No. 822,460. PATENTED JUNE 5, 1906.

A. W. MACHLET.

CASE HARDENING APPARATUS.

APPLICATION FILED FEB. 4, 1905.

3 SHEETS—SHEET 1.

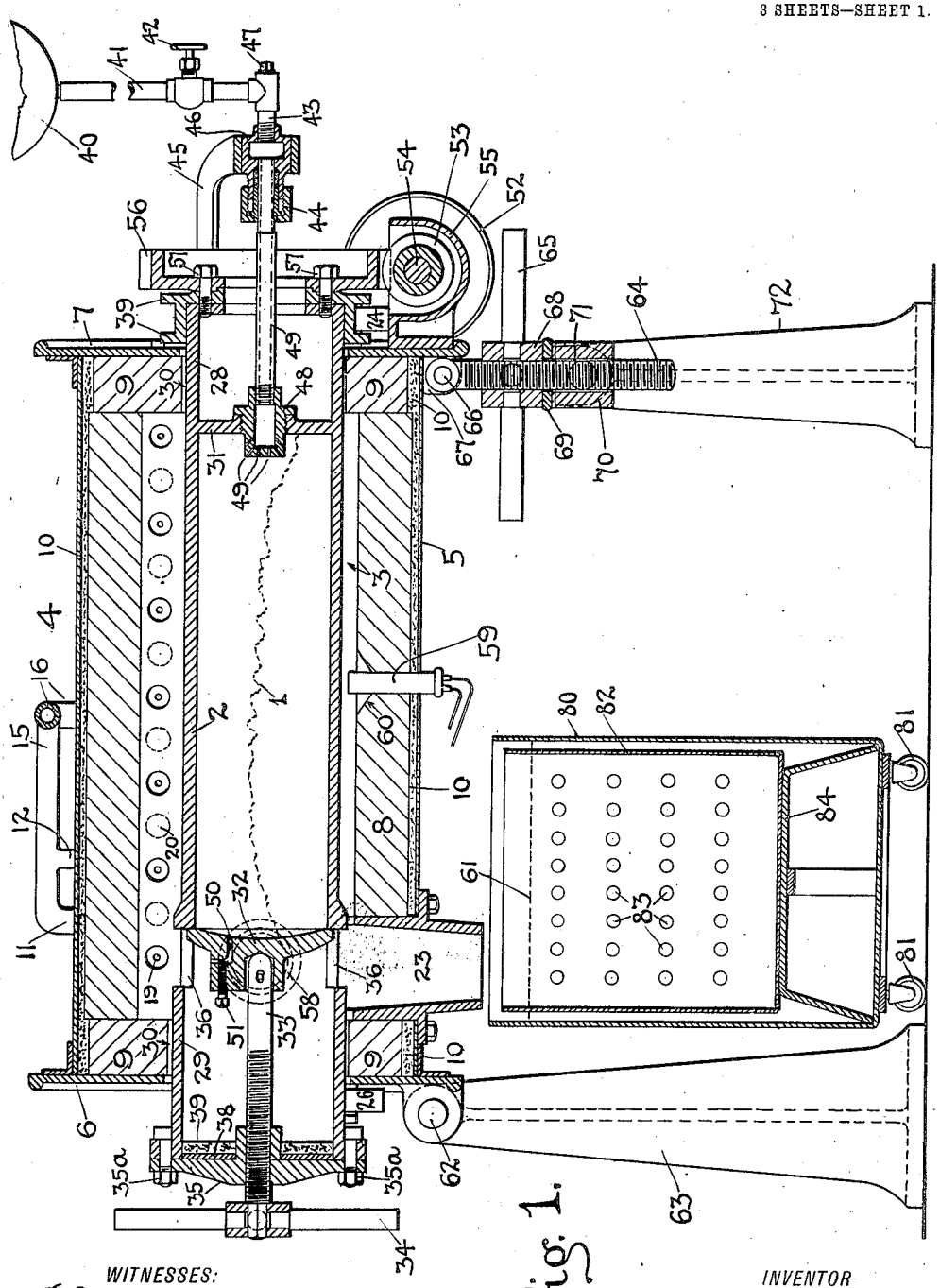


Fig. 1.

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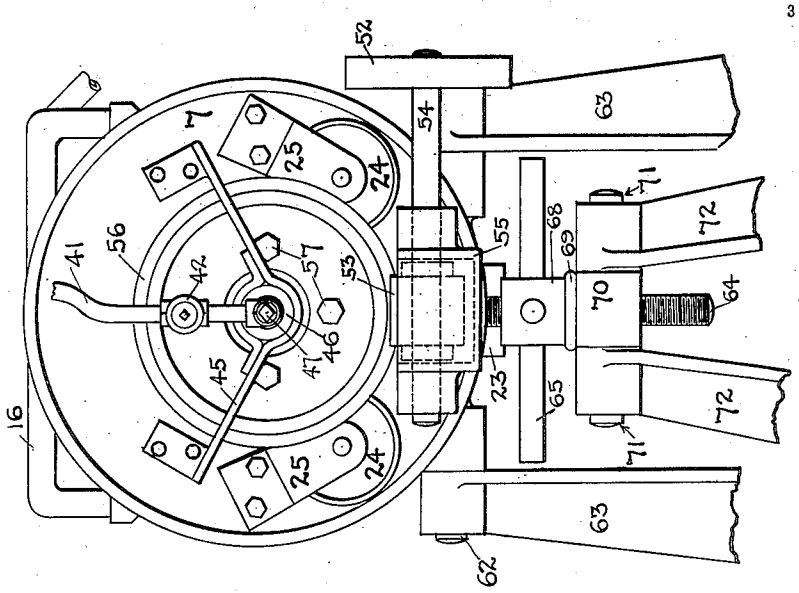


Fig. 3.

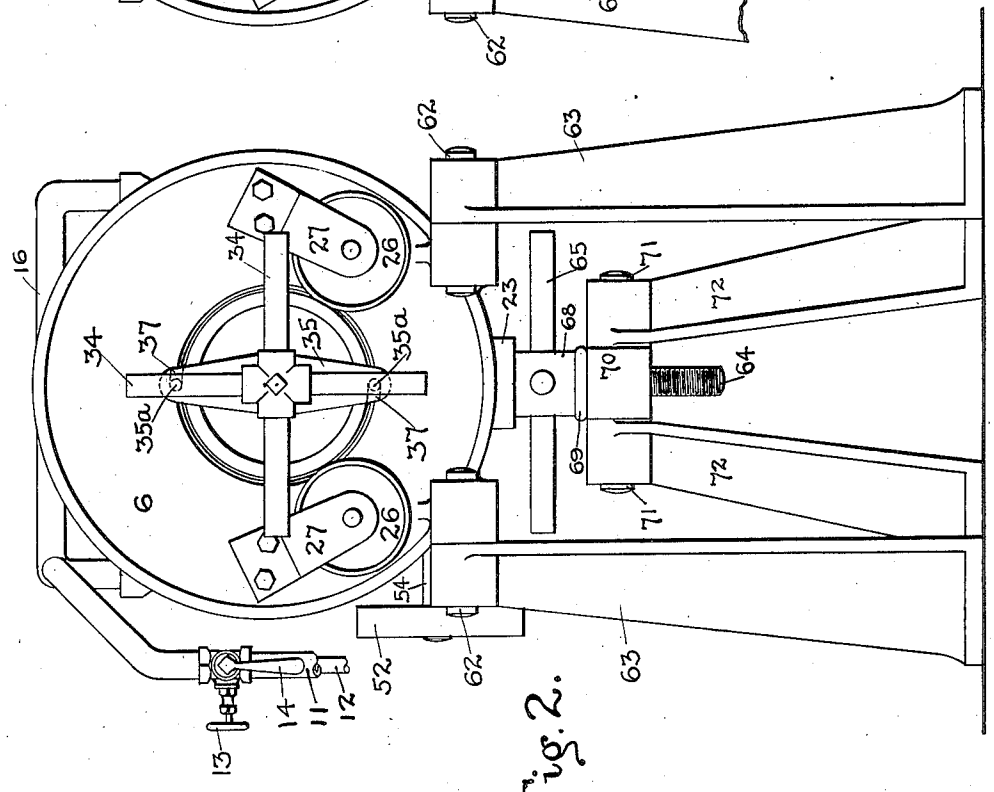


Fig. 2.

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3 SHEETS—SHEET 3.

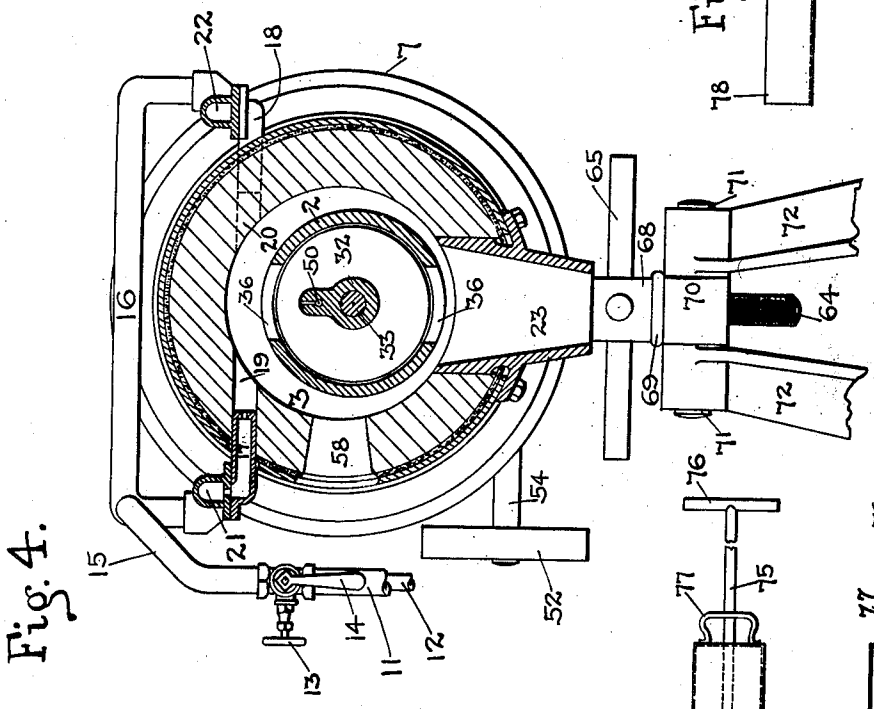


Fig. 4.

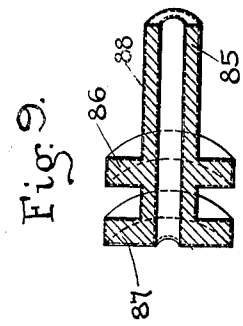


Fig. 9.

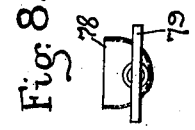


Fig. 8.

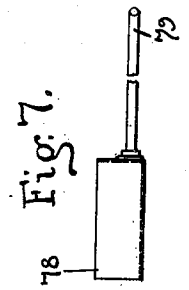


Fig. 7.

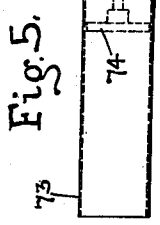


Fig. 5.

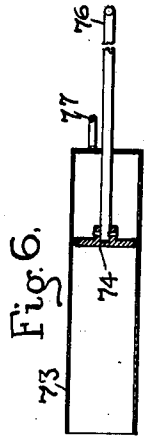


Fig. 6.

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UNITED STATES PATENT OFFICE.

ADOLPH W. MACHLET, OF ELIZABETH, NEW JERSEY.

CASE-HARDENING APPARATUS.

No. 822,460. Specification of Letters Patent. Patented June 5, 1906.

Application filed February 4, 1905. Serial No. 244,244.

To all whom it may concern:

Be it known that I, ADOLPH W. MACHLET, a citizen of the United States, residing in Elizabeth, in the county of Union and State of New Jersey, have invented certain new and useful Improvements in Case-Hardening Apparatus, of which the following is a specification.

This invention relates to the case-hardening of steel and iron articles, and particularly of small articles in bulk.

Small articles or parts in large quantities are commonly machined or shaped from wrought-iron or low-carbon steel in sheet, wire, or bar form, these metals, owing to their lack of carbon, being relatively soft, and hence easily cut and worked by machine-tools; but owing to this softness such articles are unsuited for wear, and accordingly it is the practice to case-harden them, usually by carburizing them to a depth of a few thousandths or possibly a few hundredths of an inch, so that they retain their shapes and are given sufficiently hard exteriors for the purposes for which they are intended. Case-hardening is a rapid process of cementation in which the surface of the wrought-iron or low-carbon-steel article is converted into steel or into a higher-carbon steel by heating the article in contact with carbonous material.

According to common practice the articles are packed in carbonaceous substance and heated above red heat; but the operation is slow and expensive, and the carburization extends irregularly to different depths at different points upon each article, some points often not becoming carburized at all. An excessive degree of heat must be applied for a long time in order to act through the non-conducting carbonaceous material upon the articles packed therein, and this excessive heat soon destroys the iron boxes in which the articles are usually case-hardened. In many cases also it is necessary to cool, repack, and reheat the articles in order to produce a sufficient depth of cementation.

Moreover, it is found in practice very difficult and sometimes altogether impossible to carburize the articles just as deeply as required and no deeper. In the case of thin or plate-like articles, where it is desired that the cementation shall be very shallow or thin, but still complete all over the articles, it is found to be practically impossible to attain the desired result, since the carburization is almost sure to proceed too far at some portions of the article, which consequently is rendered too brittle for use, it being desired to preserve the relatively soft and tough character of the interior of case-hardened articles. No practicable way has heretofore been found for not only insuring that the carbonization shall be of even thinness all over small thin articles, but also causing such cementation to proceed to the exact depth required, so that it would be practicable to case-harden such articles.

The principal objects of my invention are to materially reduce the cost of case-hardening articles, to insure that the case-hardening operation shall produce a shell of uniform thickness all over the article regardless of its shape, to regulate or gage exactly the thickness of the cementation or shell, to make it practicable to case-harden small articles cheaply and rapidly and uniformly in bulk, and to provide for inexpensively and effectually tempering the case-hardened articles by sudden cooling thereof.

I heat the articles to a point above redness, but below the melting-point, in an atmosphere of carbonous gas, preferably under high pressure—say from twenty-five up to one hundred pounds, or even more, to the square inch—and preferably effect gentle agitation of the articles during the heating, thus exposing all portions thereof to the gas, so as to insure the uniform penetration of the carbon from the gas at all points on the surface of the article, both outside and inside, and without regard to the shape of the same. Thus I avoid the necessity and expense of first packing the articles in carbonaceous substances in the usual manner. I use a retort made, preferably, of metal, with which the articles directly contact, so that they are quickly heated without unduly heating the retort, thus saving cost of fuel and avoiding destruction of the retort. The heat may be from about 1,500° to about 1,800° Fahrenheit. By means presently to be described the progress of the cementation may be known or predetermined, and the cementation may be arrested at any point, the thickness of the shell being determined in advance, even to a thousandth part of an inch, by an operator having fair skill in using the apparatus. I arrest the process of cementation as soon as the predetermined thickness or depth is acquired, and since case-hardened articles are usually tempered or made "glass-hard" I provide

means for suddenly cooling them while still hot—that is, before they lose the heat acquired in the carburizing-retort. This sudden cooling may be effected in any approved manner, as by plunging the articles into a cold liquid-bath. If this is done while the articles are still at carburizing heat—that is, above red heat—their tempering is effected, and this sort of tempering will answer for numerous kinds of articles where it is unimportant whether the shell has a coarse or fine grain. When the articles are chilled at this high heat, the shell acquires a coarse grain, as appears upon fracture. I therefore provide for gradually permitting the articles to cool from carburizing heat to cherry-red and then plunging them into the cooling-bath, whereby when desired a better quality of steel may be produced. When tempered in this manner, the shell appears to have a very fine grain when fractured, and the expense and delay of permitting the articles to cool gradually to ordinary atmospheric heat and subsequently reheating them for tempering are avoided, and the scaling of the surface due to such cooling and reheating is also avoided. By this means it becomes practicable to produce perfectly and evenly case-hardened finely-tempered articles which have been first shaped or machined from wrought-iron or low-carbon steel, and it is even practicable to manufacture large quantities of tools and articles and harden and temper them according to my invention which heretofore it has been necessary to produce slowly and expensively from fine high-carbon or "tool" steel. Other objects and advantages will hereinafter appear.

In the accompanying drawings, Figure 1 represents a sectional elevation, taken from end to end, of one form of a case-hardening and tempering apparatus constructed for case-hardening and tempering articles according to my invention. Fig. 2 is an elevation of the left-hand end, and Fig. 3 an elevation of the right-hand end, of the carburizing apparatus seen at Fig. 1. Fig. 4 is a vertical cross-section taken near the left-hand end of the furnace at Fig. 1. Fig. 5 is a plan, and Fig. 6 a longitudinal section, of one form of tool used in charging the apparatus with articles to be carburized. Fig. 7 is a side view, and Fig. 8 an end view, of another form of charging-tool. Fig. 9 is a sectional view of an example of a case-hardened article, illustrating a thin shell formed evenly all over the same.

The steel or iron articles to be case-hardened are represented by a dotted line 1, deposited in bulk within a retort 2, formed of cast-iron or other suitable metal, the retort being preferably about half or two-thirds full. The retort is preferably in the form of a barrel or elongated cylinder and is mounted wholly within a flame-chamber 3 of a furnace 4, the latter comprising a cylindrical or other body 5, having heads 6 and 7. The furnace is provided throughout with a refractory lining, the cylindrical portion thereof which lines the body being indicated at 8 and that portion which lines the heads of the furnace being indicated at 9, all of said lining being usually set in plaster-of-paris, (seen at 10.) The space inclosed by said refractory lining forms said flame-chamber. Any suitable fuel may be consumed in the furnace, and it may be otherwise constructed. Preferably a mixture of hydrocarbon fuel with air is used, the air being admitted through a pipe 11 and the fuel, such as ordinary illuminating or heating gas, being admitted through a pipe 12, the supply of air and fuel being regulated by valves 13 14. The air and fuel become mixed within the pipes 15 16, and the mixture is admitted to burners 17 18, inserted in horizontal openings 19 20, formed in the opposite walls of the furnace near the top of the flame-chamber.

The burners point alternately in opposite directions, as seen at Fig. 4, so as to direct the flames across the top and down around both sides of the retort and form two sets extending along the top of the flame-chamber above said retort. Two feed-pipes 21 22, extending along the furnace, connect the burners in the sets, said pipes being supplied by the pipe 16, which extends across the top of the furnace. The gas-flames are directed upon and over the retort and play down around the same and escape through an outlet 23, formed in the bottom of the furnace at the end of the retort, whereby even heating of the latter is assured. The supports for said retort are mounted upon the exterior of the furnace-heads and consist of a pair of rolls 24, carried upon brackets 25, fixed upon the right-hand head 7, and a pair of rolls 26, mounted upon brackets 27, fixed upon the left-hand head 6. The retort is formed with cylindrical extensions at its end, one extension 28 resting between and supported upon the rolls 24 and the other extension 29 being similarly supported upon rolls 26. It will be seen that said extensions project through openings 30, formed in the refractory lining 9, and through similar openings in the heads of the furnace. The purpose of supporting the retort upon the rolls is to enable it to turn during the heating thereof. A partition 31, forming the top or right-hand end of the retort, is cast between the same and the right-end extension 28, the latter being preferably of the same diameter as the retort itself.

The extension 29 is preferably of larger diameter than the retort, so as to permit the insertion and withdrawal of a cover 32, that is fitted to the left-hand end or bottom of the retort. This cover is intended to be clamped tightly upon the retort during the process of carburization, and it is removable to permit

charging and discharging the retort. A screw 33, provided with handles 34 upon the exterior of the furnace, is threaded into a yoke 35, which is fixed upon the end of extension 29 by means of bolts and nuts 35ª. By turning the screw the cover may be clamped tightly upon the retort or drawn off therefrom far enough to permit the articles 1 to drop or discharge through one of several apertures 36, formed in said extension 29 adjoining the retort and overlying the outlet 23.

In order to charge the retort, the cover, screw, and yoke are withdrawn, the latter being formed at its ends with hooks or open slots 37, which engage said bolts 35ª loosely, so that by simply turning said yoke to the left at Fig. 2 it is disengaged from the bolts and may be removed, together with the screw and cover. The extension 29 is also provided with a metal closure or head 38, having a lining of asbestos, said head 38 being fixed to the yoke 35. This head avoids waste of heat and also prevents the handles 34 from becoming unduly hot.

During the life of the apparatus the retort is alternately heated and cooled a great many times and in consequence gradually acquires a permanent expansion—that is, it slowly grows larger. Hence the apertures 30 in the furnace are made a little oversize, as illustrated, to accommodate the gradual increase in circumference of the extensions, and the periphery of the extension 29 is smooth, so that it may slip in axial direction along the rolls 26 to accommodate the permanent expansion or lengthening of the retort structure, the other extension 28 having flanges 39 to inclose the rollers 24 and prevent endwise movement of this end of the retort. The aperture 23 in the bottom of the furnace is made of sufficient dimension from left to right at Fig. 1 to accommodate the permanent lengthening of the retort, so that the aperture 36 may still overlie said opening 23 even when such lengthening has reached a maximum.

The carburizing-gas may be a pure hydrocarbon, although I have found in practice that good results are obtained by the use of ordinary city-gas, such as generally supplied for illuminating and heating in the city of Elizabeth, New Jersey. Good results can also be obtained from coal-gas and from oil-gas and also from carbureted hydrogen gas, (or water-gas,) resulting from the passing of steam through a mass of incandescent carbon and subsequent admixture of hydrocarbons or other enriching substances.

The gas which is used for cementation may be supplied under pressure in any suitable way; but for the sake of illustration I have shown a gas receiver or tank 40 which contains gas preferably at a pressure of one hundred pounds to the square inch, although a much lower or even higher pressure may be used, or in some cases the pressure may be just a little higher than atmospheric pressure. In other words, the pressure may vary from just sufficient to charge the retort to the highest that may be found practicable. This receiver is connected to the retort by means of flexible pipe 41, provided with valve 42, and a pipe 43, the latter being in line with the axis of retort 2. A gland is shown at 44 to accommodate the rotation of the retort, since the pipe 43 remains stationary. A yoke or bracket 45 is fixed upon the head 7 of the furnace to support the gland 46, into which pipe 43 is threaded. The latter is provided with a cap 47, which may be removed to give access to the interior of the pipe and gland for cleaning. Threaded into the end or top 31 of the retort is a jet or sprayer 48, having numerous apertures 49 for directing the gas in small jets into the retort, said sprayer 48 being connected by a pipe 49 to the gland 44. If oil-gas is used, any suitable provision may be used for converting the oil into gas and forcing it through the jet or spray 48 into the retort. The heat of the retort may be used for converting the oil into gas.

In operation the yoke 35 and cover 32 are removed and the articles 1 deposited within the retort 2. The yoke 35 is replaced and the nuts and bolts 35ª tightened and the screw 33 revolved to clamp the cover 32 tightly against the lower or left-hand open end of the retort. The gas and air valves 13 14 are opened and the fuel mixture ignited at the burners 17 18, the flames circulating in opposite directions over the top and down along the sides of the retort and then to the left along the bottom of the retort at Fig. 1, finally escaping downwardly through the orifice 23 in the bottom of the furnace. The valve 42 is opened, and the carburizing-gas passes from the tank 40 through the supply-pipe 41 43 49 and into the retort, the air being forced out from the latter through a vent 50, formed in the cover 32, and having an adjustable valve or screw 51, said vent remaining slightly open throughout the operation and the gas escaping therefrom igniting and constantly burning. The flames in the furnace heat the retort until the articles therein are above red heat—say from 1,500° to 1,800° Fahrenheit—this being safely below the melting-point and sufficiently hot to effect the cementation of the articles, which process may also be favored and hastened by reason of the high pressure at which the gas may be supplied to the interior of the retort. Owing to the rapidity of the cementation, a great economy is effected in fuel, since the time is materially shortened during which it is necessary to consume fuel in maintaining the heat of the retort and other parts, while of course the daily capacity of the apparatus is increased.

In order that the articles shall be exposed

uniformly to the action of the gas, I provide means for effecting gentle agitation thereof, such means in this instance consisting of a pulley or wheel 52, which is connected by movement-reducing gearing to the retort, so as to rotate the latter very slowly, thereby avoiding injury of the articles therein, which frequently are of delicate construction and particularly liable to become bent, owing to their heated condition. Said gear comprises a worm 53, fixed upon the pulley-shaft 54 and turning within a drip-pan 55 and in mesh with a worm-wheel 56, secured by bolts 57 to the right-hand extension 28 of the retort. The rotation of the latter may be very slow indeed, as its only object is to insure that each article shall be exposed all over to the action of the gas.

During the carbonizing operation fresh gas constantly enters through the supply 41 to replace the gas which has become vitiated by the absorption of the carbon elements into the metal articles, such vitiated gas escaping through the vent 50 and there producing a constant flame, which can be seen by the operator through the sight-hole 58, whereby he can ascertain by the color of such flame whether the gas retained in the retort is unduly vitiated. If so, the valve 51 may be opened a little more to permit freer escape of the gas and a more rapid inflow of fresh gas.

One advantage of the invention consists in the circumstance that the operator may arrest the case-hardening process as soon as the cementation has proceeded to any predetermined depth upon the articles, it being practicable to gage such a depth to within even a few thousandths of an inch or even less, according to the skill of the operator. In doing this the operator takes note of the time at which the articles reach the proper heat, which he can ascertain by observing through the sight-hole 58 the color of the body of the retort and which can also be ascertained by reading a pyrometer 59, which may be inserted through an aperture 60 in the bottom of the furnace and projects slightly into the flame-chamber. By comparison of the reading of the pyrometer with the appearance of the incandescent retort the operator can determine precisely when the articles have reached the required heat for cementation and may then admit the gas through the supply 41, and so cause the cementation to proceed for a predetermined length of time—say one hour or even less—according to the quality of the gas in the retort, the temperature thereof, the grade of the articles to be case-hardened, and the depth to which it is desired to have the case-hardening proceed upon the articles. The operator may make and preserve memoranda of different results obtained by the use of different qualities of gas or different pressures of gas upon different qualities of iron or steel, noting the depth to which the case-hardening proceeds under the different conditions, and from such account he may readily predetermine at any time how deep the case-hardening shall proceed upon the particular articles being treated. This exactness, which is highly desirable in many instances, is rendered possible largely because of the fact that the heat of the retort is maintained absolutely uniform throughout the process of cementation, owing to the use of burners for burning mixed air and fuel, whereby the heat of the retort may be not only regulated, but rendered absolutely uniform, and thus it becomes practicable and inexpensive to produce upon the articles shells of even predetermined thickness all over the articles, which result it has not heretofore been found practicable to obtain with certainty and in an inexpensive manner suitable for the purposes of ordinary manufacturing.

As soon as the cementation has proceeded to the desired depth valve 42 may be closed, the handles 34 may be turned to open the cover 32, and the articles may drop through the opening or chute 43 into a tempering-bath of cold water or other liquid 61.

To facilitate the discharge of the retort, I arrange to tilt the same up at its right-hand end, so that during the continued rotation thereof the articles will feed gradually down to the left-hand or bottom end and finally drop through the chute 23 into the bath 61. For this purpose I pivot or hinge the furnace at 62 upon a pair of standards 63 at the left-hand end of the apparatus and provide at the right-hand end a vertical screw 64, so that by means of said screw the right-hand end of the furnace may be elevated or tilted, together with the retort therein. The screw 64 does not turn, but is pivoted at its upper end 66 to an ear 67, depending from the furnace, and handles 65 are provided upon a nut 68, threaded upon said screw and resting upon a washer 69, carried by a block 70, pivoted at 71 to standards 72. The pivoting of the block at 71 accommodates the different angular positions assumed by the screw 64 as it rises with the furnace.

As soon as the articles are discharged from the retort the latter may be recharged without becoming cold, thus avoiding the delay and expense of reheating the same. For the purpose of recharging, the tool seen at Figs. 5, 6 may be employed, consisting of a cylindrical scoop 73, having therein a piston 74, the latter provided with a rod 75 and handle 76. The piston may be drawn to the bottom of the scoop and the latter filled with small articles and inserted within the hot retort. The operator then holds the handle 76 stationary, while he pulls out the scoop by means of a handle 77, thus gently depositing

the articles in the retort. Another form of scoop 78 is seen at Figs. 7, 8, having a handle 79. This tool may be filled with articles and inserted within the retort and then gently turned so as to dump the articles into the retort. Then the cover 32 may be replaced, the gas admitted to the retort through the supply 41, and the operation proceeds as before. Very little time is occupied in charging and recharging, so that waste of fuel is minimized. Thus the furnace may be kept in constant operation, and many charges of articles may be case-hardened every day with but little expense for labor and fuel as compared with the methods of case-hardening accepted at the present time.

While for some purposes the incandescent articles may without any cooling be dumped directly into the tempering-bath 61, still for other purposes it is desirable that the articles shall first gradually cool until they are about cherry-red, and in order to effect such gradual cooling I partly close the valves 13 14, so that only a little gas passes through the burners 17 18, just sufficient to prevent the ingress of air up through the orifice 23, thus preventing oxidation of the exterior walls of the retort. Only a slight pressure of gas in the furnace is necessary for the purpose, and this does not materially retard the cooling of the retort and the articles therein to the desired cherry-red heat. Thus while the articles are still heated from the carburizing process they may discharge into the cooling-bath, and the shells thereon may receive a fine temper. During such gradual cooling of the articles in the retort the valve 42 may be closed, so that no further carburization may take place, or, on the other hand, the valves 13 14 may be prematurely partly closed to reduce the flow of gas into the flame-chamber and permit the gradual cooling of the retort, and the valve 42 may be left open, so that cementation will continue as far as it may during such gradual cooling.

The cooling apparatus seen at Fig. 1 comprises a tank 80, which is provided with rollers 81 to run upon the floor, the top of the tank being just beneath the mouth of the chute 23. Within the tank rests a sieve 82, through whose perforations 83 the liquid circulates. The articles drop into this sieve, which rests upon a support 84, provided in the bottom of the tank, and as soon as the articles are chilled by the bath the sieve is lifted out, the liquid escaping therefrom through said perforations 83. The articles are then dumped from the sieve and the latter replaced in the tank. Any other suitable apparatus or device may be used for chilling or cooling the articles.

It will be seen that an important economy is effected, because the articles are directly in contact with the metal retort, which is subject to the heat of the flames from the burners, whereby owing to the connections of the heat through the metallic body of the retort the articles are quickly heated without the necessity of forcing the heat through the body of non-conducting carbonaceous substance. Thus not only is fuel saved, but the necessity is avoided of damaging the retort itself, the life of which is hence greatly prolonged.

When it is desired to renew the retort, however, it is only necessary to take out the screws 57, by which the worm-wheel 56 and the flanged roll 39 are attached thereto, and also to disconnect the gland 44, whereupon the retort may be pulled directly out of the furnace to the left at Fig. 1, a new one may be put in place, and the parts 39, 56, and 44 restored.

At Fig. 9 is seen an article comprising a hollow shaft 85 and flanges 86 87, formed thereon, the entire article being covered with a thin shell 88, which, it will be understood, is of uniform thickness, since both interior and exterior parts of the article are accessible to the gas.

Variations may be resorted to within the scope of my invention, and portions of my improvements may be used without others.

Having thus described my invention, I claim—

1. A case-hardening apparatus comprising a furnace having a single chamber in which the flames originate, a metallic retort wholly within said chamber, and a holder for carburizing fluid connected with said retort; said furnace being provided with supports upon which the retort is so mounted that the flames may envelop the retort throughout its length; the retort being provided with a constricted regulatable vent, and also having a normally closed opening distinct from said vent and through which the case-hardened articles may be removed; and means for effecting agitation of the articles in the retort during the heating thereof.

2. A case-hardening apparatus comprising a furnace having a body and ends, and having a refractory lining for said body and ends, said lining forming a single chamber in which the flames originate, a revoluble metallic retort wholly within said chamber, a holder for carburizing fluid connected with said retort; said furnace being provided with supports upon which the retort is so mounted that the flames may envelop the retort throughout its length, and said retort being removably connected to said supports, and also having a relatively constricted vent, and an opening to permit removal of the articles, said opening having a removable cover and means for rotating said retort.

3. A case-hardening apparatus comprising a furnace having a body and ends, and having a refractory lining for said body and ends, said lining forming a chamber in which the

flames originate, a metallic retort wholly within said chamber and having supporting extensions which protrude through said ends, said furnace having exterior supports upon which said extensions are mounted in such a manner that the retort is removable from the furnace, and a holder for carburizing fluid connected to one end of said retort; a cover and a constricted vent being provided at the other end of said retort.

4. A case-hardening apparatus comprising a furnace provided with a refractory lining, a metallic retort mounted wholly within said lining, numerous burners for mixed air and fuel, said burners forming a set extending the entire length of the retort in such a manner as to cause the retort to be heated throughout with evenness independent of the heat of said refractory lining; means being provided for subjecting the articles in the retort to a constant current of carburizing-gas during the heating of the retort and means for effecting rotation of said retort.

5. A case-hardening apparatus comprising a furnace having a body and ends and provided with a refractory lining for said body and ends, a metallic retort within said lining and having extensions which protrude through said ends, a holder for carburizing fluid connected to said retort at one end, a cover for the other end of said retort, and a manually-operable device extending without said furnace for clamping said cover, said clamping device being connected to a head which is mounted exteriorly of said furnace, and which is detachable so that the cover, clamping device and head may be removed from the furnace while the retort remains therein; said retort provided with a constricted vent.

6. A case-hardening apparatus comprising a furnace having a single fire-chamber provided with a refractory lining, a metallic retort within said fire-chamber, a holder for carburizing fluid connected with said retort, and numerous burners for mixed air and fuel; said burners being directed alternately in opposite directions and forming a series extending along said retort and placed at such intervals as to effect substantially uniform heating of the retort throughout its length, and the retort being so sustained in said fire-chamber that the flames may play freely around the top, sides and bottom of the retort, and the latter being provided with a constricted vent.

7. A case-hardening apparatus comprising a furnace having a refractory lining which forms a single fire-chamber, a metallic retort wholly within said fire-chamber, supporting means provided upon the exterior of said furnace for said retort, the latter being removable from said supporting means, numerous burners for mixed air and fuel within said fire-chamber, said retort being supported in such a manner that the flames from said burners may play freely around and beneath said retort between the same and said refractory lining, said retort having an extension protruding through said refractory lining and engaging said supporting means, the retort being removable from the furnace, and having outside of the furnace a removable cover, and also having a constricted vent.

8. A case-hardening apparatus comprising a furnace having a single flame-chamber, a metallic retort wholly within said chamber and having supporting means extending to and revoluble upon supports which are provided upon the exterior of the furnace, said retort being removably mounted at its ends upon said supports, a set of burners for mixed air and fuel within said flame-chamber, the walls of the latter coöperating with said burners to direct the flames with substantial uniformity beneath and around said retort, and a holder for carburizing fluid connected to said retort; constricted means being provided for venting vitiated gas from the retort.

9. A case-hardening apparatus comprising a furnace having a flame-chamber, a retort mounted wholly within said flame-chamber, a holder for carburizing fluid connected to said retort, and power-driven means for effecting agitation of the articles within the retort during the heating thereof; means being provided for securing circulation of the carburizing fluid within the retort during the heating thereof.

10. A case-hardening apparatus comprising a furnace having a flame-chamber, a retort wholly within said flame-chamber, supports exterior to said furnace upon which said retort is mounted for movement, a holder for carburizing fluid connected to said retort so as to supply fluid thereto during the movement of the retort, and means for effecting movement of the retort throughout the carburizing operation; said retort provided with a constricted vent.

11. A case-hardening apparatus comprising a furnace having a flame-chamber, a metallic retort wholly within said chamber, said furnace provided with exterior supports engaged by means extending from said retort, and permitting rotation of the retort, and a holder for carburizing-gas connected to the retort so as to supply the same with carburizing fluid during the rotation of the retort; means being provided for permitting gradual venting of vitiated gas from the retort during the carburizing operation.

12. A case-hardening apparatus comprising a furnace having a single flame-chamber, a set of numerous burners for mixed air and fuel within said flame-chamber, a retort in the form of a barrel within said flame-chamber, said retort provided with extensions and said furnace having exterior means to engage

said extensions so as to permit rotation of the retort, and a space being left within said flame-chamber all around the top, sides and bottom of said retort for the circulation of flames, and a holder for carburizing fluid connected to said retort so as to supply the same with carburizing fluid during the rotation of the retort; the latter provided with a constricted vent.

13. A case-hardening apparatus comprising a furnace, a closed metallic retort in the form of a barrel and wholly within the flame-chamber of the furnace and revolubly supported by its ends, the supports for said retort being outside of the flame-chamber, a holder for carburizing-gas connected with said retort, numerous burners for mixed air and fuel in said flame-chamber, and a common exhaust for the flames from said burners; said retort being disposed between said burners and said exhaust, and so mounted that it is surrounded by a flame-space on its top, sides and bottom; said retort being provided with a constricted vent.

14. A case-hardening apparatus comprising a furnace having a flame-chamber, a metallic retort in said chamber, means being provided for revolubly supporting said retort during the heating thereof, and a holder for carburizing fluid connected to said retort so as to supply carburizing fluid to the retort during the rotation thereof; said retort provided with a constricted vent.

15. A case-hardening apparatus comprising a furnace having a body and ends, and having a refractory lining for said body and ends, said lining forming a chamber in which the flames originate, a metallic retort wholly within said chamber and having supporting extensions which protrude through said ends, said furnace having exterior supports upon which said extensions are revolubly mounted, and a holder for carburizing fluid connected to said retort so as to supply carburizing fluid thereto during the rotation and heating of the retort; the latter provided with a constricted vent.

16. In combination, a closed retort formed of metal, means for causing the retort to heat quickly and uniformly throughout, and for maintaining an even temperature of the heated retort, and means connected to the retort at one end thereof for furnishing a constant supply of carburizing-gas under pressure, and a constricted vent being provided at the other end of the retort.

17. In combination, a closed retort formed of metal, means for causing the retort to heat quickly and uniformly throughout, and for maintaining an even temperature of the heated retort, and means connected to the retort at one end thereof for furnishing a constant supply of carburizing-gas under pressure, and a constricted vent being provided at the other end of the retort, and power-driven mechanism for repeatedly agitating the articles in the retort during the carburizing operation.

18. In combination, a furnace having a flame-chamber, a metallic retort mounted wholly within the flame-chamber and having an extension which protrudes from the furnace, a cover for said retort, said cover applied to the retort within the flame-chamber, releasable means exterior to the furnace and supported upon said extension, for retaining said cover, a holder for carburizing fluid connected to said retort and means for moving said retort so as to effect agitation of the articles therein constantly during the heating thereof.

19. In combination, a furnace having a flame-chamber, a metallic retort mounted wholly within the flame-chamber and having at its ends extensions which protrude from the furnace, a cover for one end of said retort, said cover and the other end of said retort being both within said flame-chamber, releasable means exterior to the furnace and supported upon one of said extensions, for retaining said cover, a constricted vent being provided at the covered end of the retort, means upon said furnace revolubly supporting said extensions, power-driven means for effecting slow revolution of the retort, and a holder for compressed carburizing-gas connected to the end of said retort opposite from said cover.

20. In combination, a furnace having a flame-chamber, a retort in the form of a barrel having ends, hollow supports extending from said ends and projecting from the furnace and revolubly mounted exteriorly of the furnace, one of said ends being in the form of a removable cover, and a removable cap closing the end of the extension which is adjacent to said removable cover.

21. In combination, a furnace having a flame-chamber, a retort in the form of a barrel having ends, hollow supports extending from said ends and projecting from the furnace and revolubly mounted exteriorly of the furnace, one of said ends being in the form of a removable cover, and a removable cap closing the end of the extension which is adjacent to said removable cover; said removable cap being attached to said removable cover so that they may be removed together, and said cap being provided with a packing.

22. A case-hardening apparatus comprising a furnace having a single fire-chamber, a closed metallic retort within said fire-chamber, a holder for carburizing-gas connected with said retort, a series of burners for mixed air and gas, said burners being all within said fire-chamber and being constructed to direct flames in alternate directions around the body of said retort throughout its length, the burners being so disposed as to effect substantially uniform heating of the retort through-

out its length; the retort being provided with a relatively minute vent, and also with a large normally closed opening distinct from said vent, through which the articles may be removed and means for effecting rotation of said retort.

23. A case-hardening apparatus comprising a furnace, a closed metallic retort in the form of a barrel and wholly within the flame-chamber of the furnace and supported by its ends, a holder for carburizing-gas connected with said retort, a row of oppositely-directed burners for air and fuel all in said flame-chamber and disposed over said retort for the entire length of the latter and so disposed as to heat the retort with substantial evenness throughout its length, and a common exhaust in the bottom of said furnace for the flames from said burners; the retort being provided with a relatively minute vent.

24. A case-hardening apparatus comprising a furnace having a refractory lining forming a single flame-chamber and provided with burners all within said chamber, a metallic retort wholly within said refractory lining, supporting means arranged exteriorly of said refractory lining, said retort being provided with means extending through said refractory lining to rest upon said supporting means, the retort being supported in such a manner as to permit of gradual permanent expansion of the retort independently of the furnace, a cover within said refractory lining for said retort, means extending to the exterior of the furnace for clamping said cover, and a holder for iron-carburizing gas connected with said retort; the latter provided with a relatively minute vent.

25. A case-hardening apparatus comprising a furnace having a body and ends and a refractory lining for said body and ends and also provided with burners, a metallic retort wholly within said refractory lining, supporting means arranged at the ends of said furnace exteriorly of said refractory lining, said retort being provided with hollow extensions beyond its ends which extend through said refractory lining, means being provided for engaging one end of the retort to prevent the latter from endwise displacement, and provision being made for accommodating endwise movement of the opposite end of the retort due to the gradual permanent expansion of the metal, a holder for carburizing-gas, a connection extending from said gas-holder through one of the said extensions and communicating with the interior of said retort, a cover at the other end of the retort, and cover-clamping means extending through the other extension to the exterior of the apparatus; the retort being provided with a relatively minute vent.

26. A case-hardening apparatus comprising a furnace, a metallic retort mounted therein, a holder for iron-carburizing gas outside of said furnace but connected with said retort, and means for effecting movement of said retort to agitate its contents during the heating of the retort; the latter being provided with a minute vent.

27. A case-hardening apparatus comprising a furnace provided with rolls, a retort in the form of a barrel and confined wholly within the flame-chamber of said furnace and having hollow cylindrical extensions projecting to the exterior of the furnace and mounted for rotation upon said rolls, and a holder for iron-carburizing gas connected with said retort; the latter provided with a relatively minute vent.

28. A case-hardening apparatus comprising a furnace, a metallic retort mounted therein and having a large opening, a removable cover normally closing said opening, means for effecting mechanical discharge of the incandescent articles from the retort through said opening, and a holder for iron-carburizing gas connected to said retort; the latter being provided with a relatively minute vent.

29. A case-hardening apparatus comprising a furnace provided with a flame-chamber and a retort, a cover for said retort, means for supplying iron-carburizing gas to and venting it from said retort, and means for tilting said furnace together with said retort to discharge the articles from said retort.

30. A case-hardening apparatus comprising a furnace provided with a flame-chamber and a retort, a cover for said retort, means for supplying gas to and venting it from said retort, and means for tilting said furnace together with said retort to discharge the articles from said retort, said furnace having a refractory lining and being provided with a chute through which said articles may discharge; said chute extending through said refractory lining.

31. A case-hardening apparatus comprising a furnace having a flame-chamber and a movable metallic retort; said furnace being provided with supports for said retort, upon which supports the retort is so mounted in the flame-chamber that the flames may envelop the retort; and the latter being provided with a gas-supply and a vent; means for effecting gentle movement of the retort; and means for effecting such a movement of the retort as will discharge the heated articles therefrom.

32. A case-hardening apparatus comprising a furnace provided with a refractory lining and also with a supporting means; a revoluble metallic retort mounted upon said supporting means and thereby wholly supported within said refractory lining so that a flame-space surrounds the retort; said retort being provided with a gas-supply and a vent; means for effecting slow rotation of said retort; and means for tilting the retort.

33. A case-hardening apparatus compris-

ing a furnace, a metallic retort, and means supporting said retort for rotation within said furnace; said furnace being provided with a refractory lining and an outlet for products of combustion, and said retort lying horizontally and being in such relation to said refractory lining and said outlet that the flames of the furnace are caused to circulate around said retort in seeking the outlet; said retort having a gas-supply and a vent, and a discharge from one end of said retort being provided through said refractory lining; means being also provided for tilting said furnace together with said retort.

34. A case-hardening apparatus comprising a furnace; a metallic retort lying therein; said furnace being provided with supports upon which the opposite ends of the retort are mounted for rotation, and the retort being surrounded by a flame-space and having a cover, a gas-supply, and a vent; supports upon which one end of said furnace is pivoted, and a screw for lifting the other end of said furnace.

35. A case-hardening apparatus comprising a furnace pivotally mounted at one end, means at the other end for tilting the same, a retort within said furnace, a cover for said retort, a discharge-passage from said retort through the wall of the furnace, and means for supplying gas to and venting it from said retort.

36. A case-hardening apparatus comprising a furnace, an inclined retort mounted therein, a discharge-passage being provided from the lower end of said retort and extending through the wall of the said furnace, and means for supplying iron-carburizing gas to and venting it slowly from said retort.

37. A case-hardening apparatus comprising a furnace pivoted at one end, a screw for elevating the other end of the furnace, a retort within said furnace and means for supplying gas to said retort.

38. A case-hardening apparatus comprising a furnace having a refractory lining, a revoluble closed metallic retort mounted within said furnace and surrounded by a flame-space, burners mounted over said retort, an exhaust-opening below the retort for the flames from the burners, means for supplying gas to and venting it from said retort during the revolution; power-driven means for turning said retort; and means for effecting discharge of the hot articles from said retort through said exhaust-opening.

39. A case-hardening apparatus comprising a furnace having a refractory lining and provided with burners, a metallic retort wholly within said refractory lining, bearing-rolls arranged exteriorly of said refractory lining, said retort being provided with cylindrical ends extending through said refractory lining to rest upon said rolls, a cover within said refractory lining for said retort, means extending to the exterior of the furnace for clamping said cover, means for supplying gas to and venting it from said retort, and means for tilting said furnace and retort; the lower cylindrical end of the latter being provided with an aperture for the discharge of articles from the retort, and the furnace having a discharge-opening beneath said aperture.

40. A case-hardening apparatus comprising a furnace having a refractory lining for its body and ends and also provided with burners for burning mixed air and gas, means for regulating the supply of air and gas, a closed horizontal cylindrical metallic retort wholly within said refractory lining, bearing-rolls arranged at the ends of said furnace exteriorly of said refractory lining, said retort being provided with hollow cylindrical extensions at its ends which extend through said refractory lining and whereby the retort is revolubly supported upon said rolls in such a manner that one end of the retort is prevented from moving endwise while the other end thereof may move endwise to accommodate the gradual permanent expansion of the metal, a gas-supply extending through one of said extensions and communicating with the interior of the retort, a cover at the other end of the retort, a discharge through the bottom of the furnace at the cover end of the retort, cover-clamping means extending through the other extension to the exterior of the apparatus, and means for tilting said furnace and retort; said furnace being provided with a pyrometer and with a sight-hole opposite the body of said retort.

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