THE PROCESSES OF STEEL MANUFACTURE.

The manufacture of steel by a process as simple as possible, at the lowest cost and of the best quality, has called forth, especially of late years, the exercise of much inventive ability on the part of both chemists and engineers, both at home and abroad. There has resulted such a variety of differing methods that some systematic classification of the processes has become very necessary. In the *Mittheilungen des Hannoverischen Gewerbe-Vereines*, Professor Heeren publishes the complete classification, a translation of which is given below, and which will be found both instructive and of value for purposes of reference. As steel occupies nearly the middle place between cast and wrought iron in its proportion of carbon, it may be prepared either by decarburizing pig iron, or, on the contrary, by causing wrought iron to absorb carbon. The processes to accomplish these ends may be arranged under five principal heads: A, Fabrication of steel by decarburization of crude or pig iron; B, by carburization of wrought iron; C, by mixing a wrought iron poor in carbon with a pig iron rich in same; D, by mixing pig iron with ore (the pig yields carbon which reduces the ore and transforms the reduced iron into steel); E, directly by means of ore; F, cast steel. Subdividing these systems, we have the following methods under each heading.

A.—METHODS BY DECARBURIZING THE CRUDE IRON.

1. Steel obtained by a long heating of the crude iron in an oxidizing atmosphere, the metal not being brought to fusion. (*a*) Tunner's method in sand, where the deoxidation is produced by means of the oxygen in the air. (*b*) Jullien's method, in forge scales or spathic ore. This produces malleable iron. (*c*) Herzeeles' method in steam; (*d*) Thomas' method in carbonic acid. The last two processes have not been employed to any great extent.

2. Natural steel: In this method, employed since the earliest times, the crude iron is melted in a refining furnace with wood charcoal, and decarburized by the ferrous oxide of the scoria. The product is purified by a repeated refining.

3. Puddling: This process is the same as the preceding, from a chemical point of view, but is practised in a reverberatory furnace heated with coal. It is necessary to purify the product by repeated refining or by transforming it into cast steel.

The construction of puddling furnaces has undergone many changes. We may distinguish (*a*) the ordinary puddling furnace with fixed hearth and heated by coal, (*b*) the same heated by lignite or peat, (*c*) the puddling furnaces of Schafhäutl and others, with mechanical rabbles designed to diminish the labor so fatiguing to the workman. These, however, have been entirely superseded by new systems. (*d*) The Danks furnace, the hearth of which is formed of a hollow cylinder placed horizontally, and turning about its axis. It gives a product of excellent quality, and is economical. The interior lining, however, is difficult to maintain. (*e*) The Ehrenwerth furnace has a horizontal circular hearth turning about a vertical axis. (*f*) The Pernot furnace also has a circular sole, which, however, is not horizontal, but slightly inclined, so that during its rotation the iron and scoria run to the lowest point and are thus in a state of continual motion; while the elevated parts of the hearth, together with the iron and scoriæ thereto adherent, are submitted to the oxidizing action of the air. Professor Heeren thinks this furnace to be the best, because it realizes the advantages of mechanical puddling without needing any special lining.

4. The Bessemer process: A current of air, finely divided, is passed through the liquid crude iron. The carbon, silicon, and a part of the iron burn, and the temperature is so highly elevated that the iron, decarburized in part or transformed into steel, remains molten. It is then run into molds.

5. Bérard's modification of the above: Air and gases are alternately introduced into the retort with different advantages.

6. Peters' process: The liquefied crude iron in a reverberatory furnace falls in the form of rain in a vertical chamber in which the furnace gases also pass, and in which air is blown so as to decarburize the metal to the desired degree.

B.—METHODS BY CARBURIZATION OF WROUGHT IRON.

1. Indian or Wootz steel: Wrought iron of extraordinary purity, obtained by treating a very pure ore in small chamber furnaces by the direct method, is hammered, made into bars, cut into short pieces, and placed in small crucibles with a few green leaves. The crucibles are hermetically sealed and heated for a long time at a high temperature. The iron is transformed into steel by uniting with it this carbon contained in the leaves, and the steel even partially melts. These half melted masses furnish the famous sword blades and plates of Persia and Damascus.

2. There are several other processes resembling the Indian, which, however, are not carried on on a large scale. There are (*a*) the Mushet process, in which wrought iron obtained by the ordinary refining method is melted with powdered wood charcoal. (*b*) The Vickers' process, analogous to the preceding, with the addition of oxide of manganese. (*c*) The Stourbridge, Brooman, Thomas, and Binks processes, based on identical principles.

3. English cemented steel: Wrought iron of the best possible quality is, in the shape of bars, packed in clay boxes, together with wood charcoal coarsely pulverized. The heating continues for two or three weeks. Without melting, the iron is changed into steel, which by remelting is transformed into cast steel.

4. Parry's cupola steel: Fragments of wrought iron, melted in the cupola with a large consumption of coke or wood charcoal, may be transformed into steel or even into cast iron according to the length of the operation. This system offers an advantageous method of utilizing scrap, and requires no special apparatus.

5. Chenot's process: In this the ore is reduced by heating it progressively with coal. A non-melted iron sponge is obtained, which is ground and separated as well as possible from the gangues by the aid of a magnet. Lastly, it is mixed with carboniferous substances, and melted under pressure. The principal disadvantage of this process is the difficulty of separating the gangues without losing the steel.

6. Casehardening has for its object the transformation of the surfaces of wrought iron objects into steel. It is done in two ways. (*a*) The pieces are placed in small sheet iron boxes and surrounded with chips of wood. The boxes are hermetically closed and heated in a forge fire, for 15 or 30 minutes, to an intense red heat. They are then removed quickly, opened, and their contents thrown into cold water, whereby the exterior steel shell is rendered as hard as glass. (*b*) The pieces are heated to a whitish red and moistened with ferrocyanide of potassium, which acts, by its cyanogen, on the iron, and transforms the surface into steel.

C.—METHODS BY FUSION OF A MIXTURE OF CAST AND WROUGHT IRON.

The two materials may be, both or only one of them, used in a melted state.

1. Bessemer steel, prepared by the ordinary method. The crude and wrought iron here are both liquid, while, as we have previously said, cast iron may be directly transformed into steel. The method most followed, and which leads most surely to the end in view, consists in completely decarburizing the crude iron in the converter, and in adding to the melted metallic iron a rigorously determined quantity of liquid crude iron. The carbon of the latter affects the previously decarburized iron, and makes a steel containing a given proportion of carbon.

2. Crucible steel is obtained by melting in crucibles a mixture of crude and wrought iron. The former liquefies first, and slowly melts the latter.

3. Martin's steel is similarly made, by replacing the crucible with a reverberatory furnace. The crude iron is liquefied under a thin layer of scoria on the concave hearth of a reverberatory furnace, heated to an intense red-white heat by a Siemens regenerator. Scraps of steel and wrought iron of all kinds in desired quantity are added, and the steel is run into molds of cast iron.

D.—METHODS BY A MIXTURE OF CAST IRON AND ORE.

Uchatius steel: The cast iron is granulated by running it into water while molten, and the grains are melted with spathic ore, peroxide of manganese, and wrought iron in crucibles. The ferrous oxide of the spathic ore is reduced by the carbon of the cast iron, and the surplus of carbon unites with the wrought iron to make steel.

E.—METHODS BY PREPARATION DIRECT FROM THE ORE.

The Siemens direct process: The ore is melted alone, without addition of reducing material, at a very elevated temperature; then the iron is reduced and transformed into wrought iron or into steel by adding coal.

F.—CAST STEEL.

For the purification of steel by fusion, cemented, forged, and puddled steel are employed. To improve the qualities of the steel, and notably to augment its hardness, diverse substances are added. Thus we have: 1, silver steel, 2, nickel steel, and 3, wolfram or Mushet special steel.

THE RUSSIAN SYSTEM OF TRADE EDUCATION.

Our correspondents at the Centennial Exposition have already briefly described the courses of study in many of the institutions of learning there represented. There is one great school, however, which is worthy of something more than passing notice; and for many reasons its exhibit may be profitably studied by all interested in the important question of how best to impart practically valuable technical education. While, with all mechanical schools, the cardinal object of the Imperial Technical School of Moscow, Russia, is to eliminate all useless or routine labor in the acquisition of a trade, and to require the student to perform only such as is best adapted, in connection with proper advice, to give the necessary knowledge, it adopts to this end a different method from any hitherto practised; and for the first time it has successfully proved the value of absolutely systematic instruction applied to the acquirement of industrial skill. The method of teaching the mechanical arts here initiated has gradually spread itself into all the Russian technical schools; and it is not unsafe to believe that, judging from the reported results, the same must eventually supersede other modes of instruction elsewhere. It is our purpose in the following to exhibit briefly the practical way in which the system is carried on.

The auxiliaries of education appointed for the teaching of any mechanical work whatever—for example, fitting—are divided into three categories. Taking fitter's work as an example, under the first division belong collections of tools used in the various operations, with which the beginner must make himself perfectly familiar before entering upon practical labor. Some of these collections are exhibited at the Centennial. There are collections of instruments for measuring, for drilling, and for finishing, models of files increased to 24 times ordinary size for the purpose of exhibiting the shape of teeth, etc., models of taps and dies magnified 6 times for the study of the direction of the angles of incision, and models of drills similarly magnified for the practical study of cutting angles; and there is also a collection of instruments and apparatus for teaching the tracing of yet unworked metal articles. Similarly in turning both in metal and wood, and in joinery, there are like collections, in which every tool is represented either in actual or in largely magnified form, so that the most accurate knowledge is thus imparted relative to every characteristic of the implements.

Having learned what he is to work with, the student is next taught practical manipulations. These are included in the second category, and it is worth while to review them. In wood turning, the pupil begins by following exercise models of various channelings, then he learns to turn a cylinder, a cone, a bullet, and so on, through thirteen articles, up to a vase and cover. In model and pattern making, the first lesson is to saw straight and along fiber, then to saw in a curved line, then to plane wood of different sections, to make joints, and the last of 25 operations is cross scarring by a skew abutting. At the forge, the student begins by forging square out of round iron, then round out of square. Nuts are next made, then screw heads of all shapes, then bolts of various kinds, then welding and steeling; and the last operation is to make welded ears to square bar iron. Metal turning starts with a simple cylinder and ends with right and left worms of a screw. Fitting begins with cleaning castings, which is followed by chiseling of various surfaces. There are 29 filing operations, beginning with the filing of thin edges according to marked lines, and ending with the filing of cast conical apertures. Then come punching and boring, drilling, and finally screw cutting.

These are merely general operations. Models are followed and the work is accurately graded, so that the beginner overcomes by degrees the difficulties presented. The teacher sees that each number of the programme is satisfactorily executed, and keeps the learner on that particular piece of work until it is mastered. Then the next operation in the series is undertaken, the instructor giving all the requisite explanations. Hence it is impossible for a student to become a good chiseler and a poor filer at once, or skillful at the drill and bungling with saw and plane. In every course the order is inflexibly followed, and the acquirement of each integral advance is the only road to progress.

Lastly comes the third category, or the practical application of all that has been learned. And here another series of lists meets us. But instead of the objects being, as it were, merely abstract, they are parts of machines, etc., selected so that in their execution all the practical resources of the art which the pupil has been studying are brought into play. The wood turner begins by producing a stuffing box cover. Then follows the shell for a step, a valve with a bullet seat, oil cups, rollers, star and bevel wheels, cylinder cover, same with stuffing box, pulley, and so on through a list of 43 pieces, ending with the chamber of a bullet valve. The model maker following models of wood joinings starts with a tongue joint, and, after producing 25 kinds of joints, scarrings, etc., begins on patterns. The list includes a grate bar, crank, puppet, wall box, sheave drum, and eccentric bevel wheels; and the eighteenth and last requirement is a set of patterns for a horizontal feed pump. The metal turner makes a steam cylinder, piston, cylinder cover, and lastly a crank shaft. The last five operations required of the fitter are the fitting of a toothed coupling, of a clutch coupling, of brasses to a plummer block by five planes, of a parallelopiped to an aperture, and the fitting of sliding plates.

That the pupil who has gone through this course becomes a skilled workman, it is hardly necessary to point out. He must be so if he succeeds in graduating at all. But all this is merely preliminary. The student has yet to learn to be an engineer, and to this end he has been taught theory for a portion of his time. He now advances to a new school of practice, namely, the mechanical works. There, while he may not labor at the bench himself, he sees others do it, and he is taught construction. There is a large force of hired workmen carrying out orders on a commercial footing, for engines and machines of all kinds. There are iron and brass founderies, engineers' shops, builders' shop, forge, joiners' and painters' shops, drawing office, and counting room. The student is obliged to study everything, from iron smelting to book keeping, and thus his course is completed.

It is the fortune of a large number of graduates of the scientific courses of our colleges, when thrown for the first time upon their own resources, to take positions as draftsmen; some few enter works to learn the practical part of a trade. The latter are neither apprentices nor skilled hands. Those who become draftsmen, not possessing as a rule the practical groundwork for an industrial career, nor from their position having opportunities for acquiring the same, too often remain draftsmen for their best years, if not for all their lives. The trade learners, meaning some day to follow their profession, perhaps learn the truth that, while the professions are overcrowded (except at the top), the trades are not, and, concluding to adhere to the trade, become educated to a certain branch, and, under the principle of the division of labor (in these times constantly expanding), find in the end that their knowledge is confined within the limits of a narrow specialization.

With such an education as we have outlined, it is difficult to imagine either of the above results; for even should professional opportunities fail, the shop is ever open to a workman whose skill is as broad as a trade itself and not confined to any one branch thereof. Such acquirements, moreover, could not be of the greatest value to any person in any walk of life. The Emperor of Germany, should he lose his crown, can earn a good living by setting type, for he is an excellent practical compositor and printer. The Queen of Eng-