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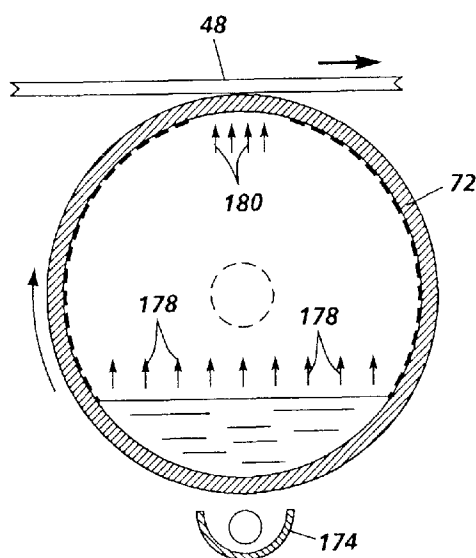
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Rank Xerox Ltd.,
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Marlow, Buckinghamshire SL7 1YL (GB)**(54) Fixing fuser roll with a phase change fluid**

(57) An apparatus for fusing images to a sheet. A fuser device is provided using a sealed fusing member (72) containing a substantially pure fluid substance or a mixture of substantially pure substances. Heat is applied, either internally or externally, to maintain the fluid in a two phase (liquid and vapor) condition. When a sheet (48) having an unfused image thereon is fed between the fusing member (72) and a pressure member

(74), the heat is transferred to the sheet to fuse the image. As a result of the two phase (liquid and vapor) state of the fluid within the fusing member there is a very uniform and efficient transfer of heat to the sheet. Thus, there is provided a device which maintains a very uniform temperature along its axis and avoids hot spots and overheating of certain portions of the fusing member due to variations in the heat source and in the transfer efficiency of the fusing member.

**FIG. 2**

Description

This invention relates generally to a fusing system, and more particularly concerns a fusing member which provides a very uniform fusing temperature along its axis and a high transfer efficiency for fusing images to a sheet. In a typical electrophotographic printing process, a photoconductive member is charged to a substantially uniform potential so as to sensitize the surface thereof. The charged portion of the photoconductive member is exposed to a light image of an original document being reproduced. Exposure of the charged photoconductive member selectively dissipates the charges thereon in the irradiated areas. This records an electrostatic latent image on the photoconductive member corresponding to the informational areas contained within the original document. After the electrostatic latent image is recorded on the photoconductive member, the latent image is developed by bringing a developer material into contact therewith. Generally, the developer material comprises toner particles adhering triboelectrically to carrier granules. The toner particles are attracted from the carrier granules to the latent image forming a toner powder image on the photoconductive member. The toner powder image is then transferred from the photoconductive member to a copy sheet. The toner particles are heated to permanently affix the powder image to the copy sheet. Most current fusers use conduction as the main heat transfer mechanism to melt toner to paper. Such systems suffer from non-uniform axial temperature distributions when various paper widths are fed through the fusing nip. Some of these problems are addressed through shaping of the heat lamp axial profile or by using multiple heat lamps to allow control of the axial heating profile.

Because heat transfer is controlled by conduction, most fusers have difficulty with transport of energy in the axial direction. Invariably, this leads to overheating of the rubber layers which is a major cause for reduced fuser life.

The object of this invention is to achieve a uniform axial temperature distribution on the surface of the roll, for any paper or film width and/or speed variation. Accordingly, it is desirable to develop a fuser which has good heat transfer properties and is able to be maintained at a uniform axial temperature.

U.S.-A-5,119,142 describes an image fixing device in which a heat exchanging roller removes heat from a portion of a belt exiting a fusing nip and returns the heat to a portion of the belt entering the nip. The heat exchanging roller has a thin conducting layer on an insulative core. In accordance with one aspect of the present invention, there is provided an apparatus for fusing images to a substrate. The apparatus comprises a pressure member and a heated fusing member, the fusing member heated so that the temperature in an axial direction along the fusing member remains substantially constant.

Pursuant to another aspect of the present invention,

there is provided an electrophotographic printing machine in which images are fused to a substrate. The machine comprises a pressure member and a heated fusing member, the fusing member heated so that the temperature in an axial direction along the fusing member remains substantially constant.

Pursuant to yet another aspect of the present invention, there is provided a method of heating a fusing member in a printing machine comprising maintaining a substantially pure fluid substance or mixture of substantially pure substances in a sealed fusing member, heating said fluid to maintain said fluid in a two phase (liquid and vapor) condition and contacting a sheet with an unfused image thereon with the fusing member so as to fuse an image thereon.

Other features of the present invention will become apparent as the following description proceeds and upon reference to the drawings, in which:

Figure 1 is a schematic elevational view of an electrophotographic printing machine incorporating the fusing system of the invention therein;

Figure 2 is an end view of a fusing device as described herein;

Figure 3 is an end view of a second embodiment of a fusing device as described herein;

Figure 4 is an elevational view showing a portion of a heating roll fixture with a mylar belt partially wrapped thereabout;

Figure 5 is a plan view of the Fig. 4 roll and belt; Figure 6 is a graph of the axial surface temperature variations of a phase change fuser and a mylar belt in contact therewith;

Figure 7 is a graph illustrating the difference of the axial surface temperature variations of a phase change fuser and a mylar belt in contact therewith and a conventional fuser and a mylar belt in contact therewith; and

Figure 8 is a graph illustrating the heat profile of a lamp and the roll surface for a conventional fuser.

For a general understanding of the features of the present invention, reference is made to the drawings. In the drawings, like reference numerals have been used throughout to identify identical elements. Fig. 1 schematically depicts an electrophotographic printing machine incorporating the features of the present invention therein. It will become evident from the following discussion that the stalled roll registration device of the present invention may be employed in a wide variety of devices and is not specifically limited in its application to the particular embodiment depicted herein.

Referring to Fig. 1 of the drawings, an original document is positioned in a document handler 27 on a raster input scanner (RIS) indicated generally by reference numeral 28. The RIS contains document illumination lamps, optics, a mechanical scanning drive and a charge coupled device (CCD) array. The RIS captures

the entire original document and converts it to a series of raster scan lines. This information is transmitted to an electronic subsystem (ESS) which controls a raster output scanner (ROS) described below.

Figure 1 schematically illustrates an electrophotographic printing machine which generally employs a photoconductive belt 10. Preferably, the photoconductive belt 10 is made from a photoconductive material coated on a ground layer, which, in turn, is coated on an anti-curl backing layer. Belt 10 moves in the direction of arrow 13 to advance successive portions sequentially through the various processing stations disposed about the path of movement thereof. Belt 10 is entrained about stripping roller 14, tensioning roller 16 and drive roller 20. As roller 20 rotates, it advances belt 10 in the direction of arrow 13. Initially, a portion of the photoconductive surface passes through charging station A. At charging station A, a corona generating device indicated generally by the reference numeral 22 charges the photoconductive belt 10 to a relatively high, substantially uniform potential.

At an exposure station, B, a controller or electronic subsystem (ESS), indicated generally by reference numeral 29, receives the image signals representing the desired output image and processes these signals to convert them to a continuous tone or greyscale rendition of the image which is transmitted to a modulated output generator, for example the raster output scanner (ROS), indicated generally by reference numeral 30. Preferably, ESS 29 is a self-contained, dedicated minicomputer. The image signals transmitted to ESS 29 may originate from a RIS as described above or from a computer, thereby enabling the electrophotographic printing machine to serve as a remotely located printer for one or more computers. Alternatively, the printer may serve as a dedicated printer for a high-speed computer. The signals from ESS 29, corresponding to the continuous tone image desired to be reproduced by the printing machine, are transmitted to ROS 30. ROS 30 includes a laser with rotating polygon mirror blocks. Preferably, a nine facet polygon is used. The ROS illuminates the charged portion of photoconductive belt 10 at a resolution of about 300 or more pixels per inch. The ROS will expose the photoconductive belt to record an electrostatic latent image thereon corresponding to the continuous tone image received from ESS 29. As an alternative, ROS 30 may employ a linear array of light emitting diodes (LEDs) arranged to illuminate the charged portion of photoconductive belt 10 on a raster-by-raster basis. After the electrostatic latent image has been recorded on photoconductive surface 12, belt 10 advances the latent image to a development station, C, where toner, in the form of liquid or dry particles, is electrostatically attracted to the latent image using commonly known techniques. The latent image attracts toner particles from the carrier granules forming a toner powder image thereon. As successive electrostatic latent images are developed, toner particles are depleted from the developer material. A

toner particle dispenser, indicated generally by the reference numeral 44, dispenses toner particles into developer housing 46 of developer unit 38.

With continued reference to Figure 1, after the electrostatic latent image is developed, the toner powder image present on belt 10 advances to transfer station D. A print sheet 48 is advanced to the transfer station, D, by a sheet feeding apparatus, 50. Preferably, sheet feeding apparatus 50 includes a feed roll 52 contacting the uppermost sheet of stack 54. Feed roll 52 rotates to advance the uppermost sheet from stack 54 into vertical transport 56. Vertical transport 56 directs the advancing sheet 48 of support material into registration transport 57 past image transfer station D to receive an image from photoreceptor belt 10 in a timed sequence so that the toner powder image formed thereon contacts the advancing sheet 48 at transfer station D. Transfer station D includes a corona generating device 58 which sprays ions onto the back side of sheet 48. This attracts the toner powder image from photoconductive surface 12 to sheet 48. After transfer, sheet 48 continues to move in the direction of arrow 60 by way of belt transport 62 which advances sheet 48 to fusing station F.

Fusing station F includes a fuser assembly indicated generally by the reference numeral 70 which permanently affixes the transferred toner powder image to the copy sheet. Preferably, fuser assembly 70 includes a heated fuser roller 72 and a pressure roller 74 with the powder image on the copy sheet contacting fuser roller 72. The fuser system will be described in more detail with reference to Figures 2-8 inclusive.

The sheet then passes through fuser 70 where the image is permanently fixed or fused to the sheet. After passing through fuser 70, a gate 80 either allows the sheet to move directly via output 16 to a finisher or stacker, or deflects the sheet into the duplex path 100, specifically, first into single sheet inverter 82 here. That is, if the sheet is either a simplex sheet, or a completed duplex sheet having both side one and side two images formed thereon, the sheet will be conveyed via gate 80 directly to output 16. However, if the sheet is being duplexed and is then only printed with a side one image, the gate 80 will be positioned to deflect that sheet into the inverter 82 and into the duplex loop path 100, where that sheet will be inverted and then fed to acceleration nip 102 and belt transports 110, for recirculation back through transfer station D and fuser 70 for receiving and permanently fixing the side two image to the backside of that duplex sheet, before it exits via exit path 16.

After the print sheet is separated from photoconductive surface 12 of belt 10, the residual toner/developer and paper -fiber particles adhering to photoconductive surface 12 are removed therefrom at cleaning station E. Cleaning station E includes a rotatably mounted fibrous brush in contact with photoconductive surface 12 to disturb and remove paper fibers and a cleaning blade to remove the nontransferred toner particles. The blade may be configured in either a wiper or doctor po-

sition depending on the application. Subsequent to cleaning, a discharge lamp (not shown) floods photoconductive surface 12 with light to dissipate any residual electrostatic charge remaining thereon prior to the charging thereof for the next successive imaging cycle.

The various machine functions are regulated by controller 29. The controller is preferably a programmable microprocessor which controls all of the machine functions hereinbefore described. The controller provides a comparison count of the copy sheets, the number of documents being recirculated, the number of copy sheets selected by the operator, time delays, jam corrections, etc.. The control of all of the exemplary systems heretofore described may be accomplished by conventional control switch inputs from the printing machine consoles selected by the operator. Conventional sheet path sensors or switches may be utilized to keep track of the position of the document and the copy sheets.

Turning now to Figures 2 through 8, a more detailed discussion of the phase change fuser will be presented. Figures 2 and 3 illustrate a cross sectional view of two embodiments of the fuser herein. The fuser roll is a sealed cylindrical member or chamber containing a pure working fluid. A heat source (174), either external to the roll (Fig. 2) or internal to the roll (Fig. 3) is used to heat the working fluid.

Initially, at ambient temperature, the pressure in the chamber must equal the corresponding saturation pressure. The chamber, substantially evacuated of air and any other non-condensable substance, is partially filled with the working fluid and then sealed. Heat is provided (either internally or externally) to raise the temperature to the desired level. At steady state the amount of heat added must equal that which is lost to the ambient. Heat transfer occurs primarily through evaporation of the liquid and condensation of the vapor. The table below lists the saturation temperatures and pressures for pure water.

Temperature, °C	Pressure, psia
20	0.4
100.6	15
108.9	20
115.6	25
121.3	30
130.7	40

Thus, for a water based system, the chamber would have to be evacuated to a pressure of 0.4 psia at ambient temperature (20 °C). The pressure increases to 40 psia when the temperature reaches 130.7 °C. The system must be designed to withstand both extremes to avoid leakage into or out of the chamber.

When a cold substrate contacts the fuser roll sur-

face it extracts heat from it. This results in a local decrease in temperature which triggers increased vapor condensation inside the roll at the region of contact. The transport of energy via latent heat produces heat fluxes which, for the same temperature difference, can greatly exceed those due to conduction. Moreover, the energy is delivered only to the cooled surface of the contact region, so that any substrate width will be heated uniformly without the occurrence of large axial temperature gradients. The high rate of heat transfer ensures small changes in fuser temperature even for very high substrate speeds.

The substrate can be copy paper, a photoreceptor or intermediate transfer belt, or a web fed film.

Fusers need to accommodate various substrate widths and thermal characteristics. Utilizing the system described herein, axial temperature variations will essentially be removed. In the case of a fuser for an electrophotographic printing machine, however, water is not a viable working fluid because for typical fusing temperatures (190 °C) the saturation pressure is an unwieldy 150 psia. Propylene glycol which has a boiling point of 187.2 °C at atmospheric pressure is a good candidate. Selective transfer of energy is best achieved with a roll as thin as is structurally viable, having a high thermal conductivity (e.g. copper). An example is shown in Figures 3 and 4. A mylar sheet 4 mils thick and 42.6 cm wide, moving with a speed of 1 inch per second (ips), contacts a phase change fuser which contains boiling water at 115.6 °C and 25 psia. The roll is made of copper 0.25 cm thick with an outer diameter of 8 cm. The wrap angle is 36° so that contact occurs over a length of 2.51 cm. The mylar film enters the wrap at 20 °C. Its axial surface temperature distribution upon leaving the wrap, was determined by use of a three dimensional heat transfer simulation program. Heat transfer by vapor condensation was represented by an average heat transfer coefficient obtained from,

$$\bar{h}_c = 0.725 \left[\frac{\rho_l (\rho_l - \rho_v) g h_{fg} k^3}{D \rho_l (T_{sv} - T_s)} \right]^{\frac{1}{4}}$$

where:

c_p = specific heat of the liquid

k = thermal conductivity of the liquid

ρ_l = density of the liquid

ρ_v = density of the vapor

g = gravitational acceleration

h_{fg} = latent heat of condensation or vaporization

$$h'_{fg} = h_{fg} + \frac{3}{8} c_p (T_{sv} - T_s)$$

D = diameter

μ = viscosity of the liquid

T_{sv} = temperature of saturated vapor

T_s = roll surface temperature

This relation is valid for pure saturated vapor condensing on the inside of a horizontal tube (Ref: Principles of Heat Transfer by Frank Kreith, 3rd edition).

There are two subtle points, however, that make this but a conservative estimate. First, this relation assumes the formation of an insulative liquid layer. In reality, since the rotating roll carries away the condensing liquid, there should be little, if any, liquid directly behind the contact zone. Secondly, even though the vapor will condense mostly along the cooled surface of the contact region, the simulation assumes the same heat transfer coefficient across the entire width of the roll. Despite these simplifications, the results shown in Fig. 6 illustrate excellent axial uniformity of the surface temperatures of the mylar film and the fuser roll. The surface temperature variation of the mylar film is less than 0.4 °C, occurring within narrow strips less than 2 cm wide on the edges, due to their proximity to the (slightly hotter) bare surface of the fuser roll.

The results with a conventional fuser of the exact same geometry and with identical operating conditions, are shown in Fig. 6. For comparison, the results of Fig. 6 are also included. Heating with a conventional fuser produces significant surface temperature variations because of the non-uniform output of the heating lamp. In this example a 2 kW lamp with the profile shown in Fig. 8 is assumed. In spite of a diffusely reflecting, low emissivity (0.1) cavity the surface heating distribution retains significant axial variation, as shown in Fig. 8. The marked improvement of the phase change fuser evident in Fig., is due to the dispersion and relatively unimpeded flow of vapor which effectively eliminates any variations of the heat source. In the case of a two roll fuser system used for narrow sheets, the temperature on the rolls outside the paper path usually rises to much higher values than desired unless some shaping of the lamp profile or multiple lamps are used. The phase change fuser will remove heat from the hot areas outside the paper path by evaporation and transport this heat to areas within the paper width where condensation will occur, thus maintaining uniform axial temperatures. without use of shaped heating or multiple heating devices.

In recapitulation, there is provided an apparatus for fusing images to a sheet. A fuser device is provided using a sealed fusing member containing a pure fluid substance. Heat is applied, either internally or externally, to maintain the fluid in a steady state condition. When a sheet having an unfused image thereon is fed between

the fusing member and a pressure member, the heat is transferred to the sheet to fuse the image. As a result of the two phase (liquid and vapor) state of the fluid within the fusing member there is a very uniform and efficient transfer of heat to the sheet. Thus there is provided a device which maintains a very uniform temperature along its axis and avoids hot spots and overheating of certain portions of the fusing member due to variations in the heat source and in the transfer efficiency of the fusing member.

Claims

1. An apparatus for fusing images to a substrate, comprising: a pressure member (74); and a heated fusing member (72), said fusing member (72) heated so that the temperature in an axial direction along said fusing member (72) remains substantially constant.
2. An apparatus according to claim 1, wherein said fusing member (72) further comprises: a sealed cylindrical member supported for rotation; a fluid contained within said sealed cylindrical member; and a heat source (174) acting upon said fluid to maintain the fluid in a two phase condition.
3. An apparatus according to claim 2 wherein said heat source (174) is external to said fusing member.
4. An apparatus according to claim 2 wherein said heat source (174) is internal to said fusing member.
5. A printing machine in which images are fused to a substrate comprising:
 - a pressure member (74); and
 - a heated fusing member (72), said fusing member (72) heated so that the temperature in an axial direction along said fusing member (72) remains substantially constant.
6. A printing machine according to claim 5, wherein said fusing member (72) further comprises:
 - a sealed cylindrical member supported for rotation;
 - a fluid contained within said sealed cylindrical member; and
 - a heat source (174) acting upon said fluid to maintain the fluid in a steady state condition.
7. A printing machine according to claim 6 wherein said heat source (174) is external to said fusing member.
8. A printing machine according to claim 6 wherein

said heat source (174) is internal to said fusing member.

9. A method of heating a fusing member in a printing machine comprising:

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maintaining a substantially pure fluid substance or mixture of substantially pure substances in a sealed fusing member (72);
heating said fluid to maintain said fluid in a two phase condition; and
contacting a sheet (48) with an unfused image thereon with the fusing member so as to fuse an image thereon.

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10. A method according to claim 9 wherein said fluid is selected from the group consisting of pure water, propylene glycol and mixtures thereof.

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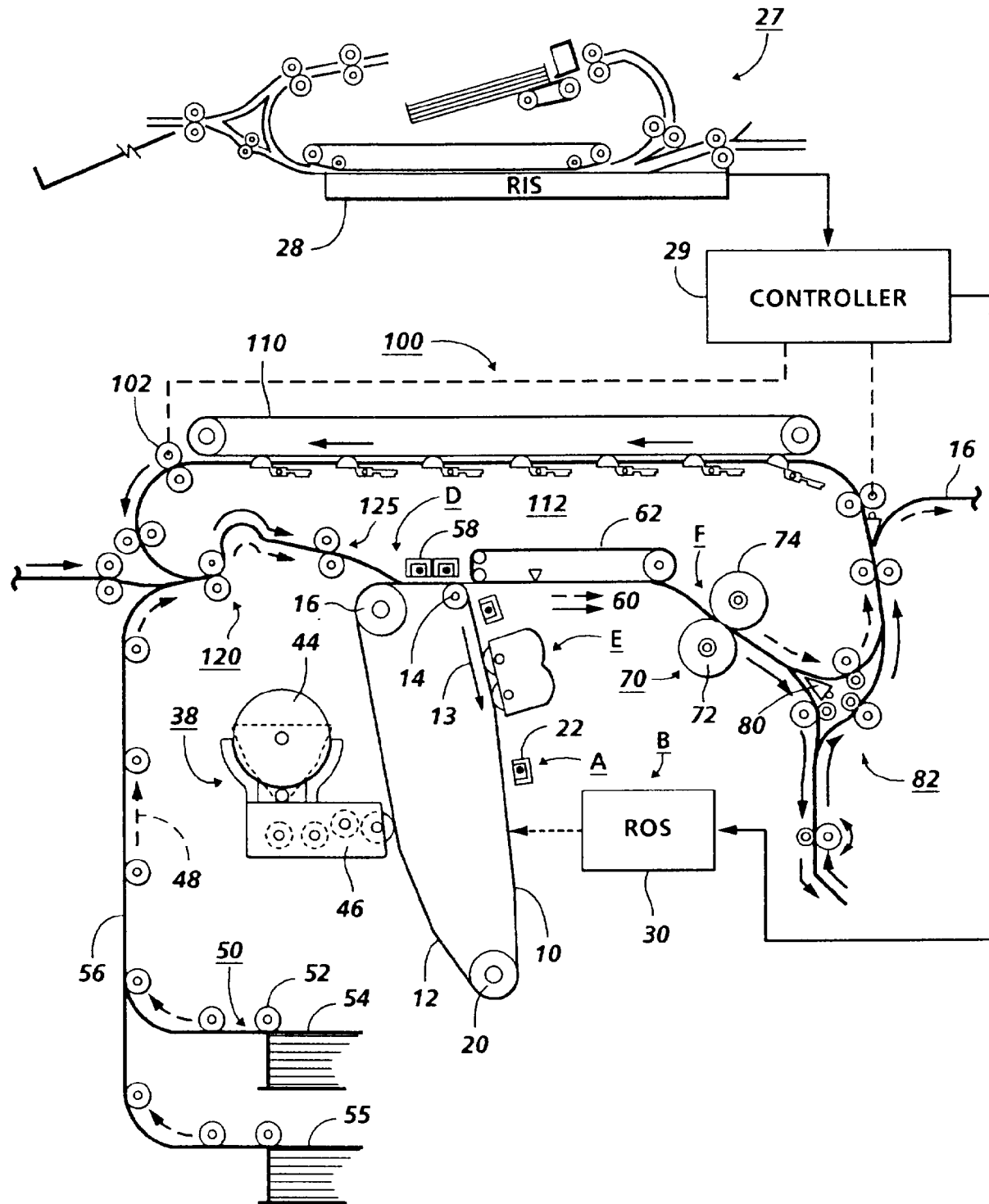


FIG. 1

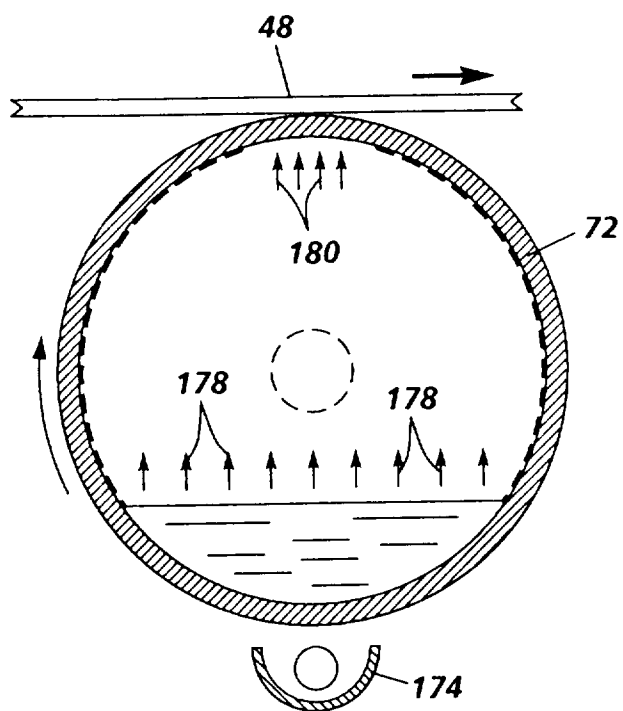


FIG. 2

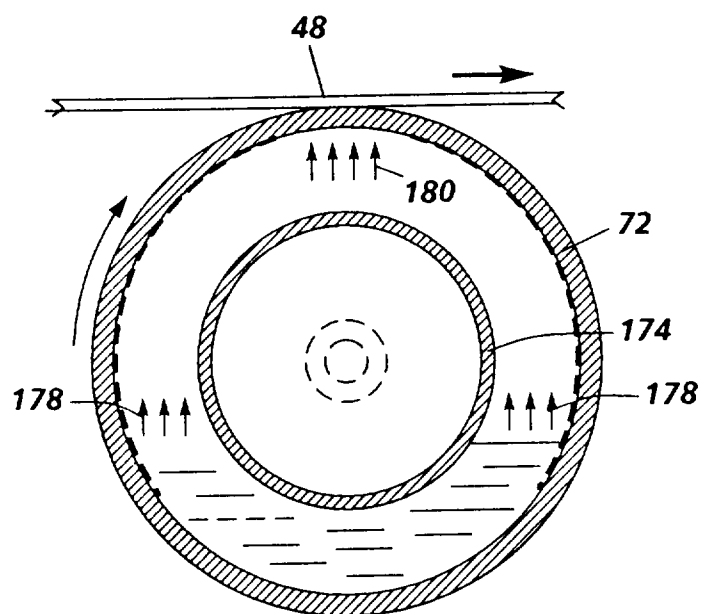


FIG. 3

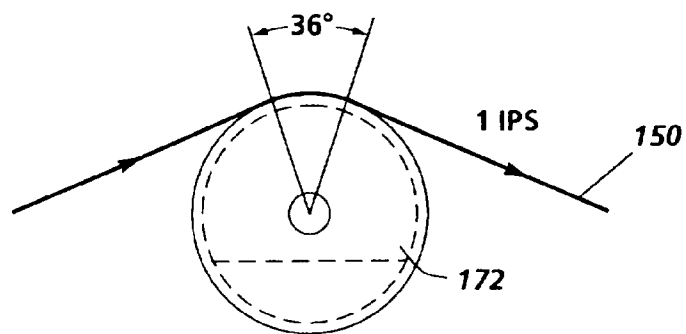


FIG. 4

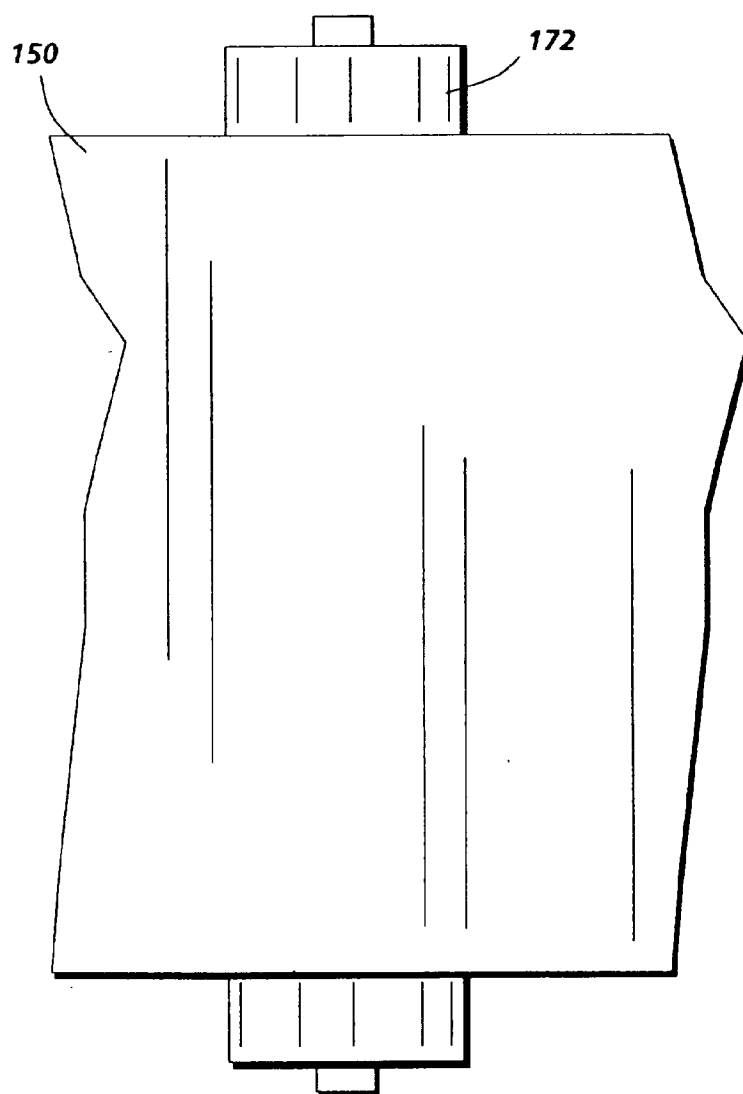


FIG. 5

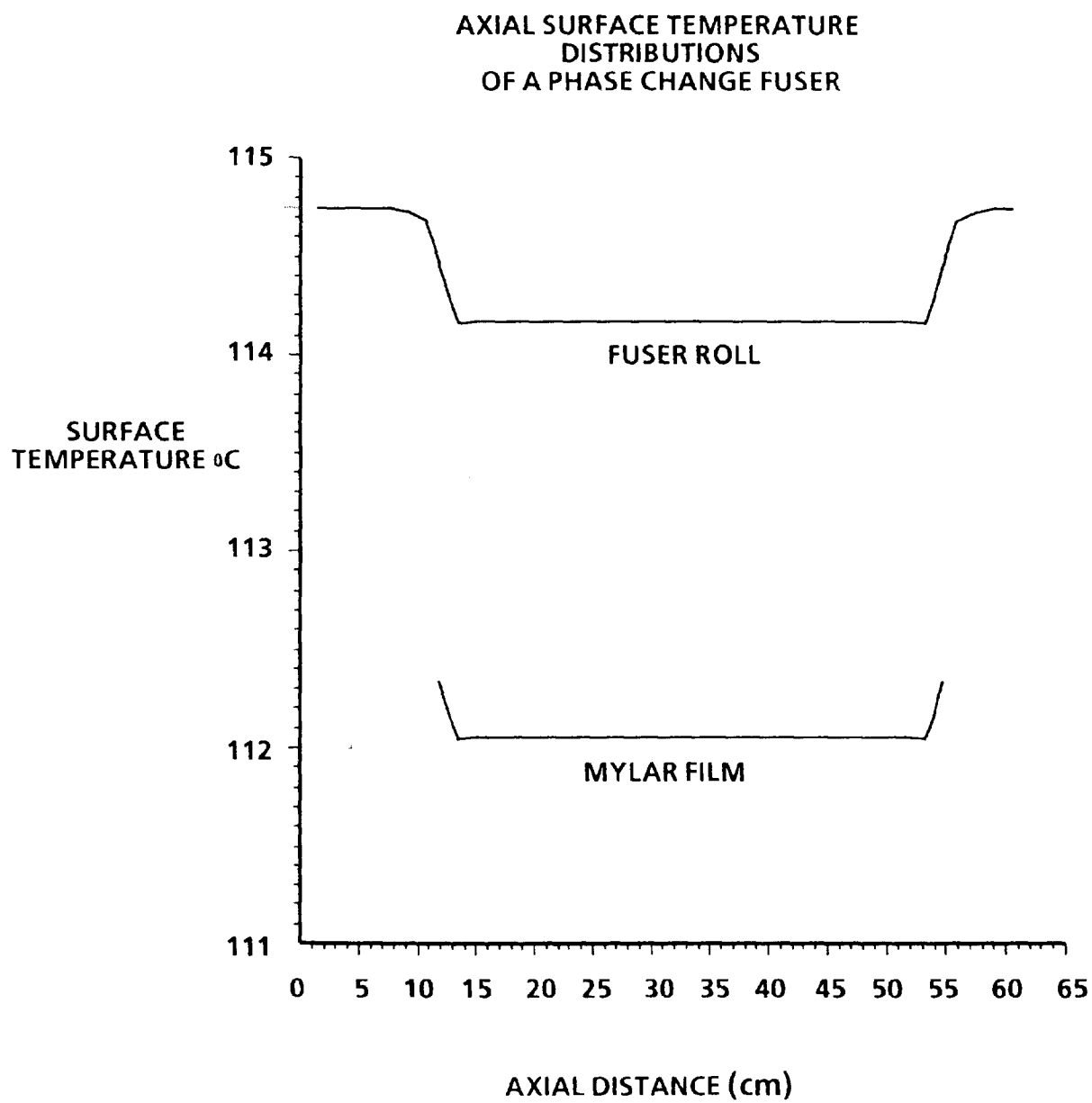


FIG. 6

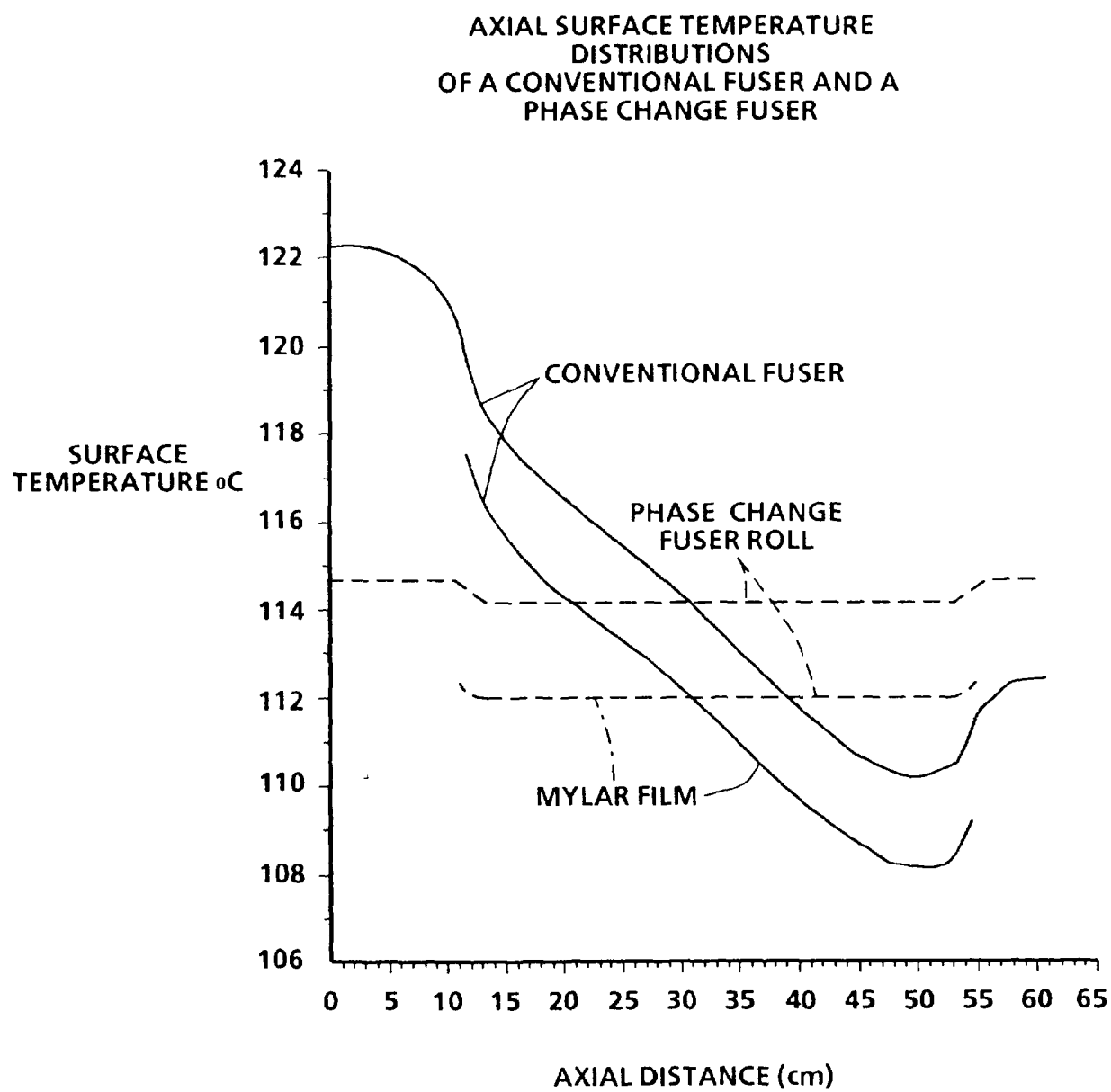
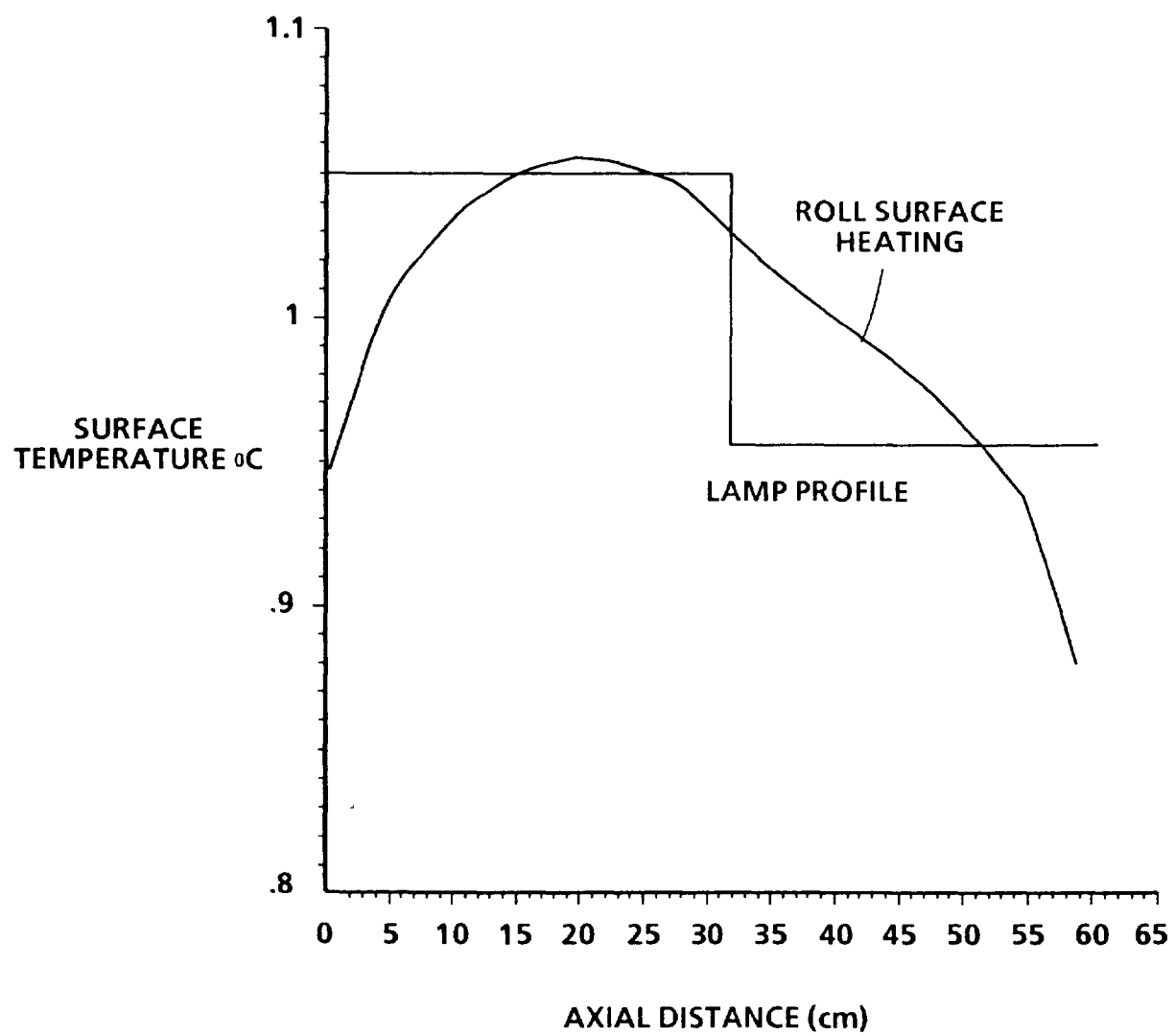


FIG. 7

**FIG. 8**