Oct. 11, 1966 C. VAN TOORN 3,278,723

ELECTRICALLY HEATED ROLL

Filed Oct. 25, 1963 4 Sheets-Sheet 1

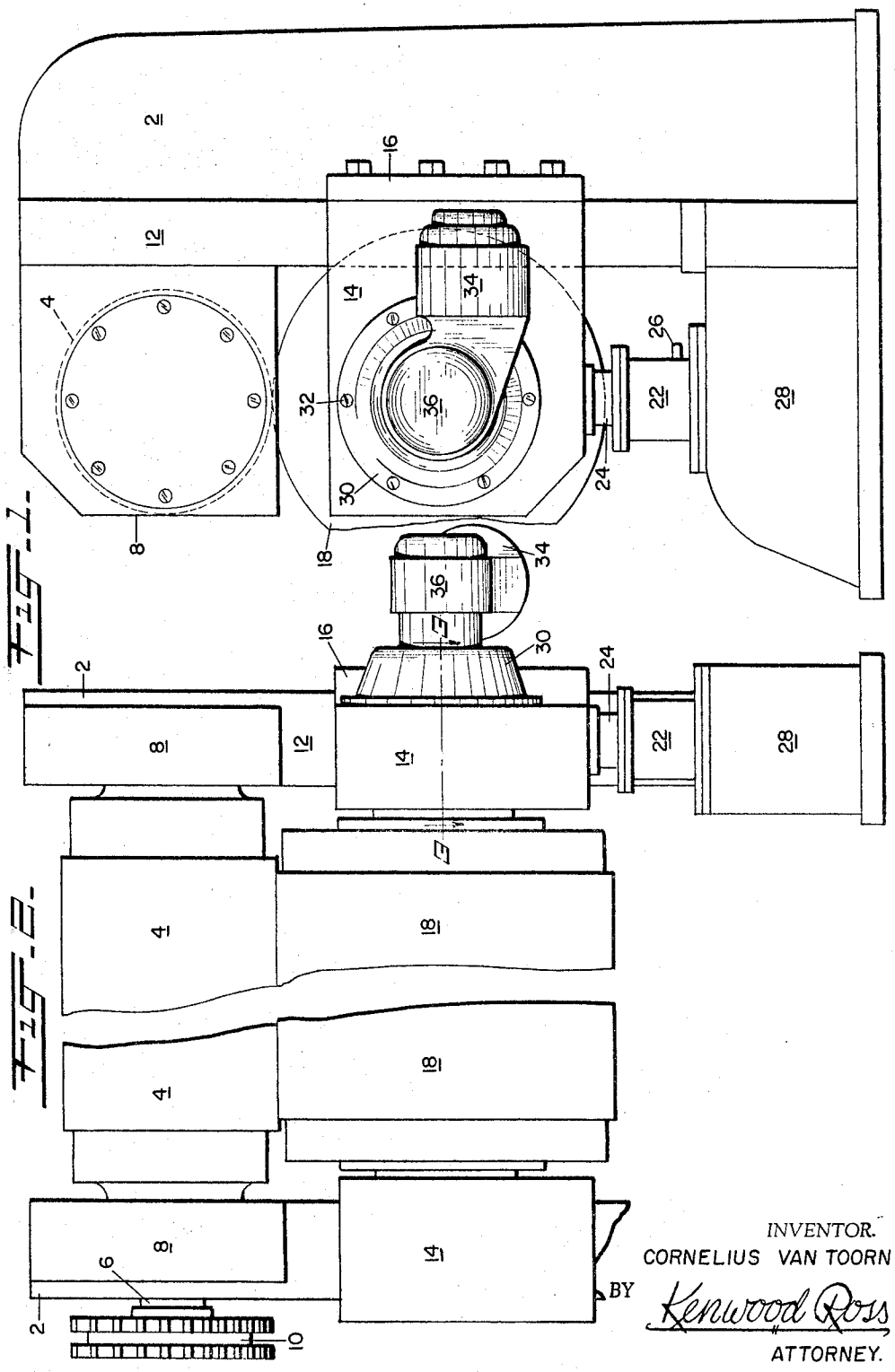

FIG. 1

FIG. 2

INVENTOR.
CORNELIUS VAN TOORN
BY Kenwood Ross
ATTORNEY.

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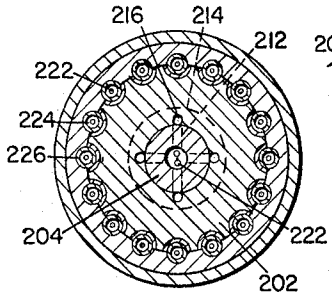

Fig. 4.

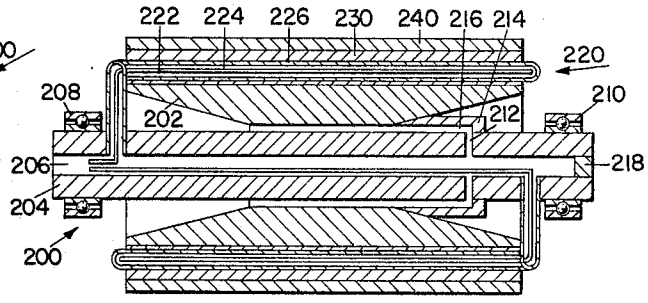

Fig. 3.

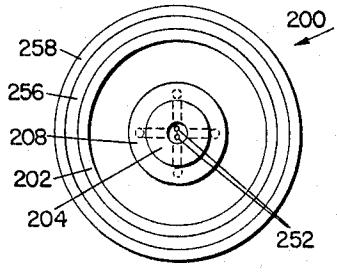

Fig. 6.

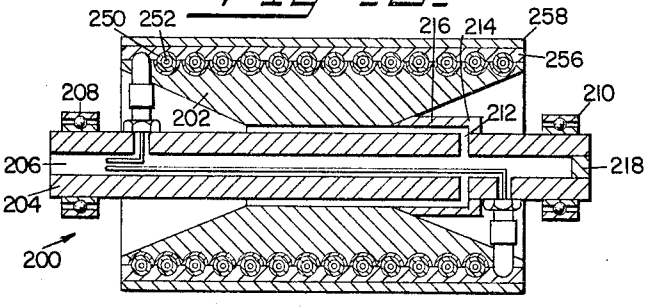

Fig. 5.

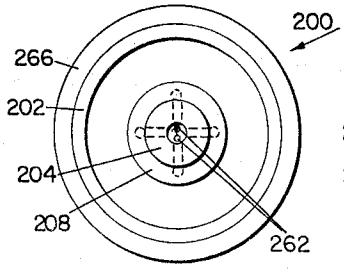

Fig. 8.

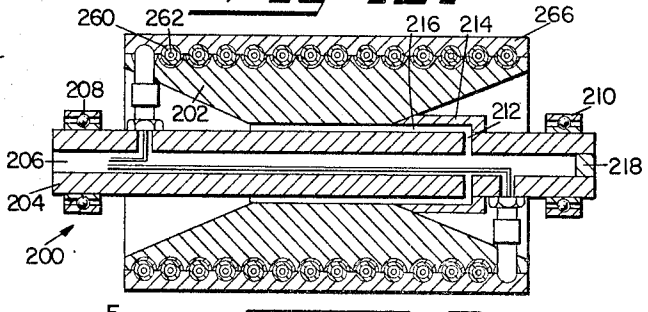

Fig. 7.

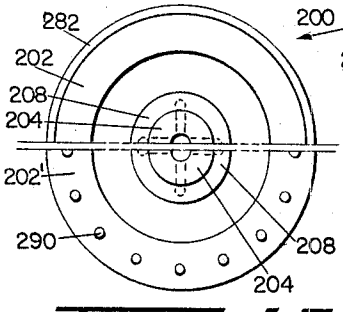

Fig. 10.

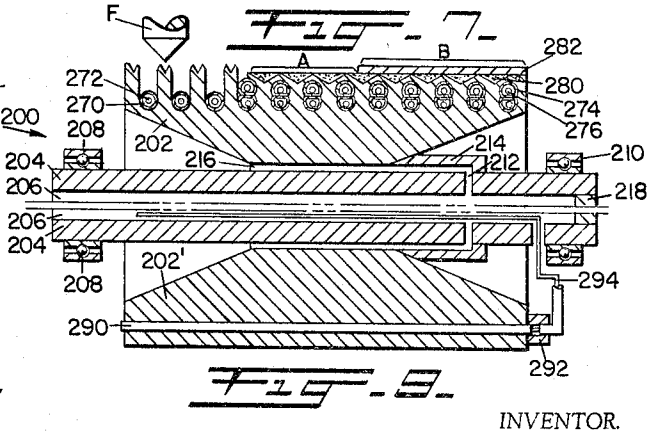

Fig. 9.

INVENTOR.
CORNELIUS VAN TOORN
BY Kenwood Ross
ATTORNEY.

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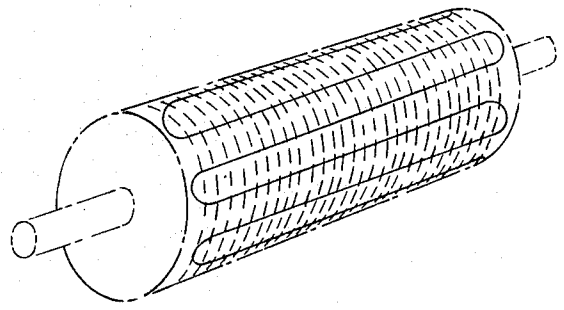

Fig. 11.

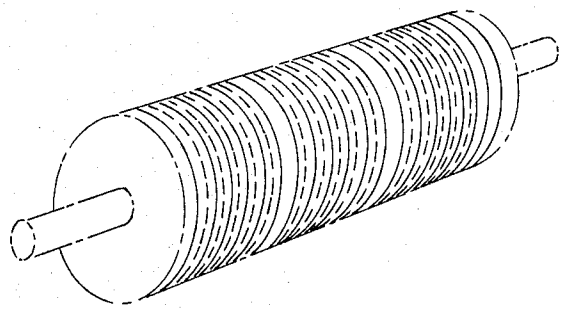

Fig. 12.

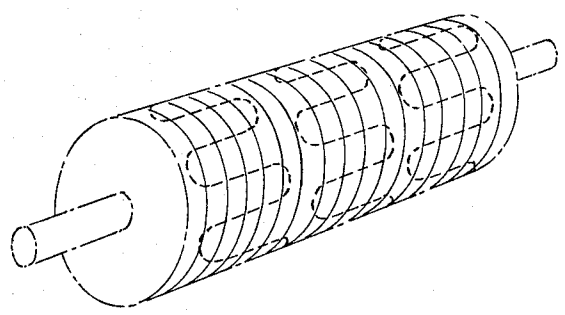

Fig. 13.

INVENTOR.
CORNELIUS VAN TOORN
BY Kenwood Ross
ATTORNEY.

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ELECTRICALLY HEATED ROLL

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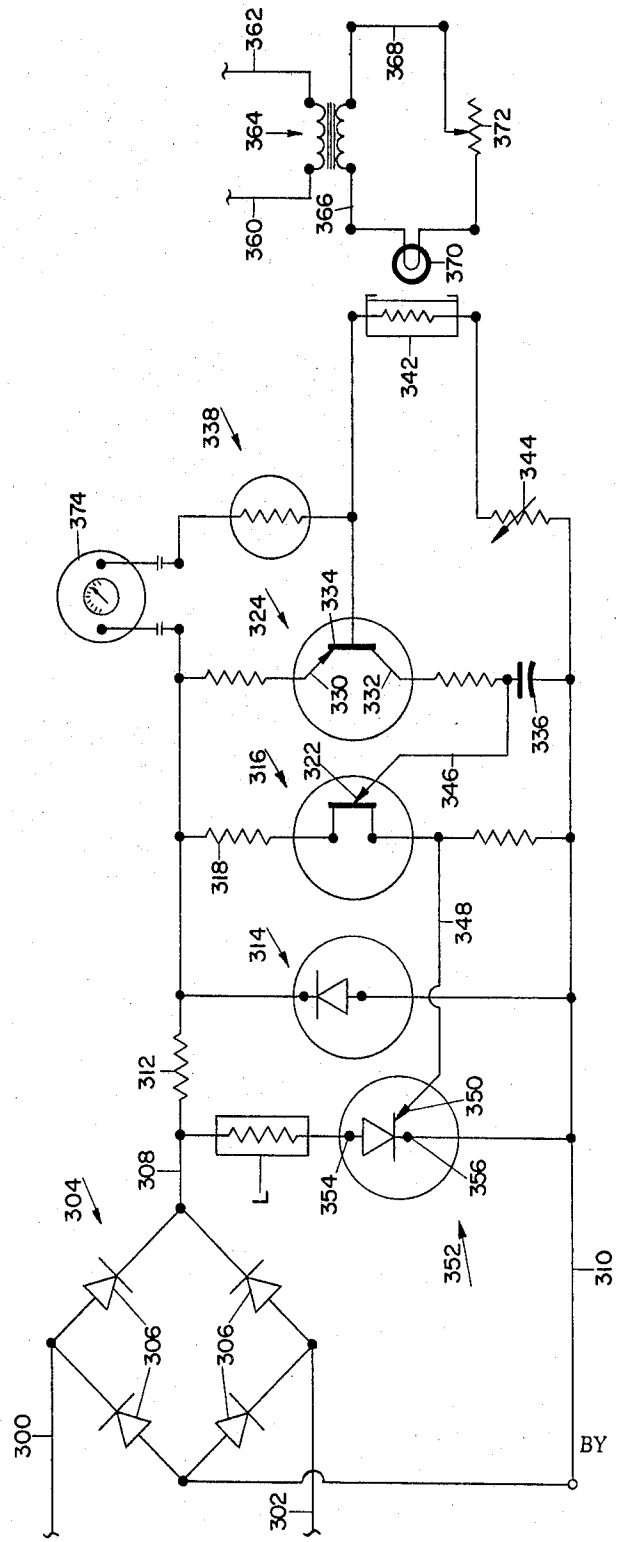

Fig. 4

INVENTOR.
CORNELIUS VAN TOORN
Kenwood Ross
ATTORNEY.

United States Patent Office

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ELECTRICALLY HEATED ROLL

Cornelius van Toorn, Cartierville, Quebec, Canada, assignor to B. F. Perkins & Son, Inc., Holyoke, Mass.

Filed Oct. 25, 1963, Ser. No. 319,072
1 Claim. (Cl. 219—470)

This invention relates broadly to new and useful improvements in the heating of rotatable rolls or cylinders or drums suitable for the drying and/or heat treating and/or ironing and/or polishing of continuous webs, bands, tapes, ribbons, filaments, yarns and other elongated articles, as in the production of paper, textiles or the like, and more particularly relates to electrically-heated rolls wherewith operating efficiency and rapid and uniform heating and/or drying under conditions of accurate and constant automatic temperature regulation are desiderata.

For various purposes, it is desirable to have a roll which may be uniformly and accurately heated throughout the entirety of its peripheral surface or throughout a smaller portion thereof, and moreover one in which the temperature may be selectively varied instantaneously and at will or otherwise positively controlled for employment in connection with the drying of a web as it is being continuously advanced relative thereto.

In the conditioning of certain materials with a heated roll, difficulties have consistently arisen in obtaining an even heating over the entirety of the roll surface, especially in the case of a paper web where the paper functions as a heat conducting medium to draw the generated heat away from the roll.

In contrast with prior art systems teaching the heating of a solid or a hollow roll, by means of steam, oil, other medium in gas or liquid form, or electricity, where the heating elements are introduced centrally of the roll, this invention comprehends a heating system wherein the generated heat is conducted outwardly to the outer or finishing peripheral layer of the cylinder, so as to offer a resultant high efficiency contributed to in part by a new and novel system of roll construction and in part by a new and novel electrical/electronic circuity to the end that the roll may be heated to and/or maintained at a desired temperature with greater speed and accuracy than has hitherto been possible with rolls incorporating electric heating elements.

In broadest aspects, one primary object of the present invention is to provide a roll having a hardened surface, and possessing structural rigidity such as to withstand the enormous physical stresses to which rolls of the comprehended types are normally subjected and to provide means cooperant therewith for electrically heating the roll characterized by a provided reliable and efficient conductivity path between the heat source and the roll surface whereby to maintain a desired temperature at the roll surface irrespective of whether or not the roll is rotating and absent a large temperature differential between the heat source and the roll surface and affording uniform drying through the entire length and/or width of the material in contact therewith.

It is another object to provide means by which the roll temperatures may be more dependably and uniformly regulated than has been heretofore possible by virtue of the heating elements being strategically positioned closely adjacent the peripheral surface of the roll and being rotatable therewith.

It is a further design hereof to provide a self-contained roll or drum or cylinder in the respect that it self-stores its heating elements as contrasted with a roll or drum or cylinder heated by adventitious means.

It is a particularly salient object hereof to provide a roll which shall be of uniform structure and density

throughout its peripheral surface in order to meet the exacting requirements dictated for such structures and to provide techniques of fabrication to insure that each roll shall be the equal of each other roll thus to guarantee uniformity of work pieces when and as two or more of such rolls are unisonly employed.

Further describing the invention broadly, the electrical elements are distributed over the roll periphery in manner to achieve a permanent main heating system which supplies the entirety of the peripheral surface of the heat roll with a given temperature under preset conditions, augmented by a secondary or supplemental heat system which is superimposed upon the permanent main heating system and is proportionally controlled to effect a supply of the superimposed balance of heat to the surface.

In contradistinction to so-called rate control systems wherein, during any change in the primary sensing circuity, the output is achieved by an instantaneous overshooting action, herein is taught a proportional control system designed to effectuate at any given moment an output, the magnitude of which is at any moment proportional to its cause. Stated otherwise, by proportional control is envisioned that any change or variation of magnitude in the sensing control circuity induces an amplification in the power system output which is distinctly proportional to the change in the primary circuity. The feedback, as an inherent feature of this distinct proportional control, is strictly physical and is represented by a heat path between the outer layer of the heat roll and a thermistor, which is physically located in this outer layer.

Among other advantages flowing from my invention may be mentioned the fact that the invention provides automatic compensation for heat demand which may vary in different applications according to the rate of product travel, product size, moisture content, atmospheric conditions or any practical combination of such factors or others not itemized, to the end that by so providing means for controlling temperature and hence the rate and degree of drying, the overall effect on the finished product represents substantial improvements as compared with that of similar products dried by any of the heretofore known prior-art drying methods.

My invention is particularly well adapted for embodiment in an electrically-heated calender roll and a device of this character is shown in the drawings for purposes of illustration, although my invention is by no means limited in this regard and may be applied to various other rotatable or otherwise movable bodies.

In such instance of specific purpose, webs of paper are adapted to pass over a series of rotating cylinders for the purpose of evaporating moisture from the web so that same leaves the last of the cylinders in a desired dried condition.

The distinguishing features of my invention, and the important structural elements characterizing the practical embodiments which are illustrated as examples, will be more particularly explained in connection with the details of construction and operation which are fully brought out in the specific description following, when read in conjunction with the accompanying drawings, in which:

FIGS. 1 and 2 are side and front elevational views respectively of calender apparatus and showing a pair of cantilevered rotatable drying rolls, embodying the novel features of the invention;

FIG. 3 is an axial cross-section of one form of roll for purposes of illustrating one construction of heated roll of the invention;

FIG. 4 is a sectional view through the midsection of the roll shown in FIG. 3;

FIG. 5 is an axial cross-section of another form of roll construction;

FIG. 6 is a sectional view through the midsection of the roll shown in FIG. 5;

FIG. 7 is an axial cross-section of another form of roll construction;

FIG. 8 is a sectional view through the midsection of the roll shown in FIG. 7;

FIG. 9 is an axial cross-section of still another form of roll construction;

FIG. 10 is a sectional view through the midsection of the roll shown in FIG. 9;

FIGS. 11–13 are schematic views of rolls illustrating various combinations of an arrangement of main or build-up circuit and modulated circuit superimposed thereover adjacent the respective outer peripheries thereof; and

FIG. 14 is a wiring diagram of a complete circuit of the proportionally electronically controlled load adaptable for employment with any of the various roll constructions of the invention.

Referring now to the drawings more in detail, the novel features of the invention will be described.

In FIGS. 1 and 2, a calender is shown incorporating side frames **2** of a pair which may take various forms and, in the usual situation, are secured on foundations and held in transversely spaced relation as to each other by transverse members (not shown) secured thereto.

An upper drive roll represented by **4**, has opposite end journal portions **6**, each rotatable in a bearing housing **8** of the respective side frame, in known manner.

A drive motor having a drive sprocket and associated drive chain, none of which are shown, is connected to a sprocket **10** of one of the end journal portions **6** of drive roll **4**. Any equivalent drive means which will continuously rotate the drive roll at a predetermined speed may be employed.

Side frames **2** are conventionally formed with vertical columns **12** on each of which a mounting means **14** is in vertically-sliding engagement and is held stationarily relative to its respective column as a gib **16** secured thereto and engageable with a rear side of the respective column.

A driven roll **18** may have opposite end portions, called hollow shifts **20**, each rotatable in suitable bearing means in its respective mounting means. Alternatively, a unitary hollow shaft may be provided which will extend longitudinally of and outboard of the opposite roll extremities.

The mounting means **14** may be unisonly elevated by any appropriate means to engage the supported driven roll **18** with drive roll **4**. For illustrative purposes, a cylinder **22** in which a plunger **24** is reciprocable may be provided for each mounting means. Pressure introduced via a cylinder inlet **26** to motivate the plunger will serve, in turn, to elevate the respective mounting means. Each cylinder **22** may be supported by an outwardly-extending portion **28** of the respective side frame.

A housing **30** is fixedly secured to one of the mountings **14** as by bolts **32** or the like, and an electric motor **34** may be associated with the housing **30** and suitably secured thereto.

A calender, thus described, being more or less conventional, further exemplification is not considered to be essential.

Conventionally, slip rings are employed to provide the electrical connections between a stationary member, such as a housing **30**, and a rotative member, such as a driven roll **18**.

Reference is next made to FIGS. 3–10 showing various types of roll constructions for purposes of exemplification.

Generally speaking, the rolls of each illustrated type envision a basic design seeming best to lend itself to ready fabrication of a calender roll which can be electrically heated with the successful effort being made to provide a concentration of the roll mass in or as near as possible to the heated surface.

In each of FIGS. 3, 5, 7 and 9 the basic construction will be observed to comprise an axially-bored cylinder,

generally indicated by **200**, comprising the roll proper, and including in each case a core section **202**, usually formed of steel and having walls which thicken linearly from each roll end toward an intermediate or central bore section, as shown, with a support shaft **204** being press-fitted into the bore and keyed to the core section in conventional manner to preclude separate rotation of shaft and roll.

The connection between core section and shaft constitutes the mechanical connection of the roll to the shaft, which connection acts as the only heat path between the roll structure per se and its cooperant shaft and also allows a cantilever effect.

Bearings **208**, **210**, preferentially of spherical roller self-aligning type are provided on the shaft at opposite sides of the roll.

The shaft is bored as at **206** to allow for shaft cooling as well as the cooling of bearings **208**, **210**.

An air cooling system (not shown) may be incorporated therewith and envisions a forcement of a supply of a gaseous fluid, such as compressed air from an outside source through the center bore from the left hand end, as viewed in FIGS. 3, 5, 7 and 9 wherefore bearing **208** is cooled by the center cooled shaft. Bearing **210** is not directly air cooled as the coolant flows radially from the shaft bore to the outer surface thereof through a plurality of radially extending coolant apertures **212** disposed in a transaxial plane in front of bearing **210** wherewith heat conduction along the shaft toward this bearing is opposed by means of a roll retaining sleeve **214** concentric with and spaced from the shaft and enclosing same in manner so as to force the coolant to flow in a counter direction through a plurality of circularly-arranged longitudinally-extending grooves or recesses **216** in the core section along the heat path in what I define as an equilibrium zone in that the heat in the path is disturbed wherewith the interface between the core section and shaft is effectively cooled.

Without such cooling means in the heat path, the residual heat would travel from the roll to the shaft and bearings and housing with a concomitant increase in the radiation area and a consequent disturbance of the equilibrium zone.

At the opposite end of the shaft, an air sealing plug **218** is disposed.

With more specific reference to FIGS. 3 and 4, roll **200** therein will be observed to be constituted in main by the previously described core section **202**.

In fabrication, the outer peripheral surface is first rough machined to a predetermined diameter and is then again so machined as to provide a plurality of semi-round or parti-circular recesses or grooves in spaced parallel relationship as to each other around the roll periphery and coaxial of the roll axis.

Each such recess is coated with a layer of an inorganic material such as aluminum silicate or equivalent cementious material preliminary to the seating therewithin of a section of a sinuously extending heating element or electrical conductor generally indicated by **220**. Said conductor is sinuously wound back and forth in each of the recesses around the roll periphery.

The conductor comprises a central conductor or resistance heat wire **222**, preferably of copper, embedded in an insulating medium **224**, preferably consisting of a mass of a refractive oxide, for example magnesium, which is extruded or otherwise formed over the central conductor to form a covering thereover, the whole being surrounded by a metallic retaining sheathing or covering **226** of a ductile metal such as copper tightly encasing the coated wire and insulating material and drawn as by dies or by rolling or the like for compressing the insulating material in situ into a densely compacted mass, the end product being capable of withstanding high temperatures.

Thereafter, the sections of the heating element, so positioned, may be operatively secured relative to the roll as

by a brazing to be held within the respective recesses against accidental derangement during the subsequent spraying operation.

A thin uniform layer of copper **230** is then sprayed, electroplated or otherwise applied, over the roll periphery and the upper exposed portions of the sections of the heating element supported thereby.

If spraying is the employed system, same may be by means of an atomizing gun with the metal being melted and the molten metal being atomized by means of an air blast and directed to the surface to be coated.

Where the metal to be deposited is in a powder form, a finely divided metallic powder may be heated to its melting point by blowing it through the flame of a blow pipe with the resulting spray being projected by an air blast toward and onto the roll.

The minute semi-molten particles constituting the spray acquire a superficial oxide coating which become incorporated into the coating being laid down, the impinging particles of metal being flattened into relatively thin half molten scales by virtue of the rapid deposition. As the coating is built up, these scales become interlocked with others preceding and succeeding same so as to allow a structure of high intrinsic tenacity, which covers the interfaces and the exposed portions of the core section between the sections of the heating element wherefore the metal in effect brazes itself to the base metal of the core section and the sheathing of the heating elements so as to allow a strong mechanical bond in the form of a high heat conductive layer in which the sections of the electrical element are encapsulated, they being fused solidly therein the said layer, thereby is constituted a superior conductive medium permitting a uniform and controllable distribution of heat throughout the entirety of the roll periphery capable of withstanding conditions of excessive heating followed by drastic cooling as may be normally expected to be encountered.

There following, a layer **240** constituted by fused colmonoy is spray welded to the outermost surface of layer **230** to provide a hard outermost working surface, the hardness thereof being according to anticipated requirements.

With more specific reference to FIGS. 5 and 6 roll, **200** constituted by the previously described core section **202**, is first rough machined to a predetermined diameter and is then further machined to provide a circumferentially-located helically-arranged semi-round continuous-from-end-to-end recess or groove around the roll periphery, in which recess is spirally wound a length of a heating element comprising a length of metallic tubing **250** such as of copper or stainless steel encapsulating a length of a conductor or resistance heat wire **252**.

Thereafter, the heating element, so spirally positioned, may be secured relative to the roll as by a brazing to prevent same from movement during the subsequent spraying operation.

A thin uniform layer **256** of copper is then sprayed, electroplated or otherwise applied over the roll periphery and the upper exposed portions of the heating element supported thereby.

There with is formed a high heat conductive layer in which the electrical element is encapsulated by being fused solidly therein, the formed layer constituting a superior conductive medium allowing a uniform and controllable distribution of heat throughout the entire roll periphery.

There following, a layer **258** constituted by fused colmony is spray welded as an outermost finished layer of a hardness desired.

Said layer **258** preferentially will have been first partly fused by an atomizing means followed by a fusion via means of a high frequency current.

With more specific reference to FIGS. 7 and 8, roll **200** comprising the core section **202** is first rough machined to a predetermined diameter and is then machined to provide a circumferentially-located helically-arranged continuous-from-end-to-end semi-round recess. The recess may be preliminarily conditioned by the coating with a layer of the above described inorganic cementious material such as aluminum silicate.

In said recess, a length of a heating element comprising a length of metallic tubing **260** such as of copper and incorporating a length of a resistance wire **262** is spirally wound.

A plurality of uniform layers **266** of chrome are then bombarded, each layer being bombarded from a different angle during an electroplating procedure designed to allow a finished surface of a desired hardness and adequately covering the roll periphery and the upper exposed portions of the heating element supported thereby.

With more specific reference to FIGS. 9 and 10 roll **200** constituted by core section **202**, is shown in its upper half portion, as illustrated, as being provided with a deep seated spirally-arranged groove circumferentially of the roll in which a continuous length of a heating element called a main source and comprising a copper tubing **270** sheathed around a resistance wire **272** is seated. Superimposed over the main source heating element in a portion only of the groove is a continuous length of a heating element comprising a copper tubing **274** sheathed around a resistance wire **276**, which heating element will serve as the heating element of one of the proportionately controlled zones identified as A, with another similar heating element superimposed over the main source heating element in a different portion of the groove representative of the proportionately controlled zone B.

With the heating elements in situ in superimposed arrangement, the groove may be swaged as by a forcing tool F so as to cause the walls of the groove to be pressed inwardly in an encapsulating manner on the heating elements.

A thin uniform partly fused layer **280** of colmonoy is then spray welded over the roll periphery and any exposed portions of the heating elements supported thereby.

Therewith is formed a high heat conductive layer in which the electrical elements are encapsulated, they being fused solidly therein the layer constitutes a superior conductive medium allowing a uniform and controllable distribution of heat throughout the entire roll periphery and allowing excessive heating followed by drastic cooling, working conditions normally expected to be encountered.

There following, a layer **282** constituted by fused colmonoy is spray welded over the layer **280** and is given a outermost finish by a high frequency means to offer a desired hardness according to anticipated requirements.

In the lower half portion of core section, identified as **202'**, as shown in FIGS. 9 and 10, said core section is envisioned as comprising a mehonite casting having a smooth mirrored outer peripheral surface and provided with a plurality of longitudinally-extending openings therethrough in spaced parallel relationship to each other adjacent to the roll periphery, in each of which openings a heating element **290** is seated, same comprising a boron bar capable of forming its own skin upon sintering so as to provide its own integral electrical insulating layer, and being coupled as by a coupling **292** to an electrical conductor **294**, only one of which, at one end of the bar, is shown.

This invention envisions that a permanent or main circuity including its roll heating elements may be employed above, so as to supply a given temperature to the outer roll surface, as comprehended in the exemplifications in FIGS. 3 and 4, 5 and 6 and 7 and 8, and further envisions that in other applications, such as illustrated in the exemplification in the upper half section of FIGS. 9 and 10, in combination with said permanent or main circuity, a proportional heat modulated controlled circuity including its roll heating elements may be employed by superimposition thereover.

Such proportional heat modulated control circuit may

be superimposed over the entirety of the roll surface or a plurality of such circuits may be each superimposed over a portion or zone of the roll surface, as will be hereinafter discussed in detail.

Such proportional heat modulated zone control system is achieved by the desired number of electric-electronic control circuities.

The roll or each zone thereof will incorporate its own temperature-sensing device designed to trigger an oscillating circuity forming an integral part of the entire electrical-electronic control and power circuity, now to be described in connection with FIG. 14 wherein is defined a direct current circuity, although it will be understood that the principles may be employed in connection with an alternating current circuity.

A voltage, 60 cycle alternating current, emanating from a current supply source (not shown) leads via leads **300**, **302** to a full wave bridge rectifier, generally indicated by **304**, and constituted by four matched rectifier cells **306**, with leads **308**, **310** leading from the rectifier to the other instrumentalities of the electric-electronic circuit.

A resistor **312** is provided along lead **308** and a Zener voltage regulating diode **314** is connected across leads **308**, **310**. A unijunction transistor, generally indicated by **316** is connected across leads **308**, **310** through resistors **318** and **320** and constitutes a three-terminal semiconductor device including the usual base-one and base-two ohmic contact and semi-conductive bar to which is made a single rectifying contact by an emitter **322**. Transistor **316** is a unilaterally conducting device, one base or terminal of which is negative with respect to the other for allowing current flow from one base to the other.

A PNP transistor, generally indicated by **324**, is connected across leads **308**, **310** through resistors **326** and **328** and is arranged in common collector configuration with an emitter base **330**, a collector base **332**, and a base **334**.

A power capacitor **336** is disposed in series with resistors **326** and **328** and transistor **324**, with the transistor serving as a variable resistor upon changes in the base voltage.

A thermistor, generally indicated by **338**, is connected across lead **308** and the common terminal **340** of the said thermistor, base **334** of transistor **324**, and a cadmium sulphide cell **342**.

The opposite side of cell **342** is connected to lead **310** along which an adjustable variable resistor or rheostat **344** is provided.

A lead **346** connects between the common connection of capacitor **336** and resistor **328** and emitter **322** of unijunction transistor **316**, and a lead **348**.

A lead **390** connects between the common connection of unijunction transistor **316** and resistor **320** and the gate **350** of a current triggered silicone controlled rectifier, generally indicated by **352**, which is connected across leads **308**, **310** in series with a load L, such as a roll.

Rectifier **352** has three terminals, an anode **354**, a cathode **356**, and said gate **350**.

Leads **360**, **362** lead from an alternating current source to a light source circuit supply transformer, generally indicated by **364**, the opposite side of which transformer is connected by leads **366**, **368** to a light source **370** with a light intensity (temperature control) variable resistor or rheostat **372** disposed in lead **368** for controlling the voltage of the filament in the light source and thereby the intensity thereof.

A pyrometer **374** is provided along lead **308**.

The operation of the circuits in the exemplification may be defined as follows.

Rectifier **304** converts the 60 cycle A.C. voltage, impressed via leads **300**, **302**, to pulsating D.C. voltage, ultimately applied to load L (the heating element in the roll or a zone thereof).

The pulsating D.C. voltage is applied along lead line **308** through resistor **312** and Zener voltage regulating diode **314** in series therewith and serving to hold the voltage relatively constantly, despite any sustained D.C. voltage variations, and serving also as the supply voltage for unijunction transistor **316** and PNP transistor **324**.

Unijunction transistor **316**, suited for use in the go-no-go type of voltage sensing here contemplated, functions to fire rectifier **352**. When its emitter voltage is less than a predetermined limit, the emitter is reverse-biased wherefore only a small emitter leakage current flows, but when it is greater than said limit, the emitter is forward-biased wherefore the emitter current flows. As the emitter current increases, the emitter voltage decreases wherefore a negative resistance characteristic is attained.

If the input signal is negative, the unijunction transistor will fire so as to trigger the pulse sensitive rectifier **352**, said rectifier allowing current to pass therethrough according to the supplied trigger voltage on its gate. Pulses will occur at the output of the unijunction transistor so long as the input signal remains positive, the output pulses being sufficient to trigger the pulse sensitive rectifier.

Thermistor **338** is a temperature-dependent resistor with a high negative temperature coefficient of resistance designed for exposure to thermal heat, as contrasted with normal resistors not so exposed to temperature, save for ambient temperatures, and responds to temperature changes sensed at the outer roll surface by effecting changes in the current flow.

In operative use, as heat is applied to the work load so as to increase the temperature thereof, the resistance is lowered. Stated otherwise, as the work load becomes more heated, the easier it conducts. Conversely, as the temperature of the work load decreases, the resistance is raised, in direct opposition to the effect of temperature changes on metals.

The collector current of the PNP transistor is controlled by the current in the base circuit which is in turn determined by the resistance of the thermistor, variable with the temperature, as aforesaid. Accordingly, the collector current likewise varies with the load temperature wherefore the PNP transistor serves as a variable resistance with values proportional to the load temperature (the temperature of the roll).

The capacitor functions as a timing capacitor for the unijunction transistor and is charged by the PNP transistor.

As the thermistor varies with the load temperature, the capacitor charges faster or slower as the resistance of the thermistor decreases or increases respectively.

With a direct current voltage impressed across leads **308**, **310**, the charge on the capacitor builds up to the peak point of the emitter voltage of the unijunction transistor and the PNP transistor assumes a negative resistance characteristic.

When the voltage on the capacitor just exceeds the peak point of the emitter voltage of the unijunction transistor, the emitter becomes forward-biased so as to cause the capacitor to discharge producing a positive pulse at the gate of the rectifier so as to trigger same by way of releasing from its blocking state so that current will flow therethrough.

After such discharge by the capacitor, the emitter of the unijunction transistor reverts back to its reverse-biased state, and the cycle is then repeated.

The rectifier functions as a conventional rectifier modified to the extent that it blocks in a forward direction until a small signal is applied to its gate. Until a pulse from the capacitor arrives at its gate, the rectifier remains in the blocking state. After the gate signal is applied, the rectifier conducts in the forward direction and continues conduction, even after the gate signal is removed.

If the instantaneous voltage is high enough to make the load current equal to or greater than the sustaining current, the rectifier will remain in the conducting state for the rest of the cycle. If it is not high enough, the

current may decrease until the next pulse arrives, when the instantaneous voltage may be high enough to sustain the current.

The rectifier may thus be observed to be turned on and off 120 times per second according to the pulsating voltage applied thereto which reaches zero 120 times per second, and each time the voltage so reaches zero, the rectifier assumes its blocking state and can only be turned on when another appropriate pulse arrives at its gate.

Therefor, the later in the cycle that the pulse arrives, the later the rectifier will be turned on, and accordingly the rectifier can be made to conduct for only a small part of a cycle or for a large part thereof.

The rectifier will stop conducting, if the current passing therethrough falls below its sustaining value; that is if the voltage across it falls below a predetermined critical value.

As a matter of actual practice, the conduction of the rectifier can be controlled by varying the thermistor within a range from between a completely-turned-off position to a substantially full time conduction (180 degree angle of conduction).

If the roll or load is operating at a fixed temperature and the temperature rises, the resistance of the thermistor decreases and the transistor base bias current falls, so that in turn the collector current decreases and the resistance increases. The average power in the load (the heaters) then drops and the temperature falls back toward its original value.

The opposite effect ensues if the operating temperature at the roll drops below the preset level.

If the temperature at the thermistor drops below the preset value, the resistance of the thermistor increases and the voltage flow at the base of PNP transistor decreases to cause more base and collector current to flow so as to charge the capacitor more quickly wherefor the unijunction transistor is caused to fire the silicon controlled rectifier so that in turn more power is thus applied to the heater to enable the temperature to return to the preset value. The reverse action takes place when and as the temperature attempts to rise above the preset value.

The cadmium sulphide cell acting as a light controlled rheostat is physically located within a suitable protective tubing (not shown) on the roll shaft, and the light source is located on a mounting (not shown) carried by the housing. The components are movable with respect to each other though they are not in physical contact with each other, their only interconnection being via the light beam directed by the light source toward the cell.

The fixed operating temperature is controlled by the cell, such operating temperature being maintained relatively constant by the action of the thermistor.

The light source provides a means for over-riding the manual temperature control device in the following manner. The resistance of the cell varies according to the intensity of the light directed thereonto so as to provide a control resistance on the roll proportional to the light source intensity.

Like the thermistor, the cell forms a voltage divider which provides a bias for the base of the PNP transistor, but unlike the thermistor, its resistance is varied by varying the intensity of light shining thereon.

Interconnected within the thermistor circuit is a temperature reading device or pyrometer, mounted on the housing, to provide intelligence as to the fixed temperature of the roll surface or of any of its zones.

With the exception of the thermistor, located beneath the outer peripheral surface of the roll, and the cell, located on the roll shaft, the balance of the electronic components are engaged with the shaft in manner wherefor the flow of coolant through the shaft is utilized for cooling the transistors, diodes, silicone controlled rectifiers and associated components.

In the three illustrative examples of windings of a permanent or main circuity and a superimposed secondary proportionally controlled circuity shown in FIGS. 11–13, the principles of supplying the entirety of the roll surface with a given temperature under pre-set conditions, augmented by a secondary system proportionally controlled to effect a supply of the superimposed balance of heat to the surface are exemplified by a variety of arrangements.

With the main circuity being incapable of holding a constant temperature due to the dissipating action of the paper or other web being passed thereover, the superimposed modulated control means allows a completely automatically controlled means so as to provide a constant temperature of determined value regardless of the conditions encountered by the main circuity.

In essence, the additional or secondary circuit is only necessary as more heat may be called for at the roll surface, and advantageously when and as the added power is required to provide the additional heat. The circuit effectuates at any given moment an output, the magnitude of which is proportional to its cause. Any change in magnitude, sensed by the sensing mechanism in the secondary circuit, induces an amplification in the power system output which is distinctly proportional to the change in the primary circuity.

In FIG. 11, a main circuity represented by dotted lines is shown as being spirally wound circumferentially of a roll and a secondary proportionally controlled modulated circuity represented by a solid line is shown as being sinuously wound axially of the roll and around the entirety of its periphery in a back and forth manner.

In FIG. 12, a main circuity represented by a solid line is shown as being spirally wound circumferentially of the roll and a series of secondary modulated circuities represented by dotted lines are shown as being each spirally wound circumferentially of the roll and in a side by side manner as to each other so as to cover different zones of the roll, it being understood of course that these zones can be of varying sizes as to each other.

That is, a zone, as the term is here employed, may comprise the entire roll periphery or a predetermined portion thereof, the heat control being accomplished by means of a plurality of circuities, one of the main heating system and one or more electric-electronic control circuities, there being one for each such zones inclusive of its own temperature-sensing-and-triggering mechanism and its own temperature-controlled electronic power source, by all of which means, a highly effective distribution of heat upon the roll surface is achievable. More particularly, the system can be so adjusted that at different zones of the roll, different heat conditions may be maintained according to the dictates found to be the optimum for that particular zone of the roll when drying any particular type of work.

In FIG. 13, a main circuity represented by a solid line is shown as being spirally wound circumferentially of the roll and a series of secondary modulated circuities represented by dotted lines are shown being each sinuously wound circumferentially of the roll and over a portion or zone of the periphery thereof.

I claim:

An electrically-heated roll comprising a rotatively mounted cylinder, means for turning said cylinder, a main helically wound resistance wire extending lengthwise of and within the outer wall of said cylinder, a series of zigzag secondary resistance wires extending lengthwise of said cylinder and arranged in spaced relation as to each other around said cylinder and in superimposed relation upon said main resistance wire, a plurality of collector rings disposed adjacent said cylinder, said main and secondary resistance wires being electrically connected to said collector rings, a source of electric energy, and connections between said collector rings and source of electrical energy.

(References on following page)

References Cited by the Examiner

UNITED STATES PATENTS

1,037,573	9/1912	Allen	219—244
1,433,674	10/1922	Carl	219—471
2,831,097	4/1958	Malewski	219—470
2,920,175	1/1960	Keen et al.	219—210
3,020,383	2/1962	Tsuneo Onishi et al.	219—470
3,037,106	5/1962	Seney	210—471

ANTHONY BARTIS, *Acting Primary Examiner.*

RICHARD M. WOOD, *Examiner.*

L. H. BENDER, *Assistant Examiner.*