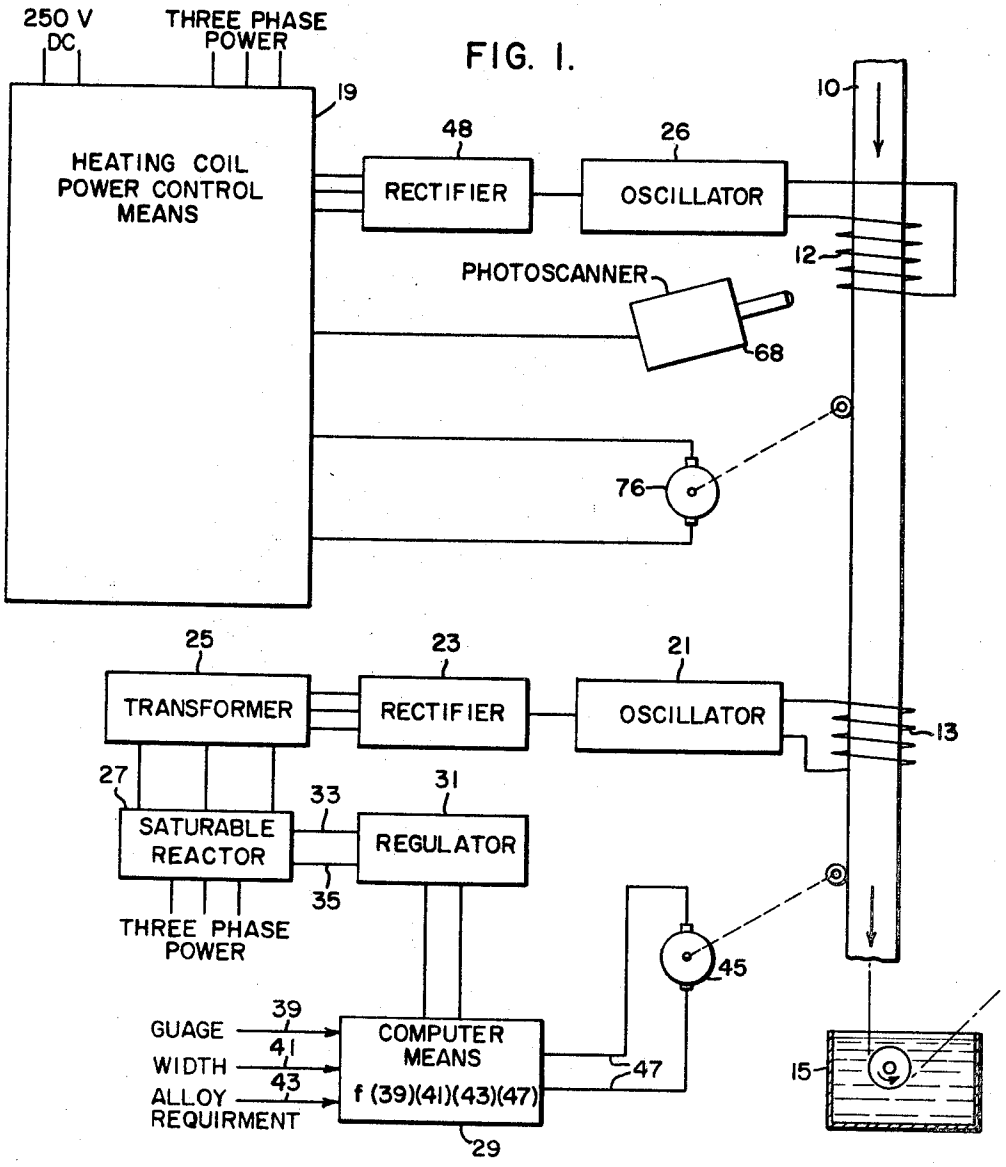
Aug. 20, 1968 A. P. BOCK ET AL 3,398,252

HEAT TREATMENT APPARATUS

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FIG. 1.



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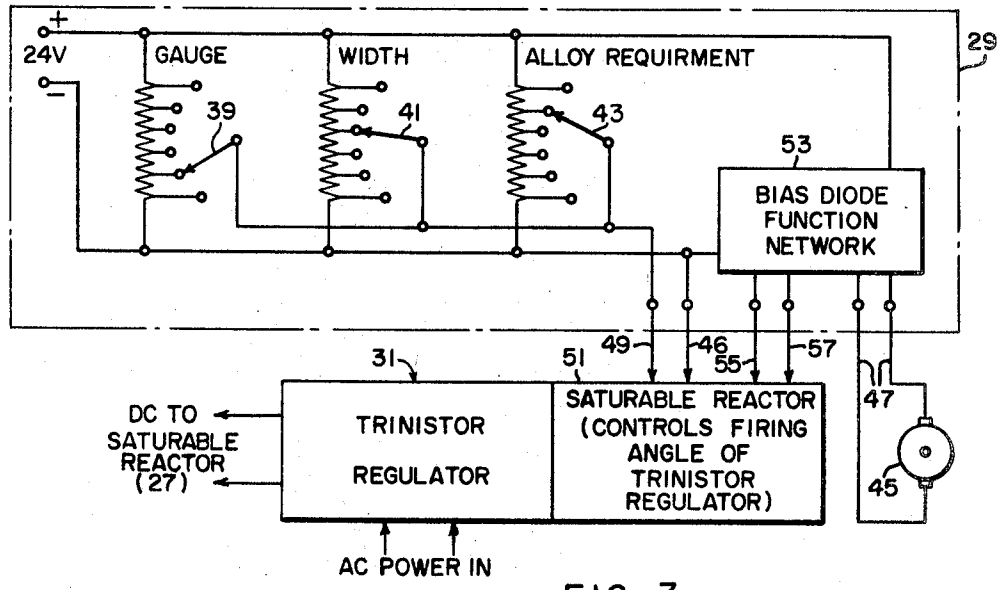


FIG. 3.

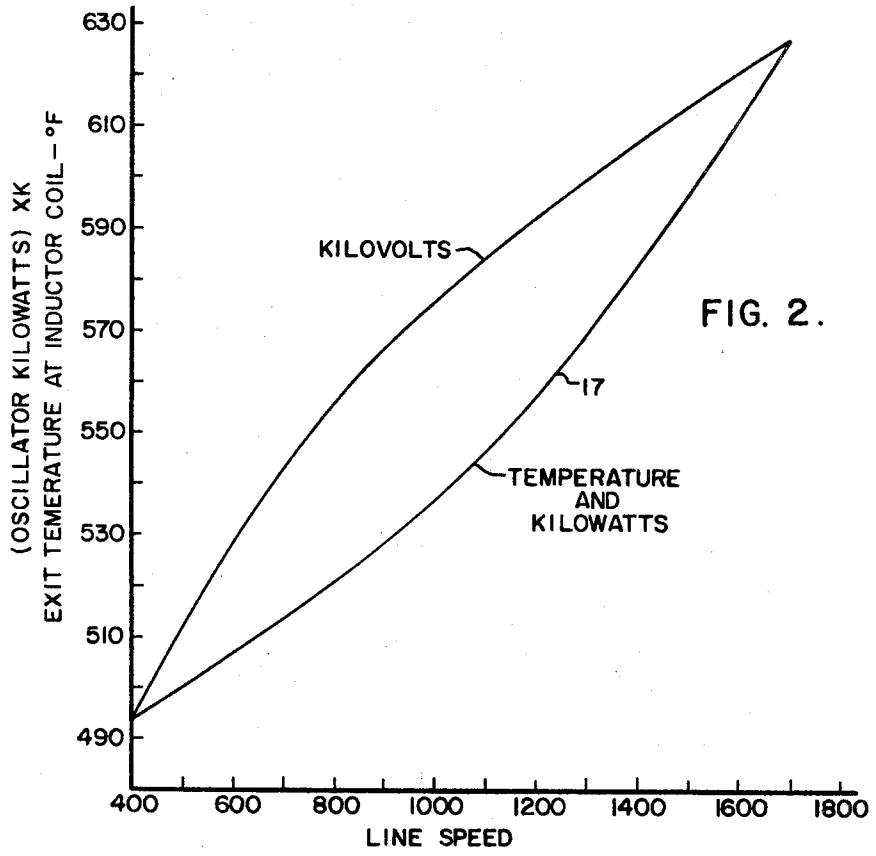


FIG. 2.

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3,398,252

HEAT TREATMENT APPARATUS

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ABSTRACT OF THE DISCLOSURE

An apparatus for continuous heating of longitudinally-advancing tin plated steel strip entering a quenching station to obtain alloying of the tin with the steel. A first heating and control means heats the strip to obtain melting of the tin along a flow-line automatically held at a fixed location along the heating line irrespective of strip speed, and a second heating and control means heats the strip further to raise the strip temperature with a high degree of accuracy to different speed-determined values by automatic regulation in reliance on the stable reference point conditions existing in the strip at the fixed site of the flow line.

It has been proposed to heat tin plated steel strip to a temperature above the melting point of the tin plating on the surface of such strip followed by quenching in a liquid bath to obtain alloying of the tin with the steel for purposes of improving the protection afforded by the tin to the steel.

It is desirable that the apparatus for performing such heating of tin plated steel strip material be operated in a continuous manner successively through a heating station and a quenching station. It is also desirable that the rate of travel of the steel strip during such heat treatment be at a relatively high production rate, and that the temperature to which the strip is heated prior to introduction to the quenching bath be accurately regulated, preferably within plus or minus five degrees F. Accordingly, it becomes an object of the present invention to provide heat treatment apparatus which is capable of obtaining such desired result.

It also is desirable to be able to regulate the production rate of operation of the heat treatment apparatus to satisfy different line demand conditions and that the travel distance of the strip to the quench bath be a fixed distance. Accordingly, with different rates of strip speed travel, the strip will be at heated temperature for different lengths of time enroute to the quench bath. To obtain a particular desired alloying condition of the strip under such variable time-at-temperature conditions it becomes necessary to vary the temperature to which the strip is heated prior to entry into such bath according to the rate of strip speed. It thus becomes another object of the present invention to provide a heat treatment apparatus for alloying of tin plated steel strip by continuous heating and quenching in a fixed travel distance quench bath, which apparatus automatically regulates the temperature to which the strip is heated according to the speed of travel of the strip through the line commensurate with the desired alloying condition corresponding to such strip speed.

In general, the present invention satisfies the above

objects by provision of an induction heating coil means through which the strip passes to obtain such rapid heating thereof as to realize melting of the tin plating on the surface of the strip along a flow line extending transversely of the strip and within the domain of such heating coil means; to observe such flow line with a photoscanner means and providing a heating coil power control means responsive to information from such photoscanner means to so regulate the output of the induction heating coil means as to obtain a fixed position of such flow line with respect to such heating coil; and to provide a second heating source and control means, separately regulatable with respect to the first heat source, including control means responsive to speed of travel of the strip to automatically regulate the effectiveness of such second control means to obtain the desired heated strip temperature automatically with the required degree of accuracy irrespective of the speed of travel of such strip. By virtue of such arrangement where the strip is heated initially to a certain fixed temperature as represented by the melting of the tin on the surface of the strip at a certain location as determined by a fixed position of the flow line observed by the photoscanner affiliated with the first heating means, such uncontrollable variables as moisture variations on the surface of the strip are eliminated for the strip as it appears to the second heating means for its final stage of heating and the function of the control means affiliated with the second heating means can be performed with a degree of certainty and accuracy based merely on known performance capability of the second heating means in response to different energy level inputs at different strip speeds and strip temperature desired to be obtained at such speed.

In accord with an alternate construction of the apparatus, the control system affiliated with the second heating means can be made to function to automatically adjust set point temperature for operation of the heating means according to line speed information, and to check the actual strip temperature obtained thereby by suitable temperature sensing means to produce an error signal to which the control means will respond to any vernier adjustments in heat applied to the strip.

Other features, objects, and advantages of the invention will become apparent from the following more detailed description of the invention when taken in connection with the accompanying drawings, in which:

FIGURE 1 is a block diagram of the heat treatment apparatus of the present invention;

FIG. 2 are curves showing operating relationships obtained by the apparatus of FIG. 1; and

FIG. 3 is a schematic representation, partially in block diagram form, showing an illustrative form of computer embodied in the apparatus of FIG. 1.

Referring to FIG. 1, the tin plated steel strip **10**, which may vary in thickness from about 4 to 15 mils and in width from 30 to 40 inches, is in continuous form and is advanced longitudinally by roller means (not shown) to pass consecutively through a first heating means in the form of an induction heating coil means **12** and a second heating means preferably in the form of second induction heating coil means **11** and thence to a quench bath **15**. The function of the first induction coil means **12** is to heat the strip **10** up to a temperature at which the coating of tin on the surface of the strip begins to melt, namely 452° F., at some longitudinal fixed location along the

length of such coil and subsequently heat the surface of such strip to a final alloying temperature of from 500 to 650° F., for example, according to travel speed of the strip, prior to introduction to the quench bath **15**. The length of the heating coil **12** is relatively short, having perhaps ten turns and being about two to four feet long, the heating capability of the coil **12** is applied to such high concentration that the tin coating on the surface of the strip **10** is made to melt along a sharp flow line (not shown) which is observable by a photoscanner **68** and has a sharp line of demarcation between the melted and unmelted tin which runs across the width of the strip. The temperature to which the strip including its tin coating is finally heated by the second coil means **13** for purposes of alloying or fusing such tin coating to a desired degree with the steel material of which the strip is composed, is determined according to a time-temperature function. It varies according to the time at which the strip remains at a certain heated temperature and the degree of such temperature. Curve **17** in FIG. 2 shows a typical relationship which may exist between the ultimate temperature to which the strip **10** is heated and the speed of travel of the strip, or line speed, for obtaining proper final alloying conditions of the strip after leaving the quench bath **15**.

The tin plated strip **10** prior to introduction to the first heating coil means **12**, may have been subject to variant degrees of preheating from previous operations performed on the strip, its surface may have more or less amounts of moisture on it, etc.; but by suitable control of the power applied to the heating coil means **12** and as affected by a suitable control means affiliated therewith, the strip **10** in being heated up to its tin melting temperature at a precise location within the coil means **12** along the heating line establishes an accurate reference point from which can readily be determined the amount of heat which must be provided by the second coil means **13** to raise the strip up to its final temperature. As presented to the coil means **13**, the strip is always introduced at the same temperature and without surface moisture which will have been evaporated by virtue of having been heated to such melting temperature. Thus, it will be appreciated that the strip **10** as heated by the coil means **12** up to the tin melting temperature is presented to the second coil means **13** in a condition which eliminates nonmeasurable heat-demand-varying conditions.

To effect and control energization of the first heating coil means **12** to obtain a stabilized fixed-position flow line heated condition of the strip **10** at a particular location in the heating coil means **12**, there may be provided a system such as shown, for example, in United States Patent 2,813,186, issued to A. P. Bock, Nov. 12, 1957. Portions of the apparatus of FIG. 2 in such patent have been shown in FIG. 1 of the present drawings in affiliation with the coil **12**. Wherein the present showing is a duplication of the showing in such FIG. 2 of Patent 2,813,186, the same reference numerals have been applied. Such apparatus comprises an oscillator **26**, which, for example, may generate a frequency of 100 kc., with its output leads connected in series with the induction coil means **12**. The oscillator **26** is availed of a direct current supply from a rectifier means **48** the input to which is regulated, hence output from the oscillator **26** is regulated, by a heating coil power control means **19**, which has been shown in block diagram form, but the details of which may take the form as shown in FIG. 2 of the aforementioned patent. Such apparatus functions responsively to information obtained from a tachometer generator **76** responsive to speed or travel of the strip **10** and to slight variations in flow line position obtained by the photoscanner **68** to so regulate the power applied to the induction coil means **12** as to obtain the desired result of so heating the strip **10** as to obtain the previously discussed stabilized flow line temperature condition. The photoscanner **68** will observe such flow line at a point within and near the exit end of the coil **12** in order to allow for some slight variation in the flow line position, and the strip **10** will leave the coil means **12** at some stabilized temperature slightly higher than the flow line temperature of 452° F., such as 465° F., for example.

The means for obtaining regulation of the power applied to the second heating coil means **13** to obtain the desired final strip temperature preparatory to introduction to the quench bath **15**, as illustrated by way of example herein, comprises an oscillator **21** having its output in series with the heating coil means **13** and which is availed of a regulated direct current supply from a rectifier means **23** which is availed of regulated three-phase alternating current by way of a transformer means **25**, which in turn is availed of regulated alternating current in its primary by a saturable reactor means **27**. Control of regulated ouput from the saturable reactor means **27** in turn is controlled by a computer means **29** through the medium of a regulator means **31** and leads **33** and **35** from such regulator via which the direct current control signal to the saturable reactor means **27** is conducted. Since the heating demand of the coil means **13** will be imposed on the strip **10**, it is a function of the thickness of such strip, the width of such strip, and the desired strip temperature which in turn is a function of the travel or speed of the strip. Such operating parameters as gauge, width, and alloy requirement are introduced as manually adjustable inputs as indicated by arrows **39**, **41**, and **43**, respectively. Information as to strip speed is fed to the computer means **29** for automatic adjustment in response thereto from a tachometer generator **45** by way of output leads **47** therefrom.

The computer means **29** can be of a relatively simple analog form which accepts information as to gauge, width, alloy requirement, and speed in the form of direct current voltage levels to produce the desired power demand signals according to the strip temperature desired. This can take the form of an exciter generator similar to that employed in the apparatus disclosed in the Bock Patent 2,813,186 having a plurality of field windings respective to the operating parameter information together with a suitable function generator to convert the speed signal information into proper form for correlation between line speed heat output from the coil, and the alloying temperature required. Alternatively, the computer **29** may simply take the form as shown in FIG. 3, employing a saturable reactor assembly in lieu of the exciter generator and employing a function generator which comprises a parallel arrangement of adjustable resistors respective to the three variable inputs **39**, **41** and **43** of strip gauge, strip width, and alloy requirement feeding a DC control signal via leads **46** and **49** to a control winding (not shown) of a saturable reactor **51** to control the firing angle of a trinistor regulator, both of which can constitute parts of the regulator **31**. The output from the tachometer generator **45** is suitably modified by a bias diode function network **53** to feed a suitable DC signal via leads **55** and **57** to another control winding (not shown) of saturable reactor **51** for effecting proper influence of the strip speed to produce a power input to the strip which obtains the relationship exemplified by curve **17** in FIG. 2.

While the invention has been described herein with respect to an exemplified embodiment of such invention, it will be appreciated that modifications may be made without departing from the true spirit and scope of the invention as intended to be defined by the appended claims.

What we claim as our invention is:

1. An apparatus for the continuous heating of tin plated steel strip while being advanced longitudinally through a heating line to a quenching medium, said apparatus comprising a first induction heating and control means for applying heat to such strip in a manner which obtains melting of the tin on the surface thereof along

a clearly distinguishable flow line extending across the width of such strip and automatically maintained at a substantial fixed location along such heating line irrespective of strip advancement speed, and second induction heating and control means including strip speed sensing means to further raise the temperature of such strip to different values dependent on strip speed under automatic regulation in reliance upon the stable reference point conditions existing in the strip at such fixed flow line location.

2. The apparatus of claim 1, wherein the first induction heating and control means includes a photoscanner in observance of the aforesaid flow line, and the second induction heating and control means includes a computer means in receipt of information from the strip speed sensing means to regulate strip temperature according to the effect of such temperature and time-at-temperature on alloying the tin plating with the steel of the strip.

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