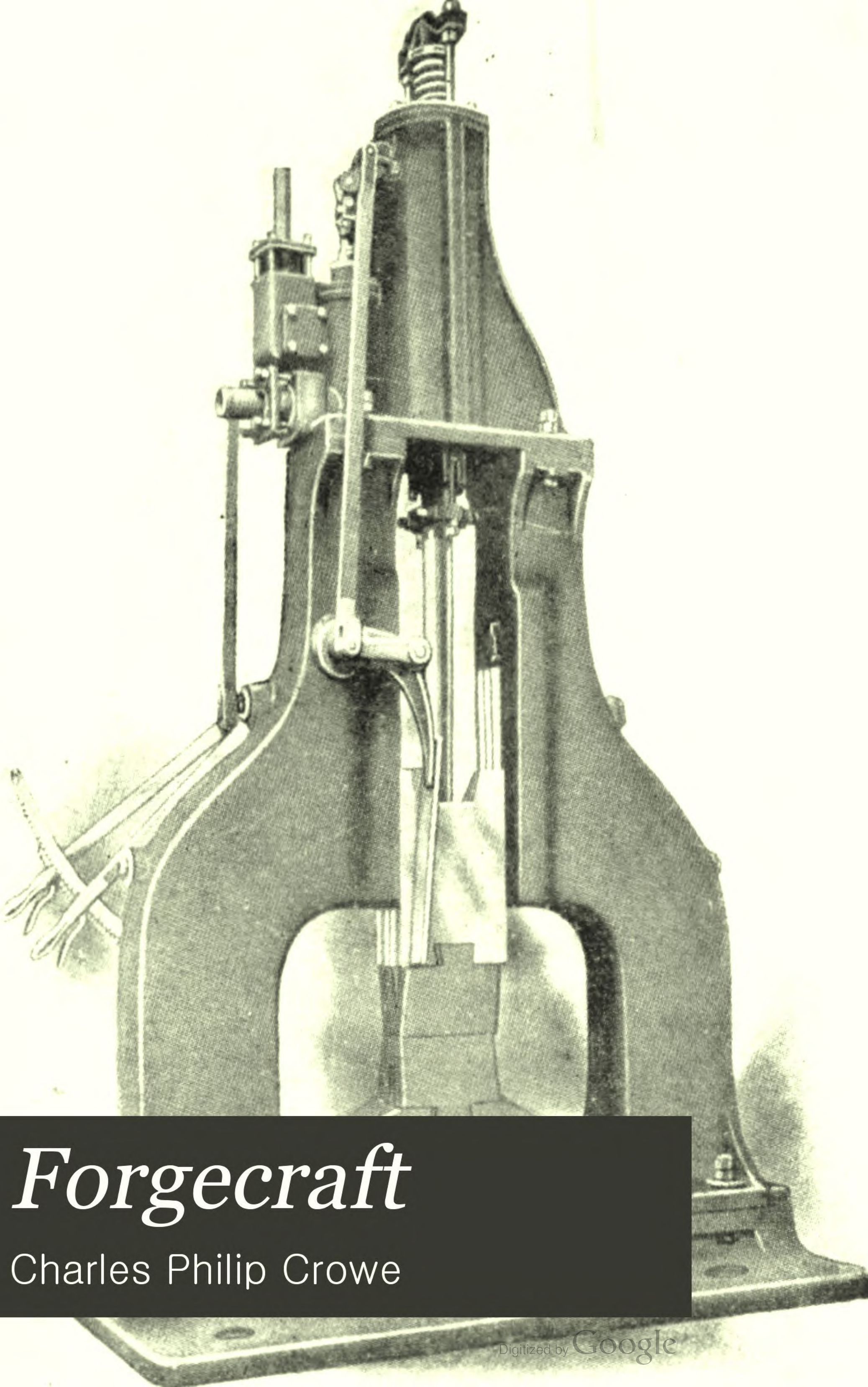

Forgecraft

Charles Philip Crowe

FORGECRAFT

BY

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PREFACE

This book is intended for the student, the apprentice, and the artisan who works at the forge. For any one who cares to understand forgecraft, some things explained here will be found profitable.

The author has found it impossible to complete many of the themes begun in this book, and had no intention of attempting to exhaust the theme when he began writing.

Forgecraft is a fundamental subject and the only argument that fully proves many of its principles is a piece of iron or steel shaped and treated properly. Intelligence rather than great strength is now recognized as the chief requisite for success in this trade. But skill can not be acquired without experience, and while knowledge of the theory is more valuable to the possessor than practical skill, the latter ought to be gained first in order that the understanding may be correct.

To all who would acquire more information on the subject of this ancient art, which is the same now as in the days of Tubal Cain, this book is respectfully dedicated.

C. P. C.

CONTENTS

ILLUSTRATIONS

INTRODUCTORY

FORGECRAFT

The *Forge* is a place where iron and steel are given thermal and physical treatment.

The *Craft* is dexterity and knowledge in giving the required shape and treatment.

Part I. Treats of the tools and materials, with instructions for using them to make certain dimensions and shapes.

Part II. Treats of welding wrought iron and steel, with instructions for preserving the strength of the materials.

Part III. Is on the treatment of steel, with instructions for making types of tools that are in common use.

The subject may be considered under four heads:

First: *Forming*—which is changing the shape of commercial bar stock in line or section.

Second: *Welding*—which is making joints by a direct contact and union of the pieces to be joined.

Third: *Fixing*—which is changing the condition of the material into a desired state of hardness or coherence.

Fourth: *Knowing*—which is from learning about the three kinds of things that are done at the forge.

In part one of this book the things treated are essential to the first part of the subject. There are many other fuels, tools, and *forms* of work equally important, but these have been chosen, and the manner of using the fuel and tools and making the forgings has been described, because they are types of all that is or can be done at the forge without knowing how to make welds or fix the condition of steel. The fundamental principles are the same when heating with other fuels or using other tools.

Drop forging dies were developed from the swages and other tools shown in succeeding chapters, and the power hammers, with all the appliances used in the forging industry, followed naturally when the methods shown in this book were not powerful enough to handle heavy pieces, or fast enough to duplicate the forms demanded.

In part two, *welding* is described and illustrated as well as the author can do it in black and white on a printed page. The color of the heat and the appearance of the metal can only be learned at the forge, and the author's hands at rest, holding the pieces in position during important stages of the work described in the text, are not as expressive as hands in action.

In part three, the standard cutting tools common in machine shops are shown with instructions and illustrations of the best way to forge them and *fix* in them that condition, or change, in the arrangement of the component parts desired. Each operation plays a part in *fixing* the state of the metal. But the process of hardening and tempering steel is of such great importance that it becomes of chief interest in a great many pieces treated in Forgecraft.

There remains learning from experience, reading, and discussion of the subject. This gives the knowledge essential to successful accomplishment of whatever kind of work there is to be done. There is such a close relation between the three parts into which this text is divided that it is impossible to know one part without learning something of the other. But the subject is progressive and the practice lessons, given in the first two parts, should be understood before attempting to learn to do the things in the third part of the book.

A TEXT BOOK ON

FORGECRAFT

WITH A CHAPTER ON METALOGRAPHY

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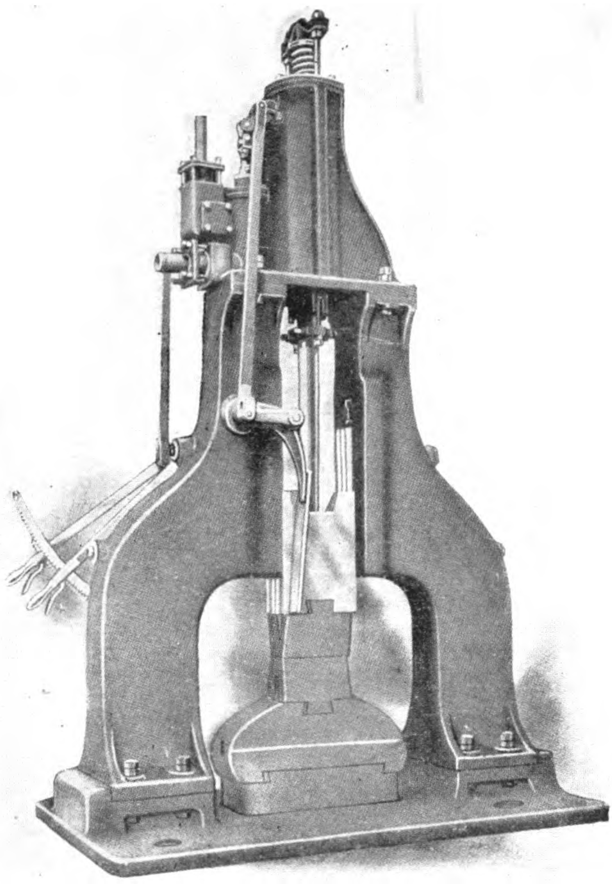


FIVE TON STEAM HAMMER.

The piston and attached hammer head weighs 10,000 pounds.

PART ONE

Part one treats of the tools and materials, with instructions for using them to make certain dimensions and shapes.

FORGECRAFT

CHAPTER I

THE FORGE

A PLACE WHERE IRON AND STEEL IS HAMMERED INTO SHAPE

If we should confine ourselves to the forge in the narrow sense of its being merely a thing or place on which a fire might be built and things heated, the subject would not be broad enough; though much might be said and written about this fireplace which is often and not improperly called a forge.

It is better to think of the forge in the older understanding of the word, when it meant a place where iron and steel were made; blooms, billets and slabs of steel or iron used to be made at the forge, which was a great place containing cupolas, furnaces, power presses, hammers, and rolls where the hot billets were finished to sizes required by blacksmiths and other users of commercial bar.

The blacksmith is so called because he works black oxide on the metal, and finishes his work black or unpolished. He is thus distinguished from the metal polisher, the tinsmith, or the silversmith, whose work is finished white or who works in white metal.

The forge, the place where iron and steel are heated and hammered into shape, is the broad sense in which the word should now be used. We find at the forge many things well worth our study.

THE HEATING PLACE

The place to build the fire should be of a size and shape suitable to the work. A small fireplace with a roof of brick or some better non-conducting incombustible material like asbestos, above it, is best for workmen who do only small work, such as tool-dressing and horseshoeing. Some work demands that the heating place must not be covered on account of the height of pieces projecting above the fire while a part is being heated, and some work requires a large resting place, in which case the hearth about the fire may be wide on all sides. Those matters are of practical value and the details can be worked out by any one preparing to do a certain class of work.

Fig. 2.

But there are other items about the fire and the fireplace which should be considered scientifically as well as practically.

OXIDATION

The blast opening, or tuyere, may be in the bottom of the fireplace so as to direct the air up into the fire, but for heavy work it is better to direct it horizontally into the fire at the bottom, for the vertical blast may work directly through amongst the coals and against the piece to be heated, and not only cool it in spots, but the excess of oxygen over carbon coming in contact with the hot metal destroys some of it and may oxidize it so profusely that it will not be in good condition for forging and can not be welded. With care and skill, the workman using a tuyere giving an upblast of air can keep just enough coals under the piece to split up the currents of air and combine with the oxygen without choking or clogging the blast. So the difficulty mentioned above may be avoided with less fuel consumption for small work than would be required in a horizontal blast.

PLACING TUYERES

When the tuyere, or blast opening, is horizontal at one side, the air currents must cross the bed of fire and be split before they turn upward, so they do not seem to bore holes through the fire as quickly as the up-blast; but as the tuyere irons can be arranged for dumping and cleaning more easily under the fire than at its side, the character of the work alone compels the use of a side blast at many fires where very heavy work is done.

The depth of the tuyere below the hearth must be at least five inches, for the natural place for the piece to be heated is level with the hearth. Long bars to be heated in the middle can not be lower than the edge or hearth of the fireplace, and blocking it up is unnecessary if the hearth is the right distance above the tuyere. This should be right at every forge, and the right depth is always the same in big or in little fires with light or heavy blast pressures.

AIR PRESSURE

The pressure of air blast at the tuyere should not be less than three ounces per square inch. This low pressure is less liable to injure metal that is being heated, as destructive oxidation would occur but slowly, and the mild blast of air will cool the piece before much injury is done. In a high air pressure of two or three pounds to the square inch, white hot metal exposed to the blast is quickly destroyed.

The hottest place is from five to seven inches above the tuyere; if enough burning fuel is piled upon it, the piece will be in the middle of the fire and that is the hottest place. Therefore, it is the best place to get a heat on the piece.

THE FIRE

The air blast from which we get oxygen passing through five to seven inches of hot fuel (carbon in proper form) furnishes oxygen and carbon in the right proportion to make heat. If it passes through less than five inches of fuel, there is not enough carbon; therefore, the piece we are attempting to heat will oxidize excessively, and if oxygen must pass through more than seven inches of fuel, there is an excess of carbon and consequently slow heating, while in extreme cases of violation of these instructions, it is absolutely impossible to get a welding heat, or a good condition for treating anything.

Fig. 3.

This is true also if the fire is too wide or long. Forge fires should be kept just large enough to surround the piece to be heated with glowing coals. Unburned coal wet packed around the fire will keep it from spreading.

FUEL

The fuel used should be coking coal, as free from sulphur, slate, and other impurities as possible. Any soft coal that crumbles easily into many sided small particles with bright and shiny surfaces is good smithing coal, if it will coke.

The only way to learn of the coking properties of coal is to try it and see if it cokes. Many blacksmiths do not bank the fire and make a supply of coke for future use. It is not necessary to do so for light work, because the experienced man can char the coal about the rim of the fire as fast as he needs it.

This charred coal which he is constantly making and using as he needs it to replenish the fire and to cover the heating piece is soft coke. Hard coke is made by getting it very hot without burning. Keeping the coal a long time very hot under a bank that is wet enough to prevent consumption makes it into hard coke. This hard coke, made by high heat, requires a very hot fire to make it burn again, and in some large forge fires hard coke, made in coking ovens and crushed to a convenient size, is a most economical fuel; at others, where the fire is small, it burns with such difficulty as to prevent its being used successfully.

The Blossburg or Peidmont coal, from mines which for many years supplied the market with smithing coal, but have long been exhausted, still remains the most common name known to blacksmiths.

CHAPTER II

FORGE TOOLS

A DESCRIPTION OF TYPES OF ALL TOOLS USED IN THE CRAFT

It is an old saying that "all arts depend on the hammer and hand," and the assertion is easily proven. Imagine, if you can, that all the arts of civilized men are destroyed, the factories, forges, furnaces, machines and tools, all gone. We are left to build them up again. How shall we begin? With fire we can produce a lump of iron from its ore, then reverting to customs of the stone age, we can pound the iron with a stone into the crude shape of a hammer. With our present knowledge of how to use metals, we would not waste time making very convenient stone hammers with depressions in the sides for the thumb and finger, as the ancients did before they learned to make the depressions deep enough to meet through the stone and insert a stick for a handle in the hole (this being a great discovery to them and doubtless marking an era in advancement of industrial art). We would merely select a convenient stone or stones with which to work our lump of iron in a sort of hammer shape with a hole through it for the handle. With the hammer and hand we could soon forge other things, and the work of rebuilding the tools and machines of civilized industrial arts would proceed rapidly, but it would always depend as it does now on the hammer and the hand.

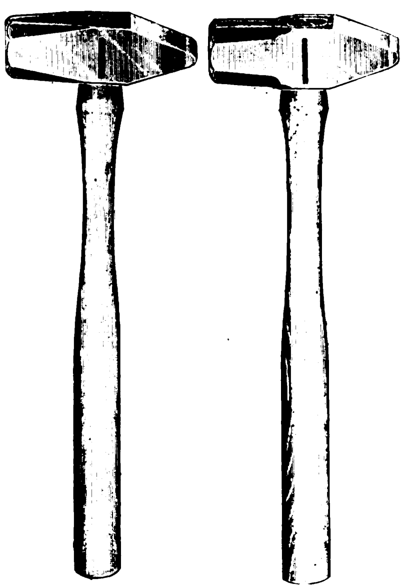


Fig. 1.

After the hand hammer, Fig. 1, the next tool necessary is the anvil, which is now made in several slightly different shapes, and by different methods. See Fig. 6.

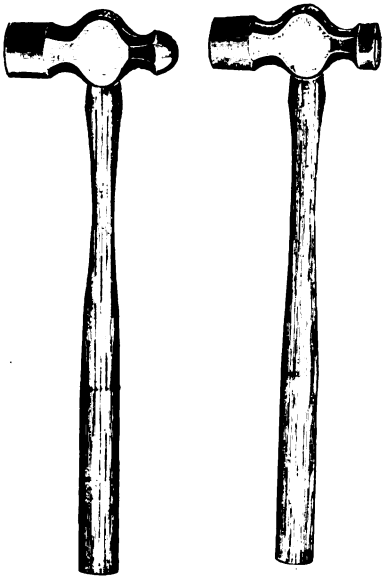


Fig. 2.

Then we must have a pair of tongs to hold our forging while it is being worked. See Fig. 7.

The hammer, the anvil and the tongs are the three tools essential to forgework, and we shall consider them in a general way.

Claw hammers, sledges, masons' hammers, ship mauls, wood choppers' mauls, pavers' hammers, etc., are specialties which may be described some other place. Of all shapes the hand hammer is the simplest, and was formerly the most common forging hammer. Now the Ball Pein hammer is the choice of most blacksmiths for general work. See Fig. 2.

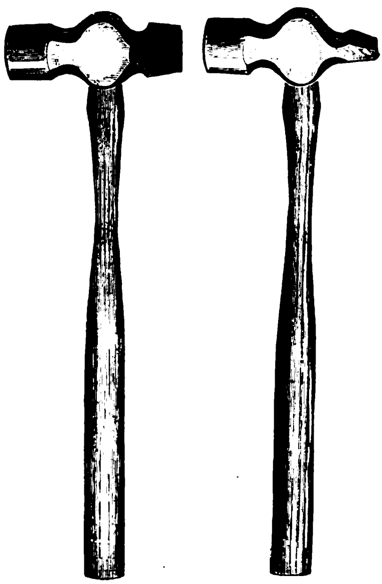


Fig. 3.

The Cross Pein hammer, with its short wedge-shaped end flattened at right angles with the eye, and the Straight Pein, with its wedge-shaped end flattened parallel with the handle, are types of hand hammers in common use for distinctive purposes. See Fig. 3. The carriage ironer's hammer in Fig. 2 is almost a Ball Pein, and would be chosen for its special work only. Others are especially adapted to turning and fitting horseshoes, and are familiar shapes to many workmen. See Fig. 4.

Hand-made hammers used to be very popular with the best smiths, but now drop forged and turned hammers are so much cheaper and come so near being as good, that it does not pay to make them by hand. A poor, cheap hammer should never be bought by a mechanic. Buy hammers of a reputable dealer and pay a fair price and you will usually get good ones.

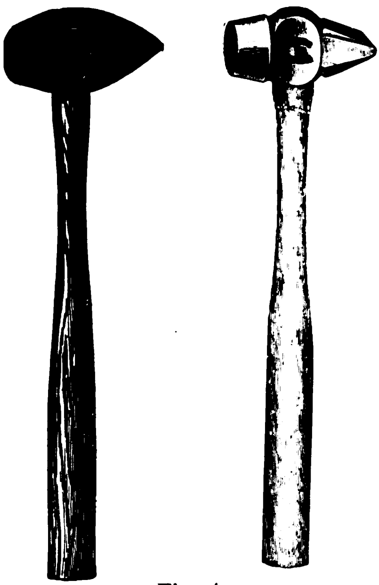


Fig. 4.

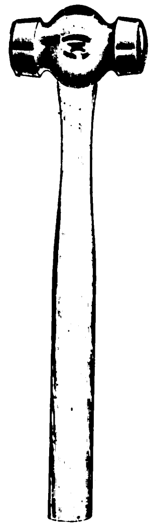


Fig. 5.

A good hammer that has been battered and used a great while will always be dented some on the face, especially around the edge, before small particles are broken out of the corners. If large chips break off the face of a hammer before it shows signs of wear and battering, it was too hard or was made of poor material, for a good hammer cannot be broken without being dinged and battered first. It follows, of course, that if the hammer in service becomes battered until a large burr or flange forms around the corner of the face without breaking off, the hammer was tempered too soft. Sometimes if such hammers are rehardened and tempered properly, they are all right, but often they will break and chip out in large flakes from the edge, because the material is not the right kind for hammers.

So in a hammer we can learn something about the trouble with all hardened and tempered steel; make it hard enough and it will break easily; leave it soft and it will batter quickly. Therefore we must choose a medium. A good hammer must be made of a kind of steel that will dent and batter slightly before it breaks with hard pounding, after it has been made so hard that a file will scratch it with difficulty. A good hammer seldom wears out in good use, but is ruined by abuse, like the

Englishman's horse, "It isn't the 'unting as 'urts the 'osses, it's the 'ammer, 'ammer, 'ammer on the 'ard 'ighway.

ANVILS

The anvil, shaped very much as we know it, is an ancient tool. Many hundred years ago they were made about the same shape they are today. Age alone would not make us respect a machine or tool, but it is a significant fact that very little change or improvement has been made in anvils during several centuries of use.

Fig. 6 shows the model with these principal dimensions of standard anvil used by leading anvil makers.

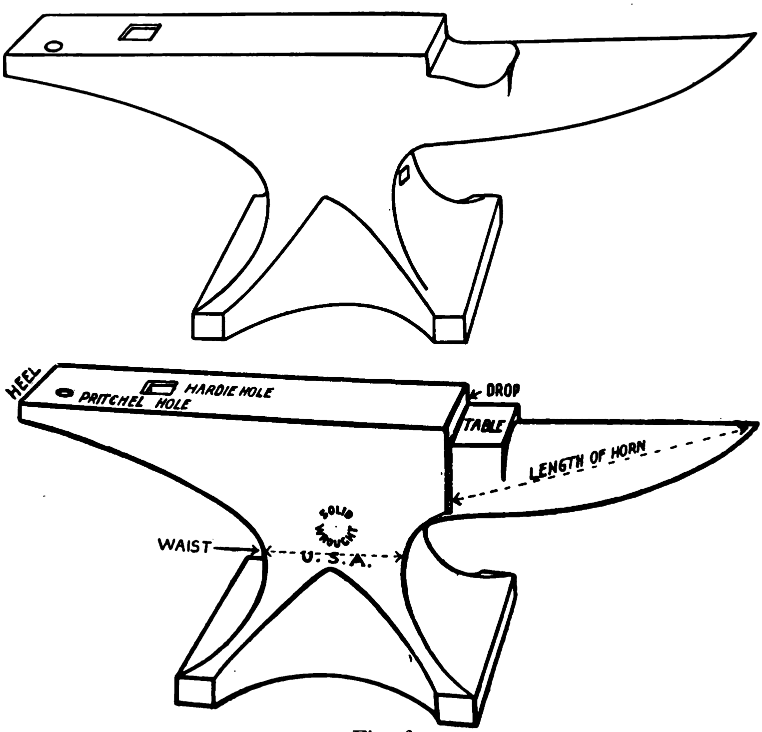


Fig. 6.

Face.	*Horn.*	*Waist.*	*Heel.*	*Drop.*	*Hardie Hole.*	*Approx. Weight.*
3¼x14½″	10″	4½″	13/16″	13/16″	7/8″	100 lbs.
3½x15¾″	11″	4¾″	7/8″	7/8″	15/16″	125 lbs.
3¾x17″	11¾″	5⅛″	15/16″	15/16″	1″	160 lbs.
4x18″	12½″	5½″	1″	1″	11/16″	200 lbs.
4¼x19″	13¼″	5⅞″	11/16″	11/16″	11/16″	225 lbs.

The dimensions and weights shown on page 13 are only an average and will vary some either way.

Some study of the lines of the anvil model which the author helped design will show that it is well adapted for universal use and there is little prospect for any great change in the shape of this tool.

It is a tool so simple in form, yet adapted to so many different forgings, that special anvils are seldom made. Almost any work that can be done on anvils of special shape can be done on the standard form, and the specialties often interfere with regular work being done.

The so-called saw-makers anvil is little more than a rectangular block of metal with a hardened face; it is more convenient for the purpose of straightening saws than a standard anvil, but could not be adapted to a general class of work.

Large anvils with two legs have been made, but are not in common use, and the demand for them is not great.

The regular anvil is most solid over the middle, here it is rigid where the most work is done. Here directly over the waist it will best endure the heavy pounding of sledges, and over the heel forked pieces can be forged, while almost any curve or bend can be made around the horn. The table is a convenient unhardened place for cutting through upon with a chisel, and pieces held end down resting on the table can be steadied against the end of the anvil face, while they are struck on the upper end as in upsetting short pieces of stock, the hardie hole, and pritchel hole are conveniently placed for anything they are to be used for.

TONGS

The tongs should be well made and kept fitted to the work they are designed to hold. Drop forged tongs of steel are now made so cheaply that making them by hand is not such common practice as it was some years ago. The best drop forged tongs like Fig. 7 are made each side of one piece; that is, the jaw and reins are forged solid. For hand tongs the best way is to forge the jaw of heavy material and weld on lighter stock for the reins.

If you cut the rivet that holds the two parts of a pair of tongs together, you will find that the jaws are forged alike, both are right handed. In a pair of jaws made to go together all of the offsets, projections, curves and dimensions are the same and in the same direction. It is a common mistake for a beginner to forge what he calls the right hand and left hand

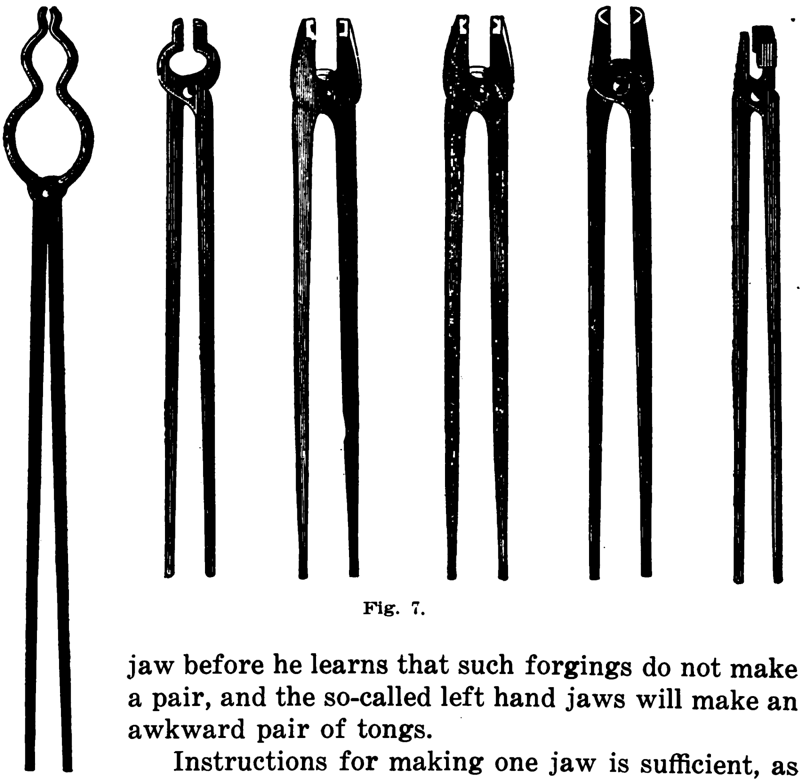


Fig. 7.

jaw before he learns that such forgings do not make a pair, and the so-called left hand jaws will make an awkward pair of tongs.

Instructions for making one jaw is sufficient, as the other should be exactly like it; then, if the first one is a good forging, a nice pair of tongs will be made.

FORGING TONGS

To make a pair of one-quarter-inch tongs, take a piece of one-inch square material of convenient length and forge a jaw eye or stub rein on one end of it as follows: Get a long heat (five or six inches) and make a fuller mark on one side about three-eighths of an inch deep, the right distance from the end to leave stock for a jaw, say three-quarters of an inch; turn the bar one-fourth over toward the left, and make another fuller mark a little deeper and just back of the first depression; turn again toward the left, and make a third fuller mark about one-half inch back of second mark three-eighths of an inch deep. Now place the first fuller mark, turned down with the middle of it over the near corner of the anvil, and draw out the jaw by hammering to width and thickness desired. Next put the jaw from you over the anvil with the middle of the second fuller mark down and opposite the far corner, and spread the eye with the hammer. Then turn the third fuller mark down on the far corner of the anvil, and draw down the stub end for handle or rein three or four inches long, cut off this forging and make another exactly like it. Weld on the reins, punch the rivet holes and fit the jaws together, then rivet them. Get them red hot again and adjust them to the piece they are intended to hold, open the jaws wide and put them in the water while hot. Close and open them while cooling and you will have a nice, easy-working, close-fitting pair of tongs.

An experienced man can forge one side of a pair of tongs like this at one heat. It is easier to make the captain than the mate, for slight variations in size of the two sides make bad work, so the mate should be exactly like the captain.

A good way for the beginner to do is to try a forging like this with cold lead for practice, then with swedes iron, which is very soft, a quite serviceable pair of tongs can be forged easily, but steel tongs wear better.

SWAGES

Swages are made in sizes the measure of the width of the groove which may be half round, octagon, square or any shape desired, the shanks or stems on the bottom swages are forged to fit the hardie holes of anvils. See Fig. 7.

The groove in the top swage is like that in the bottom swage. Handles should be made of wood long enough to allow holding the hand far enough from hot work, and the swage should not be wedged on the handle. Fig. 8 shows a top swage without a handle.

Fig. 7.

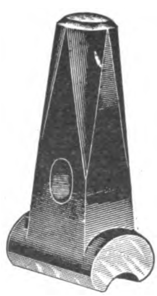


Fig. 8.

Fig. 9 is the top fuller, the curved end is half round made of any size required. Fig. 10 shows a bottom fuller which, as seen, must have a square shank fitted to the hardie hole of the anvil on which it is to be used in the same manner as the swage. When a piece of material that is being forged requires a shoulder on opposite sides of a bar, the piece is rested across the edge of the bottom fuller. The top fuller is then placed on top of the forging and struck with a sledge until the fullers form a depression on opposite sides of it to the depth required. The smooth rounded edge of the fullers do not cut or nick the forging, but leave fillets which are strong support to shoulders left where large and small sections of forgings join. Square shoulders and sharp angles are much more easily broken than rounded corners, so the inside angle or shoulder should always have as large a fillet as possible in it. The fullers are, therefore, very important forging tools, frequently used on both iron and steel work. The top fuller is often used to make depressions on the upper side of a forging as it lies flat on the anvil. From the bottom of this depression made in a thick piece, thin sections can be drawn out, leaving a fillet in the corner, as shown by illustrations in succeeding chapters. This tool is indispensable to the forge man in making machine tools for the lathe or planer. In places where the fillet can not be left inside of a corner, the forging is finished with a square faced set hammer. Fig. 11.

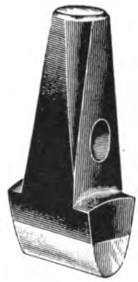


Fig. 9.

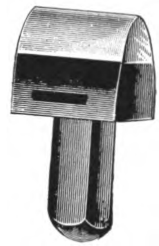


Fig. 10.

The flatter is a tool that is used in much the same way as a set hammer, but, as the face of a flatter is larger than the body of the tool, as shown in Fig. 12, there is enough spring or give to the edges of the extended corners to make


Fig. 11.


Fig. 12.

it less liable to sink into the forging and leave tool marks. It is, therefore, more of a smoothing or finishing tool for straight work, while the set hammer is distinctly a forging tool, often used to change the dimensions and shape of the piece on the anvil. The top fuller and the set hammer are perhaps the most necessary and useful tools in forge work requiring a helper.

CUTTING TOOLS

The distinctive difference between the cold chisel and the hot chisel is seen in Figs. 13 and 14. A common size for the smith's use is one and one-half inch square at the eye. The pole and bit are of equal length on both tools. The bit of a cold chisel is drawn down as a wedge, one-fourth inch thick at the thin end, and after it is hardened and tempered it is ground to a sharp edge on an angle of sixty degrees with the median line.

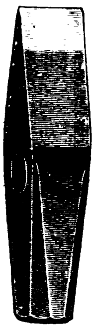


Fig. 13.

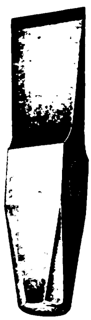


Fig. 14.

The hot chisel being intended for use on metal that is softened by heating, and often used for slicing away portions that are not wanted on a piece that is being forged, has a bit less than half as thick as that of a cold chisel and the edge is ground at just half the angle, or thirty degrees.

A hardie, Fig. 15, may be ground at either angle, according to the kind of work most frequently done with it. Hardies are sometimes used for nicking cold pieces so they can be broken at the nick, and at other times a sharp thin hardie is convenient for cutting hot metal. Bent and forked shapes, curves and angles, are sometimes correctly made by using the hardie as a forging tool, over which they can be held as it rests in place on the anvil. Pieces held against its top edge, flat side, or corner may be struck with the hammer and brought to a proper shape.

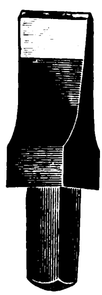


Fig. 15.

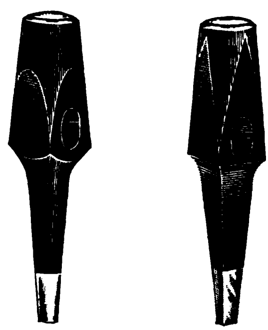


Fig. 16.

In Fig. 16 are two punches which require wooden handles by which they can be held in place by the smith as they are struck by the helper's sledge. The manner of making holes with these punches is similar to that required for successful work with the hand punch shown in Fig. 17 and is described in Chapter IV. If a ½″ hole is required in material ½″ thick, the standard hand punch is used. The stock is 80 point carbon steel; ⅝″, octagon in shape because it is best for the hand hold; 10½″ long, so the hand that holds it on the hot metal to be punched will not be burned, and the blow of the hammer will be more effective than it would be on a longer punch. It is tapered from its diameter of ⅝″ to ¼″, and shaped to suit the hole, a true straight sided taper, 3″ long and perfectly flat on the small end with sharp corners all around. If there is not enough taper to a punch of this kind, i. e., if it is more than 3″ long and the diameter given above, its sides are so parallel that it will stick in the hole after being driven down, and considerable difficulty in withdrawing it may be experienced. On the other hand, if there is too much taper or the end is not flat with corners sharp to cut their way into the metal, it will be difficult to drive and hard to make a clean, straight hole through the piece. The hammer used on this punch should not weigh less than 1½ nor more than 2 pounds, for blows delivered with a lighter hammer on the head of this punch would not be very effective at the end, 10½ inches away. A heavier hammer is apt to bend the punch, or drive it so suddenly into the material that there is no time for the hot metal to flow into the new form it is being compelled to take. The flow of metal must be carefully considered by every forge man, or many tasks will be very difficult, and his forgings will be of poor quality. With the punch described here, used in the manner more fully shown in a succeeding chapter, 7/16″ holes through ½″ metal are easily made. The cold chisel shown in Fig. 17 is made of the same kind of material as the punch.

Fig. 17.

Heading tools, like Fig. 18, are very useful when making upset head bolts. For medium sizes, 7/16″ to 15/16″ bolts,

Fig. 18.

the hole in the tool should be 1/32″ larger than the diameter of the shaft of the bolt.

Fig. 19 shows blacksmith sledges. They are sometimes made with the pein straight, or ball, like the hammers in Figs. 2 and 4. A good weight and kind for ordinary forge work is an eight-pound cross pein sledge.

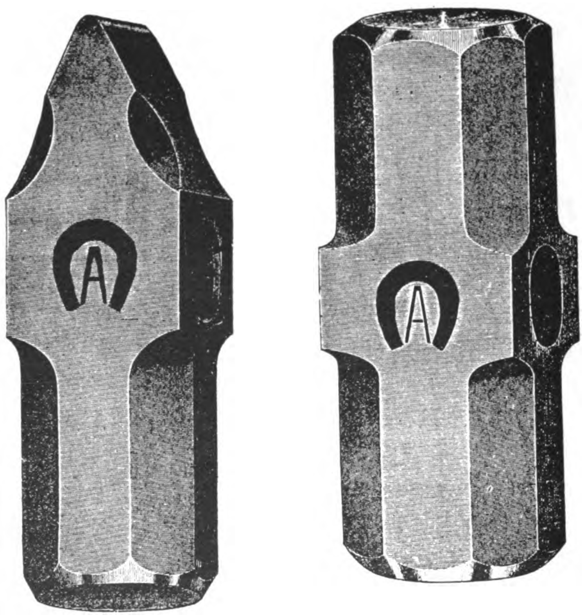
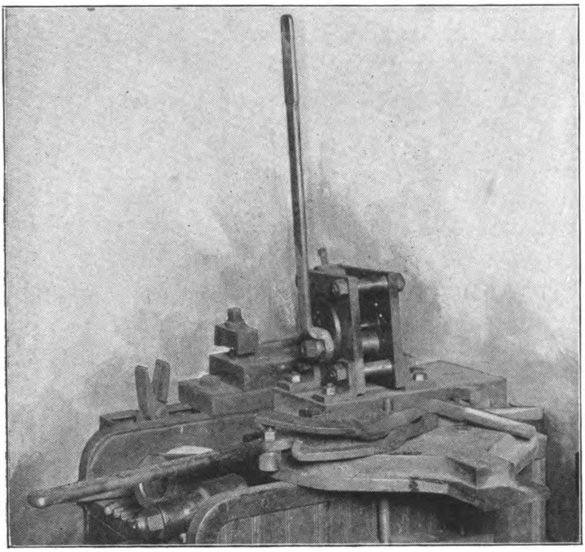


Fig. 19.

The special forging tools, Fig. 20, shown on the opposite page must be seen and used in order to be fully understood, and no attempt is made in this book to describe them fully. Every successful forge man is able to make the special tools required for his particular work, and only the regular tools common to all shops and such operations as are fundamental and necessarily performed in all forge rooms, either



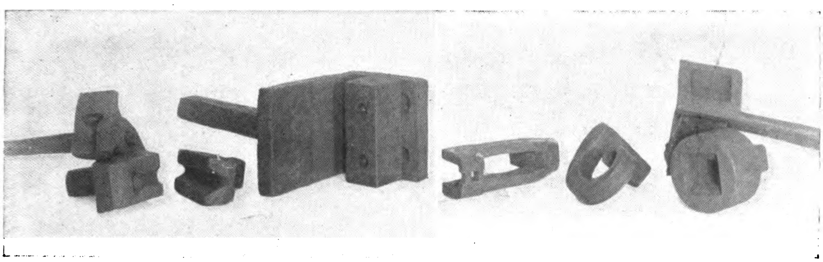


Fig. 20.

in the production of the identical things described in these pages, or so similar as to require the same kind of operation and method of proceeding with the work, will be treated of in this book.

CHAPTER III

MATERIAL USED FOR FORGINGS

Forgings are made of either iron or steel. The careful selection of materials is the first thing of great importance after the forge is properly equipped. As there are only two general kinds of material to be used, it would seem a simple problem at first glance to learn just which material would be best for any forging, but when we begin a study of the question, we find it a more complicated one than it at first appears to be, for wrought iron of at least three kinds must be considered, and steel cannot be thought of intelligently, without a definite knowledge of two kinds that are distinctly different. Wrought iron designated as common iron, refined iron and Swedes iron conveys a distinct classification of the metal. And the information that steel

Fig. 1. Loading Ore.

is either crucible tool-steel, or converted machine-steel, gives us some idea of its properties that will aid in selecting the material for forgings.

METALLURGY

The metallurgist must learn about the different kinds of iron ore and fuel, but for our purpose any information of that kind would have no practical value, so we say that iron ore, properly treated, will furnish us with the iron or steel we want. The first step in the process is the same for all kinds of material.

Fig. 2. Digging Ore.

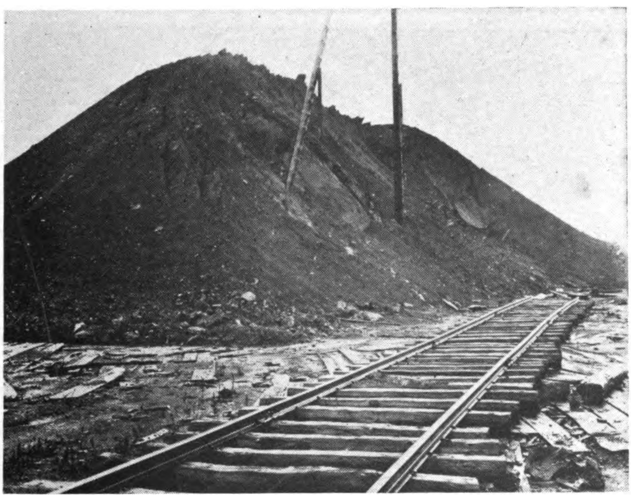


Fig. 3. Ore Pile.

Iron ore most commonly found is like red brown earth, soft and crumbly like rich loam, it is shoveled into a conveyance, hoisted to the top of the blast furnace, and dumped in along with the fuel — coke, and the flux — limestone. The heat of the furnace melts the iron in the ore, and it sinks to

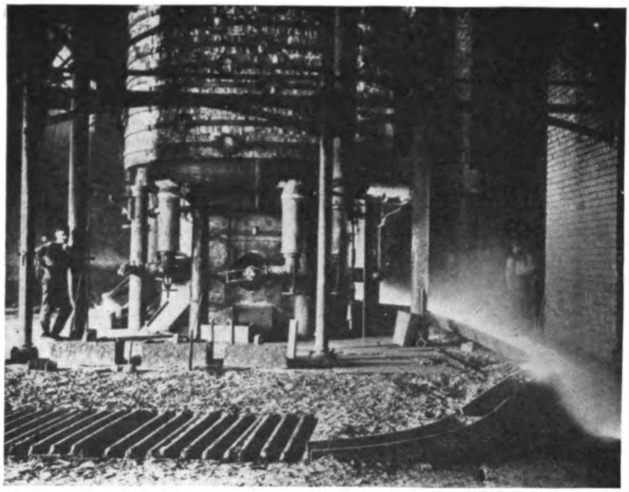


Fig. 4. Blast Furnace.

the bottom of the furnace, the flux keeps the other products from becoming sticky thick and pasty, enough to clog the

Fig. 5. Pig Iron Bed.

furnace, and causes them to float as a liquid on top of the iron. Finally the refuse is drawn off as slag, while the heavier iron flows out of a lower tap hole in the furnace, and is cooled in bars or slabs of a size convenient to handle. This is called pig iron and looks like a very rough cast iron; in fact, it is cast iron, having been cast or poured when liquid into a mold or bed of sand, where it cools and solidifies. Pig iron is the stuff out of which cast iron and malleable iron pieces are made, as well as that of which all of our forging materials are manufactured.

MANUFACTURE

It is the purpose of this chapter to give such general information about the manufacture and the consequent properties of these five kinds of material as will help the "forge man" to select and work his material with greater satisfaction to himself, as well as in such a way as to produce better forgings. The man who works at the anvil will most assuredly be happier if he knows a good deal about the metal he is working than if he knows little, and although the science of metallurgy is so great and becoming so complicated, that no one man can know it all, any one who wishes can get a good understanding of these five classes of material, and may then add the sixth, which is high speed metal, but this being only a subdivision of crucible or tool steel, it was not named at the beginning of this article, though it has become of such great importance for tool forgings, that it must have its place.

CHEMISTRY

The chemical reactions that take place in the blast furnace, and the mechanical appliances with which a modern blast furnace is equipped are subjects of great interest, involving much study on the part of one who wishes to understand them in detail. To us they may seem very simple, since we need only know what primitive men knew perhaps four thousand years ago—a hot fire separates the metallic iron from the earthy matter. They knew, too, that a blast of air made the fire hotter, so they had blast furnaces, and puddling furnaces and crucible furnaces, this was all there was to it four hundred years ago. One man could know all that was known then of metallurgy. For even as late as a hundred years ago all there was to iron manufacturing was to make pig iron by putting ore in a very hot fire in a tall furnace, with a blast under the fire and then make wrought iron bars that were afterward used as such or carbonized by the blister or the crucible process. These processes do not eliminate sulphur phosphorus and other injurious elements that may be in the pig. Hence good material depends on the selection of pure ore.

WROUGHT IRON

Wrought iron is made out of pig iron by puddling it on the floor of a furnace with the fire blown over the iron, the fire being at one end of the furnace the pig iron being put in at the other. When the iron gets sticky or pasty the puddler

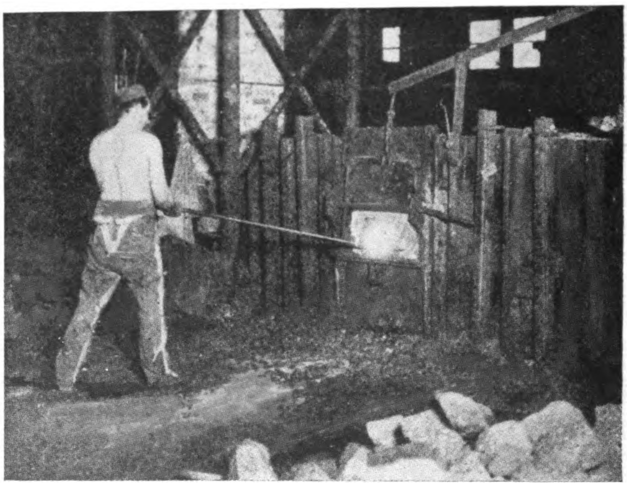
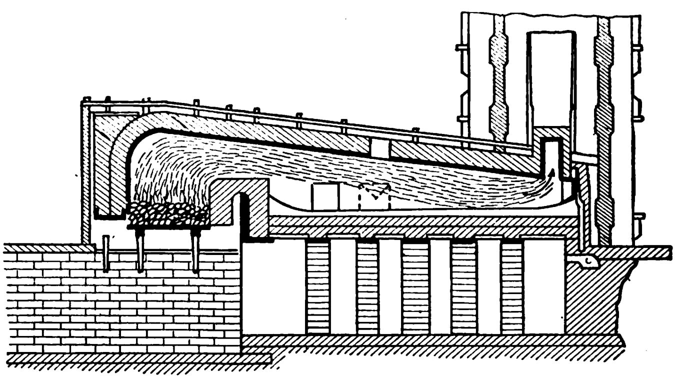


Fig. 6. Puddling Iron.



PUDDLING FURNACE.

Fig. 7.

knows it as having "come to nature" and it is pulled up into a ball. The chemical reaction reduces carbon, etc., but leaves other injurious elements in the iron that is taken out of the furnace and hammered or rolled into a bar. This bar is known as common wrought iron.

STEEL

Tool steel is made of wrought iron by melting and carbonizing it in a crucible. The iron bar is cut into scraps that will go into a clay or plumbago pot about six inches across and a foot high. This pot, called a crucible, filled with these scraps, is put into the furnace. When the iron is melted and carbonized it is poured into a mold and becomes crucible cast steel or tool steel. See Fig. 8.

These three processes — blast furnace, puddling and crucible—were in use several hundred years ago and are in use today. They are the essential steps in the progress of the metal iron from the ore to the best commercial bar of iron or steel. From these anything can be forged which it is possible to make at the forge.

Pouring Crucible Steel.

Fig. 8.

In olden times when the artisan, instead of the scientist, was responsible for the product of a furnace, the best workmen made the best iron or steel; just as some blacksmiths, who run their own shops and do their own work, make better forgings than others in the same line of business. In these modern times, mills produce material of different grades according to orders scientifically designating the quality wanted.

Common wrought iron is simply the cheapest product of the iron mill and puddling furnace.

Refined wrought iron is the same kind of material, with the flaws, seams, cracks and more of the gross impurity or slag worked out of it by cutting, piling, welding, and rolling or hammering. Common iron bars are sometimes piled and welded six times before they are sold for refined iron. The chemical constituents remain the same. The work that has been done on it, makes the price additional for refined iron.

HOT SHORT AND COLD SHORT

If there is too much sulphur in it, the bar is hot short, and is liable to be broken while bending at a red heat on a one inch radius.

If there is too much phosphorus in it, it is cold short, and may crack if bent cold to a three foot circle.

There is too much sulphur and phosphorus in all American ore, and the iron and steel makers do not take it out. When iron or steel that is very soft or very tough is wanted, the kind that is never hot or cold short, but always the same reliable metal, Swedes iron must be bought, because the ore of that country has no phosphorus and practically no sulphur in it.

IMPORTED WROUGHT IRON

Norway and Swedes iron are the same thing, and the methods of manufacture are practically alike in those countries and in this. Import duty must be paid according to the size of bars. Bars smaller than one inch by one-half inch are usually rolled down in this country from larger imported bars. A metal tag stamped "Swedes iron" must be attached to each bundle of about one hundred pounds. One by one-half inch bars and larger are each stamped "Made in Sweden." This iron is not stiff enough for some forgings, but is very easily worked. The best crucible tool steel is made in this country out of imported Swedes wrought iron.

IRON OR STEEL?

Puddling pig iron purifies it more than any other process, therefore before the best steel can be made, iron is puddled and made into wrought iron. Puddled iron contains no carbon, so carbon is added in the crucible or pot in which the wrought iron is melted for the purpose of making it into steel. It is not simply the carbon in the iron that makes it steel, but the process of manufacture. Wrought iron is formed out of a pasty or sticky mass taken from the furnace. Steel is formed out of a liquid mass poured from a container. This is always true no matter what kind of steel is meant. The distinctive difference between wrought iron and steel is that one is made from pasty masses, the other from liquid.

MACHINERY STEEL

The Bessemer and open hearth processes of steel making eliminate the puddling, and handle large quantities of melted pig iron in one receptacle or vessel. This receptacle in the Bessemer works is like a large pot or jug, capable of holding several tons of liquid metal. See Fig. 9. In the open hearth process it is a huge furnace in which many more tons of pig iron or scrap may be melted at one time and drawn out of a tap hole. In either of these methods the quality of the charge, the manner of heating, the kind of fuel and the material with which the vessel containing the liquid iron is lined, affect the properties of the metal produced. But the product is iron

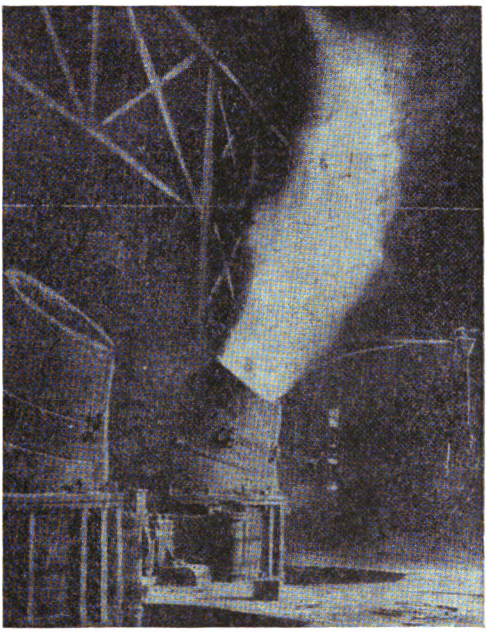


Fig. 9. Bessemer Converter.

converted into steel, converted in the liquid state, under the influence of heat. The difference between converted steel and crucible steel is as great as the difference between oleomargarine and butter; good, old fashioned, clean, sweet butter can never be replaced by the oil extracted from fats, and converted steels can never take the place of crucible steel. Puddled iron out of which crucible steel is made is like the cream that makes good butter. All of our wrought iron is puddled

Fig. 10. Steel Billets.

iron, made out of pasty masses. All of our steel is made from liquid masses, therefore iron is fibrous in its structure, the crystals are stretched into threads held lengthwise in the bar, so wrought iron has a fibrous structure, while steel has not. Fig. 11 shows the fiber and slag magnified in wrought iron. Fig. 12 is a magnified section of steel grains.

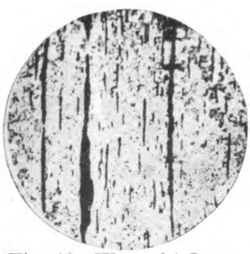


Fig. 11. Wrought Iron.

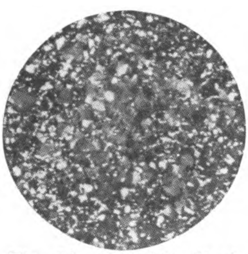


Fig. 12. Crucible Steel.

USES

For hooks and chains where absolute reliance must be placed in a given weight of metal, and for many forgings of a similar character, iron is used exclusively. Anchor chains of a large size should never be made of steel. Locomotive frames forged of good iron, put together in such a way at the welds that the fiber of the iron runs in the direction of the greatest strain, are lighter and better than any steel frame that ever has or probably ever will be made.

But the use for steel as forging material is great, first, because it is cheaper than iron, and second, because it can be made into very large pieces in very simple and easy ways, while very large iron forgings must be built up by welding. Steel ingots can be cast of almost any size, and then forged down. Steel bars do not twist as easily as iron bars, hence for crank shafts and things of a like nature, where the torsion strain is great, steel is preferred to iron.

Some forgings aside from cutting tools are made of crucible steel, but for nearly all purposes except tools, there are grades of converted steel known as structural or machine steel that are more easily forged and are equally good when finished.

Wrought iron costs 10 per cent to 20 per cent more than the cheapest steel. Its claims to superiority over dead-soft steel consist in its purity and the presence in it of slag. Just how much advantage the slag is, has never been proven; it helps give the metal a fibrous structure which, perhaps, increases its toughness and its resistance to breaking under bending, or under a sudden blow or shock. When under greater strain than it can withstand, wrought iron stretches more uniformly over its entire length than steel. Some think that the slag also assists in the welding of the material, but this is doubtful and it is probable that the easy weldability of wrought iron is due to its being low in carbon.

The properties of wrought iron are the nearest to those of chemically pure iron of any commercial material, notwithstanding its slag, which because it is mechanically mingled with the metal does not interfere with its chemical or physical behavior. Therefore wrought iron is greatly preferred for electrical-conductivity purposes and as a metal with high magnetic power for use as armatures of electro-magnets, etc. The advantages I have mentioned, the conservation of engineers and the capital previously invested in puddling furnaces are the chief factors in keeping alive the manufacture of wrought iron. It was freely predicted that the invention of the Bessemer and open-hearth processes would bring about the extinction of the puddling process, but these prophecies have never been fulfilled, although the importance of wrought iron has waned very greatly in fifty years.

JUDGING A PIECE OF FORGED WORK

The value of a forging made of these materials depends on the perfection with which it will do the work for which it was intended. If it is the right shape it has been formed correctly, and there is little difficulty in determining this, for by comparison with a sketch or template, or a piece known to be right, this factor of the value is decided.

The size is another factor more difficult for an inexperienced man to determine, usually a forging should be less than one-sixteenth of an inch more than the dimension given for each part. Commercial rod and bar stock is over-size less than one-thirty-second of an inch, but forgings that are to be machined should be larger. Practically all hand made forgings should have as much over-size as it is customary to make rods and bars in the steel and iron mills. This explains why the divisions on the measuring instruments used at the forge need not be less than one-sixteenth of an inch. All parts of hammer work that are not slightly over the dimension given in sixteenths of an inch are called "scant" or imperfect forgings, except in certain parts that will be noted.

The third factor to be considered when judging this kind of work is its fixed condition, which is closely related to its strength. This cannot be known without breaking the piece —a sacrifice that cannot be made of all forgings—therefore it is necessary to know how the surface should appear, and depend on inspection. A smooth blue-black hammered skin of oxide, free from loose scale and pits, indicates that the forging is in good condition, and if there are no visible signs of a crack or flaw it is said to have full strength. Gray-white shining surfaces indicate that a piece was hammered when cold, and that it may have been injured by such treatment. Heavy loose scale and deep pits indicate that it was injured by excessive oxidation in the fire, or was made too hot for the final hammering.

The fixed conditions of tempered steel is indicated on its polished surface by the color of the oxide formed by the last temperature to which it was raised. But as a knowing workman can produce any appearance that has been mentioned, regardless of the internal structure or composition of the material, more depends on his honesty and skill than outsiders are aware of, for when the three factors, shape, size, and apparent strength, of forgings are correct, they are said to have full value.

CHAPTER IV

BENDING RINGS AND CURVES, FORGING ANGLES, BOLTS AND NUTS AND STOCK CALCULATION

To bend a ring or curve in metal the work should usually be started on one end, as shown in Fig. 1. If the curve is to be a complete circle forming a ring made by hand and hammer

Fig. 1.

on an anvil, when half the piece is bent to the correct radius, as near as the eye of the workman can see, work should be started on the other end, and when both halves are curved over the horn of the anvil into a semi-circle, the two ends will meet if the radius is correct, making the circle or ring complete.

STOCK CALCULATION FOR RINGS

To find the length of a piece of stock needed for a circle, the thickness of the material must be added to the inside diameter of the ring, and the circumference given in the table on page 56 is the length required. Or, it may be calculated thus: If a three-inch ring is to be made out of one-half inch stock, it means that the finished work will measure four inches across from out to out and 3½ inches from center to center of stock, and the length of a piece required to make it is the measure of the circumference on the middle of the piece. This is an imaginary or median line

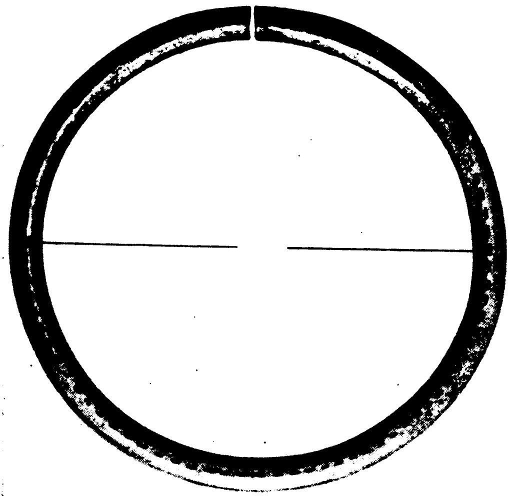


Fig. 2.

(see dotted line in Fig. 2): that half of the material outside this line must be drawn out or stretched, and the half thickness of the metal inside the median line must shorten or upset when the material is bent. We do not need to take this into consideration during our stock calculation, but must find the length of the median line as follows: $3'' + \frac{1}{2}'' = 3\frac{1}{2}''$ $3\frac{1}{2}'' \times 3\ 1/7'' = 11''$, the length of stock required to make a ring of the size wanted with the ends butted together, and because the metal usually does not shorten enough on the inside, these corners will touch first, as in Fig. 3, and the ring will be a trifle oversize, but if they are slightly beveled so that the ends can come together making a close joint the diameter will be correct.

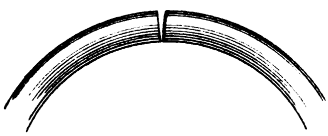


Fig. 3.

ALLOWANCE FOR LOSS IN WELDING

If the ring is to be welded an allowance for loss must be made, so some extra length will be required. How much this loss by welding will be depends upon several things. The kind of material and the appliances with which the work is done make some difference. In general, there is less material lost in welding steel than iron, for steel welding heats are not so high as for common iron, and if the forge, fire, and tools are of the best and so arranged that the kind of welding to be done can be heated quickly and handled rapidly, there need not be much waste in welding small sizes; but if the weld is large or a difficult one to get in the fire, and the appliances are not of the best for handling the work, more allowance for loss of material should be made. The chief factor, however, is the experience and skill of the operator.

A ring weld, such as we have in consideration, can be made of good iron or low carbon steel without any appreciable loss, that is, the piece of stock eleven inches long and one-half inch in thickness can be curved to a circle, scarfed on the ends without upsetting, lapped and welded so that it will measure with the instruments commonly used in the forge room to a three-inch ring, one-half inch thick all the way round. But if very fine measuring instruments are used accurately, some loss of material would be discovered, so if the ring is to be machined to exact size, an allowance of one-quarter inch (half the thickness) should be added to the length of the piece as an allowance for welding.

This allowance for welding is a constant that must be chosen according to the judgment and experience of the workman, and is more fully explained in Chapter 6, usually one-half of the diameter or thickness of the stock is sufficient. But we have seen heavy iron wagon wheel tires carefully measured to a length on the inside after bending, exactly equal to the circumference of the rim of the wheel and one full thickness of the tire added as an allowance for the loss in welding, and when the lap was long, the welding heat taken high, so that it was soft and worked out easily, there was very little excess thickness left at the weld when the tires were fitted. On the other hand, light steel tires are often measured in the same way, and nothing allowed for loss in welding, and when they are fitted there is no apparent lack of material at the weld.

TO DETERMINE LENGTH OF CURVES

There is no way to calculate mathematically with sufficient accuracy the length of a piece required to make large circles, irregular curves, and bent shapes that the smith is sometimes called on to form. In such cases the common method of using a measuring wheel which can be rolled along the required curve, and then an equal number of revolutions over the straight bar is the best way. In fact, it is the only method accurate and convenient enough to get the correct measure of tires and such large rings or bands as are used for wooden cisterns and the like. But when the curve is very small or very irregular and the measuring wheel can not be used, string measure is resorted to for hub bands, maul rings, etc., which are practically round; and for coupling pole or double tree bands, which may be rectangular in shape with round corners, correct measure can be obtained with a cord or soft wire by putting it around the piece to be banded, and then laying off an equal length on the straight piece of material of which the band is to be made. In such cases as we are considering the take up of material in bending will usually be enough to make the band a "shrink fit," that is, when it is expanded by heating, it can be put to place and when it is cooled off, it will be a very tight fit.

See table of expansion of iron and steel on page 59. If a loose fit is desired, it will be necessary to make an allowance for loss in welding and take up in bending. Boiler makers add three times the diameter of the sheet to the mathematical circumference for the take up in rolling.

To get the measure of a straight piece necessary to make curves which begin small and increase to wide sweeping bends, such as are seen in ornamental scroll work, etc., the best way is to use a piece of small soft wire. The scroll must be laid out or drawn on paper or board, see Fig. 4A, or perhaps on a metal face plate, where it can be measured with the soft wire, then the straight piece is cut the right length. Work should be begun on the small end of the scroll. Ornamental work made up mostly of curves and crooked lines is the easiest to make, because the irregularities of lines that are intended to be straight and parallel are more noticeable than slight irregularities in curves, hence greater care and skill is necessary to produce the accurate work that makes straight parts pleasing to the eye than is required on the curved parts. Here if the curves formed are smooth and artistically progressive, the work will be pleasing.

In designing a piece of ornamental work, some of the openings should be large and others small. If they are of even size, the piece will become tiresome to look at, but if the piece is well designed and well executed, it is like a tree that always pleases with its symmetry of form and unequal distances between the branches.

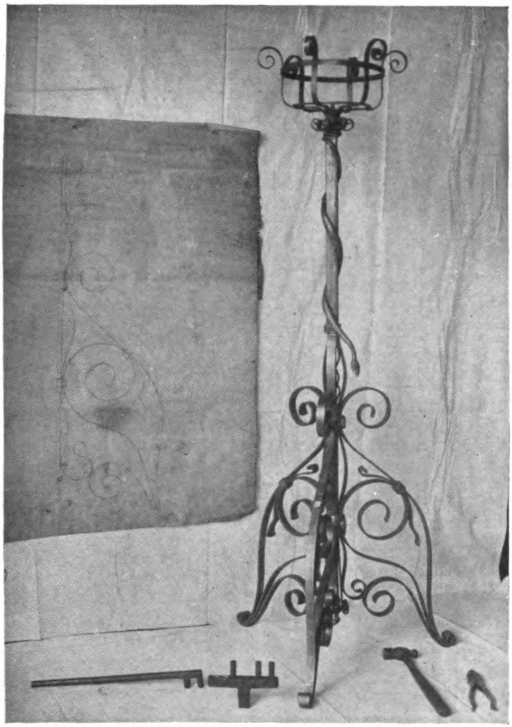


Fig. 4A.

MAKING ORNAMENTAL IRON WORK

The only special tools needed for ornamental work are scrolling irons, or, as they are sometimes called, bending forks. The one with the square shank, shown on the floor to the left in Fig. 4A, can be used in either the anvil or vise, and can be adjusted for long or short curves on thick or thin material by moving the steel pin into any of the holes; the common form of bending fork, like the one being used in Fig. 4B, is forged

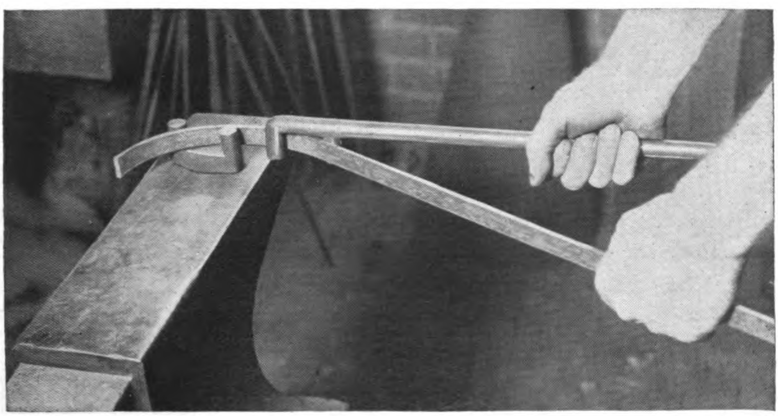


Fig. 4B.

solid and does very well for ordinary work, but sometimes it is necessary to have different widths between the forks, and the one with adjustable pins can be used to better advantage.

The sketch of one lower third of the ornamental work shown in Fig. 4A, is tacked on the wall to the left of the picture.

The total height of the piece is 55 inches, and the width 22 inches over all at the base. The three scrolls uniting in each foot of the base are made of $\frac{3}{4}'' \times \frac{3}{16}''$ iron. The flat scrolls between the legs are made of $\frac{3}{4}'' \times \frac{1}{8}''$, and the small round pieces are $\frac{3}{16}''$. The basket on top is made of $\frac{1}{2}'' \times \frac{1}{8}''$ iron, the inside curve of the lower ends of the six scrolls in the basket are soldered to the flat sides of a hexagon nut, tapped to fit $\frac{3}{8}''$ gas pipe, on which it is screwed until the end of the pipe sticks up far enough to receive the gas burner fitting. The lower end of this pipe is about three inches from the floor and is fitted to receive rubber tubing. These fittings can be removed and an electric wire drawn through the pipe would give that kind of light, or an oil lamp can be placed in the basket, as it appears in the picture. The bands at A and B are Babbitt metal cast in place, covering the binding wire. At C is a wrought iron clip shrunk on over the rivet, which holds the three scrolls in place at this point. The labor on this piece of work amounts to fifty dollars. Twenty-five dollars should be added for the design. So an original pattern of this character is well worth seventy-five dollars.

STOCK CALCULATION FOR SHAPES

The best shop practice is to use the tables of weights to find the equivalent portions. See pages 57, 58, 60, 61 for tables.

To determine the length of stock of one size required to make a given length of another size or sectional area. *Rule*: Find the weight of the size and shape that is to be forged into another size or shape and divide by the weight of the shape and size to which it is to be changed.

Example: Round stock, 2″ in diameter, is to be forged flat, $\frac{3}{8}''$ thick, 4″ wide, 6″ long.

$2''$ round $= 10.68$ $\quad \frac{3}{8}'' \times 4'' = 5.10 \quad 10.68 \div 5.10 = 2.09.$

Therefore 1″ of the round stock will make 2.09″ of the flat part, the .09″ may be allowed for loss due to the heating and hammering each 2″ of the required length, and, as $6 \div 2 = 3$, it will require 3″ of the 2″ round to make 6″ of ⅜″ × ¾″.

Round stock 1″ in diameter or smaller can be hammered into square bars ⅛″ less in thickness than the round.

Forged sizes vary by sixteenths of an inch, and another ⅛″ must be taken off, when using sizes of round over 1″, and so on up through the sizes in common use, as follows:

Round 1″ and under makes square ⅛″ less.
Round 2″ and under makes square ¼″ less.
Round 3″ and under makes square ⅜″ less.
Round 4″ and under makes square ½″ less.
Round 5″ and over may not conform to this rule.

DRAWING OUT AND FORGING SECTIONS

When drawing or stretching a piece, it should be held on the anvil at right angles and level with its face, (see Fig. 5) then the hammer blow should fall on a plane horizontal

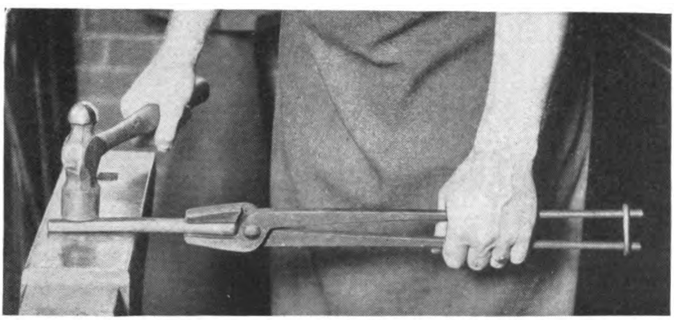


Fig. 5.

with the anvil face which is slightly convex and will cause the metal to flow toward the ends of the piece more rapidly than toward the sides. If the piece to be drawn out is enough larger than the required diameter to permit the indentation, it will stretch more rapidly by holding on top of the horn of the anvil and striking it just over the resting place; the round top of the horn acts as a fuller pushing the metal out endwise, and there is less spreading toward the sides. A similar effect can be obtained by holding and striking, as shown in Fig. 6, so the round edge of the anvil helps to draw the metal toward the end, and the piece lengthens rapidly under hammer blows effectively delivered.

The material must be kept at a forging heat. It should be made as hot as it will stand without injury and the most of the drawing out should be done while it is white

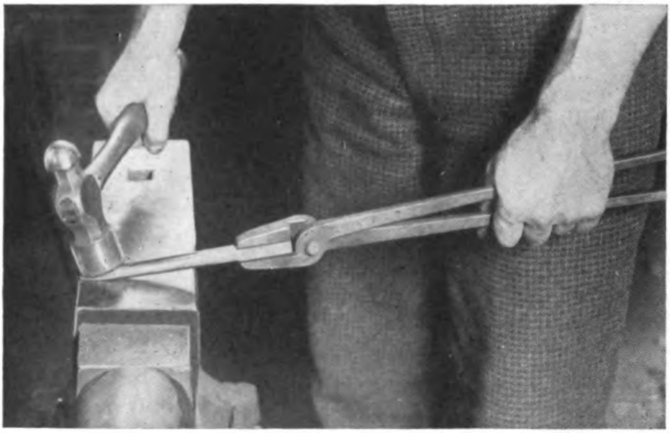


Fig. 6.

hot. The hammering may be continued while the metal is at a yellow heat, but when wrought iron cools down to red heat it splits easily, and at dark red heat it is liable to be brittle. Steel also is sometimes dangerously brittle, and should not be hammered when dark spots can be seen after the hammer blows.

Pieces should always be hammered on four flat sides, and alternate sides should be turned up to get the effect of hammer blows. The side that rests on the anvil is chilled more rapidly than the others, and the side that is struck with the hammer is lengthened and spread out the most, so it is necessary to turn it over often and hammer opposite sides equally to make the physical structure the same on all sides of a forging. Wrought iron fibre is easily separated, and internal ruptures that do not show on the surface are liable to be caused by improper heating, handling, or hammering. Each hammer blow should be heavy enough to affect the piece through half of its diameter. It should be turned over for each side to get the same effect, and kept as hot as it will stand. This is all a skilled workman can do. One may know the theory of foregcraft, but without practice he cannot learn to make good forgings.

DRAWING TAPERS

To draw out a sharp point, as shown in Fig. 7, the end should be made sharp by hammering four sides equally until the point is as sharp as desired. The piece should be kept at a convenient angle with the anvil face, as shown in

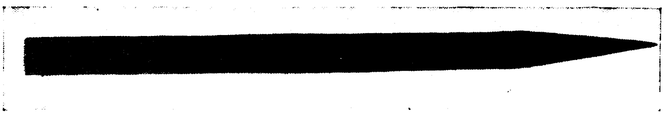


Fig. 7.

Fig. 6, and the blows delivered so that the far edge of the hammer lands in line with the edge of the anvil and over the end of the piece. After the point is sharpened square, it can be changed to a flat tapered point by hammering two of the sides until they spread to the desired width, or by hammering the corners down a round point can be made of it. When the section of the tapered point has been made into the shape desired, the length of the taper can be increased, if necessary, by hammering further back on the stock until the length and angle of the taper are correct. This is the fastest and best way to proceed with hand made forgings of this type.

The length of stock required to forge tapered points of a given length and shape, can not be determined from tables, but must be calculated mathematically, making proper allowance for loss of stock in forging. Much depends on the experience and judgment of the workman in this as it does in drawing out, upsetting, spreading and welding stock. The human element can not be determined without experience, but must be taken into account with the calculations for stock, made elsewhere in this text.

STOCK FOR ANGLES

For solid forged angles the calculation of stock is very simple. Measure one side from the outside corner to the end, the other side from the inside corner to the end, and add the two lengths together. Or measuring on the median line, we find the same result. If an angle is to be forged of ¾″ stock, each side to be four inches long on the outside, it would take a piece seven and one-fourth inches long to make it; if it must be full sized when finished, perhaps an allowance of one-eighth of an inch for loss in forging should be made, this allowance, like that of the welding, depends upon the method and the operator; and if a small curve or fillet is to be left on the inside there must be some excess of material over our calculation allowed.

FORGING A CORNER

The chief difficulty in a forging of this character is to get the full corner on the outside without making a "cold shut" at the inner corner. If a nick is allowed to start on the inside of the piece, some of the grains or fibers are broken, allowing more strain to come on the next particles, so they get broken and a crack may be worked nearly through the corner by the time the piece is finished. A skillful and experienced workman can forge this crack shut, and in cooling the metal contracts on it so that it can not be seen, then it is a dangerous weak point of a forged corner called a "cold shut." But if the piece is upset first, as in Fig. 8, and care is taken to get the initial bend over a rounded place instead of a sharp corner on the anvil, and if the piece is kept a little out (not in), that is, at an obtuse angle while the outside corner is being worked up, as in Figs. 9 and 10, and is only brought to a right angle at last. Then the forging can be finished, as shown in Fig. 11, sound and strong.

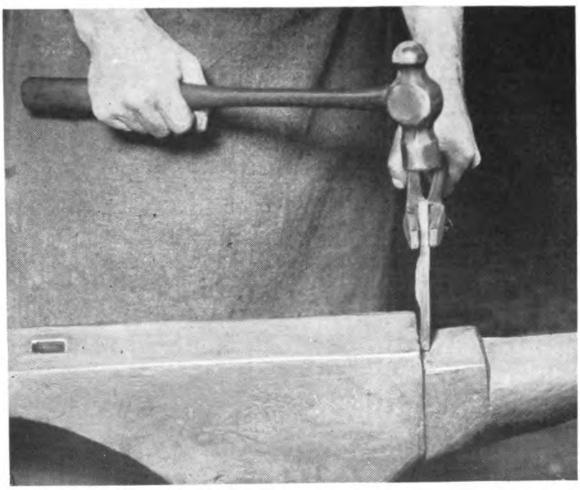


Fig. 8.

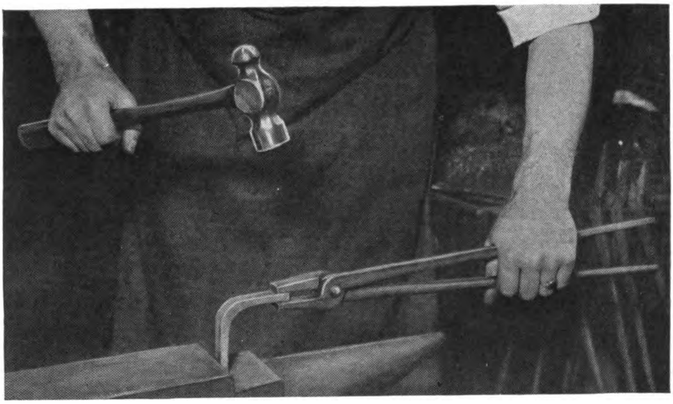


Fig. 9.

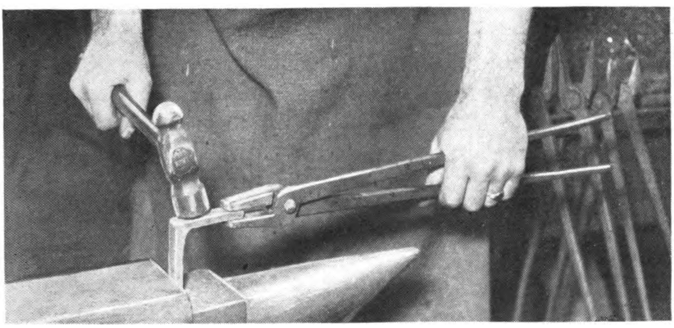


Fig. 10.

Fig. 11.

CORNER WELDS

Owing to the care and skill required to produce solid forged corners in iron or steel, they are frequently welded, sometimes two separate pieces are welded at the corner. This is the best way to make a strong, stiff corner when the angle is toward the edge of a wide piece. Fig. 12 shows two pieces

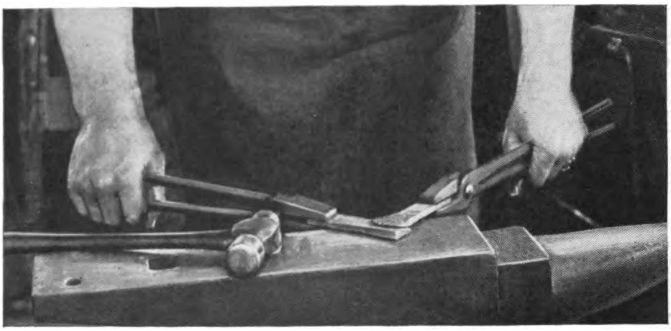


Fig. 12.

held in position for making a welded corner. See Chapter VI for further instruction on welding.

Different methods of scarfing for such welds may be followed, but the direction of the weld line through the corner is important.

A very nice way to fill the outside corner on thick pieces is to bend the piece without upsetting and work the corner true on the inside, then cut a gash with a hot chisel clear across the outside corner and drive in a blunt, thick wedge and weld it solid. This can frequently be done quicker than the upsetting necessary to produce a full corner without welding, and is as good a way or better in some cases. It is like welding a toe calk on a horseshoe; fasten it to the place by a spur driven into the larger piece, then get a welding heat on the entire part and forge it to the required shape. This is called welding on a "Dutchman" to build up a corner, or putting in a "Dutchman" to fill a crack or close a lap that has refused to weld without it, and is good practice. The dimensions of corner forgings are usually taken on the outside, where the over size is allowed.

CALCULATION FOR BOLTS

The length of a bolt is measured under the head. The thickness of the head is equal to the diameter of the shaft. The width of the head is equal to the diameter of the shaft multiplied by one and one-half, with one-eighth inch added as a constant for standard hand forged bolts.

Example: Calculate the stock for a square head 1″ bolt, 6 5/8″ long.

$1 \times 1\ 1/2 = 1\ 1/2 + 1/8 = 1\ 5/8''$ square. Find the weight of equivalent portions in the table, page 58, 1 5/8″ square = 8.978. 1″ round = 2.670. 8.978 ÷ 2.670 = 3.36 inches. In the table of decimal equivalents find the .36 is but .05 more than 5/16″, therefore 3 5/16″ of 1″ round will be required for the head of the bolt 1″ thick if it is made by upsetting round stock. 6 5/8″, length of shaft, + 3 5/16″, required for head, equals 9 15/16″ of 1″ round stock required to make the bolt.

If a solid forged bolt is required the solution is similar, for if 3 5/16″ of round stock will make 1″ of 1 5/8″ square, then 1″ of 1 5/8″ square will make 3 5/16″ of 1″ round, and as 6 5/8÷3 5″16 = 2, allow 1″ for the head and 2″ for the shaft, and the bolt can be forged out of 1 5/8″×1 5/8″ stock, 3″ long. Solid forged bolts are better than upset head bolts and welded head bolts are poorer. The stock can be calculated and the way to weld heads on bolts can be learned by reference to Chapter VI.

KIND OF MATERIAL AND INSTRUCTION FOR FORGING

Bolts—Solid forged

Low carbon machinery steel is best for solid forged bolts. Stock of a size and shape required for the head may be selected, or round bar stock, large enough to form the head by flattening the right number of sides to give the shape, is often more convenient to get. Determine the length of stock required, then with the top and bottom fullers forge a groove or neck marking the head portion from the shaft; hammer the part for the shaft on four sides until it is square, equal in diameter to that required for the round bolt shaft, then hammer the corners along the full length of stock used for the shaft, and after it is well rounded with the hammer, finish the shaft with the top and bottom swages to exact size and perfectly round.

Bolts—Upset head

The best refined wrought iron is preferable for this kind of forging. Swedish iron being the purest is less liable to "cold shut" where the head and bolt shaft join. For this method of bolt making a heading tool and its use is shown in Fig. 14. After that portion of stock required for the head is enlarged by upsetting, see Fig. 13, enough to prevent it going through the hole in the heading tool, the shaft of the bolt is put through the hole (which should be 1/32″ larger than the diameter of the shaft for medium sizes, i. e., 7/16″ to 15/16″) and held as in Fig. 14. After it is hammered to the right thickness, the round shaped head can have the flat sides made on it with the hammer by holding it as shown in Figs. 15, 16 and 17, illus-

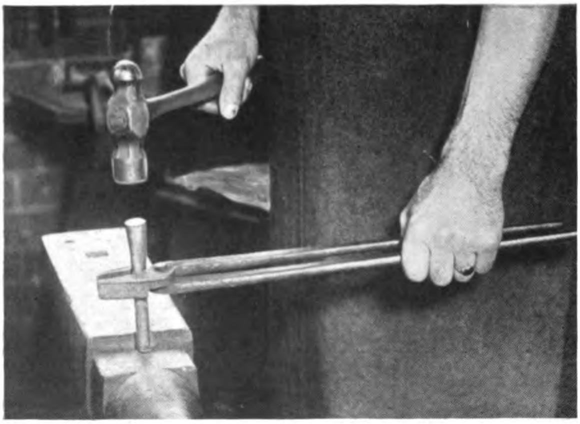


Fig. 13.

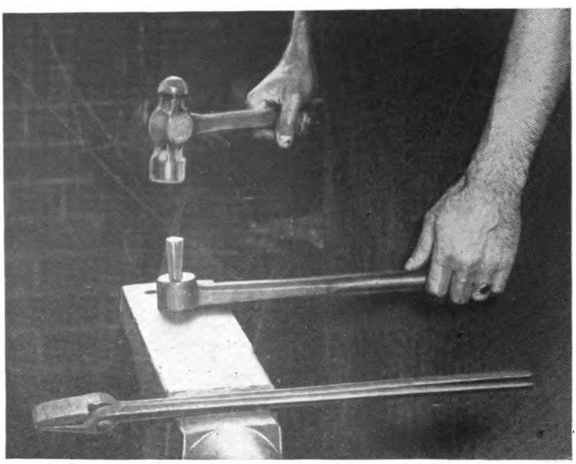


Fig. 14.

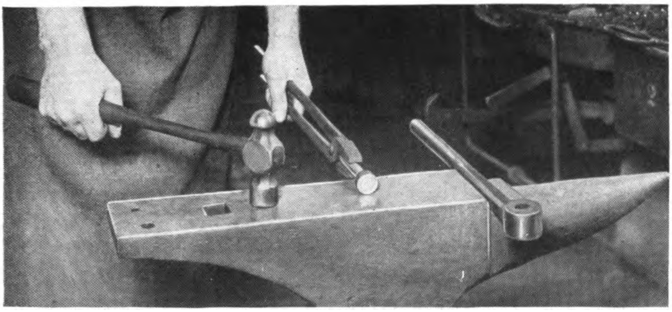


Fig. 15.

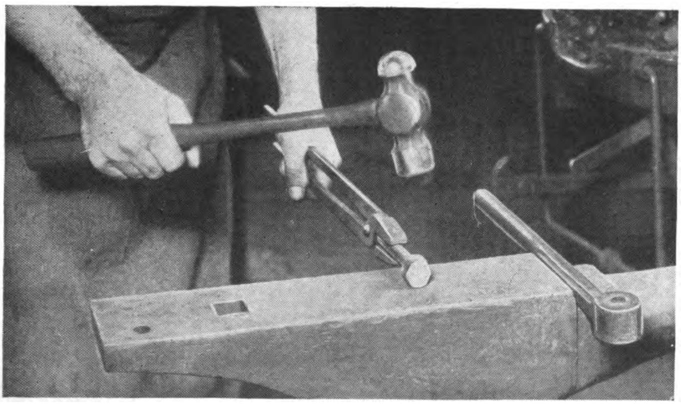


Fig. 16.

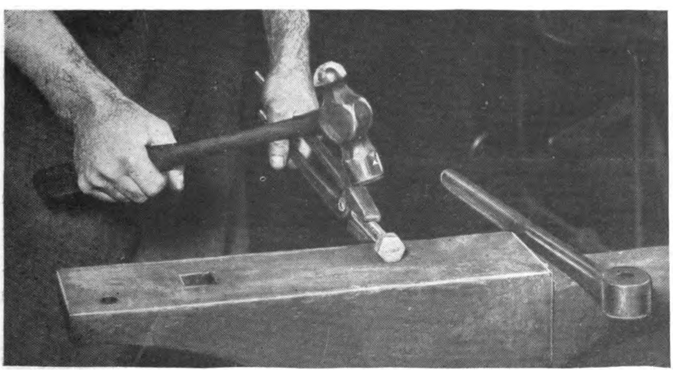


Fig. 17.

trating the making of a hexagon on the anvil. Notice that after two flat places are made on opposite sides of the round, these flat places can be held at an angle of 30 degrees with the anvil face and a level hammer blow will make the other side at the proper angle with them for a six-sided or hexagon bolt head.

Bolts — Weld head

Select any weldable material and use care to make good welded joints. This is the best way to make very long bolts by hand. Usually such bolts can be large enough to compensate for any weakness caused by welding, and they can be made cheaply. The best way to prepare and handle this kind of forging is shown in Chapter VI, Fig. 8.

Hand Forged Nuts

Swedish iron is preferable for this kind of work. A hole should be punched near the end of a bar, as shown in Figs. 18 and 19. After the small end of the punch is located at the right place, as shown in Fig. 18, it should be held perpendicular and driven two-thirds through the bar as it rests on the solid face of the anvil; then if the punch is taken out and the bar turned over quickly, a dark raised spot where the hot iron is chilled by the cold punch and anvil face can be seen on the other side, and the end of the punch should be placed on this spot and driven part way through the bar again in the same manner as at first. Now the piece should be moved to the position

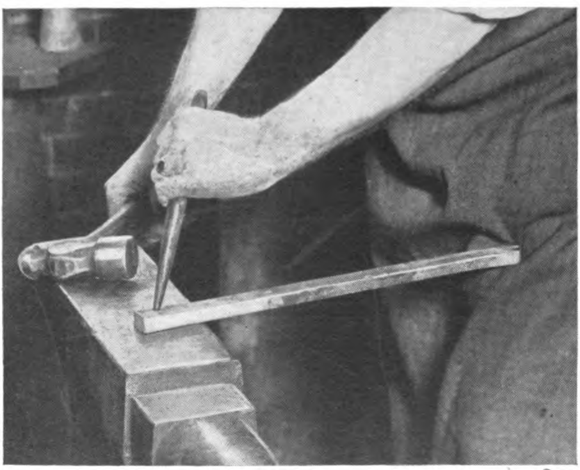


Fig. 18.

shown in Fig. 19 over the pritchel hole and the punch being driven through will force a piece of metal from the bar and a clean hole will be made. The end of the punch used for this kind of work should be flat — not sharp pointed — and it is tapered from stock ⅛″ larger than the size of the hole, to the small end, which is equal to one-half the diameter of the hole. The length of taper is six times the length of the hole, as it depends on the thickness of the stock through which the hole is to be punched. For other punches for hot work, see Chapter II, page 18.

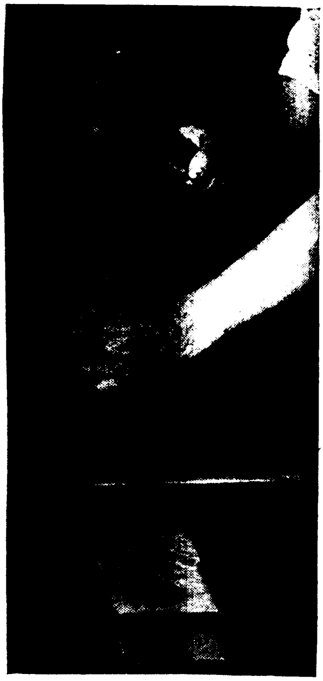


Fig. 19.

The stock for the nut is cut from the bar with a hot chisel after the hole is punched, and if the nut is to be a hexagon it should be cut with six sides, as shown in Figs. 20 and 21. The punch must be driven in the hole and kept there while the sides of the nut are flattened and trued by sufficient hammering. After the outside faces of the nut are finished, the punch should be driven into the hole exactly far enough to make it the right size, first on one face and then the other. This leaves the hole slightly smaller in the middle than it is at each end, which could be corrected by driving a drift punch having parallel sides and the right diameter through it, but ordinarily this is not necessary in such forgings of small size made by hand.

The standard size for hand forged nuts is the same as the bolt head, given in this chapter on page 45. The size of the hole in the nut is an inside dimension and should not be made over size. This is one of the exceptions to the practice of forging over-size mentioned in Chapter III, page 32.

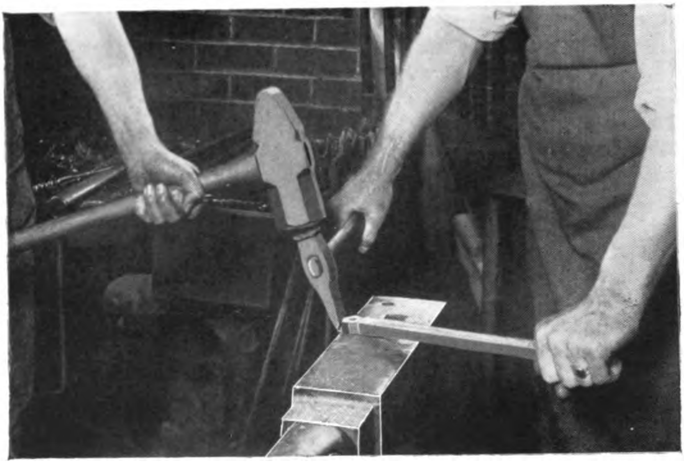


Fig. 20.

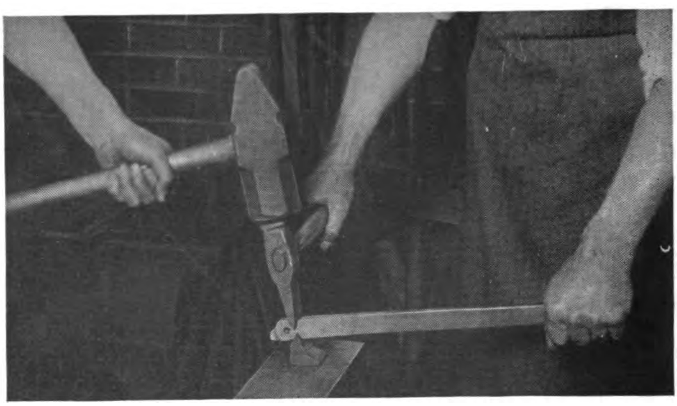


Fig. 21.

For Reference.

Diameter multiplied by 3.1416=circumference.

Circumference multiplied by .3183=diameter.

Radius multiplied by 6.2831=circumference.

Square of the diameter multiplied by .7854=area.

Diameter multiplied by .8862=side of equal square.

Area of a rectangle=length multiplied by breadth.

Doubling the diameter of a circle increases its area four times.

Side of a square multiplied by 1.128=diameter of circle of equal area.

Surface of a sphere=square of diameter multiplied by 3.1416.

Area of a triangle=base multiplied by ½ the altitude.

Area of a sector of a circle=one-half the length of the arc multiplied by the radius of the circle.

1 cubic foot of water weighs 62 1-3 pounds and contains 7½ gallons.

1 gallon of water (U. S. Standard) weighs 8 1-3 pounds.

To find the capacity (U. S. gallons) of cylindrical tanks, square the diameter expressed in inches, multiply by the length and by .0034.

The pressure of still water in pounds per square inch against the sides of any pipe, channel or vessel of any shape whatever is due solely to the "head" or height of the level surface of the water above the point at which the pressure is considered, and is equal to .43302 lb. per square inch or 62.355 lbs. per square foot for every foot of head.

Boiler Horse Power: The evaporation of 30 lbs. of water per hour, from a temperature of 30° F. into steam at 70 lbs. gauge pressure.

One pound of water evaporated from and at 212° is equivalent to 965.7 British Thermal Units.

To find the number of square feet of heating surface in tubes: Multiply the number of tubes by the diameter of a tube in inches, by its length in feet, and by .2618.

To find safe working pressure of boiler: Multiply 1-6 of tensile strength of plate by the thickness of the thinnest plate in inches and divide by ½ the diameter of the boiler. This is for single riveting, to which add twenty per cent for double riveting when all the holes have been DRILLED.

TENSILE STRENGTH OF METALS

Metal.		Pounds per sq. inch.	Metal.	Pounds per sq. inch.
Aluminum		23,000	Lead—Cast	1,800
Aluminum—bronze		80,000	Pipe	2,100
Antimony		1,000	Manganese bronze—Cast	57,000
Bismuth		3,200	Rolled.	105,000
Brass—Cast		20,000	Platinum, wire	53,000
Wire		49,000	Phosphor bronze—Cast	38,500
Copper—Cast		22,500	Wire	96,000
Wire		60,000	Steel—Cast	60,000
Gun Metal (9 cu., 1 tin)—			Wire	120,000
Cast		32,000	Tin—Cast	4,600
Wire		90,000	Wire	7,000
Iron—Cast	16,000	23,500	Zinc—Cast	5,500
Wrought	58,000	95,000	Wire	20,000

STANDARD SPECIFICATIONS FOR SPECIAL OPEN-HEARTH PLATE

Adopted by the Ass'n. Am. Steel Manufacturers, July 17, 1896.

Steel shall be of four grades—*Extra Soft, Fire Box, Flange or Boiler and Boiler Rivet Steel.*

EXTRA SOFT STEEL

Ultimate strength, 45,000 to 55,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 28 per cent. Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion. Maximum Phosphorus, .04 per cent; maximum Sulphur, .04 per cent.

FIRE BOX STEEL

Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 26 per cent. Cold and Quench bends, 180 degrees, flat on itself, without fracture on outside of bent portion. Maximum Phosphorus, .04 per cent; maximum Sulphur, .04 per cent.

FLANGE OR BOILER STEEL

Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 25 per cent. Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion. Maximum Phosphorus, .06 per cent; maximum Sulphur, .04per cent.

TEST PIECE FOR SHEARED PLATES

All tests and inspections shall be made at place of manufacture prior to shipment.

The tensile strength, limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material. The standard shape of the test piece for sheared plates shall be as shown. On tests cut from other material the test piece may be either the same as for plates, or it may be planed, or turned parallel throughout its entire length. The elongation shall be measured on an original length of eight inches, except when the thickness of the finished material is $^5/_{16}$ inch or less, in which case the elongation shall be measured in a length equal to sixteen times the thickness; and except in rounds of ⅝ inch or less in diameter, in which case the elongation shall be measured in a length equal to eight times the diameter of section tested. Four test pieces shall be taken from each melt of finished material; two for tension and two for bending.

Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material is to be similarly treated before testing.

Every finished piece of steel shall be stamped with the melt number.

All plates shall be free from surface defects and have a workmanlike finish.

STANDARD GAUGE.

U. S. STANDARD GAUGE.					BIRMINGHAM GAUGE.			
No. of Gauge	Thickness in Inches		Weight Square Foot		No. of Gauge	Thick-ness in Inches	Weight Square Foot	
	Fractions	Decimals	Iron	Steel			Iron	Steel
7-0's	1-2	.5	20.00	20.4				
6-0's	15-32	.46875	18.75	19.125				
5-0's	7-16	.4375	17.50	17.85				
0000	13-32	.40625	16.25	16.575	0000	.454	18.22	18.46
000	3-8	.375	15.	15.30	000	.425	17.05	17.28
00	11-32	.34375	13.75	14.025	00	.38	15.25	15.45
0	5-16	.3125	12.50	12.75	0	.34	13.64	13.82
1	9-32	.28125	11.25	11.475	1	.3	12.04	12.20
2	17-64	.265625	10.625	10.8375	2	.284	11.40	11.55
3	1-4	.25	10.	10.2	3	.259	10.39	10.53
4	15-64	.234375	9.375	9.5625	4	.238	9.55	9.68
5	7-32	.21875	8.75	8.925	5	.22	8.83	8.95
6	13-64	.203125	8.125	8.2875	6	.203	8.15	8.25
7	3-16	.1875	7.5	7.65	7	.18	7.22	7.32
8	11-64	.171875	6.875	7.0125	8	.165	6.62	6.71
9	5-32	.15625	6.25	6.375	9	.148	5.94	6.02
10	9-64	.140625	5.625	5.7375	10	.134	5.38	5.45
11	1-8	.125	5.	5.1	11	.12	4.82	4.88
12	7-64	.109375	4.375	4.625	12	.109	4.37	4.43
13	3-32	.09375	3.75	3.825	13	.095	3.81	3.86
14	5-64	.078125	3.125	3.1875	14	.083	3.33	3.37
15	9-128	.0703125	2.8125	2.86875	15	.072	2.89	2.93
16	1-16	.0625	2.5	2.55	16	.065	2.61	2.64
17	9-160	.05625	2.25	2.295	17	.058	2.33	2.36
18	1-20	.05	2.	2.04	18	.049	1.97	1.99
19	7-160	.04375	1.75	1.785	19	.042	1.69	1.71
20	3-80	.0375	1.50	1.53	20	.035	1.40	1.42
21	11-320	.034375	1.375	1.4025	21	.032	1.28	1.30
22	1-32	.03125	1.25	1.275	22	.028	1.12	1.14
23	9-320	.028125	1.125	1.1475	23	.025	1.00	1.02
24	1-40	.025	1.	1.02	24	.022	.883	.895
25	7-320	.021875	.865	.8925	25	.02	.803	.813
26	3-160	.01875	.75	.765	26	.018	.722	.732
27	11-640	.0171875	.6875	.70125	27	.016	.642	.652
28	1-64	.015625	.625	.6375	28	.014	.562	.569
29	9-640	.0140625	.5625	.57375	29	.013	......	......
30	1-80	.0125	.5	.51	30	.012	......	......
31	7-640	.010985	.4375	.44625	31	.01	......	......
32	13-1280	.01045625	.40625	.414375	32	.009	......	......
33	3-320	.009375	.375	.3825	33	.008	......	......
34	11-1280	.00859375	.34375	.350625	34	.007	......	......
35	5-640	.0078125	.3125	.31875	35	.005	......	......
36	9-1280	.00703125	.28125	.286875	36	.004	......	......
37	17-2560	.00664062	.265625	.2709375	37	......	......	......
38	1-160	.00625	.25	.255	......	......	......	......

All sheets of iron and steel are rolled to U. S. standard gauge unless otherwise ordered.

The low temperature (as compared with iron) at which steel plates have to be finished, causes a slight springing of the rolls, leaving the plate thicker in the center than on the edge. This is especially noticeable in plates less than 3/8 inch thick and over 66 inches wide, which may be of full thickness on the edge and yet be as much as 1/8 inch thicker in the middle.,

VARIATION ALLOWABLE

For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge.

The weight of one cubic inch of rolled steel is assumed to be 0.2833 pound.

PLATE 1/4 INCH AND OVER IN THICKNESS.

THICKNESS OF PLATE. Inch.	WIDTH OF PLATE.		
	Up to 75 Inches. Per Cent.	75 to 100 Inches. Per Cent.	Over 100 Inches. Per Cent.
1/4	10	14	18
5/16	8	12	16
3/8	7	10	13
7/16	6	8	10
1/2	5	7	9
9/16	4 1/2	6 1/2	8 1/2
5/8	4	6	8
Over 5/8	3 1/2	5	6 1/2

PLATE UNDER 1/4 INCH IN THICKNESS.

THICKNESS OF PLATE. Inch.	WIDTH OF PLATE.	
	Up to 50 Inches. Per Cent.	50 Inches and Over. Per Cent.
1/8 up to 5/32	10	15
5/32 " 3/16	8 1/2	12 1/2
3/16 " 1/4	7	10

VARIATION ALLOWABLE

The variation in cross-section or weight of more than 2 1/2 per cent from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

Plates 12 1/2 pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2 1/2 per cent variation above or 2 1/2 per cent below the theoretical weight. When 100 inches wide and over 5 per cent above or 5 per cent below the theoretical weight.

Plates under 12 1/2 pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2 1/2 per cent above or 2 1/2 per cent below the theoretical weight. 75 inches wide up to 100 inches wide, 5 per cent above or 3 per cent below the theoretical weight. When 100 inches wide and over 10 per cent above or 3 per cent below the theoretical weight.

TABLE OF DECIMAL EQUIVALENTS

OF 8THS, 16THS, 32NDS AND 64THS OF AN INCH, FOR USE IN CONNECTION WITH MICROMETER CALIPERS.

8THS.

1-8=.125
1-4=.25
3-8=.375
1-2=.50
5-8=.625
3-4=.75
7-8=.875

16THS.

1-16=.0625
3-16=.1875
5-16=.3125
7-16=.4375
9-16=.5625
11-16=.6875
13-16=.8125
15-16=.9375

32NDS.

1-32=.03125
3-32=.09375
5-32=.15625
7-32=.21875
9-32=.28125
11-32=.34375
13-32=.40625
15-32=.46875
17-32=.53125
19-32=.59375
21-32=.65625
23-32=.71875
25-32=.78125
27-32=.84375
29-32=.90625
31-32=.96875

64THS.

1-64=.015625
3-64=.046875
5-64=.078125
7-64=.109375
9-64=.140625
11-64=.171875
13-64=.203125
15-64=.234375
17-64=.265625
19-64=.296875
21-64=.328125
23-64=.359375
25-64=.390625
27-64=.421875
29-64=.453125
31-64=.484375
33-64=.515625
35-64=.546875
37-64=.578125
39-64=.609375
41-64=.640625
43-64=.671875
45-64=.753125
47-64=.734375
49-64=.765625
51-64=.796875
53-64=.828125
55-64=.859375
57-64=.890625
59-64=.921875
61-64=.953125
63-64=.984375

MISCELLANEOUS

For the area of a circle . . .	×	square of diameter by .	.7854
For the diameter of a circle . .	×	circumference by . . .	.31831
For the circumference of a circle	×	diameter by	3.1416
For the surface of a ball . . .	×	square of diameter by .	3.1416
For the cubic inches in a ball .	×	cube of diameter by . .	.5236
For the side of an equal square	×	diameter by	.8862

CIRCUMFERENCE AND AREAS OF CIRCLES

Diameter Inches	Circumference Inches	Area Square Inches	Diameter Inches	Circumference Inches	Area Square Inches	Diameter Inches	Circumference Inches	Area Square Inches
1/16	.19635	.00307	4 1/2	14.137	15.904	9 5/8	30.237	72.759
1/8	.3927	.01227	4 5/8	14.529	16.800	9 3/4	30.630	74.662
3/16	.5890	.02761	4 3/4	14.922	17.720	9 7/8	31.023	76.588
1/4	.7854	.04909	4 7/8	13.315	18.665			
5/16	.9817	.07670				10	31.416	78.540
3/8	1.1781	.1104	5	15.708	19.635	10 1/8	31.808	80.515
7/16	1.3744	.1503	5 1/8	16.100	20.629	10 1/4	32.201	82.516
1/2	1.5708	.1963	5 1/4	16.493	21.647	10 3/8	32.594	84.540
9/16	1.7771	.2485	5 3/8	16.886	22.690	10 1/2	32.986	86.590
5/8	1.9635	.3068	5 1/2	17.278	23.758	10 5/8	33.379	88.664
11/16	2.1598	.3712	5 5/8	17.671	24.850	10 3/4	33.772	90.762
3/4	2.3562	.4417	5 3/4	18.064	25.967	10 7/8	34.164	92.885
13/16	2.5525	.5185	5 7/8	18.457	27.108			
7/8	2.7489	.6013				11	34.558	95.033
15/16	2.9452	.6903				11 1/8	34.950	97.205
			6	18.849	28.274	11 1/4	35.343	99.402
1	3.1416	.7854	6 1/8	19.242	29.464	11 3/8	35.735	101.623
1 1/8	3.5343	.9940	6 1/4	19.635	30.679	11 1/2	36.128	103.869
1 1/4	3.9270	1.2271	6 3/8	20.027	31.919	11 5/8	36.521	106.139
1 3/8	4.3197	1.4848	6 1/2	20.420	33.183	11 3/4	36.913	108.434
1 1/2	4.7124	1.7671	6 5/8	20.813	34.471	11 7/8	37.306	110.753
1 5/8	5.1051	2.0739	6 3/4	21.205	35.784			
1 3/4	5.4978	2.4052	6 7/8	21.598	37.122	12	37.699	113.097
1 7/8	5.8905	2.7611				12 1/8	38.091	115.466
			7	21.991	38.484	12 1/4	38.484	117.859
2	6.2832	3.1416	7 1/8	22.383	39.871	12 3/8	38.877	120.276
2 1/8	6.6759	3.5465	7 1/4	22.776	41.282	12 1/2	39.270	122.718
2 1/4	7.0686	3.9760	7 3/8	23.169	42.718	12 5/8	39.662	125.184
2 3/8	7.4613	4.4302	7 1/2	23.562	44.178	12 3/4	40.055	127.676
2 1/2	7.8540	4.9087	7 5/8	23.954	45.663	12 7/8	40.448	130.192
2 5/8	8.2467	5.4119	7 3/4	24.347	47.173			
2 3/4	8.6394	5.9395	7 7/8	24.740	48.707	13	40.840	132.732
2 7/8	9.0321	6.4918				13 1/8	41.233	135.297
			8	25.132	50.265	13 1/4	41.626	137.886
3	9.4248	7.0686	8 1/8	25.515	51.848	13 3/8	42.018	140.500
3 1/8	9.8175	7.6699	8 1/4	25.918	53.456	13 1/2	42.411	143.139
3 1/4	10.210	8.2957	8 3/8	26.310	55.088	13 5/8	42.804	145.802
3 3/8	10.602	8.9462	8 1/2	26.703	56.745	13 3/4	43.197	148.489
3 1/2	10.995	9.6211	8 5/8	27.096	58.426	13 7/8	43.589	151.201
3 5/8	11.388	10.320	8 3/4	27.489	60.132			
3 3/4	11.781	11.044	8 7/8	27.881	61.862	14	43.982	153.938
3 7/8	12.173	11.793				14 1/8	44.375	156.699
			9	28.274	63.617	14 1/4	44.767	159.485
4	12.566	12.566	9 1/8	28.667	65.396	14 3/8	45.160	162.295
4 1/8	12.959	13.364	9 1/4	29.059	67.200	14 1/2	45.553	165.130
4 1/4	13.351	14.186	9 3/8	29.452	69.029	14 5/8	45.945	167.989
4 3/8	13.744	15.033	9 1/2	29.845	70.882	14 3/4	46.338	170.873
						14 7/8	46.731	173.782

WEIGHTS OF IRON AND STEEL

Thickness in Inches	Weight per Square Foot		Thickness in Inches	Weight per Square Foot	
	Iron	Steel		Iron	Steel
1/32	1.263	1.35	11/16	27.79	28.50
1/16	2.526	2.75	3/4	30.31	31.00
3/32	3.789	4.00	13/16	32.84	33.50
1/8	5.052	5.35	7/8	35.37	36.00
5/32	6.315	6.75	15/16	37.89	38.50
3/16	7.578	7.85	1	40.42	41.00
7/32	8.841	9.25	1 1/16	42.50	43.50
1/4	10.10	10.55	1 1/8	45.00	46.00
9/32	11.37	11.75	1 3/16	47.50	48.50
5/16	12.63	13.50	1 1/4	50.00	51.00
11/32	13.89	14.25	1 5/16	52.50	53.50
3/8	15.16	16.00	1 3/8	55.00	56.10
13/32	16.42	16.75	1 7/16	57.50	58.65
7/16	17.68	18.50	1 1/2	60.63	61.20
15/32	18.95	19.25	1 3/4	70.73	71.40
1/2	20.21	21.00	1 7/8	75.00	76.50
9/16	22.73	23.50	2	80.83	81.60
5/8	25.26	26.00	....	.....	.....

WEIGHT OF METALS PER CUBIC INCH

Cast iron............	.26 pounds	Wrought iron.........	.277 pounds
Steel	.283 pounds	Lead	.410 pounds
Copper	.317 pounds	Brass	.302 pounds

WEIGHT IN POUNDS OF A LINEAL FOOT OF OCTAGON STEEL

Size in Inches	Octagon	Size in Inches	Octagon	Size in Inches	Octagon
1/16	.011	1 3/8	5.356	3 5/8	37.23
1/8	.044	1 1/2	6.374	3 3/4	39.84
3/16	.099	1 5/8	7.481	3 7/8	42.54
1/4	.177	1 3/4	8.674	4	45.33
5/16	.277	1 7/8	9.960	4 1/4	51.17
3/8	.398	2	11.332	4 1/2	57.37
7/16	.542	2 1/8	12.793	4 3/4	63.92
1/2	.708	2 1/4	14.343	5	70.83
9/16	.896	2 3/8	15.981	5 1/4	78.08
5/8	1.107	2 1/2	17.71	5 1/2	85.70
11/16	1.339	2 5/8	19.52	5 3/4	93.67
3/4	1.594	2 3/4	21.42	6	101.99
13/16	1.870	2 7/8	23.41	7	138.82
7/8	2.169	3	25.50	8	181.32
15/16	2.490	3 1/8	27.66	9	229.48
1	2.833	3 1/4	29.92	10	283.31
1 1/8	3.585	3 3/8	32.27	11	342.80
1 1/4	4.427	3 1/2	34.70	12	407.97

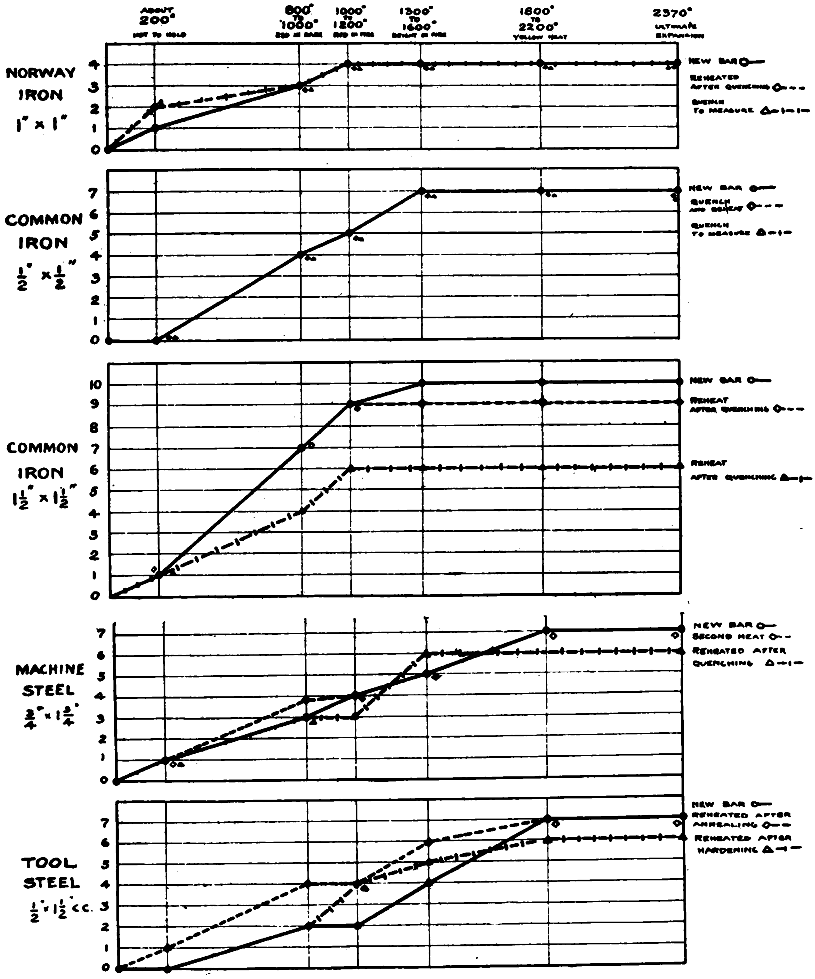
WEIGHTS OF ● AND ■ STEEL PER LINEAL FOOT

(Based on 489.6 lbs. per cubic foot.)

Size Inches	Wt. of ● 1 ft. long	Wt. of ■ 1 ft. long	Size Inches	Wt. of ● 1 ft. long	Wt. of ■ 1 ft. long	Size Inches	Wt. of ● 1 ft. long	Wt. of ■ 1 ft. long
0 1/32	.0026	.0033	3	24.03	30.60	6	96.14	122.4
" 1/16	.0104	.0133	" 1/16	25.04	31.89	" 1/16	98.14	125.0
" 1/8	.0417	.0531	" 1/8	26.08	33.20	" 1/8	100.2	127.6
" 3/16	.0938	.1195	" 3/16	27.13	34.55	" 3/16	102.2	130.2
" 1/4	.1669	.2123	" 1/4	28.20	35.92	" 1/4	104.3	132.8
" 5/16	.2608	.3333	" 5/16	29.30	37.31	" 5/16	106.4	135.5
" 3/8	.3756	.4782	" 3/8	30.42	38.73	" 3/8	108.5	138.2
" 7/16	.5111	.6508	" 7/16	31.56	40.18	" 7/16	110.7	140.9
" 1/2	.6676	.8500	" 1/2	32.71	41.65	" 1/2	112.8	143.6
" 9/16	.8449	1.076	" 9/16	33.90	43.14	" 9/16	114.9	146.5
" 5/8	1.043	1.328	" 5/8	35.09	44.68	" 5/8	117.2	149.2
" 11/16	1.262	1.608	" 11/16	36.31	46.24	" 11/16	119.4	152.1
" 3/4	1.502	1.913	" 3/4	37.56	47.82	" 3/4	121.7	154.9
" 13/16	1.763	2.245	" 13/16	38.81	49.42	" 13/16	123.9	157.8
" 7/8	2.044	2.603	" 7/8	40.10	51.05	" 7/8	126.2	160.8
" 15/16	2.347	2.989	" 15/16	41.40	52.71	" 15/16	128.5	163.6
1	2.670	3.400	4	42.73	54.40	7	130.9	166.6
" 1/16	3.014	3.838	" 1/16	44.07	56.11	" 1/8	135.6	172.6
" 1/8	3.379	4.303	" 1/8	45.44	57.85	" 1/4	140.4	178.7
" 3/16	3.766	4.795	" 3/16	46.83	59.62	" 3/8	145.3	184.9
" 1/4	4.173	5.312	" 1/4	48.24	61.41	" 1/2	150.2	191.3
" 5/16	4.600	5.857	" 5/16	49.66	63.23	" 5/8	155.2	197.7
" 3/8	5.019	6.428	" 3/8	51.11	65.08	" 3/4	160.3	204.2
" 7/16	5.518	7.026	" 7/16	52.58	66.95	" 7/8	165.6	210.8
" 1/2	6.008	7.650	" 1/2	54.07	68.85	8	171.0	217.6
" 9/16	6.520	8.301	" 9/16	55.59	70.78	" 1/8	176.3	224.5
" 5/8	7.051	8.978	" 5/8	57.12	72.73	" 1/4	181.8	231.4
" 11/16	7.604	9.682	" 11/16	58.67	74.70	" 3/8	187.3	238.5
" 3/4	8.178	10.41	" 3/4	60.25	76.71	" 1/2	193.0	245.6
" 13/16	8.773	11.17	" 13/16	61.84	78.74	" 5/8	198.7	252.9
" 7/8	9.388	11.95	" 7/8	63.46	80.81	" 3/4	204.4	260.3
" 15/16	10.02	12.76	" 15/16	65.10	82.89	" 7/8	210.3	267.9
2	10.68	13.60	5	66.76	85.00	9	216.3	275.4
" 1/16	11.36	14.46	" 1/16	68.44	87.14	" 1/8	222.4	283.2
" 1/8	12.06	15.35	" 1/8	70.14	89.30	" 1/4	228.5	290.9
" 3/16	12.78	16.27	" 3/16	71.86	91.49	" 3/8	234.7	298.9
" 1/4	13.52	17.22	" 1/4	73.60	93.72	" 1/2	241.0	306.8
" 5/16	14.28	18.19	" 5/16	75.37	95.96	" 5/8	247.4	315.0
" 3/8	15.07	19.18	" 3/8	77.15	98.23	" 3/4	253.9	323.2
" 7/16	15.86	20.20	" 7/16	78.95	100.5	" 7/8	260.4	331.6
" 1/2	16.69	21.25	" 1/2	80.77	102.8	10	267.0	340.0
" 9/16	17.53	22.33	" 9/16	82.62	105.2	" 1/4	280.6	357.2
" 5/8	18.40	23.43	" 5/8	84.49	107.6	" 1/2	294.4	374.9
" 11/16	19.29	24.56	" 11/16	86.38	110.0	" 3/4	308.6	392.9
" 3/4	20.20	25.00	" 3/4	88.29	112.4	11	323.1	411.4
" 13/16	21.12	26.90	" 13/16	90.22	114.9	" 1/4	337.9	430.3
" 7/8	22.07	28.10	" 7/8	92.17	117.4	" 1/2	353.1	449.6
" 15/16	23.04	29.34	" 15/16	94.14	119.9	" 3/4	368.6	469.4

These figures represent the theoretical weights of *steel.* Iron will run about 2 per cent lighter.

LINEAR EXPANSION OF 6" FROM 32° FAHR. TO TEMPERATURE OR CONDITION AS GIVEN, IN 64$^{\text{THS}}$ OF AN INCH.



These curves were plotted from figures procured by measuring ten test bars of each kind and condition.

*WEIGHTS OF FLAT ROLLED STEEL, PER LINEAL FOOT

Thickness Inches	WIDTH—INCHES.										
	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾
1/16....	.1060	.1381	.1594	.1859	.212	.2391	.2656	.292	.319	.346	.372
⅛....	.2125	.2656	.3188	.3720	.4250	.4782	.5312	.585	.638	.692	.740
3/16....	.319	.399	.478	.558	.638	.717	.797	.875	.957	1.04	1.15
¼....	.425	.531	.636	.743	.850	.957	1.06	1.17	1.28	1.38	1.49
5/16....	.531	.664	.797	.929	1.06	1.20	1.33	1.46	1.59	1.73	1.86
⅜....	.638	.797	.957	1.116	1.28	1.43	1.59	1.76	1.92	2.08	2.23
7/16...	.744	.929	1.116	1.302	1.49	1.68	1.86	2.05	2.23	2.42	2.60
½....	.850	1.06	1.275	1.487	1.70	1.92	2.12	2.34	2.55	2.72	2.98
9/16...	.957	1.20	1.434	1.674	1.92	2.15	2.39	2.63	2.87	3.11	3.35
⅝....	1.06	1.33	1.594	1.859	2.12	2.39	2.65	2.92	3.19	3.46	3.72
11/16...	1.17	1.46	1.753	2.045	2.34	2.63	2.92	3.22	3.51	3.80	4.09
¾....	1.28	1.60	1.913	2.232	2.55	2.87	3.19	3.51	3.83	4.15	4.47
13/16...	1.38	1.73	2.072	2.417	2.76	3.11	3.45	3.80	4.14	4.49	4.84
⅞....	1.49	1.86	2.232	2.604	2.98	3.35	3.72	4.09	4.47	4.84	5.20
15/16...	1.60	1.99	2.391	2.789	3.19	3.59	3.99	4.39	4.78	5.18	5.58
1......	1.70	2.13	2.55	2.98	3.40	3.83	4.25	4.68	5.10	5.53	5.95
1 1/16...	1.81	2.26	2.710	3.161	3.61	4.064	4.52	4.97	5.42	5.87	6.32
1⅛....	1.91	2.39	2.868	3.347	3.83	4.304	4.78	5.26	5.74	6.22	6.70
1 3/16...	2.02	2.52	3.03	3.533	4.04	4.54	5.05	5.56	6.06	6.56	7.07
1¼....	2.12	2.66	3.19	3.72	4.25	4.79	5.31	5.85	6.38	6.91	7.44
1 5/16...	2.23	2.79	3.35	3.91	4.46	5.02	5.58	6.14	6.69	7.25	7.81
1⅜....	2.34	2.92	3.51	4.09	4.67	5.26	5.84	6.43	7.02	7.60	8.18
1 7/16...	2.45	3.06	3.67	4.28	4.89	5.50	6.11	6.72	7.34	7.94	8.56
1½....	2.55	3.19	3.83	4.47	5.10	5.74	6.38	7.02	7.65	8.29	8.93
1 9/16...	2.66	3.32	3.99	4.65	5.32	5.98	6.64	7.31	7.97	8.74	9.30
1⅝....	2.76	3.45	4.15	4.84	5.52	6.22	6.90	7.60	8.29	8.98	9.67
1 11/16...	2.87	3.59	4.31	5.02	5.74	6.46	7.17	7.89	8.61	9.33	10.04
1¾....	2.98	3.72	4.47	5.21	5.95	6.70	7.44	8.19	8.93	9.67	10.42
1 13/16...	3.08	3.85	4.62	5.466	6.16	6.93	7.70	8.48	9.24	10.02	10.79
1⅞....	3.19	3.99	4.79	5.58	6.38	7.17	7.97	8.77	9.57	10.36	11.15
1 15/16...	3.30	4.12	4.94	5.77	6.59	7.42	8.24	9.06	9.88	10.71	11.53
2......	3.40	4.25	5.10	5.95	6.80	7.65	8.50	9.35	10.20	11.05	11.90

*These figures are the theoretical weights, based on 489.6 lbs. per cubic foot of steel. Iron bars will run about 2% lighter.

*WEIGHTS OF FLAT ROLLED STEEL, PER LINEAL FOOT

WIDTH—INCHES.												
2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5
.425	.478	.531	.584	.638	.691	.744	.80	.85	.90	.96	1.01	1.06
.850	.96	1.06	1.17	1.28	1.38	1.49	1.59	1.70	1.81	1.91	2.02	2.13
1.28	1.44	1.59	1.75	1.91	2.07	2.23	2.39	2.55	2.71	2.87	3.03	3.19
1.70	1.92	2.12	2.34	2.55	2.76	2.98	3.19	3.40	3.61	3.83	4.04	4.25
2.12	2.39	2.65	2.92	3.19	3.45	3.72	3.99	4.25	4.52	4.78	5.05	5.31
2.55	2.87	3.19	3.51	3.83	4.15	4.47	4.78	5.10	5.42	5.74	6.06	6.38
2.98	3.35	3.72	4.09	4.46	4.83	5.20	5.58	5.95	6.32	6.70	7.07	7.44
3.40	3.83	4.25	4.67	5.10	5.53	5.95	6.38	6.80	7.22	7.65	8.08	8.50
3.83	4.30	4.78	5.26	5.74	6.22	6.70	7.17	7.65	8.13	8.61	9.09	9.57
4.25	4.78	5.31	5.84	6.38	6.91	7.44	7.97	8.50	9.03	9.57	10.10	10.63
4.67	5.26	5.84	6.43	7.02	7.60	8.18	8.76	9.35	9.93	10.52	11.11	11.69
5.10	5.75	6.38	7.02	7.65	8.29	8.93	9.57	10.20	10.84	11.48	12.12	12.75
5.53	6.21	6.90	7.60	8.29	8.98	9.67	10.36	11.05	11.74	12.43	13.12	13.81
5.95	6.69	7.44	8.18	8.93	9.67	10.41	11.16	11.90	12.65	13.39	14.13	14.87
6.38	7.18	7.97	8.77	9.57	10.36	11.16	11.95	12.75	13.55	14.34	15.14	15.94
6.80	7.65	8.50	9.35	10.20	11.05	11.90	12.75	13.60	14.45	15.30	16.15	17.00
7.22	8.13	9.03	9.93	10.84	11.74	12.65	13.55	14.45	15.35	16.26	17.16	18.06
7.65	8.61	9.57	10.52	11.48	12.43	13.39	14.34	15.30	16.26	17.22	18.17	19.13
8.08	9.09	10.10	11.11	12.12	13.12	14.13	15.14	16.15	17.16	18.17	19.18	20.19
8.50	9.57	10.63	11.69	12.75	13.81	14.87	15.94	17.00	18.06	19.13	20.19	21.25
8.93	10.04	11.16	12.27	13.39	14.50	15.62	16.74	17.85	18.96	20.08	21.20	22.32
9.35	10.52	11.69	12.85	14.03	15.20	16.36	17.53	18.70	19.87	21.04	22.21	23.38
9.78	11.00	12.22	13.44	14.66	15.88	17.10	18.33	19.55	20.77	21.99	23.22	24.44
10.20	11.48	12.75	14.03	15.30	16.58	17.85	19.13	20.40	21.68	22.95	24.23	25.50
10.63	11.95	13.28	14.61	15.94	17.27	18.60	19.92	21.25	22.58	23.91	25.24	26.57
11.05	12.43	13.81	15.19	16.58	17.96	19.34	20.72	22.10	23.48	24.87	26.25	27.63
11.47	12.91	14.34	15.78	17.22	18.65	20.08	21.51	22.95	24.38	25.82	27.26	28.69
11.90	13.40	14.88	16.37	17.85	19.34	20.83	22.32	23.80	25.29	26.78	28.27	29.75
12.33	13.86	15.40	16.95	18.49	20.03	21.57	23.11	24.65	26.19	27.73	29.27	30.81
12.75	14.34	15.94	17.53	19.13	20.72	22.31	23.91	25.50	27.10	28.69	30.28	31.87
13.18	14.83	16.47	18.12	19.77	21.41	23.06	24.70	26.35	28.00	29.64	31.29	32.94
13.60	15.30	17.00	18.70	20.40	22.10	23.80	25.50	27.20	28.90	30.60	32.30	34.00

*These figures are the theoretical weights, based on 489.6 lbs. per cubic foot of steel. Iron bars will run about 2% lighter.

HEAT

Sensible heat is said to be that actual, Kinetic, heat energy, capable of transformation into mechanical energy.

Latent heat of expansion is a name for that heat, which is demanded to produce an increase of volume.

The Specific Heat of a body signifies its capacity for heat, or the quantity of heat required, to raise the temperature of the body one degree Fahrenheit, compared with that required to raise the temperature of an equal weight of water one degree.

SPECIFIC HEAT

SUBSTANCE.	SPECIFIC HEAT.	SUBSTANCE.	SPECIFIC HEAT.
Ice	0.504	Anthracite	0.2017
Water at 32° F.	1.000	Oak Wood	0.570
Gaseous Steam	0.475	Fir Wood	0.650
Saturated Steam	0.305		
Mercury	0.0333		
Sulphuric Ether, Density .715	0.5200	Oxygen (Equal Weights; Constant Volume)	0.1559
Alcohol	0.6588	Air (at Constant Pressure)	0.2377
Lead	0.0314		
Gold	0.0324	Air (Equal Weights Constant Vol.)	0.1688
Tin	0.0566		
Silver	0.0570		
Brass	0.0939	Nitrogen (Equal Wgts.; Constant Volume)	0.1740
Copper	0.0951		
Zinc	0.0956		
Nickel	0.1086	Hydrogen (Equal Wgts.; Constant Volume)	2.4096
Wrought Iron	0.1138 to 0.1255		
Steel	0.1165 to 0.1185		
Cast Iron	0.1298	Carbonic Oxide Equal Weights; Constant Vol.)	0.1768
Brickwork and Masonry	0.200		
Coal	0.2411	Carbonic Acid (Equal Weights; Constant Vol.)	0.1714

EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES

D. K. C.

SUBSTANCE	Coefficient for 1° Fahr.	Total Expansion between 32° Fahr. and 212° Fahr.			
		Coefficient		In Length of 10 Feet	
		Decimal	Fraction		
Aluminum (Cast)	.00001234	.002221	1/450	.02221	.2664
Antimony (Crystallized)	.00000627	.001129	1/885	.01129	.1336
Brass (Cast)	.00000957	.001723	1/581	.01723	.2067
Brass (English Plate)	.00001052	.001894	1/529	.01894	.2273
Brass (Sheet)	.00001040	.001872	1/535	.01872	.2246
Brick (Best Stock)	.00000306	.000550	1/1818	.00550	.0660
Brick in Cement Mortar (Headers)	.00000494	.000890	1/1123	.00890	.1068
Brick in Cement Mortar (Stretchers)	.00000256	.000460	1/2174	.00460	.0552
Bronze	.00000975	.001755	1/568	.01755	.2106
Cement (Roman, Dry)	.00000797	.001435	1/694	.01435	.1722
Cement (Portland, Neat)	.00000594	.001070	1/935	.01070	.1284
Cement (Portland, with Sand)	.00000656	.001180	1/847	.01180	.1416
Copper	.00000887	.001596	1/625	.01596	.1915
Glass (Flint)	.00000451	.000812	1/1234	.00812	.0974
Glass (White, Free from Lead)	.00000492	.000886	1/1130	.00886	.1063
Glass (Blown)	.00000498	.000896	1/1111	.00896	.1075
Glass (Thermometer)	.00000499	.000897	1/1111	.00897	.1076
Glass (Hard)	.00000397	.000714	1/1400	.00714	.0857
Granite (Gray, Dry)	.00000438	.000789	1/1266	.00789	.0947
Granite (Red, Dry)	.00000498	.000897	1/1111	.00897	.1076
Gold (Pure)	.00000786	.001415	1/707	.01415	.1698
Iron (Wrought)	.00000648	.001166	1/866	.01166	.1399
Iron (Swedish)	.00000636	.001145	1/873	.01145	.1374
Iron (Cast)	.00000556	.001001	1/1000	.01001	.1201
Iron (Soft)	.00000626	.001126	1/897	.01126	.1351
Lead	.00001571	.002828	1/353	.02828	.3394
Marble (Ordinary, Dry)	.00000363	.000654	1/1530	.00654	.0785
Marble (Ordinary, Moist)	.00000663	.001193	1/838	.01193	.1432
Mercury (Cubic Expansion)	.00009984	.017971	1/56	.17971	2.1565
Nickel	.00000695	.001251	1/800	.01251	.1501
Plaster (White)	.00000922	.001660	1/602	.01660	.1992
Platinum	.00000479	.000863	1/1159	.00863	.1036
Silver (Pure)	.00001079	.001943	1/514	.01943	.2334
Slate	.00000577	.001038	1/967	.01038	.1246
Steel (Cast)	.00000636	.001144	1/874	.01144	.1373
Steel (Tempered)	.00000689	.001240	1/806	.01240	.1488
Stone (Sand, Dry)	.00000652	.001174	1/852	.01174	.1409
Tin	.00001163	.002094	1/477	.02094	.2513
Wood (Pine)	.00000276	.000496	1/2016	.00496	.0595
Zinc	.00001407	.002532	1/395	.02532	.3038
Zinc 8, Tin 1	.00001496	.002692	1/372	.02692	.3230

FOR REFERENCE

Quantities of heat are measured in English units by what is termed the British Thermal Unit, or for brevity B. T. U. The B. T. U. is the quantity of heat required to raise 1 lb. of pure water from a temperature of 62° F. to 63° F.

A heat unit, frequently designated by H. U. in the French or metric system, is termed a Calorie.

The electrical unit of power is the Watt. The mechanical unit of work is the *foot pound*, or the work required to raise one pound, one foot high.

EQUIVALENTS OF POWER AND HEAT

Calorie.		B. T. U.		Ft. Lbs.		Watts.		
0.252	=	1	=	778	=	17.59		
		42.41	=	33000	=	746	=	1 H P.

H. P. or horse power being the unit for large powers.

MELTING POINTS OF METALS—MELTING POINTS OF SOLIDS

Which may be regarded as the freezing points of the corresponding liquids.

	DEGREES FAHR.		DEGREES FAHR.
Aluminum	910	Barium Chloride	2000
Antimony	806	Glass	2377
Bismuth	513	Ice	32
Brass	2860	Iodine	235
Bronze	900	Lard	95
Copper	1012	Nitro-Glycerine	45
Gold, pure	2282	Olive and Linseed oil	—4
Iridium	3542	Phosphorus	111
Iron, cast	2012	Pitch	91
Iron, wrought	2822	Potassium	144
Lead	617	Saltpetre	606
Magnesium	1382	Salt	575
Manganese	2912	Sodium	204
Mercury	—39	Spermaceti	120
Osmium	4532	Stearine	120
Platinum	3272	Sulphur	239
Silver	1832	Tallow	92
Steel	2462	Wax, bees	142
Tin	442		
Zinc	842		

Melting points above 900 are merely approximate.

BOILING POINTS OF VARIOUS SUBSTANCES

At Atmospheric Pressure at Sea Level

	DEGREES FAHR.		DEGREES FAHR.
Alcohol	173	Sulphur	570
Ammonia	140	Sulphuric Acid, s. g. 1.848	590
Benzine	176	Sulphuric Acid, s. g. 1.3	240
Coal Tar	325	Sulphuric ether	100
Linseed Oil	597	Turpentine	315
Mercury	648	Water	212
Naptha	186	Water, Sea	213.2
Nitric Acid, s. g. 1.42	248	Water, Saturated Brine	226
Nitric Acid, s. g. 1.5	210	Wood Spirit	150
Petroleum Rectified	316		

MELTING POINTS OF MIXTURES OR SOLDER

	Degrees Fahr.			Degrees Fahr.	
	Softens at	Melts at		Softens at	Melts at
3 Tin, 2 Lead	348	356	2 Tin, 7 Lead	377½	388
2 Tin, 2 Lead	365	372	2 Tin, 8 Lead	395½	408
2 Tin, 6 Lead	372	383	1 Tin, 1 Zinc	....	900

CHAPTER V

HOOKS AND CHAINS

We show in this chapter the order in which forging operations should come, and the method of calculating stock for certain things, with a view to leading to a knowledge of how to do many other things not mentioned.

The design of a good hand forged chain hook of small size is the same as for a large hoist hook that must be made with power hammers. The best shape for a hook is that described here, because the wedge-shaped section is the stiffest form for a piece of given weight.

It is our purpose to show how to make hooks and chain links by hand, and the design for large sizes being the same the work of making the heavy ones is done by following the same steps with heavy tools.

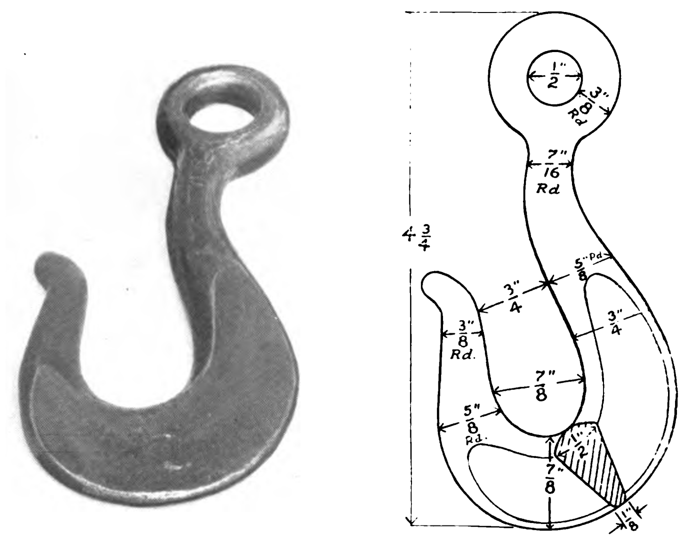


Fig. 1.

Stock of the right dimensions must be selected, and study of the shape and dimensions given in Fig. 1 shows that a flat bar will be nearer the right shape for the heavy section of this hook than a square or round bar would be, and as the thickest part of the hook is one-half inch, that thickness of flat bar should be selected. As the flat sides must be hammered to make one edge thinner, and the extreme width is seven-eighths of an inch, a bar three-quarters of an inch wide appears to be sufficient. A trial proves this to be the smallest size that will produce a hook of these dimensions without upsetting. So as economy of labor demands that a forging shall be made at the least number of heats and hammer blows possible, ¾″ × ½″ bar stock is selected. The length of a hook is not important, except for convenience in handling after it is on the chain. But if the hook must be just the length given in Fig. 1, a little calculation and good judgment would suggest a piece about five inches long. But experience will prove that it may be one-quarter of an inch shorter, or 4¾″ × ¾″ × ½″ is exactly enough material to make this hook, which is designed for a three-eighths inch chain. If that size and shape of stock is not available, some other size of flat iron, or square or round, may be used. The required length can be found by reference to the table of weights on page 60, where we find that three-quarters by half inch weighs 1.28 lbs. to the foot, and one inch by half inch weighs 1.70 lbs. to the foot, so we have the following proportion: 1.70 lb. is to 1.28 lb. as 4¾ inches is to the required length of 1″×½″ stock, 1.28 times 4.75 equals 6.08; 6.08 divided by 1.70 equals 3.57 or 3 9/16 inches of 1″ × ½″ stock will therefore make the piece. Or in the same manner we find ⅝″ sq., which weighs 1.328 to the foot, would give the proportion, (1.328: 1.28:: 4.75: the unknown length;) 6.08 divided by 1.328 is equal to 4.57. By the table of decimal equivalents, we find that fifty-seven hundredths is nine-sixteenths of an inch, so a piece of ⅝″ sq., 3 9/16″ long would be the same quantity of stock and would be sufficient to make the hook. And as 11/16″ rd. weighs 1.26 lbs., almost the same as ¾ × ½, a piece of round stock 11/16″ in diameter and 4¾″ long would make the same kind of a hook we are going to make out of ¾″ × ½″ × 4¾″.

With a piece of material of the latter dimensions, get a heat about two inches long on one end, and punch a small hole a little farther from the end than it is from either side of the piece. The punch used should be round and not more than one-quarter of an inch on the small end. It should have a straight taper three inches long and be five-eighths of an inch in diameter at the largest part. If the punch used is too large or has a short, quick taper, it will leave the metal thin on the sides and is apt to split the piece in the end. (See instructions for punching in Chapter 4.)

After the hole is punched, place the piece edgewise, just back of the hole on the bottom fuller, and with the top fuller on the upper edge directly over the bottom fuller as shown in Fig. 2, have a few blows struck with a sledge so as to mark the piece with a depression one-eighth of an inch deep on each edge. If the hole is pinched in, or closed a little by the fullering, no harm will be done, because it can be drifted out again, or will forge out naturally on the horn of the anvil.

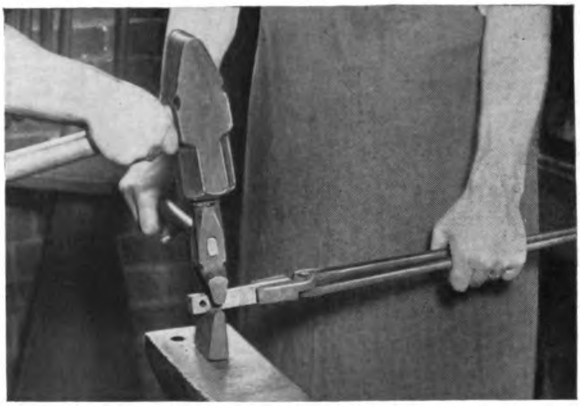


Fig. 2.

For large hooks the neck is fullered and a round boss worked up large enough for the eye before the hole is punched. Some workmen prefer this way for small hooks.

A one and three-quarter pound hammer is best for the size of work shown. The forging is completed with these tools. The shoulder back of the fuller mark should now be hammered down by holding and striking as shown in Fig. 3. This will make a tapered rectangular section, just a trifle over one-half inch square at the smallest part near the hole, and three-quarters by half an inch at the largest part.

Re-heat the piece, put the hole over the point of the horn of the anvil as shown in Fig. 4 and strike the corners and thick parts of the metal around the hole with heavy blows. Keep turning the piece around the horn, strike lightly on the thin places, and reverse the piece so that both sides will be forged out alike. The hole will now be the right size—½″ in diameter—and the metal about it will be ⅜″ round. Now place the piece on the flat part of the anvil, with the eye part of the hook projecting over the far corner, and forge the

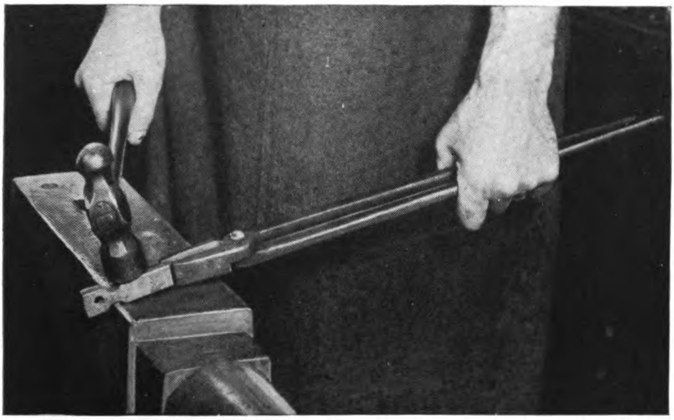


Fig. 3.

tapered rectangular part into tapered round, as large as the piece will make and not more than 1½″ long.

Next, heat the other end of the piece and draw it down to a tapered round ⅜″ in diameter at the end, and otherwise

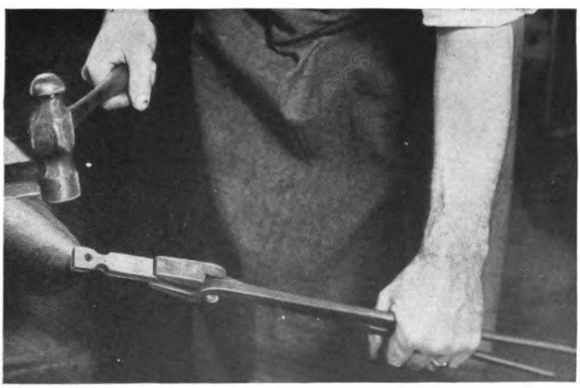


Fig. 4.

the same size and length as the other round part. Turn a small nib by bending about ¼″ of the small end over the corner of the anvil, and then heat the middle of the piece evenly through all the heavy part; hold it corner up on the face of the anvil and hammer down the corners enough to make oval edges on this thick part leaving the sides flat about two inches long. Cool the nib end and start the bend over the horn of the anvil, about one-third of the distance from the nib to the eye as shown in Fig. 5. Lay the back of the hook on the anvil face, the eye and back of the piece will then be horizontal on the anvil, while the small end of the hook is almost vertical as seen in Fig. 6. Strike this small end in such a way as to bend it closer to the back of the hook. Done in this manner, the stock will upset somewhat, while, if it is bent over the horn to the desired shape, it would stretch and batter probably making the inside edge of the hook too thin. When it is curved to within one inch of closing, it is time to hammer the bevel on the sides, and should be reheated. Take care all the time to preserve the thickness of the inside by holding at such an angle to the anvil face as will make this middle portion like a wedge with the sides beveled alike.

Fig. 5.

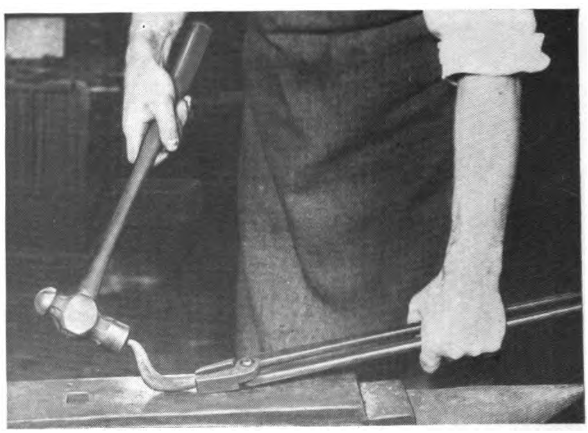


Fig. 6.

Holding and hammering this bevel, as shown in Fig. 7, will draw the hook around turning it enough to complete the curve so that the opening is three-quarters of an inch from

Fig. 7.

point to back at the closest place, while the throat is left about one-eighth of an inch wider.

Now heat one inch of the stem under the eye, dip the eye in water about half way to cool it, so a hammer blow will not knock it out of round. Rest the stem, back down, on the point of the anvil horn, and strike the eye to curve it back out of the way in loading the hook. An experienced man can make a chain hook of this kind in five heats, and it can be done in twenty minutes, but for good, smooth work, six heats and thirty minutes' time is a better allowance.

GRAB HOOKS

A grab hook is just wide enough open to admit the diameter of the chain link. They are easily made of square stock. Figure 8 shows two of them made of $\frac{3}{4}'' \times \frac{3}{4}'' \times 7\frac{1}{2}''$ the right size of stock for a $\frac{3}{8}''$ chain according to the empirical formula on page 75, which accords with good shop practice and has been verified by laboratory tests to prove the formula. After the eye of this hook is forged it may be bent toward either corner. When bent with the eye hole at a right angle with the hook point and used to catch over a link above after the chain is wrapped around a load, the link in the eye of the hook pulls more torsion than it would if the hook was bent so the point came in the same direction as the eye hole, like it does in the left hand picture. This style of hook is therefore preferable for a large class of work. These hooks can be forged on the anvil with no other tools than a hammer and punch. A careful workman will make them as smooth and free from tool marks as these pictures, by making the eye after slightly flattening two opposite side corners for one inch at the end then punching the hole and rounding the eye as shown in Fig. 4, and described for the chain hook, after this is done the bend is started as in Fig. 5. But to finish bending, the back of the hook must not rest on the flat of the anvil but in a right angle corner, or the outside corner of the square that is to

Fig. 8.

become the outer edge of the hook will be flattened. By holding the partly bent hook on the table against the end of the anvil face with the hook point projecting upward at an angle of forty-five degrees and striking on the end of the outside corner the bend can be completed and the hook closed to within 1/16″ of the link diameter, the hammer marks and the flat place made on the outside corner near the end can now be removed by drawing a slight taper with four flat sides which improves the appearance of the hook.

GATE HOOK

This hook is shown to illustrate how to forge a shoulder and twist square iron for the purpose of ornamentation. In Fig. 9 the square bar is held with one corner turned up, the hammer will land on the piece where it touches the corner of the anvil then the other corner of the square will be turned up, by hammering only the part that is over the anvil it is made round and the anvil corner forms the shoulder which marks the square part of the piece from the round, then the hook eye is bent out of this round part and a similar round part is forged on the other end of the piece and the hook bent to its proper curve.

Fig. 9.

To twist it the piece is made red hot in the middle, the cold ends of the square part can be held in tongs as shown in Fig. 10, and twisted one full turn. This makes all corners show on each side in the part that was red hot when the twisting was done and is a neat ornamental piece of work.

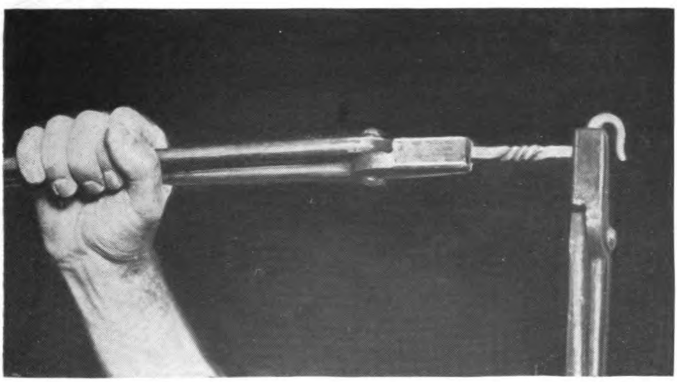


Fig. 10.

Heavy bars should have one end fastened in a vise while a wrench is used on the other end for twisting. Wrought iron should be an even red heat in the part to be twisted and cooled in water if necessary up to the place where the twist should end, for red hot iron gripped tightly in vise or tongs will be compressed and the corner of the hot metal that is crowded against the corner of the jaw of the vise or tongs will be nicked and present a broken line in the curve marring its beauty.

EFFECT OF HEAT

Irregular curves and twisting will occur at uneven or high heats. It is a curious fact that iron heated above redness does not always bend or twist as easily as it does at a fair red. At a high yellow or white heat a square bar may be held at one end while the other is twisted and sometimes no effect of the twisting will appear on the corners of the square in that part which was the hottest though an irregular and uneven twisted effect will appear in those parts of the bar that were not too hot. This is particularly true of Swedes iron. But the exact shade of color that is best for bending or twisting common wrought iron cannot be known without trial on a piece of the same composition. Owing to the varying amounts of sulphur and phosphorus in it some iron will bend or twist easily and safely at a low red heat while other pieces that are high in those impurities break with the same treatment. Wrought iron made of Swedish ore is uniform and dependable because it has very little of any other element in it. The chemical composition of steel also is usually more definitely fixed than common wrought iron, and the proper working heats for Swede's iron or steel can be more accurately stated. Intelligent workmen easily learn to vary the heat according to the quality of the material and the kind of work to be done on it. A fair red heat is always right for bending or twisting Swedes iron or steel.

The formula given here is intended to help those who know how to make hooks, to select the proper size and shape of stock for making them to suit any ordinary chain used for common purposes.

FORMULA

Empirical formula to determine the right size of stock for hand-forged *Hooks* to suit any round link stock.

l.d. is for link diameter.
D.H. is for diameter of hook stock.
L.H.S. is for length of hook stock.

Grab Hook to pull full load that the chain will stand $\begin{cases} 2 \times \text{l. d.} = \text{D. H. Sq.} \\ 10 \times \text{D. H.} = \text{L. H. S.} \end{cases}$

Hoist Hook to pull full load that the chain will stand $\begin{cases} 2\frac{1}{2} \times \text{l. d.} = \text{D. H. Rd.} \\ 7 \times \text{D. H.} = \text{L. H. S.} \end{cases}$

Chain Hook to pull half the load the chain will stand $\begin{cases} 2 \times \text{l. d.} = \text{D. H. Rd.} \\ 6 \times \text{D. H.} = \text{L. H. S.} \end{cases}$

2, 2½, 6, 7, and 10 are the constants for any size of chain made of round stock.

Example for grab hook, on chain made of ⅝″ round stock:

$2 \times \frac{5}{8}'' = 1\frac{1}{4}''$, $10 \times 1\frac{1}{4}'' = 12\frac{1}{2}''$, a piece of square material 1¼″ in diameter, 12½″ long should be used.

Example for hoist hook, on chain made of ½″ round stock:

$2\frac{1}{2}'' \times \frac{1}{2}'' = 1\frac{1}{4}''$, $7 \times 1\frac{1}{4}'' = 8\frac{3}{4}''$, a piece of round material 1¼″ in diameter 8¾″ long should be used.

CHAIN MAKING

To make a chain link, a piece of stock the right length must first be cut. If the link is of the size and shape used in the tests given in our table of tests, the calculation would be as follows: Link 2″ long, ⅞″ wide inside measure, two ⅞″ half circles make up the ends, leaving two straight sides each 1⅛″ long. As two ⅞″ half circles equal one complete ring of ⅞″ inside diameter, we must add the thickness of the stock to that diameter, and multiply by 3.1416 or 3 1/7, which is the figure most commonly used in forge work; ⅞″ plus ⅜″ equals 1¼″; $1\frac{1}{4} \times 3\ 1/7$ equals 3.93, or practically 4″ of stock required for the two ends; 1⅛″ plus 1⅛″ plus 4″ equals 6¼″, the length of stock needed for the link. This should be heated in the middle, and bent into a U shape, then the inside corner of each end should be scarfed on opposite sides as in Fig. 11, bent in and lapped for welding, one end on top of the other when the link lies flat on the anvil, as seen in Fig. 12, after which it is rounded and forged smooth on the horn. Turning

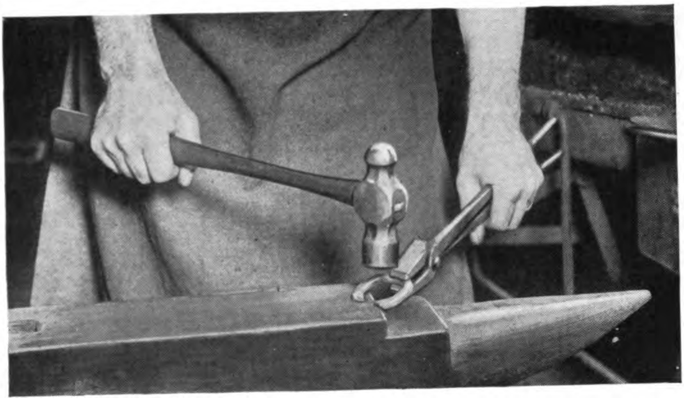


Fig. 11.

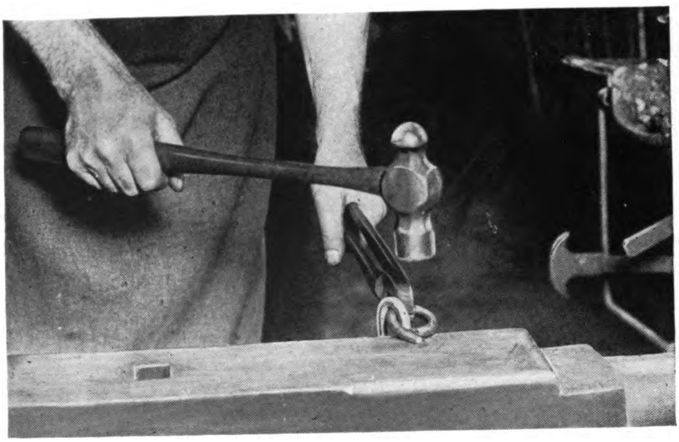


Fig. 12.

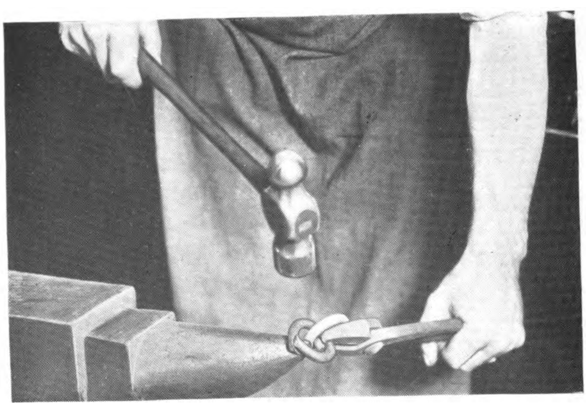


Fig. 13.

first one side and then the other to the position shown in Fig. 13.

In a chain factory small links are bent in power machines which coil long bars into oblong rings, that are afterward cut off at an angle through the metal. This sheared angle forms scarf enough for welding. Thus the chain maker of small sizes takes only one heat for each link, laps it and completes the weld also at this heat. But the best of chain, and all large links, such as short, thick anchor and hoist chains, are made of iron handled in the manner described. A smith and three or four helpers, working together, heat and bend, then heat and scarf with a top fuller and finally heat and weld each link carefully.

Standard chain links are not proportioned as the samples shown here, but are shorter and narrower. They should measure inside as wide as the diameter of the stock plus one-sixteenth of an inch, and be three times the diameter of the stock in length.

The tests tabulated on the next page are of actual results, given in such a way that it is hoped they can be well understood by those who have made no previous study of such subjects.

A large number of American iron links and many Swedes iron and other chain hooks were tested. All were forged by the same workman, carefully hammered to exact dimensions, given in preceding pages the heat treatment being the same on each piece of the same kind of stock.

SOME LESSONS TO BE LEARNED FROM THE TESTS

It will be seen by an examination of the tests given for hooks, links and rounds, that a hook of this design is well adapted for three-eighths inch chain, and that with chain wrapped around the load and fastened in the ordinary manner, 4,000 pounds, or two tons, could be lifted. But this should not be considered as a "safe load" in the usual meaning of that term, as repeated stresses of that weight would cause failure, or probably a long continued load of one ton in the hook, or two tons in the chain would result in failure somewhere, some time.

The object we have in giving the result of these tests in this manner is to show actual results and let our readers judge for themselves.

In order to determine the best kind of material for small hooks and chains, the following tests have been made on a large number of pieces. The hand made hooks were all of the same pattern and dimensions, and all specimens of like material were treated in the same manner.

CHAIN LINK TESTS

Material tested.	Load lifted without sign of failure.		Light overload with slight failure.		Heavy overload causing destruction.		Effect on piece.	
	Max. lbs.	Min. lbs.	Max. lbs.	Min. lbs.	Max. lbs.	Min. lbs.	Max.	Min.
3/8″ rd. common iron links............	4200	4000	5000	5000	10000	5200	Broke in end not welded.	Broke in end welded.

HOOK TESTS

Material tested.	Load lifted without sign of failure.		Light overload with slight failure.		Heavy overload causing destruction.		Effect on piece.	
	Max. lbs.	Min. lbs.	Max. lbs.	Min. lbs.	Max. lbs.	Min. lbs.	Max.	Min.
Hand forged Bessemer or machine steel chain hooks	4440	3000	6430	4000	7440	7260	Snapped off.	Half broken.
Hand forged Norway or Swedes iron chain hooks	2085	2000	2275	2090	4800	4000	Pulled open without crack.	
Hand forged horseshoe bar or refined iron chain hooks..................	2500	2250	3000	2500	5230	4070	Half broken and twisted.	
Soft steel drop forged hoist hooks....	2300	1960	3440	2360	4120	3920	Pulled open without crack.	

SPECIMEN STOCK TESTS

Material tested.	Load lifted without sign of failure.		Light overload with slight failure.		Heavy overload causing destruction.		Effect on piece. Elongation per in.	
	Max. lbs.	Min. lbs.	Max. lbs.	Min. lbs.	Max. lbs.	Min. lbs.	Max.	Min.
3/8″ rd., 1″ long, Swedes iron	4000	3800	4200	4000	4800	4700	.57″	.55″
3/8″ rd., 1″ long, H. S. B. or refined iron	6000	5700	6100	5800	6670	5870	.38″	.25″
3/8″ rd., 1″ long, Soft steel	6000	5600	6400	5800	9670	8100	.30″	.30″
Common iron file finished to size, 3/8″ rd., 1″ long	5000	5000	5300	5150	5640	5600	.38″	.33″
Common iron commercial bar, as it came from store, 3/8″ rd	3800	3800	4000	3900	5970	5460	.33″	.30″

For the specimen stock tests, the 3/8 inch round pieces, 1 inch long were turned down from 1/2 inch stock and file finished in a lathe, the heavy ends were gripped so that the load pulled straight lengthwise; the 3/8 inch round, common iron commercial bar was gripped on 5 inches of each end so that 4 inches of it were affected by the pull, while, of course, only 1 inch of the other specimens was affected.

One of the interesting things observed in these tests is the great uniformity of Swedes iron in every case. This is indicated by the comparatively small difference in the maximum and minimum figures through a larger number of tests for hooks, and the larger difference in the figures for refined iron and steel hooks. In fact, no Swedes iron hook was pulled open one-sixty-fourth of an inch by a one-ton load, but an increase of so small an amount as eighty-five pounds in one case and less than one hundred pounds in several cases, caused them to open, and stay open, this short distance.

One refined iron hook was sprung back to its original shape when the load was taken off, and did not take its permanent set until it had been pulled open one thirty-second of an inch by a load of three thousand pounds. The steel hooks had still greater springiness. Though one of them opened one sixty-fourth at one thousand pounds, it required a load of four thousand four hundred and forty to open another the same distance. One took a permanent set when one-sixteenth of an inch open with a load of four thousand pounds, while the other did not remain open until it had been successively loaded and opened, as follows: 4,600 lbs. 1/32″ open; 5,400 lbs. 1/16″ open; 5,730 lbs. ⅛″ open; at 6,430 lbs. ¼″ open, then it remained 1/16″ open, when the load was taken off. When a load of seven thousand one hundred pounds was applied, it began to fail rapidly, and when the load was increased one hundred and sixty pounds more, it snapped off.

There was no difference in the heat treatment. In fact, no attempt at heat treatment for the steel pieces, except to forge them and allow them to cool afterward in air. All the specimens were in their natural condition, so the variableness of steel, and the uniform reliability of Swedes iron is well shown in these tests.

Of the links broken for this test, some were rough welds, made with only ten hammer blows — two on each side and six on the end. These always broke in the welded end, but showed a clean break almost square across the weld, often leaving the point of the scarf welded to each opposite side. In some cases the break was at the tip end of the lap, but we found no portion of the weld torn loose in any of these fractures, though none of them broke with a load of less than five thousand two hundred pounds, all of the rough welds being near that figure.

The smooth, well finished welds that had been reheated and forged as neatly as possible, always gave the higher tests. Only a few links bore the maximum load of ten thousand pounds, and broke in the unwelded end as several others did at a lesser load. These fractures were not such square, clean breaks nor so coarse grained as the others, but were torn, with roughened points instead of grains showing on the broken end. Sometimes when the fracture was in the welded end, it had followed the line of welding, but as the pull required to cause such fracture was about the same as that which sometimes pulled a link apart elsewhere, this did not refute the evidence in favor of well working welds at good heats with a hammer.

The three-eighths round pieces that were pulled in two, show what might be expected of the different qualities. Swedes iron stretched enormously, and necked down to nearly one-eighth of an inch in diameter at the middle of the piece before it broke, while the American refined iron necked down to less than one-quarter inch, and the common iron to nearly one-quarter inch before breaking.

If we consider strength and reliability only, omitting the factors of possible stiffness and wear, it would seem that Swedes iron for hooks, and common iron for chain, is the safest and best material.

The slight difference in heat treatment likely to occur at the forge of a good workman makes no appreciable difference in the properties of Swedes iron, and welds that are as good as the rest of the piece are not at all difficult to make with common iron, while the reverse is true of the other kinds of material used for forgings. A chain or hook is no stronger than its weakest part, is a truism that needs no argument.

PART TWO

Part Two treats of welding iron and steel, with instructions for preserving the strength of the materials

CHAPTER VI

WELDING

WHAT A WELD IS

The short definition of the verb weld according to Webster's dictionary is, "To press or beat into intimate or permanent union."

The New Century dictionary defines the noun "weld" as "a solid union of metallic pieces formed by welding; a welded junction or joint."

"To unite or consolidate pieces of metal or metallic powder, by hammering or compression with or without previous softening by heat."

For the learner, however, a careful study of the following is recommended as containing the substance of what ought to be said on the subject.

"**Welding is** and has long been a matter of great practical importance, chiefly in the manufacture of iron and steel and of the various tools, utensils and implements made of those metals. Iron has the valuable property of continuing in a kind of pasty condition through quite a wide range of temperature below its melting point, and this is a circumstance highly favorable to the process of welding. Most metals, however, pass quickly, when sufficiently heated, from a solid to a liquid condition, and with such welding is more difficult. The term "welding" is more generally used when the junction of the pieces is effected without the actual fusing-point of the metal having been reached. Sheets of lead have sometimes been united together by fusing the metal with a blow pipe along the two edges in contact with each other, and this has been called autogenous soldering, or burning, if the heating was done with a hot iron. Still, "the difference between welding and autogenous soldering is only one of degree."—(Percy).

"The term welding is also used in speaking of the uniting of articles not metallic. Most metals when in the form of powder can be consolidated or welded into a perfectly homogenous mass by sufficient pressure without the aid of heat.

The same is true of various non-metallic substances, such as graphite, coal, and probably many others."

OTHER METALS

Welding should be thought of as a true metallic union between pieces of like material caused by heating and hammering. This in its simplest form is done with puddled or wrought iron, but low carbon steel can be welded almost as well. High carbon tool-steel can not be welded successfully by hammering, because it falls so suddenly from a hard state to a fluid at high heats.

Tool-steel of 80-point carbon, which is good for cold chisels and similar tools, can be welded solidly to iron but not to steel of the same kind.

Copper can be welded to iron at the forge, but its use in this manner is of no practical value.

USE OF FLUXES

A flux is used for converting the oxide into a fluid at a lower temperature than would make it a liquid without a flux. The oxide of a metal must be thin enough to splash off or be swept from the surfaces to be put in contact for the weld, or metallic union can not take place. Borax sprinkled on iron or steel that is at a high yellow heat will cause the thick, slimy, sticky oxide which covers it to become so fluid that it will drip or splash off when the piece is struck. As the oxide forms a scale when it is cold, any of it remaining between the surfaces that were placed in contact will prevent perfect welding of the pieces. So, for pieces which would be injured by a heat high enough to make its oxide liquid, this flux should be used.

Sand, dolomite, pulverized marble or glass when used for a flux are valuable principally for the fact that their particles clinging to the thin edges of the piece to be welded, prevent them from being burned while the thicker parts are being heated. If borax is mixed with them the chemical action is obtained also.

KINDS OF WELDS

A few simple welded joints and the way to handle them are the only illustrations that will be used in this book. These are fundamental and should be learned before attempting to make other forms of welded joints which are more difficult to handle.

Butt Welding

A butt weld is made by joining two pieces end to end. It is most frequently done with round or square pieces several feet long and not less than three-quarters of an inch in diameter; smaller sizes lose the heat quickly and bend so easily that butt welding them is more difficult than with stock over three-quarters of an inch in diameter.

To butt weld two long bars is a two man job. Hammer the corners of the ends back so the centers will touch first, then heat for welding and place them end to end; while in that position strike endwise on the cold end of one bar while the other is held rigidly enough to receive the shock of the hammer blow; this upsets the hot part and it should be hammered on the sides enough to reduce it to the right diameter and complete the work.

Jump Welding

A jump weld is joining the end of one piece to the side of another, in a manner similar to butt welding.

V, or Split Welding

If the end of a piece is split in the center, and opened to receive the side of another piece, it is called a split weld. This is an excellent way to join steel to iron, endwise; the iron piece should be split and opened in the form of a V and the steel scarfed like a wedge to fit the V; they can be put together before heating to weld and then heated and hammered endwise and on the sides, making a solid joint. Sometimes the end of both pieces is split and opened like a V and the two clefts crossed and pushed into each other where they are closed on the pieces, locking them into position for welding. This form of split or cleft welding is often practiced with steel that is difficult to join by simple lap welds.

Lap Welding

Two pieces that have been upset and scarfed are shown in Fig. 1, held in position ready for welding. The piece held by the left hand is on top of the other so the tongs in the right hand can be dropped without disturbing the position of the piece, and the hammer which is ready at hand can be caught quickly to strike the blows that will cause the plastic metal to flow into that intimate union called a weld. The face of the scarf should be 1½ times as long as the thickness

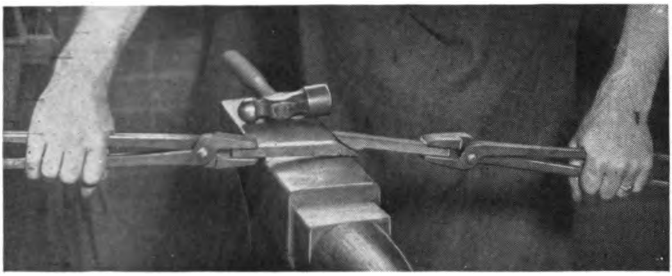


Fig. 1.

of the piece. This fixes the length, and the angle of the lap is less than 45°. The thin point of the scarf cools more quickly than the thick heel, so the point of the under piece is not touching the cold anvil. Metal conducts heat about four hundred times as fast as air, and the experienced smith has learned to avoid as far as possible the chilling effect of slow hammer blows or lingering contact of the hot material with other tools.

T. Weld

Another lap or scarf weld is shown in Fig. 2. This is called a T weld. If the material of which it is made was diffi-

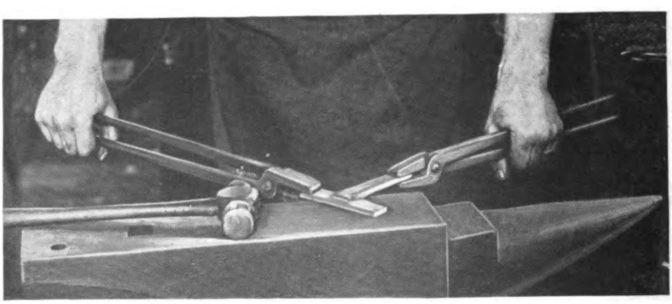


Fig. 2.

cult to weld, the piece held in the left hand could have been split and opened so the other piece would lie in the V. Then with contact on two sides, a more solid joint might be produced, or if the piece held by the right hand was larger and the material easy to weld it would be simpler to make end contact only with the left hand piece, and hold it vertical while it was struck with the hammer on the cold end, making a jump weld.

Corner Welding

The lap weld corner is stiffer than a bent corner. Rocker plates for the crooked framed sills of wood for agricultural machines, cars, wagons, carriages and the like are better if the iron fiber is crossed by such a lap and scarf weld, as is shown in Fig. 3.

When the corner is to be finished more or less than a right angle the scarf and lap should be made accordingly. When tensile strength only is required of a weld, care should be taken to keep the fiber of the stock parallel with the direction of strain. But if transverse stress will be applied to a weld

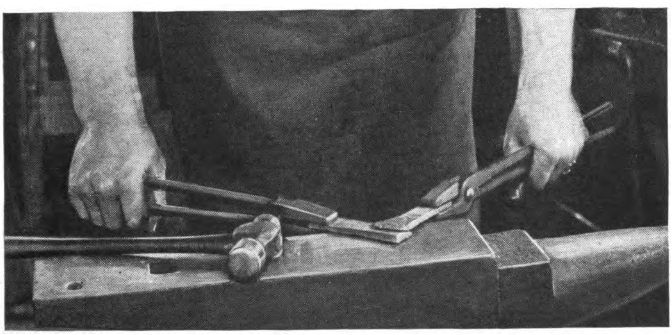


Fig. 3.

the crossed fiber which adds to the rigidity of the piece is permitted.

This does not apply to steel forging as emphatically as it does to wrought iron.

A fillet welded inside, or a "dutchman" welded on the outside, to build up a forged corner stiffens more and is often a more economical way to finish such pieces than with stock all of one piece, which makes the so-called solid forging.

FAGOT, OR PILE WELDING

A good opportunity to study welding conditions is given in Fig. 4. Only that portion of the piece which is seen in the pile or fagot on the anvil is to be welded. The rest of the bar serves as a handle or porter bar that is cut off after the weld is made and the forging is finished. As the piece is of

Fig. 4.

good size and convenient to hold it is not difficult to study the conditions that must be controlled while working with this piece.

There are only three things to be learned about this work, —

The proper heat condition must be produced in the piece. It must then be placed and kept in *the right position.* Then it must *be properly hammered.*

Allowance to Weld On

In Fig. 5 the size of the top and bottom swages is shown

Fig. 5.

to be ¾″, and the width of the bar is seen to be the same as the diameter of the round that is being finished in the swage, the thickness of the bar is just half its width or ⅜″. Now it should be observed that the pile for the weld in Fig. 4 is three times ⅜″.

Therefore the allowance to weld on is one-half of the diameter of the finished forging; this allowance is not all for loss. In fact, one half of this extra piece is not usually lost in the welding heats taken by experienced workmen, but in this as in many welded joints it is best to have that much allowance to weld on, so the piece will be of the right thickness after the hammering necessary to make the weld has been done.

Heating to Weld

Put the piece in a clean bright fire and guard against excessive oxidation by keeping plenty of coke burning around it. The depth of burning coke under the piece should be five inches, and the fire should not be over four inches wide. On top of the piece three inches of burning coke should be piled; it is then in the midst of the fire at the hottest place.

Oxidation

The oxidation that is a source of trouble when excessive, will serve as an indication of the welding heat, for the metal is sticky when its oxide ceases to be so under the influence of heat. The oxide that covers the piece that is heated to 1600 degrees Fahr. is plastic and sticky, and remains in this condition until the metal is made several hundred degrees hotter, so it can not be expelled from the joint by the shock of the hammer blows, without using a flux. It can be scraped off of the piece, but a new coat is formed so quickly that much of it would remain in the joint, causing serious defects in the weld; but wrought iron will stand heat considerably higher, so the temperature should be raised to the degree that makes the oxide a fluid so thin that it will splash when quick hammer blows strike it hard enough to make the metal flow, in the joint. If no impurity from the fuel is allowed to remain in the joint and the weld is treated in this manner, it will be as strong as the material in which it is made, if the "fixing" mentioned in Chapter 3 is right.

Strength of Welded Joints

The imperfections and corresponding loss of strength in welded joints is of more consequence in lap welds like Fig. 1. It is very difficult to determine what allowance ought to be made for loss in the tensile strength of welded rods or bars, but some conclusions may be drawn from the chain link tests given in Chapter 5, where it will be seen that some of the welded joints of the links were stronger than the rod of which they were made.

Hammering a Weld

The first blow should land over the middle of the joint as shown in Fig. 4. This allows the oxide to escape from the end of the joint as well as the sides. Rapid hammer blows should be delivered until the entire length of the joint has been covered by them, then the piece should be turned bottom side up and hammered an equal amount. Next the other two sides or edges of the joint must be hammered equally, and the welding is complete.

Forging the Weld

Fig. 6 shows the use of a top and bottom fuller to make depressions in the corners of the square forging to mark the place where another shape begins. Then after the corners of the square from the middle of the fuller marks to the end of the piece are hammered down and this part of the piece is partly rounded as it is held on the flat face of the anvil and struck with the hammer, it may be finished true to size and shape in the swages, holding it in the position

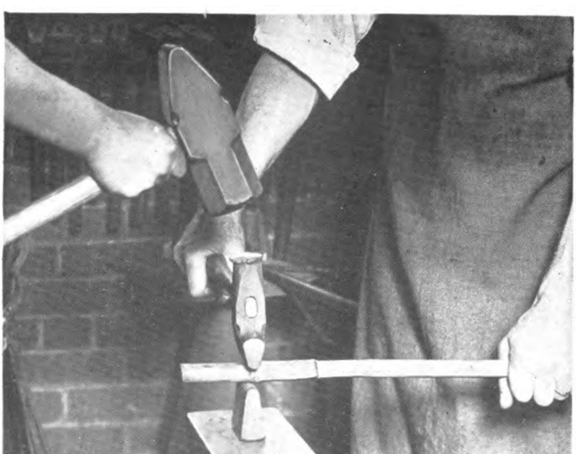


Fig. 6.

shown in Fig. 5, and turning slightly between the blows of the sledge.

A Reason for Welding

Fig. 7 shows the finished forging, and it illustrates how

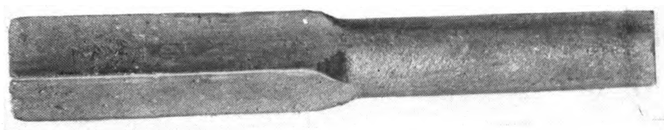


Fig. 7.

large forgings may be made out of small pieces of stock by fagoting, or pile welding.

When this amount of thermal and physical treatment has been correctly given to a weld of this size the metal is in as good or better condition than the material of which it was made. It is the way common wrought iron is changed into refined wrought iron.

It is not difficult to learn to do correctly any one of the three essentials for good work. But getting the time and manner of "proper heat," "right position," and "good hammering," correct for all sizes and kinds of material, requires much study and practice.

WELDING RINGS ON SHAFTS

A piece of square or round stock bent into a ring to fit a shaft, can be solidly welded into place. When it is some distance from both ends of the shaft it is called a collar, and

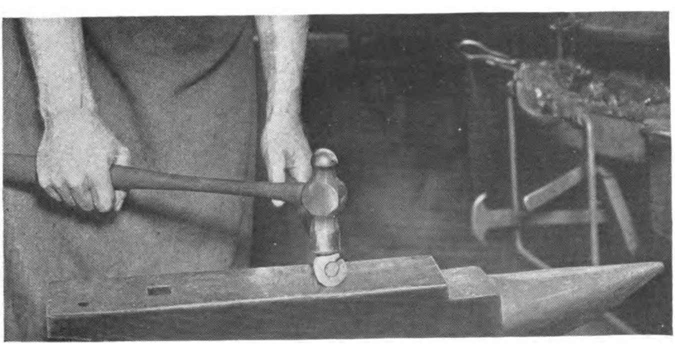


Fig. 8.

if it is flush on the end of a round shaft as shown in Fig. 8, it is a head and the piece can be used for a bolt.

Weld Head Bolts

Bolts headed in this way are not recognized as standard and an authorized size for the heads can not be given. It is customary to make them larger than the standard for bolt heads given in Chapter 4. Rings made of square stock one-fourth less than the diameter of the shaft should be bent to fit the shaft as shown in Fig. 8, the ends of the ring separated 1/16″.

To Get the Welding Heat

The shaft should be heated first to a yellow color, then the ring be put in place and both pieces raised to the white welding heat. It must then be placed in the position and the first hammer blow landed, as shown in the picture, on that quarter, to close the space between the ends of the ring, and weld it to the shaft at the same time. The next hammer blow must land on the quarter nearest the other end of the ring. This welds the ends of the ring together and the bolt head can now be forged to the size and shape desired.

EYE BOLT WELD

Work of this kind should be done as shown in the illustrations, after the end of the piece is pointed or scarfed, and the two shoulders or sharp bends made as shown in Fig. 9. That portion of stock between the shoulders is bent into a ring forming the eye, while the scarfed end lies on the bar and the shoulders meet as

Fig. 9.

seen in Fig. 10, where the piece is at welding heat and in position for the first hammer blow. It is important for the strength and symmetry of this forging that the welded joint should be kept central, the side that is uppermost gets the most effect of the hammer blows, and the metal flows away from them, so before the welding heat is lost the piece must be turned half over so the other side may be hammered enough to keep the weld joint on the median line.

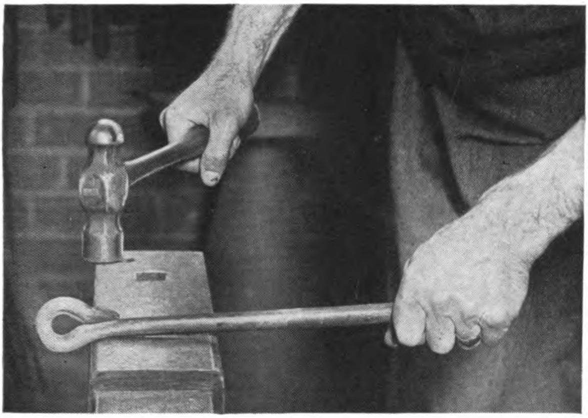


Fig. 10.

RING WELDING

Fig. 11 shows a ring in the finished eyebolt or cockeye, ready for welding. The tip or point of the scarf on the

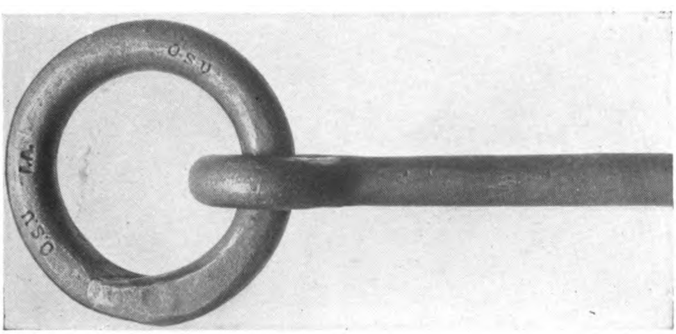


Fig. 11.

ring is lapped over until it rests on the heel or thickest part of the scarf of the other side, these points should be blunt, or rounded, not thin and sharp, or they will lose heat so quickly that they will not be welded when the piece is hammered down to size. The point of the scarf for lap welding should always have enough body to hold the heat until it is hammered enough to make the weld.

A good way to hold small pieces for making scarfs ready to lap for welding, is on a corner of the anvil as shown with a link in Fig. 12. The hammering to weld, should begin at the position shown in Fig. 13, and the piece rounded as in Fig. 14.

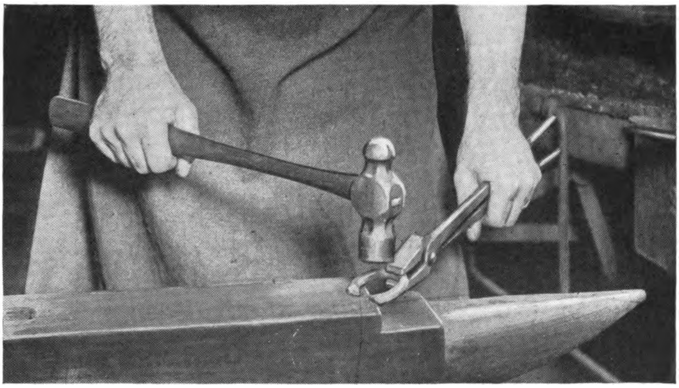


Fig. 12.

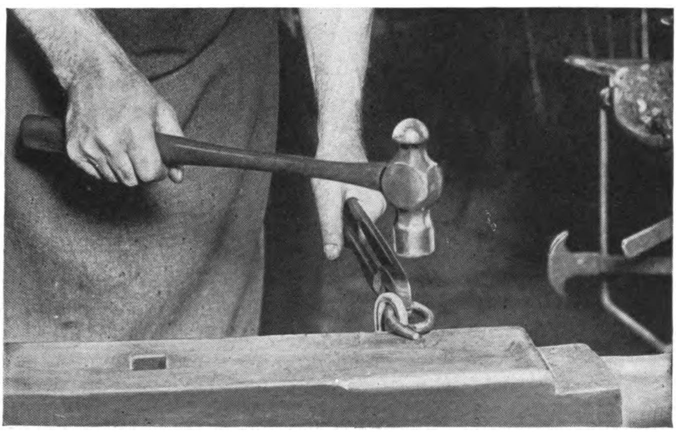


Fig. 13.

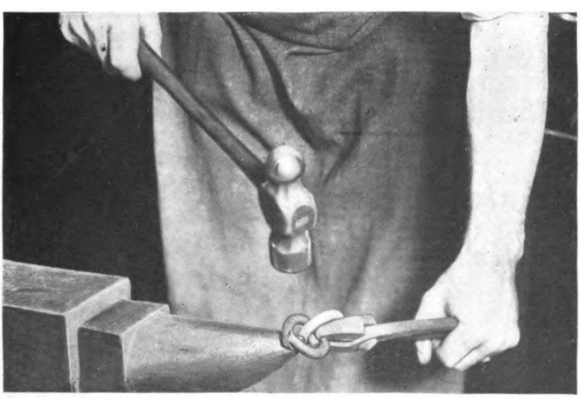


Fig. 14.

CHAPTER VII

SPECIAL WELDS: STRENGTH AND COST OF WORK

THE SWIVEL

To make a swivel, such as is shown in Fig. 1, a piece of round stock is upset and scarfed on the ends, then bent to a U shape and the scarfed ends welded on opposite sides of a nut. Then a bolt is forged with a round head and a stem about half the size is drawn down on the other end. After putting the bolt through the hole in the nut, the stem is bent into a ring and the free end of it welded to the shoulder of the bolt.

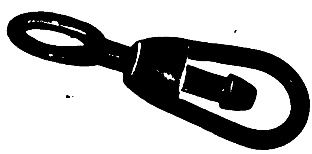


Fig. 1.

THE ROPE HOOK

A hook with an eye that has been drawn down to a smaller size than the bar, bent into a ring, and welded where the end laps on the bar similar to the cockeye shown in Fig. 9, Chapter VI, can be easily and quickly made of round stock and is good for a rope or light chain hook. See Fig. 2.

Fig. 2.

TURN BUCKLE

Six scarf and lap welds are required in the piece shown in Fig. 3. The two nuts are made by bending rings of rectangular stock and lap welding the ends, then the side bars are welded on to opposite sides of the nuts; the welds in the rings should be covered with the lap of the bars. Made in this way the fiber of the material runs in the direction of the greatest strain in service.

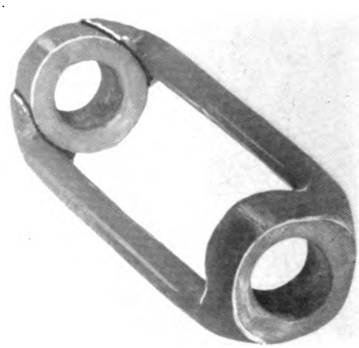


Fig. 3.

SOCKET WRENCH

This piece, Fig. 4, has three welds in it. The handle is best welded to the stem by the cleft weld method, the stem being split to sufficient depth to allow the open ends of the V to lap one-third around the handle on each side. A welded ring made of flat stock is driven part way on the other end of the stem, and after welding it in place, the socket can be formed to fit any shape of nut desired.

Where power machines are used for forging, this socket can be made more cheaply by the extrusion or squirting method in dies, such as are shown in the illustration of special tools in Chapter II., Fig. 21. For this method a piece of stock the same diameter, but some longer than the socket part outside, is put in the die and the punch forced into it forming the socket and flowing the metal of the hole to form the stem.

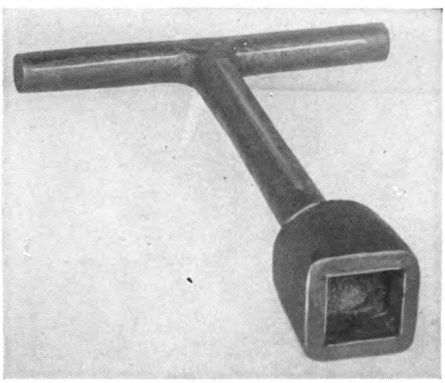


Fig. 4.

LARGE SHANK WELD

Fig. 5 represents a piece of work about the *limit of sizes* that can be made in ordinary forge fires; the stem of one inch square iron was welded to the ¾″ x 4″ by the jump welding method. Two fires are used for heating the separate pieces. Special care must be taken at this work to remove the dross and cinder from the flat piece before the

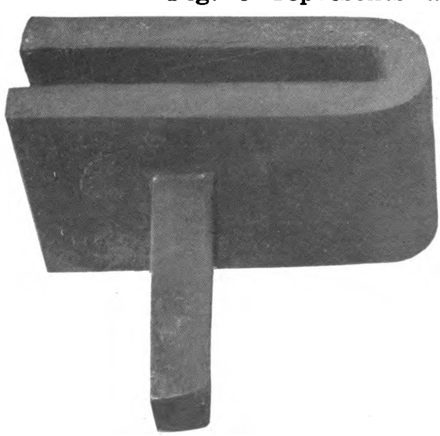


Fig. 5.

stem is placed for welding, and the center of the weld must unite first or the oxide will remain in the joint, weakening it greatly. When properly done, a tool shank, such as is shown here, can not be torn out at the weld, as the 1″ x 1″ will break easier than the joint.

FOR ORNAMENTS

Bundles of rods bound with wire can be welded at the ends, for useful purposes. In Fig. 6 are two bundles so

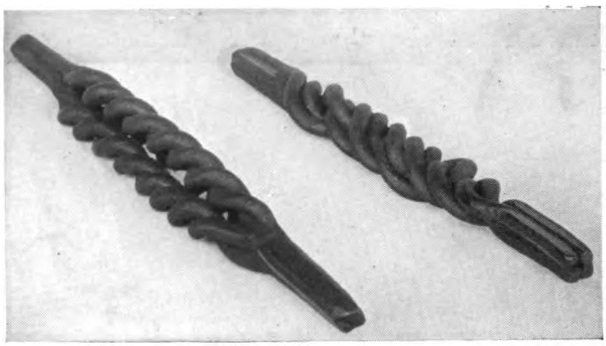


Fig. 6.

welded to be used in ornamental designs. Two bundles of two rods each were welded at both ends and twisted to the right, clockwise. After that the two pairs of twisted rods were made into one bundle welded at both ends, and twisted to the left, counter clockwise, giving the tangled effect shown in the illustration.

Many other designs can be worked out in this manner. One of the most interesting, being balls of basket work with metal ornaments inside, seen through the meshes. To make this, a larger number of rods, bundled together with the metal ornaments in their midst, are welded at both ends, and then separated along the middle by curving each rod outward to form the ball or oval that may be called for. It is not necessary to give further illustration or instruction on this phase of the subject, for whoever has made the pieces that have been described is prepared to invent and make many other welded forms.

WELDING STEEL TO IRON

Excellent tools are made with bases of material that will not harden, having material with hardening properties welded to the faces that require it. Fig. 7 shows such a tool

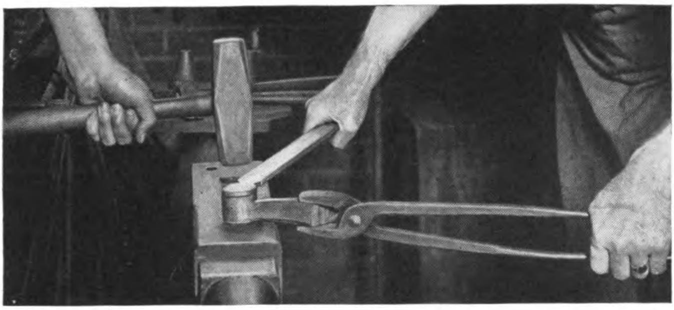


Fig. 7.

being made. The base has been forged of wrought iron, the stub end, which is held by the tongs, is scarfed ready for welding to the piece that will serve for the handle which will be ⅞″ round iron, 14″ long. In the illustration, the disc of crucible steel that is partly cut from the bar, in the right hand of the smith, is being welded by the blows of the six-pound hammer held by the helper. When heating for this weld, the large piece should be made the hottest.

USING A FLUX

When both pieces in Fig. 7 are yellow hot, borax or welding flux is put on the surfaces that are to come in contact for the weld, then the iron is made white hot, and the steel a bright yellow. The borax liquifies the oxide and is splashed off with it, or if the surface is large it may be swept off with a broom the instant before the pieces are put in contact.

DANGER OF NOT GETTING FLUX OUT OF WELD

Any borax or welding flux that remains in the joint weakens it. Usually the contact of pieces can be made in such a way that it is squeezed out of the joint as the welding proceeds. If this can not be done, it must be quickly swept off before contact is made for the weld, because any imperfection in the weld for this kind of tool would permit the thin, hard face of it to break, which it will not do when solidly welded to the unhardened back or bottom part.

USE FOR STEEL TO IRON WELD

As seen in Fig. 8, this forging is completed for a *bolt heading tool.* After the hole is drilled, the face of the top of

Fig. 8.

the tool is hardened by heating and quenching, as is fully explained in Part III of this book. The bottom or iron portion will not harden or become brittle or springy.

LIGHT FORGING

All the pieces illustrated in this book are classed as light forgings. Larger pieces and heavier welds can be made at an ordinary forge. The sizes shown are best to practice on before undertaking larger work.

HEAVY FORGINGS

Any weld or forging that is too heavy to be man handled is classed as heavy forging, and the mechanical appliances used to handle them would require more extended explanation than we have room for. Putting pieces that weigh over 100 pounds together by welding, or forging pieces that weigh over 200 pounds each, is heavy forging.

ELECTRIC WELDING

A method of welding has been invented by Elihu Thompson, which appears to be capable of being employed with a variety of metals on a very extensive scale. In this, which is known as electric welding, a current of electricity heats the abutting ends of the two objects which are to be welded. These are pressed together by mechanical force so arranged with reference to the electric current that there is a great and rapid accumulation of heat at the joint, in consequence of the greater conductivity of the rest of the circuit. This method of welding in some cases, partakes of the nature of autogenous soldering, the pieces of metal being actually fused while uniting. In other cases, as with iron, nickel, or platinum, the union may take place without fusion as in ordinary welding. In electric welding the pressure which forces the metallic surfaces together may, in the case of a plastic metal like iron, be either quiet or percussive in character. In autogenous soldering a more delicate and quiet pressure is generally preferred. In case of large articles hydraulic pressure can be used to force their surfaces into contact with each other.

Heating pieces with electric current at the junction to be welded is a good practice for many forms of welding in iron and steel, and makes the welding of other metals more simple. Bars butted together and clamped so that pressure between the abutting ends can be increased at will, become heated at the junction by electric current flowing through them until they are united by fusion or welded by sufficient pressure. As the electrical resistance is greatest at the junction, the metal welds without heating more than one diameter of the piece either way from the joint. And the practical uses to which the process can be put are many. Long seams of continuous welding in sheet steel or spot welding instead of riveting lap joints are easily accomplished by this process. It saves labor and time, besides being clean and accurate; and does not require the long training and experience necessary to learn how to make good welds at the forge.

THERMIT WELDING

Oxide of iron mixed with aluminum ignited in a crucible evolves heat twice the temperature of melted steel.

A definite quantity of iron heated in this way, and poured around the metal to be welded, heats the parts to be joined and unites with them into a homogeneous mass. Close fitting joints of broken pieces should be opened by drilling, and when a shoulder is to be formed around the joint, twice as much thermit as it takes to fill the space, and make the shoulder, should be provided in the crucible.

The chemical composition of thermit may be made to suit the kind of material that is to be welded. Thermit joints are by analysis and test for strength, the same as average steel castings. Large quantities of thermit heat so quickly as to be dangerous after being ignited in the crucible, steel chips or punchings may be added to retard the evolution of heat.

Other metals than steel and iron may be welded with special thermits. But since its invention ten years ago, the process has been limited to the metals named.

HOT FLAME PROCESSES

Melt welds are made by heating with the flame of oil or gas. New welding machinery has been developed in the last fifteen years with which oxygen is forced into the flame so that intense heat is evolved and directed to the part to be welded.

Oxy hydrogen flame is twice as hot as melted steel, and quickly melts the material locally.

Oxy acetylene flame is 1000 degrees hotter and therefore more concentrated than oxy hydrogen; when the material to be welded melts in the flame the operator adds metal with a melt bar. High carbon steel, cast iron, copper and other metals can be united by these processes.

STRENGTH OF WELDS

A perfect welded joint is as strong as the metal of which it is made. Quite often it is refined and improved so that greater strength throughout that portion of a bar that has been lap welded is not unusual. But frequently patches of oxide or other impurities are left in the joint causing weakness that must be considered. Some handbooks for engineers advise them to subtract 30 per cent. for loss of strength due to welding, and if the material is to be used to its ultimate strength that figure is an average of the most tests the author has seen. But a safe rule is to use the elastic limit of annealed material as the ultimate strength of welded sections. Good welds always stand over 30 per cent. above the elastic limit of annealed stock before breaking, so this may be considered a safe load for welded joints.

COST OF WELDING

Without full information about the method of heating and handling welds, a correct statement of the cost can not be made. But we give here an estimate of the cost of labor and heat, for scarf and lap welding, one joint at a time, as has been illustrated.

½ cent for each 1/16″, including 1/2″ round stock.
1 cent for each 1/16″, including 5/8″ round stock.
1½ cents for each 1/16″, including 11/16″ round tsock.
2½ cents for each 1/16″, including 1″ round stock.
3½ cents for each 1/16″, for sizes over 1″ round stock.

Three-quarter inch diameters and over require two or more workmen, and the power and heat required increase approximately in geometric ratio, while the size is in arithmetical progression. Square bar welds are equivalent to rounds ⅛″ larger for each inch of the diameter. Flat bars are in proportion to squares. But the corners of rectangles are more liable to injury from excessive oxidation. This injury from too much air blast,in proportion to the fire, was explained in Chapter I.

EXCESSIVE OXIDATION VALUE

There is a value also to be gained from excessive oxidation, for with a blast of air at a pressure of two or three pounds per square inch, metal that is at the white welding heat may be kept in that condition where the blast strikes it while being forged into shape. If it is kept too long a time in this strong blast, the hot portion of the bar will be destroyed. It is rapidly burned unless it is worked upon quickly while exposed to this strong blast of air.

PART THREE

Part Three is on the treatment of steel, with instructions for making types of tools that are in common use

HEAT AND TREATMENT OF IRON AND STEEL

INTRODUCTORY STEEL WORKING

There are special things made, and many methods employed in certain shops that have no commercial value to us who may never use them, but we can read of them with interest. Even if we get no financial gain from the time spent in studying them, if they increase our stock of general information and knowledge of things pertaining to our work in life they are worth while.

The efficiency of a steel tool depends as much, or more, on the way it is treated by the toolsmith, as on the kind of steel furnished by the steel maker. We shall treat the subject almost entirely from the toolsmith's point of view. There are some things few toolsmiths ever think about. For instance, you have used files for many years, perhaps; some may think we had better files, or better steel, years ago than we have now. The file has been a standard test for hardness of other tools for more years than the writer has been on earth. Yet a little careful investigation of this common tool has resulted in great improvement as reported in 1907:

"A British machine was developed for mechanically testing files and autographically recording the result. The autographic record shows the cubic inches removed by a file from a standard test bar, the number of strokes taken, the period when the file cuts most effectively, and when it ceases to cut because of being worn out. The publication of comparative results obtained from tests made on files purchased in the open market created a sensation among file makers and file users. The difference between the best files and the poorest files was so great that a manufacturer clearly could not afford to use the poorest files, even if supplied free of cost. This result, of course, merely confirmed what every intelligent shop manager already knew, but the mechanical record of the actual difference in cubic inches removed and strokes made was a more definite proof.

"The valuable result of the file testing machine's work is the great improvement that has taken place since the file maker was given the means of accurately testing his product. At the advent of the file testing machine, the best files were able to remove about 12½ cubic inches, and the best files were about twelve times as effective as the poorest. In 1907, two years after, the filemakers had so improved their product that the best file tested removed at the rate of eight cubic inches per 10,000 strokes, and 55 cubic inches of cast iron with one side of the file, or about four and two-fifths the total removed by both sides by the best files of two or three years ago.

"If it was possible to produce such a remarkable improvement in the hand file, simply because of the use of an adequate testing appliance, what might not be the result in other lines of manufacture, if rigid efficiency, so-called, is only comparative, and no one can say anything has reached ultimate efficiency. Now that attention has been called to that simple, yet perplexing tool, the file, it is entirely possible that its manufacture and action will not only be greatly improved, but changed. In fact, a radical change in file making has already been made."

Files are made of crucible tool steel, forged and hardened; they are a common standard testing piece for steel work done by toolsmiths, and this improvement in their quality will increase their reliability.

TEMPERATURES

The subject of steel treatment is not as well understood by artisans as it should be, but much progress has been made during the last decade. It is only in recent years that instruments for measuring high heats have been brought to such a degree of perfection as to make them of value to the experienced workman, and greater care and intelligence is needed to get more uniform results with the instruments than by the color of the heat radiated. In fact, one method should be used to check the other, as will be seen by a comparison of the following parallel tables copied from the same journal less than ten years ago, but published two years apart, as the temperatures corresponding to the colors commonly used to express different heats:

COLOR NAMES

TABLE 1.

FOR HIGH TEMPERATURES.

Dull red	1022° F.
Full cherry	1292° F.
Light red	1562° F.
Full yellow	1742° F.
Light yellow	1922° F.
Very light yellow	2012° F.
White	2102° F.

COLOR NAMES

TABLE 2.

FOR HIGH TEMPERATURES.

Dark blood red, black red	990° F.
Dark red, blood red, low red	1050° F.
Dark cherry red	1175° F.
Medium cherry red	1250° F.
Cherry, full red	1375° F.
Bright cherry red scaling heat	1550° F.
Salmon, free scaling heat	1650° F.
Light salmon	1725° F.
Yellow	1825° F.
Light yellow	1975° F.
White	2200° F.

"Different observers have quite a different eye for color, which leads to quite a different range of temperature covering the same color. Further, the quality of intensity of light in which color heats are observed influences in a great degree the determination of temperatures by the eye."

The difficulties in the way are again referred to in the Government reports of J. W. Reilly, Major Ordnance Dept., U. S. A., Watertown Arsenal, who says in the "Report of Tests of Iron and Steel," 1892, Vol. 29:

"It is intended to extend the observations to a general investigation of the subject of tempering steel, operating with steels covering a wide range of chemical composition. Much obscurity at present surrounds this subject, and it is not generally understood what treatment is necessary to produce maximum results as regards strength, or how the physical properties may be controlled by varying the tempering methods."

CHAPTER VIII

FORGING STEEL AND TOOL SMITHING

Forging carbon tool steel has a different effect upon the metal than similar operations on wrought iron or machinery steel because the crucible tool steel has that energetic element carbon in it, so combined with the iron and of such quantity that the structure and properties may be completely changed by the treatment. When one knows what physical changes of the properties to expect from different methods of treatment, learning how to forge it becomes a simple problem to one who knows how to heat and hammer into shape wrought iron, or the soft steels now so commonly used in place of iron.

THE HEATING FIRE

Crucible tool steel should be more carefully heated than the other materials of which forgings are made, and the intensely hot and rapid fires of gas or oil, so well adapted to heating the metals forged by others, should not be used by the toolsmith. His fire should be made of clean, soft coal, well charred or coked in sufficient quantity to cover the pieces as they are heating, and if there is a suspicion of sulphur in the fire it should be cleaned out, because red hot iron will absorb sulphur, and it is one of the worst enemies to steel. As iron absorbs sulphur, and we are not so particular about the injury to it, a heavy bar kept red hot in a fire for five or ten minutes may be used to take up the sulphur before heating the steel.

PROPER HEATS

Get the steel hot enough; don't be afraid. Toolsmiths have heard too often that time-worn advice, "Don't overheat the steel." Get it as hot as it will stand without injury and pound it hard; it will stand a yellow heat — work it fast, with rapid, hard blows until it is reduced to as near the size and shape you want it as can be done at one heat, and if cracks or flaws can not be seen, the high heat did not hurt it.

Now, if the piece has been made nearly the right size by this working, don't get it so hot next time, but finish off the corners, edges, flat surfaces, and do the bending or straightening at only fair red heats.

When a piece of crucible steel is to be reduced in size, say one-half, by hammering, it should be heated more than red hot. If it is not more than 120 points carbon, it will stand a bright yellow heat without injury, and if it is hammered promptly and thoroughly, the same amount on both sides until it is a dull red, it will be as tough and strong as it can be made without the special treatment of tempering.

If it is not well hammered while cooling from that high temperature it will be brash and weak, coarse-grained, poor looking stuff in a fracture; the hammering hard enough to affect the piece clear through its diameter with blows as rapid as they ought to be, prevents the growth of large crystals, which make the coarse grain, and if the hammering does not cease instantly at the dull red heat, just before the dark blue spots appear, the grains will be broken apart inside under the skin. That scaly, packed hammered surface may look smooth and perfect, but the steel is ruined inside, and can never be of much service as a tool.

There is greater danger in working the steel too cold than too hot, for if it is overheated and instantly struck a good forging blow it will be so cracked, checked, or bursted, that any careful man will know better than to try to use it for a tool, while if it is not hot enough when it is worked, the flaws are inside and may not be discovered even when the tool fails too quickly in service.

CUTTING AND HAMMERING STEEL

The percussive force of hammer blows is better for steel than pressing or rolling. Crucible cast steel that is intended for cutting tools is reduced from ingot size, which may be ten inches or more in diameter, by successively heating and hammering until it becomes the size and shape required, then it is nicked and broken into lengths convenient for handling as commercial bars of flat, octagon or round; the rounds of tool steel are not finished in a swage or die, as iron or soft steel would be, but like the other shapes are finished on a plane anvil with a smooth faced hammer.

Carefully observe tool steel bars and the inequalities usual to hammered work with its sharp corners and edges unlike drawn or rolled steel can be easily distinguished. So the bit or point of cutting tools should be hammered as nearly perfect as possible in size and shape to make the best tools.

CUTTING COLD STEEL

When a bar of tool steel has been nicked with a cold chisel, file, or grinder, it can be broken by striking it a sharp blow with a sledge, and this is the usual way of getting pieces the right length for tools. But it is wasteful of material, though saving of time, for it would take a deal of good time for a workman to heat and cut the lengths off with a hot chisel, and it is cheaper to waste the stock than to spend the extra time, as the portion of the steel that is shattered by the cold breaking does not extend far into the bar, and the quickest and best way of finishing tools is by cutting off the ragged edges before or after the heavy forging is done.

FORGING MACHINE TOOLS

Fig. 1 shows how to hold and hammer stock for a cold

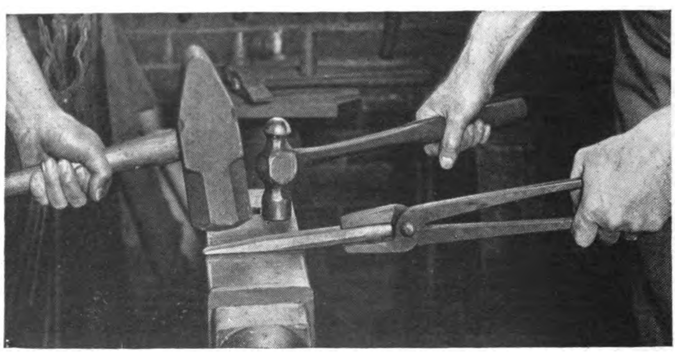


Fig. 1.

chisel; a round nose lathe tool is held and hammered in the same manner until it is the right width and thickness.

Fig. 2 shows the usual way of cutting a round nose lathe tool to shape after it has been hammered; it should be cut on line at the proper angle across the end to give the clearance necessary.

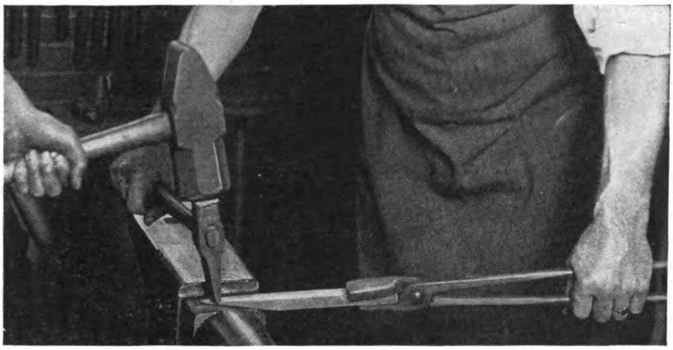


Fig. 2.

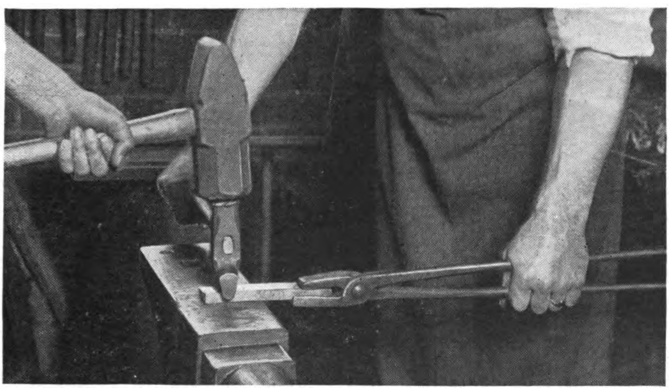


Fig. 3.

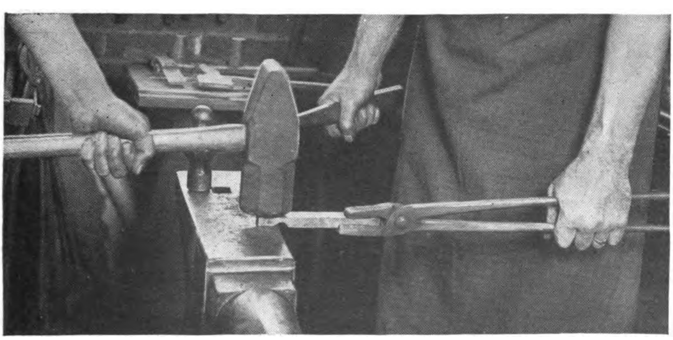


Fig. 4.

A series of eight illustrations showing the manner in which to handle a common type of machine tool that must be made at the forge, is shown here. When the steel is at a good forging heat, a fuller mark of the proper depth to leave thickness of stock right for the bit of the tool, is made as shown in

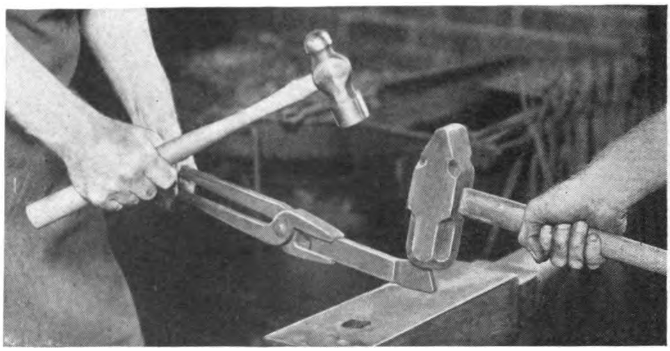


Fig. 5.

Fig. 3. It is then turned to the position shown in Fig. 4, and a few blows struck with the hammer and sledge; then it must be turned edge up and hammered lightly, see Fig. 5. Back and forth to these positions, the piece should be turned while it is being hammered to the length and thickness required.

Finishing the edges and flat sides of the bit may be done more quickly with a set hammer or flatter; both flat sides should be turned up to get the effect of hammer blows during the final smoothing of the surfaces, and the top or

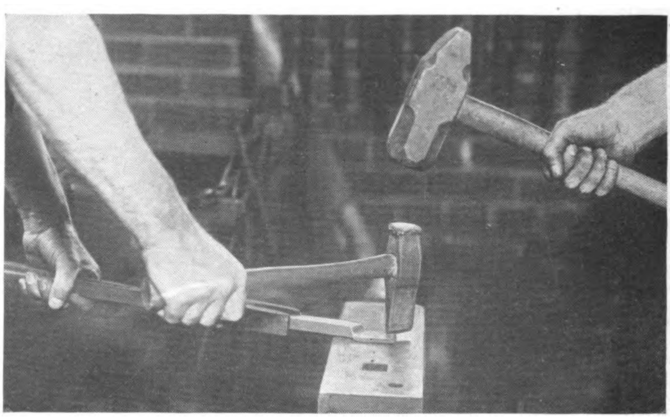


Fig. 6.

cutting edge should be turned up and given the final hammering to pack the grain and smooth its surface so that little grinding is required to bring it to a keen edge. Now the tool should be cut with a hot chisel, as shown in Figs. 6 and 7, to get rid of the surplus width on a thin tool that can not well be hammered as narrow as it ought to be without breaking the grains apart as previously described, and for the end clearance necessary to the purpose for which it is to be used.

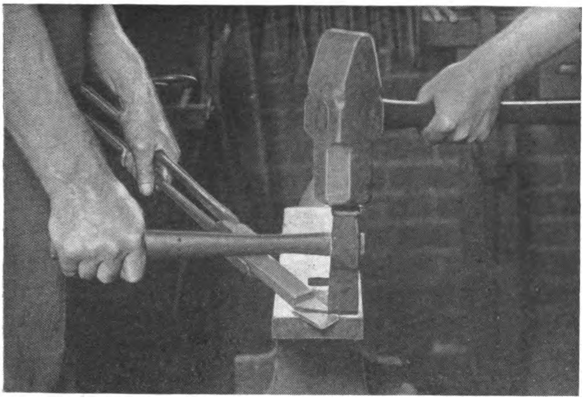


Fig. 7.

CLEARANCE ANGLE

The end clearance is usually close to 15°. In Fig. 8 a cone set up on a face plate is serving as a test for this angle, and also as a measure for the slope in the forged bit. As the

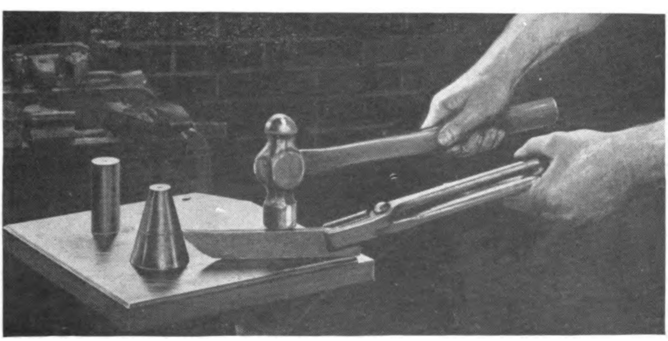


Fig. 8.

line around the cone is ⅛″ higher than the top edge of the stock of the tool where the hammer rests on it, and the end of the bit rises to the line, the slope of the tool is forged ⅛″. It is customary to cut more clearance on the end of forged tools than will be made by the grinder, therefore the tool in Fig. 8 tests right for slope and end clearance, and can be seen to have a bearing the full length of the stock on the level face plate, as all tools of this kind should have.

The bit of a cutting off, or parting tool, must be thinner on the bottom than on the top edge; this is for side clearance, and can be tested by the vertical post set up on the face plate. When the corners of the top edge of the bit touch the post and the lower corners do not, while the tool is level on the plate as shown in Fig. 9, there is enough side clearance for such tools.

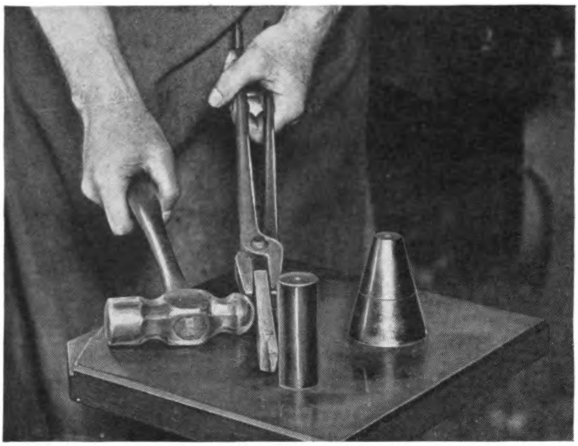


Fig. 9.

BENT TOOLS

A lathe tool of this kind is sometimes bent at the shoulder left by the fuller mark. This makes it more convenient to use as an outside threading tool.

A 30° angle is usually correct and is being tested to that degree in the illustration,

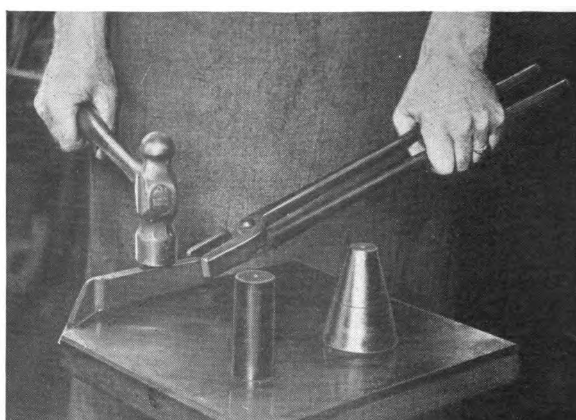


Fig. 10.

OFFSET EDGES

Another form of machine tool is made with an edge along one side of the bit which may be used for cutting with its full length, instead of with the end only, as those already shown are made to do. These are called side cutting or facing tools, and as they are to have clearance on one side only, the fuller mark should not be made clear across the flat side of the stock, but should be made, as shown in Fig. 11, deep enough on one edge only, to leave half of the stock, which is a common thickness of edge for the bits. The piece is then held and hammered in the positions shown in Figs. 4 and 5, and the surplus material cut from the bit as in Figs. 6 and 7. Then the top fuller is used again as shown in Fig. 12 to offset the edge from the body of the stock twisting the bit for side clearance of 15° as shown on the testing plate in Fig. 13.

Fig. 11.

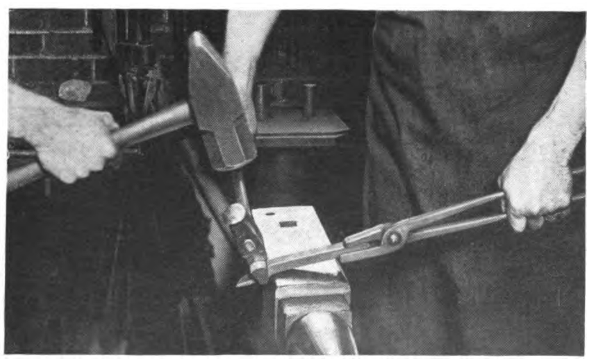


Fig. 12.

The cutting edges of these tools are usually on the left hand side as shown in the illustrations. Bits forged on the right hand side, make *left handed tools,* which are sometimes called for, but are not so commonly used in machine shops.

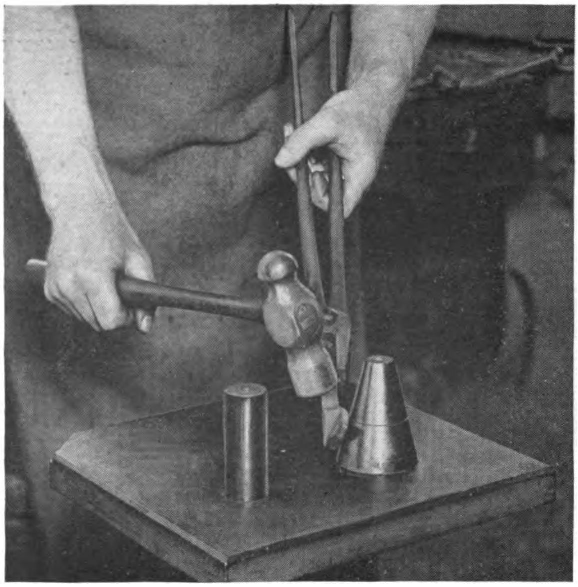


Fig. 13.

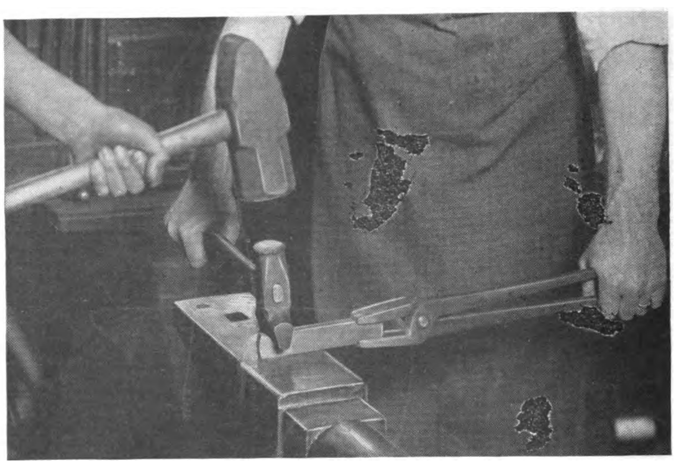


Fig. 14.

SHANK TOOLS

The diamond point tool is forged as it is held in the positions shown in the four illustrations. Fig. 14 shows

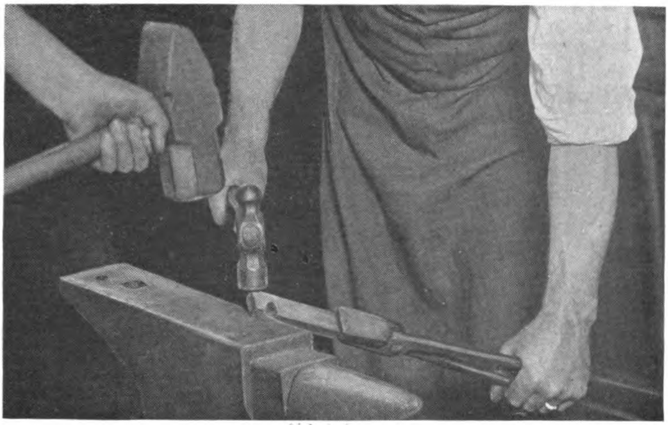


Fig. 15.

how the fuller is used to make the throat or shank of proper depth and length. Similar tools may be forged without this fullering for a throat by bending the full sized stock down and then holding as shown in Figs. 15 and 16 to hammer the shape required. The slope of this tool is cut with the hot chisel as shown in Fig. 17; that side of the bit on which the cutting edge is to be, is resting on the anvil, and the

Fig. 16.

hot chisel should be made to go through the piece so the cut will be finished on the side intended for the edge of the tool that is being made; this is important with all hot cutting to make machine tools.

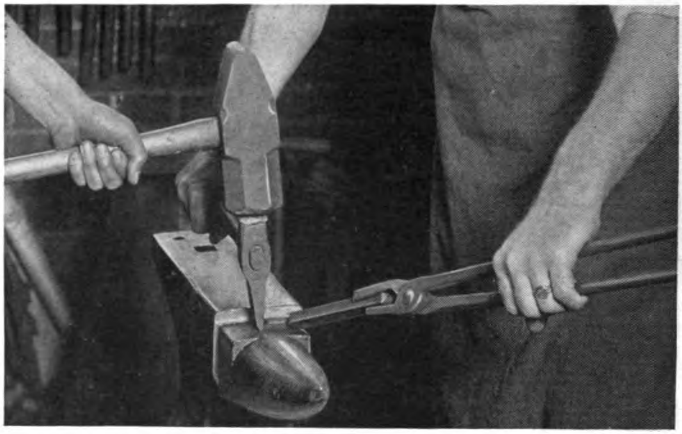


Fig. 17.

Boring, and inside threading tools are fuller marked on one edge of the stock, the same as in Fig. 14, far enough from the end to allow stock that can be drawn to the diameter

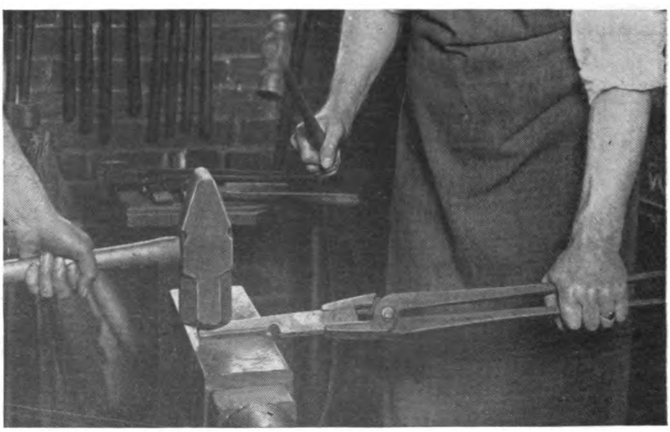


Fig. 18.

and length desired. This work is done with the hammer and sledge as shown in Figs. 18 and 19. The shape of steel pieces is finished on the flat face of the anvil; rounds of tool steel should not be swaged, but the flatter may be used if desired to smooth and straighten the forging more quickly and per-

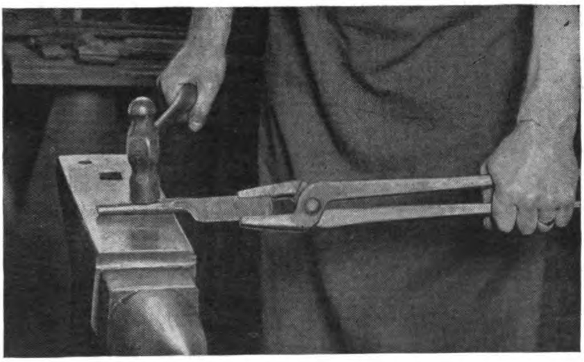


Fig. 19.

fectly than it can be done with the hammers. Bits are bent over on the ends of these forged shanks, hammered and cut to the shape and length desired; rake, slope and clearance must be provided, and may be tested as on other tools.

Forging such machine tools as are shown in Figs. 20, 21 and 22, is done by the right combination of the operations that have been described and illustrated.

HIGH SPEED TOOLS

Some self hardening steels must be forged at lower heats than carbon tool steel will stand. High speed tools are made of steels alloyed with other metals, and must be kept at a high heat when forging, as is more fully explained in Chapter 9.

THE TIME REQUIRED

A good toolsmith and helper can make and finish ready for grinding from eight to sixteen tools per hour. If he makes sixteen tools of a kind similar to those shown in the preceding Figs. in one hour, he will have to work fast and leave them so rough that it will take the machinist who grinds them about two hours to get them ready for work. On the other hand, if the toolsmith and helper spend an hour making eight well finished tools, the machinist can grind them ready for work in about thirty minutes; otherwise there is no difference in the tools, one lot can be made to do as much work as the other, for in either case the toolsmith that knows how to treat the steel will fix the physical structure and the properties of the metal in the best condition for the purpose for which it is to be used.

THE FORGING TOOLS USED

For steel of the dimensions shown (1⅛″ × ½″) the smith's hammer should weigh not less than 1½ lbs.; 1¾ or 2 lbs. would be a better weight, and will do on heavier stock as well.

The helper should have at least an eight-pound sledge, but a 12-pound sledge is necessary on heavier stock; 1½ × ¾ inch tool steel cannot be properly forged with less than a twelve-pound sledge, and if the steel is much thicker than that a still heavier hammer will be required.

A top fuller, a set hammer, a flatter and a hot chisel are the other tools used in addition to the anvil and fire. With these a toolsmith can make all ordinary cutting, punching, and battering tools of carbon steels, such as are shown in Figs. 20, 21 and 22.

When the learner can use these tools as they ought to be used on crucible steel, and follows the advice given here, he will have the forging in good physical condition, and it may be laid by to cool off, and to season for a time before receiving further treatment.

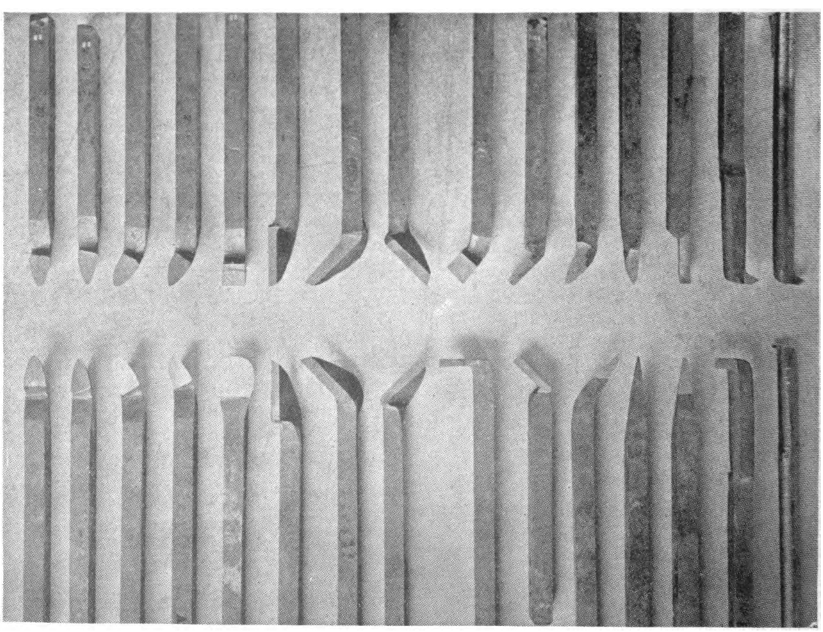


Fig. 20.

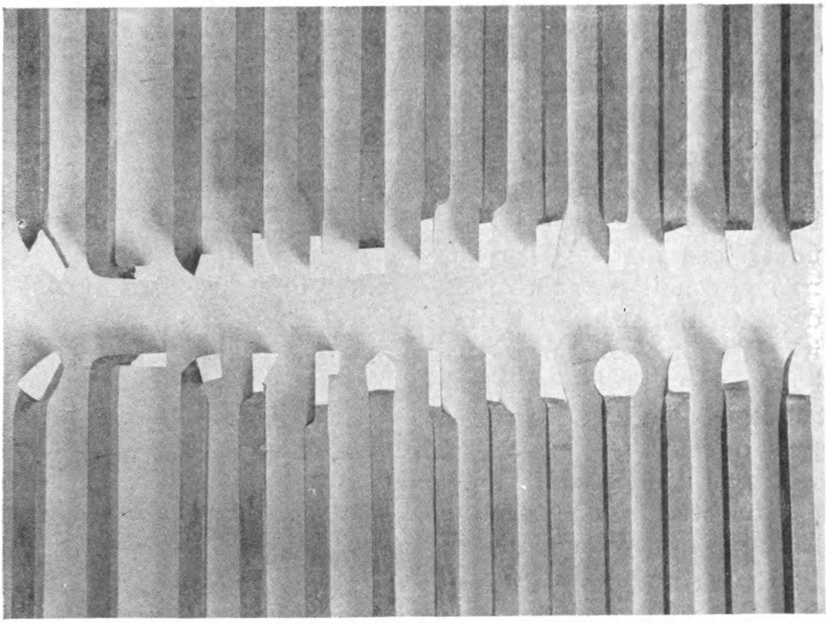


Fig. 21.

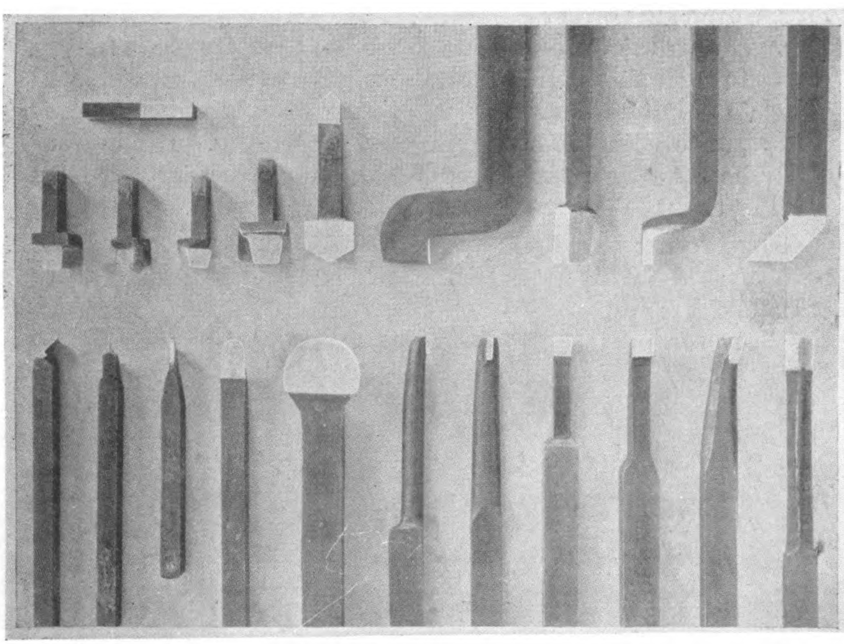


Fig. 22.

CHAPTER IX

HARDENING AND CARBONIZING

After steel is forged and has been allowed to season it is ready for further treatment. By seasoning it may be understood that it is properly annealed, or returned to its normal condition, at least, if it is left in a dry place to cool down from a red heat to the temperature of the atmosphere, it will be in its natural condition, and less liable to crack or burst when hardened, as tools so often do when the strain of sudden cooling is added to the forging strains. Besides this, there is sometimes much internal heat left in a piece that has just been hammered, and, if it is immediately returned to the fire, the steel may accidently get too hot for proper hardening before the operator is aware of it.

High carbon steel that has been machined or ground before hardening should be carefully annealed before the hardening is attempted, as such pieces are much more easily affected by heating and sudden cooling, for they have not the strong, tough hammered skin which protects the forged pieces to such an extent that with ordinary tools, such as cold chisels and lathe tools, it is not an uncommon practice to proceed at once with the hardening and tempering. It can generally be done by a careful workman before the forging heat is all lost, but it is not the best practice.

The processes and effect of annealing and tempering will be discussed farther on. Here we must consider hardening only, and the importance of having steel in the right condition, for the process must not be neglected, or many water cracks, flaws, and broken pieces will be the result. Failure to get the steel at rest before it is subjected to the violent shock of transformation from the soft and pliable state to one that is hard and brittle, causes many of the so-called mysterious breaks known to steel users.

WHY DOES STEEL HARDEN?

The reason why steel hardens can not be stated in terms that satisfy all investigators alike. It is a phenomenon that has never been explained fully and probably never will be. Much has been said and written about it that is true, and the microscope has shown to metallographists many facts about the changes that occur in the manner of the arrangements of the grains during hardening. The different color of these grains indicates that a new substance has formed, which we call "hardenite." A peculiar feature of the subject is that only one grade of carbon steel can be changed entirely into hardenite. That is, 80 point carbon steel when hardened appears when polished and etched for examination under a microscope to be a solid mass of the substance so named, see Fig. 1. While if the percentage of carbon in the hardened steel is less than .8%, patches of another substance known as "ferrite" may be seen, as in Fig. 2, and high carbon (over .8%) shows a different kind known as austinite, like Fig. 3. Ferrite will not harden, cementite and pearlite will, and one or the other of them is always found in the steel that is not hardened. Low carbon unhardened steel shows a structure of pearlite and ferrite; in medium carbon unhardened steel all pearlite; in high carbon unhardened steel pearlite and cementite.

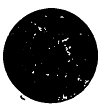


Fig. 1.

Fig. 2.

Fig. 3.

The portion that was pearlite is changed to hardenite if a piece of steel is cooled quickly from a high temperature, and in very high carbon steels so hardened, still other substances known as "austinite" and "martensite" may be seen. These grains are a new development of hardenite and differ but little from it in appearance, but it is sufficient to show that steel higher than .8% carbon is transformed by the growth of new granules within it which make it preferable to the medium steel for some kinds of tools that have hard, heavy cutting to do.

The fact is well known that 99.2% iron combined with .8% carbon makes a perfect compound, an alloy that is uniform throughout, and this saturation of iron with carbon may be called the only pure steel, and is explained more fully in Chapter XI. However, steel tool users find that when carbon is higher, keen edges will last longer, and with less carbon in the iron, tougher battering tools that are strong and hard enough may be made.

From time immemorial, toolsmiths have said, "cool the steel quickly when you have it right." The heated condition is fixed by sudden cooling. By quenching we cause the steel to show itself as it was when hot. A rapid cooling gives the status quo, the state into which the steel was brought by heating; sudden quenching fixes the hot condition, making the metal in a cold state show itself as it was when hot. Steel workers have handed down this idea from generation to generation, and until scientific investigation has agreed upon a better and clearer answer to the question, the writer has concluded to accept the traditions of men who make and treat the metal for the many uses to which it is applied.

HARDENING CRUCIBLE STEEL

This is done by cooling it suddenly from a high temperature. The manner of heating and cooling has nothing to do with the hardness, but much to do with the other conditions of the tools. Warping, bending, and checking the piece, usually result from careless work. Generally speaking, the hotter the steel is made and the more quickly it is quenched, the harder it will be, but as too high a heat will make it coarse grained, and very sudden quenching will often crack a piece, both of these things must be carefully studied.

Degrees of hardness are not easily defined and not understood alike by all. Steel that has been too hot when quenched will be more brittle and seem more hard by some tests than steel that is heated to the proper temperature and cooled at the best rate for that quality of steel, but it is weak in structure and useless for cutting tools. It will scratch glass, but it is liable to crumble, so it is best to concede that steel which is refined and made strong in structure by the hardening process is at the maximum hardness for that steel, because it is hardened to make the tool endure battering, pushing or sliding on, or into other material. Therefore, the mere fact that a diamond will scratch less deeply into coarse grained or improperly hardened steel, than into that which is properly treated, has little value to us in our present limited knowledge of the mysterious phenomenon "hardening," which changes structure and condition without altering the composition. We will show now how steel should be treated for proper hardening to what should be called its maximum hardness.

HOW TO HEAT STEEL FOR HARDENING

Small tools that have been hammered may be heated in the forge fire. There is no better fuel than good smithing coal for such work. The fire should not be excessively hot, and the fuel should be well charred or coked, with plenty of it to cover the piece. It should be glowing red, so that the steel may lie on a bed of coals at least five inches above the tuyere, and have a bank of red coals on each side of it, with several inches of fire over it, so the heating will be uniform, gradual, not too fast, and with as little oxidation as possible.

OXIDATION

Pieces that have been machined or ground before hardening are more liable to injury by oxidation than those protected with the skin made by hammering. A skin of oxide is formed on every piece that is heated to 400° F., at this temperature and up to about 1000° F., which is a low red, it is only a color that injures the material in no way except as a stain, but at a higher temperature a thick scale is formed, and the surface of a piece is left scarred and rough where the scale peels off. A well kept forge fire of good coal is not as bad for oxidation as gas or oil fires where the pieces are heated in the product of combustion. Even if the steel is heated

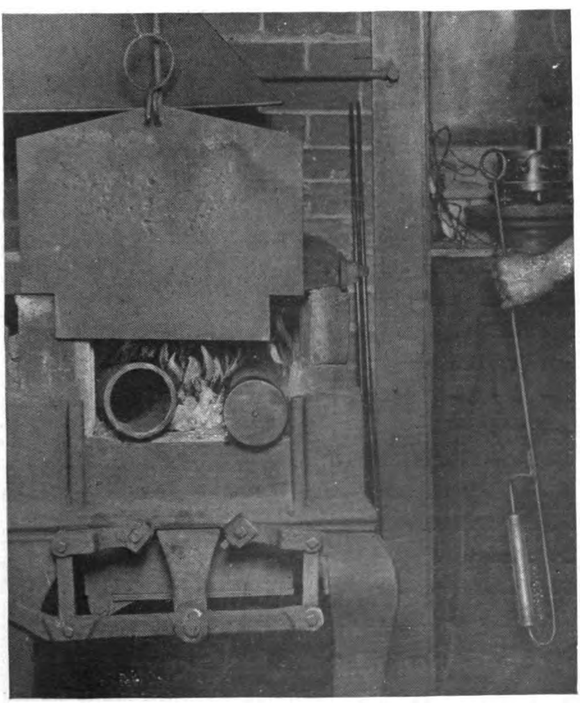


Fig. 4.

in a muffle, hollow tile, or pipe, as shown in Fig. 4, that can be closed at both ends, enough oxidation will take place to stain or color the pieces. Besides, there may be injurious chemical action from the gases, and red hot steel absorbs impurities very readily and is poisoned by some of them. Take the best available method of heating and get the steel just hot enough and plunge it immediately into the cooling bath. That is, do not let a piece get a little too hot and allow it to cool down in the fire or in the air before quenching. That would be quenching it at a falling temperature and retaining the condition it was in then, which is not the same as the transformation which takes place in steel when it is heated up to the right temperature, and the excess of oxidation at heats higher than necessary, is therefore, only part of the probable injury.

Scaling causes some reduction in the size of a piece and makes the refinishing after hardening a more expensive process. This can be lessened by heating in a bath. Alloys can be prepared which melt at known temperatures. (See tables in Chapter IV, page 64) and the heat of the steel placed in them may be regulated with a great degree of accuracy.

LIQUID BATHS FOR HEATING STEEL

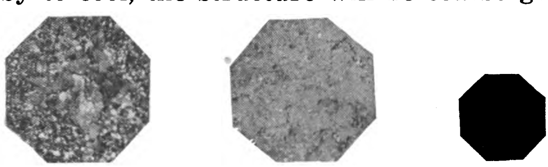
The most common use has been made of melted lead. Very accurate results can be obtained, particularly if a pyrometer is used to test the heat of the bath. In Fig. 4 the tempreature of the furnace is shown by the instruments to which the wires are attached. The same effect can be produced as often as desired with this apparatus, for the slight changes in air pressure in the fire and the condition of fuel that might contribute something to steel that was amongst the coals would not affect a piece that was inside the closed pipe or a pot of melted lead, whose temperature would remain fairly constant throughout the usual variations of a fire or the atmosphere. But the oxidation which colors polished steel would occur to some extent while the piece was being passed from the pipe or hot lead bath to the cold water bath, and some lead is apt to stick to it which hinders cooling. Besides this, the impurities of commercial lead at high heat may alter the chemical composition of some steels, and for very high temperatures, such as are required for some of the alloy high speed steels, the pipe would melt, and lead can not be used. Mercury, chloride of barium, metallic salts, and common salt are sometimes used as heating baths, and do not give off the poisonous vapors that arise from lead at high temperatures. Cyanide of potassium, which is used chiefly for the chemical effect it has on red hot iron, is poisonous to human life and gives off fumes at all temperatures that are injurious. Its use will be more fully described under the head of case hardening.

Pure lead melts at 617° F. and can be heated to double that temperature without difficulty, but it gives considerable trouble at high temperatures on account of oxidation.

Barium chloride melts at a little below 2000° F. and can be heated several hundred degrees above that point in a crucible of clay or graphite. A spoonful of soda ash will prevent its fuming, and as a film of barium chloride will stick to a piece until it is quenched, no oxidation can take place on tools heated in this bath. However, the high melting point precludes its use for ordinary carbon tool steels, as they must not be above the point of transformation of the grain, which occurs below 1600° F., when they are dipped in the cooling bath.

THE EFFECT OF HEAT ON STEEL

If crucible steel has been too hot when it was quenched, or when the last forging was done, or when laid by to cool, the structure will be coarse grained, like the first piece in Fig 5. The crystals will be large, and as the connecting places between large crystals are great, and it is a separation of crystals that causes steel to break easily, coarse grained steel is weak in structure whether it is hard or soft. Therefore a fine grained piece, like the last in Fig. 5, that is composed of the right elements is in the best condition for cutting tools. This illustration is a photograph of fractures through ¾″ octagon tool steel of .8% carbon. After it was overheated and kept at a high yellow heat for five hours and annealed, the grain size of one portion was refined by proper harden-



Coarse grain Overheated and annealed. — Refined by hardening after overheating. — Refined by hammering after overheating.

Fig. 5.

ing. Another piece was refined by forging to half size before hardening. A cutting test was made and the small piece was found to be not greatly inferior to steel that had not been overheated. The piece in the middle of the illustration was not as good as the one on the right, but better than the left hand piece.

EXAMINATION OF FRACTURE

If the composition is iron and carbon only, (which forms the only true steel when properly combined) the proper hardening heat can be quickly determined by the following experiments: Break a piece from the forged bar of carbon steel, and the grain will be bright and even with a light grayish color, and not very fine or small except perhaps around the edges where it has been packed by hammering. Now heat a piece of the same kind of steel to a low red and plunge it into water, keeping it under and moving it about to break up the film of steam that would surround it and prevent rapid cooling, and when it is cold and dry, break off another section. This fracture will appear more dense, a darker gray in color, with signs of tearing or a striated fracture, showing even, close, fine grains or crystals very small. The steel has been refined by hardening, because the heat was right for that kind of steel, and it is a fine strong silky fracture as it ought to be.

If another trial is made at a high heat, the quenched piece will show a fracture that is coarser grained, and by holding it at the high heat for some time, the crystals will grow very large. These crystals are fixed by sudden cooling and are made very bright and sparkling. Any sparkling lustre in the fracture of a hardened piece indicates that it was too hot when quenched; so it is by the lustre, as well as by the size of the grain, that a fracture tells the story of heat treatment. If the piece was not hot enough for perfect hardening, or the heating was done quickly, it will not be thoroughly refined. See Fig. 6. Though it may be partly hardened, it is not in good condition of structure for a cutting tool.

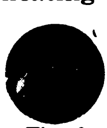


Fig. 6.

THE RIGHT HARDENING HEAT

The heat that refines any steel is the only proper hardening heat for that steel, and this heat varies with the carbon content. For 120 point carbon steel it is below 1150° F., or a low red heat. If the carbon is high, the heat should be low and vice versa.

Therefore, the following rule applies to all crucible steel: For high carbon (1.50% or more) a dark red heat, 1050 degrees Fahrenheit or less. For medium carbon (1.00% or less) a medium heat, low red about 1150° F. For low carbon (.50% and upward) heat to a full bright red, not over 1500° F.

The exact temperature for any steel can only be determined by experiments such as have been outlined above, and the rule given is intended only as a starting point from which to begin the experiments, as there are always present in steel some other elements besides iron and carbon, which have some effect on the results. These experiments must be made frequently by the toolsmith and his method varied accordingly.

CRITICAL TEMPERATURES

Tool steel that is being heated may be seen to glow suddenly, from a dull red to a clearer color, without any increase in the temperature of the fire where the coals are glowing red. The metal at a certain point increases its own heat. This is when the change in crystal size begins. It is the point of transformation, and the heightened color is caused by the action of the grains upon each other or amongst themselves. It is well called the critical point, for if now the fire is too hot this excess of heat being contributed to the steel while it is so agitated as to be raising its own temperature, will quickly overheat the piece to a degree that will create large crystals and a weak physical condition which is preserved by sudden cooling. The critical stage is at about 1100° F. in ordinary carbon steels, and as it is the point where crystals or grains that were large, irregular in size, or distorted in shape by previous treatment, such as bending, twisting, or pounding, begin returning to their natural size and shape; it is near the temperature at which the piece should be quenched to make it hard and to keep it fine grained and strong. The hardenite is forming at the critical temperature, and it is complete within a range of not more than 10 degrees above it, so any piece that is heated more than that will not be as fine grained as it ought to be when hardened, and if it was dipped when not so hot, only partial hardening, or imperfect structure of the steel would be the result. A curve showing critical and recalescence stages is given in Chapter XI.

RECALESCENCE

Steel that has been heated to a full red heat may be allowed to cool in air, and if held in a dark place, when the color of the steel has turned to a dark red, a sudden glow of brighter color may be observed which indicates an increase in temperature. This is the point of recalescence. The steel reheats itself for an instant by the transformation of its granules from one size and kind to another, and then the gradual and regular rate of cooling is resumed. Some steels have two or three such points, and they correspond quite closely to the points of transformation when the piece is being heated. The temperature of recalescence as well as the critical heat or transformation point varies with the carbon content of the steel. As it is the only perfect hardening point for any steel, the heat at which it is made maximum hard by proper quenching, those heats should be studied in every possible way. High carbon steel is transformed at a heat very much less than that required for medium or low carbon steels.

Hardened steel lacks magnetic permeability, but has magnetic retentivity. Unhardened steel lacks magnetic retentivity but has magnetic permeability until it is heated up to the critical temperature. Here its magnetic properties are suddenly lost. This fact is used in the laboratory for finding perfect hardening heats without depending on the eye for color, or the pyrometer for measuring temperatures, and it may be put to common use by toolsmiths.

COOLING BATHS

The most common medium is water for cooling steel to harden. This does not reduce the heat of a piece plunged into it as fast as mercury would at first, since mercury is a better conductor of heat, but water will take up more heat than mercury, and will cool the piece down to the temperature at which hardening is complete, or below the boiling point of water as quickly as it usually needs to be done. Mercury takes up heat rapidly; it gets hot quickly and soon is raised to a temperature of 648° F., where it boils, and steel is not completely hardened at that temperature. Hardening is finished at the boiling point of water, 212° F. Therefore, it makes very little difference how hot the water is, because the rate of cooling a piece through 1000 degrees by means of ice water is but little faster than with hot water, and it is the cooling *rate* that fixes the fine grains and hardenite of the steel. These are permanently fixed in the steel as soon as the temperature of 212° F. is reached, and will remain in that condition as long as the piece is kept below 212° F.; at this point softening begins in hardened steel. That subject will be dealt with under the head of tempering.

The water for hardening should be clean, and for perfect results must be pure. The impurities in hard water are likely to affect the results, but, as has been said about the heat of the water, there is no practical appreciable difference, unless water is so foul as to retard the cooling rate. Good, clean water is what is meant, and its effect is better if some salt is added. Alum, soda ash, sal ammoniac, and other ingredients are sometimes put in the water used for hardening, but are of no particular value except to preserve the bath and cause the surface of the steel to have a different appearance. Salt makes the chilling effect more constant and regular, as well as more rapid, while soda ash or alum makes the scale come off more freely and brightens the piece. Some of the stuff put into the water by experimenters may have a chemical action on the steel, which is more likely to be injurious than otherwise. So clean water is recommended for all ordinary tool work, and salt may be added in any quantity that pleases the hardener without fear of changing the results very markedly.

HARDENING IN OIL

Fats, tallow, grease, and oils are used for cooling some kinds of tools made of high carbon steel. When the piece to be hardened is of such shape that it is liable to crack in water, it can be dipped with more safety in grease or oil. Tools that are made with thin parts joined to thick parts, with sharp corners and angles, are very liable to break when hardened. The cooling rate in oil is slower than water, but sufficiently rapid to fix the hardenite in high carbon steels, if the section is not too large. Fish oil, linseed oil, and lard oil are chiefly used and recommended in the order named. Mineral oils are not dependable and give off foul odors that would make them objectionable, even if the results obtained by their use were found to be good. Fish oil is used especially for spring steel.

Car springs, carriage springs, and the like are usually hardened in it. The material of which springs are made is peculiarly liable to crack if hardened in clear water. It can, however, be done successfully in distilled water having enough

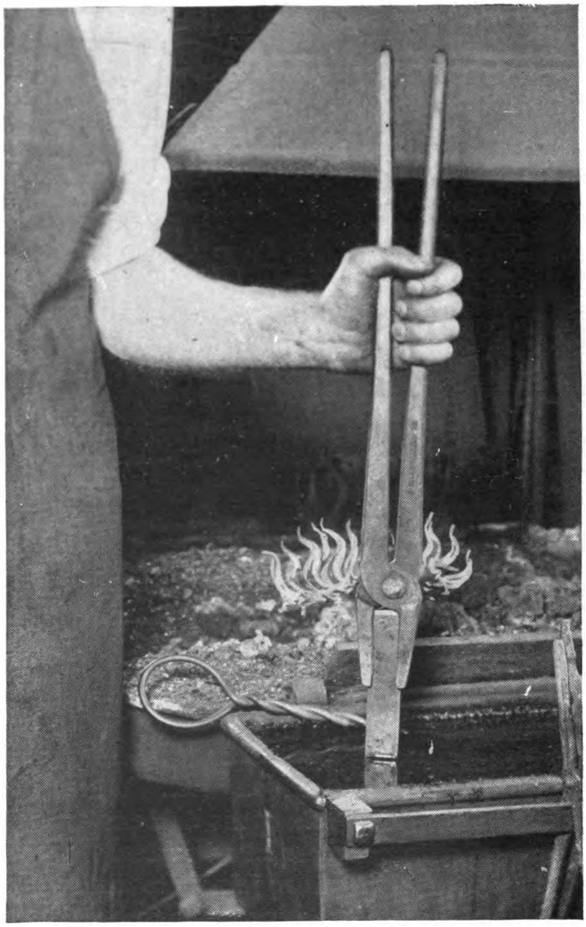


Fig. 7.

soap in it to make its chilling effects the same as oil. A blast of air is often used and cools some steel rapidly enough to make it very hard, but such steel usually contains as hardeners other elements than carbon, and is not in a true sense steel, but an alloy of steel, requiring special heat treatment that is mentioned in another paragraph of this chapter.

AVOID WARPING AND CRACKING

Chilling one side of a red hot piece before the other is chilled will cause it to warp or bend. Tools strained in this manner are liable to have cracks or flaws occur in them during the quenching. These defects are called water cracks. They show like hair lines on a smooth surface, and usually the steel can be broken easily at a water crack. Sometimes they are not deep enough to spoil the tool, but are an injury to be avoided. When water cracks are broken open, the fracture may be seen *colored with some stain of oxidation.* If the fracture is not some shade of the oxidation colors — yellow, red, and blue — it indicates that the flaw was caused by some error

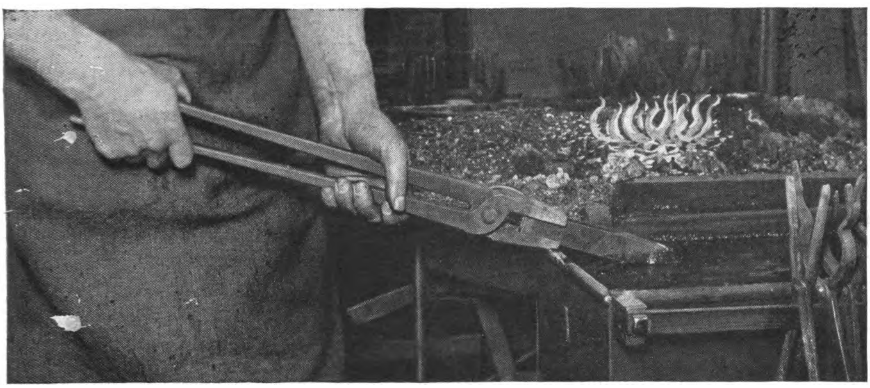


Fig. 8.

in forging or other treatment. An unequal heat on opposite sides of a piece, or plunging sidewise into the quenching bath may cause the hardening cracks or water cracks so often made by careless workmen. Properly heated steel held vertically over the cooling fluid and plunged straight to the proper depth. as shown in Fig. 7, will not warp or crack.

Tools that are to be hardened on one end only should have that portion properly heated and held in the water until it is cooled below the boiling point of water. When the cutting edge is of some length along one side of the tool, that edge should be kept under water until cold, while some heat may be left in the opposite edge. Fig. 8 shows how a side cutting tool should be turned edge down in the water.

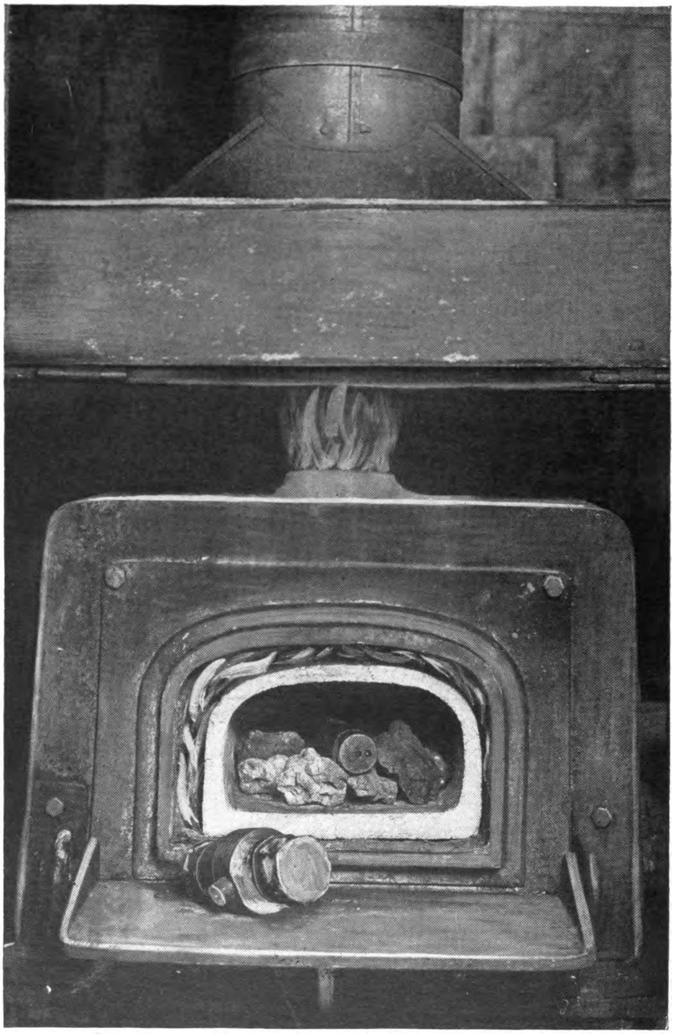


Fig. 9.

MUFFLE FURNACE

To protect from injury in the fire, a muffle of fire brick may be used. In Fig. 9 some pieces of charcoal have been placed in the muffle to use the oxygen and keep it from injuring the steel by absorbing the carbon from the surface, so that a soft skin outside of the hardened steel might result.

PACK HARDENING

On the hearth in front of the muffle furnace, in Fig. 9, is a short hollow shaft with two pinions projecting from opposite sides of a collar at the middle of the shaft. The collar and pinions only are to be hardened. Therefore the hollow shaft is filled with fire clay kept in place by a cap of tin-plate; the rest of the shaft is protected with tin-plate or sheet-steel wrappings kept in place with binding wire. When heated and quenched, only the uncovered parts of the piece will be hardened. Asbestos wrappings can be used to protect parts from the quenching bath as effectively, for properly covered parts protected from the cooling bath are not chilled rapidly enough to be hardened.

HIGH SPEED TOOLS

High speed tools were brought successfully into use in 1900. Previous to that time, Mushet steel was the only metal known that was superior for some cutting tools to carbon steel.

Mushet steel contains carbon, tungsten, and manganese, and will harden in air, hence it is known as self, or air hardening. As it hardens itself by getting cold, perhaps it would harden in a vacuum? The common practice with it is to lay the tool, after it is forged, before a nozzle through which air is taken from the blast which blows the forge fire. Here this kind of steel becomes as hard as it can be made, and is ready for use without tempering. If the heat generated by the work is sufficient to make the tool red hot, its edge will fail as ordinary carbon steel would; but unlike the carbon steel, the self-hardening steel does not have to be reheated and tempered again before it is fit for use, for while the carbon steel loses all its fixed hardness at 800° F., Mushet steel does not, though its edges will fail to cut at that temperature.

The elements tungsten, molybdenum, chromium, vanadium, or titanium may make up twenty-five per cent. of a metal now used for hard and fast cutting tools. There are other alloying elements used, but at the present time two or more of the metals named are added to steel of about one per cent. carbon to make a metal that is known as high speed steel.

The newer alloy high speed steels have the advantage of red hardness, and can not be forged, bent, or battered greatly at a full red heat. In fact, the forging must be done at a bright yellow heat, and the proper hardening heat for them is still higher. They should never be dipped in water for hardening, but in oil, or left in the atmosphere or air blast until cold. These alloy tools have greatly increased the speed at which work can be done in the machine shops, and have simplified the work of the toolsmith in the matter of hardening, while no tempering is necessary for them. The forging is more difficult, but after learning to work carbon steels, high speed steel can be successfully treated by following the instructions given by the steel makers. These instructions may differ in details, but the simplest way will give good results with any of the alloys in common use.

Prior to the introduction of these new tools, forgings could be made faster than they could be rough turned and machined, without much fitting or finishing. The new thing is a process of treatment for alloys of steel, rather than a new steel. And its development is chiefly due to the successful experiments of Messrs. Taylor and White, with the Bethlehem Steel Company's products.

TREATMENT OF HIGH SPEED TOOLS

The so-called high speed steels are easier to forge than the older self hardening products. Toolsmiths were warned not to get Mushet or Jessop air hardening steel to more than a red heat. It could be treated at 1500° F., but 1600° F. was the limit, called the breaking down point. Above that temperature the tool crumbled if touched, and was said to be burnt. The remarkable cutting that could sometimes be done with this burnt steel, doubtless led to the development of the high heat treatment for tools made of steel alloyed with some of the chromium group of metals. The amount of carbon in these tools has no influence over the treatment, which is the same though carbon content varies from 80 to 200 points. After the tools are forged to shape, they should be rough ground nearer to the size and angle than it can be well done at a forge.

TO HARDEN HIGH SPEED TOOLS

Heat to a dazzling white or like a welding heat for iron. When the tool is sweating, the edges almost melted, plunge it into oil and keep there until cold. No other treatment is needed. It is ready to grind for use. If some of the corners have dropped off under the influence of the excessive heat, the chief harm done is loss of the melted portion, for the structure will be fine and good in that which remains after grinding. However, by careful handling, it is not necessary to lose any of the metal. Some toolsmiths prefer taking the tool out of its oil bath as soon as the high heat is brought below redness on the portion forged for the bit. This latter practice will strengthen and toughen the bit by means of the internal heat remaining in the stock.

The exact temperature from which to harden some of the high speed tools is given as 2000°F. From this, cool them rapidly in liquid down to 1500° F., then slowly or naturally in air. After they are cold, reheat to 1200° F., keeping them at that temperature for ten minutes, then allow them to cool slowly and they are ready for use. High speed tools do not lose their fixed hardness at temperatures below 1100° F.; but in comparison with carbon steel tools or air hardened steels, that have been properly treated, they are not very hard. What hardness they have is retained at such a high temperature that cutting speed can be increased many times without damage to their cutting edges.

CASE HARDENING

Case hardening is converting the exterior of a piece of iron or soft steel into hardened steel, leaving the inside soft. It is best done by packing the piece in a box with carbonizing material and heating for a length of time sufficient to allow carbonization to the desired depth, then cooling the piece suddenly in water.

Cementation

Carbonizing is done in the same manner as making cement steel. In the cementation process of steel making, bars of wrought iron are packed in a furnace with alternate layers of charcoal. The furnace is sealed to prevent escape of gases and the passage of air currents. Then the inside is kept red hot for a time sufficient for the carbon of the charcoal to penetrate the iron to its center. This may take days or weeks, according to the thickness of the bars.

If only a thin skin of carbonized iron is wanted on the bars, the time of keeping them red hot must not be so long. If heated a few moments only, the skin that would be hardened by quenching is very thin, and the rest of the bar inside the skin which has been carbonized is soft, tough, and pliable as the iron was before. Hence, the name "case hardening." It is useful for a very important class of work where hardened surfaces are desired, backed up by material that will not break easily. Steel that is so low in carbon that it will not harden properly is easier to forge or machine into desired shapes, and for many reasons is often manufactured into pieces that should have all parts of the surface hard. This material, as well as wrought iron, can be case hardened by carbonizing it to sufficient depth and treating it for hardness the same as high carbon steel.

Carbonizing Materials

Wood, charcoal, bone, leather, and cyanide of potassium are each used alone or as mixtures; bone and leather mixed do not give good results; wood charcoal, or cyanide will mix with either of them and give good results. Pure carbon does not act in a vacuum, and, as the pieces should be covered in the box to prevent the oxidation of the air from hindering the result, sugar, which is a pure carbon, will not carbonize the piece unless some other substance, like bone or leather, is mixed with it. Carbonizing gases can be used, and where much work with large or odd sized pieces must be carbonized, a furnace designed to heat and conduct the carbonizing gas upon them may be installed.

The carbonizing is well done by packing the pieces in a cast iron box with granulated bone, leather, hoofs, or wood charcoal. The box should be closed and the air excluded by stopping all cracks with clay. This should be kept red hot for some time, not less than an hour for much depth to the hardened skin. A quicker way is to heat the pieces in the fire, cover the surface of the part to be hardened with cyanide of potassium, reheat until the cyanide melts, then quench it in water. Its surface will be made so hard that a file will scarcely scratch it. But a better way to use the cyanide is to melt enough to cover the pieces in a cast iron box large enough to receive them. Then by keeping the material in the box red hot for an hour or more, the depth of penetration will be considerable.

Pieces that have been polished may be hardened and colored by taking them out of the cyanide bath and dropping them into clear water.

The subject of coloring with case hardening belongs more properly with the subjects of tempering and annealing, which are treated of in the next chapter.

Depth of the Hardened Case

As seen in Fig. 10, the thickness of the hardened skin varies. The depth of penetration depends upon the time the pieces are kept hot, the temperature that is maintained, and the carbonizing materials that are used; as a rule, the hotter the pieces are, the faster the absorption of carbon will be, but too high a heat will cause the grains to grow large, and the excess of carbon absorbed just below the surface of the piece may make it brittle; a medium temperature, evenly maintained, and sufficient time in the heat, gives uniform absorption to any depth of penetration desired; the temperature should not be less than 1150° F. (a cherry red) for any steel; the proper heat for the kind of steel should be maintained for one hour to ensure a depth of penetration on wrought iron or machinery steel of 1/32″; alloy steels which contain the elements tungsten, chromium, etc., used for high speed tools, will absorb the carbon faster, while steels alloyed with aluminum, nickel, and some other elements, take in the carbon at a slower rate. The steels already high in carbon or other alloys are not usually treated by case hardening processes; low carbon steel, which is in composition about the same as puddled wrought iron, is the material of which most articles are made that require case hardening; for this the rate of penetration with good carbonizing material is about .03 of an inch during the first hour, .01 during the second and each succeeding hour. One hour of time after the pieces are red hot will carbonize the piece sufficiently for thorough hard-

Fig. 10.

ening to a depth of 1/32″. For double that depth of penetration, at least four hours of time would be required.

The pieces shown in Fig. 10 were taken from the carbonizing box and plunged into cold water; the first one had been at a full red heat for one hour, the second one for four hours. A distinct line of demarcation between the soft center and the hardened portion can be seen more distinctly in the second piece than in the first. This line may be a weak place in the piece, and the damage might have been avoided by annealing the steel after carbonizing, and then reheating it for hardening.

LAWS OF HARDENING STEEL

1. **Carbon tool steel,** heated and quenched in water or other cooling bath until cold, will be hardened and its structure changed or grain refined (small crystals) according to the heat and cooling rate.
2. The right hardening heat for any steel is fixed by its chemical constituents.
3. The hotter the steel and the more sudden the quenching, the more coarsely crystalline will be the fracture.
4. To prevent change of carbon, tools may be heated in melted glass, salt, or lead.
5. Water is a quick quenching medium. It should be kept clean.
6. Oil and grease do not cool the metal as rapidly as water.
7. Mercury or brine cools the metal more rapidly than water.
8. A quick heat and a cold bath may cause the steel to crack, or change on the outside, but not in the middle.
9. Rapid cooling gives the status quo, the state into which the steel was brought by heating; sudden quenching fixes the hot condition, making the metal in the cold state show itself as it was when hot. (This has from time immemorial been accepted by toolsmiths as the cause of hardening).
10. The proper hardening heat color, which varies with the carbon content of the steel, can be seen best in a dark room.

The subject of hardening as it has been explained and illustrated is condensed here. This guide is intended to serve for handy reference by those engaged in such work.

GUIDE FOR HARDENING

	COLOR OF HEAT.	DEGREE F.	RESULTING HARDNESS.		APPEARANCE OF FRACTURE.
1.	Bright Yellow or Cream White...	2200	Excessively hard and brittle.	Too Brittle for Tools.	Grain Coarse. Crystals large. Lustre brilliant.
2.	Yellow or Lemon................	1800	Extra hard. Will break easily.		Grain large and sparkling, but not so brilliant.
3.	Bright Red	1600	Not strong enough. Edges crumble.		Grain not so coarse, but with bright lustre.
4.	Clear Full Red or Bright Cherry.	1400	Very hard.	Used for Tools.	Grain refined, crystals small. Some sparkle.
5.	Fair Red	1200	Hard and strong.		Fine grain, no sparkle.
6.	Low Red or Cherry Heat........	1100	Very strong and hard.		Grain fine and close.
7.	Blood Red or Dark Red.........	1000	Hard and tough.		Very fine grain, good structure.
8.	Dull Red or Black Heat.........		Stronger than the bar. Not hard enough.		Grain same as in the bar.

Steel containing less than one per cent carbon may be properly hardened in water at a heat as high as No. 4 or No. 5; that containing more than one per cent carbon will harden properly at a lower temperature, indicated by color No. 6 or No. 7, in oil or water.

High speed or alloyed steel must be treated at high heats, according to instructions given by the manufacturer.

CHAPTER X

SOFTENING STEEL AND IRON

TEMPERING

A steel tool that has been properly hardened may be so brittle that its edges would crumble or break down in service; it is therefore necessary to temper it. The most common way to do this is to rub the piece with sandstone, or polish it, and then watch for the change in color as it is re-heated, either by a surplus heat left in the body of the tool when the cutting edge was hardened, or by holding it over a hot plate or metal, or in the gas flame, or over the coals of a fire. There is danger of gas or smoke stains by the last named methods of re-heating, and it is essential that temper colors should be seen and produced in clear air, or they will not be a true guide to the hardness left in the steel. Under the right conditions, the color test is a certain indication of the temperature of iron or steel, and this changes the hardness or reduces it to the point desired. The process can be learned and followed safely by careful attention to the *guide for tempering*. See pages 158, 159.

It is not necessary to have steel of the carbon content set opposite each tool named in the guide in order to make good tools, for any of the high carbons may be used for fine edged tools, and any of the low carbons would answer for the others. The list is given to serve the purpose of a guide to the selection of stock, as well as to the range of hardness best adapted to various purposes.

HEAT TREATMENT SUMMARY

.50 to 2.00 Carbon Steel heated to the right shade of red (900 to 1400° F.).	*Cooled slowly* as possible in dry lime or ashes, is *Annealed*.
	Cooled quickly as the kind and shape will stand in Mercury, Brine, Water, Oil or Grease, it is *Hardened*.

When heated after hardening, 212 to 700° F. it is *Tempered*.

TEMPERING NOTES

1. Tempering is a reduction of hardness caused by heating to not more than 700° F.

2. The ductility and elasticity are restored or increased by temper.

3. If heated by induction, a rapid rise in temperature does no harm.

4. The higher the tempering heat, the softer the piece becomes.

5. When steel is properly hardened, polished and heated, the color is a test of temper.

6. Tempering with oil prevents oxidation and increases the elasticity of the piece.

7. Defects may arise from adhering to any special process of tempering, because steel is not uniform.

8. Methods of hardening and tempering are often kept a trade secret.

OXIDATION COLOR

There are three groups of tempering colors, yellow, red and blue. All other colors named in the guide, on pages 158 and 159, or that may be seen by the temperer, are combinations of these three, and there are some curious facts that should be mentioned here in order that a beginner may not be deceived. It makes no difference in the temper color whether the piece was excessively hardened, properly hardened, or only partially hardened. Even if it were not hardened at all, temper color can be drawn just as well. It seems strange, too, that all of the colors can be made by heat and oxidation on the same piece at the same time in this way.

Heat a piece of polished hardened steel to about 400 degrees Fahrenheit, or until it has changed from a grayish white to a yellow. After allowing it to cool repolish three-fourths of the surface, and reheat to the same temperature, or until the same shade of yellow appears on the repolished part. The one-fourth yellow oxide that was not polished off, will be changed to red by this treatment. If this red quarter and one yellow quarter are left on a piece while the other half is again repolished, the whole piece may be reheated to the same temperature, and when the yellow comes on the polished parts, the red quarter will be changed to blue, the yellow quarter will become red, and one-quarter of the half that is yellow may be repolished to the natural white or gray color of hardened and untempered steel. There in a single piece that has been subjected entire to the same heat treatment, are all appearances of high, medium and low tempers, but we know it to be all of equal hardness; the same in structure and condition throughout and unlike in appearance only.

So it is only the first temper colors that should be relied upon; the color at first reheating after proper hardening is meant in these instructions and given as an indication of the condition of the steel.

Some graduation of hardness might be made by repolishing and reheating for second yellow, third yellow, or red or blue, but shades and tints of these colors are simpler and well known to men of experience, and take less time to produce.

JUDGING TEMPER BY COLOR

The surface of metals is liable to oxidation at low temperatures. Iron surfaces that are polished become blue when exposed to the atmosphere at a temperature considerably below red heat. If the heat is applied slowly while the surface is watched, it may be seen to change, first to a light yellowish color which becomes gradually darker as the surface is made hotter. This action of the air upon the polished surface of the steel is useful to a temperer, as it furnishes him a guide for reducing the brittleness of steel the required amount and retaining the other properties of the hardened piece with its structure unchanged, unless the piece is heated higher than 700° F.; below this heat the blue oxide has been formed, but is driven off at this temperature, and will show itself again and quickly disappear if the surface is repolished.

The guide names the most reliable and certain colors in their order with the temperature at which the same condition would be caused without oxidation, if the steel was heated uniformly away from an oxidizing atmosphere. It should also be remembered that many combinations of these colors may be observed on surfaces variously polished, or when the heat is checked at points between the given temperatures. This is especially true of the violet which leaves red spots on the blue if the piece is heated about 580 degrees. There is also a mixed color known as peacock, which appears if the conditions are right, between 500 and 580 degrees; but to those familiar with this process, it is well known that closer graduation by the color test is of little value except for special work on known grades of steel.

When polishing tools that are to be tempered by allowing the surplus heat in the stock to run out into the bit after it has been hardened, the portion of the tool to be tempered should not be in contact with metal, but held in a position like that shown in Fig. 1, where all sides of the bit are exposed to the air without being chilled by any other substances. After the bit of the tool is thoroughly cooled in the bath, the water or oil will remain on it until the polishing is partly done; if the moisture dries quickly, it indicates internal heat left in the bit that may reduce all hardness of the surface, and that

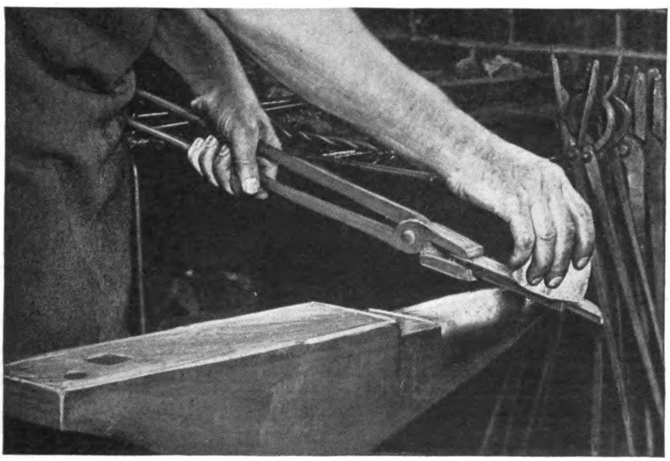


Fig. 1.

it was not cooled in the center enough for proper hardening. In this case *false oxidation colors* may appear and be rubbed off with the polishing stone to be replaced by a true color that is not an indication of the highest heat to which the bit was raised. But when sufficiently cooled by the hardening bath there is time to polish a strip along one side of it; particular care should be observed to have a bright spot at the place where the rubbing stone is in Fig. 1.

All of the temper colors may appear at this point; yellow in advance extending faintly out to the end, a narrow streak of red oxide just back of it, with blue over the shoulder of the tool continuing back into the stock a half inch or more where it blends into a combination of all these colors, making a false color if the piece was polished back close to the surplus heat that was left in the stock to draw the temper in the bit of the tool.

All tools in which temper is drawn immediately after hardening may be treated in a similar manner, if the stock or unhardened part of them will contain enough heat to raise the temperature of the cold hardened edges sufficiently.

When there is not heat enough left in the body of a tool to draw the temper on its edge, another piece of hot metal may be placed near enough to do so.

This way of drawing temper is also practiced with tools that must be quenched entire, and as there is no internal heat or other portion of the piece in condition to raise the temperature of the cutting edges, more time may be taken for polishing and the temper colors can be more clearly shown.

Sand heated in an iron vessel may be used with more precision than the piece of hot metal, and a thermometer in the sand will show the temperature, so it is not necessary to have pieces polished when this method is used. There is a good deal of uncertainty also about judging the tempered condition of steel by its color, except on work done by those of experience, and besides this the color of oxidation is not a function of the tempered condition of hardened steel, but an indication of the heat between the temperatures of about 400 to 600 degrees Fahrenheit. If a temperer polishes off a color that appears at, say, 500 degrees and then reheats the piece to a higher temperature, say, 550 degrees, indicated by a different shade of color, the effect would be about the same as though he had taken the higher temperature without polishing the second time, and it would make no difference except in the time taken to do the work, whether the steel was cooled or not before reheating.

But all the colors that have been proven and accepted as guides to the temperer, appear to chase each other from the polished surface, and show themselves at known temperatures; and the method of some temperers of re-polishing and re-heating a number of times may be suitable sometimes, but should not be adopted in common practice.

OIL TEMPERING

Heated oil may be used instead of sand, the temperature of the oil can not be made as high as the sand would endure, and it deteriorates rapidly, but is excellent for tools requiring high temper. In Fig. 2 the cast iron crucible contains linseed oil ten inches deep, and is in a gas furnace where it was heated to 425° F.; a wire screen is placed four inches under the surface of the oil and the bulb of the thermometer rests on the screen where the toothed steel cutter was put after it had been hardened; the cold steel cooled the oil down to about 400° F. and the gas fire brought it slowly up to 425° F. again, when the cutter was taken out tempered the same as if it had been polished and drawn to a straw color.

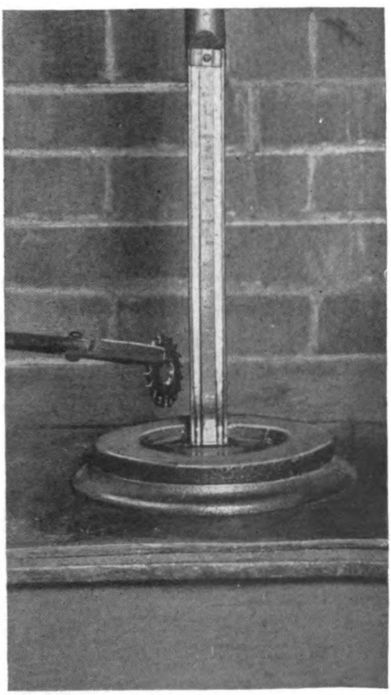


Fig. 2

The treatment for articles hardened in oil, may be changed by making the oil that adheres to them from the quenching bath burn off as the piece is held in a flame. Some experience is required before the results of this method can be made very accurate, as the quality of the oil and its rate of burning must be taken into account. For some springs, gears, and forgings, it is an excellent method, but is dependent on the skill of the operator.

OIL TEMPERED FORGINGS

Forgings of machinery steel may be toughened and strengthened by heating and quenching in oil; as this kind of steel will not properly harden the treatment is called oil tempering.

OTHER LIQUID BATHS AND METHODS

Mixtures of tin and lead which melt at the tempering heat wanted for the tools, may be made and used, either as test bars to prove the heat to which a piece is raised, or as liquids in which to heat the steel for tempering, as was shown with oil in Fig. 2.

Salt baths are sometimes used where the drawing temperature is desired at 575° F. Salt fuses at this point, and a certainty of obtaining this temperature in the steel is assured. In using this the salt is heated to 700 or 750 degrees and the steel placed in the bath. When this is done the cold metal will cause the salt which surrounds it to solidify and plainly show a white crust around it. When the steel has obtained a temperature of 575 degrees the white crust will disappear as the salt which made it has melted and mixed with the rest of the bath. This clearly shows that it is time to take the piece out of the bath and allow it to cool. Salt can be used for tempering above 575 degrees and below 900 degrees, but is not practical for higher or lower temperatures, owing to the alteration in the salt.

Gas, oil, electric or other furnaces may be heated to the temperature desired for tempering, and maintained at that heat measured with a pyrometer, if the tools are placed in a muffle where they are not injured by the products of combustion; these methods can be kept under the control of a competent foreman, and not much dependence needs to be placed in operators whose carelessness might spoil valuable lots of tools. Where large numbers of pieces are required to be hardened and tempered alike, the best equipment, which is a combination of scientific appliances and experienced operatives, should be used.

VARYING THE RATE OF COOLING WHEN HARDENING

This is sometimes confounded with tempering methods. The confusion of partial hardening, with genuine tempering, must be avoided. The slow cooling mediums partly harden steel and may make it as good as it needs to be for some kinds of work, but the right heat and a quick cooling are necessary to produce the best structure in steel. If this causes more hardenite than is useful in the tool, it may be changed back into pearlite by the slight reheating called tempering. This change begins as soon as the lowest tempering heat is reached and continues as the heat increases. So it is not necessary to hold the piece at the tempering heat any length of time, nor to cool it quickly. The desired reduction of hardenite is accomplished as soon as the piece is hot enough, and no further change takes place if it is kept hot for hours. When the piece is wanted at once it may be plunged into cold water to cool it for handling; otherwise it would be better to let it cool in a dry place in air, for seasoning and rest is a safe and good treatment to give steel of any kind or condition.

SPECIAL TEMPER

Some things can be tempered correctly by experienced workmen with nothing but their feeling and sense of time to guide them. The pieces heated for hardening are held with a light pair of tongs and submerged in the quenching medium; the sensitive hands feel the singing or tingling of the rapidly cooling steel, and when it has continued long enough, it is taken from the bath with just enough internal heat left to temper the piece without further treatment. Some kinds of toothed cutters or hollow reamers are quenched in water until the tingling of the steel has nearly ceased, then taken out and immediately put in cold oil for tempering by the internal heat of the piece; or the process is reversed by quenching first at the slower rate of oil and finishing in water.

EFFECT OF TEMPERING HEATS

At 212° F. the hardening strains are relieved and some hardenite has followed its natural impulse to return to the pearlitic state. The properties that were exaggerated by the hardening process are partly corrected. This correction will be complete in carbon tool steel a little above 600° F.

Low carbon steels of which machine forgings are made, crank shafts, gears, carriage springs, etc., which are subject to great shock, torsion and vibrational strains, are made stronger, tougher, or more elastic, grain size is restored, and the tension of parts strained when forging, is relieved by heat treatment, and they will be best fitted for their work when reheated for temper to about 700° F. Between these limits of temperature, all tempering is done, and as the color test is not reliable above 600°, other means are devised for knowing the heat in some pieces to be tempered.

CASE HARDENING FOR COLORS

The steel must be polished smooth and bright if fixed oxidation colors are desired when case hardening. If the pieces have been allowed to cool after being carbonized, they must be reheated and then quenched suddenly, the same as ordinary tool steel must be treated for hardening, but it is common practice to plunge them in cold water as soon as they are taken from the carbonizing furnace; and this latter method is followed when case hardening for color. If they have been well polished, and are packed in powdered charcoal, bone or leather, all the contents of the box may be dumped into the bath, and some oxidation colors, gray, yellow, red, blue and black may be well fixed on the surface of the metal. Brilliant colors are obtained by heating the pieces to a bright, cherry red in a cast iron box of sufficient size to contain melted cyanide of potassium enough to cover them. Take them out of the box one at a time with tongs, and drop them instantly from a foot or more above the tank into clear water with air bubbles coming up from the bottom, as shown in Fig. 3. The wrench is ready to drop onto the wire screen in the water. The coloring will be light with too much grey, if the steel is overheated, and dark colors result when the heat is not high enough; a fair red heat of 1250° F. gave the best coloring to the pieces illustrated. The lid of the cyanide box in the mouth of the furnace, Fig. 3, is raised enough to get the pieces out while the fumes are carried away by the hood over the furnace.

Workmen must beware of the splash of poisonous cyanide which flies when water from damp tongs gets in the box, and when the film of cyanide is suddenly dashed off as the pieces strike the water; hot cyanide will burn and poison the flesh so that recovery from a deep wound is doubtful. The fumes of the stuff are also deadly if taken in much quantity, but with care the material may be used with definite and perfect results for color and effects. The low cost and non-poisonous nature of the other materials makes them preferable in many cases.

ANNEALING

The operations which are the reverse of hardening, may have a similar effect on the structure of steel, and when the art of hardening is well understood, it is not difficult to learn how to reduce the ordinary hardness of steel to the least possible point, which is annealing, or to stop the reduction at any point, which constitutes tempering.

The annealed metal is in the softest condition for that metal. It has only the normal strength for material of its quality. All of its properties are in repose. It is, therefore,

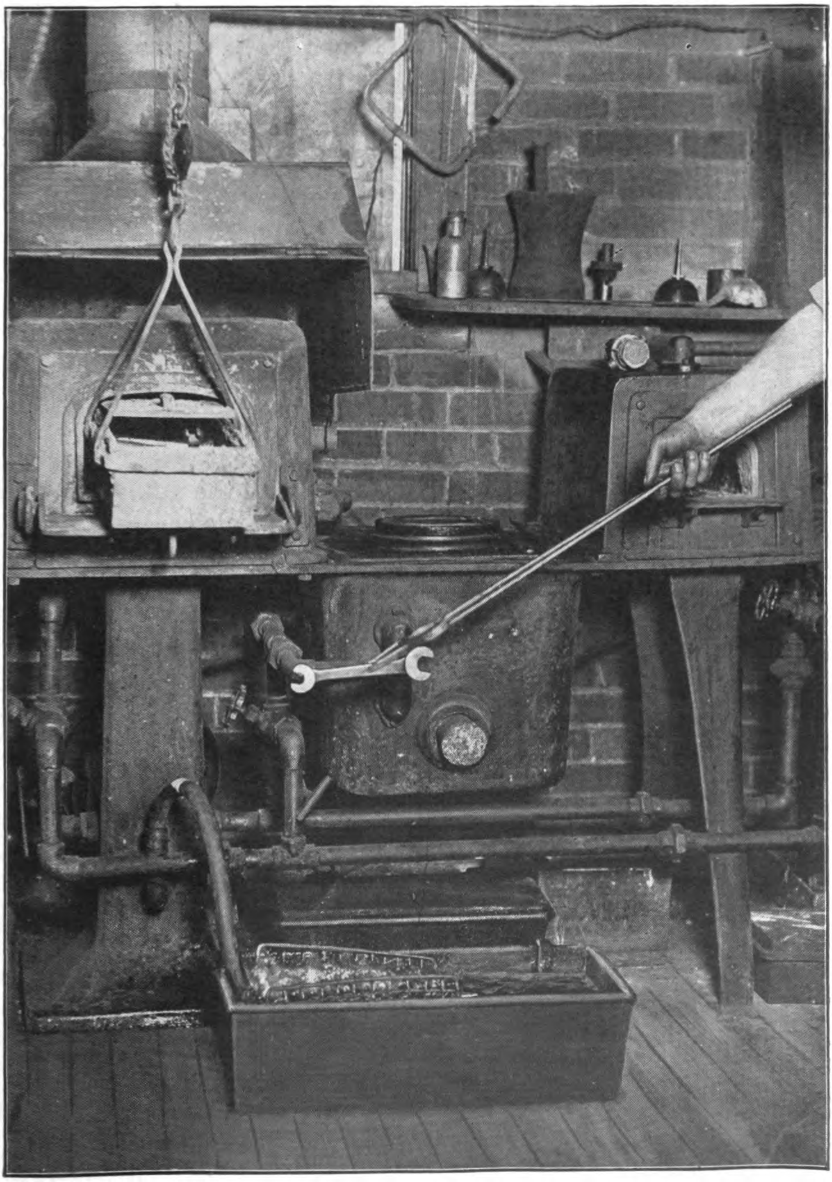


Fig. 3.

not high in tensile strength, and the elastic limit is as low as possible, but elongation and ductility are high, and it is as malleable as metal of its kind can be made.

ANNEALING HEATS

It is not necessary to harden a piece before annealing it, for its grain size will be fixed right by the proper annealing heat. This heat varies as does the hardening heat with the carbon content of the steel. For thorough annealing, the steel must be heated to exactly the same temperature as for hardening, and just as great care should be taken in the heating; but as the pieces do not have to be taken suddenly from the heat to the cooling bath, simpler methods of heating, so as to avoid oxidation and scaling, can be followed.

One of the easiest ways to heat small pieces or rods is in a gas pipe with both ends plugged to prevent circulation of air. If pulverized charcoal is packed around the piece of steel in a pipe or box, it can be heated and annealed without any injury from oxidation. Very high carbon steel should be heated to blood red, about 1000 degrees F., and low carbon may require a yellow heat which comes at 1600° F., before it will be properly annealed; that is, put in its softest condition when cold.

COOLING

The cooling rate for annealing must be as slow as possible, down to 400° F. Below this temperature no hardenite forms. Water annealing, as sometimes practiced, is done by cooling the metal in water as soon as it has fallen from the red heat of transformation to a temperature that shows red in a dark room. This arrests the seasoning in air to a normal condition and keeps the steel soft enough for ordinary machine shop practice.

True annealing is unlike hardening, where the cooling must be as fast as possible for maximum effects; here it must be slow. At least twelve hours should be given for the cooling of any piece of steel that needs thorough annealing, and if the piece is large, more time should be given. A piece five inches in diameter should have twenty-four hours' time. Pieces that are small enough to go inside of a three-inch gas pipe packed full of charcoal or brick dust, may have their cooling rate retarded so much that they will feel quite warm to the hand twenty hours after they are taken from the fire. This is accomplished by burying the pipe or box and contents in air slacked lime three or four inches. There is no better method than this. Many poorer ways have been recommended and some of them are dangerous. Pieces left in the furnace are liable to accidental overheating, or at least may retain the highest temperature they ought to get, for too long a time. This is wrong. As soon as steel is hot enough, it ought to begin cooling slowly. Its cooling rate should be retarded. This is a very different thing from holding at a high temperature for a long time, where it is not at rest, and liable to injurious chemical action on the new formed grains. The change in structure releases all grains which may have been formed in the piece by former treatment, and the slow cooling allows the crystals to adjust themselves in all parts alike.

After each process in manufacturing steel parts that are expected to be exact in size and shape, they should be returned to their normal condition by annealing. Bending, twisting, or rolling sets up strains among the crystals. Machining takes off part of the material and may leave that which remains in a tension so severe as to warp or break it when hardening. Hammering and cold rolling distorts the crystals and crushes them together. In this deformed state the metal is sometimes harder and stronger than when in its normal condition, and is used for shafting, springs, and similar things, but the compression and increased density must be relieved before the metal can be safely treated for hardening, or machined into shapes it is expected to keep.

GUIDE FOR TEMPERING

Carbon Tool Steel, after hardening, may be tempered (i. e., its hardness reduced) as desired by slowly heating it to the proper temperature. This heating alone decides the temper; the manner of subsequent cooling has no effect on hardness. The degree of heating is determined by (a) or (b).

(a) The color of the oxidation of the surface, when the steel has been polished and is heated in the open air.

(b) The thermometer in the heating furnace or in the hot fluid (as oil, tallow, lead, etc.) in which is placed the hardened steel, either polished or unpolished.

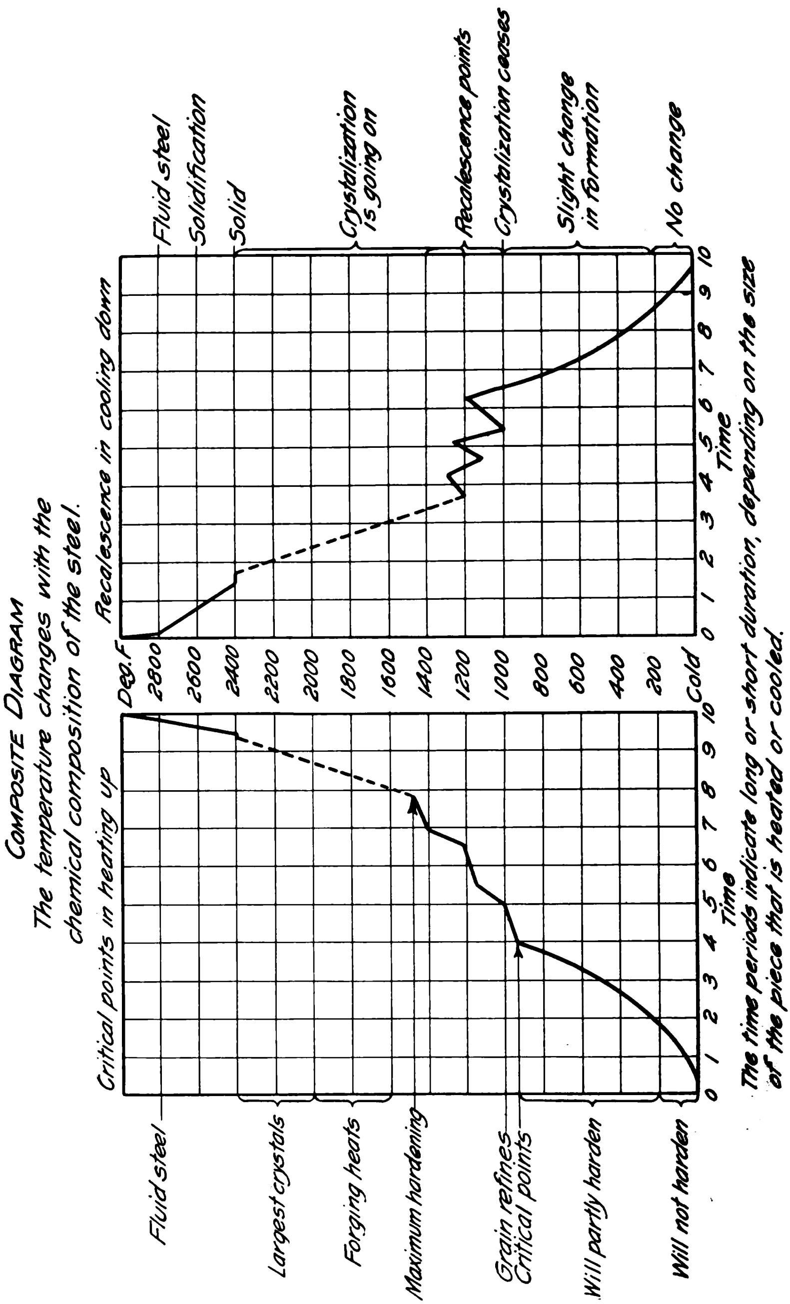
OXIDATION COLOR.	DEGREE "F."	TEMPER.	FRACTURE.	SOME APPLICATIONS.	CARBON IN STEEL ABOUT
No Color,	300		AS HARDENED	Lathe Tools, special use	1.20 to 1.50
				Hand Turning Tools for metal	1.00 " 1.40
				Milling Cutters and Lathe Tools for brass	1.20 " 1.40
				Burnishing Tools	1.20 " 1.40
				Embossing Tools or Dies, Glass Drills and Cutters	1.25 " 1.40
				Mandrels, Machinists' Scrapers	1.00 " 1.25
Light				Ball Bearing plates	1.00
Yellow,				Dies for press forging	1.10
1. *Yellow*,	400			Planer Tools for steel	1.20 " 1.50
Light		Very		Lathe Tools, regular use	1.05 " 1.15
Straw,		High		End Mills	1.20 " 1.50
Straw,	425			Milling Cutters for steel and iron	1.20
Dark				Taps and Threading Dies	1.20
Straw,				Flat Drills	1.20
				Lathe Centers	.90
				Draw Knives for wood	1.20
Orange	450			Cutting Tools for bone and ivory	1.25
or				Scissors	1.00
Gold		High		Ball Pene Hammers	.80
				Hack Saw Blades, Pipe Cutter	1.05 to 1.20
Brown	480			Circular Saw for steel	1.60
with				Reamers	1.20
Red Spots				Shears for metal	1.10
2. *Red*,	500	Medium		Drop-Forging Dies, Corn Knife, Mattock	.90
				Drill Bits for stone	.80

Wine Color with			GRAIN REMAINS	Surgical Instruments	1.25
				Some Woodworking Tools, as Chisels, Knives, Jointers, Planer Blades and Turning Tools	1.25
Blue Spots,	530			Some Woodworking Tools as Axes, Carving Tools	1.00 to 1.10
Purple,	550			Augers, Butcher Knife	.80 " .90
Violet				Circular Saws	1.15
or		Mild		Pocket Knife	.90
Peacock,	565			Shell Reamers	1.10
				Blacksmith Tools, as Flatters, Fullers, Swages	.60 to .70
Blue with				Pliers	.90
Red spots,	580			Cold Chisels	.80
		Low		Stone Chisels	.80
				Punches	.80
				Handsaws	.80 to 1.00
3. *Blue*,	600			Some Small Springs, Cant Hook	1.15
				Band Saws	.75 to 1.00
				Quarry Drills, Wedge or Glut	.60 to .70
Changes	625			Drift Punches, Wrenches	.60 to .70
to		Very		Chisels for cutting hot stock, Screwdrivers	.60 to .70
Gray	650	Low		Moulding and Cutting Tools to be filed	1.10
or				Jaws for Pipe Machine, Wire Pullers	1.10
Green,				Vise or Gripping Jaws	.90
				Some Large Springs	1.25
Shows red heat in the dark,	750	Soft, No temper remains.		This treatment improves the structure of steel and is best when done in oil.	
Black Oxide forms here.	800				

In this classification, the carbon content of the steel for each tool is considered about as recommended; should the percentage of carbon in the steel be otherwise, the temper color should be accordingly varied. In general, if the carbon percentage is low for the kind of tool, the temper should be high; and if the carbon percentage is high, the temper should be low.

ADDENDA

For those who are interested enough to continue the study of metals, this chapter is added, with the purpose of encouraging them to study the science of metallography


Composite Diagram
The temperature changes with the chemical composition of the steel.
Critical points in heating up
Recalescence in cooling down
Deg. F
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
Cold
0 1 2 3 4 5 6 7 8 9 10
Time
Fluid steel
Largest crystals
Forging heats
Maximum hardening
Grain refines
Critical points
Will partly harden
Will not harden
Fluid steel
Solidification
Solid
Crystallization is going on
Recalescence points
Crystallization ceases
Slight change in formation
No change
The time periods indicate long or short duration, depending on the size of the piece that is heated or cooled.

CHAPTER XI

METALLOGRAPHY

Metallography is defined as the science of metals with reference to their structure. Little attention was paid to the subject of metallography twenty years ago, and not much has been written on the subject, but steel users know that the physical properties of steel depend largely on the thermal and mechanical treatment it has been subjected to. All industrial metals contain impurities, and chemical analysis may show the composition perfectly, but a treatment that changes the mechanical properties very much leaves the ultimate composition unaltered, and here where chemistry fails, metallography comes to our aid.

Information concerning the constitution of metallic alloys has been greatly increased during recent years. The Institution of Mechanical Engineers in England, and also the Society in France, appointed special committees for research in this field, and the excellent work of investigation has been followed by others in this country until the study of the structure of alloys by examination of fractures that have been subjected to certain heat treatment, polished, etched and placed under the microscope has created this new department of science called metallography.

Steel being now the most useful material will occupy the greater part of this chapter, and we will follow the work of Sauveur more closely than that of any other, as his careful investigations and clear language has placed him amongst the highest authorities on the subject. He considers steel (Fig. 1) as an alloy or mixture; all of the carbon combines with a portion of the iron, forming the carbide Fe_3C. This carbide being distributed through the mass forms a compound with a structure like other binary metallic alloys.

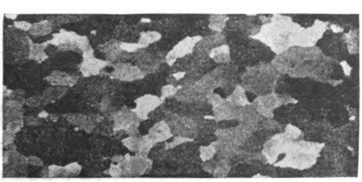


Fig. 1.

The analogy existing between the structure of frozen saline solutions and metallic alloys is almost perfect, and both classes of substances are controlled by the same laws during the formation of their structure, i. e., while freezing. (Saline solutions being liquid, while steel is solid at ordinary temperatures, prevented an earlier discovery of the identity of the laws which govern the constitution of both substances). I give here a brief statement of these laws. By dissolving common salt (sodium chloride) in water we lower its freezing point, as we all know; further additions of salt make the freezing point still lower, until the water contains a certain percentage. After the lowest possible freezing point for this saline solution is reached, any increase of salt will raise the freezing point of the brine. Dr. Guthrie says that the solution of lowest freezing point is an hydrate of the formula $NaCl + 10\ H_2O$, as he found the lowest freezing point to contain about 23.50% NaCl. Such mixtures were named by him "cryohydrates."

Saline solutions begin to freeze at temperatures corresponding to the proportion of salt which they contain; they all finish freezing at the same temperature, viz., 22° C. (71.6° F), the freezing point of the cryohydrate. If we consider water as fused ice, and the ice of cryohydrates as mechanical mixtures of salt and ice, as has been proven by using colored salts and other means, we may say that solubility and fusibility represent the same thing; applying fusibility to mixtures solid at ordinary temperatures, and solubility to those liquid at those temperatures.

The theory of the constitution of metallic alloys divides them into three classes:

I. Isomorphus mixtures.

II. Definite compounds.

III. Alloys which form neither definite compounds nor isomorphus mixtures.

We are to consider one belonging to the third class, and there are two cases or conditions to be considered, viz., those mixtures which have the lowest possible melting or freezing point, corresponding to cryohydrates and named by Dr. Guthrie "eutectic alloys;" and those containing various proportions of two component metals.

The analogy existing between cryohydrates of saline solution and eutectic mixtures of metallic alloys is perfect, and similar irregularities are observed in the cooling rate of alloys having a composition different from the eutectic mixture as with saline solutions which are not cryohydrates. For example, if silver is in excess of that required for a eutectic mixture of Ag and Cu, then when the cooling mass reaches a certain temperature the silver in excess begins to solidify (exactly as water would begin to freeze and continue to form pure ice until the remaining water and salt becomes of a composition corresponding to a cryohydrate). When the excess of silver has solidified, the separation of pure silver ceases; the cooling is arrested, or its rate retarded, and solidification of the alloy begins and continues at a constant temperature. This temperature is the point of solidification for the eutectic alloy, 770° C. (1418° F.) for a composition 28% Cu, 72% Ag, shown

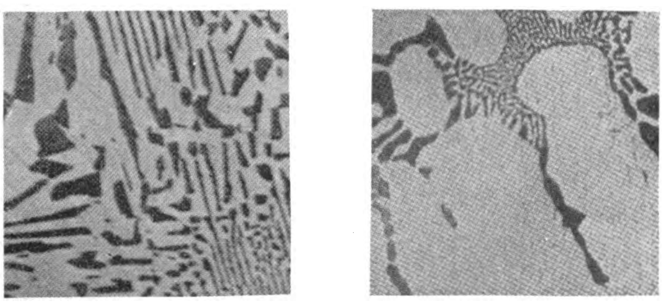


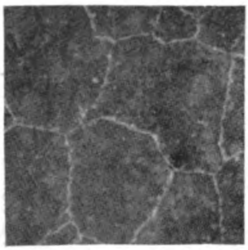
Fig. 2.

on the left in the illustration, Fig. 2; the one on the right is 65% Cu, 35% Ag. They are magnified 600 diameters.

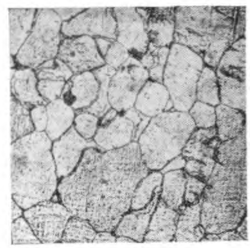
If copper is present in excess with regard to the composition of a eutectic alloy, pure copper begins to solidify at a certain temperature, this solidification of copper ceases and the cooling rate is momentarily arrested when the portion remaining liquid has reached a composition identical to that of the eutectic alloy.

Solids then containing a larger proportion of either metal than the eutectic alloy will be made up of crystalline particles of the one in excess, surrounded by the eutectic alloy. This matrix always has a definite composition and exhibits a close fracture, but the microscope shows it to be merely a mechanical mixture, of two constituents, in extremely minute crystals or plates in close juxtaposition.

The structure of iron and steel, shown in Figs. 3 and 4, will be understood by this reference to the laws which control the formation of structure in saline solutions and metallic alloys. By allowing samples of steel to cool from a high temperature and observing the rate of cooling by means of a pyrometer, when a certain temperature is reached which varies with the carbon content, a sudden retardation occurs which



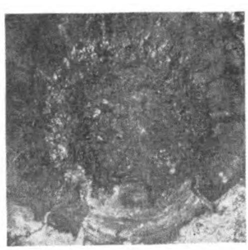
Mild Steel.



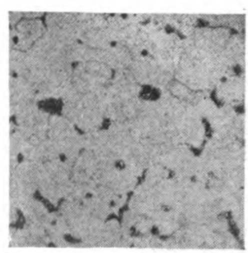
Rolled Iron.

Fig. 3.

denotes some evolution of heat. It is sometimes so intense as to produce an actual rise in the sensible temperature of the steel, a recalescence of the metal. This phenomenon, known by the name of "recalescence," and the temperature at which it occurs as the temperature or point of recalescence, is of vital importance; it is a critical temperature. In passing through



Broken Steel.



Hammered Iron.

Fig. 4.

it the steel is entirely changed, its physical and mechanical properties are altered. It is a phenomenon peculiar to iron and steel, and although the whole mass is solid at this temperature, the same separation of component parts takes place during recalescence as we have noted during the solidification of other eutectic alloys. Steel containing 0.80 per cent. carbon will at this temperature take the form or structure of a eutectic alloy of iron and the carbide Fe_3C, a mechanical mixture with a structure made up of small crystalline plates or grains evenly distributed as a result of the simultaneous segregation of the two constituents. See drawings in Fig. 5.

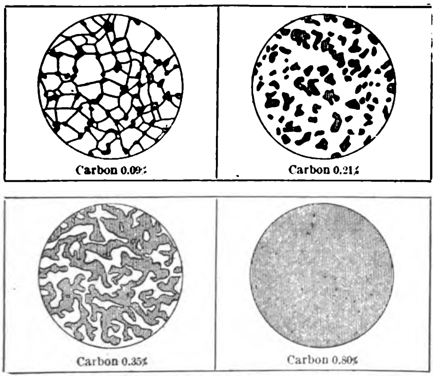
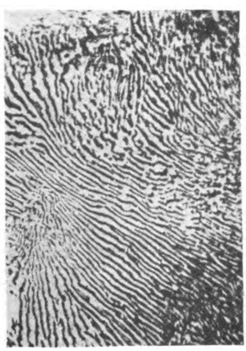


Fig. 5.

Steel containing less than 0.8 per cent, carbon (12 per cent. of Fe_3C) will be made up of crystalline grains of pure, or carbonless iron, in a matrix of the eutectic alloy of Fe and Fe_3C. Iron containing 0.8 per cent. carbon is all made up of the eutectic alloy, presenting all the structural characteristics of other eutectic mixtures, being alternate thin plates of Fe and Fe_3C seldom exceeding 1/40000 of an inch in thickness. The structure of these plates, pearlite magnified 1000 diameters, is at the right; and ferrite, magnified 130 diameters is at the left in Fig. 6.



Ferrite.

Pearlite.

Fig. 6.

Steel that contains more carbon than enough to form 12 per cent. of Fe_3C (carbide) has an excess of the carbide with regard to the composition of the eutectic alloy. As all the carbon combines with the iron, more than the right proportion of Fe_3C is present in the mass and areas of carbide surrounded by the eutectic alloy are seen under the microscope, as shown in Fig. 7, magnified 1000 diameters.

Mineralogical names have been given to these constituents. Pure iron is called "ferrite" and shows white in Fig. 8. The carbide Fe_3C, called "cementite" is black in Fig. 7. The eutectic alloy is called "pearlite." The composition of pearlite remains the same, like that of any eutectic alloy. It always contains 0.80 per cent. carbon. Ferrite and cementite can not be formed in the same metal. The relative proportions of ferrite and pearlite or of cementite and pearlite vary according to the degree of carbonization.

Low carbon steel, see Fig. 8, 0.45 per cent. carbon, magnified 1000 diameters, has a matrix of ferrite enclosing particles of pearlite. Increasing the carbon content increases the pearlite, until at 0.80 per cent carbon the metal is said to be saturated and is made up entirely of pearlite, having a

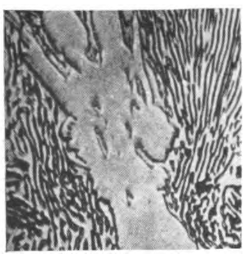


Fig. 7.
1.50 Carbon.

STEEL
POLISHED
AND ETCHED,
SHOWING
STRUCTURE
NOT
HARDENED.

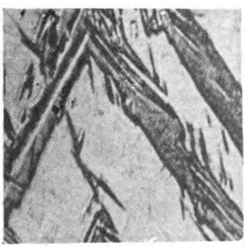
Fig. 8.
.45 Carbon.

pearly appearance (like mother of pearl). With further increase of carbon, cementite makes its appearance, increasing with the carbon content, and causing a corresponding decrease in the amount of pearlite. From its carbon content, the structural composition of any carbon steel may be calculated.

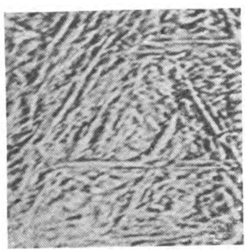
In saline solutions and alloys the rise in temperatures marks the beginning of solidification, the formation of structure takes place during a change of state, i. e., from a liquid to a solid.

Carbon steel is already in the solid state, and the heat evolved indicates internal energy, segregation of the constituents, without a change of state. This is suggestive, but not conclusive, of an allotropic transformation. It is the strongest argument of believers in the allotrophy of iron. It has not been possible to examine the structure of red hot metal, but by cooling the steel quickly, immersing it while at high temperatures in cold water, the changes, structural and others which take place during the retardations, do not occur, at least not entirely (for lack of time), and we retain in the cold metal the condition which existed at a high temperature. This treatment constitutes hardening, and we must observe the structure, or character, of hardened steel. With the microscope we see that 0.8 per cent., or saturated steel is now made up of another single constituent called "martensite," or hardenite, but if the steel was very highly carbonized we would see a mixture of martensite and "austenite," as in Fig. 9, while with 0.45 per cent. or low carbon steel hardened, we find, as might be expected, pure iron, or ferrite, and martensite in the structure after hardening, as shown, magnified 1000 diameters, in Fig. 10.

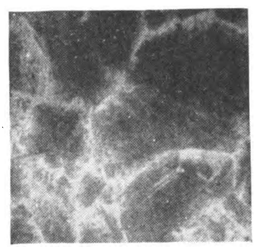
HARDENED STEEL



1.50 Carbon.
Fig. 9.



.45 Carbon.
Fig. 10.



.09 Carbon.
Fig. 11.

Fig. 11 is steel (0.09 per cent carbon) quenched at high heat, magnified 250 diameters.

Fig. 9 magnifies 1000 diameters a section of highly carbonized steel, i. e., 1.50 per cent., hardened. A new constituent may be observed here. This was named austenite by Mr. Osmand, and like the other names by which I have called the constituents of steel, this one is now generally accepted.

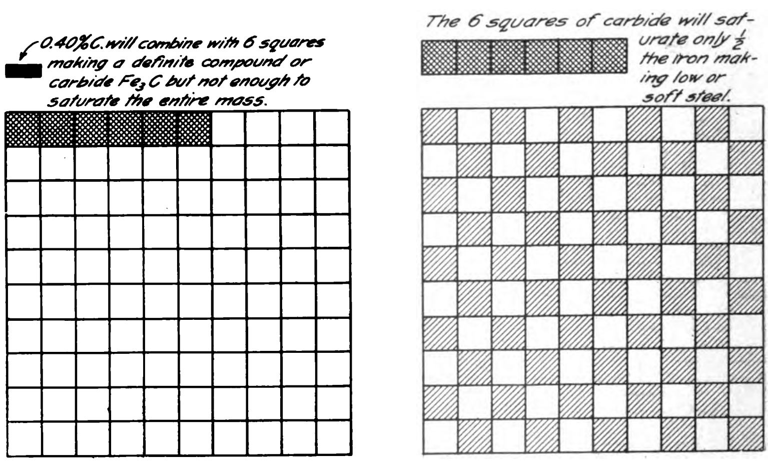
In steels quenched below the recalescence temperature, no martensite or austenite can be found; they are like annealed steel in their microstructural composition, and we know they are not sensibly hardened.

This remarkable effect of heat treatment is well known, and the difference between the mechanical properties of steel suddenly cooled from a high temperature and those properties of the same metal slowly cooled from the same temperature is evidently due to the presence of martensite, hardenite and austenite. But the cause of the hardness of martensite remains to be determined, and is a subject of investigation. Mr. Sauveur says it is reasonable to suppose that martensite is a solid solution of carbon in iron, or of the carbide Fe_3C in iron, and abandons the theory of a definite compound of iron and carbon.

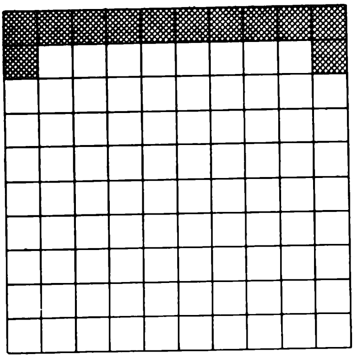
The allotropic theory is more plausible, iron itself is hard, and martensite may be a solution of carbon or Fe_3C in an allotropic condition of iron.

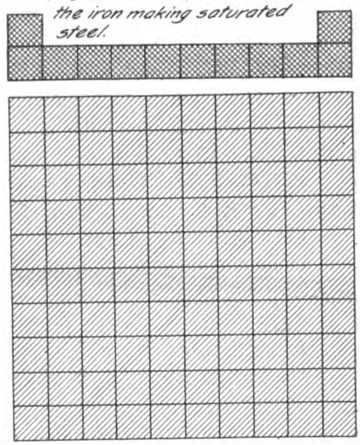
The physical properties of iron and steel do not depend on the relative proportion of their constituents, or upon the carbon content, but more largely upon the distribution, mode of occurrence, size and shape of the individual grains or crystalline particles. These characteristics are controlled by the treatment the metal is given. Slight changes of treatment, either thermal or physical, alter the structure, and the value of the microscope which supplies the means to determine those structural changes related so closely to the properties of metal has not been over estimated.

Theoretical drawings showing how iron and carbon mix forming different structure in steel.

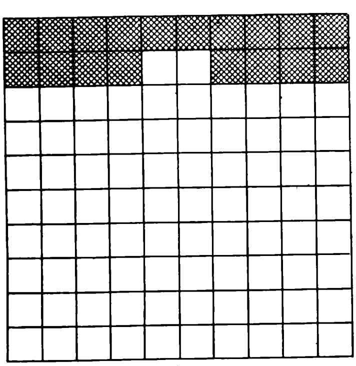


0.80% C. will combine with 12 squares making carbide enough to saturate all the iron.

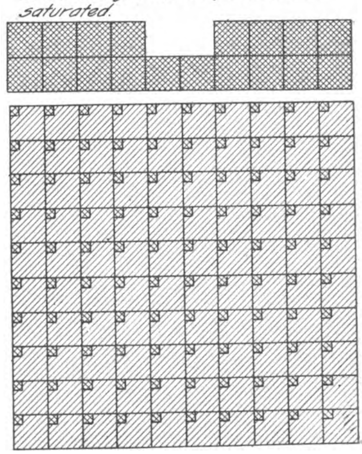




1.20% C. will combine with 18 squares making more carbide than enough to saturate the iron.



This carbide is more than enough to saturate the iron and mixes mechanically with the part that is saturated.



NOTES

One — At atmospheric temperature ferrite, which is pure iron, is called alpha.

Two — Ferrite is the largest element in any steel; it loses its magnetism at 1450° F. and is called beta iron while in this condition, and shows slightly in steel slowly quenched, and more plentifully in properly hardened steel that has been reduced by tempering.

Three — As it is made hotter, ferrite loses its electrical conductivity and absorbs heat rapidly; this condition is complete at 1650° F., where it is known as gamma iron.

Four — Alpha, beta, and gamma are the first three letters of the Greek alphabet; the names were given by metallurgists to the points where transformation occurs, with the rise and fall of temperature, and known as recalescence points or critical temperatures.

Five — Hardenite, martensite, and austenite are names for that arrangement, mode of occurrence, and appearance of the grains in steel that has been quenched at high temperatures.

Six — Carbide of iron is called cementite, expressed by the formula Fe_3C, meaning three atoms of pure iron for every one atom of carbon.

Seven — Pearlite is a mechanical mixture of ferrite and cementite that looks like mother of pearl.

Eight — Sorbite is an imperfect development of pearlite and cementite, segregated, but not so intimately mixed as to become hardenite. It occurs in partly hardened steel and is made more plentiful in alloys.

Nine — Troostite is a formation composed of the other substances and shows slightly in steel slowly quenched, and more plentifully in properly hardened steel that has been reduced by tempering.

Ten — The chemical composition remains the same, but the temperature at which these changes occur in iron is disturbed by other elements mixed with it.

INDEX

MACHINE FORGING

MACHINERY'S DOLLAR BOOKS

Published by THE INDUSTRIAL PRESS, NEW YORK

MACHINE FORGING

A TREATISE ON BOLT, NUT AND RIVET FORGING AND THE APPLICATION OF FORGING MACHINES TO FORMING, WELDING AND UPSETTING OPERATIONS ON MACHINE PARTS

BY

DOUGLAS T. HAMILTON

AUTHOR OF "AUTOMATIC SCREW MACHINES," "SHRAPNEL SHELL MANUFACTURE," "CARTRIDGE MANUFACTURE," ETC.

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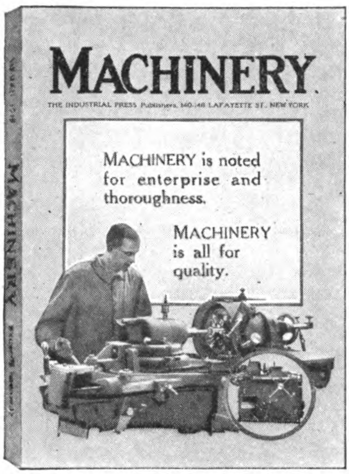
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MACHINERY

PREFACE

FOR many years inventors rarely crossed the threshold of the blacksmith shop. Hand-manipulated tools formerly were used for many forging operations which are now performed in a small fraction of the time entirely by mechanical means. In fact, a great deal has been accomplished during recent years in developing forging machines and various other classes of power-driven equipment for forge shops. The forging of bolts and rivets by machinery is an old method, but the use of machines adaptable to forging, welding and upsetting operations on machine parts ot numerous shapes and sizes, is a relatively modern development.

Since the making of bolts, nuts, and rivets is a very important and specialized branch of machine forging, the construction and use of the machines and dies employed for this work have been described in this treatise, as well as the application of machines designed for general forging operations. As the dies used for giving forgings the required shape are an essential feature of forging machines, dies designed for various typical operations have been illustrated and described in connection with this treatise.

D. T. H.

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MACHINE FORGING

CHAPTER I

BOLT HEADING MACHINES

THE bolt and nut industry in America started in a very small way in Marion, Conn., in 1818. In that year Micah Rugg, a country blacksmith, made bolts by the forging process. The first machine used for this purpose was a device known as a heading block, which was operated by a foot treadle and a connecting lever. The connecting lever held the blank while it was being driven down into the impression in the heading block by a hammer. The square iron from which the bolt was made was first rounded, so that it could be admitted into the block. At first Rugg made bolts only to order, and charged at the rate of sixteen cents apiece. This industry developed very slowly until 1839, when Rugg went into partnership with Martin Barnes; together they built the first exclusive bolt and nut factory in the United States in Marion, Conn. The bolt and nut industry was started in England in 1838 by Thomas Oliver, of Darlston, Staffordshire. His machine was built on a somewhat different plan from that of Rugg's, but no doubt was a further development of the first machine; Oliver's machine was known as the "English Oliver."

As is generally the case with a new industry, the methods and machines used were very carefully guarded from the public, and this characteristic seems to have followed the industry down to the present time, judging by the scarcity of information available on the subject. Some idea of the methods which were at first employed to retain all information in the factory in which it was originated is well

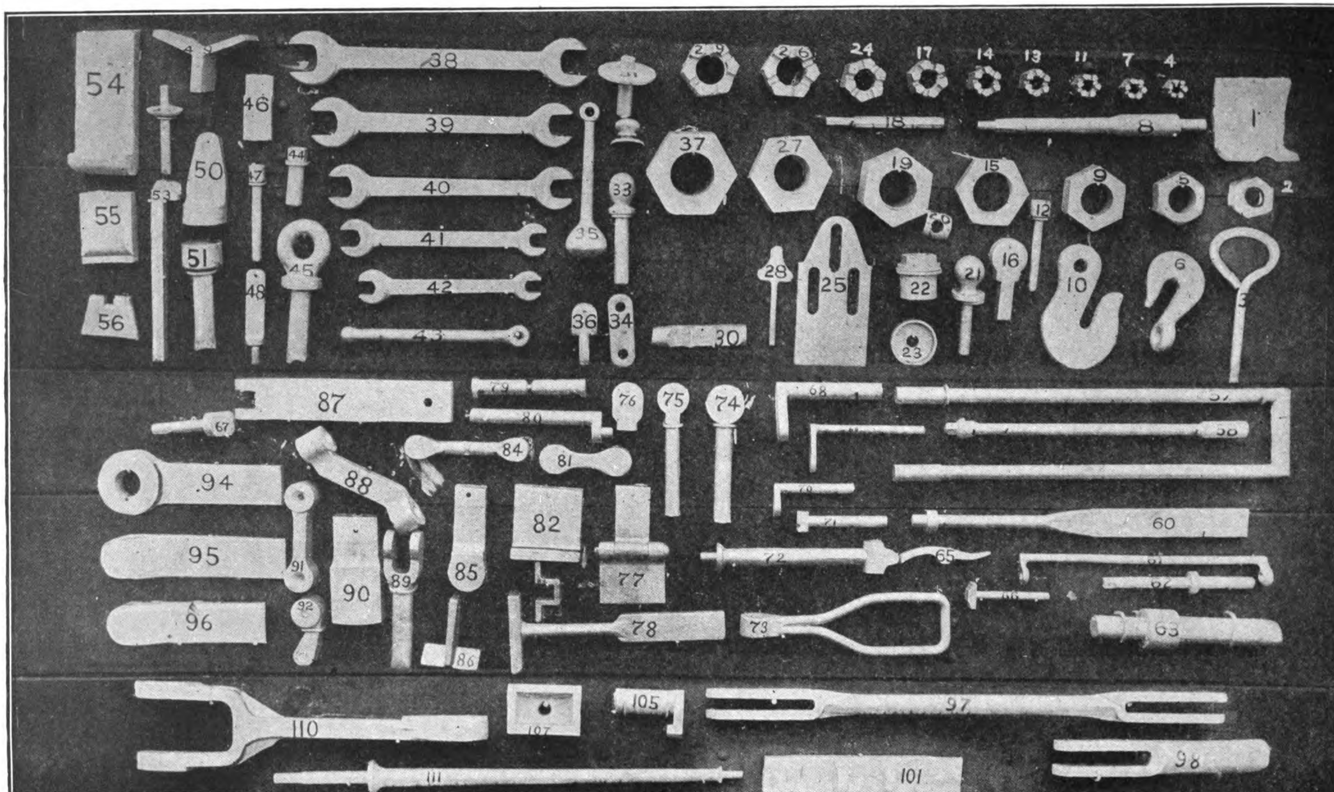


Fig 1. Examples of Forged Parts produced in the Collinwood Shops of the L. S. & M. S. Railway on Ajax Forging Machines

brought out by the following instance: In 1842, when the industry was beginning to be generally known, it is stated that a Mr. Clark, who at that time owned a bolt and nut factory in New England, and had devised a special machine for use in this manufacture, had his forging machine located in a room separated from the furnaces by a thick wall. A hole was cut through this wall, and the man who operated the machine received the heated bars from the furnace through the small hole in the wall. The only person who ever got a glimpse of the machine was the operator. The forge man was not permitted to enter the room.

Machine forging, as we know it today, is of wide application, embracing a large number of machines and processes that apply, in a measure, to almost any manufacturing plant. Machine parts hitherto made from castings are now made much more economically by the use of the drop-hammer or forging machine, and give much more satisfactory service.

Types of Machines. Upsetting and heading machines are divided into two general classes; namely, stop-motion and continuous-motion headers. The stop-motion headers have the greatest range, and are primarily used for heading bolts and for all kinds of upset forgings. The continuous-motion headers are used only for heading rivets, carriage bolts and short lengths of hexagon- and square-head machine bolts; they produce these parts at a much faster rate than is possible with a stop-motion header, but their range of work is limited. The universal practice is to shear the bars cold when working a stop-motion header, and only in special cases, when the shank at the headed piece is very short, is the side shear used.

Rivets, etc., forged in the continuous-motion header, are made by the process known as "off the bar;" that is, a bar is heated for a distance of approximately four feet, and is then pushed into the machine where the moving die acts as a shear and cuts off the blank. The latter is immediately gripped against the stationary die, whereupon it is headed and ejected. This whole cycle of movements is accomplished in one revolution of the flywheel.

Operation of Plain Bolt and Rivet Machines. Briefly stated, a plain bolt and rivet machine comprises two gripping dies, one movable and the other stationary, and a ram which carries the heading tool. The heated bar is placed in the impression in the stationary gripping die, and against the gage stop; the machine is then operated by pressing down the foot treadle shown in front of the

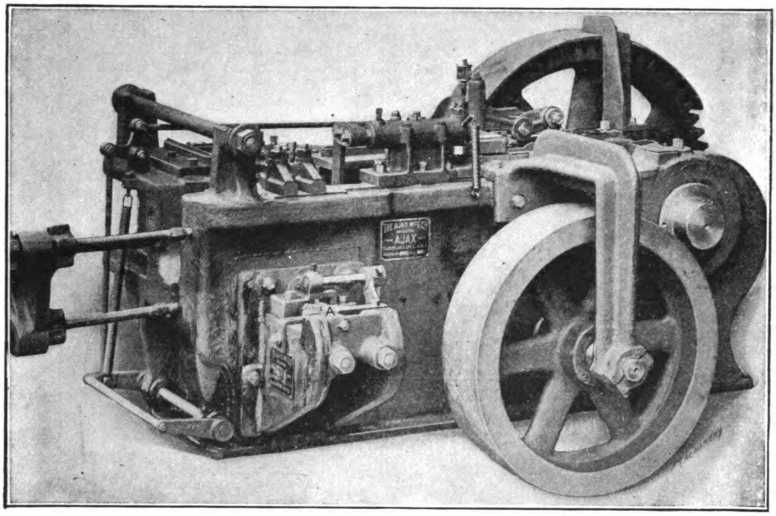


Fig. 2. Ajax Bolt Heading Machine suitable for all Types of Machine Bolts and Upset Forgings

machine in Fig. 2. As already mentioned, the stock is generally cut to the desired length before heading on this type of machine, especially when it is long enough to be conveniently gripped with the tongs; but it can be headed first and afterward cut off to the desired length in the side shear. It is also possible, in some makes of machines, to insert a cutting tool to cut off the blank before heading, when the work is not greater in length than the capacity of the machine.

There are several methods used in making bolts and rivets in a regular forging machine. In Fig. 3 is shown a diagrammatical view of a set of forging dies which have a wide range of application. In this type of dies the head on the bolt is formed by rotating the bar between the grip-

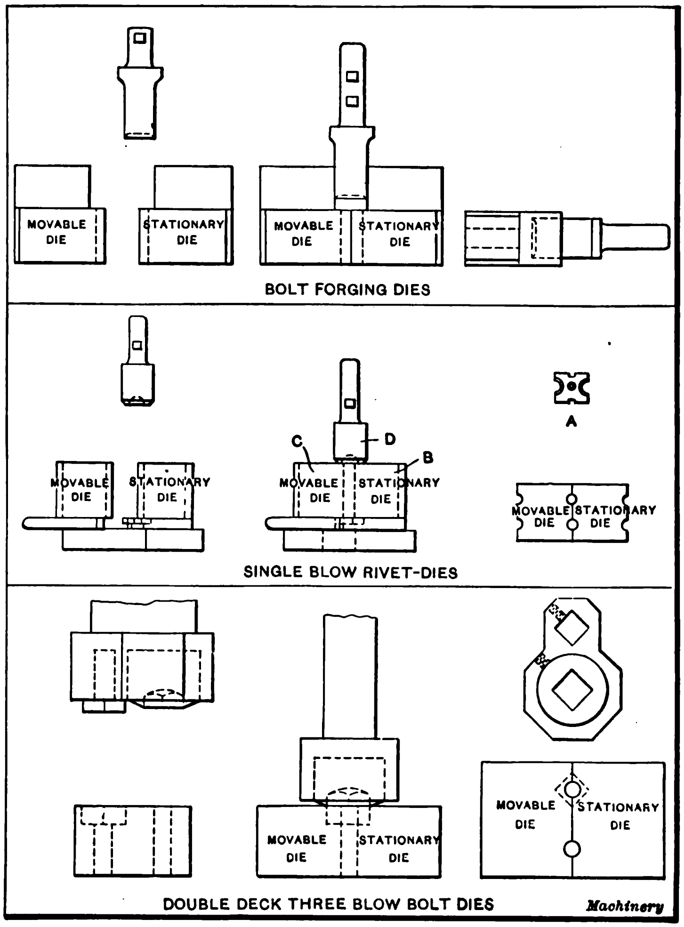


Fig. 3. Plain Bolt Forging Dies of Universal Application. Fig. 4. Single-blow Rivet Dies. Fig. 5. Double-Deck Three-blow Dies

ping dies after each blow of the plunger. For a square-headed bolt, the bar is turned twice through a space of 90 degrees, and is generally given two or more blows in each position. A hexagon-head bolt usually requires at least six blows to complete one bolt, and the shape of the head depends to a large extent on the skill of the operator. The wide range of work, however, which can be handled in dies of this type, makes them of almost universal application, especially in a railroad shop.

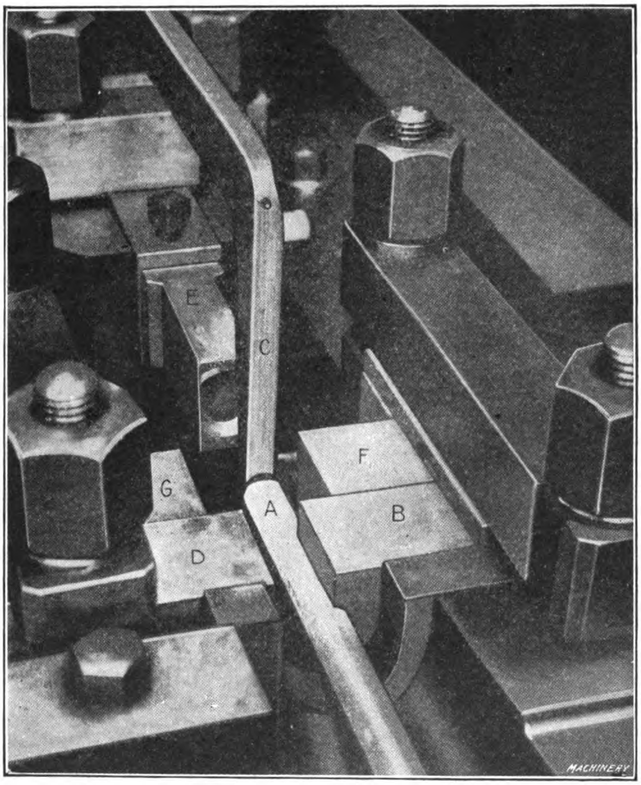


Fig. 6. First Step in the Production of Bolt Heads in Plain Forging Dies of the Type shown in Fig. 3

Fig. 4 shows a set of single-blow rivet dies which are used in a continuous-motion rivet header, and illustrates how these dies are operated in the making of a rivet in one blow. The heated stock is fed in and cut off to the exact length by a shear *A*; it is gripped between dies *B* and *C* while being cut off. Tool *D*, held in the ram of the machine, then advances, upsetting the head to the shape shown, whereupon the movable die backs out, allowing the formed rivet to drop out and the bar to be inserted to the stop, ready for the next piece. The type of bolt heading tool illustrated in Fig. 5 is known as a double-deck three-blow bolt die; its use and operation will be explained later.

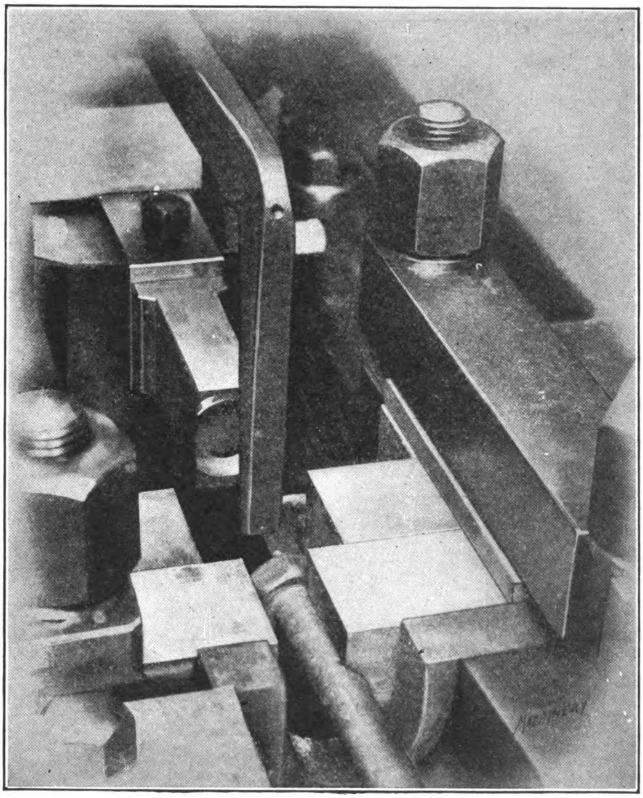


Fig. 7. Second Step in the Production of Bolt Heads

Successive Steps in Heading Bolts. Figs. 6, 7 and 8 show the successive steps followed in the forging of a hexagon-head bolt in the type of bolt forging dies illustrated in Fig. 3. Bar *A*, which is heated for a portion of its length, is placed in the impression in the stationary gripping die *B*, as shown in Fig. 6, and is gaged to length by the lifting stop *C*. The machine is then operated, and the movable die *D* closes in on the bar, gripping it rigidly. The stop now rises, and, as the ram of the machine advances, the plunger *E* upsets the end of the bolt, the blocks *F* and *G* forming a flat on each side of the upset end. The operator keeps his foot on the treadle, and as the movable die

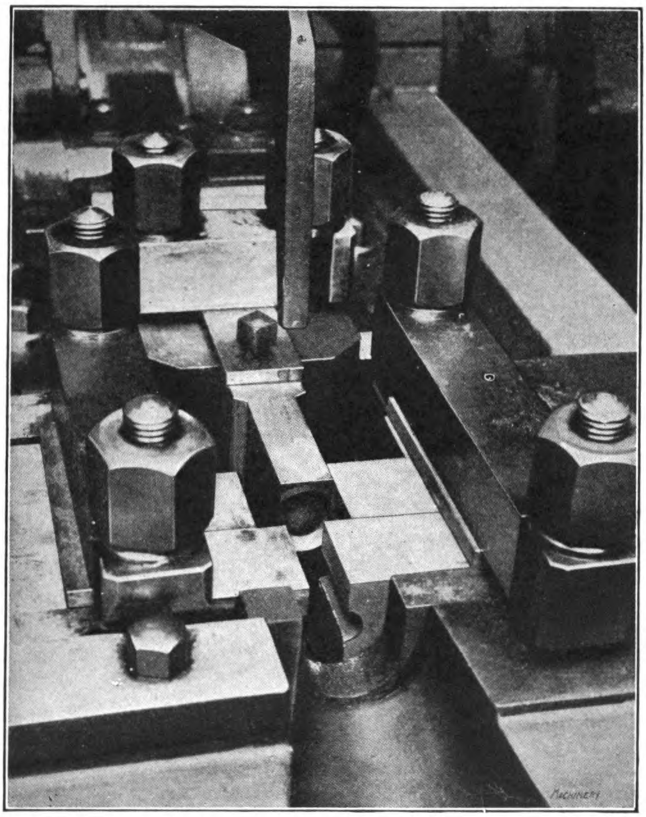


Fig. 8. Third Step in the Production of Bolt Heads

backs out, he rotates the rod one-sixth of a turn. This operation is repeated until the head has been correctly formed. The operator now removes his foot from the treadle, stopping the operation of the machine, when the dies remain in the open position, allowing him to remove the completed bolt as shown in Fig. 7. This view shows the stop down and the dies open ready for the rod to be inserted again, while Fig. 8 shows the dies open and the plunger on its return stroke.

Fig. 9 shows how the furnace and forging machine are arranged for making bolts and machine forgings in the Cleveland shop of the L. S. & M. S. Railway. The bars in this case are long enough to be gripped with the tongs, and are therefore cut off to the desired length in a power shear before heading. From the power shear the bars

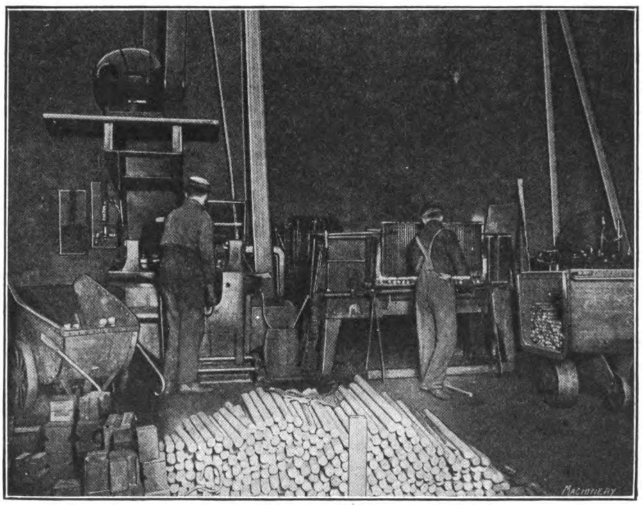


Fig. 9. Heading Bolts in a 2-inch Ajax Forging Machine

are brought to the heating furnace, in the truck shown to the right in the illustration, where one end of the bars is heated to the desired temperature. This furnace is heated by oil and is placed as close to the forging machine as possible. The man who attends to the heating of the stock places the rods in a row, and as soon as the end to be headed reaches the proper temperature, he quickly removes the heated bar and passes it to the forging machine operator, who immediately places it between the dies, operates the machine, and forms the head. In this particular example the bolt is 1¼ inches in diameter by 12 inches long, and is formed in three blows in double-deck dies of the type illustrated in Fig. 11. The dies and heading tool are kept cold by means of a constant stream of water. As soon as the bolt is headed it is thrown in the truck to the left, which is used for conveying the bolts to the threading machines.

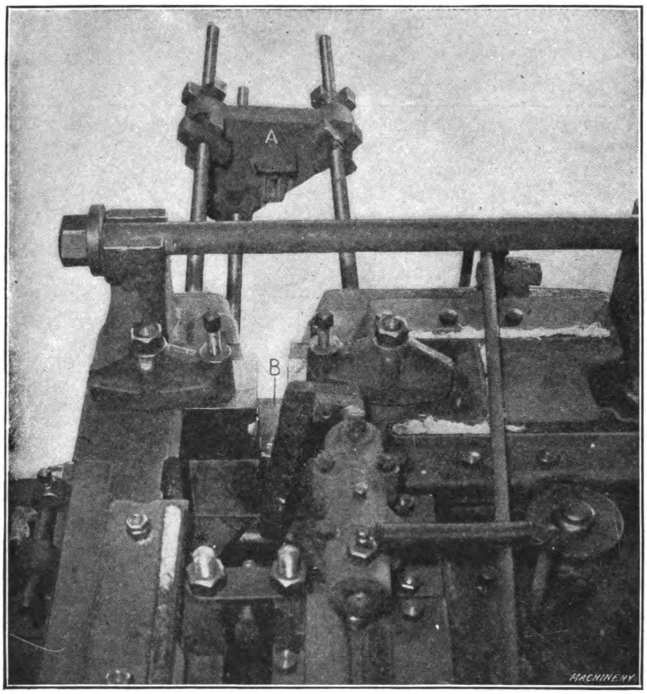


Fig. 10. View looking down into the Die Space of Bolt Forging Machine

Fig. 10 shows a view looking down into the die space of the Ajax bolt header, from which an idea of the relation between the working members can be obtained. The back stop *A* is used for locating the bar in the correct position. This stop is sometimes used instead of the swinging stop *B*. This view also shows how the gripping dies are held in the die space; a heel plate fastened to the frame of the machine and to the movable die-slide by studs and nuts, carries set-screws which bear down on the die blocks, holding them tightly in the die space.

Types of Bolt Header Dies. Fig. 11 shows a type of bolt heading dies known as double-deck three-blow bolt dies, which are used for finishing hexagon-head bolts. The two gripping dies *A* and *B*, as a rule, are made from blocks of tire steel; each gripping die is made from three pieces to facilitate machining. The lower header punch *C* is cupped out to form a hexagon, and is held in the heading tool-holder which is attached to the ram of the machine. The upper punch *D* is held in the same manner as the lower

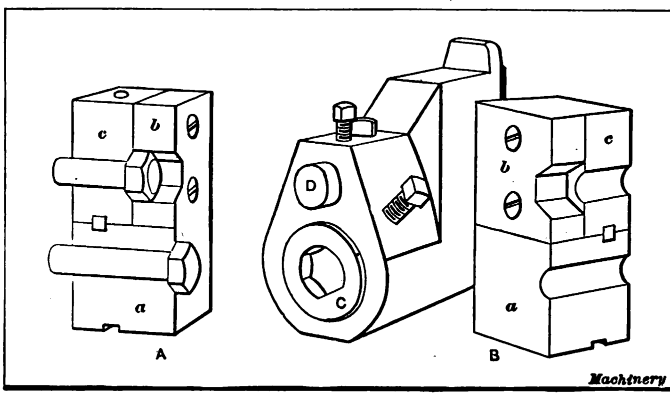


Fig. 11. Type of Double-deck Dies used in producing Bolt Heads without Fins or Burrs in Three Blows

heading punch, and forces the bolt into the hexagon impression in the dies after it has been roughly formed in the lower impression. This type of die produces a bolt free from fins and burrs, and accurate as regards size and shape. The bolt is given one blow in the lower position and then raised to the upper die impression, where it is generally given two blows.

A combination set of double-deck gripping dies for making square- and hexagon-head bolts is shown in Fig. 12. The construction of these dies is similar to that of the dies shown in Fig. 11, with the exception that these dies can be used for making both square- and hexagon-head bolts.

The punches for forming the hexagon- and square-head bolts are shown at the right and left, respectively. A general idea of the class of work turned out in a bolt and rivet header may be obtained from Fig. 13.

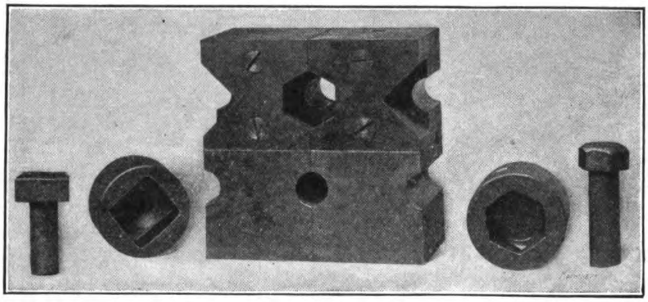


Fig 12. Combination Square and Hexagon Double-deck Bolt Dies

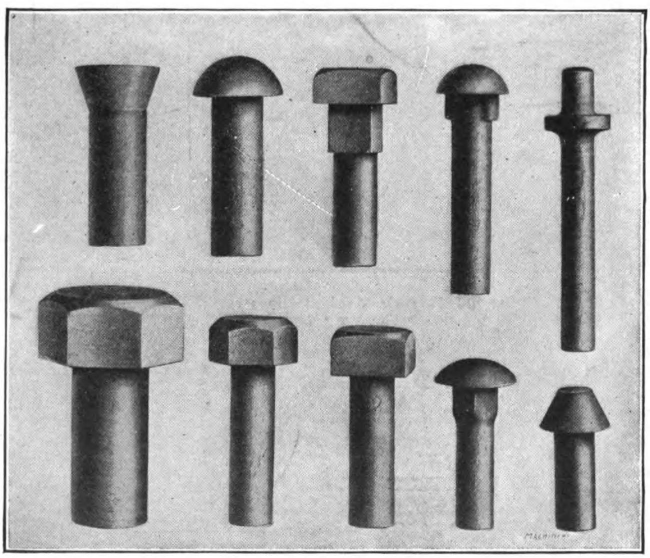


Fig. 13. Some Examples of Work turned out on National Wedge-grip Bolt and Rivet Header

Construction of National Wedge-grip Bolt and Rivet-Header. Fig. 14 shows a view of a two-inch National wedge-grip bolt and rivet header which is used for making bolts, rivets and miscellaneous forgings. There are a number of interesting features connected with this machine, one of which is the wedge-grip and automatic relief mechanism. In operating a bolt and rivet header it is necessary that the work be placed directly in the impression in the gripping dies and not between their opposing faces. Both of these dies must come tightly together, and are made to do so by the mechanism of the machine; therefore any foreign body preventing the correct movement

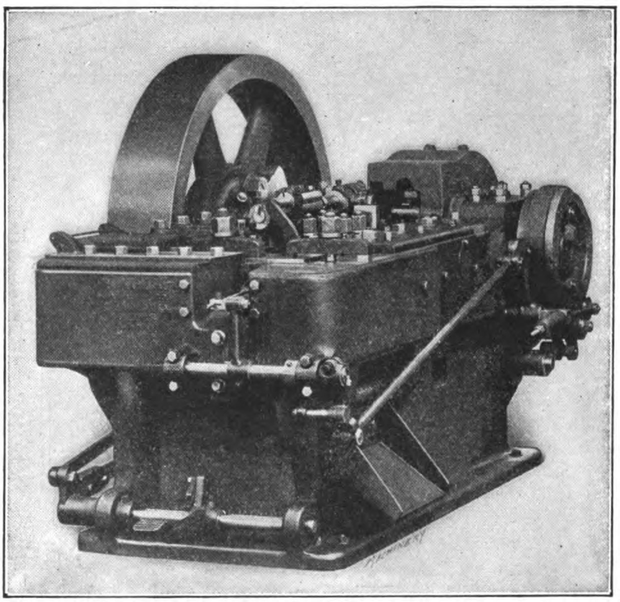


Fig. 14. Two-inch Wedge-grip Bolt and Rivet Header

of these dies would cause trouble by breaking the machine, if no special means to safeguard against this were provided. Various methods have been used, however, for obviating this difficulty, one of which is the application of a shearing pin in the movable gripping die slide, which, when the foreign body is placed between the dies, is sheared off without causing any damage to the machine. Another method, which is a special feature of the National wedge-grip header, is a spring relief, which throws the

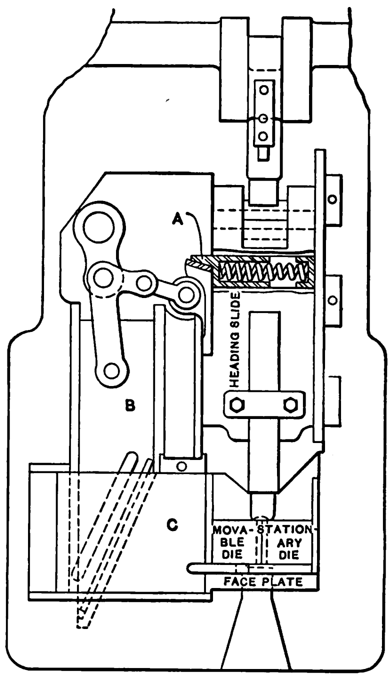


Fig. 15

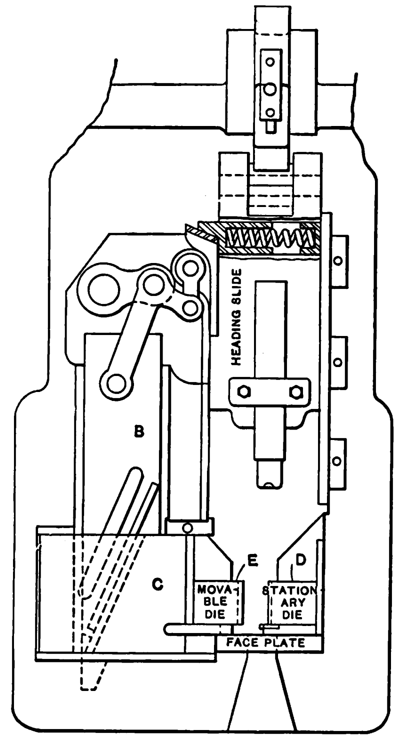


Fig. 16

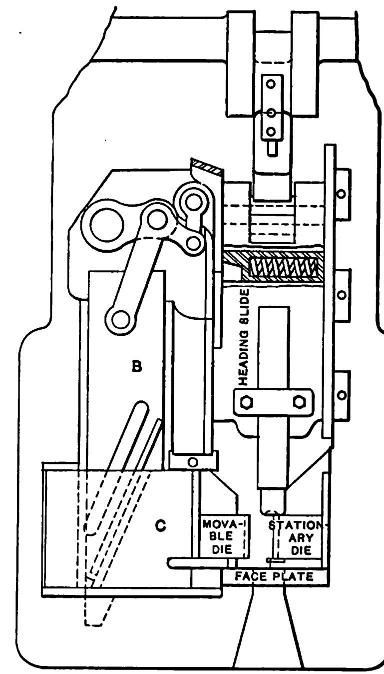


Fig. 17

Machinery

Figs. 15, 16 and 17. Diagrams Illustrating Construction and Operation of Wedge-grip Bolt and Rivet Headers

entire gripping mechanism out of action should the stock or any foreign body be caught accidentally between the dies and prevent them from closing. The action of this relief is indicated in Figs. 15 to 17. In Fig. 15 the gripping dies are shown closed and the relief mechanism does not operate. In Fig. 16, the gripping dies are shown open and the ram is at its extreme backward stroke, while in Fig. 17 the dies are open, but with the ram at the forward end of the stroke. The latter view shows what happens when a foreign body is caught between the gripping dies and prevents them from closing.

The relief mechanism consists of a spring plunger *A*, the front end of which is beveled, and which is kept in the "out" position by a coiled spring. This plunger, as indicated in Fig. 16, presses against an angular projection on the movable gripping slide. Now when a foreign body comes between the gripping dies and prevents them from closing, this spring plunger is forced back and the toggle joint operating the wedge-gripping slide remains stationary; this allows the dies to remain open, although the ram completes its full forward travel. This relief will operate up to the time the dies are closed, but when the dies are closed, the gripping pressure is positive.

An important feature of this machine is the wedge-grip for the movable slide. This consists of a slide *B* to which the toggle lever is attached, and which is moved back and forth by the latter through the movement of the crankshaft. The forward end of slide *B* is beveled and forms a solid metal backing when the gripping slide *C* is in the forward or gripping position—when the dies are closed. This means of locking the movable die during the heading operation prevents any rocking or wobbling of the slide and causes an even pressure to be exerted over the entire working surface of the dies. The stationary die *D* and movable die *E* are set so that their working faces merely touch, and the rigidity of the grip prevents any spring, so that the work can be produced without fins and burrs. By not having to set the dies ahead, the pounding or battering and premature wearing out of the dies is prevented. Fig. 18 shows more clearly how the movable and stationary dies are retained in the die space, and how they are backed up by steel liners. From an inspection of this illustration it will be seen that with this sliding wedge mechanism it is practically impossible for the dies to give or spring when in operation on the work.

Hammer Type of Bolt Header. In the type of bolt and rivet making machines so far described, the head is formed

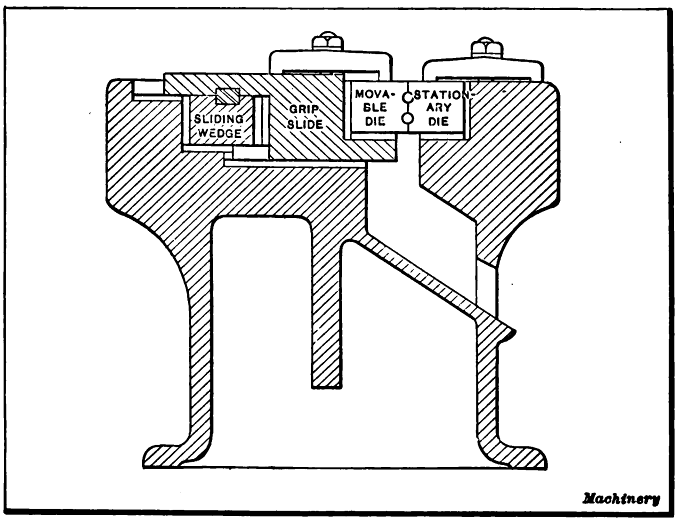


Fig. 18. Section through Die Box of the Wedge-grip Bolt and Rivet Header

by hitting the heated bar on the end and forcing it into suitably shaped impressions in the gripping dies. In the following, attention will be given to a type of bolt heading machine in which the end of the bar is first upset and the head then formed to the desired shape by the combined action of the upsetting punch and hammer dies operating from all four sides.

In the hammer type of bolt header, made by the National Machinery Co., Tiffin, Ohio, which is shown in Figs. 19, 20 and 21, the head of the bolt is formed by an end-

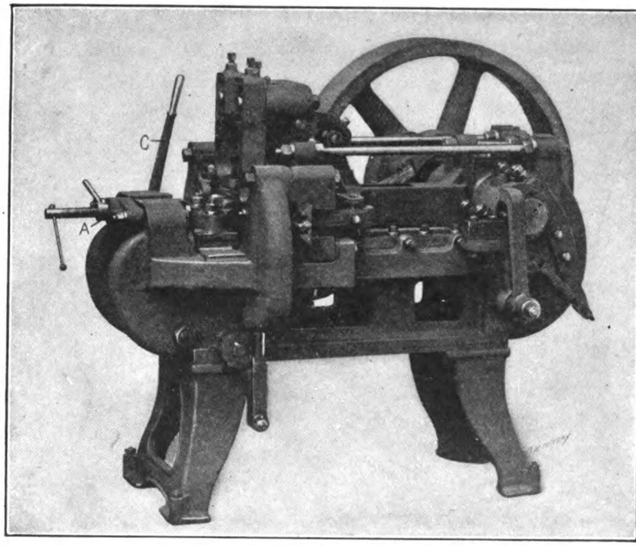


Fig. 19. Type of Hammer Header

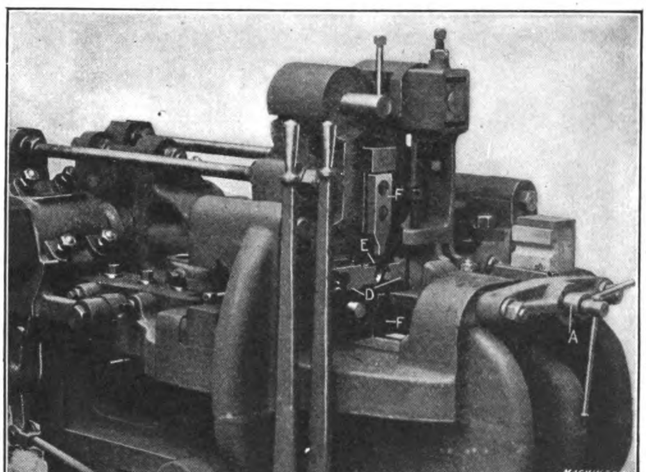


Fig. 20. View of Hammer Header showing Both Gripping Dies removed, and One Die Hanger

working upsetting punch and four hammers operated from all four sides at right angles to the axis of the bolt. In operation, the heated blank, which has previously been cut to length, is placed in a seat (when the bolt is long enough to be thus accommodated) and between the gripping dies, being located lengthwise by the adjustable stop *A*. Then by a movement of the hand-lever *C*, the dies (one of which

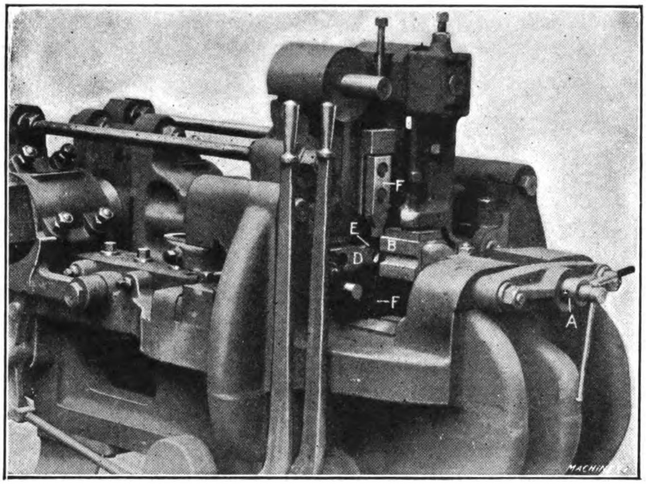


Fig. 21. View of Hammer Header showing Left-hand Die Hanger removed, and One Gripping Die in Place

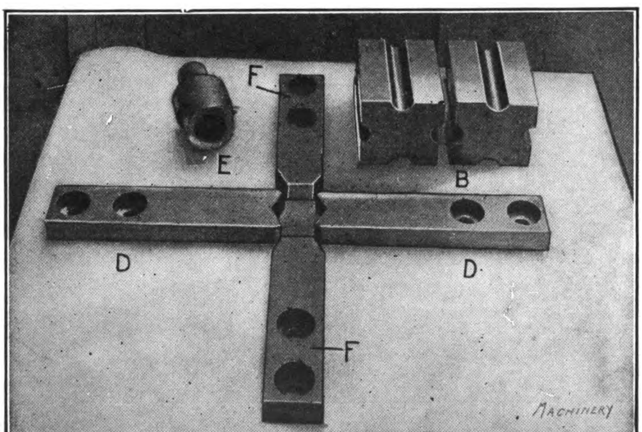


Fig. 22. Type of Dies, Hammers and Heading Tool used in the Hammer Type of Bolt Header shown in Fig. 19

is shown at *B* in Fig. 21) are closed and the machine is started. The stock is not moved during the forging operation, but is kept up against the adjustable stop, and the gripping dies are not opened until the head is completely formed. From three to five blows are struck, depending upon the size of the bolt and the finish desired, whereupon the machine is stopped and the dies are opened by operating the hand-lever, allowing the finished work to drop from the machine. The side-forming hammers *D*, Fig. 20, give two blows to every blow struck by the heading tool *E* and the vertical hammers *F*.

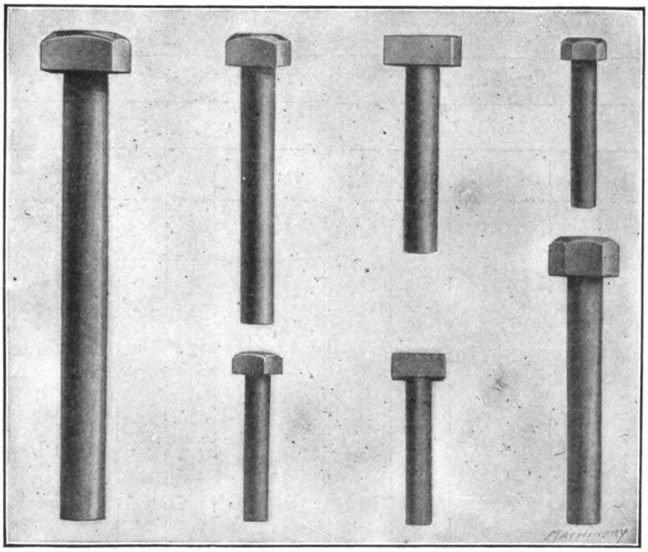
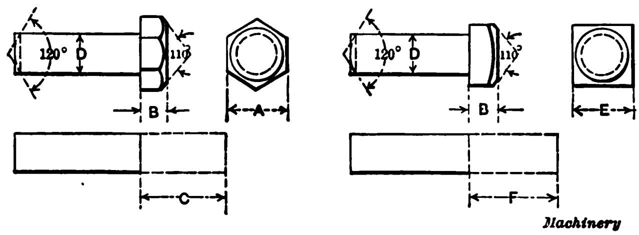


Fig. 23. Some Examples of Work produced in National Hammer Headers

The $1\frac{1}{2}$-inch size of this type of hammer header is provided with two hand controlling levers, as shown in Figs. 20 and 21. One of these levers operates the arms carrying the gripping dies, and the other operates the clutch for starting and stopping the machine. On the smaller sizes of machines, one lever controls both of these movements. Fig. 20 shows one of these hammer headers with the gripping dies and the left-hand gripping die hanger removed; this view also shows clearly the upsetting punch and the four forming hammers. Fig. 21 shows the same machine with one of the gripping dies in place, but with

Proportions of U. S. Standard and Manufacturer's Standard Hexagon and Square Head Bolts and Approximate Amount of Stock Required to Form Head



United States Standard						Manufacturers' Standard					
Dimensions in Inches						Dimensions in Inches					
D	A	B	C	E	F	D	A	B	C	E	F
1/4	1/2	1/4	1 3/32	1/2	1 9/32	1/4	7/16	3/16	23/32	3/8	17/32
5/16	19/32	19/64	1 3/16	19/32	1 3/8	5/16	17/32	1/4	3/4	15/32	11/16
3/8	11/16	11/32	1 1/4	11/16	1 1/2	3/8	5/8	9/32	15/16	9/16	13/16
7/16	25/32	25/64	1 3/8	25/32	1 5/8	7/16	23/32	21/64	1	21/32	31/32
1/2	7/8	7/16	1 1/2	7/8	1 23/32	1/2	13/16	3/8	1 3/32	3/4	1 1/16
9/16	31/32	31/64	1 5/8	31/32	1 13/16	9/16	29/32	27/64	1 1/4	27/32	1 7/32
5/8	1 1/16	17/32	1 11/16	1 1/16	2	5/8	1	15/32	1 13/32	15/16	1 11/32
3/4	1 1/4	5/8	1 15/16	1 1/4	2 7/32	3/4	1 3/16	9/16	1 9/16	1 1/8	1 5/8
7/8	1 7/16	23/32	2 5/32	1 7/16	2 1/2	7/8	1 3/8	21/32	1 7/8	1 5/16	1 7/8
1	1 5/8	13/16	2 3/8	1 5/8	2 3/4	1	1 9/16	3/4	2 1/32	1 1/2	2 5/32
1 1/8	1 13/16	29/32	2 19/32	1 13/16	3	1 1/8	1 3/4	27/32	2 7/32	1 11/16	2 13/32
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1 1/2	2 3/8	1 3/16	3 5/16	2 3/8	3 13/16	1 1/2	2 5/16	1 1/8	3	2 1/4	3 7/32
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1 7/8	2 15/16	1 15/32	4	2 15/16	4 5/8	1 7/8	2 7/8	1 13/32	3 23/32	2 13/16	4 3/32
2	3 1/8	1 9/16	4 1/4	3 1/8	4 7/8	2	3 1/16	1 1/2	4	3	4 5/16
2 1/4	3 1/2	1 3/4	4 25/32	3 1/2	5 7/16	2 1/4	3 7/16	1 11/16	4 9/16	3 3/8	5
2 1/2	3 7/8	1 15/16	5 3/16	3 7/8	5 15/16	2 1/2	3 13/16	1 7/8	4 13/16	3 3/4	5 3/8
2 3/4	4 1/4	2 1/8	5 1/2	4 1/4	6 7/16	2 3/4	4 3/16	2 1/16	5 3/8	4 1/8	5 29/32
3	4 5/8	2 5/16	6 1/16	4 5/8	7	3	4 9/16	2 1/4	5 11/16	4 1/2	6 7/16
3 1/4	5	2 1/2	6 1/2	5	7 9/16	..	..	..	..	..	..
3 1/2	5 3/8	2 11/16	7	5 3/8	8 1/8	..	..	..	..	..	..
3 3/4	5 3/4	2 7/8	7 1/2	5 3/4	8 11/16	..	..	..	..	..	..
4	6 1/8	3 1/16	8	6 1/8	9 5/16	..	..	..	..	..	..

the left-hand gripping die hanger removed. The tools used in this machine are more clearly illustrated in Fig. 22; the various members are denoted with the same reference letters as used in connection with the description of the machine. For making a square-headed bolt, the side-working hammers, of course, are of the same shape as the vertical hammers.

The type of hammer header illustrated in Figs. 19, 20 and 21 is limited in its scope to the production of square, hexagon and tee-headed bolts as shown in Fig. 23. These, however, can be produced in large quantities at a low cost, and what is more important, the product is entirely free from fins and burrs, and is shaped as accurately as is possible by the forging method. The fact, however, that it takes longer to change the dies from one size to another in this type of machine is a point against its installation in preference to the other types of bolt headers, where frequent changes in the sizes of dies are necessary.

Stock Required for Bolt Heads. In forming a head on a bolt or rivet, the heated metal on the end of the bar is upset or formed into the desired shape by a plunger held in the ram of the forging machine. To produce the head requires considerably more metal than the thickness of the head—because of the increase in diameter—and hence it is necessary to allow a certain amount of excess stock to form the head. The accompanying table gives proportions of U. S. standard and Manufacturers' standard hexagon and square bolt heads, and also the approximate amount of stock required to form the head—this information being listed in Columns "C" and "F." The excess amount of stock given is not exact, but is close enough for starting the machine, as the stop can afterward be adjusted to suit.

CHAPTER II

CONTINUOUS-MOTION BOLT AND RIVET HEADERS

CONTINUOUS-MOTION bolt and rivet headers are made in two types, one being hand-fed and the other provided with an automatic roll feed. A machine of the hand-fed type, built by the National Machinery Co., is shown in Fig. 1. In operating this type of machine, the bar, which has been heated for a length of four or five feet, is fed through a shear in the faceplate block of the machine, and as the movable gripping die closes on the bar, a blank of the required length is cut off and held rigidly in the gripping dies. The head is then formed by the forward movement of the ram which carries the heading tool. After heading, the ram of the machine recedes, the gripping dies open, and a kicker, actuated by a connecting-rod *C* from a cam on the main shaft, ejects the finished work from the dies, depositing it, through a chute, into a box. As the dies open, the operator again pushes in the heated bar until it strikes the stop, and as the movable die advances, another blank is cut off and headed as before. The machine runs continuously until the heated portion of the bar has been exhausted, when the operator takes a newly heated bar from the furnace and proceeds as before.

A bolt or rivet made in a machine of this type receives only one blow, and, therefore, for work within the capacity of this machine, the production is greatly increased over that obtained from the plain type of forging machine. One of the chief requisites in a machine of the continuous-motion type is that of securing a rigid grip on the work while the head is being formed. If the grip is not satisfactory, that is, if the dies separate, it causes the shank of the bolt or rivet to become tapered or out of round, and also re-

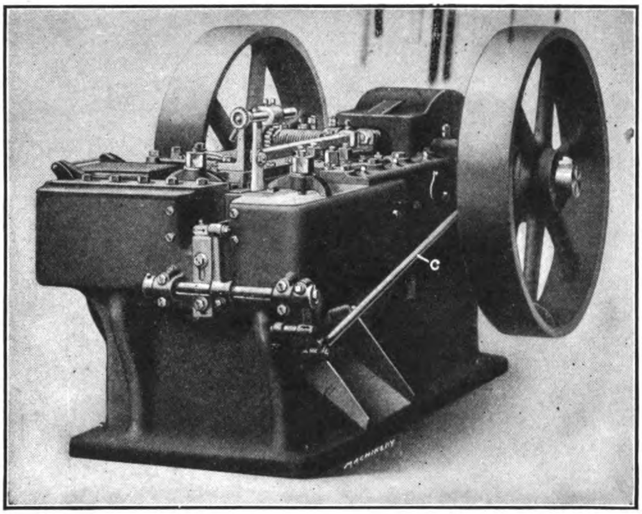


Fig. 1. Continuous-motion Wedge-grip Bolt and Rivet Header

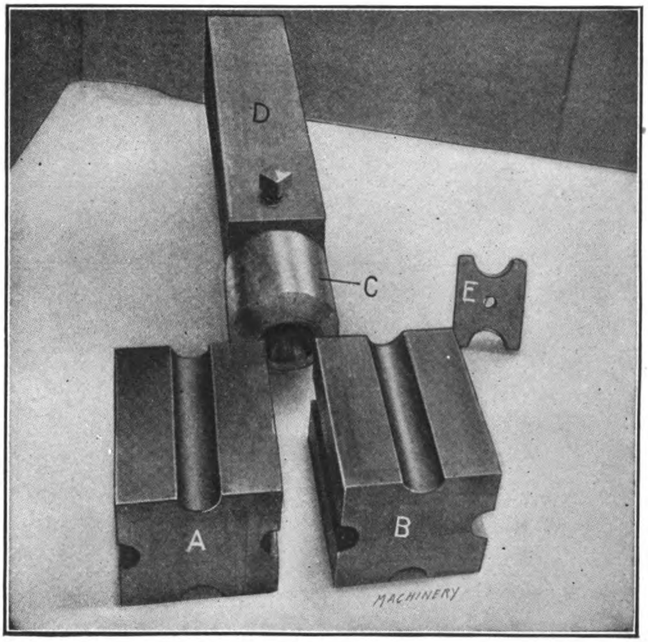


Fig. 2. Type of Dies and Tools used in the Continuous-motion Bolt and Rivet Header shown in Fig. 1

sults in fins being produced on the shank and under the head. Furthermore, unless the machine is provided with suitable slides which can be kept in proper alignment, it is difficult to secure work on which the heads are centrally located with the shanks, and also to keep the shear and movable die in correct working relation.

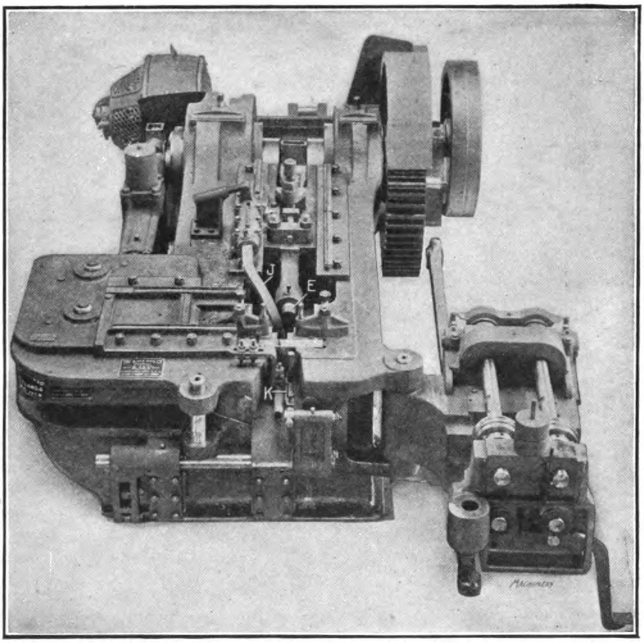


Fig. 3. Continuous-motion Bolt and Rivet Header equipped with Roll Feed Attachment

The type of tools used in the bolt and rivet machine of the continuous-motion type is illustrated in Fig. 2. The two gripping dies *A* and *B* are held in the die space of the machine by heel clamps as shown in Fig. 1. The gripping dies are provided with four interchangeable grooves, so that when one groove wears out, it is only necessary to turn the blocks. The heading punch *C*, which is held in the holder *D* in the ram of the machine, is cupped out to suit the shape of the bolt or rivet head, and is so arranged that it will be in perfect alignment with the gripping dies.

The shearing blade *E* is held in the faceplate block, and is used in cutting off the stock to the desired length. The length of the gripping dies is governed by the length of the bolt required; they are made shorter than the blank from which the bolt is made, thus allowing for sufficient extra stock to form the head.

Continuous-motion Bolt and Rivet Header with Automatic Feed. Fig. 3 shows a continuous-motion bolt and rivet header, built by the Ajax Mfg. Co., Cleveland, which is furnished with a roll feed attachment, consisting of four rollers provided with suitably shaped grooves in their peripheries. This view shows the roller feed attachment

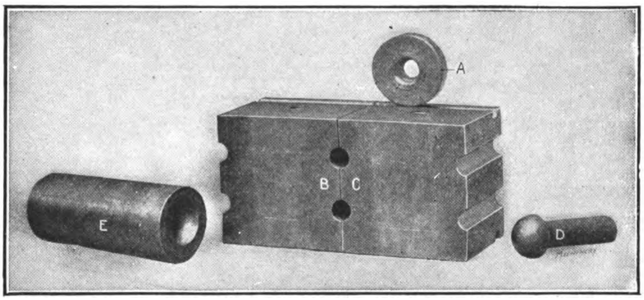


Fig. 4. Type of Dies and Tools used in Bolt and Rivet Making Machine shown in Fig. 3

swung back out of the way in order to exhibit the dies and tools. This machine is similar to the one shown in Fig. 1, with the exception of the roll feed attachment for handling the bars automatically. The tools used are shown in Fig. 4, together with an example of work produced in them. The shearing die *A*, in this case, is steel bushed and is circular instead of oblong in shape. The gripping dies *B* and *C* are provided with four grooves each, as previously described, but to change the blocks for presenting a new groove, they are turned end for end, there being no grooves in the top faces. *D* is a ¾- by 4-inch track bolt; *E* is the heading tool that is held in the ram of the machine.

A close view looking down into the die space of the machine shown in Fig. 3 is illustrated in Fig. 5. This view shows the relative positions of the feed rolls, shearing die, gripping dies, etc. The heated bar is fed by the rolls *F* through the guide pipe *G* held by bracket *H*, and through the shearing bushing *A*. This bushing is retained in the faceplate *I* which is held in grooves in the machine bed. The bar is fed directly through the cut-off bushing *A* and is gaged to length by the swinging stop *J* (see also Fig. 3). The movable die *C* then advances, cuts off the blank and carries it into the groove in the stationary die *B*, gripping

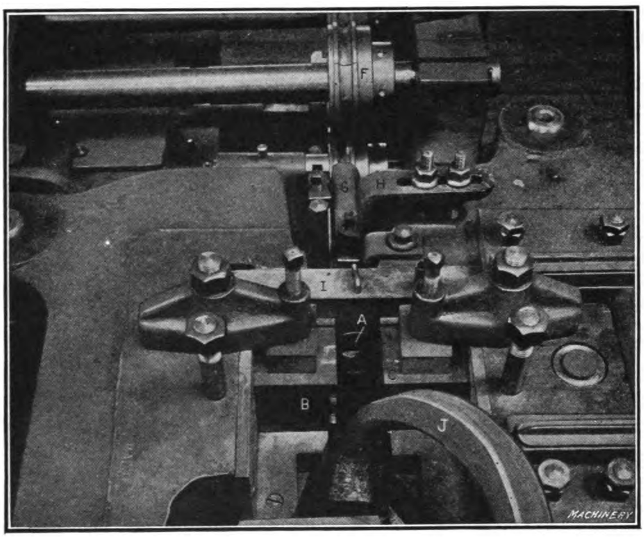


Fig. 5. View looking down into Die Space of a Continuous-motion Bolt and Rivet Header

it while the heading tool (*E*, Fig. 3) advances and upsets the end of the bar, forming the head. The stationary and movable gripping dies are held in place by straps, and are located by tongues fitting in grooves in their lower faces. The length of feed is governed by the travel transmitted to the rolls by the feed mechanism, which receives power from the main crankshaft through a connecting-rod, ratchet, pawl, gears, etc., and is adjustable at the operator's will.

The various steps in the production of a round-head rivet by the continuous-motion single-blow bolt and rivet

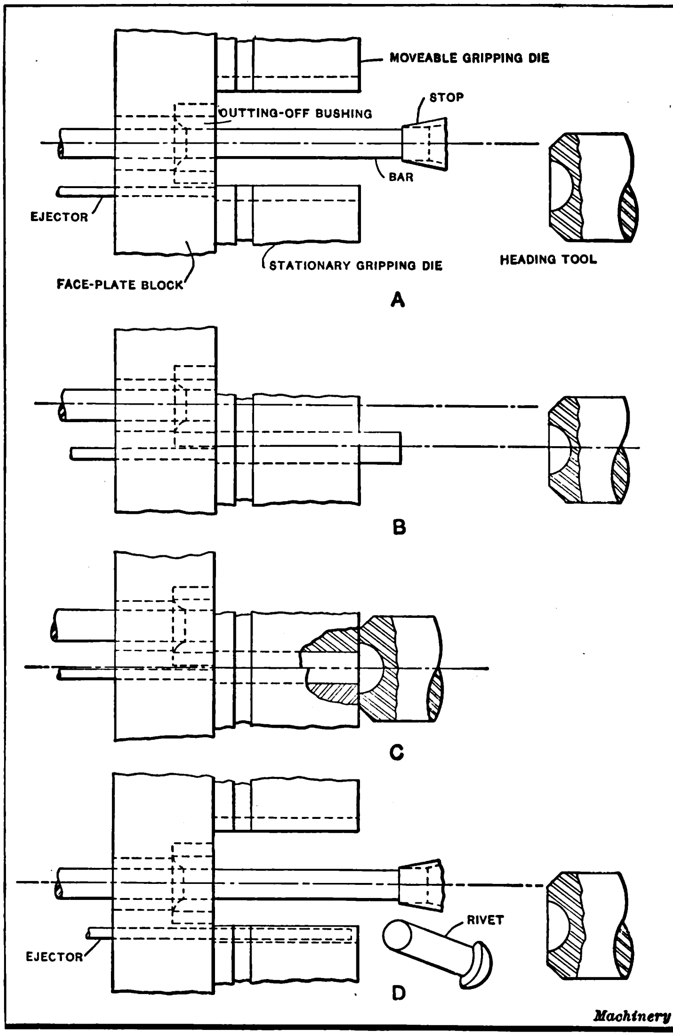


Fig. 6. Successive Steps in the Formation of a Round-head Rivet in a Single-blow Rivet Machine of the Continuous-motion Type

machine, are clearly illustrated in the diagram, Fig. 6. At *A*, the feed rolls have operated and have fed the heated bar out against the gage stop; at *B*, the movable die has advanced, sheared off the end of the bar (projecting through the shearing bushing), and carried the blank into the groove in the stationary die. When the blank is held rigidly, or in other words, when the movable die has reached the end of its forward movement, the heading tool advances, as shown at *C*, and upsets the end of the bar, forming the head. At *D*, the movable die and heading tool have retreated, the ejector pin (see *K*, Fig. 3) has advanced, pushing out the completed rivet, and the bar has been fed out again ready for a repetition of the operations.

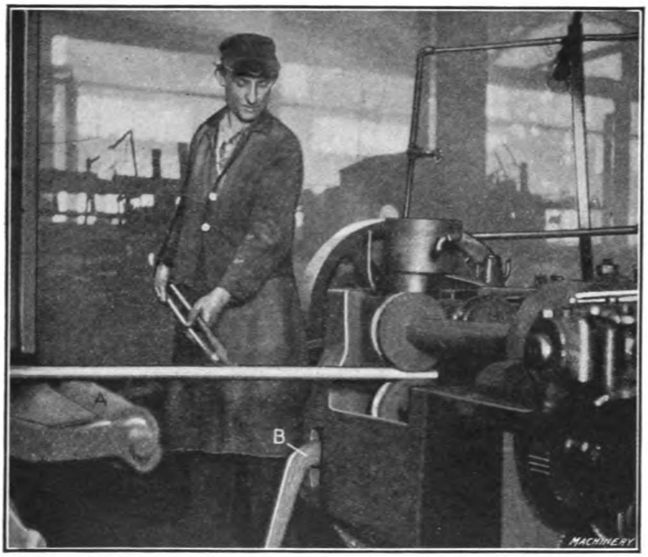


Fig. 7. Continuous-motion Bolt and Rivet Machine in Action making 1 ½-inch Rivets

Some idea of the methods pursued in the making of bolts and rivets by the continuous-motion machine process can be obtained from Fig. 7, which shows an operator attending to one of these automatic machines. The furnace in which the bar is heated (in the condition in which it comes from the mill) is located anywhere from 3½ to 4 feet from the feed rolls of the machine, and is provided in front with a roller *A*, over which the heated bar passes. The heating furnace, as a rule, is 30 feet long, so that the entire length of a bar can be accommodated.

As soon as the bar in the furnace has reached the proper temperature, the operator grips it with a pair of tongs, as indicated in Fig. 7, draws it out, and places it between the feed rolls. Then he presses down the foot-lever *B*, thus starting the machine. The heated bar is then drawn in by the rolls, fed through the cutting-off die, gripped in the gripping dies, headed and ejected at the rapid rate of forty to seventy pieces per minute.

In the manufacture of rivets, as a rule, steel containing from 0.10 to 0.12 per cent carbon is more frequently used than wrought iron, although the latter material is used in considerable quantities in some manufacturing establishments. Wrought iron for making rivets is heated to almost a white heat, but steel which contains from 0.10 to 0.12 per cent carbon is heated to only about 1400 degrees F.—a bright red color. When the head of a rivet is so shaped that it is necessary to carry the stock down far into the heading tool, the temperature to which the bar is heated must be increased, in order to make the metal flow more readily and prevent buckling.

In making rivets with long tapered heads, the operator generally finds it necessary to change the length of feed, so that a rivet having a full head without flash is formed. The reason for this is that the bars sometimes vary in size and temperature, which makes this adjustment necessary. A National continuous-motion bolt and rivet making machine is provided with means for taking care of the fluctuations in size and temperature of stock. In this machine the position of the stop is controlled by a handwheel within convenient reach of the operator, which he adjusts either way, depending upon the size of the bar, temperature of the metal, the shape of the part to be produced and the material from which it is made. When an over-size bar is encountered, the operator shortens the length of feed, as it is evident that too much stock would otherwise be supplied. When the bar is under-size, the reverse is the case. Again, when the bar is too hot, it is upset more on the end by the rolls forcing it against the stop, and of course more metal is provided than when the bar is not so hot, and consequently harder. The operator watches the pieces as they drop from the machine, and then adjusts the stop to keep the work as uniform as possible—having a full head and without flash. The feed rolls of this machine are made of chilled iron castings, and are kept cool by water jackets, insuring even temperature and minimum wear. They are operated from the main-shaft of the machine, through a

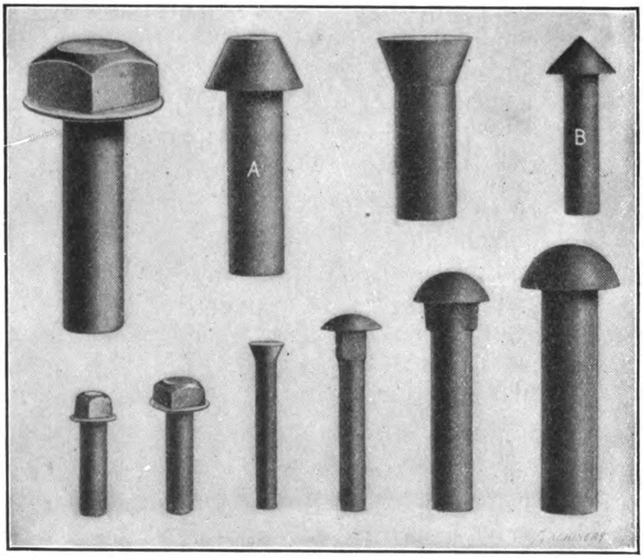


Fig. 8. Some Examples of Work which come within the Range of the Continuous-motion Type of Bolt and Rivet Headers

ratchet feed, by a connecting-rod, which is adjustable for securing variations in the feeding time of the rolls. The movements of the machine are timed so as to allow the gripping dies to remain open a comparatively large part of the revolution, thereby allowing more time for the stock to be fed in and gaged, and the dies to be well flooded and cooled at the completion of each stroke.

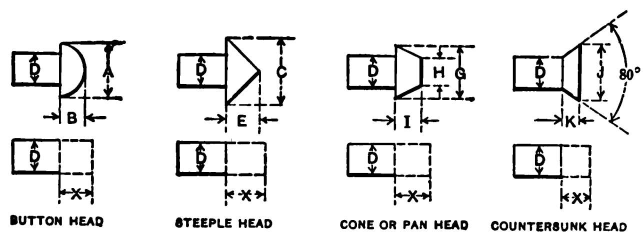
Examples of Continuous-motion Bolt and Rivet Work. Inasmuch as only one blow can be struck in a continuous-motion bolt and rivet making machine, it is impossible to produce parts which cannot be completed in one blow. Fig. 8 shows a representative group of bolts and rivets for which the continuous-motion machines are especially adapted. These machines will also handle a great variety of special work, such as square and hexagon head single-blow bolts, track bolts, etc. The cone-shaped rivets *A* and *B* illustrate the point mentioned in a previous paragraph regarding the difficulty encountered in producing work which is carried down far into the heading tool. These examples serve to illustrate the point.

Making Bolt and Rivet Dies. Bolt dies which are used in a forging machine are as a rule made from steel containing from 0.60 to 0.80 per cent carbon, and are hardened and drawn. The gripping dies are tempered hard, so that the sharp corners on the edges of the dies will not wear away rapidly. It is customary to harden these dies in either oil or water, and then draw the temper so that a file will just take hold. The heading tool, which is comparatively small in diameter, and is called upon to perform heavy duty, must be much tougher than the gripping dies. Ordinarily the heading tool is made from a tough steel containing from 0.40 to 0.50 per cent carbon, and is drawn considerably more than the gripping dies.

In making the impressions in the gripping dies for heading ordinary sizes of bolts, no allowance is made for the shrinkage of the metal. However, in drilling the hole in the dies which grip the stock when it is being headed, a liner is placed between the two halves of the die, so that when they come together on the stock, the latter will be securely held. For dies with a 1/4- to 5/8-inch hole, a liner 1/64 inch thick is placed between the opposing faces, when drilling the hole. For holes larger than 5/8 inch and up to 1 inch, a liner 1/32 inch thick is used; for holes from 1 inch up to 1 1/2 inches in diameter, a liner 3/64 inch thick is used; and from 1 1/2 inches up to and including 3 inches in diameter, a liner 1/16 inch is employed. The double-deck type of dies are made from six blocks of steel bolted and keyed together to facilitate machining.

In making bolt and rivet dies which are used in continuous-motion machines, it is customary when making rivets from ½ to 1 inch in diameter, to use bar stock which is rolled 1/64 inch under size. The dies referred to are shown in Figs. 2 and 4. The holes in the gripping dies are

Dimensions of Rivet Heads of Various Shapes



Machinery

Dimensions in Inches

D	A	B	C	E	G	H	I	J	K
1/4	7/16	3/16	1/2	1/4	7/16	1/4	7/32	29/64	1/8
5/16	35/64	15/64	5/8	5/16	35/64	5/16	17/64	37/64	5/32
3/8	21/32	9/32	3/4	3/8	21/32	3/8	21/64	11/16	3/16
7/16	49/64	5/16	7/8	7/16	49/64	7/16	3/8	51/64	7/32
1/2	7/8	3/8	1	1/2	7/8	1/2	7/16	29/32	1/4
9/16	1	13/32	1 1/8	9/16	1	9/16	1/2	1 1/32	9/32
5/8	1 3/32	15/32	1 1/4	5/8	1 3/32	5/8	17/32	1 5/32	5/16
11/16	1 3/16	1/2	1 3/8	11/16	1 3/16	11/16	19/32	1 1/4	11/32
3/4	1 5/16	9/16	1 1/2	3/4	1 5/16	3/4	21/32	1 3/8	3/8
13/16	1 7/16	19/32	1 5/8	13/16	1 7/16	13/16	23/32	1 1/2	13/32
7/8	1 17/32	21/32	1 3/4	7/8	1 17/32	7/8	3/4	1 19/32	7/16
15/16	1 5/8	11/16	1 7/8	15/16	1 5/8	15/16	13/16	1 11/16	15/32
1	1 3/4	3/4	2	1	1 3/4	1	7/8	1 27/32	1/2
1 1/16	1 27/32	25/32	2 1/8	1 1/16	1 27/32	1 1/16	15/16	1 15/16	17/32
1 1/8	1 31/32	27/32	2 1/4	1 1/8	1 31/32	1 1/8	1	2 1/16	9/16
1 1/4	2 3/16	15/16	2 1/2	1 1/4	2 3/16	1 1/4	1 3/32	2 9/32	5/8
1 3/8	2 13/32	1 1/32	2 3/4	1 3/8	2 13/32	1 3/8	1 3/16	2 17/32	11/16
1 1/2	2 5/8	1 1/8	3	1 1/2	2 5/8	1 1/2	1 5/16	2 3/4	3/4

drilled to exact size (not 1/64 inch under size, which is the diameter of stock used), and the expansion of the iron in heating gives sufficient grip, as it is only necessary to prevent the rivets from being pulled out of the dies by the return stroke of the heading tool. The reason for this is that in the continuous-motion type of bolt and rivet machine, the work is supported on the sides by the gripping dies, and is backed up by the shear, so that it is practically held in a box while the head is being formed. The same grade of steel is used for making rivet tools as for making tools for producing bolts, and the heat-treatment is also carried on in a similar manner.

Stock Required for Rivet Heads. In making rivets in a continuous-motion rivet machine, the amount of excess stock (X, in the accompanying table) required is generally obtained by trial, but when definite shapes and proportions of rivet heads have been decided upon, the amount of excess stock required can be calculated approximately. The great difficulty in giving tables covering the amount of excess stock required is that no standard for rivet heads is universally followed, with the result that a slight difference in the curve or height of the head changes the amount of stock necessary. In addition to this, the scale of the furnace, depending upon whether gas, oil or coal is used for heating, so changes the amount of stock required that a special setting of the stop in different cases is required. This is one reason why up-to-date continuous-motion rivet making machines are provided with stops which can be adjusted while the machine is in motion. It is evident, therefore, that the exact amount of stock required is a question of some nicety, and it is surprising to what extent even the scaling off in the furnace will affect the stock required for the rivet head. What are considered in some shops standard shapes and sizes for rivet heads are given in the accompanying table.

CHAPTER III

NUT FORGING MACHINES

THE plain type of upsetting and forging machine which is used to a certain extent in the manufacture of bolts and rivets, especially the larger sizes, is also used for producing the ordinary square and hexagon nuts in sizes from 2 inches up. In making nuts by this process, the diameter of the round bar from which the nut is made should not exceed the root diameter of the thread in the finished nut, so it is evident that an extremely large upset is required to produce a full nut. When large nuts are produced in a plain forging machine, the usual method is first to form an upset on the end of the bar and then pierce the hole in the nut by punching the bar back, the metal removed to form the hole in the nut being attached to the bar. This operation requires considerable pressure, and as little, if any, material is wasted, it is a very successful method of producing nuts 2 inches and larger on a commercial basis. In the following, two types of machines, especially built to produce square and hexagon nuts, will be described. One of these machines is known as the hot-pressed center-feed nut machine, and the other as the hot-forged type; the latter is applicable only to the production of square nuts.

Hot-pressed Center-feed Nut Machine. The hot-pressed center-feed nut machine, as its name implies, produces nuts by pressing a heated blank of iron or steel into the required shape, the latter first being cut off as the bar is fed into the machine. The bar stock, which is rectangular in shape, is fed in from the side through a recess in the center of the machine and placed in front of the face of the dies. Fig. 1 shows an Ajax center-feed hot-pressed nut machine that works on the principle just stated. This machine consists

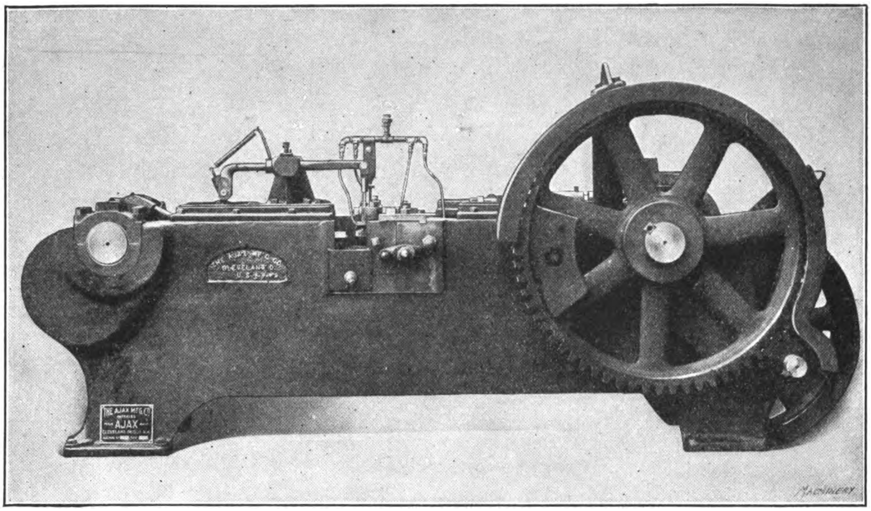


Fig. 1. Side View of Ajax Hot-pressed Center-feed Nut Machine showing Operating Side and Water Pipes for cooling Dies and Tools

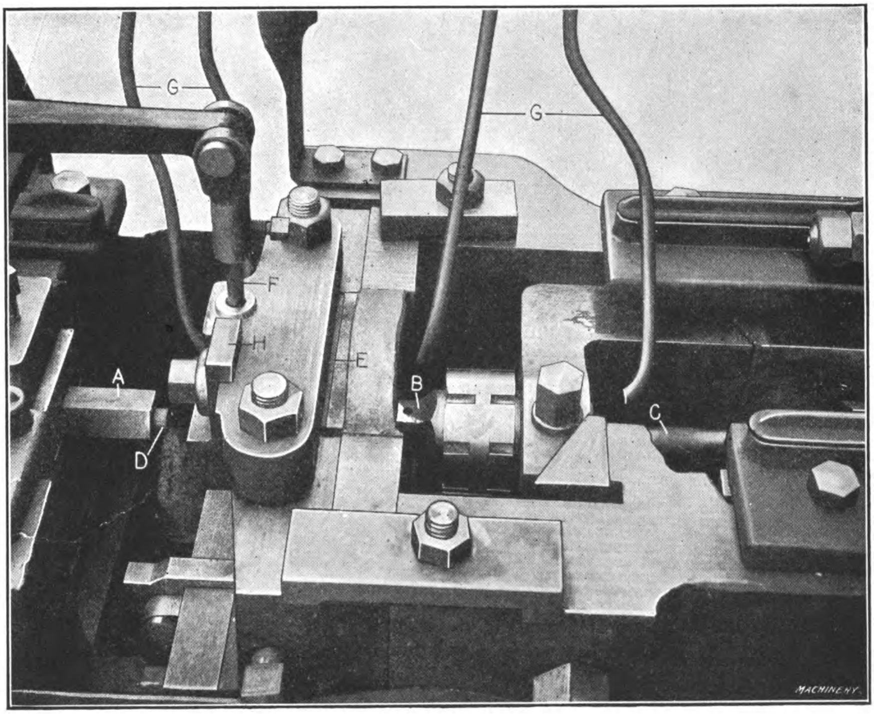


Fig. 2. Detail View of Machine shown in Fig. 1 showing Dies, Punching, Piercing, Crowning Tools, etc.

essentially of two movable rams or slides which carry the cutting-off, crowning, piercing and wad-extracting punches, respectively. One ram is operated directly from the main crankshaft, while the other is operated by eccentrics and a connecting-rod.

Fig. 2 shows a detail view of this machine, and gives some idea of the construction of the dies, tools, etc. Here

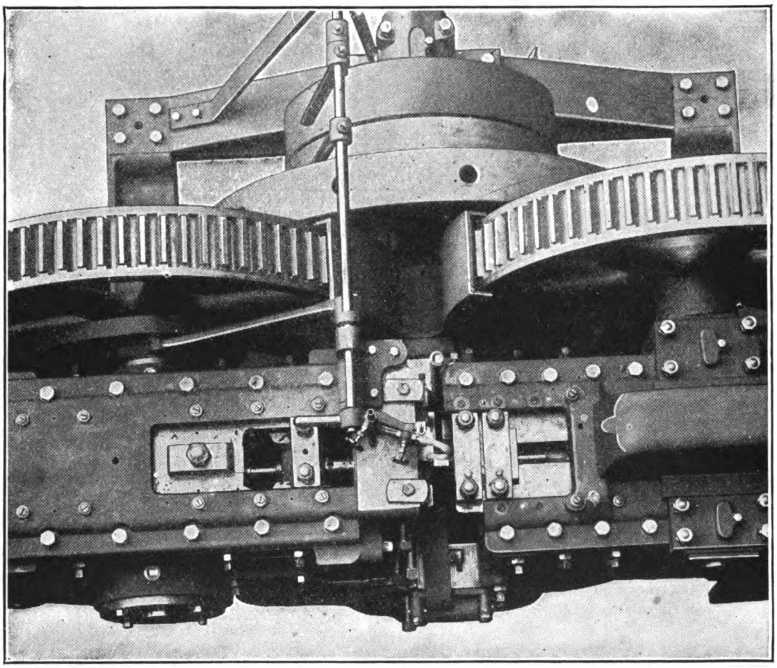


Fig. 3. Top View of another Type of Hot-pressed Center-feed Nut Making Machine

A is the cutting-off punch, *B* the crowning punch, *C* the piercing punch, *D* the wad extractor, *E* the nut dies and *F* the ejector. The pipes *G* furnish a copious supply of water to keep the dies and tools cool when in operation. A device for centering the bar in relation to the dies and tools is shown at *H*.

A National center-feed hot-pressed nut machine, which produces hexagon and square nuts in the same manner as that shown in Fig. 1 is shown in Fig. 3. In this machine, however, both rams or sildes are operated directly from the source of power by a pinion and two large gears, one gear driving each slide. The majority of manufacturers produce nuts from a material known as soft, mild, open-hearth steel, which has a comparatively fine grain, and conse-

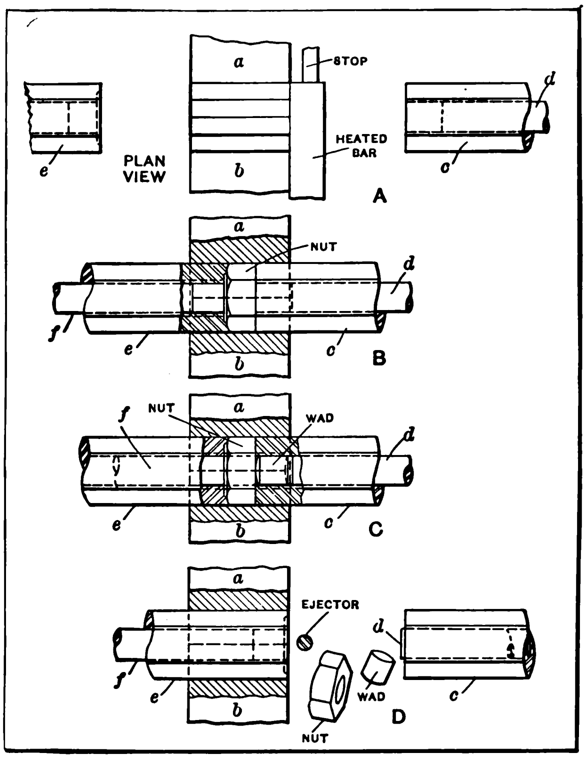


Fig. 4. Diagram of Sequence of Operations in making Nuts in a Hot-pressed Center-feed Nut Machine

quently, when forged, has less tendency to crack than does wrought iron. It can also be threaded more easily and with a smoother finish than wrought iron, owing to the fact that great difficulty is met with in working the latter material, because the grain opens up, thus making it difficult to thread. Wrought iron, however, has one point in its favor—it can be worked at a much higher temperature than steel without affecting its structure, and hence does not need to be handled quite so carefully.

Operation of a Center-feed Hot-pressed Nut Machine. In operating a center-feed hot-pressed nut machine, the rectangular bar is heated to the correct temperature for a length of four or five feet. It is then brought to the machine and fed in from the side in front of the face of the main dies, as indicated at *A* in Fig. 4. The cut-off tool *c* then moves up and shears the blank from the end of the bar, carries it into the main dies *a* and *b*, and presses it against the crowning tool *e*, which has also advanced, as indicated at *B*. The piercing tool *f* now advances, punches the hole in the nut, and carries the wad into the cutting-off tool,

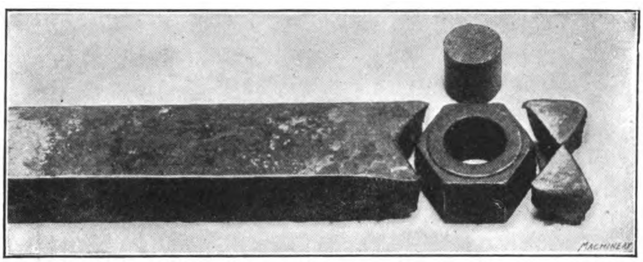


Fig. 5. Showing how a Hexagon Nut is produced from Rectangular Bar in a Hot-pressed Nut Machine

as shown at *C*; then the cutting-off and piercing tools *c* and *f* recede, and the crowning tool *e* advances, forcing the nut out of the dies. As the cut-off tool *c* recedes, the extractor *d* forces the wad out of the punch at the same time as the nut is ejected from the dies. The ejector, which is operated by a lever and cam, as shown in Fig. 3, is provided to prevent the nut from adhering to the crowning tool; this very seldom happens, however. A completed nut is produced at each revolution of the large gears.

The operations just described are repeated until the heated portion of the bar has been used up, after which the operator places the bar in the furnace to be re-heated, takes a freshly heated bar from the furnace, and proceeds as before. The machine is run continuously, and is not stopped for the insertion of a newly heated bar. Finished nuts are turned out at the rate of from 40 to 70 per minute, depending upon the size of the machine and the skill of the operator. Fig. 5 shows how a hexagon nut is produced from a rectangular bar of stock in a center-feed hot-pressed nut machine. It will be seen that considerable scrap is lost in the production of a nut of hexagon shape, viz., the wad removed to form the hole, and the triangular pieces which are removed to form the corners. On a square nut the material wasted is not quite so great, as in

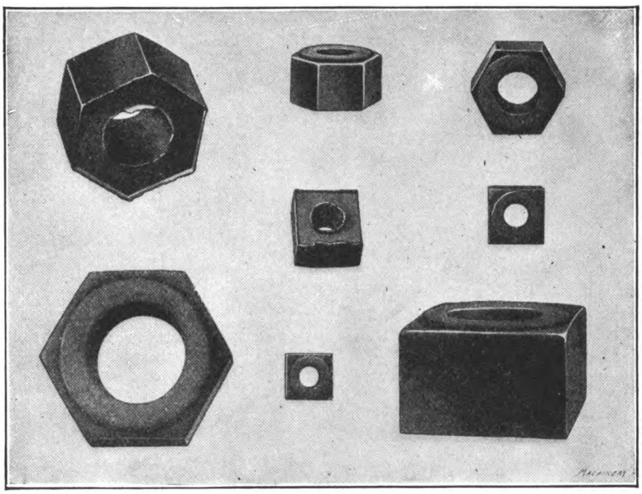


Fig. 6. Group of Square and Hexagon Nuts, showing Character of Work turned out in Hot-pressed Nut Machine

this case only the wad and a slight amount of stock, sheared off the end of the bar to form a square corner, are removed.

There are two common methods in use in nut forging. One is to set the stop so that the rounded corner of the bar is sheared off, leaving a square corner. This, of course, wastes somewhat more stock than the other method, yet to be described, but has the advantage of producing a perfect nut. The rounded corner is caused by the cut-off tool which, in removing the block of metal from the end of the bar to form the nut, rounds over the end of the bar, due to the hot metal drawing over, and thus makes this waste of stock necessary if a full-shaped nut is to be secured.

Another method in common use to save stock and at the same time produce a practically full nut, is to invert the bar after each stroke of the machine. By this method opposite sides of the bar are alternately presented to the dies, which overcomes, to a large extent, the effect of the fin on one side and the rounded corner on the other, and produces a full nut without shearing any material from the

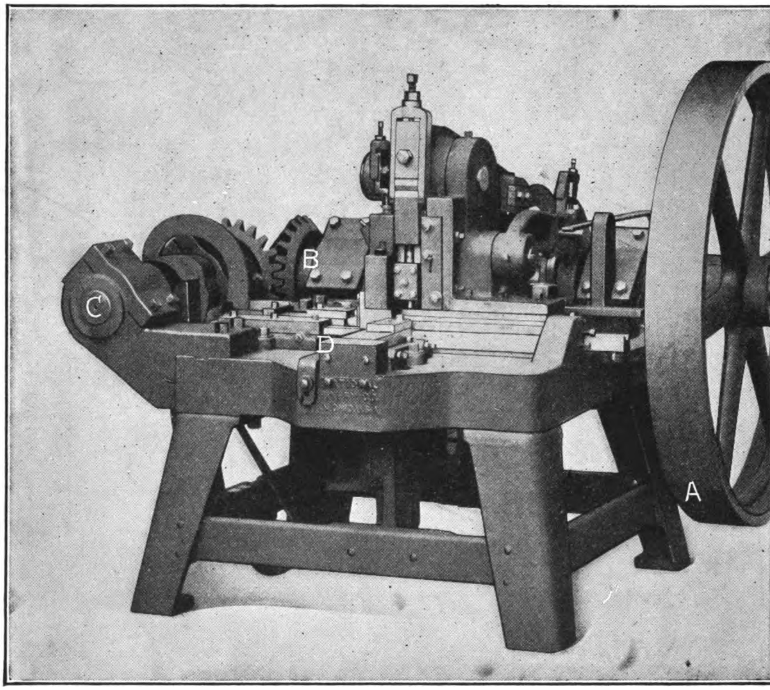


Fig. 7. Hot-forged Nut Machine used exclusively for the Manufacture of Square Nuts from Rectangular Bar Stock

end of the bar. The only objection to this method is the necessity of turning the bar, which, if heavy, soon tires the operator. On the larger sizes of nuts, the first method is used, as the bars are quite heavy and the operator would find it difficult to turn them and keep up with the operation of the machine.

Fig. 6 shows a typical group of nuts which can be produced economically and on a commercial basis in the center-feed hot-pressed nut machine. In this illustration two of the nuts show fins on the under side, both around the outer edges and the hole. This is caused by the sharp edges of the cut-off tool becoming rounded and allowing the hot metal to "leak" past the edges. The clearance allowed between the cut-off punch and dies also tends to produce a slight fin. When the tools are new the burr or fin produced is very slight, but it increases as the tools wear. These fins are removed in a succeeding operation in a burring machine.

Hot-forged Nut Machine. Fig. 7 shows a National nut making machine which is applicable only to the manufacture of square nuts, but produces this class of nuts free from fins and burrs at a rapid rate. Nut manufacturers who produce in great quantities are extensive users of this type of machine, but a concern making a variety of nuts in small quantities should not attempt to use it, owing to the delay incident to changing the dies and tools from one size to another. Briefly stated, the machine consists principally of a suitable mechanism for operating a shearing and crowning tool, four horizontal hammers which form the four sides of a square nut, and piercing and flattening punches. Power is transmitted from pulley *A* to the two shafts *B* and *C* located at right angles to each other and connected by miter gears. Shaft *C* carries eccentrics and cams which operate the left-side hammer and sizing tool for gripping the bar while it is being sheared; and shaft *B*, through cams, levers and eccentrics, operates the blank shearing tool, nut ejector, front and rear hammers, piercing punch and flattening tools.

Operation of Hot-forged Nut Machine. In order to illustrate how this hot-forged nut machine produces square nuts, the diagrams shown in Fig. 8 are included. These views show plan and sectional elevations which illustrate the relative positions of the various dies and tools, and the stages through which the nut passes before being ejected. In operating this machine, rectangular bar stock heated

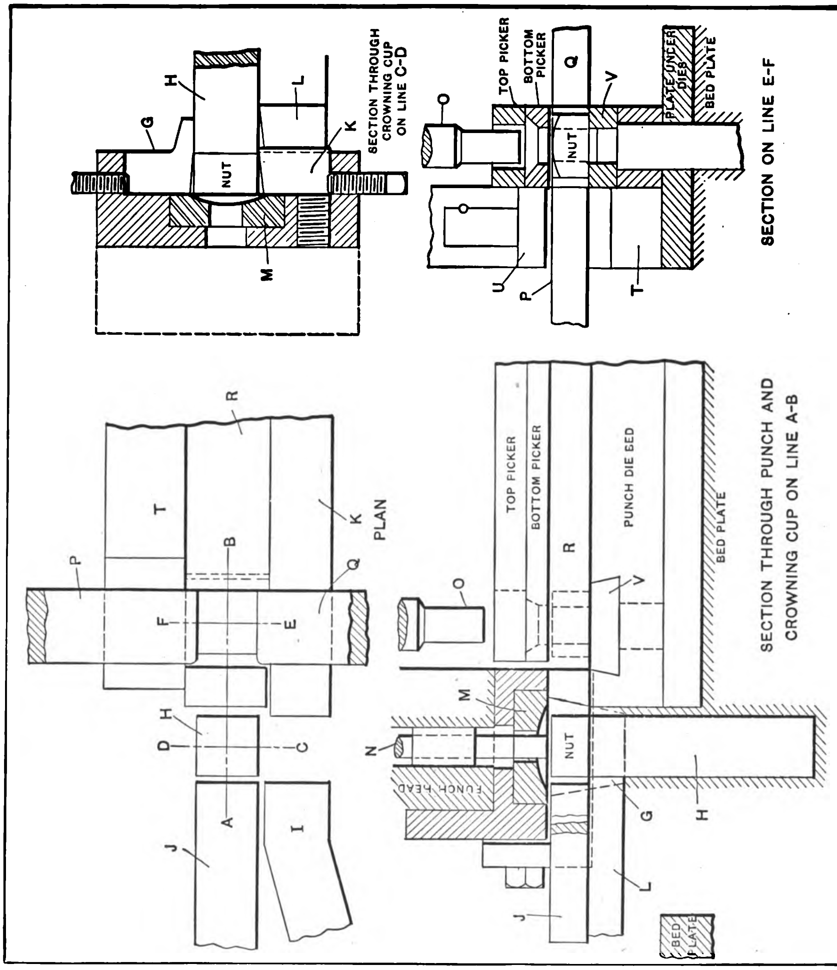


Fig. 8. Construction of Tools and Operation of the Hot-forged Type of Nut Machine Shown in Fig. 7

to a length of four or five feet is fed into the machine (see *D*, Fig. 7) along the line *CD*. The stock is equal in width to the diameter of the nut across the flats, and of the same thickness as the nut. It is fed into the machine with the greatest width horizontal and is located by the gage *G*.

As the heated bar is fed in, a shearing tool *H*, operated from the bottom of the machine, forces the heated end of the bar against the knife *K* and cuts off a suitable blank; as this tool continues to rise, it presses the nut blank into the crowner cup *M*, which is located directly above the shearing tool. While the shearing operation is taking place, the sizing tool *I*, which moves in a line parallel with the side hammer *J*, holds the bar tightly against the stationary sizer *K*.

Gripping the bar in this manner tends to give a better shearing cut. The shearing tool *H* is now lowered until its top face is in line with the bottom of the side hammer *J*, and at the same time the kickout *N*, operated through a hole in the crowner *M*, ejects the nut, preventing it from sticking in the cup. The shearing tool now remains in its "down" position while the side hammer *J* carries the nut along line *AB* until the center of the nut is in line with *EF* and directly under the piercing punch *O*.

As the side hammer *J* moves the nut blank under the piercing punch, the rear hammer *P* advances and presses the nut into the square box formed by the side hammer *J*, rear hammer *P*, stationary hammer *R* and front hammer *Q*. This tends to square up the sides of the nut and form it to the proper shape. While in this position, the punch *O* pierces the hole in the nut, forcing the wad through the die *V*, and immediately withdraws. The rear hammer *P* and side hammer *J* then return to their original positions, and the front hammer *Q* moves the nut back to the flatter bed *T*, which is located directly under the rear hammer *P*. While the nut is located on the flatter bed, the flattening tool *U*, which is over the rear hammer, comes down on the nut, gives it a slight squeeze, which corrects any distortion of the top and bottom faces caused by the squeezes between the four hammers previously described, and also serves to flatten any fins resulting from the piercing operation. The flattening tool *U* then rises, and the flatter bed *T* withdraws, allowing the finished nut to drop out of the machine. A completed nut is made at each revolution of the flywheel, and the machine is operated at from 60 to 90 revolutions per minute, depending upon its size.

Some idea of the character of the work turned out by the hot-forged nut machine can be obtained from Fig. 9, which shows a representative group of square nuts just as they come from the machine. The nuts produced by these machines are entirely free from fins or burrs, are of excellent finish, and ready for tapping directly after being forged.

Dies and Tools Used in Hot-pressed Center-feed Nut Machines. The type of dies and tools used in the hot-pressed center-feed nut machine shown in Fig. 3 is shown in Fig. 10. The reference letters used here are the same as those in Fig. 4. The dies *a* and *b*, which are reversible, are

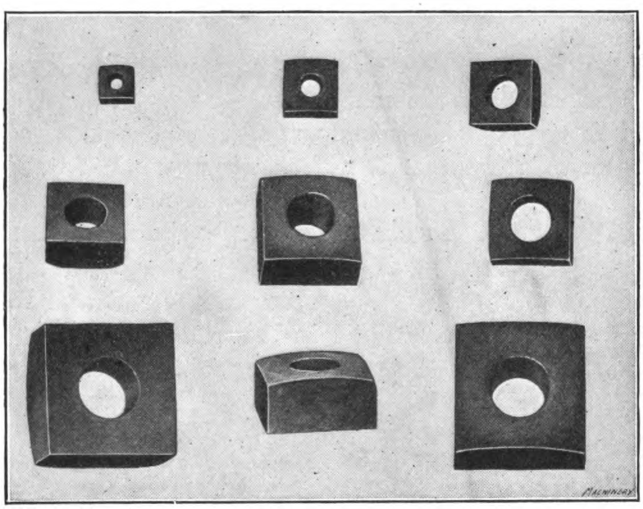


Fig. 9. Samples of Square Nuts produced on Hot-forged Type of Nut Machine—Note Absence of Burrs or Fins

usually made from chilled iron castings, and are ground to size. Dies made from this material, it is claimed, will last fully eight times as long as those made from ordinary carbon steel, but as it is somewhat of a problem to get the proper amount of "chill," many manufacturers are using a good grade of open-hearth steel instead. A crucible steel which has been found to give good results for this class of work contains from 0.90 to 1.10 per cent carbon. Some nut manufacturers have found that a certain grade of vanadium alloy steel having a carbon content of from 0.15 to 0.30 per cent gives excellent results when used for nut dies. In all cases, of course, it is necessary to harden the dies, and those made from crucible tool steel are hardened and drawn so that they can just be touched with the file, or in other words, the temper is drawn to a light straw color.

The composition of vanadium steel used for dies varies. Two grades of vanadium tool steel are recommended for forging machine dies by the American Vanadium Co., of Pittsburg, Pa. One is composed of carbon, 0.50 per cent;

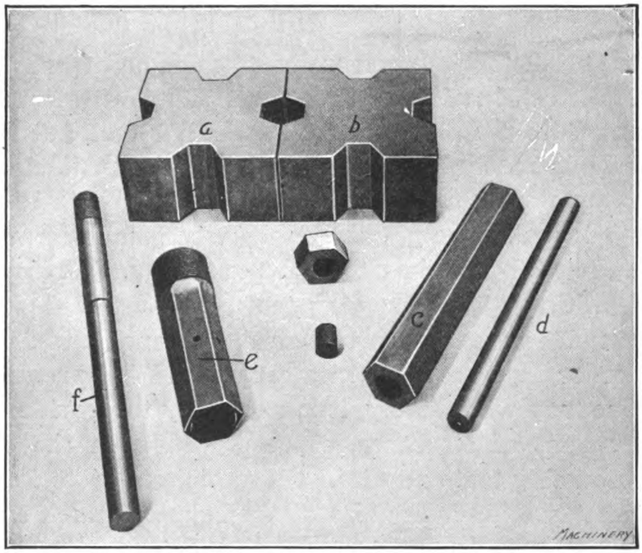


Fig. 10. Type of Dies and Tools used in making Hexagon Nuts in Center-feed Hot-pressed Nut Machine shown in Fig. 3

chromium, 0.80 to 1.10 per cent; manganese, 0.40 to 0.60 per cent; vanadium, not less than 0.16 per cent; silicon, not more than 0.20 per cent.

The heat-treatment recommended for this steel is as follows: Heat to 1550 degrees F. and quench in oil; then reheat to from 1425 to 1450 degrees F., and quench in water, submerging the face of the die only. When this method is used, the die is drawn by the heat remaining in the body and is thus tempered, and the life of the die increased.

The second kind of vanadium tool steel recommended has the following analysis: Carbon, 0.65 to 0.75 per cent; manganese, 0.40 to 0.60 per cent; vanadium, not less than 0.16 per cent; silicon, not more than 0.20 per cent. The heat-treatment for this steel should be as follows: Heat to 1525 degrees F. and quench in water with the face of the die only submerged.

The length of life of vanadium steel dies is stated to be about six times the life of dies made from ordinary high-carbon tool steel.

The cut-off tool *c* is generally made from ordinary carbon tool steel, hardened and drawn. Some attempts have been made to use high-speed steel for this tool, but as this material is rather expensive, and as this particular tool wears away very rapidly, a cheaper brand of steel is generally adopted. The piercing tool *f* when made from "Rex A" high-speed steel has been found very satisfactory for hot punching. The crowning tool *e* and wad extractor *d* can be made from carbon tool steel, hardened and drawn.

In order that the tools in a center-feed hot-pressed nut machine may work freely, it is necessary to provide a certain amount of clearance, especially between the cut-off tool, crowning tool and dies. On nuts from ½ to 2 inches in diameter (this is the size of the bolt for which the nut is used), 1/64 inch clearance is allowed. On sizes smaller than ½ inch, 0.010 inch clearance is allowed, whereas for tools used in making nuts larger than 2 inches, a clearance of from 0.020 to 0.060 inch is provided. The hole formed by the junction of the two halves of the dies is made perfectly straight, but the piercing tool is slightly tapered—being smaller at the front end. This enables it to withdraw more easily from the hole in the nut, and also increases its life. It is evident, of course, that after the hole is punched in the nut, the chilling effect of the dies (which are kept cool by water flowing over them) tends to "freeze" the nut on the piercing tool, but the slight taper on the piercing tool prevents this.

There is no allowance made in the hole of the nut to provide for shrinkage, as the holes regularly punched in nuts are made considerably larger than the root diameter of the threads on the tap. The nuts can then be more easily tapped, and the percentage of tap breakages is reduced.

In Fig. 11 is shown the shape of the dies used for making square nuts in a center-feed hot-pressed nut machine. It will be seen that these dies are made in four pieces, and it is possible to raise or lower the outside blocks *A* and *B*,

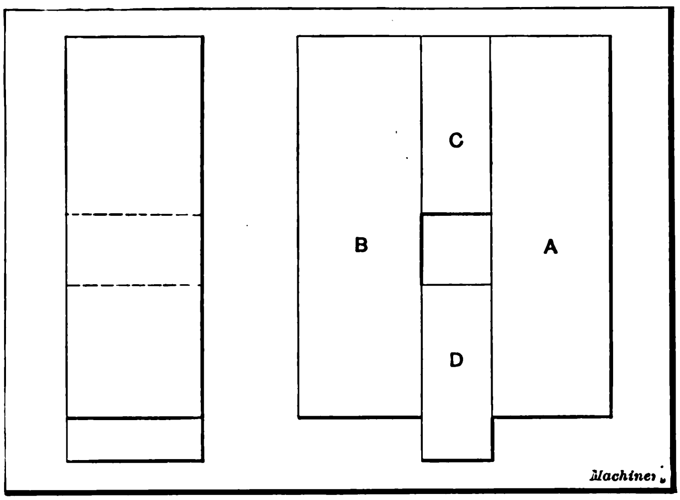


Fig. 11. Type of Dies used in making Square Nuts in Machine of the Type shown in Fig. 3

so that new cutting edges are secured. In addition to this the top and bottom dies *C* and *D* can be reserved, and also the two side pieces, thus giving long life for one redressing of the dies. As a rule, this type of dies is made from ordinary crucible tool steel containing from 0.90 to 1.00 per cent carbon, hardened and drawn, and ground all over.

Dies and Tools Used in Hot-forged Nut Machines. The four hammers used in the hot-forged nut machines are made from rectangular blocks of steel, shaped as shown in Fig. 8. The rear, front and stationary hammers are made wider than the nut, but of approximately the same thick-

Proportions of U. S. Standard and Manufacturers' Standard Hexagon and Square Nuts and Sizes of Rectangular Stock Required to Produce Them. (See notation on Fig. 12.)

United States Standard										Manufacturers' Standard									
Dia. of Bolt	Dimensions in Inches									Dia. of Bolt	Dimensions in Inches								
	A	B	C	D	E	F	G	H	I		A	B	C	D	E	F	G	H	I
1/4	1/4	1/2	13/64	17/64	15/32	1/4	1/2	17/64	15/32	1/4	1/4	1/2	7/32	17/64	15/32	1/4	1/2	17/64	15/32
5/16	5/16	19/32	1/4	11/32	9/16	5/16	19/32	11/32	9/16	5/16	5/16	5/8	9/32	11/32	19/32	5/16	5/8	11/32	19/32
3/8	3/8	11/16	5/16	13/32	21/32	3/8	11/16	13/32	21/32	3/8	3/8	3/4	11/32	13/32	23/32	3/8	3/4	13/32	23/32
7/16	7/16	25/32	23/64	15/32	23/32	7/16	25/32	15/32	23/32	7/16	7/16	7/8	13/32	15/32	13/16	7/16	7/8	15/32	13/16
1/2	1/2	7/8	27/64	17/32	13/16	1/2	7/8	17/32	13/16	1/2	1/2	1	7/16	17/32	15/16	1/2	1	17/32	15/16
9/16	9/16	31/32	15/32	19/32	29/32	9/16	31/32	19/32	29/32	9/16	9/16	1 1/8	1/2	19/32	1 1/16	9/16	1 1/8	19/32	1 1/16
5/8	5/8	1 1/16	17/32	21/32	1	5/8	1 1/16	21/32	1	5/8	5/8	1 1/4	9/16	21/32	1 3/16	5/8	1 1/4	21/32	1 3/16
3/4	3/4	1 1/4	41/64	13/16	1 3/16	3/4	1 1/4	13/16	1 3/16	3/4	3/4	1 3/8	21/32	13/16	1 5/16	3/4	1 1/2	13/16	1 7/16
7/8	7/8	1 7/16	3/4	15/16	1 3/8	7/8	1 7/16	15/16	1 3/8	7/8	7/8	1 5/8	25/32	15/16	1 9/16	7/8	1 3/4	15/16	1 11/16
1	1	1 5/8	55/64	1 1/16	1 9/16	1	1 5/8	1 1/16	1 9/16	1	1	1 3/4	7/8	1 1/16	1 11/16	1	2	1 1/16	1 15/16
1 1/8	1 1/8	1 13/16	31/32	1 3/16	1 3/4	1 1/8	1 13/16	1 3/16	1 3/4	1 1/8	1 1/8	2	15/16	1 5/16	1 15/16	1 1/8	2 1/4	1 5/16	2 3/16
1 1/4	1 1/4	2	1 3/32	1 3/8	1 7/8	1 1/4	2	1 3/8	1 7/8	1 1/4	1 1/4	2 1/4	1 3/32	1 1/2	2 3/16	1 1/4	2 1/2	1 1/2	2 3/8
1 3/8	1 3/8	2 3/16	1 7/32	1 1/2	2 1/16	1 3/8	2 3/16	1 1/2	2 1/16	1 3/8	1 3/8	2 1/2	1 3/16	1 5/8	2 3/8	1 3/8	2 3/4	1 5/8	2 5/8
1 1/2	1 1/2	2 3/8	1 11/32	1 5/8	2 1/4	1 1/2	2 3/8	1 5/8	2 1/4	1 1/2	1 1/2	2 3/4	1 5/16	1 3/4	2 5/8	1 1/2	3	1 3/4	2 7/8
1 5/8	1 5/8	2 9/16	1 27/64	1 3/4	2 7/16	1 5/8	2 9/16	1 3/4	2 7/16	1 5/8	1 5/8	3	1 7/16	1 7/8	2 7/8	1 5/8	3 1/4	1 7/8	3 1/8
1 3/4	1 3/4	2 3/4	1 17/32	1 7/8	2 5/8	1 3/4	2 3/4	1 7/8	2 5/8	1 3/4	1 3/4	3 1/4	1 9/16	2	3 1/8	1 3/4	3 1/2	2	3 3/8
1 7/8	1 7/8	2 15/16	1 21/32	2	2 13/16	1 7/8	2 15/16	2	2 13/16	1 7/8	1 7/8	3 1/2	1 11/16	2 1/8	3 3/8	1 7/8	3 3/4	2 1/8	3 5/8
2	2	3 1/8	1 49/64	2 1/8	3	2	3 1/8	2 1/8	3	2	2	3 1/2	1 13/16	2 1/4	3 5/8	2	4	2 1/4	3 7/8
2 1/4	2 1/4	3 1/2	2 1/64	2 3/8	3 3/8	2 1/4	3 1/2	2 3/8	3 3/8	2 1/4	2 1/4	3 3/4	2	2 3/8	3 5/8	2 1/4	4 1/4	2 3/8	4 1/8
2 1/2	2 1/2	3 7/8	2 15/64	2 5/8	3 3/4	2 1/2	3 7/8	2 5/8	3 3/4	2 1/2	2 1/2	4 1/4	2 1/4	2 5/8	4 1/8	2 1/2	4 1/2	2 5/8	4 3/8
2 3/4	2 3/4	4 1/4	2 31/64	2 7/8	4 1/8	2 3/4	4 1/4	2 7/8	4 1/8	2 3/4	2 3/4	4 1/2	2 7/16	2 7/8	4 3/8	2 3/4	4 3/4	2 7/8	4 5/8
3	3	4 5/8	2 11/16	3 1/8	4 1/2	3	4 5/8	3 1/8	4 1/2	3	3	4 3/4	2 11/16	3 1/8	4 5/8	3	5	3 1/8	4 7/8
3 1/4	3 1/4	5	2 15/16	3 3/8	4 7/8	3 1/4	5	3 3/8	4 7/8	..	..	..	..	..	..	..	..	..	..
3 1/2	3 1/2	5 3/8	3 11/64	3 5/8	5 1/4	3 1/2	5 3/8	3 5/8	5 1/4	..	..	..	..	..	..	..	..	..	..
3 3/4	3 3/4	5 3/4	3 3/8	3 7/8	5 5/8	3 3/4	5 3/4	3 7/8	5 5/8	..	..	..	..	..	..	..	..	..	..
4	4	6 1/8	3 5/8	4 1/8	6	4	6 1/8	4 1/8	6	..	..	..	..	..	..	..	..	..	..

ness, and the front and rear hammers are rounded on the forward corners, to facilitate the insertion of the nut. The side hammer, which carries the nut into the "box-shaped impression" formed by all four hammers, is of the same width and thickness as the nut. The crowner, flatter tool and the four hammer blocks are all made from ordinary crucible steel, hardened and drawn, whereas the shearing tool and piercing punch and die are usually made from high-speed steel. The brand of steel known as "Rex A" has been found very satisfactory for this purpose. The

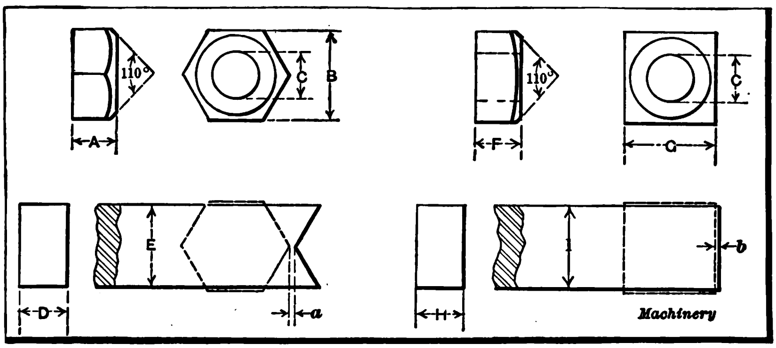


Fig. 12. Proportions of Standard Hexagon and Square Nuts; see Table on Opposite Page

tools used in the hot-forged nut machine do not wear out nearly so quickly as those used in the hot-pressed type of machine, owing to the fact that there is not the same scraping action against the surfaces of the tools.

Sizes of Rectangular Stock Used in Making Square and Hexagon Nuts. In making nuts in center-feed hot-pressed nut machines of the types shown in Figs. 1 and 2, rectangular bar stock as shown in Fig. 5 is used. To allow for upsetting the stock slightly and pressing it into the desired shape, a rectangular bar is used which is slightly thicker than the finished nut, and slightly less in width than the diameter of the nut across the flats. As explained in a previous paragraph, in order to produce a perfectly shaped nut it is necessary to waste a certain amount of stock as indicated at *a* and *b* in Fig. 12. The amount of stock wasted depends upon the size of the nut and to a slight extent upon the temperature at which the bar is being worked.

In producing a hexagon nut, only the front triangular corner is rounded (owing to the drawing over of the hot metal), whereas on a square nut, the entire front corner of the nut is rounded. A considerable saving of metal can be effected by turning the bar after each stroke of the machine, thus presenting opposite faces of the bar to the dies, as was previously explained. This can easily be done in making the smaller size of nuts where the bar does not exceed 40 to 80 pounds in weight. For large nuts, instead of turning the bar, a small amount of stock is wasted, as indicated at *a* and *b* in Fig. 12, which varies from 1/16 to ¼ inch, depending upon the size of the nut.

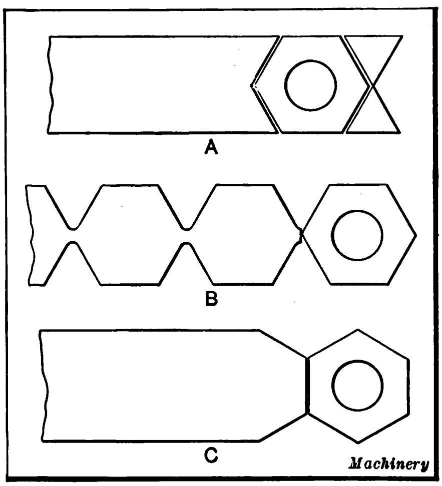


Fig. 13. Three Methods of forging Nuts

The hot-forged type of nut-making machine shown in Fig. 7 has the advantage over the center-feed hot-pressed machine of not wasting any stock. The hot-forged nut machine, however, is only suitable for the manufacture of square nuts, and is only used where this type of nut is made in large quantities.

The Indenting Method of Forging Nuts. In forging nuts, it is desirable to produce well-formed sharp-cornered nut blanks without subjecting the machine to excessive stresses, and also reduce the waste or scrap to a minimum. The common method of forging nuts is illustrated at *A*, Fig. 13. The nuts are cut or sheared from the end of the heated bar of rectangular stock and then the hole is punched in the blank. With this method, there is considerable waste, the slug which is removed from the center to form the hole and the triangular-shaped pieces which are cut from the bar between successive blanks, being scrap. In order to reduce the amount of scrap, attempts have been made to use bars of stock having V-shaped notches rolled into them, as indicated at *B*, instead of cutting away the stock and thus removing the triangular shaped pieces.

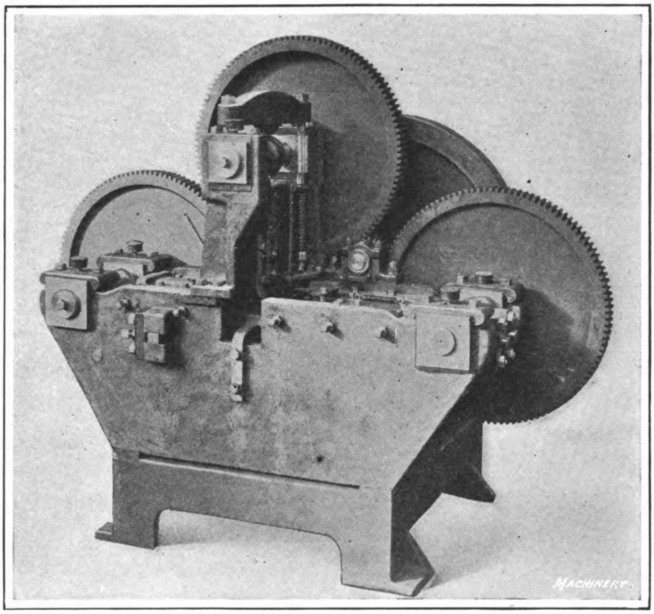


Fig. 14. Nut-forging Machine

Another plan that has been tried is shown at *C*. In this case, the V-shaped notches are formed by indenting tools on the nut-forging machine, which compress the metal on each side of the bar. Both the notched bar method and the use of indenting tools have been tried extensively during the past thirty years in the United States, England, and Germany. The use of notched stock and of indenting tools on the forging machine were both unsuccessful, partly because the machines were faulty in design and did not operate satisfactorily. When using notched bars, the entire bar of stock would usually be spoiled if one nut were spoiled. The indenting type of forging machine that formerly was experimented with also proved unsatisfactory, as stock of rectangular section was used and the indenting operation distorted the nut blanks so much that the pressures necessary to form sharp-cornered blanks were beyond the limit of endurance of both the tools and the machine.

Indenting Type of Nut-forging Machine. The Hollings nut-forging machine illustrated in Fig. 14, in conjunction with the special shape of stock used, makes it possible to produce well-formed blanks without excessive pressures and with much less waste in the form of scrap. In fact, it is claimed that the consumption of stock in an ordinary nut-forging machine operating on the principle illustrated at *A*, Fig. 13, may be as much as 50 per cent greater for the same production of nuts than in the indenting type of machine to be described. According to production figures, 3200 pounds of stock were required by the old method to produce 10,000 $\frac{3}{4}$-inch hexagonal nuts, there being 1100 pounds of scrap. By the new method only 2300 pounds of stock were required for the same number and size of nuts, there being only 200 pounds of scrap. In this case about 40 per cent more material was required by the old method.

In the operation of this machine, the heated bar of stock is fed in from the side and the V-shaped notches are first formed by the indenting tools (see Fig. 15). The cutting-off tool then moves up, severing a blank which is pushed into the die; then a punch advances rapidly and thins the slug as the stock is forced against an opposite punch which also expands the blank in the die. The first punch then recedes and the nut is compressed against the crowning tool. The hole is next pierced as the second punch continues its stroke, the slug being forced inside the cutting-off tool. The cutting-off tool and the second punch referred to now recede and as the crowning tool is advanced by cams, the nut is pushed out of the die. When the cut-off tool moves backward, the slug is ejected and at the same time the nut blank is ejected by the "nut kicker." The latter has a diagonal motion downward and outward, which insures the nut being removed from the crowning tool, as it passes clear across the face of the tool.

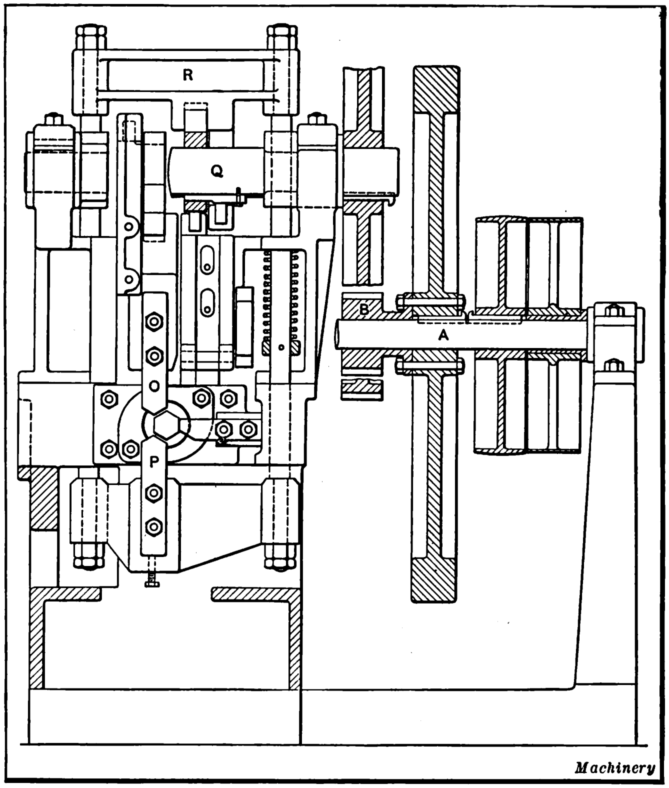


Fig. 15. Detail View of Indenting Tools and their Operating Mechanism

The cutting-off tool is held positively in its holder instead of depending on a friction grip. The punch for ejecting the slug and the piercing punch are provided with adjustable brass sleeves which are free to slide through the rear ends of the respective tool-holders, so that by piping the water to the hollow space within the crowning and cutting-off tools, water is pumped through these spaces by the action of the machine, thus cooling the tools and increasing their durability.

The driving pinion *B* is secured to the flywheel by two bolts as shown in Fig. 15, so that if a cold bar should be placed between the indenting tools, the bolts will shear off and prevent damage to the gears or other parts of the machine. The main thrust of the machine is exerted against a thrust bar which passes straight through the machine. One end of this bar is supported by spring, and the other end bears against a small cross-bar which acts as a safety breaker in case two nuts should accidentally get into the die. The tension of the spring can be regulated to give the correct pressure. The machine is so designed that the principal members are subjected to almost a plain straight tension, the twisting and side strains having been reduced to a minimum. The strain resulting from the indenting operation is also taken by vertical tie-rods and throughout the entire machine the strains are largely balanced.

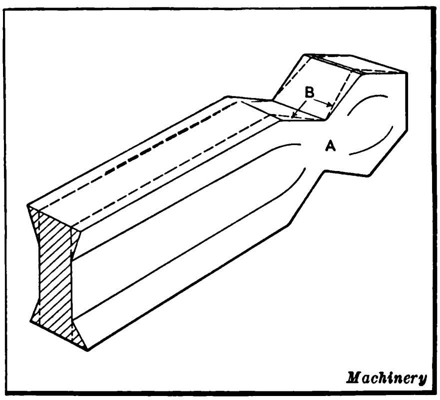


Fig. 16. Special Patented Shape of Bar used in Conjunction with Nut-forging Machine shown in Fig. 14

Special Form of Stock Used with Indenting Type of Nut Forging Machine. The special form of bar stock used in conjunction with this machine is illustrated by the perspective view, Fig. 16. The central part of the bar is of rectangular section, but the ends flare outward as the illustration shows. The object of using this special shape is to make it possible to secure well-formed sharp-cornered nut blanks and still keep the necessary pressures within commercial limits—not simply experimental limits. While it is possible to make nuts by the indenting method when using stock of plain rectangular section, such a severe blow is required that the method is impracticable as a commercial proposition. The rolling of the section illustrated in Fig. 16, therefore, is the first step in this patented process of nut forging. When the machine is operating on a bar of this shape, the indenting tools, in compressing the metal, force it outward, thus filling up the narrower section at *A*. The result is that the sides of the nut blank are approximately flat, except in the center, where the hole is to be pierced; consequently an excessive blow or pressure is not necessary in flattening the nut. When an attempt is made to form nuts from plain rectangular stock, the indenting tools force the metal outward as indicated by the dotted lines at *B*. The result is that the blank is narrow at the top and bottom and the machine is subjected to severe stresses while forming the blank. This machine may be used on rectangular stock, the same as the ordinary center-feed type, by simply removing the indenting tools. This process of forging nuts, including the machine and the special form of bar, is covered by patents which have been granted in most countries throughout the world. Ernest Hollings, 5 Kelvin Ave., Sale, Cheshire, England, is the inventor, and the process is operating on a commercial basis in Manchester, England.

CHAPTER IV

MACHINES AND DIES FOR GENERAL FORGING OPERATIONS

POSSIBLY the greatest development in forging is the application of machine methods to the production of engine and machine parts. It is now possible to forge many parts from steel and wrought iron, which formerly could be made only from castings. This means a great saving of time and expense, as not only are machine forged parts much more rapidly made than those made from cast iron or steel castings, but they also cost considerably less to manufacture in large quantities. In the following, interesting examples of different types of upsets, bending and forming operations, etc., will be illustrated and described, together with a general description of the dies and tools used. This will give an idea of the remarkable possibilities of the upsetting and forging machine in its present-day development.

The Upsetting and Forging Machine. The upsetting and forging machine might be considered to a certain extent as a further development of the bolt and rivet making machine, which was originated almost a century ago; but forging machines are built much heavier than bolt and rivet machines and are designed especially to meet the demands in the production of difficult-shaped and heavy forgings. For the heavier types of machines, the base or main frame, as a rule is made from one solid steel casting.

A typical upsetting and forging machine, made by the National Machinery Co. and designed for heavy service, is shown in Fig. 1. The bed of this machine is made from one solid casting of semi-steel. In order to provide against breakage caused by accidentally placing work between the dies, upsetting and forging machines generally have various safety devices in order to prevent serious damage to the machine. The safety device in this machine consists of a toggle-joint mechanism for operating the movable gripping-die slide. The gripping-die slide *A* is operated by two cams *B* and *C* on the main crankshaft *D*. Cam *B* serves to close the dies which grip the work; cam *C* oper-

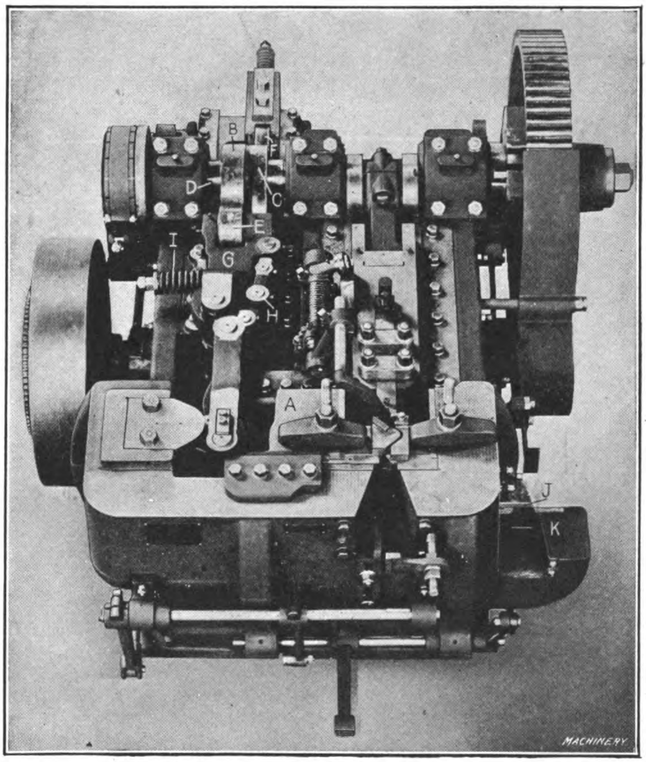


Fig. 1. Upsetting and Forging Machine having a Safety Relief Mechanism for Operating the Gripping Dies

ates the opening mechanism for the dies. These cams are in contact with chilled cast-iron rolls *E* and *F* carried in the toggle slide *G*. The automatic grip relief is controlled by the by-pass toggle *H* and heavy coil spring *I*. This toggle does not come into play until the strain is such that it would cause damage to the working mechanism of the machine, or in other words until the maximum power required to hold the movable die from springing away, is attained. The relief resetting automatically on the back stroke makes a second blow possible without delay.

Some idea of the gripping pressure exerted before the relief mechanism operates is indicated in Fig. 2. This piece, which has been flattened between the opposing faces of the gripping dies, is a 2-inch round bar of from 0.10 to 0.15 per cent carbon steel, 9⅝ inches long. The flattened portion is 3⅝ inches wide by 5 inches long and 23/32 inch thick. The piece, of course, was heated to a forging temperature before being placed between the opposing faces of the dies and was flattened to the condition shown in one squeeze. This illustrates a feature peculiar to this type of machine in that it can be used for squeezing or swaging operations, these being carried on between the opposing faces of the gripping dies. In many cases this allows work to be handled that is generally formed or flattened by the side shear J, which is operated from the movable die slide, being a continued arm of the same casting. As a rule, the side shear is used for cutting off stock, and is also sometimes used for bending operations, suitable dies or cutting tools for this purpose being held in the movable slide J and stationary bracket K.

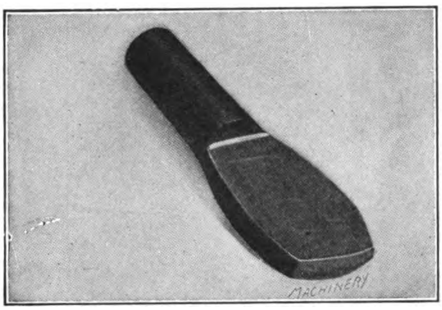


Fig. 2. Extent to which a Bar is flattened between Gripping Dies of Forging Machine before Relief operates

An Ajax upsetting and forging machine in which the working mechanism of the machine is protected from serious injury in a different manner, is shown in Fig. 3. In this machine the safety device consists of a bolt A connecting the die slide B and the slide C operating it. When any foreign body intercepts the gripping dies, the bolt A is sheared off, thus providing for a positive grip and at the same time furnishing a safety device that protects the working mechanism of the machine against the possibility of serious injury.

A good example of an upset forging operation which can be handled successfully in an upsetting and forging machine, is the castellated nut shown at *A* in Fig. 4, produced in an Ajax forging machine. This type of nut is pro-

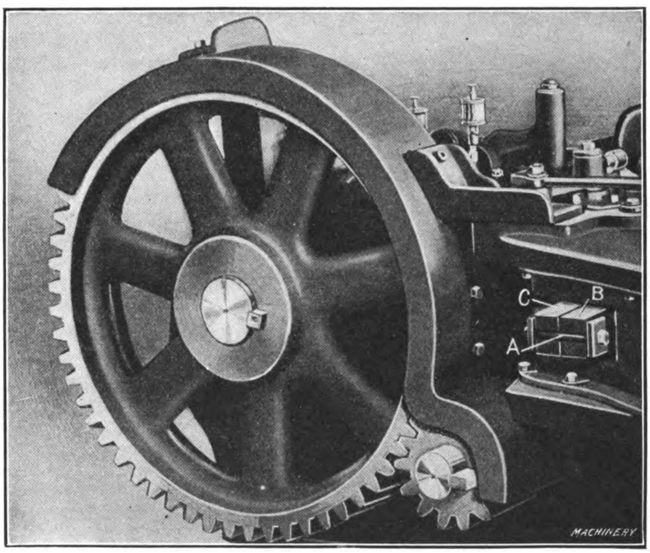


Fig. 3. Another Type of Upsetting and Forging Machine showing Safety or Shear Bolt providing a Safety Relief for the Gripping Dies

duced practically without waste of stock in from two to three blows. The gripping dies and tools used are shown in Fig. 4, and also in detail in Fig. 5, where the construction of the tools can be more clearly seen. Referring to the latter illustration, it will be noticed that the dies *C* and *D* are made in two pieces. This is done in order to facilitate the machining operations, and in many cases it enables the dies to be made at a much lower cost because of the simplicity in construction. These dies are made from scrap driving-axle steel which contains about 0.60 per cent carbon, and are hardened in the usual manner, the temper being drawn to a light straw color.

The plunger *E* which upsets the end of the bar into the lower impression in the dies, is made in three parts; this facilitates its construction and the method of manufacture. The body is made from a piece of soft machine steel, on the front end of which a hardened bushing *F* is held by a pin. The inside of this bushing is of a hexagon shape to form the sides of the nut. Screwed into the body of the

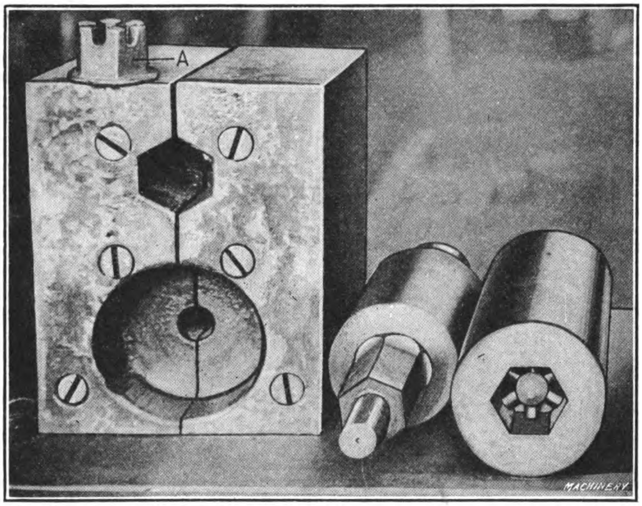


Fig. 4. Dies and Tools used in making a Castellated Nut in a Forging Machine

punch is a former *G* which is machined to such shape that six "wings," as shown, are formed around its periphery, these producing the castellated grooves in the head of the nut. The former *G* is pointed, and rough forms the hole in the nut. The top punch which is used for completely punching the hole in the nut and at the same time severing it from the bar is also made from a machine steel body *H* into which is screwed a hardened steel punch *I*, this being prevented from loosening by a pin driven through it.

The method of producing a hexagon castellated nut in a forging machine is as follows: A bar of the required size (which must not exceed the root diameter of the thread in the finished nut) is heated in the furnace to a temperature of from 1400 to 1600 degrees F., depending upon the material, and is then brought to the forging machine and placed in the lower impression of the gripping dies. Then as the machine is operated, the lower plunger advances, upsetting the end of the bar and forming the excess metal into a nut of the required shape. The bar is now quickly removed from the lower impression, placed in the upper

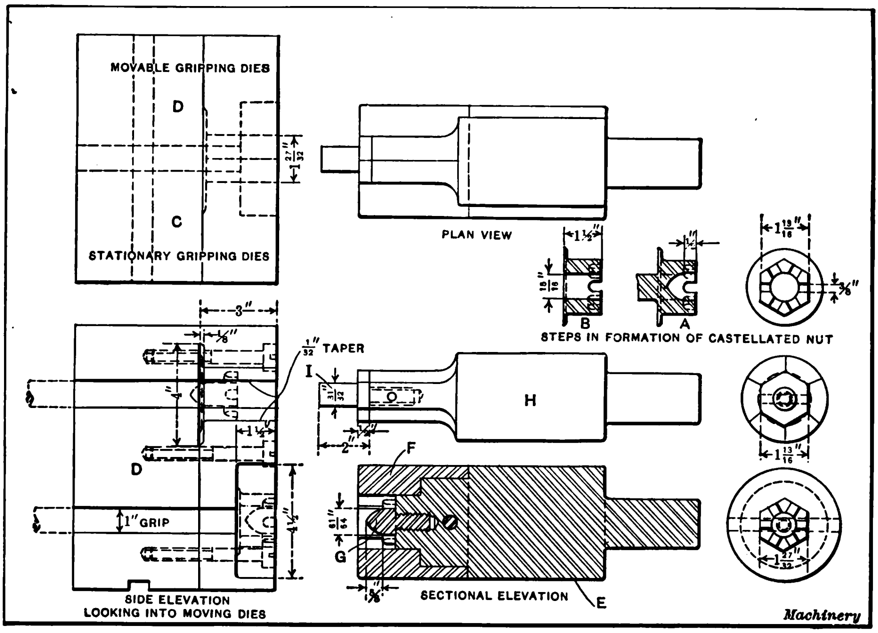


Fig. 5. Details of the Dies and Tools used for making the Castellated Nut shown in Fig. 4.

impression, and the machine again operated; whereupon the top plunger advances, completing the hole in the nut and attaching the metal thus removed to the end of the bar. These two operations are indicated at *A* and *B* in the illustration. This interesting method of making castellated nuts is used in the Collinwood shops of the L. S. & M. S. Railway. The only material wasted in the production of a castellated nut of this character is the slight excess of stock formed into a fin, which must be removed, of course, in a subsequent operation.

Another interesting example of castellated nut forging in which the excess metal is used in the formation of a washer on the nut and thus eliminates all waste of material, is shown in Fig. 6. The construction of the tools here illustrated is almost identical with

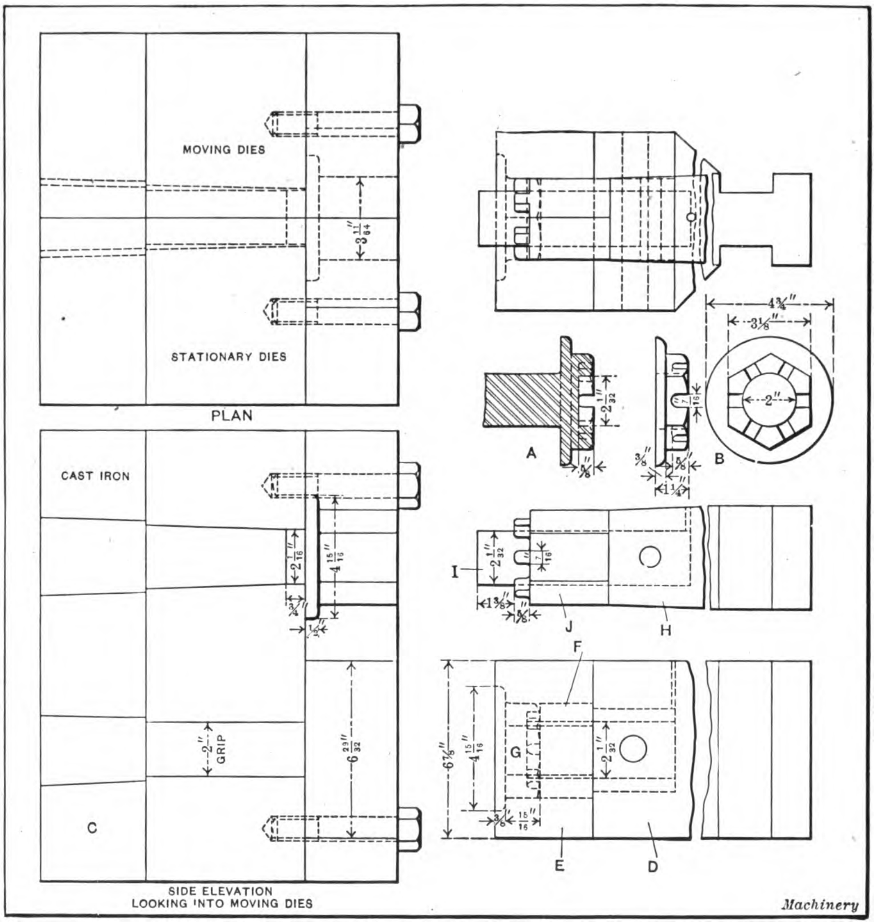


Fig. 6. Dies and Tools used for making a Combination Washer and Castellated Nut which is produced without any Waste of Stock

that shown in Figs. 4 and 5 with the exception of the punches and also the utilization of a cast-iron block *C*, for partly completing the construction of the gripping dies. The part of the gripping dies which is made from cast iron is not used as a gripping medium and hence does not need to be made from steel to provide for wear. The lower punch *D* is in this case made from machine steel and is provided with a tool-steel head *E* which is bored out and formed to a hexagon shape. Inserted in this is a sleeve *F* for forming the castellated portion of the nut. A punch *G* rough-forms the hole in the nut. The upper plunger *H* carries a punch *I* which completely

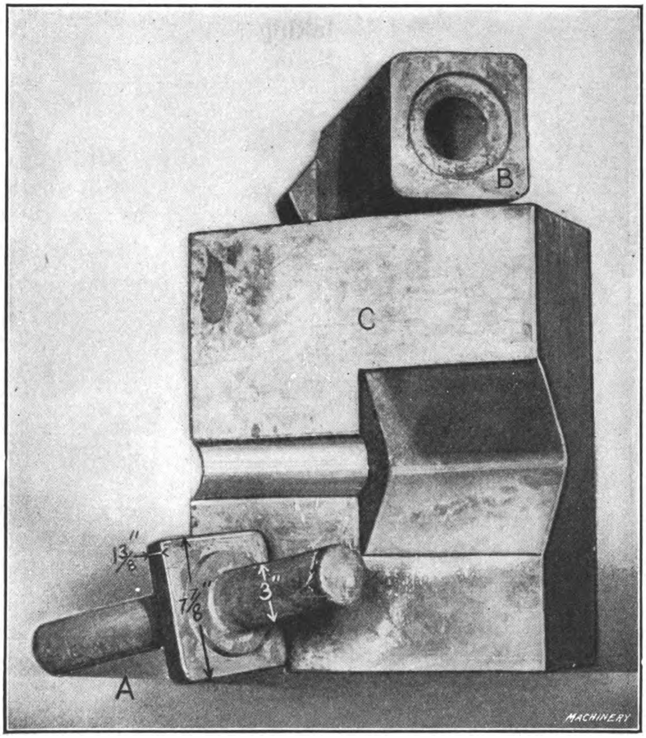


Fig. 7. Dies and Tools used in making an Enormous Upset in a 6-inch Universal Forging Machine

forms the hole in the nut by punching the bar back, and by means of the castellated washer *J* finish-forms the castellated grooves in the nut. The steps followed in the production of this combination castellated nut and washer are shown at *A* and *B* in the illustration. A 2-inch bar of wrought iron is used, and it requires a length of 4 inches to form the nut and washer.

Dies and Tools Used for Making a Locomotive Trailer Pin. The locomotive trailer pin shown at *A* in Fig. 7 represents about the maximum amount of upset which can be satisfactorily made in a forging machine and, in fact, is much greater than that usually recommended. This work was done in the Chicago shops of the C. & N. W. Railway, on a 6-inch Ajax universal forging machine. This trailer pin is made from a 3-inch round wrought-iron bar, 26 inches

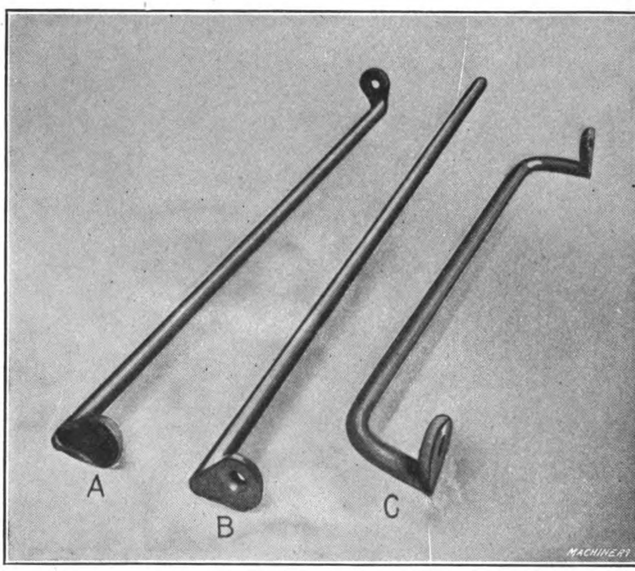


Fig. 8. Three Steps in the Formation of Ladder Treads for Freight Cars

long, and an excess amount of stock equal to $10\frac{3}{4}$ inches in length is put into the upset in one blow. The dimensions of the upset square flange are $7\frac{7}{8}$ inches across the flats and 10 5/16 inches across the corners, by $1\frac{3}{8}$ inches thick. The circular flange is $5\frac{7}{8}$ inches in diameter by $\frac{5}{8}$ inch long. After the work is given the first blow with the plunger *B*, it is reheated and the work is again placed between the gripping dies *C*, only one of which is shown. The machine is again operated and the part given another blow which serves to close up the texture of the steel and eliminates the defects caused by the structure of the steel pulling apart during the upsetting operation.

Bending and Forming Operations. The making of ladder treads for freight cars is a good example of bending and forming operations that can be handled successfully in the upsetting and forging machine. Fig. 8 shows three of the steps in the production of a ladder tread which is com-

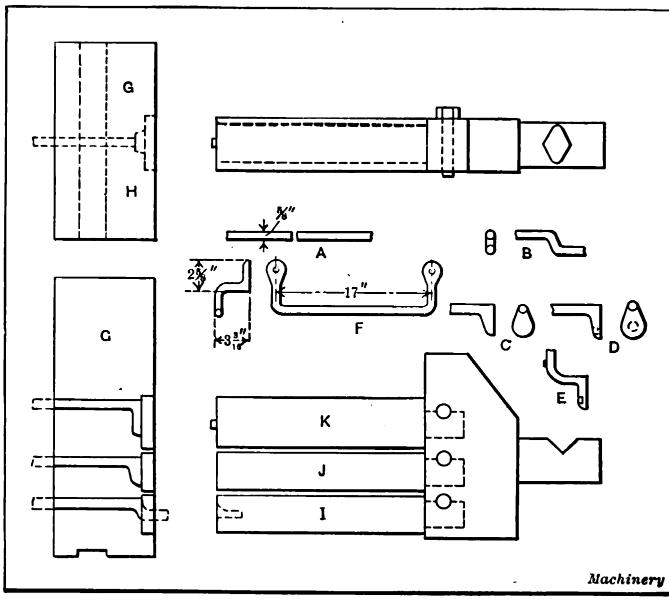


Fig. 9. Dies and Tools used in forming the Feet of Ladder Treads

pleted to the shape shown at *C* in five operations, on a National forging machine.

The dies and tools used for forming the feet of the ladder tread are illustrated in Fig. 9. The first operation is indicated at *A* and consists in cutting off a bar of 5/8-inch iron to the required length. This is heated on one end, placed in the lower impression in the gripping dies *G* and *H* and given a blow by the plunger *I* which forms the end of the rod into the shape shown at *B*. In this operation, the stock is upset just far enough so that it will not buckle in front of the dies.

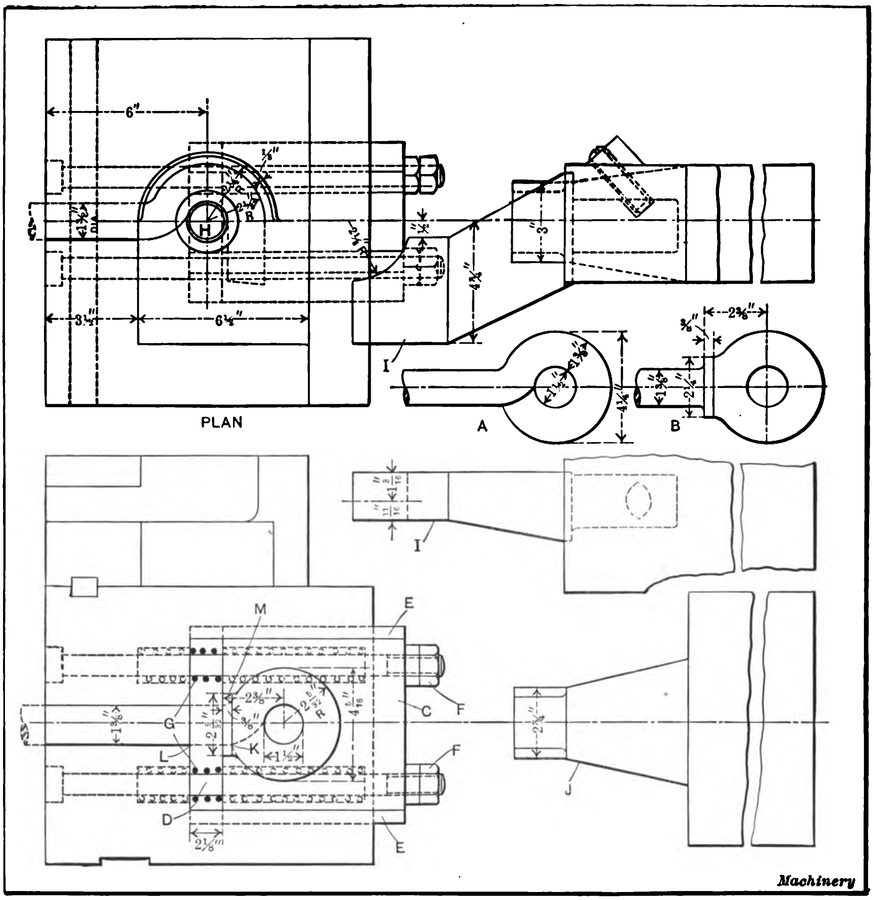


Fig. 10. An Interesting Set of Dies and Tools used in a 3-Inch Forging Machine for forming Eye-bolts in Two Blows

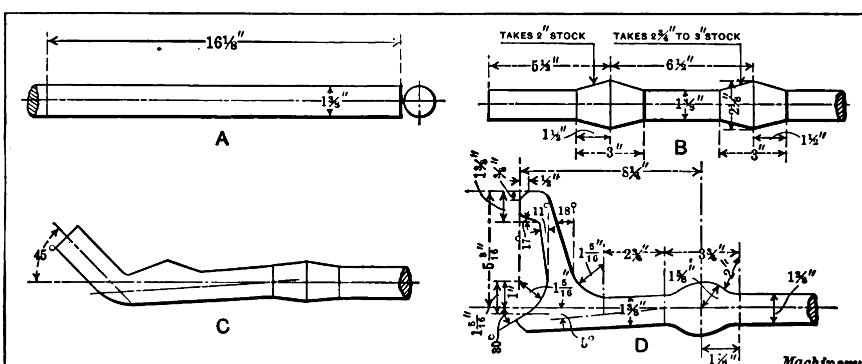


Fig. 11. Sequence of Operations on Automobile Front Axle accomplished in 3½-inch Forging Machine

The second operation bends and forms the stock back into a solid forging as indicated at *C*, this being accomplished in the second impression in the gripping dies by plunger *J*. The final forging operation, the result of which is shown at *D*, completes the foot, the upper impressions in the dies being used for this purpose; these are made the exact shape of the foot, and the plunger *K* has a pin in it which punches the hole in the foot to within 1/16 inch of passing through the 9/16-inch stock. The final operations which are performed in a bulldozer or other bending machine consist in bending both ends of the tread to the required shape. This requires two operations, which are indicated at *E* and *F*, respectively. Before the final bending, the forging is taken to an emery wheel to remove the burrs formed when forging the feet.

The eye-bolt shown in two stages of its formation, at *A* and *B* in Fig. 10, is another example of a bending and forming operation accomplished in a forging machine. This eye-bolt is made from a $1\frac{3}{8}$-inch round wrought-iron bar, and is completed in two blows in a 3-inch Ajax forging machine, using the dies and tools illustrated. The construction of the gripping dies is rather unusual and interesting. The lower impression in the dies consists of two movable members *C* which slide on four rods *D* and are provided with tongues *E* which fit in corresponding grooves in the movable and stationary gripping dies. The pins, of course, act as mediums for holding these sliding members *C* in the gripping dies. The blocks *C* are kept out against the adjustable lock-nuts *F* by open-wound coil springs *G*.

The method of operation is as follows: The stock is first heated for a portion of its length to the correct temperature, then placed in the upper impression of the stationary die, being located in the correct endwise position by the stop of the machine. The machine is then operated and when the movable die closes on the work, it grips it and at the same time forces the heated end of the stock around pin *H* held in the stationary die. Just as soon as the dies close tightly on the work, punch *I* comes in contact with the bent end of the bar and forms it around the pin *H*, bending the work into the shape shown at *A*. The dies now open and the work is removed and placed on the pin forming the center portion of the impression in the blocks *C*. The machine is again operated and as the dies close, the ram *J* advances and forces the blocks *C* forward, carrying the "eye-end" of the work along with it.

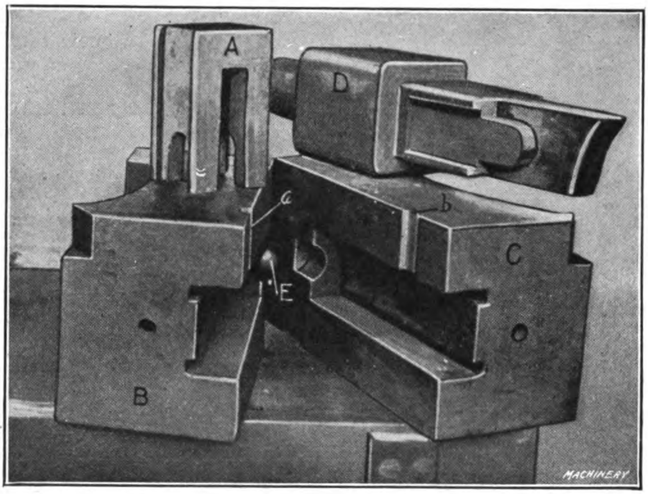


Fig. 12. Dies and Tools used for forming a Driver Brake Adjusting Rod Block in a 5-inch Forging Machine

Now as both parts of the bar—"eye-end" and body—are rigidly held in the gripping dies and movable blocks *C*, it is evident that the part of the bar at point *K* must be upset. The result of this displacement of the stock causes the formation of a shoulder on the bar at the base of the eye, formed by the circular impression *M* in the blocks *C*. The amount of stock required to form the boss at the base of the "eye" is governed by the position of the locknuts *F*. The ram *J* and gripping dies are made from steel castings. The four compression springs *G* are 10¾ inches long when extended, of ¼ inch pitch; 5/32-inch diameter wire is used and the outside diameter of the spring is 1 3/16 inches.

Dies and Tools for Forming a Driver Brake Adjusting Rod Block. A difficult forming operation accomplished in the forging machine is shown in Fig. 12. The part *A* is a driver brake adjusting rod block, used on freight cars. It is made of wrought iron and is completed in two blows in a 5-inch Ajax forging machine. The method of procedure in making this piece is first to cut a piece of rectangular bar iron to the required length and then bend it into a U-shape in the bulldozer. It is then taken to the furnace where it is heated to the proper temperature, and a "porter"

Fig. 13. A Heap of Finished Forged Coupler Pocket Filling Blocks

bar, about 3/4 inch in diameter, is also heated. This is joined to the bent piece (which is to form the block) and the latter is placed between the gripping dies, the bar being used simply as a means of handling. The dies shown at *B* and *C* are provided with half-round impressions shown at *a* and *b* through which the "porter" bar projects. As the machine is operated, the front end of plunger *D* cuts off the "porter" bar and forces the bent piece into the impressions in the gripping dies. While the piece is still held in the dies, the machine is again operated and the work given a second blow, this, of course, all being done in the one heat. The round-ended plug *E* at the end of the impression in the stationary die forms an impression in the end of the block, and serves as a spot for a subsequent drilling operation. Work of this character demands a forging machine in which a rigid gripping mechanism is provided, if excessive fins on the work are to be avoided. The reason for this is that the plunger, in forcing the metal into the dies has a tendency to separate them.

Fig. 13 shows a forging made in practically the same manner as that illustrated in Fig. 12. This part, a coupler pocket filling block, is used on freight cars by the L. S. and M. S.

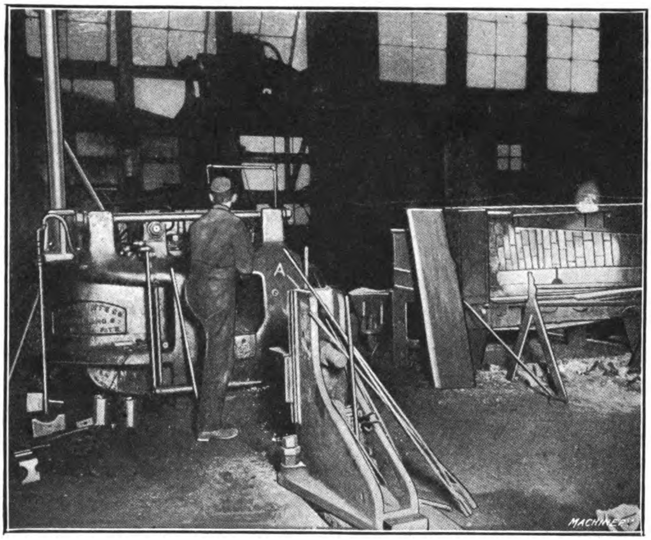


Fig. 14. Ajax 5-inch Forging Machine set up for making Coupler Pocket Filling Blocks for Freight Cars

Railway, and is made from scrap arch bars cut up into pieces of the desired length. These pieces are first formed into a U-shape in a bulldozer and are then brought to the furnace shown to the right in Fig. 14. Here they are heated to the desired temperature, then gripped with the tongs and placed on the shelf of the back stop *A*. The forging machine operator then lifts the piece from the shelf by means of a "porter" bar, and places it between the gripping dies, where the forging is given two blows and then thrown down in the sand to cool off. Fig. 13 gives some idea of how this coupler pocket filling block is produced. The piece of arch bar which has been formed to a U shape in the bulldozer still forms the end of the block, the sides or webs being formed by bending in the arch and lapping up the open ends. This can easily be seen by referring to the piece *A* in the illustration, where the joint formed in this manner is clearly shown. The burrs formed on these pieces are removed in a subsequent operation.

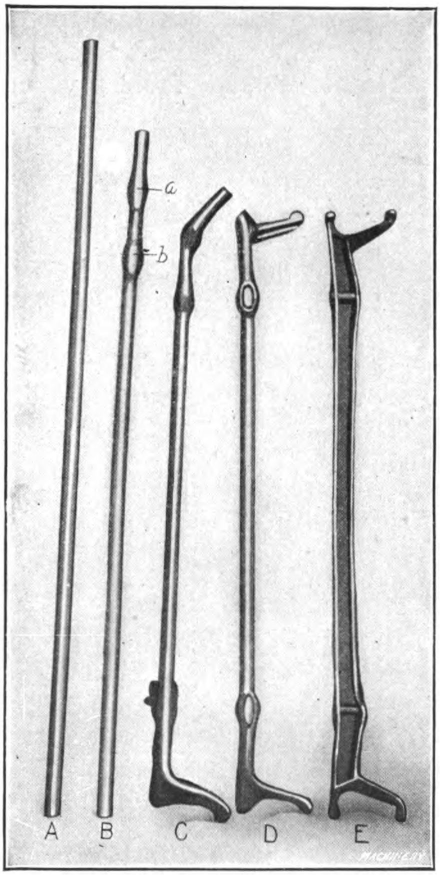


Fig. 15. Sequence of Forging Operations on the Automobile Front Axle

Forging an Automobile Front Axle. The making of the Ford automobile front axle by forging machine methods is an excellent example of the general adaptability of the upsetting and forging machine to the manufacture of miscellaneous parts from carbon and alloy steels. When used in conjunction with a steam hammer or bulldozer, there is practically no limit to the range of work which can be successfully handled. One development in forging-machine methods of unusual interest to many manufacturers is the application of forging machines to the welding of machine and engine parts. This in many cases permits the utilization of scrap metal, thus converting practically valueless material into expensive machine parts. Some interesting forging operations employed in the production of the Ford front axle and other parts, will be described in the following:

In Fig. 15 is shown a series of operations performed in the $3\frac{1}{2}$-inch "National" forging machine shown in Fig. 16, the work being the front axle for the Ford automobile. This front axle is made from a vanadium steel bar $1\frac{3}{8}$ inches

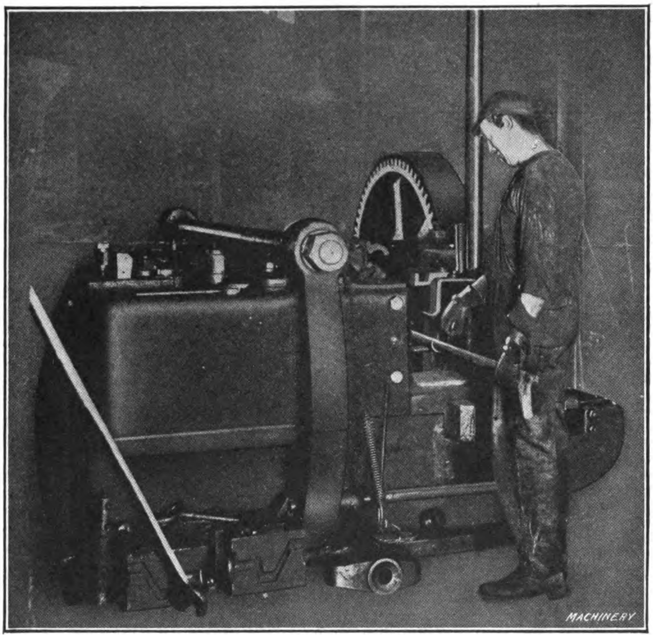


Fig. 16. National $3\frac{1}{2}$-inch Forging Machine used for the Preliminary Operations on the Automobile Front Axle

in diameter by $67\frac{3}{4}$ inches long, as shown at *A* in Fig. 15. The first forging operation consists in forming the two bulges *a* and *b*. Both ends of the bar are formed in this manner, but in separate heats. This operation, which is also indicated at *B* in Fig. 11, shortens the ends of the bar from a length of $16\frac{1}{8}$ inches to $13\frac{1}{2}$ inches, which means that $2\frac{5}{8}$ inches of stock is put into the bulges. The forging machine dies for performing this operation are shown

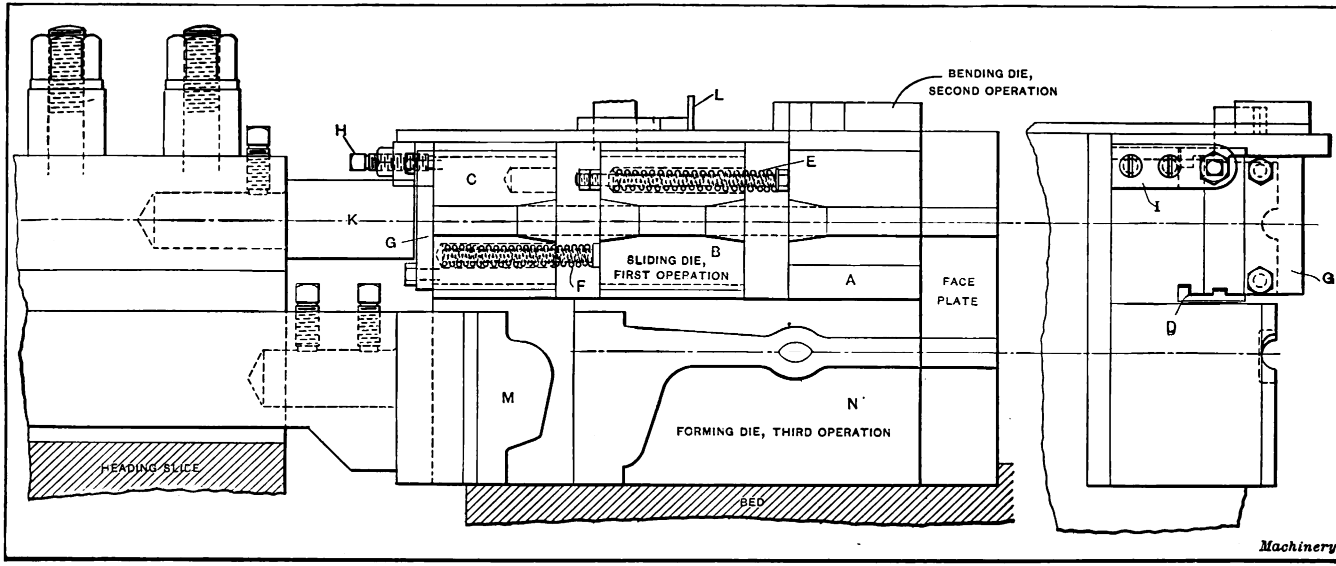


Fig. 17. Construction of Dies and Tools used in Forging Machine for making Automobile Front Axle

in Fig. 17, the bulging being accomplished in the top members. In order to form both bulges at once it is necessary to have the top members of these dies constructed in such a manner that the blocks carrying the impressions are free to slide forward when acted upon by the plunger held in the ram of the machine.

As will be seen by referring to this illustration, one half of the larger bulge is carried in block *A*, while the other half of the impression is carried in the sliding block *B*. In the opposite end of the sliding block *B* is provided one-half the impression for the smaller bulge, the other half being formed in the sliding block *C*. The sliding blocks *B* and *C* are held by tongue plates *D* to the main body of the top forging die in which they are free to slide. They are held in their outward positions by coil springs *E* and *F*. Coil spring *E* is carried on a stud held in sliding block *B*, while coil spring *F* is carried on a stud screwed into block *B* and fitting in a clearance hole in sliding block *C*. The stock when heated to the correct temperature, is located in the proper position in the dies by block *G*, which is fastened by cap-screws to block *C*, and covers the hole in the dies as indicated in the end view. Block *C* is located in its proper "out" position by adjusting screw *H*, held in block *I*, fastened to the top member of the die.

The stock which has been heated for a distance of about 18 or 20 inches is placed in the impressions in the upper members of the stationary gripping dies. The machine is then operated; the gripping-dies hold the work rigidly, while plunger *K* advances and forces sliding block *C* forward until it is in contact with block *B*. The forward movement of the ram continues until block *B* is forced up against block *A*, when the ram recedes, the dies open, and the forging is removed. It is evident that as the work is held rigidly between the opposing faces of the gripping dies, the advance of these sliding members upsets the excess metal and expands it into the impressions provided in the dies.

The next operation on the front axle, which is indicated on the top of the axle at *C* in Fig. 15, and also at *C* in Fig. 11, consists in bending the end around in order to locate the material in the required position for forming the knuckles of the axle. This operation is handled in the dies shown in Fig. 17, that member which accomplishes the work being formed on the top face of the top members of the dies. The bar which is still in its initial heat, is laid on top of the dies and in contact with the stop gage *L*. The machine is then operated, and as the dies close, the impressions formed on the projection of the top die twist the end of the bar around and form it to the desired shape.

The bar is now placed in the furnace and again heated to the proper temperature. Then it is brought to the forging machine and placed in the lower impression in the gripping die shown in Fig. 17. The forging machine is then operated, and as plunger *M* advances, it upsets and forces the work into the impressions in the lower gripping dies *N*,

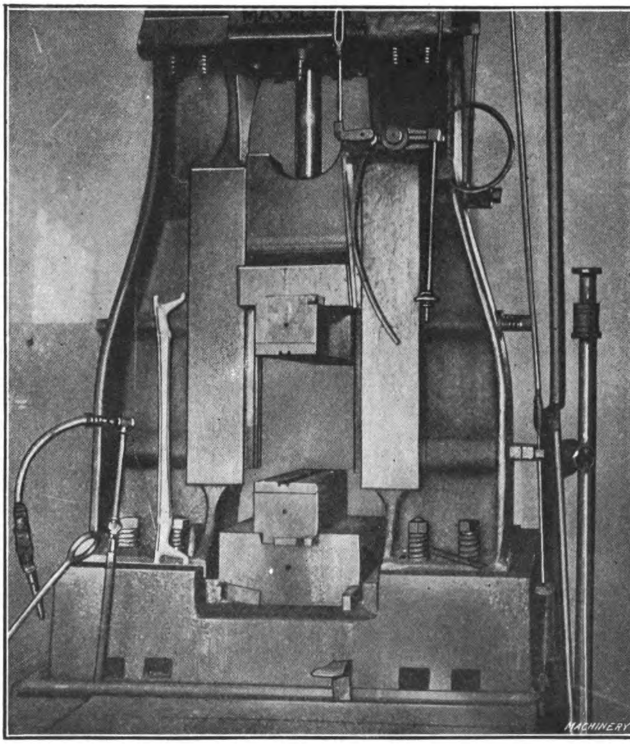


Fig. 18. "Massillon" Steam Hammer used for bringing the Automobile Front Axle to Final Shape

forming the front axle to the shape shown at *D* in Figs. 11 and 15. This completes the operations on the front axle which are handled in the forging machine. After one end of the bar has been formed to the desired shape, the other end of the bar is heated and passed through the same operations. Before the front axles are passed on to the final drop-forging operations, the burrs and fins formed in the forging machine dies are removed.

The final forming of the front axles is done under a steam hammer of the type shown in Fig. 18, the dies illustrated in Fig. 19 being used. Only one end is completed at a time; this will be seen by referring to the dies shown in Fig. 19. The axle is heated for a little over one-half its length and is placed on the lower die in the steam hammer. The oper-

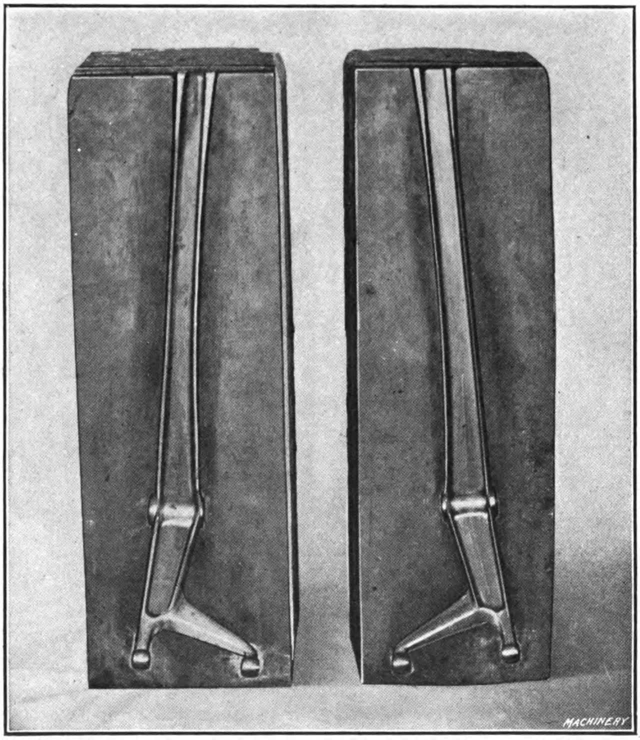


Fig. 19. Upper and Lower Dies used in Steam Hammer shown in Fig. 18 for finish-forming the Automobile Front Axle

ator is careful to locate the end of the bar so that the stock to form the knuckles is in the proper position in relation to the impression in the die before the first blow is struck; then ten successive blows are struck and the axle is removed and taken to a punch press holding a shearing die which removes the fins. It is then brought back to the steam hammer given a final blow and laid down to cool off in the sand.

After one end of a batch of front axles has been finished in this manner the other end is heated and carried through the operations described. The axles are then again taken to the furnaces, heated and placed in a fixture held in a

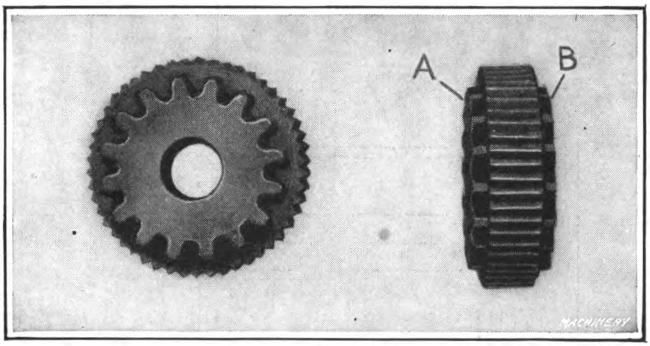


Fig. 20. Steel Disk with Forged Pinions

punch press, where they are stretched to the exact length—52½ inches.

Forming Dies for Special Steel Pinions. The making of steel disks like the one shown in Fig. 20 involves the use of forming dies of interesting design, such as were developed

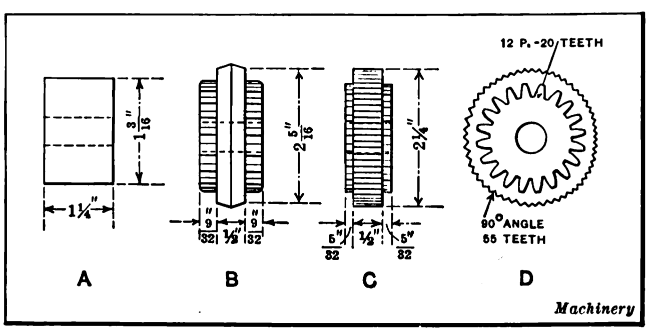


Fig. 21. (A and B) Blank before and after forging. (C and D) Finished Pinion

at the Craftsman Tool Co.'s plant, Conneaut, Ohio, where these parts are made in large quantities. Cold-rolled bar stock which is drilled and cut into blanks of the dimensions shown at *A*, Fig. 21, is used in making the disks. After the

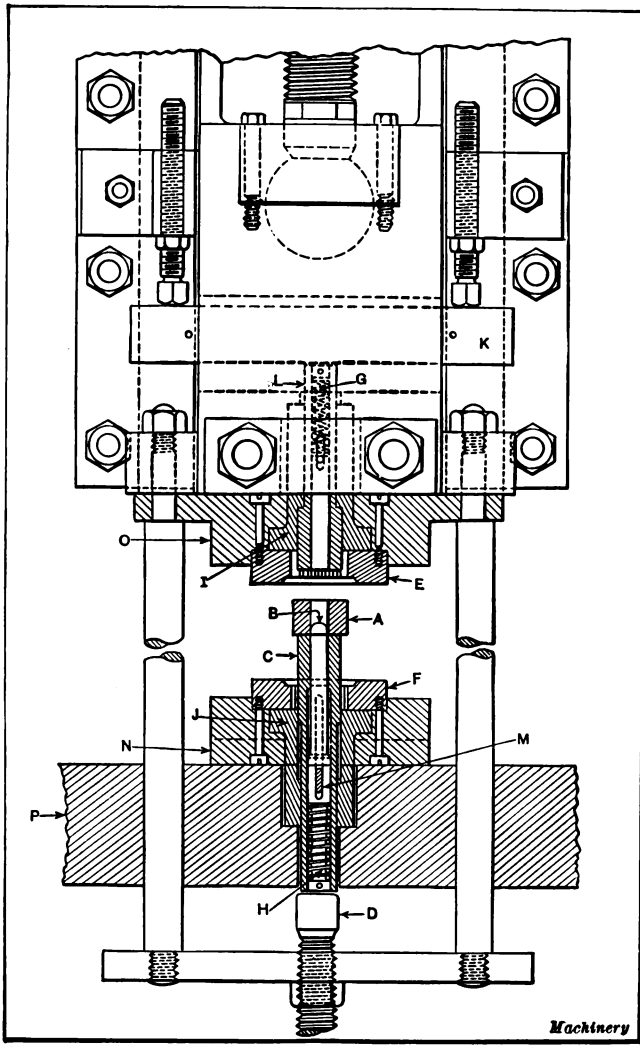


Fig. 22. Special Dies for forming Pinions

blanks have been heated to a high forging temperature, the pinion sections of the disks (*A* and *B*, Fig. 20) are formed in a back-geared forging press equipped with the special forming dies shown at *E* and *F*, Fig. 22. The condition of the blank as it comes from the dies is shown at *B*, Fig. 21.

After the forging operation has been completed, the blanks are faced to obtain the correct thickness. The saw teeth on the circumference of the disk are then milled in an automatic machine, using a forming cutter which cuts five teeth at a time. In Fig. 21 the principal dimensions of the finished disk are shown in the views of the side and face, at *C* and *D*, respectively.

The tooth sections, or pinions, *A* and *B*, Fig. 20, are formed in special dies which are constructed from steel bolster plates and bored out to receive high-speed steel forming dies *E* and *F*, Fig. 22, in which the internal teeth which form the pinion teeth of the disk have been cut. The upper and lower plungers *L* and *C* serve as strippers for the upper and lower dies. These plungers are constructed to allow for adjustment, and this feature enables the dies *E* and *F* to be ground upon their faces when the teeth become so rounded at the end as not to form perfect teeth in the pinions. Thus the cost of renewal is kept at a minimum.

In operation, the blank *A*, which has been previously brought to a high forging heat in a furnace, is placed over the pilot *B* so that it rests on the end of the lower plunger *C*. As the slide of the press moves down plunger *C* and the knock-out rod *D* both travel downward, while the pilot *B* is held stationary by means of a key *M*, which is driven through and securely held in socket *J*, and which passes through the slot in plunger *C*. The downward movement of plunger *C* is caused by the action of spring *H* which, being held in compression by a pin through the lower end of the plunger, is allowed to expand when the knock-out rod *D* is moved downward. This action, of course, forces the plunger *C* down against the end of rod *D*. The downward stroke of the press slide brings the two high-speed steel dies *E* and *F* nearly in contact, thus squeezing the hot metal blank *A* into the dies and forming the pinion teeth, as shown in Fig. 20. The springs *G* and *H*, shown at the upper and lower ends, respectively, of the plungers, serve to prevent excessive shock when striking against the shoulders in sockets *I* and *J*, that is, the springs *H* and *G* force the plungers to become seated in the sockets before the forming operation takes place. On the upward stroke of the press slide, the knock-out rod *D* comes into contact with plungers *C*, which strips the blank *A* from pilot *B*. To prevent the blanks from occasional sticking in the top die *E* on the upward stroke, the top knock-out *K* is so located as to come into contact with plunger *L*, thus forcing the blank from die *E*. When the blank comes from the press, the center hole is in perfect condition due to the accuracy of pilot *B*. Dies *E* and *F* are held in steel die-bolsters *O* and *N* by dowels and cap-screws. A heavy bed-bolster *P* is used to support the bottom die-bolster, and the top die is attached to the press slide.

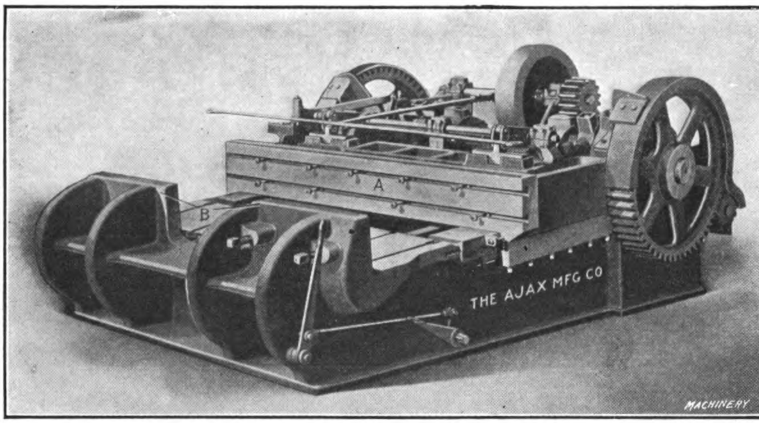


Fig. 23. No. 7 High-speed Bulldozer—an Adjunct to the Forging Machine

The Bulldozer. The bulldozer is especially adapted for bending operations and is closely allied to the forging machine; in fact, many operations can be done successfully on forging machines only when the bulldozer is used for performing a preliminary operation. This type of machine contains a cross-head which carries one member of the forming dies; the other member of the dies is held against a die-seat which is formed integral with the main base of the machine. The stock to be formed is placed between the dies and, as the cross-head moves forward, the stock, which may or may not be heated, is bent to the shape of the dies.

One design of bulldozer is shown in Fig. 23. The machine consists primarily of a moving cross-head *A* which carries one member of the forming dies, the other member of the forming dies being held against the "toes" *B* of the machine. The operations are accomplished by the forward travel of the crosshead, the work as a general rule being completed in one travel of the head. While the machine is fairly simple in construction and operation, many types of interesting forming tools are used.

The forming tools for the bulldozer can generally be made cheaper and more conveniently from cast iron, especially when they are provided with hardened steel plates where any friction takes place—that is, those parts of the tool which actually do the forming or shaping should, as a general rule, be reinforced with hardened steel plates. This enables the tools to be renewed very cheaply, as the plates when worn out can be replaced by new blocks of steel. The

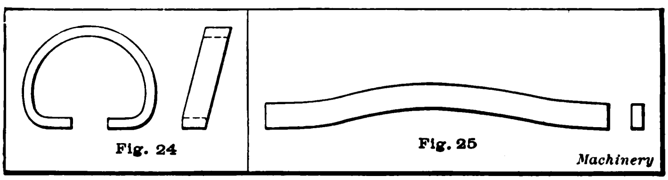


Fig. 24. The Finished Stirrup

Fig. 25. Blank after the First Operation has been performed

roller type of tool which is carried and operated by the crosshead is the best for saving material and power when it is possible to use this type. However, the type of tool to use depends largely on the shape to be formed and other requirements. In all cases where hot punching or cutting is done, high-speed self-hardening steel should be used for the working members of the tool.

Bulldozer Dies for Forming Steel Stirrups. In certain of its products, the General Electric Co. uses steel stirrups of the form shown in Fig. 24. These stirrups are made of high carbon steel of approximately $3/4$ by $3/8$ inch in cross-section. As a rather large quantity of these parts is required and as no forging machine was available, it was decided to make dies in which these stirrups could be produced on a standard bulldozer. As the dimensions must be within 1/64 inch of uniform, it was necessary to make dies that would produce work within these limits without requiring any subsequent forging which would leave hammer marks.

The sequence of operations involved in making these stirrups is as follow: A bar of steel is sheared into blanks of the required size, which are first bent to the form shown in detail in Fig. 25, this form being a development of the finished stirrup. Suitable allowance is made for the spring of the steel in order to obtain the required dimensions. The blanks are bent to the form shown in Fig. 25 between the dies *A* and *B* (Fig. 26) which are shown in the operating position, and also in cross-section in order to illustrate the construction more clearly. The die *A* is fastened to a stationary base, which is, in turn, bolted to the ways of the bulldozer and backed up by adjusting screws. It will be seen that the plates *A* and *B* overlap in order to prevent distortion of the work while it is being bent into shape. The die *B* is bolted to a supporting plate which is carried by a second plate *F* bolted to the ram of the bulldozer. The gage *G* provides for locating the blanks in the proper position.

The next step is to complete bending the work to bring it to the form shown in Fig. 24. When the ram recedes after performing the preliminary operation between the dies *A* and *B*, the work is taken out and laid edgewise on the shelves *H* and *J* of die *K*. The gage *X* provides for locating the work in the required position. When the ram comes forward, it pushes the wedge *L* against the slide *M* which travels on ways provided in the block *N*. During the first part of the operation performed in this die, the block *N* is held stationary by a locking-pin; but after the slide *M* has completed its travel, the locking-pin is released and the block *N* moves forward. A more complete explanation of this part of the work will be given in a subsequent paragraph. The slide *M* carries a form *P*, and as the slide moves to the right this form comes into contact with the work and forces it into the die *K*, thus bending the piece to a U-shape.

When the operation has proceeded to this point, the wedge *Q* located on the under side of the base pulls out the locking-pin *R* thus leaving the block *N* free to move. As the ram continues its forward movement the die *S*, which is fastened

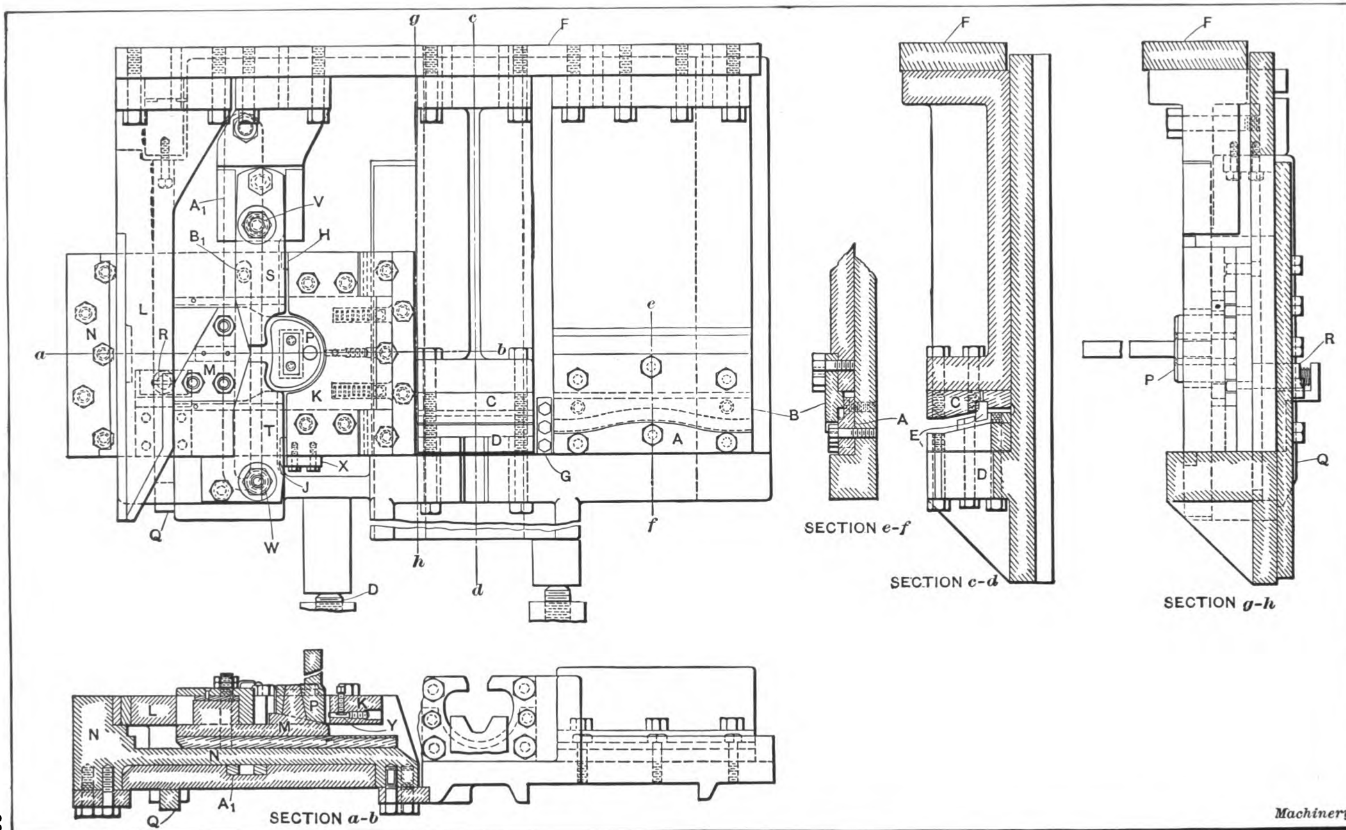


Fig. 26. An Interesting Set of Bulldozer Dies for Forming Stirrups of the Form shown in Fig. 24.

to the ram, comes into contact with one arm of the U-shaped piece on the form *P* and bends it around the form. At the same time the ram continues to move forward and pushes the slide *M* and the block *N* with it. In so doing, the other arm of the U-shaped work is pushed into the stationary die *T*, which bends it around the form *P*. At the end of the forward movement of the ram, both the dies *S* and *T* come in contact with the wedge-shaped end of the slide *M*, which forces the dies against the form *P*, thus setting the work on the form. The dies *S* and *T* are pivoted at the points *V* and *W*, respectively, to enable the dies to be moved by the tapered surfaces on the slide *M*. While this forming operation is being performed, the work is pushed against a stamping device *Y* set in the die *K*, which produces the necessary marking on the part. When the ram returns, the die is released and the slide *M* is pushed back by the springs in the block *N*; then a link draws the block *N* back.

The form *P* is now taken out of the slide with the work in place around it. The third operation consists of setting the work in the dies *C* and *D*. The purpose of this operation is to overcome the elastic limit of the material so that the piece will be set to exactly the required form. After this final operation has been completed, the form is pushed out of the work by means of the ejecting-pin *E*, leaving it in the shape shown in Fig. 24.

CHAPTER V

WELDING IN THE FORGING MACHINE

THERE are three methods in general use for welding or joining pieces in a forging machine. The selection of the one to employ depends largely on the shape of the work and other requirements. The most common method in general use is lap-welding, of which there are several applications. The next in importance is pin-welding. Butt-welding is as a rule used only where it is impracticable to handle the work in any other way.

In regard to the materials that can be handled, wrought iron can be very readily welded in the forging machine, and when proper care is taken this can be successfully done without resorting to the use of fluxes, except in unusual cases. Machine steel does not weld so readily as wrought iron, and usually it is advisable to use a welding compound on the faces of the parts it is intended to join. The following ingredients make a satisfactory flux for steel welds: To one part of sal-ammoniac add twelve parts of crushed borax. Heat slowly in an iron pot until the mixture starts to boil, then remove and reduce to a powder. Then apply the powder to the welding faces of the work shortly before removing it from the furnace, putting the work back in the furnace for a short period after applying the flux. Alloy steels, while they can be worked successfully in a forging machine, cannot be successfully welded. As a rule, parts made from alloy steels can be worked into shape only by upsetting and forming.

Lap-welding and Forming Operations. A simple example of lap-welding in conjunction with a forming operation is shown on the Ajax forging machine, Fig. 1, the various steps in the making of a draw-bar hanger being illustrated at *A*, *B* and *C*. The first operation consists in cutting a 2¼-

by ¾-inch bar of wrought iron to a length of 19¾ inches—this allowing a sufficient amount of excess material to form the two bosses, one on each end. The bar is then heated in the furnace and placed in the side shear of the machine as shown at *D*. The forging machine is now operated and the tools held on the side shear arrangement partly cut off the bar and bend the nicked end around about one-quarter turn. It is then removed from the machine, placed on an anvil, and the bent end lapped over as shown at *B*, after which it is again put in the furnace and heated to the proper temperature; it is then removed and placed in the lower

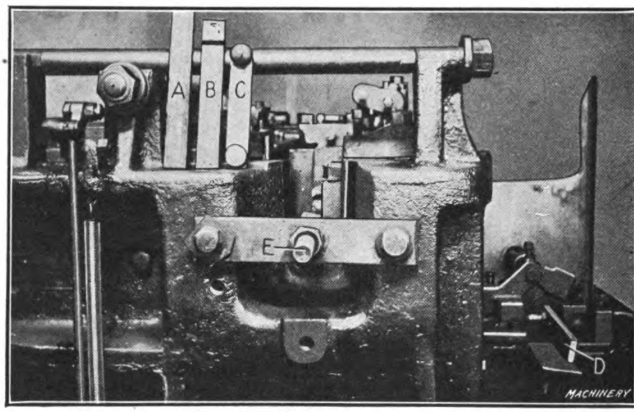


Fig. 1. Making Draw-bar Hangers in a 3-inch Forging Machine

impressions in the gripping dies, being properly located for length by the back stop *E*. The machine is then operated, completing the weld and forming the upset square boss on one end of the bar in one blow. After performing the operations described on all of the bars the other end is handled in practically the same manner, using the upper impressions in the gripping dies and subjecting the bar to three heats instead of two.

Dies and Tools for Making Locomotive Ash-Pan Handle. Fig. 2 shows a locomotive ash-pan handle that is produced in a similar manner to the draw-bar hanger shown in Fig. 1, the operations on this piece being indicated at *A*, *B*, *C* and *D*, respectively. The first operation is to cut off a bar *A* of the required length, as before mentioned, and bend one end over into the shape at *B*, putting it into the required condition for welding, forming and piercing in the forging machine. The welding and forming operations indicated at *C* are handled in the lower impression of the dies shown to the left of the illustration, the position of the work before forming being indicated by the dotted lines *E*. The lower impression is formed as shown in the end view of the dies at *F*, being provided with a draft in the impression of 1/16 inch on the diameter in order to facilitate the "flow" of the

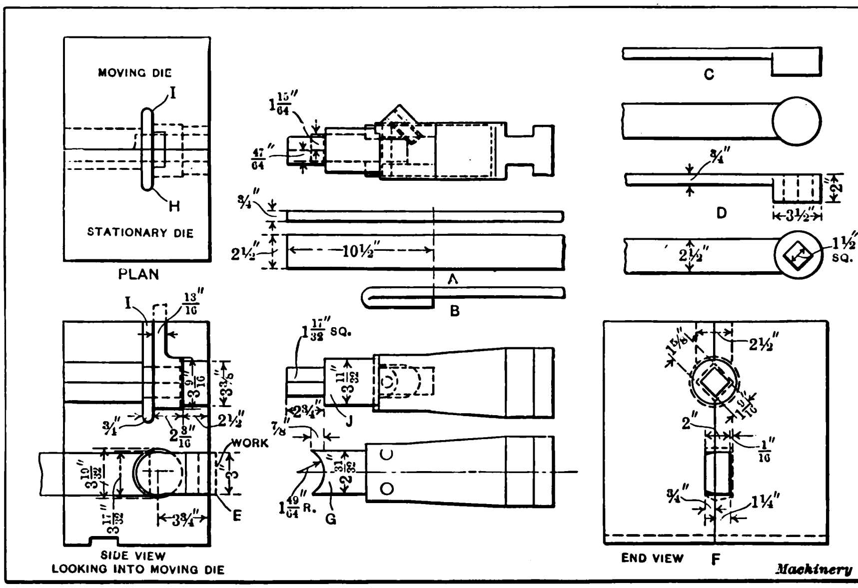


Fig. 2. Dies and Tools used in making a Locomotive Ash-pan Handle

metal and the removal of the forging from the dies. The punch *G* is made with a concave end which forms a portion of the boss and upsets the material into the desired shape at the same time.

After being welded and formed, the work is removed from the power impressions and placed in a vertical position in the upper impressions in the dies. Here the square hole, as indicated at *D*, is punched. As the gripping dies are made from steel castings, they would not stand up satisfactorily for a piercing operation, so in order to punch a clean hole two steel plates *H* and *I* are inserted in the movable and stationary members of the dies. These are so shaped that a square hole is formed when the dies come together. The hole is pierced by the punch *J*, the construction of which is shown in the illustration. Both punches *G* and *J* are made from steel forgings and hardened.

Dies and Tools for Making Car Float Stanchion Foot. Another interesting example of lap-welding which is used for the purpose of enlarging a 2-inch bar to 6 inches in diameter to form the head on a car float stanchion foot is illustrated in Fig. 3. This car part, as indicated at *A* and *B*, is made from a wrought-iron bar 2 inches in diameter, to

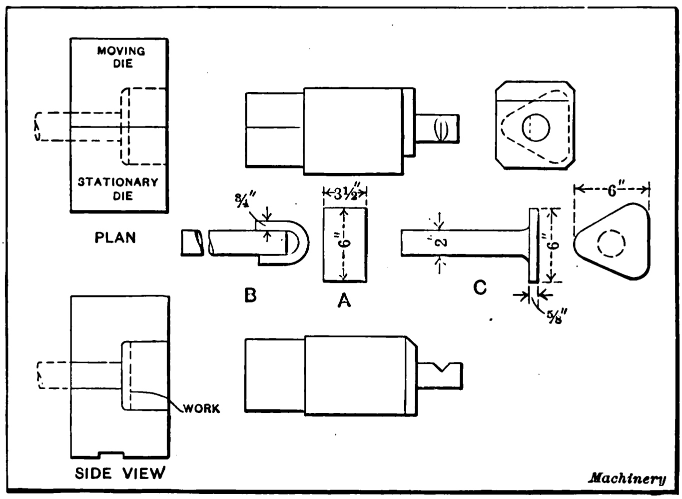


Fig. 3. Forging Machine Dies and Tools for making a Car Float Stanchion Foot

which a rectangular block *A*, 6 by $3\frac{1}{2}$ by $\frac{3}{4}$ inch, is welded. Block *A* is first cut to the required length, and bent into a U-shape in the bulldozer. Then it is placed on the round bar as indicated at *B* and the two parts are put in the furnace where they are heated to a welding temperature. The parts are now quickly removed, given a tap to stick them together, placed in the forging machine, and with one blow are formed to the shape shown at *C*. The dies and tools used for this operation, which are also shown in the illustration, are of simple construction, consisting only of two gripping dies and one plunger.

Dies and Tools for Making Locomotive Spring Bands. A lap-welding operation which is handled in a different manner from those previously described is shown in Fig. 4. This piece, which is a spring band for a steam locomotive is made from a rectangular wrought-iron bar 2¼ by ⅜ by 19 inches long. It is first bent into a U-shape as indicated by the full lines at *B*, in a bulldozer. After being bent in the bulldozer, the work is again put in the furnace and heated to the proper temperature. It is then removed from the fur-

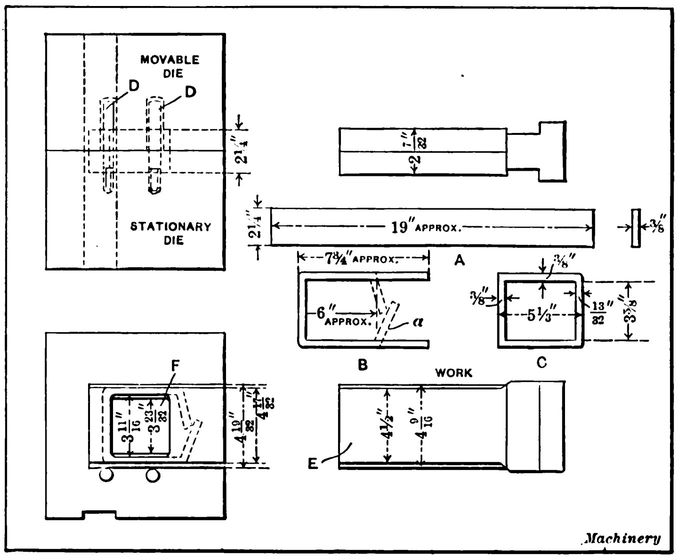


Fig. 4. Forging Machine Dies and Tools for making Locomotive Spring Bands

nace and by means of bending dies held in the side shear of the forging machine, the ends are bent into the shape shown by the dotted lines *a*—partly overlapping each other. After this operation, the piece is again placed in the furnace, heated to a welding temperature, and quickly removed and placed between the gripping dies shown to the left. The stationary gripping die carries two pins *D*, which serve as a means for supporting the work before the dies close on it. The welding and forming operation is accomplished by plunger *E*, which forms the work around the square impressions F in the dies, and at the same time welds the two ends together, forming the spring band into one piece. A particularly interesting feature about this job is the fact that the excess amount of stock formed by the overlapping ends is distributed equally along the front side of the forging, making it 1/32 inch thicker than the original rectangular bar, and thereby increasing its strength at this point.

Dies and Tools for Making Extension Handle for Grate Shaking Lever. An interesting example of lap-welding is illustrated in Fig. 5, where the dies and tools used for forming an extension handle for a grate shaking lever are illustrated. This part, as shown at A and B, is made from two pieces—a rectangular bar of wrought iron 2½ by ¾ inch, which has been sheared to an angular shape on one end, and a loop B formed from a piece of ⅝-inch rectangular bar iron bent into a U-shape in the dies illustrated to the left. The trimming of piece A and the bending of piece B is carried on at the same time with special shaped formers held to the top faces of the gripping dies. To do this, the operator first places a piece of rectangular stock of the required length in the impressions in the rear member D of the stationary gripping die; he then takes bar A, which has been previously cut to the required length and places it in the impression at the front end of the gripping die. Upon operating the machine, the moving die advances and as it carries a plunger E, it forces bar B into the suitably shaped impression in the stationary gripping die. At the same time that this operation is being accomplished, the shearing plates F and G carried in the stationary and movable gripping dies, respectively, shear off the end of bar A.

The welding of these two parts is accomplished in the lower impression in the gripping dies which hold the pieces in position while punch H advances and upsets and welds the parts together. The two pieces are placed together and put in the furnace, heated to a welding temperature, then removed and given a tap, so that they will stick together. They are then put in the lower impression of the gripping dies and the machine operated. Then as the plunger H advances it enters the loop in part B, expanding it into the

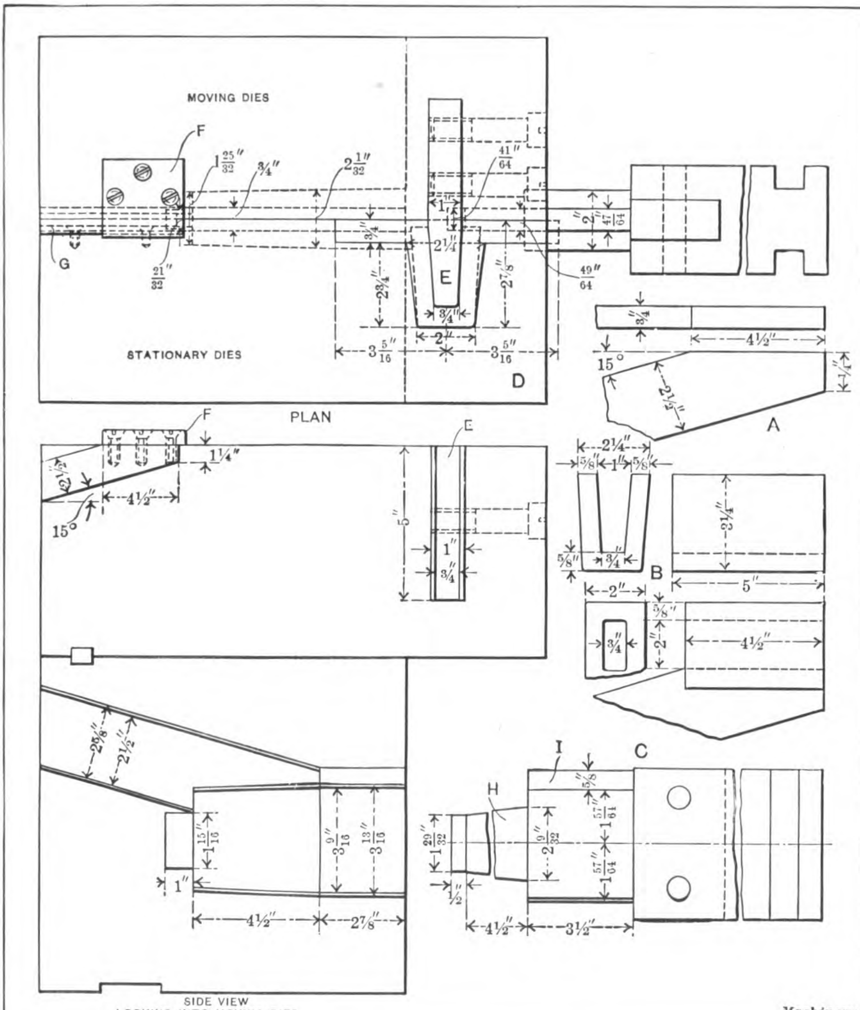


Fig. 5. Forging Machine Dies and Tools for making Extension Handles for Grate Shaking Levers

impression in the gripping dies, and at the same time, by means of the shoulder on the punch, carrying forward the excess stock and distributing it equally throughout the forging, thus joining the two parts and producing a perfectly welded joint. Punch *H* is guided when in operation by a tongue *I*, sliding in a groove in the gripping dies, and preventing side movement of the punch.

Universal Type of Upsetting and Forging Machine. The miscellaneous welded and formed parts shown in Fig. 6 were forged in the Chicago shops of C. & N. W. Railway. The forging dies and tools shown in the following illustrations constitute a few of the many interesting examples to be found in the shop mentioned. All of the examples shown in Fig. 6 were produced on the 6-inch Ajax universal forging machine shown in Fig. 7.

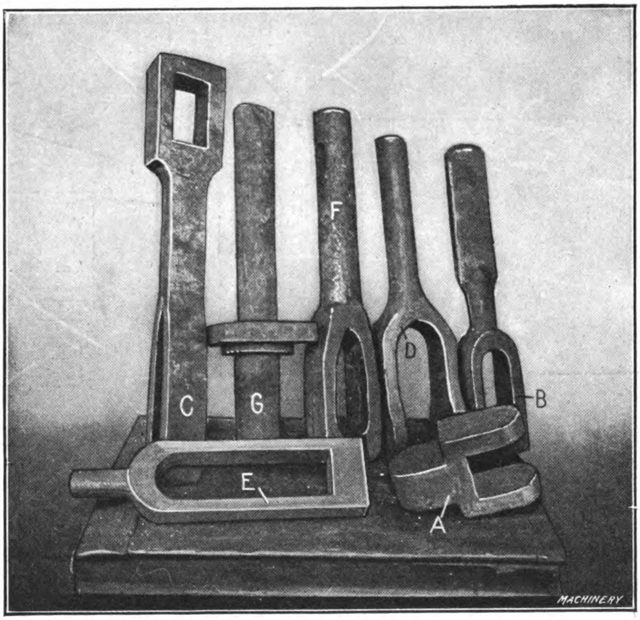


Fig. 6. Miscellaneous Examples of Lap-welding and Forming Operations accomplished on a 6-inch Universal Forging Machine

The universal type of upsetting and forging machine shown in Fig. 7 has a much greater range of possibilities for producing machine made forgings than the regular upsetting and forging machines previously described. This machine has all the features common to the regular forging machine in combination with those of a powerful vertical press operated independently of the other part of the machine. The universal forging machine is designed especially for forming such forgings as require squeezing, punching or trimming operations before or after upsetting. This often makes it possible to prepare and complete large upsets and difficult shaped forgings in one handling, and thus utilize the initial heat.

It consists mainly of a double-throw crankshaft from which are operated two header slides—one for the standard upsetting mechanism and the other for the vertical press. The upper die-holder *A* of the vertical press is op-

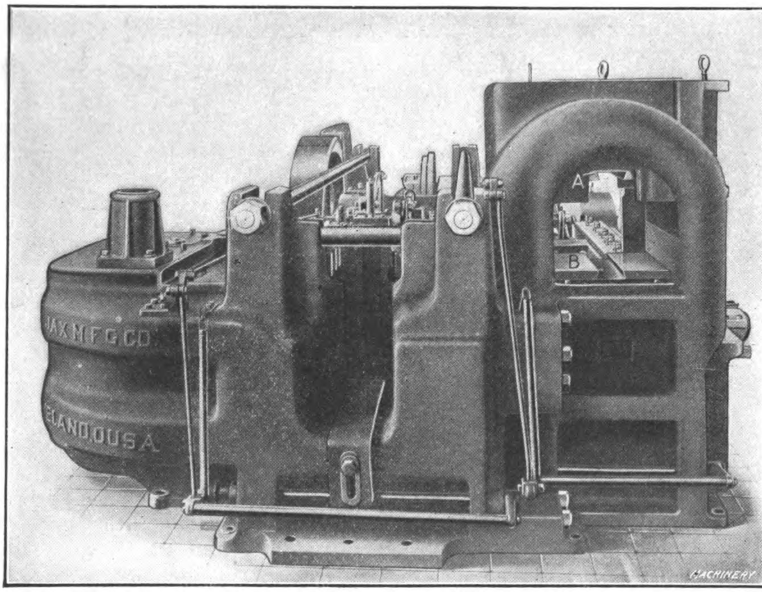


Fig. 7. Six-inch Universal Forging Machine used for making the Forged Parts shown in Fig. 6

erated by two heavy steel side links, the lower ends of which connect with eccentrics on an oscillating shaft. This die-holder is provided with means of adjustment so that the squeezing dies can be brought together or separated as requirements demand. The lower member of the dies used in this auxiliary part of the machine is held on the stationary die-holder *B*.

Dies and Tools for Making Spring Hangers. An interesting example of the utilization of scrap metal for making engine parts is the spring hanger *A*, Fig. 6. This part is made from old arch bars 1 by 4 by 5 inches with the dies and tools shown in Fig. 8. Six blocks cut off from the arch bars are piled together and riveted as shown at *A* in Fig. 9, the old holes in the arch bars serving as a means for riveting them together. This is done to hold the separate blocks in place while reaching a welding heat. After the parts have reached the proper temperature they are taken to the universal forging machine shown in Fig. 7, and placed between squeezing dies held in the vertical press. The machine is then operated, welding the pieces together

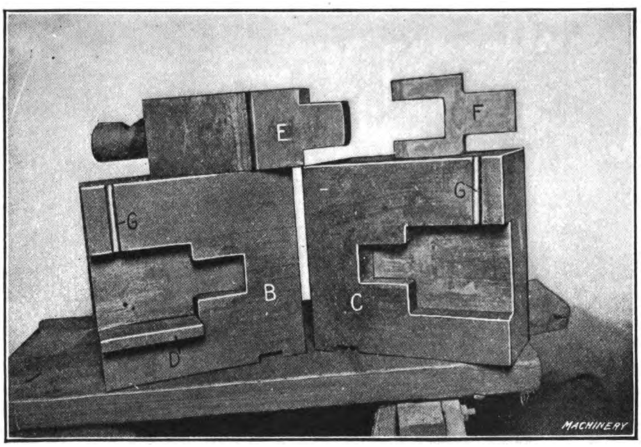


Fig. 8. Dies and Tools for making Spring Hangers in a 6-inch Universal Forging Machine

and converting them into a solid block as shown at *B* in Fig. 9.

After the separate pieces have been welded and shaped, the solid block is again taken to the furnace and heated to a welding temperature. Then it is removed and placed between the opposing faces of the gripping dies *B* and *C*, Fig. 8, these being held in the forging machine shown in Fig. 7. The stationary gripping die *B* is provided with the shelf *D* on which the heated block is placed, this serving to hold it while the dies are coming together. As soon as the dies close on the work, plunger *E* advances and displaces the stock in such a manner as to form the tail on the end of the forging *F* by simply forcing the center portion of the block back into the rear impressions in the gripping dies. This is accomplished in one heat, and when the piece is removed from the dies it is finished complete. Vent holes *G* are provided in the opposing faces of the dies to allow the excess metal to escape.

Another example of a spring hanger forging is shown at *B* in Fig. 6, the dies and tools used being shown in Fig. 10. The first operation in the forging of this spring hanger is to draw the 2-inch wrought-iron bar *A* down to the shape

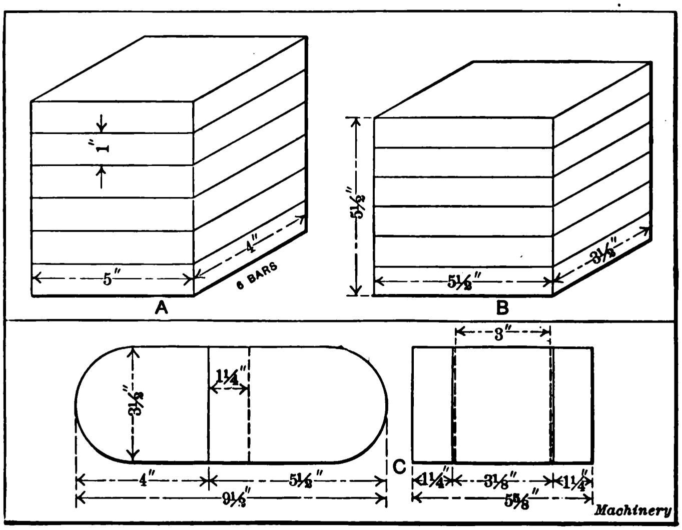


Fig. 9. Sequence of Operations on Spring Hanger shown at A in Fig. 6 and also in Fig. 8

shown at *B*, Fig. 11, in a Bradley steam hammer. This piece, after being drawn down, is heated and placed in a bulldozer, where it is bent into a U-shape as shown at *C*, the heaviest part of the piece being located at the bent end. The one-inch hole is punched through the bent end at the same time that the work is being formed. The body or shank of the hanger is made from a 1- by 4-inch piece of round edge iron *D* which is swaged down on a 4-inch forging machine to 1¾ inches round for a length of about 7 inches on one end, as shown at *E*. The bar is then heated, placed in the forging machine and upset to 2 inches in diameter in order to form completely the reinforced portion on the flat part, and at the same time reduce the end to one inch in diameter. The reduction on the end of the bar is accomplished with the plunger held in the ram of the machine.

The loop *C* is now placed on the reduced end of the rod as shown at *G* and is riveted cold, just enough to hold the two pieces together while heating for welding. The work

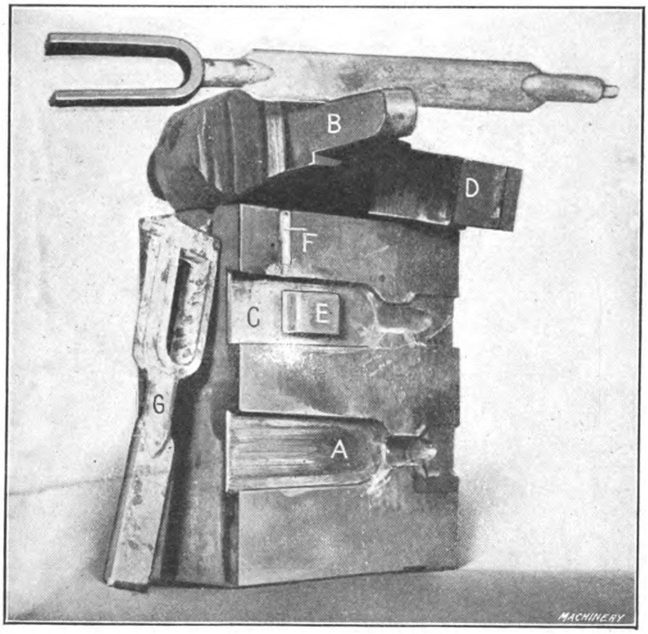


Fig. 10 Dies and Tools used in making Spring Hanger shown at B in Fig. 6—also Illustrating Pin-Welding Operation

is then raised to a good welding heat, and is quickly placed in the lower groove *A* (see Fig. 10) of the dies held in the 6-inch forging machine shown in Fig. 7, where the work is formed by the plunger *B* (Fig. 10). The reason for doing this work in a 6-inch forging machine is that the plunger travel necessary is 14 inches, and this would be impossible on a smaller machine than that having a 6-inch capacity. This 14-inch travel, of course, is after the dies have been closed on the work. After the two pieces are welded together as shown at *H* (Fig. 11) a block *a* of 2-inch square iron 3 inches long is placed in the U-end of the forging as shown at *I* and a welding heat taken. The work is then placed in the upper groove *C*, Fig 10, of the dies and as the plunger *D* advances it upsets the forging to the proper shape around the embossed center portions *E*, the excess metal flowing up through the vent holes *F* provided in the gripping dies. The finished forging is shown at *J* in Fig. 11.

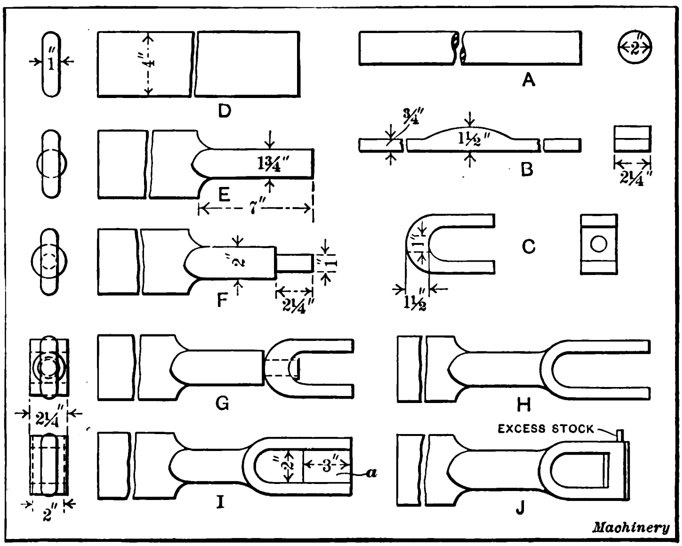


Fig. 11. Sequence of Operations performed on the Spring Hanger B shown in Figs. 6 and 10

Still another type of spring hanger which is completed in the forging machine is shown at *C* in Fig. 6. This is made from a rectangular bar of wrought iron which is first lapped over and then welded, after which the eye-end is formed to shape on the forging machine. The square hole is rough-formed by the vertical press of the universal forging machine shown in Fig. 7, and is then finished in the upper impression in the dies held in the horizontal part of the forging machine. No material is removed to form the square hole, the metal simply being expanded, increasing the width of the bar.

Dies and Tools for Making Fork End of Main Driver-Brake Pull Rod. The fork end of the main driver-brake pull rod shown at *D* in Fig. 6 is made from a 2¼-inch bar or round wrought iron which is first squeezed down flat on one end until the flattened end is 3 inches wide by 14 inches long. This operation is handled in the vertical head of the machine shown in Fig. 7. A piece of ½ by 3 by 14-inch wrought iron is laid on the flattened portion of the bar (both pieces, of course, being heated) so that they can be stuck together by the dies held in the vertical head of the universal forg-

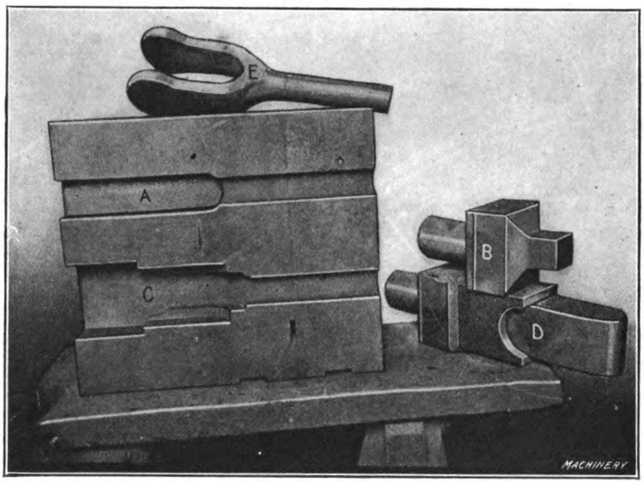


Fig. 12. Dies and Tools for making Fork End of Main Driver-brake Pull Rod shown at D in Fig. 6 in a Forging Machine

ing machine, thus holding them while the welding heat is being taken. The next step in the forging of this fork is to increase the diameter of the rod from 2½ to 3 inches square. This operation is accomplished in the upper grooves *A* of the dies shown in Fig. 12, using the plunger *B* for upsetting. The 3-inch squared end is now split for about 9 inches of its length with suitable tools held in the vertical head of the machine, and at the same time is opened up slightly. The piece is then taken to the furnace and heated after which it is placed in lower grooves *C* of the dies. One blow of plunger *D* brings it to the final shape shown at *E*.

Dies and Tools for Making Slot End of Main Driver-Brake Pull Rod. The slot end of the main driver-brake pull rod shown at *E* in Fig. 6 is made as shown in Fig. 13 from two pieces *a* of 1 by 2½-inch flat bar iron 27 inches long, one piece *b* of 3-inch square iron 3½ inches long, and one piece *c* of 2½-inch square iron 5 inches long. The two pieces *a* are clamped by a pair of tongs on the end where the block *c* is located and a welding heat is taken on the other end. The work is then removed from the furnace by the tongs

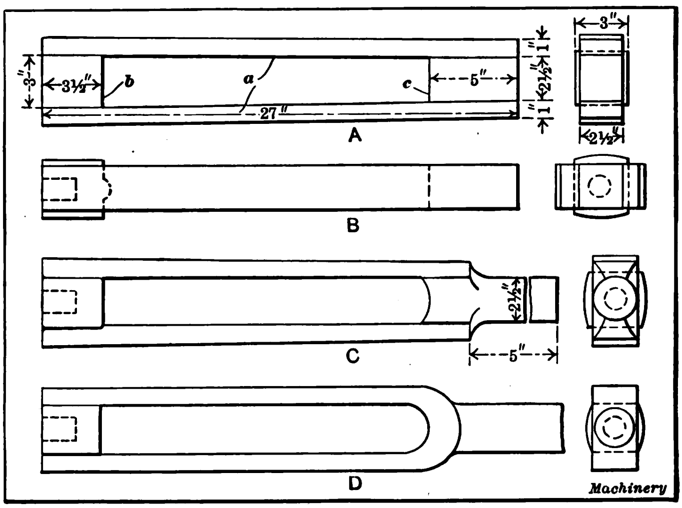


Fig. 13. Sequence of Operations performed on the Slot End of the Main Driver-brake Pull Rod shown at E in Fig. 6

and quickly place in the top groove of the dies. The machine is operated, and as the plunger, which has a punch on its front end, advances, it punches a hole in the work and displaces the stock, forming a boss on each side as indicated at *B*. The position of the tongs on the work is then reversed and the other end of the forging is heated, after which it is swaged to 2½ inches in diameter for a distance of 5 inches on this end to the shape shown at *C*. This operation is handled by the gripping dies which are provided with circular grooves located between the upper and lower impressions. The forging is again heated and placed in the lower impressions of the dies, the round part entering the plunger. The machine is then operated, forming the forging to the shape shown at *D*.

Butt-welding Bottom Connecting-Rods for Freight Cars. Butt-welding is seldom done on forging machines, owing to the difficulty generally experienced in successfully making this type of weld. The bottom connecting-rods shown at *F* in Fig. 14, are, however, produced satisfactorily by butt-welding in the Collinwood Shops of the L. S. & M. S. Railway. The stock for the forked ends *A* is sheared off from a bar of 2½ by ¾-inch wrought iron and bent to a U-shape in the bulldozer. The center portion of this connecting-rod

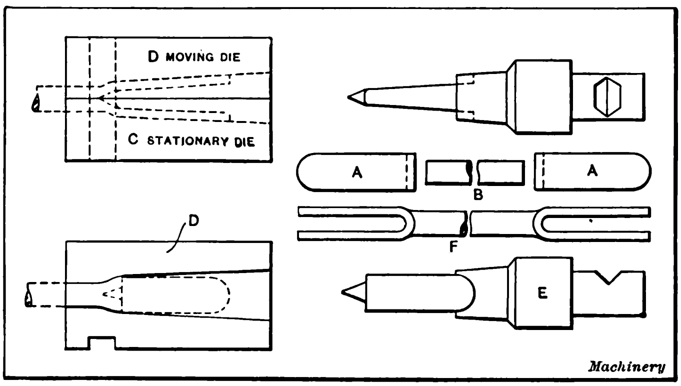


Fig. 14. Illustrations showing Sequence of Operations in the Butt-welding of Bottom Connecting-rods

is made from 1¾-inch round wrought-iron bars which are also sheared to the required length before coming to the forging machine.

The U-shaped pieces *A* and bars *B* are now placed in a furnace where they are heated to a welding temperature. The operator then removes a rod and also a U-shaped piece and butts them together; he then places the pieces which are stuck together in the impressions in the gripping dies *C* and *D*, and operates the machine. Now as plunger *E*, which has a pointed end, advances, it forces itself through the fork into the round stock, thus intermingling the grain of the material and insuring a solid weld. To prevent scale from forming on the pieces to be welded, a small jet of compressed air is made to play on them just before and while the machine is operating.

After welding, the work is removed from the gripping dies and placed between suitably shaped forming dies held in the side shear. The machine is then operated, forming the U-shaped end to the proper shape, after which the piece is thrown down in the sand to cool off. After all the rods have been completed in this manner, the other or straight end is placed in the furnace and the same procedure

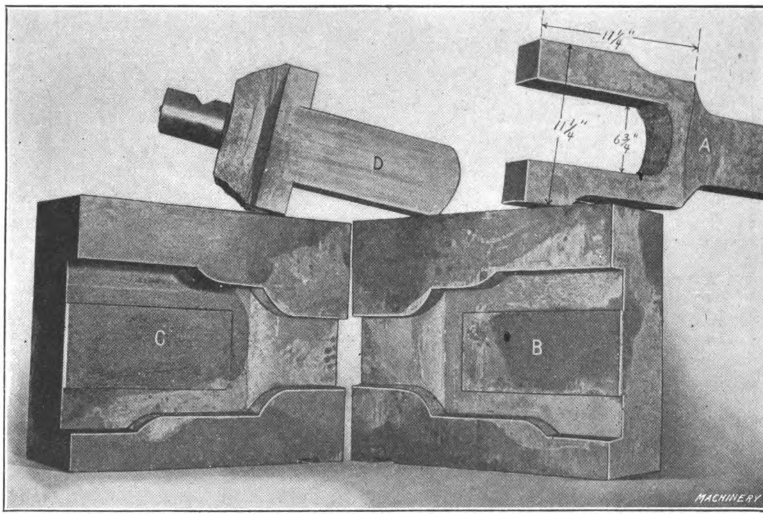


Fig. 15. Dies and Tools used in making Locomotive Main Rods in the 6-inch Universal Forging Machine

repeated. The completed bottom connecting-rods are shown at *F*. To prove that this type of weld was satisfactory, numerous tests were made to break it at the welded joints. This was not accomplished until the testing machine registered a pull of 74,000 pounds, which is equivalent to a tensile stress of approximately 30,000 pounds per square inch. As the tensile strength of wrought iron seldom exceeds 48,000 pounds per square inch, it will readily be seen that this type of weld would be satisfactory for the general run of forged work.

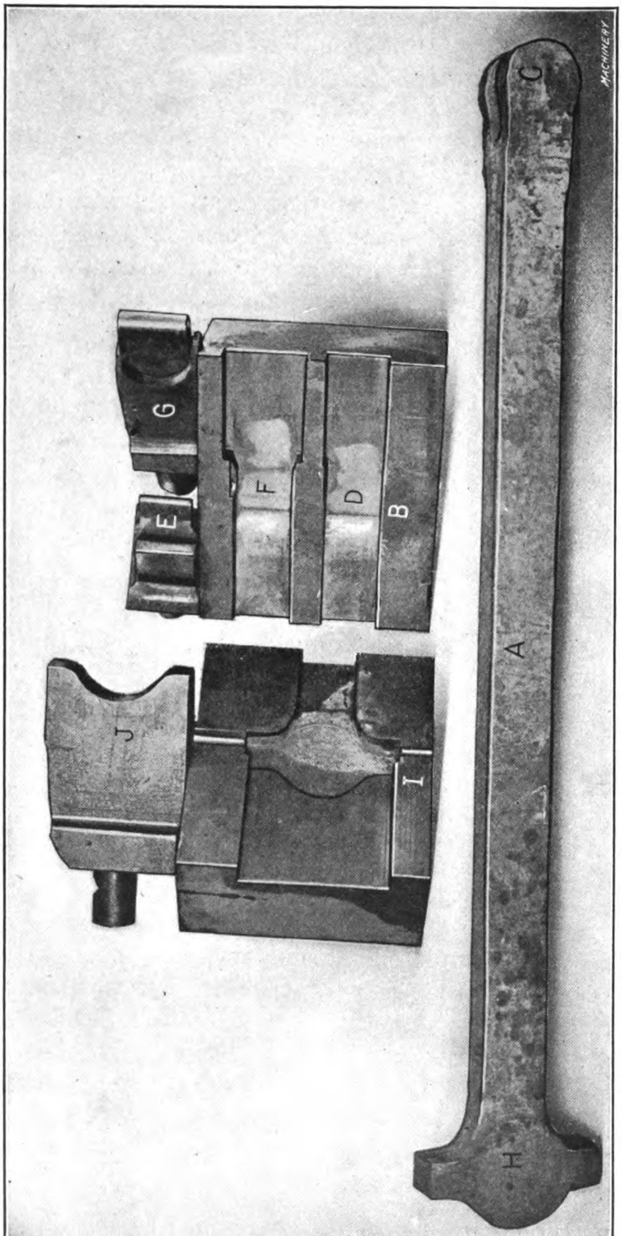


Fig. 16. Dies and Tools used in a Universal Forging Machine for making Locomotive Side Rods

Tools for Making Engine Main and Side Rods in the Forging Machine. The locomotive main rod shown at *A* in Fig. 15 is an exceptionally large piece of work made in a 6-inch Ajax forging machine in the Chicago shops of the C. & N. W. Railway. The main rod is first roughed out under a steam hammer and the end split before it is brought to the forging machine shown in Fig. 7. The roughing out of the slot and the finish-forming in the forging machine are done in one heat. In the forging machine the work is gripped by the dies *B* and *C*, and is upset and formed to shape by the plunger *D*.

Another good example of heavy forging done in the Ajax 6-inch universal forging machine is the locomotive side rod shown at *A* in Fig. 16. This side rod is made from square stock drawn down to the required size under the steam hammer and is upset and formed on each end in the forging machine shown in Fig. 7. The gripping dies, only one of which is shown at *B* in Fig. 16, are used for forming the end *C* of the rod. It requires two operations to complete this end. The first operation is performed in the lower groove *D* of the dies and consists in rough-forming the slot with the plunger *E*. The work is then placed in the upper groove *F* and completely formed to shape by means of plunger *G*.

The other end *H* of the side rod is upset and formed to shape by another set of dies—only one of which is shown at *I*. The rod, which is heated to a welding temperature, is placed in the impressions in the gripping dies and is upset and formed to the required shape by means of the plunger *J*. These two examples of machine forging illustrate very well the adaptability of the forging machine to locomotive building.

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