having light walls, that would lose their heat rapidly, it would be found necessary to apply the heat for a time. The bone will be found charred when the box is opened. Care should be observed that the charring is not *over-done*, however.

Charred bone may be used as packing material either alone or with an equal quantity (in volume) of granulated wood charcoal.

Preserving the Bone.

When the hardened articles are removed from the bath, the water may be drawn off, and the packing material taken out and dried. This may be done by placing it on top of the hardening furnace, if that be of sufficient size; if not, it may be spread out thinly and allowed to dry. This is the expended bone previously mentioned.

Expended bone may be used for packing certain classes of work in, or it may be mixed with an equal quantity of granulated raw bone and used the same as raw bone. Or it may be used for packing machine steel forgings or small articles of cast iron for annealing.

High Speed Steels.

During the past few years various makers have placed on the market steels that have revolutionized certain manufacturing methods. Cutting tools made from these steels will retain a cutting edge when extremely high speeds are employed; they are also useful when machining stock, which is too hard to be machined by ordinary tool steels.

This grade of steel when adopted by a certain concern allowed them to reduce the expense of machining stock to a degree that made it necessary for their competitor to use it also, in order to produce his work at a similar cost. As the steel was used it was found that the ordinary machine was not strong or stiff enough to do the work the tools made from it were capable of doing, and for this reason many concerns have found it necessary to purchase machinery made especially to accommodate these tools.

Extravagant claims are many times made by the manufacturers of these tools, claims which it seems were better not made; because the man who attempts to duplicate them and fails, not only loses faith in them but is skeptical regarding other steels when his attention is brought to them.

Failure to realize all that has been claimed for the steel may not always be the fault of the steel; it may come from other causes. First, the operator not being familiar with the nature of the steel, may fail to treat it properly when making it into cutting tools. Then again the stock being machined with the tools may be entirely different in composition from that used when making the tests.

It is an unfortunate fact that most tests are made with nice, clean, easily machined, cast iron when that is the material used; or with soft machinery steel, free from hard spots. Now every mechanic knows that cast iron as it comes from the ordinary foundry to the machine shop, is a varying factor; it may machine easily and we may be able to get high speeds even when taking heavy cuts, and using coarse feeds; on the other hand, the composition may be such that the same tool would not stand up if we were to run it only half as fast as when machining the softer metal.

At one time while making experiments with one of the best known makes of high speed steels, the writer was able to run a piece of cast iron in the lathe at a speed of 100 feet per minute, the cut was 1-16 inch (removing ⅛ inch of stock) and the feed 20 to 1 inch. The tool stood up nicely and turned the entire length of the piece without dulling so that it was noticeable. When we attempted to turn another piece from the same pattern which was cast from a different mixture it was found impossible to retain a cutting edge on the tool if a speed of 45 feet per minute was exceeded, retaining, of course, the same depth of cut and relative feed.

Results even more noticeable than those mentioned above are experienced when cutting what is familiarly known as machinery steel, as unfortunately all grades of steel between wrought iron and tool steel are classed under the head of machinery steel.

These facts are not mentioned to in any way belittle the value of the steel under consideration, but to show the reader that he should not get discouraged when he fails to get results paralleling those claimed by the makers of the steel. The only fair method of judging of the value of the steel to the individual is to test in comparison with the best tool he can obtain, from tempering steel.

Because a tool will not stand up on cast iron running at 100 feet per minute, as claimed by the maker of the steel, is no proof the steel is no good. It might have stood all right at 90 feet, and perhaps a tool made from ordinary tempering steel might not have stood a speed of 30 feet; in which case the high speed steel was capable of doing more than three times the amount of work of the other.

Many times a difference in cutting speed of only a few feet per minute will cause a tool to either stand well, or go down.

There is no *general* set of instructions that can be given for working this steel, as a method that proved perfectly satisfactory on one would render another unfit for use. For instance, the writer at one time contributed an article to one of the mechanical journals on the subject of "High Speed Steel," recommending extremely high heats when hardening. Shortly after the appearance of the article a letter was received from a manufacturer of a brand of this steel, saying he had read the article with much interest and agreed with everything in it except the temperature necessary when hardening, as they had found their steel gave best results when it was hardened at a *low* cherry red heat.

A trial of a tool which he sent proved it to be equal or superior to some that were hardened at the high heat mentioned.

To get satisfactory results with any brand the party using the steel should follow instructions sent with the steel as closely as possible.

It is evident to the writer from results of his own experiments and the experience of others, that when this steel is thoroughly understood, results way beyond those we are at present getting will be obtained marvelous as *they* seem now.

While the writer has made extensive experiments with the steel under consideration, and has taken advantage of every opportunity to study its composition, this study has been confined to printed statements made by those who claim to possess this knowledge.

Knowing, however, that the successful man in any line of business is he who, by studious effort makes himself master of his subject,—what is more natural than that the student considering this subject should be anxious to know the composition of this steel.

The following is an abstract of a paper read by Mr. J. M. Gledhill before the "Iron and Steel Institute," October, 1904:

The high speed steels of the present day are combinations of iron and carbon with: (1). Tungsten, Molybdenum and Chromium.

We will consider the influence of each of the elements entering into the various compositions.

Influence of carbon

A number of tools were made with the carbon percentage varying from 0.4 per cent. to 2.2 per cent. and the method of hardening was to heat the steel to the highest possible temperature without destroying the cutting

edge, and then rapidly cooling in a strong air blast. By this simple method it was found that the greatest cutting efficiency is obtained where the carbon ranges from 0.4 per cent. to 0.9 per cent. and such steels are comparatively tough. Higher percentages are not desirable because greater difficulty is experienced in forging the steels and the tools are inferior. With increasing carbon contents, the steel is also very brittle, and has a tendency to break with unequal and intermittent cutting.

Influence of Chromium

Having found the best carbon content to range from 0.4 per cent. to 0.9 per cent., the next experiments were made to ascertain the influence of chromium varying from 1.0 per cent. to 6.0 per cent. Steels containing a low per centage are very tough and perform excellent work on the softer varieties of steel and cast iron, but when tried on harder materials the results obtained were not efficient. With an increased content of chromium the nature of the steel becomes much harder, and greater cutting efficiency is obtained on hard materials. It was observed that with an increase of chromium there must be a decrease in carbon to obtain the best results, for such percentage of chromium.

Mention may here be made of an interesting experiment to ascertain what effect would be produced in a rapid steel by substituting vanadium for chromium. The amount of vanadium present was 2.0 per cent. The steel readily forged and worked very tough and was hardened by heating to a white heat and cooling in an air blast. This tool when tried on medium steel stood well, but not better than the steel with the much cheaper element of chromium in it.

Influence of Tungsten

This important element is contained in by far the greater number of the present high speed steels in use. A number of experiments were made with the tungsten content ranging from 9.0 per cent. to 27.0 per cent. From 9.0 per cent. to 16.0 per cent. the nature of the steel becomes very brittle, but at the same time the cutting efficiency is greatly increased and about 16.0 per cent. appeared to be the limit, as no better results were obtained by increasing the tungsten beyond this figure. Between 18.0 per cent. and 27.0 per cent. it was found that the nature of the steel altered somewhat and that instead of being brittle it became softer and tougher, and whilst such tools have the property of cutting very cleanly they do not stand up so well.

Influence of Polybdenum

The influence of this element is still under investigation and our experiments with it have produced excellent results, and is was found that where a large percentage of tungsten is necessary to make a good rapid steel, a considerable less percentage of molybdenum will suffice. A peculiarity of these molybdenum steels is that in order to obtain the greatest efficiency they do not require such a high temperature in hardening as do the tungsten steels, and if the temperature is increased above 1,800 degrees F. the tools are inferior and the life shortened.

Influence of Tungsten with Molybdenum

It was found that the presence of from 0.5 per cent. to 3.0 per cent. molybdenum in a high tungsten steel slightly increased the cutting efficiency, but the advantage

gained is altogether out of proportion to the cost of the added molybdenum.

Influence of Silicon

A number of rapid steels were made with silicon content varying from a trace up to 4.0 per cent. Silicon sensibly hardens such steels, and the cutting efficiency on hard materials is increased by additions up to 3.0 per cent. By increasing the silicon above 3.0 per cent., however, the cutting efficiency begins to decline. Various experiments were made with other metals as alloys, but the results obtained were not sufficiently good by comparison with the above to call for comment.

Analysis of one of the best qualities of rapid steels produced by Mr. Gledhill's firm (Armstrong Whitworth Co.), is as follows: "A. W." steel Carbon 0.55 per cent; Chromium, 3.5 per cent.; Tungsten, 13.5 per cent.

Tools made from high speed steels in order to give best results when heavy cuts and coarse feeds are employed, should be made of a form that insures strength and rigidity and must cut freely. Many times tools are made having very *little* clearance on the portion that penetrates the stock as shown at A Fig. 161; now if a coarse feed is employed it is apparent that such a tool will bear on the stock below the cutting edge, as a consequence the tool cannot cut as rapidly as the lathe carriage is traveling and it must turn in the tool post. If the operator is not attentive he will not observe the trouble, and in order to securely fasten the tool he will tighten the binding screw so tightly that he either breaks the tool post binding screw or he succeeds in binding the tool so it cannot turn, and the feed belt slips, or the pressure against the stock actually crowds off a portion of the cutting edge of the tool. It is necessary when taking heavy cuts with coarse feeds to give a tool sufficient clearance as shown at B. Fig. 161, so no part of the tool below the cutting portion will touch. Too much clearance, of course, weakens the tool and is to be avoided.

While slender side tools, diamond point, and similar tools, give excellent results when made from high speed

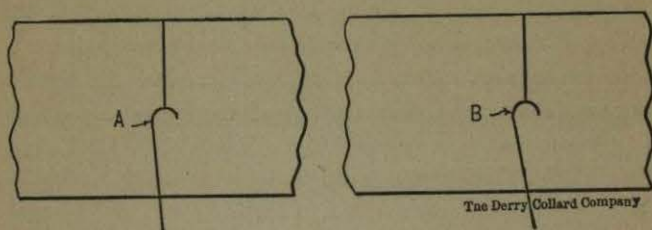

Figure 161. Side clearance of tools.

steel, the more noticeable results are obtained when heavy cuts are taken. To accomplish this it is necessary to use tools which are stubbed and strong and having as little *top rake* as is consistent with fairly easy cutting. For this reason tools having portions standing out from the shank (as a diamond point tool) are not generally satisfactory. A tool made as shown in Fig. 162, will be found to give best results when heavy cuts are taken.

Many tools are on the market which use separable cutters. These cutters may be of high speed steel which can be purchased in any of the common forms and sizes. The steel as it comes in the bar is glass hard unless it is ordered annealed. However, if *best* results are desired, it is advisable to harden it before using even when it is *not* necessary to forge it to shape.

If it is desirable to have the steel in the annealed condition, better results are obtained, generally speaking, if it is *purchased* in this condition, than if annealed in a shop that does not have the necessary facilities for maintaining a heat for a considerable length of time.

There is a difference of opinion among mechanics using this steel as to effect of annealing on the hardened

Figure 162. A good tool for heavy cuts.

tool, some claiming that tools made from steel that has been annealed will not stand as much as if made from stock that had not been annealed, while others claim best results from steel that has been annealed. The writer in his experiments has failed to notice any material difference, provided due care had been experienced in the various operations.

The writer saw not long ago some drills made from bars of a well-known brand of this steel which was not annealed. The steel was flatted, then twisted to shape while hot. After being hardened they were ground to size. They certainly stood up much better when tested than drills made from other brands whose grooves were milled from annealed bars. Whether the difference was due to the fact that one steel was annealed and the other not, or to the difference in the method of making, the writer is not ready to say. This much he does know; the drills referred to were heated to a high heat and quenched in luke warm brine, while no one knew how the others were hardened. It would not be safe to dip some brands of this steel in brine, while others work nicely when tools of certain shapes are hardened in it.

When making certain tools, as taps, milling machine cutters, dies of various kinds and similar tools it is *neces-sary* to anneal this steel in order that it may be worked to shape, and unless it is *properly* annealed it is very try-ing, as well as extremely costly, to attempt to machine it to form.

The writer has made exhaustive experiments in the annealing of this steel and has found that some of the methods advocated, work in a manner that is anything but satisfactory. It is necessary to pack the steel in the annealing box with some substance that will exclude the air as much as possible. For this reason charcoal has not worked as well as other substances. Lime, if used as a packing material, insures a good anneal if the process is carried on properly; but appears to leave a heavy hard scale on the outside. Some claim good results from a mix-ture of lime and charcoal; this the writer has not tried be-cause excellent results were obtained by packing the steel in dry clay in an annealing box, the cover being put in place and sealed, the box placed in the furnace and the steel heated to a yellow. It was allowed to cool as slowly as possible. The exact temperature necessary to heat the steel, in order to get satisfactory results depends some-what on the steel used and also on the size of the piece. Smaller pieces do not require quite so much heat as larger ones, neither should they be subjected to heat for as great a length of time.

The following method is practised in a shop that an-

neals over a ton of high speed steel per day. This steel is of several makes and the method seems to apply equally well to any of them, and is as follows: The steel is packed in long pipes with a mixture of charcoal, lime, and cast iron chips in equal quanities. The steel is placed in the furnace in the morning and subjected to heat all day the temperature which as gauged by a pyrometer, is between 1,600 and 1,700 degrees. The steel is allowed to remain in the furnace all night and cool off with it. In the morning the tubes containing the steel are removed from the furnace, covered with hot ashes and allowed to cool as slowly as possible.

While this method appears to give excellent results, I have obtained best success with fire clay as a packing material; either material may be used over and over with good results.

The idea prevails among some mechanics that this steel after being hardened cannot be annealed and then hardened again. While I have never experimented along these lines with *all* the different makes I have with sever-al of them, and found no trouble when the tool was re-peatedly annealed and hardened. I could not detect any difference in the cutting qualities of the tool after it had been hardened four or five times.

One objection raised against this steel for tools to be used in the lathe or planer, where the tool was held in a tool post and thereby subjected to the breaking strain in-cident to the manner which it was held, is, that the steel broke in the tool post when heavy cuts were being taken. This trouble may be avoided by annealing the bar, or cut-ting it to proper lengths and annealing, after which the tool may be forged and hardened. It is not considered good practice to attempt to harden tools made from this steel any where except on the cutting end, thus leaving the portion in the tool post sufficiently tough to resist the breaking action of the screw.

When annealing the steel for the purpose just mentioned above, it is not necessary to be as thorough as when it is to be worked with cutting tools, and it may be accomplished by heating the steel to a low yellow heat and burying in red hot ashes (or lime which has been thoroughly heated before the steel is placed in it), it is necessary to thoroughly protect it from the chilling effects of the air, or any material which is cold or damp.

In order to get satisfactory results in the hardened tool it is necessary after forging, to reheat the tool to a full red and allow it to cool off, thus relieving the strains incident to forging; when cool it may be reheated and hardened.

While the amount of heat necessary to insure best results when hardened steels of different makes cannot be stated arbitrarily, it is claimed for *most* of them that a *full red* heat should be employed when forging. However some makers claim best results for their steel if it is heated to a full yellow (above 1,850 degrees), at which temperature it is soft and easily worked. The forging proceeds until the temperature lowers to a good red, say 1,500 degrees, when work on the piece should cease and the steel reheated before forging is removed. It is, however, best to get instructions from makers of the steel, as to the temperature that insures best results, before doing any work on it.

In case of the smith who carefully observes the action of heat on steel I claim that he can, in a short time, find out more about the proper heat and method of working a given brand of this steel in order that the tools may

give satisfaction in the shop whose condition he understands, than it is possible for him to learn from any instructions the maker can furnish, because these instructions must of necessity be general and cannot apply to the varying conditions found in the individual shop. The careful smith will soon find out for himself at what heat the steel works best under the hammer. The heat should be one that allows the steel to work nicely. While the maker of some of these steels claim good results when it is placed in the hands of men who are not specially skillful in the manipulation of steel, I think I am safe in saying that when forging most brands, it is necessary to exercise greater caution than when forging *high carbon* steels, and every smith knows they are extremely sensitive.

If the steel is hammered when it is not hot enough the grain is fractured. If large pieces are being worked, the blows should be sufficiently heavy to cause the steel to flow as uniformly as possible; heavy blows with a heavy hammer should not be given a *light* section. The forging heat must be uniform, that is, the piece must be as nearly as possible of the same temperature at the center as the surface.

Blacksmiths are sometimes careless when working these steels, thinking that because high heats when hardening are essential to good results, any heat will do for forging. This is a great mistake as the steel is extremely sensitive but requires high heats when hardening to give it the desired cutting qualities.

A common mistake and one that has proved very costly to many concerns, consists in changing from a steel that has been giving satisfactory results for another whose only recommendation is that the representative shows testimonials from parties who have used it and claim results way beyond what is being received from the brand they are using. In all probability the other parties are machining a stock entirely different in composition and as a consequence are able to get more work out of the tools.

The writer would not be understood as saying we should always "let well enough alone" and continue to use an inferior article while his competitor was getting the best and as a consequence is leaving him way in the rear. But many times parties have discarded one steel and adopted another which was no better and in doing so they have adopted a steel that required different treatment from the one they were using at first. The smith not realizing this fails to treat it properly and the results are not as satisfactory as with the first.

If steels of different makes are used they should be distinctly marked and the smith should be given explicit instructions for working each. Generally speaking, however, it is poor policy to have several makes of this steel around at the same time.

The operator should follow instructions accompanying the steel to the letter, unless experience has convinced him and all concerned that some other method of treatment is better adapted to their needs.

However the instructions given do not always instruct, and sometimes the men sent out by the steel concerns as demonstrators know less about the steel they represent than the smith whom they are supposed to teach. This does not necessarily prove that the steel is of no value.

The smiths who are the most successful in handling these steels are the ones who are ever on the lookout for knowledge, and learn all they possibly can of its nature,

and the treatment best adapted to the needs of the shop they are in.

I think most blacksmiths who have had an extensive experience working high speed steels prefer a fire of coke when heating for forging.

Heating for Forging.

We have been taught from the time we first hardened a piece of steel that *high* heats were to be avoided, that the *lower* the heat the more serviceable the tool, provided, of course, it was sufficiently high to accomplish what we desired. Now a steel is given us which requires a *full* white heat in order to give it a condition that insures doing what we expect of it. That is, *most* makes of this steel require the high heat mentioned. If the tools to be hardened are of a form that are not injured by scaling they may be heated in an open fire in an ordinary blacksmith's forge. If, however, taps, reamers, milling machine cutters, or any form which would be injured by scaling are to be hardened, they must be heated in a gas or other furnace especially made for high heats, or in a crucible of lead heated to the proper temperature. The lead being at a very high temperature the surface has a tendency to oxidize very rapidly; this can be prevented somewhat by placing powdered charcoal on the top, which must, of course, be renewed frequently.

A very satisfactory method of heating specially formed tools of high speed steel, such as taps, dies, milling cutters, reamers and similar tools, is a muffle furnace of special design, heated by oil or gas. This furnace has two chambers one above the other. The lower chamber may be heated to a temperature of 2,200 degrees Fahr., and the temperature maintained uniformly, while the upper chamber is not heated nearly as hot. The tools may be slowly heated by placing on top of the furnace in a temperature that does away with the tendency to crack when they are subjected to a higher heat. While in the upper chamber they can be brought to a red heat. It is now safe to place them in the lower chamber and allow them to remain until they are of the proper temperature for hardening.

When electric current is available an excellent method of heating may be had that is rapid, reliable and easily controlled. The description of this method is taken from

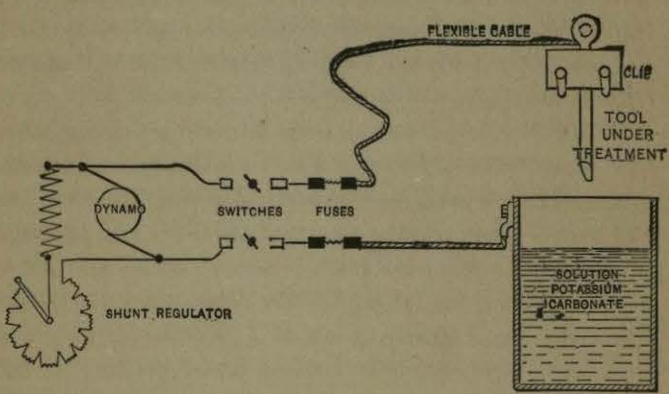

Figure 163. Apparatus for hardening tools electrically in a bath of potassium carbonate.

the abstract of paper read by Mr. J. M. Gledhill previously referred to. A brief description of this kind of heating may be of interest.

One method adopted for electrically heating the points of tools, and the arrangement of apparatus is shown in accompanying cut, Fig. 163. It consists of a cast-iron

tank of suitable dimensions, containing a strong solution of potassium carbonate, together with a dynamo, the positive cable from which is connected to the metal clip holding the tool to be heated, while the negative cable is connected direct on the tank. The tool to be hardened is held in a suitable clip to insure good contact. Proceeding to harden the tool the action is as follows:

The current is first switched on and then the tool is gently lowered into the solution to such a depth as is required to harden it. The act of dipping the tool into the alkaline solution completes the electric circuit and at once sets up intense heat on the immersed part. When it is seen that the tool is sufficiently heated the current is instantly switched off, and the solution then serves to rapidly chill and harden the point of the tool, so that no air blast is necessary.

If it is necessary to heat in an ordinary forge when hardening lathe, planer and similar tools, the point *only* of which needs hardening, a good large fire of well coked coal may be used, making sure that the fire is large enough so that no air from the blast inlet will strike the heated portion. When the desired heat has been obtained the tool is then held in a strong air blast of generous proportions. Best results are obtained if the point of the tool is held several inches away from the nozzle of the blast pipe. If an air blast is not available, dip the point of the tool in oil, raw linseed, cotton seed oil, or almost any fish oil will answer.

After hardening the tool may be ground to shape, and it is ready for use, unless projecting portions or light sections necessitate drawing the temper to insure sufficient strength. The object attained in drawing the temper is that the brittleness is reduced so the tool will not break when subjected to shock and strain incident to cutting. When the temper has been drawn the desired amount, lay the tool to one side and allow it to cool slowly where no current of air can strike it. Do not quench it when the proper temperature is reached for while it is safe to plunge certain shapes of tools made from this steel in *hot* water when at a high heat, it is not safe to quench them at tempering heats.

If such tools as milling machine cutters, taps, reamers and similar tools are to be heated for hardening, it is necessary to remove them from the oxydizing action of the air when at the high heat. To accomplish this they may be heated in specially constructed furnaces as previously described, or in a crucible of lead. The furnace described is so designed that there are three steps in the heating operation; first the cold cutter is placed on top and heated somewhat, so it is possible to subject it to a red heat without cracking it as would be the case if the cold steel were subjected to the red heat. After becoming heated somewhat it is placed in the upper chamber where it is gradually heated to a full red heat; it is then placed in the lower chamber and heated to the proper temperature to insure desired results.

If the furnace used has but one chamber it is necessary to heat the tool to a red in an open fire or where it may be heated slowly; it may then be placed in the furnace and given the desired temperature.

Now, while a crucible of lead is many times used to heat tools made from high speed steels for hardening, its use as a *permanent* means of heating is hardly to be advocated as the lead oxidizes very rapidly and the fumes are poisonous. For the same reason that it would not do to place a cold tool in the chamber of the furnace, it is nec-

essary to heat articles red hot before plunging in lead heated to a white heat. If the tool was immersed when cold into lead heated to the temperature mentioned it would spring or crack from the sudden expansion of the outer surface of the steel. The tool should be allowed to remain in the lead just long enough to insure a *uniform* heat of the proper temperature.

If comparatively large tools are to be heated in the lead, the crucible should be of generous proportions, or the contents will be cooled so much by immersion of the steel that the temperature will be lowered to a point that will necessitate reheating to bring it to the high heat required.

At times the operator is deceived as to the proper heat by attempting to get heats that insure a hardened surface that cannot be touched with a fire. The steel may be so hard, a file will have no impression on it and yet fail to give satisfactory results. Again, tools which are hardened at the temperature necessary to give this, may leave the temperature drawn until they file readily and still stand up nicely when tested at high speeds and heavy cuts. The intense heat is necessary to bring about certain chemical changes necessary to give desired results.

When the tool is heated to the required temperature it may be plunged in a bath of raw linseed, cotton-seed, or fish oil, and allowed to remain until cool. If it is an end mill, excellent results are many times obtained by quenching in boiling water, or hot brine. It is necessary to remember, however, that only the portion heated to a white may be put in water, or the part which is not so hot is liable to crack.

The writer's experience in hardening taps does not warrant his advising the use of lead as a heating medium for them; and he has seen the representatives of steel concerns selling this steel have repeated poor success when trying it. Probably the most satisfactory method is to heat in specially prepared furnaces, but such furnaces are not always available, and excellent results may be obtained by placing the tap in a piece of gas pipe closed at one end, a quantity of finely broken charcoal or coke (the writer prefers coke) may be placed in the tube and the remaining end sealed. The tube may now be heated to the desired temperature, the top removed and plunged in oil. It will be necessary to draw the temper of tools having slender teeth, this drawing is nicely done in heated sand. The amount necessary to draw the temper will depend on the use to which it is to be placed, it may be a straw, brown, or blue color, or in cases requiring freedom from brittleness the tool may be heated until a dull red shows when it is held in a shaded place, as in a barrel or keg.

When pieces have been heated for tempering, place them where no dampness or current of air can strike them, and allow them to cool off.

In the case of taps it will be found advisable to heat the shanks red hot in red hot lead, then place the *shank* in lime to cool off as slowly as possible; this may be done after drawing the temper of the cutting end.

Some mechanics using this steel, object to drawing temper, saying it should be as hard as it can be made. However, if we attain to anything like the speeds claimed for the steel, it is very quickly heated to a temperature even higher than the temper heats mentioned, so it is obvious that drawing temper for toughness can not seriously detract from its *staying* qualities and it is certainly necessary when parts that are weak are to be subjected to great strain.

Experience has convinced the writer that it is a mistake, generally speaking, to grind lathe, planer and similar tools on a *wet* emery wheel, as it requires considerable pressure of the tool on the wheel to insure its cutting, this pressure is, of course, productive of heat, the water striking the heated steel causes it to crack; especially are the above results noticeable if the grinding is done by men *not* extremely careful.

Best results follow grinding on a free cutting *dry* wheel, after which it may be finished on a free cutting grind stone.

Speeds and Feeds.

As previously stated the speed at which these steels can be used with satisfactory results depends in a great measure on the condition of the stock being machined. Many times the depth of chip and the rate of feed are entirely overlooked and as a consequence less stock is removed than if the machine was run somewhat slower and heavier cuts and coarser feeds used.

It is necessary, however, in order to have something tangible, that we have before us results of tests made with stock of various kinds and as the writer has never kept a record of results obtained in his experiments it has seemed wise to give results claimed by the makers of certain brands of this steel. The reader need not be discouraged if he is not able to duplicate the results given in the table, and yet under certain conditions he may be able to do even better.

One maker claims, that when turning bars of hard steel the stock was run at a rate of 160 feet per minute, the depth of cut ¾ inch, the feed 1-32 inch, the amount of stock removed in a day of 10 hours being about 2,500 pounds, the cutting tool being ground but once a day.

Another maker claims that twist drills made from their steel would stand from two to four times the speed of the best carbon steel, and even at the high speed would drill from 6 to 25 times as many holes before it required grinding.

He also claimed that taps made from their steel would stand three or four times the speed of regular tool steel taps, and stood up 40 to 50 times as long.

Reamers from the same steel it is claimed, were run at twice the speed of those made from ordinary carbon steel and showed an efficiency of 15 to 1.

Milling machine cutters made from another make of this steel were run at a rate of 150 feet per minute on mild open hearth steel, as compared to 28 feet per minute with a similar cutter made from regular tool steel.

Experiments in cutting cast iron in the lathe showed that a speed of from two to four times that possible when tools made from carbon steels, was used.

Hardening and Tempering Rock Drills

Drills used in drilling rock are used under vastly differing conditions, and are not all treated alike. The success of a drill depends in a large measure on the steel used, in its construction and in the treatment it receives when it is forged. As the sharpener has constant practice and his whole time is devoted to this one line of work he becomes very skillful and, while he works quite rapidly, he is extremely careful when heating and forging.

The shape of the drill has nearly as much to do with

ability to stand up as the method employed in hardening, so the sharpener should find the shape that gives best results and then stick to it as closely as possible.

The sharpening should be done at low heats and blows should be lighter as the steel cools, to prevent crushing the grain.

The heat for hardening should be the *refining* heat for the particular steel being used.

A bath of brine made by dissolving all the salt it will take in a tank or barrel of rain-water, is the one commonly used, although some sharpeners add other ingredients.

The hardening generally extends from 1 inch to 1¼ inches up from the point, the steel being heated higher up contains sufficient heat to draw the temper the desired amount.

The treatment of the steel during forging and hardening has a great deal to do with the amount it is "let down" in tempering. If the heats were low the steel will be strong and the temper may be left high; if the heats were high the steel will be brittle and the temper must be drawn considerable. We will assume, however, that the heats have been carefully gauged for both forging and hardening.

For most steels that have come under the observation of the writer, the temper should be drawn to the faintest color visible, that is, when the temper color commences to show, the drill should be checked in oil; under certain conditions, however, the temper is drawn to a light straw color.