THE FUTURE OF ELECTRIC FURNACES IN THE METAL INDUSTRIES OF INDIA

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SINCE I know little or nothing about "Light metals", I feel that my first task is to find some excuse for occupying this rostrum. Perhaps the organisers of this Symposium felt that a general paper dealing with the future of electric furnaces in the metal industries of India would promote a profitable and constructive discussion and at the same time provide some useful food for thought. Even an outline of the development and use of electric furnaces in the iron and steel industry may inspire ideas for those engaged in other metal industries.

Naturally the development and application of electric furnaces is dependent on the availability of relatively cheap electric power and their greatest development has taken place is those countries where hydro-electric generation has been possible. This availability of cheap power is especially important in countries where there is a shortage of metallurgical fuels, such as Norway, Sweden and Switzerland.

Progress of top-charge electric furnace installations in the U.S.A.

Year	Size of furnace	Size of Substation	kW/ft² hearth area	Tonnage per heat
1927	11 ft	5,000 kVA	100	12 tons
1929	12 ft	5,000 kVA	78	20 tons
1938	15 ft	12,500 kVA	110	30 tons
1940	17 ft	15,000 kVA	98	50 tons
1948	18 ft	16,000 kVA	90	70 tons
1949	19 ft	18,000 kVA	90	85 tons
1950	20 ft	25,000 kVA	110	95 tons
1951	22 ft	36,000 kVA	127	135 tons
1954	24 ft	36,000 kVA	104	150 tons
1954	24 ft 6 in	25,000 kVA	69	175 tons

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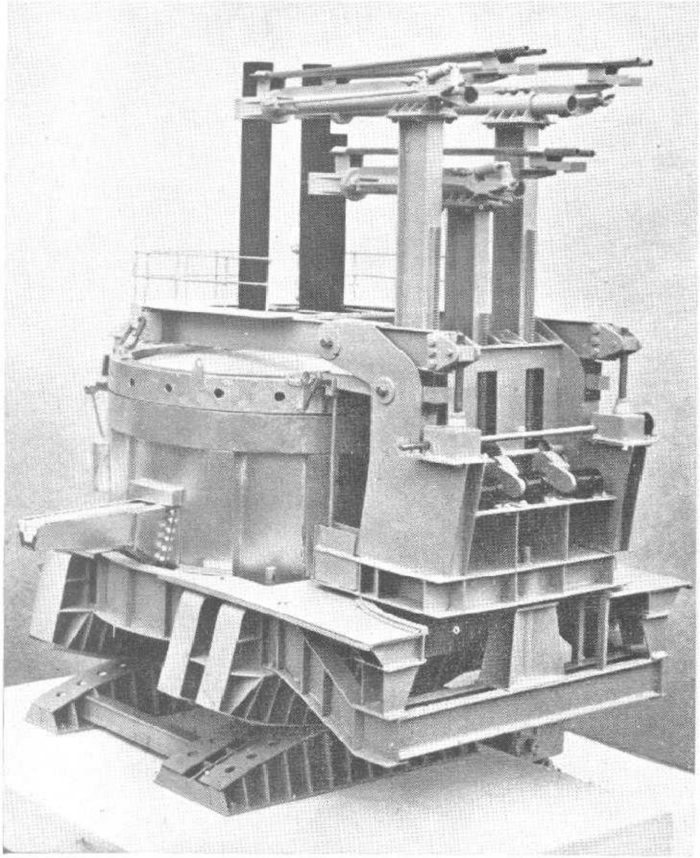
In India the natural conditions are very favourable for the development of water power. Mountain ranges stretch across the country from the Himalayas in the North to the Eastern and Western Ghats in the South, with the Vindhyas and Satpuras in the centre. The total economic hydro-electric potential of India has been estimated at 210,000 million kilowatt-hours, or 40 million kW at 60% L.F. At present, however, about one-third of this potential is being utilised, but in view of the rapid industrialisation that is taking place, it is obvious that in future cheap and abundant power should be available.

Development in the steel industry

My interest in electric furnaces dates back some twenty-five years, at a time when small capacity arc furnaces were being employed in some steel foundries in the U.K., whilst larger furnaces, up to about 25/30 tons capacity, were employed in the manufacture of special alloy steel. In some countries, such as Canada, relatively small arc furnaces were being used for the production of ordinary grades of steel, which was cast into small ingots, three to six inches square, that were subsequently rolled in a few passes into billets. A similar practice is in operation in India today, and, from what I have seen, it is very successful. Perhaps this practice in conjunction with continuous casting is a development of the future.

In 1939 in my presidential address at the Staffordshire Iron and Steel Institute, I endeavoured to crystallise my views on electric furnaces and their future. In the course of the brief discussion on this address, I did predict that within twenty-five years basic electric arc furnaces would be employed in England for the production of plain carbon commercial grades of steel instead of using the cold-metal basic open hearth process. This replacement of the cold-pig-and-scrap open hearth process by the electric arc process is rapidly becoming an established fact in the U.K.



A modern 60-ton electric arc furnace for melting steel.
(By courtesy of the Electric Furnace Co. Ltd.).

At the Rotherham branch of the United Steel Cos., they are replacing twenty-one basic open hearth furnaces by six 150-ton basic electric arc furnaces which will have an annual capacity of 1,350,000 ingot tons. These furnaces, which have a 24-ft diameter hearth, have a transformer rating of 40,000 kVA. It is anticipated that the first furnace will commence production in 1963, a fact which probably reflects one to the advantages of employing electric arc furnaces, namely, the speed with which they can be installed.

A similar experiment was undertaken several years ago by the Round Oak Steel Works, Brierley Hill, which is a subsidiary of the Tube Investments Limited. At this plant I understand that two 60-ton capacity electric arc furnaces are successfully competing with the open hearth furnaces at the same works in the production of plain carbon and special steels. This plant, which has recently been described in the technical press[1], appears to possess several important features which enable it to be employed either for bulk ingot production or for the manufacture of special alloy steels.

The replacement of open hearth furnaces by electric arc furnaces would appear to be due to the following factors:

1. The capital cost of an electric furnace plant is only 60% of the cost of an open hearth plant of similar annual capacity;
2. The electric furnace offers more precise control of the metallurgical process;
3. The thermal efficiency of the electric furnace (63·9%) is much greater than that of the open hearth furnace, which under the best conditions is under 30%.

A large capacity electric arc furnace (60 tons and over) can produce steel with a power consumption of 550 kWh per ton, and since a modern efficient thermal power station should be able to generate power at the rate of one kWh/pound of boiler slack, this is equivalent to a consumption of 550 lb of low grade coal per ingot ton. In the cold-metal open hearth furnace fired with producer gas, the coal consumption would be approximately $5\frac{1}{2}$ to 6 cwt of good quality producer coal per ingot ton.

Durrer and Heintze[2] have demonstrated that the refining of high percentages of liquid pig iron is a commercial proposition under Swiss conditions. It is obvious, however, that all these developments depend on the availability and cost of electric power.

In certain localities, such as South India, where there is a shortage of metallurgical coke, the electric reduction furnace, or the submerged arc furnace is being successfully employed commercially for the production of the ordinary grades of pig iron. In view of the limited supply of metallurgical coke in India, together with the tremendous hydro-electric potential, the further expansion of pig iron production in this type of furnace would appear to be in the national interest. To be economical, the price of 1 lb of coke should be 1·8 times the cost of 1 kWh of power.

Indirect arc furnaces

Indirect arc or arc radiation furnaces, in which the heat is produced by an arc formed between two electrodes above the charge and transferred to the charge by radiation and reflection, have a very limited application in the steel industry, but they are extensively employed, where cheap power is available, in the production of special irons and non-ferrous metals.

This type of furnace usually consists of cylindrical steel shell, through the axis of which two graphite electrodes enter the furnace. The steel shell may be lined with either acid, basic or neutral materials according to the process being employed or the metal being melted. These shells can be easily and quickly changed, giving great flexibility. In order to increase the life of the lining, it is usual for these furnaces to be of the rotating or rocking type. They would appear to offer the following advantages:

1. They ensure a regular supply of hot metal, thereby assisting continuous operation in the casting bay.

2. There is a more accurate control of temperature, which eliminates many foundry and casting bay troubles.
3. Since the furnace chamber is practically gas-tight, oxidation losses are reduced to a minimum and a higher metallic yield should be obtained.
4. A cold furnace can be started with cold materials and the charge be ready for tapping within two or three hours, or less in the case of some non-ferrous metals. It is possible to melt brass in twenty to twenty-five minutes with a power consumption of 280 to 300 units per ton. At one plant known to me, the replacement of the crucible process for melting brass by the indirect arc furnace resulted in an overall saving of 25%.
5. In works producing a wide range of specifications and different types of ferrous and non-ferrous metals, spare shells, which can be quickly changed, can be kept at hand, thus giving great flexibility.

This type of furnace would appear to offer many advantages for the production of a wide range of metals and alloys, especially brass, copper and alloys, bearing metals and special cast irons.

Induction furnaces

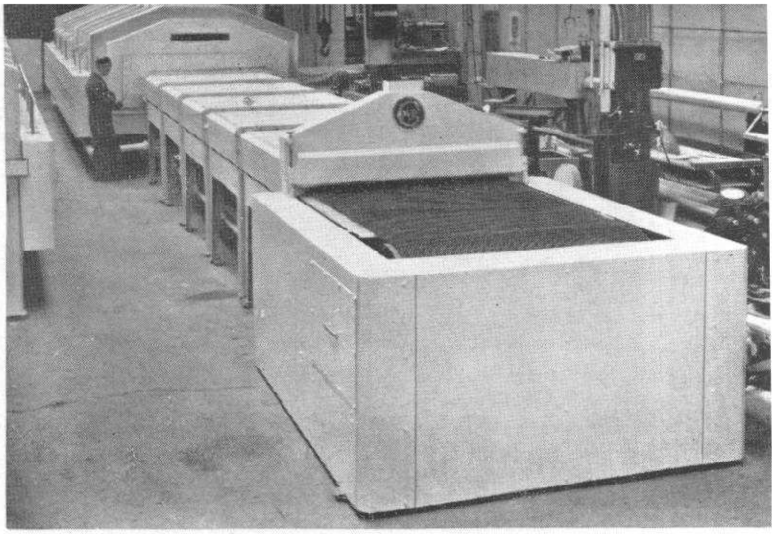
The high frequency induction furnace is rapidly replacing, if it has not already replaced, the crucible process for the manufacture of high grade special steels, largely because :

1. There is no carbon pick-up, which is very important when making very low carbon steels.
2. Sulphur contamination is unknown.
3. Temperature control is definite and accurate.
4. A high degree of homogeneity is obtained owing to the motion of the bath due to currents induced therein.
5. There is a high conservation of alloying elements since oxidation losses are reduced to a minimum.

This type of furnace is usually supplied with a current at 1,000 to 2,000 volts with a frequency of 1,000 to 2,000 cycles per second. They consist of a refractory crucible which is surrounded by a water-cooled copper primary coil. This refractory crucible may be either acid, basic or neutral in character. When melting a material which is a conductor of electricity, whereby a secondary current can be generated in the metallic bath, the crucible is made of a non-conducting material, such as silica or magnesite, but when melting a material which is a non-conductor the lining is constructed with a conducting material, such as graphite.

The current supplied to the primary coil in the low frequency furnaces is frequently at 2,200 volts and 900 amps., with a frequency of about 8 to 9 cycles per second. Although the high frequency furnace has largely replaced the low frequency furnace in the steel industry, low frequency furnaces find an appreciable application in the non-ferrous industry.

This type of furnace was first applied in the brass industry in the U.K. in 1922, but since that time there has been a considerable extension of its employment in this direction. Since the temperature can be very accurately controlled and volatilisation losses reduced to a minimum, its employment has an economic importance. It has been shown that the cost of producing brass for extrusion billets is about 60% lower when using the induction furnace than melting in coke-fired crucible furnaces.



Continuous belt type of electric resistance furnace suitable for brazing.
(By courtesy of G. W. B. Furnaces Ltd., England.).

The core type of induction furnace has also been used for the past thirty years for the melting of aluminium. In this type of furnace a secondary current is induced in a ring of metal located between the primary coil. The upper part of this ring is connected with the metallic bath, whereby the heat generated by the induced current is transferred by conduction and convection into the charge in the main melting chamber. The successful application of this type of furnace, however, depends on several factors including :

1. The size and shape of the loop or ring ;
2. The current density at which the loop is operated ;
3. The type of refractory which is employed for the lining or crucible ;
4. The thickness of this refractory lining.

Some of these factors tend to limit the application of this type of furnace, which in the non-ferrous industry is chiefly restricted to the melting of brass, tin and zinc.

The melting of aluminium and alloys containing aluminium in this type of furnace frequently presents difficulties owing to the fact that any aluminium oxide formed adheres to the walls of the channel, thereby interfering with the operation of the unit. This type of furnace is used, however, in the aluminium industry and the usual capacity varies from 300 to 1000 lb. These furnaces have a rating of 35 to 100 kW and give a melting rate of about 150 to 500 lb per hour.

The mains frequency furnace

In recent years the mains frequency furnace has found an increasing application, especially in the steel industry, where the greater turbulence of low frequency melting can be advantageously utilised. It is claimed that this increased turbulence imparted to the bath results in cleaner steel and more homogeneity.

In the aluminium and non-ferrous industry, the mains frequency furnace can generally overcome those problems which are associated with the channel type of furnace. Whereas the melting of aluminium and manganese bronze, phosphor-bronze and gun-metal may present troubles in the channel type of induction furnace, these troubles are not encountered in the mains frequency furnace.

The mains frequency furnace is almost identical with the high frequency furnace in construction, but it takes a current at mains frequency of 50 cycles per second, thereby eliminating the need of providing an expensive generator. It also produces, as already mentioned, a greater turbulence in the metallic bath. Although this increased turbulence has certain beneficial effects, it does tend to have a deleterious effect towards the life of the lining. Perhaps the most serious disadvantage of this type of furnace is the fact that a pre-cast plug of metal must be employed for starting the furnace operations.

Induction heating is also finding an increasing application in industry. By varying the frequency of the current in the primary, it is possible to vary the degree of heat penetration, which in certain applications is an important and attractive feature. The relatively small space requirements of this type of heating makes it an attractive proposition in the production line, but there are many difficulties associated with its application.

Resistance furnaces

In resistance furnaces the heat is produced by the electrical resistance of a definite conductor, which limits the maximum temperature that can be attained. Whereas in arc furnaces the maximum temperature is about 300°C, in resistance furnaces the maximum temperature is limited by the temperature at which the heating elements fail. This maximum temperature depends on the type of heating element employed. With a nickel-chromium alloy this maximum temperature is about 1000°C, but with silicon-carbide temperatures to about 1,750°C are possible. In carbon resistance furnaces even higher temperatures are attainable.

This type of furnace is chiefly employed for the heat treatment of metals and alloys, although it can be used for melting low melting point metals and alloys. Owing to the fact that the atmosphere and temperature can be very accurately controlled, it is an ideal furnace for heat treatment purposes. It is finding an increasing application for bright annealing and similar applications.

The power factor of resistance furnaces is generally very good and requires very little correction, whilst the load factor depends on the mode of operation. If the furnace is worked continuously a very steady load factor can be obtained. If intermittent operation is unavoidable, the furnace should, as far as possible, be warmed up during the "off-peak periods" when cheap power is usually available. It is obvious, however, that whenever possible, continuous operation of the furnace is the most economical procedure.

Electrically heated soaking pits have been adopted at a few plants. The heating elements generally consist of troughs of silicon carbide with high purity coke. They extend the whole length of the pit. The electrical energy is supplied by electrodes located in the end walls and the radiant heat is transmitted to the stock through arched openings in the brick work. When heating cold ingots the power consumption is about 330 kWh per ingot ton, which represents a thermal efficiency of 75%. With a relatively short track time this consumption can be reduced to 30 kWh per ingot ton.

Frequently these electrically heated pits are equipped with fuel burners, so that they may be heated to a predetermined temperature by an alternative and cheaper fuel, after which electrical energy is used for the final soaking, which permits very accurate control of the requisite rolling temperature.

Vacuum melting and treatment

During recent years considerable attention has been given to the vaccum melting and treatment of steel and other metals. These high vacuum furnaces may be provided with either induction or resistance melting units. The 600 lb (272 kg) vacuum furnace recently installed in Sheffield is provided with an induction melting unit, although some smaller units are equipped for resistance melting. The small high vacuum furnace at the Banaras Hindu University is of the resistance type. At present this furnace is being employed for a series of investigations on aluminium alloys and the benefits of this treatment would appear to be encouraging.

Considerable advantages can be achieved by brazing in vacuum as reported by Bernhard and Bumm[3].

Brazing

The principles and practice of brazing are so well known that there is no necessity to describe the process at length. Brazing is a convenient method of joining components, which themselves are easy to manufacture, whereas the manufacture of the complete unit which they form, might introduce difficulties. The production of intricate shapes or articles can be simplified, therefore, by brazing individual components to form a complete unit. The important aspect, however, is to ensure that the finished product is sufficiently strong to withstand the stresses and strain to which it will be subjected during service. The strength must approximate that of the machined units.

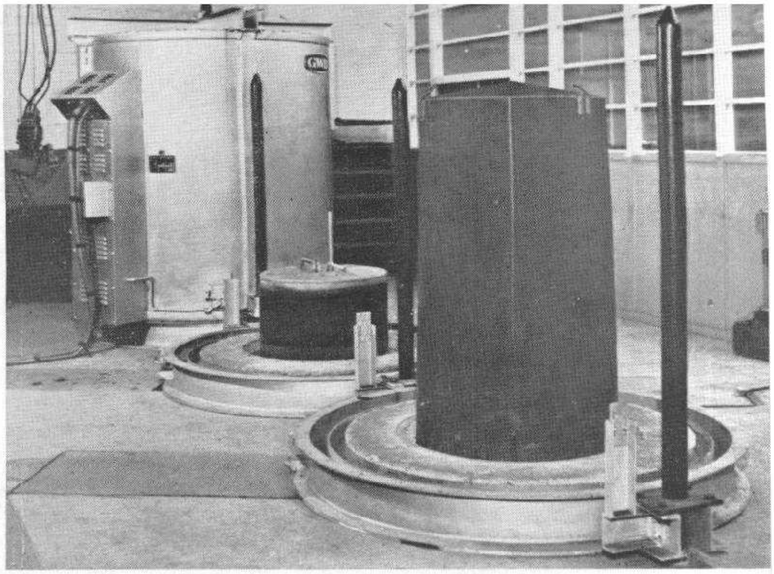
In this method of production, oxide-free parts or components are assembled, either by jigs or other mechanical means, and a brazing metal or alloy is applied on or near to the faces to be joined. The whole assembly is then heated in a suitable furnace to the melting point of the braze metal. This operation demands careful control of temperature and the furnace atmosphere, for which purpose an electrical furnace can be recommended owing to the more precise control which it affords.

These furnaces may either be batch type, semi-continuous or continuous, although the latest development is the employment of batch type vacuum equipment. This method is of special interest when it is desirable to avoid oxidation or the occlusion of gases.

When brazing comparatively small units the process can be performed in a continuous furnace of the continuous belt type. The assemblies are placed on a mesh conveyor belt, usually of nickel-chromium or some heat resisting alloy, and passed through a pre-heating, heating and cooling zone. Naturally this continuous operation offers many attractions, but for the heavy articles it may be necessary to employ a "belt-type" furnace. In this type of furnace the parts to be brazed are stacked on a base over which is placed a removable cover. The atmosphere within this cover can be controlled as desired. A heating bell is then placed over this protective cover. One heating bell can be employed alternatively for the treatment of several stacks. This type of furnace provides very accurate control of temperature and furnace atmosphere and is an ideal unit for brazing heavy articles.

The future

It would appear that the future adoption of electric furnaces in the various branches of the metallurgical industry in India will depend on the relative cost of power and other methods of heating. The development of India's vast hydro-electric potential, however, should result in a considerable expansion in this direction. The cleanliness of electric furnaces and the precise control that they afford, offer many distinct advantages. Even when the cost of electricity exceeds the cost of other forms of heating, electric furnaces, carefully selected for each particular job, may merit installation owing to lower melting losses, increased metallic yield and a higher quality of the product.



"Bell-type" electric resistance furnace suitable for brazing.
(By courtesy of G. W. B. Furnaces Ltd., England).

References

1. Walker and Whitfield.—Iron and Coal Trades Review, April 22nd, 1960.
2. Durrer and Heintze.—J. I. and S. Inst., May 1959,
3. Bernhard and Bumm.—Vakuum Techn., October 1958.