July 21, 1942. J. R. GIER, JR 2,290,552

HEAT TREATING FURNACE

Filed Sept. 26, 1939 2 Sheets-Sheet 1

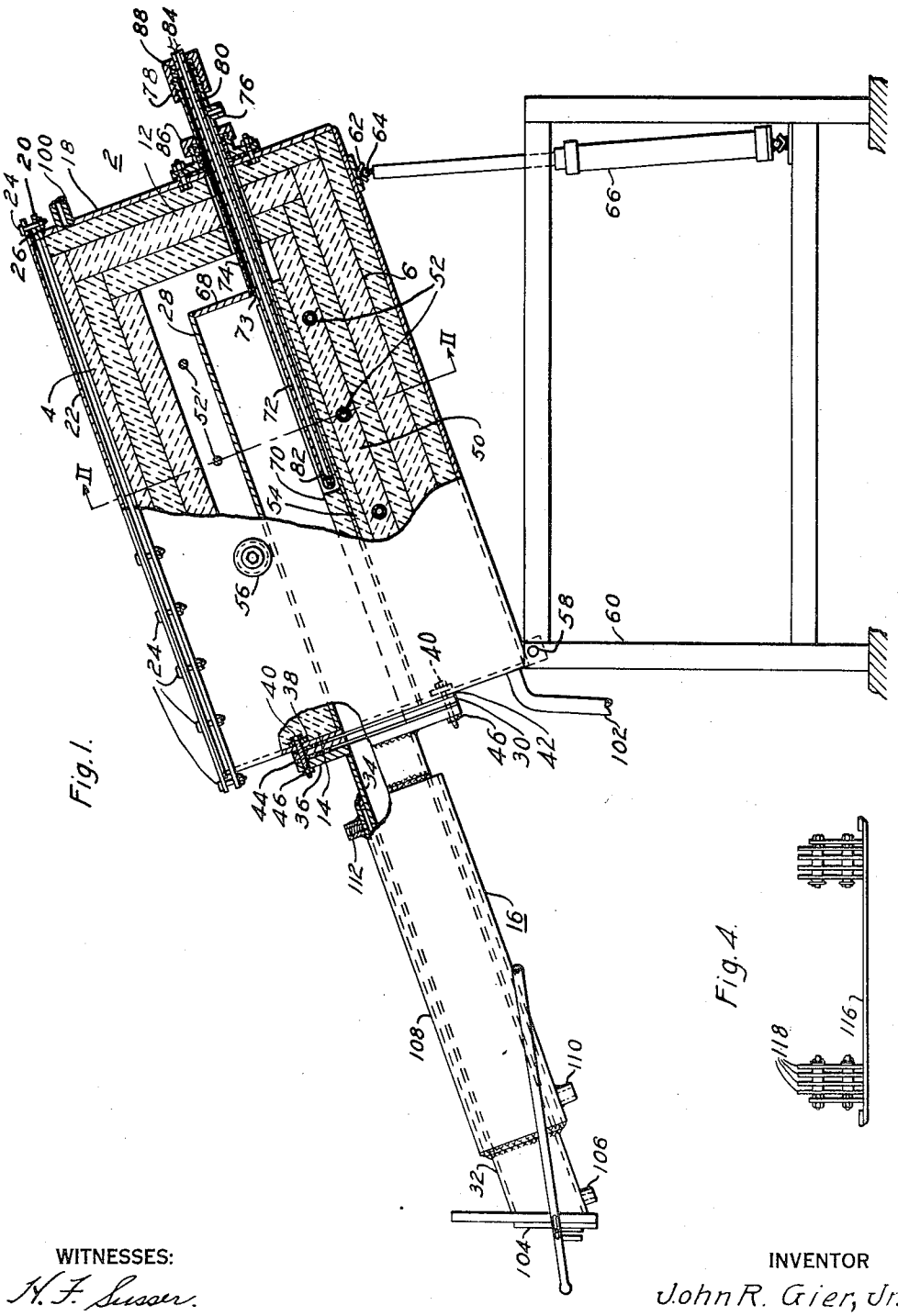


Fig. 1.

Fig. 4.

WITNESSES:

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HEAT TREATING FURNACE

Filed Sept. 26, 1939 2 Sheets-Sheet 2

Fig. 3.

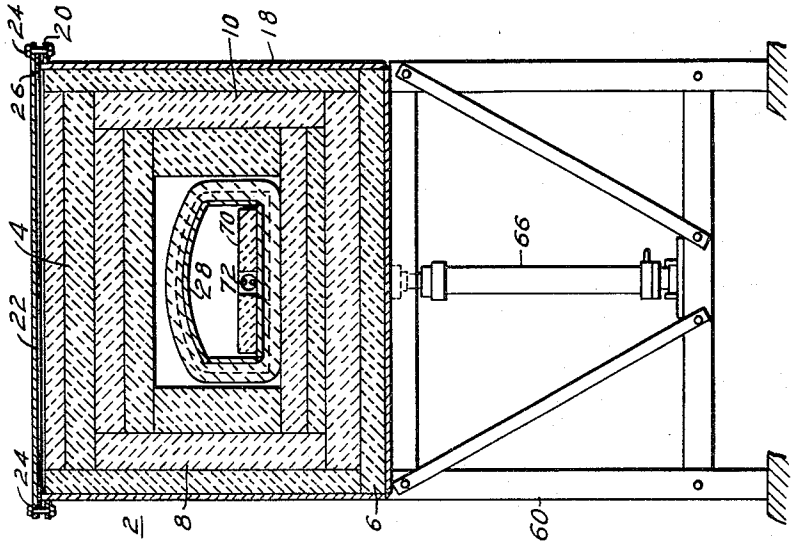
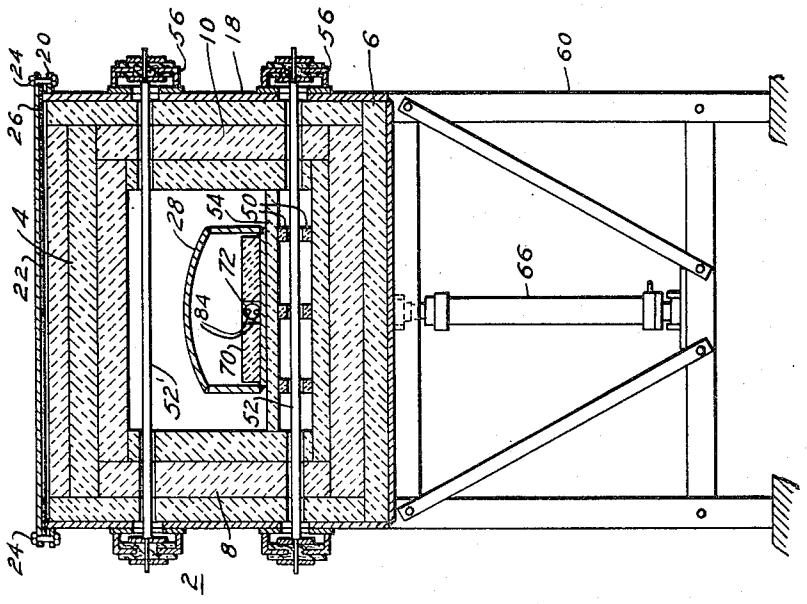


Fig. 2.



WITNESSES:

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UNITED STATES PATENT OFFICE

2,290,552

HEAT TREATING FURNACE

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Application September 26, 1939, Serial No. 296,587

4 Claims. (Cl. 266—5)

My invention relates generally to electric furnaces, and more particularly to furnaces especially adapted for the heat-treatment, at elevated temperatures, of tool steels in the form of tools, dies, and the like, while enveloped by an inert or protective atmosphere for the purpose of uniformly hardening the article heat treated.

One of the primary purposes of my invention is to provide a furnace in which tool steel articles including those made of high speed tool steels may be hardened for subsequent use, free from any of the types of damage heretofore usually experienced, the more important of which are oxidation, decarburization, distortion and cracking.

Oxidation and decarburization are caused by chemical reaction of elements in the steel with certain elements in the furnace atmosphere at high temperatures. Oxidation produces an undesirable surface scale and decarburization produces a soft surface layer, the metal thereof being deficient in carbon. Through the use of certain protective reducing gas atmospheres steels are now commonly prevented from scaling but these atmospheres do not ordinarily prevent decarburization.

To prevent both oxidation and changes in surface carbon content on all types of tool steel during heat-treatment requires a reducing atmosphere such as a mixture of hydrogen and nitrogen which may contain CH_4 up to 2% and not more than traces of CO_2 and H_2O. Ordinary controlled atmosphere hardening furnaces are incapable of maintaining a protective atmosphere of the necessary purity and exactness of composition.

It is a purpose of this invention to provide a furnace in which protective atmospheres of high purity and accurately controlled composition may be maintained to prevent both oxidation and decarburization of all tool steels during heat-treatment.

In the widely used and more expensive tool steels which must be heated to maximum temperatures in the range of 1700° F. to 2300° F., more or less, for hardening, decarburization can be extremely rapid due more to high temperatures required for carbide solution than to any direct effect of alloy content. Heretofore, it has been the practice to allow for surface damage as well as for distortion by leaving extra stock on the tool which had to be removed after hardening, by one or more finishing operations, such as grinding and hand stoning for fine interior contours; all of which add greatly to the cost of the tools and dies.

It is, accordingly, an object of my invention to provide a furnace for the heat-treatment of tool steels, especially at elevated temperatures in the range of 1700° F. and higher, from which oxidizing agents can be effectively kept out of contact with the charge, whether such agents come from the air or are occluded gases contained in the charge, or fire brick of the furnace, or come from other sources.

Damage by distortion includes the irregular or unpredictable changes in dimensions or contour of the tool in excess of the normal and determinable increase in specific volume which always accompanies the hardening of steel with the production of martensite. Both distortion and cracking can be easily avoided by cooling the tool or die in air for hardening, or, following my procedure, by cooling in an appropriate protective gaseous atmosphere. So cooling for hardening, of course, restricts the number of steels which can be treated in a furnace having provisions for hardening tool steels which include the step of cooling in air (gas). This restriction, however, is not at all serious or objectionable since it parallels the previous requirement, namely, that the steels considered are those requiring temperatures in the neighborhood of 1700° F. or even higher for the hardening process. Such steels in practically all cases are capable of, and preferably are, hardened while enveloped by a protective gas and can be successfully hardened without damage in block sizes up to 2" thick and even more, and in lengths limited only by the capacity of the furnace.

Accordingly, it is a further object of my invention to provide a furnace for the heat-treatment of tool steels at temperatures in the neighborhood of 1700° F. and above in which the charge can be completely enveloped by a non-oxidizing, non-decarburizing gas, which furnace has provisions for permitting the cooling of the charge while enveloped by the same atmosphere, to prevent distortion and cracking. The furnace of my invention has several basic features and innovations which enable me to harden tool steels of the character aforesaid without surface contamination, with dimensional changes confined to those which are predictable, and without decarburization. In other words, I have devised a furnace in which I can harden tool steels with clean and fully hardened surfaces having the wanted dimensions and free from cracks, warpage, or high internal stresses so that the article can be used immediately after hardening with the minimum of further grinding, or stoning, or other finishing treatment, and in most instances without the need of any finishing treatment.

A furnace following my invention, adapted to achieve the heat-treatment of tool steels without damage, should have provisions for heating and cooling the charge within a controlled atmosphere, and for moving the charge through the

different heat-treatment zones of the furnace without harmful contamination of that atmosphere, as might occur, for example, with the opening of outside doors. In use, a satisfactory atmosphere must be delivered to the furnace, particularly to its main heating chamber, and must remain innocuous to the hot charge while in contact with it.

Additionally, the charge must be so supported in the different heat-treatment zones of the furnace so that it will heat and cool uniformly and freely but without distortion from sagging under its own weight; and since the furnace is for use in commercial fields, it must be low in initial cost and long of life, low in upkeep expense and cost of operation, easy to manipulate, and simple to operate. Broadly, therefore, it is among the objects of my invention to devise a simple means in the form of a commercially-acceptable furnace adapted to the heating and cooling of tool steels in a protective gas so that the steels will be hardened without damage.

It is an object of my invention to provide a furnace in which the widely used and more expensive tool steels can be heat-treated whereby the necessity for machining, grinding, or stoning after the heat-treatment is kept to a minimum, and in most cases entirely eliminated.

The type of furnace I prefer for carrying out the heat-treatment of tool steels as aforesaid employs an elongated metallic muffle having a closed end with the other end open but closed by a suitable door means. The muffle preferably is inclined with the closed end upward so that when the lighter-than-air protective gas is admitted to the upper end of the muffle it will fill completely the upper portions of the muffle and be forced downward toward the door by the pressure of more incoming gas. When the door for the open, lower end of the muffle is opened, contaminating air can and will enter the muffle, and combine with the protective atmosphere, which if combustible, will burn therewith to form products of combustion which are confined to the lower end of the muffle from whence the products can be purged through a suitable gas-outlet pipe thereat and before they intermingle with the protective atmosphere in the upper part of the muffle. If the protective atmosphere is non-combustible, then the entering air will be purged. The incline of the muffle, therefore, encourages fractionating between the protective gases on the one hand, and the undesirable or harmful contaminating gases, on the other hand, and which usually are heavier than the protective gases customarily employed. Because of the incline of the muffle, the undesirable gases will remain at the lower level near the door whereas the protective gas will be entrapped in the closed upper end of the muffle. Consequently, by confining the heating zone to the upper portion of the muffle the charge will be enveloped by the practically pure protective atmosphere although contaminating gases might be present within the lower end of the muffle. In furtherance of these results, the protective gas-inlet is located at or near the top of the muffle and by providing a continuous flow of gas from the gas-inlet at the top of the muffle, downwardly through the muffle, and then out through the gas-outlet at the bottom of the muffle, a clean and pure protective atmosphere will always envelope the charge because the downward flow of pure gas opposes the upward transport of contaminating gas by diffusion, and because the flow of pure gas flushes out any occluded gas given off by the charge.

Accordingly, it is at once perceived that I deem it to be a very important feature of my invention to provide in a furnace for heat treating tool steels while enveloped by a protective atmosphere, an inclined heat-treatment chamber closed at its upper end and having its charge insertion and removal openings at its lower end so that the important possible sources of contaminating gases are confined to the lower end of the muffle.

This furnace may also be used to advantage in hardening steels that require liquid quenching. Several pieces may be heated together in the protective gas and may then be withdrawn one at a time for quenching without contaminating the atmosphere around the work remaining in the furnace. This is not possible in conventional types of controlled atmosphere hardening furnaces having but a single door and a horizontal hearth.

The tilted muffle or hearth is an important feature of my invention since this enables me to move work directly into the heating chamber.

There are many other features and details to my invention in addition to those more specifically mentioned above which will be apparent from the following description thereof taken in connection with the drawings, in which;

Figure 1 is a vertical, longitudinal view, partly in section and partly in elevation, of the furnace built in accordance with my invention, and in which the heating means is in the form of non-metallic resistor rods of the silicon carbide type. This figure further shows a charging tray in its position in the upper part of the muffle;

Fig. 2 is a cross-sectional view, taken substantially on the line II—II of Fig. 1 of the furnace, with the furnace proper adjusted to horizontal position;

Fig. 3 is a view similar to Fig. 2 but showing in a modification wherein electrical ribbon resistors are employed for heating the furnace; and

Fig. 4 is an elevational view of a tray for supporting a charge inside the muffle of the furnace during the heat-treatment process.

In the preferred embodiment of my invention, I employ a furnace with its heat treating chamber inclined but to make the furnace adaptable to uses other than the heat-treatment of tool steels, I construct the furnace in the shape of a rectangular prism elongated in a general horizontal direction with provisions for pivoting one end and raising or lowering the other whereby the heating chamber may be inclined as preferred, or horizontal for other uses, although it is obvious that the heat-treatment chamber might be inclined by other expedients.

In general, and referring more particularly to Figs. 1 and 2, the furnace **2** comprises refractory and insulating walls defining a heating chamber. The walls are constructed of fire brick and refractory tile, and perhaps other heat-insulating material, in any customary manner, and include a top wall **4**, a bottom wall **6**, side walls **8** and **10** respectively, a closed end wall **12**, and, lastly, an end wall **14** provided with an opening through which a muffle, indicated in its entirety by the numeral **16**, extends.

The furnace walls constitute the furnace proper and are encased in a metallic shell **18** which completely encases the furnace proper except for such openings as are necessary for

terminal and the outer appurtenances that go with a furnace of the general type described. However, it is to be understood that in accordance with the common practice of the art the appurtenances extending through the metallic shell are usually secured thereto gas-tightly. In the particular embodiment shown, the bottom of the metallic shell and the upstanding sides are welded into an open-topped box having a flange 20 completely around its surface near the upper edge. The shell further includes a metallic top 22 suitably bolted to the flange 20 through the medium of a sufficient number of bolt and nut devices 24 so that, in conjunction with a gasket 26 interposed between the edge of the box and the top, the shell is made gas-tight. However, the end of the shell contiguous to the end wall 14 is also provided with an opening approximately fitting the muffle 16 so that the muffle may be inserted into and withdrawn from the furnace without tearing down the walls.

The muffle itself comprises two contiguous sections in open communication, one of which is within the furnace proper and includes the heating zone for the charge, while the other section extends outwardly from the furnace proper and provides a combined charging and cooling zone. The inner section 28 of the muffle is preferably elongated and includes an integral portion which extends almost to the end wall 12 of the furnace. The other, lower end of the section 28 terminates in a flange 30 outside of the shell 18, which extends completely around the periphery of this muffle and provides a means by which the muffle is secured to the furnace proper. The second or outer section 32 of the muffle has interior walls 34 aligned with the inner section of the muffle, and the upper end of this section 32 is also provided with a flange 36 completely around its outer periphery at one edge thereof.

To secure the complete muffle in place the inside of the shell about the furnace opening is provided with a reenforcing frame ring 38 which may be welded or otherwise secured to the shell about the opening through which the muffle passes. This frame ring is apertured to receive a plurality of bolts 40 extending through corresponding apertures in the shell and flanges 30 and 36. A gasket 42 is interposed between the outside of the shell and the flange 30 while a second gasket 44 is placed between the flanges 30 and 36. By suitably tightening the nuts 46 on the bolts 40 the muffle structure is gas-tightly secured to the furnace proper.

In the embodiment shown in Figs. 1 and 2, the bottom wall 6 of the furnace has longitudinally-running spaced piers 50 apertured to receive lower heating rods 52 which are non-metallic resistors of the silicon carbide type available to the art, it being understood that the side walls 8 and 10 and the shell 18 have suitable provisions to receive these rods.

Supported on the spaced piers 50 is a non-metallic refractory base plate 54 having a high thermal conductivity, and the inner section 28 of the muffle rests on this base plate. Upper heating rods 52' may also be provided to aid in the heating of the furnace, and are similar to the heating rods 52 projecting through the furnace walls. Electrical power is conveyed to and conducted from the heating rods through terminal structures 56 which are preferably such as to render the outer shell gas-tight in spite of the apertures in the metallic shell. Terminals of this character are well known to the art and any appropriate type may be employed.

In order to provide the necessary tilt or incline to the furnace, one end of the furnace, and preferably that end having the opening through which the muffle extends, is pivotally mounted at its bottom on the stationary shaft 58 secured in a furnace-supporting frame work 60, while the other end of the furnace bottom is provided with a downward-facing angle 62 into which fits a small roller 64 of a pneumatic or hydraulic jack, schematically indicated at 66, and having its lower end pivotally fixed to the frame work 60.

From the structure thus far described, it can be at once perceived that by suitable manipulation of the jack 66 the furnace proper may be inclined to any desired angle with respect to the horizontal.

For a muffle having an inner section 36 inches long and an outer section of approximately the same length, with a cross-section having a 10 inch width and 5 inch height, I have found that, for the purposes of my invention, an incline of about 20° with the horizontal has enabled me to heat treat tool steels without damage. With these dimensions the top of the lower opening in the muffle section 32 is on a level which is below the muffle section 28 and below a very substantial part of the muffle section 32.

When the furnace is so inclined, the closed end wall 12 is obviously raised with respect to the other end wall 14, and the same holds true for the adjacent ends of the muffle. The upper end of the muffle section 28 is closed by an end plate 68 which may be suitably gas-tightly welded thereto so that a protective atmosphere admitted to the muffle will tend to rise and occupy the upper portions thereof although it is to be understood that in actual operation sufficient gas is admitted to the muffle to permeate its entire interior.

The structure of the inner section 28 of the muffle is completed by a floor plate 70 which is preferably formed of a non-metallic refractory such as alumina with a suitable binder. The floor plate 70 is provided with a recess 72 starting at about the mid-point of the section 28 and extending upwardly to the upper end of the floor plate which terminates a very short distance, perhaps an inch or two from the end plate 68 of the muffle. This recess is provided for the reception of a thermal-responsive device by which the temperature within the muffle can be measured and the heating of the furnace controlled by proper appurtenances.

The temperature-responsive means is combined with gas-inlet means for admitting a protective or controlled atmosphere to the inside of the muffle. To this end, the end plate 68 is provided with a small aperture or opening 73 in line with the recess 72 of the floor plate and a suitable pipe 74 is gas-tightly welded to the muffle about this aperture, the pipe extending upwardly and outwardly of the furnace through suitably-formed holes in the end wall 12 and shell 18. The protective atmosphere is admitted to this pipe through an inlet 76 which is gas-tightly but removably provided on a portion of the pipe 74 outside of the furnace proper. The protruding part of the pipe 74 has an open threaded end 78 into which is insertable a pipe 80 of a length sufficient to extend substantially to the bottom of the recess 72, with the end of the pipe at this point closed. The pipe contains a thermo-cou-

ple junction 82 from which wires 84 run for the length of the pipe 80 and beyond to any suitable indicating or controlling apparatus. The pipe 80 is necessarily of an exterior dimension smaller than the interior dimension of the pipe 74 so that the incoming gas from the inlet 76 may flow through the annular space between the two pipes and into the muffle by way of the aperture 73.

Any suitable gas-tight packing joint 86 can be provided between the pipe 74 and shell 18 where the former passes through the latter, and similarly, a gas-tight packing joint 88 can be provided between the pipe 80 and the end 78 of the pipe 74. Since constructions for such packing or stuffing joints are common the details of these are not here described with any great particularity.

The inner section 28 of the muffle and the pipe 74 are preferably made of a metal which will not absorb or react with carbon at high temperatures. I prefer to use commercially pure nickel for these elements for reasons described in my copending application, Serial No. 296,586 filed concurrently herewith, entitled "Heat-treating furnace" to which reference may be made for further details. This copending application is also assigned to the Westinghouse Electric & Manufacturing Company. I also prefer to permeate the inside of the furnace proper by a protective atmosphere to pervent oxidation of the outside walls of the nickel muffle and to this end the upper part of the shell 18 is provided with a gas inlet 100, and the lower part is provided with a gas outlet 102, the gas outlet having a downwardly-extending pipe terminating considerably below the bottom of the furnace proper.

The outer section 32 of the muffle serves a dual purpose in my furnace, as a charging or purging chamber for a charge first inserted into the muffle, and as a cooling chamber for a charge after it has been heated in the furnace proper. This section 32 has an end opening controlled by a raisable door 104 having door-operating mechanisms preferably constructed and arranged as described in my aforementioned application, although any appropriate door-operating mechanism can be utilized. At a muffle inclination of 20° the top of the opening through which a charge is inserted into or removed from the muffle through the end opening for the section 32, whether the top be defined by the door in fully open or in partially open position, will be considerably below the inner muffle-section 28 and below most of the outer muffle-section 32.

In operating my furnace the muffle is first purged by admitting the protective atmosphere through the gas inlet 76 from where it flows through the muffle and is exhausted through a gas outlet pipe 106 at the bottom end of the muffle, although a certain amount of this gas, which is under a slight pressure, will seep out through any crevices that might exist between the door 104 and its frame. Additionally a small vent may be provided for exhausting protective atmosphere. In actual practice the protective atmosphere may be dissociated ammonia or pure hydrogen and since these are combustible, it is preferable to ignite the gas coming out of the vent or through the crevices aforesaid.

When the door 104 is opened to insert or remove a charge any air entering the muffle will react with combustible protective atmosphere in contact therewith and a flame may be observed on a substantially horizontal plane substantially level with the top of the exposed opening at the end of the muffle section 32, through which the charge passes. Accordingly the products of combustion and any unburned air do not rise to any considerable height in the muffle but are confined to the lower positions from where they are immediately swept out of the muffle through the outlet-pipe 106. Since no contaminating gas gets into the heating zone no extensive purging is required in the charging chamber after the furnace has been prepared for operation, and an intermediate door between the contiguous heat-treatment zones of the muffle is unnecessary, so that the zones are in open communication.

Assuming a charge to be heat treated has been placed in the section 32 and door 104 closed, the muffle may be then purged by having the protective atmosphere flow through it for a short time, at, if necessary, an increased rate of flow, but because no contaminating gases reenter the heating chamber with the insertion of the charge, it can be almost immediately pushed into the heating chamber. Moreover, any occluded gases in the charge are swept out of the heating chamber by the normal flow of the atmosphere before the charge has attained a temperature at which it would be damaged by them. The heating zone constitutes the major length of the section 28 at the higher end where the heat generated by the rods 52 and 52' is concentrated. After the proper heat-treatment, the charge is brought back into the section 32 which now acts as a cooling chamber, being provided with a water jacket 108 having a water inlet 110 and outlet 112 to facilitate and control the cooling. After the charge has been subjected to a suitable cooling treatment in the charge-cooling zone of the muffle section 32, the door 104 may be again opened and the charge removed. The furnace is then ready for the heat-treatment of another charge.

The tilt of the muffle is preferably such that clean and pure atmosphere will always occupy the heating zone within the muffle 16, but it must not be so great that the charge inside the muffle will slide downwardly due to its own weight. The floor plate 70 in the muffle has a high coefficient of friction so that the angle of tilt might be somewhat greater than that which would be obtained if a metallic floor plate alone were provided instead. Additionally, the nonmetallic refractory floor plate 70 prevents the charge from sticking to the floor of the muffle since this furnace necessarily is operated at relatively high temperatures. The charge is moved inside the muffle by any suitable pusher or puller rod projected through a normally closed hole in the door 104.

In order to provide a means upon which the articles to be heat treated may be conveyed from place to place in the muffle, I provide a tray which has features cooperating with the muffle for improving its efficiency. The details of this tray are more fully described in my aforesaid application, but generally comprise an open framework bottom 116 of a length substantially that of the main heating zone in the muffle, which can be approximately two-thirds of the length of the section 28, upon which a charge-carrying wire screen may be placed. The open framework bottom 16 comprises spaced narrow skid bars providing gas passages betwen the bars, so that gas admitted to the recess 72 can freely pass through the spaces between the skid bars and

through the wire screen, so that the articles on the tray, which are being heat-treated, are substantially completely enveloped by the gas. To each of the ends of the bottom 116 are secured upright, spaced radiation shields 118 whose contour corresponds to the effective open area in the muffle proper but being slightly smaller. These shields improve the heat distribution about the article or articles on the tray and aid in confining the heat of the heating zone to the length of the tray. Consequently, the heat in the charge-treating zone between the sets of radiation shields at the ends of the tray, is relatively evenly distributed.

Fig. 3 shows a modified form of my invention, the muffle section 28 being provided with helical resistor ribbons wound around it. In this construction a layer of non-metallic electrically-insulating refractory paste is first placed on the outside of the muffle section. The helical resistor ribbon is then wound around the muffle and a second layer of paste placed about it. The refractory is then solidified and the helical resistor is, in effect, embedded in the refractory. Suitable terminals are, of course, provided.

I have very successfully hardened tool steels in the furnace described by the use of a suitable protective atmosphere. The controlled or protective atmosphere must be, of course, judiciously chosen, based on the chemical laws of mass action, and there are three basic types of atmospheres which could be adapted to the hardening of tool steels without surface damage. These are (1) mixtures containing 20 to 40% CO which tend to be actively carburizing or decarburizing unless their CO_2 content is closely regulated, (2) pure H_2 which slowly decarburizes and is actively reducing to all steels, and (3) pure N_2 which is totally inert so far as oxidation and decarburization are concerned.

In selecting an atmosphere for tool hardening from this group the primary considerations are:

(1) The gas should preferably be capable of protecting all steels against loss or gain in surface carbon and not require adjustment of composition to suit various steels.

(2) The gas should be strongly reducing if high chromium steels are to be heat-treated without oxidation.

(3) The gas should be simple to prepare and not require elaborate processing.

Active gases containing a high percentage of CO are not entirely satisfactory because their carbon pressure and reducing power are both dependent on the CO–CO_2 ratio and, therefore, cannot be separately controlled. This characteristic is not objectionable in treating plain carbon and low alloy steels for which the reducing power of this type of gas is adequate over the entire working range of carbon pressures. However, for high chromium steels of low carbon content this gas is unsuited for bright hardening as it must be made highly reducing to prevent tarnish and this would require a high CO–CO_2 ratio such that the gas would be actively carburizing.

Nitrogen lacks the reducing character needed in a protective atmosphere; moreover, it is expensive when purchased in bottles and must be further purified. When it is prepared from combusted gases it is much cheaper, but expensive processing equipment is required. This leaves pure hydrogen as the most favorable type of gas atmosphere. It is, however, not acceptable because of high cost and the need for further purification.

Fortunately the equivalent of pure hydrogen cn be secured at moderate cost by dissociation of commercial ammonia which yields an extremely pure gas containing one part by volume of nitrogen and three parts of hydrogen. Dissociation is easily accomplished by passing the ammonia over a catalyst such as nickel heated to 1750–1850° F. (954–1010° C.). As dissociated, it is so inactive that a soft skin does not form on 1.5% carbon steel soaked in it at 1850° F. (1010° C.) for one hour and its composition does not need adjustment to the requirements of the steel to be hardened. Its reducing character permits hardening of stainless steel without tarnish.

Although dissociated ammonia does decarburize slowly, any carbon lost from the surface of the steel subjected to the treatment is replaced by carbon which is diffused to the surface from the interior of the steel thereby preventing serious impoverishment of the surface layer. This is possible because of the slow rate of carbon transfer from the steel to the gas. When even this small loss is objectionable, as in treating very thin sections, the gas may readily be made completely non-decarburizing or actually carburizing by the addition of small proportions of hydrocarbon gas. Thus it is possible to regulate the carbon pressure of the gas between wide limits without decreasing its reducing power. This is not possible in the type of atmosphere containing high percentages of CO in which the carbon pressure and oxygen pressure are not independent.

Dissociated ammonia must be very dry for successful use in a protective atmosphere for tool hardening. A moisture content of 0.3% by volume (dew point −30° F. or −35° C.) at the work surface is generally satisfactory, but a drier gas is preferred since oxygen combines with hydrogen at the furnace temperatures to form water vapors which damage the steel. Additionally, the rate of decarburization decreases rapidly with increased moisture content.

It is not sufficient to put a dry gas into a furnace; it must be maintained dry while it is there in contact with the work. This means that oxygen and oxygen yielding compounds from the air, from the furnace brickwork, or from any other source must be excluded, or removed as by flushing so that the work will not be damaged. My furnace is exceptionally well-suited for the purpose.

The furnace described herein has been employed for the hardening of blanking and forming dies, as well as miscellaneous tools. Practically all the requirements of these dies or tools can be met by selection of the following types of tool steels, all of which harden by gas cooling even in large sections.

No.	C	Cr	Mo	W	V
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1	0.7	4	----------	18	1
2	0.8	4	8	1.5	1
3	1.5	11	1	----------	0.2
4	1.0	5	1	----------	0.2

Tool steels of the composition indicated and others have been successfully hardened without damage in my furnace and many other alloy steels can be hardened in the same manner; thus, as example, I have hardened to hardnesses of 630–665 D. P. H. (57–59 Rc) springs of stainless

steel containing 12% Cr and .3% carbon and retained a bright surface. This is an illustration of the exceptional performance of my furnace when using dissociated ammonia for the protective atmosphere.

As an example of the heat-treatment of tool steels I have successfully hardened a die block made from high Cr steel, No. 3 of the above table. The die was machined to finish size with no allowance for clean-up after hardening. It was set on the tray and placed in the entrance chamber which was purged and flushed for about 15 to 20 minutes. The work was then moved into the heating chamber where it was heated to between 1300° and 1400° F. for a short period of time, and then was soaked at temperatures between 1832–1868° F. for about 1 hour or somewhat longer. Since the danger of decarburization is practically eliminated by the use of the suitable controlled atmosphere, soaking times may be as long as desired without damaging the steel surface. After this soaking, the work was withdrawn into the charging chamber where it cooled naturally under the protection of the gas to a point at which the work could be taken out of the furnace without objectionable tarnish. The total time in the furnace for a particular job runs from 1 to 4 hours depending on the size of the work. Hardened in this manner, the die had a scale-free surface that was as hard as the underlying metal, and had a uniform hardness of 745–770 D. P. H. (63–64 Rc). I have also hardened No. 2 steel in a total heat treating time in the furnace of about 40 minutes equally divided between soaking and cooling, the soaking being at a temperature of 2200° F. The article so hardened was a lathe tool and came out bright and clean with a uniform hardness of 64 Rc. The protective atmosphere was dry dissociated ammonia with no hydrocarbons added.

In the fully hardened state the steel will have a slightly greater volume than before hardening, the volume decreasing with tempering and approaching the initial volume as a limit. As these volume changes are characteristic and definite in amount for each steel, their effect on dimensions may be predetermined and compensated for in machining the tool before hardening so that its final dimensions after hardening will be correct and thus the need for finish grinding is eliminated.

By adding one or two percent of natural gas or other hydrocarbon gas to the furnace atmosphere it is made carburizing, although its action will be quite slow. In such an atmosphere high speed steels may be given the equivalent of a carburizing pack-hardening treatment. For example, a specimen of 18–4–1 high speed steel was heated at 1875° F. (1020° C.) for 2 hours in dissociated ammonia containing 1.4% methane and then cooled naturally in the gas. The surface hardness was 880 D. P. H. (67.5 Rc) and the core hardness 645 D. P. H. (58 Rc). This treatment is useful for producing high superficial hardness on high speed steel tools for use where maximum heat resistance is not required.

While I have described my invention in a preferred form it should be understood that its methods of operation, purposes and results are also parallel to those more particularly described and claimed in my aforesaid copending application.

I claim as my invention:

1. A bright-hardening metal-treating furnace of the type described for bright-hardening chromium-containing steels, comprising an inclined tube-like metal muffle having a lower end provided with a lower opening, and an upper end comprising a closing means whereby the upper end of the muffle is closed against extraneous gas-flow; movable closure means for said lower opening; means in said furnace for providing a heating zone in the upper part of said muffle, whereby the steels may be heated to temperatures for hardening; means for providing a cooling zone in a lower part of said muffle, whereby the steels may be cooled after being heated in said heating zone; movable metallic heat-barrier means between said cooling zone and said heating zone, said heat-barrier means permitting a gas-flow between the zones; and gas-passage means for permeating said muffle with a generally downwardly flowing lighter-than-air controlled atmosphere; the incline of the muffle being such that the top of the opening through which a charge may be inserted into or withdrawn from the muffle when the said movable closure means is in opening position, is on a level which will tend to cause contaminating gases resulting from the flow of air into the muffle to be confined to the lower end of the muffle.

2. A bright-hardening metal-treating electric furnace of the type described, comprising a tube-like metallic muffle, means for heating a portion of said muffle to provide a charge-heating zone therein, means for cooling a second portion of said muffle to provide a charge-cooling zone therein, means for supporting said muffle at an incline with the charge-heating zone higher than the charge-cooling zone, said muffle having a lower opening through which a charge may be inserted and withdrawn, movable closure means for said lower opening, the incline of the muffle being such that the top of the opening of said muffle, as exposed when the closure means is moved to opening position, is on a level below the charge-heating zone and a substantial part of the charge-cooling zone, closing means gas-tightly secured to the upper end of said muffle, gas-inlet means at the upper part of said muffle for supplying a controlled atmosphere to said muffle, and gas-outlet means at the lower part of said muffle, below the top of said lower opening, for venting gases from the muffle, whereby the controlled atmosphere in said muffle flows generally downwardly.

3. A metal-treating muffle-furnace of the type described adapted for substantially damage-free hardening of chromium-containing steels, comprising a tube-like metallic muffle, means for supporting said muffle at an incline, said muffle having closing means at its upper end whereby the upper end of the muffle is closed against extraneous gas flow, the lower end of said muffle being provided with an opening through which a charge may be inserted into and withdrawn from the muffle, movable closure means for said opening, means for heating one portion of said muffle, means for cooling a second portion of said muffle, said one portion and said second portion of said muffle being in open communication, gas-passage means, comprising a gas-inlet at the upper part of said muffle, whereby the inside of said muffle may be permeated with a generally downwardly flowing lighter-than-air controlled atmosphere, the incline of said muffle being such that the top of the opening through which a charge may be inserted or withdrawn from the muffle when the said movable closure means is in opening position, is on a level which will tend to cause

contaminating gases resulting from the flow of air into the muffle when said movable closure means is in opening position, to be confined to the lower end of said muffle, said gas passage means including a gas-vent at said lower end of said muffle.

4. A metal-treating furnace of the type described adapted for substantially damage-free hardening of chromium-containing steels, comprising non-metallic insulating and refractory walls defining a heating space, an outer metal casing for said walls, an inclined metal muffle having a lower open end through which a charge may be passed, said muffle comprising an upper portion in said heating space and a lower portion outside of said walls, said muffle being gas-tightly secured to said casing, means for providing a charge-heating zone in said upper portion of said muffle, means for providing a charge-cooling zone in said lower portion of said muffle, said upper portion and said lower portion of said muffle being in open communication, closing means gas-tightly secured to the upper end of said muffle, said walls having an end-wall adjacent to the closed upper end of the muffle, movable closure means for said lower open end of said muffle, gas-inlet means at the upper end of said muffle, gas-venting means at said lower end of said muffle whereby the muffle may be gas-permeated with a generally downwardly flowing lighter-than-air controlled atmosphere, means for admitting a controlled atmosphere between said casing and said upper portion of said muffle, and means for venting the controlled atmosphere therefrom, the incline of the muffle being such that the top of the opening at said lower end of the muffle when said movable closure means is in opening position, is below said upper portion of said muffle and below a substantial part of said lower portion of said muffle.

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