Springs for Ordinary Purposes

are made from 1.00 to 1.10 per cent. carbon crucible steel. For many purposes, an open hearth steel is used with satisfactory results.

Springs for Locomotives

are made by some manufacturers of crucible steel containing .90 to 1.10 per cent. carbon, and by others of a steel containing .80 to .90 per cent., while in many cases very satisfactory results follow if open hearth steel, made especially for the purpose, is used.

Springs for Carriages

are made from crucible steel containing .80 to .90 pel cent. carbon, but many more springs of this character are made from open hearth and Bessemer stock than from crucible, because it answers the purpose and is much cheaper.

Taps

are made of crucible steel containing 1.10 to 1.25 per cent. carbon in many shops, while others claim better results from steel containing 1.25 to 1.40 per cent.

Taps for Tapping Nuts,

generally called machine taps, give best results if made from steel containing 1.00 to 1.10 per cent. carbon.

Causes of Trouble.

While most of the causes of trouble when steel is hardened have been considered under the various topics presented, it has seemed wise to group together the more common causes, in order that they may be referred to more readily by the reader.

Uneven Heats.

Probably the most common cause of trouble is uneven heating of the piece in forging, annealing or hardening. As a consequence, violent strains are set up which cause the piece to crack or, in the case of heavy pieces, to burst. The different parts of the piece being unevenly heated, must, when cooled, contract unevenly; and when two portions of a piece adjoining each other attempt to contract unevenly—that is, one contracting more or faster than the other—and both being rigid to an extent that makes it impossible for them to yield one to the other, there must be a separation at the point where the uneven temperature occurs.

High Heats.

A very common cause of trouble consists in heating steel too hot for the purpose. High heats open the pores of the steel, making the grain coarse and causing the steel to be weak. When the piece is broken, it has a honeycomb appearance—looks full of holes, so to speak. Now, as there is but a very thin layer of steel over these holes, when pressure is applied the surface over the holes caves in, and the steel is unfitted for doing the maximum amount of work.

Steel which has been overheated may be restored —unless the heat was high enough to burn or disintegrate the steel—by reheating carefully to the refining heat and quenching; but it can never do the amount of work possible, had it not been overheated. Yet, it will be much better than if left in the condition the high heat placed it.

Then again, high heats have a tendency to cause the steel to crack when hardened. This is especially true if the piece be cylindrical in shape. Cylindrically shaped pieces will not stand the amount of heat that may safely be given a piece of almost any other shape without cracking, although the effect on the grain and the ability of the steel to stand up and do the maximum amount of work possible would be the same in any case, regardless of the form of the piece or the method of applying the heat.

Too Rapid Heating.

While it is advisable to heat steel as rapidly as possible consistent with good results, it should not be heated *too* rapidly, as corners and edges will become overheated before the balance of the article has reached the proper heat; and even if they are allowed to cool down to the proper heat (apparently), the grain has been opened at these portions, and violent strains are set up. This is one of the places where experience seems to be the only guide and where the instructor

can only give suggestions, which should be heeded and worked out by each hardener.

Heating Too Slowly.

In attempting to avoid heating too rapidly, do not go to the opposite extreme and allow the steel to "soak" in the fire, or soft surfaces will result, and the steel is not as good as if heated properly.

Fire Cracks.

There are a number of causes for steel cracking in the fire. Among the more common are, first, the cold air from the blast, if the work is heated in a blacksmith's forge. Then again, it may be heated in a gas flame having an air blast. The air may be turned on too much, resulting in cold air jets striking the heated steel. If a charcoal fire is used, it is the custom of some hardeners to throw cold water on the fire. Now, if the steel is red-hot, the water has a tendency to cause it to crack in the same manner as if the air from the blast came in contact with it.

Large articles plunged in a crucible of red-hot lead, cyanide of potassium, or any substance where they are exposed to violent heats, are very liable to crack, especially if there are heavy and light portions adjoining each other. The unequal expansion tears the steel apart at the point where the unequally heated portions adjoin each other. This may be avoided by heating the articles nearly to a red in some form of fire where it would heat more slowly, then plunge in the lead to bring to the desired heat; or, the article may be immersed in the red-hot contents of the crucible, left for a moment and withdrawn, immersed again, leaving a trifle longer, and so continue until it reaches the desired heat.

If a piece of steel is immersed in a crucible of red-hot lead or similar material for a certain distance so that part of the piece is out of the red-hot material, it should be moved up and down in the molten mass, or the part below the surface will expand more rapidly than the adjoining metal. If the article were immersed and withdrawn, repeating this operation until the desired result is obtained, the heat being applied gradually, the expansion is more uniform, and the heat is imparted to the adjoining stock so it can yield to an extent that does away with any tendency to crack.

Cold Baths.

Extremely cold baths are the cause of a great deal of trouble when pieces of irregular contour are hardened. It is nearly always advisable, when hardening articles made of high carbon steel, to warm the contents of the bath somewhat. Many hardeners claim that oil heated to a temperature of 100 degrees to 120 degrees will harden steel harder than if it were extremely cold. It will certainly cause it to be tougher.

Improper Forging.

This is the cause of a great amount of trouble when steel is hardened. While the writer claims best results from steel properly forged, he is aware that much better results are obtained from steel machined to shape than if the articles were heated or hammered in any but a proper manner.

Steel to be made into tools whose cutting edges are on or near the end should not be nicked with a chisel

and broken, as the portions at the end are rendered unfit for cutting purposes.

Do not straighten steel that is to be hardened without heating it red-hot.

Do not attempt to harden a tool of irregular shape unless it has been annealed after blocking out to somewhere near to shape.

Do not take it for granted that because you have held a piece of steel in the fire and stuck it into water, it is necessarily hard. Try it with a sharp file before brightening the surface preparatory to drawing the temper, as much valuable time may be saved if the piece should prove not to have hardened.

When you get a piece of steel that you are in doubt about, it is advisable to cut a small piece of it from the bar and harden it, noticing the amount of heat necessary to produce desired results. If this is not done, trouble may follow when the article is hardened. It is better to experiment with a small piece of steel than with a costly tool.

Do not use any but *chemically* pure lead in a crucible intended for heating tools, or you will not get as good results as you might otherwise have.

Do not think that because the surface of red-hot lead appears to be at about the proper heat, that the contents nearer the bottom of the crucible are necessarily of the same temperature; because, generally speaking, the deeper you place a piece of steel in the contents of the crucible the hotter it becomes. Being ignorant of this fact, workmen spoil many valuable articles, and then think the lead has an injurious effect on the steel, not knowing that it is the amount of heat given rather than the method used in applying it that caused the trouble. Impure lead will injure the surface of the steel, but will not alter the appearance of the grain if the temperature is right.

Remember that steel heated for annealing should not be subjected to heat for a longer period of time than is necessary to produce a *uniform* heat of the desired temperature. Steel overannealed does not work as well in the various operations of machining, neither will it harden and temper as satisfactorily as though properly treated.

Remember that heating is a process of softening steel, and cooling is a hardening process. The slower the process of cooling is carried on the softer the steel will be; consequently, it is never advisable to place red-hot steel that needs softening in cold or damp lime or ashes.

Always use a clean fire. Dirty slack fires are a source of a great amount of trouble, as they cause the surface of the steel to be covered with a sulphurous oxide.

A fire of new coals should be used (when using a charcoal fire) for heating steel. Dead coals require more blast than is good for the steel.

Ten pieces of steel are cracked as a result of *uneven* heating to every one that is the result of a defect in the steel.

Do not think that because the surface of a hardened piece of steel is not scaled that it is not overheated. Every degree of heat given it above that necessary to produce the desired result unfits the steel for doing the maximum amount of work possible for it to do.

Always harden on an ascending heat. Never heat a *little* too hot and allow to cool down to the *proper* heat,

as the grain of steel remains in the condition the last heat leaves it. To refine, it is necessary to allow it to cool off, and then reheat to the proper hardening heat.

It often happens that the hardener is blamed for things he is entirely innocent of. A man in this position is liable to have enough spoiled work to account for that is the result of his own carelessness or ignorance without being obliged to shoulder the shortcomings of others. It may be that some careless blacksmith has forged a tool at heats which unfitted the steel for the purpose for which it was intended. He may have heated the steel too hot, and opened the grain, causing brittleness, or he may have had uneven heats when he was forging, thus setting up internal strains which would cause the steel to crack when hardened. Then again, the tool maker may have attempted to straighten the piece without heating it red-hot, in which case it is almost sure to spring when hardened. Or, in the case of a long reamer or tap, the flutes may have been milled with a dull cutter, which would, of course, get duller the longer it was used, with the result that by the time the last flute was milled the tool would have been stretched very materially. This is especially true on the side where the last cuts were taken, as the cutter would be duller than when the flutes on the opposite side were milled, and the uneven stretching of the stock would, of course, spring the reamer.

Another difficulty would also present itself. The dull cutter would glaze the surface of the tooth that came in contact with the dulled portion of the mill, and any surface of steel which is glazed, whether it be from the action of cutting tools or grinding wheels, will not harden in a satisfactory manner. This difficulty is more pronounced in the case of a piece glazed from the action of grinding wheels. While a glazed surface might not be considered objectionable, if it was to be ground away after hardening, yet it is not always considered advisable to grind the cutting faces of reamer and milling machine cutter teeth. There is no good

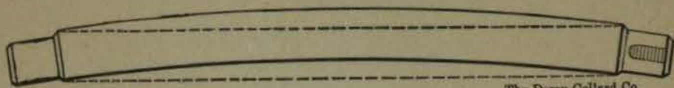


Figure 156. The spring of a mandrel.

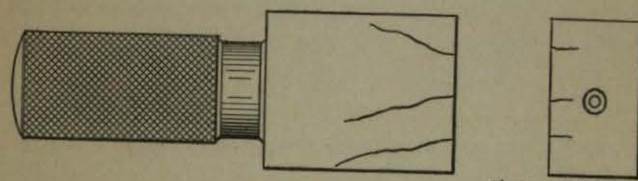
excuse for using dull tools when machining steel. Not only does it lead to trouble when the pieces are hardened, but it is a means of wearing the tools out much faster than if they were kept sharp. Neither can as much nor as good work be done with dull tools.

It is often the case that a careless workman will mill the flutes in a long reamer, tap, or similar tool, without supporting the work properly. In this way the tool is sprung, first one way, then the other. This not only results in a crooked tool, but there is no knowing where it may go when hardened. Many times hardened pieces are sprung by heating when grinding. This is especially true with pieces that may have sprung when hardened. Take, for instance, a long mandrel which may have gone in the direction shown in Fig. 156. Now, if this mandrel were placed in a grinder and ground in a manner that caused it to become heated on the side that is already curved out, as shown in cut, it would spring still more.

Many times thin, flat pieces are sprung from the

expansion of one side when ground in a surface grinder. The side which comes in contact with the wheel becomes heated, while the opposite side, from contact with a mass of cold iron—the table—remains cool. The side which heats must expand, with the result that the piece is curved in the direction of the heated side.

When flat pieces which are hardened are ground with a glazed wheel or one too fine for the purpose, they are very liable to crack, commencing at the edge or end where the wheel leaves the work. Fig. 157 represents a rectangular gauge which cracked as a result



The Derry Collard Co.

Figure 157. Cracked gauge.

of grinding. The fault was laid at the hardener's door, and he, poor fellow, was doing his best to harden the gauges in a satisfactory manner, so he said the steel was no good. An investigation showed the cracks to be from the end where the wheel left the gauge when grinding in the surface grinder. The vise which held the piece was turned one-quarter way around, and it was found that the cracks were from one *side*, instead of the end of the piece. An examination of the wheel revealed the fact that it was too fine for the purpose, and that it was badly glazed. A coarse wheel, free from glaze, was substituted and the gauges were found to be sound after grinding.

Not only may hardened steel be sprung and cracked from heat generated when grinding, but it may also be cracked if water is run on it, unless due care is observed. If the operation is hurried to the extent that it becomes heated, even when the water is running on it, the water cools the piece, which is instantly heated again and then cooled. This sudden expansion and contraction causes the steel to become cracked in innumerable places, these cracks running in all directions. This trouble may occur when grinding pieces of almost any shape. The cracks may occur on the surface of a cylindrical piece, on the flats of a square, or on the face of an article being ground. Fig. 158 represents a disc whose face was cracked, as represented, when ground, with a stream of water running on the work. The fault did not lay in using water, but in forcing the grinding faster than the wheel could properly cut the metal.

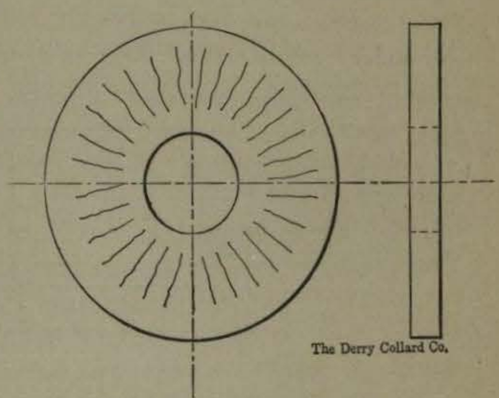


Fig. 158. Disc cracked from being ground too rapidly.

These few facts are pointed out, because it often happens that when these troubles arise, the party doing the hardening is blamed, and unless he is sufficiently

versed in the action of emery wheels on surfaces of steel, he naturally thinks the fault is either in the steel or in his method of treating it.

Very often milling machine cutter teeth are softened when ground, the hardener being blamed as a consequence. It is not good practice to use a very fine wheel when grinding tools of this description, neither should too hard a wheel be used. Ordinarly an emery wheel made of 60 to 90 emery will be found about right, and be sure the face of the wheel is not glazed. Should it become glazed, use a piece of emery wheel somewhat coarser than the one in use to remove the glaze. This also makes the face of the wheel open, and lessens the liability of heating.

Many times the writer has seen workmen using a tool ground in a manner that made it impossible for it to *cut*. It was forced into the stock, and broke it off. The tool could not stand this treatment, and gave right out, the workman in the meantime saying things about the hardener. When the tool was properly ground, it worked all right.

Some mechanics do not seem to realize that there is a proper speed to run stock or cutting tools, in order to get desired results. As a consequence, they either run them much too fast, with the result the tools can not stand up, or they are afraid they will exceed the proper speed, and, as a consequence, do not produce anywhere near the amount of work they might.

When cutting a key way or spline in a tool that is to be hardened, the tool maker should avoid sharp corners, as they are an invitation for a crack when the steel is rapidly cooled in the bath. While an article having sharp corners is not as liable to crack when hardened by the process termed Pack Hardening as when treated in the ordinary manner, it is not advisable to in any way weaken a tool, or give it an invitation to crack. Consequently, avoid sharp corners as far as possible, or cuts or deep scratches that tend to weaken the article.

A milling machine cutter, made with light, weak teeth, can not be made to stand up when in use; the teeth being slender and weak, break like pipe-stems. Cutters with teeth of this description require greater care when hardening, to avoid overheating. Being slender, they spring and break. Do not blame the hardener if they fail to give satisfaction when in use.

Another source of trouble is fine teeth in milling cutters, reamers, and similar tools. The teeth, being fine, fill with chips, and in the case of milling machine cutters, the oil not being able to get to the teeth, can not conduct away the heat generated, which has the effect of drawing the temper to a degree that makes it impracticable to use them.

A short time ago the writer's attention was called to a side tool for use in an engine lathe. The tool was made from a well-known brand of steel, which is generally considered one of the best steels on the market. It was claimed that the tool could not be made to keep an edge on a mild grade of machine steel running at a periphery speed of 30 feet per minute, taking a fair cut.

An examination of the tool revealed the fact that it was ground in such a manner that the cutting edge had no backing. It might possibly have stood up if the material being machined had been wood instead of steel. Because the tool would not stand, the hardener was considered as being to blame. When

properly ground, it stood up all right *without* re-hardening.

Milling machine cutter teeth are many times ground with too great an angle, and the cutting edge, not having backing, gives way. Or it may not be given as much clearance as it should have. As a consequence, the heel of the tooth rubs, and the friction resulting trom this contact of the heel of the tooth with the material being machined produces heat, which softens the tooth. It is tried with a file, found to be soft, and the hardener is blamed.

Many times the liquid supplied to keep cutting tools cool, and to lubricate the cutting edges, can not reach the cutting edges of the tool. As a consequence, it becomes heated and the temper drawn. This is especially liable to happen to tools used on automatic screw machine work, where heavy cuts are being taken.

Twist drills, used in drilling very deep holes in steel, are very liable to receive insufficient lubrication, unless supplied with oil tubes, because the oil which is fed down the flute is forced back by the action of the chips and the angle of the flutes.

Taps are allowed to become clogged with chips, and break; the hardener is blamed, because the tap, it is claimed, is too hard. Broaches break from the same cause, and the trouble is placed at the hardener's door. Reamers are allowed to become clogged, the cutting edge chips off, and it is said the steel is burnt.

Cases of this character might be enumerated by the thousands, but it is needless. The tool maker should bear in mind that a place must be provided for the chips made when a tool is cutting, or roughly machined surfaces or broken tools (possibly both) must follow.

Welding.

When it is considered necessary to join two pieces of iron, thus making them one, or when it is desirable to join the two ends of a bar, thereby making a ring, it is accomplished by the process called welding.

This is of inestimable value as applied to the mechanic arts. Not only may iron be welded to iron, but steel may be joined to steel by this process. Iron may also be joined to steel.

It is accomplished by heating the metal to a temperature that makes the surface of a pasty consistency, which for soft steel should be a dark white, for iron a scintillating white, while for tool steel it should be a bright yellow. The formation of a soft pasty layer on the surface of the steel is an absolute necessity, in order to effect a union of the pieces of metal. This operation is assisted by scattering fusible substances on the surfaces to be united, as these protect the work from oxidation. These substances are termed *fluxes.* Among those most commonly used are borax, clay, potash, soda, sand and sal ammoniac. Ordinary red clay, dried and powdered, is an excellent flux for use when welding steel, and is one of the cheapest known. Borax melted and powdered is called the best of known fluxes, but it is so expensive when used in large

quantities, that its use is confined to the finest tool steels and alloy steels where it is not possible to heat the metal as hot as a lower grade of steel.

A very good flux, whose cost is about one-half that of borax, is a mineral barite, or heavy spar. It does not fuse as readily as borax, however, but forms an excellent covering for the heated surface of the steel. It is necessary to furnish this coating for the surface of the steel, in order to prevent oxidation; for if any portion is oxidized, no matter how small the portion may be, it furnishes a starting point for a break or fracture when the piece is under heavy stress. Although steel may be welded, it is a job to be avoided when the welded piece requires hardening.

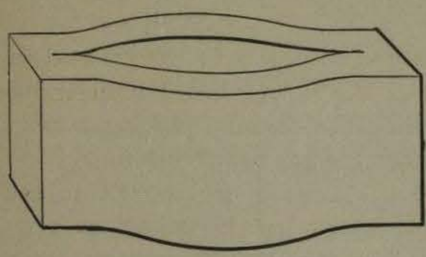
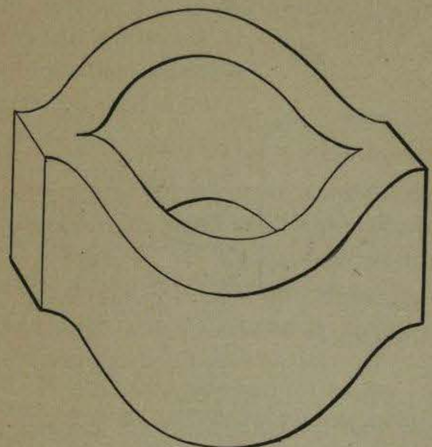


Figure 159. First operation on special swaging die.

Pieces are welded and afterwards hardened which remain intact, but it is not advisable unless the weld is to be made by a smith skilled in this particular branch of the business, and even then it is attended with varying results.

The writer was at one time connected with a manufacturing concern who built 50 machines for swaging wire. The operation of reducing the diameter of the wire was accomplished by dies known as swaging dies. These were actuated by hammers working inside of a large ring. This ring was made of tool steel, and in order to save expense, it was considered advisable to take flat steel of the desired size to allow for finishing all over, bend in the form of a ring and weld the ends. A very skillful smith was given the job, but when finished and hardened, the rings broke apart at the weld. When broken to examine the grain, it was evident that the smith had used extreme care, yet a small portion of the welded surface was found to be oxidized; consequently, it could not unite at that place, and a rupture started from that point.



The Derry Collard Co.

Figure 160. The special swaging die finished.

The method of procedure was changed, stock sufficiently large was procured and split, as shown in Fig. 159. It was then opened until it resembled Fig. 160, and was afterward hammered to shape. Before shaping by hammering, however, the sharp corners were removed by means of a chisel. After machining to the desired size to allow for grinding, they were hardened as described under Hardening Large Rings, with the result that not one was lost.

While steel can be welded if great care is used, it is very apt to result disastrously if the steel is to be hardened. Not only has this been the writer's ex-

perience, but it seems to be the experience of most practical writers on the subject.

Other Things.

Substitute for Borax.

The following rule for preparing a substitute for borax for use in welding high carbon tool steel was given the writer several years ago by a blacksmith who was considered as an expert in welding steel. He claimed that steel could be welded by use of this flux at a lower temperature than is required with borax:

Copperas	2 ounces.
Common Salt	6 "
Saltpetre	1 ounce.
Black Oxide Manganese	1 "
Prussiate of Potash	1 "

All pulverized and mixed with 3 lbs. good welding sand.

Charred Leather.

While it is possible to purchase charred leather of a desirable quality, so much depends on the condition of this article that it is always advisable to prepare it in the shop where it is used, if possible.

Use heavy leather, as scraps left when shoe soles are punched. Never use light leather, as there is little goodness in it after charring. The very best article for the purpose can be procured from shoe shops.

To char the leather, fill one or more hardening boxes with small pieces, place the cover in position and seal with fire-clay. Place in the furnace, leaving it just long enough to char sufficiently, so it can be pounded fine. Do not expose it to the action of heat long enough to destroy the "*goodness*" of the leather.

A very satisfactory method is to fill boxes, 9x9x36 inches, with the leather scraps, sealing the covers as described, and placing them in the furnace at night after the work has been withdrawn. The remnant of fire and the heat of the furnace are sufficient to char the leather during the night. As previously stated, do not overchar. It should be exposed to the action of heat only long enough to break in pieces readily when pounded. If smaller boxes are used, it is not advisable to leave in the furnace over night. They must be watched, and taken out when the leather is charred sufficiently.

Charred Bone for Colors.

It is necessary, in order to obtain nice colors, that the work be polished and absolutely clean; unpolished surfaces will not color. Grease also prevents the obtaining of satisfactory work.

Pack the work in boxes as previously described, except that charred bone is used as packing material. When it has run the proper length of time, remove the box from the furnace, and dump into a tank of water having a jet coming up from the bottom. Better colors are obtained if a bath is used having an air pump con-

nected with the inlet pipe, as illustrated in Fig. 134. This shows an easy way of putting in an air pipe, connected with inlet water pipe. Soft water in the bath gives much better results than hard, although very satisfactory results may be obtained with hard water if the air pipe is connected as described. When hardening for colors by the method under consideration, it is essential that the box be held very close to the top of the water when dumping the work; the box should be inverted quickly, to prevent the air striking the work before it reaches the water. If the air comes in contact with the metal, the surface assumes a blue-black color. This is sometimes desirable, but not in connection with work packed especially for hardening for colors.

When the work is cold, it may be removed from the bath and boiled in clean water. Dry in sawdust, and oil the surface either with sperm oil or vaseline. This has the effect of making the colors more prominent, and it will also keep the steel from tarnishing or rusting.

To Char the Bone.

It is sometimes considered desirable to use bone rather than leather, and it is thought that the expended article would not give the necessary hardness. Yet it may be necessary that the articles be tough. This may be accomplished by taking raw bone, filling a small hardening box with it, placing the cover in position, and sealing with fire-clay. When the day's work of hardening is taken from the furnace, the box may be placed in it, the door shut, the fire extinguished, and the box left until morning. If the furnace is one 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