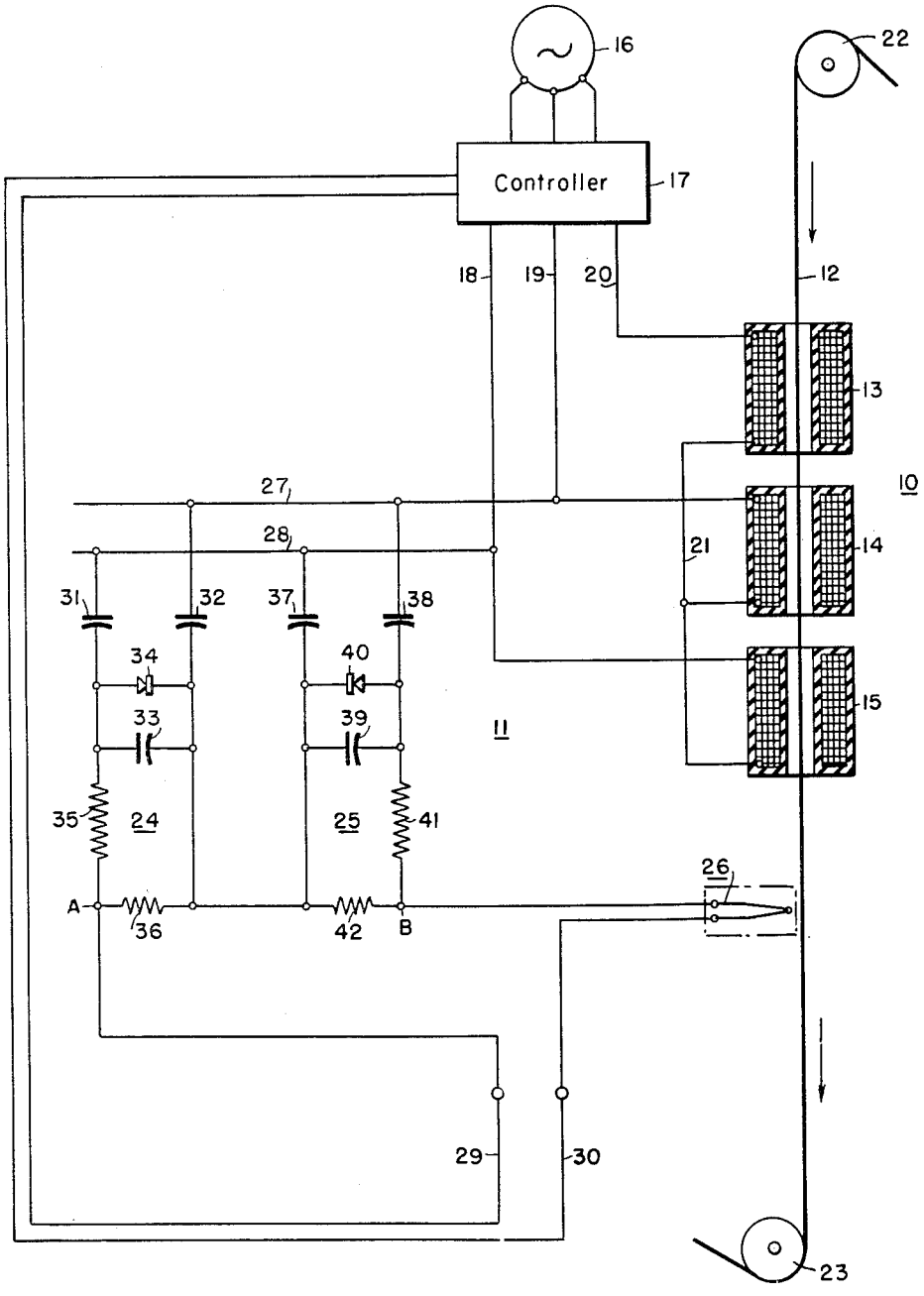
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COMBINATION CONTROL SYSTEM FOR CONTINUOUS HEAT TREATMENT

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WITNESSES:

E. A. McCloskey.

Wm. B. Sellers.

INVENTOR

Robert M. Baker.

BY

F. E. Browder

ATTORNEY

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COMBINATION CONTROL SYSTEM FOR CONTINUOUS HEAT TREATMENT

Robert M. Baker, Catonsville, Md., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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My invention relates to a control system for apparatus for heat treatment of metallic strip; and more particularly relates to a control system for maintaining a constant temperature in moving strip during continuous heat treatment thereof.

One of the difficult problems encountered in the continuous induction heat treatment of strip material is that of controlling the temperature of the strip within narrow critical limits. Absence of accurate and quick responsive control will often result in a defective material which must be scrapped.

It is an object of my invention to provide an improved control system for the continuous heat treatment of moving metallic strip.

It is another object of my invention to provide a control system for the continuous heat treatment of moving metallic strip which will maintain the temperature of the strip substantially constant during heat treatment.

A further object of my invention is to provide a control system for the continuous induction heat treatment of moving metallic strip which will compensate for sudden line voltage fluctuations substantially as they occur.

It is a still further object to provide a substantially constant temperature in the strip as it leaves the heating member.

These and other objects of the invention are effected as will be apparent from the following description and claims, taken in accordance with the accompanying drawing which forms a part of this application.

In the single figure of the drawing is illustrated an induction heating apparatus according to my invention.

In accordance with one preferred embodiment of my invention, a control system is provided for use with apparatus for heat-treating strip metal by inducing currents therein through the medium of transverse magnetic flux; that is, transverse to the direction in which the strip is traveling. One such apparatus is that described and claimed in my Patent No. 2,448,009, dated August 31, 1948. It is understood that the present invention is applicable to the heat treatment of magnetic and non-magnetic strip, respectively, and applies equally well to other strip heating apparatus, and even apparatus where gas heating is employed. In the latter case, the controlled element would be a gas valve and the voltage responsive circuits, to be described later, would be replaced by gas flow indicators with radically different time constants.

Referring to the drawing in detail, I illustrate apparatus employing my invention for heat treatment of metallic strip, such as aluminum alloy or the like.

The apparatus illustrated in the drawing comprises heating means or coils **10**, means for applying power to heating means or coils **10**, means for moving strip material through the heating means or coils **10**, and a control circuit indicated as a whole by the reference number **11** for controlling the temperature of a moving strip **12**.

The heating means or coils comprise three serially connected induction coils **13**, **14**, and **15**. The coils **13**, **14**, and **15** have an opening centrally located therein through which the strip material **12** is passed for heating.

Power for heating the strip material is supplied from some suitable external three-phase source, such as illustrated by the reference number **16**. Power from the source **16** is connected to the three coils **13**, **14**, and **15** through a control member **17** and conductors **18**, **19**, and **20**. The three coils **13**, **14**, and **15** are serially connected by conductor **21**.

Strip metallic material **12** is moved through the coils **13**, **14**, and **15** by means of rolls **22** and **23**, which are driven by some satisfactory means, not illustrated.

A control circuit **11** is illustrated as comprising two compensating circuits **24**, **25**, and a detector or sensing element **26**. One phase of power source **16** is connected to circuits **24** and **25** through conductors **27** and **28**. The compensating circuits **24** and **25** are connected serially with the detector element **26**, and the output of control system **11** is connected to the control member **17** through conductors **29** and **30**.

The compensating circuit **24** of the control circuit **11** comprises capacitors **31**, **32**, and **33**, a rectifier **34**, and resistances **35** and **36**. Circuit **25** of the control circuit **11** comprises capacitors **37**, **38**, and **39**, a rectifier **40**, and resistances **41** and **42**. The rectifiers **34** and **40** are poled such that the capacitors **33** and **39** are charged up to the peak voltage of the power source **16**. The values of the resistances **35** and **36** are such so as to give circuit **24** a long resistance-capacitance time constant. The values of the resistances **41** and **42** are such so as to give circuit **25** a relatively much shorter resistance-capacitance time constant than circuit **24**. The detector element **26** is a temperature sensing element of the type which is sensitive to infrared radiation from the strip **12**. One side of the detector element is connected to the power controller **17** through resistors **42** and **36** and a conductor **29**. The other side of the detector **26** is connected directly to the controller **17** through conductor **30**.

An aluminum alloy strip **12** passes over a roll **22** and then downward through the induction heating coils **13**, **14**, and **15** where the strip is inductively heated through the medium transverse magnetic flux.

The strip **12** passes from the heating means or coils **10** and travels past the temperature sensing element **26**. The strip **12** then passes around a roll **23** to other apparatus (not shown) for other possible handling, controlling or treating.

The temperature of the strip **12** is sensitive to changes in the voltage at the power source **16**, to changes in the speed of the strip, and to changes in the gauge of the strip.

The temperature sensing element **26** responds variably in accordance with the temperature of the strip **12**. The intelligence from this element **26** which is located immediately below coil **15** of the heating means **10** will be adequate for control purposes when the above-mentioned quantities vary slowly as compared to the time required for the strip **12** to traverse the length of the heating means **10**. However, rapid changes in the voltage at the power source **16** will occur and the temperature sensing element **26** cannot sense a changing requirement until that portion of the strip **12** in the heating means **10** at the time of the change has had time to move down in close relation to this element **26**.

Since circuit **24** has a long time constant and circuit **25** has a relatively shorter time constant than circuit **24**, due to the action of the rectifiers **34** and **40**, the direct-current voltage appearing across resistor **42** will thus follow closely the momentary variations in supply voltage; whereas, the voltage across resistor **36** will retain for some time after a sudden change in supply voltage a direct-current voltage proportional to the supply voltage

existing before the sudden change occurred. Thus, the difference voltage between points A and B will be proportional to the amount of sudden change in supply voltage 16. The values of resistors 35, 36, 41, and 42 are chosen so that zero difference voltage is produced under steady state voltage conditions or when the supply voltage 16 is varying slowly. The difference voltage is connected in series with the direct-current output voltage of the temperature sensing element 26.

Assume that the terminal voltage on the inductive heating member 10 has suddenly dropped. The voltage across resistor 42 will be lower than the voltage across resistor 36, and the difference voltage is in such a direction as to oppose the voltage put out by the temperature sensing element 26. This results in a lowered output voltage being supplied to the control member 17. Thus, the effect is the same as if the temeprature sensing element 26 had immediately responded to a decrease in strip temperature and controller 17 will start immediately to correct the discrepancy.

Thus, we see that the voltage responsive circuits 24 and 25 are anticipating in their action and initiate a correction immediately upon the occurrence of a sudden change in line voltage. The other quantities such as strip speed and strip gauge vary slowly and can, therefore, be compensated for by the temperature sensing element 26 without excessive variations in strip temperature.

While I have shown my invention in a preferred form, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit thereof.

I claim as my invention:

1. In apparatus for the heat treatment of moving metallic strip and operable with a power supply providing an output voltage and having a control member, the combination of an induction heating member adapted to be connected to said power supply to receive said output voltage, a control circuit connected between said induction heating member and said control member, said control circuit comprising a temperature detector element and first and second control networks, said temperature detector element providing an output signal responsive to the temperature of the moving strip, said first control network having a first time constant and being connected to said power supply to be responsive to variations in said output voltage to provide a first control voltage, said second control network having a second time constant and being connected to said power supply to be responsive to variations in said output voltage to provide a second control voltage, with said first and second control networks being connected to said temperature detector element such that said output signal is combined with said first and second control voltages for controlling the temperature of said strip.

2. In apparatus for the heat treatment of moving metallic strip and operable with a power supply having a control member, the combination of an induction heating member adapted to be connected to said power supply, a control circuit connected between said induction heating member and said control member, said control circuit comprising a temperature sensing element which produces an output voltage dependent upon the temperature of the strip as it leaves the induction heating member, voltage responsive means consising of a first circuit with a long time constant and a second circuit with a relatively shorter time constant than said first circuit, means for comparing the output voltage of said first and second circuits to produce a difference voltage proportional to a sudden change in supply voltage to said induction heating member, and means for applying the output of said temperature sensing element in series with said difference voltage to the control member to maintain a constant temperature in said moving strip.

3. In apparatus for the heat treatment of moving metallic strip and operable with a power supply having a control member for regulating the voltage from the

power supply, the combination of an induction heating member adapted to be connected to the power supply through the control member, a control circuit connected between said induction heating member and the control member, said control circuit comprising a temperature sensing element for producing a voltage dependent upon the temperature of the strip as it leaves the induction heating member, voltage responsive means consisting of a first circuit with a long time constant and a second circuit with a relatively shorter time constant than said first circuit, means for comparing the outputs of said first and second circuits to produce a voltage proportional to a sudden change in supply voltage, and means for applying the output of said temperature sensing element in series with said difference voltage to the control member to maintain a constant temperature in said moving strip.

4. In apparatus for the heat treatment of moving strip-like material and operable with a power supply providing an output voltage and having a control member, the combination of an induction heating member adapted to be connected to said power supply to receive said output voltage, a control circuit connected between said induction heating member and said control member, said control circuit comprising a temperature sensing element having an output signal and first and second voltage compensating circuits which are responsive to variations in said output voltage, with said first voltage compensating circuit including a first time constant network and providing a first control signal and said second voltage compensating circuit including a second time constant network and providing a second control signal, with said temperature responsive element being connected to said first and second voltage compensating circuits such that said output signal is compared with the difference between said first and second control signals to thereby control the temperature of said strip.

5. In apparatus for the heat treatment of moving metallic strip and operable with a three-phase power supply providing an output voltage and having a control member, the combination of an induction heating member adapted to be connected to said power supply through said control member to receive said output voltage, a control circuit connected to said control member and one phase of said power supply for maintaining a substantially constant temperature in said moving strip, said control circuit comprising a temperature sensing element having a first output signal and first and second voltage comparison circuits responsive to variations in said output voltage, with said first voltage comparison circuit providing a second output signal and said second voltage comparison circuit providing a third output signal, with said first and second voltage comparison circuits being connected to said temperature sensing element such that said control circuit is operative to control the heat treatment of said strip in response to said first, second and third output signals.

6. The apparatus of claim 1, with the first time constant of said first control network being longer in duration than said second time constant of the second control network.

7. The apparatus of claim 4, with the first time constant of said first time constant network being of different duration than the second time constant of said second time constant network.

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