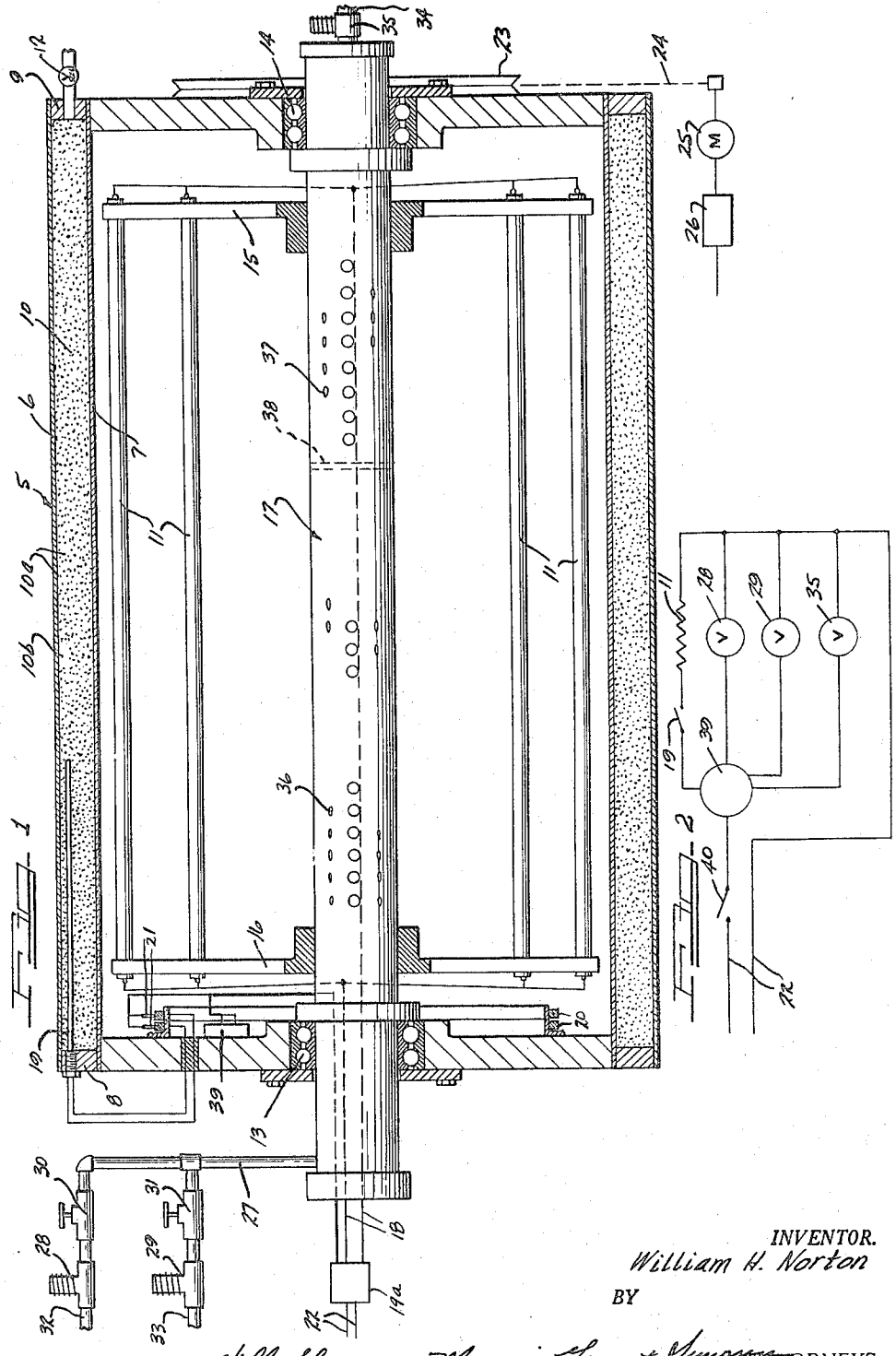
Dec. 13, 1966 W. H. NORTON 3,291,204

HEAT TRANSFER ROLL

Original Filed March 16, 1961 3 Sheets-Sheet 1



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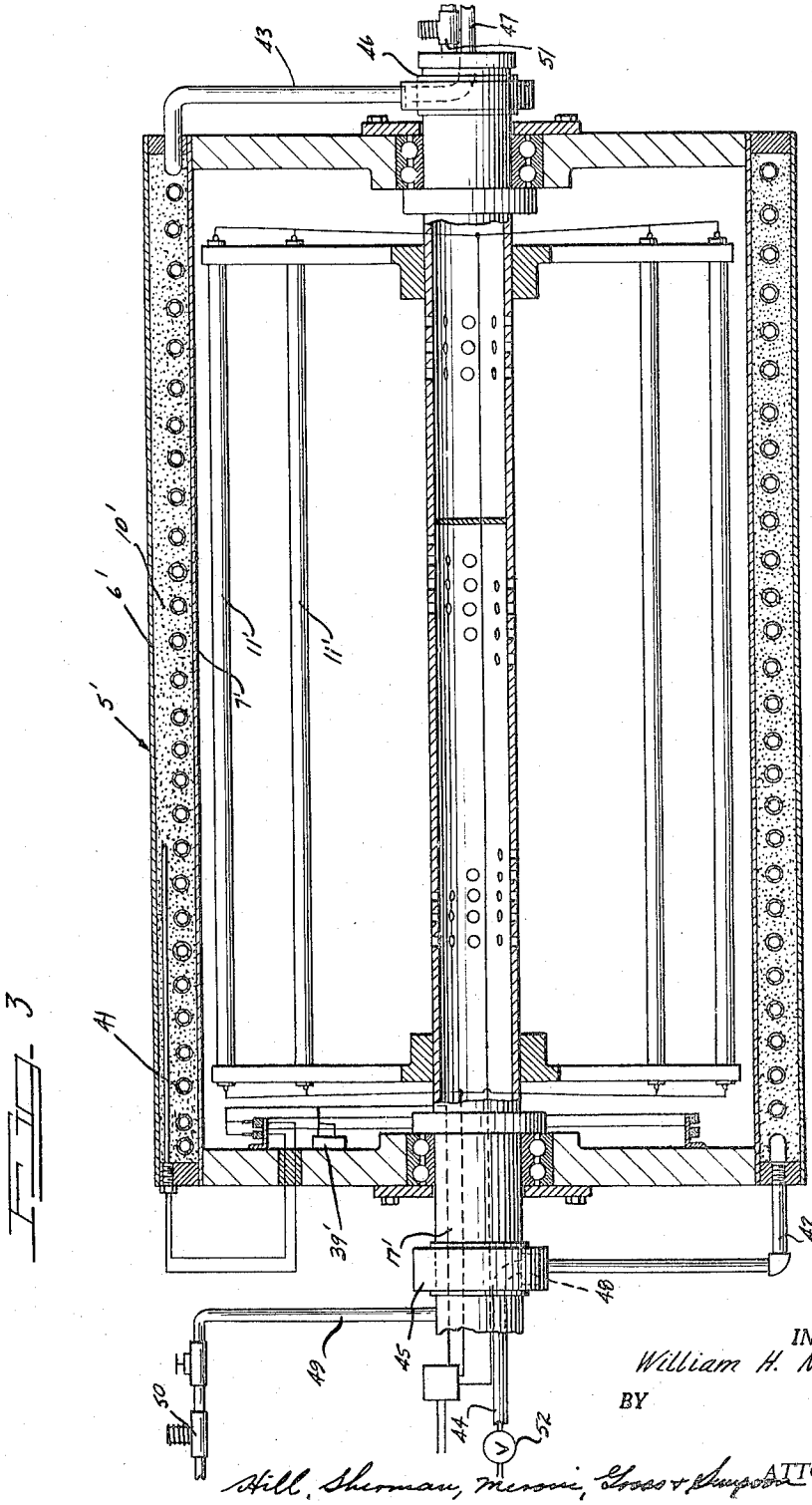


FIG. 3

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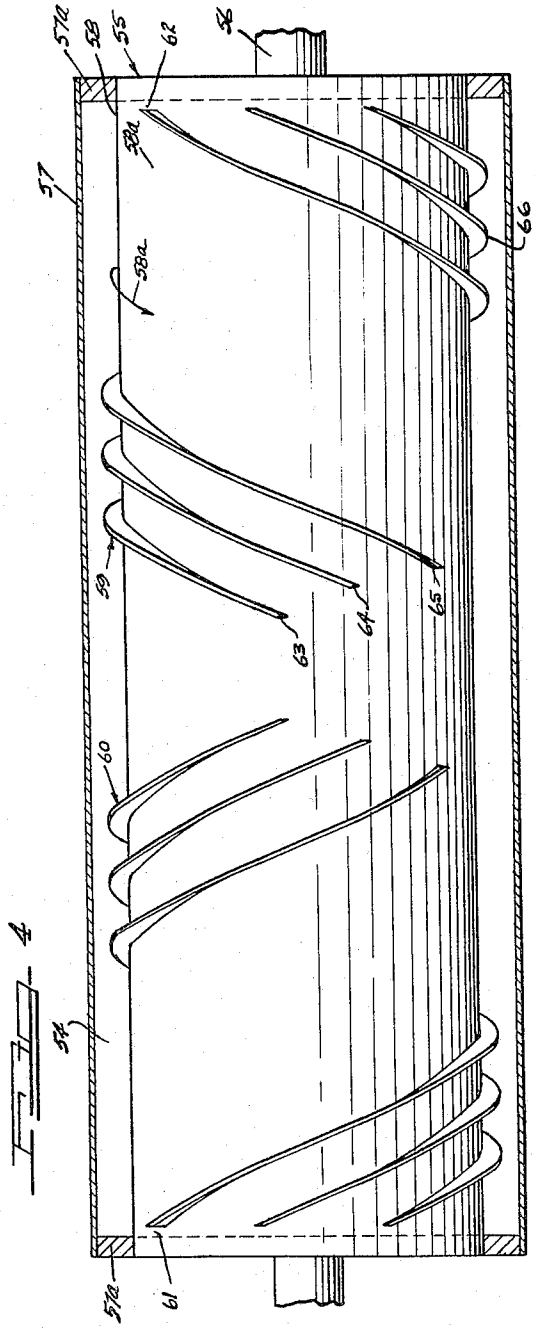


FIG. 4

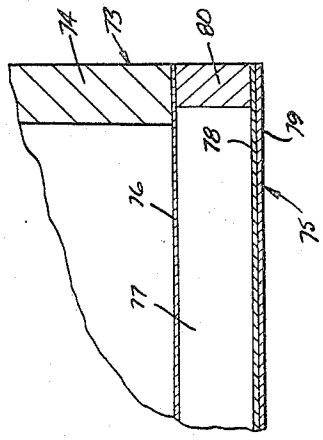


FIG. 6

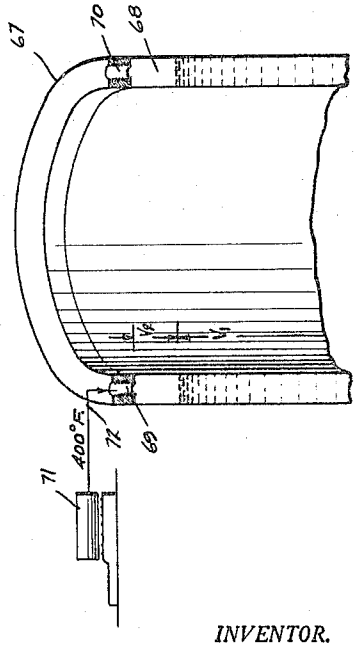


FIG. 5

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United States Patent Office 3,291,204 Patented Dec. 13, 1966

3,291,204

HEAT TRANSFER ROLL

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Original application Mar. 16, 1961, Ser. No. 96,313, now Patent No. 3,216,489, dated Nov. 9, 1965. Divided and this application Aug. 13, 1965, Ser. No. 487,647

3 Claims. (Cl. 165—89)

The present invention relates to improvements in heat transfer rolls and particularly to a roll which is internally heated during normal operation and is rapidly and automatically cooled at the termination of an operating run, and the present application is a division of applicant's copending application Ser. No. 96,313, filed March 16, 1961, now U.S. Patent 3,216,489, issued November 9, 1965.

The present invention contemplates the provision of an electrically heated heat transfer roll having a cylindrical outer shell and a concentric inner shell forming a chamber therebetween containing a heat transfer fluid and preferably a eutectic composition. The roll is rotatably mounted on a hollow shaft with electrical heating elements supported on the shaft. The hollow supporting shaft is stationary and provides a container for electrical leads and a conduit for air. An exhaust valve is positioned at one end of the shaft and low pressure and high pressure inlet valves at the other end of the shaft. The valves are preferably electrically operated so that they can be switch controlled for operation of the unit such as by a centrifugal switch. At the time of start up the exhaust valve is closed and the interior of the roll is pressurized with a low pressure air and the heating elements are actuated. At the end of an operating run the exhaust valve is opened and high pressure air is blown through the drum through openings in the shaft for rapidly cooling the drum interior. Other operating arrangements are possible as will be described and the rapid cooling may be effected by cooling coils embedded in the eutectic material.

An object of the invention is to provide an improved rotary heat transfer roll with improved effectiveness and efficiency well suited for a variety of manufacturing operations wherein a cylindrical heat transfer roll surface moves in engagement with a material to be heated.

Another object of the invention is to provide an improved heat transfer roll construction having an increased margin of safety and well adapted for uses in the presence of materials which are of an inflammable or an explosive nature.

A still further object of the invention is to provide an improved heat transfer roll which can be very rapidly cooled when it is stopped so that the temperature of the roll can be maintained above the temperature of materials subject to thermal degradation for high speed operation and the roll immediately cooled when stopped to prevent damage to the material and the possibility of conflagration or explosion.

A still further object of the invention is to provide an improved heat transfer roll wherein uniform heating of the outer surface of the roll is obtained through the use of a eutectic composition.

Other objects and advantages will become more apparent with the teaching of the principles of the invention in connection with the disclosure of the preferred embodiments thereof in the specification, claims and drawings, in which:

FIGURE 1 is a vertical sectional view taken through the axial center of a heat transfer roll embodying the principles of the invention;

FIGURE 2 is a diagrammatic illustration of a control circuit for the roll;

FIGURE 3 is a sectional view taken through the axis of a rool embodying a modified arrangement for rapidly cooling the roll;

FIGURE 4 is a vertical sectional view of a heat transfer roll with the inner shell shown in full to illustrate construction for obtaining a uniform temperature along the roll;

FIGURE 5 is a vertical sectional view shown in somewhat schematic form of a roll standing on end illustrating steps in the method of filling the roll; and

FIGURE 6 is an enlarged detail sectional view of a portion of heat transfer roll insulating a construction for the outer shell.

As shown on the drawings:

As illustrated in FIGURE 1, a heat transfer roll **5** includes a plurality of shells, illustrated as including an outer shell **6** with a cylindrical outwardly facing surface for engaging a surface to be heated. The roll includes an inner shell **7** which is illustrated as cylindrical and concentric with the outer shell **6** and at the ends of the shells are annular end walls **8** and **9** which with the shells define a heat distributor chamber **10**. The chamber **10** is provided with a heat distribution material which is preferably eutectic composition **10***a*. The eutectic composition will be solid at normal room temperatures and will become liquid at normal heating temperatures. A preferred eutectic composition will melt at 275° F. and will be usable to 1000° F. Other eutectic compositions are suitable and for certain conditions are useable from 450° F. to 2000° F.

The eutectic materials will solidify at room temperatures and therefore the problem of leakage when the machine is at rest is not present. Other heat transfer fluids which tend to damage the materials with which they come in contact are not used and the problems of providing positive seals and inspection before usage are therefore avoided. Further, the eutectic composition is much easier to handle and store and the price per pound is very appreciably less than other heat transfer fluids. The eutectic composition has a lower specific heat factor than other organic substances, which is an advantage. The eutectic composition has no boiling point and a wider practical safe range of operation. It has a good conductivity factor, higher than liquid metal. For example, sodium has the highest conductivity factor of metals and of course would be unsafe for use. Sodium has a conductivity factor of 47 while a eutectic composition suitable for use has a conductivity factor of 58. A eutectic composition which has been used and found suitable and which is within the class of preferred eutectics is commercially available under the trade name Quick Temper 275. The eutectic is inert, easy to handle and can be safely stored over a period of time. Another advantage is its viscous properties, for example in the suitable heating range of 500 to 700° F. The viscosity is higher than liquid metal, and the eutectic composition will adhere to the surfaces of the shells for improved heat transfer in the event air spaces are left.

The eutectic composition may be placed in the chamber **10** when the shells are assembled or may be placed therein in the fluid state through a filling opening provided for that purpose. The chamber shown with a pressure relief valve fitting **12** for the relief of internal pressures which may develop and the relief valve may be removable so that its connection can be used as a filling opening.

The eutectic material in the chamber **10** is preferably arranged so as not to completely fill the entire void and to therefore leave an air space for expansion. In some circumstances it may be acceptable to use a liquid in the

chamber **10** instead of a eutectic composition. A liquid such as oil is suitable but must have a flash point above the operating temperature. The air space for expansion is shown at **10***b* and may be only large enough to permit normal heat expansion of the heat transfer material **10***a* in the chamber **10**, inasmuch as the valve **12** will relieve undue expansion due to overheating or the like.

Within the rotor **5** adjacent the inner shell **7** is a heating means preferably in the form of a plurality of tubular electric heating elements **11**. The heating elements are stationary and the rotor **5** is mounted for rotation about its axis on end support bearings **13** and **14**. The heating elements are preferably of the tubular type with wire resistance elements embedded in compacted electrical insulating material within the tubes, and extend axially within the rotor. As the rotor is moved in rotation about the heating elements, heat energy is transmitted to the eutectic composition within the chamber **10** to cause it to become liquid, and the liquid composition will evenly distribute the heat energy to the outer shell **6**.

The rotor and the heating elements are supported on a shaft **17** shown as being hollow to contain electrical conductors **18** which are connected to the heating elements **11**. The elements are stationarily supported at their ends by radial support members **15** and **16** which may be in the form of spiders secured to the shaft. The support bearings **13** and **14** are also mounted on the shaft.

For controllably regulating the heat of the rotor the electric current to the heating elements **11** is controlled by a temperature responsive switch control member **19**. This may be of the switch type or of the resistance thermometer type and the arrangement is shown schematically for purposes of illustration in FIGURE 2.

The control **19** is electrically coupled to the circuit through slip ring and brush elements with the slip rings shown at **20** connected to leads from the control **19** and with the brushes as shown at **21** connected to the control circuit. Within the rotor **5** adjacent the inner shell **7** is a heating means preferably in the form of a plurality of tubular electric heating elements **11**. The control circuit is shown in FIGURE 1 for purposes of illustration only as including a control relay **19***a* which is omitted in FIGURE 2. Electricity is supplied from the supply line **22**. When the eutectic composition in the chamber reaches the desired temperature, the switch of the control **19** will open the circuit to the electrical heaters **11**, and as will be appreciated, various control circuits may be employed. A centrifugal switch **32** is employed to control heating and cooling of the drum as a function of its rotation as will be described.

The slip rings **20** and the brushes **21** are shown as preferably located within the roll **5** so as to be surrounded by an atmosphere of non-explosive air, as will later be described.

The roll may be rotated by the friction of engagement with a surface to be heated or may be driven in rotation at a suitable speed. As illustrated, a pulley **23** may be attached to the end driven by a suitable belt **24** which in turn is driven by a motor **25** operated by a motor control **26** which determines the operation and speed of operation of the motor.

As illustrated in FIGURE 1, the roll **5** is provided with means for pressurizing the interior during operation to prevent the accumulation or entry of any combustible gases, such as might be given off by material being heated. An air supply line **27** connects to the hollow shaft **17** and is supplied with a source of low pressure air for pressurizing the roll and is also provided with a source of high pressure air for cooling the roll rapidly at the termination of an operating run. The low pressure source of air is controlled by an electrically operated valve **28** connected to a low pressure source **32** with a regulator valve **30** in the line. The high pressure air is controlled by an electrical valve **29** connected to a high pressure source **33** and a regulator valve **31** is connected in the line. The

low pressure source **32** provides a high volume supply of air to establish a positive internal air pressure in the roll. For example, a positive pressure of 3 pounds per square inch or more of pure fresh air eliminates the possibility of accumulating an explosive atmosphere within the roll. Wiring and connections are within the hollow shaft or within the roll and explosion-proof operation is therefore accomplished. The discharge of the hollow shaft **17** is provided with a discharge line **34** which is controlled by an electrically operated valve **35**. The valve **35** is closed during normal operation to permit pressurizing the roll.

The source **33** is a high pressure high volume source and supplies cooling air which flows through holes **36** into the roll. The air leaves through holes **37** also communicating between the interior of the shaft and the roll and a partition **38** may be provided in the hollow shaft to insure that the air will pass through the drum before it leaves through the discharge valve **35**. This supply of air is also used before beginning operation to flush out the internal roll area and insure that the roll will be filled with fresh air. As will be understood, the cooling effects at the end of a run are completely compatible with the low pressure explosion-proof operation. The air supply line **27** in the discharge control valve **35** serve dual purposes in controlling flushing of the roll before operation, pressurizing the roll during operation, and cooling the roll at the end of an operation or when stopping. Flushing the interior with air immediately cools the heating elements **11** and accomplishes a radical temperature reduction on the face of the roll at an accelerated rate in the order of 5 to 1 or as much as 10 to 1 as related to cooling time under static conditions, the cooling being proportional to the total air flow rates provided.

The valves **28**, **29** and **35** are preferably electrically actuated such as by a centrifugal switch **39**. As illustrated in FIGURE 2, the electrical power for the mechanism is derived from a main switch **40** connected to the centrifugal control switch **39** which is mounted on an end wall within the roll. The centrifugal switch is provided with multiple contacts so as to operate the heating elements **11** and each of the valves.

As a typical operation, as the main switch **40** is closed, the centrifugal switch **39** will open the exhaust valve **35** and the high pressure supply valve **29** so as to flush the interior of the roll **5** and exhaust any accumulated vapors. As soon as the roll starts moving, the centrifugal switch closes the valve **35**, closes the valve **29**, energizes the heaters **11**, and opens the low pressure valve **28** to pressurize the interior of the roll. If desired, the centrifugal switch may first purge the interior of the roll just as the roll starts rotating and the heaters may be actuated as the roll reaches operating speed.

At the end of an operating run, as the roll is stopped or slowed down the heaters **11** are de-energized and the valve **35** is opened while the high pressure valve **29** is also opened to discharge high pressure air into the interior of the roll to effect rapid cooling.

Many materials are processed on heating rolls which are subject to thermal degradation. Inasmuch as material temperature is in relation to source temperature and dwell time, for practical operation rolls are operated at a much higher temperature than is required in the processed material. This permits higher take-off speeds and increased output. Whenever it is necessary to stop the roll it is necessary that its surface temperature be immediately reduced below either the melt point or a point of thermal degradation of the material as quickly as possible. For instance, many rolls operating at 300° F. surface temperature, must be dropped to 200° F. quickly before shutdown to avoid serious damage to whatever material is being run. For example in running material webs, damage done during cool down forces the rejection of lengths of material. The longer period of cool down experienced, the larger the cost of rejected materials. Of course, with-

in limits, the take-off speed can be reduced as the temperature falls so as to maintain a constant input value to the web during stopping. This could be controlled by slowing down the motor by the motor control 26. The present invention however contemplates cooling at an extremely rapid rate so that a correlation between speed and temperature does not have to be maintained over any substantial shutdown.

In some instances, the centrifugal switch 39 can be replaced by or combined with time delay relays so that the programming is primarily keyed to time rather than rotational speed for shutdown. Various ratios of time temperature and rotation are possible and are determined by the factors of the material being run, actual speeds used and rate of cooling of the roll. A timed operation is possible with the use of a clock although a centrifugal switch operating through relay controls effects a saving in the price of equipment used.

In the arrangement of FIGURE 3, a roll 5′ has a construction similar to that of FIGURE 1 but is cooled by liquid flowing through heat exchange coils 41 embedded in the heat transfer eutectic 10′ between the outer shell 6′ and the inner shell 7′. Liquid such as cold water is conveniently used and a very rapid cooling is effected with the heat being removed from the surface of the outer shell 6′ at a very rapid rate to effect almost instantaneous cooling. With this type of cooling the heating elements 11′ need not be cooled, although the electrical energy is turned off, and a cooling of the roll will be effected.

Cold water coolant is supplied to the coils 41 through an inlet line 42 which rotates with the roll 5′ and is connected to a rotatable liquid conducting connector 45. The connector 45 may be in the form of a rotatable outer jacket with a chamber 48 therein filled with water. Water is supplied to the chamber from a supply line 44. The water is discharged at the other end of the drum through a line 43 connected to a rotating connector 46 leading to a water discharge line 47. The water will usually be drained from the coils 41 for normal operation.

Cooling with the arrangement of FIGURE 3 can be rapidly accomplished without a flow of air and while maintaining the interior of the roll pressurized. Air pressurization is accomplished by an inlet line 49 controlled by a valve 50 leading to the roll interior. An outlet valve 51 may be provided but is kept closed during operation. Valves 50 and 51, and a valve 52 controlling the cooling liquid, may be controlled manually or by timer operated switches, or by a centrifugal switch 39′.

As a brief summary of operation, with reference to FIGURE 1, at start-up the electrical heating elements 11 are energized and high pressure air is flushed through the interior of the roll 5 by opening the valve 29 and the exhaust valve 35. The exhaust valve 35 is then closed, and the high pressure valve 29 is closed and a low pressure valve 28 is opened to maintain the interior of the drum under pressure with clean fresh air. Heat is transmitted uniformly to the outer surface of the roll 5 through the eutectic material 10. At shutdown a rapid flow of cooling air is again admitted to the interior of the roll 5 by opening the valve 29 and by opening the exhaust valve 35 so that the material in engagement with the roll will not be damaged when the roll is stopped.

Thus it will be seen that I have provided an improved heat transfer roll which meets the objectives and advantages above set forth. The roll is compact and reliable in operation and employs simplified connections and controls which are reliable and which are explosion-proof.

While various eutectic compositions will be satisfactory in accordance with the foregoing disclosure, a preferred eutectic is a mixture of sodium and potassium nitrites and nitrates mixed to obtain a low melt point. This mixture will obtain a melt point of 275° F. or less and an operating range of 275° F. to 1000° F. has been used. The resultant eutectic also obtains a high specific heat of approximately 0.4 which is desirable in that it stores a substantial amount of energy. The thermal conductivity is also good being 58 B.t.u. per hour per foot per degree Fahrenheit. This conductivity is highly advantageous over organic materials, for example, and certain organics have a conductivity as low as $\frac{1}{100}$ of this value. The cost of this eutectic mixture at current prices is about 13¢ a pound whereas other materials run substantially higher in cost. The boilnng point of this eutectic mixture runs up to 1440° F. providing a good operating range. Boiling points on organics, and even fire resistant fluids are much lower. The material has been used with various metals for the roll including aluminum, brass, copper, rubber and plastics, with silver solders and zinc plates and no corrosion has occurred. The eutectic mixture does not have a flash point which is objectionable in organic materials. In summary, this compound has been found to be advantageous from substantially all standpoints for the purposes described.

FIGURE 4 illustrates a form or roll constructed for obtaining uniformity of temperature axially along the roll. The natural tendency of a heat transfer roll is toward a hot center and cold end. To overcome this a series of fins are installed in the chamber to create a circulation of heated eutectic from the center hot spot toward the ends which will obtain uniform temperature along the roll.

A roll 55 is shown in FIGURE 4 supported for rotation on a shaft 55 and provided with a cylindrical outer shell 57 surrounding and spaced radially from a coaxial inner shell 58 in order to provide a chamber 54 therebetween. The chamber contains a heat transfer liquid such as a eutectic of the type described above.

Mounted on the inner shell 58 are a series of outwardly projecting vanes 59 and 60 which provide surfaces that face outwardly in an axial direction so as to circulate eutectic axially. The helical vanes 59 and 60 are arranged so that they extend in a direction from the center to the end being wound in a direction opposite the direction of rotation of the drum which is indicated by the arrow 58*a*. Short spaces 61 and 62 are present between the ends of the vanes and the end walls 57*a* of the chamber 54. The inner ends of the vanes are spaced apart in an axial direction as shown by the ends 63, 64 and 65 for the vanes 59. The vanes extend successively further toward the center of the chamber 54 so that each vane will catch a separate circumferential area of heat transfer liquid and in effect pump it outwardly. The vanes do not extend fully to the outer wall 57. The liquid will be pumped outwardly from the center and will be returned by circulating flow to the center for reheating. It will of course be understood that in some circumstances it may be desired to secure the vanes to the inner surface of the outer cylindrical shell 57.

FIGURE 5 is provided to illustrate a preferred method of filling the heat transfer roll of the invention. A roll 67 is shown with inner and outer shells to provide a chamber 68 for heat transfer fluid. A eutectic is filled into the chamber 68 preferably a mixture of sodium and potassium nitrites and nitrates. Two openings 69 and 70 are provided in the end of the chamber, one for filling and the other for permitting the escape of air.

The eutectic is provided from a heated container 71 which heats the material to 400° F. This liquid material is filled into the opening 69 as indicated by the filling line 72.

The chamber 68 is filled to a percentage of its full volume with the percentage being critical. I have found that the chamber can be filled to a volume ranging from 60 to 90% of the total volume and is preferably filled to substantially 80% of its volume. As illustrated in FIGURE 5, the chamber is filled to the level represented by V_1 which is in the range of 60 to 90%, and is preferably 80% of the total volume which is represented by V_1+V_2. The remaining air space V_2 of course will be in the range

of 10 to 40% of the total volume and will preferably be 20% of the total volume.

The eutectic is then permitted to cool and shrink and when cooled to substantially room temperature the openings **69** and **70** are closed so as to seal the chamber **68**. At operating temperatures which are substantially above 400° F. the air in the space V_2 will compress but will not reach dangerous levels which would rupture the chamber **68**.

For example in a chamber filled to 80% of total volume with the above eutectic at 400° F., and sealed, operation was conducted at an operating temperature of 670° F. at an internal air pressure of 26 pounds per square inch. The original filling at 400° F. was convenient and eliminated the moisture from the chamber in the roll and from the eutectic.

FIGURE 6 illustrates a preferred construction for certain environments providing a rolling surface having good heat transfer properties, having a long wearing life, and being free from corrosive action from the materials engaged from the air. A roll **73** has end walls **74** for supporting an inner shell **76** with a cylindrical concentric outer shell **75**. The shells are separated by an annular end wall **80** to form a chamber **77** therebetween for heat transfer fluid. The outer shell is formed of layers and an inner layer **78** is preferably of metal and the outer layer **79** is of hard chrome.

Thus I have provided an improved apparatus and improved method which meets the objectives and advantages above set forth. The construction presents an improved and reliable heat transfer roll adapted for numerous heat transfer operations wherein a surface must engage a heat receiving surface without sliding friction and transfer heat energy thereto.

It will be understood that the rolls **4**, **5** and **6** are each provided with suitable heating means such as by electrical elements non-rotatably positioned in the rolls, similar to the structures of the other figures of the drawings. The rolls of FIGURES 5 and 6 are also provided with suitable supports for rotatably supporting the rolls and this may be done in any satisfactory manner as will be appreciated by those skilled in the art.

The drawings and specification present a detailed disclosure of the preferred embodiments of the invention, and it is to be understood that the invention is not limited to the specific forms disclosed, but covers all modifications, changes and alternative constructions and methods falling within the scope of the principles taught by the invention.

I claim as my invention:

1. A heat transfer roll comprising:

an outer roll shell,

an inner roll shell concentric with said outer roll shell,

annular spacers spacing said roll shells apart and forming an annular liquid tight chamber containing a heat transfer liquid in the space between said roll shells,

heating means heating the inner of said roll shells and the heat transfer liquid in said annular chamber,

bearing means supporting said heat transfer roll for rotation,

at least two oppositely disposed helical fins within said chamber and extending radially of one of said shells toward the other shell and terminating in radially spaced relation with respect to the other shell,

said fins extending helically along said one of said shells in opposite directions from locations disposed on opposite sides of the transverse center of said one of said shells toward said annular spacers, to circulate the hot liquid toward the cooler ends of said outer shell and return the liquid toward the transverse center of said outer shell.

2. The structure of claim **1**,

wherein at least two pairs of fins extend helically along said one of said shells in opposite directions from locations disposed on opposite sides of the transverse center of said one of said shells, toward said annular spacers and terminate in axially spaced relation with respect to said annular spacers.

3. The structure of claim **1**,

wherein at least two pairs of fins extend generally radially outwardly of the inner of said shells in opposite directions from locations disposed on opposite sides of the transverse center of the inner of said shells and terminate in substantial radial spaced relation with respect to the inner periphery of the outer of said shells,

and wherein the axial ends of said fins are spaced axially inwardly of said spacers.

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