Yttrium has been mentioned as an alloying element for steel, but it is only found in combination with a few rare minerals, and consequently is only seen in the laboratory. It belongs to the same chemical group as aluminum, and if it were found to be beneficial to steel it could not be obtained in sufficient quantities for commercial use.

Cerium and lanthanum have been combined with iron in the electric furnace to make an alloy that will give off luminous sparks. The maximum sparking effect seems to be obtained with about 50% of iron, and this will light illuminating gas. The sparks are obtained by striking the alloy with steel similar to the way flint was used before the days of matches. Some such combination might be used for generating the spark in internal-combustion engines. One such alloy was sold to the match trust and killed, as they feared competition from its use.

CHAPTER VII

Working Steel into Shape

Rolling

After the iron ore has been reduced to pig metal, and this refined and combined with the other ingredients that go into the making of the different grades of steel, and then cast into ingots, the ingots are sent through slabbing rolls, as shown in Figs. 52 and 53. The slabs thus formed are then rolled into the numerous shapes that are used for manufacturing purposes.

The slabbing mill, with a single pair of rolls and stationary table, which is used by many steel makers, is shown in Fig. 52. In Fig. 16 is shown the mechanically operated grip that has just brought an ingot from the soaking pit, and dropped it onto the carrier that conveys it to the rolls, and Fig. 17 shows the same ingot just as it has made its first pass through the slabbing mill. After this the mill is reversed and the ingot passes back through another section of the rolls to further reduce it. After some four or five passes back and forth through the rolls, during which time it is turned over so as to roll all four sides, it is sent to other rolls that reduce it to commercial shapes.

In Fig. 53 is shown the three high mill with tilting table. This has a double set of rolls, and for the first pass of the ingot the end of the table next to the rolls is lowered to receive it as it comes through. The rollers of the table are then reversed, and while reversing the end of the table is elevated, as shown in the illustration, and the ingot sent back through the upper rolls. The rolls, as well as the tilting table, are controlled from the platform of the pulpit, shown to the right of the picture. In this design a much narrower mill can be used for the same number of passes than in the design of mill shown in Fig. 52.

After slabbing the metal, various kinds of rolling mills are used to get the steel into the shapes desired. Many times the different mills are combined so as to make the rolling operations continuous from the steel furnace to the finished product. In some cases the desired shape is finished before the metal has had time to cool off after leaving the fur-

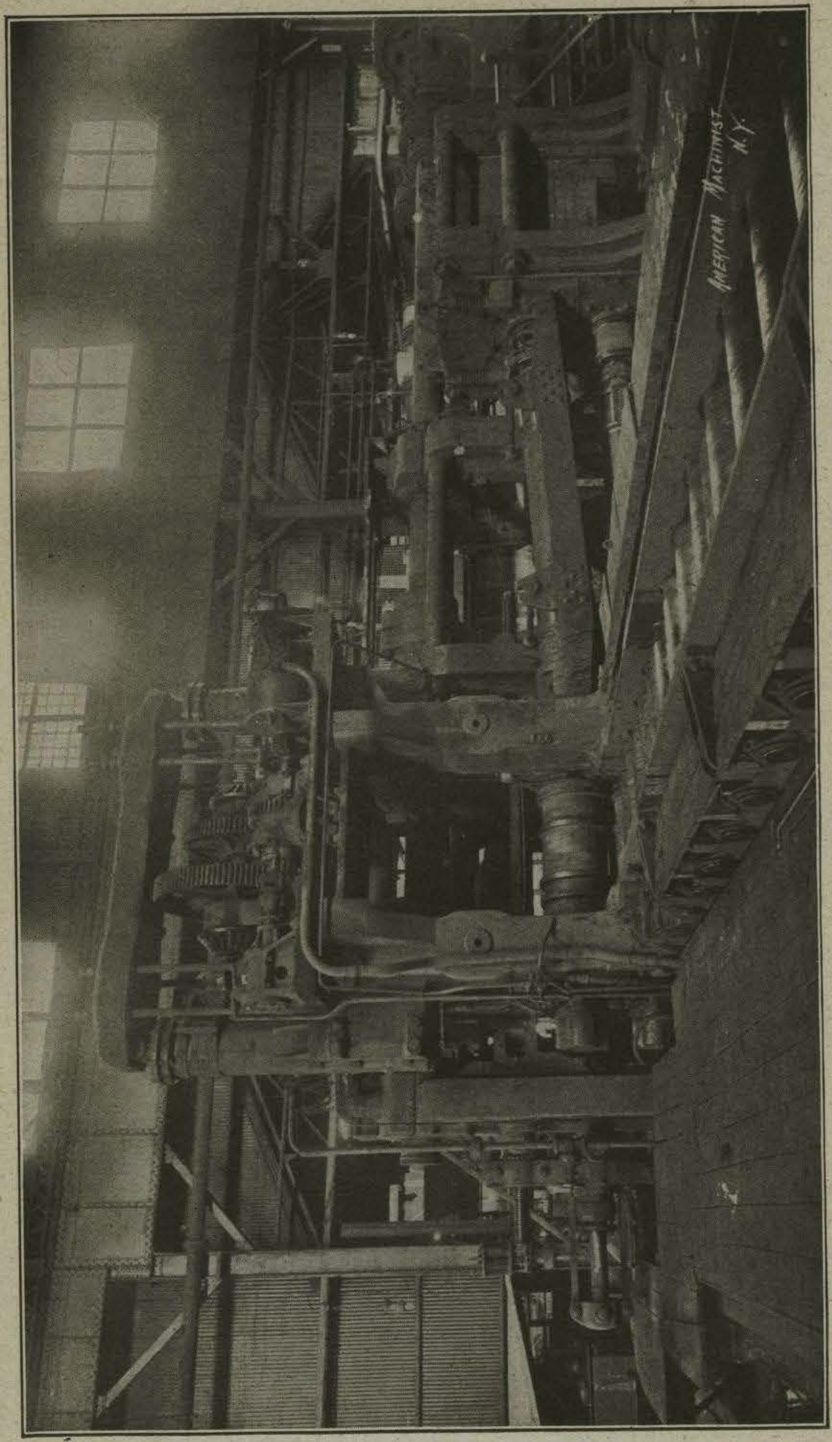

Fig. 52. — Slabbing rolls; first roll that ingot passes through.

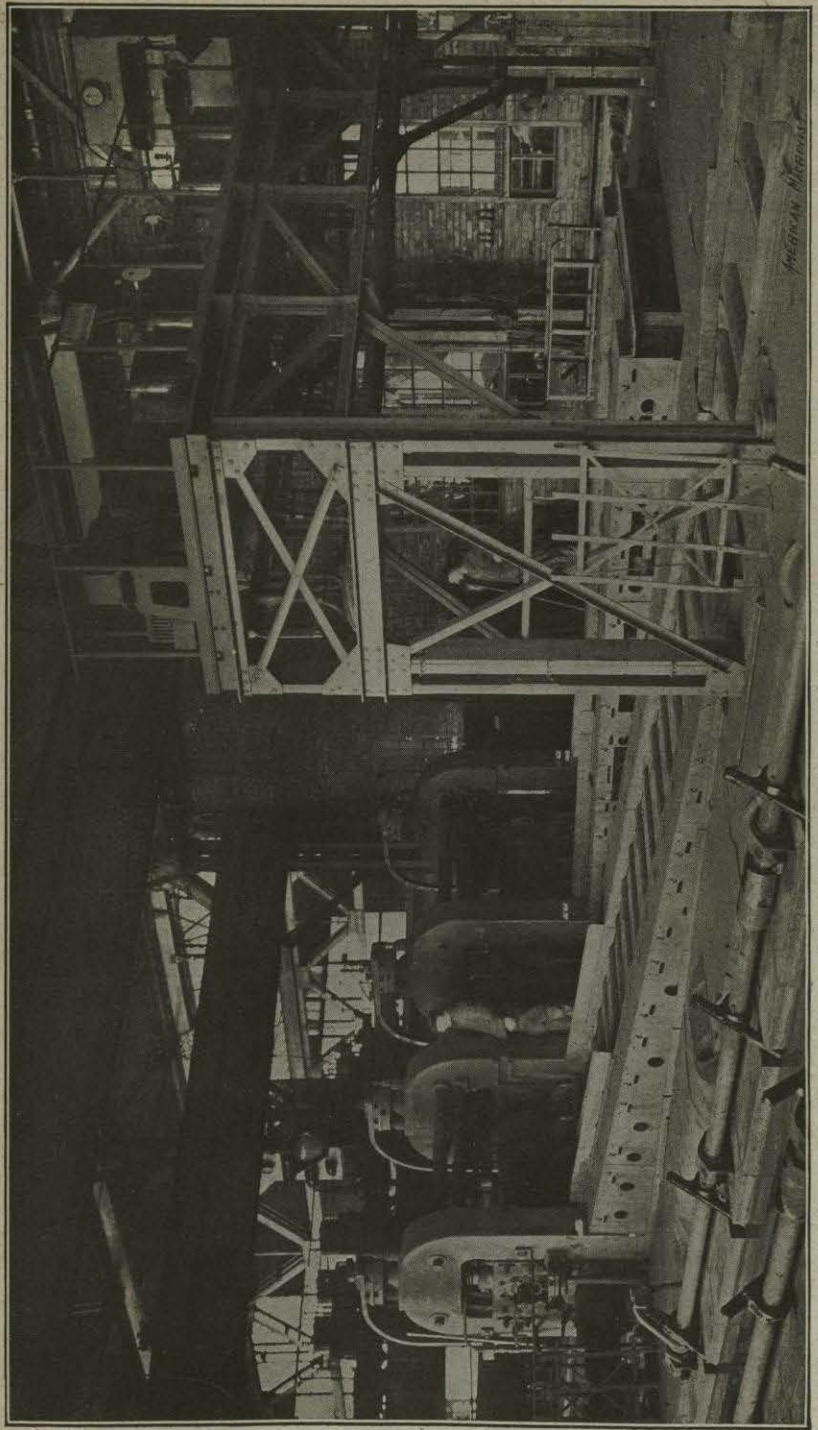

Fig. 53. — Rolls with tilting table and pulpit.

nace in which it was refined. In Fig. 54 is shown the metal being reduced to rods in a wire mill, and the kind of rolls used. Here the rods run into a track as they leave the rolls, and this guides them to the next roll that further reduces the metal in size.

CRYSTALLINE STRUCTURE OF METAL

Steel that has cooled slowly from the liquid state, as is the case with that which has been cast into ingots from the converter, furnace, or crucible, forms into crystals which do not show the same structure throughout. The outer shell of the ingot will have a different structure from the rest of the mass due to its cooling quickly, and therefore it is under strains until the center of the ingot has cooled. The top of the ingot also has an area of abnormal crystallization which is due to segregation. There is, however, the same general crystalline character in the largest part of the ingot.

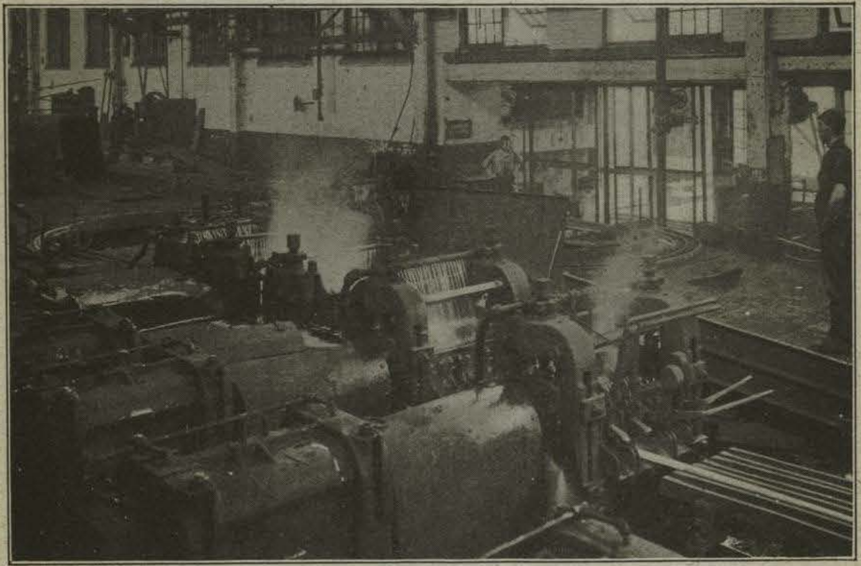

FIG. 54. — Rod mill with track and water-cooled rolls.

In passing the steel between rolls, to reduce it to the sizes and shapes wanted in the finished material, this crystalline grain is broken up and a new grain which is much finer takes its place. The best results are obtained if the rolling is completed at a temperature just above its highest point of transformation, as at or just above this point a new grain structure is born which makes the metal more homogeneous.

This formation of grain continues after the steel leaves the rolls and until it has cooled below its lowest point of transformation, below which point no more change will take place.

In rolling steel it is frequently heated to from 2000° to 2400° F., and it would seem that this would seriously damage it. This would be so if it were not for the fact that the mechanical pressure exerted upon the metal by the rolls breaks down the large crystals formed by this high temperature, and reduces them to a small size. The final size of the crystals is, therefore, dependent upon the temperature of the steel at the finish of the rolling process.

Finished steel has a finer grain structure if the last rolling operation receives the metal at a temperature which is falling from 1650° F. to 1400°, which are the highest and lowest points of transformation, than if it was finished at 2000° F., or any temperature above the highest point of transformation. On the other hand, if the rolling be continued after the temperature of the steel has fallen below the lowest point of transformation, strains are set up which make the piece unfit for most uses until it has been thoroughly annealed.

RULES FOR ROLLING

Four rules might be established in rolling steels which will affect the final size of the grain so as to make it what it should be, and these are:

First.—The rolling operations should be continuous from the highest temperature employed down to the finishing temperatures, as long waits, such as are generally made necessary when the metal is formed roughly to shape and size at a high heat, then allowed to cool and a little work done upon it at the lower temperature, are liable to cause a coarse grain that cannot be made fine by the last rolling.

Second. — There are better results obtained if the steel is passed several times through the rolls with a small reduction in the size of the metal each time, than if a large reduction is made with a very few passes.

Third.—In rolling a large piece a great reduction can be made during the first pass through the rolls, and the amount of reduction gradually decreased with each passage through the rolls until the finishing roll gives it just the right amount of reduction conducive to the making of the grain as fine as the steel will assume.

Fourth. — The steel should reach the finishing roll so that the temperature will be falling from 1650° F. to 1400° while it is passing through the rolls. It should not be allowed to go below 1300° until all the rolling operations have been finished.

HIGH AND LOW TEMPERATURES

Steel is so mobile at very high temperatures that it yields to distortion by the crystals sliding past one another, but as the temperature decreases the mobility of the mass becomes less, and less sliding is possible. The crystals then crush against each other, and at the lower temperatures a crushing of the crystals only takes place.

To obtain the very best qualities in a 0.50% carbon steel that it is possible to produce, the work of rolling should be completed just at the time when the ferrite is separating from solid solution. Rolling the work below the temperature at which this occurs, which is while the metal is cooling from 1650° F. to about 1300°, greatly increases the brittleness of the metal. Rolling the steel at a higher temperature lowers the strength, owing to the coarser grain which is given the metal. For steels of all other carbon contents it is logical to assume that the same rules hold good, but it is possible, although not probable, that further investigations may change them.

Steels are rolled in a large variety of standard shapes, such as round, square, oblong, hexagon, octagon, tubes, and L, T, U, I shapes, etc., and can be obtained in nearly any special shape desired, providing enough is wanted to pay for the making of rolls.

Casting

APPARATUS FOR MELTING

Casting steel consists of pouring the metal in a fluid state into molds which give it the desired shape. These shapes can be given most any kind of an intricate form owing to the shape being given the mold by a pattern and cores.

Many different methods are used for melting the steel, and some of these are the same in principle as those used for converting the blast-furnace metal into steel.

Pig iron and steel are melted together in the cupola, but this is not a normal product. It is a hybrid metal sometimes called semi-steel which is useful for special purposes, but fundamentally different from any kind of steel. It is a little better than cast iron, and is a very cheap mixture comparatively.

The open-hearth furnace is used a great deal for melting steel, for steel castings, and might be considered the cheapest method of turning legitimate steel into castings. Scrap steel and iron are used in this furnace, but they are melted under an oxidizing flame, and the metalloids are almost entirely eliminated, thus giving a definite starting point from which a known and regular metal can be made by the addition of recarburizers. Both the acid and basic open-hearth processes are used for steel castings.

The Bessemer converter in small sizes, often known as "the baby Bessemers," is extensively used for making steel for castings. There are many modifications of these small converters, such as the Tropenas converter, the Stoughton or long tuyere converter, and others. The Tropenas converter process is largely used when making steel castings, and this if properly run gives good results in the castings. In the Bessemer converter the blast is blown in at the bottom, while in the Tropenas process the air is blown at a low pressure upon the surface of the molten metal. Some four to seven inches above this set of tuyeres is another set, which supplies air to burn the carbonic oxide, the upper set not being operated until the blowing is well under way.

The crucible process has been used to some extent for small castings, and to cast some of the special alloyed steels. Its condition of "dead-melt" gives a more quiet metal, generates less gas when the metal comes in contact with cold surfaces, and the castings are more apt to be free from blow-holes; in fact, a German foundry, by using special care in the mixing of the metal, melting it, and making the molds, guarantees castings free from blow-holes, and makes castings of any composition of metal from wrought iron to high-carbon or high-speed steels.

This method produces the best steel castings, but it is the most expensive way of making them.

The electric furnace is just beginning to be used for melting the metal for steel castings, but it promises very good results as the phosphorus and sulphur can be reduced to a trace, and the oxygen and nitrogen can be very materially reduced.

RISERS, GATES, ETC.

In making steel castings about 40% of the melt is used to supply risers, sprues, gates, etc., and there is consequently a loss in remelting these.

The risers, which are sometimes called sink-heads, run from the top of the mold to the casting and are put on all thick sections of the casting to feed the metal to it while it is cooling and shrinking. These must be kept from solidifying until after the casting has become solid.

The sprue is the name given the opening into which the metal is poured, and this runs from a basin in the top of the mold to a pocket, which is usually located near the bottom of the casting. From this lower pocket to the opening in the mold, which is to form the casting, are cut other openings so the metal will be able to flow in. These openings are called gates. This arrangement is made necessary to prevent the liquid metal from tearing up the mold, as it would do if poured directly into the opening that forms the casting. The metal left in these when the casting is poured has to be broken away from and chipped and sawed off of the casting. They are then remelted to make other castings.

COMPOSITION OF STEEL CASTINGS

Steels with various alloying materials and of numerous different compositions are being used for castings to-day. The carbon content of these varies with the use to which the casting is to be put. Over 0.70% carbon is seldom used in castings, owing to its making the steel too hard to machine, and in complicated shapes the shrinkage cracks are liable to become dangerous.

In the ordinary steel castings manganese should not exceed 0.70% for soft castings and 0.80% for hard ones, as more than this is liable to make the metal crack when shocks are applied to it. Silicon may have a percentage of 0.10 in the soft castings, and 0.35% in hard ones without diminishing the toughness. Aluminum is used by many in making castings, as it has a great affinity for oxygen, and will remove the last trace of this from the iron. It also aids in dissolving the gases. It has a tendency to make the metal sluggish, but it enables it the better to run through small passages as without it the metal foams and froths when it comes in contact with cold surfaces, thus impeding the flow and chilling the advance guard of the stream. Aluminum should oxidize out of the steel, and not show over 0.20% when the steel is analyzed, but it is better if only traces are left, as it decreases the ductility.

Sometimes the phosphorus is allowed to be as high as 0.08%, but when the castings are to be submitted to physical test the phosphorus and sulphur should be kept below 0.05%.

The physical properties of ordinary steel castings should be above the figures in the following table:

	Hard Castings	Medium Castings	Soft Castings
Tensile strength in lb. per square inch.....	85,000	70,000	60,000
Elastic limit in lb. per square inch........	38,500	31,500	27,000
Elongation percentage in 2 inches.........	15	18	22
Reduction of area per cent...............	20	25	30

A chemical composition which has given good results for locomotive side frames analyzed as follows:

Carbon..	0.27	per cent
Manganese....................................	0.57	" "
Silicon..	0.26	" "
Phosphorus....................................	0.048	" "
Sulphur..	0.033	" "

Test bars from this showed a tensile strength of 68,870 pounds per square inch, an elastic limit of 36,450 pounds per square inch, an elongation of 20% and alternating vibrations of 4707.

VANADIUM-STEEL CASTINGS

As vanadium gave good results in rolled steels, it was utilized in steel castings. In one case the usual mixture gave a steel showing a tensile strength of 68,580 per square inch, an elastic limit of 36,290 pounds, an elongation of 20%, and resistance to alternating vibrations of 4706. To the above mixture was added 0.22% of vanadium. With this product added the following figures were obtained: tensile strength, 77,160 pounds per square inch; elastic limit, 46,450 pounds per square inch; elongation in 2 inches 20%, and resistance to alternating vibrations, 14,971.

It is in resistance to vibrational stresses that vanadium shows its superiority. The above tests were made on an alternating bending machine by gripping the test bar rigidly at one end and bending the free end upward and downward $\frac{1}{8}$ inch from its axis. It gave a total length of stroke of $\frac{1}{4}$ inch, and this at the rate of about 30 strokes per minute.

Before adding vanadium in the furnace it is necessary to reduce the oxides in the molten metal, as vanadium has a great affinity for oxygen. If any of the oxides remain in the metal, the vanadium will scavenge them out and go off in the slag; but as it is too expensive to use for the bulk of the scavenging, the oxides should be removed as completely as possible by other materials before the vanadium is added to the steel. It will then reduce what oxygen is left to mere traces if the correct percentage is used. In order to be assured that enough vanadium was used to seize all of the oxygen and carry it off to the slag, there should be enough put in the bath to show from 0.10 to 0.20% in the steel after it is made into castings and given a chemical analysis. If too small an amount is used, or it is not properly mixed with the bath, it may go off into the slag without seizing all of the oxygen and removing that from the steel. Thus the microscopic gas bubbles caused by the oxygen will not be removed and the cohesive force exerted between the molecules will not be strengthened. Thus the steel will not be benefited.

In using the acid open-hearth furnace for melting steel, the vanadium is added to the mixture just before tapping. The slag is raked from the top of the molten metal, the ferro-vanadium thrown in and the whole allowed to stand a few minutes, so that the vanadium will thoroughly mix with the metal.

As about 40% of the steel melted for castings goes back to the furnace, in the shape of risers, gates, and sprues, to be remelted, the vanadium is lost in these, owing to its oxidizing out during the melting process.

TITANIUM

Owing to the difficulty of obtaining the ferro-titanium, up to the present time, it has not been used to any extent in steel castings. Owing to its great affinity for oxygen and nitrogen, it removes these from the metal. This should make the steel castings free from blow-holes, and make a more homogeneous metal. That it does increase the static and dynamic strengths, as well as the wearing qualities of steel, without increasing the hardness, has been amply proven.

The ferro-titanium is not an expensive alloying material, and, as it is best to add it to the ladle after tapping, it is easy to handle without greatly increasing the cost of castings. After adding the ferro-titanium the ladle of metal should be held about six minutes before pouring the molds, in order to give the titanium a chance to do its work. This does not chill it, as might be supposed, as titanium has a tendency to retard the cooling of molten steel, and it will pour as freely and smoothly at the end of the six minutes as a ladle full of ordinary steel will directly after tapping. It also adds some good properties to iron castings.

NICKEL-STEEL CASTINGS

Nickel added to steel in percentages of from 1.50 to 3.50 combines a high tensile strength and hardness, and a very high elastic limit, with great ductility; therefore it is being used for steel castings with good results.

For some time it has been cast in large castings, such as rolling mill gears and pinions, and it is now being cast by a few foundries in small castings such as are used for automobile parts. It is difficult to cast in castings that have a thinner section in any of their webs, ribs, etc., than ¼ of an inch.

The ductility which lessens the tendency to break when overstrained or distorted, combined with the very high elastic limit, makes it valuable for such parts as crank-shafts on internal-combustion engines. These have been cast of nickel steel and given satisfaction in use, although forgings are much better for this purpose. Front axles, of I-beam section, have also been used successfully on automobiles.

Nickel-steel castings show a tensile strength of from 78,000 to 88,000 pounds per square inch, an elastic limit of from 50,000 to 58,000 pounds per square inch, an elongation in two inches of from 25 to 30%, and a reduction in area of 40 to 48%. This brings the elastic limit up nearer to the tensile strength than in the ordinary steel castings as well as increasing this and the elongation and reduction of area. This would indicate a greater resistance to shock and compression and the rendering of castings more ductile and tough than those made of the ordinary steel.

DIRECT STEEL CASTINGS

In this process the metal is taken direct from the furnace to a heated mixer where the proper materials are added to make the required quality of steel. The metal can be kept liquid as long as desired in the mixer, and its chemical properties adjusted by the addition of different materials. The mixer is kept full by transferring metal from the furnace. When the metal is wanted for casting the mixer is tapped and the metal run into ladles, from which it is poured into the molds as in other castings.

It produces a better and finer grained metal by the mixer reducing the gases which come in contact with the metal in the cupola or furnace.

Castings of direct steel can be obtained with guaranteed physical properties as follows: tensile strength, 70,000 pounds per square inch; elastic limit, 35,000 pounds per square inch; elongation in 2 inches, 25%, and reduction of area, 40%.

These castings can be forged, welded and case-hardened, and will machine as easily as machinery steel. They can also be bent freely when cold before breaking.

MANGANESE STEEL CASTINGS

Manganese steel with the manganese ranging from 12 to 15%, and the carbon contents high, is being successfully cast and used for such parts as have to resist wear from gritty substances such as are encountered in rock crushers or in machinery used around concentrators.

Manganese steel has the peculiar properties of being so hard that it cannot be machined in combination with a malleability which enables it to be headed cold when made into rivets, and a toughness which gives it remarkable ability to resist wear and shock stresses as well as cold bending.

When they leave the mold manganese steel castings are about as brittle as cast iron, but by heating them to about 1850° F. and quenching in water, they are given their properties of great toughness and ductility.

Owing to their being too hard to machine, all finishing must be done by grinding, but where it is desired to make a fit by machining, such as boring out a hub, a piece of metal that can be machined is placed in the mold and the manganese steel poured around it. By making this piece with numerous fins the manganese steel will shrink around it so that it will be nearly as firm as a solid casting.

The gases generated in pouring the metal are so low that the molds can be rammed very hard and with a fine sand. In this way surfaces are obtained that are nearly as smooth as finished castings, and but little grinding is required when a finished surface is desired.

Its shrinkage is about double that of ordinary steel when cast, and it cannot be cast in any very intricate shapes, nor can it be cast in any section which is thinner than $\frac{1}{4}$ of an inch.

When properly heat-treated manganese steel castings will show a tensile strength of 140,000 pounds per square inch, an elastic limit of 55,000 pounds per square inch and an elongation in 2 inches of 45%.

CHROME STEEL CASTINGS

Where a great hardness is desired such as that required in the manufacture of projectiles, chromium is added to steel that is to be cast. This gives the metal a mineral hardness that cannot be obtained with any other alloying material, and also refines the grain.

The uses to which these castings can be put is limited, however, owing to the difficulty of machining. The castings cannot be made in any intricate shapes or thin sections, owing to the difficulty of making the metal flow easily, but for such things as projectiles no better steel has been found for casting, and its use is increasing.

Forging

For those parts which cannot be produced from the rolling-mill shapes, or have not the proper strength when made in castings, forging is resorted to and there are several different ways of turning out these forgings: by hand, under a steam hammer, in a hydraulic press, or in a drop-forging press. The cost of these different methods of production depends largely on the number of pieces required of the same shape, but the size of the piece to be forged, as well as the components of the steel, have an influence on which is the best as well as the cheapest method to use.

FORGEABILITY OF DIFFERENT STEELS

Some of the special alloy steels are very difficult to forge. Chromium steel is the most difficult of all, owing to its mineral hardness. If kept above 220° F., however, it can be forged successfully, and it should never be allowed to fall below this. Nickel added to this steel, giving nickel-chrome steel, makes it slightly easier to forge, but even then the metal should be kept at a bright yellow color during the forging operations. As steel melts at 2500° F., this means that a forging of any size will need reheating several times before it is completely formed into shape. Nickel steels are more easily forged than those mentioned above, but they must be handled carefully, owing to the tendency of fissures to appear.

The vanadium steels are more easily forged than either of these, and if due care is taken to increase the heat gradually at first — that is, this steel should not be plunged into the heat all at once — no trouble will be experienced afterward. Titanium steel is similar to vanadium as to its forgeability, but it heats up more slowly and retains a forging heat longer. It also has less of the "hot-short" property than other steels, and hence should forge well.

Silicon in small percentages does not affect the forgeability of steel, but in large amounts it gives steel a fibrous grain, and is therefore used principally for springs. But in the last few years this steel has been forged into gear blanks to quite an extent. In this case the blanks should be made in the form of forged rolls, and not cut from bars, in order to avoid the fibrous structure.

The aluminum, tungsten, manganese, and other alloyed steels are not used to any extent for forgings, as those before mentioned show superior qualities, and some of the last named are much higher in price.

Some of the carbon steels, particularly those that are high in carbon, cannot be heated to a temperature over 1800° F., without burning the metal, and when once burned it cannot be returned to its former state without remelting. A vanadium-chrome steel will give as great strength as a nickel-chrome, and can be forged as easily as a 0.40% carbon steel.

The higher the carbon content the more danger there is of burning, and a steel with 1% of carbon is very difficult to forge at all, owing to the comparatively low temperature to which it is possible to heat it, and the comparatively high temperature at which the forging operations must be finished without danger of cracking the piece, owing to its brittleness. Thus high carbon steel should not have the heat fall much below its highest point of recalescence, which is above 1650° F., during any of the forging operations. Those forgings will be strongest that are finished just as the temperature reaches this point. The smith must also regulate the weight and effect of the blows so that the forging will be finished just as it reaches this point. This will prevent the formation of large crystals, give the piece a dense, homogeneous grain with the molecules holding together with a high cohesive force, and result in the steel having an increased strength. Any kind of steel can be forged if the proper temperature is maintained while passing it through the different forging operations, and the forgings will be much stronger than steel castings, and in many cases stronger than rolled steel.

Thanks to the electric and autogeneous welding process in combination with die-forging with either the drop hammer or the hydraulic press, all of the highest grades of alloyed steel can be turned into forgings successfully, and their strengths and elongation retained, but this is almost impossible by the hand or hammer-forging methods, especially if welds are made necessary by the shape of the piece. One of the alloy steels that is being manufactured into die forgings has the following chemical composition: chromium, 1.50%; nickel, 3.50%; carbon, 0.25%; silicon, 0.25%; manganese, 0.40%; phosphorus, 0.025%; sulphur, 0.03%.

In the annealed state this shows the following physical characteristics: tensile strength, 120,000 pounds per square inch; elastic limit, 105,000 pounds per square inch; elongation in 2 inches, 20%; reduction of area, 58%.

When properly heat-treated, that is, quenched in oil and drawn, these characteristics became: tensile strength, 202,000 pounds per square inch; elastic limit, 180,000 pounds per square inch; elongation in 2 inches, 12%; reduction of area, 34%.

EFFECT OF TEMPERATURE ON THE GRAIN

The high temperatures, of from 2000° to 2400°, that steels are subjected to when forging would seem to indicate that the metal is weakened by overheating, but such is not the case, as forgings show greater strength than the same metal formed into shape in any other way, unless it be the rolled steels.

Steel, when heated to the above temperatures, coarsens in grain and the grain becomes crystalline in nature. This makes it so mobile that it yields to distortion by the crystals sliding past one another, but as the temperature decreases the mobility of the mass becomes less, and less sliding is possible. If then forged the crystals would crush against each other; and when cool the crystals themselves will crush.

These coarse crystals, that are formed by the high temperatures, are reduced by the hammering process in the drop-hammer press, or the squeezing process in the hydraulic press, until the crystalline structure is broken up and a new grain that is much finer takes its place.

If the piece is not allowed to cool below its highest recalescence point during the forging, and the forging is finished just as it reaches that point, or a little above it, a new grain structure is formed, that makes the metal more homogeneous. This formation of grain continues, after the steel leaves the press, until it has cooled below its lowest recalescent point, at which point it sets, and no more change will take place until it is reheated to the recalescence point. These two points occur in most steels at about 1650° and 1400° F., but some of the special alloys show a wide variation from this.

Thus it will be seen that if a forging is finished while it is too hot, the grain will be coarse and crystalline and the metal will not have the cohesive force that it should, and therefore the piece will not be as strong as a forging should be. On the other hand, if it is hammered, or squeezed, in a forging press after it has become too cold, the crystals will be crushed and the result will be the same, but if it is forged at the proper heat, the grain will be fine, dense, and homogeneous, and the cohesive force will be greater than was the case before it was forged. This will naturally increase the tensile strength and elastic limit.

Many poor forgings are turned out by raising the temperature of the metal too suddenly. Certain molecular changes take place in the heating of all steels, and of the alloy steels in particular, which are liable to cause fissures in the core of the metal. These may not show in the finished product as they do not always break through the skin or outer shell of the forging. Thus, by heating suddenly, the outer shell becomes red before the core has had an opportunity to absorb any heat, and the outer shell expands, causing great strains on the core of the piece. In the case of a high percentage of nickel these fissures become more pronounced than with the other alloys.

At a temperature of about 600° F., or a bright blue, most steels lose their ductility, and are not fitted to resist strains imposed upon them by the differential expansion of an unevenly heated metal. Therefore the rise in temperature from the normal to 600° should be a gradual one, but after this it may be brought up to the forging heat as quickly as is desired.

To remove the internal strains caused by working the metal, all forgings, no matter how they are made, should be annealed before using, as the shocks to which the forging may be submitted will concentrate at the point where these internal strains are the strongest, causing it to break at that point. The case is very similar to the machinist notching a bar in order to break it. The heat treatment that is given the pieces after they are forged is an important factor, if the greatest strength and the best wearing qualities are to be given the metal, as the best forgings can be ruined by improperly heat-treating them afterward.

Small forgings are usually tumbled, and large ones pickled in a diluted