WARREN S. CASTERLIN.

Steel Working and Tool Dressing

A Manual of Practical Information for
Blacksmiths and All Other Workers
in Steel and Iron

By

WARREN S. CASTERLIN

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FOREWORD.

While many of us are engaged in different vocations, we are all trying to add to human joy and happiness. Every human being is born with defects for which he cannot be held responsible. The wants of the savage are few, but as civilization increases, the intellectual horizon widens and the brain demands more and more. Every human being longs to be happy, to satisfy the wants of the body with food and with raiment, also to feed the mind according to its capacity, with wisdom, love, art, philosophy and song. Man has advanced just in proportion as he has mingled thought with his work; just in proportion as he has succeeded in getting his hands and head into partnership. Every brain is a field where nature sows the seeds of thought, and the crop depends upon the soil.

To those who lack breadth of mind and depth of thought, who thus are looking for the elixir of life—for some philosopher's stone—I say drop the miraculous and superstitious. We know that in mechanics nature is supreme and that the attraction of gravity will always remain the same. We know that the relation between circumference and diameter can never change. No intelligent mechanic dreams of depending upon or asking any supernatural aid. He knows that he works in accordance with certain facts and that the laws of science are as unchangeable as the sun in its journey through the heavens.

Every science rests on demonstrated facts. Ignorance being darkness, what we most need is intellectual light. One of the most important things to teach is that the universe is natural, that man must be the teacher of man and that by the development of the brain we can avoid many of the dangers, some of the evils and obstructions, and take advantage of some of facts and forces of nature. By invention and industry we can supply to a reasonable degree the wants of the body, and by thought, study and effort we can in part satisfy the hunger of the mind.

PREFACE.

Mechanics, in searching for scientific and practical knowledge, naturally turn to those whose experience has been long and varied. Mine covers a period of more than half a century, and in distributing this information to my brother blacksmiths it is my aim to give information that is impossible to get at colleges and technical schools, and at a price which is within the reach of all.

My knowledge has been acquired by study and travel from the Atlantic to the Pacific, through thirty-five states, and from the extreme north of Canada, through the southern states, to the Gulf of Mexico. Many things contained herein have cost me much money and time.

If any reader find anything here in which he is not interested let him pass it by, as there are others who may appreciate it. I don't expect to please everybody. Some may say I have been too general in my remarks, while others may say I have taken up too much time in minor details.

I may say that my education, outside of practical experience over the anvil, consists in what I could gather in a term of less than six months in a country school, but as this book was written solely for the benefit of my brother blacksmiths, some of whom have no more education than myself, all will probably understand the language and terms I have used, which are common in the smith shop, much better than if technical terms were used that the mass of mechanics know nothing about.

It will be my aim to do the greatest good to the greatest number, and this includes the smith of village and country. These mechanics are as a rule after knowledge and information and are willing to accept it, no matter whence it comes. The very brightest smiths I have instructed out of several hundred came from the country villages and rural districts.

The all-important questions with the smith are: Is my argument sound? Is it based on common sense and logic, or have my 57 years at the anvil in many of the largest and best shops in the United States been a failure? As to this my readers will be the judge.

The time is past for doing work by main strength and by guess. We are doing it in these days upon scientific principles, with good tools and a knowledge of how to use them.

It is needless to say that I am indebted to other practical men for much information of value, and wish to give the fullest acknowledgment to the knowledge I have gained thereby. I recall the names of many, but A. L. Davis, of the Ludlum Steel Works, Pompton, N. J., gave me more information in relation to steel and its treatment than any man I ever saw. As I do not want to wear "borrowed plumes," I cannot refrain from thus giving him personal credit.

I shall not try to impress upon your mind that I am the only man in the United States who can work cast steel, but I do say to you that I am probably the only blacksmith in North America that has made cast steel a special study for more than half a century. I have worked in more different shops, done more traveling, and spent more time and money to perfect myself in the art of steel working than any other man on the continent. The lamented Garfield once said, " I would rather be right than be President." I would rather be right among enemies than be wrong among friends. Yet I want the friendship of every brother smith. I want to give my brother mechanics as much knowledge as possible upon various matters, and what I do must be given here, for I shall never revise this book again. I have tried to do my duty. I have been cautious at every stroke of the pen. I have reached back over my eventful years of continuous work on cast steel, tool making and tool dressing, with a view to setting up guide boards to warn my brother mechanics of the dangers that lurk along their pathways.

The weight of years and the effects of hard work both mentally and physically are bringing me near the end; seemingly it is almost in sight, and it is my earnest desire when the time comes for me to pass to the Great Unknown that the pupils I have instructed can join hands in saying, " He was our friend and benefactor. Peace be to his ashes."

THE AUTHOR.

Steel Working and Tool Dressing.

The Apprentice Question.

The cry among blacksmiths is, " There is no one learning the trade." To me it is no wonder, when I am so familiar with the class of work that the apprentice is put at for the first six months or a year, the tools he has to work with and some of the shops he has to work in—many of them with no fire or heat of any kind when the weather is from 10 to 20 degrees below zero. Some of the shops are without windows and some are without doors.

Now, reader, draw your own conclusion as to what the blacksmith must be that will accept and endure such conditions and make no effort to improve them. When a boy that has been raised in a good family, and has some education and at least a thimbleful of brains, steps into such a shop just mentioned and sees the conditions generally, it drives him back to the plow, or to the city, which in my opinion is far worse.

Let me give you a little sketch of what I have seen scores of times, in shops where I have worked. Here comes Johnny Brown, who is to enter upon his first day of apprenticeship, and as he enters the shop a broad smile comes over his face, carrying with it an air of satisfaction, to think that he is going to learn a trade. But as I look at him I cannot help but feel sorry for him, and my feelings are magnified and multiplied by the thought of what I have passed through and had seen so many times.

Johnny takes off his coat and hangs it up. He steps up to the blacksmith, or "boss," as some of them like to be called, and asks what he shall do. He is told that he can blow the fire and strike. In a moment in comes a team of horses to be shod that weigh about 1500 lbs. each. The blacksmith tells him to sweep off the mud, or sand, from their feet, as the case may be, and then to pull off the shoes. Bear in mind that this is his first day in a blacksmith shop.

Johnny gets the shoeing box and after trying to cut the clinches, about which he has had no instructions, he takes the pinchers and begins to pull off the shoes. He gets the pinchers fast under the shoe and is wringing and twisting to get them out. The horse makes a lunge and jerks its foot away from the boy, the pinchers being fast in the shoe, and the next move the horse makes it upsets the shoeing box. This frightens the other horse and it makes a side jump, setting its foot on top of Johnny's. By this time the other horse steps in the shoeing box, and begins to switch her tail, squeal and kick, and if Johnny is not mixed up with the shoeing box under the horse's feet he can consider himself lucky. The blacksmith shouts to the boy,

"Didn't you know better than that?"

I ask why he should expect that boy to do differently. The blacksmith had never given him any instructions, had never shown him how to cut the clinches, as he should have done, nor did he tell him how to rest the foot on his knee when pulling off the shoes. This is just the proper time for some one to say to Johnny,

" Better put on your coat, and go home and help your father till the soil and get your bread and butter much easier than wrestling with kicking horses for which you will get only a few cents per day, and there will not be one-tenth part of the danger."

After Fifty-Seven Years.

Now, Mr. Reader, if you are a horseshoer, you mighty well know that what I have related is the truth. Bear in mind it does not come from the pen of a newspaper reporter, but from a practical blacksmith that has been working at the business for 57 years and well knows whereof he speaks.

I am not trying to discourage young men or boys from learning some mechanical occupation, but I am trying to discourage boys and young men from accepting and enduring such hardships, methods and customs as have been in vogue in Europe for several centuries and in this country for many years. However, I am glad to be able to say that the custom of binding out a boy to stay or serve a certain length of time at a trade regardless of abuse is a thing of the past. What an absurd idea to think of serving seven years under a " master " as they styled themselves, to learn what should be and can be learned in two years; yes, less. Life is too short to waste in that way. For if we are going to get any comfort out of this life, we must get it some time between the cradle and the grave.

The great trouble has been and is yet that the mass of blacksmiths don't want the boys of this advanced age to have any more advantages or comforts than they had when they were apprentices. How many times I have heard blacksmiths say,

"That is the way that I had to do when I learned my trade."

They never let a chance slip to tell about learning their trade and how long they served. They want all beginners to follow in the rut of ignorance and superstition that they followed, regardless of the advantages this advanced stage of civilization has to offer our young men.

I once knew a very bright mechanic who, whenever he saw anything in the works of nature that at times seemed to clash with other things, would remark, "That is one of Mother Nature's mistakes," and I think the class of blacksmiths that I have been describing are some of Mother Nature's mistakes. But don't think from what I have said that all blacksmiths are of the type just mentioned, for you will find some just as good men that have followed blacksmithing as you will in any occupation or walk of life. And why not? In considering the requirements of this trade, it should be composed of the very best of brain and brawn, depth and breadth, that Mother Nature is capable of producing.

The trade of a general blacksmith requires more brains, more deep thought and sound reasoning—more stick-to-it-iveness and determination—than any other three trades combined. When I say this I refer to the whole smithing business, which includes the working of iron and steel in every branch of forging.

This unpleasant, dangerous, slavish work, which the apprentice has to endure in the average blacksmith shops does not end there. It is the same in locomotive and machine shops. I have seen the smith in locomotive shops have a big, heavy heat, and two helpers swinging sledges of from 15 to 20 lbs. weight until their faces were as red as the hot iron, with their veins swollen to double their normal size, and their hearts making more than double the usual number of beats, and the perspiration running and not a dry thread of clothes on them, with the thermometer at 90, and doing this in a shop with no ventilation to let out either smoke or gas, and the smoke so dense that you could not see half way across the shop. The men that were doing this work were getting perhaps $1.50 per day and the smith perhaps $2.75; while the timekeeper, clerks and draughtsman were getting from $4 to $5 per day. Yet, it does not take one-half as long for the draughtsman to prepare himself for his position as it took the farrier or smith.

Discovery of Cast Steel.

Cast steel was first discovered by one Benjamin Huntsman, a watchmaker, in the year 1770, in England. This man lived at Attercliff. He became dissatisfied with his watch springs. "If," thought he, "I can melt a piece of steel and cast an ingot, its composition should be the same throughout." He succeeded, and his steel became famous, and Huntsman's ingots were in universal demand. The process was wrapped in mystery. The most faithful men were employed. The work was divided. Large wages were paid and the most stringent oaths of secrecy were taken.

One winter's night, as the tall chimneys at the Attercliff Steel Works belched forth smoke, a belated traveler knocked at the door. It was bitter cold and the snow fell fast. The stranger, a common farm laborer, seeking shelter from the storm, awakened no suspicion. The foreman scanned him closely and at last let him in. Feigning to be worn out by fatigue, the stranger sank upon the floor and was seemingly fast asleep. That, however, was far from the fact. Through stealthily opened eyes he caught glimpses of the mysterious process. He saw workmen cut bars of steel into bits, place them in crucibles which were thrust into the furnace and the fires were bedded until the steel melted. The workman drew forth the glowing crucible and poured the contents into moulds. Huntsman's factory had nothing more to disclose. The secret of making cast steel was stolen, and the improvement in cast steel has been going on ever since.

Making Cast Steel.

I understand that seven-tenths of all the cast steel produced in Europe is manufactured in Sheffield, England. In the United States there are from fifteen to twenty mills, perhaps more. During my travels in the New England States for the past few years, selling steel, I found that the steel made by William Jessup & Sons gave better satisfaction for general machine shop work than any one brand on the market. There are several firms in this country that make good steel at times, but the all important question with the consumer is to know who makes good steel all the time, and to this I will answer by saying, not one of them. They all claim to do it. Some of them do come nearer to it than others.

The process of making cast steel is so delicate that it is absolutely impossible to get the quality and temper the same in different heats. Some of them, however, come very close to it. Cast steel means steel that has been melted and poured into a mould which, when cold, is called an ingot.

Bessemer steel was discovered by one Henry Bessemer, but the crucible cast steel trade holds its own in spite of his great discoveries. Chemical analysis plays a very important part in the manufacture of Bessemer and Siemens steel, and even of the comparatively small quantity of crucible cast steel, which is still used for purposes where it is not required to be hardened or tempered.

It is possible to judge very accurately of the quality of those metals from the chemical analysis, almost as much so as from the results of mechanical tests, such as the breaking strain, and the contraction of the area of fracture. But in what we may call, for the want of a better name, the legitimate cast steel trade, chemical analysis, though it tells a good deal, does not tell us everything. The analysis of steel shows the amount of other ingredients which it contains besides nine-tenths, or more, of iron which forms its basis. The amount of carbon, silicon manganese, sulphur, phosphorous, etc., may be ascertained with considerable accuracy, and the information thus obtained is often of the utmost importance. But it is quite possible to make a comparatively low-priced but inferior steel which will show precisely the same chemical analysis as the best crucible cast steel. That this is a fact, has been demonstrated over and over again beyond all possibility of a doubt. It is sufficient reason why the best steel makers have been willing to pay a high price for good iron for so many years.

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We already know much of the chemistry of steel, and what remains to be learned is as certain some day to be discovered as the fact that Newton discovered the laws of gravitation.

The best razor steel is said by the manufacturers to contain one and a half per cent of carbon. Practical experience by tool-makers has demonstrated this to be a mistake. The information I have been able to gather in my fifty-seven years' experience proves to me conclusively that 85 or 100 points is better than one and one-half per cent of carbon. It carries a smoother edge.

One hour's conversation with a good practical smith or tool-maker is of more value to the average smith than a whole week's would be with the manufacturers, as all of their knowledge is of a theoretical nature and not practical. Their knowledge has been handed down from one to another and consists of what a man can get without soiling his clothes or hands. That class of knowledge, my dear reader, is too cheap and common. It is the other kind you want. The kind that is obtained only with the coat off and the sleeves rolled up. Young men brought up in luxury and ease seldom get much of this latter kind of knowledge.

The best razor steel must be melted from evenly converted steel. It will not do to mix hard and soft steel together or to melt it from pig. Steel made this way will not possess the requisite amount of body, consequently the cutting edge of the razor will not stand. It must be melted from the steel converted from iron made from ore containing manganese. It will not do to add the manganese in the form of spiegeleisen or ferro manganese. Carbon and manganese exist in combination with iron not chemically combined in certain definite proportions but alloys as mechanical mixtures in any proportion.

We know that carbon exists in combination with iron in two forms, either combined carbon or free carbon. Is it not possible that manganese may also exist in two forms? And although the razor steel must have been boiled in the pot for half an hour at least after it was melted to kill it and make the ingot pipe, is it not possible that the mechanical mixture of the carbon and the manganese is less homogeneous in steel made by the cheap process than is that made by the old-fashioned method?

It has been stated that the finest qualities of steel when hardened show a more perfect regularity in their crystallization, when examined under a microscope, than common qualities, and I venture to suggest that a possible explanation of body in steel may be the absence of injurious ingredients combined with the perfectly homogeneous presence of the advantageous ingredients.

Hardened steel is crystallized steel; and perfect regularity of crystallization in steel which is required to be ground to a fine cutting edge may perhaps never be secured except by the slow and expensive old-fashioned method. The principal reason why Bessemer and Siemens steel have failed so completely to supersede crucible cast steel for purposes where the better qualities are required is that they cannot be more sound without the addition of silicon or manganese.

In melting common steel the metal must be poured into the mould as soon as possible after it has become perfectly fluid and as hot as the tensile strength of the pot will allow.

Crucible Cast Steel.

In making the higher qualities of crucible cast steel a similar mode of treatment would produce very strange results; the molten steel would boil over in the mold; the fracture of the ingot when cold would show a series of bubbles like a sponge and its specific gravity would scarcely exceed that of wood. Some of these bubbles or honeycomb would weld up when the ingot came to be forged, but by far the greater number would be coated with an oxide which would make a weld impossible. The bar, if it were not entirely consumed by the fire, would be so full of imperfections, technically called seams, as to be perfectly useless. To obviate this disastrous result, it is necessary to boil the steel for nearly half an hour after it has become fluid. Then allow it to cool down to a certain temperature before it is poured into the mould. This process is called "killing the steel" and it is an axiom that the higher the quality of the steel, the more "killing" it takes. It is in this part of the process of melting crucible cast steel that its special virtue consists, and the cost and quality of the cast steel produced depends in a large degree upon the skill brought to bear upon it. Though you may convert iron into steel in the crucible, you cannot convert bad steel into good steel in the crucible. But you may put pure steel into the pot and by bad management, by not "killing" it properly, pervert it into bad ingots. Now this "killing" of the steel is precisely what cannot be done in the Bessemer or Siemens processes without the addition of a large amount of manganese or silicon so that the steel becomes brittle when hardened.

When iron is made into steel in a converting furnace, it is assumed that the oxygen of the air in the converting pot unites with the charcoal and is soon made into carbonic oxide excluded by the white hot iron and forced by it to part with as much carbon as is sufficient to reduce it to carbonic acid. It has been ascertained that metals have the power of absorbing or exuding many times their own bulk of gas, and possibly the carbonic oxide when it has parted with the amount of carbon necessary to reduce it to carbonic acid, is not then expelled from the iron, but may remain, and requires to be expelled in the metal pot by boiling. Be this as it may, it is a fact that if it be required to make blister steel harder than about 1.4 per cent of carbon, it is necessary to convert it twice over.

Another fact which may throw some light upon the question is that blister melted directly after being taken from the converting furnace requires more "killing" than that which has been exposed to the air for some time. The fact that the presence of manganese or silicon helps largely to kill the steel may possibly be accounted for on the theory that the carbonic acid unites with the manganese or silicon and becomes a solid.

Some Kinds of Iron.

Pig iron is melted direct from ore in a blast furnace and contains from 3 to 5 per cent of carbon. When remelted, it is called cast iron. Spiegle iron is precisely the same, but contains in addition from 5 to 15 per cent of manganese.

Bar iron, which is often called wrought iron, is pig iron which has been smelted and deprived of nearly all its carbon either in a puddling furnace or other analogous process. The spongy mass or ball of iron is usually hammered or rolled into a bar.

Puddled steel is precisely the same as bar iron, except that the process of puddling is stopped when rather more than half of the carbon has been removed from the pig iron. There are consequently no hard and fast lines between bar iron and puddled steel.

Although there are an infinite number of intermediate stages between the softest bar iron and the hardest puddled steel, and although it is impossible to state the exact percentage of carbon which marks the dividing line between one and the other, it is usual to call all puddled steel bars which cannot be hardened in water, bar iron, and all those which can be, puddled steel. This dividing line falls somewhere near a mixture containing one-half per cent of carbon.

Blister steel is bar iron which has been converted into steel in a converting furnace and varies in the amount of carbon which it contains from ½ to 1½ per cent. There are, of course, an infinite number of degrees of carbonization between hard heats and mild heats.

Single shear steel is produced by melting half a dozen bars of blister steel together. Only those bars are chosen in which the process of conversion has been carried on so far that the outside of the bar is steel and the center of the bar iron. When these are melted together and hammered or rolled down to a small dimension, the result produced is a mechanical mixture of iron and steel, a material which combines great tenacity with the capability of carrying a moderately hard cutting edge and is much employed for certain kind of knives.

Double shear steel is produced by drawing down single shear to suitable sized bars and re-welding two of them together, so that the mixture of iron and steel may be more perfect.

Cast steel is steel that has been melted in a pot or a crucible and poured into a mould, thus becoming an ingot, which is afterwards hammered or rolled to the required size. It may be of different tempers, varying in the percentage of carbon which they contain from ¾ or less to 1½ or more.

Various Tempers.

The different tempers may be arrived at in various ways. For a great majority of purposes there can be no doubt that the best way is to put into the melting pot broken pieces of blister steel converted exactly to the temper required, and the more quickly the steel is converted, and the more carefully all bars which are harder or softer than the temper required, or which are flushed or aired, are rejected, the better. Blister steel, when carefully taken up or selected, will produce a cast steel with the greatest amount of elasticity when hardened.

In all cases the mode of manufacture must be adapted to the objects which it is most important to secure.

In addition to the mode of operation already mentioned, there are two other ways in which the same percentage of carbon may be secured. You may either put cut bar into the pot and fetch it up to the required temper with charcoal, or you may put broken pig into the pot and let it down to the required temper.

A fourth operation, which for most purposes is the best of all, might be enumerated, namely; the selection of blister steel slightly harder than the temper by the addition of a small quantity of somewhat milder cast steel scrap.

Converting Furnaces.

The process of converting iron into steel is carried on in a converting furnace. This furnace consists of two stone troughs called converting pots, each of them about 4 feet wide, 4 feet deep and 12 feet long, placed side by side with a fire underneath them, the flues of which conduct the heat all around each pot. These troughs or pots are built of slabs of a peculiar kind of fire stone, possessing the property of not cracking if heated slowly to a high heat and allowed to cool gradually. These slabs are united together with a mortar made of ground fire clay. Over the two pots is built a vault of fire brick and the whole is enclosed in a dome of red brick to prevent as much as possible the heat from escaping. At the bottom of each pot is placed a layer of charcoal, coal broken up in small pieces from one-quarter to one-half inch square. On this a layer of bars of iron is placed which is covered with charcoal. Another row of bars of iron follows, and so on until the pot is filled with alternate layers of charcoal and iron. It is then carefully closed with a thick cover of clay made of fire clay and some other materials, a species of mud which accumulates at the grinding wheel, and is, of course, the material of the grindstone worn away—a substance which will resist long exposure to great heat and renders the top of the pot practically air-tight.

In order to test the progress of conversion and to ascertain the precise moment when the fire should be permitted to go out, two or three bars of iron are allowed to protrude through a hole in one of the pots made for that purpose. These bars are technically called "tap bars" and are drawn and inspected at or near the close of the process, and are tightly packed in white ashes where they pass through the end of the converting pot, so that no air may find its way to the charcoal inside. The converting pots, full of alternate layers of iron and charcoal and hermetically sealed, are gradually raised to nearly a white heat and kept at about that temperature for a week or more, according to the amount of carbonization required. Another week is occupied in the process of cooling, which must be done slowly, in order to prevent the pots from cracking. After which the cover is broken up and removed, and the bars which went into the furnace bars of iron are taken out of it bars of blister steel, so-called from the bubbles or blisters which have arisen on the surface during the conversion.

Chemical Changes.

Some of the charcoal has been consumed during the time at which it was white hot, but a considerable proportion of it remains and is taken out of the furnace as black as it went in. A chemical change in the composition of the bars has taken place. They were originally pure iron, or nearly so, containing perhaps one-quarter per cent of carbon or less, were fibrous in their structure and would bend double without breaking. After the process of conversion they have become carbonate or carbide of iron or steel, containing from one-half to one and one-half per cent of carbon, according to the length of time they have been in the furnace and the degree of heat to which they have been subjected.

They are now more or less crystallized in their nature and can be broken by a slight blow of a hammer. The converting furnaces in use vary in size, some holding as much as thirty tons of iron, and others not more than fifteen tons. The iron gains slightly in weight by being converted into steel. The process occupies about three weeks, and a pair of pots may be used from twenty to forty times before they are worn out and have to be replaced by new ones. As in every other process, in the manufacture of steel or the process of conversion, it has to run the gauntlet of many perils. Sometimes the pots crack, air is admitted to the furnace, the charcoal is burned, and in bad cases even the iron is oxidized. Bars which have thus missed conversion are technically said to be aired, and even when very slightly affected may easily be discovered in consequence of their having almost lost the tendency to become rusty. If the furnace be raised to too high a heat, the surface of the bars will melt, and when they are drawn it will appear glazed. There are even instances where unskilled converters had heated the furnace under their care to such a degree that the whole mass of iron and charcoal had been fused together and the end of the furnace had to be taken out to remove the contents.

During the process of conversion the outside of the bar of iron is turned into steel first, and in a spring heat the center of the bar remains iron, though when the bar is broken, the crystals of iron have lost their brilliancy. In technical language, the bar is said to be " full of sap," though the sap is killed. In a single shear heat the fracture shows more steel on the outside and less iron in the center, until in a double shear heat the fracture shows about equal proportions of iron and steel.

It is important that the transition from the one to the other should be as gradual as possible. When the line of demarkation is violent or sudden, the process of conversion has been carried on too rapidly and the bars of blister steel so converted are said to be flushed.

A short time longer in the furnace will make the steel a melting heat, the crystals will be large and in exceptional cases will reach across the bar.

The Melting Furnace.

The melting furnace consists of a row of oval melting pots, one in front of the other, and deep enough to allow of sufficient coke to cover the lids from each melting hole. A flue leads in old-fashioned furnaces into a flat stack, each flue having a separate flue in the stack. But many furnaces are now made with short flues for each hole leading in a main flue with ends in a single square chimney.

The application of gas to the melting of steel has been successful, but for the highest qualities coke is principally used, as the control which the melter has over the temperature of each pot, which sometimes requires keeping back and sometimes hurrying on, is supposed to be more absolute, although in Pittsburgh gas is now used almost entirely for melting steel.

The pots in which the steel is melted are generally made in a room adjoining the melting furnace. They are composed of a mixture of different clays which are best adapted to stand a great heat. A small quantity of ground coke, as well as of ground old pots, is also added. Great care is taken that the clay is absolutely disintegrated and perfectly mixed together. This is accomplished by treating it in a trough. The pots are moulded in an iron flask by means of a wooden plug and are slowly dried at the back of the stack, and the night before they are used gradually heated to a dull red, a process called annealing.

Pot making is a very important part of the manufacture of cast steel. It is absolutely impossible to make good cast steel if the pots are defective. Each pot lasts a single day and is used three times. In it are about fifty, forty-four or thirty-eight pounds of steel successively. The object of lessening the weight of each successive charge is to bring the surface of the molten metal to a different place in the pot, because the flux or scum which accumulates on the surface has a chemical action on the silica of the pot, which is consequently decomposed for some depth just at that point and the pot is reduced in thickness. The bar steel is first carefully selected of the exact temper required. All flushed or aired bars are rejected. After it has been broken up into small pieces and carefully weighed, it is conveyed to the pot, which has already been placed in the melting hole through an iron funnel called a charger. The lid is carefully adjusted and the melting hole filled with coke.

The degree of heat to which the furnace is allowed to go is controlled by means of the two flues into either of which can be inserted a fire brick if required. A brick in the melting hole flue lessens the heat by lessening the draft. The head melter periodically inspects the pots and gives the final instructions to the puller out and decides the precise moment when the steel is dead melted and the holes sufficiently burnt down to allow of its being turned or poured into the mould with a fair chance of producing a sound ingot. When the puller-out has put on his sacking wraps which envelop the arms and legs and which are soaked with water to protect him from the heat, he raises the pot with a pair of pulling-out tongs and lifts it from the hole to the floor of the furnace. The lid is instantly taken off with a pair of lid tongs and the scum or flux is removed with a skimmer from the surface of the molten steel which is then poured into a cast iron mould formed of two halves tightly wedged together. The interior of the mould has been previously covered with a coat of coal-tar soot to prevent the ingot from adhering to it.

The melting of the higher qualities of steel is a process requiring the greatest skill; and one of the principal reasons why the trade has become to such a remarkable extent localized in Sheffield is the importance to this branch of the trade of being able to select from a large class of more or less experienced workmen the few exceptional men in whom sound judgment, technical skill and steady habits are combined.

The chances of accident in the melting of steel are many and various. Not only badly made pots, but badly annealed or badly worked pots, are sure to " run " and be practically of no value. Should a piece of coke accidentally find its way into the pot, the ingot will show a bright, sparkling fracture. Under the hammer it will prove " hot short " and crumble to pieces. If the steel is not in the fire long enough, it will turn fiery and produce a honeycombed ingot, and the same result will follow if it be too hot when it is poured. If it remains too long in the fire, it will turn " dead." The fracture of the ingot will look scorched, and though exceptionally sound, it will be brittle if hard, and wanting in tensile strength if mild.

If the molten steel be chilled before it is poured into the mould, which may be detected by the stream skimming over, as it is termed, the fracture of the ingot will appear dull in color and full of small holes or honeycombed.

All ingots having a proportion of one per cent, or more, if properly melted, will pipe; that is to say, the steel in the center of the ingot will settle down as it cools, leaving a hollow space in the middle of the top of the ingot to the depth of from three to five inches. When the ingot has become cold, the hollow part must be broken off until the ingot is sound, and before this fracture has had time to rust, the ingots must be carefully examined. The ingots which are not properly melted must be rejected, and the exact percentage of carbon which each ingot contains must be marked upon it. An experienced eye can judge of the percentage of carbon contained in an ingot to a wonderful nicety by the appearance of the fracture. Every tenth per cent is marked and an experienced hand will detect a difference between, for example, 1.3 and 1.35 per cent. In order to reduce the ingot of cast steel to the size and shape required by the consumer, it must be reheated, and when hot enough, hammered or rolled to the dimensions ordered.

Great care must be exercised in this process not to harm or overheat the steel, and to prevent this the bar must be entirely turned around in the fire, and ground fire clay or sand and borax sprinkled upon it. In many cases it is necessary to give the surface of the bar, after it has been once drawn down under the hammer, a welding or " wash " heat to close the small honeycombs which are scattered here and there on the surface of the ingot. It is a matter of great importance, especially with large ingots, that they should not be hammered until they are thoroughly heated or " soaked " through, and it is of equal importance that they should not be too long " soaking " in the fire, especially in a dry fire, or one without blaze. The effect of hammering steel is to make it crystallize in very small crystals, a result which greatly improves its quality, but at the same time exposes it to the risk of various accidents in the process.

Forging and Rolling.

The forging and rolling of cast steel requires experienced workmen and a considerable outlay of expensive machinery. It is seldom that a workman attains exceptional skill in many departments, and loss is sustained by the often changing faces or rolls, so that these processes cannot be satisfactorily or cheaply carried on upon a small scale, and this is one of the chief reasons why the crucible cast steel trade has to such a large extent become localized in a single town.

It might be supposed that when the best quality of iron had been selected and the greatest care used in the process of manufacture the result must of necessity be good steel and the troubles of the manufacturer would be over. But this is not the case by any means. The greatest difficulty has yet to be faced. The results may be of good steel, but good steel only for certain purposes. There was a time in the Golden Age of steel manufacturing when steel was steel, and if it did not answer the purpose for which it was required, it was taken for granted that the fault lay with the workman. In some cases the manufacturer altered the percentage of carbon, but the "temper" of the steel was kept a profound secret from the consumer in most cases, no doubt, because the manufacturer had very vague ideas on the subject himself. Chemical analysis was unknown in the trade; the despotic sway of the "rule of thumb" reigned supreme. Now it is customary for the manufacturer to take the consumer into his confidence and not only to inform him of the percentage of carbon which the steel contains, but also to give him the benefit of his opinion as to the purposes for which it is or is not suitable. Formerly if the consumer discovered this, it was entirely due to his own wit.

There can be no doubt that for many purposes a considerable latitude may be permitted if the steel has the good fortune to fall into the hands of a clever workman who understands how to "humor" it; but next to quality —by which is meant percentage of phosphorous, sulphur, etc., combined with some other obscure points of crystallization—the most important thing is temper or percentage of carbon. For some purposes, indeed, temper is of more importance than quality. Nothing is more common than for steel to be rejected as bad in quality, because it has been used for a purpose for which the temper was unsuitable. The size and shape generally furnished come close to the purpose for which steel is likely to be used.

For example, octagon steel is usually used for chisels, and small squares for turning tools, but 1¼ inch square may be used for a turning tool or a cold set, and 1½ inch round for a drill or a boiler cap, and the manufacturer has to puzzle his brain to discover whether the chances are in favor of its being used in the lathe room or in the blacksmith shop. It cannot be too often reiterated how important it is when ordering steel to state the purpose for which it is to be used.

Steel Tempers.

Of course the number of tempers of steel is infinite, but the following is a list of the most useful. We will measure carbon by per cent and points, 100 points making 1 per cent of carbon.

Razor temper is the same nearly as all cutlery, about 90 points. This is good also for wood cutting tools of all descriptions.

Turning tool temper is from 100 to 125 points, and this includes general machine shop tools, such as diamond points, side tools, slotting tools and cutting off tools.

Chisel temper is from 70 to 85 points, according to the class of work to be done.

Die temper, such as stamping dies, forging dies, is 65 to 95 points. In these tools the surface only is required to be hard, and where the capacity to withstand great pressure and strain is of importance. This temper may be easily welded by any good smith.

The chisel temper is an extremely useful temper, combining as it does great toughness in the unhardened state with the capacity of hardening at a low heat. It is consequently well adapted for tools when the unhardened part is required to stand the blow of a hammer and where a hard cutting edge is required, such as cold and chipping chisels.

As to welding cast steel, it is extremely difficult after you get above 1 per cent carbon, and can be done only by a skillful smith.

File temper is about 1¼ per cent carbon.

Annealed steel has nearly all the properties of lead, being very soft and malleable.

Hardened steel has nearly all the properties of glass, being very hard and brittle.

Tempered steel is hard but at the same time elastic.

The chemical changes which take place during these processes have not yet been discovered.

It is a remarkable fact that the specific gravity of hardened steel is less than that of unhardened steel. Steel, of course, expands with the heat, and when it is allowed to cool slowly regains its original size. But if it be cooled suddenly, the only known way in which it can be hardened, it does not quite reach the small size of the unhardened state.

Steel Treatment.

However complicated the details of the manufacture of cast steel may be, the complications involved in its subsequent use are still greater. It would be impossible to lay down exact rules for each of the thousand and one tools in which steel is used. The treatment of each tool in each process which it undergoes is an art that can only be learned by practice. The utmost that can be done is to lay down certain general rules which may explain to some extent the most important details of manipulation. All steel may be regarded as involving a question of compromise. Each tool requires a certain degree of hardness. The problem is how to secure the maximum amount of toughness that is compatible with it. To secure this, the first step that must be taken in bringing the steel into the shape required is to heat the steel as little as may be before it is forged, and in the process of forging to hammer it as much as possible. The worst fault that can be committed is to heat the steel more than is necessary. When steel is heated it becomes coarse-grained, its silky texture is lost and can only be restored by hammering.

If the temperature be raised above a certain point the steel becomes what is technically called " burnt " and the amount of hammering which it would require to restore its fine grain would reduce it to a size too small for the required tool, and the steel must be condemned as ruined.

Overheating in the fire is also the primary cause of cracking in the water. One of the principal reasons why a high quality of steel is required for certain purposes is that it will suffer less injury by being heated and reheated than inferior qualities of steel.

In heating steel, the happy medium must be attained between heating it too much and too little, and between letting it lie too long " soaking " in the fire and not " heating " it through. Both the degree of temperature and the duration of the heat must be carefully watched.

Some tools, such as circular cutters, files, etc., after they are forged into the shape required must have teeth cut into them. Before this can be successfully accomplished a preliminary process has to be gone through. The process of hammering or forging the steel into the shape required has hardened it to such an extent as to make the cutting of teeth into it impossible or difficult and it must consequently be annealed. This process consists in reheating the steel as carefully as before and afterwards allowing it to cool as slowly as possible. Any process that cools steel slowly is a good annealing process, and the slower the better.

Many tools are only required to be hard on a small part of their surface, and it is important that the unhardened parts should possess the maximum of toughness and the minimum of brittleness that can be attained. The process of annealing, or slow cooling, leaves the steel coarse-grained, and gives it the maximum ductility.

Heating and Cooling.

The special danger to be avoided in hardening each kind of tool must be learned by experience. Some tools will warp, which is generally caused by irregular hammering. Tools of one shape must cut the water like a knife. Those of another shape must stab it like a dagger: some tools must be hardened in a saturated solution of salt, the older the better; others are best hardened under a stream of running water. Most tools have a tendency to water-crack if taken out of the water before they are absolutely cold. Where the edge of a tool only is hardened, care should be taken to move it up and down in the water so as to continually change the water level lest the tool should crack at the dividing line. Steel contracts in hardening and contracts differently where it is cooled suddenly from what it does in the places where it is cooled slowly. If the hardened part joins the unhardened part too suddenly, the steel at the junction will be in a dangerous condition from the tension which predisposes it to crack, and it is wise to lessen the amount of tension by distributing it over as great an area as possible.

In some tools, where the shape necessitates a great difference in the rapidity of the cooling of the various parts, it is often wise to drill holes in the thicker parts where they will not interfere with the use of the tool.

So many causes may produce water-cracks that it is often difficult to point out the precise cause in any given case. The most common one in the over-heating of the steel in one or the other of the various processes through which it has to pass. A second cause may be found in the over-melting or too long boiling of the steel. A third cause may sometimes be discovered in the addition of too much manganese. A fourth cause may curiously enough prove to be a deficiency of carbon—one of the most common causes of water-cracking in files. In some cases too much carbon will produce the same effect. A fifth cause may be the presence of phosphorous in the steel. This may possibly be the fault of a stingy consumer, who will not pay a price sufficient to admit of good quality of iron being used. There is nothing so dear as cheap steel.

The workman can judge by the color which the steel has assumed in heating the extent of the elasticity it has acquired, and can then give to each tool the particular degree of temper which is the best adapted to its special purpose. The various colors, through which tempered steel successively passes are as follows: White, straw, gold, copper, purple, violet and blue. Of course, in passing from one color to another, the steel passes through the intermediate colors. It really passes through an infinite series of colors of which the seven above mentioned are merely selected as convenient stages.

In tempering steel, regard must be had for the quality most essential in the special tool to be tempered. For example, a turning tool is required to be very hard and is generally taken out of the water hot enough to temper itself down to a degree so slight that no perceptible color is apparent, while a spring is required to be very elastic and may be tempered down to a blue and below.

Hardening in oil is a mode of treating steel which is of special value for certain tools *only*. To give any scientific explanation of the change which takes place in the hardening and tempering of steel is impossible.

In speaking of the various foreign substances which are found in cast steel, it has been a fond dream of the steel melter to discover some substance which will transmute common cast steel into best cast steel. The most universally used of these is peroxide of manganese mixed with a little salammoniac, chromate of potash, and prussiate of potash. Even ground feldspar and broken glass are used by some steel melters. Manganese either in the form of spiegeleisen or of ferro manganese is also used. It prevents to a large extent the formation of honeycombs in the ingot and increases the welding capacity of the steel. It gives the steel greater tenacity when hot, so that it may be heated to a greater heat without cracking under the blow of the hammer or the tension of the rolls, but it must be very cautiously used as it undoubtedly increases the brittleness of the steel and its tendency to water-crack.

Special Steel.

Tungsten, in the form of a metallic alloy, is used to a considerable extent in the manufacture of a special steel sometimes called "mushet" steel, which is frequently made so hard that it does not require to be hardened in water. It is used principally for turning tools which can be driven at a higher speed than usual. Special steel of this kind is the finest grained that can be produced, but is so brittle that it can only be used by exceptionally skilled workmen. A special steel for taps called mild centered cast steel, is made by converting a cogged ingot of mild cast steel so that the additional carbon only penetrates a short distance. These bars are afterwards hammered or rolled down to the size required and have the advantage of possessing a hard surface without losing the toughness of the mild center. It is much to be regretted that no easy method of testing cast steel has been invented. A single test is of comparatively small value, as a second-rate quality of steel may stand very well the first time that it is hardened, but deteriorates much more rapidly every time it is re-hardened than is the case with steel of a high quality.

For many tools the capacity to withstand a high amount of breaking strain slowly applied is not so much required as its capacity to withstand a sudden shock. The practical consumer of steel must buy the steel which he finds by experience to be best.

The converting, melting and forging of steel requires as much dexterity as the arts of skating, riding or swimming. To arrive at perfection in these arts is difficult to those who do not inherit from skilled ancestors the facility to learn them, hence the trade has become localized in a few centers of which Sheffield and Pittsburgh are the oldest and by far the most important. The arts of forging, hardening and tempering, which are necessary for the further manipulation of the steel after it leaves the hands of the manufacturer require equal dexterity, so that the art of steel making, if not mysterious, is very complicated.

The real mystery lies in the chemical explanation of the effects produced ;and when chemists have explained the phenomenon of hardening and tempering steel, they may possibly discover why cast steel, made from Dannemora iron, is superior to the imitations of it. At present I presume the candid chemist must admit that there are more things in best crucible steel than are dreamed of in philosophy.

It is only recently that blacksmiths and other mechanics have begun to find out what can be done with cast steel, and their education has only commenced. The mechanic who is properly educated is the man whose hand follows obediently the clear and ready promptings of a well-developed brain.

Steel Properties.

Steel can now be made much cheaper than iron, and is very much stronger. Crucible cast steel is the best and strongest steel made. In order to give you some idea of the strength of best cast steel, I will say that a bar one inch square has been known to stand a strain of 283,833 pounds before breaking. Next in quality comes the open-hearth and Semens-Martin, then the Bessemer, which is the cheapest steel made. Bessemer and open-hearth are used largely in bridge work and building material. Nearly all steel tire is made from the open-hearth. These steels, like cast steel, are made with different carbons also.

Steel has been rolled so thin that it would take 5000 sheets of them piled on top of each other to make one inch. No other metal is so enhanced in value by labor. One pound of good steel is worth 10 cents and one pound of steel wire from $3 to $7, one pound of sewing-machine needles from $5 to $10, one pound of fish hooks from $10 to $20, one pound of jewel screws for watches $35, one pound of hair springs for watches $16,000. There are about twenty different concerns in this country making cast steel and about as many in Europe, and nearly all of them do at times make good steel, but the all-important question with consumers is uniformity. What you want to know is who can give you the same temper every time, and to this I will answer: Not one.

Alloyed Steel.

I shall now take up the family of alloyed steels. The most common among them is the self-hardening steel. For the past fifteen years the English self-hardening steel called "mushet," has been considered the best, but the Americans have, as usual, forged ahead and have lately brought out a high-speed steel that has driven the English "mushet" out of our market entirely. This American high-speed steel, as it is called, was first discovered in the Bethlehem Steel Works at Bethlehem, Pa.

I am told it was chance or blunder at first. However, it set the whole steel world to guessing and experimenting, and it was soon greatly improved until they have at this writing a steel that does more than thirty times the amount of work produced with a carbon tool, and to all appearances, the end is not yet. I had a description of self-hardening steel written out, with instructions for working, but the great improvement in high-speed steel has made it a back number, and of course the instructions are of no use on the high-speed steel.

Self-hardening steel is a steel which, owing to tungsten and manganese, hardens when cooled in air or an air-blast, and retains its hardness almost up to a red-heat. Self-hardening steel is so hard in what may be called its natural state that it cannot be machined, drilled, planed, or turned in a lathe. It is so extremely hard and brittle that I have had pieces 4 inches long drop off from the end of the bar while forging a tool.

Self-hardening steel has the essentials of retaining its hardness when heated almost to a redness, therefore, it may be used for lathe tools or other cutters on hard work and rough castings at a much higher speed than is possible with ordinary steel, which would be softened by the heat caused by the high speed. This is the only valuable feature of self-hardening steel. As for a finishing tool, it has not been able to compare with good carbon steel, but I am reliably informed that some steel makers have lately produced a high-speed steel that makes finishing cuts very good; so much so that they are making twist drills, taps, dies and reamers out of it, which are doing good work.

One of the most noted steels in the alloyed family is nickel steel. The addition of a few per cent of nickel to mild steel adds greatly to its strength, so that nickel steel is considered the strongest steel made. It has some peculiarities, among them it does not rust as readily as carbon steel; it cannot be rolled, and does not harden by any ordinary methods—about 29 per cent being the limit. This addition of nickel does not apply to the high carbon or tool steel and to this class it has thus far proved to be detrimental; yet in my opinion there is a great future for steel containing a small per cent of nickel.

Tool Steel.

It is of the utmost importance that tool steel should be sound. Blacksmiths, tool dressers and machinists should closely examine every piece of steel before working it, perhaps into expensive tools to be thrown in the scrap pile when done.

The end of a bar should be examined closely for a pipe, and cut off as long as any sign of the pipe remains. A pipe is caused by the shrinking in the center of the ingot after being poured from the crucible. If there is reason to suspect a pipe, file the place and the pipe will be revealed, if there is one. The end of a pipe is shown by a bright spot resembling a star; the steel is not solid in that star and will not make a good cutting edge, and should be cut off as long as that star appears.

The users of steel should not get the words quality and carbon confused. Quality means the material that the steel is made from and carbon means temper only. The word carbon is used instead of temper, to determine the fitness of steel for certain jobs. If for cold chisels, chipping chisels, flagging chisels, fullers, set-hammers, 65 to 85 is suitable; while I generally recommend 75 carbon. For cold chisels, if a smith be an expert at tools or making cold chisels, a chisel can be made from 70 carbon that will do more work and stand more abuse, than any other temper; yet to do this the tool dresser must know what his temper is when he begins. In selecting steel for all kinds of chisels, I say get the steel as low in carbon as possible and yet have it high enough.

My opinion as to the amount of carbon a tool should have does not exactly agree with some of the steel makers, as I am from five to ten points lower in carbon on some tools. Their knowledge is based on what Tom, Dick and Harry have told them at various times in different shops, and in no case was the steel maker a practical smith, nor had he ever worked any steel up into tools. His knowledge is of the office or stand-up collar kind. My knowledge is based on fifty-seven years' continuous experience on cast steel and sweating over the anvil in many of the largest shops in the United States. Now, if their hearsay knowledge is better than my practical knowledge, then I beg their pardon.

Now if we take a milling cutter from steel of 70 carbon, the second time we work it out, it is not as good as it was the first, and the grain or molecules are not quite as fine, and the third time it is still coarser, and the fourth time it is good for nothing. Now we will take a piece of 100 carbon, and we find that after being hardened four times, the grain is fairly good, but the molecules have increased in size some.

Next, we take a piece of 125 carbon and after being hardened and re-hardened six times, there is no perceptible difference in the grain, and the higher we go in carbon, the less change there is in re-hardening. A man that has any knowledge of steel, knows that a piece of steel of moderate carbon hardened at the proper heat is much finer grain than before it was hardened. Now as we increase in carbon, this theory changes, and when we get up to 150 points, there is no difference in the grain of a piece that has been hardened or a piece that has not.

This is why a certain class of tools are better made from high-carbon steel.

Wood-Cutting Tools.

It is more essential that tools belonging to the wood-cutting family, such as axes, hatchets, drawing knives, plane bits, cutlery and surgical instruments of all kinds, should be made from steel of the proper carbon and of best quality, than any other tool made, for the following reasons: If we make a cold chisel or a lathe tool from steel either too high or too low in carbon, and work the steel properly, the tool will do perhaps a fair amount of work, but with wood-cutting tools, it is different, the tool might stand, that is, not break nor batter, but would not cut good on account of the hairy edge, and no amount of sharpening can do it any good. When cutting pine or soft wood, you will notice that there is a kind of fuzz sticking to the edge, and there is absolutely no remedy for it. This small tool might stand to cut knots, and perhaps cut off a nail, and not seem to affect it, but the hairy edge is still there and there is no possible way to improve it. Therefore, be careful in selecting steel for such tools. Re-hardening such a tool will not improve the cutting quality any, and the chances are that it will crack in the hardening, and the grain or molecules will increase in size and diminish in strength as they increase in size. This class of tools mentioned should be made of 85 to 90 carbon, the finer we can get the grain and have the carbon right, the better. If we make a lathe tool from 70 carbon, the edge will burr up on cutting hard material and seem to be soft; if we re-harden it and leave it harder, which must be done by increasing the heat, then it will crack or break and the grain will look coarse and fiery. Let me say again that quality has nothing whatever to do with temper or carbon; when steel gets above 90 points carbon, it begins to assume that brittle crystalline nature which is characteristic of cast iron, and will not stand hard blows or sudden jars.

How many times I have heard it said that Brown or Jones was a great smith. He welded two bars of steel. Then they say that Smith is no blacksmith, because he tried to weld a bar of steel together that flew all over the shop. Now, we find on investigation that the first man had welded a bar of steel which was only 60 points carbon, which any blacksmith could weld without borax, and yet this man Brown is held up as a criterion wherever he is known, while the second man has been trying to weld steel of 150 points carbon, which is absolutely impossible to do, and if he had any knowledge of carbon in steel, the first thing he would have ascertained would have been how much carbon there was in the bar. In welding any piece of steel, always test it to find out how much carbon it contains, and then heat it as hot as possible without scintillating. Then you will make the belt weld possible to make on steel.

You ask, how am I to judge and find out how much carbon the bar contains? Cut off a little piece or cut part way off and draw down to say ⅜ inch square; then heat it to a good yellow heat, and if it is 150 carbon, it will drop apart when you tap it with a hammer. If it does not drop off at this yellow heat, then heat it a little hotter, say a white heat, and try that. If it does not drop off, heat it a little hotter, and if it stands a heat where it begins to sweat, or the flux starts to run, then it is perhaps 70 carbon, or less; and if it is only 65 carbon, it will stand to be bent around and welded without anything on it, and the various heats at which it drops apart are a positive indication of its carbon.

Cast steel is so sensitive to heat that in starting with a blood red every degree of heat added causes a change in the size of the molecules until the limit is reached, when disintegration begins. The effects of heat are permanent and sure. It is a fact that every variation of temperature which is plain to the naked eye will leave a structure corresponding with that variation when the steel is cold.

It is of the utmost importance to the steel maker and blacksmith to try to acquire a knowledge of it in order that he may not be fooled by steel makers or workmen.

Burnt Steel.

The word "burnt" steel is a common one among blacksmiths, but it is a term I seldom have to use, from the fact that after getting more knowledge of cast steel, we find that it has not been burnt, but over-heated; it is simply heated up to the third or granular condition; it is the beginning of disintegration and the end of plasticity.

Steel is not burnt until it is destroyed for all purposes and for all time. For instance, when the steel maker made that steel just before it was ready to pour from the crucible, it was many times hotter than it could be heated in a smith's fire.

Restoring burnt steel is impossible. Restoring overheated steel is as easy as rolling off a slippery log. Let the bar or end which has been overheated get cold, heat it up to a good blood red and let it cool, and it is just as good as ever it was. Then take the same piece and overheat it again, and while hot plunge it in the water, cooling off entirely, then break off the end, and the grain will be as coarse as pig iron. Then heat to the same blood red for restoring, lay it down and let it cool. When cold, heat to a fair heat for hardening, plunge it in the water and cool off, then break off a piece and the grain is as fine as silk and in good condition.

Now, brother blacksmith, just do a little thinking, as you read this, then try the experiment and you will begin to realize how much there is to know about steel and how little the average smith does know.

It is possible for a good tool dresser to judge steel as to its carbon by cutting it off. If cutting steel of 150 carbon, we have only to mark it, turn it over, and place the cut over the hardy hole, hit it a blow. It drops off, and if only 100 points carbon, it may take a couple of blows, and if only 80 carbon, it will take several. If only 70 carbon, it will have to be cut half around the bar, and then it may take eight or ten good blows. If only 60 carbon, it is next to impossible to break it at all, even after cutting it all around deep. This is another method of judging steel as to carbon. However, the heat at which the bar was finished has much to do with its breaking. If it was finished at a low heat, it will break much quicker than if finished at a high heat. For all tools requiring a fine edge for cutting purposes, such as lathe tools, drills, taps, dies, reamers, milling cutters, axes, razors, pocket knives, fine saws, gravers' tools (where sharp edge with great endurance are required) and for a hundred other purposes, crucible cast steel is best. It stands at the head of all steels yet made and will remain so until some genius shall remove from the cheaper steels the elements that unfit them for this purpose.

It does not harm steel any more to upset it than it does to draw it out. Good cast steel has no more grain than cast iron, or shoemaker's wax; what grain there is, runs in every direction. The tempering of a tool as far as some particular color is concerned, or the water that it is tempered in, is the least important point or secret in working cast steel. Yet there is a great success in hardening tools, that does not consist of any particular color or hardness, but of giving it foundation, and this must be done with both hammer and water. If we harden a cold chisel, as most smiths do, stick it in the water 3/8 or 1/2 inch, and then let the temper down to the desired color. I care not what color you leave it, it will not stand. Why? Because the foundation is good for nothing. It gives way. It upsets. It has no backing.

The Tempering Bath.

When I was called to the Pennsylvania Railroad shops in Altoona, Pa., to give their blacksmiths and tool dressers instructions on cast steel, they had seven men dressing cold chisels. After I had finished, three men were doing the same work. Many times I have heard machinists say to the tool dresser:

" Some of your chisels stand good, and some don't."

" Well," says the tool dresser, " I don't see why that is, because I tempered them all alike." And perhaps some of them were 70 carbon and some 125 carbon, yet he tempered them all alike.

Some years ago, I was called to a large shop in Boston, to give their tool dressers some instructions, and when I went to show one how to dress the chisel, he shouted:

"Never mind that; I can pound steel as well as any man. All I want to know is what you put in the water to temper with."

I soon found out there was nothing in the man except what he ate.

The blacksmiths are deceiving themselves, as they think the whole secret of working steel successfully lies in the tempering bath. They say it makes steel tough; so it does, but few of them know why. I will tell you. It is because the steel can be hardened at a lower heat, and the lower the heat you can harden steel at, the better.

The conditions of steel after cooling depends entirely upon the amount of time consumed in cooling. If the steel be cooled instantaneously, it is exceedingly hard, and the quicker it is cooled the harder it will be. If I can find a compound for hardening steel that will cool steel off quicker than the one I have, I will pay a good price for it. However, out of the many hundreds of recipes that have been palmed off on the blacksmiths for hardening steel, there are no more than a half dozen chemicals that will even assist in hardening tool steel; the most important is common salt. Please don't waste money on quack nostrums for either hardening or welding.

I have heard the saying for more than fifty years that you must not heat steel, hot—that you must work it at as low a heat as possible. That argument is absolutely false. For explanation, I will take a bar of steel 1½ inches square, and to forge any tool out of it, we heat it to a low heat, and with light hammers and sledge on it for a few heats, what have we done? I will tell you: We have only skinned it. Or, in other words, we have drawn the outside and the center has scarcely been moved. Consequently, in the center between the hot and the cold, there is a dividing line, and where this dividing line is, there is a great strain from contraction. One is pulling one way, and the other is pulling the other way, and the moment you plunge that steel in water to harden it, at this dividing line there is a strain and generally a rupture, and if it is not cracked when it comes out of the water, the crack shows up the next time it is heated.

The Heating Process.

Now I say, heat that bar *very slowly* and heat it clear through and heat it as hot as possible without having the molecules separate. When properly heated, we will put, say a 14-pound sledge on it as hard as a man can pull down. Now we have worked that steel clear through, and there is no dividing line. Consequently, there is no strain, and when the tool is hardened, it comes out of the water as sound as a dollar.

This very act of drawing a large bar of steel at a low heat, the outside hot and the inside cold, and with light sledge and hammer, has done more damage, spoiled more steel, cracked more tools and caused more "cuss" words than any other bad practice to which steel has been subjected.

It amuses me when I look back and think of what nonsensical ideas I have heard advanced. For instance, that of heating water nearly to the boiling point to harden steel in. What nonsense! Such men as that are not capable of doing their own thinking.

I wish it was possible at all times to have my water colder than ice. I presume their idea is to keep the steel from cracking. It is not the water that cracks the steel. It is the heat and bad hammering to which the steel has been subjected before the hardening. If the steel is properly made and properly hammered, I want you to tell me how it is going to crack or crook in tempering.

Suppose we have a piece of steel 10 inches long, of good quality, and the ingredients are evenly mixed and it is evenly hammered. The molecules are of the same size throughout, and we heat this to the proper heat, then harden it, how is it going to crack it?

If you make two tools from the same bar of steel and one breaks and the other stands good, then it is evident that you are at fault, and that the steel is good. Now set to work and find out the cause, and do away with the cause. It is very evident that you have done something which you ought not to have done. I hear you ask, What? Uneven heating, uneven hammering. Too high heat. Heated streaked, which is very dangerous.

Now, to prove this, I will take a piece of good steel and forge a butcher knife, making it very thin, less than $\frac{1}{16}$ inch thick. I fill up my tub with ice, and heat this thin knife and plunge it in the cold water, and it will come out as straight as it went in. If it does not, then there is a cause for it and I will find out the cause and do away with it. "An ounce of prevention is better than a pound of cure." Do not make knives, or anything else simply as you see others do it; have a reason for everything you do. Do not follow the ruts and paths that others have made unless you are sure they are better than your own. It is at times well enough to imitate those whom we know to be our superiors; otherwise, pattern after none.

Imperfect Tempering.

During my travels in the past fifty years, I have seen at different times and shops not less than a wagon load of hammers with the peans dropped off, some with the bottoms off, flatters with the bottoms off and some broken through the eye. Most of these tools were nearly new, had been used only a short time, and the only remedy they knew was to make more. Now, the proper thing to have done was to ask why those tools broke before being half worn out. There is surely a cause for it. I will tell you the cause: When the hammer was being forged or fullered in from the eye, the fuller had caused great strain and pressed the top from the hammer and it was left in that strained condition. Now, if it had been heated and set up on end and struck one blow, the strain is then all gone and the steel is in its normal condition. The cause of the bottom of a flatter jumping off is exactly the same, and the same remedy should be applied. The cause of a flatter or chisel bursting in the eye, may be that the steel is poor or what I call "cold short," but some break when the steel is fairly good, in which case there was great strain in the eye when punched. If it had been re-heated and set up on end, one blow would have taken all the strain out, and it would have lasted until worn down to the eye.

Another cause is, it may have been too high in carbon, which is a very common cause, for if a smith can't tell how much carbon a bar of steel contains, then he will make the tool from any bar that happens to be the right size.

I wish to say a little more about the necessity of steel having a foundation, taking as an illustration the anvil. Many times I have had blacksmiths call my attention to their anvil, being lower in the middle than on the ends, but as to the real cause, they knew absolutely nothing about it. The reason is that the body of that anvil was made from a poor quality of soft iron, scarcely better than muck bar, then the steel was welded on, which was not over 3/8 of an inch thick, and was no doubt properly welded, but the continuous hard hammering in one place had caused this soft muck iron to settle or give way, and what could the steel face do but to go with it. Now, if the body of this anvil had been as solid as even good wrought iron, every one of those anvils would have lasted twice as long.

Variable Steel.

For a little more proof, let me say that in the days when I learned my trade, the sledges were all made from wrought iron with a steel face 3/8 inch thick welded on it. This would stand possibly six months, owing to the work that was done with them, and as the soft iron gave way or settled, so would the face, and in the end, break almost invariably in three pieces. The steel was of the best quality and properly welded, but as soon as the iron moved the weld was bursted and the face soon came off. Sometimes if the iron was quite solid, the weld would become crystallized and then come off.

No man can weld a steel face on an iron sledge and have it stand very long unless he puts it in a V shape. Nor can he weld two pieces of cast steel together of high carbon so that they will not come apart after upsetting and drawing out a few times, and if any man doubts this, let him try the experiment and he will find this to be a fact. All blacksmiths and tool dressers know that cast steel is variable.

If the fracture of a bar of cast steel, after being broken, shows uneven coarse grain on one side and fine grain on the other, it shows that the bar has been unevenly heated or much hotter on the side having the coarse grain; the heater has allowed the bar to lay in the furnace with one side exposed to the flame, and the other side protected and he has neglected to turn the bar over. If the outside of the bar is fine and the center coarse, the bar has been very hot all through, and has been finished with light blows of the hammer, or has been passed in the rolls lightly; it has been worked superficially and not thoroughly. If the whole outside of the bar is coarse grain and the center is fine, the steel has been heated too hot on the outside and too quickly; it has not had time to get hot through, and it has had too little working in the finishing. If the grain is dark with the appearance of heavy India ink tint, the steel has been finished too cold, and it will be brittle. If the grain is very dark, especially about the center, looking almost black, then it has been finished entirely too cold, the grain is disintegrated, and the bar is fit only for the scrap pile.

When a cold chisel, lathe tool, or any tool breaks, and the fracture looks white and coarse grain, it has been too hot when hardened. If a cold chisel, or hardy, or axe break in a circle, there is a strain in it, which may have

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A Heat to Avoid

[illegible] blacksmiths who are not aware [illegible] or fatal blue heat should [illegible] all kinds of steel, also iron.

[illegible] experiments that I have made from time [illegible] me that it is very dangerous [illegible] steel at that temperature, but as to [illegible] mechanics will realize, until [illegible]

[illegible] mechanic can make a test for [illegible] Take a strip of iron or steel [illegible] that can be easily bent [illegible] off the scale on one side until [illegible] a clear metal surface. Place the [illegible] bright side up over the fire [illegible] get hot enough so that the bright surface [illegible] pale blue. Then bend the piece [illegible] and it will break or crack before it gets [illegible] there will appear checks or short cracks on [illegible] the main break and parallel to it. Iron or [illegible] grade will act this way. This will account the many so-called mysteries [illegible] ols. For an illustration. I [illegible] does not exactly fit, it is a [illegible] fore hammering it in shape. [illegible] brought to this blue or [illegible] ll invariably cause fractures [illegible] discovered until the boiler has [illegible] me effect will be produced if the hammering [illegible] a flange which has cooled [illegible] lue heat. From this it f [illegible] e worked at a red heat if [illegible] nen cold, or at the ordinary temperature [illegible] Boilermakers or machinists who [illegible] ust described will by all means [illegible] steel at this dead or fatal blue heat. [illegible] hammering at this heat makes the steel [illegible] or separates the molecules, and [illegible] will restore it.

Now, reader, when you consider what I have [illegible] I think you will realize that there is something [illegible] about cast steel. In my school of instruction [illegible] task I have is to convince my pupils how [illegible] about cast steel, and how much there is to [illegible] when I have accomplished this, I consider my task [illegible] done, but it takes much longer to accomplish [illegible] some than with others.

There are mysteries or facts pertaining to the working of cast steel as well as the making, which cannot be explained; at least I have no language to do it, and when presented to the average mechanic they look very absurd and unreasonable. I [illegible] mention a few of them. For instance, the laying [illegible] forged from a high grade been caused by hammering or hardening. If a hardy or axe has a crack in it straight from the edge, it has been too hot. If the crack is back from the edge and runs crosswise, the steel is of poor quality. If a bar of steel, after being heated, has a thick, heavy scale on it, throw it in the scrap pile at once; if the scale is thin and of silky appearance and small and round, it is a strong token of good steel and is perhaps high carbon, and a hundred and one other signs which you can find elsewhere in this book.

A Heat to Avoid.

There are thousands of blacksmiths who are not aware how necessary it is that the dead or fatal blue heat should be avoided in working all kinds of steel, also iron.

The many experiments that I have made from time to time has fully convinced me that it is very dangerous to work any kind of steel at that temperature, but as to how fatal this heat is, few mechanics will realize, until they make a test or see it done.

A boilermaker or any mechanic can make a test for himself in a few minutes. Take a strip of iron or steel plate, say ¼ x 1½ inches wide, that can be easily bent at the anvil, and grind off the scale on one side until bright enough to expose a clear metal surface. Place the strip thus prepared with the bright side up over the fire and allow it to get hot enough so that the bright surface has become blue, a low or pale blue. Then bend the piece in a V shape, and it will break or crack before it gets down flat and there will appear checks or short cracks on each side of the main break and parallel to it. Iron or steel of any grade will act this way. This will account for the many so-called mysterious failures in work and tools. For an illustration, I will take a boiler flange. If it does not exactly fit, it is a custom to put on heaters before hammering it in shape. In this way, the flange is brought to this blue or dead heat, and the hammering will invariably cause fractures, and the cracks may not be discovered until the boiler has been in service. The same effect will be produced if the hammering is kept up on a flange which has cooled from a red heat to this fatal blue heat. From this it follows that iron or steel should be worked at a red heat if possible and if not possible, then cold, or at the ordinary temperature of the shop. Boilermakers or machinists who will try this experiment just described will by all means avoid working iron or steel at this dead or fatal blue heat. In tool dressing, hammering at this heat makes the steel flaky, it disturbs or separates the molecules, and nothing but re-melting will restore it.

Now, reader, when you consider what I have told you, I think you will realize that there is something to learn about cast steel. In my school of instructions, the hardest task I have is to convince my pupils how little they know about cast steel, and how much there is to know, and when I have accomplished this, I consider my task half done, but it takes much longer to accomplish this with some than with others.

There are mysteries or facts pertaining to the working of cast steel as well as the making, which cannot be explained; at least I have no language to do it, and when presented to the average mechanic they look very absurd and unreasonable. I will mention a few of them. For instance, the laying of any tool forged from a high grade of steel down on the wet ground to cool, or laying the same in a draft of air to cool off, or laying it on a pile of fresh coal to cool, or allowing a cold blast of air from the bellows to strike it during the process of forging, or allowing the steel to soak for a long time in the fire after being hot enough to forge, or allowing water to be spattered on it while red-hot after being forged; any of these is very injurious to steel, and there are a dozen others that I might mention, but I have not time. On the other hand, there are so many sayings that are weak and absurd, pertaining to cast steel, and with no reason or foundation whatever, except that they were born of men with small heads, and the little brains they had were given to superstition, miracles and witchcraft, instead of common sense and mechanical science. There is the spoiling of cast steel by upsetting it, the heating of water to harden steel in, rubbing chalk on any thin piece of steel to keep it from warping, and many others too numerous and ridiculous to mention.

Arrangement of the Shop.

The shop should be roomy and have plenty of light except at the fire where tool dressing and hardening is done. This should be so arranged that the tool dresser can shut off as much of the light as is necessary when hardening tools, either by curtain or otherwise, as no man can do a perfect job of hardening when there is too much light. Plenty of light when forging is not only all right but a necessity. I have many times been asked why I want the light shut off when heating to harden. I answer, " So that I can readily determine the heat I have on my steel."

The arrangement and location of tools have much to do with the room and convenience in a shop. In cities where room is scarce, the bellows, if you use one, can be hung overhead, and if properly hung will blow just as good as if it were on the floor. It is a good idea to put bellows in the corner. This protects two sides from getting holes punched in it from bars falling against it.

After the forge has been located and the bellows hung, the next in order is the anvil. Its location depends much on the class of work to be done. If you are dressing tools exclusively, you want the anvil as close to the forge as possible. Every smith who knows his business wants to get to the anvil as quickly as possible after he takes his tool from the fire.

There must be a way to get rid of the smoke from both stove and forge. It has been a custom for many years for some blacksmiths to work without either stove or chimney, and if they had a chimney, it was generally wrong end up. It is just as easy to build a chimney that will draw as one that will not draw. The shape of the chimney has but little to do with the draft, the secret lies in the flue. After building the chimney up about six inches above the forge, let it lean gradually toward the fire with each layer of brick, until it gets up high enough to begin the hole or mouth and have this hole in the center of the bulge, 10 x 3 inches. Let this run in the square flue or bottom of the chimney. The throat of the chimney should be not less than 10 x 10 inches inside and as much larger as you care to make it. Bear in mind that the larger you make the throat of the chimney, the better and stronger will be the draft and in making the throat larger make the chimney higher. Make the throat or flue gradually large at the rate of 3/8 of an inch to each foot from the bottom to the top, or nearly so. Have this bulge project out at least 6 inches toward the fire and have the mouth in the center of this bulge. If you follow these directions, the chimney will take out both gas and smoke, and all of it.

If a chimney built on this plan be carried in height to, say, 40 feet, and the size of the flue be made, say, 15 inches, tapering as per directions, the chimney should have such a draft that it would be detrimental to the fire, as it would keep the blaze in a whirl and take up the final coal also. Some blacksmiths have for an excuse that their chimney is in a bad location. The location has nothing to do with it, if the chimney is high enough. Bear in mind that heat expands and that the chimney takes in heat as well as smoke, and the object of building the throat as instructed is plain. A chimney built with the mouth larger than the throat takes in more than it can swallow. It is like biting off more than you can chew. On the other hand, when the mouth is the smaller, the hot smoke entering the mouth expands. This causes a suction that pulls up everything with it. I have seen a great many chimneys that had *too much* draft, which is easily regulated. The chimney just described will draw up cold air very readily, and when you come to put a fire at the bottom and heat the air, the draft is doubly strong.

Some thirty-five years ago I was traveling through the northwestern part of Pennsylvania, dressing mill picks for the flouring mills. I went to a shop to get the use of a fire and noticed that the chimney was larger than common and also higher. I dug out the fire, lighted the shavings, took hold of the bellows pole, and began to blow. To my surprise, I saw the shavings going up the chimney on the gallop. I called the blacksmith's attention to it. He stepped behind the chimney and took out a brick which let in more air. This was equivalent to making the mouth larger. Things that are out of the ordinary make an impression on the mind that stays with us through life.

My object in relating these things in detail is to prove conclusively that they are facts and are gathered from practical experience. One man who built a chimney this way told me he had laid up and torn down that chimney four times before he got it to suit him.

Some smiths say they would not have a chimney in a shop; " What good are they? " My reply is, " They take out the smoke, take out the gas, take out the sulphur, keep the tools from being eaten up with rust, and take out the foul air."

The Forge and Fire.

The smith's fire is of great importance in a well-regulated shop. Blacksmiths are not plenty who understand how to build or lay up a good fire, and many of them build up and tear down every few weeks.

The improved iron forges that are on the market in these days save the trouble of laying up a fire as we had to do in the bellows days. The blacksmith who wants a small fire fills the cavity or space for the fire with stone, brick and clay, leaving only a space for the fire about as large as a quart bowl. Then he says he will have a good fire and a small one. The first time he builds a fire the space is so small that the sides at once become red-hot and all the melted iron slag and dross run on the sides of the fire and stick to it, as the space is so small, and in a short time his fire is filled up completely and then he cannot get any wind and the next time he builds a fire he breaks it off with a hammer and knocks out the whole side of his fire; then more brick and clay are needed to build it up again. In a few days he repeats his past experience and so on all through life, wasting several days' time each year in repairing his fire.

Build up your fire and leave a square space not less than 10 inches each way. Build the sides up straight, or nearly so, for 5½ inches above the box or grate and when done fill it up with dirt from the forge. Now, dig out just enough to build a fire in, take it out down to the tuyere and build your fire in it as soon as finished. This fire will last you as long as you live and be a good fire. The dirt that you put in will hold the heat and the cinders, and the hot slag will not stick to it. You can take out the cinders with a poker and not disturb the sides of your fire.

A forge built in the old way out of board, stone, brick and clay will hold the heat better than an iron forge will, but that kind of a forge takes up too much room and cannot be moved, if necessary to do so. Get a new iron forge and blower complete and you can set it up ready for use in 30 minutes. I shall not say anything about the bellows, as they have about passed out of existence. But, as far as wind is concerned, a good bellows will give a certain amount of wind with less outlay of strength than any other thing ever devised. A man who has a good bellows properly hung need not exchange it for a fan blower. Yet, if I were to start in business again, I would put in an iron forge and a fan blower.

Making a Wood Forge.

Get 2 x 4-inch sticks long enough for four posts, and saw them off so they will be about as high as the anvil. Let the front ones stand on a slant so that the bottom stands in about 8 inches. This will give room so that your toes are not stumbling against the bottom of the forge. Nail strong cleats from one post to the other, so as to hold the bottom solid. This will save laying up from the floor, and it is just as good as if laid from the bottom. This forge has one advantage over the iron forge, it keeps the heat in, and you don't lose any from the bottom, which is some saving. But, it is quite a job to build a forge and set your box or tuyere. It is also a dirty job, and it is not advisable for any smith who rents a shop to build a forge of this kind. He had better get an iron forge, and when he wants it moved it can be done in a very few minutes.

Greasing a Bellows.

Never grease a bellows unless it is old and stiff. Then in order to do it properly, take a sponge or wet cloth and dampen the leather thoroughly, then apply a little Neatsfoot oil. Do this as soon as you have dampened the bellows. Don't chain up your bellows at night. Let it lay down flat in its normal condition. A bellows, when properly made, has as much leather in it up and down as it has in width. That is, if a bellows is 36 inches in width, it should measure 36 inches or more at the large end when stretched open. If it is a little more, no matter. But if it is less it does matter. It is a rule with some smiths when hanging a bellows to hang it level. That is, to have the center plank of the bellows level. This is only a matter of opinion. If it is 3 inches lower or higher, no matter; it works just as well. It is very necessary that a bellows should be put up solid. The posts should be nailed to the floor and the top well braced. The point of the bellows where the bands are should not be close to the fire. It dries the wood and the bands get loose and it soon goes to rack. This is an important feature and should be remembered.

Welding.

When we weld a piece of wrought iron, it becomes melted, or should be, and runs together. Not so when we weld cast steel. The steel has not melted at all, and the only flux that we have is borax, or some other artificial flux, and it does not form a complete union of the metals, but has made a good glue joint, and it does not take very much hammering, upsetting and hardening to tear the artificial weld apart, consequently a weld should never be made where there is to be a cutting edge, for it will be a complete failure. I admit that a fairly good job of sticking or gluing can be done. For instance, cast steel drills or jumpers for drilling granite may be welded and stand fairly good, perhaps until they are worn out. Yet, they were never really welded.

The Anvil.

The height of an anvil should depend upon the height of the smith that is to use it. If there is much heavy striking or steel punching and such work, we would want it as low as possible, so as to give the helper a chance to strike a hard blow and do it easy. A helper can strike a much harder blow on an anvil 2 feet from the floor than he can if it is 3 feet. The rule that holds good for all kinds of smithing is to stand up straight, let the arms hang down, then double up the fingers and set the anvil so that the knuckles just rub on its face. No matter about your height, if you are 5 feet or 7 feet, this rule is correct for all. Insist that your anvil be raised or lowered as circumstances may require. If the anvil is for heavy forgings or wagon work, then it will be better set farther from the forge and parallel with the forge, and the heavier the work the farther the anvil should stand from the forge.

It is not necessary to get a long stick of timber and cut a hole in the floor or dig down several feet to set the block in. Just get a plank 1½ or 1¾ inches thick, saw off 4 pieces as long as necessary to raise the anvil to the required height; about 19 to 20 inches is right for most anvils. Join these four pieces together so that the top will be just the exact size of the bottom of the anvil. If the anvil is 11 inches each way, the bottom should be at least 16 inches square. Saw off the bottom so that it will lean to you 1½ inches for the 20 inches. Then saw off the top of the block so that the anvil will lean from you a little. Take a piece of the plank about 6 inches and 2½ wide and round off one side until it fits nicely in the hollow of the anvil at the bottom. Nail this to the block at the bottom of the anvil, both in front and back. This upholds the anvil to perfection, and at any time you want to take it from the block, raise it up, straighten it, and it will come out as easy as if there were nothing to hold it. This block being hollow, the anvil does not touch in the center. In fitting the anvil to this block, shave off the block until the anvil touches at the four corners only.

Dressing the Anvil.

This is of great importance to many country smiths who are in need of anvil dressing, and it may look like a big job to the average smith. Yet, it is comparatively easy. First, I build a large fire with not less than a bushel of coal and good coal. If it has been coked, so much the better. Lay the anvil in the fire face down. Blow lightly, taking at least 40 minutes to bring it up to a red heat. The reason why I take so long a time to heat the face is that if I should drop the anvil in the intensely hot fire and heat as quickly as I could, the body of the anvil would still be cold, which would result in tearing the steel loose. Pack the coal around the anvil so as to keep the heat in, blow a little, then stop for a time, then blow again, and so on until you can get the face hot. When the face is heated evenly, bring it out, set it on the block. If the face is hollow in the center, which it is likely to be, take your flatter, or slick, as it is sometimes called, and with a good heavy sledge work your face down level or nearly so. If it is left a trifle hollow in the center, say ⅛ of an inch, no matter. Don't strike it on the side. Take your hot chisel and dress or cut it off as narrow as you want it. That steel face is packed down on the iron solid and even. If it is not welded thoroughly, it will stay there a long time, but if you strike it on the side, it will surely loosen the face. Next measure the width, which must not be level, but full in the center. Lay a straight edge across the face. Let it touch in the center and the cut edges should be $\frac{1}{8}$ of an inch below the straight edge. Have this fullness extend about 4 inches and have the corner next to you quite round, say ¼ of an inch, and have this round corner made so as to fit the round corner in the flat side of the back part of a cold chisel when you are dressing it. The next 4 inches toward the hardy hole should be just a little full in the center, say $\frac{1}{16}$ of an inch; the balance of the face clear to the end must be level.

Hardening Anvils.

For the corners, bear in mind that the first 4 inches from the horn is finished. Next to this or about in the middle of the face file off the back corner for about 3 inches to a short round, and for the next 3 inches file it off to a straight bevel. This bevel will be found very useful in dressing chisels or other tools when it is necessary to put the bevel on them with hammer instead of filing. Then leave the balance of the face with sharp corners and make both sides of the anvil the same, except the first 4 inches from the horn where the round corner next to you is a long round made to fit the bit of a cold chisel. Such an anvil face is better adapted to do any kind of work than any other shape. Now we are going to harden this anvil. Before we commence to harden, we will get a barrel—the larger the better—saw it in half; fill half full of clean water with a half-bushel of clean salt thrown in it and stir until dissolved. Next get two tubs and fill them with water. Be sure and have plenty of water. Have a big fire and lay two bars of iron on each side of the fire so that the anvil will move easily back and forth through the fire so as to heat the face evenly and the whole length. When the face gets to a low red, take it from the fire, and rub on plenty of pulverized Cyanide of Potassium and Prussiate of Potash, equal parts. Then lay back in the fire and heat to a red heat, not white, but a red. Take it out and drop in this tub of water which we have previously prepared. Drop the face in, say 4 inches. Then stick your arm into the tub and with your hand throw the water up against the face as fast as possible. Have a man then with a pail to dip the water out of the other tubs and pour it in your tub just as fast as possible, so that you have plenty of cold water to throw up against the face, and when you have the face cool, let it down in the tub and leave it there until it is cold. Don't undertake to draw any temper, as there is no danger of getting it too hard. When cold, take it out and rub the face with a brick until you have the face smooth.

Anvils are so cheap these days and so many are making them that it is hardly advisable to waste much time on old, worn-out anvils, as the majority of anvils that were made years ago were faced with a steel of very low carbon and it is almost impossible to get them hard enough. In order to handle the anvil easy, take two bars of iron 2 feet long and fit in the holes in the middle of the anvil. These are called porter bars.

Dressing Mill Picks.

There is no work known to smithing which so few men understand as that of dressing mill picks. The weight and size of mill picks depend upon the fancy of the miller. Some want picks 1½ lbs., the next may want 4½ lbs. However, I sell more 3-lb. picks than all other sizes combined. For ordinary size, take a bar 1½ x 1⅛ inches. First mark the bar off in picks, according to the weight of the pick wanted. Mark the center for the hole, if holes are wanted. Some have no holes, but are used in a socket for the purpose. After the hole is punched in the center, heat and cut off, not straight across, but at an angle, which reduces the labor of drawing down to the bit. In drawing down the bit, take it on the large part of the horn. Have a hammer made like a cold chisel hammer and draw down with the peen end, and have the helper use the peen end of his sledge, and you can draw it out in one heat. When drawn out to the proper thickness, have it a trifle narrow. Then cut the end off straight across, and heat to a low black red and begin this packing process by putting from ten to twenty blows on it as hard as you can strike, turning it over occasionally and holding it level on the anvil. Then return to the fire. Don't stick it in the fire, as you will get it too hot, especially the corners. Hold it above the fire, say two or three inches, and heat it to a black red only and repeat this hammering three or four times. Then it is done, but don't turn it up on the edge and go to hammering it. One blow on the edge will destroy the good effects of all these hard blows that you put on them. The hard blows that you put on the flat side packed the steel and made it dense and solid and gave it double the tenacity of steel in its ordinary state. I hear you say that the pick was spread out and the edges are uneven. Suppose it is; all the miller wants is to know that the pick will cut. If on any job it is necessary to have the edge straight, cool off the pick or tool, and file the edge straight. Now we have the pick dressed. Harden it as follows: Have your fire in good shape and lay the pick on a bar of iron so as to keep it from working down in the fire. Keep the pick up clear from the fire and heat slowly. Turn it over often, so as to heat even to a low red. Then plunge in the bath and cool off instantly. That end being done, then go through the same performance with the other. It is best to cool off the bit only in the tempering bath, say about 2 inches. Then take out and cool off in the tub. The colder you can keep it the better it will harden the pick. If by chance you should get one too hot, lay it aside and dress it over again, as it will not stand. If a pick comes back broken, put your magnifying glass on and see what was wrong. If the steel is coarse and white, it was too hot when you hardened it. If the steel is very fine and of a gray white, it is all right and must have been broken through carelessness; if the steel is of a dull gray, it is good for nothing. Watch the scales that fall from the steel as you are working it. If the scales are large and thick, throw it in the scrap pile. If the scales are small and thin, like fish scales, the quality is good.

The Bath Tub.

We must have two bath tubs, one with the hardening bath in and one with clean water only. Two in a very small shop take up some room, besides the salt in the hardening bath is continually eating off the hoops on the tub or barrel. To avoid this, I get a large barrel and saw off, so as to leave the barrel 30 inches high. Get a large barrel; then a small barrel or half barrel, and rivet on a couple of handles and run a stick through it, and suspend it in the barrel of water; then you have the whole business in a nutshell, and the water around the barrel or tub, with the hardening bath in, will keep the hoops from being eaten off with rust, besides being very handy, as they should be, both together, for after plunging the tool in the bath to cool off, the salt in it makes the tool white and it must be dipped in the clean water to rinse it. This tub or barrel with the tempering bath in it should be arranged with a cover on it to keep the dust and dirt out. This cover can have a hinge on it, so as to open only about one-third, and when not in use, drop it down. To prevent this outside barrel from freezing in cold weather, set a stick about 3 inches square in the barrel. This will prevent the barrel bursting, as the ice rises up around this stick, and the hardening bath will never freeze so long as you have salt enough in it to harden good.

Coal for Fuel.

There has been a good deal of argument as regards the best coal for smithing purposes and particularly for tool dressing and steel work. It is much more essential to have good coal, free from sulphur, for forging and welding than any other branch of smithing. It is the sulphur that makes coal unfit for welding; it is the sulphur that unfits coal for tool dressing. So far as the mere heating a piece of steel to forge or harden, it matters not how that heat is produced, the only question of importance is, can we get the desired amount of heat in the proper time and have the tool free from sulphur and slag. Outside of these two points just mentioned, the question of heat is not even good moonshine.

Anthracite coal for some purposes is superior to any other coal ever discovered. It is free from smoke; it has the greatest heat and is very solid. A fire properly made with the right kind of a fire box or grate, will last at least three hours and longer without cleaning. This makes it very desirable for a tool-dressing fire. There can be more work done in a certain length of time with this hard coal than any coal yet discovered. Yet Bituminous has some advantages over it, as being light and loose, you can put irons of irregular shape in the fire and not disturb the fire, and the soft coal has several other good points—you can light a fire with a few shavings or a little waste, when with the Anthracite, it would require blocks of wood. This coal requires much more wind and will soon go out if left with no draft. Coke is a *good* fuel for tool dressing after being broken up, but it is a tedious job to break it by hand, and until it is broken it is almost worthless. It is, as a rule, fairly free from sulphur. When a fire is found to be full of sulphur in any coal, the only safe rule is to heave it out. Sometimes water thrown in the fire will drive out considerable sulphur, but not enough to cleanse it. In doing work, when particular welds are to be made, such as welding up stays on reach plates, or welding steel in tools, great care should be taken to select coal as free from sulphur as possible. It pays to take the time and lay some first class coal aside for such work. In burning soft coal, have a bushel or more of coke laid aside for special work.

All kinds of coal are better kept under cover, as the rays of the hot sun destroy their virtue. Fine Bituminous coal is better than the lump, as the purest and best coal breaks easily. Coal that makes too much smoke is undesirable for many kinds of work. Such coal should be charred up or coked for steel work. The time taken in coking it is well spent.

Selecting a Tool Dresser.

The manufacturers in this advanced age are looking for the most modern machinery, the best tools, the best machinists, the best material, but in their hardening department you find only an ordinary blacksmith to do the hardening and tempering. There is not a man in the employ of any shop, large or small, who can make and save the money that a good, practical steel worker can. To make a success, it is absolutely necessary that he should know what is inside of the die or tool which he is about to harden. He should understand the amount of carbon in the steel as well as its quality. It is also essential that he understands what the tool is to be used for. There are thousands of expensive tools sent to the scrap heap for no other cause than that they were made from steel which was not suitable for the work they were intended to do.

There have been a host of articles written from time to time relative to hardening with cyanide. Cyanide will not answer in every case, but there are some places where it is all right. For instance, we have a wire die with a hole in the center which we want very hard—much harder than the outside. The first move is to bring that die up to a low red, and the longer we are doing that the better. Bear in mind that if you are going to use the cyanide, it can be hardened at a little less heat than without. After it gets to the proper heat, have a piece of cyanide in a pair of tongs and just touch the hole, and the cyanide will instantly melt and run; then plunge it in the cold water and draw no temper. If we have some ¾-inch taps to harden, unless we are extremely careful in heating, we will at some time get the delicate teeth a little too hot or hotter than the body and as quick as we have heated the teeth hotter than the body, we have reduced the strength of those teeth. If we had daubed on the cyanide in addition to the extra heat, what kind of a mess would we have made? If you want to use it, do so. But use your brains as to when and what on. Now, while cyanide, like all other case-hardened material, hardens only skin deep, it does harden deep enough in those delicate teeth of the tap to cause them to crumble, and much more especially after the tap has been overheated.

The process of making and hardening all tools belonging to the cold chisel family covers a greater field of secrets and science than any other tool or class of tools ever made by mortal man. The principle embodied in the making and dressing of these tools enters largely into all kinds of tools made or dressed by the tool dresser or blacksmith.

Cold Chisels.

The proper size for cold chisels, chipping chisels and cape chisels, both round and flat, is ¾-inch octagon, and some shops use ⅞-inch and of 70 to 80 carbon. However, the ¾-inch size is the best for all work where it is possible to use that size; as there is not so much resistance to the blow of the hammer as there is in the ⅞-inch bar. A short chisel has the advantage over a long one. You may say that a long chisel wears so much longer. So it does, but the gain in work that the short chisel does over the long one soon pays for the small loss of steel.

The length of steel required for a chisel is 6½ inches. In cutting up the steel for chisels, select the ends that are in the best shape or nearest square across, and round them up for the head, then when you draw out the chisel bit be very careful that there are no laps or flaws of any kind, as a lap will surely make a flaw. Heat to a yellow or bright orange, and if you have no power hammer at hand, teach your helper to draw them out with the peen of the sledge. Do this on the horn of the anvil. Have him put every blow directly on the top of the horn. You can even up the blows by drawing the chisel steadily backward. The advantage of this is that it draws the chisel out in half the time and draws it out without so much edging up which must be avoided in all chisels. Draw the chisel down nearly to what you want it, having it a trifle narrow. By the time it begins to get cold, perhaps not quite cold enough to finish, which must be done at a low heat, say to a black red or just so that you could see that it is a trifle red, then hold it in the round part of the anvil face and put the hard blows on it with a hammer of 3½ lbs., made expressly for this work. Then turn it over and go over the other side the same. Put the blows on as hard as you can, and strike level, holding the chisel level on the face, and when you turn it over be sure to get it level before you strike. When it is too cold, return it to the fire, not putting it in, but holding it up from the fire about one inch and move it back and forth and turn it over, so as not to get it too hot. Heat it evenly. Take it out often, look at it, and the moment it gets the least bit red repeat this hammering. Go down on one side, back on the other, and over the middle. Then turn it over and do the same on that side, but don't turn up and strike it on the edge. Repeat this hammering three or four times or more. Do not forget to put the blows on as hard as possible; that is what does the business. It packs the steel and makes it dense and increases its strength fourfold. If you should turn that chisel up and hit it one blow on the edge, you have unpacked the steel, made the grain coarse and destroyed its strength. You have undone all the hard blows you have put on the chisel. The object in holding this chisel absolutely level is to keep it from breaking the grain after it is packed; and the hammering on both sides so evenly is to avoid putting strains in it.

Hardening Cold Chisels.

Now we will harden it. First have your fire in good order, well charred down, so that the smoke does not bother. Hold this chisel over the fire (not in the fire) about one inch above or more. Blow lightly, moving it back and forth, turning it over, and now and then taking it out of the fire to see what heat you have got. When you have it to a dark orange color or beefsteak red, take it from the fire and plunge it in the bath and as soon as you take it from the fire, dip it not less than three inches. When cold, take it out and give it a quick dip in clear water. This washes off the salt and strong brine which the bath has left on it. Rub it off with a coarse emery stick. As we have not heat enough left in the chisel to draw the temper down, we will hold it over the fire and help it, being careful to move it back and forth, taking plenty of time. The longer you are drawing the temper the more even you get it and the better job you have done. Keep this about three inches above the fire, which depends largely upon how hot the fire is. When done, we want at least 1½ inches of temper of the one color. To do this, you must go slow and watch it. I hear you say that this takes longer than the other way. Suppose it does; the chisel, when properly dressed this way, will do more work than ten dressed in the old style. There is no tool that is used so much and understood so little as a cold chisel. In fact, there are but very few smiths that know how much work can be got out of a chisel when properly dressed. In order to fully illustrate, I will cite a circumstance that happened in the Brooks Locomotive Works, at Dunkirk, N. Y., when I was a tool dresser there. One of the machinists whose business it was to chip out a recess in the steel axles of the driving wheels about one inch wide and six inches long in hard tough steel, went to the tool dresser who had been dressing the chisels and who was considered good on them, and got fifteen chisels, and it took the whole fifteen to finish up the one keyseat, as it may be called. Then he came to my fire and got one chisel, and with this one chisel he chipped out eight of the keyseats. Draw your own conclusion. I want every blacksmith that reads this to follow these instructions closely.

There are some tools that must be hammered as much on one side as on the other. Consequently, you knock off with one blow what you put in with the other. That is why a diamond point should be made of higher carbon steel than side tools, or cutting-off tools. This "packing" theory applies to high carbon tools, yet it must not be carried too far. If we pack a high carbon tool too much and at too low a heat, it makes it flaky like pie crust and it will split off in flakes.

The rules just mentioned apply to the machine shop, but the jobbing smith can see at once that the theory applies to everything that has got a flat surface.

Flat Cape Chisels.

The same theory applies to a flat cape chisel as to a chipping chisel, except that it has to be kept narrow and cannot be made thin as far back as a chipping chisel. The method of forging does not require much explanation. They are drawn out flat, the same as a cold chisel, turned up on the edge, flattened down at the point for about two inches back in the opposite direction; gradually getting thicker and narrower. A cape chisel is supposed to be the widest at the point and taper back gradually so that in case it is necessary to cut a keyseat, it will clean itself; otherwise, the same directions apply as to the cold chisel.

Round Cape Chisels.

Some mechanics call round cape chisels "gouges," but they are not. They are altogether different. They are made the same as a flat chisel, except that they are put in a swedge and hammered, which makes the bottom round. This chisel must be packed in the swedge and at a low heat. If the chisel is a very narrow one, then it can be packed on the flat side, taking care to keep the point or cutting edge full width. When done, take a sharp, thin chisel and cut the bevel from the flat side. All sizes of round cape chisels are made on the same principle and hardened as chipping chisels, except it is not necessary to harden them up quite so far. It is necessary to have a swedge expressly for making round cape chisels, and instead of running across the anvil, it must run lengthwise, and four or five different sizes of swedges —5/8-inch being about as large as will be used much, and 1/8-inch about as small as will ever be needed. Care must be taken not to get the rounds too deep. When ready to harden, lay it on top of the fire upside down and heat very slowly until it is a dark red, then plunge in the water and cool off entirely. Rub off with an emery stick and set it on the fire, shank down, and run the temper down to a blue, then drop in the water. This leaves the shank soft and prevents it breaking off. The top of these swedges should be of cast steel.

Flogging Chisels.

Flogging chisels are what the average smith calls a cold cutter. They are made from various sizes of square steel, varying from 1¾ to 1⅛ inches. For the average class of work, cutting off tires and general cold cutting in jobbing shops, 1¼-inch is heavy enough. The thickness depends on the class of work you have to do. Have them as thin as possible and have them stand. First punch the eye, then draw down the end for the head to a square and leave it much the highest in the center. The object is twofold; it brings every blow from the sledge exactly in the center, besides keeping the head from splitting off, as it would do if the steel was high carbon.

The proper carbon to be used in flogging chisels is from 70 to 80. If for track work, where the tool is to be used by inexperienced men, 70 is best.

Heat for Packing.

The proper heat for packing is just so that you can notice a red; then take your flatter and let your helper come down on it as hard as he can with half a dozen blows. Turn it over every few blows, so as to keep the steel free from strains. When it begins to lose its heat and gets too cold, return it to the fire. Lay it on top and heat slowly and evenly, turning it over in the fire often and when at the proper heat, a black red, repeat this packing process with flatter and sledge four or five times. It is perhaps a little wider at the cutting edge than it should be, but do not hit it on the edge; let it cool and file it off.

Do not have the bit much wider than the steel, and if for track work, cutting steel rails and such work, a little narrower is better. Do not have the cutting bit straight across; have it a little round, it stands much better. Now harden it. Heat to a low beafsteak red nearly up to the eye and plunge in the bath not less than 2½ inches and hold it there until it has cooled. Then rub off and let the temper run to a purple for hard track work, and for jobbing shop work down to a pigeon blue. However, these colors depend much upon the carbon; if the steel is above 80, reduce the colors. If you lack heat to run colors down, hold it over the fire and look at it often.

Hot Chisels.

Hot chisels—some call them splitting chisels—are made the same as a chipping chisel, so far as working the steel is concerned. For country shops, 1⅛ inches is large enough. Draw them down very thin and fairly wide, as the width adds to the strength. Punch a hole or eye two inches from the end. Draw the end down to a square for the head of the chisel, and leave it highest in the center. Cut the bit end off 2½ inches. Draw down thin and pack with hard blows, as has been explained before, and when done harden the same as the chipping chisel, letting the color down to a sky blue. It is very essential that every shop should have at least one very thin hot chisel for trimming, which cannot be done with a thick chisel. They can be made from 1 or 7/8-inch steel and of a little higher carbon. This trimming chisel, as I shall call it, can be made very thin and yet do the work it is intended to do. In using hot chisels when the work is thick, or heavy, dip the chisel in the water often; it helps to preserve the packing. Bear in mind that any of these chisels which have been properly packed would do a surprising lot of work without hardening at all. If a hand cold chisel is made of 90 carbon steel, and properly packed at the right heat, it would do very well at ordinary work if it were not hardened.

A chisel made from 1¼-inch square steel of the best quality and of about 75 carbon, will, if properly made, hardened and tempered, cut a ¾-inch bar of octagon cold chisel steel 1500 times without dressing or grinding, and this is only medium, as I have made chisels that did nearly double that amount of work. This to the inexperienced steel worker no doubt looks unreasonable, but if you are a practical smith and will follow the rules laid down here closely, you will then change your mind.

Heads of Chisels.

It pays to harden the heads of all chisels of less than 80 carbon, which is done as follows: After the head of the chisel has been rounded up, heat to a low red and stick in the hardening bath ¾ of an inch, and let ru down to a light sky blue. This will increase the wear[illegible] the heads. When a chisel of any kind gets badly battered on the head, don't undertake to weld it up; just set it in a hole in a swedge block and take a flogging chisel and trim it all off. It will then last longer than if welded up, as the steel on the head is compact and dense from the many blows it has had from the sledge and will last a long time before it gets that way again. Cold chisels of less than 75 carbon will batter down very fast. The better way with them is to stick the chisel over the face of the anvil, and hit it on the head and drive it back towards you. That will knock off a part of it and turn the chisel around and knock off the rest.

Use of Chisels.

The using of a cold chisel, or chipping chisel, is a matter of much importance. The angle or bevel at which the bit should be ground depends largely upon the work to be done, but for all ordinary jobs the angle of a three-cornered file is proper.

If we have a chisel 1/8 inch thick on the bit and we grind it back so that the bevel is 1/4 inch long, how can we expect that chisel to stand up under hard blows on hard metal? Take this same chisel after it is broken and grind it so that the bevel is at the angle of a three-cornered file, and it will in all probability stand first class. In chipping hard work it is very important that the chisel should be held up close to the work. Do not strike it when it is 1/8 or 1/4 inch from the work. Its liability to break is doubled in case you are chipping cast steel. After working with the chisel a while the edge of the chisel becomes glazed and will not hang to the work, besides it gets loaded and all the little bits of iron and file chips that touch it, hang to it, and it does not cut good. Take it to the grindstone and grind it a little, no matter whether it is dull or not, and it will stick to the work better. On small work, where a very sharp edge is necessary, instead of grinding the thick chisel, have a thin one and the same angle of grinding will do.

A round chisel is put in a swedge block or anvil swedge and bent round. This must be done at a low heat, so as not to destroy any more of the packing than is absolutely necessary after it is properly packed and evenly heated. Lay it on a swedge and set a large fuller on it and when it is bent down and properly crooked, it can be packed a little more with the fuller. File up before bending and have the bevel the same on both sides, except for some special work. These gouges are very useful tools and should be made of selected steel of about 70 carbon. Have all sizes from 3-inch circle to 1-inch.

Bevel on Chisels.

It sometimes becomes necessary to forge chisels of various kinds, also mill picks to a sharp edge with the bevel on them. This can be quickly done in the following manner:

After drawing out the bit or end of the chisel, have it long enough to admit of cutting off about $\frac{3}{16}$ inch. Lay it on the hardy straight across and hit it one blow to make a crease sufficient to hold it to its place; then drop the tool down, or rather drop your left hand very low and keep it on the hardy in the cut. Then finish cutting it off and you have as perfect a bevel as can be made with a file. You will be surprised when you try this to see how nicely it works. This should be done before it is packed, as it disturbs the grain of the steel and would partly destroy the effects of the packing.

Open-Hearth Steel for Chisels.

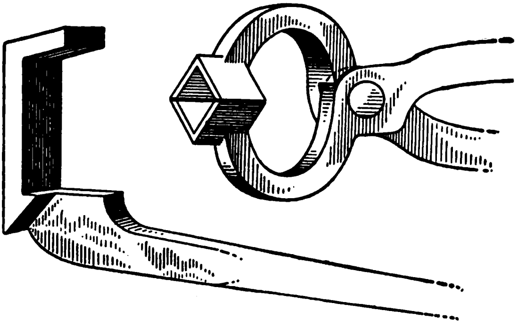
There is much open-hearth steel sold for chisels under the name of cast steel, or tool steel, and there are but few blacksmiths or green tool dressers that can tell it even by working. They simply find out that it is poor steel. This is how to judge it. It does not scale off as much as crucible steel, and the scale that sticks to the chisel is a coppery color. It looks spotted and does not clean off like good crucible tool steel. Bear in mind that steel that does not scale off when hardened at the proper heat has something radically wrong with its make-up. The head of a chisel of good cast steel of about 80 carbon will split open in from 7 to 16 places, and the cracks will be very small and close together, and the smaller the cracks and the more of them, the better the quality of the steel. In judging the steel by the head of the chisel, we must take in consideration the size hammer that was used with it. If the hammer used on one chisel was ¾ of a pound and on the other chisel made from the same bar, the hammer was 2 pounds, the first chisel would have the most cracks and the finest cracks, and the chisel used under the large hammer would have coarser cracks.

Dressing Granite Tools.

In dressing granite tools the same theory applies that is used in dressing cold chisels, except that instead of dipping them and letting them down to a certain color, they must be plunged; that is, cooled off entirely, and by this method we get absolute uniformity and avoid cracks and stains in the steel which is bound to come at the dividing line. We may avoid the cracks, but there is more or less strain in all steel that is dipped or partly cooled off and run down to the proper color, and the steel must be of extra good quality if it does not show cracks in the future working.

GOOD HOLDING TONGS.

The illustration shows a pair of tongs for holding cold chisels, bolts with head, or round, octagon, square, oval or flat iron. It is something of a job to forge them, but the two illustrations, showing different stages of forging, will make it plain. The sketch at the left shows the jaw partly forged. This jaw is forged out flat the same as common tongs; then the jaw is bent around at right angles; then the front end of the jaw, say 1⅛ inch, is bent again at right angles. The next move is to shoulder down for the handle. Then you have a jaw like the sketch on the left. Now heat the flat space between the two bends and bend it until you get a true circle, then drop the front part of the jaw into the square swedge and set the top swedge in the center of the jaw, hit it a good blow with a sledge and it is then at right angles as in the sketch. Be sure that they are bent exactly alike. Next drill a hole and rivet together, as stated. If you have any doubts of being able to forge a pair the first time get a bar of lead and experiment.



Read the article on dressing cold chisels, which covers the ground completely, except the heat at which it is hardened must be a little higher, but not enough to raise a scale. The granite that these tools are to cut is extremely hard and a tool hardened at as low a heat as cold chisels are hardened at would make the chisel for granite work entirely too soft, and after they have been used for a few minutes the edge would have a round feeling to your thumb on the flat side. The steel turned over when it should have split off in very fine particles leaving the bit end of the tool smooth, even after hard use.

If the process of packing the steel described in the cold chisel instructions is closely followed and the edging is avoided, you can leave the granite tools extremely hard and yet have them stand. Read the article on "Dressing Mile Picks," as the theory there is the same. Bear in mind that these granite tools must be thin and in drawing them down, do your edging up the first move you make. Then take them on the round corner of the anvil face and draw them out, which does it without spreading the steel, the end so much sought after, and it is accomplished in half the time. Now, mind, after you have begun to pack the bit you are forbidden to strike that bit one blow on the edge. I hear you say, "It's too wide." Then you are to blame for not edging it up more in the beginning. The writer does the most of his drawing on the horn which does not spread the bit so much.

The bits of chisels for cutting granite should be drawn very thin back so that they will have at least 1/4 inch of wearing surface, tapering a little to the edge. The more you do of this work the more cut you can put in each time, both as to quality and length of bit. The writer gives the tool from half to three-quarters of an inch, but new beginners must be content with much less. Look out when done that each bit stands in the center of the tool, not leaning to one side. If it does, it will vibrate or tremble, which destroys the result of the blows. Get proficient in this work; there is a host of it to do.

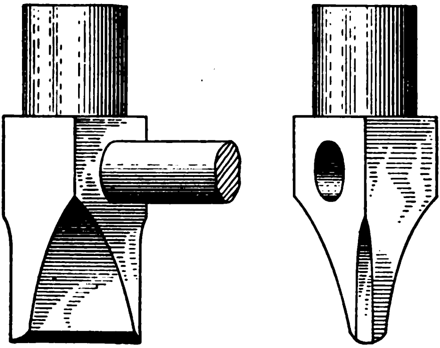
Tempering Tools.

In tempering tools, first the steel should be heated to the proper heat, then dipped at once in plenty of good cooling bath, the larger the quantity the better the results. This is called hardening. The steel or tool so hardened may be too hard for some kinds of work, making it necessary to reduce the hardness. Cold chisels and hot chisels are only partly dipped, and left to run down to the proper hardness, which is known by the color, varying according to the steel, and the work the tool is designed to do. When the steel or tool is hardened all over, great care should be taken that the tool is entirely cold when being removed from the bath. Tools that are wholly immersed in the bath and taken out before they are entirely cold, will invariably crack. Taps, dies, reamers and other tools for cutting steel should, after being properly hardened, be polished with emery cloth or sand paper, so that when letting down the temper to the proper color the color can be plainly seen. Some smiths harden taps and other tools by dipping them in water, holding them there until partly cold, and then taking them out with the outside cold and the inside hot. The result is that the tool cracks, perhaps in several places, and is spoiled. Leave them in the water not less than 5 minutes, or more, until they are stone cold, and there will be no cracks, if they were properly forged. Have the last work done on them at a low heat.

There is no metal known to man that in working up needs so much science, skill and brains as cast steel. While we have hundreds and thousands of blacksmiths in the United States, I think it is safe to say that not more than one in every thousand understands cast steel enough to make and dress his own tools as they should be. How many smiths are there who can find out how much carbon a bar of steel contains that they are about to make a tool from? It is just as essential to do that as it is to have good steel. Suppose you are going to make a pritchel punch for shoes, and you make it from steel of 60 carbon. What is the result? The first time you drive it in a shoe, it doubles up, and you have got to dress it every few minutes. You make one from 120 carbon, and it will break just as fast as the other doubles up. If you get a good quality of steel of 90 points carbon, you will pritchel out shoe after shoe without dressing or straightening your punch. I tell you most earnestly this method of being able to judge steel as to carbon is an important matter. Some smiths learn after long and continuous practice to harden one class of tools, but the moment you shift them to some other class of work, they are lost. They not only spoil the tools, but waste the stock. All this is the result of a lack of knowledge of cast steel. I say, brother smiths, make steel your study and remember that irregular heat makes irregular strains. All tools for hardening should be heated on top of the fire, if possible. If your fire is not large enough, make it larger, as fuel is cheaper than steel. Provide plenty of good clean coal, or coke, well-cleaned, and have an even blast; these are essential points in tempering. Beware of too much light when heating steel to harden. It will lead you astray.

A PEAN HAMMER.

The illustration shows two sketches of an angled pean hammer for making mill picks, cold chisels and welding wagon tires. It is useful in the smith shop. The one illustrated is made from 1⅝ inch square steel. In weight it should be not less than 3¾ pounds, and in diameter across the face, not less



than 1⅝ or 1¾ inches. The first move is to punch the eye. Lay the hammer on the anvil with the hole up, then take hold of the face end and turn the hammer to your left until the corner is up, then weld it, and there is no mistake. You can shoulder down the round end with a set hammer. Have it smallest at the shoulder. Make the eye $\frac{11}{16}$ x 1 inch. Have the face very round, and harden as per instructions already given.

Soft Hammers.

In making butcher knives, drawing knives, or any tool where the edge has to be drawn down to avoid battering the anvil face, it is necessary to have what is called a "soft" hammer, made with double face. It can be forged the same as ordinary hammers. Both ends can be used instead of one. Now to harden this hammer, heat one end only, and let the temper run down to a screwdriver temper, which is very soft, below a pale blue, or just a little harder than unhardened steel, and leave the other end as soft as possible. This hammer will be found very useful on many jobs. It should be about 2½ lbs. weight. Next softer than this comes the copper hammer, which is indispensable in a repair shop. Make any shape you like, and don't use too long. When the face has become badly battered, knock out the handle and dress it up. Heat only to a dark red. Next comes the Babbit hammer, which is very useful on finished work. Delicate bolts can be driven out with impunity. This Babbit hammer is very useful in straightening finished work or anything that is polished. Make yourself one of each kind. You will be pleased with them. Yes, make one out of lead; it will be useful.

Why Does Steel Harden?

The question, "Why does steel harden?" is an old one, and up to the present time has not been answered. You need not be surprised if you make the same tools from the same bar on different days, and find that they are not alike. Also colors will vary. You may let a chisel run down to an indigo blue, lay it away for a few days, then look at it and find to your surprise that it is too hard, or too soft. Remember that a mechanic's greatest skill or ability is much easier brought out in the forenoon than in the afternoon. In the forenoon he is not tired either mentally or physically.

Taking the Strains Out of Steel.

If after forging a tool, for instance, a flatter or slick, as some call it, or any piece where there has been very many heats, the tool is naturally in strains, and when done should be heated slowly or evenly to an orange color and if a flatter or hammer set it up on the end and hit it one blow on top; this will completely relieve it of all strains. This answers the same purpose as it would to take the harness from a tired horse and let him lie down and roll. Cast steel is like an intelligent man. If properly treated, you can do almost anything with it, but you must not push it beyond its capacity. There seems to be no limit to the work it will do when properly hammered and tempered, and you will never get done learning how to improve on working it, and when we take into consideration what can be done with it, all other metals are as a drop in the bucket compared with it. It is almost impossible to mention any kind of work that cast steel is not connected with, either directly or indirectly.

Heating Steel in a Lead Bath.

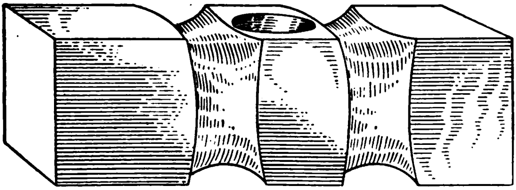
In heating steel in a lead bath for hardening, it should first be heated in a fire or oven until it is thoroughly heated through, then drop it in the lead bath, and let it come to the desired heat. If it should be a large piece or tool with sharp corners, great care must be taken, as the intense heat of the lead will heat these corners so quick. That is, before the center or body of the steel gets hot. Consequently, there is a great strain between the hot and the cold. There is the diminishing line and this is the exact spot where the crack begins. This intense heat and the cold in so short a space make a great strain in the steel, and the application of water makes it separate, and if the steel does not crack after being heated as described, then it must be of the best quality and even then cannot withstand a second operation of this kind. In selecting lead for heating for hardening much care should be taken to get it pure and of the best quality. In heating lead for this work, the fire must be deep, or nearly as deep as the crucible is long, then you can get a perfectly uniform heat. Stir the lead occasionally and keep the heat the same top and bottom, and sprinkle a little pulverized charcoal over the top of the hot lead. This will keep the lead from wasting away. If the lead is left open, the top soon turns to dross and is quite a waste.

Making a Twist Reamer.

First get a bar of ½-inch round steel, or square, of about 80 carbon. It is best to make these reamers short and have more of them, say about 3 inches long, for a ½-inch reamer, that is, ½ inch at the large end. They should be made carefully as to size at the large end. Blacksmiths, as a rule, would want them $\frac{1}{32}$ inch over size, so that bolts and rods with a thread on would go through the hole. Shoulder down about enough from the ½-inch round bar to draw out to 3 inches long. When done, have it tapering so that the small end is about $\frac{5}{16}$ inch. However, there is nothing particular as to the size of the small end. The ½-inch bar of steel will flatten out about the right width for the large end; perhaps a little full. Now, after you have the square part or shank made and the flat part properly drawn out to the proper taper, heat it close to the shank; that is, the flat part; screw it in the vise and take a monkey wrench and screw it up until it fits the flat part to be twisted, and twist it to the left. Care must be taken not to twist it too much, as the hammering on the edge works more twist in it, and twist only a little at a time. The twist in the point can be done with a hammer; the twist will come in as it is hammered. Do not get too much twist. When you have the twist in evenly, then heat to a medium heat and hammer with a light hammer on the top, or edge, of the twist; this will spread it as it packs it, and repeat this hammering at a low heat each time,

HAMMER FORGING.

The illustration shows a hammer partly forged. At this stage of the forging it is necessary to drive the eye pin again to stretch the hole. If we hold it over the hole in the anvil after the sides of the eye have been drawn out, it will bruise the ears of the hammer. When you have the hammer hot, insert the eye pin and lay the hammer on the link made for that purpose over the hole and the hammer will not creep. Then when the hole is large enough the corners of the flat space of the hole must be battered down with the hammer. Move the link towards the edge of the anvil, draw the hammer on the link and drop your hand down, having the hammer corner up, and you have a chance to batter all the eight corners down and do a good job and not alter the shape of the hammer.



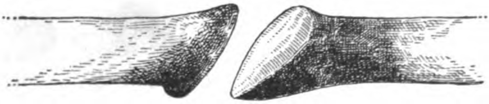
until the edge that you have been hammering is almost as wide as the groove or hollow, taking care to have the edge next to your right hand a trifle the highest, as that is the edge that does the cutting. Remember that this twist is just the opposite from the twist in a drill, which is very necessary to keep the reamer from drawing in. In doing this hammering, care must be taken to do it evenly, commencing at the large end and following down to the point, turning the reamer carefully as you go towards the point. No matter about the size of the point. Have a pair of calipers set the size you want the large end, allowing but a trifle to dress off; about 1-64 inch is enough if you have done a close job of hammering. Be sure to keep the edge towards the right hand the highest.

Use of Reamers.

Before you undertake to file it, anneal it in the fire over night. It will require about four sizes of round files. Begin at the large end to file and change to smaller files, as you get nearer the point, and in filing out this groove, be very careful not to file the top part of this cutting edge. When you have the groove finished, then take a flat file, and file off the flat side, taking care to leave the file a little to the right, so as to leave the edge next to the left hand the highest, giving it the cut and clearance. The amount of clearance needed is about 1-64 inch, and great care must be taken to get this clearance the same the whole length of the reamer. To do this, begin measuring the reamer at the largest end. Set the calipers so that it touches both cutting edges, that is, on each side. Then turn it on around, and see how much clearance you have got. See how much it lacks of touch-ing the back edge, and this will show just how much clearance the reamer has got. Then repeat this, measuring every half inch clear to the point. Bear in mind that it must have about so much clearance. If not, it binds and does not cut freely. Consequently, the temper would have to be drawn and filed over again. This clearance is absolutely necessary. If it has too much clearance, it jumps, and will not cut a round hole. The last thing you do before hardening is to see that the cutting edge towards your right hand is clean and sharp, as the least touch with the round file on the edge takes away the cutting quality. When ready to harden, heat slowly to a low orange red, and plunge it in the bath, and hold it there until it is cold, then wipe dry and rub off with your emery stick, so that you can see the color run, and bring

MAKING READY FOR A WELD.

The two pieces shown herewith give the correct way of preparing for a weld, just as those shown on page 103 indicate the wrong way of making ready, although that way is perhaps the common way. The dross, the sulphur and the slag, must all be removed, and the scarf should not be made in the hollow shape. Otherwise, the outer edges weld first and consequently retain all the slag in the hollow of the scarf and it is almost an impossibility to make a good weld. The pieces shown here are made right. Instead of being hollow they are full in the center (convex) and the instant one piece is laid on top of the other, the first blow forces all the slag out and more hammering welds the center clear out to the edge. If we have hardly heat enough to make a perfect weld, a second heat will weld the outside solid as the center is already welded.

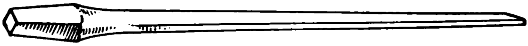


it down to a light purple, then cool off. Be careful not to get it hard above the cutting part. These tools are among the most important used in a carriage, wagon, or general blacksmith shop. Every shop should have at least a set of them in exact sizes; that is, each size should be just large enough so that a bolt of that size will go through the hole after it has been reamed out with this reamer. In making these reamers the proper size, you have only to run the reamer clear through and the hole is just the proper size for the bolt, and no guess work, nor holes too small or too large. It is a great advantage when you do good work to have the bolts and rivets fit all the holes, which prevents rattling and wear. A set of these reamers will last a shop half a lifetime, if properly used; cut faster, cut easier; cut just the size you want, and save mistakes, besides being the most economical reamer ever made. The small end or point of these reamers can be filed to a point, the same as any ordinary twist drill. Every blacksmith should have a set of these reamers, ranging in size from $\frac{3}{16}$ to 1 inch, and as many more as they feel able to have. The larger sizes of these reamers can be used with a tap wrench, and when you get above the $\frac{3}{4}$-inch size, it is much easier to turn them with a tap wrench. No man knows the value of them until he has used them. To prove their value, I will give the following example:

Suppose you had a platform gearing ironed and by mistake you had drilled or punched, as the case may be, some hole $\frac{1}{16}$ inch too small. Now, if you take that iron off, there are anywhere from 5 to 25 burrs to take off and sometimes more. It is probably a place near the center and cannot be put under the drill, and if it could, the hole only wants to be $\frac{1}{16}$ inch larger, and if you undertake to drill that hole larger with a drill so near its size, the drill will screw in and break. If the hole is to be enlarged so as to take a $\frac{5}{16}$-inch bolt, I will take a reamer marked $\frac{5}{16}$ on its shank and ream it to the exact size in less time than you can unscrew one burr.

I defy any smith to deny one assertion I have made pertaining to reamers, if they are familiar with them, and, if not, they have only to try them and be convinced. Get out of the old rut you have been plodding along in for years; get good tools, or make them.

A REAMER.



The sketch illustrates a reamer showing the shank to go in the bit stock and the edge or cutting part.

Twist Drills.

A twist drill is made upon the same principle, except the twist is put in the other way, or opposite from the reamer, and instead of being drawn down to a point or a taper, it is kept uniform, or nearly so, the point a trifle the largest. The twist should not be very long in the small size drills; two inches is enough. Bear in mind the longer the pod, or twist, the more apt to break. In making drills of any size from $\frac{3}{8}$-inch and under, draw your steel down round to the size of the drill wanted; then flatten, as in making the reamer, taking care not to get it too thin, which can best be found out by trial. For all sizes from $\frac{3}{8}$-inch and down the twist can be put in best with a hammer, as explained in making reamers.

To show how much more a hand-made drill will stand than a machine-made drill, I will relate a circumstance. I had a great many $\frac{3}{8}$-inch holes to drill in cast steel $\frac{7}{16}$ inch thick, of at least 80 carbon, and the best I could do with a machine-made drill was about one-half dozen holes; then I must go and grind. I first selected good steel and made a $\frac{3}{8}$-inch drill and it bored 52 holes through this $\frac{7}{16}$-inch steel without grinding. No machine-made drill that I ever used would do one-quarter that much. I will explain why. In the first place, they are made from a cheap grade of steel; they are milled out instead of being hammered, and the steel is only in its natural state. While the hand-made drill has been refined and packed with the blows of the hammer, the grain has become dense and fine and is much improved above its normal condition, besides being made of the best crucible cast steel and of the proper carbon.

I have not one word to say against machinery or improvements of any kind. In fact, I want the improvements, as the best is none too good. Yet, there are some kinds of tools that are much better made by hand, and the most important of these is the cold chisel. I do not advise blacksmiths to make twist drills less than $\frac{1}{4}$ inch in size, except it is for some special job, as it takes longer and requires more patience to make a drill $\frac{3}{16}$ than of $\frac{3}{8}$-inch size. The machine-made drills are cheaper when you get below $\frac{1}{4}$ inch, as they are made with shanks the same size as the drill, although they must be used in a chuck. Every blacksmith should have one of these drill chucks.

Setting a Drill Over.

When a drill has run to one side, the only remedy is to take a cold chisel, after the drill has been started about

⅛ inch deep, and make two or three good cuts in the side where you want the drill to run to; their depth should be in proportion to the amount you want the drill to move over. Bear in mind this must be done before the drill has got very deep. When an iron has been marked through a hole with a scratch awl, it is then necessary to mark that with a center punch for drilling, and if this center punch is not in the center, then it is necessary to set it over, or sometime the drill running crooked will cause it to run to one side. The drill can also be set over with a round cape chisel. But, when the drill is straight and the chuck runs true, and the hole is properly marked or centered, this trouble does not occur.

Starting a Drill.

It is a very common practice among blacksmiths and helpers in starting to drill a piece of work to set it under the drill and screw down the drill in the center punch mark before starting to turn the drill, and the result is that as soon as the drill is started, one or both sides of the drill lips snap off. There are various reasons why it may break, chief among them (in seven cases out of ten) it is not half made, or the drill may be of too high carbon, the steel may be poor, perhaps the work did not set level, the drill may have a flaw in it, the piece being drilled may not have been secured, and many others. The proper way to do is to test a drill as soon as you have made it.

Testing Tools When Making.

A good way is to take a small flat fine file, 6 or 8 inches long, about half worn out. Try the drill on the cutting edge. If the file will take hold of it a little, so that you could in case of necessity file it up sharp, then it is just right. This same method applies to a cold chisel, a hardy, a plane bit, a drawing knife, butcher knife, knives for bolt clippers, punches, nippers, cutting pliers, and many other tools.

Colors for Tempering.

Even with all the description of colors that can possibly be given, the smith is liable to err. For instance, I may say, harden it to a cherry heat. What color of cherries have I reference to? There are a dozen varieties, and as many different colors; some so dark that if steel was heated only to that color, it would not harden at all; some so light that if high carbon steel were heated to its color, it would scintillate or drop to pieces. The colors vary from the lightest to the darkest, which makes it impossible to give the reader anything like a safe rule to go by. The color of blood is much more safe and then there is a difference. The blood of the human body is quite different from that of the sheep. The blood of a sheep is much lighter as a rule than the blood of the cow or ox. Therefore, I am put to my wit's end to know how to make the average blacksmith understand the exact color. Oranges and lemons afford about as safe a guide to go by as anything I know of, and may be classed as follows: First, the light lemon, then the full lemon, then the dark lemon. The first or light lemon might do for forging low-carbon steel, but it would have to be very low not to exceed 60 points. This heat might be called a " white heat," which I think would be the proper name for it, and if tool steel of 90 carbon was heated to this color, it would scintillate and fall to pieces. The full lemon would do for forging steel of 80 points carbon. The dark lemon would do for forging steel of 90 or 100 points carbon. Then comes the light orange, the medium orange, and the dark orange. The light orange is suitable for forging steel of 100 points carbon, such as lathe tools. The medium orange is about right for steel of 150 carbon. The dark orange is about the proper heat for mushett or self-hardening steel and is also the color or heat at which steel of moderate carbon should be hardened.

Steel workers must bear in mind when tempering steel that the various colors are not always the same. For instance, the purple on some pieces of steel will be very much brighter than the same color would be on other pieces of steel, also that the different kinds of steel scale off very differently. Some will be white as silver, while others will be black. However, it is common for steel of high carbon to scale off more than low, and the amount that each piece scales off depends largely on the amount of heat at which it was hardened at.

All steel workers should bear in mind that the formula for the combining of the various ingredients in the making of cast steel is vastly different from the working of it into tools after it is made.

Hammering Cast Steel.

It is an old saying and a very common one among blacksmiths that the more you hammer and work steel, the better it is. This old adage is a mistake. I have repeatedly forged difficult and complicated jobs of cast steel when it was necessary to heat and reheat a great many times before it could be completed. When finished it was necessary to file it, which was impossible, as it was so very hard that a file would not touch it. It was very coarse grain and of an extremely crystalline nature, and all of this was caused by this continuous and excessive reheating. Some steel requires more hammering than others. For instance, a piece of common steel made of inferior material, that is, very coarse grain, and having very thick scales rising on it when hot, which fall to the floor like bits of iron, will stand lots of hammering and will be the better for it.

Learn to put your blows on even, or the same distance apart. The necessity of doing this is made plain when you take a round rod and flatten it. You will see that there are hollows in it. If it had been flattened with a flatter, then it would be even or straight, and if the blows of the hammer were evenly distributed, it would then be straight. Let us take a $\frac{5}{16}$-inch round rod and commence to flatten it, and put the blows just ¼ inch apart, or advance ¼ inch each blow. The rod, when flattened in this manner, is perfectly even. Now, we will flatten the next piece and strike at intervals of ½ inch, and then go over it again. It is simply impossible to get the edges straight. It is full of humps and hollows, looking like the furrows in a field just ploughed, and while this uneven hammering does not show on a flat bar as it does on a round, yet the necessity for distributing the blows even is just as great. Suppose we were making some kind of a cutting tool of cast steel and made the tool throughout with this uneven hammering, then the tool would be full of strains, and when dropped in the water to harden would either warp or crack, unless it were an exceedingly good piece of steel. There is still another reason for hammering even; the work is more uniform when finished and requires less work and filing to finish, besides being true and straight.

Work in Bad Weather.

Steel workers, tool dressers, and mechanics generally, should avoid as much as possible doing delicate or particular work when the atmospheric conditions are unfavorable. In my own experience I have been amazed at the misconception and faulty calculations I have made in damp, foggy weather, or on days when the air was heavily charged with electricity and thunder storms were pending. It is admitted in most large factories that from 10 to 20 per cent less work is done on rainy days, or days threatening storm. Don't tackle a complicated or delicate

A HANDY WRENCH.

The illustration, Fig. 2, is much more handy than an S wrench. It will turn nuts when an S wrench would be helpless. This shape of wrench is the best known. It is easy to make and a good smith will make a dozen in a day. They are forged with an ordinary boss all on one side. Punch or drill a hole, not in the center but in front of the center, as shown at Fig. 1, so as to leave all the strength in the back end of the jaws. After the holes have been drilled, cut out the center with a hack saw and harden about as hard as a cold chisel.

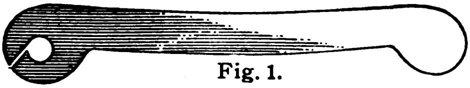


Fig. 1.

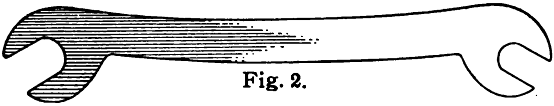


Fig. 2.

job when you don't feel well, or when some business affairs are pushing you to the wall.

Making a Trap Spring.

If for a flat spring, as trap springs generally are, and in the shape of the letter V, select a good quality of steel of moderate carbon, about 70, and draw the spring to its proper thickness. In finishing up the spring to its proper thickness and in finishing up the spring, pack it just as directed in making a cold chisel, and where the bevel comes have it the widest. When finished ready to bend, heat at a very low heat, not hot enough to harden, and don't bend it by striking with a hammer, as that will disturb the packing more or less. Just stick a big round punch in the hardy hole, and after heating to a red heat, catch hold of both ends with a couple pairs of tongs and wrap it around the punch towards you, having the ends about as far apart as you want them, then call it ready to harden. In bending this spring, don't get it hot enough to raise a scale, as that destroys the packing, also the virtue of the steel. Now, when it is ready to harden, heat it very carefully in the blaze, mostly to a low red, and drop it in cold water. When entirely cold, take it out and it has scaled off like a new dollar. Next get a long keg or a small barrel, lay it on the forge, having it so that it will be dark inside, heat the spring slowly by holding it over the fire say 4 inches above, and only blow a trifle. Let it heat slowly and keep sticking it in the barrel, or box, every few seconds, then back over the fire again and so keep on until you can just see that it is getting a trifle red, then lay it down on some warm ashes to cool. When it is cold, test it in this way: Place it on the floor so that one end sticks up and while there take a sledge and strike it on the end, which will smash it together. Do that a few times, then take it and screw it in a vise, bringing the ends together. By that time you will begin to realize that you can make a spring. If you hit the spring while on the floor, it will bound up ten feet or more, and come down as sound as a dollar, not going together more than 1/8 of an inch. It will stand just such tricks a hundred times or more. Bear in mind that color has nothing to do with this method. Tempering springs varies. For a gun spring, or anything in that line, it would be well to harden in oil. To harden in oil, hold the spring over the blaze after you have dipped it in oil, moving it back and forth until fine sawdust sprinkled on it burns, then lay it down to cool.

SCARFING A WAGON TIRE FOR WELDING.

The illustration shows both the improper and proper way to make a scarf to weld a tire easily. When the tire is in its normal condition, one end is below the other at least 1/2 inch as shown at Fig. 1, and in placing the ends together for welding, the bottom end is raised up and put on top of the other as in Fig. 2, and the strain presses the ends together and holds them solid until the first heat is taken. In scarfing the ends the corners should be cut off. This keeps the end from spreading out, thus making it necessary to edge it up.

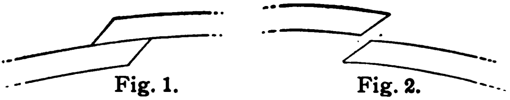


Fig. 1. Fig. 2.

Learning to Work Steel.

In the course of my instructions, at home and in various railroad locomotive and machine shops, and in general machine shops in different parts of the United States, including the Bethlehem Steel Works at Bethlehem, Pa., my hardest task has invariably been to convince the tool dresser how little he knew about cast steel and how much there is to know. When I go into such shops to give instructions, the blacksmiths look at me with crooked eyes and scowl. Their first thought is that I have come there to reduce the force, or encourage piece work. (There is no man on earth dislikes piecework more than I do.) In some cases, where there were quite a number of tool dressers, the force was reduced, or some put on other jobs, due to the fact that after the instructions had been given less than one-quarter of the men could do the work. But, in case a smith had to look elsewhere for a job, he could very easily get it at an advance in wages, and the company had paid for his instructions.

Some years ago I was called to Boston to give the tool dresser in a very large machine shop instructions on the scientific principles of working cast steel and tool dressing. He knew nothing of my mission until informed by the general superintendent. He was a man well along in years. After the superintendent went out, he said to me:

" Well, mister, I don't think it is worth while for you to bother with me. I have been working steel for 50 years, and I made up my mind long ago that one piece of steel was about as good as another and that one man can work it as good as another."

" My quick reply was: " I fully agree with you that it is not worth while to waste any time with you," and picked up my kit of tools and walked out. I soon found the superintendent and told him what the smith said.

" Well," said he, " I am not in the least surprised; that man began at the wrong end of his trade; he goes backwards." Pointing to a row of a dozen smiths, or more, he added:

" You go down there and watch those smiths, and pick out one that you think would make a tool dresser and give him the instructions." I did so, and selected a young man whom I found out afterwards was just " out of his time," and when he learned that I had selected him, his joy knew no bounds. To-day he is head tool dresser in a large shop.

MAKING READY FOR A WELD.

The two pieces of round iron illustrated show how the average blacksmith makes ready for a weld. They are what he calls a first class job but are not. The scarf is a hollow, holding about a thimbleful of dross, sulphur and slag which we want to get rid of before we put the pieces together to weld. It is impossible to do it where the scarf is made in the hollow shape. The outer edges weld first and consequently retain all the slag in the hollow of the scarf and it is almost an impossibility to make a good weld. The pieces shown on page 91 are made right. Instead of being hollow they should be full in the center (convex) and the instant one piece is laid on top of the other, the first blow forces all the slag out and more hammering welds the center clear out to the edge.

Boring Bits.

Keep your bits for boring wood in a dry place; a drawer well lined with tallow or grease of some kind is good.

Danger in Rehardening Tools.

There is much more danger in rehardening tools that have been laid with steel than there is of tools made from solid steel. When we plunge a tool in the bath to cool, if it is solid steel, the shrinking is very nearly even. If iron and steel, the shrinking is very uneven from the fact that the difference between cast steel and wrought iron is very great, and if it be an anvil or sledge, the hard blows that it has been subjected to has crystallized the metals (especially the iron) at the dividing line, or where the union took place, and the moment they begin to shrink there is a separation, and every time they are rehardened the danger of separation increases. You may take the very best wrought iron anvil made, one that has never been used, and begin heating and hardening it, and after it has been hardened a few times, the face is loose in several places, and this can be carried on until the face is entirely loose.

In solid steel tools, you will notice that some steel cools off much quicker than other kinds. I like to have steel cool off instantly. Steel that is a long time cooling off is the steel that is apt to crack. There is some steel that will invariably crack when hardening, regardless of what kind of treatment you give it, or how carefully it is hardened. It is caused by some mismanagement in mixing or making, such as too much killing, or not enough, or many other mishaps which often occur. But in spite of this fact, some steel makers are ever ready to saddle the whole blame on the blacksmith. When steel, after careful treatment, proves to be worthless, return it to the makers, or those from whom you get it.

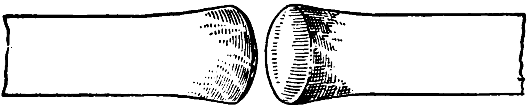
Bear in mind that the average hardware man knows nothing about steel, either as to carbon or quality, yet he will assume to know and to talk wise. If you buy steel, hold the man that sold it responsible for both the steel and the labor lost on it. There are two dozen concerns, or more, making steel in the United States, and many of them can and do make good steel, but with the smith uniformity is the all-important question.

Heating Steel for Hardening.

In heating steel to harden, heat slowly, heat evenly, heat clear through, taking care to keep a good body of coal between the blast and the steel. Do not let the steel work down on the bottom of the fire so that the cold air strikes it. If the steel or tools are not heated evenly, there will be irregular strains and the tool will crack. When a tool is brought back to the tool dresser to be redressed, and he learns from the machinists that the tool has done extra good work, take your little fine file, kept for the purpose, and try the bit. Then place it over the corner of the anvil, break off a piece, put your glass on it, examine the grain, and you will then know just how to put that tool in the same shape again. Remember in these days you can get steel suitable for any purpose.

A WELDING BAR.

The illustration shows the proper way to prepare a bar for a butt weld and have the center full or round. Get the center



welded first and the outside is easily welded, the center being full, the dross and slag flies out the first blow. It needs no further explanation. When it can be done, it is the proper way to weld a round bar from ⅞ inches up.

Do not work up old or short lathe tools into cold chisels; the steel is too high in carbon; the heads will snap off and the bit will many times jump off an inch or more. Do not expect to get a dozen bars of steel (although you get them from one place and at one time) and have them all alike. However, this does happen when the bars are all from one ingot.

Hardening Delicate Tools.

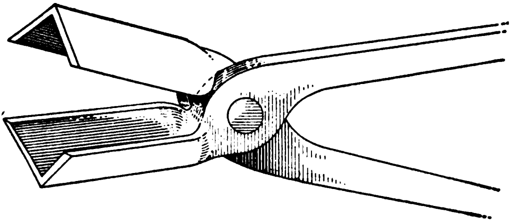
This can be done very well in a lead bath if you understand it, and the first essential thing necessary to harden small tools safely is to have a good quality of lead. Next, if you are hardening tools with sharp or thin edges, or points, it will be necessary to have two pots of lead. Why? Because if you are hardening, say a small tap, the edges of the threads are small and delicate, and if the lead bath is hot enough to heat them hot enough to harden them, the lead will heat these little points or edges too quick and make a dividing line; between the teeth and the body of the tap there is a strain, and while the thread was perhaps not overheated, it made a sharp dividing line, also put a strain in it. Now, if you have much work in hardening small tools, have two lead pots. Harden in the fire. If you get the two pots, have one just hot enough to bring the tap or tool to a very low red—not hot enough to harden. Then when the tool gets as hot as the lead will make it, take it out and dip it in the hotter pot, until it gets to the proper heat. Then take it out and plunge in the hardening bath immediately.

Heating Steel Streaked.

In forging any expensive tool from solid cast steel, if unfortunately you should, when nearing the finished stage, get your steel hot in streaks, you have already put irregular strains in it, and the only way to take them out is by hammering. Heating the steel all over to an even heat relieves it, but not entirely. This is why so many tools crack in hardening and tempering. Sometimes such tools do not crack in the process of hardening, but when you come to temper them, I mean by this letting the temper down by heat, either by what heat was in the back part of the tool, or by holding it over the fire, or otherwise, then the cracks show up. Too much care cannot

USEFUL TONGS.

The sketch illustrates probably the most useful pair of tongs of any in the shop. Begin forging the same as any common flat tongs, only make the jaws thin and wide. This pair holds ⅝ inches round, ⅝ inches square, ¾ inches half round and half oval, and ¼ inches flat, and it holds either size better than any other tongs. If you make your tongs right it is not necessary to have as many pairs as some shops have, and then boast of how many they have, when one third that number properly made would hold everything and do it much easier and better. Forge out the jaw 1¼ inches wide, about 3/16 inches thick and 1½ inches long. Then lay the flat end of the jaw in a square or right angle swedge, set the top swedge in the center, smash it down and it is done. In holding flat iron, these tongs grasp the iron on the outer edge of the jaw, consequently it cannot move. While these jaws are thin they are much stronger than other tongs as they are on an angle. Make them large enough to hold 4 inches and small enough to grasp ⅛ inches square. Rivet together, as before stated.



be exercised in heating steel to harden and allow plenty of time in letting it run down slowly. It is time well spent.

Hardening Shear Blades.

Shear blades and knives for nail machines belong to one family, so far as manipulation is concerned. Heat the blade to be hardened on the edge that does the cutting. Heat only to a low red, plunge them in the bath and cool off entirely. Then rub the edge off with emery stick and draw the temper over the fire. Shear blades for wrought iron should run down to a purple. For nail machines they will stand a good strong copper color. But the color at which they are allowed to run to depends very much on how much carbon the blade contains. Shear blades of all kinds should be made from steel of not less than 90 points carbon.

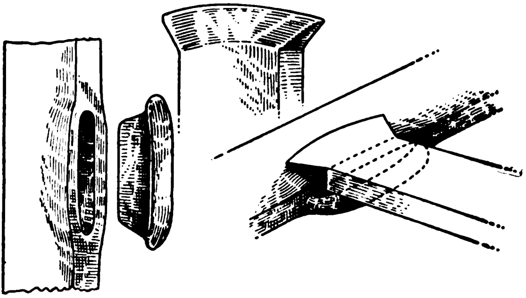
Making a Drawing Knife.

This is a tool that is needed in every shop, and the wood worker cannot get along without it. The size of steel required depends entirely upon the size of knife wanted. If for a wagon-maker or a general wood worker, the method in which the knife is forged has much to do with the size of the steel. The common way to forge a knife is to take a piece of steel 7/8 x 3/8, of about 80 carbon, about 10 inches long. The first move is to heat to a good yellow heat and bevel down on one side, and use that for the back. Make this bevel short, and as you begin to bevel, the bar will begin to crook. But that matters not. When you have this bevel as long as you want, say within an inch of the end, begin to bevel for the edge, and the bar will begin to straighten, and before you get it beveled enough it will be bent back the other way; then straighten back so that your edge crooks a little in front.

Bear in mind when the knife is done, it must be what we call breasting in front. It should be breasting about ½ inch, that is, fuller in the middle of the knife or blade. However, it can be made as little or as much as you want. We will make this cutting edge about 9 inches long, and will measure off 9 inches, and fuller down to draw out the shank for handles.

A SHAFT IRON.

The illustration shows a shaft iron, ready to weld the T piece on for the cross-bar. The long piece is split open and a wedge inserted. After the wedge is driven in, take a moderate heat and tap it just enough to weld it fast, then scarf it short but not too thin. Make the scarf on the T piece to be welded on to go on the cross-bar just as in the illustration. You should have lots of stock, and can take a soft head and make a perfect weld in one heat, and when done the weld instead of being the weak spot is the strongest.



A better way is to cut in a little with a hot chisel instead of fullering; cut in say ⅜ of an inch, then take the hot chisel and cut out a piece Before cutting, lay a small piece of band iron on the face and cut on that. It saves the chisel and prevents a lap. Better take a half round file and file out the notch a little; that will leave the bottom clean, with no chance for laps or flaws of any kind. Then put a set-hammer on it and smash down. Draw out the shank, say about 3/8 x 1/4 inch or less. Cut this shank off 2 3/4 inches. This blade is now fullest in the center. When all is done, heat each shank in the shoulder and bend towards the edge so that the shank is 3/8 of an inch towards the edge, which is about right. When you have the other end finished as above, the knife is ready to finish. Take just a little of the breasting or crook out of it, and with your soft hammer draw the edge down thin at a low heat. Bear in mind that from this time on you must reduce the heat at which you do the packing, until you get the edge down thin. Using the soft hammer avoids marking or bruising the anvil face.

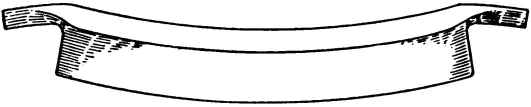
Edge and Temper of the Drawing Knife.

The best plan for drawing this edge thin is to turn around, get on the other side of the anvil, and draw this edge on the edge of the anvil face next to the horn. This last drawing or packing on the edge must be done at a low heat. When you think you have it done, heat to a low or black red, and go over the edge, holding the knife level, and strike level and at the same low heat each time. If you heat this edge to a yellow heat, it is spoiled, and it will never carry a good edge. If you have the back beveled down thin enough, the edge packed evenly from one end to the other and at a proper heat, and the knife is true and in good shape, you are ready to file and harden it. If the knife is a little more than 1¼ inches, or a trifle less, no matter.

Now, let us harden it. Make a good sized fire of coal, well charred and fine, so that the knife can be run through it easily; take the knife in a pair of tongs that will hold it good by the shank, and run the knife through the fire, edge down. Blow lightly; keep the knife moving; raise it up out of the fire to see how hot it is, and drop it back in the fire again. Keep it on the move, so as not to get it too hot in any one place. Move it along the whole length of the edge, and when you get it hot enough to harden the whole length, plunge it in the hardening bath. When you take it out, it has hardened only about one-half inch up, which is shown by the scales not drop-

A DRAWING KNIFE.

The sketch shows a drawing knife made from steel ¾ x ¼ inches. An ordinary drawer shave should be about 9 inch cut when done. The first move is to shoulder down for the handles and have them about 2½ inches when drawn out, crook the knife as much as shown in the illustration or about ½ inch in the center out of a straight line. In beveling down for the edge it will slightly work back. Work the two bevels on at the same time, but when done, have about ½ inch crook. After the knife is forged, proceed to harden by holding the edge down in the fire. Be sure and keep it moving so as not to get any one place too hot. When you have an even heat the whole length about one third back on the blade, plunge it in the water. Then rub off so as to see the color and draw over the fire and blow but little, if any. Draw to a blue. Now wind a wet rag on the blade so as to keep the blade from drawing temper. Scarf the end of the shank and weld on iron handles as long as wanted.



ping off any higher, and that is just right; it is just what we wanted. We are trying to keep the back as soft as possible. Take your emery stick and rub oil on one side, so as to see the color run down. Hold it about 3 inches over the fire, and move it back and forth, as you did when heating to harden. Don't blow much; keep drawing it back and forth. Go slowly; take at least ten minutes to draw the color down. Next, wrap the edge of the knife with a rag next to the shank, and keep the rag soaked with water to prevent drawing the temper in the edge while you are welding on the shanks for the wood handle. Make the weld at right angles. This will save bending the handles.

Protecting Tools When Hardening.

In hardening delicate tools that have been polished, where it is necessary to harden without raising the scale, or for hardening files so as not to interfere with the cuts or teeth, make a paste of equal parts of salt and wheat flour, mixing with water to about the consistency of mud, and waste this over the file or tool to be hardened, heating it to a fair red heat. Then plunge in the hardening bath, and hold there until entirely cold. Take out, clean off, and if it is some tool which must have the temper let down, do it slowly. Files need no drawing.

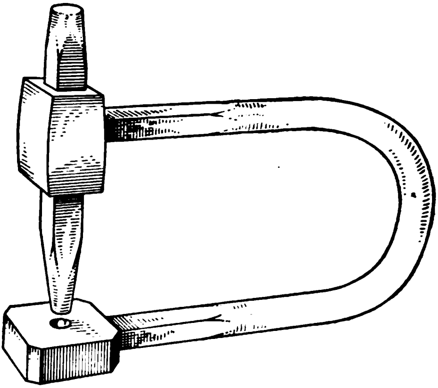
Charcoal for Working Steel.

It has been going the rounds for many years that charcoal is the best fuel in which to harden steel. There is absolutely nothing in it. It matters not what you heat steel in so long as it is free from sulphur. Corn cobs are just as good as anything if you can get the desired heat.

In sections where it can be had, a mixture of one-third Bituminous and two-thirds Anthracite makes a good fire for general tool dressing.

A CLEVIS PUNCH.

The sketch illustrates a clevis punch. This is a very useful tool in a wagon shop or a jobbing shop. It is easily done when you start right and the proper manipulations follow each other. The head is forged the same as a T head bolt, only from heavy material. Let us forge one to punch 3/16 inch holes. It can be forged solid, or the head can be welded on. We will weld it on. Take 7/8 inch square Norway iron or good soft steel and weld it on, making a good weld. Now forge the bottom like a heading tool. Lay on a piece of steel 1/4 inches thick, making a good weld. Draw out the ends and weld together in the center, having the distance between the shoulders not less than 9 inches—10 inches is better. Next drill a hole in this T end about 3/8 inches. Center it from both sides and let the holes meet in the center as near as possible. Drive a square punch in and get the square with the square of the iron. As you drive the punch in, draw the ends out while the punch is in the hole and keep drawing and stretching the hole until a 1/2 inch square punch will go through. Cool off the punch and heat the head to a good white heat. Take it to a vise and lay the head between the vise jaws and hammer the socket to stretch the hole 1/64 of an inch larger than 1/4 inch, then finish up the punch smooth and square. Insert it in the head or socket and hammer



each end of the socket down until it fits the punch nicely. Let it get cold and file up. Take a square file and dress out the socket to make it smooth, then grease the punch and drive it through the socket, and dress it out carefully with a file until it fits closely. Drill your hole in the steel end the size wanted and take a reamer and ream out the bottom of the holes so that all punchings will drop out. When the steel end is filed up, harden and let it run down to a copper color. Now bend around in a clevis shape, as shown, and it will punch a 3/16 inch hole through 3/16 inch iron. This tool is a useful one in a smith shop. Make all sizes from 1/8 up to 7/8 inches and as many more as you need. Use stock according to the size of hole it is to punch.

It is well enough when ordering steel to advise the makers what it is to be used for and after that use your own judgment. Try different kinds and you will soon see that it is practicable to do some of your own thinking. Steel makers understand the process of making tool steel, but as to working it after it is made, they are better adapted to sit in the office and give orders. When you have settled on a grade or brand of steel, and find that it is suitable for certain kinds of tools, do not let the steel maker flatter you with a promise that he can give you the same steel every time, both as to quality and carbon.

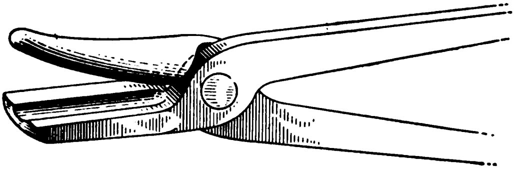
Another old whim that has been going the rounds for fifty years is that of selecting an old file to make some special and perhaps expensive tool. Any smith that has a little horse sense should know that the cuts in a file will never work out, unless ground out, but will keep working in deeper, and again nearly all files are made from a cheap grade of steel, and open-hearth at that, which costs about 4 cents per pound, while at present good steel is worth 10 cents and upwards. There are some brands of steel for granite tools and rock drills as low as 7 cents that do very well for that class of work, but for machine shops and smith shops it is not good enough in quality.

Quality of Steel.

The quality of steel depends upon the quality and quantity of good Swedish iron used in its manufacture, and the temper depends upon the amount of carbon in it. When we speak of quality, we have reference to what the steel is made from. When we speak of temper, we refer to the amount of carbon, and with practice the eye will train itself to readily distinguish the difference in both cases.

HANDY TONGS.

The sketch illustrates a pair of tongs for holding bands, also for holding mill picks, axes, hardy, and other tapering tools.



They are easily made and are very effective in taking a grip on bevels or tapers. They hold flat iron better than common flat tongs. A good smith will make a pair in 2 hours. Make them from steel.

Cast steel is the most wonderful and useful metal known to man, and there is no limit to the amount of work it will do when properly heated, properly hammered, properly hardened, and properly tempered. You will never get done learning how to improve working it. It is hard to think of any kind of work that cast steel is not connected with, either directly or indirectly. If the tools that you use are made of wood, copper, brass, or iron, cast steel was used in producing that tool.

Wonderful metal! Yes, king of metals, and we are just beginning to find out what can be done with it and how to work it properly. I say to all steel makers, you have a wonderful trade. You should be proud that you are worthy of the name " steel worker."

In selecting steel for any tool, if you are going to err in carbon, get too low rather than too high. Just right is best.

Nigger Heads in Files.

Sometimes files will get what we call " nigger heads " in the teeth. This is caused by a small piece clogging the teeth, which will invariably plow deep furrows in the work. They should be removed at once. Some files are more subject to them than others. This depends upon the angle of teeth generally. It is necessary sometimes to take a scratch awl to get them out, as a file brush is not stiff enough. These " nigger heads " must all be taken from the file before you begin to draw file a piece of work. The best method of filing a piece of work is to draw file it. This is done by grasping the file at both ends, holding it in front of you, at the same time holding it level. If you want to do the cutting when you push from you, have the file handle in your right hand. If you want to cut when pulling towards you, have the file handle in your left hand.

To file anything smooth is not difficult, but to file a narrow piece flat, true, and level, is very difficult. If you have a small short piece which you want to file level or flat, take the piece in your right hand and the file in your left. Set the point of the file on the bench and draw the piece from the point of the file back to the handle, and it will be absolutely true and level. It is sometimes necessary to file the bit or cutting edge off your hot chisel. For this take a short file and a fine one.

Do not file hot iron with fine files. Do not file hot iron with any good file that you use for other work. It clogs the teeth and soon ruins the file. If it is necessary to file anything hot, have a double cut file, and keep it for that purpose. A machine cut file is all right for flat files, but round files cut by machinery as a rule are but of little use.

Some files are much more given to chattering and squeaking than others. There is no remedy for this chattering of files. However, they get over that when about half worn out. Sometimes this chattering and squeaking is caused by the work not being solid in the vise, or the vise jaws don't touch at the top, which is very necessary. When the sharp corners get worn off from the vise, it is a source of great annoyance, and it should be dressed.

Welding Wrought Iron.

When welding wrought iron the iron melts and forms a flux of its own; not an artificial flux, as we use in welding cast steel. If cast steel could be melted so as to form a flux of its own, then there could be perfect welds made of steel, and a cutting edge of cast steel with a weld in it would be just as good as a whole piece. But inasmuch as this cannot be done and we have to use an artificial flux, and also that the steel cannot be heated to the scintillating point, we must not expect a perfect union; merely a good job of "gluing." In welding iron where we have a good clean fire, free from sulphur, it is then no advantage to have anything to form a flux. The only thing to be gained by a flux would be to keep the corners or edges from wasting away. In case we had a bar to weld and had no stock to spare, then the clean sand for flux would be very good, as it would prevent the iron from wasting away until it blows hot enough to weld.

For a flux for welding iron or soft or low carbon steel, there is a slag which runs from the furnace where they weld with scrap iron. It is very heavy and hard to pulverize, but when you once get it fine, it is the best flux for welding wrought iron and soft steel ever discovered by man. I mean just what I say. It is very cheap and has an important advantage over borax and other welding compounds: that is, the steel or iron is clean when done, and is free from dross scale and other dirt, which is a very commendable feature in welding steel tires or axles, or any work that requires to be smooth. The first and among the best welding compounds contained nothing but good borax and fine Norway turnings, and this is improved a little by the addition of a little carbonate of iron, say 4 ounces to the pound.

Open-Hearth Steel for Forgings.

There is no steel so good for forgings in all kinds of work, as open-hearth steel. It is almost entirely free from the troublesome elements that affect all grades of Bessemer. Never forge a job from Bessemer when life or limb depends on the weld. It may look entirely sound and at the same time there is nothing welded except the extreme outside. Bessemer steel is fairly good for forging tongs, if you draw out the handles solid instead of welding, as is usually done; but if you weld them they are liable to come apart just when you want them. Open-hearth steel of moderate carbon is easily welded and when the forging is done looks much better than if made from Bessemer.

For certain kinds of tongs and some other tools, cast steel of moderate carbon, say about 60 points, is good, as it is stiffer and can be made lighter, which is sometimes of great importance for extra good tools; but if to be used by careless workmen that get their tongs red hot and plunge them in the water, then the open-hearth is best. It is always advisable in forging from steel of any kind to avoid welding, by solid forging. There are but very few smiths, especially in the country and small towns, who are aware of the peculiar and complicated pieces of work that can be forged solid.

Forging from Bessemer Steel.

Any forging from Bessemer steel is always rough, and if it is to be welded to anything, great care should be taken, as a weld in Bessemer is very uncertain. There is no steel so troublesome to weld as Bessemer. Nearly every blacksmith can remember when he has had trouble to weld some steel tire, made by the Bessemer process. The cause of poor quality is that it is the cheapest process known to make steel, and the various kinds of impurities such as phosphorous and sulphur are not taken out. Remember that crucible cast steel is the king of steels when made from good material.

Holding Tongs.

If you have to lay out all the strength you have got to hold your work steady on account of having tongs not suitable for the work you are doing, then your mind is detracted from where it should be. Consequently, your work suffers in quality when done. Suppose we undertake to dress a cold chisel with a pair of hawkbill tongs that touch only on the point. It wiggles around, also up and down, and is part of the time on the floor. Is it any wonder that the average blacksmith fails to make tools stand? Yet he don't know what is the cause. He does his work about as well as his neighbor smith and makes no further inquiry.

Chances of Cracking Steel in Hardening.

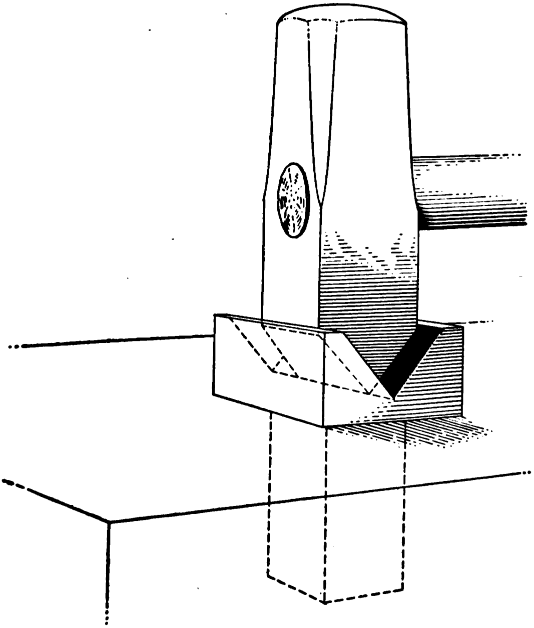
This can be reduced one-half by plunging. By this I mean putting the tool in the hardening bath all over and keeping it there until entirely cold. Then draw the temper to the proper hardness, which is determined in most cases by the color.

Iron Will Cease to be Made.

The time is not far distant when iron will cease to be made. That time will come when a process is discovered to make steel that can be welded as readily as iron. I ask, why should iron be made after that? Steel can now be made cheaper than iron, and is very much stronger. Crucible cast steel of moderate carbon is several times stronger than iron. To more fully illustrate the strength of crucible cast steel, I will say that a bar one inch square has been known to resist a strain of 233,833 pounds before breaking, and there are thousands of the very best steel men in the world working to improve cast steel. I am told that they have produced a steel which is almost indestructible, but it is so hard and tough that it is absolutely impossible to turn it, drill it, or plane it in any way. Now this discovery calls for another; that is,

A USEFUL SWEDGE.

The sketch illustrates a right angle or square swedge which is a very useful tool in any shop. The top swedge is so easy to make that it needs no comment. For the bottom swedge



take steel 2 inches square. If you use smaller steel it will be necessary to upset it in the anvil hole until it spreads out to 2 inches by 1¾ inches. Cut the center out, but be careful not to cut down too deep. It is best to make the top swedge first, then you can use it in making the bottom one. You will be surprised how many times they will be used. Smash the square down until it is 1¾ inches wide at the top. Harden carefully to a low blue.

a fine quality of carbon tool steel that can be made to cut it. And taking all these things into consideration, it is very evident that cast steel is only in its infancy, and this grand onward march of science in all industries will continue just as long as we continue to build school houses and encourage temperance.

Swedge Block.

A swedge block is a very useful tool in any blacksmith shop, if properly made. There are many different models, or kinds. Some of them are nearly worthless, as they contain but little that the average blacksmith can use. For instance, in the case of swedges for making six-sided nuts. On two sides, sometimes on three sides, the average blacksmith will not use one in a lifetime. The trouble is that they are made by those who know nothing about the requirements of a blacksmith. A swedge block properly made should be about 18 inches square and about 4 inches thick. One side should be composed of large, round swedges from 3 inches down, decreasing by ¼ inch. These swedges should run down to at least ¾ of an inch and all told would fill up two sides. One side should be a hollow about the circle of a tire of a front wheel. This will serve for bending the tire, also the various irons around a wagon. Now, we have but one side left. This should be filled with oval swedges, 1½ inches down. These are very useful in a blacksmith shop and should not be overlooked. Now, let us have some round holes from 3 inches down to ¾ of an inch, varying by 1/4 inch. Then make a hollow for forging a ladle and use the balance of the space for square holes, except two or three long holes for use when working on axes. Now, we have the block complete and have nothing except what is useful in most any smith's shop. How are you to get this kind of a block? Get some good pattern-maker to make it for you. Have a dozen cast and sell the other eleven to your neighbor blacksmiths. The blocks will sell and the pattern is a very easy one to make. If there is very much work done in the shop, I would recommend making the block larger, say 22 inches square. This will give space for more swedges and more holes of various shapes.

Making a Boss of Round Iron.

In forging a boss, say of 3/8-inch round, heat the rod to a good welding heat and bend around not quite to right angles, with a light hammer. This will bevel the end and make the side next to you a little the longest. When you see that this edge is out long enough to thin out for a lap, bend up at right angles, or straight up and down, not too high, say 1/2 inch, or according to the size of the boss wanted; then batter down with a hammer until nearly down. Take the edge of the hammer face and draw the thin part of this boss over to you, and batter it down thin, spreading it around the rod. Next take a welding heat, and a few blows makes a perfect weld and a good boss. The same boss can be made without welding by battering it straight down, but care must be taken not to let it lean towards you too far, as it will then make a "cold shut." When this boss is made of very poor iron, it is economy to lay it down and when cold drill instead of punching, as there is great danger of splitting when being punched. Besides, a hole that is drilled is much the best and fits the bolt better. If I had a great many to make, I should make a form or die and I could then make them in half the time and have every one exactly alike.

To make this die I would make a tool like a bottom swedge before the crease or round is put into it, leaving it blank or plain. I would now drill in the thickness of the boss with a drill, just the size I wanted the boss when done. Then fuller-in for the stem, and it is done. Then I would make another impression on the same tool and in this I would drill a hole a little larger than I wanted, and I would place the boss in this form when I wanted to punch it and by so doing I would avoid all possibility of bursting or splitting, besides they would all be uniform.

Cold Shut.

If by chance we get a "cold shut" or a crack in a piece of forging, there is but one remedy, that is to take a thin chisel and cut it out, while this may weaken the job if it is where it cannot be upset. But even then it is stronger and much more durable with it cut out than with it in. A "cold shut" is a miserable thing and should be avoided. A lap is nearly as bad as a "cold shut." Cold shuts generally come in such work as forging a boss, or in bending a square corner and many other kinds of work, and they are dangerous whenever they appear. In some pieces of forgings it is necessary to have a square corner as in making a pair of shoeing pinchers, or nail nippers, and to do this and not pull down the shoulder of the stock as a set-hammer would do, we take a hot chisel and cut part away, but this is a delicate job and can be done only with great care. In doing this it must be driven down with a set-hammer until it is as low as the bottom of the cut; then take a coarse file and clean out the corner. This will prevent any lap or " cold shut " and is the only safe way.

Sulphur in Coal.

All kinds of coal, except charcoal, contains sulphur. The average coal has more or less sulphur in it, sometimes in quantities that makes a weld impossible, and in this case there is but one perfect remedy, that is to throw the coal all from the fire. In hard or Anthracite coal sometimes salt will help; sometimes water thrown on the fire with a broom will help, but to heave the coal from the fire is the best. Sulphur does not bother so much when you have a good blast or plenty of wind. Every smith should remember that no weld is safe that is made in a sulphurous fire. A supply of coke or coal with the sulphur burned out should be kept on hand for welding purposes.

Drawing a Wide Bar of Steel.

In drawing a wide bar of steel that is very thin, it must be heated evenly and as hot as the carbon or temper will allow and must be done with as hard blows as possible, so that the center will be moved as well as the outside. For, if it is not, it will be very apt to crack when hardened. A light blow only moves the grain of the steel about so far, and when it has ceased to move there is a dividing line. There is the point of strain; there is where the crack begins in hardening.

Best Forgers Not Always Best Tool Dressers.

The best forgers are not always the best tool dressers. A man, to be a good steel worker, must be capable of great thought and reasoning power. I can look back at hundreds of good carriage and wagon blacksmiths and scarcely one of them is capable of dressing his own tools. Just imagine a smith dressing his chisel a couple of times to cut off a set of tires 1½ x ½ inches and thinking nothing of it as it is a common occurrence with him and with his neighbor smith and so he goes plodding along in that same rut that his predecessor traveled in during their whole lives. If by chance he makes a chisel that does considerably more work than it ordinarily did, it does not set him to thinking. They never ask themselves the question, "Why is that?" And set to work to investigate and find out the cause, and do it that way every time. When a tool does not stand, it is a common thing to hear them saying, "The steel is good for nothing." Yet, once in a great while he dresses it so that it does a fair amount of work. If you make a chisel do a certain amount of work with one dressing, why can't you make it do that much work next time you dress it and every time? Now, my brother blacksmith, just reason a little with yourself and profit by this.

Hardening Die Blocks.

To harden die blocks of large size, say 8 inches square, the only proper way to heat them is in a covered furnace and they must not be put into the furnace when the furnace is at high heat and the blocks cold. If the furnace is hot then the blocks must be heated over some slow fire until they are sizzling hot, and this must be done slowly. Then put them in the furnace with but very little blast and heat slowly and turn around and over often, and for this size block you should consume at least not less than two hours, and three are better, in bringing it to a red heat. If you drop this block down in a common forge fire, the corners will immediately become hot, and the body of the block will still be cold. Consequently between the hot and the cold there is a sharp dividing line. This is the exact spot where they break when dropped in the water. The corner that was so hot drops off up as far as it was hot, from the fact that there was great shrinking and great strain at that particular point. Whereas, if the whole block had been heated evenly and slowly, there would then be no dividing line and the block, if good steel, will come out of the water sound. The larger the body of water that it is hardened in, the better the result, and if you can have a large pipe or hose pressing a good sized stream of water on the face part of the block, it will be better. The stream of water flowing up against the face cools it and drives the hot water out over the top of the barrel, which keeps it cool around the block. In case you have no hose or pipe to throw a stream against the face of the die, run your arm down in the barrel and throw the cold water up against the face with your hand, and when cold leave it in the water not less than one hour or more. When you take it from the water, don't let the wind blow on it, or the cold air strike it, or don't lay it down on the damp, cold ground; lay it in a warm, dry place.

Cracks and Seams.

When tool dressers or hardeners find that their tools are cracking under their treatment, they are apt to assume that as they are working in the ordinary way there must be something wrong with the steel. It is either seamy or harder than usual, not uniform in temper, or it is of inferior quality. All or any of these conditions may exist and be the cause of the trouble, but every man should bear in mind that he is also a variable quantity and that the machine of self does not run with perfect regularity. Now, it is as easy to find out whether the fault is in the steel as it is in the man. When this is once determined, the remedy is easily applied.

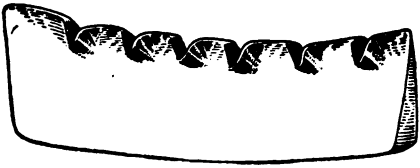
If the axe is cracked a circle shape in the corners, the corners have been overheated, or hotter than the middle of the blade, and by breaking off the corners the coarse grain will tell the story. If the crack is in the middle in a circle, the center was too hot and breaking off a little piece will prove this also. If the crack is nearly in a straight line, it is evident that there is a seam in the steel. Remember that there is a vast difference between a seam and a water crack. A seam is caused by a gas bubble which has not been closed up or worked out by hammering or rolling; it always runs in the direction of the work. The walls of a seam are always more or less smooth; the surface having been rolled together under heavy pressure during the rolling or hammering. The walls of a water crack are never smooth. They are rough, uneven and gritty, and they may have any of the temper colors caused by the action of the water and heat. There will never be any question as to which is which.

Water Annealing.

The water anneal described in this book is in no way injurious to tool steel, and like all other methods has its friends and its enemies, but of one fact I am positive that the water anneal can do no harm, and no matter how many times it is repeated, the steel still retains all of its original qualities, and if it is properly done, it is always in its normal condition. To get a perfect job done, don't hammer the tool until it gets cold and anneal it at the same heat. But heat it again to a low red, about as hot as it should be to harden, and let it cool off to the desired heat and plunge it in cold water. By watching and listening closely when you plunge it in the water, you will soon be able to tell by the sound whether it has annealed or not. A good job of annealing always looks as if it had hardened; that is, it has scaled off and looks speckled.

STEEL FOR AN AXE.

The sketch illustrates the steel to put in an axe. The shape and the beards are such as to make it stay in the axe head



or slit until it is hot enough for a weld. When you take it from the fire the first time, jam it against the anvil, setting the steel up in the slit.

Never lay a piece of steel or a tool just forged down on fresh coal or on a piece of cold iron to cool. Lay it on some ashes or cinders.

Welding Small Steel Rods.

For welding small steel rods, say ⅛-inch round, which get cold almost instantly, take a bar of cast steel 1½ inches square, and cut off a piece one inch longer than the width of your anvil face, and draw the ends down a little and turn the ends over the face of the anvil on each side. Heat this to a good yellow and lay it on the anvil face. Then bring out your two small pieces to be welded and lay them on top of this hot bar of steel, which will keep them from cooling off, and you can make a good weld in one heat.

Merits of the Hardening Bath.

The mass of blacksmiths who are not versed in working steel think that my success in working steel lies in the material that I use in the hardening bath, as the following will show: I was called to Boston some years ago to give instructions in a large machine shop. I began my instructions as I usually did by explaining to the smith the necessity of proper hammering. His first remark was:

"O, never mind that; I can hammer steel as well as any man can. Just tell me what you put in the tub to harden and I will be all right."

He thought that all the tools I had sent them got their good qualities from the mixture in the pail, and that this composition was composed of some wonderful stuff flavored with witchcraft or hypnotized by the devil, and if he only knew its contents or formula he could then go forth and make Damascus swords that would never get dull and slay thousands.

My brother smith, this is only a fair illustration of many of the men I have been instructing for the past 40 years or more. Is it any wonder that I am prematurely gray? Is it any wonder that my head is bare?

Working in a Small Fire.

Some blacksmiths have a mistaken idea that they are saving to use a small fire. This is quite apt to be the case in small country shops and more especially where fuel is expensive. This is not so. If we undertake to work with a small fire, the first objection is that every time we put a piece of iron in the fire to heat it, we must take the scraper and make some repairs to the fire. Then we have so little fuel that the heat is all spread out, and we are now losing both time and coal. Now, let us build a proper fire. We will have not less than eight quarts of coal on each side of the fire. The coal after a time forms a bank and helps to keep the heat in. Don't tear this bank away, and the longer it is there the more solid it becomes and the more it will retain the heat. It is not necessary to disturb this bank.

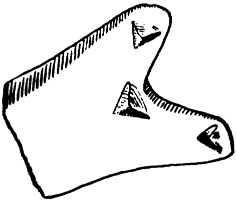
When building a fire, just dig out enough coal to get down to the grate or tuyere. You may say that in doing some particular kinds of work it would be necessary to tear this bank away, in order to get down in the fire. That is a mistake. Let the bank alone and raise your fire by piling on the coal, and you will then get the required heat and be farther away from the grate or fire-box, and the farther away from the fire-box you get your work, the less the sulphur will cut your iron in welding. If you have a good body of coal on the fire, it does not require so much repairs. If you have a bellows that doesn't furnish the required amount of wind, throw it out at once. One of the great faults with bellows is that so few smiths understand hanging them. If they are properly made and properly hung they will blow with very little effort.

Making Shoer's Buttress.

This tool should be made from the best steel obtainable. It should be selected with as much care as if you were going to make a razor. It should be of about 80 carbon steel. Most horse-shoers are apt to get them too large; that is a great mistake; 1¾ inches wide is plenty and 2¾ inches long is enough. Shoulder down and draw out the shank about 2 inches long and weld on to $\frac{7}{16}$ inch round iron. After it is welded on, finish up the blade, flatten it out, don't edge it any more. If it gets too wide or too long, cut it off. The object is not to disturb the packing. The same thing applies to this tool as does to a cold chisel, and when once it is packed, it must not be disturbed. The shape of the blade is obtained by trimming off with a hot chisel. When the shape suits you, make the blade a little hollow, or full on the bottom, especially on the edge; it works better. Bear in mind that the last hammering must be done on the edge or bit at a very low heat and with good hard blows. When ready to harden, heat the whole blade to a blood red and plunge in the bath tub, then rub off with emery stick and hold over the fire, heating it very slowly and let it run down to a blue. The handle or standard is sometimes forged on solid. Sometimes a hole is punched in and riveted on. This can be done as you like. The length depends on the length of the man's arm who is to use it, as does its shape. When a smith understands it, a good buttress is so easily and quickly made that no man should work long with a poor one. Do not be afraid of getting them too thin. If you have no hoof shears or pinchers for cutting hoofs then use this tool. It beats a knife all out.

STEEL FOR BAR OR PICK.

The steel for crowbar or pick should be cut in a swallow tail shape as shown in the sketch, and driven well up in the bar. Don't cut the slit in the bar any farther than is really necessary. After the steel has been driven up in the slit, smash the iron down on the three beards in the steel. This will hold them while taking a good heat. The end of the swallow tail shape of steel will fill up the slit cut in the pick to receive the steel and makes a clean job. Make the split in the steel to hold the steel in as short as possible. A long slit covers up the steel.



Hoof Knives.

These tools should be made of Jessop's cutlery steel, about 5/8 x 1/8 inch, and from 85 to 90 carbon. In making this tool, very much the same rules as those laid down for making a butcher knife should be observed. These knives are forged with a little crook or belly in them. After it has been packed, as explained in making the butcher knife, care must be taken not to disturb this denseness which we have put in by this packing process and the less we disturb this, the better edge the knife will hold. When the crook is put in the point, heat just as short as possible and not any hotter than is absolutely necessary. In packing, do the last hammering on the cutting edge. This holds good on all tools with a flat surface that can be packed.

When you come to hardening, have your fire well charred and loose. Draw the knife through the fire edge down, taking it out often to see the heat, and when heated evenly the whole length and only about half way up the blade to a low blood red, plunge it in the water, and draw the temper over the fire very slowly, and the slower this is done the more even the temper will be drawn. This theory applies on all tools, and don't forget it. One knife made from good steel after the above rules is worth a dozen that you would buy.

Reaming Out Holes.

The only way to get holes exact is not to depend upon any drill, for when the drill is dull it is smaller than when it was sharp, as the corners are worn from the lips of the drill. Sometimes it is necessary to have several hundred holes drilled to fit exactly certain sized bolts, pins or plugs, and it is next to an impossibility to get different drills of the same size. To do this speedily and exact, drill them with a drill that is, say 1-64 inch smaller. Then take a straight shank twist drill that is 1-64 inch larger than the hole wanted, and shoulder it down about

1¼ inch back from the point, and draw the back point down for about ¾ inch. Then straighten or true up so that it will run true, and when cold file the point small enough to enter the hole made by the other drill. Then straighten or true up so that it will run true and when cold file the point small enough to enter the hole made by the other drill. Then set your calipers or edge to the bolt or pin to be used. File to a true taper from point back to shoulder, and when you have it nearly small enough, get a piece of copper or brass, drill a hole through it with your drill, which is 1-64 inch too small and take the reamer and ream out the hole and try your bolt or pin in it. If the hole is too large, file a little more from the reamer, but go slow; file only a little at a time and go on until you get the reamer so that it cuts a hole which will admit the bolt or pin easily. See that the reamer has the proper amount filed out of the flute so as to give the chip plenty of room.

If you have followed instructions carefully, the drill cuts a hole just a little too large for the bolt or pin. Then harden it, rub off with emery cloth and draw the temper to a yellow or deep straw color and cool off. It is now ready for trial again and we find it cuts a hole too large. Now take it to your grindstone and grind it a trifle, being careful to keep the edge the highest. Then ream out another hole and so on until you get it just the size you want. If the steel in your drill is good and you have hardened and tempered it perfectly, this reamer will ream out ten thousand holes and keep its original size, and it is the only way to get a large quantity of holes just the same size. The expense of making the reamer is but little. For all mechanics who are doing gun work, or automobile work, or any kind of particular repairing, or new work, these reamers are very useful and don't be afraid of getting too many of them on hand. If you had them varying by one hundredths up to ¾ of an inch, after using them for a time you would wonder how you ever got along without them. They can be made upon the half-round system explained elsewhere in this book; but bear in mind that a half-round reamer is not so certain or exact when a perfectly round hole is wanted, as these half-round shapes do not have bearing enough to keep them steady. However, for all ordinary work they are good enough. Now, the question arises how am I to hold these various reamers that I have made out of these straight-shank twist drills? You will find a cheap but effective drill chuck which any good smith can make in a short time fully illustrated elsewhere in this book. It can be made to use in a bit stock or drill.

Heavy Forging.

The theory of forging heavy work is very different from that of forging light work. In forging light work the system of splitting and spreading is used. In heavy work this is absolutely impossible, as it would require such very large iron that the system of solid forging is not practical. If we were to forge a T to be ½ inch round when done by the solid system, we would take 1¼ x ½-inch Norway or Swedish iron, fuller down and draw out to ½ inch square, then split the other end and turn out to the T shape, then finish to ½ inch in swedges. Now we will make the same forging of 1¼ inch round; say 10 inches long, and when done this will require one

A BRAKE ROLLER SECTION.

Figs. 1 and 2 represent a section of a brake roller and show the standard properly made and ready to be welded on a jump heat. The standard is high or full in the center, and the moment it is dropped on the roller the first blow throws the dross and slag out. The two pieces unite in the center which is the all important part. After the first two blows, instead of using a hammer the smith has a fuller of about ½ inch size, and the helper has one also. They use the round part of their fullers which fits the place nicely and they have a perfect weld the first heat. The crook in the section of the roller is to allow it to get down in the fire which straightens back as the weld is being made. If you imitate these illustrations it is all nonsense to make a poor weld.. Upset the round piece where the weld is.

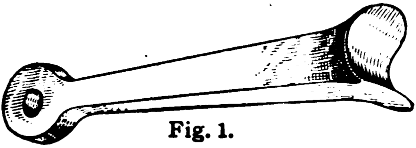


Fig. 1.

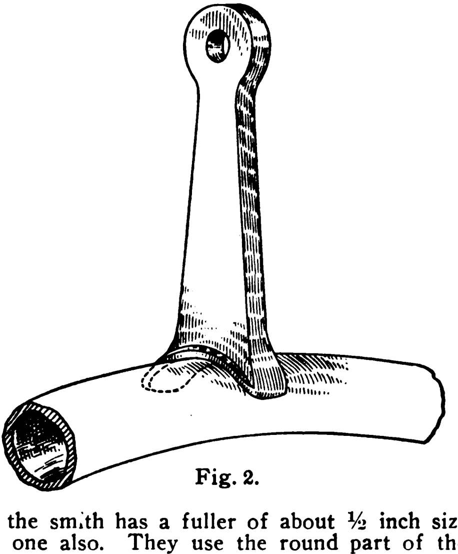


Fig. 2.

piece 21 inches long, and the other 11 inches long. This long piece we will upset in the center as much as we think it will work away in welding. This done, we take the piece 11 inches long and cut it out in a V shape, taking care not to have the ends of the V too long. Then take a good heat and upset it on a bar 1¼ inch. It will then not quite go on to the piece of 1½ that has been upset in the center for the weld, so we just turn the points of the V, and scrape out a little. Now we are ready for the weld. First show your helper just what and how you want him to do, then there is no hitch. Take the long piece and bend it a little in the center or bulge, then drop it in the fire belly down, also put the other piece in. In heating these, don't turn them over nor take them out of the fire unnecessarily, as that wears out your fire and gets unnecessary dirt and slag on the parts to be welded. Heat to a good white heat; bring them out and quickly brush off the slag and dirt from both parts to be welded, the helper having a short piece of a wet broom kept for that purpose. Lay the long piece on the anvil and set the short piece on it. Let the helper hit it on the end two or three blows. Then drop your tongs and let him drop his sledge, and each take a fuller, say ¾-inch size, the smith welding the side next to the helper, and the helper welding the side next to the smith, taking care to do as much welding the first heat as possible, as all subsequent heats are only secondary affairs or what might be called a "mash," as it is impossible to heat points of contact to a welding heat the next time, hence the necessity of having the first heat as clean and hot as possible.

In this simple forging we can cut off from either ends to the length required. But in case there was an eye or other work on the end which made it necessary to have the bar of a given length when done, we must then calculate on this by having plenty of stock in the weld and aim to have it a little short and then draw to the required length. In case you get the required length and still have stock to spare in the weld, then take a thin hot chisel and chip off until the proper size is obtained. For this a very thin chisel is best, as it is easy to run the thin chisel in or out as the case may require and the thin chisel works much nicer and does it better and quicker.

Wise Heads.

Those who are wrapped up in their own importance often tell you how long they have worked at the business. I ask, what does that signify? I find plenty of men who have grown gray at the business and yet do everything by main strength and ignorance. Many of them never worked in but one shop and they are just the ones that don't want to be told of any improvement over their own method.

The writer has received many valuable points from ignorant, illiterate men. To prove my assertion, I will mention a circumstance where some workmen were loading heavy machinery on a car and were raising it with derrick and tackle. They had raised it as high as they possibly could and the tackle block struck against the derrick when it lacked only one inch of being high enough to swing on the car, and after consulting over it a long time they decided it would have to be let down to shorten the rope. Just then a laborer from some other work chanced to go by and inquired what was bothering them. The boss, who had more ignorance than brains, asked him if it was his business. However, one of the workmen told him that the ropes were just one inch too long. "Wet the ropes," said the laborer. They did so, and they shrunk so much that they had one inch to spare. Be careful, dear reader, how you answer a man. He may shrink the ropes on you, or ask you to ride some time when you are on foot.

Hammering Steel Round.

If you want to make a square bar of steel round and have no swedges, hammer it 8 square first, then 16 square, and then round. By this method you will be able to get it round; otherwise it may get in a three-cornered shape. When it is impossible to get it round without a swedge, it is best to do this hammering on the round part of the anvil face, or at least where it is a little full, as it cannot be done so quickly on the flat face, nor so good. If you lay a straight bar of steel or iron on the anvil face where it is perfectly flat, every time you hit it you are crooking it. Therefore, it is impossible to keep it straight. If the anvil face is perfectly flat, it is absolutely unfit for any kind of smithing.

Filing a Round Rod.

If filing a round piece of steel or iron, take two single cut files, put one on top of the other with the shank or tang one on each side open, and slip over the rod to be filed. Then pull back and forth, squeezing on them a little as you pull toward you and slacking up as you push back. This will file the rod true and three times as fast as any other method.

Making a Drill Run True.

In making a drill run true, too much pains cannot be taken in making it run straight. A drill that wobbles is short-lived. The strain is so great it must break. Suppose the drill shank is properly fitted in the socket or chuck, and the bit is $\frac{3}{16}$ inch out of the center, what is the result? You start the point in the center punch mark, and that holds the point. Now, that drill must either break, bend, or drill a hole larger than the bit. A drill bit can be at least one-fourth harder and stand when it runs true. When a drill runs true you can put one-quarter more pressure on it and have it stand.

Making Six-Sided Nuts.

In making six-sided nuts without a swedge instead of cutting them off on the flat side as you would to make a square nut, cut them on the edge about one-quarter. Then turn over and cut on the opposite side as much. Place the cut on the edge of the anvil, bend it over a little and turn over and knock off the corners. Then turn over and bend the other way, and knock off the corners as before. You then have it nearly in a six-sided shape. Cut off and punch half through, turn up on the edge and hammer to six sides. Then turn over and drive a punch through and hammer again, and you will find that with a little practice you can make them as good and as fast as if you had a swedge. Six-sided nuts are not a common thing, except in machine shops and even then they are bought ready made. Therefore, it will not pay to have any tools for making them. A six-sided nut is a poor thing when they are to be often unscrewed and taken off, as the corners soon get worn, and are then worthless.

Fast Forging.

Fast forging consists of knowing what to do first, and what to do next, and so on until the job is done. By so doing, you avoid mistakes and save alterations. For instance, if you are using the fuller and get too deep, it takes some time to bring that back by upsetting or otherwise.

Gloss on Steel.

The gloss on a bar of steel is significant of two things. First, it may have been finished under the hammer at a low heat, and it may be high in carbon. Bear in mind that it is possible to have a fine gloss on a bar of poor quality steel as well as on good steel. It is the hammering when cold that puts the lustre on.

Rivets in Tongs.

Tongs, pinchers, or any similar tools, where the leverage or bearing is on the one fulcrum bolt, are constantly getting loose and becoming oblong, and putting in new rivets does not remedy the trouble, as the hole is worn out of round. The only perfect guard against this trouble is to put in a socket bulb and bolt, which is a perfect preventive. There are several advantages.

A pair of tongs to grasp say ½-inch bar should ordinarily have a bolt or rivet in them of not less than ⅜ inch. In the device just mentioned a ¼-inch bolt is large enough. The bulb or round ball which this bolt passes through should be ½ inch in diameter, with ¼-inch hole drilled through the center, then drill the holes through the tongs ¼ inch and countersink with a round end. Countersink both jaws on the inside deep enough to allow the tong jaws to come together, or nearly so. Then drop the ball in place and put the jaws together and put a bolt in the jaws through the ball and screw up the nut until snug, and your tongs are as strong as if you had a ½-inch bolt through them. Bear in mind that this bolt has no strain on it except to keep the jaws together. The strain is all on the steel ball so long as the bolt is kept screwed up tight, and the friction is but a trifle.

Forging a Clevis End for a Connecting Rod.

Select a bar of good iron or soft steel about 1 x ½ inch. Shoulder down about 1¼ inches and draw down. Then shoulder down on the other end, leaving a lump of about 1 inch. When the ends are drawn out, cut off to the desired length, say, about 1½ inches. Cut both ends the same length. After being drawn out, forge a boss on both, and have them both the same length from the shoulder or lump left which was the full size of the stock. If you want a $\frac{5}{16}$-inch bolt in it, punch a round hole in one side, say $\frac{5}{16}$ inch scant. Pick up your short square pin made for the purpose, and drive it clear through. Heat the heavy part in the center and bend the boss ends around until the bosses are even. Hammer them down to the proper width for such thickness of the lever as is going to be used. Fuller in the large part and dress down the stub to weld on the rod, say, 2 feet or whatever length is wanted. Straighten and turn up. Drill a $\frac{5}{16}$-inch hole down through the square hole that you punched out and you have a good job. When a larger connecting rod is wanted, use larger stock. Soft steel is good for such forgings, such as the ends of wagon tires, etc.

Hand Saws.

Because a certain tool has had greater sales than any other is no proof that it was in any way superior. The quality of a saw, like many other tools, depends upon the material used in its manufacture. Saws differ very much in the methods of making. Nearly all tools after being made are then heated and hardened. This is not so with saws. They are made of high-carbon steel, at least high enough so that the saw after being rolled out and finished is hard enough. The heating of each saw after making would be impracticable, if not impossible, which makes it necessary to use a grade of steel that will be hard enough when done to hold an edge without hardening.

Some saws are made, or ground, so that the backs are thinner than the bottom or where the teeth are, which they claim does not require setting. Such saws may work for a time in very dry lumber, but for all classes of work they are failure. They soon begin to bind and are good for nothing until they have set put in them, and some are so high in carbon that the least attempt to bend the tooth will break it. Saw teeth that break in setting are not so good as those that are a little too soft. So to solve the whole matter, I say, don't buy a saw of any kind unless it is fully warranted. My theory is, if a man is making tools that he does not warrant, he had better go in some other business.

Surface Hardening.

The condition of the surface of steel has much to do with its successful hardening and working. A slight film adhering to the surface of steel will prevent its hardening properly. The steel may harden under the film and not be hard upon the immediate surface, and in almost every case a hard, strong surface is necessary to good work. It is important that a piece of steel to harden well should have a clean surface of sound steel. All bars and forgings of steel have upon the surface a coat of oxide of iron and immediately beneath this a thin film of decarbonized iron. Neither of these substances will harden, and in every case where a hard bearing surface or a keen cutting edge is desired, these coatings must be removed.

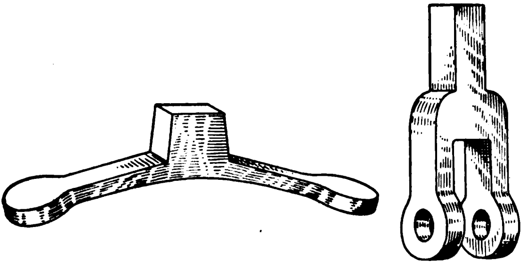
There are a hundred and one reasons why tools crack and warp or spring in hardening, and to explain or convince you of this I will relate a circumstance which took place when I was dressing tools for a large axle works some years ago. We had a great many reamers to harden from 10 to 15 inches long and from 3/4 to 1 1/8 inches in diameter, and these reamers had to be nearly straight. If they were out of true, they could not be used, and we were warping upon an average one-half of them. I found that reamers cut from the same bar would not harden all alike; some would come out absolutely straight and others would crook, perhaps 1/8 inch or more. I made up my mind that there was a cause for this, so I went out to the machine shop and examined a lot of reamers that they had prepared for turning, and found that some of them were centered for turning $\frac{1}{16}$ inch out of the center. For an experiment, I took four that were marked out of center and four that were exact in the center, and told the foreman that four of them would spring and four of them would come out straight, and of course he wanted to know what I judged by, but I would not tell him. So when I took them out of the bath four were crooked and four were perfectly straight. Not satisfied with this, we carried the experiment farther. We got 40 reamers and took pains to center them exactly in the center, and out of the 40 there were just 38 that came out of the bath straight enough to be used. That completely settled the reamer question. Then again there are dozens of reasons why a piece of steel may crack or crook in hardening. It may have a little too much manganese or silicon either of which work strange things with steel sometimes, besides the thousand and one things pertaining to cast steel that man has not yet discovered. Many hundreds of times tool dressers have had to take a " jacking up " from the boss or foreman for cracking or warping a tool for which they were not to blame, and the boss probably knew as little about the real cause as a child unborn.

Hardening Springs.

Returning to my theme of surface hardening, in the manufacture of railroad, wagon and carriage springs, it is not necessary to pay any attention to these coatings. The body of the steel hardens well, giving the required elasticity, therefore the thin film of oxide does no harm. However, to all bearing and cutting edges such coatings are fatal. The ordinary way of preparing steel is to cut the skin off and this is sufficient if enough be taken off. But suppose you have a piece not evenly forged or not full enough that a cut may be taken off on all sides, the moment it is quenched in the water or hardening bath, it begins to cool, shrink and contract. There is an uneven strain and if this steel is not of excellent quality, the tool comes out of the bath warped or cracked, and sometimes the tool dresser has got to submit to reproof. In small tools $\frac{1}{16}$ inch, and in medium-sized tools, say up to 2 or 3 inches diameter $\frac{1}{8}$-inch cut off will be plenty; in large tools and dies, especially in shaped forgings, it

A CONNECTING ROD.

The two pieces illustrated are the end of a connecting rod. The sketch at the left with a lump in the center shows the forging partly made which is simple and very easy to forge. The ends are drawn down, leaving a lump in the center. The boss is forged on the end, and it is bent around like the other piece, the part where the lump was left being forged down to a square ready for welding on a rod. On a cheap job they can be forged from round iron with a boss on each end, then bent around in the center until in a clevis shape and welded on the rod.



would be better to cut away $\frac{3}{16}$ inch. In many cases sufficient hardness can be obtained by pickling off the surface scale, but this will not do where thorough hardening is required, because the acid does not remove the decarbonized skin. It seems to be impracticable to remove the decarbonized skin by the action of acid for if the steel be left in the acid long enough to accomplish this, the acid will penetrate deeper, oxidizing and ruining the steel as it advances. Grinding is frequently resorted to, being quicker and cheaper than turning, planing or milling. When grinding is used, care must be taken not to glaze the surface of the steel, or if it should be glazed, the glaze must be removed by filing or scraping.

In the manufacture of files it is customary to grind the blanks after they are forged and before the teeth are cut. After the blanks are ground they are held up to the light and examined carefully for glaze. Every blank that shows by the flash of light that it is glazed is put to one side. These glazed blanks are taken by other operations and filed until all traces of glaze are removed. If this is not done, the file when hardened will be soft at the tips of the teeth over the whole of the glazed surface. This testing and filing of blanks involves considerable expense and would not be done if it were not necessary. This glaze does not appear to be due to burning, the stones being run in water and the blanks are handled in the bare hands of the grinders.

Temper Colors and Cracks.

Many times after knives, shears, blades and dies are hardened and tempered, they require grinding to bring them to exact dimensions. This is usually done on emery wheels, with an abundance of water, and so no temper colors are shown, indicating heat, it is assumed that no harm can be done. That is the very spot where lots of valuable work is destroyed. The tempered piece is put on the wheel in a flood of water, the work is rushed, and the piece comes out literally covered with little surface cracks running in every direction, sometimes invisible to the naked eye, and until the machinist learns better he condemns either the steel or tool dresser, or both. Sometimes a round bearing or expander pin is hardened. Examined by means of a file, it appears perfectly hard. It is then ground not quite heavy enough to produce surface cracks, but still heavily and on a glazed wheel. It is found that the surface, soft only a thousandth of an inch, has been cut off and the steel is condemned at once because it will harden only skin deep. Take a sharp file and draw it over the surface, and it will be found that underneath the surface the steel is perfectly hard. Now, grind lightly on a sharp, clean wheel and reharden, and the surface will be found to be perfectly hard. Ground heavily again on the glazed wheel it becomes soft as before.

These operations can be repeated with the same results until the whole piece is ground away. Such difficulties occur more with emery wheels than with grindstones. Experience shows that these bad results occur almost invariably on glazed wheels. It is rare to find any bad work come off from a clean, sharp wheel, unless the pressure has been so excessive as to show that the operator is either foolish or stupid. There are but few grinders who understand this matter and those that do will not run any wheel more than one day without dressing, nor even a whole day if the work is continuous and they have reason to apprehend danger.

Mistakes in Forging.

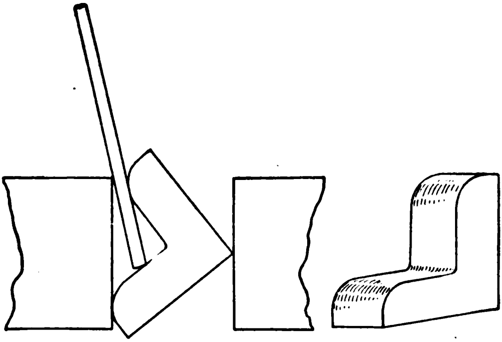
When you have made a mistake in forging, don't waste any time in trying to remedy it by putting in Dutchmen or wedges. Throw it in the scrap heap. The time you waste trying to fix it would in many cases forge a new piece.

Hardening a Hammer.

First get your fire in good shape; get the cinders out of it and have it clean with plenty of coal charred. This takes out the smoke. Heat the face of the hammer slowly until it is low red, taking it out of the fire now and then to see the heat, at the same time turning it around so as to heat it even, about as you would a cold chisel, and when at the proper heat plunge the whole hammer in the bath and cool off entirely. When cold rub off with emery cloth so that you can see the color when it comes. Now set it on the end in the fire face up and watch the color as it comes, raising it out of the fire occasionally to see how hot the pean is getting. If the face comes to the proper color, before the pean is hot enough, then cool off the face and heat the pean again until it is the proper heat and plunge that also. If the pean gets hot before the face is run down to the proper color, then raise it out of the fire and hold it above the fire until the face gets to its proper color and then plunge. Keep it in until entirely cold, rub off the pean, and draw the same as the face. However, it matters but little what color the pean is left, if a round pean, as it cannot very well break or batter. The face should be left to a blue, bordering on purple. Of course, the color depends much on the carbon of the steel that the hammer is made from. If from 80 points carbon, the above colors are right, but if it be higher carbon, let it down to a deep blue, and remember that a deep blue is harder than a light blue. If made from steel of only 70 carbon, a full purple is none too hard. This is the best method of hardening a hammer ever discovered, as it does away with the dangerous dividing line entirely.

A FILING KNUCKLE.

The sketch illustrates a filing knuckle and its use. It is made from a piece of tool steel, bent around at right angles. This is a very useful tool. It often happens that you want to file the edge of a flat piece of band iron to a bevel. Place the piece of band iron in the hollow square, opening the vise until the knuckle goes in as shown. Let one man strike on the band iron and the other on the corner of the knuckle, and it will hold it as solid as if screwed in the vise flatwise. As to forging it this needs no explanation. A view of the knuckle is shown at the right in the sketch.



Any tool that can be hardened by plunging is much better than the method of dipping to a certain depth and holding there, as that is what makes the dividing line. Of course, it is not practicable to plunge all tools, even if it could be done, as it would consume too much time in drawing. This method of hardening a hammer applies to all blacksmiths' and machinists' hammers, whether round or flat peans, large and small. To explain why this method is so much better than any other, will say that the hard steel tapers off into the soft so gradually that there is no dividing line. By the old method of hardening a hammer is dipped in about ½ or ¾ of an inch and held there. The hard and soft steel are then within ⅛ inch space, consequently there is the weak place. Hundreds of times I have seen the face and pean jump off just where this line was and by this plunging method a very poor piece of steel can be hardened without cracking.

Norway Iron.

In working Norway iron, when there is much fitting and bending to be done, it must be remembered that the pores or grain of the iron are very open and have not got their natural strength.

Greatest Strength in Tools.

In tempering a tool to get it perfect and at the same time give it the greatest possible endurance, it is necessary to have the hardened part intergrade with the soft by imperceptible degrees.

Some Causes Why Tools Break.

Poor steel, too high carbon, too high heat in hardening, strains caused by uneven hammering and abuse by the user.

Oxide and Slag.

Oxide, slag and scale are more apt to stick to steel of low carbon than high.

Chipping With the Cold Chisel.

In chipping with a cold chisel, give it a fair chance. Hold it at one angle, and when it becomes necessary to change that angle, strike carefully. The capability of a chisel to do a large amount of work depends very much upon its user.

Sprinkling Water on Hot Steel.

If at any time the cinder or slag should cling to your steel that you are forging, don't put water on the anvil to knock it off, but take a coarse file and remove it. Sprinkling water on cast steel when hot is one of the most injurious practices that it can be subjected to.

High Carbon Steel for Reamers.

In making expensive reamers, taps, milling cutters, or when the labor is the chief item of cost and when tools are required to retain the exact size, they should be made of a good quality of high carbon steel. Tools that require to be intensely hard and have to be rehardened and retempered often should also be made from a fine quality of high-carbon steel.

Hardening Round Steel.

In hardening steel bolts, great care must be taken in the heating so as to prevent cracking in the water, or even after being taken out. Remember that a piece of round steel is more apt to crack in hardening than any other shape. It must not be heated over a blood red; that is for cast steel, and must be left in the water for several minutes until entirely cold, if not, it is liable to crack.

Bolts and Set Screws.

Bolts and set screws are sometimes made of machinery or Bessemer steel of low carbon, and if the carbon is just right they can be plunged and draw no temper, and this system, so long as the carbon is just right, is a perfect one, as it insures uniformity, saves the time of drawing and avoids the danger of getting them to hard or too soft. In all cases heat them evenly and avoid sharp dividing lines in heat, especially near the head, or shoulder, or a bend.

Filing Bolt Heads and Set Screws.

In filing a bolt head or set screw to get it square, after filing one side, then turn it over and file the opposite side, and file it parallel or straight with the side first filed. Then file off each side, and it is very easy to get it square; otherwise you are liable to get it diamond shape.

Making a Hoop.

In making a hoop for a barrel, tub, or anything else where the hoop requires much flare, crook the iron edgewise before you bend it, and the amount of flare that you get depends upon the amount of crook you put into it before it is bent around. This saves the trouble of drawing the hoop or band after it is made, which leaves it much smoother.

Don't File Steel Hot.

Filing steel hot spoils the file and you cannot make any headway. The hot steel clogs the file teeth and a few strokes are enough to spoil the file. However, in some cases it is necessary to file iron or steel hot. For instance, we had a lap or a cold shut which was very necessary to take out. A good coarse file was the best thing that we could take to get it out, and for this purpose the file should be very coarse and double cut. But for finishing a job, or sharpening a tool, filing hot is out of place. This filing hot applies on wagon work many times where there is superfluous stock and not enough so that it can be cut off with the thin hot chisel. The hot filing is then not only advisable but the best method. Don't file cold iron or steel with the file that you keep for hot filing.

Chipping High Carbon Steel.

Chipping high-carbon steel puts a glaze on the chisel which makes it necessary to grind the chisel often. Friction also hardens the steel and many times it is impossible to cut it with the best file. I have seen it many times when it was so hard that it would glaze the file over as if the file were too soft. Sometimes it would plow furrows into the file. The remedy for this is to heat it to a low red and let it cool, and if this does not relieve it you should anneal it. Care should be taken in selecting steel for work when much filing and drilling of holes is necessary, as many times you will strike a hard spot that cannot be drilled or annealed, and the steel has to be laid aside, thus causing the loss of much labor. However, for straight work, when a high polish is required, high-carbon steel is susceptible to a higher polish than low-carbon and for the same size would be stiffer.

Hammering a Bar on All Sides.

In drawing out a bar of steel, it is necessary to hammer it on both sides. If the hammering is done all on one side, and the steel is to be hardened, it is bound to crook. It is equivalent to wetting a basswood board on one side and placing it with the dry side to the stove. It will soon warp around several inches. Hammer it on one side the whole length of the heat, then turn it over and hammer it on the other side and the strain is all taken out.

Hardening Annealed Steel.

When hardening steel that has been annealed, it is best to heat it to the heat suitable for hardening and let it cool. Then heat it again and harden. By this method it is harder, is fully back to its normal condition, and will harden at a less heat.

Dip all steel in water as soon as it leaves the fire. Do not take it out of the fire and look at it a few minutes before you dip it in the water. Get it into the water as quickly as possible.

Too Hot to Harden.

If you get steel a little too hot to harden when it is taken from the fire, letting it cool down does not help it a particle. The only proper way is to reheat it and rehammer it, if possible. If this is not possible, then let it get cool and heat it again to the proper heat.

Cast Steel of 60 Carbon for Tongs.

Cast steel of moderate carbon makes the best tongs. The object of making tongs of cast steel is that they can be made very light and yet be stiff and strong, and if it is necessary to weld them in making, it is much easier, and when once properly welded they can be depended upon. A weld in Bessemer is not to be depended upon. Don't make tongs of high carbon; the jaws will drop off and especially so when there is sharp or square corners. Care must be taken in forging tongs to avoid laps and "cold shuts," as they are already equivalent to a flaw and will get deeper with each jar of the steel. The steel used in tongs should vary according to the kind and size of tongs. From 60 down to 40 carbon may be used.

Steels of the Alloy Family.

Prominent among them is the manganese steel, which is both hard and tough to a degree not found in any other steel. It is so hard and strong that, like mushett or self-hardening, it cannot be machined with the best tools that can be made. Castings made of it are almost indestructible. They could be hammered into all kinds of shapes as if they were made of soft steel. Yet they are too hard to be turned or milled. The ordinary hardening process, it is said, toughens this steel instead of making it brittle. Up to the present time all attempts to anneal this steel have failed, and its intense hardness is proof that manganese is what produces the hardness in self-hardening steel. We are just beginning to find out what can be done and made in the way of tool steel. Where is the end?

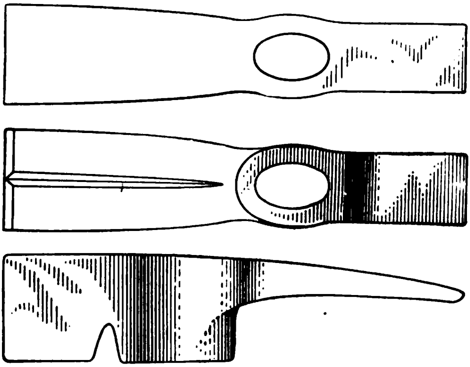
Terms Used by Steel Makers.

There are many terms used by steel makers which would be classed as shop terms, yet the steel users or tool dressers are not familiar with them or their effects. It may be well to mention a few of them. "Blow holes," or small cavities, generally round, are formed in the ingots, as the steel cools, by bubbles or gas which cannot escape through the already cooled surface. "Burned" steel is steel that is reduced to oxide by excessive heating. "Dead melting" or "killing" is a very common term with steel makers. It means melting steel in the crucible until it ceases to boil. It is then dead; it lies quiet in the crucible and when properly "killed" it will set in the mould without rising. "Dry" steel is so-called when its fracture is sandy looking without lustre and without a proper blue cast. "Fiery" steel has a brilliant lustre; it is evidence of high heat. The "grade" means quality or kind, such as crucible, open-hearth, Bessemer, spring, machinery, tool, or special tool. It does not indicate carbon or temper. "Honey-comb" is a term usually applied to ingots unsound from "blow holes" and a large majority of defective steel may be traced back to "honey-combed" ingots. A "lap," or as some hammermen call it, a "cripple," is caused by bad hammering or by improper grooves in the rolls. By careless rolling, a portion of the steel is lapped over itself, the walls are oxidized and cannot unite.

"Over melted" steel is steel that has been kept too long. The very best material may be ruined in a crucible if kept in a furnace too long after it has been killed. A "pipe" is a cavity formed in the end of an ingot. When it cools, the outside cools first, then the shrinking separates in the middle, forming a hollow, or as the

AN ADZE EYE.

The three sketches illustrate an adze eye hammer, either for carpenter's use or a shoeing hammer. We will make one by selecting a piece of steel suitable in quality and size for a



shoeing hammer, 1½ x ¾ inches. First punch a hole which you can have either oval or flat. Flat will be best for a beginner. Don't punch the hole the full size at first; leave it small. Then cut down with hot chisels as shown. Draw out thin for the claws. Then take the face end, and draw in shape. Drive in the eye pin and draw out the socket with a set hammer or fuller, until the socket is as long as you want it, say 1¼ or 1½ inches. Now you have the hammer forged. In hardening, take the claws first, heat only to a low red and plunge in the water, cool off, rub off, and draw the temper over a fire free from smoke, and go slow down to a deep blue. Draw the face end in the fire and keep dropping water on the jaws to keep them cool. When hot, dip in, say 1 inch, and let it run down to a deep blue. A hand forged hammer made from good steel will last a lifetime.

steel makers call it a "pipe." A "pipe" is usually at the top of an ingot. It may occur anywhere. "Restoring steel" is that which steel makers do with over-heated steel. They heat the piece to be restored to a blood red or a deep red and keep it there a few seconds and then let it cool slowly, when its grain becomes fine again and its fiery lustre, which is characteristic of over-heated steel, disappears. This is called "restoring." But the very best restoration for over-heated steel is not to over-heat it. I have tried dozens of schemes for restoring steel and this is the best I know of. Bear in mind that over-heated steel is not burnt steel. When the steel begins to scintillate or fall apart, it has been burned, in which case do not waste any time on it. Throw it away at once, as cast steel is too cheap in these days to waste any time on restoration. Do not deceive yourself with the idea that because steel is low in carbon that it cannot be overheated. It can be spoiled with excessive heat as well as high carbon. A bar of steel may be first class in quality and be either high or low carbon. Quality has reference to the stock or material which the steel is made from and carbon means temper only.

Square Shoulder.

In places where it is necessary to have a square shoulder, it is sometimes advisable to cut in with a thin, hot chisel, but be careful not to cut too deep. It is best to have a file at hand and file out the bottom of the cut, for if there is the least trace of the cut left in the steel it will surely make a crack, and at every jar of the tool that crack will grow deeper, until the tool breaks. Take a piece of steel of 90 carbon and bend a portion at right angles, or in other words, make a square corner. File it up absolutely square and when polished smooth in the corner. Even the use of a sharp, hard scratch awl in the corner would make the beginning of a crack. Never make a square corner unless it is absolutely necessary.

Fitting or Shaping.

In fitting or shaping iron or steel it is best to go slow. If it needs twisting, it is better not to twist it enough than to twist it too much, as twisting or crooking too much is liable to change it elsewhere. Do not get nervous when fitting a particular job. Let me tell you of a circumstance that happened in a shop where I was working many years ago, before the days of drop forging. There was a carriage ironer in the shop where I worked and he had made a shifting rail for a top carriage, forging all the sets and standards from Norway iron. The arm rests, on each side, also the standards for the lazy back, were welded on solid and it was a first-class job, besides being expensive. He had the shifting rail done, except welding it together in the middle. He cut it off, made his scarfs, welded it and got a good weld, also just the right length, so that every standard dropped in the eye or hole where it belonged. But there was a little wind or twist in it, he took it to the vise, put his wrench on it and twisted it about what he thought was right. He tried it and found he had twisted it too much, so he put it in the vise again and twisted it back, and in so doing he put another crook in it. Then he went to take that out, and put in another. Then he began to get nervous, and every time he took it to the vise he put in an additional crook and took none out. He was getting extemely nervous going back to the seat to try it, and when it was on the seat it fitted no where, stood at all angles and looked like a " gun fence." He then raised the shifting rail high over his head and started for the anvil, intending to thrash it over the anvil, which would have ruined it for all time. There was another blacksmith standing near; he quickly grabbed the rail and told the smith not to make a fool of himself, saying, " Let me take it." He quietly looked it over, went to the vise and twisted it a little, then looked at it again, then gave it another twist, then gave it a third twist, went to the seat and every standard dropped in its place and fitted like a duck's foot in the mud. Now, this trouble came through extreme nervousness and passion. If the man had let the smith thrash it over the anvil, as he had intended to do, it would have destroyed at least two days work, and this was saved by a cool head. This nervous man was just as good a mechanic as the country could produce, but at times allowed his passion to get the best of him. If you are like this man when you fail to make, fit, or do a job after trying the second time; just lay it down and go at something else, or go out of the shop for a time, and turn your mind to something else; it will be money in your pocket, and besides such fits of passion are unhealthful and dangerous. Many a man has died in such paroxysms. I knew a blacksmith that would throw his tools out of doors, also the work he was doing. I saw him at one time making a dash for a carriage and some of the oval iron did not just suit him, and he went to the back door and tried to throw the piece in the mill pond, but as the pond was too far off, he only got it about three rods out into the deep mud; not less than 15 inches deep. As good luck would have it, it was the last and only piece of that kind of iron in the shop or town and the customer was coming after the carriage that night, so there was nothing else to do but to go after that piece of iron out in the black muck of the pond. He tried to hire the apprentice to go, but he would not, so he pulled off his boots, rolled up his pantaloons, and waded out in the mud to get the iron. It proved to be the best thing that ever happened to him, as it cured him of giving way to his passion. I worked for a man once who during such fits of anger would take some of the most valuable tools in the shop and break them to pieces. Now, brother smith, if you are so unfortunate as to have this bad temper, I hope I have said enough to cure you.

Putting Water on the Anvil.

In case it is necessary to put water on the anvil to throw off the slag and scale, don't stick your hammer in the water to do it, as the water swells the handle and the heat shrinks it, and it soon gets loose and wears out the handle very fast. The writer considers a hammer handle of good hickory properly made worth at least one dollar after it is properly fitted in the hammer. The habit of putting water on the anvil is a poor one. In making a cold chisel, when we have the chisel packed and made as dense as possible, there is a coating or polish put on the surface by hammering it at a low heat, and it looks like a piece of Russian stove pipe. This polish or coating helps to stiffen the chisel and if you put water on the anvil when hammering the chisel, this polish is thrown off and decreases the strength of the chisel most wonderfully. Therefore, it is very essential that this polish should be left on. To more fully illustrate this, I will propose that we make two chisels, draw them down very thin, leaving one a little thinner than the other. When done, we will take the thick one and grind off this outside coating or polish until it is the same thickness as the other. If we lay each chisel over the hardy hole and hammer it until each one breaks, it will take considerable more blows to break the chisel that was not ground, although it may be considerably thinner than the other one. This should be conclusive proof that my theory relative to the polish being valuable is correct. If after making any kind of a chisel it becomes necessary to alter the shape, do it at the lowest possible heat, as any heat that is hot enough to raise a scale destroys the virtue of the steel according to the heat.

Welding Steel in Iron.

After welding steel into iron, it should be necessary to draw it. But don't undertake to draw it at a low heat, as at a low heat the steel is very much harder than the iron. Consequently, the iron will pull away from the steel. Heat it to a good yellow heat and draw with good solid blows, then you have drawn it clear through.

Crystallization and Its Effects.

While iron that has been crystallized is entirely worthless, it is quite different with cast steel. When iron has become crystallized as a rule it is caused by vibration. The molecules seem to be four times as large as when the iron was in its natural condition and when heating to work will burst apart in small particles and is very rotten. Nothing but puddling and reworking will restore it. Not so with steel. After a cast steel spring has been crystallized and breaks when reheated and hammered, it assumes its natural condition. For instance, steel drills and " jumpers," as some call them, will often jump about 6 inches from the head, which is caused invariably by using too light a sledge. The larger the steel, the heavier the sledge or striking hammer should be. Steel of high carbon does not crystallize as quickly as low carbon. It has been claimed by some good mechanics that steel does not crystallize, and I partially agree with them, especially as to high carbon steel. Steel that has become crystallized is brought back to its normal condition as soon as it is heated and worked, and the higher the carbon the less working it needs.

Wagon Tires Crystallize.

When I was an apprentice, we had occasion to put on two new tires for a man who was carting on the road constantly. When we cut off the bars we found that they were extra good Swedish iron. We saved the two or three feet that were left to make nuts and for other work that required good iron. After a year or more this same man came back with those wheels for another new set of tires. The boss remembered that they were extra good iron and so he bought them to work up, and when we come to work it we could not make anything of it, the grain of the iron being five times as large as when it was put on. The continuous jar and jolting over the stones had crystallized it so completely that it was worthless. Now for the steel. Some years ago I worked in a drop-forge shop and on one of the drop hammers there was a very crooked peculiar shaped spring which took me some little time to make and it broke quite often. Sometimes the spring would stand a week; sometimes three months, and the springs were all made from the same bar of steel and by the same man (I made them myself), and knowing that they were made from good steel, I decided to see whether that steel was crystallized or not, so I took one of the springs and worked it up into butcher-knives, and better knives I never made. Thereafter, I saved all the springs and worked them up into anything they were suitable to make. That just settled the theory that cast steel crystallizes so that reheating will not restore it. It is said by railroad men that a steel bridge will crystallize and must be replaced with a new one. That is possible, as the steel is a cheap quality and very low carbon, about 25 to 35. But as to good tool steel getting crystallized enough so that heating will not restore it, in my opinion it is all moonshine. Sometimes stone drills break off about 6 inches from the top when they have been used with too light a sledge. That does not signify that the steel was crystallized.

How They Make Money.

There can be as much science and skill displayed in getting ready to do a job as there is in doing the job. There are but few blacksmiths in the country that have the tools suitable or necessary to do the work that they are doing and yet some of them make money. How do they do it? I will tell you. They do their work by main strength and by guess. They pinch their families, save all they make, and some of them have the first cent they ever earned. To the good mechanic, one who is capable of deep thought, such a life is but little better than that of a hermit. I am very sorry to say that sometimes blacksmiths are ignorant, illiterate, self-conceited, ungentlemanly, unneighborly and greedy, and often at sword points with their neighbor blacksmiths. They are seldom in any shop except their own. Some of them would rather stand on the street corner and watch a chance to get a job from their neighbor blacksmiths even if they do it for half price.

Setting Axles.

No job or piece of work known to the craft has there been so much controversy over, so far as the proper system is concerned, as that of setting carriage axles. I have listened to the arguments and read the articles of hundreds of smiths and few have the least idea as to the principle of doing this job. I have seen axle sets by the score, some of them costing much, but they are as absurd and ridiculous as a ladder would be to climb to the moon.

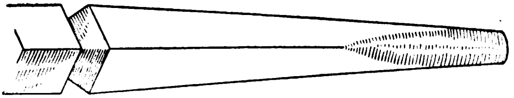
Can a man expect a wagon to run easy with the wheels 8 inches wider at the top than at the bottom? Or, how can wheels run easily with the front one inch narrower than the rear? Suppose that some of these rules of pitch and gather are good or partly so, then after the wheel is hooped say three or four times and gets 1½ inches more dish in it than it had when new, does the wagon still run right? No; and the only way to keep that axle and those wheels in a perfect condition to run easy is to set the axle every time you alter the dish of the wheels. This, of course, is too much trouble. Therefore, the only thing that we can do is to make the wheels run perfect when new and they have but little dish in them. If an axle were set in such a manner that we could pull the axle out of the wheel carefully, and leave the wheel standing alone, that is, perfectly balanced; then that axle was set absolutely perfect, and any other method is wrong.

Gather and Dish.

How are we to go about to do this work properly? First we want an axle set, not a patented one, not a brass one, nor one that costs ten dollars. Take a piece of board of the proper length, about 2 or 3 inches wide, and an inch thick. Put 3 screws in it so as to fit the length of the arm, one near the shoulder, one about ½ inch from the end or thread, and one in the other end, so as to set on the arm near the collar. This will answer to measure the axle top and bottom. Place the same number of screws in this board, or stick, to measure the front with. This axle set has cost about ten cents and when done is as good a set as can be made. Now, we will proceed to measure that wheel and see if the bottom spoke is plumb, and I don't care a fig whether it is or not; we will stand this wheel up near the side of the shop, so that we can lay a board on the top of the wheel and against the shop, in order that when we get it balanced we can keep it there while we get the position of the spoke. Knowing how near the spoke comes to being plumb, we will put the axle in and see where it must be bent, if at all, to fit in that wheel and not disturb its position when the other wheel is on. When we have the one arm fitted, except front and back, we will, using the side of the axle set for this, set it perfectly straight and there is no gather back or front. We have the axle gauge fully set and we know that it is absolutely perfect. We then put all of the wheels out of the way, as we have no further use for them. Then we take this gauge and set the other three arms like the one we have just set, and the job is finished. If the wheels are true and all the same dish, you can put them on the axles. Set them one behind the other and stoop down so as to be even with the two axles and the wheels will be so nearly in line that you cannot see the front wheels. I hope this will settle the axle question for all time with every blacksmith that reads this article.

AN EYE PIN.

The illustration is a sketch of an eye pin, showing the first process. Forge to a taper the size wanted, then turn up on the corner and flatten down to an oval shape as on the point.



Let it be flattened clear to the head or end. The shape is regulated by the amount it is flattened. The piece left in the end at the left is to screw in the vise while filing it up. When finished a tap of the hammer will break it off. Eye pins should be made of high carbon steel, say 90 points.

Do superintendents of machine shops, when they are putting up pulleys and shafting, give them gather and pitch? Do they have them leaning one way or the other? No; everything must be absolutely straight and true. Very well; if wheels in machine shops must be hung true and straight, the same theory is good in wagon wheels. In doing such work as this, use your brains; do a little thinking and do not follow the paths and ruts that others have made until you have investigated and found them to be right.

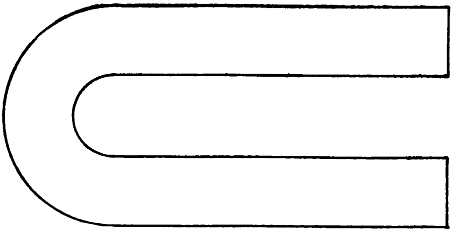
The gift or ability to track an axle properly cannot be termed mechanical genius. It should be called reasoning power.

Deceptions in Steel.

The testing of steel to find out its ingredients is done by chemical analysis. However, this is not final or conclusive in every respect. All good steel shows a good analysis. But it sometimes happens that a good analysis is made in the case of poor steel. Therefore, it is very evident that chemical analysis does not reveal everything. It is quite possible to find several bars, all good steel. each making tools that do a surprising amount of work. Yet, each bar is different from the other. I will give a few illustrations of this fact. It happens occasionally that a cold chisel when heating to harden will, in spite of any reasonable care, heat first on the extreme end or point, say for ¼ inch, and nothing will prevent it, except to lay a small piece of cold iron under it. For this I have a small piece with a rod welded on it. This makes it easy to handle. Some steel will scale off more than others when hardening. It is generally conceded that steel that scales off white or silvery is a high-carbon steel. In many instances this is a fact, but not always. Some steel scales but very little and has colors on the hardened part; this is a very poor steel. Some steel will have a thin small scale rising on the surface when heating to harden, just before it gets hot enough to harden. This denotes good steel. Some steel can be heated to a good orange color before any scale will raise. When steel has a thick, heavy scale it is invariably poor steel. Don't make expensive tools of such steel. It is a waste of both time and material. In making expensive tools, it is best to test the steel, both for quality and carbon. How shall we do this? For carbon, heat until it scintillates, or falls apart. If it drops apart as soon as it gets to a white heat, it is high carbon. If it can be heated so that the flux starts, it is low carbon. For quality, draw down the end as thin as a cold chisel and pack it well at a low heat. Then harden it, and before the temper runs down, take a light hammer and break it, and see how much it will stand before breaking, and when it breaks, note the color. If very white and sparkling it is poor steel; if of

HOLDER FOR STAMPING TOOLS.

The sketch shows a holder for stamping tools octagon or round which cannot be held on the face of the anvil, being bound to slip and many times spoiling a stamp on the anvil face. It is made of round iron, welded like a chain link, about 1¼ inches longer than the face of the anvil on both sides, and bent down at right angles on each side. Spread the sides open wide enough to let a cold chisel of ¾ octagon lay easy between them on the anvil face. It saves the stamps and the picking up of the tool, which will invariably fly off from the anvil. It takes but a few minutes to make it and it is very useful. Have one for every size of cold chisel. It holds round tools also.



a fine grain and a bluish cast, it may be used for good tools.

Dressing Picks.

Use largely the same practice that is used on cold chisels. In selecting steel for such tools, don't get the steel above 75 points carbon. This will stand a good heat and weld nicely. As to the shape or size of the pick to be dressed for an ordinary dirt pick, ¾ inch square or ⅞ inch octagon, is about right. Flatten down the steel to an edge, letting the point spread out like a swallow's tail. Then take a hot chisel and cut out the center in the shape of the letter A. After you have cut the piece out, take the hot chisel and cut two nicks in it. This will raise up two little spurs. Let the steel get nearly cold before inserting in the pick and drive it well in, having the pick hot and the steel cold, being careful not to split the pick up farther than necessary, for if you do the iron draws down and covers up too much steel. After you have jammed the steel well up in the pick, let the helper hit it a couple of good blows, and the little three-cornered spur will hold the steel solid while you get a good soft heat on it. If you see that the steel is not welded good, put on some more borax, take another heat and give it some lively blows. Bear in mind that you cannot make a good weld unless you get it hot enough to make the flux flow nicely. Or, in other words, heat it as hot as you can and not injure the steel. In doing this kind of work, it is essential to know what the carbon is in the steel and you had better test this before you weld the steel in.

Welding Wagon Tires.

In cutting off the tire, make a mark on some part of the felloe and remove the bar and for most tires allow three times the thickness which it will take up in bending. Low carbon or soft tires will take up a little more. It is best to allow a plenty, as you can cut it off if too much. Now run the tire and allow about 3/8 inch for weld and waste, for a 2 x 5/8-inch tire. Then get ready to scarf it for the weld. Cut the corners off on each side. Scarf very short and not too thin. But instead of putting the scarfs together as usual, we put the two flat sides together. See that the tire instead of coming together even is bent so that one end hangs down below the other nearly an inch. Take the lower one and place it on top. That makes them crowd together, which holds them in place solid while we take a good soft heat. We do most of the hammering on the flat side and stop and run it to see how it is for size. If a little small, we turn it up on edge and narrow it up to size.

Welding Light Steel Tires.

After they have been worn and the corners are round and when the steel is high in carbon, and sometimes with lots of phosphorous, it is just impossible to weld them. Take a moderate length lap and heat as hot as you dare and hammer it entirely on the flat sides. *Don't touch* it on the edge. If too wide, take your hot chisel and trim off to the width of the tire. Don't strike it on the edge. If you do, it tears the weld apart. As to the amount of draft to give a wheel, there is no rule to go by, as it depends entirely upon the wheel's condition. More than half the wheels are hooped too tight. After a wheel gets a certain amount of dish in it, then its strength decreases very fast. There is a conservative estimate that five wheels are hooped too tight in the cities where there is one in the country. There are five poor jobs done at smithing in the city, where there is one done in the country.

A File Brush.

A file brush is a necessity in any shop where files are used. They cost but a trifle and soon pay for themselves, especially on fine files and single-cut files. In using a file brush, care should be taken to draw it across the file in line with the cuts or teeth. To clean a wood file, stick a file in hot water or in cold water, then hold over the fire. This swells the wood and it soon drops out, and if you have no file brush, take the sharp end of a stick and run it through the teeth. This will clean them fairly well. A file does more work and much faster when kept clean.

Cut The Tangs from Files.

The necessity of cutting the tang from every file before using is evident when I tell you that I have been laid up with a crippled thumb or hand caused by the file working out of the handle when using, and the sharp point running in the hand or under the thumb nail. This is more dangerous with small files than with large ones. Cut them off as soon as you get them; they are of no use. I have seen many a man in my time carrying a crippled hand caused by the point of a file. Cut them off until they are at least $\frac{3}{16}$ inch diameter, they will stay in the handle just as well, and save you much trouble.

Slag for Welding.

One of the very best fluxes known is slag which drips from the furnace where wrought iron scrap is worked over. It is the oxide iron and when cold is very hard. It must be broken up with a hammer. The best way to pulverize it is to get a large nut of almost 1¼-inch hole and put the pieces in it and set a punch on it that fills the hole. Take a heavy hammer and pound it very fine. Set this burr on some heavy piece of iron, a swedge block or old anvil is good. The finer you get this the better, and use the same as you would sand, only not so much and for all kinds of low-carbon steel it is the best thing I ever saw. The only thing against it is that it is so very cheap; some blacksmiths like things that are dear.

Copper Jaws for a Vise.

One of the first things to be done after buying a new vise is to make a pair of copper jaws for it. This protects the teeth and it holds better, as the copper is soft and yields to the shape of the piece being held when the pressure is applied. Then the vise does not have to be screwed so tight to hold the work and the vise is protected from the blows of the hammer and many rakes from the file and chisel. These copper jaws improve the grip of any old vise where the teeth are worn off. After the copper jaws have been in use for a while they become hard and stiff and do not yield to the work as readily as they did. Then heat them just to a red.

Drop them in the water and they will be soft and pliable for a long time. When the jaws get full of cracks and cuts, straighten them out and hammer them, this will close up the cracks; then fit them to the vise jaws as before. It is not advisable to use them all the time, as they would be cumbersome or clumsy, especially when you have irons to bend to sharp corners. A pair of tongs, when lined with copper, hold the work with much less pressure and do not mar the work.

Making a Ferrule.

If the ferrule is to be made of copper, or iron, cut it out, as shown in the illustration, unless it is intended to have the ferrule the same size at both ends. After the piece is cut to the proper shape, then file a bevel on the edges to be brazed and bend it so that these bevels come on the inside. This leaves a little space for the brass to run in. Before this is bent around, heat to a red and cool off. This makes it so soft that it can be bent around with the fingers. Then take a round punch the proper size, screw it in the vise and fit the ferrule up nicely; that is, have the edges to be brazed so that they come together even and just touch. It is sometimes troublesome to get these edges close together. It can be done by opening the vise not large enough to let the ferrule in but so that it has a good opening, then lay the ferrule over it, and stick a punch through the ferrule and hit the end of the punch. This brings them snug together. Then take a small three-cornered file, open the vise so as to hold the ferrule and run the file through the crease, this will clean it out and make a space for the brass to flow in. Some use what is known as spelter, which is small particles of soft brass. Care must be taken to sprinkle it even along this crevise, made by having the bevel inside, and if sheet brass is used it must be not more than ⅛ inch wide, and in either case it must be watched closely while heating and as soon as it flows, remove it from the fire, and drop it in the water. If it is not removed from the fire just as soon as it melts, it will huddle up in heaps. Clean out the inside with a round file or a half-round, as the case may be. The same rules apply to brazing iron ferrules, except that copper can be used in place of brass and is stronger. The rules given here for brazing are for blacksmiths only, and I shall not lay down any hard and fast rules except for such work as I am familiar with.

Steel Above 96 Points Carbon Will Not Weld.

It is not safe or advisable to undertake to weld cast steel above 90 points carbon. When steel is to be welded to iron there is a chance to do a good job and the steel, if properly worked, will hold a good edge until it is worn down to the iron. In welding steel to wrought iron in all ordinary small pieces, have the iron as hot as possible, except in the case where the iron to be welded is very much larger than the steel, when judgment must be used as to the amount of heat. Too much heat on a large piece of iron would overheat the steel and cracks would follow, as the steel would be burnt; and when the steel had become hot enough to crack, the particles or molecules would separate and the virtue and life of that steel would be gone for all time and it would never carry a good edge, nor would it stand hard blows.

Cutting a Large Bar of Steel Cold.

Cut around the bar about as deep as you can with a flogging chisel. Then take a thinner chisel and cut in a little deeper all around. Now take a thick flogging chisel that will fill the cut made. Put some oil in this cut. Place the bar with the cut about $\frac{1}{4}$ inch from the edge of the anvil and put the chisel in the cut where the oil is and let the helper swing over on it with a heavy sledge. Less than a half dozen blows will break it. If the bar is so large that this method fails, I doubt if you find anything better and you will have to cut it hot.

There is less contraction and expansion in high-carbon steel than in low.

The Dividing Line in Hardening Steel.

This dividing line, as I will call it, is a very critical point and should be avoided as much as possible. I will explain why: We will take a splitting chisel, for instance, and dress it. When we get ready to harden it after heating it to the proper heat, we will dip it in the hardening bath, if we have one, if not, in clean water, about $1\frac{1}{2}$ inches, and hold it there. At the edge of the water is the dividing line. This is its weak point, and if the chisel gets a hard strain it is enough to break it. This dividing line is just the exact spot where it will break. I will take a bar of steel 1 inch square, 6 inches long, and heat it hot enough to harden the whole length; dip it in the water, say half the distance, and hold it there until cold. Then we will return it to the fire and heat it again red hot. We will lay it down, let it cool, and when cold I will lay it on some place where just the ends have a bearing. I will hit it a good blow with a sledge, and it will break in that dividing line, let it be near the center or near the end, and yet there are no visible flaws or cracks. That dividing line, the weak spot, will remain there until the steel is hammered again. Nothing else will take it out. There are several ways to avoid it. The best is to plunge the splitting chisel in the bath and cool it all off. Then there is no possibility of a dividing line, as the hardness tapers just as gradually as the heat did. If this method is too slow for splitting chisels and general work, dip the chisel or tool in say 2½ inches of water, lower it in the water for ¾ of an inch, and draw it out gradually. You will have no dividing line and this method is perfectly safe. There have been thousands of tools broken at the dividing line and no one could tell the cause. There is no system or method of hardening steel known to man that is as good as to plunge it and then draw the temper to the proper color or hardness. But it is too slow for some work.

Tempering by Color.

When you rub off a tool so as to see the color as it runs down, care must be taken to know just how much you have rubbed it off, or in other words, how much you have polished it. For illustration, I will take a cold chisel, say 1¼ inches wide. Dress it and harden it as usual. Rub it off with the emery stick until it is bright enough to see the color as it runs down. Take a finer piece of emery cloth and rub one edge of the chisel more, that is, put a finer and smoother polish on one edge than on the other. When the heat draws the color down in this chisel, of course it comes down as much on one side as on the other. It could not be otherwise. Plunge it in the water when the color on the rough polished side gets to the desired point, say a purple. The color on the side that was polished highly with the fine cloth is a bright copper or straw color. Do you see how easily it is to be deceived? If you polished it very much with fine cloth and let it run down to what you thought was right, it would be too soft. If you happened to polish one side more than the other when the heat drove the color down, you would say it was too soft on one side and that the temper did not run down even. Just give this a little thought. The lack of knowledge on this very point has caused untold trouble. I have seen blacksmiths hundreds of times, in hardening dies and chisels, by chance polish one edge more than the other. When the color ran down they would say that one side was too hard and get a hot iron from the fire and draw it down to the color of the other side. They had a chisel with one side soft and the other just right and the consequence is the tools soon came back to be hardened again.

Packing Steel Makes It Dense.

After you have packed a piece of tool steel and made it dense, it takes longer to heat it, from the fact that the steel is more solid and harder than before. The amount of heat it will stand after being refined depends upon the make of steel, also the carbon. Some steel can be heated to a good red heat and no signs of scale raising and another piece may have a very thin, fine scale raised at a much less heat, sometimes before it gets red. This is a good sign for chisel steel.

Good Fires.

There are any number of blacksmiths that are fairly good mechanics, yet they cannot keep their fires in order. Let this class of smiths take the cleanest forge and the best fire and in a few hours it is worn out. The fire gets full of cinders, slag and ashes and they cannot get any heat. Then they find fault either with the coal or the bellows, or both. Some smiths have the fault of turning the work over in the fire so often that they keep the fire worn out and no heat can be gotten out of it. Every smith should aim to keep a good bank on each side of his fire. This keeps the heat in and saves time and fuel. This bank, if kept wet for a time, soon becomes hard and solid. In many of the small jobbing shops they try to do their work with too small a fire, which is a saving at the spigot and a leaking at the bung.

Forging a Hammer.

In forging a hammer a regular routine of motions is necessary and various tools to be used in relation, which are as follows: Five different sizes of fullers, beginning with the ½-inch size, and when you have finished with the ½-inch size, return it to the rack in exactly the opposite position. That is, the head where the bottom was and by so doing you make no mistake in using the same size fuller twice, and follow this method up until the largest or last fuller is used. This method insures perfect uniformity and will apply to any job where different sizes of fullers are used, and the same rule applies to swedges. However, there is only one or two sizes of swedges required on forging a hammer.

Vises.

Vises sometimes lose their power, and it often becomes necessary to reduce their friction. To accomplish this, clean off both screw and box. When you have the threads thoroughly cleaned, take the collar from the front side, heat it to a red heat, and coat it over with borax. Then lay some spelter or brass on it, and heat until the brass melts evenly. Cool off, file the surface or bearings smooth, and your vise will be in good shape and have all of its original power. Remember that metals of different natures running together as steel and brass, or iron and Babbitt metal, have less friction than two metals of the same kind. A brass box and a steel screw make the best vise screw that can be made. They not only reduce friction, but take less oil and in case it gets dry will not cut so soon as two metals of the same kind. Various machines could many times be made to last a long time when the joints have become rickety from long use or neglect of oiling, by just taking a thin plate of brass the proper length, cleaning off the journal and bending the brass to fit. Put in a little oil and the journal will run nicely, and as soon as the brass gets worn smooth, it will run much easier, require less oil, and last a long time. Many a mowing machine, washing machine, and clothes wringer have been set aside when a few minutes work and a few pennies worth of brass manipulated with a little brains and common sense would have converted them into durable and useful articles.

Vise for Filing and Fitting.

The average blacksmith's vise lacks leverage from the fact that the top of the jaws are too far from the box or screw, which decreases its power wonderfully. The holes in them to admit the screw and box are often so much larger than is necessary that it makes the vise weak and it bends in the hole. A vise to be strong and serviceable should measure not more than 3½ inches from top of box to top of jaws. Every shop should have not less than two vises; one of 80 pounds and one of 50 pounds. In doing light work on a heavy vise too much time is lost in changing. A vise for filing and fitting should never be used for hot irons.

Putting Steel Into Axes.

The first thing is to select the proper steel. As to temper or carbon about 80 or 85 points is about right. It should be about 1¼ x 1½ inches. Before splitting the axe open to receive the steel, be sure you have cut out all the old steel, and do not cut or split the axe down any farther than is really necessary, as the farther you let the steel into the axe the more steel will be covered with iron. After you have cut the steel the proper length before drawing it down to a thin edge, crook the steel edgewise in the shape of a circle, drawing the thin edge on the inside of the circle, and when you get it to the proper thickness the piece of steel will be worked back straight, or nearly so. Now, to make that steel stick in the axe, cut 3 or 4 nicks in it, say ⅜ inch deep. Don't cut straight across, but at an angle. This will turn the sharp edges out and they will catch into the iron, and when hammered a little the steel cannot get out. Before taking a heat to weld this steel in the axe cut off a small piece of the steel and test it for carbon; that is, to see how high a heat it will stand before scintillating or dropping apart. Heat it about as hot as you can and be sure it will not drop apart, and when as hot as you think the steel will stand before scintillating or dropping apart, bring it out and give it a couple of good jams against the anvil. This will put it clean up in the axe where it belongs. Then lay it on the anvil and have your helper instructed beforehand to put the blows on as lively as possible and if you think you did not have it hot enough to weld, put it back in the fire at once, because you cannot weld it unless it is hot enough, and do not keep turning it over in the fire too often. That wears your fire out and hinders getting a good heat. After it is thoroughly welded in and drawn down to the required thickness, get the axe the shape you want by trimming it off with a hot chisel, and finish.

In drawing out axes, be sure to do the last hammering at a very low heat on the edge, being careful at the same time to hold the axe level. When done, let it cool off and file to shape. If you harden it at the proper heat. and let it run down to a pigeon blue, that axe will cut the hardest knot that ever grew in wood, and if by chance you ever fail, ask yourself the question, what did I do that was wrong, for there was surely something wrong. After heating, to harden, plunge it in the bath about 2 inches, *not less,* and let it run down to a pigeon blue.

Forging Clips.

To forge a clip circle requires about one inch square Norway iron. These clips are split out and turned down, but before this is done we must fuller in so as to prevent a "cold shut," and the size of the fuller to be used depends upon the distance the clips are to be apart when done. If to go over an 1⅛-inch axle, we should use a ⅞-inch fuller and fuller down just enough to take away all possibility of a cripple or a "cold shut." Then turn up one piece which you split out for a clip, and forge the clip, and finish it up. Then bend it back out of the way, and forge and finish the other the same. If they are too close together for 1⅛-inch, fuller in and draw them between the clips until they are the proper width. If they are too far apart, fuller down a little more, and take a round-cornered set-hammer and drive them together on the outside, not more than is absolutely necessary. If the iron is too heavy when done take a very thin hot chisel and clip off all the surplus, saving all these little pieces of thin Norway. They will come handy sometime.

When you have a tire that is difficult to weld, just raise up the corner of the weld, and slip a piece of this thin Norway in and it will weld nicely. In forging these clips it is some times advisable to punch a small round hole and then split into the hole and forge as before. This hole makes a nice round shoulder, and leaves a good finish. If by chance we get the spaces between the clips larger than we want, heat it a good soft heat and upset them. Then, if too heavy, chip off until it is the proper size. In forging such work it is necessary to have different sizes of set-hammers; some with the round corner next to you and some with it on the opposite side: some with the corners a little round and others with the corners a deep round. Then with these necessary tools, hard or particular forging is made easy.

The Need of Good Tools.

No man can do good work unless he has tools necessary for the job. If you have not got the tools, make them. If you are working for others and they refuse to let you make the tools which are necessary, then pack your grip and leave the job. I would advise an apprentice or a beginner at this work to forge one out of a bar of lead. He can do it much quicker than from iron, and in case he makes a mistake, there is no loss, as the lead can be melted up and used again. By this method you can get just what you want, and will find out just how much stock you want. This is also good for old hands when they have a complicated piece of forging to do. The old scrap of lead can be melted over any number of times and be as good as ever. In melting over the scrap lead, have the mold so the bars will be square. A piece of stove pipe or thin sheet iron makes a good mold; bend up the sides and ends. A bar 1 inch square is a size that will be used more than any other. If you get the lead in the pig, the pig or bar can be cut up with the hot chisel to any required size. I advise all apprentices to have plenty of bar lead on hand and when they have leisure, forge some work which they are not familiar with. It is time well spent.

Filing or Using a File.

In beginning to file any piece of work, whether iron or steel, the oxide should first be taken off with an old file as it is so hard, as a rule, that it destroys a new file very quickly. Then take a new file; if for iron, take a double-cut first, as it cuts much faster, and finish with a single-cut or what makers call a mill file. The length of the file to be used depends entirely upon what it is to be used for. If you have very much to take off, a 16-inch file is none too long. Draw the file the whole length and bear on only when you push forward. Bearing on the file when you pull back, breaks off the teeth. When you have your work nearly completed, take a short file and a single-cut which cuts finer and much smoother. In finishing, when there is much strain in the corner, a little fillet should be left which adds very much to its strength. This can be done by grinding the corner from the file. Good filers are like good dispositions, born, not made. If mother nature has not laid the foundation for a good filer, no amount of practice or instructions will ever accomplish it. Some work at filing does not look like filing at all, the cuts do not run parallel, they run in a zig-zag manner, and the piece of work filed looks as if it had been in a tumbling barrel. The same applies to some forging which looks as if lightning had struck a scrap heap and scattered it. This style of filing is done by those chaps who work the file both ways, that is, back and forth, trying to do as much cutting when the file comes back as when it goes forward.

When I began my trade, files were all made in England and cut by hand. They were made of the best quality of cast steel, as they had nothing else, and not more than one out of a hundred would fail. When they were worn out they were saved to work up in various tools and aside from the cuts in them they made just as good a tool as any steel. The making of a file by machinery has but little to do with its poor quality; it is the stock or steel in it. However, I prefer hand-cut files. When files are worn out, throw them away. Every time one tries to make anything out of them he loses his time and probably his temper.

Wedging a Hammer on the Handle.

This is an important job, as well as a particular one, and men are very scarce who understand it. In order to wedge a hammer on the handle properly, the hammer must be properly forged to begin with. If it is properly forged, the hole or eye is the smallest in the center, making the hole the largest on the outside, the difference in size being about $\frac{1}{32}$ of an inch, and the hole should be punched so that the handle will hang in a little. This should be ascertained in the beginning. Take a common flat file and push it in the eye as far as possible, then put the face of a hammer against the edge of the vise bench or anything that is straight, then look at the end of the handle and see how far it is from the bench or straight edge. In fitting the handle into the eye, go slow, shaving and filing off a little at a time, so that when you get the handle in the hammer far enough, it will touch all over, or fill the hole all up. This is very important. It is what makes the handle stay in its place. It is what keeps it tight. Now, after we have driven the handle in the eye as hard as possible, we find in consequence of the hole in the hammer being the smallest in the center that the handle does not fill the hole on the opposite side by $\frac{1}{8}$ inch or more. We must be sure that the handle sticks through $\frac{5}{8}$ of an inch. Take a cold chisel just the width of the hole and split this, driving the chisel well into it, and leave it there until we have a wedge made of yellow pine or black walnut. Then screw the hammer in the vise if it has been filed up nicely. We don't want to mark or bruise it. Put your copper jaws on the vise. If you have none, get some, as you need them. Work out the chisel and have the wedge ready. Drive it in as far as possible, leaving the wedge long enough to drive in. Be sure that both handle and wedge is perfectly dry. Saw off both wedge and handle, leaving it about 3/16 of an inch long. Screw the hammer in the vise again, as you had it when you first drove the wedge, and take a cold chisel and use the edge. Where it is just as thick as the wedge, put it on the wedge and drive the wedge down farther, at least 3/16 of an inch below the end of the handle. Take a small hammer and rivet the end of the handle over the wedge. It will batter down and nearly fill the slit. Don't stick your hammer into water to splash on the anvil, it swells the handle, and when it gets dry it is smaller, and consequently gets loose. It matters not what kind of work you are doing, nor how hard the work is, if the hammer is properly made, and the handle is seasoned, made of good timber, and put in according to these directions, it will stay there for years, or until worn out. This plan applies to sledges, carpenter's tools, or any tool that is used with a wood handle. If in case it becomes necessary to take the handle out to dress the hammer, or for any cause whatever, there is but one way that the handle can be got out. Take a gimlet or bit the size of the wedge and bore out as much as possible, and what you don't get out by boring, pick out with a scratch awl or a narrow chisel. When you have all of the wedge out that you can get out, drive the handle in a little farther if possible. Then turn upside down and screw in a vise with good sharp jaws, and squeeze the ends of the handle together. Then make a punch out of a hard piece of hickory to just fill the hole and you can drive the handle out.

Pins or Drifts for Enlarging Holes.

In wagon shops, also jobbing shops, it is necessary to have a lot of round pins; also square ones, from 2 inches long up. These pins are good things to have around a shop and cost but little. The length of each pin should vary according to size. A 3/8-inch pin should be about 2½ inches long; a ¾-inch pin should be about 4 inches long. These pins should be made of high-carbon steel, as the head will not batter up so quickly. In punching a hole, leave it a little small, pick up the sized pin that you want your hole and drive it through, then you know that the hole is just right. You should, if you are doing wagon work, have all sizes from 3/16 to 1¼ inches. Then you are ready for business. Just think of the work that these pins will save you in the course of a year. Have a set of figures and stamp the size on each pin. Then you are sure the hole is right, also have a full set of letters, the cost is but a trifle compared with their usefulness.

Drilling Machines.

These are very important in the smith shop and there are many different kinds. There are a host of cheap drilling machines on the market selling at a low price which are not as a rule worth shop room. Buy good machines and tools.

Open-Hearth Steel for Chisels.

There is much open-hearth steel sold for cast steel, especially in the octagon shapes, for the various tools of the chisel family, and there are but few blacksmiths that can tell it from the ordinary cast steel. Chisels made from open-hearth steel as a rule do not scale off when hardening, but look black and streaked. This is a peculiar feature of open-hearth steel, and in forging bear in mind that steel that does not scale off when hardened at a fair heat has something radically wrong with it. Open-hearth steel is made of different carbons as well as cast steel. The head of a chisel made from open-hearth steel when it turns over splits apart in large cracks. For instance, the head of a chisel of good cast steel of about 80 carbon will split open in about 7 to 10 different places, and the cracks will be small and close together, and the smaller the cracks or splits and the more of them the better. In judging the steel by the head of the chisel, we must take into consideration the size of the hammer that was used on it. If the hammer used on one chisel was ¾ of a pound and on another chisel made from the same bar the hammer was 2 pounds, the first chisel would have the most cracks and the finest cracks, and the chisel used under the large hammer would have small, coarse cracks and fewer of them, and if the steel was above 80 carbon, the chisel used under the large hammer would probably have the head split off in pieces.

Dressing a Stone Hammer.

There is a great deal of this class of work to be done in different parts of the country, and but very few understand it. Overheating is the source of the greatest trouble, while heating too quick is another. Suppose you have a stone hammer to dress. As soon as you have the handle out, you plunge it down in the fire, no matter how hot. The corners are heated to a white heat, while the center of the hammer is yet black. The great strain that has already taken place between the two extremes has already laid the foundation for a crack. You then proceed to dress the face, and during this first heat the center was hardly red in the middle and if it was, no matter, the internal strain which is the foundation of nearly all cracks is there, and as soon as you drop it in the water it shows up and, if not, they will show the next time it is heated, if it doesn't break before. Now let us go at this hammer properly and scientifically. Instead of plunging it in the midst of this hot fire, we will lay it on top of the fire and to one edge, letting it heat slowly for at least 15 minutes, so as to bring it up to a red heat and dress it. The main object is to get the corners square. Some want the center the lowest, this can be done with a fuller. When the face has been properly dressed, return it to the fire and heat it slow, very slow, and only to an orange color, not higher, and plunge in the center of the bath and hold it there. Put the whole hammer in and cool as quickly as possible, and don't take it out until it is cold. The top or cutting edge of this stone hammer is to be heated and handled the same way, except it is to be packed on the flat side with the heavy hammer or flatter, at a low heat. If this spreads the sharp end too wide, set it up on the end on a piece of copper kept for that purpose. This will keep the face from being battered up. Cut off the edge with a hot chisel, but don't hit it on the edge. Be sure to do this packing at a low heat and harden the same as the other end. Don't draw any temper. It will be all right; the only possible chance for failure is in getting it too hot.

Don't be afraid to harden it at a low heat—so low that you may think it will not harden, but just try it this once to please me, and your customers will also be pleased, as they will get double satisfaction. In heating this hammer to harden it must be done on top of the fire, and when it gets nearly red, raise it at least two inches above the fire. This gives it a good chance to heat, even if it takes a little longer, but it is time well spent.

Low and High Carbon.

The difference in low and high-carbon steel is easily told when cutting up the bars. The high-carbon breaks off with less blows and is harder to hammer. The outer edges of low-carbon steel when cut cold become pressed together and look like iron.

Judging steel as to the exact amount of carbon is somewhat uncertain, as the heat at which the bar was finished has much to do with it. The size of the molecules or grains depends very much upon the heat at which the bar was finished. The lower the heat, the finer the grain; the higher the heat, the coarser the grain. The lower the heat when the bar is finished, the smoother the surface will be and the higher the polish.

The difference between high-carbon steel and low is readily told by chipping it with a cold chisel. The higher the carbon, the harder it will chip; the lower the carbon, the better the chisel will hang to it, and the lower the carbon, the better the chisel will hold its depth of chip and the longer you can cut the chip. The higher the carbon, the shorter the chip will be, the more gloss will be on the part chipped, and the quicker the chisel gets dull. When drilling the chips of the high-carbon will be fine; the chips of the low-carbon will be coarse and hang together. If you have two pieces to drill, one of 30 carbon and the other of 80, and use the same amount of pressure and the same drill on each of them, the chips of the low-carbon will be double the thickness of the others and will look coarse and ragged.

Bending Low-Carbon Steel.

Some classes of steel take up more in bending than others. The higher the carbon, the less the take up. When bending two bars of steel tire, you will sometimes find that one has taken up much less in bending than the other; that is, after being cut the one of high-carbon did not bend as small as the other, and will be more troublesome to weld.

Steel Breaking from Frost.

It is an old whim that has been handed down ever since steel was made that it is more liable to break in cold weather, or when it has frost in it. That is nonsense. Look at the hundreds of thousands of miles of steel rails stretched over the earth, and there are no more broken rails in winter than in summer. People say so because they hear others say so.

Detecting the Amount of Carbon.

High-carbon steel can be detected when hardening by the way it scales off. The high-carbon will scale nearly clean; the low-carbon will have some scales remaining on the steel.

Having Low-Carbon Steel Just Right.

The necessity of having low-carbon steel just right is much greater than in high-carbon. If in making a tool that requires high-carbon we vary a few points, either higher or lower, it will make but very little difference. Not so in low-carbon tools. If too low, it will not hold its edge; if too high, it will break. In order to judge steel by its looks we must understand its conditions.

Waste of Material in Small Fires.

In making welds in a small fire, care must be taken as the material wastes much faster than in a large fire with a good body of fire between the grate and the weld.

Upsetting Iron.

The upsetting of iron is much more dangerous than upsetting steel. It does tool steel no harm to upset it if it packed again and the higher the carbon the less it injures it.

Tool Dressers' Fire.

A tool dresser's fire, to be right, should be entirely enclosed, except a space in the front to get to the fire. This keeps the light away from the steel, and when you raise it from the fire, or to one side, you can then see just how much heat you have got; whereas, if we hold it out in broad daylight or in the sunshine the amount of heat will be mere guess work.

Making a T Weld on Flat Iron.

Great care should be taken in preparing a scarf on flat iron not to get the edge too thin and the scarf too long. Suppose we weld a T on a shaft iron for the cross bar which may be of iron or soft steel, as the case may be. The width and thickness depends upon the size of the shaft; it is ordinarily 1¼ x $\frac{5}{16}$ inches. It is advisable to reinforce the iron when the weld is to be used by upsetting it, or by cutting a slit in it with a hot chisel, say ¼ or ⅜ inch deep, and drive in it a wedge or Dutchman, as it is commonly called, about as long as the iron is wide. This will swell out the iron and make it considerably thicker. Take a light heat, enough to weld it nicely, then scarf it and be careful not to make the scarf too long, or the edges too thin and be careful not to lap too much. Take a good soft heat in a clean fire free from sulphur. When I say a good soft heat, I mean as hot as possible and not have the weld splash out or crumble off when you take it from the fire. If you fail to get a good heat and a proper lap to make a good weld the first time, there is but little chance to take a second heat. If it is necessary to take a second heat be sure to have plenty of hot coal over or on top of the weld. Have an old rasp near by and while hot scrape off all the slag and cinder from the weld. This can be easily done while it is yet hot. This improves the looks and saves files when you come to finish it, as the oxide and slag which adhere to the iron when cold destroys files in a short time.

To jump round iron on a flat bar, upset the flat piece a little; countersink the spot where the weld is to be made so that a round pean of a hammer would fit in it. Upset the round piece so as to fit this countersink. Punch a hole to let the gas and flux out during the welding and allow the two pieces to unite much better than by any other method.

Making a Spring.

In making a spring, never file it on the flat side after the packing has been done, as the filing cuts off the very best part of the steel. When the steel has a polish on it caused by the hammer, it is the support of the spring. Don't disturb it either by filing or by heat.

Square Corners.

For a square corner in a ½-inch bar, if we have an anvil with a round corner of the proper shape, we will forge the corner by bending and upsetting. First heat to a white heat and bend over the round corner, not to right angles, but nearly so. Then take a welding heat and upset both sides of this corner, taking great care not to let it get around to right angles, as that is what starts a cold shut and will do it at one heat, especially if the corners of the anvil are sharp. If the corners are round and the work is kept from right angles, there is no danger. Any size corner can be made this way. To forge a square corner in 2-inch square iron, heat the piece to a white heat, cut it about half in two and bend around while hot at right angles. Now we have a gap or a vacant space in the shape of a square. We will now find out exactly what size of square iron will fill this cavity and cut off a piece 2½ inches longer. This will allow ⅛ inch on each end to batter up and work over. Have the helper take his piece out just as if he were going to weld it and show him just where and how to place it and just what you want him to do and how to do it. Heat each piece to a good scintillating point. Bring them out on the anvil and have the helper brush off the welds with his broom. Place the square chunk in the proper place and have the helper put his blows on top and the smith put his on the other side next to the helper. Then turn down and put a few blows on the flat side, keeping the work during this operation on the round corner of the anvil, which prevents the " cold shut " from working in it. If you want this inside corner square instead of round, a very few blows with a set hammer will do it. But remember that the squaring up of the inside corner must be done the very last thing.

Drawing Steel with a Hand Hammer.

In drawing either steel or iron, the blows should be distributed as evenly as possible. To better explain, say, we have a ⅜-inch round rod which we want to flatten out. If we get the blows a little too far apart, there is a hollow in the edge. If we get them just the proper distance apart, the edge is straight. This shows the necessity of even hammering. In drawing a bar, it is not necessary to turn it over every blow you strike, but follow it with the blows all on one side as far as the heat goes, then on the other. The bar will thus be even and smooth and you have done the work with few blows.

Steel Making.

There are several methods of making cast steel, but none so good as the crucible process. Cheap steel is invariably expensive. Don't work steel in a dirty fire. The heat at which cast steel of various kinds hardens must be learned by experience. If you are going to weld cast steel to iron, before doing so take a piece of the steel and test it; find out just how high a heat it will stand without scintillating. It is time well spent. The cracking of tools during the hardening process is ninety-nine times out of a hundred caused either by irregular heating or irregular hammering.

Adieu.

And now, dear reader, the time has come when I must bid you adieu. I have urged the practice of great and good principles upon your understanding that you may win the precious prize of being a successful and respected mechanic, which is the stepping-stone to a happy and contented life. I have urged and stimulated you to be faithful and persevering, that you may be eminent in your profession, by due observance of the rules and truths selected from my experiences of three-score years and ten, battling with thousands of obstacles and tens of thousands of all classes of humanity with whom I have come in touch during this long and eventful term of service.

It has been my aim to give some information that will interest every mechanic in whose hands this book may chance to fall. Take the information that you have gathered from this work and combine it with your own knowledge; don't rely wholly upon others.

The writer cares nothing for beaten paths, nothing for the footsteps of others. He goes across the fields, through the woods by winding streams, down the vales and over the crags, wherever mechanical genius or the beauties of nature lead. Some authors have written lines that are inspired with laughter and words that are wet with tears. I have done neither. Possibly I have not written to please all, but what I have written, my whole heart has been in, and what I have done has been done with an eye to the welfare of my brother mechanics.

Again I entreat you to seize heartily and earnestly every opportunity afforded for advancement and no matter from what source it may come, grasp it when it presents itself, and by so doing you will rise to usefulness where the wise and good shall shine like the stars in the Heavens, and when Mother Nature calls you to the Great Unknown beyond, you can say " I am ready to meet what all the dead have met."

I love to look upon a young mechanic. I silently ask what will he accomplish? If he has genius, will he contend for the master mechanic's chair? If he has skill, will he employ it like Astor and Girard to satisfy his lust for wealth, or will he employ it to alleviate and assist his brother mechanic? If the gift of eloquence be hidden within him, will he use it like Patrick Henry or John Adams, battling for human rights, or will he wage war against truth and duty, and thus sink to degradation? As I raise these queries, I tremble for his fate.

I feel a desire to bear a part in imparting to him a knowledge that I would have eagerly grasped in my younger days. As a fruit of this desire, I have written this book. May its success equal the sincerity of my wishes for the young mechanic, so that he may say this man was our benefactor, and we trust that he is peacefully resting on the beautiful Isle of Somewhere. In return, my last wish is that you may all live as long as you like and have what you like as long as you live. Farewell.

WARREN S. CASTERLIN.

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