to indicate that the maintenance of the lining of the furnace bottom is likely to prove a troublesome matter, owing to the necessity for preserving openings in it for the negative electrodes. On this account the writer does not expect to see the Girod type of furnace employed for the production of structural steel or of rail steel, which demand large units and low producing costs.

In its own special field, however, the Girod steel-refining furnace would appear to have a promising future before it, and the number in use will no doubt be rapidly increased as the good points of the furnace become better known and appreciated.

CHAPTER VI

THE STASSANO ELECTRIC STEEL FURNACE AND PROCESS

Major Ernesto Stassano, of the Italian Army (Artillery), appears to have been the first electro-metallurgist to apply electric heating *on a practical scale* to the smelting and refining of iron and steel.

Stassano's first English Patent, No. 11604, describing an electrically-heated furnace for producing steel direct in one operation from iron ore was taken out in 1898, and experimental trials were commenced with this furnace at Rome in 1899. Fig. 39 shows a sectional elevation of this earliest form of steel-smelting furnace. Although this design was soon discarded by the inventor, it is interesting to note that it closely followed the blast-furnace form, and that this type of furnace has been copied in the successful electric iron-smelting furnaces of Grönwall and Heroult, now operating in Norway and in California (see Chapter III., p. 27). Stassano's early attempts to produce steel direct from the ore in one operation were doomed to failure for the reasons given in Chapter III., and the trials of the process and furnace at Darfo in Northern Italy in the years 1900—1902, led to no practical or financial success.

The Italian Government became interested however in the furnace, and instituted trials of the same for refining the special brand of steel used for manufacturing shells and ammunition at the Royal Arsenal, Turin, the first 250-kw. Stassano furnace being erected here in 1903.

Since that year the Stassano electrical method of refining mild steel used for shells has been in continuous operation by the Italian Military Authorities at Turin. A new company, the Forni-Termo-ellettrici Stassano, was also formed in 1905 to take over the assets of the earlier company, and an electric steel works was planned and partially erected at Turin. This works was equipped with six furnaces ranging from 100 h.p. up to 1,000 h.p. capacity, and produced chiefly steel-axles for railway carriages, waggons and motor-cars. The venture was not a financial success, and in 1909 one portion of the electric furnace plant was transferred to the works of the Elba Company at Portoferraio, and the remainder to the works of the Milan Steel

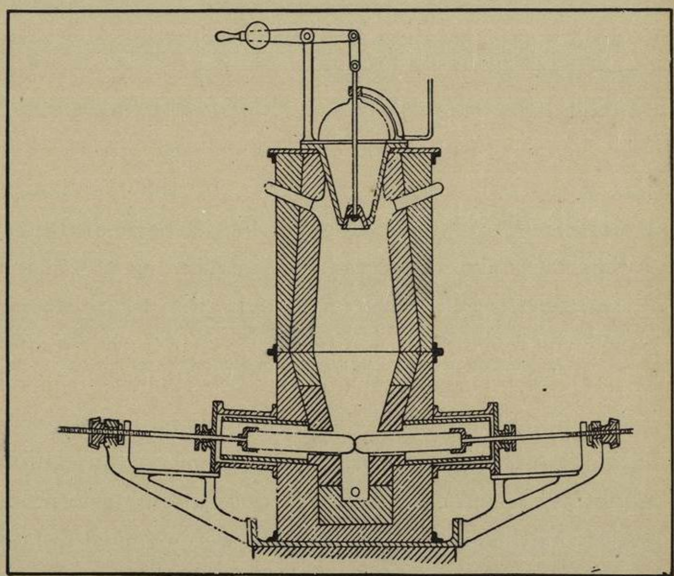


Fig. 39.—The Stassano Furnace, earliest form.

Company. In the light of the latest developments of electric steel refining, it would appear that this early attempt to run a steel works entirely by electricity was somewhat premature, and that even to-day, with seven years additional experience of electric steel refining at one's command, there are comparatively few places in the world where a similar undertaking could be carried on with commercial success.

The Stassano electric steel-refining furnace has proved most successful when used (in the 250-kw. size) as a refining and melting furnace in steel foundries where small and intricate

castings are made and form the chief portion of the output. A large number of these small furnaces, producing 1 ton of steel per charge, are now at work, or in course of erection, in various parts of the world.

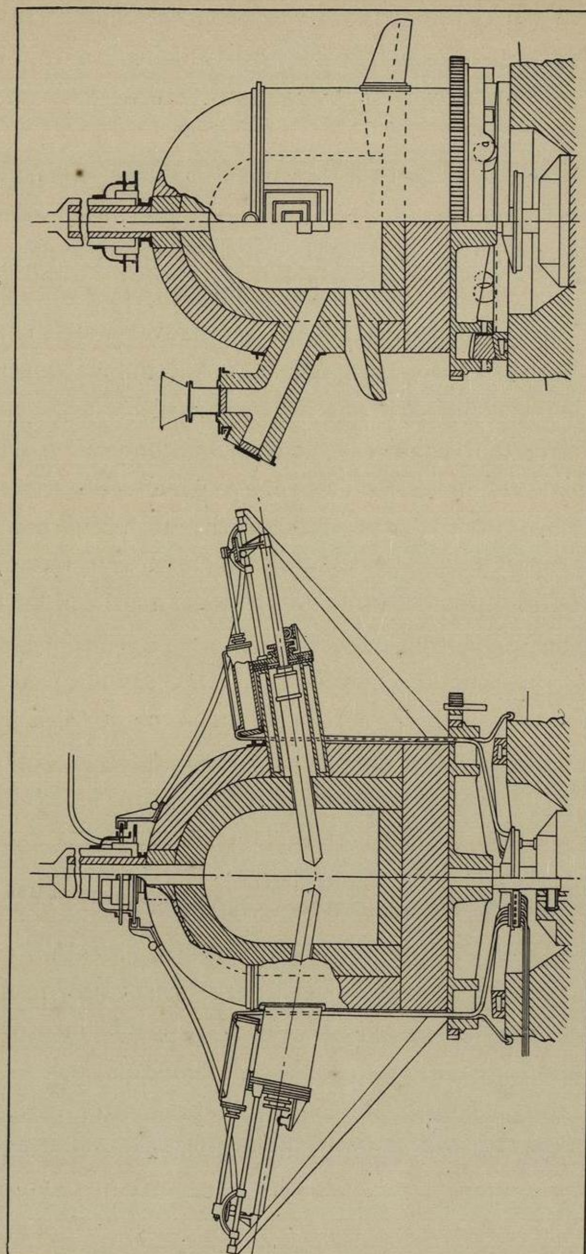
The power consumption of the Stassano furnace per ton of steel produced, according to the published figures, would appear to be higher than that of the Heroult and Girod types, and although in the smaller furnaces this disparity is not of great importance, on account of the higher selling value of the steel castings produced, it becomes a considerable handicap when the cheaper varieties of rail and constructional steel are to be manufactured. Owing to the higher power consumption per ton of steel produced, the 1,000 h.p. Stassano furnaces which were erected at the Forni-Termo-elettrici Stassano works at Turin did not prove very successful and, so far as the writer is aware, no Stassano refining furnace of this size is now under construction. As regards the smaller furnaces, between ten and twenty are in operation or in course of erection in the leading steel-producing countries, and some details of this type of furnace will now be given, together with tests of the steel produced, estimates of working costs, and information (so far as this is available) concerning the steel works where this type of furnace is in use.

The Stassano Rotary 200 h.p. Furnace (First Form).

This furnace was of the arc type. The special feature which differentiated it from all other electric arc furnaces for iron and steel refining was the use of the rotary principle in order to obtain a better mixing of the charged materials and a more uniform heating effect. This design is protected by English Patent No. 8288 of 1902, and the following description was given by the inventor himself in an article published in 1908 in the Journal named below.[1]

Figs. 40 and 41 show diagrammatically that the rotary electrical furnace consisted of a sheet-iron cylinder with a conical

[1] *Electro-chemical and Metallurgical Industry*, August, 1908.



40. 41.

FIGS. 40 and 41.—The Stassano Rotary Furnace, first form, in Sectional Elevation.

roof, lined on the inside with refractory material. The melting chamber was also cylindrical, with a cupola of fire-brick. Suit-

able openings were provided for the electrodes, which projected towards the centre of the furnace, their ends being at proper distances from each other for the formation of the arcs, and at a convenient height above the bottom.

The electrodes were protected on the outside by water-cooled cast-iron cylinders fitted to the mantle of the furnace. The movement of the electrodes was controlled by guide-rods fitted outside the furnace. To the end of the carbon electrodes a metallic rod was attached, the end of which was connected to a flexible cable leading beneath the furnace to the slip-rings for current supply.

Above each of the water-cooled cylinders which protected the external portion of the electrodes, a small hydraulic pressure cylinder was provided; the piston rod of this was connected with the metallic rod of the electrodes, and thus controlled the movement of the electrodes and regulated the distance between their terminals within the furnace.

The lower part of the furnace, somewhat above the bottom, was surrounded by an L-shaped rail of cast-iron running upon conical rolls. Below the rolls there was another cast-iron rail, resting on the inclined top of the pit-wall and forming the support of the furnace. The longitudinal axle of the furnace was, therefore, inclined by a certain angle against the vertical.

The furnace was revolved by means of a strong gearing at the bottom. Insulated copper rings were attached to the head wheel, which by means of copper bars and the above-mentioned elastic cables, transmitted the current to the electrodes. The current was supplied from the generator to a series of brushes, disposed round the top of an iron support in the centre of the pit and cables. These brushes and slip-rings maintained continuous connection between generator and electrodes during the rotation or standstill of the furnace. Besides the brushes, there was a distribution valve, mounted on the top of the stationary iron support, which distributed the water for the pressure regulators and also for the cooling cylinders protecting the electrodes.

The discharge was at the bottom of the melting chamber; opposite to it another opening was left for charging. In the centre of the brick cupola an exit was provided for the volatile products of the furnace reactions. Through this exit the gases escaped into a metal tube shut by a sand valve, and leading to a vessel filled with water, from which the gases might escape into the open air. This arrangement prevented air entering from the atmosphere into the melting chamber. No air could enter by the charge or discharge holes, since the pressure inside was higher than outside.

It was claimed by Stassano that this design fulfilled satisfactorily the three essential conditions of good work in electric steel refining, namely, (1) a neutral atmosphere in the melting chamber, (2) highest possible arc temperature, (3) good admixture of the molten materials without contact with the electrodes.

The following figures, based on the practical results obtained with the 200 and 1,000 h.p. rotary furnaces at Turin, show the average power consumption and output per charge for the different classes of steel produced :—

TABLE XVII.

—	Power Consumption.	Output.
200 h.p. Furnace:		
Steel for projectiles .	1,250 kw. hrs. per metric ton	653 kgs.
Mild steel for castings .	1,260 „ „ „	730 „
1,000 h.p. Furnace:		
Steel ingots for projectiles . . .	958 „ „ „	3,900 „
	918 „ „ „	3,900 „

The percentage of the scrap recovered as steel in the Stassano type of furnace is unusually high, owing to the exclusion of air from the melting chamber, and consequent absence of any loss from oxidation during the refining process. In melts where

the charge and output have been weighed, the loss due to oxidation was only 1½ per cent.

As regards the cost of working, the trials at Turin yielded the following figures per ton of steel produced :—

TABLE XVIII.

	£ s. d.		£ s. d.
Electrodes 10 kgs.	0 2 6		
Refractory materials	0 8 0½	to	0 12 1
Wages for three men	0 9 11		
Water for cooling purposes . . .	0 0 6		
	£1 0 11½	to	1 5 0

An estimate based on the results obtained at an installation at Bonn, in Germany, gave the following figures :—

TABLE XIX.

	Per metric ton of cast steel. £ s. d.
1. Raw materials, including addition of chromium to finished steel	3 9 5
2. Electric power (1,000 kw. hours at ·536 penny per kw. hours)	2 4 8
3. Refractory materials for linings	0 11 10
4. Labour	0 9 11
5. Interest and depreciation	0 4 11
6. Electrodes	0 2 6
7. Water for cooling purposes	0 0 6
	£7 3 9

The New Form of Stassano Furnace.

The new Stassano furnace combines the advantages of both the rotary and tilting type, and is protected by English Patent No. 8901 of 1911. The following description is based on that given in the Patent Specification :—

The furnace comprises a casing of sheet-iron or other material, enclosing a melting chamber A (Fig. 42) of refractory material. This chamber in the case of small furnaces has the form of a hollow sphere, with the lower portion cut away by a plane constituting the bottom of the furnace. In furnaces of large dimensions, the interior cavity has preferably the form of an ellipsoid, with the bottom similarly cut away in the lower portion. This form of furnace chamber has the advantage that the walls of refractory material are rendered more resisting, and can be reinforced by a filling or envelope B of refractory earth. At the same time, the chamber serves to reverberate better the heat emanating from the arc or arcs.

After describing the system of electrode arrangement and control which follows closely that of the earlier furnace, the Patent Specification describes the special feature of the new furnace in the following terms:

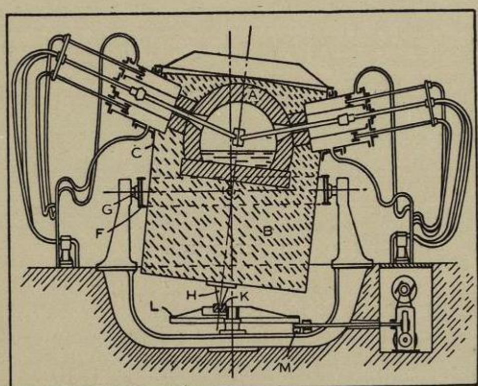


Fig. 42.—The Stassano Rotary Furnace, latest form, in Sectional Elevation.

The mounting of the furnace is effected as follows:—

At two diametrically opposite points of the casing (see Figs. 42 and 43), are two pivots (D) mounted in two supports (E) rigidly connected with a ring encircling the casing, and having two pivots (G) arranged at an angle of 90° with respect to the pivots (D). The pivots (G) are supported by the standards, which are connected together by a stirrup passing below the bottom of the furnace. From the method of construction it is apparent that the furnace chamber is so suspended that its vertical axis can assume any inclination to the vertical. The casing (C) has projecting from its lower end a pivot (H) the axis of which coincides with that of the casing. The end of this pivot is rounded, and has a bearing in a groove or socket formed in a member (K) adjustably mounted on a spoke of a wheel (L) journalled on the stirrup. The wheel (L) can be rotated by any suitable means, as for example, by means of teeth on its periphery engaging a pinion (M) operated by means of a shaft and worm gearing, driven by a small electric motor. By turning the

wheel (L) on its axis the pivot (H) is displaced in a circle, so that the axis of the furnace traces out a cone with a circular base. This movement, by reason of the double suspension of the chamber, imparts a rotative movement to the molten mass contained in chamber (A), which movement may be continuous or intermittent, corresponding to the motion of the wheel (L). The wheel can, if necessary be turned alternately first in one direction and then in another. By this method of suspension, the furnace body oscillates simply on the points (D) and (C), and can be subjected at will, either to a rotary or to a tilting movement.

Figs. 44 and 45 show the older type of furnace installed at the Royal Arsenal, Turin, Italy, and Figs. 46, 47, and 48 are photo-

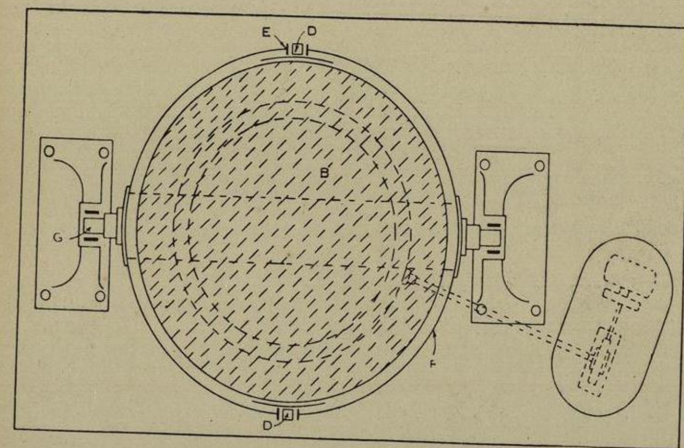


Fig. 43.—The Stassano Rotary Furnace, latest form (plan).

graphs of the new rotary furnaces, taken at the works of the Electroflex Steel Company, Newcastle, England.

No figures have yet been published showing the power consumption or costs of operating this new type of furnace. No doubt these figures will soon be available; for two furnaces of this type have been erected at the works just named during 1912 also one in Russia and another in Austria.

As regards the total number of Stassano furnaces now operating, a comparative table of the Electric Furnaces in operation compiled by the Gröndal-Kjellin Company in 1909, gave the number of Stassano furnaces at that date as eleven, and the aggregate tonnage capacity as 16·90 tons steel per day. If we add to this total the five furnaces referred to above, we obtain a total of sixteen furnaces, with a daily capacity of 24 tons of finished steel. These may be seem small totals, in comparison with the figures for the Heroult and Girod furnaces given in Chapters IV.

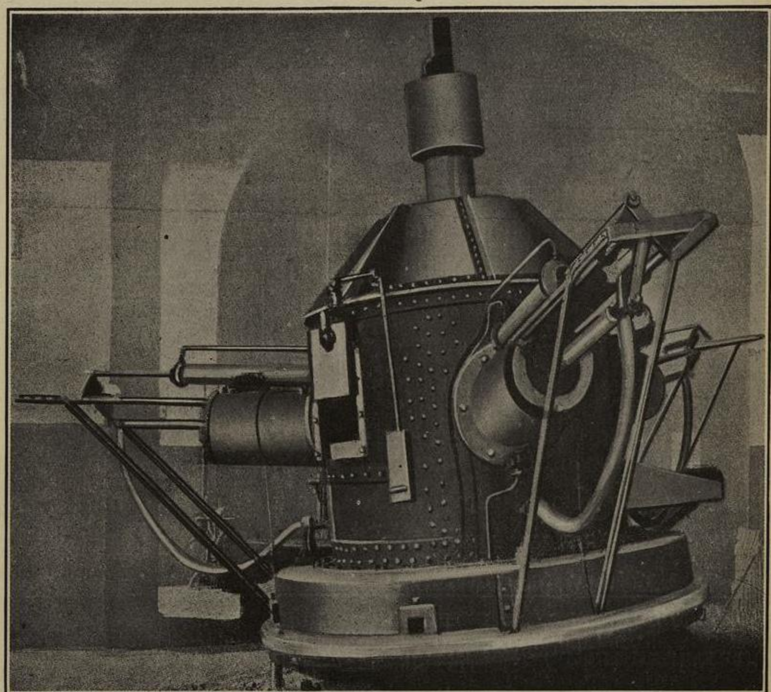


FIG. 44.—The Stassano Rotary Furnace (250 h.p.) at the Royal Arsenal, Turin.

and V.; but as already explained, the Stassano Rotary furnace has been found most satisfactory in the small-sized units, producing only 1 ton of steel at each tapping operation; and the aggregate capacity of the sixteen furnaces now operating is therefore bound to be small.

As proof of the opening which now exists in Europe and America for small electric furnaces in foundry work, the follow-

ing extracts from speeches delivered at the Fifteenth Annual General Meeting of the American Electro-chemical Society during a general discussion upon the *Electrometallurgy of Iron and Steel*, are not without interest.

"We have some 6,400 foundries in North America, and very many of these are looking seriously into the production of small steel

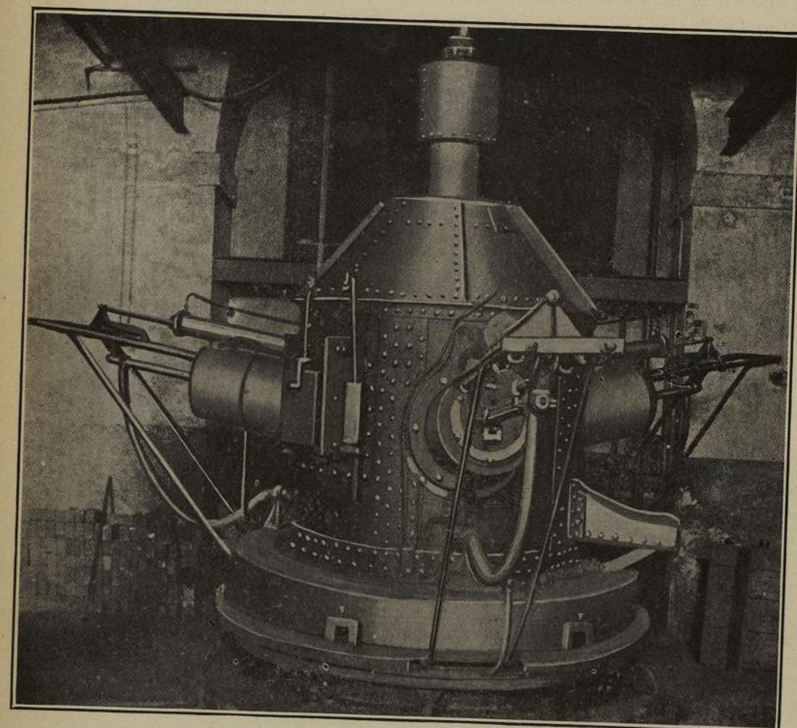


FIG. 45.—The Stassano Rotary Furnace (250 h.p.) at the Royal Arsenal, Turin.

castings. I would recommend that our members take up the matter seriously and in such a way that with a minimum of first cost and disturbance in an existing establishment, a small electric plant can be installed and operated, using only steel scrap and billets, preferably pre-heated by means other than electric—say the soaking pit, or regeneration of gas and air." *R. Moldenke.*[1]

"I have had a great many inquiries from foundrymen throughout

[1] *Transactions of the Amer, Electro-chem. Society*, Vol. XV., pp. 253—254.

the country as to how they could make their own steel castings to fill a wide variety of specifications, and in many cases the expense was almost a negligible quantity. The proposition was to be able to get delivery and to get quality. Those two elements were demanded, and a tonnage, in some cases, not to exceed 1,000 lbs. In many cases they want to make a comparatively short campaign in each one. If some process can be developed which will enable a manufacturing concern itself to make its own steel castings to fit in with its equipment, that is, fit the equipment it is manufacturing as it wants them, there will

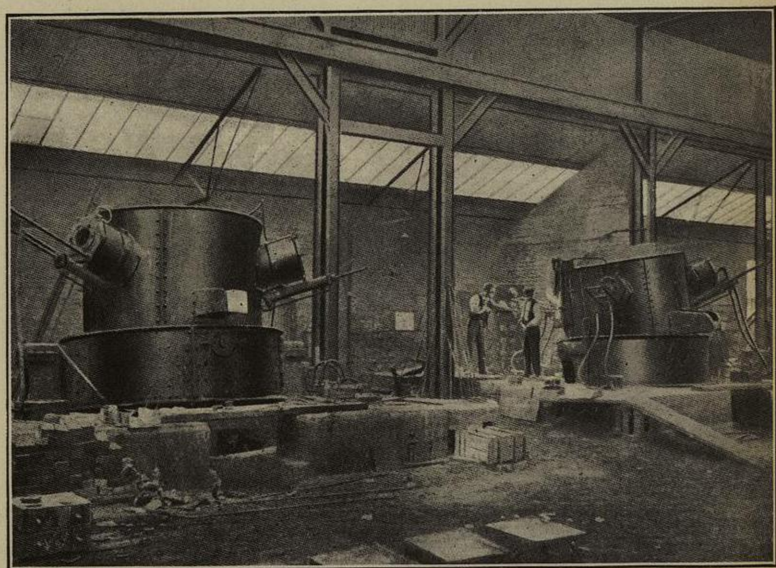


FIG. 46.—The Stassano Furnace at the Works of the Electro-Flex Steel Co., Newcastle, England.

be a demand for them. If the process will utilise waste material about the plant, that is, iron borings, steel borings and such material as that, so much the better, and every plant has quantities of that kind of material. It has seemed to me for a long time that the electric furnace was a solution of the problem." *H. M. Lane.*[1]

The following are details of individual installations:

Bonner Fraser Fabrik, Bonn-on-Rhine, Germany.—A 250 h.p. furnace of the older type was installed here in 1908. This furnace is operated by three-phase current supplied from the

[1] *Transactions of the Amer. Electro-chem. Society*, Vol. XV., pp. 253—254.

generating station of the Berggeist-Brühl Electricity Works. The current is supplied at a pressure of 5,500 volts; this is reduced to 100 volts between the two phases by a transformer placed near to the furnace. The cost of the current at the furnace terminals is ·536 penny per kw. hour. The raw materials used at this works are usually cuttings, turnings and scrap, costing from £2 19*s.* 6*d.* to £3 4*s.* 5*d.* per metric ton. Three and

FIG. 47.—The Stassano Furnaces and Casting Shop at the Works of the Electro-Flex Steel Co., Newcastle, England.

a half hours are required to produce complete fusion, and a further one and a half hours for the refining operation, equal to five hours per charge as poured. The entire charge of fused metal is poured at once and is used for fine steel castings, the usual composition of the refined metal being carbon ·08 to ·18 per cent., sulphur ·03 per cent.; phosphorus ·06 per cent. Occasionally castings of tool steel are produced, containing ·70 to 1·30 per cent. carbon, with or without the addition of nickel, chromium, or tungsten.

The "Elba" Company at Portoferraio.—This Company has taken over two of the Stassano furnaces operated earlier by the Stassano Electric Furnace Company at Turin, and according to Catani[1] had been working these furnaces with cold charges. The "Elba" Company, however, possess both a smelting

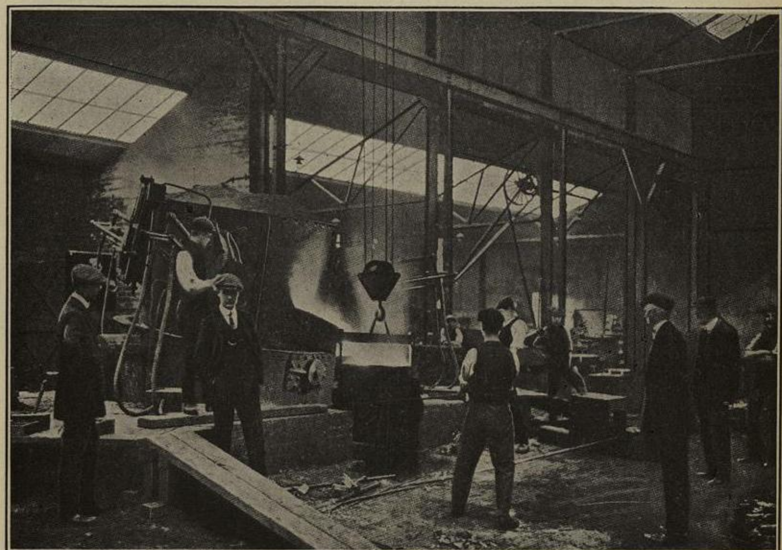


FIG. 48.—The Stassano Furnaces at Newcastle (discharging).

works and a Bessemer-steel plant at Portoferraio, and it is more than probable that liquid charging of the Stassano furnaces, in accordance with the most modern development of the electric steel refining process, has been adopted at this works.

The Stassano Electric Furnace Company.—Although this Company was not a financial success, some details of the equipment of the works at Turin may not be out of place here. The works were supplied with three-phrase current at

[1] See paper read before the Iron and Steel Institute in London, in October, 1911.

21,500 volts, by the Societa Anonima Elettricita Alta Italia, and the current pressure was then reduced by special transformers to the voltage required for working the furnaces. The six furnaces were of the following sizes and type:—

Horse-power.	Current.	Voltage.	Ampères.
2 at 100 . .	Single-phase .	75	1,000
2 at 200 . .	Three-phase .	100	900
2 at 1,000 . .	Three-phase .	150	2,700

The current supplied to the Steel Company varied between 350 kw. and 800 kw. (between 20 and 42 per cent. of the total capacity of the furnace plant). The steel castings produced were used chiefly for railway and automobile constructive work.

Weicheisen-Stahlgiesserei L. Gasser at St. Polten, in Austria.—This steel works has operated a 250 h.p. Stassano furnace of the older type since September, 1909. The current supply is taken from the distribution system of the Elektricitatswerk, St. Polten, and no difficulty has been experienced in running the furnace in parallel with the town's lighting and power systems. The raw material used for charging the furnace consists of 15 per cent. of hard steel scrap and the remaining 85 per cent. of wrought iron turnings, etc. During the early trials of the furnace the power consumption averaged 1,010 kw. hours per ton of material charged. No doubt this figure has been reduced as more experience has been gained in the use of the furnace, but no later figures are available for publication.

As regards other installations, the *Societa Elba* has one 1,000 h.p. at its works in Liguria, Italy; the *Fonderia Milanes d'Acciaio* has two 100-h.p. and one 250-h.p. furnaces in operation at its works in Milan; and at Odessa, in Russia, the steel foundry of J. J. Hoehn has two 250-h.p. furnaces of the new type, either in course of erection or in use. The Italian Navy yard is also about to adopt the Stassano furnace and process.

Chemical and Physical Tests of the Stassano Steel.

Catani, in the paper read before the Iron and Steel Institute in October, 1911,[1] has given a large number of tests of Stassano steel, and from the tables given in that paper the following figures have been taken:—

TABLE XX.

200 H.P. ROTATING AND TILTING FURNACE, PRODUCING A SOFT STEEL FOR CASTINGS. AVERAGES OF A LARGE NUMBER OF TESTS WITH DIFFERENT CHARGES.

CHEMICAL TESTS.

Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
·235 C	·195 Si	·047 S	·031 P	·546 Mn
·207 C	·236 Si	·043 S	·027 P	·421 Mn
·360 C	·140 Si	·052 S	·036 P	·486 Mn

PHYSICAL TESTS OF THE SAME STEELS.

No.	Tensile strength. in kgs. per sq. mm.	Elongation, per cent.
1	(Average) 43·5	18·2
2	(Average) 41·2	19·0
3	(Maximum) 45·0	19·4

The following are the average test results of steel made in the 1,000-h.p. furnace and intended for projectiles:—

TABLE XXI.

CHEMICAL TESTS.

No.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1	·310 C	·242 Si	·037 S	·023 P	·877 Mn
2	·450 C	·061 Si	·039 S	·029 P	1·211 Mn

[1] *Transactions of Iron and Steel Institute*, October, 1911.

PHYSICAL TESTS OF THE SAME STEEL.

No.	Tensile Strength in kg. per sq. mm.	Elongation, per cent.
1	58·0	21·4
2	70·0	17·0

In conclusion, the following analyses of special steels, made in the newer type of rotating and tilting 200-h.p. furnace may be given:—

TABLE XXII.[1]

—	Per cent.	Per cent. Carbon.	Per cent. Silicon.	Per cent. Sulphur.	Per cent. Phosphorus.	Per cent. Manganese.
Nickel Steel .	5·60 Ni	·180	·123	·048	·007	·780
Tungsten Steel .	1·56 W	·960	·123	·018	·018	·600
High Speed Steel	1·27 W 3·50 Cr	1·56	·062	·012	·010	·979

Note on Working of Stassano Furnaces in U.S.A.

Schmelz, of Detroit, reports[2] that the power consumption of the latest design of Stassano furnace is lower than the figures hitherto published. He himself has obtained two successive charges from one of these furnaces with power consumptions of 787 and 810 kw. hrs. per metric ton respectively, while the average over a long period of time for this furnace was only 900 kw. hrs. These figures are for cold charges.

[1] More recent tests of Stassano electric steel will be found in the Appendix, p. 232.
[2] *Iron Trade Review* (U.S.A.), December 5th, 1912.