

May 18, 1965

P. E. SCHNEDLER

3,183,718

MEASUREMENT OF TEMPERATURE OF CONTINUOUS STRIPS

Filed March 2, 1960

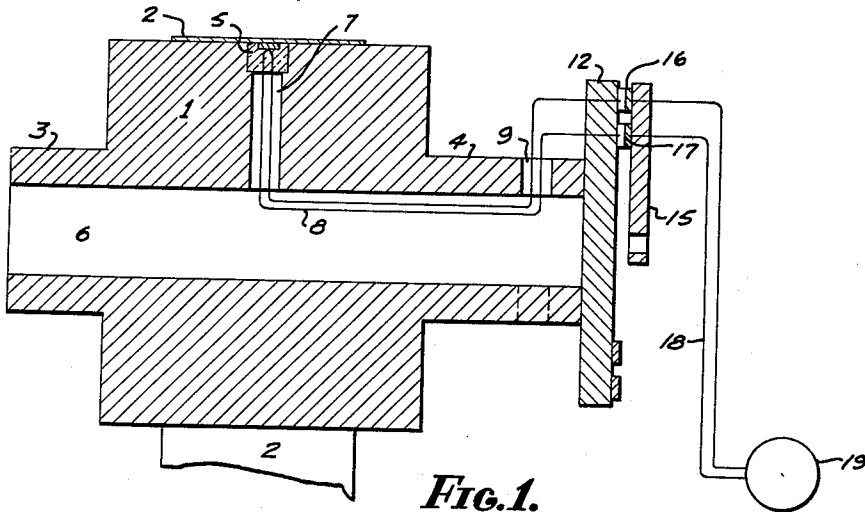


FIG. 1.

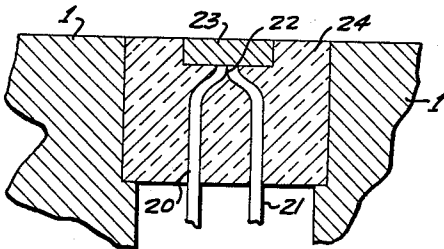


FIG. 3.

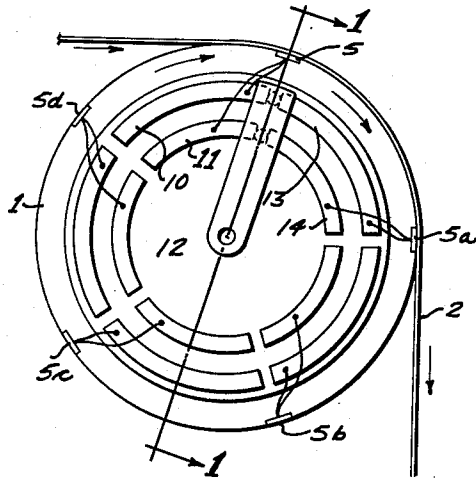


FIG. 2.

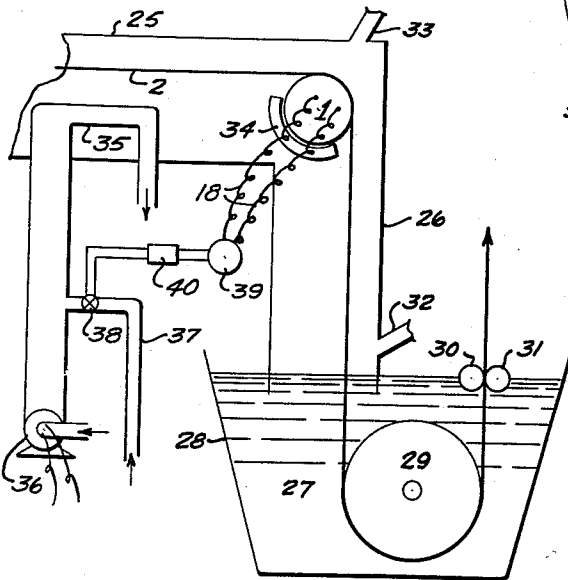


FIG. 4.

INVENTOR.
PAUL E. SCHNEDLER,
BY *Allen & Allen*
ATTORNEYS.

1

3,183,718

MEASUREMENT OF TEMPERATURE OF CONTINUOUS STRIPS

Paul E. Schnedler, Middletown, Ohio, assignor to Armco Steel Corporation, Middletown, Ohio, a corporation of Ohio

Filed Mar. 2, 1960, Ser. No. 12,325
8 Claims. (Cl. 73—351)

This invention deals with the problems involved in the measurement of the temperature of continuous strips and in the maintenance of the temperature of the strips within the certain desired limits. Such measurement and control is desirable in many fields including the production and treatment of paper, plastic, rubber and the like. It is useful in the annealing of metals where the temperature of the strip is often difficult to determine by other means, and it is useful in the heat treating of such metals as aluminum and steel where changes in the emissivity of the surface make temperature-sensing elements which depend on heat emission or radiation inaccurate. It may be used in such operations as the baking of films of paint or enamels on metal or other strips, where it is desirable to know the temperature of the strip rather than the temperature of the surrounding atmosphere. The utility of the invention is by no means restricted to high temperature heat treatments.

While the invention finds utility wherever such measurement and control are desired, it will be described in an exemplary but non-limiting embodiment having to do with the measurement of the temperature of a metallic strip just before it enters a bath of molten coating metal in a continuous coating process.

The Sendizimir United States Patents 2,110,893, 2,136,957 and 2,197,622 describe continuous coating processes and apparatus. In general a metallic strip to be coated is first cleaned of foreign materials in such a way as to produce upon its surfaces a thin and uniform film of oxide. Thereupon it is passed into an elongated reducing furnace in which it is subjected to a relatively high temperature. It passes from the reducing furnace through a cooling hood and thence through a snout into a bath of molten coating metal while the strip and the entrance portion of the bath are protected by a neutral or reducing atmosphere. The function of the cooling hood is to reduce the temperature of the strip to a temperature close to that of the bath. In many instances the temperature of the strip entering the bath is slightly higher than the temperature of the bath so that heat absorbed by the bath from the strip helps to keep the bath molten. However this may be, in any given coating operation the temperature of the strip should bear a controlled relationship to the temperature of the bath since the coating operation can be rendered less effective by too great a temperature differential in either direction. It will be understood that the optimum coating temperatures for different coating metals bear a relationship to their respective melting points and hence will differ from each other.

Hitherto great difficulty has been encountered in attempts to measure the temperature of moving strands or strips under circumstances such as those above outlined. Changes in the emissivity of the material preclude the obtaining of accurate readings from radiation type pyrometers. High ambient temperatures make accurate optical recordings impossible. Contact-type thermocouples have not hitherto proved practicable because no way had been devised to maintain an adequate contact between the thermocouple and the surface of the strip. Where a temperature differential between the strip and the bath of molten metal is desired, efforts have been made to measure the temperature of the bath at a position close

2

to the entering metal, and compare it with the temperature of the bath elsewhere in the coating pot. This gives at best an indirect indication, and does not show with sufficient rapidity the changes actually occurring in the temperature of the strip.

It is an object of this invention to provide a means and method for the measurement of the temperature of a continuous strip, which will not have the disadvantages previously outlined.

It is an object of the invention to provide a continuously acting temperature measuring means which is inexpensive, simple to construct, positive in use, and, when connected to a recording device, is capable of furnishing a continuous record of actual changes in strip temperature as they occur. In connection with the furnishing of such a continuous record, it is possible to control the temperature of the strip by manual or automatic means.

These general objects, and the more specific objects of the invention which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, are accomplished by that procedure and in that apparatus of which the aforesaid exemplary embodiment will now be described. Reference is made to the accompanying drawings wherein:

FIG. 1 is a semi-diagrammatic cross sectional view of a roll device used in the practice of the invention.

FIG. 2 is an end elevation of what is shown in FIG. 1.

FIG. 3 is a partial cross sectional view of a thermocouple and associated elements.

FIG. 4 is a partial sectional view of the end of a continuous coating apparatus showing a portion of the cooling hood, the snout, the bath of molten metal, and indicating the location of the temperature measuring device of this invention. The figure also illustrates a mode in which the temperature indication can be used to control the temperature of the strip.

Briefly, in the practice of the invention a series of thermocouples is mounted in connection with the periphery of a roll in such a way that good thermal contact is maintained between the surface of the strip and each thermocouple during a portion of the rotation of the roll, but in such a way that the strip is not dented or distorted. The strip is caused to wrap around a substantial portion of the circumference of the roll, say 90°, so that each thermocouple in turn will come into thermal contact with the surface of the strip and remain there throughout a given portion of the rotative cycle of the roll. The several thermocouples are connected to a commutating switch, a portion of which rotates with the roll, the commutating switch being so arranged in connection with the number and placement of the thermocouples in the roll that a substantial portion of the travel of each thermocouple with the strip can be allowed for heating or cooling of the thermocouple by the strip, while another portion of the travel is utilized for reading time in connection with a measuring or recording device. In one aspect of the invention, a heating or cooling means is provided acting primarily upon the thermocouples when not in contact with the strip so as to maintain them at a temperature approaching the temperature of the strip.

Referring first to FIGS. 1 and 2, the index numeral 1 represents a roll over which a strip 2 passes. The roll may be of any substance which is sufficiently wear resistant and is capable of withstanding the temperatures involved. For example a ceramic roll may be used; but a metallic roll can usually be more readily manufactured, and is quite suitable for the purposes of this invention providing the thermocouples are insulated from it in such a way as to be substantially unaffected by the transmission of heat through the body of the roll itself. It will be seen that the strip will be in contact with the roll

3

throughout a substantial arc of its circumference, say 90°. For the sake of simplicity the roll has been illustrated as a short roll and the strip as a narrow strip; but it will be understood that the roll may be lengthened as required to handle wide strips. Since in the exemplary embodiment of the invention the roll 1 will be located at the exit end of the cooling hood, the roll will be provided with reduced end portions 3 and 4 which will be mounted in suitable bearings for rotation (not shown) so that the moving strip may drive the roll.

The entire apparatus of FIG. 1 including the commutating switch hereinafter described, may be located wholly within the cooling hood. However, if desired, the reduced end portions 3 and 4 can be caused to extend through the side elements of the cooling hood, being provided with gas-tight glands or bearings. At intervals about the periphery of the roll 1 thermocouple assemblies will be mounted. One of these assemblies is indicated in FIG. 1 at 5. The interior of the roll is hollow as at 6 and there will be a passageway 7 from the thermocouple assembly 5 to the hollow interior of the roll. Thus a pair of wires 8 from each thermocouple assembly may be carried through the hollow interior of the roll to a position near an end thereof where, passing through another passageway 9 in the reduced end portion 4, these wires may be connected to conductive segments 10 and 11 on the insulative support 12 forming a part of a commutating switch.

In the construction of the commutating switch, care should be taken to avoid the use of any metallic combination for the segments and the contacts which would itself be productive of an electric current in the leads to the measuring or recording device.

FIG. 2 is semi-diagrammatic in that five thermocouple assemblies have been indicated at 5 to 5d inclusive spaced about the periphery of the roll 1. Each of these thermocouples is connected as above described to its own conductive segments on the commutating switch element 12. Thus the thermocouple assembly 5a is connected respectively to segments 13 and 14, etc.

The other portion of the commutating switch comprises an insulating element bearing a pair of contacts 16 and 17. The element 15 is held against rotation, so that its contacts will pass over each pair of segments on the element 12 in succession. The contacts 16 and 17 are connected by a pair of leads 18 to a device 19 which will either be a current measuring device adapted to give an indication of the current generated at a thermocouple, or a device adapted to give a continuous record, or a device adapted to automatically control the temperature of the strip. Such devices, calibrated in degrees of temperature are well known in the art. It will be clear from FIGS. 1 and 2 that the measuring or recording device will be connected successively with each of the thermocouple assemblies in the periphery of the roll 1.

The thermocouples themselves may be made of any of those metallic combinations which have hitherto been found useful for the measuring of temperatures. For example, but without limitation, Chromel-Alumel thermocouples may be used. So also couples of iron and constantan, or of platinum and platinum-rhodium, and many others will be found useful in the practice of the invention. As the skilled worker in the art will recognize, the couples themselves may be chosen in the light of the temperature ranges and environment to be measured. The problem of securing good thermal contact between the thermocouples and the strip is solved in this invention as indicated in FIG. 3. A thermocouple is formed from two wires or rods 20 and 21 of dissimilar metals welded together at their ends as at 22. A block of metal 23 of good thermal conductivity, adequate wear resistance, and adequate chemical inertness to the surrounding conditions is joined to the thermocouple and serves as the heat-transmitting contact between the thermocouple and the strip. Various metals may be used depending upon the condi-

4

tions. Aluminum and copper are effective. However, in the particular embodiment being described the metallic block 23 is preferably of silver. The thermocouple may be silver-brazed to the block 23. The silver block will not be subject to corrosion in the atmosphere of the cooling hood, and it will be found to have adequate wear resistance and excellent heat transmissivity.

The thermocouple and metallic block are mounted in a piece 24 which insulates the thermocouple and block from the body of the roll 1 both thermally and electrically. The piece 24 may be and usually is of ceramic material where the roll 1 is of metal; but other substances may be used which have a sufficiently low thermal conductivity and are so employed (if electrically conductive) as not to short the thermocouple. Thus a metallic piece could be used if it had a thermal conductive characteristic sufficiently low so that the thermocouple would not indicate merely the temperature of the rolls. Sintered metallic structures are exemplary. In a ceramic roll, a ceramic piece 24 would not be necessary for operability; but it is is advantageous to provide for removal and replacement of the thermocouples. The precise degree of thermal insulation is not a limitation on the invention. The effect is to make the thermocouple more rapidly responsive to the temperature of the strip irrespective of the general temperature of the roll 1. The contiguous surfaces of the roll and the metallic block 23 are flush with each other, and the outer surface of the piece 24 may either be flush or slightly recessed. It is within the scope of the invention to crown the roll 1 slightly so as to insure the contact of the metallic block 23 with the surface of the strip as it passes over the roll.

Size is not a limitation on the invention; but the thermocouple assemblies are usually small. The metallic block 23 for example may be a disc of metal about 1/4 of an inch in diameter and about 1/16 of an inch in thickness.

In the particular embodiment five thermocouple assemblies are equally spaced about the periphery of the roll 1. Each thermocouple is read for an arc of about 72° allowing 18° of arc for a pre-heat. At low rotational speeds, a high speed recorder may show a variation in reading, indicating an increase in thermocouple temperature during the reading period. If greater accuracy and less fluctuation is desired, more thermocouples can be installed around the periphery of the roll 1, so that a greater portion of the arcuate travel of each thermocouple with the strip can be utilized for pre-heating prior to reading. For example, ten thermocouples placed around the periphery of the roll, assuming again that the strip wraps around 90° of the circumference of the roll, will allow 54° of arcuate travel for pre-heating and 36° of arcuate travel for reading, thereby resulting in more uniform readings and possibly somewhat more accurate readings. It will be clear that the slower the rotational speed of the roll, the more thermocouples will be necessary to obtain uniform and accurate readings. The use of indicating or recording instruments of slower response will result in readings which are more uniform but with a slight decrease in accuracy. In this invention there is no limitation on the diameter of the roll, and the same number of thermocouples will give the same accuracy of reading irrespective of the diameter of the roll so long as its angular speed is the same.

As shown in FIG. 4, where 25 is the end of the cooling hood of a reducing furnace, the roll 1 may be used as the turn-down roll for the metal strip 2. The strip will pass through the snout 26 which dips into the bath 27 of molten coating metal in the pot 28. The direction of the strip is reversed within the pot by a roll 29 so that it exits upwardly. Exit rolls 30 and 31 are generally used. As has been indicated the strip will be cooled down in the cooling hood 25 from a high temperature in the furnace (not shown) to a temperature close to that of the molten metal 27 in the bath. The

5

molten metal may be zinc, zinc containing a small amount of aluminum, aluminum, tin, or others. Reducing gases, where used, are generally caused to enter the system through ports 32 in the snout and ports 33 at the end of the cooling hood. Since a cooling of the strip 2 is being accomplished, the ambient temperature in the hood and snout will generally be somewhat lower than the temperature of the strip. As a consequence, in temperature measurement, the strip will heat the thermocouples. This will explain the use of the expression "heating up time" hereinabove; but it will be appreciated that the utility of the apparatus of this invention is not limited to circumstances in which the temperature of the strip is higher than the temperature of the surrounding atmosphere or adjacent mechanical elements.

An even higher degree of accuracy and response can be achieved by the use of external heating or cooling devices around that portion of the roll which is not in contact with the strand. Such a heating or cooling device is indicated diagrammatically at 34 in FIG. 4. It may constitute an electric radiant heater or a fluid-cooled means. It may be limited in extent axially of the roll 1 so that it covers essentially only that part of the roll which carries the thermocouples. In this way it is possible to limit the heat loss or gain of the thermocouples by radiation or conduction during the period in which they are not in contact with the strip. For example, if a strip at approximately 1300° F. is passed over the roll 1 when it is operating in an ambient temperature of 700° F., each of the thermocouples will be significantly cooled, mostly by radiation after breaking contact with the strip. By placing an electrically heated element 34 close to the roll, the temperature of the thermocouples may be maintained close to the temperature of the strip so that as soon as each thermocouple contacts the strip it will assume strip temperature within a very short time. The temperature of the heating device 34 may be controlled by a differential potentiometer actuated by the thermocouples in contact with the strip.

The readings obtained from the temperature measuring device of this invention may be used in the exemplary embodiment to vary the conditions in the furnace or the cooling hood or both so as to maintain the desired correlation between the actual temperature of the strip and the temperature of the molten metal bath 27. In the exemplary embodiment, the hood 25 is provided with a plurality of ducts 35 extending through it for cooling purposes. These ducts are not open to the inside of the hood. Air at atmospheric temperatures may be blown through the ducts by one or a plurality of blowers 36. Where control of the temperature of the strip 2 is to be exercised through measurements of the exact temperature of the strip, one way of doing this is diagrammatically illustrated in FIG. 4. Here a branch conduit 37 for combustible gas or other fuel is connected into the duct 35 and is provided with a solenoid operated valve 38. The leads 18 from the thermocouple roll 1 may be connected to a controlling potentiometer 39 which in turn is connected through a relay 40 to the solenoid valve 38. The arrangement may be such that when the temperature of the strip 2 falls below a predetermined value, the valve 38 will be caused to open, resulting in the admixture of gas or other fuel passing through the duct 35. Within the duct there will be an automatic igniter so that upon the opening of the valve 38 the air-fuel mixture in the duct 35 will be ignited. In this way the duct 35 will be caused to have a warming rather than a cooling effect upon the atmosphere within the hood 25 and hence upon the strip 2. It will be understood that if the temperature of the strip then reaches a predetermined maximum the operation of the potentiometer and relay will be to close the valve 38 so that the continued movement of air through the duct 35 will have a cooling effect. This is illustrative of a mode of automatic temperature control.

6

The currents generated by the thermocouples in the roll 1 may be caused through a suitable multiplication of elements to control a plurality of ducts in the hood 25; and the connection of the thermocouple roll to the controlling potentiometer 39 does not preclude its connection also to a temperature recording means such as 19 described above.

The apparatus of this invention has been found to give an accurate temperature reading and to respond very rapidly to changes in the strip temperature.

Modifications may be made in the invention without departing from the spirit of it. The invention having been described in an exemplary embodiment, what is claimed as new and desired to be secured by Letters Patent is:

1. In a device for the purpose described, a roll over which a strip of material may be passed with the said strip conforming to a substantial portion of the circumference of the said roll, a series of thermocouples spaced peripherally about said roll in such position as to be in controlling thermal contact with such strip, a commutating switch comprising an element rotating with said roll and bearing segments to which leads from said several thermocouples are attached, and a stationary member bearing contacts coacting with said segments and connected to a measuring device, the placement of said segments on said first mentioned element, and the circular extent of said segments, being such that said measuring device will be placed in electrical contact with each thermocouple during the latter portion only of the travel of such thermocouple with said strip, there being a substantial portion of said travel during which each such thermocouple may assume a temperature controlled by the temperature of said strip without being in electrical connection with said measuring device.

2. The structure claimed in claim 1 wherein said roll is a metallic roll, and wherein each thermocouple is electrically and thermally insulated from said roll.

3. The structure claimed in claim 2 wherein each thermocouple is attached to a metal plate having a surface flush with the periphery of said roll and thermally insulated therefrom.

4. The structure claimed in claim 2 including a means in proximity to the surface of said roll in an area not contacted by said strip for maintaining said thermocouples in said area at a temperature close to the temperature of said strip.

5. In combination means providing an enclosed space in which a strip of material passing therethrough is altered as to temperature, said space containing heating and cooling means, a roll having an outer surface over which the said strip of material is caused to pass for a substantial arc of the rotation of the roll, and a series of thermocouples spaced peripherally about the surface of said roll, each thermocouple comprising elements of dissimilar metal welded together at an end, said end being attached to a block of metal of good heat conductivity located substantially at the peripheral surface of said roll, each said thermocouple being located in and supported by a mass of thermally insulative material inset into said roll and serving to insulate said thermocouple and its plate thermally from said roll, means for deriving electric currents from said thermocouples while in contact with said roll, said means including a commutating switch having a rotating element comprising segments attached respectively to leads from the several thermocouples, said segments being less in circumferential extent than the circumferential extent of the contact of said strip with said roll, said segments being so placed as to enable electrical connection to be made to said thermocouples individually during the latter portion only of their travel with said strip, which portion is substantially less than the full extent of said travel, and a connection between said means for deriving electric currents and said heating and cooling means such as to

control the temperature of said strip of material within said enclosed space.

6. A roll structure for the purpose described comprising a roll having an outer surface over which a strip of material is caused to pass for a substantial arc of the rotation of the roll, and a series of thermocouples spaced peripherally about the surface of said roll, each thermocouple comprising elements of dissimilar metal welded together at an end, said end being attached to a block of metal of good heat conductivity located substantially at the surface of said roll, each said thermocouple and its respective block being located in and supported by a mass of thermally insulative material inset into said roll and serving to insulate said thermocouple and its block thermally from said roll, said structure including a commutating switch having a rotating element comprising segments attached respectively to leads from the several thermocouples, said segments being less in circumferential extent than the circumferential extent of the contact of said strip with said roll, said segments being so placed as to enable electrical connection to be made to said thermocouples individually during the latter portion only of their travel with said strip, which portion is substantially less than the full extent of said travel.

7. The structure claimed in claim 6 wherein the number of thermocouples is chosen in connection with the speed of rotation of said roll and the circumferential extent of the contact of said strip with said roll such that a contact between a measuring device and said thermocouples individually may be made through said commutating switch in close enough succession to cause said measuring device to give a smooth reading.

8. The structure claimed in claim 7 including a temperature controlling means approached to the surface of said roll in the peripheral area thereof not contacted by said strip and acting on said thermocouples to maintain them at a temperature approaching that of the strip.

References Cited in the file of this patent

UNITED STATES PATENTS

1,578,280	Gibson	Mar. 30, 1926
1,759,220	Brown	May 20, 1930
1,971,666	Webster	Aug. 28, 1934
2,032,407	Frickey	Mar. 3, 1936
2,114,029	Perry	Apr. 12, 1938
2,237,036	Krough	Apr. 1, 1941
2,267,775	Wetzel	Dec. 30, 1941
2,428,129	Smith	Sept. 30, 1947
2,431,473	Flynn	Nov. 25, 1947
2,566,468	Taylerson	Sept. 4, 1951
2,666,799	Barsy	Jan. 19, 1954
2,698,872	Brofit	Jan. 4, 1955
2,712,236	Bennett	July 5, 1955

FOREIGN PATENTS

824,117	Germany	Dec. 10, 1951
---------	---------	---------------

OTHER REFERENCES

Industrial Engineering Chem. (IEC), vol. 18, No. 7, July 1926, pages 728 and 729.

ISAAC LISANN, *Primary Examiner*.

LEONARD FORMAN, *Examiner*.