

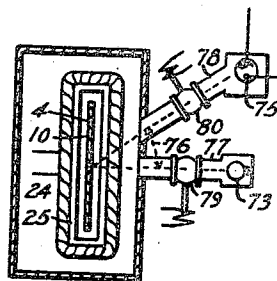
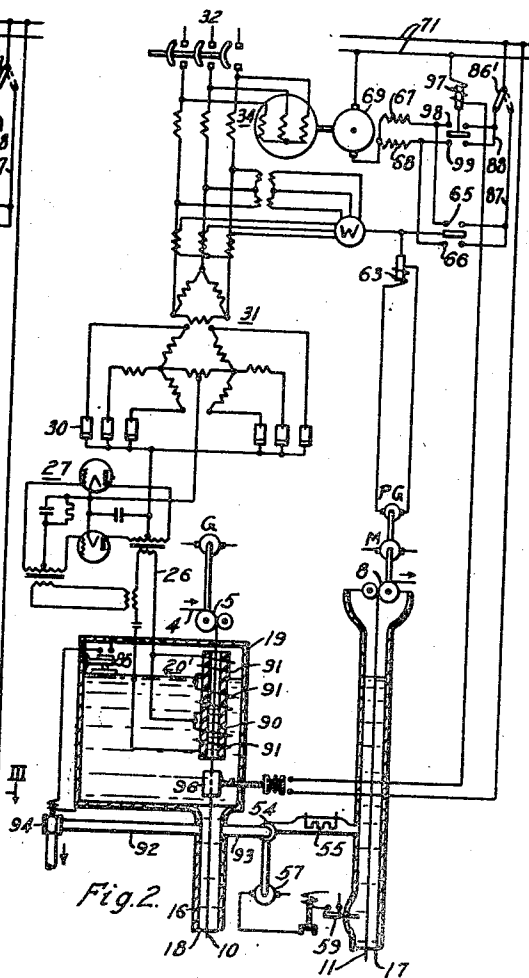
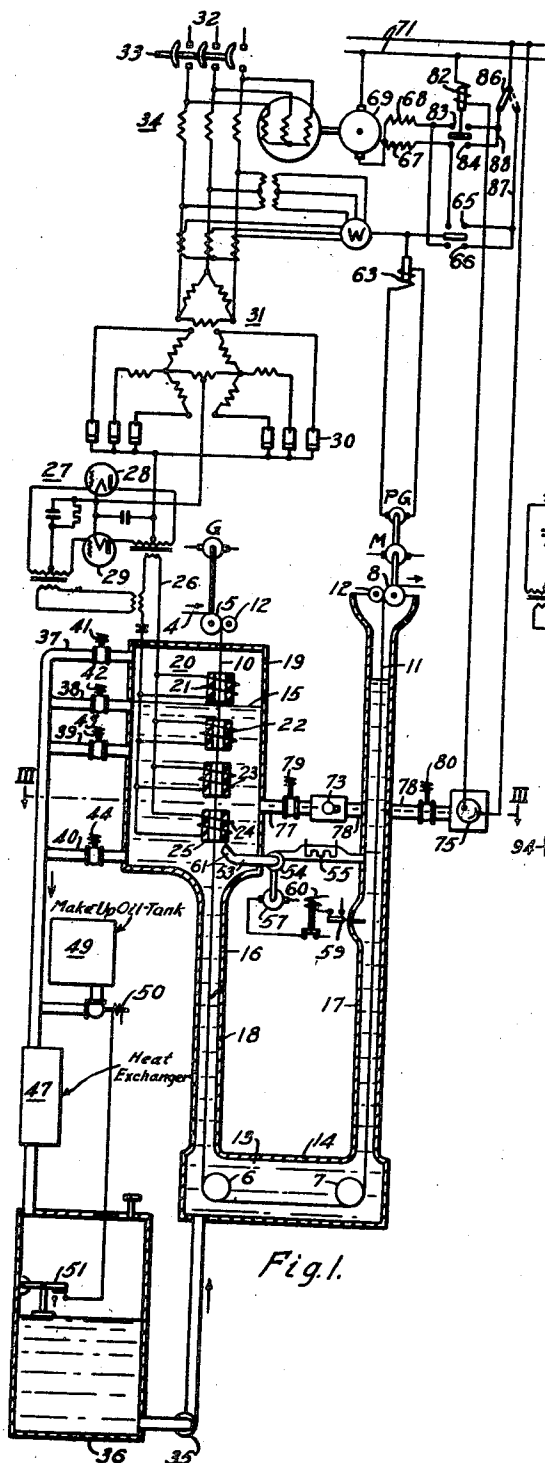
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OIL-BATH TINPLATE-FLOWING APPARATUS AND THE LIKE

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OIL-BATH TIN-PLATE FLOWING APPARATUS AND THE LIKE

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My invention relates to cooling or quenching means, or to a combined heating and cooling apparatus for a substantially vertically extending portion of a flexible elongated electrically conducting member which is continuously moving downwardly, in the direction of its length. While my invention is of generic application, the most important present application contemplated for my invention is in the cooling, or in the heating and cooling, of a tinplated steel strip, particularly a strip on which the plating has been applied electrolytically, so that it is necessary to heat the strip to the melting-point of tin, in order to melt or "flow" the tin, so as to change it from a matte surface to the familiar bright, smooth surface, which is required, not only for its appearance, but also for its protective qualities in completely covering and protecting the steel which is underneath the plating. My invention is also particularly applicable to apparatus utilizing inductive heating-coil means for heating the strip, particularly where the inductive heating-coil means is at least partially immersed in a non-oxidizing oil-bath, or other liquid-bath.

My present invention is an improvement over the apparatus which is shown and described in a companion application of Robert M. Baker and myself, Serial No. 464,040, filed October 31, 1942 (abandoned), for a Tinplate-flowing apparatus, in which the inductive heating-coil was disposed in air, and the downwardly moving strip, after passing through the heating-coil, was passed into a quenching-tank. My present invention relates to improvements in the quenching-tank or liquid-bath, and it also relates to means for inductively heating the strip in oil, or in some other preferably non-oxidizing bath-liquid, the inductive heating-means being either altogether immersed in oil, or at least having its lower portion immersed in the oil, so that the strip which is being heated becomes submerged in the oil before it gets hot enough to oxidize in air.

It is the experience of some operators, that apparatus for performing the tinplate-flowing operation in a non-oxidizing oil produces, for them, a product having a superior finish, or a more uniform product, than they can obtain with apparatus in which the heating-operation is performed in air. Heretofore, tinplate-flowing apparatus utilizing hot oil as the medium for raising the temperature of the strip to the melting point of tin has had numerous disadvantages, including the disadvantages of requiring a relatively long exposure of the strip to the hot-oil bath, in order to bring the strip up to the required tem-

perature, the danger of overheating the bath when the rate of movement of the strip is reduced or stopped altogether, and the hazard of several costly fires which have resulted from the ignition of the oil itself.

The principal object of my present invention is to provide a tinplate-flowing apparatus in which heat is inductively introduced in an oil-immersed strip, so that the strip heats the oil, rather than contrariwise, the rate of electrical energy-input into the inductive heating coil being sufficiently high so that the rate of heat-input into the strip greatly exceeds the rate of heat-loss from the strip to the oil within the region of the inductive heating-coil. In this manner, the length of the apparatus is greatly reduced, and the heat-loss to the oil is minimized. Furthermore, the hottest part of the oil is at a point which is well submerged in the oil-bath, so that the danger of ignition of the oil is altogether eliminated. Means can be provided for producing an oil-circulation in the inductive-heating zone, whereby the oil is prevented from reaching a temperature as high as the maximum temperature of the strip, or the oil immediately surrounding the heated strip may be confined in an insulating shield or liner, so that only a very small quantity of oil is raised to the maximum temperature of the strip, and that oil is immersed in a larger body of oil, which not only protects it from coming into contact with air, but also acts as a fairly efficient heat-insulator for very greatly reducing the heat-loss to the oil.

Another object of my present invention is to provide an improved liquid-bath quenching means which is so formed or partitioned as to provide a quenching-leg of restricted section, through which the strip to be cooled passes, in combination with liquid-circulating means for maintaining a liquid-flow contrary to the movement of the strip.

A further object of my present invention relates to means for reducing the rather considerable amount of oil which is continuously carried away from the bath by the strip, in the form of an oil-film on the strip as it leaves the bath. This oil which is carried away on the strip presents a problem, not only in its subsequent removal from the strip, but also in requiring rather large amounts of make-up oil which must be continuously added to the bath. It is known that the oil becomes thinner, or less viscous, as its temperature is increased, and thus it is an object of my invention to provide an apparatus in which heated oil is economically supplied to the portion

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of the oil-bath from which the strip emerges, means being provided for keeping the oil substantially quiescent in this portion of the bath, and preferably for supplying the heated oil thereto at a rate which is approximately the same as the rate at which the oil is carried away from the bath by reason of the film on the strip.

Still further objects of my present invention relate to novel means for controlling the supply of high-frequency electrical power to the inductive heating-coil means, in such manner as to properly control the hottest temperature of the inductively heated strip. In the previously mentioned companion application of Baker and myself, a light-sensitive scanning-means was shown, for holding the flow-line to a predetermined point within the length of the inductive heating-coil, which may be approximately 90% of the way through the coil. In my present invention, where the inductive heating-operation is performing under an opaque oil, this light-sensitive scanning-means is not available during the normal operation of the apparatus, but I provide means whereby the apparatus can be started, and initially run for a relatively short period of time, with the oil drained down below the level of the inductive heating-coil, so that the light-sensitive scanning-means can be utilized for holding the flow-line steady, and for initially determining the desired setting of a wattmeter or power-responsive regulator under the particular operating conditions, after which the oil may be admitted to the heating-coil, and the control thereafter be turned over to the wattmeter-regulator, according to the setting previously determined. I also provide, either as an alternative, or as an additional regulating-means or safeguard, a thermostat which is responsive to the hottest temperature of the oil, for exercising a control over the regulator or the power-input into the inductive heating-coil means.

With the foregoing and other objects in view, my invention consists in the apparatus, parts, combinations, systems and methods, hereinafter described and claimed, and illustrated in the accompanying drawing, wherein

Figure 1 is a diagrammatic view of circuits and apparatus illustrating my invention;

Fig. 2 is a similar view of a portion of the equipment, showing a different form of embodiment; and

Fig. 3 is a substantially horizontal sectional view of the scanning-mechanism, on the plane indicated by the line III—III in Fig. 1.

In Fig. 1, I illustrate my invention in apparatus for heating and cooling a tinplated steel strip, or other electrically conducting elongated member 4, which is continuously moving, in the direction of its length, over rollers 5, 6, 7 and 8, to provide a downwardly moving portion 10 and an upwardly moving portion 11. The strip is held against the rollers 5 and 8 by means of pinch-rolls 12, respectively, and said rollers 5 and 8 are mechanically connected, respectively, to a generator G and a motor M, so that the strip may be pulled by means of the motor M which is connected to the roller 8, and tension can be maintained on the strip by means of the generator G driven from the roller 5.

In accordance with my invention, I provide a liquid-bath 13, comprising a container 14, holding palm-oil 15, or some other liquid quenching-agent, preferably non-oxidizing. The container 14 is provided with upstanding legs 16 and 17 for respectively receiving the downwardly and up-

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wardly moving portions 10 and 11 of the strip 4. The container-leg 16 which is traversed by the downwardly moving strip-portion 10 is provided with a lower portion 18 of restricted section, and an upper portion 19 of relatively enlarged section. The container-leg 17 which is traversed by the upwardly moving strip-portion 11 is preferably of restricted section substantially throughout its length.

In accordance with my invention I also utilize inductive heating-coil means 20, at least the lower part of which is immersed in the bath-liquid or oil in the enlarged upper portion 19 of the container, on the side of the bath which is traversed by the downwardly moving strip-portion 10. In the particular form of embodiment of my invention shown in Fig. 1, the inductive heating-coil means 20 comprises four vertically spaced coils 21, 22, 23 and 24, each of which is provided with its own insulating shield or liner 25, in the form of a tube surrounding the strip 4 within the coil. It is to be understood, of course, that any number of heating-coils may be utilized.

As described in the previously mentioned application of Baker and myself, high-frequency electric current or power is supplied to the inductive heating-coil means 20 from the tuned output-circuit 26 of an oscillation-generator 27, which is illustrated as comprising two oscillator-tubes 28 and 29. High-voltage direct-current power is supplied to the tubes from rectifiers 30 which are energized from a polyphase transformer 31, deriving its power from a three-phase supply-line 32, through a breaker or other switching unit 33. The three-phase supply-connection is illustrated as including an induction regulator 34, or other means for regulating the supply-voltage, and hence the power supplied to the oscillation-generator 27.

In accordance with my present invention I provide a liquid-circulating means, which is illustrated in the form of a motor-driven pump 35 which supplies liquid to the bottom of the liquid-bath 13 from a sump-tank 36 which is big enough, and low enough, to permit the entire liquid-system to be drained into it.

The liquid which is pumped into the bottom of the liquid-bath 13 moves upwardly in the restricted-section quenching-portion 18 of the container-leg 16 through which the downwardly moving strip-portion 10 is passing. At the top of this quenching-leg 18, the moving liquid discharges into the enlarged upper portion 19 which contains the inductive heating-coil means 20.

In the form of embodiment of the invention shown in Fig. 1, the return-path for the circulating liquid is provided by any one of four overflow pipes 37, 38, 39 and 40 which are provided at different levels in the enlarged upper container-portion 19, at different heights, said overflow pipes being provided with electrically operated valves 41, 42, 43 and 44 respectively whereby the height of the liquid in the liquid-bath 13 may be regulated according to which overflow valve is opened. The overflow liquid passes downwardly through a heat-exchanger 47, where it is cooled, and then to the sump-tank 36. I also provide a make-up oil-tank 49 which discharges into the heat exchanger 47, and thence into the sump-tank 36, under the control of an electrically operated valve 50, which is controlled by a float-switch 51 in the sump-tank 36, so that the quantity of liquid normally existing in the sump-tank may be suitably controlled.

In accordance with my present invention, I also

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provide means for maintaining a substantially quiescent body of heated oil in at least the upper portion of the container-leg 17 which is traversed by the upwardly moving strip-portion 11. As an economical means for providing this body of heated oil, I preferably tap some of the heated oil, either at the top of the restricted-section quenching leg 18, or immediately underneath the inductive heating-coil means 20, and I divert as much as may be necessary, of this heated oil, through a pipe 53, a pump 54, and a heater 55, to a point or points below the surface of the liquid in the outlet-leg 17. The pump 54 is driven by a pump-motor 57 which is under the control of a vane, thermometer, or other means 59 for detecting a movement of the liquid in the exit-leg 17, or for detecting a downward movement of the heated oil in said leg. The vane or equivalent control-means 59 controls a relay 60 which controls the operation of the pump-motor 57 so as to supply heated oil to the top of the exit-leg 17 at about the same rate at which oil is carried off by reason of the oil-film on the upwardly moving strip-portion 11. In the form of invention shown in Fig. 1, the supply of diverted heated oil is obtained by means of an upturned pipe 61 which is disposed immediately below the bottom liner 25 of the bottom inductive heating-coil 24, so as to obtain the hottest oil available.

As shown in the previously mentioned companion-application of Baker and myself, I control my three-phase power-supply by means of a wattmeter W, or other means which is responsive to the input-power into the transformer 31, and hence responsive to the high-frequency inductive-heating power or current which is supplied to the heating-coils 21, 22, 23 and 24. I have further illustrated the wattmeter W as being provided with a restraining magnet or solenoid 63 which is energized from a pilot generator PG which is mechanically connected to the strip-driving motor M so as to be responsive to the speed of the strip 4. The wattmeter W has a make-contact 65 and a back-contact 66, for respectively energizing a bucking series-field winding 67 or a boosting series-field winding 68 of a regulating-motor 69, the power for the regulating-motor being obtained from a direct-current relaying-bus 71.

I have also provided a second regulator-control, in the form of a reflected-light scanning-means, which comprises a light-source 73 and a light-sensitive means such as a photo-electric cell 75, the light-source 73 sending a light-beam at approximately right angles to the surface of the strip 4, at a point approximately 90% of the way through the inductive heating-coil means 20, while the dispersed light from the underheated matte surface of the strip reaches the photo-electric cell 75 at a 35° angle 76, as shown in Fig. 3, and also as set forth in the previously mentioned joint application of Baker and myself.

Because of the opaque nature of the palm-oil 15 which I prefer to use as the quenching-agent or bath-liquid, it is necessary to lower the liquid level of the liquid-bath 13 sufficiently to clear the scanning-means 73-75, as by opening the lowest overflow-valve 44. The scanning-means may be placed either within the enlarged upper container-portion 19 of the liquid-bath 13, or, as shown in Fig. 1, it may be placed outside of said enlarged upper portion 19, and communicating thereto through two substantially horizontal pipes 77 and 78, which respectively transmit the light-beams from and to the light-source 73 and the photo-electric cell 75, said pipes being provided

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with electrically operated valves 79 and 80, respectively, which may be opened, after the liquid-level has been lowered, thereby admitting the passage of the light rays. In practice, the pipes 77 and 78 will be very slightly tilted, sufficiently to drain the bath-liquid when the lowermost overflow valve 44 is opened.

As shown in the previously mentioned joint application, the photo-electric cell 75 controls the energization of a relay 82 having a make-contact 83 and a back-contact 84, for respectively energizing the boosting series-field winding 68 or the bucking series-field winding 67 of the regulating-motor 69. I also provide a selector-switch 86, by which it is possible to energize either the conductor 87 which energizes the contacts 65-66 of the wattmeter W, or a conductor 88 which energizes the contacts 83-84 of the photo-electric cell relay 82.

In the operation of the form of my invention which is shown in Fig. 1, the tinplated strip 4 passes the roller 5, and starts down in the downwardly moving portion 10, at a certain temperature, which may be of the order of 150° F. Since tin melts at approximately 452° F., the strip must be heated to a slightly higher temperature, say not over 475° F., by the time it finishes passing through the inductive heating-coil means 20. It is then necessary to quench the strip, or to cool it to a lower temperature, which may conveniently be taken to be 150° F., although other quenching temperatures may be utilized.

The recirculating cooling liquid is supplied to the bottom of the liquid-bath container 14, at a temperature which may be somewhat lower than the quenching-temperature of the strip; for example, the liquid may be admitted to the bottom of the tank or liquid-container 14 at a temperature of 130° F. It will be understood, of course, that automatic temperature-maintaining means or circulation-controlling means may be utilized for maintaining a predetermined bath-temperature at the bottom of the quenching leg 16 or 18, but such means have been omitted from the drawing for the sake of simplicity of illustration, and because any means, known to the art, or devised by the operator, can be utilized for this purpose, or this control may be purely manual, if desired.

The upward rate of flow of the bath-liquid in the restricted-section lower-leg portion 18, in the bath-leg 16 which is traversed by the downwardly moving strip-portion 10, is such that the strip-temperature shall have been reduced to a predetermined value, such as 150° F., by the time the strip reaches the second roller 6, which is in the bottom of the liquid-bath 13. In the form of my invention which is shown in Fig. 1, the heated oil, or other quenching liquid, which flows up out of the restricted lower portion 18, enters the enlarged upper portion 19 which contains the inductive heating equipment, and overflows from said enlarged upper portion 19 through one of the three upper overflow pipes 37, 38, or 39, depending upon how much of the inductive heating-coil means 20 is desired to be submerged within the oil 15 of the liquid-bath. My apparatus may be operated, either with the entire inductive heating means submerged, as by opening the topmost overflow valve 41 and closing the other three overflow valves 42, 43 and 44, or it may be operated with only a selected portion of the lower part of the inductive heating means submerged, as by opening one of the intermediate overflow valves 42 and 43.

The form of my invention which is shown in Fig. 1 utilizes a construction of the inductive heating-coil means 20 such that the downward movement of the strip 4 through at least the lower portion of the inductive heating-coil means, or through those of the insulating shields or liners 25 which are entirely submerged, draws the palm-oil or other bath-liquid downwardly through said submerged shield or shields, thereby creating a rapid circulation of oil or other bath-liquid within the enlarged upper portion 19, thus preventing the oil from attaining a temperature anywhere near as high as the hottest point of the strip. This means has been devised in order to avoid any possibility of ignition of the oil, and to minimize deterioration of the oil. The rate of energy-input into the inductive heating-coil means 20 is so great that the downwardly moving strip-portion 10 is very rapidly heated by the induced high-frequency currents therein, so that the strip is heated inductively much more rapidly than the strip can heat the oil by heat-transfer as a result of its contact with the oil.

If palm-oil is utilized as the bath-liquid 15, its temperature must be kept, at all points in the system, above its solidification-point, which is somewhere around 100° F., and the heat-interchanger 47, the make-up oil-tank 49, the sump-tank 36, and all of the oil-valves, pipes, and pumps must all be controlled so that the temperature does not fall too close to this solidification-temperature, during the operation of the device.

In the exit-leg 17 of my liquid-bath 13, I provide a body of oil which is substantially quiescent, that is, which substantially does not move except for the said amount of oil which is carried off by reason of the oil-film on the upwardly moving strip portion 11 as it leaves the liquid-bath. An important feature of my invention is the provision of means, in addition to the container-construction which provides this quiescent-liquid leg 17, for causing at least the top portion of this quiescent body of oil or bath-liquid to be heated, over and above the normal oil-temperature or strip-temperature. Thus, if the oil in the bottom of the bath 13 is at a temperature of approximately 130° F., and the strip at a temperature of approximately 150° F., the oil in the exit-leg 17 of the bath would normally have a temperature between 130° and 150° F. In accordance with my invention, I make the oil considerably hotter, before the strip leaves the top of the oil in this exit-leg 17 of the bath, so that the oil will adhere to the strip in a much thinner film than if it were at the aforesaid lower temperature of the order of 130° to 150° F. The strip is not materially heated by this small quantity of quiescent heated oil, because it passes through the oil too quickly, but the oil-film is heated, and thereby considerably reduced in thickness.

In accordance with my invention, any suitable means is provided for maintaining this heated body of quiescent oil in the upper portion of the exit-leg 17. In Fig. 1, the body of circulating oil is tapped at its hottest point, namely, immediately below the inductive heating-coil means 20, and is supplied, either at the temperature at which it is, or at a still higher temperature acquired through the medium of a heater 55, to the upper portion of the exit-leg 17, and the rate of supply of this heated oil to the upper portion of the leg 17 is preferably so regulated as to substantially match the rate at which oil is carried away by reason of the oil film on the upwardly

moving strip-portion 11, under the control of the vane or equivalent control-means 59.

In the operation of the form of my invention which is shown in Fig. 1, two different control-means are shown, one involving the use of the wattmeter W, and the other involving the use of the light-sensitive scanning-means 73-75. Since the light-sensitive scanning-means cannot be utilized if the bottom portion of the inductive heating-coil means 20 is immersed in the dark, opaque oil, it is necessary, in the normal operation of the device, as illustrated in Fig. 1, to rely on the wattmeter-control. When a tinning "line" is first placed in operation, however, the exact settings of the wattmeter W and of the speed-responsive restraint 63, are not known, as they depend upon the thickness and width of the strip 4, the normal operating-speed of the strip, the efficiency of the high-frequency conversion, the rates of heat-transfer, and the various temperatures which are involved. Under these circumstances, it would be necessary to start the operation of the device on a guess, as to the proper control-settings, and then to operate the device long enough for the strip to come through at the final end of the "line," where it could be inspected, and necessary adjustments made, either in the way of increasing or decreasing the heating and cooling cycles, until the correct adjustments are obtained, meanwhile producing a large quantity of strip that would have to be scrapped.

In accordance with my invention, as shown in Fig. 1, I provide very satisfactory means for at first, for a very brief while, operating the "line" with the inductive heating-coil means 20 in air, and I utilize the light-sensitive scanning means for automatically holding the flow-line at the 90% point or other point within the inductive heating-coil means 20, so that the strip comes through, from the very first, in an acceptable manner. It should be understood, of course, that the strip does not normally materially oxidize, when properly heated in air, avoiding undue overheating, because the strip is moving very fast, and it remains hot such a very small instant before it plunges into the quenching-liquid, that it does not have time to be seriously harmed by oxidation. The only handicap suffered, therefore, by very briefly operating the apparatus with the heating-operation performed in air, will be to produce a reflowed strip which is saleable, but possibly not of the highest obtainable quality, or uniformity, or other characteristic which is obtainable by heating in oil. When the proper operating-conditions have been selected by the light-sensitive scanning-means, the proper settings of the wattmeter-control can then be noted and adjusted, and the selector-switch 86 may then be manipulated to transfer the control to the wattmeter W, while the overflow valves may be manipulated to bring up the height of the liquid in the enlarged container-portion 19 so as to cause the inductive heating-coil means 20 to be submerged as deeply as may be desired. In making this transfer, any slight difference of heat-loss from the strip within the heating-coils may be allowed for, to compensate for operating in oil rather than in air.

In Fig. 2, I show a form of embodiment of my invention in which the inductive heating-coil means 20' utilizes a single insulating shield or liner 90, the top end of which extends above the liquid level in the enlarged container-portion 19. The liner 90 is surrounded by one or more heating-

coils 91, which may be entirely submerged, or only partially submerged, or submerged as deeply as may be desired, the liner 90 being extended upwardly, above the heating-coils 91, if necessary, to keep the top of the liner 90 above the oil-level. Since the top of the liner 90 is thus above the oil-level, oil cannot enter through the top of the liner and circulate out through the bottom of the liner, under the influence of the drag of the fast-moving strip which is moving downwardly through the liner, with the result that a small body of oil remains trapped in the liner, without substantial circulation, as indicated in Fig. 2.

In this form of embodiment of my invention, therefore, as shown in Fig. 2, a small quantity of oil is trapped within the bottom of the liner 90, and in due course it becomes heated substantially to the temperature of the hottest part of the downwardly moving strip-portion 10. It will be noted, however, that the hottest part of this oil is at the bottom of the liner 90, where it is in contact only with the interior of the body of oil which is contained in the enlarged upper container-portion 19, where it is out of contact with air, and where it is also fairly well heat-insulated by the relatively quiescent body of oil in the enlarged upper container-portion 19, said body of oil itself gradually becoming heated, but only relatively slowly, during long-continued operation of the apparatus. This form of my invention thus results in a very minimum heat-loss to the oil, the rate of heat-transfer between the heated strip and the oil being approximately the same as the rate of heat-transfer between the heated strip and air in inductive heating systems in which the heating-coils are located in air.

Since the recirculated liquid, in the form of my invention shown in Fig. 2, is not to be circulated through the enlarged upper portion 19, containing the inductive heating-coil means 20', the take-off pipe 92 for the recirculated quenching-liquid and the take-off pipe 93 for the heated oil-supply to the leg 17, are both tapped off from an upper portion of the restricted quenching-portion 18 of the liquid-bath at a point or points below the point where the restricted leg-portion 18 merges into the upper enlarged portion 19. The overflow pipe 92 for the recirculated liquid contains an electrically operated valve which is controlled by a float-switch 95 in the enlarged upper portion 19, in such manner as to preserve any desired oil-level with respect to the inductive heating-coil means 20'.

In Fig. 2, I also illustrate a form of control-means which may be utilized either as a back-up safety-measure in addition to any other control means, or it may be utilized as an alternative control-means which may be relied upon in the normal operation of the device, to maintain proper flowing-conditions for the tinplate, by controlling the temperature at which the heated strip leaves the bottom of the inductive heating-coil means 20'. To this end, I have illustrated a thermostat 96 which responds to the oil-temperature at a point immediately below the liner 90, and which is utilized to control a relay 97 having a make-contact 98 and a back-contact 99, for energizing, respectively, the bucking series-field winding 67 or the boosting series-field winding 68 of the previously described regulating-motor 69.

In Fig. 2, this thermostat-relay 97 is shown in place of the photo-electric-cell relay 82, with a selector-switch 86' whereby automatic operation may be obtained either in response to the thermostat 96 or the watt-meter 70. It is to be un-

derstood, however, that other forms of control may be utilized, in conjunction with the thermostat 96. This thermostat 96 is particularly applicable to the form of invention in which a small body or column of oil is trapped, statically, within the lower portion of the liner 90, so that, in a few seconds' or minutes' time, according to the time-constants involved, this oil will have attained substantially the same temperature as the hottest portion of the strip, so that the thermostat 96, in oil immediately under this hottest point, in a substantially static body of oil, responds to the strip-temperature far more sensitively than a similar thermostat disposed in air, where fresh supplies of air are constantly sweeping downwardly through the liner, being dragged along by the swiftly moving strip.

In all forms of embodiment of my invention, it will be understood that the usual safeguards and precautions will be utilized, as are well known and understood by those skilled in the art. I have undertaken to simplify my illustration and description by omitting such obvious things as temperature-regulators, flow-regulators, speed-regulators, tension-regulators, and cooling-means for the high-frequency conductors, all of which may take any conventional or desired forms.

In both of the illustrated forms of my invention, the induction regulator 34 may be regarded as being broadly representative of any regulating-means for varying the relation between the rate of electrical energy-input into the strip 4 and the speed of the strip 4, as the broad object of the induction regulator is to be able to control the temperature which is reached by the strip. It is obvious that this temperature-control can be accomplished either by changing the rate of heating without changing the speed, or by changing the speed without changing the rate of heating, or by simultaneously changing both the speed and the rate of heating, in such manner that the relation or ratio between these two rates is changed.

In the foregoing description, and in the appended claims, the word quenching is used in the broad sense of immersing a hot object in any liquid or gas in order to cool it.

While I have illustrated my invention in only two different forms of embodiment, it will be obvious that my invention is susceptible of great variety in its precise forms of embodiment, both as to structure and operation, without departing from the broader aspects of the invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. In combination, a liquid-bath means, the main body of said liquid-bath means having an extent and a temperature suitable for cooling a rapidly moving flexible elongated member to quench the same, a relatively small top-surface region of said liquid-bath means being at an elevated temperature which is lower than the temperature to which said rapidly moving flexible elongated member must be heated, in its desired process of treatment, an inductive heating-coil means disposed in said top-surface region of said liquid-bath means, at least the lower part of said inductive heating-coil means being immersed in said liquid-bath, work-feeding means adapted to rapidly move said flexible elongated electrically conducting member, in the direction of its length, downwardly through said inductive heating-coil means, for quickly heating said elongated mem-

ber, and then on through the rest of the liquid-bath, for cooling said elongated member, and means for energizing said inductive heating-coil means with high-frequency current of enough power so that the rate of heat-input inductively induced in the elongated member greatly exceeds the rate of heat-loss from the elongated member to the liquid of the bath within the region of the inductive heating-coil means, characterized by said liquid-bath means having a lower portion of relatively restricted section and an upper portion of relatively enlarged section, both sections being traversed by said downwardly moving portion of the elongated member, liquid-circulating means for causing an upward movement of the liquid in said lower portion of relatively restricted section, said upwardly moving liquid discharging at least partially from said restricted lower portion into said enlarged upper portion, said liquid-circulating means including means for withdrawing liquid from said upper portion and causing it to return to the bottom of said lower portion, at least the lower part of said inductive heating-coil means being immersed in the liquid in said enlarged upper portion.

2. In combination, a liquid-bath means, the main body of said liquid-bath means having an extent and a temperature suitable for cooling a rapidly moving flexible elongated member to quench the same, a relatively small top-surface region of said liquid-bath means being at an elevated temperature which is lower than the temperature to which said rapidly moving flexible elongated member must be heated, in its desired process of treatment, an inductive heating-coil means disposed in said top-surface region of said liquid-bath means, at least the lower part of said inductive heating-coil means being immersed in said liquid-bath, work-feeding means adapted to rapidly move said flexible elongated electrically conducting member, in the direction of its length, downwardly through said inductive heating-coil means, for quickly heating said elongated member, and then on through the rest of the liquid-bath, for cooling said elongated member, and means for energizing said inductive heating-coil means with high-frequency current of enough power so that the rate of heat-input inductively induced in the elongated member greatly exceeds the rate of heat-loss from the elongated member to the liquid of the bath within the region of the inductive heating-coil means, in combination with an insulating shield surrounding the elongated member within at least the lower portion of said inductive heating-coil means, and so disposed that the downward movement of said elongated member draws liquid downwardly through said shield, whereby to reduce the extent of the liquid-contact with the portion of the elongated member which is being heated.

3. In combination, a liquid-bath means, the main body of said liquid-bath means having an extent and a temperature suitable for cooling a rapidly moving flexible elongated member to quench the same, a relatively small top-surface region of said liquid-bath means being at an elevated temperature which is lower than the temperature to which said rapidly moving flexible elongated member must be heated, in its desired process of treatment, an inductive heating-coil means disposed in said top-surface region of said liquid-bath means, at least the lower part of said inductive heating-coil means being immersed in said liquid-bath, work-feeding means adapted to rapidly move said flexible elongated electrically

conducting member, in the direction of its length, downwardly through said inductive heating-coil means; for quickly heating said elongated member, and then on through the rest of the liquid-bath, for cooling said elongated member, and means for energizing said inductive heating-coil means with high-frequency current of enough power so that the rate of heat-input inductively induced in the elongated member greatly exceeds the rate of heat-loss from the elongated member to the liquid of the bath within the region of the inductive heating-coil means, in combination with an insulating shield surrounding the elongated member within said inductive heating-coil means, the top of said shield being above the top of the liquid, whereby liquid-circulation within said shield is substantially avoided.

4. In combination, a liquid-bath means, work-feeding means adapted to rapidly move a flexible elongated member, in the direction of its length, through the liquid-bath means, said liquid-bath means having guide-means therein for so guiding said elongated member as to provide a substantially vertically extending, downwardly moving portion of said elongated member which moves downwardly through the top surface of the liquid-bath into the bath, and an upwardly moving portion of said elongated member which moves upwardly through the top surface of the liquid-bath out of the bath, means for heating the upper portion of the downwardly moving portion of the elongated member, liquid-circulation cooling-means for causing an intermediate portion of the elongated member, within the liquid bath, to be bathed by a continuously flowing supply of cool liquid, and means for keeping the bath-liquid relatively quiescent in at least the upper part of the bath-portion which is traversed by said upwardly moving portion of the elongated member, whereby the liquid in said quiescent-part of the bath is heated to a temperature approaching the exit-temperature of the elongated member, whereby the liquid-film-deposit of the exiting elongated member is reduced.

5. In combination, a liquid-bath means, work-feeding means adapted to rapidly move a flexible elongated member, in the direction of its length, through the liquid-bath means, said liquid-bath means having guide-means therein for so guiding said elongated member as to provide a substantially vertically extending, downwardly moving portion of said elongated member which moves downwardly through the top surface of the liquid-bath into the bath, and an upwardly moving portion of said elongated member which moves upwardly through the top surface of the liquid-bath out of the bath, means for maintaining an upward liquid-circulation in a portion of the bath which is traversed by said downwardly moving portion of the elongated member, means for heating the upper portion of the downwardly moving portion of the elongated member, and means for diverting at least some of the heated, upwardly circulating bath-liquid from the bath-portion which is traversed by said downwardly moving portion of the elongated member, and supplying said diverted heated bath-liquid to a point or points below the surface of the bath-portion which is traversed by the upwardly moving portion of the elongated member whereby the liquid-film-deposit of the exiting elongated member is reduced.

6. The invention as defined in claim 5, in combination with means for additionally heating the

diverted bath-liquid before supplying it to the bath-portion which is traversed by the upwardly moving portion of the elongated member.

7. In combination, a liquid-bath means, work-feeding means adapted to rapidly move a flexible elongated member, in the direction of its length, through the liquid-bath means, said liquid-bath means having guide-means therein for so guiding said elongated member as to provide a substantially vertically extending, downwardly moving portion of said elongated member which moves downwardly through the top surface of the liquid-bath into the bath, and an upwardly moving portion of said elongated member which moves upwardly through the top surface of the liquid-bath out of the bath, said liquid-bath means having two leg-portions of relatively restricted sections, traversed respectively by said downwardly and upwardly moving portions of the elongated member, liquid-circulating means for causing a liquid-flow contrary to the movement of the elongated member in at least the restricted-section leg which is traversed by the downwardly moving portion of the elongated member, means for heating the downwardly moving portion of the elongated member before it reaches its restricted-section leg of the liquid-bath, and means for supplying heated bath-liquid to a point or points below the surface of the restricted-section leg which is traversed by the upwardly moving portion of the elongated member, the rate of supply being approximately the same as the rate at which liquid is carried away from the bath by reason of the film on the upwardly moving portion of the elongated member.

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Number
496,208
1,043,089
1,355,521
1,517,910
1,717,460
1,802,667
1,811,522
1,890,065
1,900,842
1,937,420
1,943,802
1,984,335
1,995,811
2,057,582
2,076,368
2,079,867
2,141,382
2,154,928
2,176,583
2,184,740
2,192,303
2,281,334
2,293,047
2,329,188
2,357,126
2,369,748

Number

Name

Date

Procunier ----- Apr. 25, 1893
Gibbs ----- Nov. 5, 1912
Alexander et al. ----- Oct. 12, 1920
Kirschner ----- Dec. 2, 1924
Mascuch ----- June 18, 1929
Slepian ----- Apr. 28, 1931
Shover et al. ----- June 23, 1931
Meehan ----- Dec. 6, 1932
Northrup ----- Mar. 7, 1933
Wood et al. ----- Nov. 28, 1933
Northrup ----- Jan. 16, 1934
Crapo ----- Dec. 11, 1934
Long ----- Mar. 26, 1935
McKean et al. ----- Oct. 13, 1936
Fyler ----- Apr. 6, 1937
Meyers ----- May 11, 1937
Ferm ----- Dec. 27, 1938
Zuschlag ----- Apr. 18, 1939
Cook ----- Oct. 17, 1939
Hansell ----- Dec. 26, 1939
Ferm ----- Mar. 5, 1940
Somes ----- Apr. 28, 1942
Deneen et al. ----- Aug. 18, 1942
Deneen et al. ----- Sept. 14, 1943
Nachtman ----- Aug. 29, 1944
Nachtman ----- Feb. 20, 1945

FOREIGN PATENTS

Country	Date
Great Britain -----	Sept. 21, 1926
Great Britain -----	Feb. 28, 1935

REFERENCES CITED

The following references are of record in the file of this patent: