on a foundation of lumps of small coal into huge pyramidal heaps which are kindled at the windward side and allowed to smoulder for months, being prolonged as may be requisite by fresh additions of ore and fuel at the opposite extremity. The ore may be calcined with an addition of only one-twentieth of its weight of coal, if it contains, as in the blackband, a large proportion of bituminous or combustible matter; whilst a clay ironstone may require as much as one-fifth of its weight of coal. The calcination in heaps is very uncertain on account of the irregular distribution of the heat, some parts of the ore being scarcely affected, whilst others are overheated and melted so that they can be smelted only with difficulty.

This plan is only adopted in districts where fuel is very cheap. During this process the ore loses about one-fourth of its weight on account of the expulsion of water, "OH_2," and carbonic acid and the combustion of the bituminous matter. A portion of the sulphur is also burnt off, entering into combination with the oxygen from the air to form sulphurous acid gas. Many ores are rendered much more porous by this process, and are more easily smelted.

In South Wales the ore is roasted in furnaces or running kilns resembling lime kilns, into which it is thrown at the top alternately with layers of small coal, the roasted ore being raked out at the bottom of the furnace.

The usual process of smelting ores requires a very high temperature, and is carried out in a blast furnace. The blast furnace being at work or, as it is technically called, in "blast," it is kept filled to the top or throat by continually adding to the furnace, the smelting mixture of ore, fuel, and flux as the charge works down, the supply of air or blast under a pressure of from 2 to 5 lbs. in furnaces worked by coke or of 1½ to 2 lbs. in charcoal furnaces being maintained through the tuyeres near the bottom ot the furnace, except when the top is opened for the introduction of the charge when the blast is shut off. The oxygen of the air injected through the twyers meeting with incandescent fuel is in a great measure immediately converted into CO_2, carbonic acid, with the production of the maximum amount of heat within a short distance of the tuyeres, the CO_2, carbonic acid gas, so produced ascending towards the throat of the furnace passes over a large mass of heated fuel and is quickly reduced to carbonic oxide, CO, each volume of CO_2 forming 2 volumes, of carbonic oxide with a corresponding reduction of temperature in the lower part of the boshes where this is effected.

The CO, carbonic oxide, so produced, along with perhaps a smaller proportion derived from the deoxidation in the same manner of the carbonic acid expelled from the limestone used as a flux, then becomes the principal and active reducing agent in the blast furnace, ascending it meets the mixture of heated ore and flux which is descending towards the hearth; the porous oxide of iron thoroughly heated and calcined while in the upper part of the furnace is readily permeated by the gas with the reduction of metallic iron. The formula thus produced is:

$$Fe_2O_3 + 3\,Co = 3\,Co_2 + 2\,Fe$$

The iron thus reduced to the metallic state in passing downwards towards the hearth of the furnace comes into contact with a large amount of heated fuel and combines with a varying amount of its carbon; a further carbonization being probably effected by the decomposition of carbonic oxide by the reduced metal with the production of the fusible of carbon and iron with various impurities constituting what is known as pig iron. It has been attempted to mark out with some considerable accuracy the various zones or limits within which the specific reactions occurring in the blast furnace are confined. The cycle of operations by which the oxygen of the blast is converted into carbonic acid with its almost immediate reduction to carbonic oxide, in its turn again becoming CO_2 by its reaction upon oxide of iron, is repeated as the gases ascend through the furnace so long as the temperature remains sufficiently high to effect the decompositions; the escaping gases however always contain a large proportion of CO which burns with its characteristic flame though masked by the volume of yellow flame emitted at the mouth of the furnace if the gases are allowed to escape. The upper portion of the furnace is occupied by the raw materials charged into the furnace which are there being heated by the ascending gases; towards its lower boundary and within 20 ft. of the top of the furnace the mass is at a dull red heat and the ore suffers reduction by the contact with carbonic oxide with the production of a spongy metallic mass. A little lower down the limestone suffers decomposition and the descending spongy metal begins to absorb the carbon from contact with the fuel, which absorption continues through to where the temperature has attained a bright redness and it is here that the sulphur, phosphorus, silica are to a large extent reduced from the materials of the charge and combine with the pig iron. In the boshes the heat attains to a very bright redness and the descending charge of spongy metal with slag-forming materials undergo thorough fusion in their descent. In the crucible or hearth where the heat is at its greatest intensity, or whiteness, the fused metal and slag separate, the fluid pig iron forming the low stratum above which is the layer of fluid slag. If you add too much limestone for a flux the metal separates imperfectly. By thus adding a suitable material to flux, the pig iron separates from the slag in the hearth of the furnace, the latter rising to the top of the bath of molten metal and protecting it from oxidation by the action of the blast. The slag is allowed to run away through an opening and the metal is tapped out at intervals of 12 hrs., or in the hæmatite districts of the north every 6 hrs.; for this purpose the blast is turned off, the tap hole broken open by an iron bar and the metal runs into a series of grooves, furrows, or channels formed in the sand of the floor near the furnace or into cast iron moulds. The furrows are of the D section and arranged in parallel rows, the top end of each row communicating with a common channel along which the metal runs to supply the furrows in that row; this channel or feeder is known as the sow. The principal dimensions of the furnace recently erected at Middlesboro' are: diameter of hearth, 8 ft.; diameter at bosh, 28 ft.; total height from hearth to platform, 85 ft.; cubical capacity, 30,085 feet. This furnace is worked with hot blast at a temperature of about 1,100° Fahr., with a pressure of 3¾ lbs., and the product is stated to be from 490 to 500 tons of pig iron per week. A well-built furnace will often last five years without requiring to be blown out for repairs. The average tensile strength of pig or cast iron is about 7 tons per sq. inch. For the useful applications of cast iron 8 varieties are commonly recognized; nos. 1, 2 and 3 are decidedly grey irons of different shades, being the greyest; they are distinguished by the sparkling, largely crystalline appearance of the broken surface and are called melting iron because they are chiefly used for fine castings; no. 4 is best grey forge iron; no. 5 grey forge; they do not become so liquid when melted, but they are tougher and better fitted for purposes where strength is required; grey cast iron is usually regarded as the proper or normal product of a blast furnace in good working order.

To obtain iron in a fit state for rolling into strong bars it is necessary to deprive the cast iron as far as possible of all foreign matters except a small proportion of carbon, of which a quantity not exceeding 1-200 is found to increase the toughness of the iron. To obtain this a process of puddling, either mechanically or otherwise, is generally employed. The charge of a puddling furnace consists of only 4 or 5 cwt. of pig iron, which is usually broken into fragments and piled in heaps around the sides of the furnace, and in about 20 minutes it begins to melt. If it were allowed to become very rapidly liquid the iron would be oxidized only to a slight extent upon the surface, and the object of the puddling furnace would be defeated; accordingly, a workman rakes the melting fragments into a cooler part of the hearth, and exposes fresh surfaces of the metal to the oxygen of the air in the furnace. The pig iron is placed in a furnace called a reverberatory furnace, where the metal is placed in small lumps on the hearth and the flame is reverberated back through an arch immediately on to the broken pig. The material is then worked until the whole of the metal has become fused to a pasty condition. This stirring is proceeded with while the metal froths and swells up very much and evolves numerous bubbles of carbonic oxide gas, indicating the removal of the carbon from the iron. In a short time small clotted lumps of the purified iron separate or come to nature in the melted metal; then it is not long before it is nearly deprived of its carbon, and purified iron has thus been separated and is then taken out and hammered under a heavy hammer, which strikes rapidly, and the melted slag is forced out in white hot showers from between the particles of iron and thus becomes welded together into a compact mass of metal of an oblong form which is rolled out into bars of 10 or 12 ft. long and 4 in. wide and sold as merchant bar iron. There are various methods of manufacturing wrought iron, but the subject is too extensive to deal with in this paper.

It has been stated that steel forms an intermediate link between ordinary cast and malleable iron and unites in a greater or less degree the properties of both. The following are the principal methods of making steel:

1. The Catalan forge directly from the ore.

2. From pig iron by fusion and partial oxidation in the hearth fusery.

3. From pig iron by a similar process in the puddling furnace.

4. By exposing bar iron to the action of solid carbonaceous matter at a temperature below its melting point. This method is known as conversion by cementation, and the amount of change produced is mainly dependent upon the time employed. When merely a surface coating of steel is required, the process is known as case hardening; while, if sufficiently long continued, the iron may be completely converted into cast iron. The process for making malleable cast iron is the reverse; viz., by exposing cast iron to heat in closed vessels filled with finely powdered hæmatite. The surface is decarburized at the expense of the oxygen of the peroxide of iron, with the production of a malleable coating. In the above process steel is produced without melting, and is converted into bars by hammering and rolling in a similar manner to malleable iron.

5. The cemented or blister steel produced in no. 4 is broken up into small pieces and melted in crucibles with or without fluxes, in quantities from 60 to 80 lbs. This is Huntsman's process, and is used extensively for cutlery and tool steel.

6. By blowing air through molten pig iron, until it is wholly or partially decarburized. The necessary amount of carbon is restored by the addition of highly carburized pig, such as spiegeleisen in small quantity. This is what is known as the Bessemer process.

The practice of melting steel was intro-