Aug. 19, 1958 E. J. LIMPEL 2,848,566

INDUCTION HEATING APPARATUS FOR FUSING VITREOUS ENAMEL

Filed Feb. 1, 1954

FIG. 1.

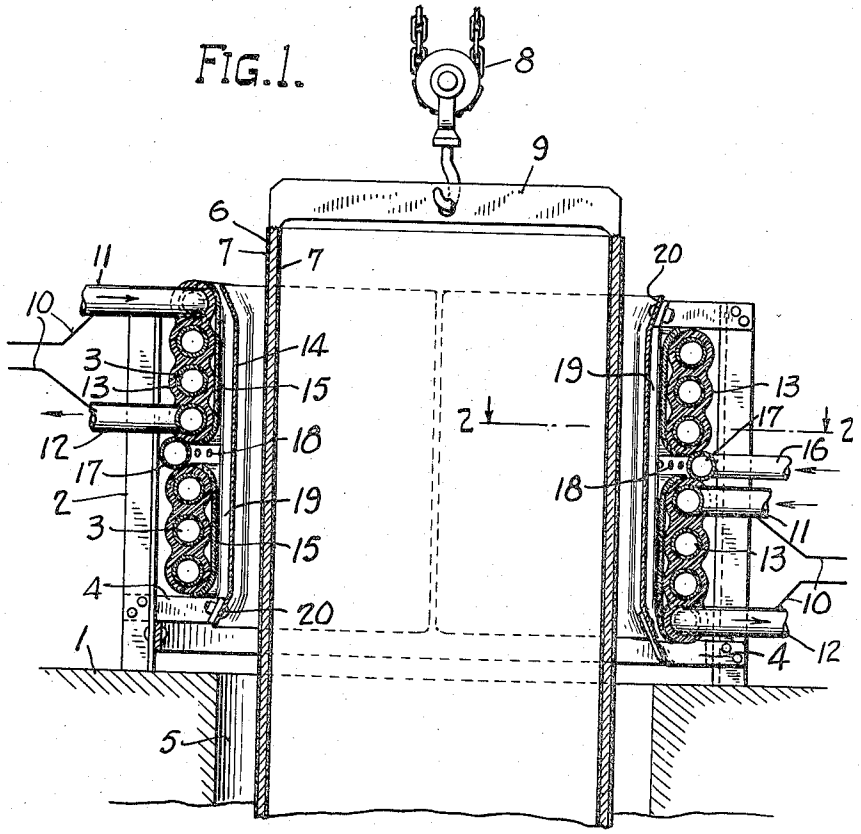


FIG. 2.

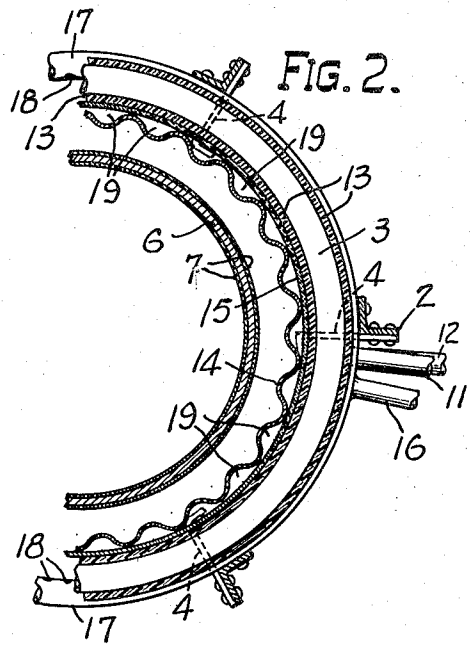
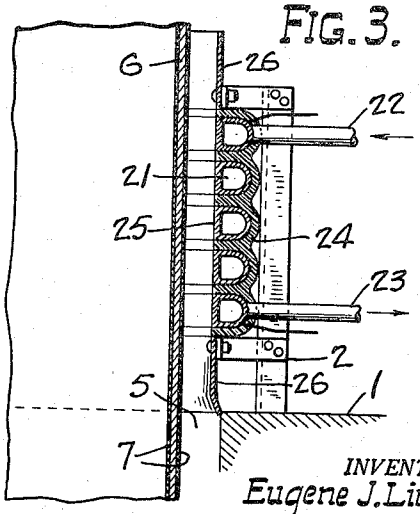


FIG. 3.



INVENTOR.
Eugene J. Limpel
BY
Andrus & Sceales
ATTORNEYS.

United States Patent Office 2,848,566 Patented Aug. 19, 1958

2,848,566

INDUCTION HEATING APPARATUS FOR FUSING VITREOUS ENAMEL

Eugene J. Limpel, Fox Point, Wis., assignor to A. O. Smith Corporation, Milwaukee, Wis., a corporation of New York

Application February 1, 1954, Serial No. 407,546

8 Claims. (Cl. 219—10.49)

This invention relates to an induction heating apparatus for firing a vitreous enamel coating on a steel article.

The use of induction heating for fusing a vitreous enamel coating on steel has been shown to have several advantages over furnace firing in that the heat is developed in the steel article itself due to the current induced therein and any gases driven out of the steel on heating can escape through the coating before it reaches a molten condition. In furnace firing, the outside surface or coating is initially heated so that gases driven off from the steel have to pass through the molten coating and are apt to form boiling defects in the coating.

The present invention is directed to an induction heating apparatus for progressively firing a vitreous enamel coating on a hollow metal article, such as a pipe or a smokestack, whereby the power requirements are substantially reduced due to the use of heat reflective surfaces in combination with the induction coils.

According to the invention an induction heating coil is disposed adjacent the coated steel article and spaced out of contact therewith. By energizing the coil, a current is induced in the article to heat the same to a temperature sufficient to fuse the vitreous enamel coating to the article.

To reduce the heat loss through radiation, a heat reflective member is disposed in spaced relation between the article and the coil. The member is formed with a polished heat reflective surface facing the article so that heat radiated from the article will be reflected back toward the same.

To prevent the reflective surface from oxidizing and losing its polished condition, a cooling fluid is introduced into contact with the surface of the reflective member adjacent the coil and is directed longitudinally along the surface to the ends of the coil. At the ends of the coil the reflective member is bent outwardly to deflect the fluid away from the coated article and prevent the stream of fluid from disfiguring the coating.

In a second embodiment of the invention the induction coil is formed with a generally cylindrical surface facing the article. The surface is polished and serves to reflect the heat back toward the article in a manner similar to that of the reflective member of the first embodiment.

By use of the reflective surface, the heat loss is substantially reduced and this results in a considerable reduction in power requirements.

The drawing furnished herewith illustrates the best mode presently contemplated of carrying out the invention set forth hereinafter.

Figure 1 is a vertical section of the induction heating apparatus showing the heating of a tubular member;

Fig. 2 is a fragmentary transverse section taken on line 2—2 of Figure 1; and

Fig. 3 is a fragmentary vertical section of a modified form of the induction heating apparatus.

The induction heating apparatus comprises a base 1 which supports a generally annular frame 2. An annular, hollow, helically wound induction heating coil 3 is disposed within frame 2 and is supported by brackets 4 which extend inwardly from frame 2.

The base 1 is provided with an opening 5 which is axially aligned with frame 2 and coil 3. A pipe 6 or other metal article to be fired is adapted to be drawn upwardly from opening 5 through coil 3.

The pipe 6 is coated on the inner and outer surfaces with a vitreous enamel or glass frit 7 which is to be progressively heated and fused to the steel pipe as the pipe moves upwardly within coil 3.

The pipe 6 is moved upwardly in relation to coil 3 by any conventional apparatus. As shown in Figure 1, a chain hoist 8 is attached to a bracket 9 welded to the upper end of pipe 6 and upward movement of chain hoist 8 draws the pipe upwardly through coil 3.

To maintain alignment of pipe 6 within opening 5 as the pipe is moved therethrough suitable guides, not shown, may be associated with the opening.

As shown in Figure 1, the coil 3 may consist of two axially aligned sections connected electrically in series to provide in effect a single continuous coil.

Current is applied to the coil 3 through lines 10 and the current in coil 3 induces a current in the portion of pipe 6 passing within the coil to heat the same. A temperature in the range of 1500° F. to 1600° F. is required to fuse the enamel 7 to the steel pipe. The temperature developed in pipe 6 is determined by the current applied to the coil and the number of coil turns.

To cool the coil 3, a cooling fluid such as water is introduced into one end of each section of the coil through conduit 11 and withdrawn from the opposite end of the coil through conduit 12.

The turns of coil 3 are insulated from each other by an insulating material 13, such as resin impregnated cotton tape, which is wrapped around the coil turns and baked at an elevated temperature for an extended period. The material 13 functions to provide an insulated spacing between the turns of the coil 3.

As the heat developed within the portion of pipe 6 passing through the coil 3 tends to radiate to surrounding objects having a lesser temperature, particularly the coil 3 and frame 2, a plurality of independent generally curved reflectors 14 are disposed in a spaced relation within coil 3. Reflectors 14 are in a concentric relation with coil 3 and serve to reduce the radiation heat loss.

The reflectors 14 are formed as a series of separate curved sections rather than as a continuous tubular member so as to prevent any appreciable current from being induced therein. A high temperature insulating material may be disposed in the gaps between the adjacent edges of the reflectors.

Reflectors 14 are spaced radially outward of the pipe 6, and the inner surface of reflectors 14 facing the pipe is polished or otherwise treated to provide a mirror-like reflecting surface.

The reflectors 14 extend longitudinally beyond the ends of coil 3 and the ends of the reflectors are connected to frame 2 by bolts or the like to secure the reflectors in position within the coil.

To space reflectors 14 from coil 3 a sheet of an insulating material 15, such as asbestos paper, is disposed on the inner surface of the coil 3.

The reflectors 14 are made of a metal, such as aluminum or silver or gold plated steel, which will withstand high temperature and can be polished to a highly reflective condition. To prevent oxidation of the reflective surface at high temperatures, the reflectors should be cooled. As shown in Figure 1, cooling fluid, such as air, is introduced from a supply conduit 16 into a hollow dis-

charge ring **17** which is disposed outwardly between the sections of coil **3**. The inner periphery of ring **17** is provided with a plurality of circumferentially spaced openings **18** through which the fluid is discharged against the outer surface of reflectors **14**. The insulating sheet **15** is interrupted at the position of ring **17** to permit the flow of fluid against the reflectors.

To permit the fluid to pass longitudinally of reflectors **14** to either end thereof, the reflectors are formed with a series of longitudinally extending corrugations. The fluid discharged from ring **17** passes longitudinally of the reflectors through a series of circumferentially spaced longitudinal passages **19**, defined by the corrugations of reflectors **14** and insulating sheet **15**, to the ends of the reflectors to cool the same.

To deflect the fluid away from the coated pipe and eliminate the possible disfigurement of the coating by the stream of fluid, the ends of the reflectors **14** are bent or flared outwardly, as shown at **20**.

In operation, the pipe **6** is initially coated with the vitreous enamel **7** by spraying, dipping or the like. The coated pipe is then disposed within opening **5** and the chain hoist **8** is connected to the bracket **9**.

Current is applied to the coil and the pipe is then slowly drawn upwardly through coil **3** by operation of the hoist to progressively fire the coated pipe and fuse the coating to the steel throughout the length of the pipe.

The article may be progressively fired from the bottom up or from the top down as desired.

It has been found that applying a current of about 3000 amperes to a coil having 10 turns resulted in the article or pipe being heated to a temperature of about 1550° F., thereby producing a very satisfactory fusion of the coating to the pipe. The speed of movement of the pipe was about $1\frac{1}{16}$" per minute.

The present invention may be applied to the firing of a vitreous enamel coating on either the inner surface or outer surface or both surfaces of a hollow article. Similarly the induction coil may be disposed either on the outside of the article or on the inside of the article to fire the coating on either or both surfaces of the article.

In addition, to progressively fire the coating it is necessary that there be relative movement between the article and the coil. This relative movement may be accomplished by moving the article in respect to coil, as disclosed in the above description, or conversely, by moving the coil in respect to the article.

A second embodiment of the invention is shown in Fig. 3. In this embodiment a hollow, helically wound induction coil **21** is carried by frame **2** and is disposed in axial alignment with opening **5** in position to receive the pipe **6** in a manner similar to that of the first embodiment.

A cooling fluid is introduced into the hollow interior of coil **21** through a conduit **22** and withdrawn from the coil through conduit **23**.

The turns of the coil are insulated from each other by an insulating material **24**, such as asbestos or transite, which is disposed between the turns.

The heat radiated from the pipe is reflected back toward the same by providing the inner portion of the coil **21** with a generally cylindrical surface, indicated by **25**. In cross section each turn of the coil has a generally flat face facing the pipe. The surface **25** is a heat reflective surface formed by polishing the coil or metal plating the same.

The surface **25** functions similarly to the reflectors **14** of the first embodiment. However, as the reflective surface is a part of the coil itself, the cooling fluid flowing through the hollow interior of the coil serves to cool the surface **25** and prevent oxidation thereof.

To increase the reflective surface area, a pair of reflective rings **26** are secured to the frame at the ends of the coil **21** and in effect increase the length of the reflective surface.

The reflective surface of rings **26** is made of highly polished aluminum or silver, gold or copper plated steel, and the rings are suitably secured to frame **2** to maintain the rings in position with respect to the coil.

In operation the apparatus of Fig. 3 functions similarly to that of the first embodiment with the pipe being moved through the coil to progressively heat the pipe to a temperature in the range of 1500° F. to 1600° F. to fuse the enamel to the pipe.

The reflective surfaces of coil **21** serve to reduce the radiation losses of heat and increase the effectiveness of the firing by reducing the power requirements.

Various modes of carrying out the invention are contemplated as within the scope of the following claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

I claim:

1. Apparatus for firing a vitreous enamel to a steel article, comprising an induction heating element, means to energize said element and induce a current in said article to heat the same to a temperature sufficient to fuse the vitreous enamel coating to the steel article, means for reflecting the heat radiated from the article back toward the article, said metal being selected from the group consisting of aluminum, silver, gold and copper and means to cool the reflective surface to prevent oxidation and tarnishment thereof.

2. Apparatus for progressively firing a vitreous enamel coating on the surface of a steel article, comprising an induction heating coil to receive the article, means to energize said coil and induce a current in said article to heat the same to a temperature sufficient to fuse the vitreous enamel coating to the steel article, means associated with the inner surface of the coil and disposed generally concentric to the axis of the coil for reflecting the heat radiated from the article back toward the article, said metal being selected from the group consisting of aluminum, silver, gold and copper, means to cool the reflective surface to prevent oxidation and tarnishment thereof, and means for imparting relative movement between the coil and the article to effect a progressive heating and fusing of the enamel to the article throughout the length of said article.

3. Apparatus for firing a vitreous enamel coating on the inner and outer surface of a tubular member, comprising an annular induction heating coil to receive the tubular member, means to energize the coil and induce a current in said member to heat the same above the temperature required for the fusion of the vitreous enamel coating to the member, a heat reflective metal surface selected from the group consisting of aluminum, silver, gold and copper and disposed on the inner face of said coil concentric to the axis of the coil and extending coextensively in an axial direction with the coil and being highly polished to reflect the heat radiated by said member back toward the same, and means for cooling said reflective surface to prevent oxidation and tarnishment thereof.

4. Apparatus for firing a vitreous enamel coating on a steel article which comprises, an induction heating coil, means to energize said coil and induce a current in said article to heat the same to a temperature sufficient to fuse the vitreous enamel coating to the steel article, a heat reflective metal member selected from the group consisting of aluminum, copper, gold and silver and disposed inwardly of the coil and having a heat reflective inner surface facing away from said coil to reflect heat radiated from the article back toward the same, means for introducing a gaseous cooling medium into contact with the outer surface of said member adjacent the coil and directing said medium longitudinally along said last named surface to cool said member and prevent oxidation of the heat reflective surface, and means associated with said member and disposed at an end of the coil for directing the gaseous medium away from the article to

prevent the medium from contacting the coating on said article.

5. Apparatus for firing a vitreous enamel coating on a steel article which comprises, an induction heating coil disposed adjacent the article and spaced therefrom, means to energize said coil and induce a current in said article to heat the same to a temperature sufficient to fuse the vitreous enamel coating to the steel article, a heat reflective member disposed in spaced relation between the coil and the article and having a heat reflective surface facing said article to reflect heat radiated from the article back toward the same, said member being formed with a plurality of generally longitudinal grooves and having an end thereof projecting longitudinally beyond the corresponding end of said coil with the projecting end of said member being bent away from the article, and means for introducing a cooling medium into contact with the surface of said member adjacent the coil and directing said medium through said grooves to the bent end of said member with said bent end serving to direct the medium away from the coated article, and said medium serving to cool the member and prevent oxidation of the reflective surface.

6. Apparatus for firing a vitreous enamel coating on the inner and outer surfaces of a tubular steel article, comprising an induction heating coil disposed concentrically of the article and spaced outwardly thereof, means to energize said coil and induce a current in said article to heat the same to a temperature sufficient to fuse the vitreous enamel coating to the steel article, a heat reflective member disposed in spaced relation between the coil and the article and having a heat reflective surface facing said article to reflect heat radiated from the article back toward the same, an insulating material disposed between the coil and said reflective member, said member having a plurality of generally longitudinally extending grooves in the outer surface thereof adjacent said insulating material and said member extending longitudinally beyond the ends of said coil with the ends of said member being bent away from said article, and an annular supply member carrying a cooling medium and having a plurality of outlets disposed to direct said cooling medium between the windings of said coil against the outer surface of said reflective member, said medium passing longitudinally through said grooves to the ends of said member to cool the member and prevent oxidation of the reflective surface and being deflected away from the article by the bent ends of said member to prevent the medium from contacting the coating thereon.

7. Apparatus for firing a vitreous enamel to a steel article, comprising a hollow induction heating element with a surface of said element being formed with an

exposed generally flat configuration in an axial direction to define a heat reflective metal surface, said surface being highly polished and being selected from the group consisting of aluminum, copper, gold and silver and serving to reflect heat radiated from the article back toward the same, means to energize said element and induce a current in said article to heat the same to a temperature sufficient to fuse the vitreous enamel coating to the steel article, and means to introduce a cooling medium into the hollow interior of said element to cool the same and prevent oxidation of the reflective surface.

8. Apparatus for progressively firing a vitreous enamel coating on the inner and outer surface of a tubular article, comprising a hollow induction heating coil formed of a plurality of turns and adapted to receive said article, the inner portion of each turn of said coil facing said article being provided with an exposed generally flat configuration in an axial direction and defining a heat reflective metal surface selected from the group consisting of aluminum, copper, gold and silver, means to energize said coil and induce a current in the article to heat the same to a temperature sufficient to fuse the vitreous enamel coating to the steel article, means to introduce a cooling medium into the hollow interior of said coil to cool the same and prevent oxidation of the reflective surface, a pair of generally cylindrical reflective metal members disposed in axial alignment with the coil at either end thereof, said heat reflective surface and said reflective members serving to reflect the heat radiated from the article back toward the same to increase the effectiveness of the heating operation, and means for imparting relative movement between the coil and the article to effect a progressive heating and fusing of the enamel to the article throughout the length of said article.

References Cited in the file of this patent

UNITED STATES PATENTS

1,321,492	Thornton, Jr.	Nov. 11, 1919
1,431,997	Unger	Oct. 17, 1922
1,981,629	Northrup	Nov. 20, 1934
1,997,761	Bailey et al.	Apr. 16, 1935
2,040,767	Dudley	May 12, 1936
2,202,758	Denneen et al.	May 28, 1940
2,672,550	Vaughan	Mar. 16, 1954
2,676,234	Lackneret et al.	Apr. 20, 1954
2,687,464	Crawford	Aug. 24, 1954
2,730,599	Ronay	Jan. 10, 1956
2,781,437	McArthur	Feb. 12, 1957

FOREIGN PATENTS

310,458	Great Britain	Nov. 20, 1929
645,387	Germany	May 26, 1937