No. 847,588. PATENTED MAR. 19, 1907.

A. W. MACHLET.

CASE HARDENING.

APPLICATION FILED APR. 13, 1905.

3 SHEETS—SHEET 1.

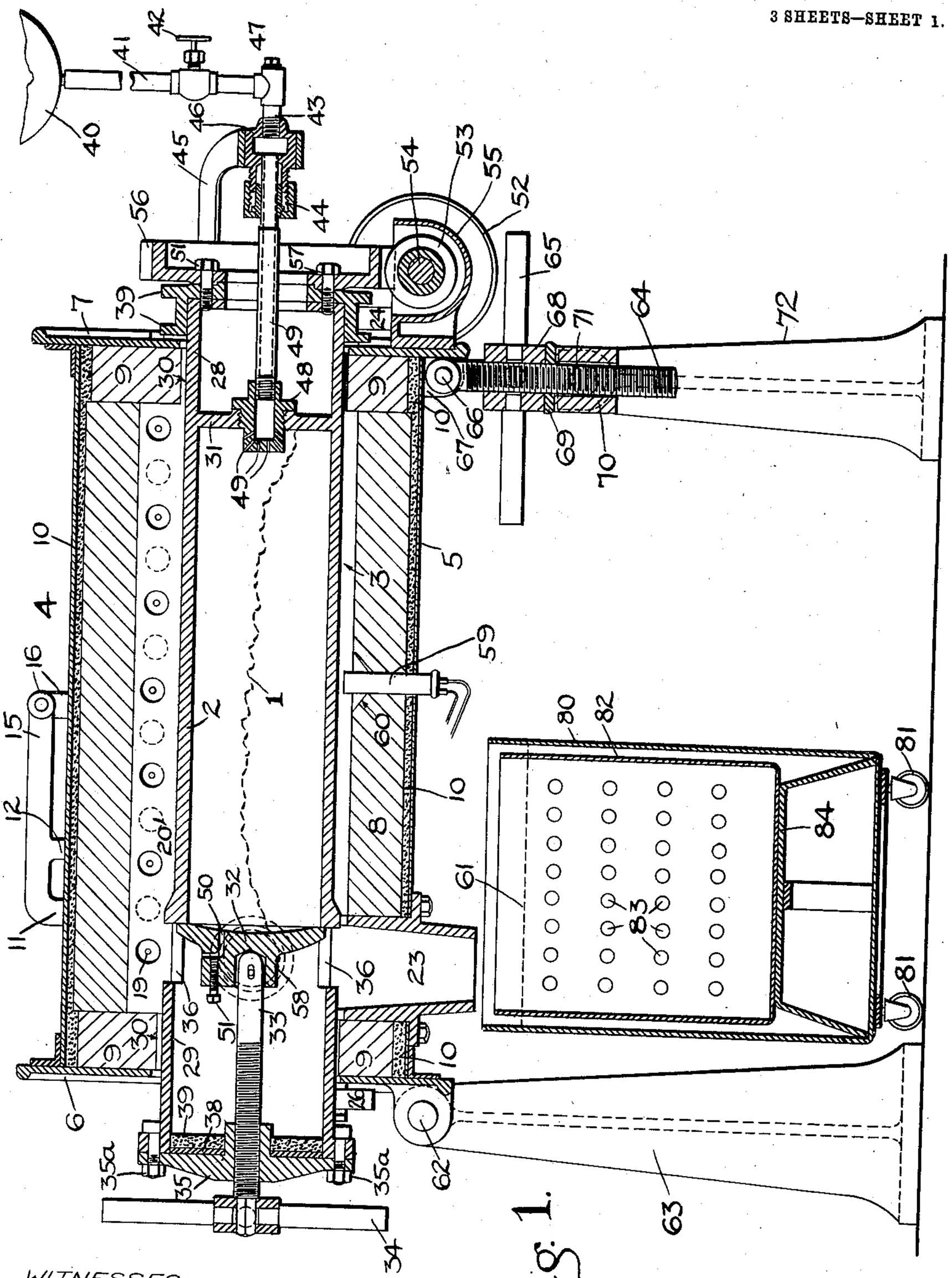

Fig. 1.

WITNESSES:
William M. Hilbert
Albert Nathan

INVENTOR
Adolph W. Machlet
BY B. B. Stickney
ATTORNEY

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3 SHEETS—SHEET 2.

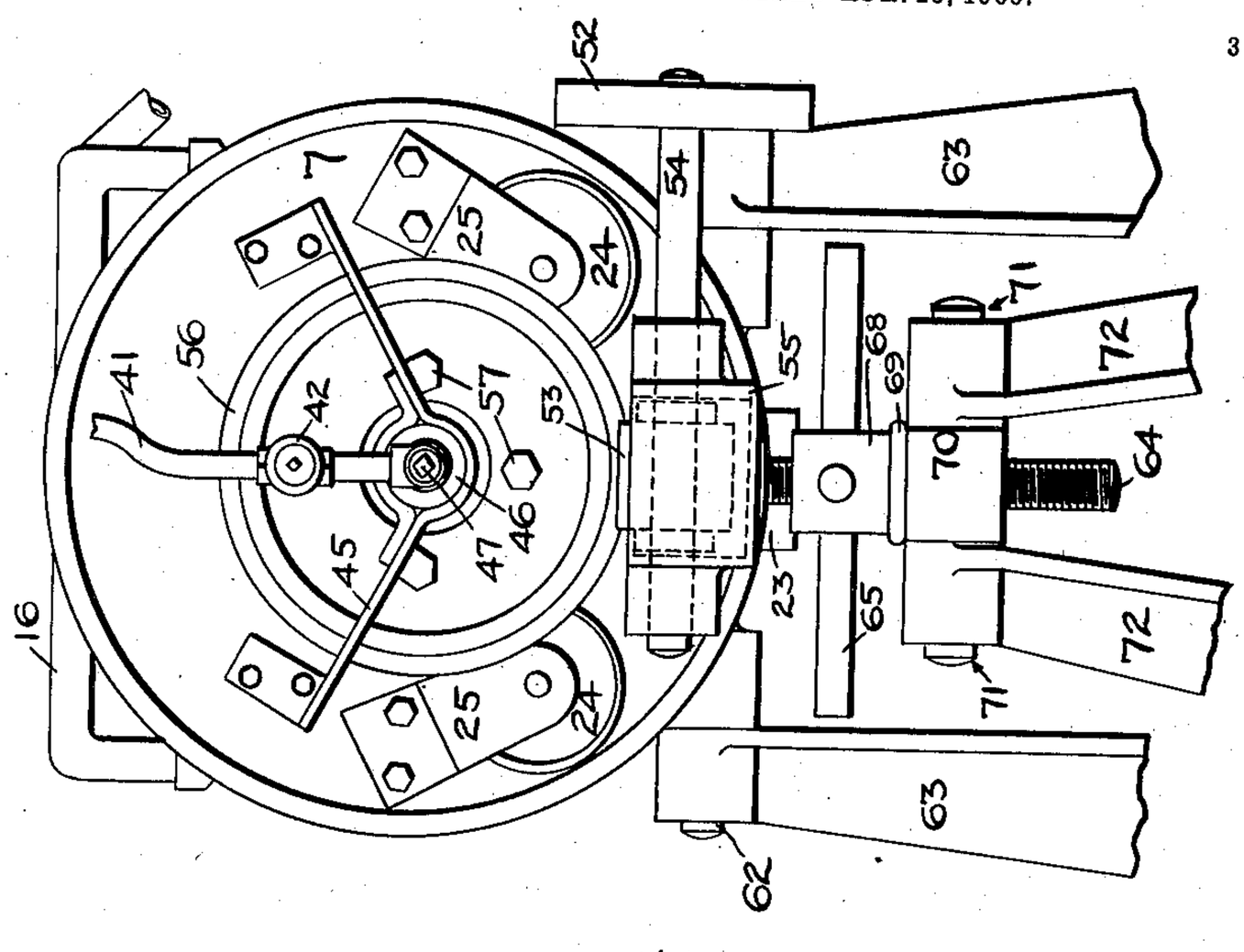

Fig. 3.

Fig. 2.

WITNESSES:
William M. Hilbert
Albert Nathan

INVENTOR
Adolph W. Machlet
BY Geo. C. Stickney
ATTORNEY

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3 SHEETS—SHEET 3.

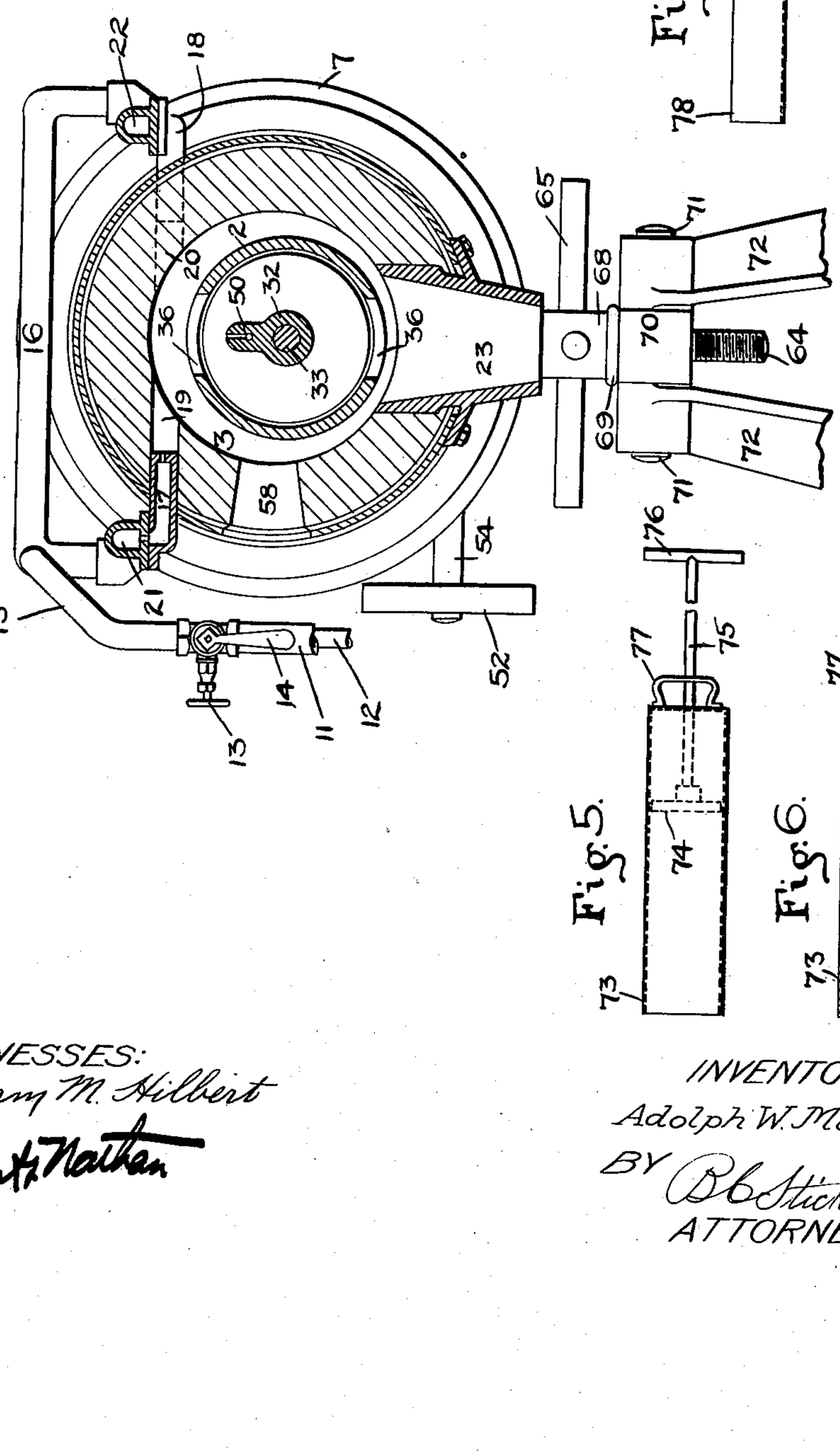

Fig. 4.

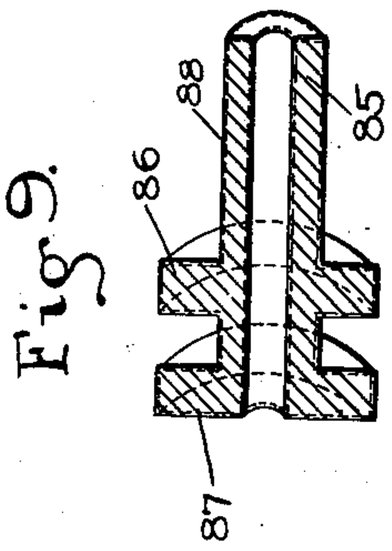

Fig. 9.

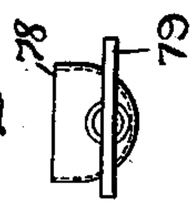

Fig. 8.

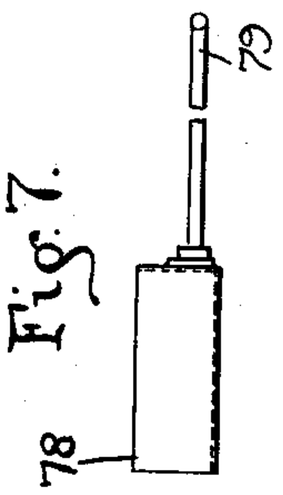

Fig. 7.

Fig. 5.

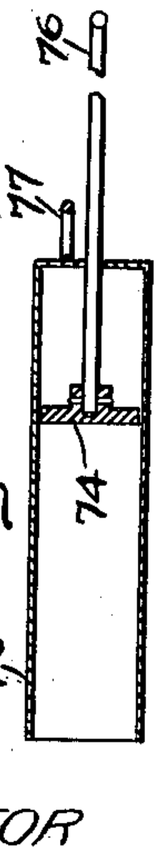

Fig. 6.

WITNESSES:
William M. Hilbert
Albert G. Nathan

INVENTOR
Adolph W. Machlet
BY B. B. Stickney
ATTORNEY.

UNITED STATES PATENT OFFICE.

ADOLPH W. MACHLET, OF ELIZABETH, NEW JERSEY.

CASE-HARDENING.

No. 847,588. Specification of Letters Patent. Patented March 19, 1907.

Application filed April 13, 1905. Serial No. 255,356.

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, 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 is 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 an apparatus constructed for case-hardening and tempering articles acccrding 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 at about the line X X of 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 exmple 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 it. 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 discharge 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 over size, 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 object is merely to insure that each article shall be exposed all over to the action of the gas, and that all sides of each article shall come uppermost in turn, since the gas acts better on the top side than on the bottom side of any article in the retort. 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 convection 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.

Having thus described my invention, I claim—

1. The process of case-hardening low-carbon-steel articles to form thereon shells of uniform and exact predetermined thickness, consisting in placing the articles in a metal retort, closing the retort, filling the retort with carburizing-gas, uniformly heating the articles throughout by applying heat evenly to the exterior of the retort so as to heat the same uniformly throughout until its temperature reaches from about 1,500° to about 1,800° Fahrenheit, maintaining the heat substantially uniform and turning the retort during the cementation of the articles, and arresting the cementation at the expiration of a predetermined interval of such length that the articles are cemented to the predetermined depth.

2. The process of case-hardening low-carbon-steel articles to form upon each thereof a shell of uniform and exact predetermined thickness, consisting in placing the articles in a metal retort, closing the retort, filling the retort by carburizing-gas, applying heat uniformly to the exterior of the retort until the articles reach carburizing heat, maintaining the heat of the articles uniform while causing fresh carburizing-gas to circulate constantly through the retort, turning the retort to cause different sides of the articles

to come uppermost during their cementation, and arresting the cementation at the expiration of a predetermined interval of such length that the articles are cemented to the predetermined depth.

3. The process of case-hardening with uniformity low-carbon-steel articles to form upon each thereof a shell of uniform and exact predetermined thickness, consisting in placing the articles in a metallic retort, closing the retort, filling the retort with carburizing-gas, applying heat uniformly to the exterior of the retort until the articles are heated uniformly above red heat but safely below the melting-point, maintaining the heat substantially uniform throughout the carburizing of the articles, maintaining a supply of fresh carburizing-gas during the cementing of the articles, turning the retort during the cementing operation to cause different sides of the articles to come uppermost, and arresting the cementation at the expiration of a predetermined interval of such length that the articles are cemented to the predetermined depth.

4. The process of case-hardening in bulk with uniformity low-carbon-steel articles to form upon each thereof a thin shell of a uniform and exact predetermined thickness, consisting in placing the articles in a metallic retort, closing the retort, filling the retort by carburizing-gas, applying heat evenly around the retort until the articles are uniformly heated to a predetermined carburizing heat, maintaining such temperature approximately uniform throughout the retort for a predetermined time, constantly displacing the vitiated gas by fresh supplies of carburizing-gas during the heating of the retort, agitating the articles during the carburizing operation, while the retort remains closed, and arresting the cementation at the expiration of a predetermined interval of such length that the articles are cemented to the predetermined length.

5. The process of case-hardening in bulk with uniformity low-carbon-steel articles to form upon each thereof a thin shell of a uniform and exact predetermined thickness, consisting in placing the articles in a metal retort, closing the retort, filling the retort with carburizing-gas, in a state of high compression, uniformly heating the articles throughout by applying heat evenly to the exterior of the retort so as to heat the same uniformly throughout until its temperature reaches from about 1,500° to about 1,800° Fahrenheit, maintaining the heat substantially uniform during the cementation of the articles, and withdrawing the articles in an incandescent condition at the expiration of a predetermined interval of such length that the articles are cemented to the predetermined depth.

6. The process of case-hardening in bulk with uniformity low-carbon-steel articles to form upon each thereof a thin shell of a uniform and exact predetermined thickness, consisting in placing the articles in a metallic retort, closing the retort, filling the retort with carburizing-gas under a pressure high above atmospheric pressure, applying heat uniformly around the exterior of the retort until the articles are uniformly heated above red heat but below the melting-point, maintaining the heat uniform throughout the carburizing operation, causing the vitiated gas to escape, maintaining a supply of fresh carburizing-gas under similar pressure during the heating of the retort, and arresting the cementation at the expiration of a predetermined interval of such length that the articles are cemented to the predetermined length.

7. The process of case-hardening steel or iron articles, consisting in confining the articles in an atmosphere of carburizing-gas within a closed retort, heating them while so confined to a temperature above red heat but below the melting-point, effecting agitation of the articles while being so confined and heated, and while the retort remains closed, to an extent to expose all surfaces of the articles to the gas, replacing the vitiated gas by fresh carburizing-gas during such heating and agitation, and arresting the cementation as soon as shells are formed upon the articles.

8. The process of case-hardening small steel or iron articles, consisting in confining them in bulk in an atmosphere of carburizing-gas within a closed retort, heating them while so confined to a temperature above red heat, but below the melting-point, tumbling the articles while so confined and heated, and while the retort remains closed, and arresting the cementation as soon as shells are formed upon the articles.

9. The process of case-hardening small steel or iron articles, consisting in placing them in bulk in a metallic retort, filling the retort with carburizing-gas, within a closed retort, applying heat around the exterior of the retort until the articles are heated above red heat, maintaining the heat substantially uniform throughout the retort, effecting repeated movements of the retort so as to agitate the articles therein, permitting the vitiated gas to escape, maintaining a supply of fresh carburizing-gas, and arresting the cementation as soon as shells are formed upon the articles.

10. The process of case-hardening steel or iron articles, consisting in placing them in a metallic retort, closing the retort, substantially surrounding the retort by a series of controllable flames sufficient to heat the articles above red heat but below the melting-point, maintaining the flames substantially

uniform, effecting rotation of the retort, passing a current of iron-carburizing gas through the retort while it remains closed, during such heating, and arresting the cementation as soon as shells are formed upon the articles.

11. The process of case-hardening steel or iron articles, consisting in confining them in an atmosphere of carburizing-gas, heating them while so confined to a temperature of about 1,800° Fahrenheit, arresting the cementation as soon as shells are formed upon the articles, causing the articles to cool gradually to a suitable degree for hardening and immediately subjecting them to a hardening cool bath.

12. The process of case-hardening steel or iron articles, consisting in confining them in bulk in a metallic retort, applying controllable flames to the exterior of the retort sufficiently to heat the articles uniformly to a carburizing temperature, passing a current of carburizing-gas through the retort during such heating, until the cementation has formed a shell on the articles, reducing said flames to an extent to permit the articles to cool gradually to a suitable degree for hardening, and immediately plunging the articles into a cooling-bath to harden them.

13. The process of case-hardening steel or iron articles, consisting in confining them in a metallic retort, applying controllable flames to the exterior of the retort sufficiently to heat the articles uniformly to a carburizing temperature, passing a current of carburizing-gas through the retort during such heating, until shells are formed on the articles, turning the retort during the cementation, to cause different sides of the articles to come uppermost in the retort, reducing the flames to an extent to permit the articles to cool gradually to a suitable degree for hardening, while the retort remains filled with the carburizing-gas, and immediately plunging the articles into a cooling-bath to harden them.

14. The herein-described process of case-hardening low-carbon-steel articles, consisting in confining them in bulk while heated uniformly throughout to a predetermined carburizing-point, in a current of compressed carburizing-gas, venting vitiated gas before it becomes incapable of burning brightly in air, maintaining the heat of the articles at a predetermined degree throughout substantially the entire period of cementation, and arresting the cementation after such predetermined duration as causes the shell of the exact thickness desired to be produced.

15. The process of case-hardening low-carbon-steel articles, consisting in confining them in bulk in a metallic retort, causing the current of compressed carbonized gas to flow through the retort during substantially the entire cementing operation, heating the retort with substantial uniformity throughout, maintaining the heat at a substantially uniform degree sufficient to heat the articles therein to a predetermined carburizing-point, until thin shells are formed on the articles, cooling the retort to a point where the articles are at suitable hardening temperature, and immediately plunging the articles into a hardening-bath.

16. The process of case-hardening low-carbon-steel articles, consisting in heating them uniformly throughout to a predetermined degree high above red heat, confining them in a current of compressed carburizing-gas and maintaining the temperature uniform at said degree while so confined, arresting the cementation at the completion of the predetermined length of exposure such that thin shells of a predetermined depth are formed upon the articles, causing the articles to cool gradually to a suitable degree for hardening, and immediately plunging them into a hardening-bath.

17. The process of case-hardening low-carbon steel or iron articles, consisting in heating them to a degree above redness but below the melting-point, confining them while so heated in an atmosphere of carburizing-gas, until thin shells are formed upon the articles, causing the articles to cool gradually to a suitable degree for hardening, and immediately plunging them into a hardening-bath.

18. The process of case-hardening steel or iron articles, consisting in making them sufficiently hot for cementation, confining them in a current of compressed carburizing-gas while so heated, until thin shells are formed upon the articles, causing the articles to cool gradually to a suitable degree for hardening, and immediately plunging them into a hardening-bath.

19. The process of case-hardening steel or iron articles consisting in heating them in bulk to a degree above redness but below the melting-point, confining them while so heated in a current of compressed carburizing-gas, until thin shells are formed upon the articles, agitating the articles during the process of cementation, gradually cooling the articles until they reach a hardening heat, and immediately subjecting them to a hardening-bath.

20. The process of case-hardening steel or iron articles, consisting in confining them in bulk in a metallic retort and in contact with the walls thereof, heating the retort with substantial uniformity throughout until the articles reach a uniform carburizing heat, passing a current of compressed carburizing-gas through the retort while so heated, agitating the articles during their cementation, and arresting the cementation as soon as thin shells are formed upon the articles.

21. The process of case-hardening steel or

iron articles, consisting in confining them in bulk in a current of highly-compressed carburizing-gas, heating them uniformly throughout while so confined to a degree of heat sufficient to carburize them, effecting agitation of the articles while being so confined and heated, and arresting the cementation as soon as shells are formed upon the articles.

ADOLPH W. MACHLET.

Witnesses:
SAMUEL R. OGDEN,
PHILIP C. OSTERMAN.