ELPIT—The Electric Soaking Pit

G. Schjelderup

THIS paper deals with the history, development and present status of the electric soaking pits. The general aspects will be brought out and to some extent be complemented by reference to various installations which are now operating.

A historic summary will have to start with the earliest type of unheated soaking pits which depended on the excess temperature of the steel ingots when charged. The inconvenience of these pits caused them eventually to be dropped in favour of fuel fired pits as production rose and the steel making units increased in size. Transport problems, scheduling and specialisation have in some cases lead to the practice of letting ingots go cold to be reheated later for rolling.

At the present time the major tonnage of steel ingots is processed through fuel fired pits,—the fuel being gas, or fuel oil depending upon local availability and cost. A relatively small, but ever larger tonnage, however, is presently being processed through electric soaking pits. This development dates back to 1915 when Mr. T. F. Baily, U.S.A. with whom we now have an agreement, came up with the idea to heat soaking pits with electricity by using a resistor consisting in principle of a silicon carbide trough filled with coke.

A trial was then carried out at Donner Steel Corporation, but this did not result in the adoption of electric soaking pits at that time. The method found some use for metal melting, but went later gradually out of use.

We had at that time the good fortune to come across Mr. Baily's idea, and as a result it was decided to build an experimental electric soaking pit at Christiania Spigerverk Iron and Steelworks, Oslo, where we then had abundant supplies of electric power.

The pit was a success, and since 1927 our entire ingot production has been processed extremely economically through electric soaking pits.

For many years it was believed that electric soaking pits would only be economically feasible in Norway where the cost of hydro-electric power was unusually low in the past years, but after World-War II it became clear that electric power was becoming relatively cheaper and cheaper compared to fuels, and thus use of electric soaking pits became economically attractive in countries such as England, France and Germany. Considerable improvements have since been introduced.

All the engineering and sales activities had been carried out by Christiania Spigerverk, Iron and Steelworks, in their own name, but having proved the soundness of the idea, a special company was formed in 1954 for the purpose of introducing, selling and further developing the electric soaking pit.

We have now succeeded in obtaining orders for about 40 units, 26 of which are operating, and 13 being designed or erected.

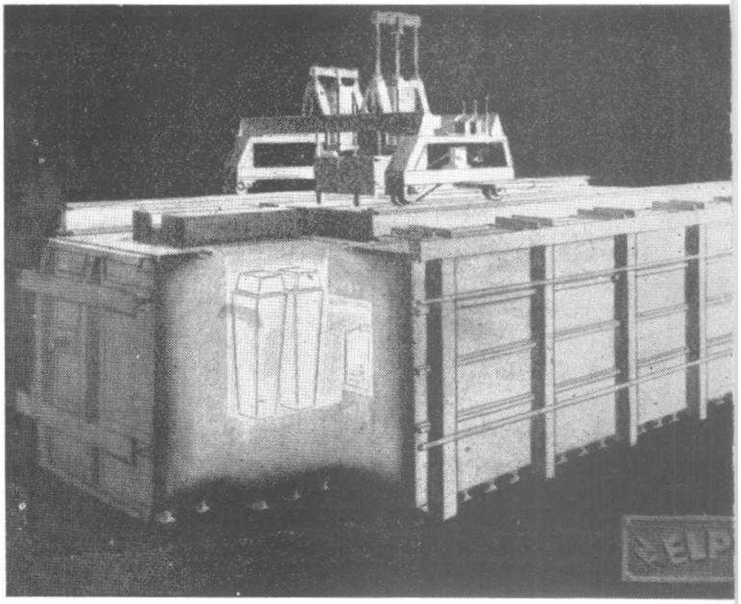
The ELPIT, as we call our design of electric soaking pit, is the only type of its kind in the market anywhere in the world.

Furnace description

An installation is very simple, and consists of only two main blocks of equipment, namely the pit proper and the electrical equipment.

Fig. 1 shows an artist's impression of the pit itself which consists of a rectangular steel casing

Fig. 1.



Mr. Gunnar, Schjelderup, President, Christiania Spigerverk, Oslo, Norway.

heavily bound in rolled steel sections, and containing the refractory lining and insulation to form a closed unit. The internal brickwork divides the pit into a number of cells each of one or more ingots capacity depending upon their size. Each cell is provided with a cover handled by a special cover lifting machine which spans the pit.

The heating elements are coke-filled troughs which run the entire length of the ELPIT through arched openings in the walls which separate the cells. From this resistor the energy is transmitted mainly by radiation resulting in extremely uniform ingot heating.

Electrodes (Fig. 2) are led through the end walls to connect with the elements.

Fig. 3 shows a transformer casing containing three separately controlled single-phase transformers. These transformers have provision to vary the secondary voltage for power adjustments.

This may be done manually, but the most usual today is to use a completely automatic control circuit which adjusts the voltage to maintain the power input at pre-selected levels according to pit temperature.

The control instruments and circuit components are standard electrical equipment which are mounted together on a centrally located control panel such as shown in Fig. 4. This panel is for a 3-resistor ELPIT and comprises a common section with temperature control instrument and fault indicating device and a separate section for each resistor with meters for secondary volts and kilowatts, transformer tap changer position indicator, integrating kWh-meter as well as switches, push buttons and signal lights for circuit breaker control and auto/manual selection.

The transformer may be placed in any available space within reasonable distance from the pit. The most convenient arrangement is, however, the one shown in Fig. 5 where the transformer is placed at one end of the pit in the adjacent bay with the control panel placed on top of the transformer cell.

As the heating is based on resistance elements, the power factor is very close to unity. This makes the ELPIT a very desirable load on the network inasmuch as it improves the power factor and stabilises the load of the mill as a whole. For this reason it should be possible to obtain favourable power contracts for such plants.

Four main ELPIT types

Various types of pits have been built, each to meet a specific set of requirements.

While several ELPITS may be built together in a common casing, there are basically 4 types which have so far been found practical.

Fig. 6 shows schematically pit brickwork, resistor troughs and ingots. Depending upon the heating capacity required, each row of ingots may be heated by 1/2, 1, 1½ or 2 resistors. The first type of pit will have a high holding capacity and a relatively

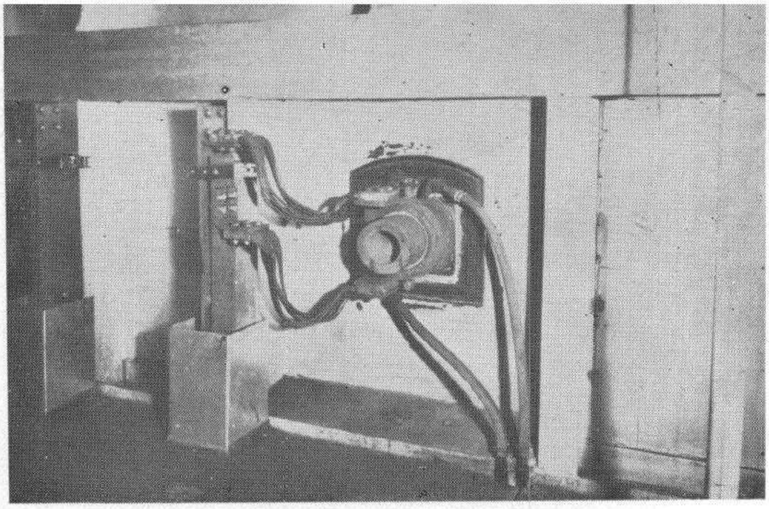


Fig. 2.

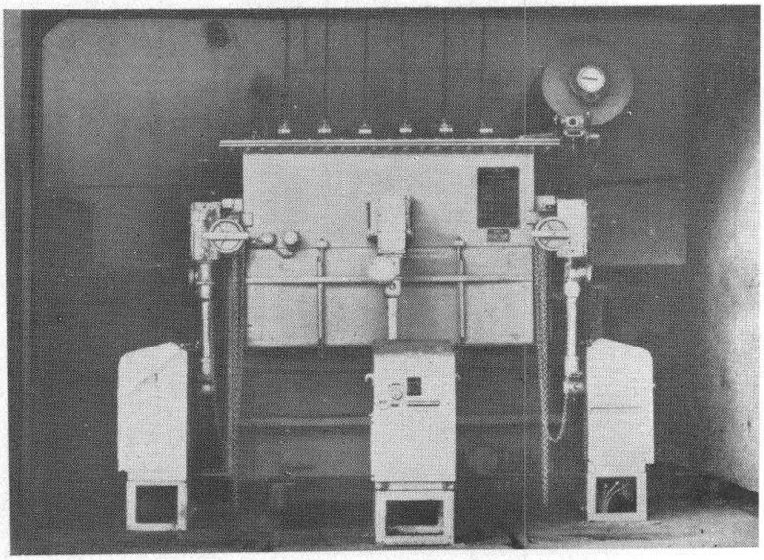
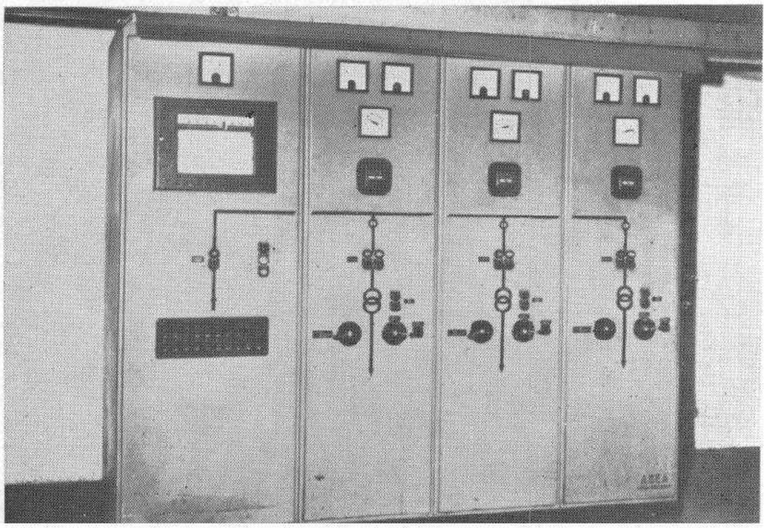


Fig. 3.

Fig. 4.



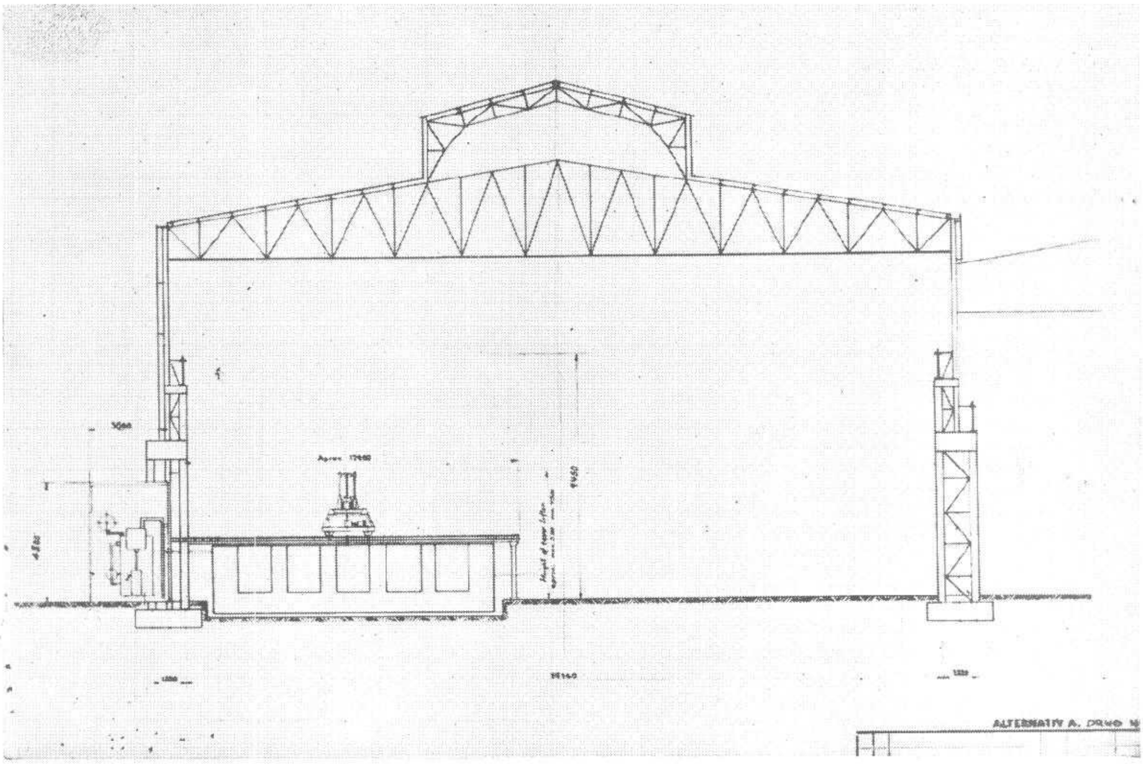
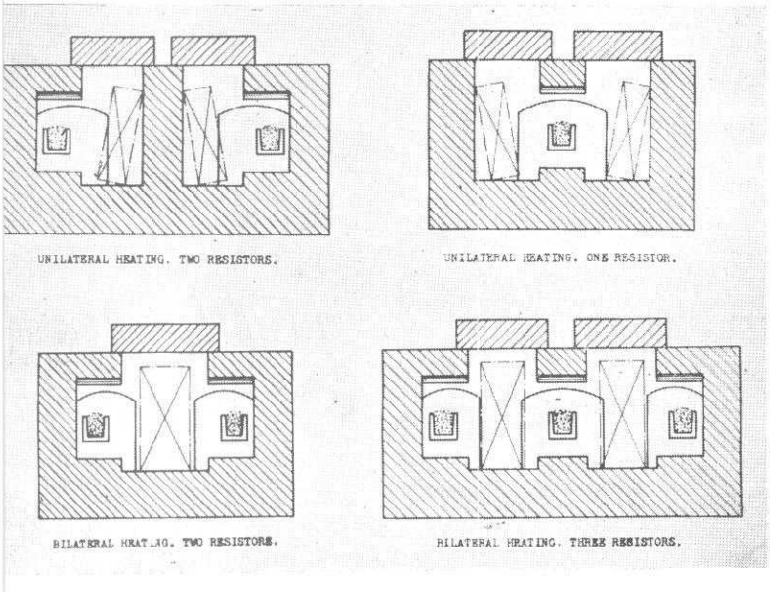


Fig. 5.

small investment in electrical equipment, while the last type has a relatively small holding capacity and a large investment in electrical equipment. The first would be chosen if the ingots arrive with short track-time and merely require soaking and very little further heat addition. The high power unit is chosen for those applications where the ingots or slabs are charged cold or with long track-time.

Fig. 6.



For intermediate conditions of temperature, track-time and ingot size, one of the other two types may be the answer.

Single resistor type

In what follows we shall study examples of each type and we begin with the single resistor ELPIT as the one installed at Appleby-Frodinham Steel Co., England. (Fig. 7).

The pit has overall dimensions of 43×19 feet with 2 rows of 4 cells each. The resistor trough is here placed in the middle in such a manner that it radiates energy to both sides where eight 10-ton slab ingots are placed one in each cell. The resistor is connected to a 900 kVA single phase transfomer. The standing losses are about 300 kW, and the power available to heat steel is about 600 kW, but normally very little additional heat is required by the ingots. The latter arrive to the soaking pit area from the open hearth melting shop in batches of 80 tons which correspond to the content of one ladle. Track-time for the first heat is very short, and usually amounts to about 100–120 min. reckoned from start of tapping furnace to finish charge.

The old practice was to charge these ingots which still had molten centres to unfired Gjers pits since they would be too hot to charge directly to fuel fired pits.

A Gjers pit is seen behind the ELPIT in the figure.

Occasionally it had beed possible to roll an ingot directly from the Gjers pit, but normally these ingots would have cold ends and corners and they were therefore normally transferred to the gas fired pits where they remained about 10 hours for soaking.

The purpose of the ELPIT in this instance was to serve as a "glorified" Gjers pit where the ingots could be soaked and kept ready for rolling. With well over 2,000 tons being passed through the ELPIT per week, a considerable reduction in ingot handling and a corresponding increase in the heating capacity of the soaking pit plant as a whole, have been experienced.

The slabs are normally passed straight on to the plate mill reheating furnaces without surface conditioning, and practice has shown that for the removal of minor surface defects a slight amount of scaling is sufficient.

While the ELPIT is inherently and normally operated with a reducing atmosphere which prevents scaling, it has in this case been found necessary to introduce a small amount of air to provide about 0·3% of scale. This has proved sufficient to yield the same relative tonnage of acceptable slabs as from the gas fired pits even though the latter makes considerably more scale.

Ingots with larger defects may not be dressed in this manner in either type of pits, and the slabs are then cooled down and flame scarfed before they are passed on to the plate mill.

The average energy consumption when accounting for all the energy required for heating up, idling and waiting as normally occurs in steel plant production, is 20–25 kWh per ton which corresponds to 17,000 to 22,000 kcal/ton.

ELPITS of this same type are also operated at Hallastahammar, Sweden, at the Spigerverk, Oslo, Norway, and since early 1959 also at The Danish Steelworks, Denmark.

Double ELPIT

The next general type to be considered is the double ELPIT, where there is one resistor per row of ingots. This, incidentally is the original arrangement which we first tried and have been using for the last 30 years.

(Fig 8). The largest to date of this type are the two pits at Phoenix Rheinrohr, Duisburg, where they have up to now operated 16 ton convertors. They are, however, now commencing operation in their new Thomas shop where they will produce heats of 70–80 tons or 10 ingots, which fills one double pit.

Apart from ELPITS, this mill operates modern one-way fired soaking pits burning mixed coke oven and blast furnace gas.

The control panels for all the pits are placed on an elevated platform from which all cover lifting machines are also operated.

It has been found that the ELPITS are more effective as production units than one had hoped. With ingots having short track-time, the production is higher than from the gas fired pits due to the fact that the ELPITS may be recharged as soon as a cell is empty.

Fig. 9 shows the production results at Phoenix over a 3-week period about 6 weeks after the installation went into operation. The figures are typical of both double units, but the production refers to one double pit.

In spite of the unfavourable conditions with only 2 ingots per heat, the production was between 2,500

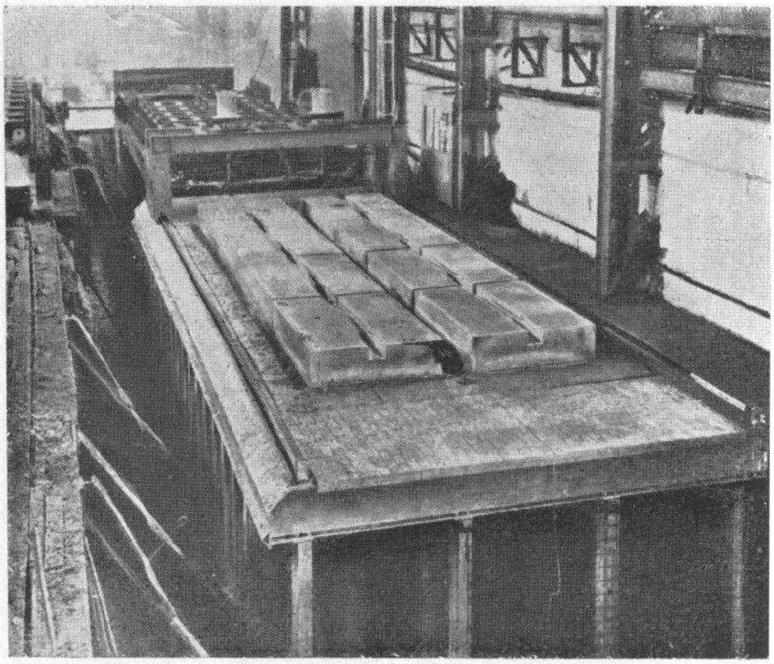
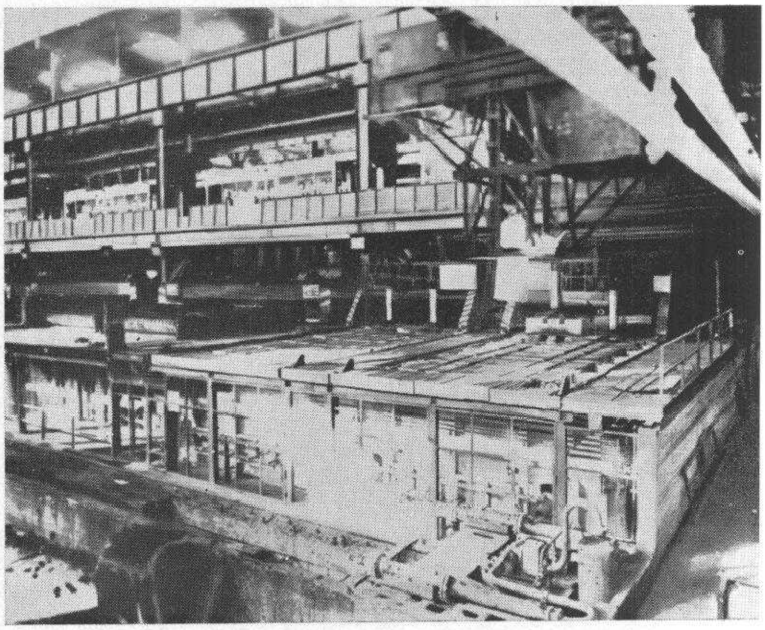
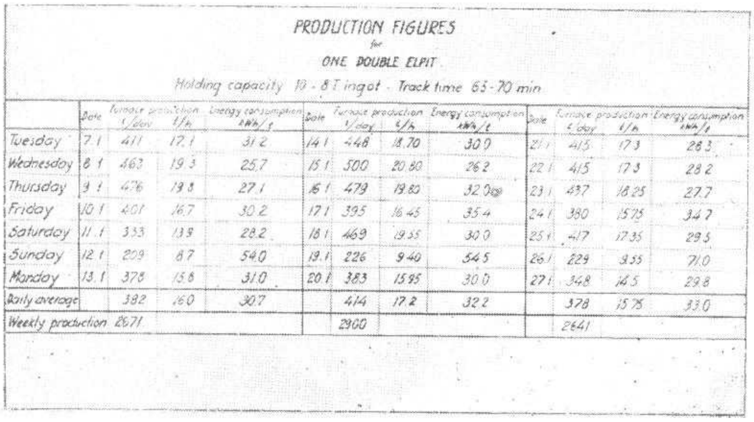


Fig. 7.

Fig. 8.





PRODUCTION FIGURES
for
ONE DOUBLE ELPIT
Holding capacity 10 - 8 T ingot - Track time 65-70 min

	Date	Furnace production		Energy consumption	Date	Furnace production		Energy consumption	Date	Furnace production		Energy consumption
		t/day	t/h	kWh/t		t/day	t/h	kWh/t		t/day	t/h	kWh/t
Tuesday	7.1	411	17.1	31.2	14.1	448	18.70	30.0	21.1	415	17.3	28.3
Wednesday	8.1	463	19.3	25.7	15.1	500	20.80	26.2	22.1	415	17.3	28.2
Thursday	9.1	476	19.8	27.1	16.1	479	19.80	32.0	23.1	437	18.25	27.7
Friday	10.1	401	16.7	30.2	17.1	395	16.45	35.4	24.1	380	15.75	34.7
Saturday	11.1	333	13.9	28.2	18.1	469	19.55	30.0	25.1	417	17.35	29.5
Sunday	12.1	209	8.7	54.0	19.1	226	9.40	54.5	26.1	229	9.55	71.0
Monday	13.1	378	15.8	31.0	20.1	383	15.95	30.0	27.1	348	14.5	29.8
Daily average		382	16.0	30.7		414	17.2	32.2		378	15.75	33.0
Weekly production		2671				2900				2641		

Fig. 9.

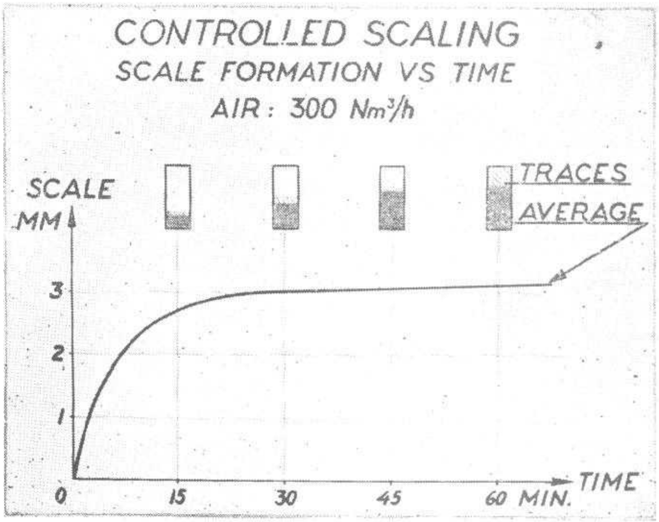


Fig. 10.

and 3,000 tons/week per double pit or 5,000-6,000 tons/week for both pits combined.

With on average track-time of about 65-70 minutes for 8-ton square ingots, the energy consumption amounts to about 30 kWh/ton (26,000 kcal/ton) including Sundays as working days.

When the new Thomas shop comes in with larger heats it is expected that the production will be still higher, and that the energy consumption in the future will be reduced to a weekly average of 20-25 kWh/ton.

The next two double ELPITS are already ordered, and are expected to go into production this spring. We have every reason to believe that further additions to the soaking pit plant will be ELPITS as the existing gas fired pits have sufficient capacity to handle cold ingots and heats with long track-time arriving from the open hearth shop, etc.

A particular problem which faced us at this mill, was to devise a method for selective scaling of the ingot surface for the purpose of removing scabs. These scabs which are caused during teeming by relatively rapid top-pouring, are normally concentrated near the bottom of the ingot, but may also appear higher up if metal is splashed on to the mould.

Fig. 10 shows diagrammatically how this problem was solved by introduction of air for a short period during the last part of the soaking period. The scale first forms near the bottom of the ingot and reaches higher up as time goes by. It is particularly interesting to note how very quickly an average scale thickness of 3 mm. is formed.

For a practical application of this method it has been found most convenient to introduce air at a constant rate for a certain length of time which is determined by the operator by inspection of the ingots as they are charged.

By the use of this method it is possible to retain full control of the scale formation and thus combine the advantages of scale-free heating with those of surface conditioning by scaling to achieve optimum results.

Besides, it may be mentioned that the heat which is generated during the oxidation process is sufficient to maintain the pit temperature even though the power is turned off.

There are several installations where there are pits of this type, but we shall just mention a few of these here.

Fig. 11 shows one of the smaller units installed and Hallstahammars AB, Sweden. The ingot size in this mill is 2, 5 tons, and 2 such ingots are placed in each cell. The holding capacity is 50 tons. We draw attention to the fact that they are not using a regular soaking pit crane, but only a simple hand-operated pair of tongs which are carried on the hook of a standard over-head crane. This method of ingot handling may be used because the heat radiation from the small cell openings is not objectionable. With large single cell soaking pit constructions this method would not be possible.

This same method of charging with hand-operated tongs is used at Christiania Spigerverk, Oslo, Uddeholm, Nykroppa, Sweden and the Danish Steelworks, Denmark.

At the Spigerverk, at Hallstahammar, and later also at Acesita in Brazil where they are building 4 double ELPITS there will be no other heating facilities except ELPITS.

Fig. 12 shows a fairly large double ELPIT installed at Norrbotten Ironworks in the north of Sweden. The ingot size is about 5 tons and the products rolled are sections and rails. The transformers and the high tension equipment are placed on the ground floor of the control house at the back end of the pit. The control panel is placed on the next level overlooking the pit. The operation is, however, completely automatic, and does not require anything but routine attention by the soaking pit operators.

Fig. 13 shows curves giving the relationship between track-time, production rate and energy consumption based on practical results obtained from the soaking pit at Norrbotten. Each curve is based on a certain track-time corresponding to a certain average ingot temperature when charged. Standing losses being practically constant irrespective of whether the pit is standing empty or ingots are charged, it is a relatively straight-forward mathematical relationship which is represented. The curves are valid for one heating cycle or for any extended period provided the average track-time and the average production expressed as ton/hour for the whole period are known.

3-resistor type

Going on to the next general type of ELPITS, namely those with 3 resistors, which may be regarded as a combination of the single resistor and the double ELPIT inasmuch as the central wall of the double pit has been removed and a central resistor placed there instead, one will appreciate that the central resistor will materially increase the heating capacity and improve the temperature uniformity, but the extra cost of the resistor and the electrics must be considered.

Fig. 14 shows the units operating at Consett Iron and Steel Company Ltd., in England. These pits were put into operation in the late summer 1958. Each of these units has 8 cells placed in 2 rows of 4 each. In each cell can be placed two 10-ton ingots or one 20-ton ingot making the holding capacity of each unit 160 tons.

The transformers and high tension equipment are here again placed on the ground level behind the pits, while the control panel is located on platform level. The pits are intended to be used for tonnage heating of hot ingots arriving normally with short track-time, but with the risk of bunching of heats and longer track-time being present, the three-resistor type of ELPIT was chosen for ingots of this size.

Other pits of this type are operated at Domnarfvet Steelworks, Sweden, in their plate mill, and another unit will also be operating at South Durham Iron and Steel Company Ltd., where it is now being erected.

Fig. 15 shows a 3-resistor ELPIT at Ugine, France, where they are charging ingots up to 2 tons each. Here the ELPIT was chosen not for tonnage production, but for gentle heating of quality steels. The ingots when charged may be at an average temperature of say 700°C, and one of the main objects is to reheat and soak these ingots without scale formation, and absolutely evenly to avoid over-heating and other metallurgical difficulties associated with ingot heating.

The energy consumption in this case is higher per ton of ingots than for the high tonnage installations so far described. The advantages, however, more than balance the energy cost, and at Ugine all difficult qualities are presently processed through the ELPIT.

Due to the closed construction the ELPITS may be operated with controlled atmosphere, and at Ugine equipment has been installed to generate a strongly reducing atmosphere. By balancing the carbon potential of the atmosphere against

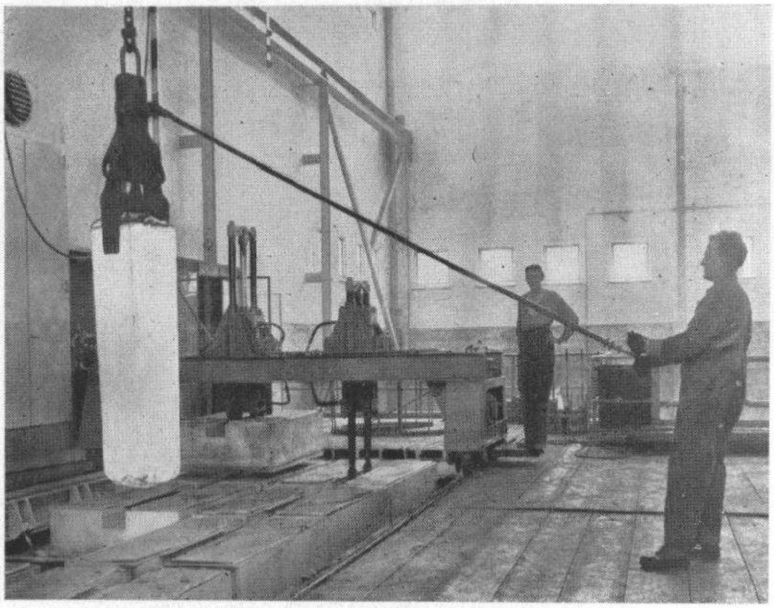
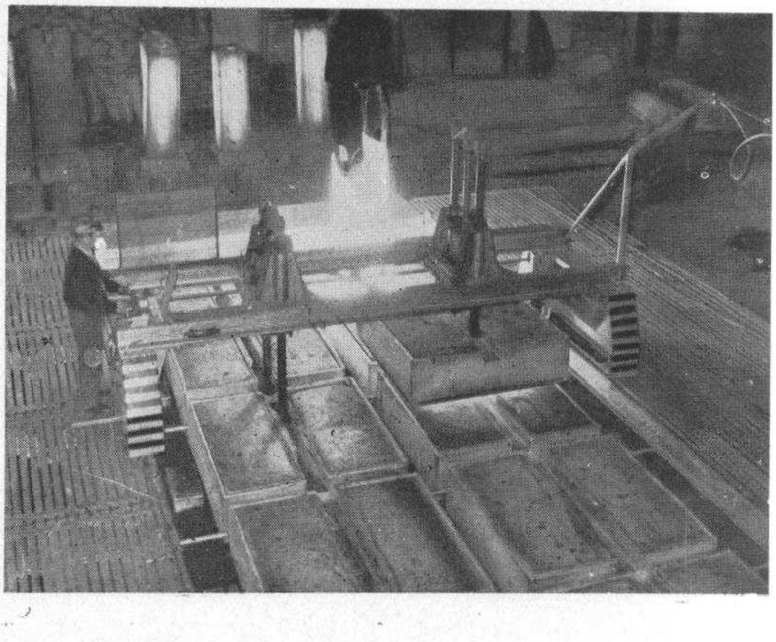


Fig. 11.

Fig. 12.



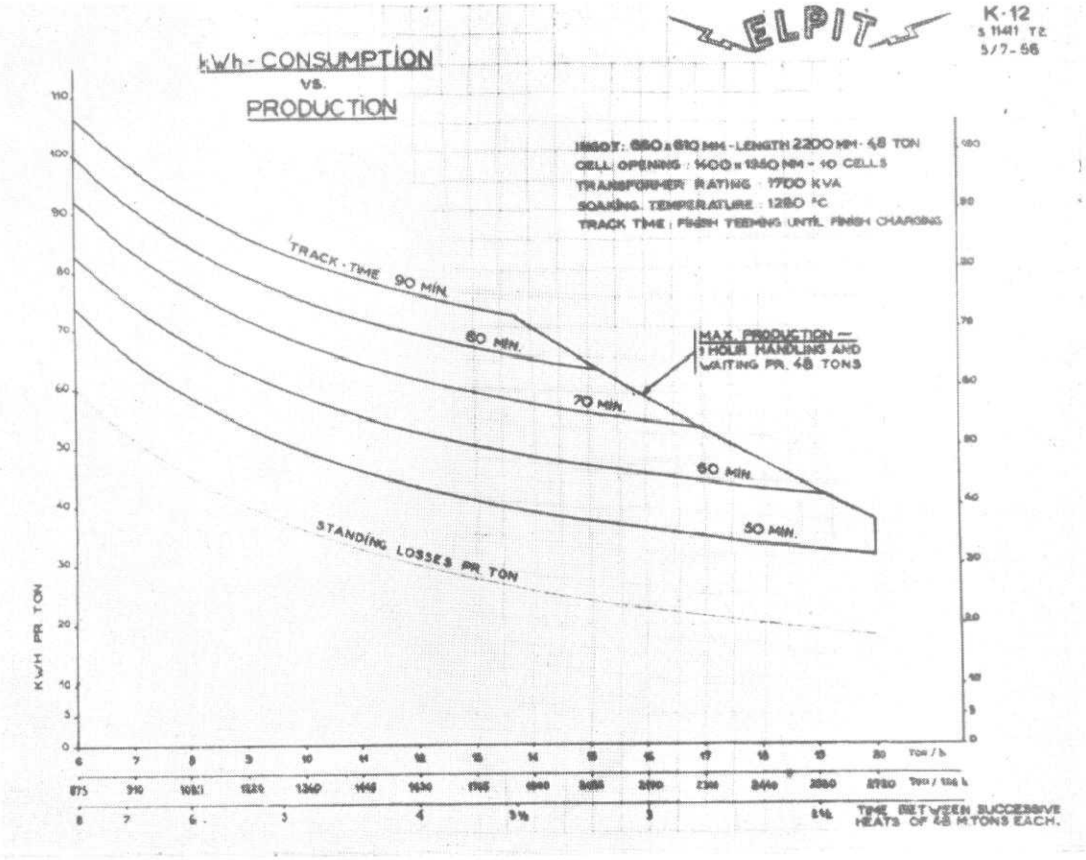
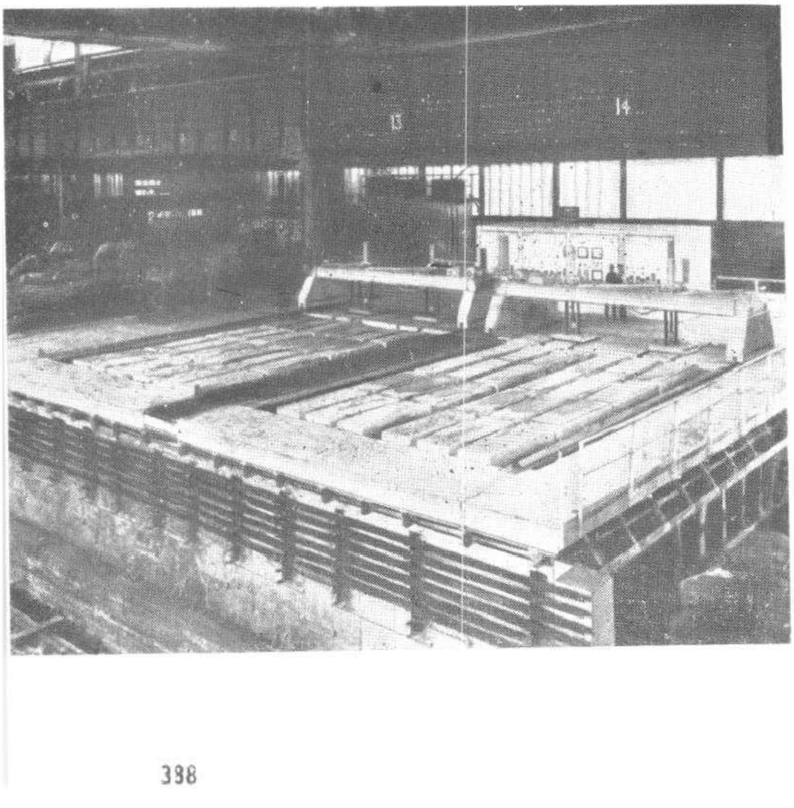


Fig. 13.

Fig 14.



the carbon potential of the steel which is being heated it is possible to prevent decarburisation of the ingot surface and even to carburise the surface if this is desired.

Fig. 16 shows a microphotograph of an 80 m dia. billet rolled from a 470 square ingot where the carburised surface may be observed. Free cementite appears in this case to a depth of 0·45 mm, but more or less may be obtained by varying the carbon potential of the atmosphere as well as the time.

The second and third unit similar to the first one are now ordered, and will be erected by end of 1959.

2-resistor type

Fig. 17 which shows the ELPIT at Colvilles Ltd., Scotland, is an example of the last mentioned type, namely the 2-resistor ELPIT where each row of ingots has a resistor running along each side in a closed construction making it an independently controlled section. The resistors may each be connected to a separately controlled transformer or be, as in this case, connected in series to a single transformer since the combined length of the 2 troughs is not excessive.

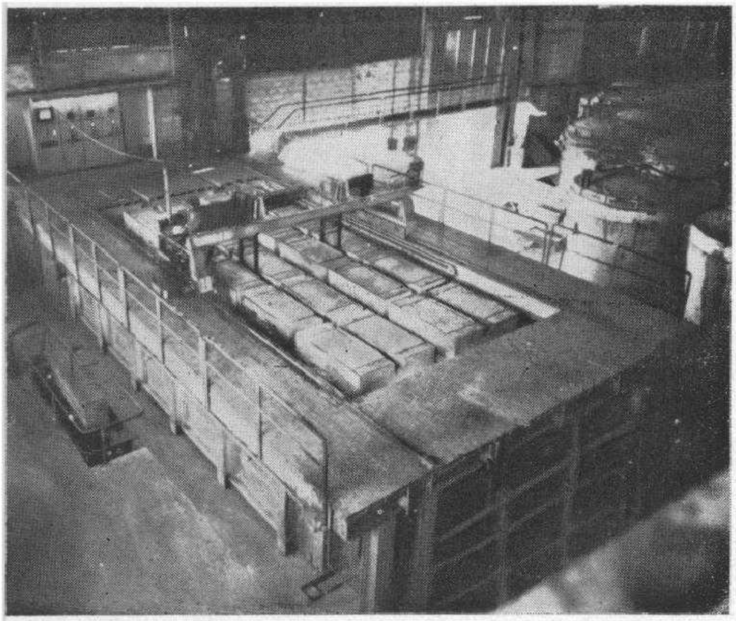


Fig. 15.

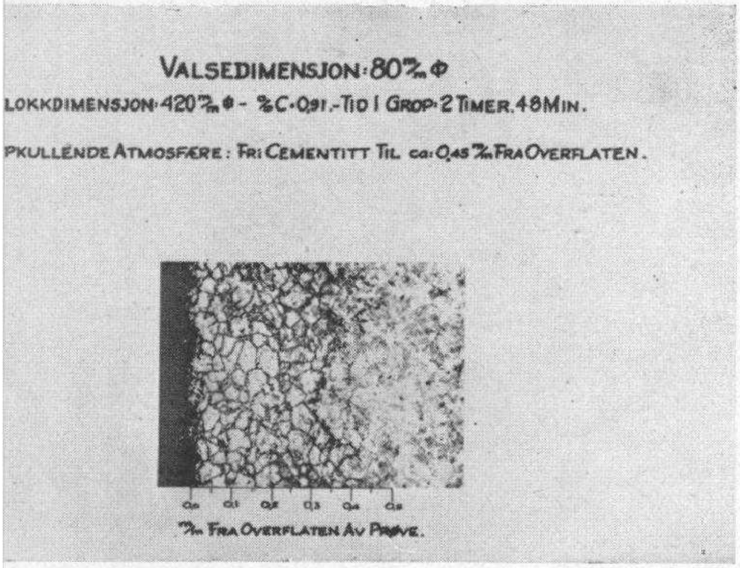


Fig. 16.

The purpose for which this ELPIT was installed was to heat heavy composite slabs for rolling into stainless clad plate. Each composite slab represents a considerable investment in material and labour by the time it is ready for rolling, and the relatively high cost of electric heating from cold is therefore more than balanced, and certainly warranted in this case, as rejects which may be due to faulty heating is today nil.

The theoretical energy required to heat the steel amounts to approximately 250 kWh/ton from zero to 1,250°C, but the actual energy consumption charge-to-ready including losses will, for a cold charge, be in the region 330–360 kWh/ton depending on the weight of charge and the time allowed for soaking. Normal heating and soaking cycle for 10-ton slabs amounts to about 20 hours when heated from cold.

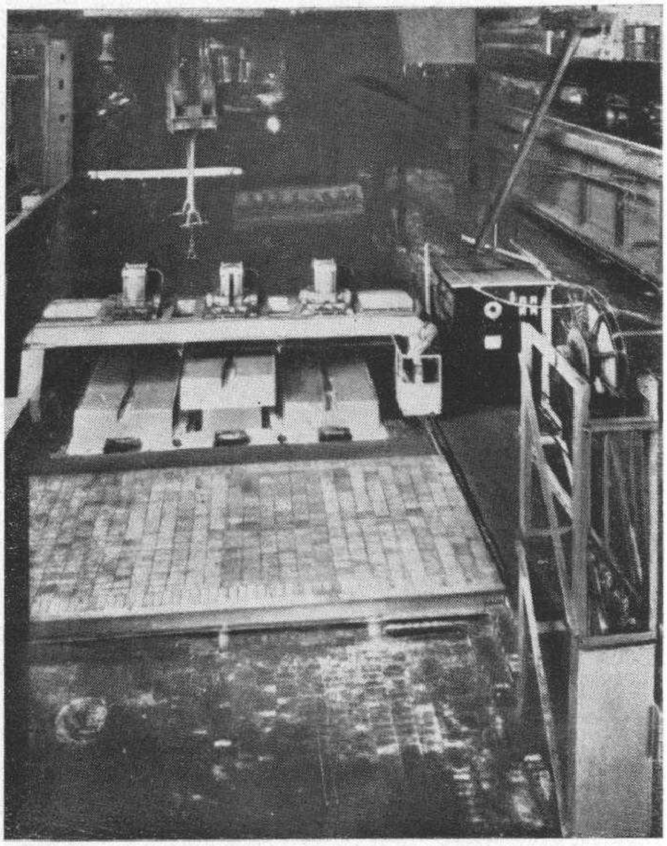
Besides this pit there is only one other unit of this type, the first one of its kind built at Phoenix Rheinrohr, Lierenfeld.

Fig. 18 shows a cylindrical ingot as it is being drawn to the pipe mill. The pit, which is a semi-experimental unit, heats ingots 1·5–4 tons each, and has conclusively proved that the uniform heating and absence of scale yield better pipe with more uniform wall thickness. The lack of scale, and the closer tolerance to which the pipe may be rolled result in extra footage for the same ingot weight.

Forge furnaces

We have so far dealt with the principle of ELPIT as originally developed in connection with soaking pits. Brief mention should also be made to the interesting fields of applications in forge furnaces and special furnaces where the advantages of electric

Fig. 17.



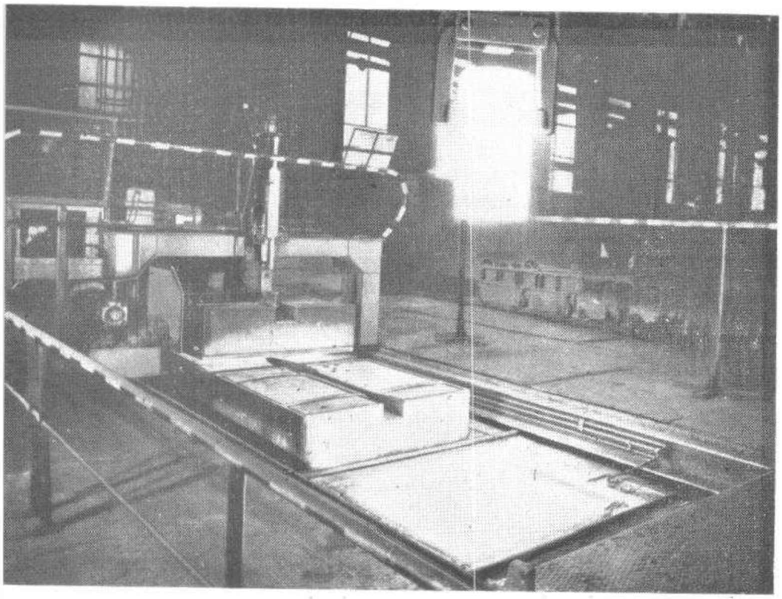


Fig. 18.

heating and atmosphere control would be considerable, but have been so far unattainable due to lack of suitable heating elements in this temperature range.

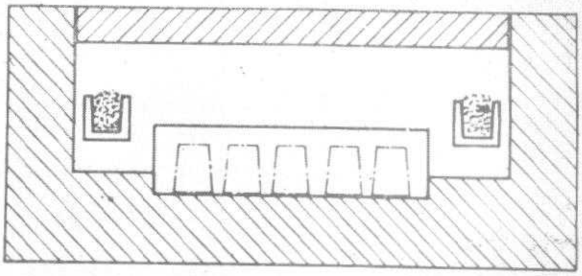
Fig. 19 shows schematically 2 types of forge furnaces which are at present operating. The upper type has a fixed hearth while the lower one is provided with a bogie.

The first forge furnace was built at Commentry in France in 1957 for the purpose of heating tool steel.

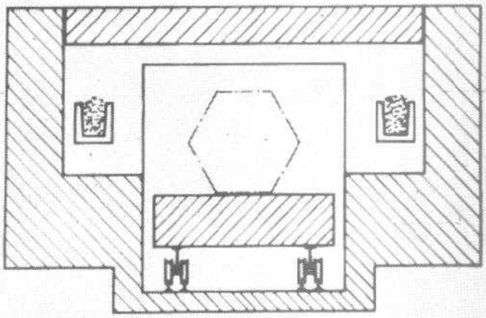
Fig. 20 shows this furnace at the right, while at the left is an oil fired preheating furnace. The usual production cycle calls for preheating the 220 mm square billets in the oil fired furnace. The preheated billets are at the end of the day transferred to the electric furnace at a temperature of about 700-800°C. This charge of about 4-6 tons is heated during the evening and soaked during the night for a period of 6 or 7 hours at full temperature before forging operations commence in the morning. During the night, small quantities of oil are introduced to assure completely scale-free heating.

During the day while forging, the process calls for several reheating operations. A larger quantity of oil or gas must therefore be introduced during day time to maintain a reducing atmosphere. It has proved impossible to avoid scale formation entirely during the day, but the amount is insignificant in comparison with what is formed in the conventional forge furnaces and amounts to about 0·1 to 0·2 mm. The furnace has been a success and enquiries for a larger unit of the same type have been received.

Fig. 21 shows the bogie furnace which was put into production in the late summer of 1958 at Ludwig von Roll'schen, Eisenwerke AG. in Switzerland.



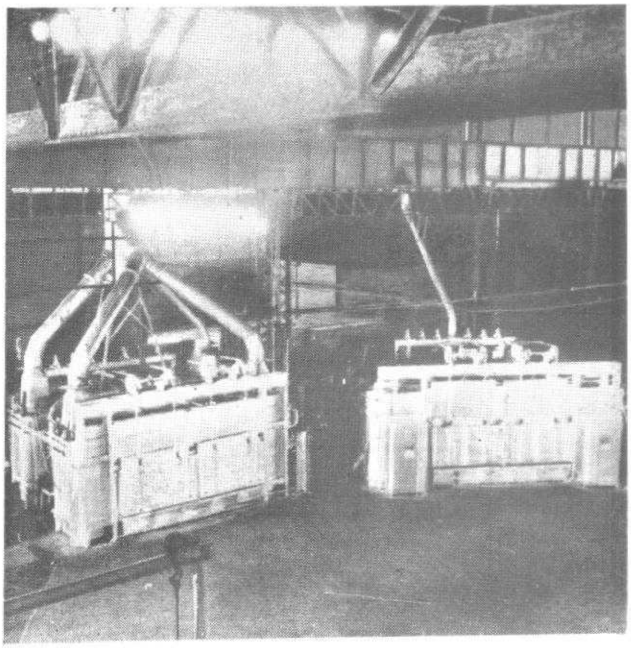
FORGING FURNACE. TWO RESISTORS.



CAR-TYPE FURNACE. TWO RESISTORS.

Fig. 19.

Fig. 20.



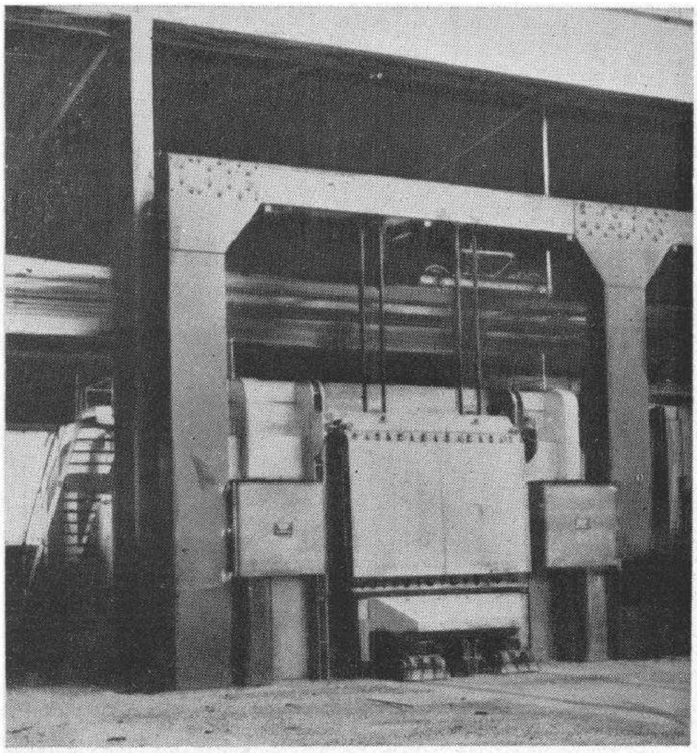


Fig. 21.

The furnace is designed for a maximum charge of about 50 tons and was built to be used for finish heating. Certain steel qualities require extremely careful preheating, and the electric furnace is therefore also used to heat large ingots from cold. Before charging the cold ingots the furnace is cooled down and later brought up with the steel. The energy consumption is of course very high, but the customer has found this expenditure entirely justified. This furnace represents therefore the ultimate in flexibility inasmuch as it may be used for very critical preheating as well as for scale-free finish heating. Subsequent heat treatment at intermediate temperatures may also be carried out.

These first two installations will undoubtedly be followed by many more as soon as the advantages connected with this type of heating become better known to the industry.

Cost and maintenance

It is hoped that what has already been said will have made it clear that the electric soaking pit can no longer be regarded as a novelty, but as a practical development which has proved its worth under the most diverse circumstances.

Compared with fuel fired pits of the most modern design it has been found by experience that for the same holding capacity the all inclusive cost of ELPITS such as foundations, buildings, etc. will normally be about 20–25% lower than for fuel fired pits.

The cost of maintenance will vary from one installation to the next, but based on production tonnage one may safely reckon with less than with fuel fired pits. Included in the maintenance charges is the cost of replacing the resistor troughs which have a normal life of 12–18 months. Depending on the production the cost of resistors alone amounts to about 2·5–3 d/ton.

Coke consumption averages about 1 lb per ton of ingot and amounts to about 2·5 d/ton.

The brickwork is much less subject to erosion than in a fuel fired pit since it is mainly exposed to radiation. Maintenace depends mainly on the care taken by the crane operators during charging and discharging of the pit, and to some extent on the shape of the ingots.

Plant maintenance in general is greatly simplified by the fact that there are very few pieces of moving machinery and also by the complete absence of auxiliary equipment such as fans, flues, dampers, recuperators, etc. which normally are required where waste gases must be disposed of. The electrical equipment is otherwise of such a type that little attention is required.

Now a pertinent question would be :

Where to install ELPIT ?

As has been described earlier in this paper, ELPITS are operated by both special steel and tonnage mills, and we believe it is correct to claim that ELPITS may be installed economically in most mills.

Important factors to be considered are cost of electric power, savings due to lack of scale formation, quality of heating and possibility of operating with controlled atmosphere, space requirements and low cost charging equipment available, simplified maintenance and last but not least, comfortable working conditions.

The usual price of electric energy in Europe ranges from 0·5–1·2 d/kWh. A few steel mills generate their own electric power by using their own gas, and it is interesting to note that these companies have calculated that the heating costs are in favour of ELPITS if the energy consumption is less than 35–40 kWh/ton.

While pure energy costs may be the most important economic factor in tonnage steel works, the savings in scale are also important, and even when employing controlled scaling to improve surface quality one may safely calculate with a scale saving of 1% or more depending upon ingot size. Net savings in scale alone may often more than pay for the total heating costs.

For tonnage mills, the ELPIT requires hot steel with relatively short track-time in order to be economically feasible, and we expect from experience that 30–50% of the total soaking pit capacity should be provided by ELPITS, with the balance being fuel fired.

When heating special steel, however, or when faced with special operating conditions, one will find that the overall costs may be in favour of ELPITS even though the direct energy costs may be relatively high.

With special steel, the advantages of careful heating combined with atmosphere control may be decisive.

In another case, the low standing losses may be important. On the average it will cost between 5 and 10 kW/ton of holding capacity to hold the pit at full temperature. Full advantage of this feature is enjoyed by mills operating their melting equipment continuously while rolling on one or two shifts only.

For the pit operators, the combination of a well insulated furnace and small cell openings means lower temperature on the operating floor and in the crane cab. While important in temperate climates such as that of Europe, it would seem that the similar reduction of the ambient temperature would be even more valuable in tropical climates as a means towards improving the working conditions.

In mills where space and building conditions have made it impossible to install pits it would be possible to do so when using ELPITS. These pits do not require any flues, and when using a hand-operated pair of tongs it would also usually be possible to operate conventional cranes within the existing building without having to incur the cost of lifting the roof and install stiff-mast soaking pit cranes, which are required in connection with modern single-cell soaking pit designs.

Conclusion

We could elaborate on other features, some of which in many cases may actually be of greater importance in connection with a particular installation, but from what has already been said we hope to have made it clear that an ELPIT offers possibilities which are not attainable with conventional fuel fired pits.

In our opinion electric heating of high temperature furnaces will be a natural development in the coming years, which will undoubtedly see an ever increasing shift towards generation and distribution of energy in the form of electricity. Atomic generation of electric energy which today is in its infancy, will undoubtedly in a few years be common all over the world, and we shall probably find that the cost of electric energy in the future will become ever cheaper in relation to other forms of energy.