THE METALLURGICAL ARTS AT THE PARIS EXHIBITION.

BY F. LYNWOOD GARRISON,
Delegate of the INSTITUTE.

[*Concluded from vol. cxxx, p. 125.*]

FIRMINY STEEL WORKS.

The exhibit of this company was one of the best of the steel works of central France. It contained a large number of iron and steel metallurgical products, some of which possessed peculiar interest, a series of cast irons were shown, some containing fifteen per cent. manganese, also chrome cast iron with twenty-five per cent. chromium; silicon-spiegeleisen with fifteen per cent. silicium and eighteen per cent. manganese.

Some of the products of the Rollet cupola furnace for refining iron were also shown. It is claimed that the iron made in this furnace contains but .004 per cent. phosphorus. The so-called Rollet Process is essentially a remelting of pig iron with additions of iron ore, limestone and fluorspar in a cupola furnace. The Firminy Company have deservedly a high reputation for their excellent production of steel projectiles, axles, car and carriage springs, and particularly gun carriages. Agricultural tools are also extensively manufactured; a specialty is made of Siemens-Martin steel for rifle barrels, large quantities having been supplied for the famous Lebel rifle.

The Firminy Company claims to have been the first works in France to adopt the Siemens-Martin process. Eight furnaces are now in operation, about equally divided between acid and basic, the magnesite used in the latter coming from Styria. Since 1870, large quantities of this steel have been manufactured into heavy ordnance. An interesting series of samples of iron and steel united by the Verdee process and used for dies, shears, etc., were exhibited. By this process a steel face is cast upon a wrought-iron

body; the union of the two metals appears to be perfect, judging from the fractures.

Another specialty of this company is the manufacture of steel wire of exceptional tensile strength. They claim to be able to produce three-millimetre wire having a tensile strength of 250,000 pounds per square inch. Some 2·7-millimetre steel wire exhibited was claimed to possess as much as 270,000 pounds per square inch. The Firminy Company were among the first to manufacture crucible steel shells, chilled and tempered, and recently they have acquired celebrity for their armor-piercing projectiles of chrome and tungsten steel. They claim to have special methods of tempering these steels, the details of which are kept secret. The exhibit contained a series of thirteen railroad tires of various sizes, the largest being nearly ten feet in diameter and weighing 1,540 pounds. Very large forgings are not made to any extent at Firminy, their largest hammer being only thirty tons; the comparatively small ones, however, which they make, appear to be excellent in every way. There is only one blast furnace at present in operation at Firminy, with a daily production of about ninety tons. The following are analyses of the ores used:*

Locality.	SiO ₂ .	Al ₂ O ₃ .	CuO.	Fe.	Mn.	Ph.	S.
Spiliazeza, Greece, .	2·0	—	2·2	35·0	19·5	0·03	0·02
Mokta el Hadid,							
Algiers,	6·0	1·0	1·0	58·5	1·5	0·03	0·02
Elba,	12·0	0·5	1·0	50·0	—	—	0·03

The following are analyses of the pig iron and spiegel-eisen produced: †

	C.	Si.	Mn.	Ph.	S.
Foundry iron,	3·40	3·20	0·10	0·07	0·02
White forge iron,	3·20	0·40	1·02	0·07	0·07
Silico-spiegeleisen,	1·42	17·00	18·09	0·085	trace
Spiegeleisen,	4·00	4·50	15·00	0·07	0·01

COMMENTRY—FOURCHAMBAULT COMPANY.

These works belong to the central or Loire group. The company has a capital of 25,000,000 francs, and, like many of the other large establishments of the kind in France, was

* *Journal of Iron and Steel Institute*, November 2, 1889, p. 394.

† *Ibid.*, p. 395.

built up by combining a number of small concerns. The works are divided into two principal groups, the collieries and the metallurgical establishments. The latter consist of the blast furnace and foundries of Montlucon (Allier); the forges and wire works of Fourchambault (Nièvre); the steel works of Imphy, and the Fourchambault and Nevers construction works. There are six blast furnaces at Montlucon, producing over 50,000 tons per year, which pig iron is celebrated for its purity and general excellence.

The Fourchambault Wire Works were established in 1818, by the Boigues family; they produce from 3,500 to 4,000 tons of wire per year.

The fifteen-ton open-hearth (Siemens-Martin) furnaces, located at the same place, are three in number, and produce about 20,000 tons of steel per year.

The Imphy Steel Works contain three open-hearth and two crucible furnaces, with hydraulic cranes for handling ingots, etc. The entire production amounts to about 12,000 of ingots and 1,500 tons steel castings per year. These works were the first in France to develop the production of steel castings. The Imphy Works are celebrated for wagon springs and for most of the higher grades of various kinds of steel. The display which this company made at the Exhibition was particularly complete and illustrative of its productions. It was divided into three classes—metallurgical products, illustrations of the working of their mines, and models, etc., of public works (*travaux publiques*), for which this company had supplied material.

MARREL FRÈRES (Rive-de-Gier Works).

These works, located on the Loire, were specially laid out for the production of steel in large masses. They have cast ingots up to eighty-five tons in weight and claim to be able to cast them up to 140 tons. A new 100-ton hammer is about completed at these works, the principal dimensions of which are as follows:

Weight of the falling mass,	100 tons.
Weight of the anvil block,	800 tons.
Maximum height of fall,	6 metres.
Steam cylinder diameter,	2 metres.

This steam-hammer will be used with two 180-ton steam cranes and two others of fifty tons each. It is established in a large shed, in which there is already working a fifty-ton steam-hammer, along with 100-ton cranes.

The furnace plant consists of four thirty-five-ton open-hearth furnaces, from which are produced the large ingots for the manufacture of guns, armor plate, etc. They also have a crucible steel plant, and produce considerable quantities of chrome steel.

ST. LOUIS-MARSEILLES IRON WORKS.

This company is one of the largest and most important in the south of France. It has long been celebrated for the production of superior foundry and forge pigs, spiegel-eisens, ferro-manganese, silico-spiegel (up to fourteen per cent. silicon), ferro-silicon (up to fourteen per cent. silicon), and ferro-chromium.

The following analysis is of the ferro-manganese, made by this company:

	<i>Per Cent.</i>
Iron,	6'23
Manganese,	85'40
Silicon,	0'466
Combined carbon,	7'100
Graphitic carbon,	0'560
Sulphur,	trace
Phosphorus,	0'165
Copper,	0'060
	<hr/>
	99'984

Ferro-silicon (made in blast furnaces of the above company):

	<i>Per Cent.</i>
Iron,	82'60
Manganese,	2'50
Silicon,	12'60
Combined carbon, }	
Graphitic carbon, }	2'10
Sulphur,	0'054
Phosphorus,	0'088
Copper,	trace
	<hr/>
	99'942

Ferro-chrome (made in blast furnaces of the above company):

	<i>I.</i>	<i>II.</i>
<i>Chromium</i> ,	61'23	35'97
<i>Iron</i> ,	30'17	57'28
<i>Manganese</i> ,	1'35	1'20
<i>Carbon</i> ,	6'07	4'21
<i>Silicon</i> ,	1'11	1'21
<i>Phosphorus</i> ,	0'05	0'03

It seems that it is very difficult to obtain these alloys containing over sixty-five per cent. chromium in blast furnaces; the richer ones are usually made in crucibles. Messrs. Holtzer & Co. have obtained some with as much as eighty per cent. chromium and eleven per cent. carbon in this manner.

LONGWY IRON AND STEEL WORKS.

These works, one of the most important in the eastern district (Meurthe-et-Moselle and Luxemburg) were established under their present management in 1880, with a capital of 15,000,000 francs, afterwards increased to 20,000,000. The Longwy Company has a number of different establishments, including the three blast furnaces of Mont St. Martin, the three blast furnaces of Prieuré, the basic Bessemer steel works at Longwy, and one or two smaller establishments. The works, as a whole, cover an area of thirty-nine acres, and have, besides, important concessions in iron ore properties. The company own the Mont St. Martin, Herserange, Moulaine and Valleroy mining tracts, and have an interest in those of Hussigny and Godbrange. Besides the ore from their own mines, the company use a certain quantity of Luxemburg and Bilbao ore to produce special grades of foundry iron. In making basic pig, ores from different sources are used. The following analyses are averages of a large number of samples taken on delivery at the furnaces.

	Iron.	Man- ganese	Silicon.	Lime.	Alu- mina.	Sul- phur.	Phos- phorus.
<i>Longwy—</i>							
Hussigny red,	39	0'20	12'5	8	7	0'20	0'7
Herseange,	38	0'15	13	9	6	0'30	0'7
Godbrange,	37	0'15	15	9	7	—	0'6
Coulmy,	42	0'25	17	4	7	—	0'6
Hussigny lime,	28	0'15	10	22	5	0'25	0'5
Herseange lime,	26	0'15	10	24	5	0'25	0'5
<i>Luxemburg—</i>							
Sauvage,	42	0'15	13	6	7	—	0'5
Rumelange gray G,	35	—	8	14'5	7	0'05	0'7
Rumelange gray W,	34	—	8	15'5	6'5	0'10	0'6
Rumelange gray K,	33	—	8	17	6'5	0'10	0'6
Rumelange gray P,	34'5	—	8	16	6	—	—
Rumelange gray B,	33	—	8	17	7	—	—
Rumelange yellow K,	38	—	5	13	5	0'15	—
Schiffange yellow S,	29'5	—	9'5	22'5	2	0'15	—

The following table gives the principal data of Longwy Company's blast furnaces. The first three are the Mont St. Martin, the next two the Prieuré furnaces, the sixth the Longwy, and the seventh the Moulaine furnace.

BLAST FURNACES.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Height,	61'0	60'0	59'5	62'2	62'2	72'2	60'7
Diameter at top,	15'1	13'4	12'3	15'3	15'4	15'4	9'2
Diameter at bosh,	21'3	16'1	18'0	19'7	19'7	23'0	16'7
Diameter at crucible (high),	10'5	9'8	7'2	8'0	8'0	8'2	8'2
Diameter at crucible (low),	8'2	9'8	4'9	7'4	7'4	8'2	8'2
Contents in cubic feet,	13'420	9'040	9'465	12'290	12'290	16'950	8'617
Hot blast stoves — C=Cowper; W= } Whitwell, }	5 C	4 C	—	3 W	4 W	6 C	Cast-iron pipes.
Number of tuyeres,	4	4	4	4	4	4 lar. 2 sm.	—
Pressure of blast in mm. of mercury,	11-12	10-11	—	10-11	10-11	11-12	—
Temperature of the blast,	—	—	1370°	to 1480°	F.	—	—
Daily production of basic iron in tons,	75	55	—	60	60	80	—
Date when furnaces were put in blast,	1880	1887	Out of blast.	1885	1884	1889	Out of blast.

The limestone used for the furnace is obtained from Saint Charles and Bellevue, the former carrying 2'5 per cent. silica and three per cent. of alumina, the latter four per cent. silica and 3'25 per cent. alumina, both containing about fifty-two per cent. of lime. The Mont St. Martin blast furnaces have been specially adapted for the basic process. The following are analyses of the different grades of pig iron produced by these furnaces:

GRADE.	Manganese.	CARBON.		Silicon.	Sulphur.	Phosphorus.
		Comb.	Graph.			
Special foundry No. 1,	1'30	3'20	0'40	2'70	0'02	0'09
Special foundry No. 2,	1'10	3'05	0'50	2'10	0'04	0'07
Special foundry No. 3,	0'90	3'00	0'60	1'80	0'06	0'06
Special foundry No. 4,	0'85	2'50	1'30	1'40	0'09	0'06
White basic,	1'50	3'00		0'20	0'04	2'00
Mottled basic,	2'00	3'20		0'35	0'02	2'20

The analyses of the last two samples (basic pig) are interesting, as they are supposed to combine all the elements which constitute an ideal basic pig, viz: low silicon, very low sulphur, high phosphorus, and a moderate amount of manganese. The following analyses of the slag obtained from these furnaces will be of interest in this connection :

	Silica.	Alu- mina	Pro- toxi- de of Iron.	Pro- toxi- de of Man- ganese.	Lime.	Sul- phur.
Vitreous basic,	32'5	16'5	1'4	1'6	46'0	0'8
White basic,	31'4	14'4	0'9	1'1	50'0	1'1
Yellow basic,	31'5	14'9	2'6	1'5	48'5	1'3
Black basic,	32'2	15'0	3'0	2'4	45'0	1'4
Foundry,	33'0	17'0	1'3	—	46'5	—
Foundry,	34'0	14'0	1'3	1'0	47'0	—

The pig iron is conveyed direct, while still liquid, to the basic Bessemer converters, which are located between the blast furnaces and the principal rolling mill. The three fifteen-ton converters are arranged around the same pit and are served by the same central casting crane, assisted by three primary and two secondary ingot cranes. The daily output of the three converters is from 250 to 300 tons, or a weekly production of from 6,000 to 7,000 tons. The basic linings of the converters last from 160 to 170 blows, the plugs from sixteen to twenty-five blows. The dolomite is calcined in three cupolas with natural draught, the firing lasting eight hours; the whole charge of the cupola is drawn at one time. From sixty to seventy tons of basic slag are produced daily, carrying from fifteen to 16'5 per cent. of phosphoric acid. It is ground and sold as a fertilizer for

about thirty-five francs per ton at the works. The dolomite used for the basic lining is obtained from Ciney and Liège, the former containing about 0·8 per cent. silica, two per cent. alumina and iron, and ninety-six per cent. lime and magnesia, the latter 1·5 silica, 2·3 alumina and iron, and ninety-four per cent. lime and magnesia.

The following diagram (*Fig. 20*) shows the order of the elimination of elements in the pig under treatment in the basic Bessemer converters. The next diagram (*Fig. 21*) shows the composition of the slag during the operation.

The Longwy Company has adopted a scale of grades for their steel, and publishes the following table of tests and analyses to show the quality. The tests are made with round forged bars, sixteen millimetres in diameter, of 100 millimetres in length, the analyses being approximate averages:

SCALE.	Tensile Strength. Kg. Per Sq. mm.	Elongation. Per Cent.	Manganese.	Carbon.	Phosphorus.
No. 1, hard,	75 to 70	12 to 14	0·1 to 1·2	0·3 to 0·35	about 0·1
No. 2, hard,	70 to 65	14 to 16	0·85 to 1·0	0·26 to 0·3	about 0·1
No. 3, medium,	65 to 60	16 to 18	0·7 to 0·85	0·22 to 0·26	about 0·1
No. 4, medium,	60 to 55	18 to 20	0·6 to 0·7	0·18 to 0·22	about 0·1
No. 5, soft,	55 to 50	20 to 22	0·5 to 0·6	0·15 to 0·18	—
No. 6, soft,	50 to 46	22 to 24	0·6 to 0·8	0·10 to 0·12	0·08 to 0·01
No. 7, very soft,	46 to 42	24 to 26	0·4 to 0·0	0·09 to 0·1	0·08 to 0·01
No. 8, extra soft,	42 to 38	26 to 28	0·25 to 0·4	0·08 to 0·09	0·05 to 0·08
No. 9, special,	under 38	over 28	0·25 to 0·3	0·08	0·03 to 0·05

The ingots made at Longwy are taken direct to the rolling mills, of which there are several. The appliances include a universal rolling train with rolls twenty-nine and one-half inches in diameter, also a train of three high rolls. There is a train of reversible twenty-six inch rolls, driven by a 2,500 horse-power engine. There is a fifteen-ton steam-hammer in the same building, with a reheating furnace, and crane for handling the ingots.

The reheating furnaces are worked in connection with vertical boilers, heated by the waste gases. The works are lighted by electricity. A testing machine of 100 tons, of the Marié type, is employed for flexion and traction tests, and another machine of the Trayvou type is employed for compression and other tests.

PONT-À-MOUSSON (Meurthe-et-Moselle).

These are one of the most important smelting works in the east of France; they have four blast furnaces, each making about forty-five tons of foundry pig daily, the most of which is made on the spot into pipe. The pipe foundry is one of the largest of the kind in France, having twenty-five vertical casting pits, and capacity for making nearly

FIG. 20.

two miles of pipe per day, varying from $1\frac{1}{2}$ inches to 6 feet in diameter and 13 feet in length. An example of the largest work was shown at the Exhibition, in the form of a socketted T-pipe, 13 feet long and 6 feet internal diameter in both limbs, which were moulded without a pattern and cast vertically.

The Pont-à-Mousson Company is one of the most flourish-

ing concerns in France. It was established in 1856 by Mansuy & Co., with a paid-up capital of 1,600,000 francs, and in 1886 was formed into a company with a capital of 2,047,500 francs. It is stated that since their foundation some 6,000,000 francs have been spent on the works, the greater part of which was drawn from the profits. In 1888, the total length of cast pipe produced was 547 miles, about

FIG. 21.

one-fourth of which was exported. The whole plant gives employment to over 1,300 men.

DENAIN AND ANZIN COMPANY.

The works of this company are located in the northern district near Valenciennes. They consist of ten blast furnaces and two Bessemer plants of two ten-ton converters each besides numerous puddling and reheating furnaces. Four of the blast furnaces were represented by models at the Exhi-

bition. They have Whitwell stoves, and pneumatic hoists for ore and coke. The most interesting part of these furnaces is the device for getting rid of the slag, which is granulated by running it into a large semi-circular basin placed in front of the furnaces, which receives the waste water from the tuyeres and other cooling appliances. The basin is divided by a middle wall, so that one-half is allotted to each pair of furnaces. The granulated slag is removed by a bucket elevator into cars and taken to an adjoining works, where it is converted into bricks and artificial stone. These bricks have a good surface, resist frost, and, although very strong, are sufficiently open texture to allow nails to be driven into them.* The total annual production of pig-iron at these works is about 150,000 tons, of which 120,000 tons are converted into steel and malleable iron in the company's own works. They employ over 4,000 men, which, with their families, form a settlement of over 10,000 persons in the vicinity of the works. The company have established schools, hospitals, infirmaries, etc., for their welfare, which seems to be considered to an exceptional degree.

The following grades of iron and steel are made at the Denain & Anzin Works :

<i>Grade.</i>	<i>Carbon. Per Cent.</i>	<i>Tensile Strength. Kilogs. per mm.</i>	<i>Elongation, † Per Cent.</i>
1 Extra soft homogeneous iron,	·04 to ·06	33 to 35	29 to 31
2 Soft homogeneous iron,	·06 to ·08	35 to 37	27 to 29
3 Merchant iron,	·08 to ·12	38 to 40	25 to 27
4 Soft construction steel,	·15 to ·20	42 to 46	22 to 25
5 Medium soft construction steel, ·20 to ·30		45 to 50	18 to 22
	Limit of elasticity,		
6 Steel for springs, etc.,	·39 to 41	59 to 62	15 to 20
	kilog. per mm.		
7 Steel for springs, etc.,	45 to 48	65 to 70	10 to 15
8 Extra hard tool steel,	—	70 to 80	8 to 10

VALENCIENNES WORKS (Nord).

The foundries, forges and steel works of Valenciennes, in the Department of the Nord, are situated between the Escaut and the line from Valenciennes to Cateau. They cover an area of more than 60,000 square metres. Some

* *Engineer* (London), November 8, 1889, p. 387.

† Calculated on a bar 200 millimetres long.

60,000 tons of steel are annually produced by the Bessemer and the Siemens-Martin processes of manufacture. The works employ 1,500 hands, and are fitted with steam-hammers of fifteen, ten and three and one-half tons, respectively, a rolling-mill for the production of plates, a reversing rolling-mill, rail-testing machinery, foundries, a forge with twenty-eight puddling furnaces, twelve reheating furnaces and four trains of rolls, capable of producing 50,000 tons of iron per annum. At Trith-St.-Léger, near Valenciennes, the company own another forge, with fifteen puddling furnaces and auxiliary reheating furnaces and rolling-mills. They have also four blast furnaces at Jarville, near Nancy, where they produce annually about 100,000 tons of pig iron.

The Valenciennes Works use the oölitic ores of Chavigny, which are smelted at Jarville, some addition of mangani-ferous ore being made in the blast furnace. A proportion of phosphoric pig from England and Germany is used in the converters. The new large rolling mill recently erected at these works consists of three pairs of twenty-four-inch rolls in one line, driven directly by a two-cylinder horizontal engine of 5,000 horse-power. The feeding arrangements are very complete, including line rollers on both sides, carriers for shifting the blooms from groove to groove at each pass.

Sixteen Gijers soaking pits, with cranes for working same, are now in operation at these works, this establishment being one of the few in France in which the soaking pit has been adopted.

NEW PROCESSES.

Under the head of new iron and steel processes, or perhaps, to speak more exactly metallurgical devices, which have been introduced in France, within the last ten years we might place three. The Valton-Rémaury system of chrome iron-ore linings for open-hearth furnaces, the so-called Robert process and the Rollet process for producing purified castings. The Robert process, however, can only be called new by courtesy, for to any one familiar with the development and early history of the Bessemer process, it is evident that it is simply a resurrection of one or more of

the ideas and methods used by Bessemer in developing his process as it now exists.

CHROME IRON-ORE LININGS.

The use of these ores as neutral linings for open-hearth furnaces seems to have been experimented with in several of the works on the Continent and in England for a number of years past. The works of Bell Bros., at Port Clarence, near Middlesborough, England, appear to have gone into the thing rather more extensively than elsewhere, but with what results I have been unable to determine.

The ore is first roasted, then made into bricks or else broken into lumps (none larger than about three inches in diameter), which are bound together with lime mortar. Such bricks are very expensive, but last a long time, and, it is claimed, in the long run, are much more economical than dolomite linings. Bricks, however, need not be used, as the hearth and sides of the furnace can be lined with a mixture of three parts chrome iron-ore and one of lime, as free as possible from silica. The chrome ore should be as rich as possible, containing from forty to forty-five per cent. of Cr_2O_3 .*

It is claimed that this lining resists equally well silica and silicious slags and remains neutral to strong bases. At the Putiloff Steel Works near St. Petersburg, Russia, it was found that the chrome-ore linings did not work well unless covered with a layer, about two inches thick, of dolomite or quartz; the dephosphorization being effected by this means and by the use of lime or dolomite fluxes. It is stated † that in the Finnish and Russian open-hearth steel works chrome-iron ore beds are no longer used, as it was found that the larger lumps broke away from the material composing the furnace bed and rose through the molten metal, thus causing the bed to wear away rapidly. This breaking away of the larger lumps does not take place at once, but only after the furnace has been in operation some time. On the other hand, Rémaury claims that one furnace at Alais,

* *Iron* (English), September 30, 1887, p. 304.

† *Journal of the Iron and Steel Institute*, No. 1, 1889, p. 341.

in France, has been running with the same bottom for three years.

At the Port Clarence Works (Bell Bros.) the charges, I understand, consist of ten tons of pig iron, three tons of iron scrap and two tons of steel scrap, to which afterwards limestone and iron ore are added. After melting from two to five hours, the slag is tapped off, carrying with it about fifty per cent. of the phosphorus. More iron ore is then added. The time required to convert one charge varies from nine and one-half to ten hours. From 0.7 to 0.8 per cent. of ferro-manganese is added in the casting ladle. It is claimed that the steel thus produced contains only from 0.02 to 0.04 per cent. phosphorus—a small amount of chromium seems to be taken up by the steel. The pig iron used averages about the following composition: Carbon, 3.6; silicon from 1.8 to 2.5; phosphorus, from 1.5 to 1.6; sulphur, 0.02 to 0.06, and manganese, 0.5 to 0.6 per cent.

ROBERT-BESSEMER STEEL PROCESS.

The Robert converter, or, as I have termed it heretofore, the Robert-Bessemer converter,* is a slight, if any, modification of what was known as the Walrand converter, which was erected at the Stenay Steel Works (Meuse), France, in September, 1885.† The Walrand converter seems to have been successfully operated, for several years with both acid and basic linings, in a number of places in France and Germany. It was not, however, until given the name of Robert or Bookwalter steel process, that it attracted any considerable attention. As this converter is fully described in the above-mentioned paper, it will be unnecessary to give any details in this place, except to mention that the converters have a D-shaped cross section, are mounted on trunnions like a Bessemer converter (*Figs. 22 and 23*). The tuyeres are all in the same horizontal plane on the flat side of the converter, with their axes at various angles to its horizontal axis. The converters are mostly

* "The Robert-Bessemer Steel Process," *Journal of the Iron and Steel Institute*, No. 2, 1889, p. 266.

† *Journal of the Iron and Steel Institute*, No. 2, 1886, p. 659.

FIG. 24. The Walrand Converter.

FIG. 25. Adamson's Converter.

that when the blast is turned on it will impinge on the surface of the metal. In *Fig. 25*, we have shown a form of converter patented in England by Daniel Adamson in 1863*. In the specification, Adamson states that the tuyeres may be placed horizontally or diagonally towards the bottom of the converter. In another description of this converter, it is stated that when only small amounts of metal are used the inclination of the converter can be so varied as to bring the tuyeres near to a horizontal line.† This expedient is sometimes resorted to with the ordinary Bessemer converters; it can, therefore, hardly be considered uncommon.

What is claimed as novel in the Robert converter is "a combination of several parts in a converter having a flat side in which flat side are ranged the tuyeres in a plane horizontal to the axis of the converter, and all in the same plane." "The tuyeres having an inclination to enable a rotary motion to be imparted to the metal bath and being so disposed that by tilting the converter in the trunnions the depth of the metal over the tuyeres can be regulated."

Without commenting upon the alleged novelty of the Robert converter, it should be stated that it seems to have produced excellent results wherever put in operation; but whether this is due to any new principle or to any combination of several old ones, I am unable to determine. It is, however, as Sir Henry Bessemer states,‡ "unquestionably true that in certain cases small converters can be used to great advantage."

Some of the claims for the Robert converter seem reasonable enough, while others are, as far as I know, unsubstantiated.

For instance, it is claimed, with the Robert converter, that the loss of iron from the cupola to the ingot is only from twelve to thirteen per cent. in acid lined and from sixteen to seventeen per cent. in basic lined. I have heard it stated on good authority that with some of the acid-lined

* English patent, December 22, 1863, No. 3,233.

† Adamson's Converter, *Engineer* (London), 1864, vol. 18, p. 147.

‡ *Journal of the Iron and Steel Institute*, No. 2, 1886, p. 639.

converters used in this country this loss was reduced under ten per cent.

This is difficult to believe for several reasons, but chiefly to what appears to be an abnormal amount of *brown smoke* produced during the blow. M. Gautier states that in France, with small converters, no one could make a ton of steel with less than twenty per cent. waste of pig iron.* In small converters the oxide of iron has not time to burn the other elements, so it goes off in red or brown smoke, hence the greater waste. The exceptionally high temperature which is obtained in the Robert and in all small converters is due to a great extent to the extra oxidation (burning) of the iron. "It is a practical fact that the weight of pig iron required to make a ton of steel in small converters was much more than that required in a converter of the ordinary size.† It is claimed that the Robert is the only side-blown converter which is suitable for the 'basic process, as the large amount of slag produced would soon choke up a similar fixed converter.

ROLLET PROCESS FOR PRODUCING PURIFIED CASTINGS.

The process of fining castings, as here described, is intended to be auxiliary to the manufacture of special qualities of steel, its object being to eliminate sulphur, phosphorus and silicon from the castings. It consists in melting castings or pig, or maintaining them at a very high temperature under a double action, slightly reducing and slightly oxidizing, in the presence of a slag obtained by admixtures of limestone or lime, iron ores and fluorspar, in proportions depending on the quality of the pig or castings employed. The apparatus employed for this purpose, *Fig. 26*, is a blast furnace or modified cupola, using coke and a hot blast. The burdens are introduced in the same way as in blast furnaces and cupolas. It consists of a part *A*, an independent shaft *C*, several rows of tuyeres *FFF*, a siphon arrangement *SS*, for separating metal from slag, and of a front chamber *M*. Externally, it is composed of sheet iron

* *Journal of the Iron and Steel Institute*, No. 2, 1886, p. 673.

† Gautier, *Journal of the Iron and Steel Institute*, No. 2, 1886, p. 673.

and steel; internally, at the bottom, it is lined with any suitable refractory material, preferably with magnesia. It is cooled externally at all parts liable to injury by currents of cold water. The tuyeres are arranged in several rows, above one another. They are water tuyeres and project into the furnace. The hearth is situated as near as possible to the lower row of tuyeres. A single hole *K*, serves for tapping both the metal and the slag. In tapping, the metal is separated from the slag by means of the siphon, *SS*, which is so arranged in relation to the hole *QO*, as to prevent the blast from blowing through. The metal flows out at *LSS*, and the slag at *QO*. The tuyeres are arranged in several rows, to facilitate the melting of all the substances charged. They are arranged one above the other, so as to raise the temperature along a line passing in front of their nozzles, and so ensure a good working. They project inwardly, so that their ends may not get clogged by the colder and more decarburized matters which descend along the walls. The approximation of the lower row of tuyeres to the hearth is intended to prolong the action of the blast upon the slag, which at that point is light and frothy, and upon the metal which flows down through it, so as to ensure a greater elimination of phosphorus. The separation of metal from slag, as soon as both are removed from the action of the blast, is carried out so as to prevent the phosphorus already eliminated from going back into the metal, a result which would be produced by the reduction of the phosphoric acid of the slag by the action of the coke and the metal. Another object of the separation is to prevent too great a recarburization of the metal. The temperature of the blast is as high as possible, viz: 400° at least, so as to ensure the good action of the tuyeres. These would otherwise get clogged by the slag, which is always very refractory and stiff, or by the decarburized metal which forms at their ends. The furnace being in operation, metallic iron is formed, by the action of the blast and the iron ore upon the cast iron or pig, on the bottom part of the walls, where it adheres, thus forming, after working twenty-four to thirty-six hours, a substitute for the original lining.

The furnace may thus be run for an indefinite period of time. But it will be preferable, after two or three months' working, to reline the upper portion, as the bricks will then

FIG. 26.—Rollet Cupola.

be worn out by attrition. The production is from fifty to seventy five tons per day of twenty-four hours. The product obtained usually has a white, spongy appearance. The slags are yellowish white. They contain almost all the

phosphorus eliminated from the cast iron or pig in the state of phosphoric acid, and only a part of the sulphur in the condition of sulphide. The elimination of the sulphur is complete up to ninety-nine per cent., and even more. That of the phosphorus amounts to eighty or eighty-five per cent., in exceptional cases to ninety per cent., and more. And as the recarburizing action of the coke sets a limit to the decarburization of the cast iron, a casting once treated may be treated again in the same manner, by which means, beginning with any sort of castings, a carburized iron purer than the best Swedish iron used for cementation can be obtained. The carburized iron thus obtained may be used in Siemens furnaces with acid bottoms, where it may be employed to a greater extent than cast iron or pig, and so diminish the weight of wrought iron be required. It may be puddled, in order to produce iron destined for melting on acid bottoms, for crucible melting, or for cementation. It can also be used as cement steel for crucible melting, mixed with iron.*

This process or metallurgical device for purifying iron castings appears to be as yet in but an elementary stage of development. I have not, at least, seen or heard of any reliable data obtained from a steady prolonged use of the furnace. It would therefore appear premature to pass an opinion upon its merits.

I think it very doubtful, however, if such a large amount of phosphorus can be eliminated in this way, although I believe a large proportion of the sulphur might be so eliminated.

In concluding this report I cannot but feel how incomplete it is and how little it shows of the advances France has made in the iron and steel industries. If the great Paris Exhibition of 1889 teaches us nothing else, it will have fulfilled its mission in showing the world the remarkable thrift and industry of the French people. France has had enough disasters within this century to have forever ruined any country similarly situated, and yet we see her to-day, while perhaps not so powerful and rich, as vigorous and enter-

* *Jour. Iron and Steel Institute*, No. 1, 1890, p. 154.

prising as ever. It is easy to understand how so small a country as England should be rich and powerful, for she has had no disastrous wars to sap the strength, and within her comparatively tiny borders are vast stores of coal and iron, to say nothing of the strong and vigorous race which develop and use them. The mineral resources of France, on the other hand, are, as far as we know, very much more limited, and as we have seen, a very large proportion of the coal and ores she consumes are imported. Truly, Helvetius has said, "*le bonheur des peuples dépend et de la félicité dont ils jouissent au dedans et du respect qu'ils inspirent au dehors.*"

PRECIOUS STONES.

BY GEORGE F. KUNZ.

[*A Lecture delivered before the FRANKLIN INSTITUTE, February 17, 1890.*]

[*Concluded from vol. cxxx, p. 182.*]

The families with iridescent interior layers are the following: among the cephalopods, the nautilus and the ammonites, the latter wholly fossil. In both these groups the removal of the outer layers of the shell reveals the splendid pearly surface beneath. Modern nautilus shells are often "cleaned" with dilute acid to fit them for use as ornaments, and frequently this is done partially, elaborate patterns being formed by leaving parts of the white middle layers to contrast with the pearly ground. Among the fossil ammonites, the same effect is produced, very often naturally by decay of the outer layers; and no artificial pearl work can equal the richness of color displayed by many of these specimens.

The subdued beauty and purity of the pearl now renders it even more popular than before, and it never commanded such high prices as during the past ten years. At present no jewel is considered in quieter or better taste than the pearl. This unusual demand has had the effect of greatly stimulating the search for them, especially on the west coast of Australia, Thursday Island, the Sooloo Archi-