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DECARBURIZATION OF IRON OR IRON ALLOY CASTINGS

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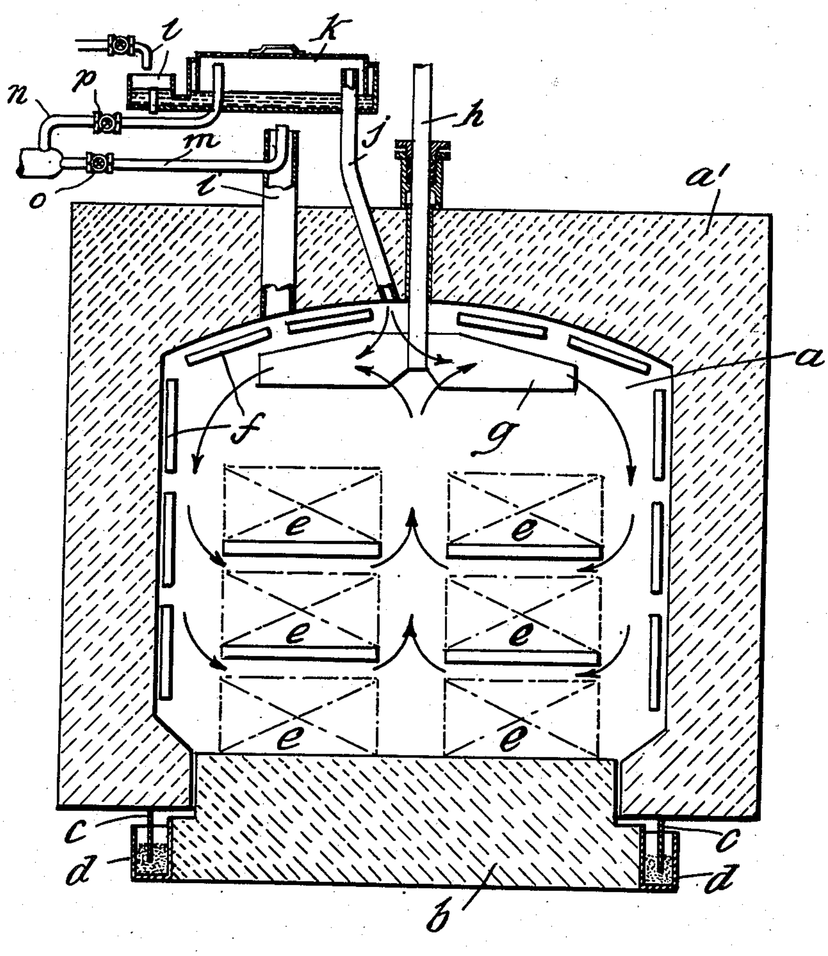

INVENTORS
PETER FRANCIS HANCOCK
FRIEDRICH WILHELM KARL SCHULTE
BY
A. Fr. Deller
ATTORNEY

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DECARBURIZATION OF IRON OR IRON ALLOY CASTINGS

Peter Francis Hancock and Friedrich Wilhelm Karl Schulte, Erdington, Birmingham, England, assignors to Birlec Limited, Erdington, Birmingham, England

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It is already known to decarburise (that is, anneal) iron or iron alloy castings by a gaseous process which comprises heating the castings to a temperature of between 850° and 1100° C. in a substantially gas tight furnace which is initially filled with air, circulating the gaseous products of the reaction of the air with the carbon content of the castings, and reconditioning the said products at a point out of contact with the castings, by the addition of a controlled quantity of air and/or steam whereby part of the carbon monoxide content of the products is converted to carbon dioxide, and the composition of the gaseous atmosphere in contact with the castings is maintained within certain compositional limits such that the said atmosphere is decarburising but substantially non-oxidising to the castings.

The practical application of this prior process necessitates the use of instruments for the measurement of the composition of the decarburising gaseous atmosphere in contact with the castings, which instruments are equipped with auxiliary electrical devices which operate automatically, to open or close the valves through which the atmosphere reconditioning air and/or steam is admitted to the reconditioning zone of the furnace, should the composition of the said atmosphere deviate beyond the desired compositional limits at any stage in the annealing cycle.

The principal object of the present invention is to render the known decarburising process self-regulating so that the use of controlling instruments of any kind is obviated.

A further object of the invention is to provide a gaseous process for decarburising iron or iron alloy castings which ensures, in an automatic manner, that the correct amount of decarburising gas is fed to the castings to balance the carbon available for removal, which carbon amount varies with such features as the size of the castings, the mass of the charge of castings to be decarburised, the carbon content initially in the castings and which decreases as the process proceeds towards completion, the temperature at which the process is carried out, and the time taken to complete the process.

In the said known gaseous decarburising process, excess gaseous products produced within the furnace are vented to waste, and another object of the invention is to make effective use of the heat content of the said vented products.

Yet another object of the invention is to use the said vented products for generating steam to be added to the circulated gaseous products within the furnace for reconditioning the said circulated products before the latter are returned to the charge of castings which is being decarburised.

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A further object of the invention is to provide a self-regulating gaseous decarburising process which will "fail safe," that is to say, which will be terminated or slowed down automatically without detriment to the castings being decarburised, should any part of the decarburising apparatus fail or become defective.

A still further object of the invention is to provide decarburising apparatus which, when once it has been set up and adjusted for decarburising one charge of castings, may be utilised for decarburising any other charge of iron or iron alloy castings without any further change in its set up or adjustment.

In accordance with the present invention, a process for annealing iron or iron alloy castings comprises heating a charge of castings to a temperature of 850° C. and 1100° C. in a gas tight or substantially gas tight furnace, within which temperature range the carbon content of the castings reacts with the available oxygen initially present in the furnace atmosphere to produce a gaseous mixture containing CO and CO_2, circulating the gaseous products of the reaction in a closed system and venting the excess products from the furnace, burning the vented products, utilising the heat of combustion of the said vented products to raise steam in a steam generating and supply plant operating at or below a predetermined maximum percentage of efficiency, and introducing steam from the said plant into the circulation system at a position out of contact with the castings so that, in operation, the process is self-regulating in that the circulated gaseous products are reconditioned to maintain the composition of the atmosphere in contact with the castings within limits such that the said atmosphere is decarburising but non-oxidising to the castings. The terms "gas tight" and "closed system" are employed in the present specification and appended claims in the sense which is commonly accepted in modern furnace art, i. e., in the sense that the system is practically leak-proof. These terms mean that the gas tight furnace or closed system are as practically proof as possible against fortuitous and uncontrolled leakage of gases from and/or air into the furnace or closed system so that the composition of the atmosphere in contact with the carbon-containing, ferrous-base castings can be controlled to produce the desired results of decarburisation without oxidation of said castings.

Neither term is intended to exclude the controlled entry of steam and/or air into or the controlled exit of furnace gases from the system since said controlled entry and exit are essential to the present invention.

Preferably the amount of steam fed to the circulation system is predetermined by arranging for the steam generating and supply plant to operate at a percentage of efficiency which does not, at any time during the annealing cycle, substantially exceed 17%.

If desired, a small predetermined flow of air may be superimposed on the steam supply to the circulation system so as to reduce the hydrogen content of the furnace atmosphere at the end of the annealing cycle, thereby minimising the risk of explosion when the charge is unloaded from the furnace. When such an air flow is provided, the efficiency of the steam generating and supply plant must be so reduced, and the air admitted in any given unit of time so determined that, in combination with the steam supply, reconditioning requirements at the termination of the decarburising cycle, are satisfied but not exceeded. Thus the air must be arranged to flow at a rate which is less than the equivalent rate of flow of reconditioning steam that it would be necessary to supply at the termination of the annealing cycle, were no air to be added to the steam.

Before commencing to heat the charge of castings, the furnace atmosphere may consist of air only; alternatively, by purging the treatment chamber wholly or partially, the atmosphere may consist of oxygen, steam, carbon dioxide or a mixture of any one or more of these gases with air and/or carbon monoxide.

In order that the invention may be more readily understood and carried into practice, reference will now be made to the accompanying diagrammatic drawing, which is a cross sectional elevation of one example of a furnace, charged with castings, and its associated steam generating and supply plant suitable for carrying out the process of the present invention.

The furnace shown in the drawing comprises a chamber *a* formed within a heat insulating structure *a'*, and a hearth *b* made of similar material. Around a hearth-receiving opening at the bottom of the chamber, there is provided a depending flange *c* which, when the hearth is in position, enters a sand-containing trough *d* provided around the said hearth.

The structure *a'* is a fixture and any suitable mechanism is provided for lowering the hearth out of, and returning it into, the chamber opening so that a charge of castings *e* may be loaded on to and removed from the hearth when in its lowered position.

Internally of the chamber, the structure is provided with a number of heating elements *f* and with a fan *g* which is carried by a driven shaft *h* journalled, in a gas tight manner, in the chamber roof.

The chamber roof is formed with a gas vent *i* and a steam and/or air inlet *j*, the vent being arranged to terminate below a boiler *k* mounted externally of the furnaces. Any suitable automatically controlled water supply means *l* are provided for maintaining water at a constant level within the boiler.

The inlet *j* opens into the furnace chamber in the vicinity of the eye or centre of the fan *g* and into the boiler above water level.

An air supply pipe *m*, having a branch *n* which also opens into the boiler above water level, extends into the mouth of the vent *i* for supplying combustion air thereto. The flow of air along the pipe *m* and branch *n* is controllable by cocks *o* and *p* respectively.

The fan is so constructed and driven that it circulates the furnace atmosphere in the direction indicated by the arrows. Also the charge *e* is so stacked upon the hearth that the top of the charge is spaced from the fan. Consequently, any steam and/or air admitted to the chamber *a* through the inlet *j* is unable to oxidise the castings when the said castings are in a heated condition, since the said air and/or steam is intimately mixed with the atmosphere circulated by the fan before coming into contact with the castings.

When a charge of castings has been loaded on the hearth and the latter has been raised into the furnace opening, air is supplied through the pipe *m* and branch *n*, the fan *g* is rotated, and the charge is heated by the elements *f*.

At the commencement of the annealing cycle, the charge of castings is surrounded by the air within the chamber *a* and as the said charge is heated, the carbon content of the castings reacts with the oxygen in the air to produce the gaseous products which include a mixture of CO and CO_2 and which are circulated within the chamber by the fan.

At the same time any excess gas within the chamber flows through the vent and is ignited at the open end of the latter by a pilot burner (not shown), whereupon the water in the boiler is heated and the steam generated is mixed with the air flowing from the branch *n* into the chamber *a* at the eye of the fan where the gases are out of contact with the castings, the air, or air and steam mixture, mixes with the circulated gaseous products to convert a proportion of the CO content of the said products into CO_2 thereby reconditioning the products to produce an atmosphere which is decarburising but non-oxidising to the castings, and which is then returned to and circulated through the latter.

The following figures are an actual example of the results obtained by carrying out the process in a furnace charged with approximately five tons of iron castings stacked upon the hearth in such a manner as to enable the circulating gases to penetrate easily into and through the stacks.

After charging the furnace and commencing the heating, a constant flow of 50 cubic feet per hour of air was fed to the furnace chamber through the branch *n*, boiler *k* and inlet *j*.

Four hours after the commencement of the heating cycle, the interior of the furnace chamber reached a temperature of 900° C. and sufficient excess combustible gaseous products commenced to flow through the vent to enable them to be ignited at the outlet end of the vent for generating steam in the boiler.

Two hours later, the charge reached a temperature of 1050° C. and gas production, due to the reaction between the carbon content of the castings and the furnace atmosphere, was at its maximum; consequently, steam was also being generated in the boiler and introduced into the chamber at a maximum. The carbon dioxide content of the atmosphere in contact with the castings, was 4% as measured, on a dry basis, by an Orsat analytical apparatus.

At eighteen, thirty and thirty-eight hours respectively after the commencement of the annealing cycle, the carbon dioxide content, as measured by the said apparatus, was 8%, 11% and 9½%; after thirty-eight hours of treatment, the flame at the vent was extinguished, the heating of the charge terminated, the supply of air cut off, and the charge was allowed to cool within the furnace preparatory to withdrawal.

It will be noted from the above example that the composition of the reconditioned atmosphere in contact with the castings, varies from time to time as the annealing cycle proceeds; in addition, the rate of production of the gaseous products of the reaction between the said atmosphere and the carbon content of the castings and, consequently the volume of the excess products that are vented from the furnace, also varies. These variations in the composition and volume of vented products causes the efficiency of the steam generating plant to change as the annealing cycle proceeds, and the said plant is so constructed, arranged and adjusted that at no time during any annealing cycle does it exceed a calculated maximum efficiency otherwise conditions would be set up in the furnace under which the castings would be oxidised.

The efficiency of the steam generating and supply plant may be regulated in a variety of ways, for example, by burning only a proportion of the total volume of the excess gas produced, by the degree of completeness to which the said gas is burnt, by the rate of heat transfer from the burning gases to the steam generating plant, by varying heat losses from the said plant, by the amount of condensation permitted in the steam supply pipes between the steam generator and reconditioning zone of the furnace, or by blowing to waste a predetermined proportion of the generated steam; in practice however, the efficiency is regulated manually prior to the commencement of the first annealing process in a particular furnace, by adjustment of the air that will be mixed with the vented products to be burnt and, automatically during the progress of each annealing cycle, by the variation of the rate of heat transfer to the steam generating plant consequent to the gradual changes in the volume of the gaseous products that are vented from the furnace as the annealing cycle proceeds.

The efficiency of the steam generating and supply plant, insofar as the invention is concerned, is defined as the ratio of the sensible heat of the steam which enters the furnace for reconditioning purposes (as distinct from the steam actually generated, some of which may condense and flow back to the generating plant, or be discharged or escape to waste) to the total calorific value of the gas produced by the reaction of the carbon content of the castings with the decarburising atmosphere.

The desired efficiency of any particular generating and supply plant may be adjusted, by trial and error, by varying any one or more of the regulating factors referred to above. However, when once this desired efficiency has been obtained, the plant operates in a self-regulating manner for any charge of castings that may be inserted into the treatment zone of the furnace, and for any treatment temperature.

It is to be understood that the plant is not self-regulating to a degree such that it maintains the composition of the decarburising atmosphere exactly uniform throughout each annealing cycle or that it maintains the relation between the volume of steam generated and the amount of carbon removed from the castings exactly linear. However, the plant is self-regulating within sufficiently close limits for practical purposes in the sense that it maintains the composition of the atmosphere in contact with the castings within the limits necessary to ensure decarburisation, without simultaneous oxidation, of the castings at all stages of each annealing cycle, and the term "self-regulating," when found in the claims thereof, is to be understood as being used in this sense.

In order that the self-regulating characteristic of the process may be more readily understood, the decarburising reactions involved and the relative volumes of steam supplied to the reconditioning zone and the resulting gas produced, may be considered.

As previously stated, in the initial stages of the process the carbon content of the castings reacts with the oxygen of the air within the gas-tight or substantially gas-tight furnace, to produce CO and CO_2; excess gas mixture vented from the furnace is burnt at the outlet from the vent *i* to generate steam in the boiler *k*. Now, assume that the charge of castings is being annealed at 1050° C. and that, of the total steam which is being generated at a particular stage of the annealing cycle, 100 cubic feet per hour is being fed to the chamber *a* through the inlet *j*; then the effective decarburising reactions are:

(i) $$H_2O + C \rightarrow H_2 + CO$$

(ii) $$2H_2O + C \rightarrow 2H_2 + CO_2$$

The CO/CO_2 ratio desired in the resulting gas mixture in the treatment zone to ensure that the said mixture is of maximum decarburising power, while remaining non-oxidising to the castings, is about 3:1 and therefore reaction (i) must predominate over reaction (ii) also in the ratio of 3:1.

Further, a certain amount of steam must pass through the furnace unchanged so that the resulting gas mixture of H_2, CO, CO_2 and H_2O may satisfy the equilibrium of the water gas reaction which, at 1050° C. is approximately equal to 0.5, thus

$$CO_2 + H_2 \rightleftarrows CO + H_2O$$

and

$$\frac{(CO_2) \times (H_2)}{(CO) \times (H_2O)} = 0.5$$

To satisfy these conditions, the decarburising reactions (i) and (ii) in composite form, may be written thus:

$$8H_2O + 4C \rightarrow 5H_2 + 3CO + CO_2 + 3H_2O$$

Hence, every 100 cubic feet of steam generate 150 cubic feet of gas mixture having the composition of 41.7% H_2, 25% CO, 8.3% CO_2 and 25% H_2O. The calorific values of H_2 and CO are 325 and 322 B. t. u.'s per cubic feet respectively; the heat content of each of 150 cubic feet of gas mixture (disregarding sensible heat) is therefore:

$$150 \times [(.417 \times 325) + (.25 \times 322)] = 32390 \text{ B. t. u.'s}$$

Now to generate 100 cubic feet of steam at atmospheric pressure from water at 10° C. the heat required is 810+4878=5688 B. t. u.'s which is considerably less than the heat content of the corresponding volume of the generated gas mixture. Therefore provided the boiler and steam supply plant is constructed so that the efficiency of the said plant does not exceed

$$\frac{5688}{32390} \times 100 \times 17.5\%$$

the decarburising process will be self-regulating.

For instance, should the 100 cubic feet of steam per hour which is being supplied to the treatment zone of the furnace become insufficient in relation to the amount of carbon available for removal from the castings, then the decarburizing reaction (i) increases at the expense of the reaction (ii) and the percentages of H_2 and CO in the gas mixture produced and the volume of the said mixture, increase. Consequently the total heat content of the gaseous mixture produced by the reaction between the atmosphere in contact with the castings and the carbon content of the castings also increases and this, in turn, increases the amount of steam generated and supplied to the treatment zone, thereby tending to compensate the said steam deficiency.

Similarly, should the 100 cubic feet of steam supplied to the treatment zone be too great for the amount of available carbon, then reaction (ii) increases at the expense of reaction (i), thereby reducing the heat content and volume of the gas produced and vented from the furnace and consequently the amount of steam generated in the boiler and fed to the said reconditioning zone.

Again, suppose that the castings are decarburised at the other end of the optimum temperature range, namely at 850° C., at which temperature the CO/CO_2 ratio in the atmosphere contacting the castings should be in the region of 2:1 for maximum decarburisation without oxidation, and the value at which the water gas reaction attains equilibrium is in the region of 0.9.

Under such working conditions, similar calculations show that each 100 cubic feet of steam produce 147.5 cubic feet of gas mixture having an approximate composition of 10.8% CO_2, 22.2% CO, 43.0% H_2 and 24.0% H_2O, a calorific value of approximately 210 B. t. u.'s per cubic foot and a total heat content of 30,975 B. t. u.'s. The required efficiency of the steam generating and supply plant is, therefore,

$$\frac{5688}{30975}\times 100=18.4\%$$

From these calculations it will be seen that the maximum efficiency of the steam generating and supply plant is approximately the same over the entire annealing temperature range of 850° C. to 1100° C. and that a plant which is so constructed that it will never operate at an efficiency substantially in excess of 17% will be self-regulating, for all practical purposes, over the whole of the said temperature range.

However, it is to be understood that the above calculated efficiencies of 17.5% at 1050° C. and 18.5% at 850° C. are the theoretical maximum efficiencies at which the steam generating and supply plant can operate without creating oxidising conditions within the treatment chamber; in practice, the plant will be regulated to operate at somewhat lower efficiencies to ensure that such oxidising conditions will not be created.

When once the desired conditions of operation have been established, by trial, the process obviates the necessity of providing special instruments or apparatus for varying the supply of reconditioning air and/or steam as the annealing cycle proceeds, and makes use of the heat energy available in the vented gas; moreover, should the furnace and/or steam generating and supply plant cease to operate effectively during any stage of the annealing cycle, the failure will be "safe" in that the process will be brought automatically to a standstill without any detrimental effect upon the charge; thus failure or partial failure of any part of the steam generating plant or of the air supply, will lead to a cessation of or a reduction in the supply of steam and/or air to the treatment chamber; for example, blockage of either the vent *i*, or of the supply *j*, will lead to a reduction in the steam supply; again, accidental extinguishing of the flame at the outlet from the vent *i*, or failure of the water supply means *l* will lead to stoppage of the steam supply; whereas, failure of the combustion air supply through pipe *m* will reduce the efficiency of the said flame and lead to a reduced steam supply.

Having described the process of the invention and illustrated a suitable furnace and associated plant for carrying out the process, it will be understood that, if desired, various modifications which are consistent with the appended claims may be made without detracting from the spirit or scope of the invention or sacrificing any of the advantages thereof.

We claim:

1. A self-regulating process for annealing and gaseously decarburizing carbon-containing, cast-iron castings without substantially oxidizing said castings which comprises heating said castings in a furnace substantially tight to uncontrolled leakage of gases and having an oxygen-containing atmosphere to a temperature between about 850° C. and about 1100° C. to react the carbon contained in said castings with oxygen contained in said atmosphere to produce combustible gases in said furnace, venting a portion of said combustible gases from said furnace, burning said vented combustible gases under controlled combustion conditions to generate steam in an enclosed, water-containing boiler having a steam-generating efficiency not more than about 17%, mixing steam generated by said boiler with gases in said furnace out of contact with said castings to produce a furnace atmosphere containing combustible gases and steam, circulating said furnace atmosphere in contact with said castings whereby said castings are decarburized without the iron contained therein being deleteriously oxidized.

2. A self-regulating process for annealing and gaseously decarburizing carbon-containing, cast-iron castings without substantially oxidizing said castings which comprises heating said castings in a furnace substantially tight to uncontrolled leakage of gases and having an oxygen-containing atmosphere to a temperature up to about 1100° C. to react the carbon contained in said castings with oxygen contained in said atmosphere to produce combustible gases in said furnace, venting a portion of said combustible gases from said furnace, burning said vented combustible gases under controlled combustion conditions to generate steam in an enclosed, water-containing boiler having a steam-generating efficiency not more than about 17%, mixing steam generated by said boiler with gases in said furnace out of contact with said castings to produce a furnace atmosphere containing combustible gases and steam, circulating said furnace atmosphere in contact with said castings to decarburize said castings without deleteriously oxidizing the iron contained therein.

3. A self-regulating process for annealing and gaseously decarburizing carbon-containing, cast-iron castings without substantially oxidizing said castings which comprises heating said castings in a furnace substantially tight to uncontrolled leakage of gases and having an oxygen-containing atmosphere to a temperature between about

850° C. and about 1100° C. to react the carbon contained in said castings with oxygen contained in said atmosphere to produce in said furnace an atmosphere containing a ratio of carbon monoxide to carbon dioxide having such a relation to the temperature that at about 850° C. said ratio is at least 2:1 and at about 1100° C. said ratio is at least 3:1, venting a portion of said atmosphere from said furnace, burning the combustible components of said vented atmosphere under controlled combustion conditions to generate steam in an enclosed, water-containing boiler having a steam-generating efficiency not more than about 17%, mixing the steam generated by said boiler with the gases in said furnace out of contact with said castings, and circulating the mixture of steam and gases in said furnace in contact with said castings to decarburize said castings without deleteriously oxidizing the iron contained therein.

4. A self-regulating process for annealing and gaseously decarburizing carbon-containing, cast-iron castings without substantially oxidizing said castings which comprises heating said castings in a furnace substantially tight to uncontrolled leakage of gases and having an oxygen-containing atmosphere to a temperature up to about 1100° C. to react the carbon contained in said castings with oxygen contained in said atmosphere to produce in said furnace an atmosphere containing a ratio of carbon monoxide to carbon dioxide having such a relation to the temperature that at about 1100° C. said ratio is at least about 3:1, venting a portion of said atmosphere from said furnace, burning the combustible components of said vented atmosphere under controlled conditions to generate steam in an enclosed, water-containing boiler having a steam-generating efficiency not more than about 17%, mixing the steam generated by said boiler with the gases in said furnace out of contact with said castings, and circulating the mixture of steam and gases in said furnace in contact with said castings to decarburize said castings without deleteriously oxidizing the iron contained therein.

5. A self-regulating apparatus for annealing and gaseously decarburizing carbon-containing, cast-iron castings which comprises an insulated chamber substantially tight to uncontrolled leakage of gases and having a detachable hearth, means for heating said chamber, at least one gas-circulating device located inside said chamber, a gas-venting conduit extending through the wall of said chamber, an enclosed steam-generating boiler having a steam-generating efficiency not exceeding about 17% and cooperatively positioned near the gas-outlet port of said gas-venting conduit, a water-supply conduit extending into said steam-generating boiler, a steam-supply conduit extending between said boiler and said chamber and having a steam-outlet port within said chamber for directing steam into said chamber in proximity to said gas-circulating device.

6. A self-regulating apparatus for annealing and gaseously decarburizing carbon-containing, cast-iron castings which comprises an insulated chamber substantially tight to uncontrolled leakage of gases and having a detachable hearth, electrical means for heating said chamber to elevated temperatures, a gas-circulating fan located inside said chamber, a gas-venting conduit extending through the wall of said chamber, an enclosed steam-generating boiler having a steam-generating efficiency not exceeding about 17% and cooperatively positioned near the gas-outlet port of said gas-venting conduit, a water-supply conduit and an air-supply conduit extending into said steam-generating boiler, a steam-supply conduit extending from inside said boiler into said chamber and having a steam-outlet port within said chamber for directing steam into said chamber in proximity to said fan.

7. A self-regulating apparatus for annealing and gaseously decarburizing carbon-containing, cast-iron castings which comprises an insulated chamber substantially tight to uncontrolled leakage of gases and having a detachable hearth, electrical means for heating said chamber up to about 1100° C., a gas-circulating device located within said chamber, a gas-venting conduit extending through the wall of said chamber, an air-supply conduit extending into said gas-venting conduit, an enclosed steam-generating boiler having a maximum steam-generating efficiency of not more than about 17% and cooperatively positioned near the gas-outlet port of said gas-venting conduit, a water-supply conduit and an air-supply conduit extending into said steam-generating boiler, and a steam-supply conduit extending from inside said boiler into said chamber and having a steam-outlet port within said chamber for directing steam into said chamber in proximity to said gas-circulating device.

8. A self-regulating apparatus for annealing and gaseously decarburizing carbon-containing, cast-iron castings which comprises an insulated chamber substantially tight to uncontrolled leakage of gases and having a detachable hearth, electrical means for heating said chamber to a temperature between about 850° C. and about 1100° C., a gas-circulating fan located within said chamber, a gas-venting conduit extending through the wall of said chamber, an air-supply conduit extending into said gas-venting conduit, an enclosed steam-generating boiler having a steam-generating efficiency not more than about 17% and cooperatively positioned near the gas-outlet port of said gas-venting conduit, a water-supply conduit and an air-supply conduit extending into said steam-generating boiler, and a steam-supply conduit extending from inside said boiler into said chamber and having a steam-outlet port within said chamber for directing steam into said chamber in proximity to said fan.

PETER FRANCIS HANCOCK.
FRIEDRICH WILHELM KARL SCHULTE.

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Certificate of Correction

Patent No. 2,557,379 June 19, 1951

PETER FRANCIS HANCOCK ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 6, line 8, for "thre-" read *here-*; line 74, for "×17.5%" read *=17.5%*;

and that the said Letters Patent should be read as corrected above, so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 4th day of September, A. D. 1951.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.