July 5, 1966 D. BEGGS 3,259,527

ELECTRIC HEATING ELEMENTS FOR CARBURIZING ATMOSPHERES

Filed Oct. 21, 1963 2 Sheets-Sheet 1

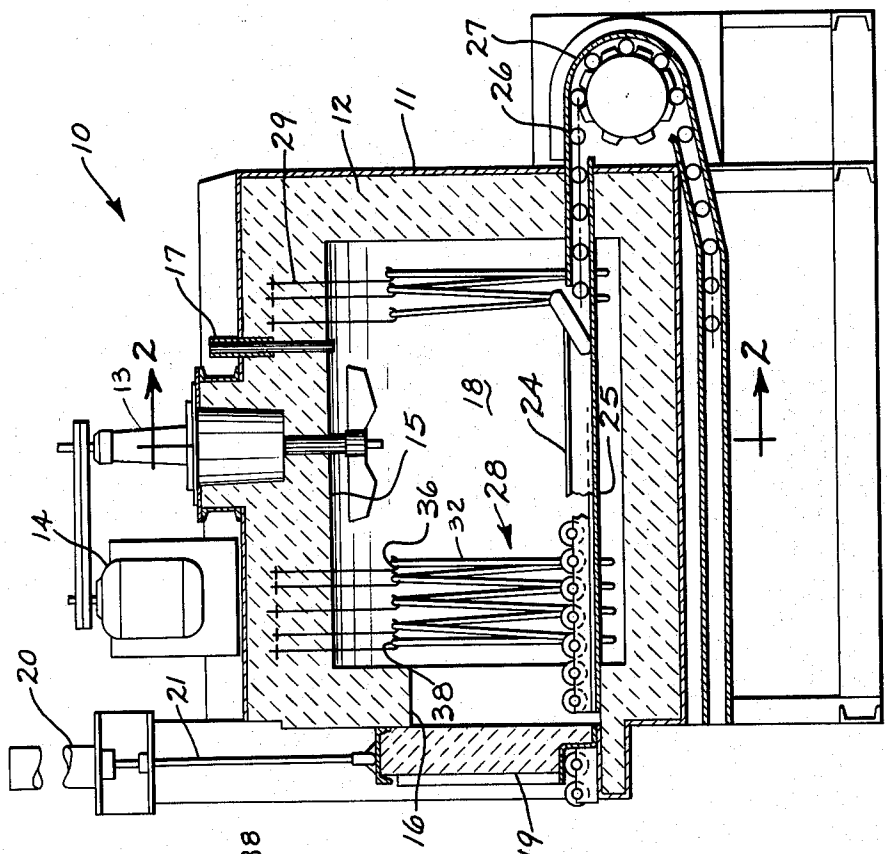


Fig. 1.

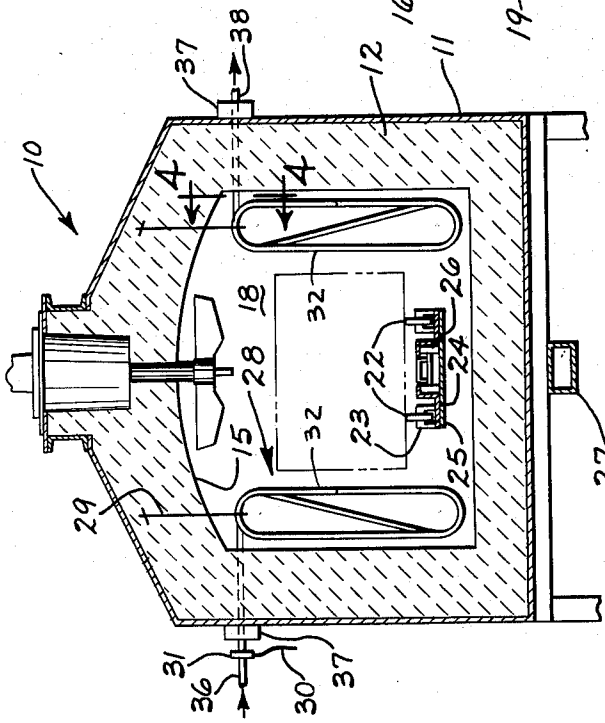


Fig. 2.

INVENTOR.
DONALD BEGGS
BY
Alfred L. Patmore, Jr.
Thomas A. Meehan
ATTORNEYS

July 5, 1966 D. BEGGS 3,259,527

ELECTRIC HEATING ELEMENTS FOR CARBURIZING ATMOSPHERES

Filed Oct. 21, 1963 2 Sheets-Sheet 2

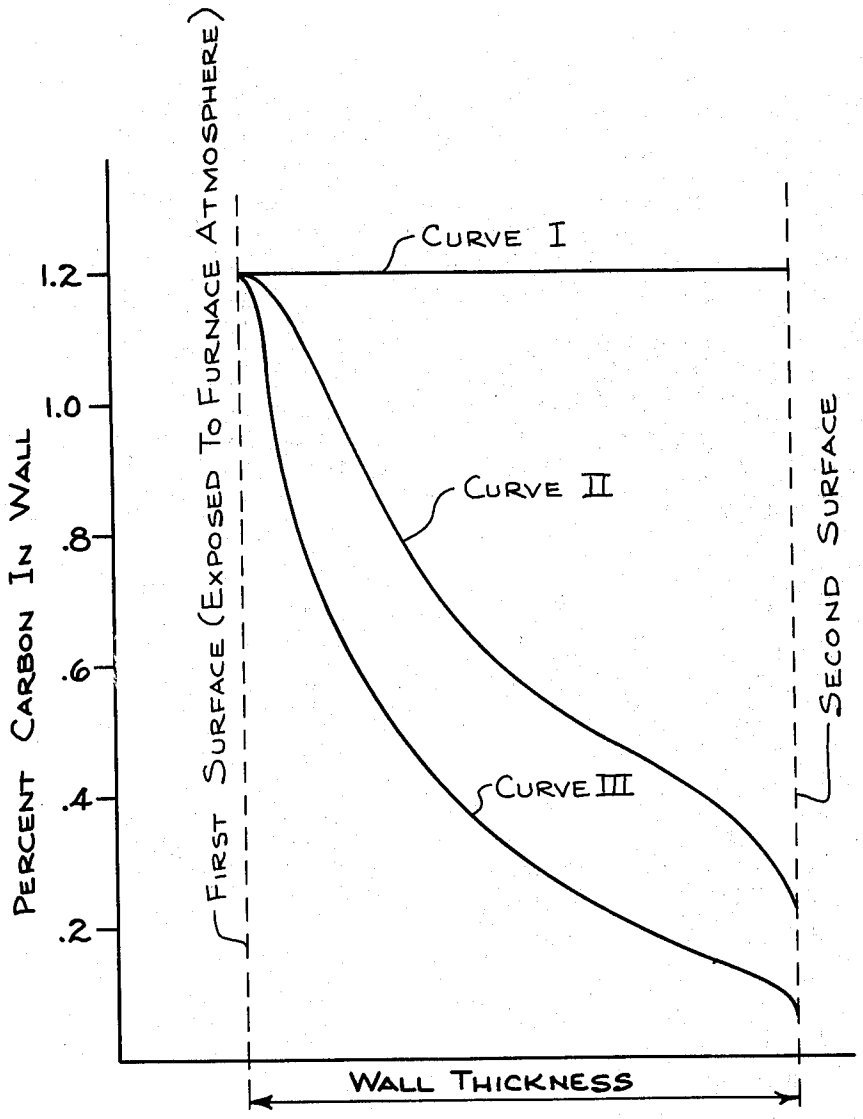


FIG. 3.

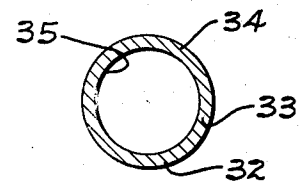


FIG. 4.

INVENTOR.
DONALD BEGGS
BY
Alfred L. Patmore, Jr.
Thomas A. Meehan
ATTORNEYS

United States Patent Office

3,259,527

Patented July 5, 1966

3,259,527

ELECTRIC HEATING ELEMENTS FOR CARBURIZING ATMOSPHERES

Donald Beggs, Toledo, Ohio, assignor to Midland-Ross Corporation, Toledo, Ohio, a corporation of Ohio

Filed Oct. 21, 1963, Ser. No. 317,613
9 Claims. (Cl. 148—16.5)

This invention relates to a method and an apparatus for heating an industrial furnace, and, more particularly, to an improved electrical heating method and an electrical heating element for use in a carburizing furnace.

Carburizing occurs when appropriate gases including carbon compounds penetrate the outer layers of the crystal structure in a suitable workpiece. The gases undergo reaction, and carbon atoms therefrom stay in the workpiece.

The carbon content of a workpiece to be carburized, or case hardened may, for example, fall between 0.20 percent and 0.60 percent. By proper control of the atmosphere and temperature of a carburizing furnace, and residence time therein, surface carbon content of a workpiece may be changed as required to accomplish a desired metallurgical result. For example, a surface carbon content of 1 percent to 1.2 percent may be provided, as well as a case of substantial thickness having a higher carbon content than the interior. Diffusion of carbon introduced into the surface of the work provides the case, and occurs at a rate which depends upon several factors, including, ultimately, the "carbon potential" of the carburizing atmosphere.

Carbon potential of a fluid, as used herein, and in the appended claims, indicates the carbon content to which that fluid will carburize steel if equilibrium is reached. It is customarily measured in percent of carbon in thin strips of steel which have been brought to substantial equilibrium with the fluid atmosphere and have a substantially uniform carbon content throughout the strip. The carbon potential of a carburizing gas depends upon temperature as well as upon composition.

Electrical heating elements have been designed and used in the past in furnaces containing carburizing atmospheres. However, prior art electrical heating elements have been unsuccessful in a normal industrial application, for example a case hardening operation, because of their relatively short life and high maintenance costs, when compared to other heating means.

This relatively short life of electrical heating elements results from the following: first, the electrical heating element, when at elevated temperatures, is continuously being carburized by the furnace atmosphere. In a relatively short period of time, excessive carburizing occurs, and carbides formed at grain boundaries cause the element to become brittle.

A second problem, which results from the above mentioned condition, namely the build-up of carbides at the grain boundaries, is the change of electrical resistance of the electrical heating element when subjected to a carburizing atmosphere. The electrical resistance of the heating element increases as carburization thereof proceeds.

It is the primary object of the instant invention to provide an improved method and apparatus for electrically heating a carburizing furnace.

It is another object of the invention to provide an electrical resistance heating element having a relatively long and maintenance-free life.

It is still another object of the invention to provide an electrical resistance heating element having superior properties for use in a carburizing operation.

Further objects of this invention will become apparent from the following specification and drawings in which:

FIG. 1 is a vertical cross sectional view of a furnace, and showing one embodiment of an electrical resistance heating element according to the instant invention, with a portion of the electrical resistance heating element being omitted;

FIG. 2 is a vertical cross sectional view taken along the line 2—2 of FIG. 1;

FIG. 3 is a graph showing carbon distribution curves taken across the wall of an electrical resistance heating element, first, of a prior art type and second, of a heating element embodying the method and apparatus of the instant invention; and

FIG. 4 is a cross sectional view of an electrical heating element, constructed according to the instant invention, taken along the line 4—4 of FIG. 2.

Briefly, the invention relates to a method and apparatus for heating a carburizing furnace. A first surface of a metallic electrical heating element, having opposed major surfaces, is exposed to a carburizing atmosphere having a predetermined carbon potential. The second surface of the element is exposed to a decarburizing medium capable of transferring carbon from the second surface. The decarburizing medium has a carbon potential appreciably less than the carbon potential of the furnace atmosphere. Preferably, the decarburizing medium has a sufficiently low carbon potential that the carbon content of the heating element surface is maintained at a level below the minimum at which carbides deposit at grain boundaries.

Referring to FIGS. 1 and 2 of the drawings, a conventional heat treating furnace is generally indicated at **10**. The furnace comprises a metallic casing **11** which encloses a refractory structure **12**. A circulating fan **13**, mounted on the casing **11**, is driven by a motor **14**. The refractory structure **12** defines a heat treat chamber **15** and a furnace opening **16**. A conduit **17**, in fluid communication with the chamber **15**, supplies a carburizing gas to the chamber **15** maintaining a continuous first atmosphere **18** having a predetermined carbon potential, in the chamber **15**. The conduit **17** is in communication by connecting piping (not shown) with a manifold (not shown) which receives a carrier gas from a conventional endothermic gas generator (not shown), and a hydrocarbon gas, e.g., methane, as required, to maintain the required carbon potential.

A typical carrier gas which could be enriched with methane to provide the first atmosphere **18**, in a case hardening heat treat operation comprises, for example:

	Percent by volume
CO_2	Trace
CO	20.7
H_2	38.7
CH_4	0.8
H_2O	Trace
N_2	Balance

Dew point 20° F.

The precise carburizing atmosphere composition required to provide a given carbon potential varies from furnace to furnace, and depends, among other factors, upon the tightness of the furnace. Methane could be blended with the foregoing carrier gas to maintain the first atmosphere **18** at a carbon potential of 1.2 at 1700° F. The following analysis would be typical for a furnace comparatively free of gas leaks:

	Percent by volume
CO_2	Trace
CO	19.5
H_2	43.5
CH_4	2.0
H_2O	Trace
N_2	Balance

Dew point 5° F.

The furnace opening **16** is sealed to the outside atmosphere by a furnace door **19**. The door **19** is opened and closed by the operation of an air cylinder **20** having a connecting rod **21** attached to the door **19**.

In a typical case hardening heat treat operation, steel parts, for example gears, are placed on one or more pallets (indicated by dashed lines in FIG. 2) and are introducted into the furnace opening **16**, after a conventional purging procedure in a furnace vestibule (not shown) which is contiguous to the furnace opening **16**. The pallet rides on a double row of rollers **22** which are mounted for rotation on horizontal axles **23**. The axles **23** are supported by Z-shaped channels **24** which rest on a plate **25**. The plate **25** is supported by the refractory structure **12**. A chain conveyor **26**, (shown only in FIG. 1), which rides in a sealed housing **27**, moves the pallets in and out of the furnace in a conventional manner.

The door **19** is electrically interlocked with a vestibule door (not shown) so that the first atmosphere **18** is continuously maintained. All other means of ingress and egress to the heat chamber **15** are also "gas sealed" to contain the first atmosphere **18**.

Electrical resistance heating elements according to the instant invention are generally indicated at **28**, and are supported by hangers **29** suspended from the refractory structure **12**.

While the heating elements **28** are illustrated as having a tubular cross section, other embodiments using different configurations are within the scope of the instant invention. For example, the electrical resistance heating element **28** could have a "plate" type configuration.

Electrical power conduits **30** are connected to a mounting block **31** which is electrically connected upon a metallic resistance member **32** of the heating element **28**.

Referring to FIG. 4, the metallic resistance member **32** comprises a wall **33** having a first major surface **34** and a second opposed major surface **35**.

An entrance end **36** of the metallic resistance member **32** extends through the refractory structure **12** and the casing **11**, being insulated from the casing **11** by one of several connectors **37**.

A decarburizing medium capable of transferring carbon from the second surface **35** is provided. In the embodiment shown, the decarburizing medium is gaseous, and is circulated through the tubular heating element **28**, entering at the entrance end **36** (connecting piping not shown) and leaving at a discharge end **38**. The discharge end **38** is insulated from the casing **11** and the refractory structure **12** by another of the connectors **37**.

The number of heating elements **28** in any particular furnace will depend on the particular heat treating operation and the furnace design selected for that particular operation.

The decarburizing medium can be any one or a combination of a number of fluids, or can, as subsequently discussed in more detail, be a solid. The main requirement is that the medium must be able to effect, either directly or indirectly, a carbon transfer from the second surface **35**.

The improved result achieved by the instant method and apparatus is shown graphically in FIG. 3 of the drawings. It should be noted that Curves I, II, and III are all ideal curves. Each of the curves represents the percent of carbon (ordinate) in the wall of the heating element at different positions across the wall thickness (abscissa).

Curve I represents the result when an electrical resistance type heating element is subjected to a furnace atmosphere having a carbon potential of 1.2 along its first surface. In this prior art method, the opposed second surface of the heating element is not subjected to a fluid medium capable of effecting a carbon transfer. Therefore, curve I represents the condition found in prior art electrical resistance type heating elements after being subjected to a carburizing atmosphere in a furnace for a period of time. As seen from curve I, the heating element is carburized until equilibrium is reached, whereby the carbon gradient is constant across the wall thickness. In Curve I, the heating element wall has been carburized to a constant carbon content of 1.2 percent which causes a substantial increase in electrical resistance. Also, the excessive carburizing causes the formation of carbides at grain boundaries and consequent embrittlement. Both of the above occurences shorten the useful life of a heating element considerably.

Curve II represents the carbon content of the wall of a heating element having its first surface exposed to an atmosphere with a carbon potential of 1.2, and having its second surface exposed to a decarburizing fluid medium, or in other words, to a fluid medium having a carbon potential appreciably less than the carbon potential of the furnace atmosphere.

The fluid medium used was atmospheric air. The air was constantly circulated past the second surface thus effecting a carbon transfer from the second surface to the air. The result obtained by performing this carbon removal is best seen in comparing curve I with curve II. The carbon content of the second surface of the heating element shown in curve II is approximately 0.25 percent as compared to the 1.2 percent carbon of the element depicted in curve I. The increase in electrical resistance of the heating element shown in curve II, as compared to its original resistance, is a fraction of that of the curve I element. Even more important, carbides are prevented from forming at grain boundaries and, therefore, the heating element does not become "brittle" in operation.

Curve III represents carbon distribution in a heating element through which a fluid medium consisting of a mixture of atmospheric air and the products of combustion of natural gas, comprising essentially methane gas, was circulated past the second surface to effect a carbon transfer. Curve III is translated to the left and downwardly of curve II on the graph, thereby indicating that the carbon content for any given position across the heating element wall thickness is lower. Such a carbon distribution causes even less change in electrical resistance of the heating element than that depicted in curve III, and causes no appreciable embrittlement.

FIG. 3 shows that a mixture of atmospheric air and products of combustion causes more effective decarburization than did atmospheric air. It is believed that the presence of carbon dioxide, water vapor, or both in the mixture facilitates the surface reaction of decarburization, and is responsible for this difference.

It should be noted that while two specific fluid mediums have been disclosed for effecting a carbon transfer relative to the second surface of a heating element, there are numerous other decarburizing mediums which might be used and are within the scope of the instant invention. Some of these other decarburizing mediums are, for example, steam or solid mediums such as Ferric-oxide (Fe_2O_3).

The method of the invention for carburizing ferrous metal work in the carburizing furnace **10**, which includes heating the furnace **10** and the work by passing electrical power through the metallic resistance member **32**, includes maintaining a first carburizing atmosphere **18** in the heat treat chamber **15**. The metal work, for example gears, is placed on pallets and introduced into the heat treat chamber **15**. If the heat treatment is a case hardening operation, the first atmosphere **18** has a controlled carbon potential varying from 1.00 percent to 1.40 percent at a carburizing temperature between about 1700° F. and 1850° F.

The first major surface **34** of the metallic resistance element **32** is exposed to the first atmosphere **18**. The second major surface **35** of the metallic resistance element **32** is exposed to a decarburizing medium. In the specific apparatus disclosed this is accomplished by cir-

culating the medium, which is a fluid, through the interior of the tubularly shaped resistance member 32. When a solid decarburizing medium such as iron oxide is used, the tubular member 32 can merely be packed therewith.

The composition of the first atmosphere 18 is controlled to provide a carbon potential at the carburizing temperature necessary to give a predetermined carbon distribution in the work.

The carbon potential of the decarburizing medium exposed to the second surface 35 is appreciably less than the carbon potential of the first atmosphere. Air, products of combustion with excess air and steam all have a carbon potential of zero. It will be apparent that a decarburizing medium having a somewhat higher carbon potential can be used, but that there is usually an economic disadvantage. In any event, the medium should have a sufficiently lower carbon potential to prevent the formation of intergranular carbides in the element, and the carbon potential thereof should ordinarily be less than that of the carburizing atmosphere by at least 0.5

In a preferred method, natural gas, consisting of relatively pure methane, is ignited and the products of combustion of the natural gas are mixed with 100% excess air. This mixture is the decarburizing medium exposed to the second surface 35. In other words, for each cubic foot of natural gas used, approximately 20 cubic feet of air are needed to supply 100% excess air. While natural gas is used in this example, the method of the invention is not limited to using natural gas.

However, by using a combusted air-gas mixture, an additional advantage is obtained in that the temperature of the combusted air-gas mixture is approximately 1800° F., or roughly the same as the temperature inside the furnace. Therefore, there is no appreciable heat transfer across the wall 33 of the heating element 28 when the combusted air-gas mixture is introduced into the heating element 28, and variations in electrical properties and the chances of "hot spots" are minimized.

By using the method and apparatus of the instant invention after the element has reached equilibrium conditions with its surroundings, the amount of the element wall 33 that is carburized (note FIG. 3) is so small that its resistance is not affected by the carburization to change appreciably the temperature of the element at a given voltage. Furthermore, embrittlement by massive carbides at grain boundaries is avoided. Therefore, an electrical resistance type heating element having a relatively long effective life is obtained.

While the present invention has been disclosed in connection with a specific arrangement of parts and with a specific disclosure of decarburizing mediums, it should be expressly understood that numerous modifications and changes may be made without departing from the scope of the appended claims.

I claim:

1. In a carburizing furnace, an electrical resistance heating element comprising, in combination, a metallic resistance member comprising wall means having first and second opposed major surface, said first surface being exposed to a carburizing atmosphere in such furnace, means for establishing and maintaining in contact with said second surface a decarburizing medium capable of transferring carbon from said second surface, said decarburizing medium having a carbon potential appreciably less than that of the carburizing atmosphere, and electrical conduit means for supplying electrical power to said metallic resistance member.

2. An electrically heated furnace comprising, a refractory structure defining a heat treat chamber, means for maintaining a first atmosphere in such chamber, said first atmosphere having a predetermined carbon potential, an

electrical resistance element comprising wall means having first and second opposed major surfaces, said first surface being exposed to said first atmosphere and effective to supply heat to said chamber, means for maintaining adjacent to said second surface of said element a decarburizing medium capable of transferring carbon from said second surface and having a carbon potential appreciably lower than that of said first atmosphere, and electrical power means in communication with said element.

3. An electrically heated furnace according to claim 2, wherein said electrical resistance element has a tubular cross section.

4. An electrically heated furnace according to claim 3 wherein said means for establishing and maintaining a decarburizing medium includes conduit means for circulating a decarburizing gas within said tubular resistance element.

5. In a method for carburizing metal work in a carburizing furnace which includes heating the furnace and the work by passing electrical power through a metallic electrical heating element having first and second opposed major surfaces the improvement comprising maintaining a carburizing atmosphere within the furnace in contact with the first major surface of the heating element, controlling the carbon potential of the atmosphere to accomplish a prescribed carburizing treatment and maintaining in contact with the second major surface of the heating element a medium having a carbon potential at least 0.5 less than that of the atmosphere.

6. In a method for carburizing metal in a carburizing furnace, the improvement according to claim 5, wherein the medium consists essentially of atmospheric air.

7. In a method for carburizing metal in a carburizing furnace, the improvement according to claim 5, wherein the medium consists essentially of a mixture of atomspheric air and the products of combustion of methane gas.

8. In a method for carburizing metal work in a carburizing furnace which includes heating the furnace and the work by passing electrical power through a metallic electrical heating element having first and second opposed major surfaces the improvement comprising maintaining a carburizing atmosphere within the furnace in contact with the first major surface of the heating element, controlling the carbon potential of the atmosphere to accomplish a prescribed carburizing treatment and maintaining in contact with the second major surface of the heating element a medium having a carbon potential appreciably less than that of the atmosphere.

9. In a method for carburizing metal work in a carburizing furnace which includes heating the furnace and the work to a predetermined temperature by passing electrical power through a metallic electrical heating element having first and second opposed major surfaces the improvement comprising maintaining a carburizing atmosphere within the furnace in contact with the first major surface of the heating element, controlling the carbon potential of the atmosphere to accomplish a prescribed carburizing treatment, maintaining in contact with the second major surface of the heating element a medium having a carbon potential appreciably less than that of the atmosphere and supplying the medium to the second major surface at a temperature substantially the same as the predetermined temperature.

References Cited by the Examiner

UNITED STATES PATENTS

2,359,157	9/1944	Roth	13—20
2,621,218	12/1952	Juckniess	13—20 X
2,768,277	10/1956	Buck et al.	13—20 X
3,179,735	4/1965	Robinson	13—20

DAVID L. RECK, *Primary Examiner.*

C. N. LOVELL, *Assistant Examiner.*