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A GLIMPSE OF STEEL MANUFACTURE

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A NATION'S place to-day in the scale of civilization is in direct proportion to its consumption of iron. So immense is the use of this metal that nearly every town of any importance in the United States has some kind of iron or steel industry. Pennsylvania leads in the production of iron, although much of the ore used is produced outside the state. Cheap coal and proximity to markets give the state the leadership in this industry.

The plant to be described in this article is that of The Pennsylvania Steel Company of Steelton, Pennsylvania. It is a typical example of a well organized modern industry, owning its mines, mills and repair shops and importing little else than the raw materials needed for its products. The works cover several hundred acres, give employment to from six to eight thousand men, and are surrounded by a busy city largely inhabited by the employees. The company's specialty is the manufacture of steel rails and structural forms.

The beginning of the transformation of iron ore into steel is at the blast furnace, a view of which is given. (See Figure 1.) It is seen nearly surrounded by huge piles of ore, coke, coal and limestone. (See also Figure 2.)

Most of the ores used here are obtained from the mines south of Lake Superior, the great ore-supplying region of the eastern furnaces. Here the ore is mined cheaply, secures cheap transportation via the Great Lakes, and is delivered at Cleveland, Conneaut and Buffalo near the eastern markets.

The ores belong to the class of hematite ores and their color is some shade of red or brown. The material may vary in size from

large chunks to fine red dust. The ores contain an average of seventy per cent of oxid of iron and twenty per cent of silica, together with small percentages of lime and very small quantities of sulphur and phosphorus. The presence of the last two in any but the smallest quantities condemns any ore for steel manufacture.

A blast furnace, as will readily be seen, is really a group of structures making a manufactory in itself of considerable extent. In the

FIG. 2. *Storage plant of the Bethlehem Steel Co., at Bethlehem, Pa. (Traveling crane in the background.) This plant is capable of storing over 300,000 tons of material.*

illustration, the furnace may be recognized by its round cap-like covering. Its base is enclosed in the building. The three tall iron cylinders are called "stoves." Their use is to heat the air before it is forced into the furnace. The building to the left contains the blowing engine, a powerful machine whose use is to force air through the stoves and into the furnace. (See Figures 1 (frontispiece) and 3.)

Ore, coke, limestone, and sometimes coal in definite proportions are carried to the top of the furnace and dumped into the fiery interior. (See Figure 4.) An arrangement at the top prevents the gas from escaping at each dump. Near the bottom, air is forced into the furnace through huge pipes called tuyeres (pronounced tweérs). This air is heated in the stoves to a very high temperature. In order to endure the heat, the furnace is lined with fire brick through which streams of water are kept in circulation. The heavy molten iron sinks to the

bottom of the furnace where it is drawn off from time to time; the lighter slag floats upon the iron and is drawn off by an aperture above that for iron.

So much for a brief statement of what can be *seen* taking place. The changes inside the furnace are complex in their details, but the general principles are simple. If iron could be obtained pure, it would not need to pass through the blast furnace. However, nearly all of this metal found in nature is combined in some way with some other element, usually oxygen, for which it has a very strong affinity. This strong attraction which each has for the other is shown by the readiness with which iron "rusts" or oxidizes when it is exposed to the air.

The ancients, for the most part, could only smelt iron, that is, obtain it from ores which were nearly pure iron. With such ores all that was necessary was to get heat sufficiently great to melt the iron, when it could be cast at once into the desired forms. However, ores of such purity were rare and soon exhausted, and iron was so expensive in the dark ages, that, it is said, ancient buildings were pulled down for the iron they contained.

The oxids of iron are plentiful, there being but few countries which do not contain them in considerable quantities; but the oxygen must be eliminated in order to make the iron available. For this purpose coke is employed. Coke, as is well known, is bituminous coal from which the tar and volatile gases have been expelled by heat. It is, therefore, nearly pure carbon. This carbon in contact with iron and at a high temperature takes away the oxygen and leaves the iron free. It also, of course, furnishes a fuel for the furnace at the same time. Charcoal was formerly used for this purpose.

However, this is not enough. Much of the ore looks like red stones; that is, in all ore there is more or less rock composed largely of silica, a pure form of which is seen in quartz. If this silica were not gotten rid of, there would be an unmanageable mass of rock and iron. For this difficulty limestone is the cheap and efficient remedy. At a high temperature lime and silica unite to form a fluid or flux which is drawn from the furnace from time to time. The use of the limestone which we noticed in piles around the furnace is thus apparent.

At regular periods hot air is forced into the furnace at high pressure to furnish oxygen for burning the coal and coke. This is called the blast and gives its name to this type of furnace. As may be imagined, the heat within is intense. The iron is purified and melted, the silica is fused with the lime, and the hot gases are drawn off by pipes at

FIG. 3. Blast furnaces, showing stock houses, engine houses, etc., of the Bethlehem Steel Co., Bethlehem, Pa.

the top of the furnace and are used to heat the blast. When enough iron has collected at the bottom, the furnace is tapped and the molten fluid is run into a car and carried away to be converted into steel at once or is cast in small bars called "pig iron." The process is continuous and unless there is an accident, a furnace runs night and day for years. The scene at the tapping of a blast furnace is one of weird beauty, especially at night. The stream of molten metal shoots from

FIG. 4. *Filling the furnace. The Bethlehem Steel Co., Bethlehem, Pa.*

the furnace and glides along the channels prepared for it. (See Figure 5). Each workman knows exactly what to do and helps to guide the dangerous stream as easily as a gardener would manage his irrigation ditch.

The first step in steel manufacture is now taken. The product of the blast furnace may be used for cast iron, wrought iron, or steel. At this plant it is wholly used for the latter. Before going further it would be interesting to inquire what is steel, a question not easily answered with accuracy. If iron is mixed with small quantities of different elements, the resulting mixtures have various qualities. For instance, if iron contains as small a fraction as one-half of one per cent of sulphur

FIG. 5. *Casting pig iron at the works of the Bethlehem Steel Co., Bethlehem, Pa.*

or phosphorus, it is brittle and quite unfit for steel making; if mixed with about five per cent of nickel, the famous nickel steel is produced. Other results are obtained by combining different substances with iron in various proportions. Ordinary steel is pure iron containing from one to six thousandths of carbon. Why so small an admixture of carbon will change soft, pliable iron into strong, rigid steel, is not understood. It will be seen that the essential process of steel manufacture is to purify the iron and introduce the proper amount of carbon.

There are in general two processes of steel manufacture, the Bessemer and the open hearth. The former was perfected by Sir Henry Bessemer the middle of the last century and ranks among the world's greatest inventions. Steel was made before this, it is true, but at so great expense as to put it beyond use in ordinary operations. In the old process, bars of iron were surrounded by fine charcoal and placed in a tight crucible. The whole mass was heated for days in a furnace and it was found that in some way the carbon of the charcoal had entered the iron, making a good quality of steel. By years of experimenting Bessemer developed his pneumatic method of steel manufacture

which is used the world over for medium and low grade steel. The open hearth process is of more recent invention and is rapidly coming into extended use.

We left the molten iron at the blast furnace from which it is either taken directly to the steel department or cast into "pigs" or small bars, the latter course being followed if the iron is to be stored or shipped away. This iron contains impurities which would condemn it for steel manufacture, among them sulphur, phosphorus, oxygen and by far too much carbon. If the Bessemer process is to be used the molten iron is taken to that department and poured into a pear shaped vessel called a converter. (See Figure 6.) A blast of air under high pressure is turned into the converter and forced through the molten mass. Instead of cooling the fluid, the union of the oxygen of the blast with the carbon and other impurities develops heat enough to make the iron as fluid as water and it seethes and boils, while a brilliant flame of burning gas shoots from the converter's throat.

The experienced director can tell by the color of the flame the

FIG. 6. A view in the Bessemer department of the Pennsylvania Steel Company, Steelton, Pa. An upturned converter is seen at the left. To the right is the ladle. The converter is being tipped to pour its charge into the ladle.

precise moment when the impurities are burned out and at that time the blast is turned off and a quantity of "spiegel iron" is added. This is a mixture of iron, manganese and carbon. The blast has taken out the carbon and has left considerable oxygen scattered throughout the iron. If it were worked at this stage the steel would crumble, and it was this difficulty that delayed the development of the process until the use of spiegel became common. The manganese is greedy for the oxygen and takes it away from the iron; the carbon, which must be in proper proportion, remains and forms steel. In this way tons of steel are made

FIG. 7. *Open hearth process. Casting a steel ingot at the works of the Bethlehem Steel Co., Bethlehem, Pa.*

at a "blow" and the metal has become greatly cheapened. This stage of the process is indeed picturesque, especially at night, although the gloom of the building in daylight serves as a background for the display. The huge converter vomiting streams of flame and sparks is a scene not soon forgotten.

The open hearth process is not so interesting to the average observer as but little of the process can be directly observed. (See Figure 7.) Beneath the floors are galleries and passages for hot gases which are led to the furnace. This is a large, brick-lined, oven-like structure.

so poised that it can be tipped apparently as easily as a huge teakettle. Into it gas and air are admitted so as to burn at the mass of iron. When one attempts to look into this furnace nothing but a blinding glare of light is seen, but looking through colored glass, the iron is seen spluttering much as water in a kettle. At the proper time spiegel is added and the iron becomes steel. The hot gases resulting from the combustion are led away to heat the air which enters the furnace. This process is slower than the Bessemer and offers better opportunities for testing the steel and regulating its quality. It therefore produces a finer grade of steel.

From either process the steel is cast into molds which are rectangular boxes about seven feet long and set upright on little cars. This toy train radiating scorching heat goes to the rolling department where the steel bars are taken from the molds. This metal is now ready to be cut or pressed into rails, plates, or the thousand and one forms into which the metal is formed. The bars are heated in a gas furnace to a white heat and then are rolled into the desired shape. If, for instance, a rail is to be made, the bar is passed through rolls which have troughs shaped the reverse of the rail. The troughs become smaller as the rail is rolled, so that a bar about five feet long is pressed into a rail sometimes sixty feet in length. For rolling plates the same process is followed except that smooth rolls are used and the bar is flattened to the desired thickness, somewhat as dough is pressed under the rolling-pin.

These three steps are common to most steel manufacturing plants. Many details have been omitted and a complete description of the plant would require a volume. The whole force is organized into departments, each of which is under the supervision of a superintendent who is responsible for his department. The chemical laboratory, tensile testing department and electric power plant are among the interesting divisions. The company maintains a temporary hospital with a surgeon in attendance to care for the workers who may be injured in the accidents that are liable to occur.

One of the strongest departments at Steelton is that of bridge construction, and a paragraph upon it may be of interest. Suppose, for example, a railroad orders a bridge. The engineering department of the road first determines the principal features, as the length, width, load to be supported, number of spans, and as many other details as he may see fit to specify. He embodies these features in a draft or drawing of the structure called the working draft. From this the drafting

department of the plant makes a detailed plan in which not only the size, shape and dimensions of each piece are shown, but even the size and position of each rivet hole is determined by direct calculation. This work is done with great care and frequently revised, for an error in this office means a costly mistake elsewhere. The draft is finally submitted to the purchaser and if approved is sent to the proper shop and the parts are cut or cast into the required shapes.

There is an education in visiting and studying a large industrial plant, to be found in no other way. Such a plant is the product of minds trained by years of study, experience and experiment. If one tries to comprehend too much in the first visit, he is sure to be bewildered. It is far better to visit each department separately, and when the work of each is understood, to view the plant as a whole. I think I am safe in saying that entrance to most works, except where the processes are secret, is easily obtained by a courteous request, especially by a teacher. Such visits are recreative as well as educative.

CLIMATIC FACTORS IN RAILROAD CONSTRUCTION AND OPERATION*

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THE use of railroad publications as material for geographical study has long been advocated. In the past, localities which became preëminent in industry and strength were located along some water way, the chief path of travel and transportation. The advent of the railroad allowed the growth of centers of life apart from river banks and ocean fronts. In many countries, as in the United States, the prominent lines of trade do not agree in direction with the

*This article was originally prepared as a thesis in the course in General Climatology (Geology 19) given by Professor R. De C. Ward in Harvard University. It has been rearranged, and to a great extent rewritten, for publication. The material was collected chiefly from the *Engineering News*, *Engineering Magazine*, publications of the American Society for Civil Engineers, *Railroad and Engineering Review*, *Railroad Gazette*, *Scientific American*, *Scientific American Supplement*, and books of travel.