

Feb. 3, 1959

T. MUNKER

2,872,173

METHOD AND APPARATUS FOR HEAT TREATING MATERIALS
IN A CONTINUOUS OPERATING FURNACE

Filed March 15, 1954

3 Sheets-Sheet 1

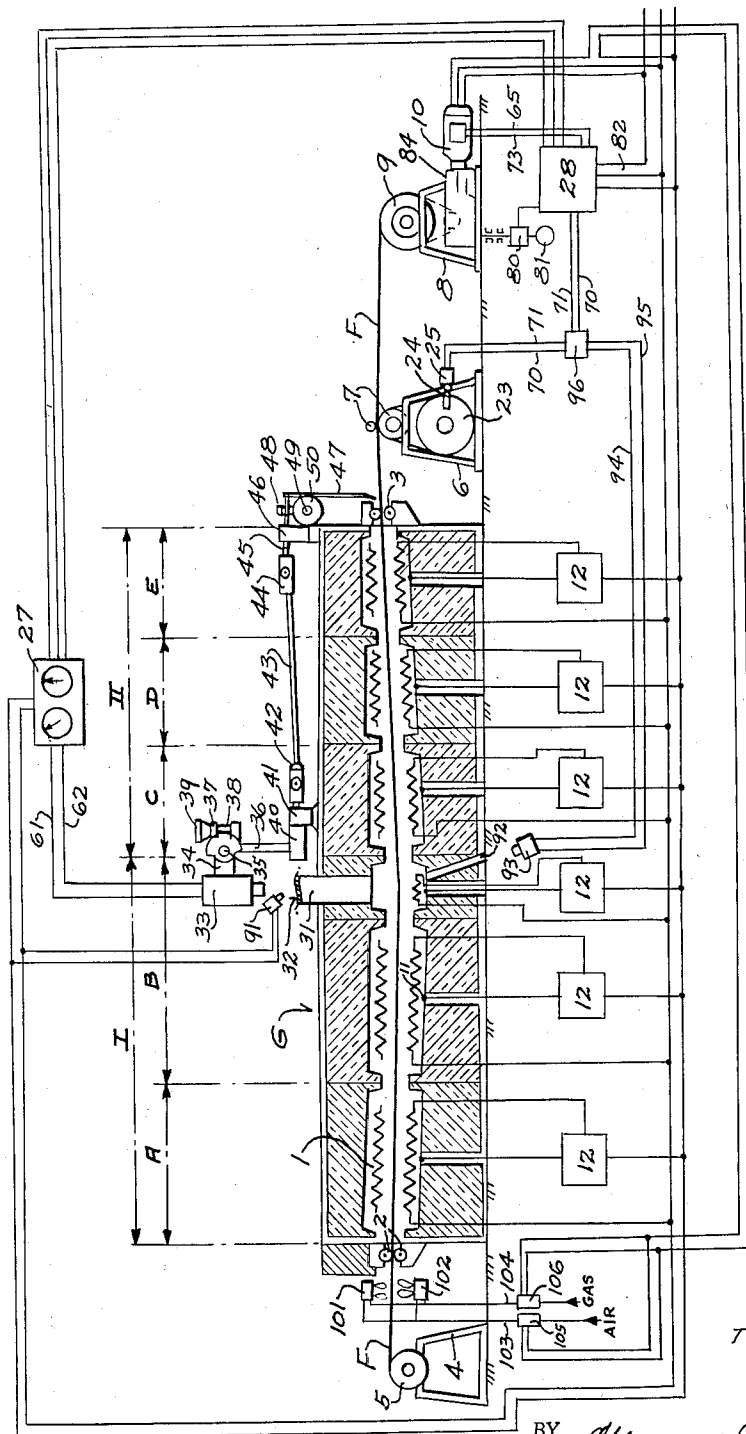


Fig. 1

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3 Sheets-Sheet 2

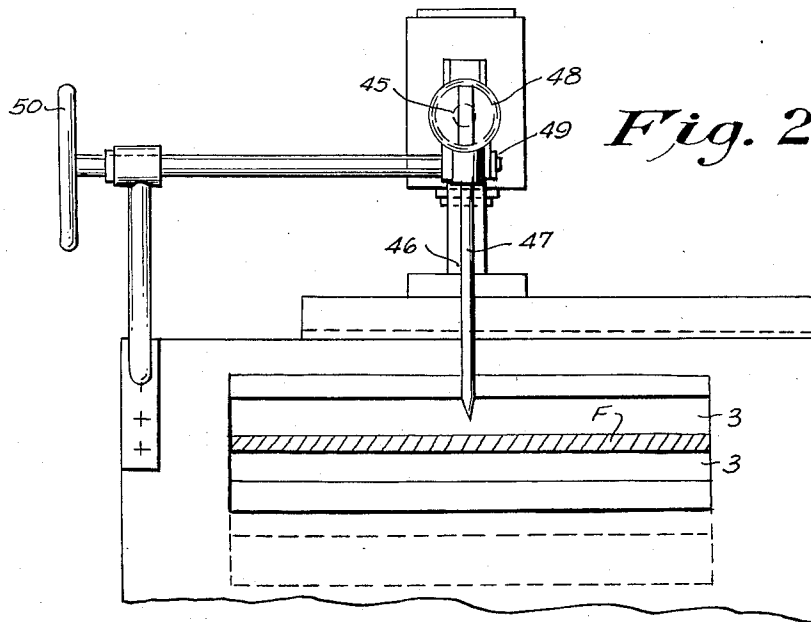


Fig. 2

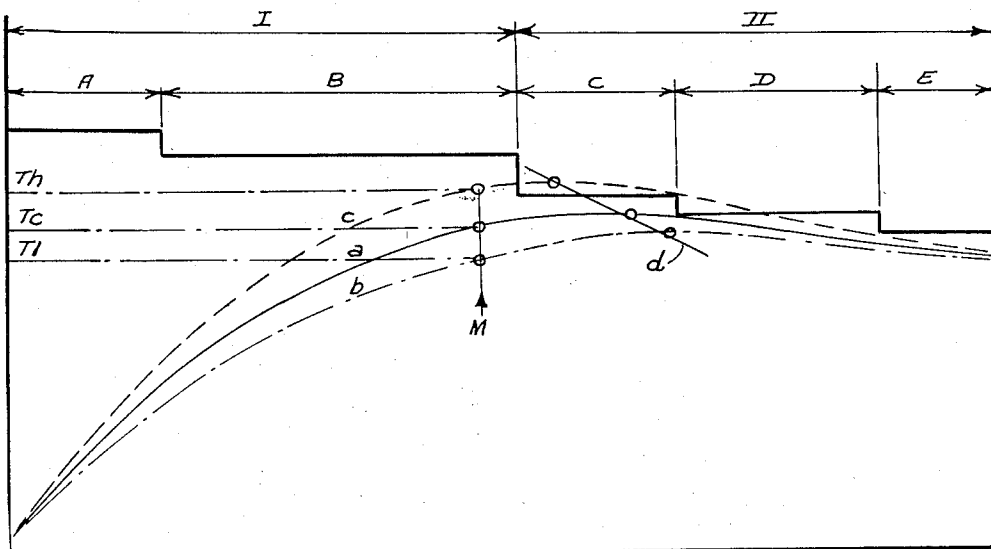


Fig. 4

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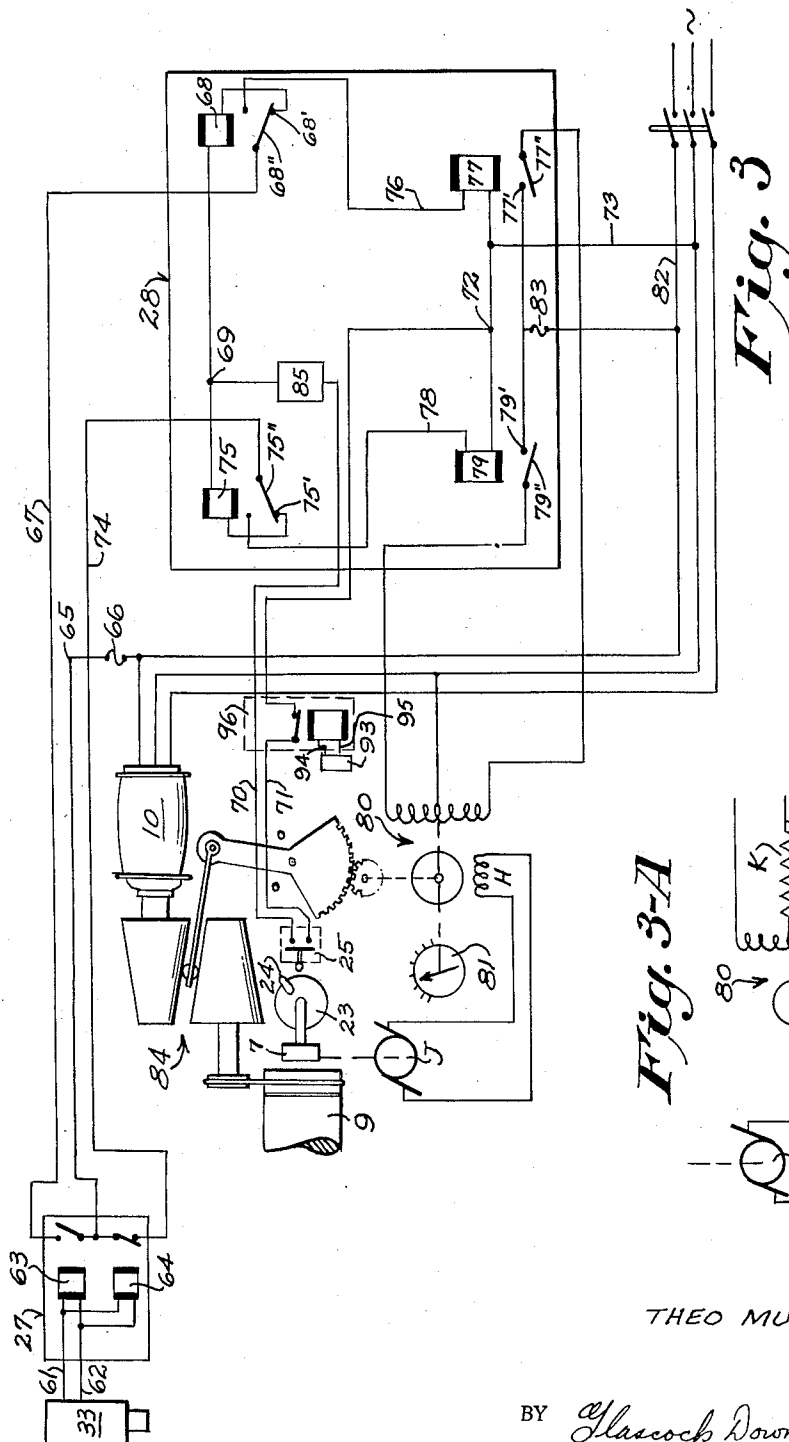


Fig. 3-A

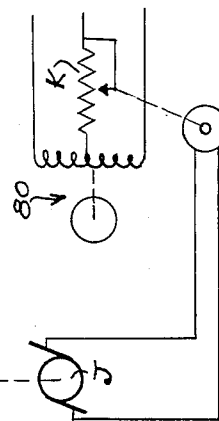


Fig. 3

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METHOD AND APPARATUS FOR HEAT TREATING MATERIALS IN A CONTINUOUS OPERATING FURNACE

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Application March 15, 1954, Serial No. 416,008

Claims priority, application Germany December 12, 1949

5 Claims. (Cl. 263—3)

The present invention relates to a system for heat treating materials in a continuously operating furnace and to apparatus for carrying out this method. This application is a continuation in part of my copending application Serial No. 199,182 filed December 5, 1950 now patented under No. 2,676,008, dated April 20, 1954.

More particularly, the invention relates to a system for heat treating materials in a continuous manner, in which the materials to be treated are passed through a continuously operating furnace in which the rate of travel of the material through the furnace is regulated in accordance with the temperature of the material being treated at a point within the furnace.

Heat treating of material in a continuously operating furnace is applied in numerous branches of industry. For example, in the manufacture and processing of articles or bands or strips of metal or metal alloys, ceramic materials, glass, cellulose materials and their combinations, synthetic resins and other materials, furnaces are utilized in which the material to be treated is heated throughout or is surface heated to the extent desired, whereby the material or article, as the case may be, is subjected to changes in its physical state or properties. Such heat treating measures are also applicable to the lacquer coating art. Continuously operating furnaces of this type frequently have zones of different temperatures so as to be able to subject the material to be heated to a time controlled heat treatment. The adjustment of the heat treatment is effected with a view of obtaining as high an output as possible and of imparting the desired properties to the material as uniformly as possible.

It is known in the art to regulate the temperature of heat treating furnaces of this character by a heat sensitive device, for example a pyrometer, and to utilize the measurements obtained thereby to control furnace conditions.

I have ascertained through long research in connection with industrial furnaces, that known systems do not result in a control which is free from objection, because the temperature of the material does not stand in an unequivocal relation with the temperature development in the various furnace zones.

It is therefore a primary object of the present invention to provide a novel and effective system of heat treating materials to impart the proper characteristics thereto and automatically control the development of temperature in all the furnace zones in dependence upon undesired changes of furnace operating condition, and upon given changes in the heat receiving properties of the treated material which may be occasioned by the thickness, breadth, quality of material, or surface condition thereof.

A further object is to provide a safe and efficient system of heat treating materials in which, in order to improve the production output and to obtain, if desired, special properties in the material being treated, provision is made for subjecting the material entering the furnace to a very high heat effect.

A further object is to improve and equalize the sus-

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ceptibility to heat radiations of the surface of the material to be treated for avoiding irregular thermal influences thereof when passing through the furnace. For this purpose the material entering the furnace is subjected to a very high heat shock in a medium by which its surface is uniformly matted or darkened for reducing its power of reflection of heat radiations. Such a matted or darkened surface has a higher susceptibility to heat radiations than a bright or polished one and practically does not alter its thermally effective structure even when passing a non-uniform furnace atmosphere. Really it has been found that for reaching a given annealing temperature bright metal sheet needs a longer time of heat treatment in the furnace, that means a larger furnace installation or a lower speed of passage through the furnace due to its high heat reflection than a material which has been matted or darkened according to my invention. Thus, the economy of a furnace installation is improved by my invention.

Furthermore by this preliminary heat shock treatment any foreign matter like traces of oil or grease disappear from the surface of the material to be treated either by evaporating or by chemical reaction e. g. burning away or are no more locally effective due to the general change of the surface structure. When burning away the material is additionally heated up without costs.

Furthermore due to said uniform matting or darkening of the surface of the material to be treated there is practically no more need for special precautions to get a proper average value of temperature and to adjust the point of measurement to distinct e. g. central regions of the material to be treated when measuring its heat radiation during its heat treatment inside the furnace.

In case of heat treatment of organic materials like foils of artificial resins, lacquer layers etc. the matted or otherwise pretreated surface may be restored to its original state after having passed the furnace, e. g. by calendaring. On the other side the matting of the surface by heat shock can be assisted by mechanical means like rough rollers.

An additional object is to provide a novel and effective automatic control system for heat treating furnaces and which control system is insensitive to short term changes in the heat properties of the material being treated at the measuring point.

A further object is to provide an automatic control device, under visible control, which can be adjusted to a desired measuring point on the material being treated.

It is desirable, say, in an electrically heated muffle furnace for the continuous annealing of metal strip, to set to a desired temperature some of the furnace zones through which the strip travels. Since, for practical reasons, a continuous resetting of the furnace is unsuitable, with the total width of the furnace otherwise uniformly utilized, the rate at which the material travels through the furnace may be varied in accordance with the momentary thickness of the strip, and in such a way that approximately the same quantity of material passes through the furnace in the same time. In this example this means that a thinner strip travels through the furnace quicker than a thicker strip. For these reasons, furnaces working on the above principle are provided with regulating appliances in order to be able to a great extent to alter the rate at which the strip to be annealed travels through. For their control, such furnaces are generally fitted with speed tachometers, so that the rate of travel of the material to be treated may be adjusted for a certain thickness of strip or some other dimension of the object to be annealed.

This working method involves various drawbacks, since it has been found in practice that the temperature conditions in annealing furnaces do not always remain con-

stant, in spite of the adoption of regulating devices for ensuring uniform furnace temperatures. Thus, for instance, heating elements may temporarily fail through defects. Besides that, normally in such furnaces different substances, such as different metals or metal alloys, are annealed, which occasionally have different specific heats, and thus the time required for annealing, the annealing temperatures and the rates of travel will change. Also the utilizing of the greatest possible effective width in such furnaces is not always the same, since with less utilization of the width, the rate of heating becomes quicker and the speed at which the treated material passes through must be greater than with maximum utilization of the furnace width.

Great differences in the heating up of the material also arise from distinctive surface conditions thereof. As is well-known, a dark or mat surface absorbs more heat through radiation than a light-colored or bright surface, which under certain circumstances may even be reflecting. Under these circumstances it is difficult each time to determine the correct rate of travel. In practice, great mistakes are made for this reason, since the various influencing factors are continually fluctuating during service, with adverse results on the output of the furnace, as well as on the quality, economy and uniformity of the treated material.

In contrast thereto the present invention relates to a system of heat treating materials which is first of all characterized by a continuously operating furnace including plural aligned sections the temperature of one of which lies above the critical treatment temperature of the material and by control means for regulating the speed of travel of the material so that the temperature of the material when passing said section remains below the critical value. The present invention is particularly suitable for the treatment of heated and annealed material, for instance, for annealing and heating semi-finished products of metal and metal alloys, likewise for the continuous drying or surface treatment of protective or other coatings in furnaces through which the material travels and for the drawing or pulling of metal strips or bands through continuously operating furnaces as well as for similar fields of application. It is then preferable to use a radiation pyrometer arranged at a distance from the annealed material in accordance with its optical dimensions and which is directed with its optical axis onto the workpiece, including thereby also a device adapted to maintain the temperature at a required value. Thus it is possible for the control appliances for the furnace to be rapidly and automatically brought into action by relay devices whenever a desired tolerance range of the desired temperature is exceeded. The value of the temperature measurement indicated by the appliance may also serve as an auxiliary means in the case of manual control, in order to permit proper adjustment to the correct rate of travel of the material through the furnace. Consequently, by the invention, an automatic regulation of the speed of material travel is possible in the furnace through the provision of at least one pyrometer for determining the warmth or heat content of the material itself, the pyrometer through its indicating equipment causing power impulses and thus the actuation of automatic regulating devices.

The invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 is a diagrammatic view, partly in longitudinal section, of the invention including the control circuits,

Fig. 2 is a partial view on an enlarged scale looking from the right in Figure 1 taken at the exit end of the furnace,

Fig. 3 is a detailed wiring diagram of the control installation of the invention,

Fig. 3-A is a similar view of a modified form of a portion of the control circuit, and

Fig. 4 is a graph of the temperature conditions existing in the furnace in an embodiment of the invention.

In the drawings is illustrated a heat treatment installation for annealing metal strips. The installation includes a furnace generally denoted at G and consisting of a tunnel-like structure including a longitudinally extending heating channel or passage of flat rectangular cross-section as apparent from Figure 2. In longitudinal section the axis of the furnace forms an obtuse angle. Along the inner walls of the furnace there are arranged a plurality of heating elements 1 which are adapted to be controlled independently of one another or in groups in a manner known per se in connection with influencing the heat output or heat content of the different zones of furnaces of this character.

In the particular arrangement shown, the heating elements consist of electric heating means although it is clear that the heating means can be constituted by gas burners or other known types of heating arrangements can be utilized.

The inlet or entrance end of the furnace is at the left side of Figure 1 and in front of the inlet there is arranged a set of gas Bunsen-type burners 101, 102 for abruptly heating up both surfaces of the material F to be treated. For this purpose the burners are arranged in two aligned rows across the width of the material F and on both sides of it. In the gas and air supply lines 103, 104 there are arranged valves 105, 106 electromagnetically controlled in accordance with the operation of the main driving motor 10 for preventing the material in treatment from being damaged or even burnt away by the very hot flames in case of a drive stoppage. When the driving motor is started the valves are opened and the gas and air mixtures leaving the burner outlets are ignited by electric sparks or continuously burning pilot lighting flames. By thus abruptly heating up the material, it undergoes an intense heat shock influencing its metallurgical structure. Furthermore, its surfaces are equally matted or darkened as by superficial oxidation of the material and the surface impurities such as grease etc., and therefore becomes better prepared for equally absorbing the heat rays in the following furnace sections. The described gas flames can be replaced by hot air jets, by hot fluid baths of molten salts or metals, by inductive heating or otherwise operated to give the same effect of abruptly heating up the material and equally darkening its surfaces. In connection with the hot air jets the same can constitute the exhaust from a gas turbine. The hot fluid bath of molten metal is the type utilized in metallurgy as, for example, for quenching wires, such as a bath of molten lead. Fluid baths in the form of salt melts are of the type used for refining or annealing steel or light metal. The inductive heating can be effected by any means known in the art. In this respect the before-described installation differs from known arrangements for preventing the open air from entering in to a furnace filled with inert or other gas by generating a gas veil by small gas flames at the furnace entrance. This known gas veil does not abruptly heat up the material in treatment or equalize its surfaces.

At the inlet a pair of rollers 2 is mounted to rotate about a horizontal axis mounted in suitable brackets fastened to the outer furnace wall. A pair of rollers 3 is mounted at the outlet or exit end of the furnace at the right side of Figure 1. In advance of the inlet of the furnace there is disposed a pedestal 4 which supports the feeding reel or drum 5 from which the material F to be treated is fed. At the exit end of the furnace and beyond rollers 3 is a pedestal 6 on which is mounted a pair of conveying rollers 7. Rearwardly of this pedestal in the line of travel of the material is another pedestal 8 on which is mounted the winding reel 9. These parts will be referred to in more detail hereinafter.

The heating passage extending through the furnace is sub-divided into several zones, each provided with heat-

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ing elements 1 adapted to be independently controlled. In accordance with the teachings of the present invention, two principal zones have to be distinguished. The first of these comprises the zone or zones in which the material to be treated is still in the process of heating up, or in other words its heat content is still rising, and the second zone comprises the following sections of the heating passage in which the material to be treated reaches its highest temperature and then cools down.

Thus in Figure 4 there is disclosed the temperature distribution in heating region I which comprises the furnace zones A and B and the heating region II which comprises the furnace zones C, D and E. As will be hereinafter described, in accordance with the teaching of the invention, the heating of these zones is controlled in such a manner that in relation to the heat receiving qualities of the material being treated, a temperature above the critical treatment temperature of the material exists in a part of the second heating region comprising the furnace zones C, D and E.

The temperatures of the heating elements or wall surfaces in the different furnace zones are controlled in a known manner by temperature measuring devices such as pyrometers 11 or other thermo-responsive elements of known types. In the embodiment shown, the measured value ascertained by the measuring device or pyrometer 11, for example the thermo-current of a thermo-element, is utilized for controlling a control means 12 governing the current to the heating element. This control means can comprise in a known manner a fall-lever instrument, a mercury switch and a switching relay. By this control means the temperature of each of the different heating zones is maintained at a predetermined constant value. Such a fall lever instrument is only one example for an instrument sensitive to changes of current or temperature and adapted to operate the mercury switch, relays, etc. Such instruments are commonly used and well known in the art.

The material F to be treated, for example a brass strip, passes from the feeding reel 5 through the heating passage, the various furnace zones, in free suspension between rollers 2 and 3 so as to avoid damage during passage through the furnace. The pairs of rollers 2 and 3 provide adequate support. After leaving the pair of rollers 3, the strip passes between conveying rollers 7 and is wound upon the winding reel or drum 9 which is driven by an electric motor 10.

The lower roller of the pair of rollers 7, through the intermediary of a pulley connected to said roller and a belt trained over the pulley drives a control cam 23 mounted in the pedestal 6 and carrying a control plug 24. In the line of movement of this plug 24 there is arranged a cam switch 25 of known design constituting part of the control arrangement for controlling the speed of travel of the material to be treated. This will be described in detail hereinafter. It is believed clear however that the cam switch 25 is actuated by the plug 24 always after a certain constant length of material to be treated has passed the roller pairs 7 between two successive actuations of cam switch 25. The arrangement is preferably proportioned in such a manner that the material which is still inside the heating channel or passage of the furnace at the time of the last control impulse of switch 25 will have almost passed through the furnace when the next or subsequent control impulse occurs.

The heat sensitive element 33 or means that is influenced by the radiant energy of the material to be treated, while it is generally in the heating passage in the furnace for controlling the speed of travel of the material, is not, as in known installations, disposed at the exit end of the furnace or adjacent the pair of rollers 3 but in accordance with the invention the location of this heat sensitive element (or in other words the measuring point of the radiant energy, emanating from the material being heated) is inside the limits of the heating passage,

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that is, well within the length of the furnace, and at a point in the heating region I adjacent or in proximity of region II. This heat sensitive element detects the radiant energy of the material being treated at this measuring point and regulates the speed of passage of the material in accordance with the temperature of the material at the detecting point to maintain the temperature of the material below the critical treatment temperature while it passes through the second region II or the furnace zones C, D and E. As previously indicated, the material reaches its desired treatment temperature within the second region, and the temperature of the furnace in a part of this region is above the critical material treatment temperature. Thus the detection of the material treatment temperature occurs at a point in its passage where it is still heating up.

To accommodate the heat sensitive element 33, the wall structure of the furnace is provided with a channel or passage 31 for transmitting rays. This channel is closed by a window 32 which is permeable to the rays to be measured. The window consists of a special glass or is made of a suitable salt such as CaF_2 and is as thin as possible in order to avoid radiation losses, and moreover is dome-shaped or curved to diminish the risk of cracking. This window is replaceable in order to facilitate the cleaning thereof or exchanging windows. In addition, the window is so mounted with relation to the passage 31 as to avoid the leaking of hot air from the furnace or, in those instances where the furnace is operating with inert gases, to prevent the entrance of air thereto.

The heat or radiation measuring device or element indicated at 33 is mounted on an arm 34 which is pivoted on a horizontal shaft 35 extending generally transverse to the axis of the furnace. This shaft 35 is carried by a normally vertical arm 36. The arm 34 is combined with a toothed segment 37 which is in mesh with a worm wheel 38 on a shaft mounted on the arm 36. A hand wheel 39 controls the worm wheel. Therefore it is possible to tilt the heat sensitive measuring device 33 about the axis of shaft 35 and thereby to adjust the optical axis in the plane of Figure 1. The arm 36 extends from a shaft 40 rotatably mounted in a bracket 41 arranged on the top of the furnace. The shaft 40 is connected to a shaft indicated diagrammatically at 45 by spaced ball or universal joints 42 and 44 and an interconnecting link 43 also denoted diagrammatically. The shaft 45 is mounted in a bracket 46 carried on the top of the furnace on the exit end thereof and a pointer 47 is mounted on shaft 45 and extends downwardly toward the line of travel of the material being treated at an area immediately rearward of the rollers 3 and thus just beyond the exit end of the furnace. A worm gear 48 is provided on shaft 45 in mesh with a worm 49 carried by a shaft supported on a suitable standard mounted on the furnace wall and on which shaft is mounted a hand wheel 50; see also Fig. 2. Thus it follows that the distance of the point of rotation of the optical axis of the heat ray measuring device or element 33, namely the central line of its pivot axis 40 with relation to the surface of the material to be treated at the measuring point in the region of the detecting channel 31, is the same as the distance of the central line of the axis of the shaft 45 from the surface of the material to be treated rearwardly of the furnace exit, namely as the length of the pointer 47. Therefore the position of the pointer 47 with relation to the material F being treated corresponds to the lateral position of the measuring point on the material inside the heating passage, so that the detecting element 33 is directed toward the material inside the furnace in the same relation as is the pointer 47 exteriorly of the furnace. This provision for transversely adjusting the optical axis of the heat or radiation detecting means is a decided advantage if several narrow strips of material to be treated are simultaneously passing through the furnace side by side, since it is of importance that the optical axis of the radiation detecting

device be not directed to the space between adjacent strips.

The circuits connected to the measuring device or element 33 have been indicated schematically in Fig. 1 and are further detailed in the showing of Fig. 3.

The heat sensitive measuring device 33 energizes by means of the relays 27, the speed control device 28 also influenced by the cam switch 25 or the barrier photocell 93 or by both. By means of wires 61, 62 the measuring device is connected to the circuit with the relay device 27 in which one of the relay contacts 63 or 64, respectively, is actuated in a manner known per se, for example by a phase sensitive bridge work, by the measuring instrument or device 33, when the material temperature is above or below the adjustable range of tolerance, respectively.

For instance the relay 63 is actuated by a material temperature that is too high and is connected on the one hand by a circuit including wire 65, and fuse 66, to one phase of the power supply line to the electric motor 10 and on the other hand through wire 67 and the normally closed respectively fixed and movable contacts 68' and 68'' and armature of the time delay (slow release) relay 68 to the connecting point 69, thence via device 85 (to be described below) by wire 70 to cam switch 25, over wire 71 to connecting point 72, through wire 73 to the neutral wire of the electric motor 10. Through this current arrangement fed from the supply line of electric motor 10, the control circuit is rendered operative only when the strip is moving.

Thus relay 64, which is responsive to the opposite deviation of temperature, is connected through wire 65 to the same phase of the electric motor 10 as is relay 63 and on the other side by wire 74, the normally closed respectively fixed and movable contacts 75' and 75'' and armature of time delay (slow release) relay 75 to connecting point 69, then by wire 70 to cam switch 25, then by wire 71 to connecting point 72 and further by wire 73 to the neutral of the electric motor 10.

Thus if relay 63 is actuated, time relay 68 responds so that during the adjusted working time of the relay its normally closed contacts are open and its operating (normally open) contacts are closed. Thus wire 67 is disconnected from the circuit of the connecting point 69 and is connected through wire 76 and the coil of reversing switch 77, which includes respectively fixed and movable contacts 77' and 77'', to the wire 73. If on the other hand relay 64 is actuated, time relay 75 responds whereby during the adjusted working time of the relay its normally closed contacts are open and its operating contacts are closed. Thus wire 74 is disconnected from connecting point 69 and is connected by wire 78 and the coil of reversing switch 79, which includes respectively fixed and movable contacts 79' and 79'', to wire 73. Therefore when the relay 63 is actuated, reversing switch 77 is operated during the holding time of time relay 68 and when relay 64 is operated reversing switch 79 is operated during the holding time of time relay 75. In this manner servo-motor 80 comprising also an angle indicator 81 is driven in a known manner by the three-phase network 82 including fuse 83, in one or the other direction respectively, and thereby controls the speed of the material to be treated, for example by a conventional variable speed control gear indicated diagrammatically at 84 in Fig. 1, in the same sense.

This control can also be effected electrically by influencing the field of the motor driving the furnace conveying equipment. By feeding the motor through grid-control rectifiers, the control can be effected by altering the grid voltage. In addition a Ward-Leonard control system may be utilized.

Preferably between the time relays 68 or 75 respectively and the cam switch 25, for example in the circuit between connecting point 69 and wire 70, is disposed a momentary or snap contact device 85 of any desired or known form for maintaining the time of effectiveness

of cam switch 25 constant and short, independently of its speed of rotation and therefore independently of the speed of travel of the material being treated through the furnace. In addition, this device 85 prevents a repeated regulation when the cam switch happens to be closed for a longer period. The snap contact device is an instrument well known in the art which includes a biasing spring snapping off when released to close the contacts and immediately jumping back for only momentary closing the contacts. In lieu of a snap contact device a momentary operating time relay of any type known in the art can be utilized.

In order to exclude over-control or hunting as far as possible, the relays having contacts 63 and 64 are adjusted in such a manner that they respond only at the respective limits of an adjustable tolerance range of the radiation detecting or measuring element or device 33.

To maintain the prescribed course of temperature of the material to be treated as accurately as possible, it is of advantage to provide that the alteration of speed by the automatic control is proportional to the existing drive speed. For instance this may be done in such a way that each control impulse does not simply effect always one and the same numerical change of speed but effects a change of speed proportional in degree to the respective speed of travel of the material as it is moving through the furnace. With a high rate of passage, therefore, the change of speed through one control actuation or impulse is thus greater than the speed change occurring if material is being fed through the furnace at a lower rate or at low speed.

One way in which this may be done is shown in Fig. 3, in which the speed of rotation of the transmission-adjusting motor 80 is controlled by the energization of an auxiliary motor winding H fed from a tachometer generator J driven from the machine itself, as by being belted or connected to roll 7 of Fig. 1, which rotates proportionately to the strip travel speed. Thus, when a control impulse reaches motor 80, it will respond for a time fixed by the control circuits already described, but at a speed proportional to the strip speed. Hence, the change in speed of strip travel will vary with its existing speed at the time the control is exercised.

A modified form of such a proportional speed change arrangement is diagrammed in Fig. 3-A, in which a potentiometer K in the control circuit of the motor 80 is driven by either a speedometer shaft influenced by the main machine drive, or alternatively by, as shown, a tachometer generator J driven as in the preceding paragraph from the machine drive. Other arrangements for influencing the magnitude of the speed change in accordance with the momentary or existing speed of the machine will be apparent to those skilled in the control art. When using a motor fed through grid-controlled rectifiers the proportional speed change can be caused by inserting into the grid circuit a graduated resistance the steps of which have different resistance values. United States Patents Nos. 2,508,640 to Kuhlmeier and 2,627,594 to Sawyer are illustrative showings of thyatron-controlled A. C. motors whose speed depends upon the grid resistance.

Since speed of travel or passage of the material F is also a function of the mass of the material being treated per unit of time, the above mentioned speed changes may also be controlled in dependence upon the thickness of material or on the size of the pieces, if discrete pieces are being treated, or on the distance existing between discrete pieces in the instance where the material consists of discrete pieces of work and is fed through the furnace on a conveyor. Thus in instances where thin materials are being treated, the alteration in speed is to be greater than is the speed alteration when thicker materials are being treated.

If the material to be treated does not consist of a

single or coherent strip but is comprised by individual work pieces traveling through the furnace at intervals, it is essential that the heat measuring devices be effected only when a suitable section or spot of the material to be treated is actually in the range of the optical axis of the radiation measuring device. This may be effected for instance by material, in passing through the furnace, actuating mechanical means or by abutting against a stop on a lever or optically by the material interrupting a light ray energizing a photocell. In the embodiment illustrated in Fig. 1 the control impulse is effected optically and photoelectrically.

To effect this control, on the top of the furnace adjacent the radiation detecting or radiation device 33, there is mounted a spot light 91. Beneath the furnace and generally subjacent light passage 31 is another light passage 92 extending through the masonry forming the bottom of the furnace and beneath the exit or lower end of this light passage 92 there is mounted a photocell 93. The arrangement is such that the optical axis of the ray of the spot light passes through the cover window 32, the measuring ray or light passage 31, the area of the line of travel of the material to be treated and the light passage 92 to energize the photocell 93. This photocell 93 is a component of a light ray barrier installation of known kind and for instance by wires 94 and 95 actuates a relay 96 whose contact influences the speed control via wires 70 and 71. This prevents regulation occurring except when a workpiece is in position to influence the pyrometer 33.

It should be noted that the photocell 93 may respond in a spectral range of rays which is not provided in the furnace. For instance a cell responsive to only very short-wave radiation may be utilized. It is also possible to use suitable filters for excluding any undesired radiation from the radiation sensing device 93.

As has already been set forth in the foregoing, the measuring or detection of radiation or radiant energy of the material being treated is effected in a point in heating region I adjacent to or in proximity to heating region II in which latter region the temperature is above the critical treatment temperature of the material. The speed of passage of the material to be treated is controlled by this radiation measuring in such fashion that according to the heat receiving capacity of the material being treated, the material is always moved through the heating region II or what may be termed the superhot region, so rapidly that it does not stay therein, so that it is not subject to this heat in this region for a sufficient length of time to heat up beyond the critical treatment temperatures of the material. This critical treatment temperature of the material of course depends on several factors with particular reference to the peculiarity of the material and the results to be obtained by the heat treatment process.

For instance, when treating metals and metal alloys, especially when soft annealing, it is necessary to take into consideration the fact that the material to be treated undergoes metallurgical alterations or changes, especially with regard to its structure. Particularly, the material recrystallizes and thus homogenization, heterogenization and growth of grain occurs. The process of recrystallization occurs very rapidly when the necessary temperature has been reached, and it starts more quickly if the material has been hardened by a previous cold rolling or a cold drawing, as is the case with strips and wire.

On the other hand, the soft annealing process determines the fineness and regularity of the grain. The more rapidly the required recrystallization is reached, the finer will be the grain structure and this is a most desirable result. Since in accordance with the invention the temperature of the heating passage of the furnace in the critical heating region II is higher than the temperature of the material to be treated, a quick recrystallization and a correspondingly fine grain structure can be

attained. By using a very high initial or heating up temperature in region I, for example, an existing cold hardness may completely be removed and by reason of the fine grain structure attained the material may attain a deformability suitable for deep drawing purposes which previously has not generally been attained, and, if obtained, rather infrequently and only with such precautionary measures as serve seriously to reduce the output, if one follows known annealing processes.

An additional advantage of quick and intensive heating up consists in that the oil residue which often remains on the surface of the material to be treated, from previous treatment steps to which the material was subjected, is more readily removed by the heating effect. In other words this oil residue blazes off more readily, resulting in a clean and fine appearing surface of the finished strip and eliminating the necessity of special washing or degreasing steps for removing the oil layer or film.

In addition, utilizing the invention, a predetermined residual hardness of, for example, one-eighth to one-fourth hard, can be obtained with certainty by imperfect recrystallization at a lower maximal temperature. Known methods of furnace control do not permit or allow necessary supervision and maintenance of critical temperature of treatment of the material. However, in accordance with the invention the mechanical qualities of the annealed material such as the yield point, the breaking strength, the Brinell hardness with decreasing elongation values can be improved. However, since the production of a uniform degree of recrystallization becomes more difficult with higher values of residual hardness, it is in general not advisable to demand a residual hardness exceeding one-fourth hard.

The maintenance of a predetermined residual hardness during soft annealing has the commercially important advantage that the additional process hitherto necessary for repeated hardening by a cold rolling or drawing is eliminated. Furthermore, with the same adjustment of the zone temperature, the speed of passage of the material to be treated and therefore the output of the furnace installation in general, are for the most part substantially increased due to the lower set temperatures of the material, when following the teaching of the invention.

It has been found by experience that the optimal results are obtained when the highest treatment temperature of the material is adjusted in such fashion that it lies a little above the momentary recrystallization temperature of the material. This adjustment, on the one hand, avoids an excess of loss of heat energy by furnace losses and the like, and on the other hand, prevents a coarsening of grain and a change of crystal phase, both effecting the undesired qualities in the material. Similarly, in a drying process, the qualities of the finished product may suffer by an extended heat treatment.

Thus in the case of a brass alloy containing 63% Cu and 37% Zn, a β -brass may form along with α -brass, or in the case of an aluminum alloy containing Cu and Mg extensive homogenizing, combined with a certain age-hardening, may occur, particularly if the cooling of the semi-finished products is effected too quickly. The same is true with regard to the treatment of steel.

In addition to the heating up condition, the cooling process may be controlled, in accordance with the invention in order that by a retarded cooling the time-dependent homogenizing and heterogenizing processes may be correctly controlled and thus a desired softness of the material may be obtained. Therefore, in accordance with the invention, all necessary theoretical conditions of temperature can be set and definitely maintained in dependence on the actual radiation of the material in the furnace. With the known processes and control thereof, this facility is not possible since, in view of the possibility of over-heating, the temperature of the furnace cannot be set higher than the critical treatment temperature of

the material for reasons of safety. This involves not only a higher input of working time and heating energy with the same output but likewise requires a larger furnace or installation. However, following the teachings of the invention the highest allowed temperatures in the furnace passage can be used, and due to the higher speed of passage of the material to be treated, a furnace of a given size effects a higher output of material or a predetermined output of material can be produced by a furnace plant smaller in size or in the number of furnaces.

The same and similar viewpoints are equally true when utilizing the invention for drying material that is continuously fed through a furnace. Additionally the invention may be advantageously utilized for heating up material to the temperature of hot deformation.

The location of the radiant energy measuring device 33 in the heating region I as adjacent or in proximity to the heating region II, in an area in advance of that spot where the material to be treated has reached its highest temperature, therefore provides the additional advantage for measuring techniques, that at the measuring point there is no great difference of temperature between the material to be treated and the walls of the furnace passage. Therefore, erroneous measuring caused by partial reflection of the higher radiation of the furnace walls on the surface of the material to be treated can be avoided. On the other hand, for preventing any cooling of the material to be treated in the measuring zone, it is preferable to keep the temperature of the walls of the furnace somewhat higher than the temperature of the material to be treated. In the case of annealing furnaces, a difference in temperature of about 30 to 50° C. has proven to be satisfactory. With materials of stronger or better reflecting qualities, the difference of temperature degree can be slighter or lower.

Additionally the temperature of the furnace wall in the treatment passage may bear such a relation to the temperature of the material to be treated (which is indicated by the radiation measuring device) and the control so correlated that if there is a drop in the temperature of the material to be treated the wall temperature can be lowered to a similar extent.

It is also possible, in order to prevent undesired furnace wall radiation, to arrange protective screens. This step is recommended particularly if the furnace plant is subdivided into only a few zones.

The principle of the invention has been graphically shown by the temperature graph of Figure 4 with relation to one embodiment. The lengths of the furnace from the inlet, on the left side, to the exit on the right side, are plotted as abscissae and the temperatures of the different heating zones A to E, as ordinates on the stepped curve. The curve *a* designates the temperatures of the material to be treated under conditions which are correct for the particular embodiment, namely in the case of the correct rate of travel through the furnace. As can be seen, the material to be treated reaches its allowed highest temperature represented by a circle on the line *d* and the temperature of the furnace area C is above this temperature. According to the invention the temperature of the material to be treated is measured at the end of the heating region I, namely at the point of measurement M where under correct conditions of operation the correct temperature *T_c* is measured by the radiation measuring device 33 which under such circumstances will not initiate control impulses. If by a change in the heat receiving capacity of the material to be treated, for example by a change in the thickness or in the surface qualities of a metal strip, the material is insufficiently heating up, the course of temperature in the material may, for instance, change into the curve *b* furnishing an insufficient maximal temperature *T_h* on the line *d* but also at the measuring point M. Therefore, as has been described in detail in the foregoing, the control installation is adjusted in such a manner that the radiation

measuring device 33 effects control impulses to reduce the speed of passage of the material to be treated to such an extent that the material is able to receive heat in order that the prescribed temperature course thereof will rise and correspond to curve *a*.

If, on the other hand, for the same reasons the material to be treated is heating up in region I too high or too quickly, for instance along the curve *c*, it would reach the forbidden maximal temperature *T_h* and would be damaged without an appropriate adjustment of its speed of passage. Therefore in such instances, the radiation measuring device 33 initiates an impulse causing an acceleration in the speed of passage of the material until the correct course of temperature according to curve *a* has again been reached. It is evident that the graph of temperatures shown in Figure 4 is only diagrammatic and that the incorrect curves *b* and *c* have been represented exceedingly far away from the normal curve *a* only for ease of understanding. As a matter of fact and as is the case in control devices of this character, the control device in accordance with the invention also responds to small deviations in temperature occurring at the measuring point M, so that the deviations in temperature that occur stay within the adjustable range of tolerance of the radiation measuring device 33 and any deviations within this range can be neglected.

The following examples will serve to explain the effectiveness of my invention:

Sheet brass in strip form of 621 mm. width and 0.5 mm. thickness, having a critical annealing temperature of 620° C., was annealed in a continuously operating furnace having a length of 6 meters and subdivided into five heating zones. For avoiding superheating of the brass strip passing the furnace at the usual speed of 1200 mm./minute, corresponding with an output of 250 kg./hour, the temperatures of the five furnace zones had to be kept at 750°, 700°, 600°, 570°, and 550° C. respectively. The specific consumption of current was 135 kwh./1000 kg.

Now in a second experiment using the heat control means according to my invention, the same brass material was annealed in the same furnace in which the temperatures of the five zones were kept at 830°, 800°, 650°, 580°, and 540° C. respectively. The speed of travel automatically was brought up to 2500 mm./minute corresponding to an output of 418 kg./hour, the temperature of the brass strip nowhere in the furnace exceeding 600° C. and thus safely remaining under the critical value of 620° C., though the furnace temperature in the middle zone was far above said temperature. The specific consumption of current dropped down to 117 kwh./1000 kg.

Thus by my invention the gain in output is improved by about 67% and the saving of energy input amounts to more than 13%.

In a third experiment, the preheating gas burners in front of the furnace inlet were operated, the temperature conditions inside the furnace remaining the same as in the second experiment. With this preheating the speed of passage of the brass strip again automatically was brought up to 3000 mm./minute, corresponding to an output of 600 kg./hour by using the control means.

Thus the gain in output is doubled in comparison with the prior art, without any risk of overheating the material in treatment.

What is claimed is:

1. In apparatus for the heat treatment of materials, of the type having a furnace passage and drive means for propelling the material through said furnace passage and including plural individually controlled heaters distributed within said furnace along the path of travel of the material, means controlling the heaters to provide different treatment temperature zones for such material including a first zone where the temperature of the material is rising and at least one immediately succeeding zone where the material attains a desired critical temperature and in which

the zone temperature is above the desired critical temperature, sensing means operatively associated with the first zone at a point in proximity to said second zone to thus sense the temperature of the material at an intermediate point in said furnace passage, automatic means controlled by said sensing means for varying the speed of travel of the material imparted by said drive means to maintain the temperature of the material at a desired value in passing through the passage, and means responsive to the speed of travel of said material for regulating the magnitude of the speed variation produced by said automatic means.

2. Apparatus in accordance with claim 1, in which said automatic means comprises a variable speed drive transmission and a motor for adjusting the setting of said transmission, and in which said means responsive to the speed of travel of said material comprises a control for the speed of said last-named motor.

3. Apparatus for the heat treatment of materials, a furnace passage, drive means for propelling material through said passage, means for heating the passage to provide a first heating region where the temperature of the material is being elevated and a succeeding region maintained at a temperature above the critical treatment temperature and in which the material attains a critical treatment temperature, said drive means including a motor and a variable speed drive transmission, means cooperatively disposed with respect to said first region for sensing the temperature of material therein, means for periodically adjusting said transmission in accordance with said sensing means to vary the speed of material travel so that its temperature does not exceed the critical treatment temperature in passing through the passage, means for regulating the time of operation of said last named means, and means for modifying the operation of said regulating means in accordance with the instantaneous speed of travel of said material.

4. Method of achieving an improved and more uniform heat reception by material in industrial heat treatment which comprises moving material to be thermally treated to and through a heat treatment zone, matting opposite surfaces of the material by applying heat to the opposite surfaces of the moving material immediately prior to entry of the material into said heat treatment

zone so as to impart to the surfaces an oxidizing temperature while maintaining the interior of the material cool in relation to and in comparison with its surface temperature and controlling said application of heat in response to movement of the material through said zone.

5. In a system for heat treating materials, means defining a furnace passage through which material passes, forwarding means for moving material through the passage, a first heating means arranged inside said passage for imparting heat to the material as it moves there-through, control means for said first heating means operative to establish predetermined temperature conditions within said passage, second heating means arranged immediately in front of the entrance of said passage and adapted to extend completely across the width of the material to transfer heat to said moving material before it enters said passage so as to subject the material that is to be heat treated in the passage to an intensive application of heat of such short duration as would impart to the surface of the material an oxidizing temperature while the interior of the material is maintained cool in relation to and in comparison with the surface temperature of the material, second control means for said second heating means, and means interconnecting said second control means with said forwarding means so as to regulate said second control means in accordance with the operation of said forwarding means.

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