CHAPTER XXXVIII.

LAYING-OUT OF THE MILL.

Arrangement of the Stands.—The two rolls with their housings and attachments complete, as previously described, constitute a "stand" of rolls; there may be two, three, or more stands on one bed-plate, coupled up in one line by means of coupling-boxes and spindles, constituting "a train" of rolls, driven by one engine. The first one or two stands, which serve to reduce the bloom to a form larger than, but roughly resembling, the shape of the finished piece, are known as the roughing, and the last stand as the finishing, set. In modern practice it is an exception to see more than two stands coupled together, particularly for a reversing mill, where a long line of heavy rolls makes the engine much less prompt in reversal, and throws a severe strain on the couplings at the leading end of the train; there is, however, a more important reason for avoiding the practice.

When the roughing and finishing rolls are all coupled together, they all make the same number of revolutions per minute, and as the bar keeps getting longer and longer in each pass, it must take an ever-increasing time to pass through the mill, so that the first set of rolls are running empty for the larger part of their time. If the speed of the whole train is high, the shock on the first roughing passes, which deal with a large section, is severe, and apt to cause breakages, so that the speed of the whole train must be kept down to avoid accident. This difficulty is overcome when the mill is split up into sections, each portion being driven separately, in the case of smaller mills, either by belts, ropes, or gearing from one engine, or, in the case of larger, by separate engines, so that each part travels at the speed most suited to its own particular portion of the work. By running the roughing rolls at lower speeds, heavier draughts and fewer passes may be used, thus reducing the length of the rolls, and consequently increasing their strength, while at this reduced speed a larger production can be obtained with less risk of breakages. If the finishing rolls can use up the roughed blooms fast enough, the roughing rolls need never run idle, and the output in that case is immensely greater. The finishing stands, which start with pieces of smaller section, can with safety be run much faster, so that not only may a larger number of roughed blooms be rolled off in the same time, but as they cool less, because of the shorter time taken in rolling, they will be finished at a higher temperature; this means considerable saving in power and wear and tear of machinery, particularly at the finishing grooves, where wear is a consideration of the greatest importance. Longer bars can, therefore, be rolled, or in some instances smaller mills may be employed for finishing the bars, whose section, when nearing completion, is much less than at the commencement of the operation.

Now, although one engine may drive two sets of rolls when coupled up in line, while two engines, each of nearly the same power, may be employed when the mill is thus split up into two sections; yet if more than twice as great an output can be obtained from the same rolls in a given time, when so driven, (the only additional space required in the buildings being that needed for the second engine), and all this with practically no extra labour, the first cost of the second engine is clearly more than justified. Then the wisdom of disconnecting the train in the centre and adding a second engine at the other end of the train, as has been done with beneficial results in many works, becomes obvious.

The Three-high Mill *versus* the Reversing Mill.—The three-high and the reversing mill alike possess advantages and disadvantages. If the mill is intended for cogging or roughing plain rectangular sections, it will be seen, as explained previously, that provided the grooves in the three rolls of a three-high mill are of the same width, but the depths of the grooves in the top and bottom rolls vary, twice as many passes may be got from the three rolls (fig. 390) as could be obtained from the two rolls (fig. 375), so that fewer stands of rolls will be needed, or lighter draughts may be used. If the top roll of the reversing mill is, however, made movable, as may be, and now usually is, done in large mills, this advantage of the three-high disappears. On the other hand, where special sections, or "shapes" as they are termed in America—such, for instance, as rails—are to be produced, it will be found that only half of the passes (see fig. 392) in a three-high can be used, because the *form* of the groove must vary, and not only its one dimension, and, therefore, a groove in the middle roll can match only one groove at a time in either of the outer rolls. In that case the three rolls will only give as many passes as two, and the additional roll becomes a serious item where a great variety of different sections have to be produced, because the stock of costly rolls requiring to be kept is increased 50 per cent.—a heavy addition to the capital outlay of the mill. Moreover, the middle roll, having twice as much work to do as either of the others, wears out faster than they do, and so causes considerable inconvenience.

When only moderate-sized ingots were used, a three-high cogging, followed by a two-high reversing finishing mill, was a not unsuitable combination, for the reasons outlined above; but the growth in the size of the ingot, and the use of a movable top roll, have rendered the employment of a three-high cogging mill generally inadvisable. Nevertheless, during the last ten years, several three-high cogging mills have been put down in Germany, where ingots run smaller than in England or in the States.

One peculiarity of the three-high mill is that the engine driving it runs continuously in one direction, and may therefore be provided with a flywheel to absorb the surplus energy given out by the engine when the rolls are running empty, the energy so stored being available subsequently when the piece is entered. For this reason the engine driving a three-high mill will generally do as much work as two engines each with the same size of cylinder, coupled together, when used to drive a reversing mill, with a corresponding saving in the first cost of the engine power. Moreover, an engine having a flywheel may be fitted with an automatic early cut-off gear, effecting considerable economy of steam, and may easily be made compound and condensing, in which case the consumption of steam is about half as much as in the reversing non-condensing engine.

Although there are two cylinders for the reversing engines and only one for the flywheel engine, the former, unlike the latter, do not run continuously, but are stopped and started as needed, often several times in a minute; and as they stop when the mill is empty, the consumption of steam may even be less, when doing the same work in each, unless the three-high mill can be kept continually fed with material as fast as it is rolled. Though undoubtedly some steam, which has done little useful work, is unavoidably wasted each time an engine is reversed, this is not the chief cause of the higher steam consumption of reversing engines; it is simply that an early cut-off of the steam cannot be conveniently obtained in them, because the steam must frequently be carried nearly the full length of the stroke, to enable the engines to be handled promptly. The ability to vary the power instantaneously between very wide limits, by a simple movement of the lever of a reversing engine, is of very great value, and the absence of this flexibility, when the engine is compound, is the chief reason why compound reversing engines have not been more generally employed.

An important advantage in the three-high mill is that several pieces may be in the rolls at the same time, following each other in regular sequence; where several stands are coupled together this is yet more advantageous, for it is very rarely practicable in a reversing mill to have more than one piece in the rolls at a time, because the number of turns the mill must make in each direction depends upon the length to which the piece has been rolled out.

The reversing mill, however, has this point in its favour, that it starts from a state of rest and draws the piece in gently, while as soon as it has fairly gripped it, the speed is rapidly increased, and the bar may leave the rolls at a considerably higher velocity than is the case with the three-high, and that without causing shocks. Again, should a piece be presented larger than the mill can properly take, reversing engines simply refuse work and pull up, before any injury is done to the machinery; or should a piece by any means not enter fairly, the engine can be instantly reversed, and the piece got out and entered again properly, with very little loss of time. Or, again, should a guide break or become displaced, and the piece being rolled consequently curl round the roll, or get "collared," as the men term it, in a reversing mill it can be promptly wound out again while hot, whereas in a three-high it would require to be cut out by hand when cold, after having, in all probability, broken the rolls. Incidents of this kind which, in the case of a mill driven by an engine provided with a flywheel, cause a jam and the loss of much valuable time, even when they do not result in a costly breakdown, are less likely to occur, and are unimportant, when the mill is driven by a pair of reversing engines, because the reservoir of power in the latter case is the elastic force of the steam stored in boiler, under the direct control of the engineman, and not the energy stored in a heavy flywheel, which cannot be controlled, and bears down all opposition at the cost of a breakage—the very bane of the mill manager's existence.

For this reason, during the last few years the single flywheel engine in several large three-high mills, both on the Continent and in the States, has been replaced by a pair of reversing engines, such as are used for reversing mills, the extra consumption of fuel being regarded as a lesser evil than the costly breakages connected with the use of a flywheel; while the advantages of a gentle grip and rapid finish are considered worth more than any saving of steam coal. In such a case the third roll is a needless expense, and so also are the lifting tables, but as the stock of costly rolls was in existence, it was thought well to retain them, in spite of the extra friction incurred by driving them.

The present tendency is distinctly towards the use of reversing mills for heavy sections, and for all mills with rolls more than 20 inches in diameter, all over the world; while for small mills rolling pieces which can be handled with the tongs, the three-high mill meets all requirements, and is cheaper to put down and more rapid to work than a reversing mill, as well as more convenient for small work and short lengths. The small mills make so many more revolutions per minute than the larger ones, that they are less easily started, stopped, or reversed.

In somewhat larger mills, if the section does not require edging, the rolls in a three-high mill may be so contrived that the piece need never be turned over at all, and the bar may, in that case, be rolled right off with the same side upwards the whole time; and, therefore, a very simple lifting appliance will suffice to lift the end of the bar up to the top set of grooves, and enable a good output to be obtained on pieces up to half a ton each, with very little labour and no complicated machinery to get out of order or wear out.

When the ingot or billet is too heavy to be conveniently manipulated by hand, or by a simple lifter, so that mechanical appliances have to be employed at the rolls, the feeding tables for the three-high mills are more complicated than the beds used with reversing mills; for not only must the feed rollers be driven, stopped, or reversed at will, but the whole appliance must be lifted and lowered at each pass, and the driving power conveyed to the rollers when they are in any position. The conveying of power in this way, through so many intermediate parts, adds to the complication of the mechanism, increasing friction, wear and tear, and the liability to breakdowns. The tables must, moreover, be made immensely strong to stand rapid lowering with a heavy ingot on them, difficulties which all increase rapidly with the size of the mill, and the weight of the piece to be rolled. Accordingly the three-high system is not now usually employed in this country, except for mills of moderate size, and to deal with comparatively small pieces, the cogging mills being now nearly all reversing mills on the Continent, and even in the States, because of the much greater simplicity of the feeding rollers and appliances.

It is not always easy to determine which system to employ for moderate sized mills; the first cost, wages, and fuel all have to be considered. In some cases, one stand of rolls in a three-high may serve for the work which would in a two-high, require two stands, while, with one stand, no transfer skids are required. If no live rollers are employed in either case, and if the pieces are heavy, fewer men can work a reversing mill, as no lifting has to be done. An equal output may be obtained with either system, and each case requires to be carefully considered on its own merits, but the most marked advantage in the use of a three-high will be in those cases where flats are produced, and the piece can be rolled continuously with the same side uppermost. Obviously a 15 × 15 inch ingot could not be reduced to a 4 × 4 inch billet, unless it were turned on edge a large number of times, and for such work the reversing mill would be found most suitable.

British and Foreign Practice.—The three-high mill is as essentially American as the reversing mill is characteristically English. Though there are one or two large three-high cogging mills in America, cogging mills there are, broadly speaking, of the reversing type, but those for rolling girders, even as much as 24 inches deep, and the large mills for rolling angles and bars, which in this country would be reversing mills, are, in the States, all three-high, and fed from lifting tables. Most of their rail mills, and all their plate mills, which in England are invariably of the reversing type, are likewise three-high, while a large three-high mill is very rarely seen in this country, most of the three-high plate mills which were tried over here having been altered.

The two systems appeared at about the same time, and though naturally the three-high would at first be most employed in America, and the reversing mill here—*i.e.*, in their respective countries of origin—we would expect, that in process of time, one or other system would have established such a marked superiority over its rival, as to ensure its adoption on both sides of the Atlantic. Each country, however, broadly speaking, adheres to its original practice, except that the cogging mills put down in the States, during the last eight or ten years, are all of the English reversing type.

As has been already explained, the three-high mill, when used for sections such as rails, requires three rolls to give the same number of passes as may be obtained from two rolls in the reversing mill. In this country, where orders are given out in small quantities at a time, and for a great variety of sections, bridge rails, flange rails, double-headed and bull-headed of all weights per yard being required, a heavy stock of rolls must be kept, and in that case the cost of the third roll needed for the three-high mill would be a serious additional expense. Consequently all our rail mills are reversible. In America, on the contrary, only the flange rail is made to any extent, and large orders are obtainable for such rails, all of so nearly the same section and weight, that only a trifling alteration of the finishing pass is needed. This final pass is made in a separate pair of short rolls, and these alone need changing. Under such conditions the three-high mill doubtless gives the greatest output. Tram rails in America are, however, rolled in reversing mills.

Another fact which, in the first instance, has probably had much to do with influencing the relative practice of the two countries is, that in our own country boilers with large shells have always been employed, and that such boilers, when fired by the waste gases from the heating furnaces, were not considered safe for more than 40 or 50 lbs. pressure per square inch. With these pressures no appreciable economy is obtainable by cutting off at an early period of the stroke in non-condensing engines. Reversing engines must have their valves so set that steam can be admitted from the boiler for 65 per cent. of the stroke, or there will be a point at which the valves of the one cylinder are closed to the live steam, and the other crank not sufficiently over the centre to ensure starting. Should the engine chance to stop in that position, it cannot be restarted without being first turned round through a portion of a revolution, a proceeding involving much loss of time. With such pressures reversing engines consume as little steam as any other non-condensing engine. Indeed, at Codnor Park, where the plate mill engines originally ran in one direction, and were afterwards fitted with reversing gear, there was found to be a slight saving of steam due to the alteration.

In America, on the other hand, boilers with small shells were commonly adopted, and sectional boilers of the Babcock and Wilcox type were used at an early date, both types being suitable for pressures up to 80 or 100 lbs. per square inch. The Porter Allen and Corliss engines, both American inventions, were available to take advantage of these higher pressures, by cutting off high-pressure steam early in the stroke, giving a distinct inducement to employ continuously running engines in the States.

On the Continent the three-high mill was the first to be used, and is still retained for many purposes, though the larger mills recently constructed have been made on the reversing system, in spite of the high price of fuel in Europe.

Influence of the Cost of Fuel and Labour.—The relative cost of fuel and labour in the Old World and the New have materially influenced practice on the two continents. In some parts of the United States natural gas issues from the ground, is conveyed in pipes for long distances, and is sold at prices comparing favourably with the cheapest coal. In most parts of America fuel is much cheaper than in Europe; in the Connellsville region the cost of coal at the pit's mouth, including royalties, taxes, interest on capital, and all other charges, is said* to be only 50 cents. per 2,000 lbs.,

* *British Iron Trade Commission*, 1902, p. 24.

or 2s. 4d. per English ton, and the cost of converting it into coke and loading the coke into railway waggons, a further 40 cents, or, say, 1s. 10½d. per ton. It is also carried on most of the American railways for a third of the amount charged by the English railways.

The disadvantage of the great distances which, in many cases, separate the coal and ore deposits in America, and which some of the best authorities, less than a generation ago, thought a fatal bar to any chance of her successfully competing in the markets of the world* have been surmounted with characteristic American energy and ingenuity.† By the provision of special mechanical appliances for getting the ore, and for loading it into specially designed steamers on the great lakes, whence it is transported in enormous waggons, on what are practically the steelmakers' own railways, it is carried for sums much smaller than are expended on transporting material a much shorter distance in this country. Some of the materials are carried from 500 to 800 miles. Such methods of transport, however, demand the aggregation of capital, and the construction of plants, on a scale at present unknown in Europe, where in most cases there is no sufficient demand to justify such expenditure.

In most places on the Continent, fuel is dear and of poor quality, and economy at the furnaces and boilers is a matter of much greater moment than in America. In the Continental works triple-expansion engines and compound reversing engines, driven with steam of 150 lbs. pressure per square inch and over, with a condensing plant into which all the engines in the works exhaust, are met with much more frequently than elsewhere.

In many countries at the present time, unskilled labour is obtainable at rates of pay which the native inhabitants of the country would not accept. In the Northern States of the Union managers obtain unskilled workers from amongst the crowd of immigrants arriving continually from every country under the sun; in the Southern States they employ negro labour. In Westphalia much of the unskilled labour is Polish, and in Luxemburg, Italian.

As the rate of wages continues to rise, and the rate of interest on capital to decline in all countries, it will everywhere become more and more necessary to replace manual labour by machinery, a change which should be welcomed and not opposed by the workmen, for the introduction of improved machinery invariably before long raises the status, and increases the earnings of the workers.

America, driven to it by high wages, has led the way in perfecting methods for handling material rapidly by machinery, instead of slowly by hand labour, and to this most of her success in iron and steel manufacture is due.

The rate of wages in the United States ranges from one and a half to as much as three or four times those paid in Great Britain, and attracts the best workmen from the Old World, who carry with them a knowledge of all that is best in the practice of the countries they come from. Owing to these high wages, the great and constant aim of the American manager is to displace unskilled labour by the introduction of labour-saving devices, most of which have originated in America, where such appliances are employed to an enormous extent, and have been brought to a pitch of perfection unequalled on this side of the Atlantic.

By attention to what would seem trivial economies in the time required to handle the ingot from casting pit to finishing mill; by the provision of ample boilers and heating furnaces, so that the mills shall neither slow for

* *Iron and Steel Inst. Journ.*, 1875, p. 141.
† *Ibid.*, 1890 (special American volume), p. 47, *et seq.*

want of steam nor stand for lack of steel; aided by the rivalry between different gangs of workmen, whose output is not restricted by trades union rules, the production of American mills has been enormously increased. By attention to such points the output of the South Chicago and the Edgar Thompson rail mills has been raised during the past ten years from 600 to 1,200 tons per 12 hours, without any radical alterations having been made in the mills themselves.

On the Continent of Europe, where wages are lower than in England, in some cases only about half the English rates, many more men are employed about the mills than would be tolerated in the States, or indeed are common in this country, where the cost of fuel and labour is intermediate between the extremes of the two continents. It is necessary to know all the attendant conditions, before it is possible to say how far it pays, in any given case, to replace hand labour by mechanical appliances. The latter require an enormous expenditure of capital, involving heavy annual charges for interest, depreciation, and replacement, besides the expense of ordinary wear and tear, and, therefore, unless wages are high, mechanical appliances are not necessarily a profitable investment. There is a tendency among Americans to unduly multiply mechanical appliances, even where their own high rates of wages are paid. It is said that recently when the leading steel works of the States were formed into one Corporate body, it was discovered that some of the smaller concerns were earning a better return on their capital, than were some large ones fitted with the latest labour-saving appliances. The wages saved by the latter did not in all cases equal the increased expenses due to wear, depreciation, and capital charges. It is also reported that a well-known American engineer called at a Continental works to offer a labour-saving device, the use of which, basing his estimate on the rate of wages to which he was accustomed, would, he claimed, save them a certain sum per ton of output; great was his astonishment to find, when the pay-sheet was produced for his inspection, that the whole sum paid for labour on the work in question was less, when done by hand, than the sum he expected his machine to save.

When no mechanical appliances existed for handling masses of hot metal, muscular power was the first and indispensable qualification for a roller, who expected the millwright to keep the mill in order for him. In these days when machinery does all the heavy work, we still draw our rollers from much the same class, and train them in the same way. It is no disparagement to these men, who do wonderful work in very rough and ready ways, to say that they would be all the better for some engineering training which would make them less disposed to look askance on anything "new-fangled." In America an engineer is placed in supreme charge of the mill, and, on the Continent, a university graduate very often occupies this position.

Natural Resources and Protective Tariffs.—The nature of the ores and other natural resources, and the character of the demand existing in different countries, have largely determined the directions in which their steel works have developed. Before the era of steel Great Britain had for years been accustomed to supply the greater part of the world with most of the wrought-iron it used, and already possessed a large stock of rolls for producing every variety of sections, which rolls her manufacturers were anxious to continue to use. Foreign markets and their wants were known, could be catered for, and had to be retained. The bulk of the demand at home was for plates to be used in the construction of boilers, bridges, and ships (of which latter England long built and owned more than all the other nations of the world combined); hence her plate mills were more numerous, and generally better equipped than those of any other country.

In countries protected by import duties, the manufacturers turned their attention to the supply of such material as could be used within their own borders, and did not hope to supply outside markets; in many of the Continental states the home demand was so limited and varied, that the steel works were compelled to lay themselves out to supply a very miscellaneous class of work. Before the discovery of the basic process of steel making, the steel maker was almost confined to the use of pig made from the hematite ores of Cumberland or Spain, which were situated more conveniently with respect to England than to any other European country, but the discovery of Messrs. Thomas & Gilchrist has now enabled the countries of Europe to utilise their native ores.

Much less fuel is used in steel works since the introduction of soaking pits and other modern economical methods, so its price is not as material a factor in the cost of steel production as it once was; therefore those countries on the Continent of Europe who possess cheap phosphoric ores and good means of inland communication, and whose prevailing rates of wages are low, now find themselves in a position to contemplate an export trade, which in some instances they are fostering by keeping up the price to the home consumer, who is debarred by hostile custom dues from purchasing elsewhere, and so are able to make a corresponding reduction in price to the foreigner.

In the United States heavy import duties have always been maintained for the purpose of shutting out the foreign maker, but this new country opens up so rapidly, that the demand for iron and steel is continually overtaking the supply; so urgent is the demand that the inhabitants, rather than limit consumption, consent to pay 20 to 75 per cent. protective duty. By this means the American steel maker has preserved, for his own exclusive enjoyment, the whole custom of a civilised population of some 80,000,000; thus assured of an ever increasing demand at profitable prices, he can safely expend money on his plant on a scale which would be reckless, if it were attempted in countries less favourably circumstanced. For the past twenty years the United States have been constructing new railways at an average rate of over 5,000 miles a year, and now have nearly 200,000 miles of line to maintain. The rails are all of one type, and the enormous demand has justified the development of the rail mills to an extent impossible on this side of the Atlantic. Street tramways are increasing there with the same astonishing rapidity. One large works, the Johnson Steel Company of Lorain, roll practically nothing but girder rails for tramways. The need for fencing and telegraph wire on her boundless prairies is just as pressing, and the rod rolling mill has been developed to meet the apparently inexhaustible demand.

The question which at present is seriously exercising the minds of the steel makers in Europe is, how far the economy which should naturally follow the enormous scale upon which the manufacture is conducted in the States, assisted further by the command of ample capital to enable full advantage to be taken of any future inventions, will enable the American manufacturer to capture the trade in other markets, during the next depression of the trade in his own land; and even to import to countries protected by substantial tariffs. Some authorities consider this to be more than probable, and not unlikely eventually to become permanent: others, on the other hand, regard the high cost of living in the New World, the probabilities of serious disputes with the workmen in the near future, and the necessity for paying interest on the exceedingly liberal sums given for the purchase of the concerns absorbed into "The Combine," as likely to raise the cost of American steel to a point which will always leave a margin for the European maker.

America has accomplished so much in the past, which the best authorities on the subject considered impossible, and has developed her steel industry with such enormous rapidity and energy, that it is not surprising that makers on this side the Atlantic should feel some anxiety, as to what she may accomplish in the future.

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CHAPTER XXXIX.

FORGING STEEL BY THE STEAM HAMMER.

Rolling Mills and Hammers Compared.—The rolling mill is a most efficient appliance. It turns out work in large quantities with great rapidity, and with remarkable economy in fuel and labour; all the pieces made by it are true to gauge and precisely alike, but it can only produce those of regular shape having a uniform cross section throughout their entire length, while a fresh and costly set of special tools, in the form of rolls, are needed for every new section it is required to produce. Hence a draughtsman, preparing designs for constructional work, must select those rolled sections, for the production of which he knows that rolls already exist, unless so large a quantity of a new section is needed as will justify the preparation of a set of rolls wherewith to make it; and if he studies economy and rapidity of construction, he will confine himself to those common sections which are obtainable at short notice from a considerable number of works.

The hammer, on the other hand, is much more adaptable, and can work material into practically any shape, with the aid of very few and simple tools. Only in exceptional cases is it expedient to provide special tools, and then only as a means of economising labour, not as an indispensable condition of production; nor are such tools anything like so costly as the rolls required for use in a rolling mill. Consequently articles can be made under the hammer for much the same price per piece, whether one or many are required, and the designer is therefore not so limited in his choice of the form of forged articles.

On the other hand, the cost of any piece shaped under the hammer is much greater than that of the same piece rolled in a mill. The hammer has an intermittent, not a continuous action, and therefore shapes the ingot much more slowly than a rolling mill, with the result that it cannot finish off the work at one heat, as a mill usually does. The increased number of heats necessitates the consumption of more fuel, and involves a greater loss of metal by oxidation in the furnace. A hammer also requires more steam and many more men to work it, while its output is much less than that of a mill; nevertheless, each has its own field for profitable employment.

Tilting Tool Steel.—The first steam hammers employed on steel were those used in Sheffield for tilting tool steel, all the best qualities being still finished by this means. A bar, if hammered, is much superior to another made from the same ingot by rolling, because the workman, guided by his eye, can work the metal by a rapid succession of light blows, right up to the instant when the blue heat appears, thus preventing the formation of large crystals during cooling, and imparting to the bar that extreme regularity and closeness of grain found in the velvety fracture of a high grade tool steel.

The cold ingot is "topped" by breaking off from the top one-third to one-fifth of its length which contains the pipe; the remainder is carefully examined, and before it goes to the hammer any surface defects, however trifling, are cut out with a hammer and chisel, or by pneumatic chipping tools, which do three or four times more than can be accomplished in the same time by hand labour. The belief common in Sheffield, that ingots which have been long in stock and are well rusted make the best tool steel, is probably based, among other things, on the fact that exposure to the weather has removed the skin, and exposed flaws just below the surface, which otherwise would have escaped detection, and would have been worked up into the bar. Occasionally ingots are pickled in acid with the object of discovering such flaws.

The ingots are heated in what in Sheffield is called "a muffle." It is not really a muffle, but a hollow fire made with large coals and blown with a fan blast, a few bricks and a plate of iron being used to confine the heat, the arrangement differing little from an ordinary smith's hearth, and being provided with a similar form of hood and chimney to carry away the products of combustion. The workman, when finishing the bars under the smaller hammers, usually sits on a small board slung from the roof by a long link, which enables him to remain seated, and yet leaves him free to move to and from the hammer as is necessary. The workmen become exceedingly expert, and get the bars so beautifully true and neatly planished that it is not easy to distinguish, on a casual examination of the surface,