This invention relates to the hardening of high-speed-steel tools, of about 18% tungsten steel. The tungsten gives the alloy ability to remain hard at high cutting speeds, producing heats on the tool-cutting edges of say 1000 to 1100 degrees F. The tool-steel alloy usually includes chrome, vanadium and a small proportion of carbon.

The hardening range is very much higher than in ordinary metal treatments, such as carburizing for example, and the high heat has to be delicately controlled and timed, and the subsequent cooling is also attended with unusual difficulties.

The tool must be finished before hardening, and must retain its sharp cutting edge and its shape during the severe treatment, and then must cut equally well over its entire shape. Its hardness must be even, so that it will cut just as well at one place as at another. The tool must not be exposed to injury. Moreover it must not suffer more severe treatment in one place or spot than another. It has not heretofore been found feasible to avoid overheating the tips of the teeth.

The cutting edges in the bottoms of the grooves or notches are in proximity to the body of the shaped tool, and therefore it has not been found feasible to have these lower cutting edges as hard as the tips. Since the bottom of the groove is close to the heavy body of the hob or other tool, said body must absorb heat rapidly, necessitating therefore the application of over-heat heretofore; and consequently the tips of the threads, the tips of cutter-teeth, have become overheated, and injured. In order to bring the depressed portions to the required point of heating, overheat has been applied. But the raised cutting edges are remote from the body and do not lose their overheating to the body, but retain it, to their injury.

The edge of a drill might become ruined, or misshapen from the heat. It would shrink.

If it was attempted to insert the cold work in a muffle which had been so overheated as to be capable of raising the work to the required degree of hardening heat, say 2350 degrees F., it would be found that a strain was set up in the work. The delicate part would overheat quickly, and the body-part was apt to crack before hardening.

The work could not be put into a cold muffle, as it would take too long to bring the muffle and the muffle-furnace to the required heat. So the muffle of the prior high-speed-steel-hardening art was first brought up to a high heat, and the high-speed tools were put right into that high heat, to receive their entire heating directly from the original heat of the muffle.

It was found that if the work was inserted in cold condition and brought slowly up to the heat required for the body of the tool, it necessitated overheating the fine parts.

To reduce the trouble from overheating, the expedient was resorted to of preheating the work, so that the final heating up of the heavy body of the tool would not require too much time, it being hoped not to over-expose the delicate portions of the tool.

The prior processes therefore included a method of stepping-up by one or more preheats, followed by a quick final high heat of 2350 degrees. The preheats ranged from approximately 1500 to 1800 degrees Fahrenheit.

In the prior method, the tool was placed in a preheating muffle having a temperature of 1860 degrees. Its injury happened at the high heats.

It was found that the work should not be exposed to the final heat for longer than six or seven minutes. That is why preheating was resorted to, because the heavy part must not be left in the overheated muffle longer than was absolutely necessary. It was very difficult to avoid injuring the edges of the forming tool if exposed as long as six or seven minutes.

The tools were apt to crack, even with all this step-up preheating. The final speed of heating was such that strains are set up in the metal of the tool, in spite of preheating.

Either the high fine edges were heated too long (if the body was up to proper heat), or else (if the fine edges were heated only for the proper length of time), the body was not heated for a sufficient period. In cooling, whether in air or in liquid, the tool was subject to liability to crack.

At each step, the work had to be removed from the sealed muffle, thus exposing it to the air. The whole mass, the work, the muffle, and the furnace, had so much heat that it would cool very slowly, so that the work would anneal (instead of hardening), if it should be attempted to cool it while it remained in the hot muffle in the heated furnace.

The surface of the steel was exposed to oxidation in the shop atmosphere, and to scaling, and decarburization; and the final result was, on that account, an inferior tool, because it was soft on the surface, and it was soft because it had been robbed of its carbon or other hardening elements. On certain tools, such as bits, lathe-tools, etc.
the soft surfacing or skin was ground away; but, in taps, forming-tools, thread-chasers, hobs, cutters of all kinds, reamers, and any tools of irregular shape, it was impracticable, and in many cases, even impossible to grind away those soft skins, without spoiling the form or pitch or shape of the tool.

The tools also suffered because of attempts to avoid decarburization. These attempts resulted in slight carburizing of the edges. This had the effect of reducing the fusing point of these edges. Thus at least they became rounded or dulled, and sometimes caused incipient melting. The change in the alloy of the steel would be sufficient alone to reduce its cutting efficiency. When the carbon was lost, its hardness was reduced, and there was other deleterious effect. The present invention avoids either decarburizing or augmenting the charge of carbon in the alloy of the tool.

In attempting to avoid decarburization of these high-speed steel tools, a carbonous atmosphere was employed, and in many cases the work became over-carburized therefrom. There would be a loss of carbon from the fine tool. Loss of carbon is not incurred from transference as in the prior art preheating. The tool is not transferred or exposed to air. The controlled atmosphere of the retort enables the tool to be given the necessary time of heating, and enables the body of the tool to absorb the necessary heat. All parts of the tool, the fine edges and the body are exposed to the same heat, for the necessary time. They are heated uniformly throughout, leaving the metal all over in the same condition; not decarbonized or over-carbonized. The alloy continues the same.

The present invention aims to reduce or eliminate troubles inherent in overheating, and to avoid injury especially to the fine edges and thin portions; to avoid sudden exposure of the work to high heat; to economize fuel; to expedite the heating; to avoid the loss of carbon at the heating; to avoid injury from prolonging heat treatment of light tools to the same period as is desirable for heavy tools; to reduce the length of the heating period; to avoid loss of carbon; to avoid oxidation; to improve the cooling-hardening process and render it less severe to rapid cooling of heavy tools, without injury; and to improve quenching of the heavy tools in oil, without injury; to avoid the formation of scale on the tools; to secure the retention of the original cutting edges on both thin and heavy tools; to increase the output; and to enable the frail tools to stand up as well as the heavy ones.

According to the present invention, the necessity for the stepping-up preheats is eliminated. The steel without exposure to injury is gradually raised to the proper heat.

Dies, plates and chasers used in cutting or finishing threads are among the tools that may be successfully hardened by this process, since no refinishing or grinding is necessary.

A large high-speed tool such as a hob for cutting worms, can be treated in this way, and can be cooled with sufficient rapidity, notwithstanding its bulk, by the hereinafter explained use of copper-shot, which absorbs the heat, so that the hob cools with sufficient speed to harden.

The high-speed steel tool (having a melting point of some hundreds of degrees F. above the melting point of ordinary tool-steel) may thus be treated by the novel hardening process, including heating the tool while immersed in a slow current of gas, which does not oxidize or carburize the high-speed steel; the heat of the tool being brought up from room temperature steadily and gradually until it reaches about 2000 to 2250 degrees F. The heat is still immersed in the current of gas. After this high heat has continued for say twenty to thirty minutes, the heating up of the tool is discontinued and it is cooled-hardened while still in the gaseous envelope, the duration of the cooling being either short or long, according to the result desired. The tool in some cases becomes cool so quickly that it may harden without quenching; and the hardening may take place while the tool is in the container through which (if desired) the current is slowly passing. There may be no current at the cooling stage, in some cases. No scale forms. There is no loss of carbon.

Other features and advantages will hereinafter appear.

In the accompanying drawings,

Figure 1 is a sectional elevation illustrating the improved heating of high-speed-steel tools, and the novel means for accomplishing the results herein set forth.

Figure 2 illustrates the heated work as being rapidly air-cooled, the work, while still enveloped in controlled gas, having been removed from the furnace for that purpose, permitting the heated furnace to be immediately employed for heating up the next batch of cold work.

Figure 3 is a perspective view of the bottom portion of a retort having a working-supporting floor or tray provided with gudgeons set into bayonet-slots in the body of the retort.

Figure 4 illustrates a manner of piling hobs and heavy tools or bodies, and the use of a pyrometer.

Figure 4 illustrates a manner of stacking heavy taps, and other tools, for heating.

Figure 5 shows heavy work withdrawn from the furnace, but still enveloped in the gas, but being more rapidly cooled than by air.

Figures 6 and 7 are sectional elevations showing the heating of heavy tools, and the quenching thereof in oil, without exposing the heated tools to attack from the air.

The high-speed tools may be piled in cobhouse fashion, or preferably, and rendered ready for rapid cooling of heavy tools, without injury; and to improve quenching of the heavy tools in oil, without injury, to avoid the formation of scale on the tools; to secure the retention of the original cutting edges on both thin and heavy tools; to increase the output; and to enable the frail tools to stand up as well as the heavy ones.

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The high-speed steel tool (having a melting point of some hundreds of degrees F. above the melting point of ordinary tool-steel) may thus be treated by the novel hardening process, including heating the tool while immersed in a slow
heating. While the heat is rising, the heat of the furnace is never much above the heat of the work, at any event. Hence the heat, as it is supplied, is allowed to become diffused in the work. There is at no time any serious discrepancy (if any) between the temperature of the fine edges and thin portions of the tools, as compared with the temperature of the rest of the tools. The thin tools reach maximum desired heat at the same time that the heaviest reaches the same desired heat.

From the top of the container rises a lifting-rod 21, co-operating with a tackle 22 to lower and raise the container and work; and the rod is made hollow, and connected through a flexible tube 23 to a source 24 of supply of prepared gas; provision being made at 25 for reducing or completely shutting off the supply, and at 26 for disconnecting the tube.

The rising in the heat of the work may be continuously observed by a pyrometer 27, whose fire end or element 28 is protected by a loose tubular jacket 29; pendant from a plate 28, Figure 1, that closes a small opening 30 in the center of the cover 21, which may consist of separable segments. Element 28 may be arranged in a central location (Figures 1, 2 and 4) in the group or pile of work-pieces, or extend into central holes in the pieces themselves (Figure 3). The accuracy of the reading of the pyrometer 21 may therefore be depended upon, for the heat from the burner 18 cannot penetrate to the centrally placed element 28 without imparting to the work-pieces 10, etc., the degree of heat that is exhibited by the pyrometer.

It should be desired for the base 19 to be attached to the bottom 12 of the canister, it would be lifted out of the furnace therewith, and form a support for the cooling canister. The supply of prepared gas may be detached at 26, and connected to the next charge or its canister, for lowering into the furnace.

The container 13 may be made of highly refractory material, to withstand the high heat aforesaid. It may be an alloy of iron and chrome for example. Or it may be a non-metallic substance, carbonborundum or other highly resisting material.

Care is taken in practicing the novel method to place the cold work in a bath or envelope of gas that is neutral to the tool-alloy, to avoid any chemical reaction, which would be injurious to the tools. The enveloped tools 18, etc., are exposed to heat, whereby they are gradually heated to the desired high point for hardening; and during the heating, the tools remain bathed in the neutral atmosphere, which preferably is in the nature of a current, which flows down through the tool-container 13; the container with the tools being dropped within furnace 17. The gas is preferably trapped in the container, and the current is so slow that only a little of the gas escapes from the open bottom of the container; the gas wasting from the bottom of the container and escaping into the furnace. There is no action of the gas upon the tools.

The high point of heat, from 3000 to possibly 2000 degrees, may be reached by possibly 20 minutes. The tools may be heated in say 20 or 30 minutes, whereupon the closed-top container 13 is lifted right out of the top of the furnace through the opening 16 and deposited upon a floor-support for cooling, in the room atmosphere, while another batch, in another closed-top container or retort, is substituted in the furnace, avoiding waste of time and heat. The second batch and container are duly removed and replaced by a third batch and container, and so on; each container being placed in unbroken connection with the source 24 of prepared gas, which therefore envelopes the tools during the cooling which is a final step in the hardening process.

The tool not being exposed to the action of the oxygen in the air, does not check or surface-spoil in any degree; nor does it have to be surface-ground, but retains its perfect pristine shape, with undulled edges, readily for use. No scale forms; there is no loss of carbon or other elements. From the beginning of the heating until the tool reaches the desired cooled condition, whereby it finally reaches its desired hardened state, it stays right in the container 13, and is continually enveloped in the prepared gas, whereby it is protected from exposure.

It may be noted that exceedingly slow and prolonged cooling of the heated high-speed steel would not be desired, for it would result in annealing the same.

Examination of the finished high-speed tool under a microscope, reveals uniformity of texture right up to the edge or surface of the tool. No carbon or other element whatever is lost, even from the outer surface. Upon hardening a small, thin heat-treating or small, thin tool and a quarter-inch drill simultaneously with a heavy square tool about three-fourths of an inch thick, in the same container for the same length of time, and enveloped in the same prepared gas, it is found that the small tools and the heavy tool all come out of the treatment in perfect condition, the small ones the same as the heavy one.

In practicing the prior art, a preheated tool may have been so small that it should not be exposed to the high finishing-heat more than approximately a minute or a minute and a half. Largest preheated pieces should not be in the high finishing-heat of the prior art more than six to eight minutes. It was therefore a drawback of the prior art, that the work was not able to withstand high heat for a satisfactory length of time, without becoming subject to injury, especially to the fine edges, and to deterioration in the quality of material.

In practicing the present invention, the work can have a great range in sizes, and the small tools could be in the high heat in the retort together with the large tools, for approximately twenty minutes, or even up to thirty minutes, and none of the edges of either the small pieces or the largest, would be injured; and the degree of hardness, and the grain, and the structure, would be found to be substantially the same, throughout the different pieces, small and large.

According to the present invention, the heat is brought up slowly, so that the body reaches the same heat as the thin edges and at the same time. In practicing the prior art, the heavy body absorbed heat from the thin portions, when the heating was too rapid and the fine edges or projections would be overheated. The present invention overcomes such difficulties. It is gradually heated, as the metal, up to 3000 degrees; the duration of the process may be ten or fifteen minutes or more. It depends upon the weight of the charge.

The great difference between the new invention and the old process, is seen when the cold work is put into the retort, which may be cold, and which goes into the illustrated furnace.
furnace may be cold, or it may be at 2000 or 2100, 2200, 2300 or 2350°. There is no liability.

4. The body will absorb the heat from the high points, having sufficient time to do so, on account of the gradual slow application of heat to the retort, that is, the slowly heating body will absorb excess heat that may have reached the points or edges, and hence they will not heat faster than the body, and so will not deteriorate. Where it would normally require three or four minutes for a heavy tool to absorb the heat, any attempt to heat it in only one minute, would cause the thin parts to crack off from the heavy parts. That is why the speed of heating up must not exceed the capacity of the tool to absorb that heat. The heating must keep in balance with the increase in heat.

A fairly heavy tool would take twenty minutes of heating; and a small, thin tool would become heated in five minutes; but they are put into the retort at the same time, the light piece with the heavy piece, and remain twenty minutes, and the small piece does not suffer.

To avoid unequal hardening of the depressed portions and the projecting portions, the degree of heat should be the same and the time of exposure should be the same.

The heat has to penetrate through the slowly heating container or retort, but only as rapidly as the work is able to absorb it. Heat is absorbed in going through that retort and through the gases therein.

The work may be set up or piled around the element-containing pipe in the center of the retort. The element may go down inside a hob 31. The element is therefore placed which is last reached by the heat which comes in through the retort, and to make sure that the indicated heat has reached the work, the element is placed in the center. If it is a big tool, the element is placed as near as possible to the center.

No product of combustion has access to the element 28 that is measuring the heat. The heat is measured inside of that retort and right inside of the work, whether it is a hob or a number of tools.

When the pyrometer 27 indicates the desired high point of heat, it shows that the work has absorbed enough. To make sure, the heat is left on a few minutes longer, so that the heat may diffuse evenly throughout the work, or come to a balance.

The hanging element is inserted through the top of the retort. The connection 23 from the supply of controlling gas may be connected all the time to the retort. The gaseous atmosphere is thus under control all the time, without changing anything, as the work proceeds from cold to the required heated condition, and during the cooling. The connections are outside the heat. The upper piping 23, etc., is out of the heat. The work and container and element are removed from the furnace.

Upon cooling, the smallest tool is found to be just as hard as the largest; and vice versa. This is done without damaging the small and frail one.

The tools would not cool fast enough if they were left in a muffle-furnace, but would come out in an annealed state.

Thus by this invention, the high-speed-steel tool, after the described heating, may be hardened without quenching, by cooling it while it remains in the controlled gaseous atmosphere in the retort 13, which may be deposited upon a doorstand for quick cooling, while remaining connected to the prepared gas-supply.

It is not desired to quench in liquid many classes of work. Without using liquid this retort may be taken out and set in a cooling receptacle 32, whilst the tool is poured around it, Figure 5, so as to take the heat out of the retort 13 and the work 10 as fast as desired. Such a quantity of copper can be employed, as to get the right hardening. Enough copper is used to reduce the temperature by 1500 or 1000 degrees, in a given time, sufficiently short to cause hardening. If the piece is very heavy, more copper 34 must be put in a basin 35 around the retort, so that it will not cool too slowly.

The extraction of heat from heavy tools, by aid of copper, is approximately as rapid as the above-described cooling of light tools in the gaseous atmosphere. Heavy tools at Figures 3 and 4, still confined in the retorts, may be thus readily hardened by cooling with copper or its equivalent, in instances where room-cooling would be too slow. The copper absorbs the heat as rapidly from the container and its work, as may be desired; dependent upon the bulk of the copper. Copper is a good heat-conductor, and is as efficient when surrounding the retort, as if the hot work had been removed from the old muffle (after unsealing it) and cooled in the open air; but this invention eliminates the oxidation and deterioration of the old cooling by air-exposure of the work hot from the muffle.

If the tool weighs ten pounds, the cooling will be too prolonged, without artificial cooling means. This is because the heat of the heavy tool itself becomes diffused right around the exterior of the retort, and such surrounding heat must be quickly reduced.

The surrounding heat cannot be taken away promptly if using a muffle- or muffle.

At Figure 5 is seen the closed retort, surrounded by the shot. The copper extracts the heat from the retort.

In practicing the present invention, to accelerate the cooling of the work still more, or to quench exceptionally heavy tools, the retort 13, Figures 6, 7, is brought to the surface of a quenching medium (usually oil). Then the work-tray 36 is lowered from the retort 13 into the oil bath 37 for quenching. All the time the work in the retort is protected by the surrounding gaseous atmosphere or envelope, until it is immersed in the oil. The work 10, etc., after being heated, is thus cooled apart from the furnace, but without taking it out of the retort, so that the gaseous envelope is not broken at any time.

When using a muffle, there was no satisfaction in controlling the rate of cooling of the hot tools. They were quenched in oil. They were injured in the air on the way to the oil-tank, or in any event the air would attack the tools.

The retort may be brought to or posed over the top surface of the oil, and then may be dropped until the bottom edge of the retort is just immersed in the oil, coming to rest upon shelf 64, when the tool rest or tray 36 may then drop down into the bath with the work, for
quenching, without further immersing the body of the retort, and without waste of gas or exposing the heated work to air.

At Figure 7, the retort is posed right above the surface of the oil, and the tray is allowed to settle from the retort into the oil. Thus the work is quenched without access of air thereto.

The work-elevator 38 goes inside of tube 21, and is lowered into the oil, Figure 7. The injury arising at the transferring from preheating muffles, was made worse by transferring the tools from the high-heating stage to the quenching stage, whether cooled in open air or in oil.

It will be observed that in any event (air-cooling, copper-cooling or oil-quenching), the high-speed-steel tools are not at any time taken from the controlled gaseous atmosphere in the retort.

The gaseous atmosphere that is put in at the top of the closed retort, no matter what it may be, has to be expelled at the bottom, so that it will be a uniform gaseous atmosphere throughout.

When the tool was taken from the preheating furnace and suddenly put in the old high-heat muffle, its edges were overheated before its body rose to the same degree of heat as those edges. The heat of the overheated muffle itself was the heat that went into the work by prior processes, unevenly heating the fine parts and heavy bodies; but in using this novel process, the heat that goes into the work is the heat that is being applied to the outside of the retort, slowly, and with even heating of all light and heavy parts; the heavy parts having sufficient opportunity to absorb overload from the fine parts.

In using a muffle as in the prior methods, the heating-up could be done only for the first batch in any day. At the charging of the second batch, the muffle would be in red-hot condition, and it could not do the same thing as is done with the cold retort, viz., the work could not be placed in a cold retort, and then heated up with the retort.

It was not practicable to put cold work in a cold muffle-furnace, and bring it all up to the highest heat, in an attempt to avoid preheating, for upon removing the hot work from the old muffle, how could it be reheated? The muffle-furnace remained hot. Obviously a fresh cold charge could not have been put into that furnace, with the idea of slowly and evenly and uninterruptedly bringing the charge and the furnace together up from cold condition to the top heat.

The furnace was already at top heat.

The muffle-user had to take his tools out, whereas the present invention retains them in the retort, and in five hours the novel cycle may be repeated ten times; ten new lots. In the same furnace several new charges may be put on another, without ever cooling the furnace down. It would happen only with the first charge that the cold retort would be heated up with the cold furnace.

The work being put in the cold retort, and the retort being put into a cold furnace, all can be brought up to the heat together. Or the cold retort and work may be put into a hot furnace, and the heating of the work must await the heating of the retort which contains it. At no time is relatively unheated work suddenly exposed to high heat.

It is not necessary to heat the work to the high pitch of the prior processes, nor is it de-carburized or the alloy changed in any way that would affect it detrimentally.

Some high-speed-steel tools may be heat-hardened by this invention at 2000 or 2100 degrees F. The present invention permits some reduction in heat, as much work can be hardened at 150 to 200 degrees lower than heretofore, or even at a still lower point. Because the surface is protected, hardening at a lower range of temperatures is rendered feasible.

The highest grade of hardness has been obtained at 2100 by this invention.

The gas may be varied for use with different alloys. One kind of high-speed steel will absorb more, another less, and the gas must be proportioned or balanced accordingly, as the alloy may require. One has more tungsten, another more molybdenum, another has more nickel, another has more iron, and therefore the gaseous atmosphere has to be varied to suit the purpose, and avoid changing and deteriorating the alloy of the tool.

It is an important feature that there is control of what may occur to the surface of the heating high-speed-steel tools.

The retort may be a chrome-nickel alloy with high heat-resisting qualities. Other refractory material may be used, for example, graphite, or carborundum. Carborundum can withstand 2500 degrees F. The retort shown is distinguished from an ordinary case-hardening retort, because the latter is not made of refractory material, the heat of case-hardening not exceeding from 1600 to 1700 degrees F.

The gas flowing through the retort for protecting the high-speed steel tools is prepared in the form of anhydrous ammonia, which is cracked before entering the retort in which the work is being treated. This prevents nitriding the high-speed tools. The gas is neutral. If the plain ammonia were introduced into the retort containing the tools, the heat of the retort would crack the ammonia, and the released nascent nitrogen would nitride the tools. But since the ammonia is cracked before being taken into the retort, it ceases to be active before entering the retort, since it is not nascent after the cracking.

In the gas used in the heating of high-speed steel tools, there is a small percentage of carbon, such that no tendency arises of carbon passing from the tools into the gas, or vice versa, so that the proportion of carbon in the high-speed tool steel does not become altered, and the fusing point thereof is not changed. An equilibrium of carbon is maintained between the gas and the high-speed steel.

At Figure 3 the retort is lifted and deposited by the aid of a cross-bar 40, to the hollow member of which the supply tube 23 is attached. The element 28 extends up to the top of the hollow central rod 21, and emerges from the top thereof. At this view the work-tools are stood upon a tray 36, which rests upon a disk or plate 41, which may rest upon detachable cross-bars 38, set into holes 42 in the retort, and preferably joined in the form of a staple.

At Figures 3, 4 and 6, an additional pyrometer 43 may have an element 44 extending down into the heating chamber of the furnace, to ascertain the heat of the furnace close to the retort.

At Figures 4 and 5, the upper ends of heavy tools may be set into guide-holes formed in a disk 45 at the top of the retort chamber, the disk being mounted upon the top of a hollow column 46 which rises from the annular tool.
At Figure 5 the central column may consist of the lower end of the central rod 21. At Figure 6, the tool-tray 38 rests directly upon the removable cross-bars 30. After the bell retort has been poised above the oil 37, the supporting bars 35 may be withdrawn after the bottom of the bell has been set down into the upper portion of the oil, so that there is no access of air to the hot tools, and then the tray with its tools may be let down into the oil to quench them, as seen at Figure 7. The tray is lowered and raised by the rod 33, which is provided with a top handle or cross-bar 48. Escape of gas at the top is prevented by a gland at 49, Figure 7.

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

Having thus described my invention, I claim:

1. A process of hardening which consists of enclosing and fixing work in a bell envelope, to form a hardening unit, inputting a stream of protective gas into the top of the bell envelope substantially continuously, to surround said work and venting the gas at the bottom of the envelope, during substantially the entire process, heating said envelope and thus indirectly heating said enclosed work, removing said unit to a quenching place, quenching said unit, and thereby chilling and hardening said work while fixed in said envelope and substantially surrounded by gas from said stream.

2. The process of hardening work by abrupt chilling, which consists of enclosing work in an envelope provided with a top hole and a bottom hole, introducing a substantially continuous stream of protective gas at the top hole and venting same at the bottom hole and first heating, then quenching the envelope, whereby the enclosed work is hardened while protected by the gas.

3. A process as in claim 2 wherein the protective gas comprises cracked ammonia.

4. A process as in claim 1 wherein the protective gas comprises hydrogen and nitrogen in substantially the proportions of 3 to 1.

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