If you are reasonably sure the steel used was practically free from injurious impurities and is low in carbon, it may be dipped in a bath of water or brine. Should there be any doubt as to this, dip in raw linseed oil.

If the article being hardened is a cutting tool, or something requiring a fine, compact grain, better results will follow if it is left in the box after being subjected to the action of carbon, the box removed from the fire, and the whole allowed to cool. When cold, the article may be reheated to a low red, and hardened.

While the writer has used a low grade steel in making various forms of tools, and had excellent results when they were put to the use for which they were intended, he cannot recommend its use, unless the parties doing the work select stock suited to the purpose and exercise due care when hardening.

While this subject might properly be classed under the heading of Case Hardening, it has not seemed wise to the writer to do so, because case hardening, according to the interpretation usually given it by mechanics, is simply a process of transforming the surface of the article into a condition that allows it to become hard if plunged red-hot into water. Hardness is apparently the only object sought, but such is not the case when the subject is considered in its proper light.

When applying this principle to tools, it is necessary to consider the requirements of the tools. Knowing this, it is necessary to proceed in a manner that will give the desired results.

If it is considered advisable to make certain tools of a low grade steel, treating it as described, it is necessary to select steel adapted to the tool to be made.

It is never advisable to use Bessemer steel bought in the open market, because it does not run uniform. Always use open hearth steel, procuring it, if possible, of a quality that will give satisfactory results. Steel, with a very small percentage of phosphorus and other impurities, may be obtained from any reliable maker, if the purpose for which it is to be used is stated when ordering.

Special Steels.

To one interested in working steel, the history of the development of this industry furnishes a remarkably interesting study.

Steel may be grouped under four general heads, the name given each class being selected on account of the method pursued in its manufacture.

Probably the oldest of all known steels is the cemented or converted steel. This steel is made by taking iron in the form of wrought iron bars, packing them in a fire-brick receptacle, surrounding each bar with charcoal. This is hermetically sealed, and heat is then applied until the whole is brought to a degree of heat that insures the penetration of a sufficient quantity of carbon. Experience proves that carbon will penetrate iron at about the rate of one-eighth of an inch in twenty-four hours; and as bars of about three-quarter inch thickness are generally used, it requires three days for the carbon to penetrate to the center of the bar (⅜-inch). The furnace is then allowed to cool, and the iron bars, which are converted to steel, are removed. They are found to be covered with blisters, hence the name, Blister Steel.

When examined, the bars are found to be highly crystalline, brittle steel. When this form of steel is heated and rolled directly into commercial bars, it is known as German Steel.

If blister steel is worked by binding a number of bars together, heating to a high heat, and welded under a hammer, it is known as Shear Steel, or Single-Shear.

If single-shear steel is treated as above, the finished product is known commercially as Double-Shear Steel.

Until within a comparatively few years these three classes of converted steel were practically the only kinds known in commerce.

Crucible Cast Steel.

As this is the standard steel used for fine tools, a brief study of the methods used in its manufacture may be of interest to the reader. Benjamin Huntsman, a clockmaker, is supposed to have been the inventor of this process. It occurred to him that he might produce a more uniform and satisfactory article than was to be had at that time for use in manufacturing springs to run his clocks. The method he had in mind consisted in charging into a crucible broken blister steel, which was melted to give it a homogeneous character.

While Huntsman thus founded the crucible steel industry, which has been of incalculable value to the mechanic arts, he met with many difficulties. These have been overcome by later inventions, notably those

of Heath and Mushet, until to-day it is possible, with skill and care, to produce a quality of steel which, for strength and general utility, has never been equaled, despite the claims of some blacksmiths that the steel of to-day is not as good as that produced 25 to 50 years ago.

Competition has rendered it necessary to run cutting tools, or stock, as the case may be, much faster than was formerly the case, which made it necessary to make steel containing a higher percentage of carbon than was formerly the case. As stated in a previous chapter, when high carbon steels are used, it is necessary to exercise great care in heating for the various processes of forging, annealing and hardening, As high carbon steels are more easily burned than those containing a lower percentage, it is necessary to put them in the hands of skilled workmen, for, unless the steel is to be worked by men understanding its nature, it proves to be a very unsatisfactory investment, and is often condemned because it will not stand as much abuse as a steel of lower carbon; but if properly treated, will do many times the amount of work.

Alloy Steels.

In order to accomplish certain results, steel is made containing other metals. To distinguish them from steels, which depend on the quantity of carbon present for their hardening properties, they may properly be termed "alloy" steels, the amount of the hardening property present determining the quality of the steel. As these steels can generally be run at a higher periphery speed and cut harder metals than carbon steels, they are very valuable at times, and in some shops are used altogether. As a rule, they are more easily injured by fire than carbon steel, and, consequently, extreme care must be exercised when working them.

When high carbon steel is alloyed with other hardening properties, a steel is produced which will be found more efficient for machining chilled iron than the regular high carbon steels. However, as the nature of steel of this character depends entirely on the amount and kind of the alloy used and the amount of carbon present, no fixed rule can be given for the treatment. It is always best to follow as closely as possible directions received with the steel.

The writer has seen milling machine cutters, punch press blanking dies, and other tools, which were to cut very hard, "spotty" stock, give excellent results, when made from a reliable alloy steel, where carbon steels would not stand up.

If the amount of certain hardening elements be increased to a given point, the steel hardens when heated red-hot, and is exposed to the air. It is styled "Air Hardening Steel," more generally known, however, as Self-Hardening Steel.

Self-hardening Steel.

It was not originally the intention of the writer to mention self-hardening steel, because there are so many different makes of the article, each differing from the other to an extent that the method employed to get satisfactory results, when using one make, would prove entirely unsatisfactory when applied to another.

Self-hardening steel has a field of its own, and is very useful when made into tools for certain work. It

is used very extensively in cutting hard metals, and can be run at a high periphery speed, because the heat generated does not soften the tool, as is the case when carbon steels are used.

No *general* instructions can be given for working the steel, because the composition of the different makes varies so much that the treatment necessary, in order that one brand may work satisfactorily, would unfit another for doing the maximum amount of work possible for it to do.

A very common error in shops where a make of this steel is used, and another brand is to be tried, consists in attempting to treat the new brand in the same manner they have been treating the other, regardless of instructions furnished.

As previously stated, the treatment suited to one brand would render another unfit for use, and as the reputation of a brand depends on the results attained, the makers are very careful when selling steel to state plainly the treatment it should receive. The buyer should see that the directions are followed implicitly.

When purchasing self-hardening steel, it is advisable to investigate the merits of the different makes. In practice, certain brands prove best for cutting cast iron, while another brand, which will not do as much work when cutting cast iron, proves to be more desirable when working steel. Other brands, which give satisfaction when made into lathe and planer tools, prove useless when made into tools having projecting cutting teeth, as milling machine cutters, etc.

As previously stated, the different makes of self-hardening steel require different methods of treatment. One gives best results when worked (forged) at a full red heat, while another requires a much higher heat. As the steel is less plastic when red-hot than most carbon steels, it is necessary to use *greater* care in regard to the manner in which it is hammered. A *heavy* hammer should be used, if a large section is to be forged, as it is necessary to have it act uniformly on the entire mass, or the surface portion will be drawn away from the interior, and, as a consequence, a rupture will be produced. Small pieces should be forged with lighter blows, or the steel will be crushed.

Do not attempt to forge when the temperature is lowered to a point where the steel loses its malleability, or it will be injured.

It is very necessary that a *uniform* heat be maintained throughout the piece. Do not think, when working a small section, that it is safe to forge when it has cooled to a *low* red, because some heavier portion has not cooled below a full red.

Do not allow the steel to cool off from the forging heat. After forging, place the piece in the fire again, and allow it to come to a uniform bright red. Do not allow it to "soak" in the fire, but it should be heated at this time without the aid of the blast. When it has reached a *uniform* red heat, remove from the fire, and allow it to cool in a dry place, not exposed to the action of any draft.

While most self-hardening steels will become hard enough when cooled in the air, it is sometimes necessary to have the tool extra hard. In such cases, it may be cooled in a forced blast. Some steels give better results if cooled in oil, others require cooling in hot oil, while others may be cooled in hot or cold water. Generally speaking, however, it is not advisable to bring

most brands of this steel in contact with water when red-hot.

While it is generally admitted that self-hardening steels are principally valuable for lathe, planer, and similar tools, when cutting hard metals or running at high speeds, there are makes which give excellent satisfaction when annealed and made into such tools as milling machine and similar cutters.

When it is necessary to have the stock in an annealed condition, it is advisable to procure it in this state, as the manufacturer, understanding the composition and nature of the steel, is in a position to anneal it in a more satisfactory manner than the novice. However, if it is considered advisable to anneal it in the factory where it is to be worked, it may be accomplished. Different makes of steel require treatments differing from each other, the treatment depending on the element used to give it its hardening qualities. Some brands may be annealed sufficiently to work in the various machines used in working steel to shape by heating to a bright red and burying in green pine sawdust, allowing it to remain in the sawdust until cool.

Most brands may be annealed by keeping the steel in an annealing furnace at a bright red heat for from twenty-four to forty hours, then covering with hot sand or ashes in the furnace, and allowing to cool. It should be about the same length of time cooling as it was exposed to the heat. It is necessary many times to machine it with tools made of the same quality of steel, on account of the natural hardness and density of the stock. It is claimed that tools made of certain brands of self-hardening steel give better results when cutting chilled iron than tools made of high carbon alloy steels, The writer cannot substantiate this claim, as he has never been able to get as good results as when using an extra high carbon alloy steel, *properly* treated.

However, it is safe to say that used for machining (roughing) work in the lathe, planer, and similar machines, can be made to do many times the amount of work in a given time than would be the case were ordinary carbon steel tools used.

Much better results may be attained, however, than is usually the case, if makers' instructions are implicitly followed.

On account of the rapidly growing popularity of certain makes of this class of steel, many swindles have been perpetrated by unscrupulous parties, claiming to be representatives of a reliable house. A tool made, as they claim, from the steel they were selling is submitted for trial. It proves to be all that could be asked for, and a quantity of steel is ordered sent C. O. D. When this is received and paid for, it is found to be of no use. Parties purchasing steel of any but known and reliable steel concerns do so at a great risk, as a number of manufacturers have found to their sorrow.

Steel for Various Tools.

There is no one topic connected with this work that caused the writer so much anxiety as the one under consideration, because a temper of steel that gives entire satisfaction when used in one shop, would not answer when made into tools intended for the same, or

similar purposes, in a shop situated on the opposite side of the street. This is simply because in one case the operator who forged or hardened the tools understood handling the steel, and in the other case a man totally incompetent was entrusted to do the work.

Then again, steels of certain makes are more free from harmful impurities than others. A steel containing a low percentage of these impurities can safely have a higher percentage of carbon. Certain steels which are low in their percentage of phosphorus can have a greater amount of carbon than other steels which contain more of this harmful impurity.

A tool made of 1.4 per cent. carbon steel low in phosphorus will not cause as much trouble as if made of a 1.25 per cent. carbon steel containing a greater amount of phosphorus, but its capacity for cutting hard metals, and holding its edge when running at high speeds, is much greater.

Knowing the tendency in many shops to use a high carbon steel, and realizing the advantages of so doing, the writer would advocate the use of such steels, were it not for the fact in many cases the results have been anything but satisfactory, because men totally unfit for such work were employed to forge and harden the tools made from them.

But it has seemed wise to give the tempers of tool steel suited for certain purposes, the reader bearing in mind that in many cases it is safe and advisable to use a higher carbon, provided due care is exercised when working it during the various operations of forging, annealing and hardening. As previously stated, steel of a certain make and temper giving excellent results in one shop does not always give satisfactory results in some other shop on the same class of work. Knowing from experience that the variable factor is the man working the steel, rather than the steel itself, the writer has deemed it wise to quote the experience of various steel makers, rather than results of his own personal experience.

Degree of Hardness	Percentage of Carbon	Should be used for
Very hard	1.5	Turning and planing tools for hard metals, small drills, gravers.
Hard	1.25	Tools for ordinary turning and planing, rock drills, mill picks, scrapers, etc.
Medium hard	1.	Taps, screw thread dies, broaches, and various tools for blacksmiths' use.
Tenaciously hard	.85	Cold sets, hand chisels, reamers, dies, drills.
Tough	.75	Battering tools, cold-sets, shear blades, drifts, hammers, etc.
Soft	.65	Battering tools, tools of dull edge, weld steel for steeling finer tools, etc.

While the foregoing table gives the tempers of steel that can safely be used for the purposes specified, it is many times advisable to use steel of a higher percentage of carbon.

Then again, it is sometimes best to use a low carbon steel of good quality, in order to get the maximum amount of toughness in the interior portions, packing the finished tool in a box containing charred leather, as

explained under Pack Hardening, and running for a sufficient length of time to get an extremely hard surface when hardened. By adopting this method, it is possible to get a cutting surface that will stand up when running at a high rate of speed, and yet be strong enough to resist extremely rough usage.

When it is desirable to get the steel *extremely* hard and very deep, in order to allow for grinding, and yet have the tool sufficiently tough to stand up, use a *high* carbon steel, pack in a box as described, running in the fire at an extremely low heat; quench in a bath of raw linseed oil.

In order to provide a guide for use in selecting steel suitable for various purposes, the following list is given. It is the result of the writer's experience, and information picked up here and there. A very noticeable fact, however, must be taken into consideration, namely: mechanics in the same class do not advocate the use of steel of like tempers, even when making tools of the same kind, to do the same class of work under the same, or similar circumstances, so no rule can be given arbitrarily.

The reader should, however, bear in mind that steels, which contain impurities to any considerable degree, cannot safely be used with the percentage of carbon mentioned. But as most of the leading steels on the market have received their standing because they are practically free from these impurities, it is safe when using them to use the percentages of carbon mentioned.

There are several makes of crucible tool steel on the market, which are exceptionally low in their percentage of impurities, and when using these, it is safe to use a higher carbon than the one mentioned, provided due care is used when heating for the various operations of forging, annealing and hardening.

In the following pages the term crucible steel is intended to denote crucible tool cast steel.

The term cast steel is often misunderstood by mechanics, and many are of the opinion that any cast steel is tool steel. Such, however, is not the case, for the products of the Bessemer and open hearth processes are cast steel in the same sense that crucible steel is, yet they are not understood as tool steels, although products of both processes which were highly carbonized have been sold to parties as tool steel.

Arbors for saws.

Saw arbors, and similar articles, when made from crucible steel are made from a stock containing .60 to .70 per cent. carbon. When made from open hearth steel the percentage of carbon is about the same, although some manufacturers claim good results when a lower percentage is used.

Arbors for milling machines.

Milling machine arbors when made from crucible steel give good satisfaction if a steel of .70 to .80 per cent. carbon is used. Unless they are to be hardened, better results are obtained if the steel is worked to shape without annealing, as it is much less liable to spring when subjected to strain in use. In shops where great numbers of these arbors are used crucible steel is considered very costly. In such cases open hearth steel containing .40 to .60 per cent. carbon is often used. Many times a stock containing a higher percentage is used.

Augers.

Augers for wood-work are made from crucible steel of .70 to .80 per cent. carbon.

Axes

are made from crucible steel containing 1.00 to 1.20 per cent. carbon.

Barrels for Guns

are made from crucible steel containing .60 to .70 per cent. carbon, while some manufacturers use an open hearth steel containing .50 per cent. carbon, and others claim to use the same steel with .60 or even .70 per cent.

Centers for Lathes

are made of crucible steel containing .90 to 1.10 per cent. carbon.

Chisels for Working Wood

are made from crucible steel containing 1.15 to 1.25 per cent. carbon.

Chisels for Cutting Steel,

where the work is light, give good satisfaction when made from crucible steel containing 1.25 per cent. carbon.

Cold Chisels,

for chipping iron and steel, work well if made from crucible steel containing .90 to 1.10 per cent. carbon. Trouble with cold chisels is more often the result of poor workmanship than an unsatisfactory steel.

Chisels for Hot Work

may be made of crucible steel of .60 to .70 per cent. carbon.

Chisels for Cold Work,

for blacksmiths' use, are made of crucible steel containing .70 to .80 per cent. carbon.

Chisels for Cutting Stone

are made from .85 per cent. carbon crucible steel.

Cutters for Milling Machine Work

are probably made from a greater range of tempers than almost any other tool used in machine shop work, some manufacturers never using a steel containing over 1.00 per cent. of carbon, on account of the liability of cracking. Cracking is, however, a result of careless working, and as much more work can be done in a given time with a cutter made from a high carbon steel, it is, generally speaking, advisable to use such steels. Cutters, 2 inches and smaller, may safely be made from crucible steel containing 1.25 to 1.40 per cent. carbon. Cutters, 2 to 3 inches, 1.15 to 1.25. Larger than 3 inches, or if of irregular contour, 1.10 to 1.20 per cent. carbon. There are several alloy steels on the market which give excellent results when made into cutters of this character, provided extreme care is taken in heating.

Cutters for Pipe Cutting

may be made from crucible steel containing 1.20 to 1.25 per cent. carbon.

Cutters for Glass

are made from crucible steel containing 1.25 to 1.40 per cent. carbon.

Dies (Threading) for Bolts

and similar work, made from stock having rough, uneven surfaces, may be made from crucible steel containing .70 to .80 per cent. carbon. However, when the dies are hardened by the process described under Pack Hardening, steel containing 1.00 to 1.10 per cent. works nicely, stands well, and holds a good edge.

Dies for Screw Cutting,

to be used by hand or in screw machine, may be made from crucible steel containing 1.00 to 1.25 per cent. carbon.

Dies for Blanking or Punch Press

work are made from crucible steel containing .90 to 1.10 per cent. carbon. When the articles to be punched are small, and the stock to be worked is hard, steel containing 1.00 to 1.25 stands better than the lower carbon steel for small dies. Some manufacturers use a steel containing 1.25 to 1.40 per cent. carbon, provided it is low in percentage of impurities. When the work is not of a shape that requires great strength on the part of the die, open hearth steel containing .40 to .80 per cent. carbon is used. The die in this case should be hardened according to directions given for hardening tools made from machine steel.

Dies Used for Swaging

metals are made from crucible steel, the percentage of carbon varying according to the character of the work to be done. When the die is not to be subjected to very severe usage, a steel containing .90 to 1.10 per cent. of carbon may be used. Where a deeply hardened portion is desirable, a steel containing 1.20 to 1.25 per cent. works nicely.

Drawing Dies

are made of crucible steel containing 1.20 to 1.25 per cent. carbon.

Dies for Drop Forging.

As the product of different steel manufacturers varies so much, and the requirements are so varied for work of different kinds, it is advisable to submit the article to be made to some reliable steel manufacturer, letting him furnish a steel especially adapted to the work to be done. Ordinarily a crucible steel is used containing .40 to .80 per cent. carbon. However, many manufacturers consider it best to use a good quality of open hearth steel containing the proper percentage of carbon. Small dies, or those having slender portions requiring great strength, are made of the higher carbon.

Drills—(Rock Drills),

for quarry work, are made of crucible steel containing 1.10 to 1.25 per cent. carbon.

Drills—(Twist).

Small drills are made of crucible steel of 1.25 to 1.50 per cent. carbon, while larger drills require a steel of 1.00 to 1.25.

Files

are made of crucible steel of 1.20 to 1.40 per cent. carbon. Files of inferior quality are made of open hearth steel.

Hammers for Blacksmiths

use are made from crucible steel of .65 to .75 per cent. carbon.

Hammers for Machinists'

use are made from crucible steel of .85 to 1.15 per cent. carbon. For the ordinary sizes steel containing 1.00 per cent. works nicely.

Hardies for Blacksmiths

are made of crucible steel of .65 to .75 per cent. carbon.

Hobs for Dies

are made of crucible steel of .90 to 1.00 per cent. carbon, when they are to be used for cutting a full thread in a die. If they are to be used for sizing only, a steel containing 1.20 to 1.25 may be used, as it will hold its size and form longer than if made of steel containing less carbon.

Jaws for Bench Vises

are made from crucible steel of .80 to .90 per cent. carbon. Open hearth steel is, however, extensively used for this purpose.

Jaws for Chucks

are strongest if made of crucible steel containing .85 to 1.00 per cent. carbon, although many times they are made from a good quality open hearth steel.

Jaws for Cutting Pliers

are made from crucible steel containing 1.10 to 1.25 per cent. carbon. When they are to be used for cutting piano or other hard wire, they are made from steel containing 1.40 to 1.50 per cent. carbon.

Jaws for Gripping

work in various fixtures are made from crucible steel of .80 to .90 per cent. carbon.

Jaws for Pipe Machines

are made from crucible steel containing 1.00 to 1.20 per cent. carbon.

Jaws for Screw Threading Dies,

having inserted jaws or blades, are made of crucible steel of 1.00 to 1.20 per cent. carbon.

Jaws for Wire Pullers

are made from 1.00 to 1.20 per cent. carbon crucible steel.

Knife Blades.

When crucible steel is used, a stock containing .9 to 1.00 per cent. carbon is selected.

Knife Blades,

to be used for whittling and general wood-working, are made from 1.10 to 1.25 per cent. carbon crucible steel.

Knives—Draw Knives

are made from crucible steel of 1.20 to 1.25 per cent. carbon. Many times, however, they are made of open hearth steel.

Lathe Tools

for ordinary work are made of crucible steel containing 1.25 per cent. carbon. For turning hard metals or running at high rate of speed, use steel containing 1.40 to 1.60 per cent. carbon.

Lathe Tools.

For turning chilled iron, a high carbon alloy steel works better than a straight carbon steel.

When it is desirable to run at very high speeds, use a self-hardening steel.

Machinery Crucible Steel

contains .55 to .65 per cent. carbon.

Mandrels.

Custom differs in various shops. Some mechanics consider it best practice to make mandrels up to and including 1 inch of crucible steel, and for sizes above 1 inch advocate the use of machine steel, case hardened. Others claim best results from crucible tool steel for all sizes. Mandrels, however, do not require a steel containing as high a percentage of carbon as cutting tools. Small mandrels give good satisfaction when made from steel of from 1.00 to 1.10 carbon, larger sizes made of steel containing .80 to 1.00 per cent.

When mandrels are hardened by the process known as Pack Hardening, a steel containing .75 to .90 per cent. will give excellent results.

Mowers.

Lawn mower knives, .90 to 1.00 per cent. crucible steel, although in many instances they are made from open hearth steel.

Planer Tools for Stone,

.75 to .90 per cent. carbon crucible steel.

Planer Tools for Wood-working

machinery are made of crucible steel containing from 1.10 to 1.25 per cent. carbon.

Planer Tools.

If the tools are large and the metal to be machined is comparatively soft, crucible steel containing 1.25 works nicely. If, however, high speeds are desired or the metal to be cut is hard, a steel containing 1.40 to 1.50 per cent. carbon gives better results, provided care is exercised in heating for forging and hardening. If the stock to be cut is extra hard or it is desirable to run at speeds higher than is practical when using tools made from carbon steels, it is advisable to get a reliable self-hardening steel.

Punches for Hot Trimming,

.85 to 1.00 per cent. carbon crucible steel. Some mechanics claim as good results if the punch is made of open hearth steel of .60 to .80 per cent. carbon, while others make both punch and die of open hearth steel. These tools may be hardened in the ordinary manner or they may be hardened according to directions for hardening tools made of machine steel.

Punches for Blanking Work

in punch press. The percentage of carbon desirable depends on the stock to be cut and the skill of the operators doing the hardening If crucible steel is used, a range of .90 to 1.25 per cent. carbon is allowable, depending on the character of the work. Many times, however, such punches, if of a shape and size that insures strength, are made of .40 to .80 per cent. carbon open hearth steel, and hardened as explained under Making Tools of Machine Steel.

Punches for Blacksmiths

should be .80 to .90 per cent. carbon crucible steel

Punches for Railroad Track Work,

about .85 per cent. carbon crucible cast steel is advisable.

Reamers.

Small reamers, which are to be used continuously, should be made from crucible steel of 1.25 to 1.50 per cent. carbon. When they are to resist great strain, steel of 1.00 to 1.25 per cent. may be used. Excellent results will follow if steel containing .90 to 1.10 per cent. carbon is used, and the reamer hardened by the method described under Pack Hardening. This is especially true if the reamer is long or slender, or of a shape that betokens trouble when it is hardened.

Saws (Circular) for Wood,

about .80 to .90 per cent. crucible steel.

Saws for Cutting Steel

are made from 1.25 to 1.50 per cent. crucible steel.

Scrapers for Scraping Surfaces,

1.50 carbon crucible steel. Although many scraper hands claim best results from using a high carbon alloy steel.

Screw-Drivers,

small, .90 to 1.00 per cent. crucible steel; large, .65 to .80 per cent.

Stamps for Stamping Steel,

1.25 to 1.50 per cent. carbon crucible steel.

Shafts for High Speed Machinery

are many times made from crucible steel, containing .65 per cent. carbon.

Spindle Steel,

same as shafts.

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 pei 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