

MODERN MELTING AND HOLDING FURNACES FOR LIGHT METALS

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THERE are so many types of furnaces which are used for melting light metals. The modern melting plants incorporating an outline on the design of the furnaces and the experience gained by the leading manufacturers of such types of furnaces are described in brief in this paper.

In foundry practice, two different types of operation are performed, viz. the regular melting operation and the combined melting and holding operation.

The coreless mains-frequency crucible-type induction furnace as shown in Fig. 1 is used for melting operations to an ever increasing extent. The metal is held in a rammed ceramic crucible whose life will extend from one to five years dependent on attendance and maintenance. The metal to be melted or the liquid melt constitutes the secondary part of the furnace transformer. The heat is generated in the melt by the watercooled primary coil. The furnace is tilted by hydraulical means and the quantity of metal poured at a time can be adjusted to requirements.

The power installed in the furnace, i.e. the electromagnetic forces, provoke a more or less intensive bath motion which favours the melting of chips and thin-wall material but does not affect the melt. In contrast to the metal in furnaces heated by means other than induction, the metal in the above crucible-type furnaces is in contact only with cold air, so that the loss in weight of the bath is kept very low. Generally, the weight loss in the crucible-type furnace can be attributed almost exclusively to the burnt impurities whereas in the oil-fired rotary drum-type furnaces there is an additional loss of aluminium, the total loss being higher by 2 per cent despite the salt covering.

Because of its simple shape, the crucible is more easily cleaned than the channels of an induction channel-type furnace. The crucible-type furnace can be started with heavy scrap whereas the channel-type furnace must be started with a determined quantity of liquid metal which must be maintained also between individual melting or holding operations. If require-

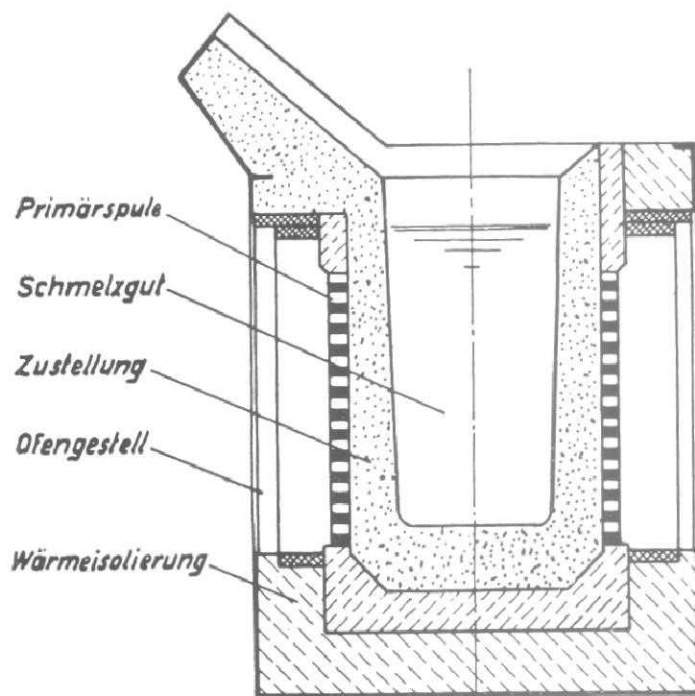


Fig. 1.

Sectional view of the coreless induction furnace.

ments demand an intermittent operation, the advantage of the crucible-type furnace lies in the absence of power losses as it is not necessary to hold any liquid metal at temperature. The channel-type induction furnace has lost much of its former importance because of the difficulties in melting chips, the onerous channel cleaning operations and the waste of power when the metal is held at temperature during breaks.

Generally, the cost of melting with electric means is considered to be too high. The economics of the cost of melting in an induction crucible-type furnace with

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those of melting in an oil-fired rotary drum-type furnace is given in Table I below :

TABLE I

Economy in the mains-frequency crucible type induction furnace as compared with the oil-fired rotary drum type furnace.

1.	Economy of metal, 2% = 20 kg, each DM 2	...	...	40'00
2.	Economy of wages	...	...	5'00
3.	Oil consumption, 190 kg, DM 20,—/100 kg. of oil	...	...	38'00
4.	Economy of salt	...	...	8'00
5.	Economy of lining material	...	...	0'80
Altogether				91'80
6.	Minus power consumption, 578 kWh/ton × DM 0'09 kWh	...	...	52'02
Total economy				DM 39'78

The metal economy given under Table I is the most important. As the oil consumption of the drum-type furnace is added to the economies made with the crucible-type furnace, the power consumption of the crucible-type furnace must be subtracted from the sum of the individual economies. The final economy, therefore, comes to almost DM 40'0 per ton. Thus, it can be said that the melting cost is the same in the two furnace types and that the gain lies in the reduced metal loss.

The standard sizes of crucible-type furnaces with their data such as capacities from 300 to 3,000 kg, respective power, melting rates in kg/hr, and power consumption in kWh/ton are given in Table II given under.

TABLE II

Holding capacity (kg)	Electric power (kW)	Melting rate kg/hr, for 700°C	Power consumption kWh/ton for 700°C	Furnaces built until Oct. 30, 1960
300	100	200	570	6
600	150	250	570	12
1,000	250	450	550	29
2,000	450	850	540	11
3,000	700	1,250	540	20
Total	28,600	51,600		78

The figures in columns 3 and 4 relate to a final temperature of 700°C and to a heated-up furnace run with a heel of liquid metal which is held back in the furnace to speed up the following melting operation and reduce the power consumption. The figures in column 5 relate to the number of plants built in the course of the last 7 years.

A plant made up of three core-less mains-frequency crucible type induction furnaces each with a capacity of 1,000 kg light metal and an electric power of

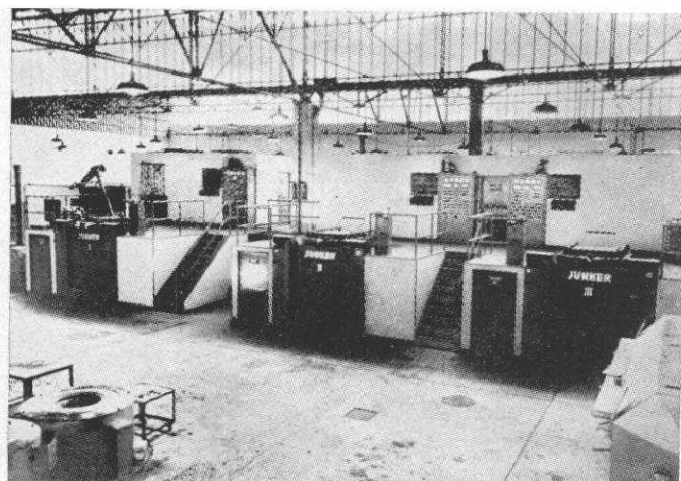


Fig. 2.

Plant comprising three coreless mains-frequency crucible-type induction furnaces.

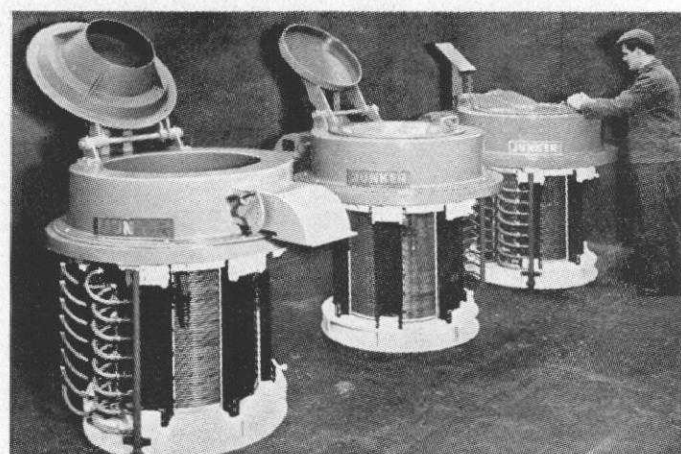


Fig. 3.

Coreless mains-frequency crucible-type induction furnace with removable crucibles (capacity of 150 kg and electric power of 90 kW).

250 kW (Fig. 2) has been run for some length of time in an important light metal works in Brazil for the production of pigs, pistons, permanent-mould and sand-mould castings. A furnace of capacity of 3 tons and an electric power of 700 kW is operated in an important Swiss concern to produce billets and slabs. Such furnaces are also in wide use in other foreign countries.

Fig. 3 shows three mains-frequency crucible-type induction furnaces of 150 kg capacity each to melt magnesium also.

The melt is held in a removable steel crucible which, after the melting operation, is placed into either a holding furnace or a casting machine. The same furnace type can be designed for tilting operations.

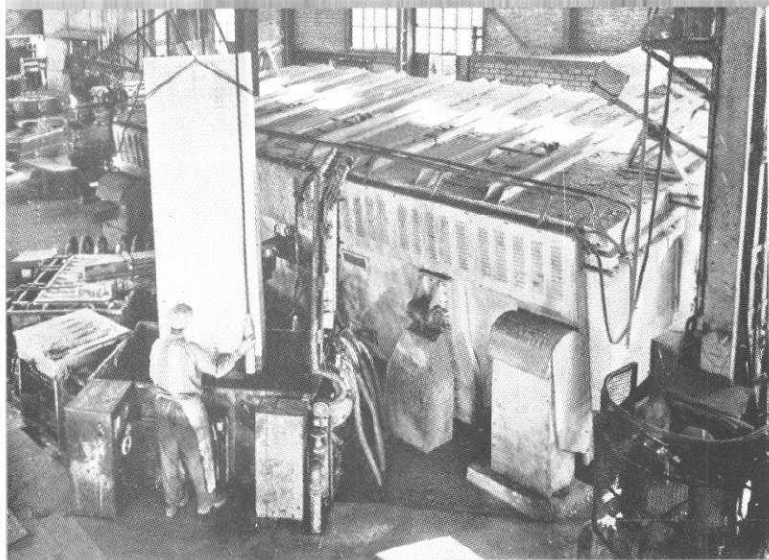


Fig. 4.
Electrically heated hearth-type furnace (capacity
of 18000 kg of light metal).

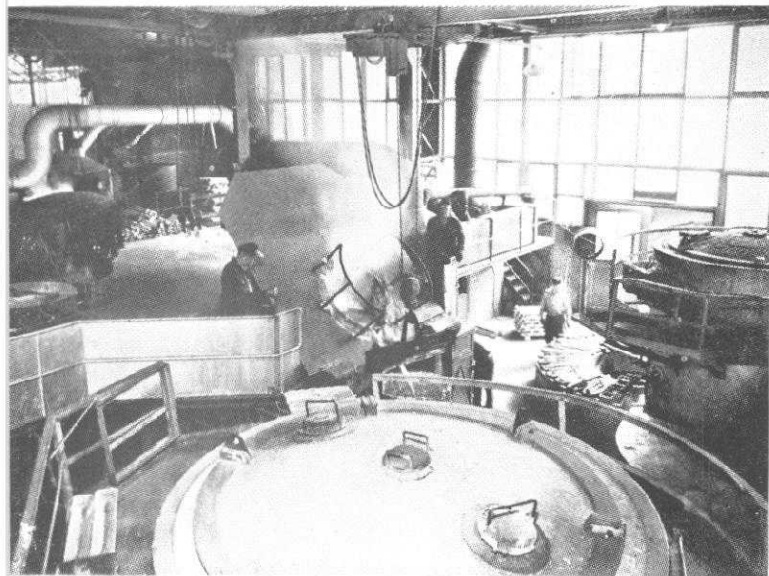


Fig. 5.
Light-metal plant comprising a coreless mains-frequency crucible-
type induction furnace and two induction-heated mixers.

The magnesium is then held in a cast steel crucible and the metal is poured from the crucible into ladles. Steel crucibles cannot be dispensed with when magnesium is melted as the known ceramics have not the necessary resistance to the metal. Aluminium, however, would rapidly corrode and use up any steel crucible.

The molten aluminium should be kept at temperature for some time after the melting operation, so that the somewhat lighter slag and the gases may separate

from the melt. The metal could be held in the mains-frequency crucible-type induction furnace but 30 minutes, as are approximately required for holding, would be lost to the melting operation. Practice proved the advantage of separate and independent melting units so as to have pourable metal available in the holding furnaces at any time.

Type and design of the holding furnaces vary in conformity with different operating requirements. Remelting works prefer either resistance-heated hearth-type furnaces or induction-heated mixers.

Electrically heated hearth-type furnace

A hearth-type furnace with a capacity of 18 tons used for the continuous casting process is illustrated in Fig. 4. The highly resistant electric heating elements are accommodated in the ceiling and make up for the heat loss of the furnace. The liquid metal is not treated with salt or chlorine in this furnace as they would affect the heating elements. Therefore, such treatment should be performed before the metal is transferred to the hearth-type furnace.

Induction-heated mixers

A mains-frequency crucible-type furnace with a capacity of 2 tons and 2 induction-heated mixers each with a capacity of 9 tons are shown in Fig. 5. The mixers are equipped with a lateral channel to make up for the heat loss. The low power installed in the mixers does not provoke any perceptible channel, walls are much less subjected to growing than those of a channel-type induction melting furnace. The liquid metal in the mixers can be treated with salt and chlorine. The metal is tapped through a lower spout. As the impurities float to the bath surface, the metal tapped from the furnace is clear.

The power of both the hearth-type furnace and the mixer can be increased to a higher value than is necessary to make up for the heat loss. Thus, slight superheating of melt and correction of composition is possible in both types. The advantage they both have over fuel-fired furnaces is that the metal in these furnaces does not absorb any gas during holding periods.

The two furnace types are suitable to feed not only continuous casting machines or permanent moulds but also ladles for pouring into sand moulds or smaller holding furnaces from which the metal is ladled or continuously poured. In medium-size works, the metal is often poured from the melting furnaces direct into small holding furnaces where it is held for some time. The small holding furnaces are also either resistance-heated or induction-heated.

Stationary resistance-heated crucible-type furnace

The best known of the small holding furnaces is the stationary furnace with replaceable crucible which is

resistance-heated from without and used to feed permanent moulds or pressure casting machines (Fig. 6). The liquid metal can be cleaned in this furnace by means of salt and chlorine. Then the metal should be held for approximately 30 minutes. The furnace need not be held at temperature during operation. The main disadvantages of the furnace are the high wear of the crucible and the power consumption in continuous operation, which is higher than that with a channel-type furnace.

Tiltable crucible-type furnace

A furnace equipped with a rammed ceramic crucible which can also perform as a ladle is illustrated in Fig. 7. The crucible is closed by a cover with incorporated heating elements. The furnace is tiltable and the metal can be poured either in small quantities or steadily into a continuous casting machine. The liquid metal should be cleaned with salt and chlorine prior to placing the cover on the furnace, so that the heating elements are not affected. The ceramic lining is much cheaper than a graphite crucible but the power consumption in continuous operation is higher than that of a channel-type furnace. The furnace need not be held at temperature during breaks.

Stationary induction-heated holding furnace

This furnace as shown in Fig. 8 is also equipped with a rammed ceramic crucible which is heated by means of lateral induction channel. The bath can be cleaned with salt or chlorine. The power consumption in continuous operation is lower than that of the resistance-heated furnace but the furnace must be held at temperature during breaks, i.e. a heel must be left in the crucible, so that the total power consumption increases. The liquid metal is ladled from this stationary furnace and is either poured into permanent moulds or used for pressure casting processes.

Tiltable induction-heated holding furnace

The furnace described above can be had for tilting operations as shown in Fig. 9. The channel is in front to keep the metal inside when the furnace is tilted, so that the electric connection with the metal in the crucible is not interrupted. The furnace lends itself to smooth tilting operations as are necessary to feed a continuous casting machine. Several companies pour the metal from the furnace direct into bigger permanent moulds.

Induction-heated automatic light-metal pouring furnace

The automatic casting furnace (Fig. 10) is an offspring of the channel-type induction furnace. The furnace is used to feed pressure casting machines or permanent moulds with shot weights of more than 4 kg. The shot quantity can be adjusted with an accuracy of ± 20 grams. This accuracy does not

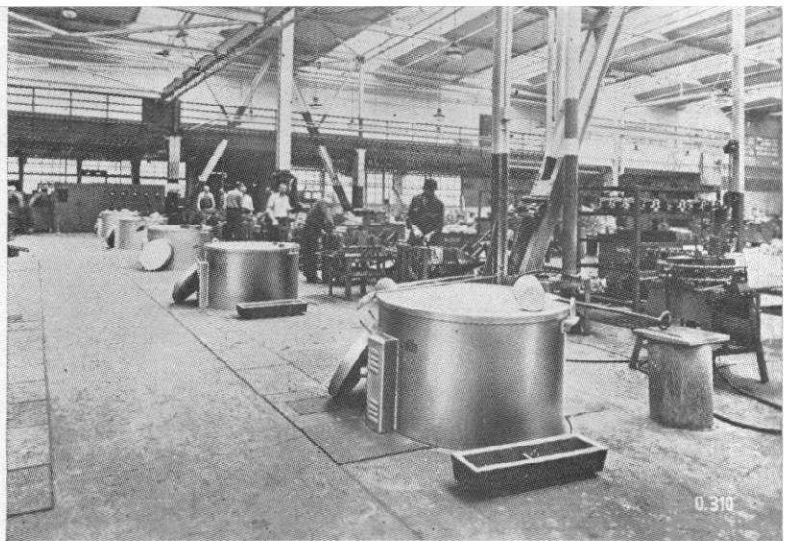


Fig. 6.
Stationary resistance-heated crucible-type furnace for light metals in an automobile works.

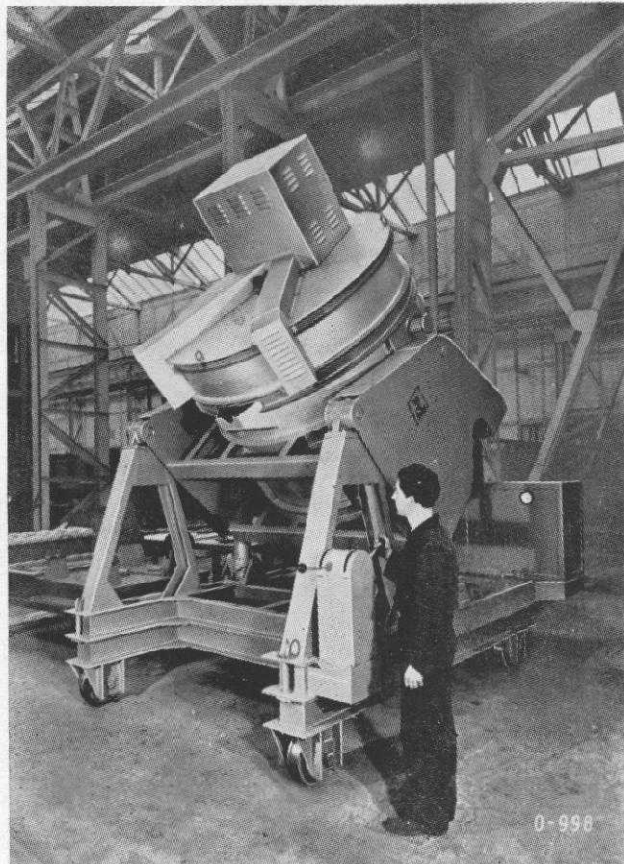


Fig. 7.
Tiltable crucible-type furnace (capacity 2,200 kg of light metal), equipped with electric ceiling heating elements.

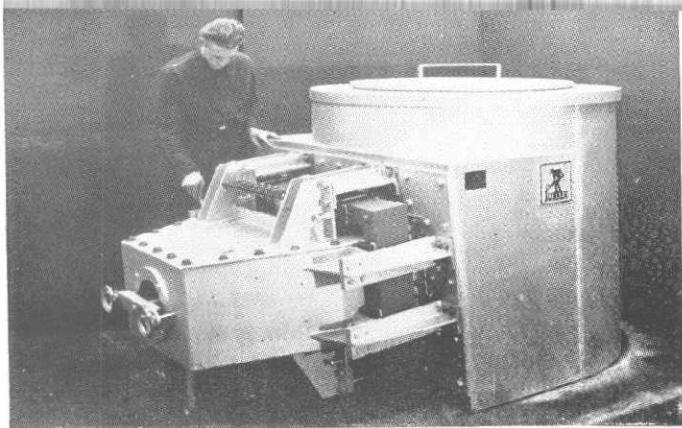


Fig. 8.
Stationary induction-heated holding furnace (capacity of 400 kg of light metal).

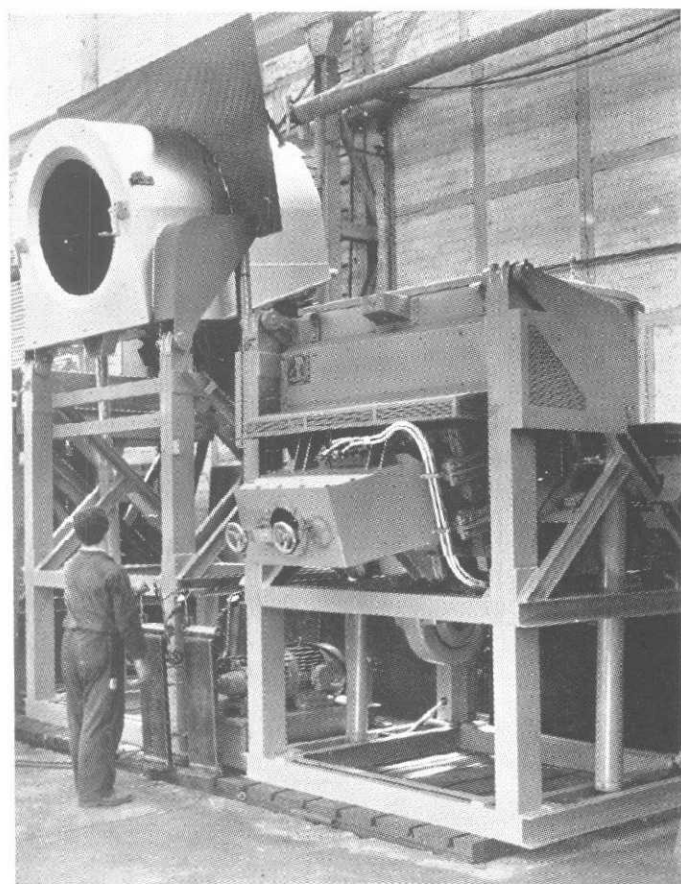


Fig. 9.
Tiltable induction-heated holding furnace (capacity of 750 kg of light metal).

depend on the height of the bath level. The liquid metal is taken at a point below the bath level and is thus very clean. The furnace helped to improve the

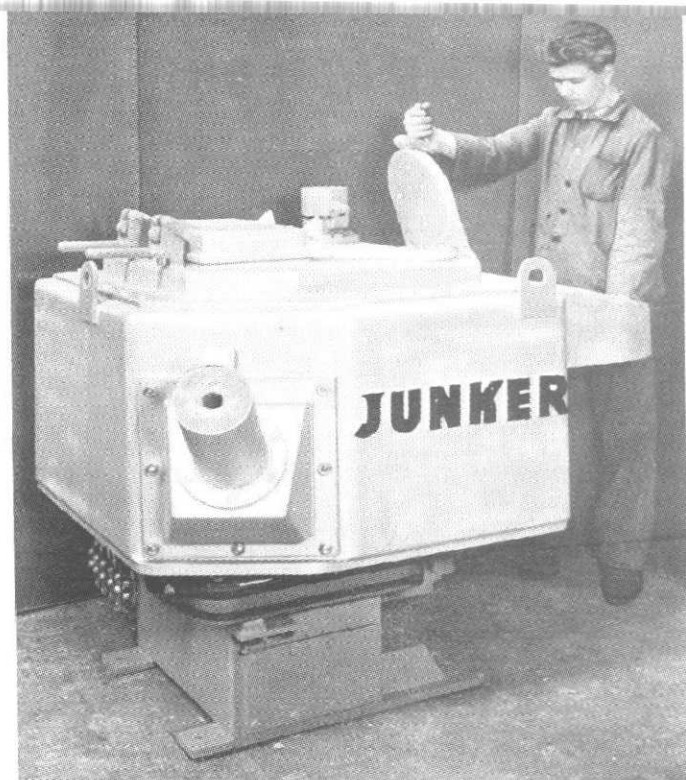


Fig. 10.
Induction-heated automatic light-metal pouring furnace.

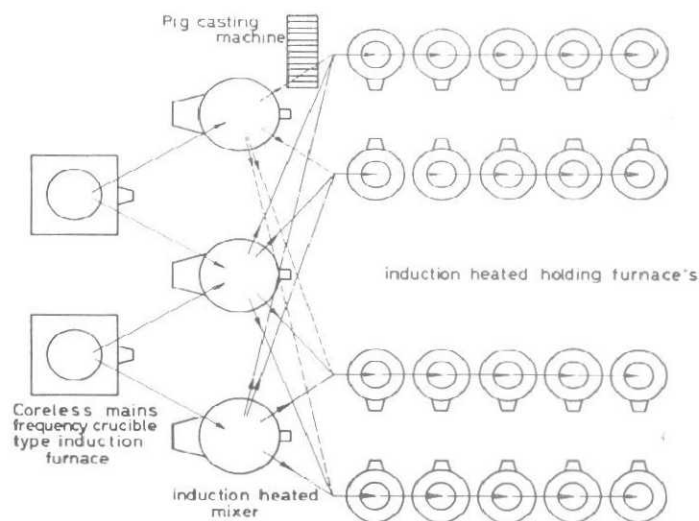


Fig. 11.
Model of a modern large-size light-metal foundry.

physical and mechanical properties of materials and ameliorated the working conditions for the operators.

Modern foundry practice

In a large-size light metal foundry plant, as per

layout given in Fig. 11, the metal is melted in coreless mains-frequency crucible-type induction furnaces and then fed through a runner into mixers containing different alloys, part of which is poured into a pig conveyor. The balance is transported in ladles to induction-heated holding furnaces, each holding furnace being fed with the alloy that is wanted at the place. Thus, melting operations are entirely independent from pouring operations and vice versa. The equipment described can be combined with continuous casting or similar machines. A medium-size foundry, however, cannot afford such an extensive expenditure.

In a medium-size light metal foundry as per layout shown in Fig. 12, a mixer can be dispensed with. The metal is melted and the composition built up in the coreless mains-frequency crucible-type induction furnace. Then, the metal is transferred into the holding furnaces where each lot is cleaned and left for 30 minutes. Different alloys are built up in turn in the mains-frequency furnace. The melting operation and the metal taking, however, are dependent on each other. Therefore, holding furnaces should be big enough to contain sufficient metal to pour until the next lot of liquid metal is supplied from the melting furnace.

The mains-frequency crucible-type induction furnace is not so suitable for foundries with small-quantity production. The smallest size of this type of furnace is too big for an economic small-quantity production of metals or alloys.

Small-foundry requirements are met by two basic furnace types, viz. resistance-heated crucible-type furnaces and twin-chamber channel-type induction furnaces.

Tiltable resistance-heated crucible-type furnace

This furnace, as shown in Fig. 13, is well known and is heated by lateral resistors and can be shut down during breaks in operation. Although the crucible wear and the relatively high power consumption increase expenses, the furnace is most suitable for small foundries as it can be used to melt pigs, return

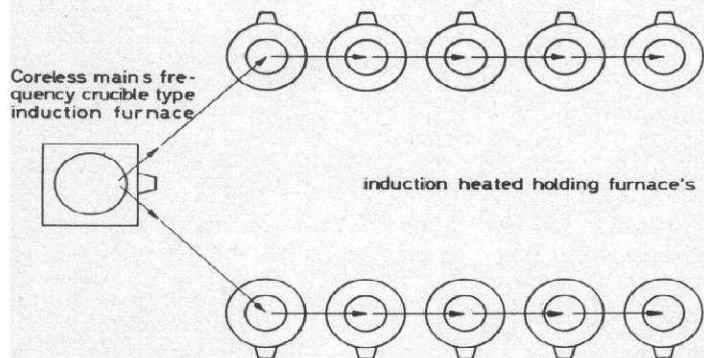


Fig. 12.

Model of a modern medium-size light-metal foundry.

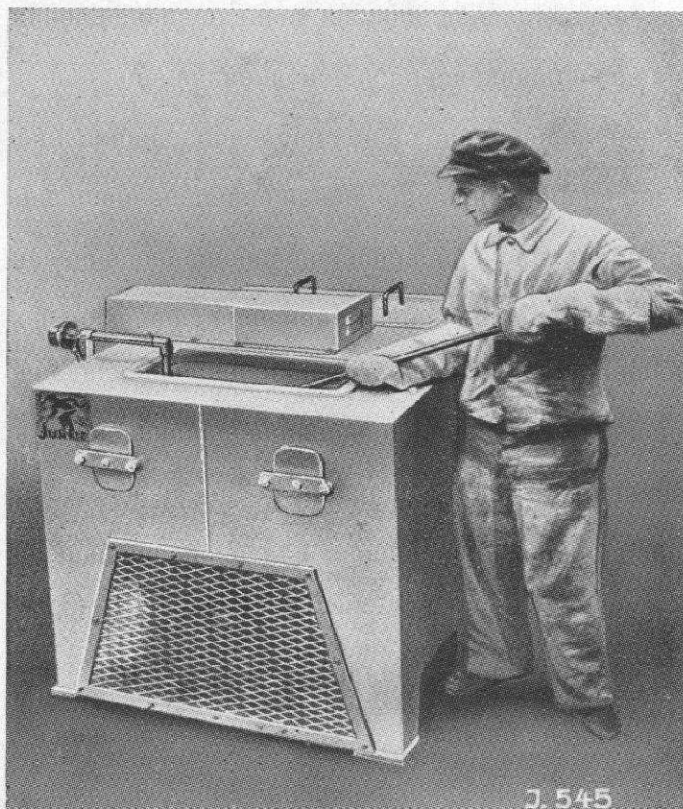


Fig. 13.

Tiltable crucible-type resistance-heated furnace (capacity of 500 kg of light metal).

Fig. 14.

Twin-chamber channel-type induction furnace, with horizontal channel.



scrap and ordinary scrap. The melt should be cleaned periodically.

Twin-chamber channel-type induction furnace

(a) With horizontal channel

This furnace (Fig. 14) is equipped with a melting

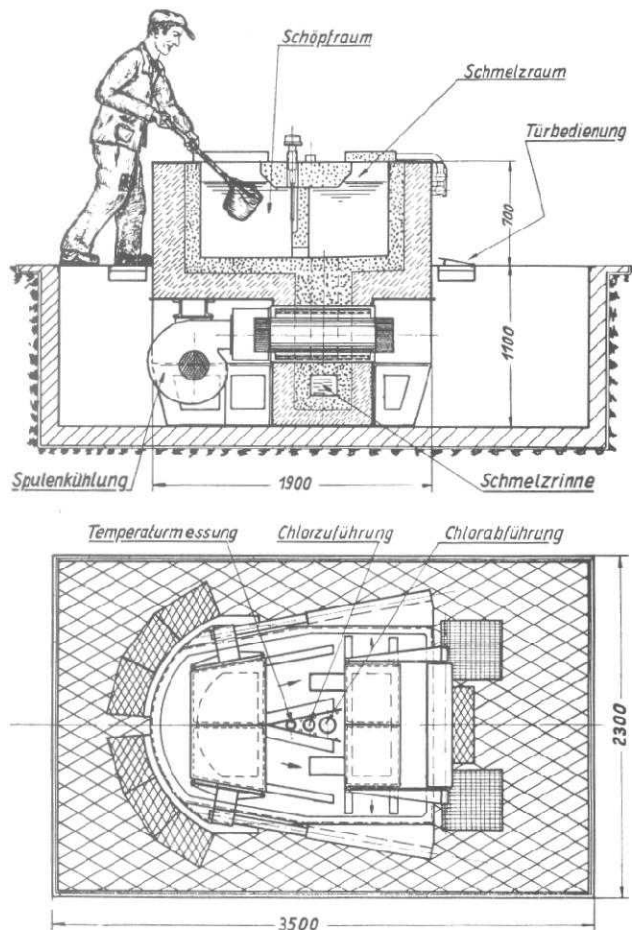
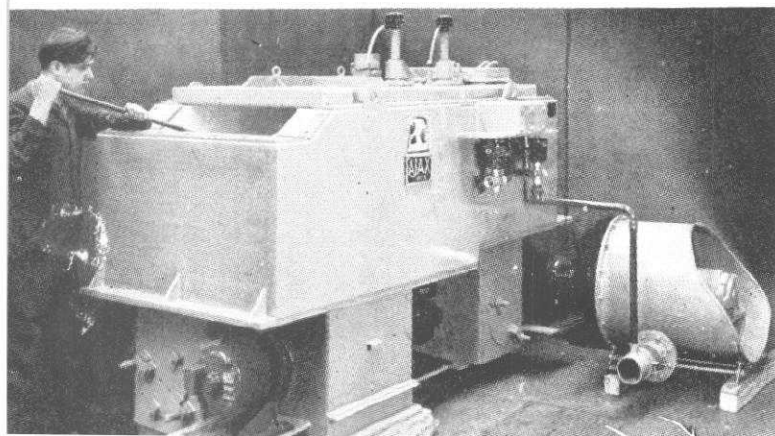


Fig. 15.
Twin-chamber channel-type induction furnace,
with vertical channel.

Fig. 16.
Induction-heated automatic melting and
pouring furnace for light metal.



chamber and a ladling chamber. The metal taken from the ladling chamber is relatively clean. The rammed ceramic lining is replaced approximately every two years and the power consumption is relatively low. The channel-cleaning operations make the furnace less desirable, particularly for small foundries. The furnace must be held at temperature during breaks.

The impurities adhering to the scrap form deposits on the channel walls. Therefore, it is essential to melt aluminium pigs. The channels should be cleaned carefully to avoid any damage to the furnace lining. The furnace described is equipped with a horizontal channel, so that some of the impurities are transferred from the melting chamber to the ladling chamber. An advantage is that the furnace is set up on floor level and that a pit is not required.

(b) With vertical channel

In this type of furnace (Fig. 15) which comprises also two chambers, the channel, however, ends only in the melting chamber. The metal flows through a small aperture in the partition into the ladling chamber, so that the impurities are withheld in the melting chamber. But with this furnace a pit cannot be dispensed with.

Induction heated automatic melting and pouring furnace

The automatic melting and pouring furnace (Fig. 16) which also comprises two chambers, is an offspring of the previously described furnace. The furnace can pour automatically any quantity of metal with an accuracy of ± 20 grams irrespective of the height of the bath level.

Regular melting furnaces are not equipped with a temperature control as, generally, the metal is not poured into moulds directly from the furnaces. An immersion thermocouple is used to check, whether or not, the melt has its proper temperature. Holding furnaces and combined melting and holding furnaces are temperature-controlled. As soon as these temperature is reached, the power supply to the furnace is automatically cut off. As the melting heat is generated in the metal charge itself, induction furnaces give the highest temperature accuracy of the melt. The heating elements of resistance-heated furnaces are hotter than the melt, so that the melt is subjected to an after-heating effect.

Summary

It can be said that the oil-fired and gas-heated furnace types are being replaced to an ever widening extent by electrically heated furnaces. Fuel stockage and drawing-off channels are thus dispensed with and the quality of metals is appreciably improved by the absence of any gas take-up during melting and holding operations. Electrically heated furnaces are much more economical although the capital cost of such furnaces is usually somewhat higher.

Mr. H. P. S. Murthy, NML: Mr. Ostler has shown a number of illustrations of furnaces possibly developed by his firm. We would, however, be interested in the technical feature and design, lining materials and their behaviour vis-a-vis the service conditions. May I, therefore, request Mr. Ostler to give a full description of at least one furnace?

Mr. F. Ostler (Author): The coreless mains frequency crucible-type induction furnace (Fig. 1 in the paper) is being lined with a ceramic material containing about 60% Al_2O_3 and the rest SiO_2 . The lining life is about 1 to 5 years depending largely on how the furnace is handled. The life will be shorter when you go to very high temperatures for making special alloys like aluminium-titanium alloys. This is our experience in making normal aluminium alloys—the life on an average is about 2 years. The furnace can be charged with all kinds of material i.e. heavy scrap, chips, sheet scrap, etc. and the metal loss is low. The ramming operation is done by hand using wet material, air-dried for 2-3 days and then slowly heated up. The lining time for crucible type furnaces is about 4-6 days and for channel type furnaces about 14 to 21 days.

Mr. H. V. Bhaskar Rao, NML: I would like to know whether the author is aware of the use of zircon lining in aluminium holding furnaces and the advantages of zircon lining as compared to be usual aluminium silicate lining. Zircon does not get wetted by aluminium and being heavy, any chipped refractory does not form an inclusion in the metal.

Metal tight lining is governed by the careful method of ramming as well as positive co-efficient of expansion of the lining material.

Mr. F. Ostler (Author): Zircon lining was not tried out in our furnaces so far, as it is expensive until now. The lining done by us is very good and keeps very long. If the lining is properly done, there is no difficulty. I think zircon linings cost as much as about five to six times as compared with the normal linings. My opinion is that it is not worthwhile to go for zircon linings, at least in Germany as the normal lining life in crucible-type furnace is about 1-5 years.

Mr. K. Srinivasan, National Machinery Manufacturers Ltd., Bombay: Using Indian refractories under Indian conditions in Otto Junker Furnaces, what life the author would expect of these refractories?

Mr. F. Ostler (Author): I have been watching our furnaces for making cast iron in two Indian firms. Both use the same type of furnace with Indian made lining material. One of them gets 100 heats whereas the other gets 30 heats only. In the same type of furnace for malleable iron they make 200 heats. It all depends upon the choice of lining materials and their maintenance. It is, therefore, very difficult to give a proper answer to the question raised.

Prof. G. R. Bashforth, UNESCO Expert in Ferrous Metallurgy, Banaras Hindu University, Varanasi: For the benefit of people who are not acquainted with the

mains frequency type of electric furnace, it should be explained that this furnace is similar in construction to the high frequency electric furnace; but it possesses the advantage of operating with an ordinary mains frequency of some 50 cycles per second instead of 1000 to 2000 cycles per second in the case of the high frequency furnace. This fact eliminates the necessity of having an expensive transformer, thereby saving capital cost. The low frequency current induces greater turbulence in the metallic bath than what is encountered with higher frequencies and this feature may or may not be advantageous according to the process being employed.

Perhaps the greatest disadvantage of the mains frequency furnace, is the necessity of employing a precast plug to form the secondary circuit when starting up the furnace. On subsequent heats in this type of furnace it is either necessary to use a precast plug, or to leave sufficient metal from the previous heat in the furnace to form this secondary circuit. In this aspect the mains frequency furnace is similar to the low frequency electric furnace, but it is, of course, of much simpler design and construction.

It would be interesting to have Mr. Ostler's views on these points.

Mr. F. Ostler (Author): Regarding shorter lining life, we have in Germany, furnaces working for high alloy steels—both for high frequency and low frequency. Both the furnaces cause turbulence and owing to it we get about 19.6 to 19.8% Cr, when we put in 20% Cr. There is no difference between the two types of furnaces. Even the lining life in both furnaces is the same. Naturally when you are coming to the plastic points of the lining material, say, a basic lining material up to 1650-1700°C, and go on with high power, then I agree that you will have a wash-out in the furnace bottom. Regarding material for starting the furnace for melting light metals and copper you can start with normal billets and ingots available in the market. No bigger dimensions are necessary. For cast iron and steel, the minimum dimension is 200 mm for 50 c/s. Sometimes the precast plug is regarded as a disadvantage. Generally in foundry practice, you melt more metal than you need for the moulds in the foundry to be on the safe side. Instead of pouring the surplus in sand, you can pour in a sand mould and so get a plug. You may fill the mould with big scrap and pour in the surplus metal to obtain a plug from less liquid metal.

Mr. H. P. S. Murthy, NML: Regarding the point raised by Mr. K. Srinivasan about Indian refractory materials, I would like to say that we have induction furnaces in our laboratory and the lining of the same is being done by us. We do find that it is not so much chemical composition itself of the refractory material as grain size distribution, the bond, the way of ramming, etc. that control the life of the lining. The Indian refractory materials will be quite comparable with refractory materials all the world over.