is provided so as

to be capable of giving deviation to the calorific values of the plurality of heaters. In the control method disclosed in Patent Literature 4, in heating, the predetermined setting value of each deviation setting instrument is changed according to the kind (size, shape, etc.) of a product to be treated and the pressure and temperature of atmospheric gas, whereby by the detected value sent from one temperature detector, the calorific values of the plurality of heaters are controlled in the state in which deviation is given to the calorific values. Thereby, as in the case where the plurality of heaters are controlled individually, the product to be treated can be heated in the state in which the temperature of the whole of the product to be treated is uniformized.

[0013]

These methods are to homogenize the in-furnace temperature distribution of the whole of the product to be heat treated by setting a deviation value for each heating zone in addition to the conventional temperature control in which individual burners or heaters are controlled independently. Unfortunately, these methods are insufficient as a method for homogenizing the treatment temperature of a longer-length workpiece to be heat treated such as a longer-length product because in the heat treatment furnace in which, as shown in FIG. 1, the heat sources are disposed on the peripheral wall so as to correspond to the heating zones, and on the other hand, no heat source is provided on both end walls, a remarkable decrease in temperature occurs in the end portions of the longer-length product as compared with the central portion thereof.

CITATION LIST

PATENT LITERATURE

[0014]

Patent Literature 1: Japanese Patent Application Publication No. S62-4828

Patent Literature 2: Japanese Patent Application Publication No. H05-271751

Patent Literature 3: Japanese Patent Application Publication No. S62-112726

Patent Literature 4: Japanese Patent Application Publication No. H04-52215

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0015]

An objective of the present invention is to provide a method for heat treating longer-length products, in which in a cylindrical batch-type heat treatment furnace with opposite ends thereof being enclosed and being provided with heat sources on the peripheral wall thereof, and on the other hand, is not provided with heat sources on both end walls thereof, the effective furnace length capable of heating the overall length of a product to be heat treated to a uniform temperature (for example, ±10°C or less with respect to the target temperature) is extended, and even if the space length in the furnace is the same, a product to be heat treated that is longer in length than before can be heat treated, and to provide a method for manufacturing longer-length products, which uses the above-described heat treating method. Another objective of the present invention is to provide a heat treatment furnace used when the heat treating method and the manufacturing method are carried out.

SOLUTION TO PROBLEM

[0016]

To achieve the above objectives, the present inventors first examined the temperature distribution especially in both end portions of a product to be heat treated (longer-length product), when heated by using a conventional heat treatment furnace having no heat source on both end walls thereof.

[0017]

FIG. 2 is a diagram showing one example of temperature distribution in the longitudinal direction of a product to be heat treated in a conventional heat treatment furnace for longer-length products. FIG. 2 shows a measurement result obtained by using the conventional heat treatment furnace shown in FIG. 1, showing a measurement result in the heating zone in the endmost portion of the furnace and in the heating zone next to this heating zone in the endmost portion. In FIG. 2, the product temperature on the ordinate is represented by a temperature difference with respect to the target temperature, which is the basis.

[0018]

As shown in FIG. 2, the temperatures of the product at positions in the range from the vicinity of the middle of the endmost heating zone to the adjacent heating zone to the endmost heating zone were equal to the target temperature or close to the target temperature. However, the temperatures of the product at positions in the range from the middle of the endmost heating zone to a portion close to the end wall of furnace did not reach the target temperature, and the temperature of the product at the position close to the end wall of furnace was about 80°C lower than the target temperature. Although not shown in FIG. 2, the same tendency was also recognized in the heating zone in the endmost portion on the opposite side of the heat treatment furnace. That is, in the conventional heat treatment furnace shown in FIG. 1, uniform heating cannot be performed throughout the overall length of a product to be heat treated.

[0019]

In the actual operation, as shown in FIG. 2, the position of the end portion of the product to be heat treated (longer-length product) is located in the vicinity of the middle of the endmost heating zone of furnace (in this example, at a position of 1.4 m away from the end wall of the heat treatment furnace), and is decided so as to be within the range of the effective furnace length.

[0020]

To prevent this decrease in temperature in the end portion of the product to be heat treated, the whole of the endmost heating zone of the heat treatment furnace was heated to a temperature higher than the temperature of central heating zones (heating zones other than the endmost heating zone), and the product temperature in this case was measured.

[0021]

FIG. 3 is a diagram showing temperature distribution in a longitudinal direction of a product to be heat treated in the conventional heat treatment furnace for longer-length products, showing the case where the furnace endmost zone is heated to a temperature higher than the temperature of central heating zones (herein, referring to the heating zones lying between two endmost heating zones). FIG. 3 shows a measurement result in the endmost heating zone of the furnace and in the adjacent heating zone to this endmost heating zone.

[0022]

At the time of testing, the temperature of the product to be heat treated in the central heating zones was set at the target temperature, and the temperature of the product to be heat treated in the endmost heating zones was set so as to be 20°C or 40°C higher than the temperature of the product to be heat treated in the adjacent heating zone to the endmost heating zone. For comparison, the measurement was also made in the case where the temperature of the product to be heat treated in the endmost eating zone was set at the target temperature that is the same as the target temperature for product to be heat treated in the central heating zones.

[0023]

As shown in FIG. 3, in the vicinity of the middle of the endmost heating zone, the product to be heat treated overheats exceeding the target temperature, and on the other hand, in the end portion of the product to be heat treated close to the end wall of furnace, the decrease in temperature still remains. Heating is not performed uniformly throughout the overall length of the product to be heat treated.

[0024]

Successively, the present inventors studied a method in which the heat dissipation from the end portion of product is restricted by heat-insulating plates installed on the outside of the end face of the product to be heat treated, and the quantity of heat is gradiently given to the endmost heating zone of furnace and the adjacent heating zone to the endmost heating zone of furnace. The reason for our study is that, with this method, it can be anticipated that the product to be heat treated will be prevented from overheating remarkably in the vicinity of the middle portion of the endmost heating zone, and the decrease in temperature of the product to be heat treated will be suppressed.

[0025]

FIG. 4 is schematic views showing a general configuration of a heat treatment furnace provided with heat-insulating plates, FIG. 4 (a) being a transverse sectional view, and FIG. 4 (b) being a longitudinal sectional view. In the heat treatment furnace shown in FIG. 4, twelve heat-insulating plates 9 made of SUS304 are installed in a lapped manner on the outside of the end face of the product to be heat treated, which is placed on a trailer 4. By using this heat treatment furnace,

measurement was made of the product temperature in the case where the heating quantity of the endmost heating zone was made somewhat higher than that of the adjacent heating zone to the endmost heating zone.

[0026]

FIG. 5 is a diagram showing a measurement result of temperature distribution of a product to be heat treated (longer-length product) in the endmost heating zone and the adjacent heating zone to the endmost heating zone, the measurement result being obtained by using the above-described heat treatment furnace provided with the heat-insulating plates. For comparison, the temperature distribution in the case where the heating quantity of the adjacent heating zone to the endmost heating zone is made equal to that of the endmost heating zone is shown.

[0027]

From the result shown in FIG. 5, it can be seen that in the case where the allowable range of temperature distribution throughout the overall length of the product to be heat treated is made ±10°C or less with respect to the target temperature, by somewhat increasing the heat input in the endmost heating zone relative to that in the adjacent heating zone to the endmost heating zone, the product to be heat treated can be heated uniformly by restraining the overheat of the product to be heat treated to the upper limit or less of the allowable range in the vicinity of the middle portion of the endmost heating zone and by avoiding the decrease in temperature in the end portion of the product to be heat treated.

[0028]

Unfortunately, this heat treatment furnace has a problem that the product to be heat treated is cooled by cooling gas introduced from the end wall of furnace after treatment; however, the cooling rate decreases because the gas is blocked by the heat-insulating plates 9, and the time period required for cooling increases about two to three times the conventional cooling time period. Also, it is necessary to study the number of and installation locations of the heat-insulating plates depending on the number of and sizes of the products loaded on the trailer, so that it cannot be said that this configuration is practical.

[0029]

Accordingly, the present inventors made an attempt to make a temperature distribution homogeneous over the product to be heat treated positioned in the endmost heating zone of furnace by subdividing the endmost heating zone such that the length of division thereof is shorter than the length of a central heating zone, by disposing a heat source in each division, and by applying weighted heating (gradient heating) only in endmost heating zones. That is, the present inventors studied the application of a method for controlling the temperature of the end portion of the product to be heat treated by varying heating outputs of heat sources of divisions of the endmost heating zones (hereinafter, referred to as a "division gradient heating control method").

[0030]

The present invention has been made to provide a method for heat treating longer-length products of item (1) described below, a method for manufacturing longer-length products of item (2), and a heat treatment furnace of item (3) used for the heat treating method and the manufacturing method.

[0031]

(1) A method for heat treating longer-length products, in which a cylindrical batch-type heat treatment furnace opposite ends of which are enclosed and the inside space of which is divided into a plurality of heating zones along a longitudinal direction is used, a longer-length product to be heat treated is charged into the heat treatment furnace, and heat treatment is performed, wherein

the heat treatment furnace is configured so that, among the heating zones, an endmost heating zone thereof is subdivided into a plurality of divisions each having a length shorter than the length of a heating zone other than said endmost heating zones; and a heat source is disposed in each division of the endmost heating zones, and the heat treating method includes a series of steps of:

(Step 1) in advance, determining the heating output pattern of each heat source in each division in the endmost heating zone based on the measurement result of actual temperature in the end portion of the product to be heat treated at the time of heating; and

(Step 2) controlling a heating output of an individual heat source, at the time of heat treatment for the product to be heat treated, based on the heating output

pattern of each heat source determined in step 1 and further the measurement result of in-furnace temperatures of each division of the endmost heating zones and of each of heating zones other than the endmost heating zones.

[0032]

In the method for heat treating longer-length products of the present invention, if, in step 2, the heating output of each heat source in each division of the endmost heating zones is adjusted, at the time of heat treatment, based on the measurement result of actual temperature in the end portion of the product to be heat treated, the temperature control of the product to be heat treated can be carried out with higher accuracy.

[0033]

In the method for heat treating longer-length products of the present invention, if, in steps 1 and 2, an electric heater is used as the heat source, the heating output pattern is adjusted easily, and if the heating of the product to be heat treated is by way of radiative heating, accurate temperature control is carried out easily.

[0034]

(2) A method for manufacturing longer-length products, wherein heat treatment is performed by using the method for heat treating longer-length products of the above item (1).

[0035]

(3) A heat treatment furnace for longer-length products, which is a batch-type heat treatment furnace having a cylindrical shape opposite ends of which are enclosed and the inside space of which is divided into a plurality of heating zones along a longitudinal direction and which is used to heat-treat a longer-length product to be heat treated which is charged into the heat treatment furnace,

wherein the heat treatment furnace is configured so that, among the heating zones, an endmost heating zone thereof is subdivided into a plurality of divisions each having a length shorter than the length of each of heating zones other than the endmost heating zones; and a heat source is disposed in each division of the endmost heating zones,

and wherein the furnace at least includes:

means for determining the heating output pattern of each heat source in each division of the endmost heating zones;

means for measuring the in-furnace temperature of each division of the endmost heating zones and of heating zones other than the endmost heating zones; and

means for controlling the heating output of individual heat source for each division of the endmost heating zones.

[0036]

If the heat treatment furnace for longer-length products of the present invention further includes means for measuring the actual temperature in the end portion of the product to be heated, the temperature control of the product to be heat treated can be carried out with higher accuracy.

[0037]

In the treatment furnace for longer-length products of the present invention, if the heat source is an electric heater, the heating output pattern is adjusted easily, and if the heating of the product to be heat treated is by way of radiative heating, accurate temperature control is carried out easily.

ADVANTAGEOUS EFFECTS OF INVENTION

[0038]

According to the method for heat treating longer-length products of the present invention, when heat treatment is performed by using the cylindrical batch-type heat treatment furnace opposite ends of which are enclosed and which is provided with the heat sources on the peripheral wall thereof, while no heat source being disposed on either end wall thereof, even if the space length in the furnace is the same, the effective furnace length can be made longer, and the longer-length product to be heat treated can be heated throughout the overall length thereof to a uniform temperature with high accuracy. Thereby, the equipment refurbishment cost for a furnace body can be reduced significantly.

[0039]

A method for manufacturing longer-length products of the present invention is the one using the above-described heat treating method, and by using this

manufacturing method, a longer-length product having no variations in quality characteristics can be manufactured.

If the heat treatment furnace for longer-length products of the present invention is used, the heat treating method and method for manufacturing longer-length products of the present invention can be carried out easily.

BRIEF DESCRIPTION OF DRAWINGS

[0040]

FIG. 1 is schematic views showing a general configuration example of a conventional heat treatment furnace for longer-length products, FIG. 1 (a) being a transverse sectional view, and FIG. 1 (b) being a longitudinal sectional view.

FIG. 2 is a diagram showing one example of temperature distribution in a longitudinal direction of a product to be heat treated in a conventional heat treatment furnace for longer-length products.

FIG. 3 is a diagram showing one example of temperature distribution in a longitudinal direction of a product to be heat treated in the case where an endmost heating zone is heated to a temperature higher than that in central heating zones by using the conventional heat treatment furnace for longer-length products.

FIG. 4 is schematic views showing a general configuration of a heat treatment furnace provided with heat-insulating plates, FIG. 4 (a) being a transverse sectional view, and FIG. 4 (b) being a longitudinal sectional view.

FIG. 5 is a diagram showing a measurement result of temperature distribution of a product to be heat treated in an endmost heating zone and the adjacent heating zone thereto, the measurement result being obtained by using the heat treatment furnace provided with the heat-insulating plates.

FIG. 6 is a diagram exemplarily showing a measurement result of temperature distribution of a product to be heat treated in the m-zone and the adjacent heating zone thereto in the case where a division gradient heating control method is applied.

FIG. 7 is a diagram showing a study result obtained by heat transfer simulation, showing the relationship between the intensification amount of heat input in the m-1 zone in the case where a division gradient heating control method is applied and a temperature deviation range.

FIG. 8 is schematic views exemplarily showing a general configuration of a heat treatment furnace used for a method for heat treating longer-length products of the present invention, FIG. 8 (a) being a transverse sectional view, and FIG. 8 (b) being a longitudinal sectional view.

FIG. 9 is a schematic view showing the installation positions of thermocouples on a product to be heat treated charged into a heat treatment furnace in Example.

FIG. 10 is a diagram showing one example of a measurement result of temperature in the end portion of a product to be heat treated at the time of heating, which was obtained in Example.

DESCRIPTION OF EMBODIMENTS

[0041]

1. Method for heat treating longer-length products

A method for heat treating longer-length products of the present invention is the one that uses a cylindrical batch-type heat treatment furnace opposite ends of which are enclosed and the inside space of which is divided into a plurality of heating zones in a longitudinal direction, wherein each of endmost heating zones of the heat treatment furnace is subdivided into a plurality of divisions each having a length shorter than the length of each of heating zones other than the endmost heating zones, a heat source is disposed in each division, and the heat treating method includes the following steps 1 and 2:

(Step 1) in advance, determining the heating output pattern of each heat source in each division of endmost heating zones based on the measurement result of actual temperature in the end portion of a product to be heat treated at the time of heating.

(Step 2) controlling the heating output of individual heat source, at the time of heat treatment for the product to be heat treated, based on the heating output pattern of each heat source determined in step 1 and further the measurement result of in-furnace temperature of each division of endmost heating zones and of each of heating zones other than the endmost heating zones.

[0042]

Since the number of divisions in endmost heating zones does not exert an influence on the solution of problems of the present invention, hereunder, for convenience of explanation, the endmost heating zone is also represented by "m-zone", and the endmost heating zone on the opposite side "n-zone", wherein as the m-zone and n-zone is equivalent, the m-zone is referred hereinafter.

[0043]

FIG. 6 is a diagram exemplarily showing a measurement result of temperature distribution of a product to be heat treated in the m-zone and the adjacent heating zone to the m-zone in the case where the division gradient heating control method is applied. In this example, the m-zone as being the endmost heating zone is equally subdivided into three divisions as being m-1 zone, m-2 zone, and m-3 zone, numbering from the end, and gradient heating in which the amount of heat (heat input) was increased in the m-1 zone only was performed.

[0044]

In FIG. 6, "after refurbishment" means the case where gradient heating is performed by using the heat treatment furnace in which the m-zone is subdivided into three divisions, and "before refurbishment" means the case of the conventional heating system where the same heat treatment furnace with the m-zone being subdivided into three is used, the amount of heat in each of m-1 zone, m-2 zone, and m-3 zone is constant, and thereby the gradient heating is not applied. The intensification ratio of the amount of heat in the m-1 zone in the case of after refurbishment was set to +35% by referring to the study result obtained by the after-described heat transfer simulation shown in FIG. 7.

[0045]

As being evident from the result shown in FIG. 6, by applying the division gradient heating control method in endmost heating zones of furnace, the whole of the product to be heat treated can be heated uniformly by suppressing the overheat of the end portion of the product to be heat treated within the tolerable range and by avoiding the decrease in temperature in the end portion thereof.

[0046]

FIG. 7 is a diagram showing a study result obtained by heat transfer simulation, showing the relationship between the intensification amount of heat input

in the m-1 zone and a temperature deviation range in the case where the division gradient heating control method is applied. In this description, the "temperature deviation range" is a difference between the highest value and the lowest one in the temperature distribution of the product to be heat treated along the m-zone and the adjacent heating zone to the m-zone. As shown in FIG. 7, in the case where the intensification amount of heat input in the m-1 zone is zero (that is, the conventional heating system in which gradient heating is not performed), the temperature deviation range is about 80°C, whereas the temperature deviation range is decreased by the gradient heating, and indicates a minimum value of 10°C when the intensification amount of heat input is +35%.

[0047]

The above is an explanation of the case where the m-zone is subdivided into three, and the gradient heating is performed. In general, it has been revealed that the overall length of the product to be heat treated including the end portions can be heated to a uniform temperature by subdividing each of endmost heating zones (the m-zone and the n-zone) of furnace such that the length of division thereof is shorter than the length of a central heating zone, and by controlling the heating outputs of divisions of the endmost heating zones. Thereby, even if the space length in the furnace is the same, the effective furnace length can be enlarged significantly.

[0048]

The heating outputs of divisions of the endmost heating zones that are obtained by subdividing the endmost heating zones of furnace as described above can be controlled by determining, in advance, the ratio of output of the heat source in the division of endmost heating zones (hereinafter, referred to as a "heating output pattern") based on the actual temperature measurement result in the end portion of the product to be heat treated at the time of heating so that the temperature distribution in the end portion of the product to be heat treated becomes homogeneous in the entire region of the endmost heating zones of the furnace.

[0049]

FIG. 8 is schematic views exemplarily showing a general configuration of a heat treatment furnace used for a method for heat treating longer-length products of the present invention, FIG. 8 (a) being a transverse sectional view, and FIG. 8 (b) being a longitudinal sectional view. In this heat treatment furnace, among a plurality of heating zones shown in FIG. 1, the endmost heating zone, that is, the m-zone is subdivided into three divisions as being m-1 zone, m-2 zone, and m-3 zone, and similarly, the other endmost heating zone on the opposite side, that is, the n-zone is subdivided into three as being n-1 zone, n-2 zone, and n-3 zone.

[0050]

As shown in FIG. 8, this heat treatment furnace is a cylindrical vessel opposite ends of which are enclosed, and the peripheral wall of the furnace is of a double construction consisting of a water-cooled wall 2 and a heat-insulating wall 3, and each of both end walls thereof is also of a double construction consisting of a water-cooled wall 7 and a heat-insulating wall 8. On the inner peripheral surface of the peripheral wall of furnace, an electric heater 6 is disposed as a heat source for each division and each of other heating zones. On both end walls of the furnace, the heater 6 is not provided.

[0051]

The reason why in the heat treatment furnace used for the heat treating method of the present invention, endmost heating zones (the m-zone and the n-zone) each is subdivided into a plurality of divisions (m-1 zone, m-2 zone, and m-3 zone; n-1 zone, n-2 zone, and n-3 zone) each division having a length shorter than the length of a central heating zone is as follows. For example, as shown in FIG. 3, when a longer-length product is heat treated, if the whole of the endmost heating zone is heated to a higher temperature than the target, the product to be heat treated overheats in the vicinity of the central portion of the endmost heating zone, while the temperature decreases in the end portion of the product to be heat treated close to the end wall of furnace, and heating cannot be performed uniformly.

[0052]

That is, the reason why the endmost heating zone of the heat treatment furnace of the present invention is subdivided into a plurality of divisions is that the output ratio of each heat source in each division can be adjusted by subdividing the

endmost heating zone. Although, in the heat treatment furnace exemplarily shown in FIG. 8, the number of divisions of the endmost heating zone of furnace is three both in the m-zone and n-zone, the number of divisions of the endmost heating zone of furnace may be determined appropriately based on the status quo of temperature decrease in the endmost heating zone, which has been grasped in advance.

[0053]

The reason why the heating output pattern of each heat source in each division of the endmost heating zone is determined in advance based on the measurement result of actual temperature of the end portion of the product to be heat treated at the time of heating is that both end portions of the longer-length product should be heated uniformly.

[0054]

The measurement of actual temperature of the product to be heat treated corresponds to the temperature measurement in individual division constituting the endmost heating zone of furnace, and the temperature measurement can be made by installing thermocouples in predetermined locations in the end portion of the product to be heat treated. By this measurement of actual temperature, the result of temperature measurement in the end portion (the portion receiving heat mainly from each heat source of each division) of the product to be heat treated is determined in advance so as to correspond to each of subdivided divisions of the endmost heating zones, and based on this result, the heating output pattern of each heat source (the output ratio of individual heat source) in the individual division of the endmost heating zones is determined.

[0055]

As a desirable example of the heating output pattern, there is available a pattern in which the m-zone in the endmost portion of furnace is subdivided into three divisions, and the intensification amount of heat input in the m-1 zone of these divisions is set to +35% as shown in FIGS. 6 and 7. With this pattern, it can be expected that the temperature deviation range of the product to be heat treated in the m-zone and the adjacent heating zone thereto will be suppressed to about 10°C or less.

[0056]

When the longer-length product is heat treated, the heating output of individual heat source is controlled based on the heating output pattern of each heat source determined as described above and further the measurement result of in-furnace temperature of the endmost heating zones of furnace and of central heating zones (heating zones other than the endmost heating zones). This is for the purpose of heating the overall length of the product to be heat treated to a uniform temperature with high accuracy.

[0057]

That is, in the endmost heating zones of furnace, the product to be heat treated is heated with the preset heating output pattern predetermined as described above, and further, considering the measurement result of in-furnace temperature of the endmost heating zones of furnace and of heating zones other than the endmost heating zones, the heating output of individual heat source is controlled. Thereby, variations in furnace temperature caused by the changes of the number of products to be heat treated and/or of the position thereof in the furnace can be suppressed, and the accuracy of uniform heating of the overall length of the product to be heat treated including end portions can be improved.

[0058]

In each division of the endmost heating zones of furnace, the heating output pattern has been set in advance. However, since the heating output is changed by the heating output control based on the measurement result of in-furnace temperature at the time of actual heat treatment, the heating output pattern sometimes departs from the preset pattern.

[0059]

It can also be said that the method for homogenizing a temperature distribution in a product to be treated described in Patent Literature 4 shares similarity with the heat treating method of the present invention with respect to the fact that the temperature is controlled after the predetermined setting value of each deviation setting instrument has been changed according to the kind of a product to be treated before heating.

[0060]

The main purpose of the method described in Patent Literature 4 is to carry out the temperature control of a plurality of heating zones with the detection value of single thermometer by using the deviation setting instrument provided in each zone. In contrast, the heat treating method of the present invention is a method in which, to prevent the decrease in temperature in the end portion of the longer-length product, the heating output pattern is set in advance by further subdividing only the endmost heating zones, and the heating output of heat source in the individual division is controlled considering the measurement result of in-furnace temperature of each division. Therefore, the heat treating method of the present invention obviously differs from the method described in Patent Literature 4.

[0061]

Also, in the method described in Patent Literature 4, the control is carried out with a constant setting value, whereas, in the present invention, the heating output pattern sometimes shifts from the preset pattern. Therefore, the heat treating method of the present invention differs from the method described in Patent Literature 4 in this respect as well.

[0062]

In the method for heat treating longer-length products of the present invention, an embodiment mode can be used in which the heating output of each heat source in each division of endmost heating zones of furnace can be adjusted based on the measurement result of actual temperature of the end portion of the product to be heat treated at the time of heat treatment. The actual temperature of the end portion of the product to be heat treated is measured in the actual heat treatment by thermocouples installed in the end portion of the product to be heat treated.

[0063]

In the actual heat treatment, since the number of and the position of products to be heat treated in the furnace are different, after the heat treatment has been started with the preset heating output pattern, the heating output of individual heat source is controlled based on the measurement result of in-furnace temperatures of the endmost heating zones of furnace and of heating zones other than the endmost heating zones.

[0064]

In the method for heat treating longer-length products of the present invention, an embodiment mode can be used in which the heating output of heat source in each division can be adjusted based on the measurement result of actual temperature in the end portion of the product to be heat treated. In the case where heating outputs of heat sources in all of subdivided divisions of endmost heating zones are adjusted, this adjustment can be performed in various modes according to the temperature measurement result, such as a mode in which the heating outputs for all divisions are adjusted, or a mode in which the heating output of heat source in only one of divisions is adjusted.

[0065]

By using such a mode of embodiment, the variations in temperature in the end portion of the product to be heat treated is further decreased, and more accurate temperature control of the product to be heat treated can be carried out.

[0066]

In the method for heat treating longer-length products of the present invention, as the heat source for heating the product to be heat treated, an electric heater is preferably used. Although a burner, a radiant tube, or the like can be used as the heat source, the electric heater is suitably used because the heating output pattern is adjusted easily.

[0067]

Also, in the method for heat treating longer-length products of the present invention, if the heating of the product to be heat treated is by way of radiative heating, accurate temperature control can be carried out easily. However, in the case where the temperature of only the end portion of the product to be heat treated is controlled with the predetermined heating output pattern as in the heat treating method of the present invention, if convection occurs in the furnace, even if the heating output pattern is determined, the heating is not performed with this heating output pattern, and accurate control is difficult to carry out.

[0068]

Therefore, it is desirable to use the heat treating method of the present invention to carry out the control in a vacuum heat treatment furnace or the control in a heat treatment furnace in which radiative heating is performed in a gas atmosphere

having a low heat capacity, such as hydrogen gas. It can be said that, among them, the method of the present invention is preferably used for the control in the vacuum heat treatment furnace because of the difficulty in control of gas in case of hydrogen atmosphere.

[0069]

According to the above-described method for heat treating longer-length products of the present invention, in the case where used is the cylindrical batch-type heat treatment furnace opposite ends of which are enclosed and which is provided with the heat sources on the peripheral wall thereof, while no heat source being disposed on both end walls thereof, even if the space length in the furnace is the same, the effective furnace length can be made longer, and a product to be heat treated that is longer than before can be heated throughout the overall length thereof to a uniform temperature with high accuracy.

[0070]

In the method for heat treating longer-length products of the present invention, either one of the endmost heating zones of furnace may be divided, and the above-described effect can be achieved on the side that is divided.

[0071]

2. Method for manufacturing longer-length products

A method for manufacturing longer-length products of the present invention is the one that heat treatment is performed by using the above-described method for heat treating longer-length products of the present invention.

[0072]

In the general practice of manufacturing of longer-length products, only the heat treatment process is carried out by the heat treating method of the present invention, and the processes other than the heat treatment process are carried out by conformity to a customary method.

[0073]

According to the method for manufacturing longer-length products of the present invention, in the heat treatment process, since a product to be heat treated that is longer than before can be heated throughout the overall length thereof to a uniform temperature, a longer-length product having no variations in quality

characteristics, such as mechanical properties and corrosion resistance, can be manufactured.

[0074]

3. Heat treatment furnace for longer-length products

A heat treatment furnace for longer-length products of the present invention is a batch-type heat treatment furnace for longer-length products, which has a cylindrical shape opposite ends of which are enclosed and the inside space of which is divided into a plurality of heating zones in a longitudinal direction, and into which a longer-length product to be heat treated is charged to be heat treated. This heat treatment furnace has a feature of having a configuration described below. The heat treatment furnace of the present invention is configured so that, among the heating zones, an endmost heating zone is subdivided into a plurality of divisions each having a length shorter than the length of each of heating zones other than the endmost heating zones, and the heat source is disposed in each of the divisions. The heat treatment furnace of the present invention at least includes means for determining the heating output pattern of each heat source in each division of the endmost heating zones, means for measuring the in-furnace temperature of each division and of each of heating zones other than the endmost heating zones, and means for controlling the heating output of the individual heat source for each division and each of other heating zones.

[0075]

The heat treatment furnace for longer-length products of the present invention has a general configuration exemplarily shown in FIG. 8. In the configuration exemplarily shown in FIG. 8, each of endmost heating zones (m-zone and n-zone) in of furnace is subdivided. However, the heat treatment furnace may be configured so that either one of the endmost heating zones is subdivided.

[0076]

The reason why an endmost heating zone is subdivided such that the length of division be shorter than the length of a central heating zone in the heat treatment furnace of the present invention is that, as described in the heat treating method of the present invention, the endmost heating zone is subdivided, and the output ratio of

the heat source disposed in the individual division of the endmost heating zones is adjusted.

[0077]

The reason why the heat treatment furnace of the present invention at least includes a means for determining the heating output pattern of each heat source in each division in the endmost heating zones is that both end portions of the longer-length product are to be heated uniformly. The phrase "at least" means that the heat treatment furnace may have a means for determining the heating output pattern of each heat source in heating zones other than the subdivided divisions of the endmost heating zones.

[0078]

In determining the heating output pattern, as a procedure, first, it is necessary that the measurement result of temperature in the end portion of the product to be heat treated has been determined in advance so as to correspond to each division constituting the endmost heating zones of the furnace. This measurement result of actual temperature can be obtained in advance by measuring the temperature by installing thermocouples in the end portion of the product to be heat treated. Next, based on the measurement result of actual temperature, the heating output pattern of each heat source in each division of endmost heating zones of furnace (the output ratio of individual heat source) is determined. This heating output pattern can be set by the operator based on the measurement result of actual temperature.

[0079]

Also, a system can be adopted in which, for example, an output pattern setting instrument is installed in the heat treatment furnace, the relationship between the measurement result of actual temperature and the heating output pattern to be set is inputted in advance into the output pattern setting instrument, the output pattern setting instrument selects, on receipt of signals of the temperature measurement result, a proper heating output pattern based on the individual temperature measurement results, and an output indication is given to each heat source in each division of the endmost heating zones.

[0080]

Therefore, as the means for determining the heating output pattern, available are various methods such as a method for determining the heating output pattern artificially based on the thermocouples installed on the product to be heat treated and the measurement result of actual temperature, a method for determining the heating output pattern automatically by using the output pattern setting instrument, or the like.

[0081]

The reason why the heat treatment furnace of the present invention has the means for measuring the in-furnace temperatures of each division of the endmost heat zones and of each of heating zones other than the endmost heating zones and the means for controlling the heating output of each heat source for each division and for each of other heating zones is that by controlling the heating output of the heat source in each division and other heating zones, fluctuation in furnace temperature during heat treatment is suppressed, and the accuracy of uniform heating throughout the overall length of the product to be heat treated including the end portions is improved.

[0082]

As the means for measuring the furnace temperature of each division and each of other heating zones, a temperature detector that has conventionally been used to measure the in-furnace temperature may be used. For example, a thermocouple can be used.

[0083]

As the means for controlling the heating output, an output controller or the like can be used. The output controller is configured so that the target value of in-furnace temperature is inputted therein in advance, signals transmitted from the temperature detector are compared with this target temperature, and a control signal is sent to the heat source while PID control is carried out.

[0084]

The heat treatment furnace for longer-length products of the present invention that further has means for measuring the actual temperature in the end portion of the product to be heat treated enables more accurate temperature control of the product to be heat treated.

[0085]

As the above-described temperature measuring means, available is a thermocouple that is installed in the end portion of the product to be heat treated at the time of actual heat treatment and can measure the temperature.

[0086]

If the above-described heat treatment furnace for longer-length products of the present invention is used, the heat treating method and method for manufacturing longer-length products of the present invention can be carried out easily.

[0087]

The mode of practical heat treatment operation using the heat treating method of the present invention is as follows: as the heat treatment furnace, a vacuum heat treatment furnace provided with electric heaters as the heat sources is used.

(1) In performing heat treatment, first, the in-furnace temperatures in central heating zones excluding endmost heating zones of furnace are collectively controlled until the in-furnace temperature reaches an initial target temperature (a temperature lower than the product temperature required finally for the product to be heat treated).

(2) After the initial target temperature has been reached, all of divisions and other heating zones are shifted toward an individual control system, and the in-furnace temperature of each of divisions and other heating zones is individually controlled until the in-furnace temperature reaches an ultimate target temperature (the product temperature required finally for the product to be heat treated).

(3) Regarding the endmost heating zones of furnace, gradient heating is controlled with the preset heating output pattern by using the division gradient heating control method.

(4) The in-furnace temperature of each of divisions and other heating zones is finely adjusted so that the temperature of the product to be heat treated becomes the control value.

EXAMPLE

[0088]

The temperature distribution in the end portion of a product to be heat treated was examined by using the heat treatment furnace of the present invention having the configuration shown in FIG. 8, by charging a metal tube into the furnace as the

longer-length product to be heat treated (longer-length product), and by heating the metal tube by applying the heat treating method of the present invention. For comparison, the similar examination was made of the case where the conventional heat treating method was applied.

[0089]

The heat treatment furnace used had a construction such that the inside space thereof is divided into a plurality of heating zones including a m-zone and a n-zone, and each of the heating zones has a length of 3 m. The m-zone as being an endmost heating zone is subdivided into three divisions as being m-1 zone, m-2 zone, and m-3, numbering in that order from the end, while the n-zone as being the other endmost heating zone on the opposite end is subdivided into three divisions as being n-1 zone, n-2 zone, and n-3 zone, numbering in that order from the end. Each of the subdivided divisions constituting the m-zone and n-zone as the endmost heat zones has a length of 1 m.

[0090]

The product to be heat treated was placed in the heat treatment furnace so that the tube end to be heat treated is positioned in the m-1 zone in the endmost heating zone as being the m-zone, and a total of five thermocouples were installed on the product to be heat treated. These thermocouples were installed at four positions where first position is 600 mm away from the end wall of furnace and other three intermediate positions are equally spaced with 200 mm interval from the first position and from each other, and the last position is 1500 mm away from the end wall of furnace.

[0091]

FIG. 9 is a schematic view showing the installation positions of thermocouples. In the n-zone as well, thermocouples were installed at a total of five positions on the product to be heat treated in the same way as in the m-zone. The encircled numerals of 1 to 5 and 6 to 10 in FIG. 9 indicate the installation positions of thermocouples.

[0092]

Heating was started by equalizing the output of each heat source in each of three-divisions of the endmost heating zone (m-1 zone, m-2 zone, and m-3 zone) of

the m-zone to the output of central heating zones, that is, by making the output ratio 100% with respect to the heat source in the central heating zone. Thereafter, heating was performed by varying the output ratio of m-1 zone to 142% and the output ratio of m-2 zone to 85% (the output ratio of m-3 zone was not changed, still being 100%).

[0093]

That is, in the test of Examples, the division gradient heating control method used in the heat treating method of the present invention was applied. The output ratio in this test was determined and set based on the measurement result of actual temperature of the product to be heat treated obtained in advance. In the n-zone as well, heating was performed by varying the output ratio in the same way in process of heating.

[0094]

FIG. 10 shows one example of a measurement result of temperatures in the end portion of the product to be heat treated. FIG. 10 is charts on which the measurement result of temperatures of the product to be heat treated is recorded automatically. The encircled numerals 1 to 10 in FIG. 10 indicate the product temperatures measured by using thermocouples at the installation positions shown in FIG.9.

[0095]

As shown in FIG. 10, in the time period from the start of heating (temperature rise) to output change (gradient heating start), among the temperatures measured by individual thermocouples, the temperatures of the product to be heat treated especially measured at positions close to the end portion (encircled numerals of 1, 2, 6 and 7) deviated far from target temperature ± 10°C, and the difference over the target temperature was about 50°C at a maximum.

[0096]

It can be seen from the charts that after the outputs given to the heat sources in the m-1 zone and the m-2 zone had been changed as described above and the gradient heating had been started in process of heating, as marked up by oval marks (broken lines) in FIG. 10, the temperatures of the product to be heat treated were kept

within ±10°C with respect to the target temperature at all temperature measurement positions.

[0097]

FIG. 6, explained before, is a diagram obtained by summarizing one example of the measurement result of temperatures in the end portion of the product to be heat treated, the measurement being made as described above. In the case where the output ratios of all of the three-divisions (the m-1 zone, m-2 zone, and m-3 zone) of the m-zone were made 100% (indicated as "before refurbishment" represented by outlined square marks (□)), at a position close to the end portion of the product to be heat treated (in the vicinity of the middle of the m-1 zone), there was a temperature difference of about 45°C over that of the adjacent heating zone to the m-zone. In contrast, in the case where the heat treating method of the present invention was applied (indicated as "after refurbishment" represented by solid circle marks (●)), the temperature difference over that of the adjacent heating zone to the m-zone reduced significantly to within 7°C.

[0098]

From the results shown in FIGS. 10 and 6, it could be confirmed that by applying the heat treating method of the present invention, the effective furnace length of the cylindrical batch-type heat treatment furnace having no heat source on both end walls thereof can be extended, and the temperature control for controlling the temperatures throughout the overall length including the end portions of the longer-length product to be heat treated to within ±10°C with respect to the target temperature can be carried out sufficiently.

INDUSTRIAL APPLICABILITY

[0099]

According to the method for heat treating longer-length products of the present invention, the effective furnace length can be extended, and the longer-length product to be heat treated can be heated throughout the overall length thereof to a uniform temperature with high accuracy.

According to the method for manufacturing longer-length products of the present invention that uses the above-described heat treating method, a product

having no variations in quality characteristics, such as mechanical properties and corrosion resistance, can be manufactured. Also, if the heat treatment furnace for longer-length products of the present invention is used, the heat treating method and manufacturing method of the present invention can be carried out easily.

Therefore, the heat treating method of the present invention, the method for manufacturing longer-length products to which this heat treating method is applied, and the heat treatment furnace of the present invention can be utilized effectively for the heat treatment and manufacture of longer-length products.

REFERENCE SIGNS LIST

[0100]

1: electric heater, 2: water-cooled wall, 3: heat-insulating wall, 4: trailer,
5: product to be heat treated, 6: electric heater, 7: water-cooled wall,
8: heat-insulating wall, 9: heat-insulating plate

WHAT IS CLAIMED IS:

1. A method for heat treating longer-length products using a cylindrical batch-type heat treatment furnace with opposite ends thereof being enclosed and with an inner space being divided into a plurality of heating zones along a longitudinal direction, wherein the longer-length product to be heat treated is charged into the heat treatment furnace, and heat treatment is performed, and wherein the heat treatment furnace is configured so that, among the heating zones, each of endmost heating zones is subdivided into a plurality of divisions each having a length shorter than that of each of other heating zones than the endmost heating zones; and a heat source is disposed on a peripheral wall of the furnace in each of the divisions of the endmost heating zones and each of the other heating zones, and no heat source is disposed on end walls of the furnace,

the heat treating method comprising the steps of:

(Step 1) in advance, determining a heating output pattern of each heat source in each division of the endmost heating zones based on a measurement result of an actual temperature at the time of heating in an end portion of the product to be heat treated at positions each corresponding to each of the divisions of the endmost heating zones; and

(Step 2) controlling the heating output of individual heat source, at the time of heat treatment for the product to be heat treated, based on the heating output pattern of each heat source determined in step 1 and further a measurement result of an in-furnace temperature for each division of the endmost heating zones and of each of the other heating zones,

wherein the heat sources each disposed in the respective heating zones are separated from each other, and each heat source is configured to directly heat the product to be heat treated, and

in step 2, the heating output of each heat source in each division of the endmost heating zones is adjusted, at the time of heat treatment, based on the measurement result of the actual temperature in the end portion of the product to be heat treated.

2. The method for heat treating longer-length products according to claim 1, wherein, in steps 1 and 2, an electric heater is used as the heat source.

3. The method for heat treating longer-length products according to claim 1 or 2, wherein the product to be heat treated is subjected to radiative heating.

4. A method for manufacturing longer-length products, wherein heat treatment is performed by using the heat treating method described in any one of claims 1 to 3.

5. A heat treatment furnace for longer-length products, the heat treatment furnace comprising:

a batch-type heat treatment furnace having a cylindrical shape with opposite ends thereof being enclosed and with an inner space being divided into a plurality of heating zones along a longitudinal direction for heat-treating a longer-length product charged into the heat treatment furnace, wherein among the heating zones, each of endmost heating zones is subdivided into a plurality of divisions each having a length shorter than that of each of other heating zones than the endmost heating zones; and a heat source is disposed on a peripheral wall of the furnace in each of the divisions of the endmost heating zones and in each of the other heating zones, and no heat source is disposed on end walls of the furnace;

means for measuring an actual temperature at the time of heating in an end portion of the product to be heat treated at positions each corresponding to each of the divisions of the endmost heating zones;

means for determining a heating output pattern of each heat source in each division of the endmost heating zones based on the measurement result of the actual temperature at the positions in an end portion of the product to be heat treated;

means for measuring an in-furnace temperature for each division of the endmost heating zones and for each of the other heating zones; and

means for controlling a heating output of individual heat source for each division of the endmost heating zones and each of the other heating zones based on the heating output pattern of each heat source and the in-furnace temperature for each division of the endmost heating zones and for each of the other heating zones,

wherein the heat sources each disposed in the respective heating zones are separated from each other, and each heat source is configured to directly heat the product to be heat treated, and

the means for controlling adjusts the heating output of each heat source in each division of the endmost heating zones, at the time of heat treatment, based on the

measurement result of the actual temperature in the end portion of the product to be heat treated.

6. The heat treatment furnace for longer-length products according to claim 5, wherein the heat source is an electric heater.

7. The heat treatment furnace for longer-length products according to claim 5 or 6, wherein the product to be heat treated is subjected to radiative heating.

FIG. 1

PRIOR ART

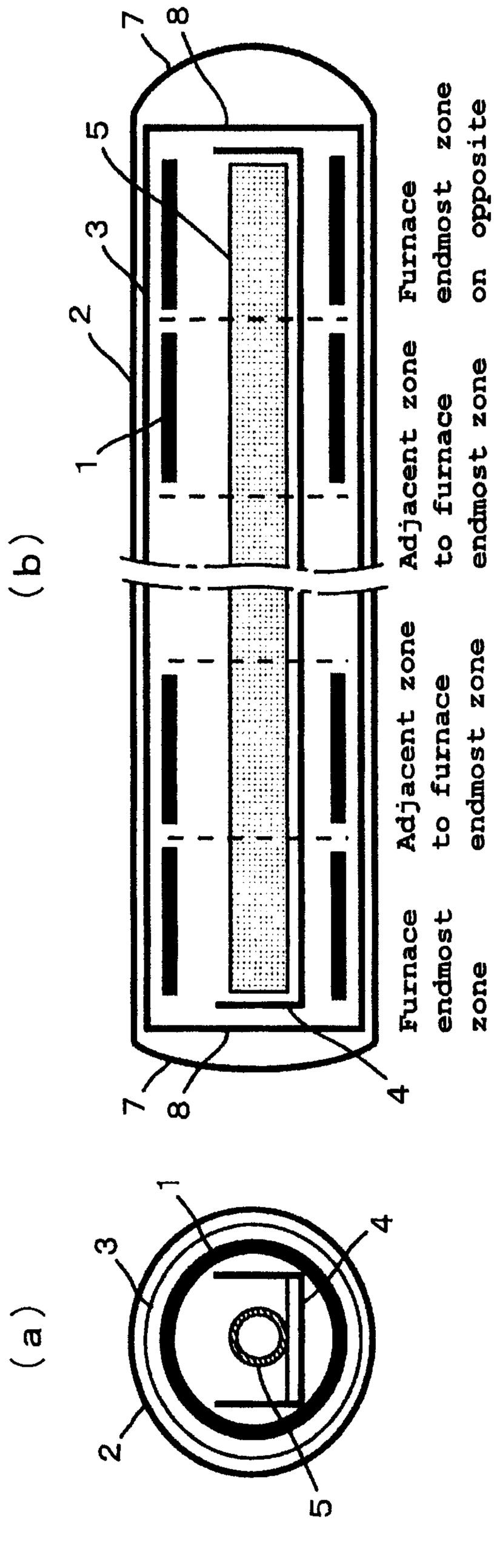


FIG. 2

PRIOR ART

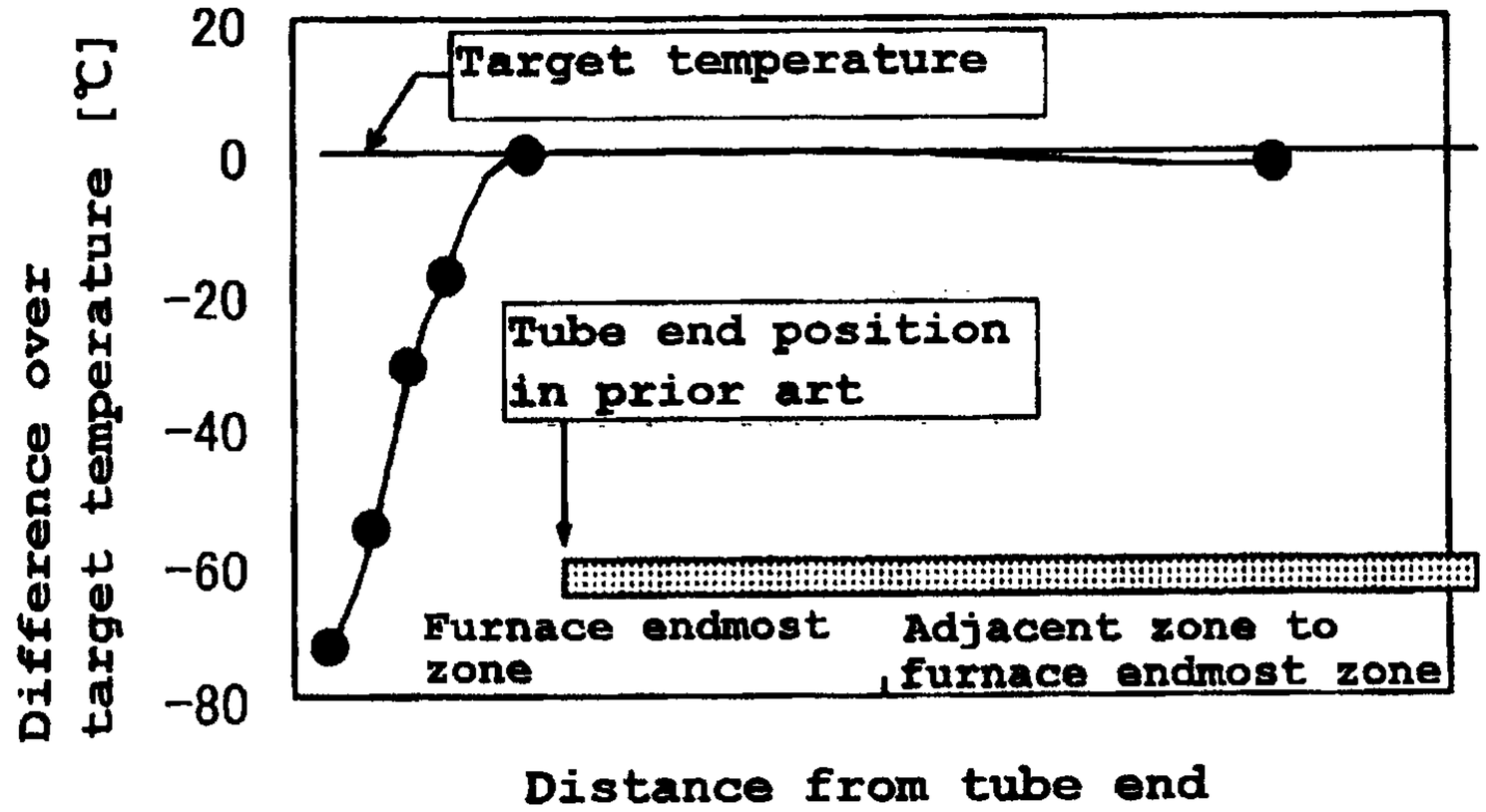


FIG. 3

PRIOR ART

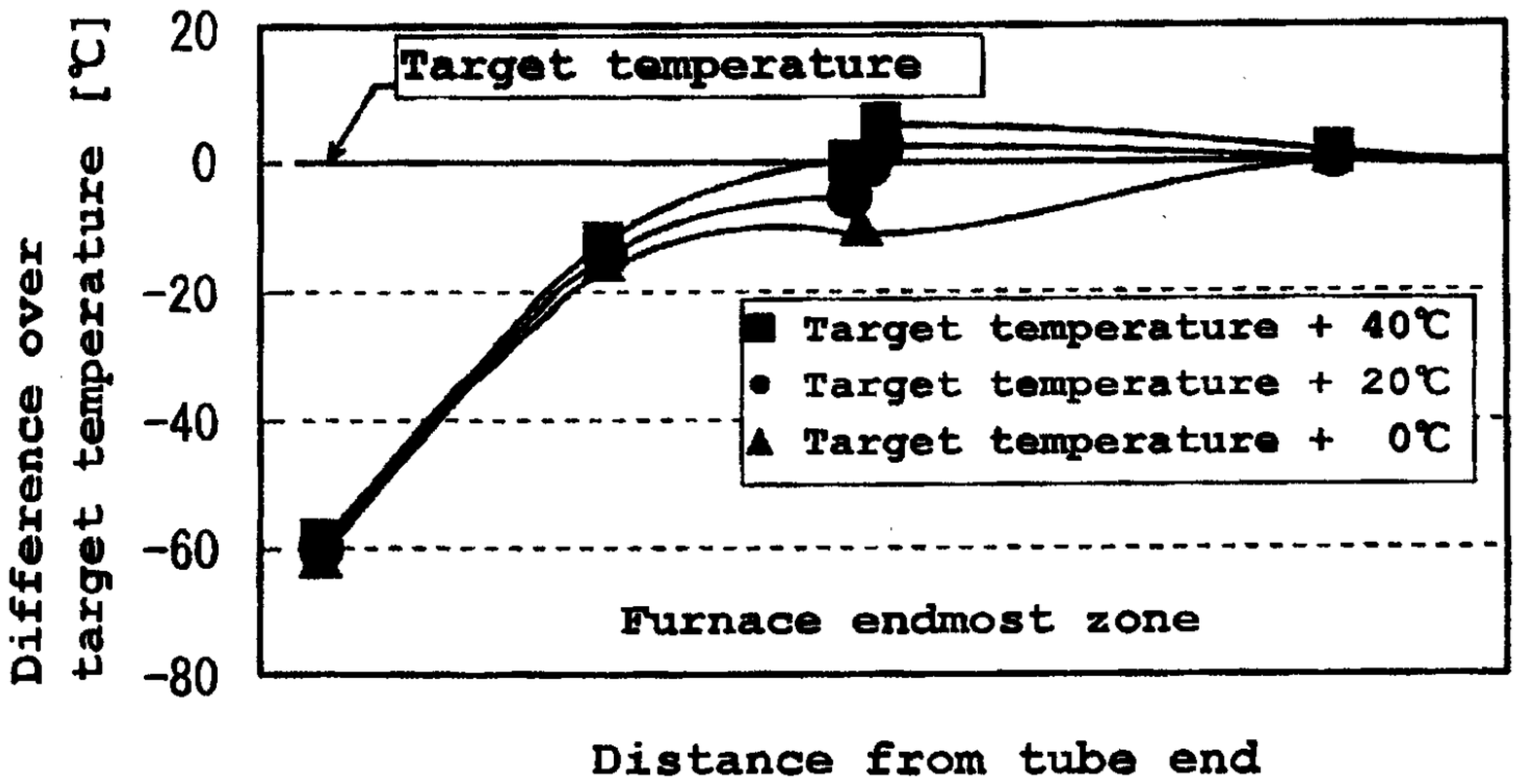


FIG. 4 PRIOR ART

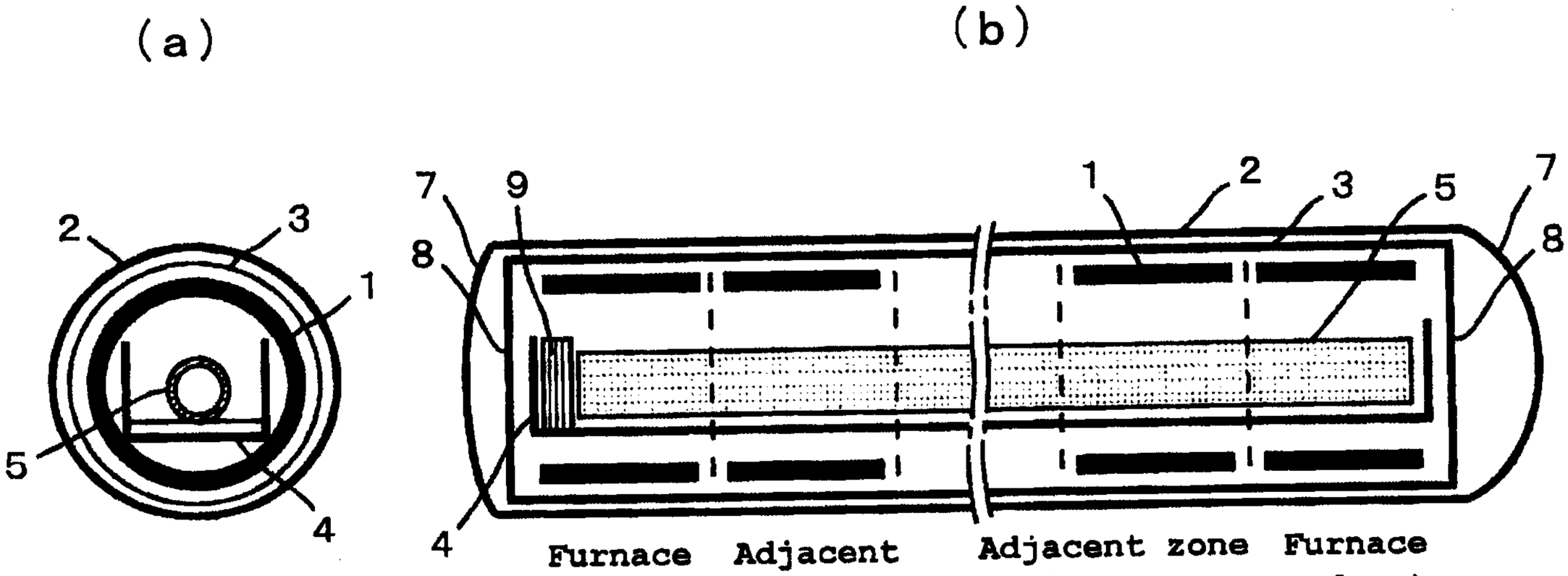


FIG. 5

PRIOR ART

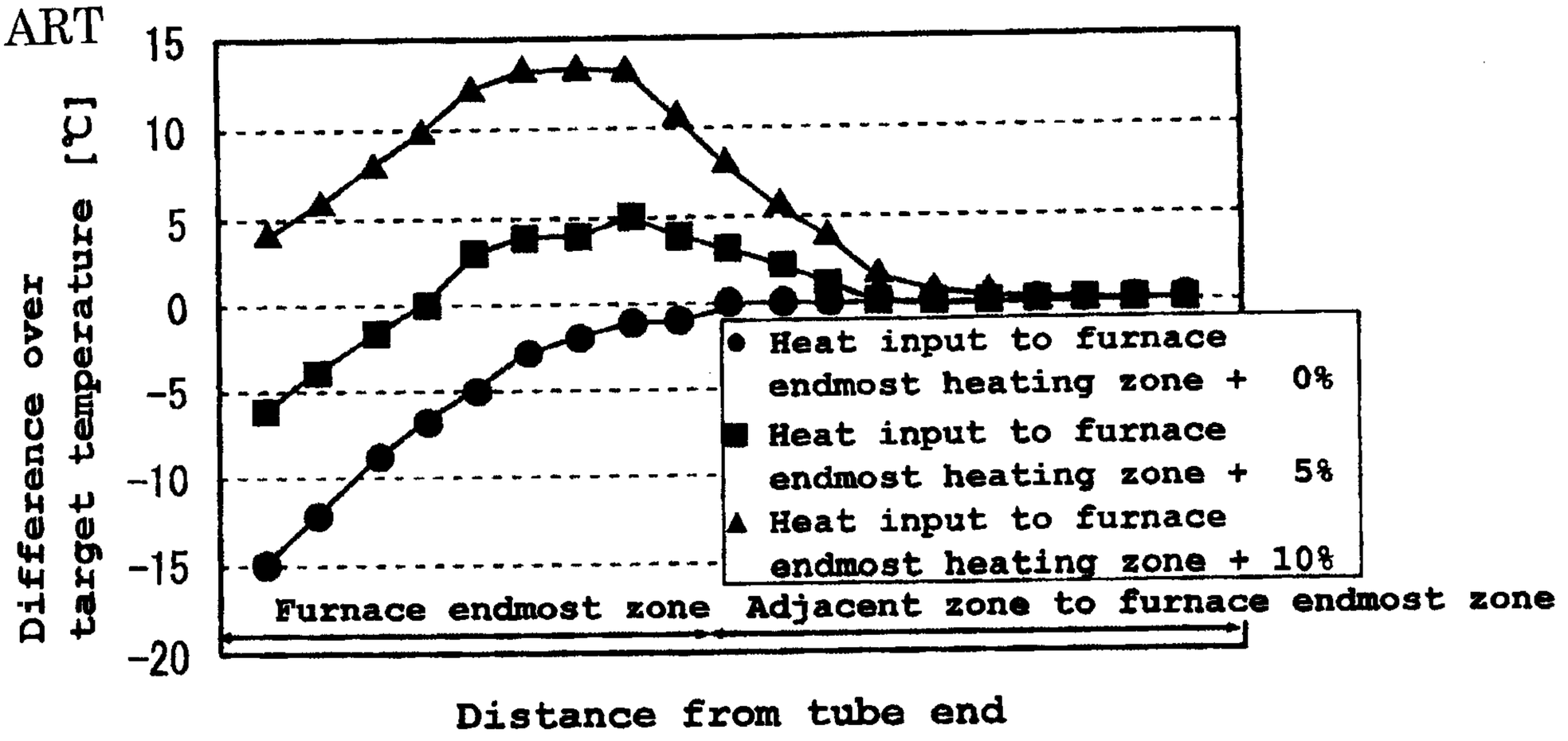


FIG. 6

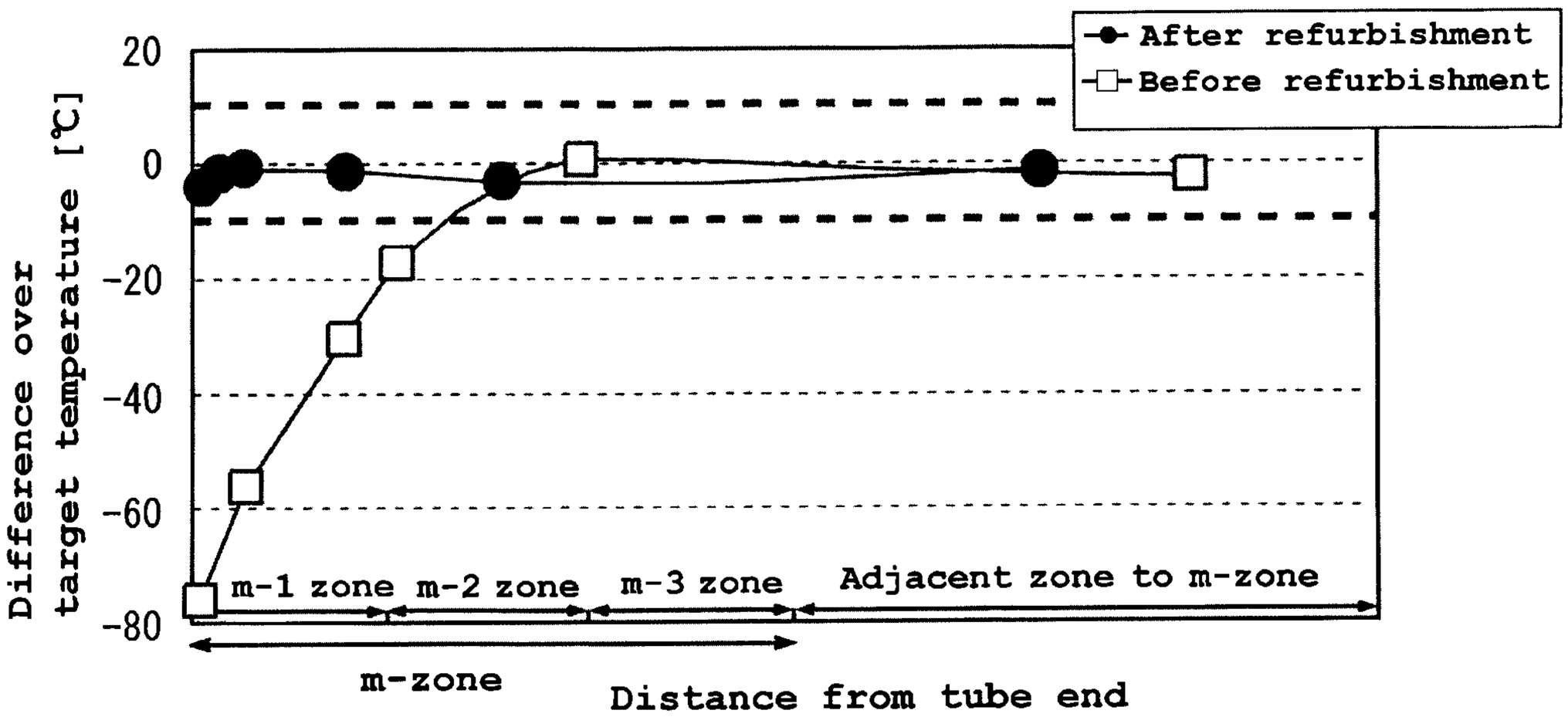

After refurbishment
Before refurbishment
20
0
-20
-40
-60
-80
Difference over target temperature [℃]
m-1 zone
m-2 zone
m-3 zone
Adjacent zone to m-zone
m-zone
Distance from tube end

FIG. 7

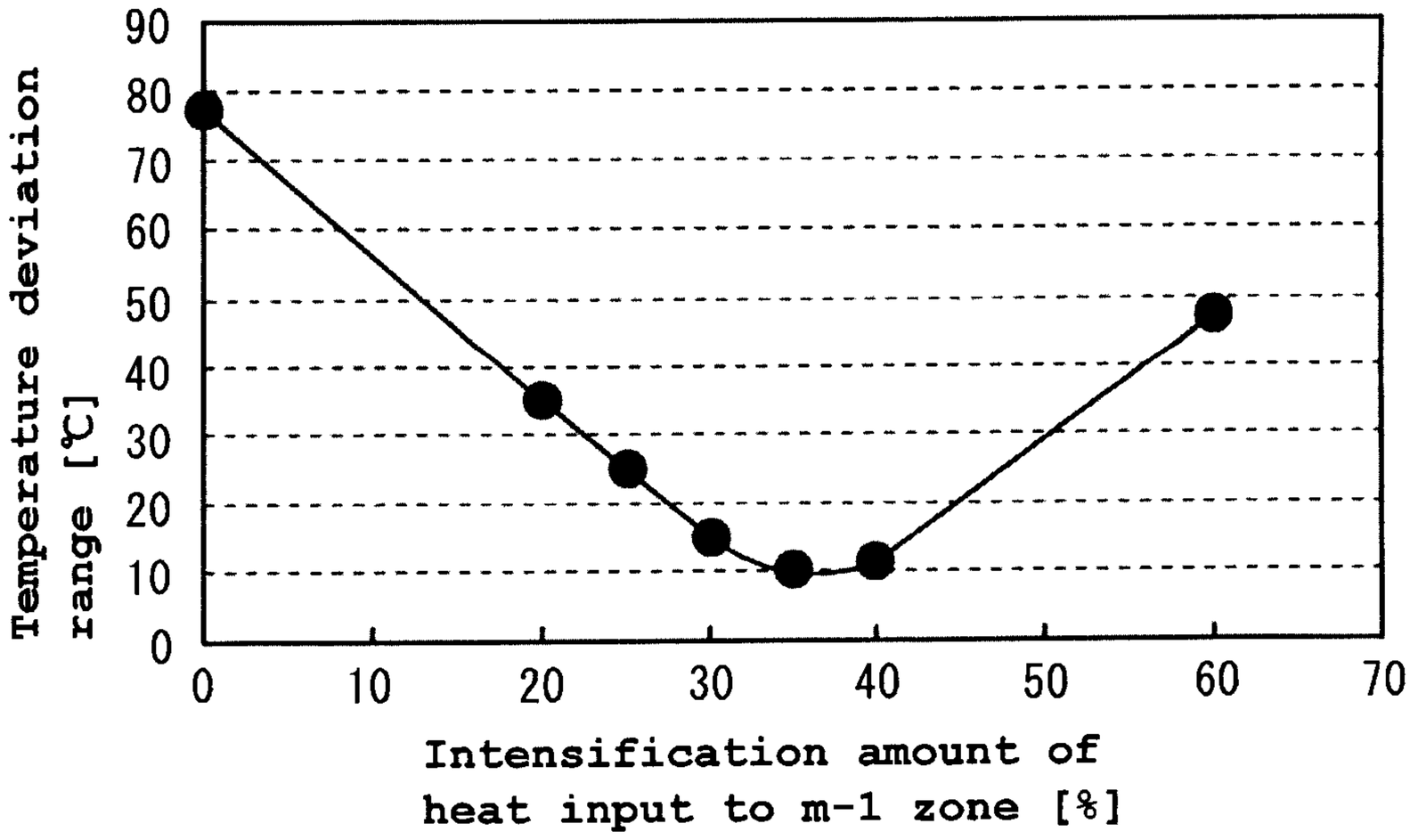

90
80
70
60
50
40
30
20
10
0
Temperature deviation range [℃]
0
10
20
30
40
50
60
70
Intensification amount of heat input to m-1 zone [%]

FIG. 8

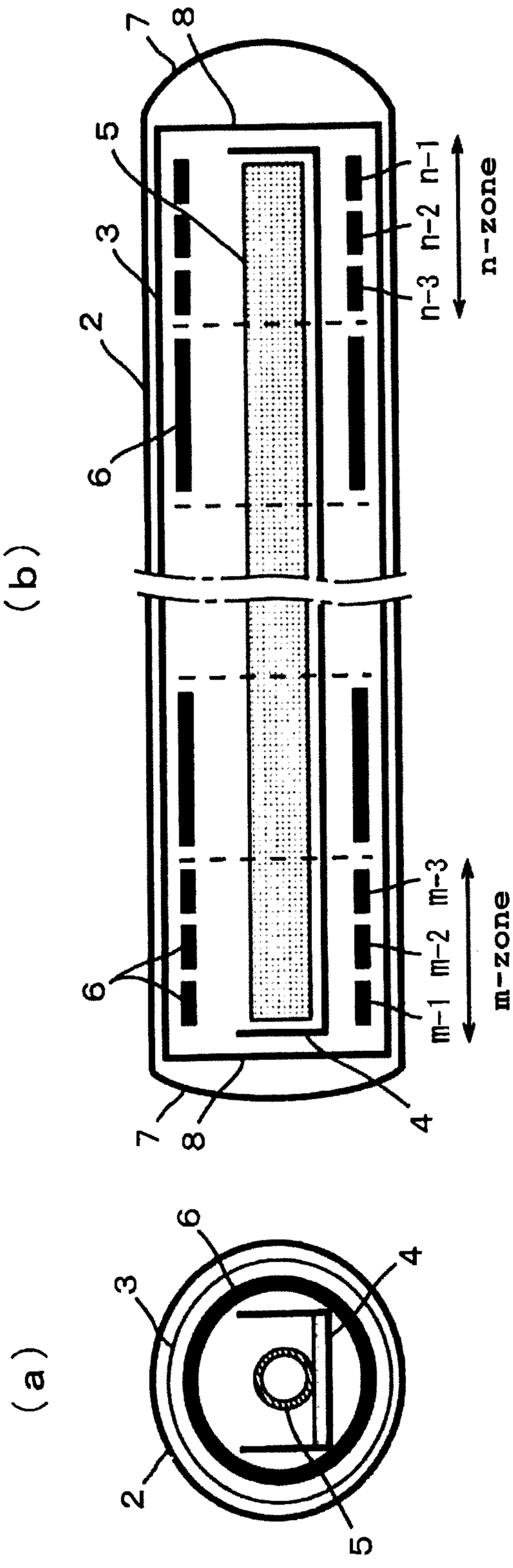


FIG. 9

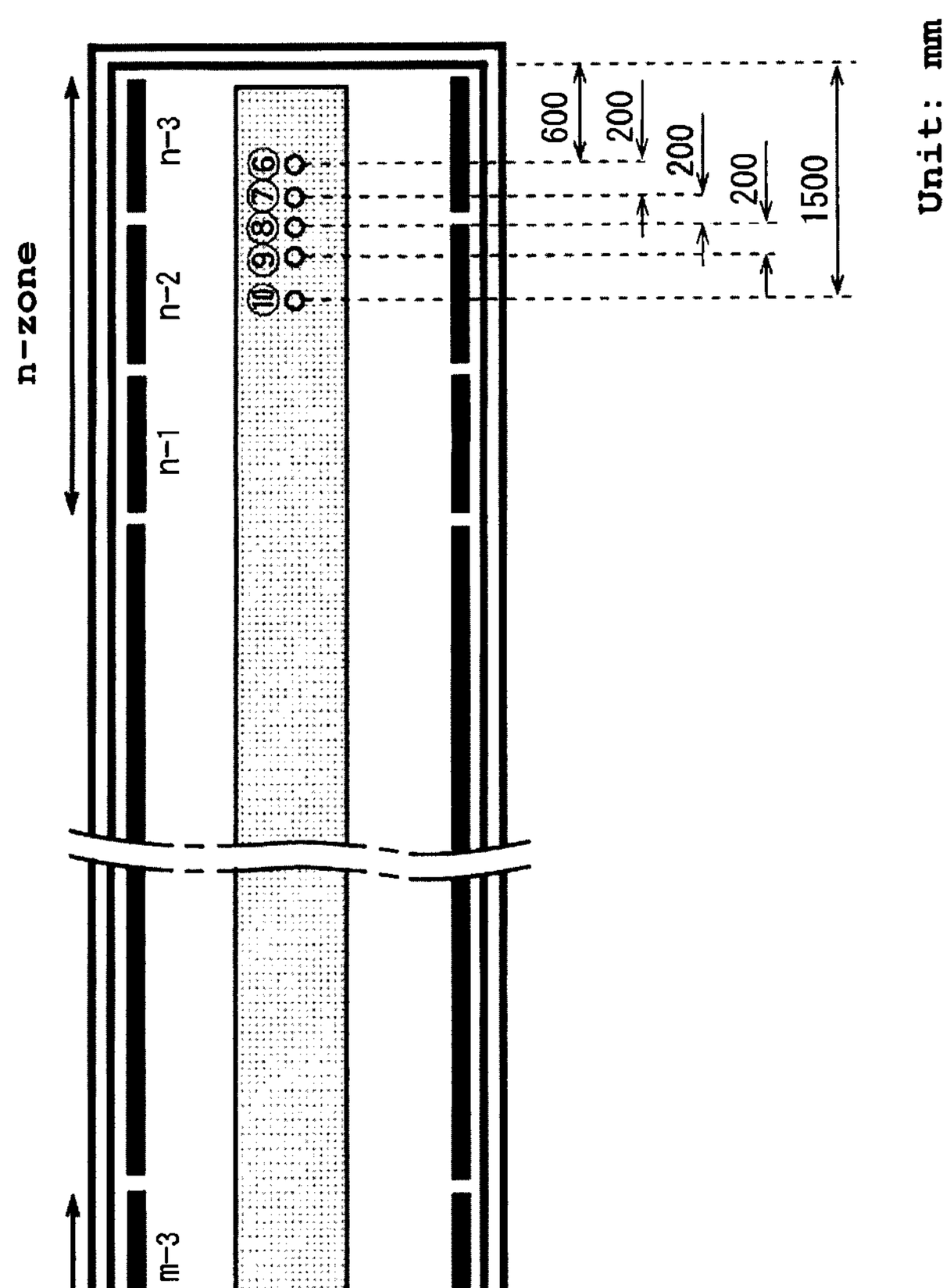
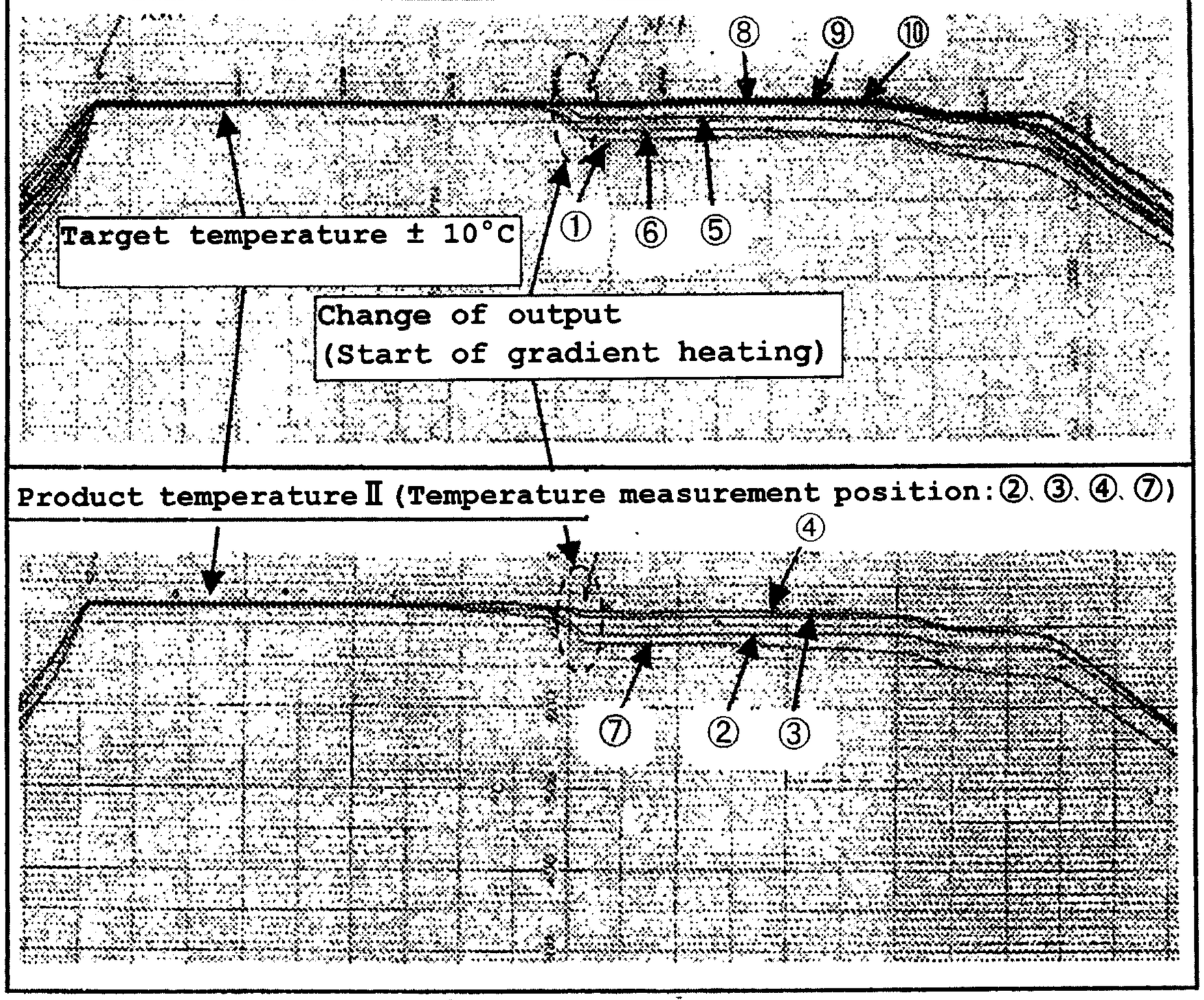
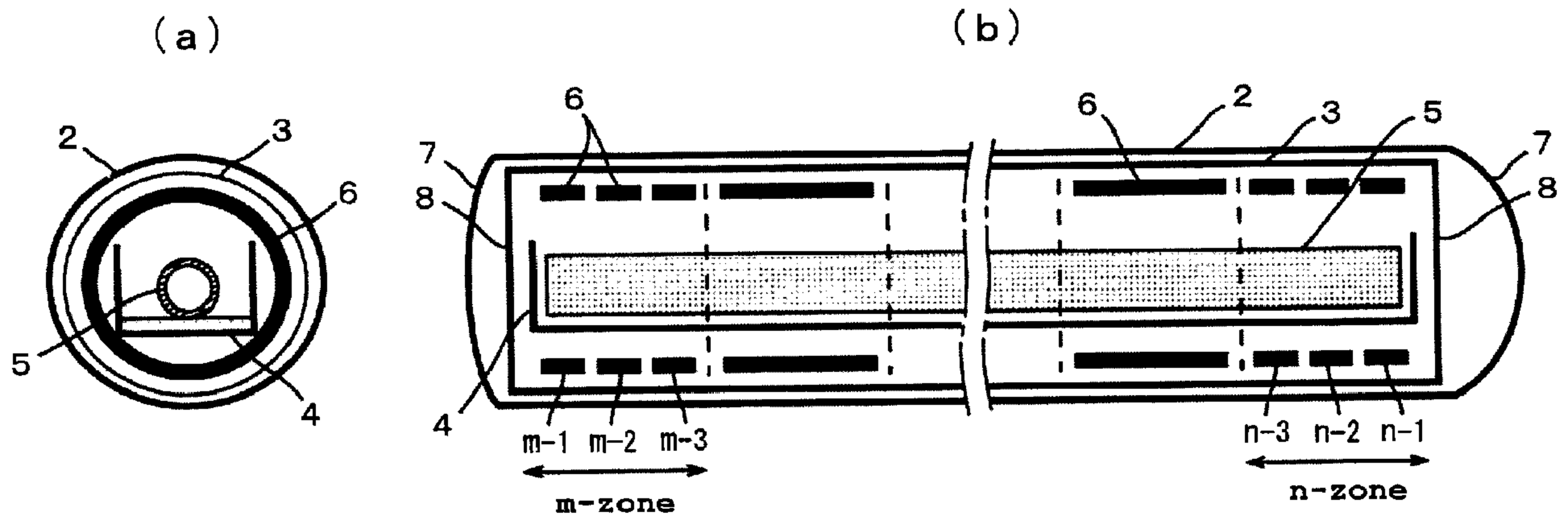

n-zone
n-3
n-2
n-1
⑥
⑦
⑧
⑨
⑩
600
200
200
200
1500
Unit: mm
m-zone
m-3
m-2
m-1
①
②
③
④
⑤
600
200
200
200
1500
6
5
7
8

FIG. 10


Product temperature Ⅰ (Temperature measurement position: ①、⑤、⑥、⑧、⑨、⑩)
⑧
⑨
⑩
Target temperature ± 10°C
①
⑥
⑤
Change of output
(Start of gradient heating)
Product temperature Ⅱ (Temperature measurement position: ②、③、④、⑦)
④
⑦
②
③


(a)
2
3
6
5
4
(b)
6
2
3
5
7
8
6
7
8
4
m-1
m-2
m-3
m-zone
n-3
n-2
n-1
n-zone