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METAL HEATING FURNACE SYSTEM

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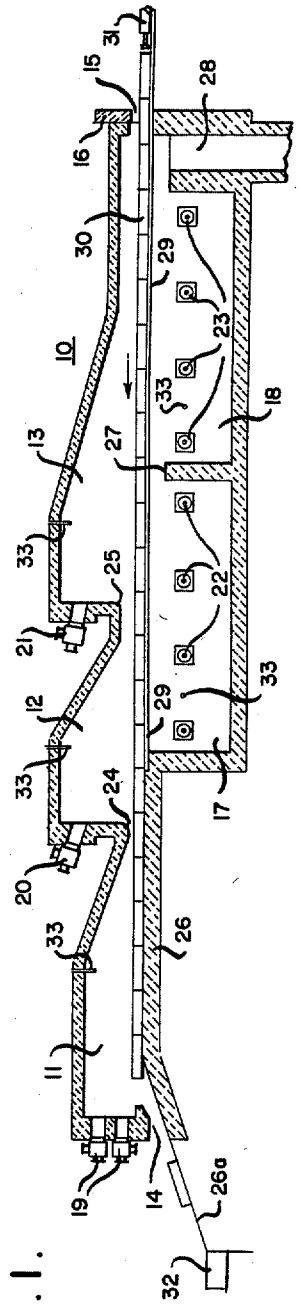


Fig. 1.

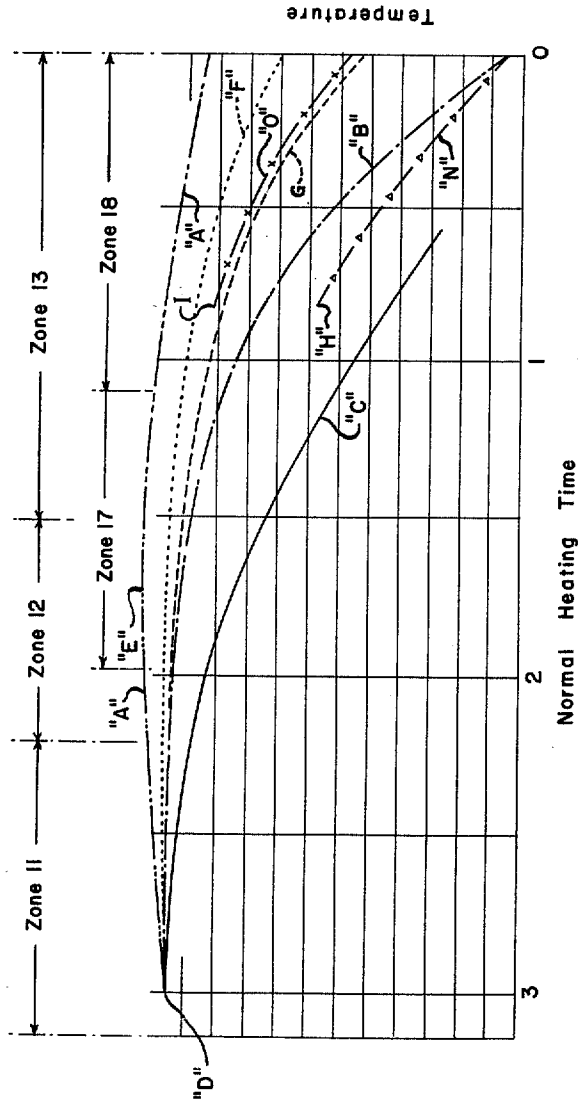


Fig. 2.

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METAL HEATING FURNACE SYSTEM

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This invention relates to a new heating furnace system for metal workpieces, especially those of relatively thicker section such as slabs, billets, bars, solid rounds and other shapes. More particularly, this invention includes a new method of operating a continuous metal heating furnace, such as those for slabs and the like, in the event of delay or interruption, to inhibit the burning or washing of the hotter metal as well as the production of underheated metal therefrom when operation resumes.

Heretofore, in the event of a mill delay or other interruption, it has been a common practice in some places to reduce the furnace temperature during such delay at least in portions of the furnace other than the soaking section at the discharge end, for example, of three-zone pusher-type slab-heating furnaces. Even in that case, the furnace temperatures toward the charge end remain materially hotter than the temperature of metal workpieces therein. Consequently, in the event of delay in the movement of workpieces through the furnace the temperature thereof at least in the heating area will increase beyond the desired normal work temperature curve for such work. This problem is more significant and complex with metal workpieces of relatively heavier section and in furnaces employing relatively high thermal heads for optimum production capacity. Heretofore, upon resumption of operation after delay, hotter metal which had remained beyond the normal period in the heating area of the furnace could not thereupon be subjected to normal furnace heating temperatures without risk of or actual washing and burning. On the other hand, relatively colder metal entering the furnace upon such a resumption of operation became adjoining and adjacent to such relatively hotter metal. Such relatively colder metal, moreover, would not come up to desired hot metal or finish temperature for rolling or other mill treatment in the normally allotted time when not subjected to normal furnace temperature and prescribed thermal head along the movement line. In order to try to overcome the dilemma, a common prior practice provides for a further stoppage of the movement of work going through the furnace after resumption of operation when such relatively colder metal had substantially displaced all of such hotter metal from the heating area of the furnace. Or, in another practice, the hotter metal present in the heating area of the furnace during the delay was actually subjected to washing and the possibility of burning by increasing the furnace temperature too much in order to try to get the colder newly entering metal up to finish temperature by the time it was discharged from the furnace. Both such practices involve economic detriment and disadvantages from the

point of view of optimum capacity production and operation.

In the new system of this invention, the foregoing difficulties may be overcome by providing a heating furnace with a plurality of top heating zones and a plurality of bottom zones along the movement or pass line therein for the metal workpieces to be heated, such zones, save for a final soaking zone at the discharge end of the line, being normally and constantly operated to provide respectively increasing temperatures in the metal workpieces passing therethrough, and, sequentially operated or adjusted from charge toward discharge end following a delay or other interruption of normal movement of workpieces through the furnace to achieve after such delay the inhibition of washing and burning of the hotter metal, the avoidance of further movement interruption or stoppage along the pass line and the heating of the colder newly charged metal to desired finish temperature by the time of its discharge.

Other objects, features and advantages of this invention will be apparent from the following description and the accompanying drawings, which are illustrative of one embodiment only of our invention, in which,

Figure 1 is a schematic view in elevation and longitudinal section of a continuous heating furnace, for slabs or the like, provided with five zones and adapted to be operated following any delay or interruption in the movement of workpieces therethrough to inhibit overheating of hotter metal, and, underheating of colder metal entering such furnace following such delay or interruption, without having to incur any further delay or interruption; and

Figure 2 is a schematic diagram of furnace and workpiece temperatures respectively for the furnace illustrated in Figure 1 to show both a normal functioning of such furnace and a superimposed functioning thereof following a mill or other delay or interruption in the movement of the workpieces therethrough.

Referring to Figure 1 of the drawings, a slab heating furnace 10 is provided having three top zones respectively numbered 11, 12 and 13 and two bottom zones respectively numbered 17 and 18. The zones extend between a discharge opening 14 for workpieces heated and soaked in furnace 10 and a charge opening 15 for the entry of relatively cooler workpieces to be heated. Opening 15 has a movable door 16 therefor. The top zones 11, 12 and 13 are separately directly fired and heated by end burners respectively numbered 19, 20 and 21 which are independently regulatable respectively either manually or automatically through various types of controls. The bottom zones 17 and 18 are separated by a wall 27 and respectively directly fired and heated by side burners 22 and 23 which are independently regulatable either manually or automatically. Thus separately selective heat inputs, burner turndowns and burner shut-offs may be provided for each of the zones.

It will be understood that various kinds of burners may be respectively utilized in the zones of furnace 10 and may operate on one or more fuels, usually either fuel gas or liquid fuel. Further, different arrangements of zones may be provided in whatever furnace structure is selected with preferably at least four heating zones, to heat as zones 12, 13, 17 and 18 do and provide the flexibility required for optimum functioning of our invention. In furnace 10, the zone 11 at the discharge end of the

heating zones is preferably a soaking zone where hot metal temperature is maintained and any remaining lag between center and surface temperatures in a particular workpiece is taken up to produce the usually desirable same finish temperature at surface and center before the particular workpiece is discharged through opening 14 to slide down down apron 26a.

Combustion gases originating in each of the five zones flow toward the charge end of furnace 10 and exit through flue 28 at the rear end of zone 18. It will be recognized that although flue 28 is a bottom flue, practices of this invention may use a top flue or flues at both the bottom and top of the furnace, preferably adjacent the charging end. Such combustion gases in the case of those originating in zone 11, the soaking zone in the illustrated embodiment, will pass beneath the noses 24 and 25 respectively marking the rear ends of zones 11 and 12 and will also pass over the front and back ends of zone 17, the wall 27 being a back end for zone 17 and front end for zone 18 in furnace 10 as shown. The respective heating zones in furnace 10 are offset in the direction of movement of workpieces, as indicated by the arrow, from the charge end toward the front or discharge end of furnace 10. As shown, the heating zone order from charge toward discharge as demarked by the front boundaries of such heating zones are zones 18, 13, 17 and 12, respectively.

Furnace 10 preferably is lined with refractory and workpieces in the form of slabs 30 passing therethrough are first supported on water-cooled skid rails 29 above bottom zones 17 and 18 and then move onto a solid hearth 26 before being discharged. Workpieces 30 are intermittently but constantly moved by a pusher 31 through furnace 10 in a continuous line in the course of a normal operation. A mill table 32 may be provided to receive the hot metal from furnace 10 and transfer it to a hot strip rolling mill or other equipment in the mill.

In a given normal operation of furnace 10 with slabs 30 passing therethrough continuously at a predetermined rate without interruption, a predetermined relatively high thermal head may be maintained in furnace 10 for optimum production capacity by holding the furnace at a temperature such as that represented by a heating curve "A" (dash-and-double-dot line) illustrated in Figure 2. Temperature sensing devices 33 may be employed as indicators of curve "A" for control purposes and any desired adjustment thereof. Predetermined furnace heating curve "A" as illustrated will result in a selected thermal distribution along the length of the furnace such that the surface and center temperatures of slabs 30 will respectively follow an optimum surface temperature curve "B" (dash-and-dot line), as indicated by pyrometric or other methods, and a center heating curve "C" (solid line) under the selected operating conditions of furnace 10. The selected finish temperature of both surface and center of each workpiece will be reached at a point "D" in zone 11 near exit 14 as shown on the Figure 2 diagram.

Thus, in a given normal operation, each incoming workpiece 30 will be preheated and then heated to higher temperature, with due regard for any time needed substantially to overcome lag between center and surface temperatures, before the workpiece leaves the heating zones as it passes beneath nose 24 to enter the soaking zone represented in furnace 10 by zone 11. And, in such normal operation, the furnace temperature in providing as much thermal head as possible, may achieve a peak temperature at point "E" in excess of 2400° F., when slabs, for example, are being heated.

In the event of a scheduled or of an unscheduled mill delay even when of long duration and when heating relatively thick metal workpieces, furnace 10 may be operated under this invention upon the resumption of operations following such delay to inhibit overheating of the metal which remained in the furnace 10 during the delay and underheating of the newly incoming cooler metal workpieces 30 pushed into furnace 10 following such delay because the respective heating zones in furnace 10 are, under our invention, respectively operated to achieve such results. Moreover, such resumed operation will not have to be discontinued temporarily to allow such relatively cooler metal to come up substantially to desired finish temperature.

By way of illustration only, and not by way of limitation, let it be assumed that furnace 10, which under a normal operation is represented by the curves "A," "B" and "C" and the time units shown on Figure 2, encounters a mill delay or interruption under which additional metal workpieces cannot be charged into furnace 10 and those therein are stopped and remain within the furnace during such delay. In that situation, the persons operating furnace 10 would turn the burners 20, 21, 22 and 23 down as far as possible and where it is anticipated the delay might be relatively long the burners in zone 12 might be turned off. Generally, burners 19 would be allowed to continue to fire zone 11, the soaking zone, in a normal manner since in that zone the furnace temperature approximates the actual temperature of the work which actual temperature is virtually at the selected finish temperature as shown in Figure 2. Such turndown in the heating zones would lower the furnace temperature there, one exemplification being indicated by the dotted line "F" superimposed on Figure 2 in correlative relation to distance within the furnace from the charging end. However, such reduction in the firing of zones 12, 13, 17 and 18 would not be able to maintain the metal workpieces 30 in these zones at normal surface temperatures represented by curve "B." Instead, the temperature of the stopped workpieces 30 between zone 11 and the charging end of furnace 10 will rise in the exemplification of the curve indicated by the dash line "G" at about the time the delay terminates for the furnace heating area delay period curve "F."

Upon such a resumption of continuous operation at the end of such delay a relatively cool slab (hereinafter referred to as slab 30N) is pushed into abutment with the last slab of hotter metal in the furnace during the delay (hereinafter referred to as slab 30F) to restart the continuous movement of metal workpieces through furnace 10 along the pass line therein. And, burners 21 and 23 may be turned up somewhat to increase the furnace temperature in those zones 13 and 18 as more relatively cooler slabs enter through opening 15 to achieve a furnace temperature condition between curves "F" and "A." As the first newly entering slab 30N passes along skids 29 within zones 13 and 18 its surface temperature will be increased in a manner such as that indicated by a curve "N" (dashes and triangle line). The immediately preceding slab 30F of hotter metal will be pushed along therewith and somewhat increased in surface temperature as indicated by a curve "O" (dash and X line). After movement of the two exemplary slabs 30F and 30N into furnace 10 for a distance represented by a vertical ordinate through a point "H" on Figure 2, the surface temperatures of those slabs will respectively be at points I and H, the height of the ordinate between those two points representing the surface temperature difference at that time and place for the given example. Hence, the furnace temperature of furnace 10 must be kept below curve "A" for the illustrated embodiment substantially and respectively until that last hotter metal slab 30F has substantially passed out of each of the heating zones 18, 13, 17 and 12 respectively in the course of its movement toward the discharge end of the furnace. At the same time, enough heat must be put into heating zones sequentially from the charge end to bring the curve like curve "N" of a relatively cooler slab as close to curve "B" as possible until the furnace is brought wholly back to normal operating conditions. In this invention, with our provision in furnace 10 of four offset or overlapping inde-

pendently fired heating zones, it is possible to accomplish such protection of hotter slabs and heating of cooler slabs with a resumption of continuous operation and thereby to avoid overheating hotter slabs moving through zones **18**, **13**, **17** and **12** and to avoid underheating the adjacent cooler slab following such hotter slabs. Thus, as slab **30F** crosses above wall **27**, burners **23** in zone **18** can be turned up to normal operating level with, in some cases, the possibility of an even greater rise in the rate of firing of the burners **23** to raise, if desired, the zone **18** portion of curve "A" slightly above its normal operating temperature condition to help bring succeeding temperature curves similar to curve "N" even closer to curve "B" until normalcy is wholly restored to furnace **10**. Further, substantially, as slab **30F** passes nose **25** the burners **21** for zone **13** can be turned up to normal level or temporarily slightly above as in the case of burners **23** for zone **18**; as slab **30F** passes the discharge end of zone **17**, the burners **22** for that zone can be turned up to normal level or temporarily slightly higher as described above; and as slab **30F** moves under nose **24** to go into zone **11**, the burners **20** firing zone **12** would be turned on or turned up to normal level, as the case may be, or temporarily fired slightly higher as described above until complete restoration to normal operating conditions has been made pursuant hereto. Such sequential increase in the firing of the successive zones **18**, **13**, **17** and **12** taught by this invention will mean that even though the last hotter metal slab **30F** is not overheated, the first slab **30N** entering the furnace upon resumption of continuous operations after such delay will virtually have its surface temperature and center temperature respectively on the curves "B" and "C" by the time it reaches zone **12** and that will be the case even though there has been no additional interruption or stoppage or further holding of the relatively cooler slabs entering furnace **10** after such delay.

It will be realized by those having skill in the art to whom this invention is disclosed, that certain compromises may be employed in matters of sequence and intensity for the firing of heating zones in a practice of this invention and, further, that various modifications may be made in the illustrated structure and in the described exemplification without departing from the spirit of our invention or the scope of the appended claims.

We claim:

1. In a heating furnace system for metal workpieces of heavier section, the steps comprising, in combination, intermittently pushing such workpieces in a continuous line through at least four heating zones extending along the top and bottom of said line, providing one soaking zone along the terminal portion of said line, said top and bottom heating zones being in respectively at least partially opposed and partially offset relation along said line, independently heating said heating zones, conducting combustion gases from a plurality of said zones to a common outlet, and raising the temperature of said heating zones along the top and bottom of said line and sequentially toward the discharge end of said line substantially upon the exiting from each heating zone of relatively hotter workpieces when they are generally in juxtaposition to relatively cooler workpieces in said line.

2. In a heating furnace system for metal workpieces of heavier section, the steps comprising, in combination, intermittently moving such workpieces in a continuous line through a plurality of heating zones extending along said line, providing at least two of said heating zones along the top of said line, providing at least two of said heating zones along the bottom of said line, said top and bottom heating zones being respectively offset in the direction of said line, independently heating said top heating zones respectively, independently heating said bottom heating zones respectively, and sequentially increasing the heating of said respective top and bottom heating zones proceeding in the direction from the charge toward the discharge end of said line following a resumption of operations after a delay in the movement of workpieces along said line, whereby continuous operation may be maintained upon such resumption of operations despite differential temperatures existing in workpieces newly admitted to said line after such resumption of operations.

3. In a heating furnace system for metal workpieces of heavier section, the steps comprising, in combination, intermittently moving such workpieces in a continuous line through at least five top and bottom heating zones around said line, said heating zones respectively extending along the direction of said line, independently heating said heating zones respectively, and sequentially increasing the temperature of at least four of said respective top and bottom heating zones proceeding in the direction from the charge toward the discharge end of said line following a resumption of operations after a delay in the movement of workpieces along said line, whereby continuous operation may be maintained upon such resumption of operations despite differential temperatures existing in workpieces introduced into said line after such resumption of operations.

4. In a heating furnace system for heating slabs or the like, the steps comprising, in combination, independently and respectively directly firing preheating upper and lower heating and soaking zones along the path of movement of said slabs, pushing said abutting slabs in a continuous line successively through said zones, said preheating, upper and lower heating and soaking zones extending along said line respectively between the charge and discharge ends thereof, lowering the temperature in said preheating and heating zones during any significant delay in the movement of said slabs or the like along said line, and increasing the temperature in said preheating and upper and lower heating zones respectively and successively above and below said line upon a resumption of movement following such delay as the last of said slabs to enter said charge end prior to such resumption respectively and substantially is pushed out of said preheating and heating zones respectively, whereby normal operating conditions may be restored without any discontinuance of movement following such resumption and without overheating of hotter slabs in any of said zones during such delay or underheating relatively cooler slabs entering said charge end following such resumption.

5. In a heating furnace for slabs or the like, apparatus comprising, in combination, a supporting hearth in said furnace for said slabs during movement thereof through said furnace, said furnace having a charge end and a discharge end adjacent the back and front ends respectively of said hearth, at least three top-fired furnace sections positioned above said hearth and extending generally between said charge end and said discharge end, said top-fired furnace sections having transversely extending front and back walls, independent burner means mounted in said front walls respectively to directly fire said top-fired sections in a direction counter to the direction of movement of said slabs, the bottom edges of said top-fired furnace sections comprising noses adjacent the upper side of said hearth and of slabs moving along said hearth beneath said noses, a plurality of bottom-fired furnace sections positioned beneath said hearth and extending substantially from said charge end forwardly for a major part of the length of said furnace, said bottom-fired furnace section having transverse front and back walls with the upper edges thereof adjacent to the underside of the respective proximate portions of said hearth, the respective front and back walls of said bottom-fired furnace sections being longitudinally offset relative to the respective front and back walls of said top-fired furnace sections, said bottom-fired furnace sections together having a greater length than the length of that one of said top-fired furnace sections nearest to

said charge end, independent burner means mounted in said bottom-fired furnace sections to directly fire the same, a common flue means in said furnace to serve as an outlet for combustion gases originating in more than one of said furnace sections, and means to push said slabs along said hearth through said furnace, whereby said slabs or the like within said furnace during any delay may be pushed substantially past the successive front walls of successive furnace sections proceeding toward the discharge end before resuming an increased normal operating condition temperature in the respective furnace section just passed thereby avoiding overheating of hotter metal and underheating of relatively cooler metal pushed into said charge end following resumption of operations after such delay.

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