March 23, 1954 J. T. VAUGHAN ET AL 2,673,274

STRIP HEATING

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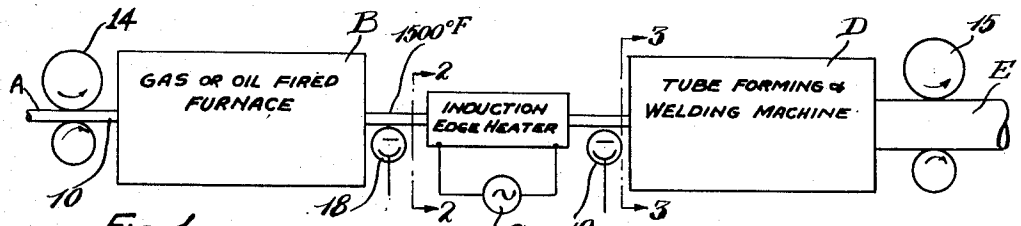


FIG. 1

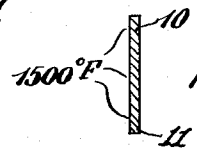


FIG. 2

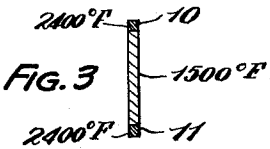


FIG. 3

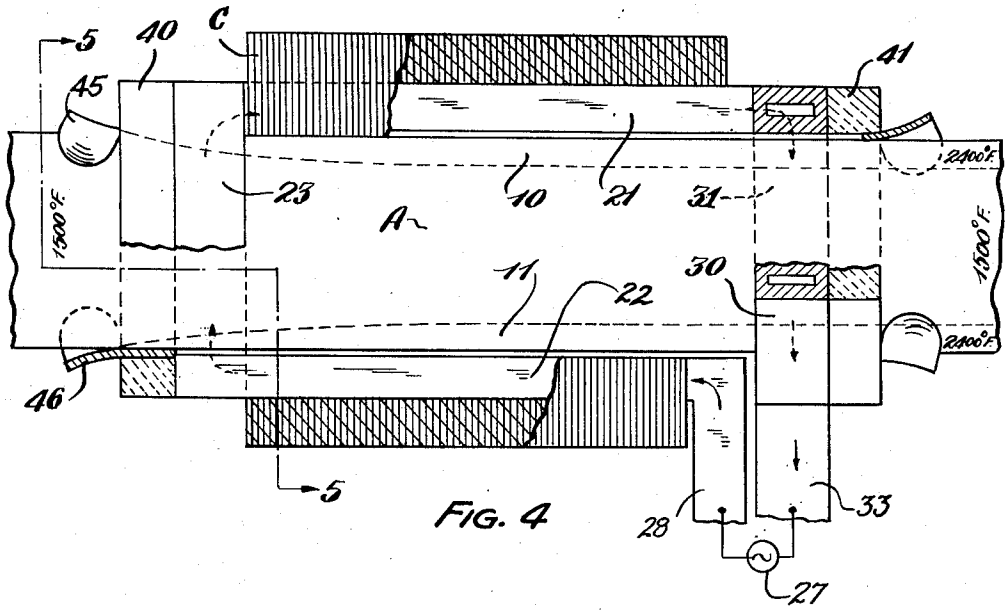


FIG. 4

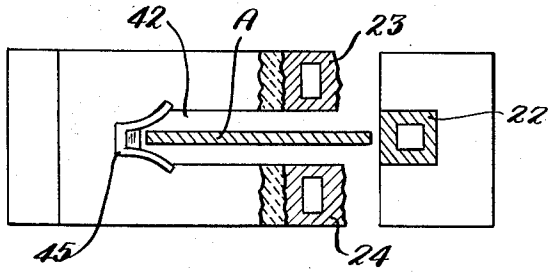


FIG. 5

INVENTORS
JOHN T. VAUGHAN
BY JAMES W. WILLIAMSON
Alfred C. Body
ATTORNEYS

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STRIP HEATING

John T. Vaughan, Hudson, and James W. Williamson, Cleveland, Ohio, assignors to The Ohio Crankshaft Company, Cleveland, Ohio, a corporation of Ohio

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4 Claims. (Cl. 219—6)

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This invention pertains to the art of continuous seam welding of strip into pipe or tube and, more particularly, to the heating of the strip to the forming and welding temperature.

The invention is particularly adaptable to the heating of low-carbon steel strip and, although not so limited, will be described with particular reference thereto.

In the art of welding strip into pipe, it has been conventional in the past to cut the strip to width, form it into the desired shape and bring the edges of the strip into pressure-welding engagement. The strip is formed either cold or hot. In cold forming, the strip at room temperature is moved past suitable power-driven forming rolls. The forces required to cold form strip and the stresses imposed on the forming rolls are relatively high, particularly at high strip speeds. In fact, the power required has limited the speed of cold strip mills for high speed seam welding. If the strip is hot formed, many of the problems of cold forming are eliminated because, with the strip heated to elevated temperatures in the region of 1500 degrees or above, it is relatively plastic and the forces required to bend it are much less than when cold. However, while hot forming eliminates the problems of cold forming, it introduces the additional problem of heating the strip to the desired temperature. Ordinarily, oil- or gas-fired furnaces are employed for this purpose and they heat the entire width of the strip to the forge-welding temperature. The center of the strip is heated for the purposes of facilitating the forming while the edges are heated for the purposes of putting them in a condition such that when pressed together, the edges will unite and weld. The furnaces employed for hot forming are relatively long, their length depending on their rate of heating and the speed of movement of the strip. The rate of heating of the furnace in turn depends upon the furnace design and the flame temperature.

With gas- or oil-fired furnaces, the rate of heat transfer to the strip depends to a large extent on the temperature difference between the strip at any one point and the corresponding point of the furnace. Accordingly, in order to obtain reasonably rapid rates of heat transfer to the strip as it heats in the furnace, the temperatures of the flame or of the furnace itself must also be progressively increased. These higher furnace temperatures impose enormous thermal strains and stresses on the furnaces and the life expectancy of the hot end of the furnace is rather low and the maintenance costs go up rather sharply.

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In fact, it has been found that the portion of the furnace required to bring the strip from 1500 degrees up to 2400 degrees, the welding temperature, involves over 90 per cent of the maintenance cost of the furnace while only being a relatively small fraction of the total length of the furnace. Further, in order to obtain rapid rates of heat transference to the strip, the whole strip is subject to and heated to the higher temperature even though, if it were only heated to 1500 degrees, the forming could then be readily accomplished. This is wasteful of heat and tends to form scale over the entire width of the strip.

The present invention contemplates progressively heating continuous lengths of elongated strip to a suitable hot-forming temperature such as 1500 degrees for low-carbon steels, this temperature having been found to be sufficiently high to form the strip with a minimum of mechanical pressure. The strip may be heated by any known means such as an oil- or gas-fired furnace, inasmuch as the maintenance cost for heating up to 1500 degrees are relatively low. Once the strip has been heated to this temperature, means are then employed to generate the heat directly in the strip, and preferably only in the edges, to bring the edges up to the pressure-welding temperature of approximately 2400 degrees for low-carbon steel. Any known very rapid means may be employed for generating the heat directly in the strip; but, in accordance with the preferred embodiment, high-frequency induction heating is employed to induce concentrated high-frequency electric currents to flow only in the edges of the strip which rapidly heats the edges only from 1500 degrees to the desired and necessary 2400 degrees. This heating is so rapid that the heat does not have time to be conducted to the center portions of the strip. The induction-heating furnace, to all intents and purposes, operates cold and, therefore, maintenance problems can be a minimum. The only heat which the furnace receives comes as a result of radiation or a minor amount of conduction from the heated strip itself. In the absence of the strip, the furnace would be cold. Such radiated or conducted heat, if it becomes excessive, can be readily removed by employing water cooling of the furnace itself. The induction-heating process of the edges is so rapid that the edges can be raised from the 1500 degrees as they emerge from the radiant-type furnace to the 2400 degree welding temperature in a distance of not over twenty inches; whereas, if the strip were to be heated in conventional

manners as above described, a distance of approximately thirty feet would be required.

The invention further contemplates a high-frequency inductor for heating the edges of the strip which comprises a pair of elongated conductors, each disposed adjacent and parallel to one longitudinal edge of the strip and energized from a high-frequency source of electric current so that the currents in the edges are flowing in opposite directions. A stack of magnetically-permeable laminations with the plane of each lamination transverse to the length of the conductor are disposed along the outer sides of each of the conductors. The conductors are connected in electric series relationship by end conductors which extend transversely to the length of the strip and has a central slot through which the strip may pass. Suitable guides and insulating members are employed to prevent contact of the edges of the strip with any portions of the conductors.

In view of the above, it is an object of the present invention to provide a new and improved method and apparatus for progressively heating continuous lengths of metallic strip to the forming and pressure-welding temperature which is relatively simple in construction, occupies a minimum of floor space, requires a minimum of maintenance and shut downs for repairs and which rapidly and effectively heats the strip to the desired temperatures.

Another object of the present invention is a new and improved method of progressively heating continuous lengths of metallic strip comprising uniformly heating the entire strip to hot-forming temperature employing a radiant-type furnace and, subsequently, heating the edges to the pressure or forge-welding temperatures by generating heat directly within the edges in what may be termed a "nonradiant-type furnace" such as a high-frequency induction furnace.

Another object of the present invention is a new and improved method for continuously heating strip which comprises heating the strip by a radiant-type furnace to a suitable hot-forming temperature and, subsequently, heating the edges of the strip only to a pressure of forge-welding temperature by inducing high-frequency electric currents to flow in a concentrated form in the edges only of the strip and then bringing the edges into pressure-welding engagement.

Still another object of the present invention is the provision of a new and improved high-frequency induction coil for heating the edges of a preheated strip to the forge-welding temperature which comprises a pair of conductors adapted to be disposed in close-spaced parallel relationship with the edges of the strip, the conductors having stacks of magnetic laminations along their length and end conductors extending transversely to the length of the strip having slots through which the strip may progressively move.

The invention is comprised of certain parts and arrangement of parts, a preferred embodiment of which will be described in detail in this specification and illustrated in the accompanying drawing which is a part hereof, and wherein:

Figure 1 is a schematic view of a strip heating, forming and welding apparatus embodying the present invention;

Figure 2 is a fragmentary sectional view of Figure 1 taken approximately on the line 2—2 thereof showing the srtip temperatures as it leaves the gas or oil-fired furnace and enters the induction-edge heater;

Figure 3 is a fragmentary sectional view of Figure 1 taken approximately on the line 3—3 thereof and showing the temperatures of the strip as it enters the strip forming and welding portion of the apparatus;

Figure 4 is a top elevational view partly in section of the induction-edge heater of Figure 1; and

Figure 5 is an end elevational view of Figure 4 partly in section taken on the line 5—5 thereof.

Referring now to the drawings wherein a preferred embodiment is shown for the purposes of illustrating the invention and not for the purposes of limitation, Figure 1 shows a section of a long length of metallic strip A having edges 10, 11 entering a gas or oil-fired radiant-type furnace B to be heated uniformly across its width to approximately 1500 degrees and then entering a high-frequency, induction-edge heater C to have the edges 10, 11 heated to approximately 2400 degrees and then entering a tube forming and welding machine D where the strip is formed to the shape of the tube and the heated edges 10, 11 are brought into pressure-welding engagement to emerge from the right-hand end of the welding machine as a tube or pipe E. The strip is shown as being advanced through the combination of the three pieces of apparatus by pairs of drive rolls 14 located to the left of the furnace B and drive rolls 15 located to the right of the tube-welding machine D. These rolls may be power driven and are relatively conventional. They form no part of the present invention.

The gas or oil-fired furnace is shown schematically only. It may be of any known or desired construction capable of uniformly heating the entire width of the strip A to any desired temperature which, for low-carbon steel, will be in the vicinity of 1500 degrees. It has been found that this temperature is sufficiently high to enable the tube forming and welding machine to readily shape the strip to the final desired shape without requiring excessive mechanical pressure or excessive mechanical powers. On the other hand, this temperature is low enough so that the temperatures in the furnace B may be sufficiently low that the maintenance cost of the furnace B will be at an absolute minimum at least when compared with furnaces which must heat the entire strip to the pressure or forge-welding temperature which is in the neighborhood of 2400 degrees. A photoelectric cell 18 is shown just to the right or exit end of the furnace B which may be connected through a suitable and known control apparatus to control the internal temperature of the furnace B or to control the speed of movement of the strip A.

The edge heater C is preferably of a type which generates heat directly in the edges 10, 11 of the strip A; and, by so generating the heat directly in the edges, is not subject to the excessively high temperatures to which it would be subjected if radiant-type heat were employed to heat the edges. High-frequency induction heating is one method which will accomplish this heating of the edges while all temperatures of the furnace itself may remain at relatively low temperatures and, if necessary, may be water cooled to remove any heat received in the furnace due to radiation from the heated strip or due to conduction when the strip touches portions of the heater. As shown in Figure 3, the edge heater C preferably heats the edges 10, 11 only to a temperature of 2400 degrees, which temperature is just short of the fusion temperature for low-carbon steel while

high enough to allow a weld to take place if the edges are brought into pressure engagement while in the heated condition.

Figure 1 shows a photoelectric cell 19 positioned just to the right of the edge heater C and focused on the edges 10, 11 to control the temperature of these edges as they emerge from the edge heater. This photoelectric cell 19 may be connected through suitable known apparatus to control the power output of the high-frequency power source 27 for the edge heater C.

The strip A thus passes into the tube forming and welding machine D with the center portion thereof at a temperature of approximately 1500 degrees and the edges 10, 11 heated to a temperature of approximately 2400 degrees. The tube forming and welding machine D forms no part of the present invention except as it may be in combination with the other portions of the apparatus. This machine may be from any conventional construction capable of rapidly forming the strip A to the desired final shape and bringing the edges 10, 11 into the necessary pressure relationship so as to effect the desired final weld.

It will be appreciated that the strip could be advanced into the tube-forming machine D at a temperature of 1500 degrees and formed to the desired final shape and then the edges 10, 11 heated by an edge heater C to the pressure-welding temperature of 2400 degrees and then brought into pressure-welding engagement by an additional portion of the machine D.

So far as we know, the combination of a gas or oil-fired furnace to heat strip uniformly to a forming temperature in combination with an edge heater which generates heat directly in the edges has never before been proposed.

The edge heater shown is preferably of a high-frequency induction-heating type. Figure 4 shows a preferred embodiment of such an edge heater. In Figure 4, the strip A is shown moving from left to right. The inductor comprises a pair of elongated conductors 21, 22 which extend in close-spaced parallel relationship to the edges 10, 11 respectively of the strip A. These conductors have high-frequency electric currents flowing therethrough in opposite directions, which high-frequency currents induce oppositely flowing high-frequency currents to flow in the edges 10, 11 and these currents, because of the surface or skin effect of the high frequency and the proximity effect of the conductors 21, 22, tend to cling to the edges 10, 11 and will rapidly heat the edges 10, 11 from the initial temperature of 1500 degrees to the desired final temperature of 2400 degrees. The left end of the conductors 21, 22 are connected together by a pair of end conductors 23, 24 which extend in spaced relationship transversely to the length of the strip A above and below respectively the upper and lower surfaces of the strip.

The opposite or right-hand end of the conductor 22 is connected to a high-frequency power source 27 through a fish-tail lead or conductor 28 which connects to the right end of the conductor 22 and extends transversely away from the strip A.

The right-hand end of the conductor 21 connects to a pair of conductors 30, 31 which extend transversely of the strip over and under respectively to a position just to the right of the fish-tail lead 28 which they connect to a fish-tail lead 33; which, in turn, connects to the other terminal of the power source 27.

These conductors are all preferably of hollow construction and cooling water, through suitable plumbing connections not shown, may be circulated in a conventional manner through the conductors to remove any heat generated in the conductors by the electric currents flowing therethrough or due to radiation from the strip to the conductors.

The inductor just described will satisfactorily heat the edges 10, 11 of the strip A very rapidly from the 1500-degree initial temperature to the required and desired 2400-degree final edge temperature and this temperature rise of the edges may be obtained in distances as low as ten inches, depending upon the speed of movement of the strip A and the amount of high-frequency energy supplied to the edge heater C. With inductors of this type, it is preferred that the strip not come into electrical contact with the conductors. Accordingly, means are provided for guiding the strip through the inductor. Such means include a block 40 of insulating material 40, 41 at the left and right-hand end of the inductor respectively. Each block has a slot 42 slightly larger than the cross-sectional dimensions of the strip A so that the strip may pass freely therethrough and this slot is aligned with the space between the conductors 23, 24. A pair of metallic guide members 45, 46 are mounted on the block 40 so arranged as to guide the strip through the inductor, the insulating block 40 permitting contact of the guide 45 with the strip without any electrical currents passing between the two metallic members.

With the invention just described, it is possible to obtain the B. t. u. efficiency of the gas or oil-fired furnace without the high maintenance cost normally required with such furnaces for heating metallic material to the 2400 degree welding temperature. Further, it is possible to obtain the advantages of rapid induction heating with its ability to heat a metal locally so rapidly that the heat does not have time to be conducted thermally to other cooler portions of the metal. Also, the over-all distance required to heat the strip, from the time it enters the furnace until the time it enters the forming and welding equipment, is very materially reduced. The use of induction-edge heating permits of extremely accurate control of the temperature of the edges so that they are neither overheated nor underheated and this control may be such as to immediately compensate for any changes in temperature which is not true of a gas furnace which has a considerable time lag required to correct for changes in temperature of the material as it leaves the furnace.

As stated above, it is possible to form the strip into the shape of a tube while at the 1500-degree temperature, subsequently heating the edges to the forge-welding temperature and then bringing them into pressure-welding engagement. In such event, the edge heater would preferably be of a type as described in the copending applications of Phillips N. Sorensen, Serial No. 58,228 filed November 4, 1948, now Patent No. 2,632,840, and Serial No. 86,066 filed April 7, 1949, now abandoned, which inductors are particularly adapted to heating a pair of close-spaced edges rapidly to the pressure-welding temperature.

It will be appreciated that in order to fully describe the invention and to comply with the patent laws, a preferred embodiment of the invention has been described and that the invention is not to be limited to this specific embodi-

ment. Obviously, modifications and alterations of the preferred embodiment will occur to others upon a reading and understanding of this specification and it is out intention to include all such modifications and alterations insofar as they come within the scope of the appended claims.

Having thus described our invention, we claim:

1. The method of progressively heating continuous lengths of strip material for forming and welding of the edges, which comprises radiating heat uniformly against said strip while in the flat state to heat same to a hot-forming temperature and subsequently flowing high-frequency currents in the edges of said strip while still in a flat state to heat said edges to a plastic forge-welding temperature and then forming said flat strip into a tube and bringing said edges into pressure-welding engagement.

2. The method of progressively heating continuously moving steel strip to the forming and welding temperature, which comprises moving said strip while flat through a radiant-type furnace to heat same to a temperature in the region of 1500 degrees, moving said strip while still flat through a high-frequency induction furnace and inducing concentrated high-frequency currents to flow in the edges only of said strip to heat the edges to the forge-welding temperature, rapidly forming said heated strip into the desired final shape and bringing said highly heated edges into pressure-welding engagement.

3. In an inductor for progressively heating the edges of a continuously moving strip of metallic material, comprising a pair of conductors in spaced parallel relationship and having spaced oppositely-facing, relatively-narrow workpiece-adjacent surfaces, each adapted to be disposed opposite and along a substantial length of an edge of said strip, a stack of magnetic laminations on each of said conductors with the plane of each lamination extending transversely to the length of the conductors, and end conductors extending transversely across the path of movement of said strip and having a slot therein adapted to pass the strip therethrough in parallel close-spaced arrangement with said elongated inductors.

4. In a high-frequency inductor for progressively heating the edges of a continuously moving strip of metallic material, comprising a pair of elongated straight conductors disposed in spaced parallel relationship and having spaced oppositely-facing, relatively-narrow workpiece-adjacent surfaces adapted to receive therebetween the strip of material to be heated, with the edges thereof in close-spaced relationship with said conductors over their entire length, magnetic laminations disposed about the sides of said conductors extending transversely to said conductors and the path of movement of said strip and means for energizing said inductor.

JOHN T. VAUGHAN.
JAMES W. WILLIAMSON.

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