duced by Huntsman at Sheffield in the year 1740, and is still carried on in substantially the same manner at the present day.

It is difficult to find the exact limit beyond which wrought iron passes into steel. Bar iron containing as much as two parts of carbon in 1,000 of metal would be so decidedly hardened by chilling as to be termed a steely iron, and a slight increase in the quantity would produce mild steel such as the homogeneous metal of which cannon and armour plates are forged. A proportion of carbon amounting to three parts in 1,000 is contained in the Bessemer steel rails, and in the steel of which spades and hammers are commonly made. Steel employed for tools commonly contains 10 or 12 parts of carbon in 1,000. When the carbon amounts to 14 parts in 1,000 the steel becomes more fusible and resembles white cast iron. Bar iron, which contains only a minute proportion of carbon has a tensile strength of about 57,500 lbs., nearly 26 tons, an inch; (the Board of Trade gives 5 tons a square inch as the working strain to which it is safe to expose bar iron in actual practice), but where the proportion of carbon amounts to three or five parts in 1,000 the tensile strength is increased to 90,000 or 100,000 lbs., 40 or 45 tons, a square inch, while it is still soft enough to be easily punched and flanged. Such a metal is well suited for boiler plates and similar purposes. The presence of carbon makes iron more capable of retaining magnetism. We will now commence to manufacture steel by what is known as the cementation process. The process of cementation, by which, until lately, nearly all English steel was produced, consists of heating bar iron in contact with charcoal in a closed chest until it has acquired a proper proportion of carbon. The cementation furnace is dome shaped, the hearth is divided by a grate containing a coal fire, the flame of which circulates all around the fireclay chests or pots placed on each side of the grate; these pots contain seven or eight tons of bar iron, together with charcoal necessary for its conversion into steel. A small opening is left at about the middle of one end of each chest through which the end of one of the bars undergoing cementation is allowed to project; this proof bar is withdrawn from time to time through a small hole in the wall of the furnace for the purpose of watching the progress of cementation. The charcoal is ground from hardwood, with which there are sometimes mixed a little common salt and some ashes of the charcoal. The bars of iron should be of the purest description if the best steel is to be produced. They are about 3 ins. broad, ½ in. thick. In order to fill the troughs the workman stands on an iron platform between the two, and sifts the cement powder into them so as to form a layer of ½ in. deep, upon which the bars are placed standing upon their edges, about 1 in. apart; more cement is then placed, and so on until the pots are filled. A temperature of about 2,000° Fahr. is required to enable the bar iron to acquire a proper proportion of carbon, and the pots are maintained at this temperature for a period according to the hardness of the steel required; four days being sufficient for producing steel of which saws and springs are made, while eight or ten days are required for the very hard steel of which cold chisels are made. The fire is then let down, and some days elapse before the troughs are cool enough to be opened. About three weeks are generally occupied in converting bar iron into steel; about 16 cementations a year are executed by a single furnace. The bars are found to have blisters on their surface, and so it is called blister steel. This blister steel is broken up into pieces of a convenient size for packing close together, and about 30 lbs. of it are introduced into a tall, narrow crucible about 2 ft. high, made of fire clay mixed with black lead, and provided with a closely fitted cover. These are placed in a small furnace, holding six, twelve or more, about 6 ft. wide and 2 ft. deep. Hard coke, broken into small pieces, is employed to raise the crucible to a bright red heat; the steel is then introduced, the crucible covered, and the furnace filled with coke; when the steel is melted the crucible is lifted out, and its contents poured out into a cast iron mould previously heated. The mould is in two halves, closely fitted together, so that it may be coated inside with coal tar soot. For the production of large castings of steel the requisite number of crucibles must be emptied into the mould as nearly at the same time as possible. At the factory of Krupp, a casting of 16 tons may be produced in this way, 400 men well drilled to co-operate in emptying 1,200 crucibles so that the melted steel may flow into the gutters leading to the mould. But great improvements have been made in the manufacture of cast steel by the Siemens process and introduction of the regenerative gas furnaces. Cast steel has the serious defect of being brittle at a high temperature, so that it is forged with difficulty, and does not admit of being welded readily. A method of correcting this was patented by Heath in 1839, which consists simply in adding to the cast steel in the melting pot about 1-100 of its weight of Mn. CO_2, the result of the action of heat upon a mixture of black oxide of Mn. and charcoal or some other containing carbon, such as coal tar. The blades of knives are made of cast steel welded on to an iron tang. Siemens gas producers are rectangular chambers of fire brick; the combustible gases are hydrocarbons, the product of the distillation of coal in the upper portion of the producer; CO, formed by the reduction of the CO_2 produced at the firebars by the combustion of the fuel which, passing over the heated coke or carbonaceous matters formed in the upper layers, combines with an additional atom of C with the production of 2 vols of CO, thus $CO_2 + C = 2CO$. The regenerators are vaulted chambers of firebrick placed beneath the furnace in which are stacked masses of brick work through which the air and gas is admitted into the furnace. The charge consists of 9% of pigiron, 6% of spiegeleisen; the process from the first to last occupies 10 hours. An average charge consists of 20% of pig, 20% Bessemer steel scrap, 10% rough puddled iron, 15% Siemens scrap, 15% old iron borings, 20% iron shearings, after which 7½% of spiegeleisen is added.

The simplest method of making steel is the Bessemer process, which depends solely upon the removal of the carbon by forcing air through the liquid metal, and if this process be arrested before the removal of the carbon is completed, the metal will have the composition of steel, but if all the carbon is burnt out so as to obtain wrought iron it is then converted into steel by adding spiegeleisen, which contains 82% of iron, 10% Mn., 1% Si., 4% C. The converter in which this process is carried on is made of wrought iron boiler plate and lined with fireclay or other refractory material to protect it from oxidation. It is generally large enough to contain 10 tons of cast iron for a charge and is suspended on trunnions so that it may be easily tilted for charging and discharging, a 6-ton converter is generally about 11 ft. high and 5½ ft. wide. Through the bottom of this vessel there are several openings to admit the blast of air which is blown in at a pressure of 15 to 20 lbs. a square inch, produced generally through a large blast engine for that purpose, through 35 holes from 7 tuyeres with 5 holes each. The converter, having been heated by burning a little fuel within it, is charged with pigiron which has been previously melted in a separate furnace, a pigiron containing a large proportion of graphite and silica and a small proportion of sulphur and phosphorus being selected. The air bubbling through the liquid metal induces an intense combustion of the iron, producing a large quantity of the black or magnetic oxide of iron (the same as you see round a blacksmith's anvil) which is carried up by the force of the blast, together with the nitrogen of the air which does not act upon the iron. The bubbles of this gas being forced up through the melted metal effectually mix the unoxidized portion with the melted oxide, which converts the carbon of the cast iron into CO and the silica into silicic acid, the latter combining with some oxide of iron to form a slag which appears as a froth at the mouth of the converter. The silica is always oxidized before the carbon, and during the first ten minutes very little flame is seen at the mouth of the converter. In this process a portion of the iron itself is the fuel undergoing combustion, the temperature is much higher than that of the puddling furnace in which coal is the fuel, for a given quantity of oxygen in the act of burning iron produces 1-3 more heat than in the act of burning carbon. The operation usually lasts for only 20 minutes, its termination being indicated by the almost total disappearance of the flame of CO, but a far more exact method of ascertaining when the requisite amount of carbon has been removed consists of viewing the flame through a spectroscope, when the color is first yellow or orange, but it gradually changes to blue or violet as the amount of CO increases; the disappearance of these line marks indicates within a few seconds the conclusion of the process. If Bessemer iron were required the contents of the converter would now be discharged into a ladle, which is swung around to the mouth of the converter, and from the ladle into the moulds, situated around the pot, but to produce good malleable iron from this process very high priced pig has got to be procured, so this prevents the application of this process for the production of good malleable iron. In order to convert the decarburized metal into steel the requisite proportion of C is added in the form of spiegeleisen. A special variety of white cast iron containing a large quantity of carbon in chemical combination together with manganese, which is obtained by smelting in a blast furnace with charcoal a spathic iron containing a large proportion of managnese, such as that from the Brendon Hills (Somersetshire, Eng.) which contains: Fe., 83%; Mn., 10.71%; Si. 1%, and C, 4.32%. The presence of Mn. is probably of great importance with regard to the use of spiegeleisen as an ingredient of Bessemer steel. It is introduced in a melted state, generally melted in a cupola elevated above the level of the mouth of the converter, and run through channels in a molten condition into the mouth of the converter, which is tilted into a horizontal position to receive it; the blast being stopped during the addition, and afterwards turned on again for a few seconds when the converter has resumed its former position, in order to diffuse the spiegeleisen through the liquid iron, after which the steel is transferred to the mould, being poured for that purpose into a large ladle lined with loam and swung around the pit over the moulds arranged, the metal running out of the ladle from the bottom in which is placed a fire-clay plug. By this process 200 tons of steel weekly is produced which would require by the old process of melting blistered steel, 4,730 crucibles and 760 melting furnaces.

The effect of hammering, or rolling, increases the tensile strength, for the ingots of Bessemer steel which gave a mean tensile strength of 27 tons per sq. inch had it increased to 68 tons by hammering or rolling.

The proportion of carbon in the steel has such an important influence upon its properties that it is constantly necessary to determine its amount by chemical analysis.

The most simple and expeditious process is that due to Eggertz. Iron containing com-